response materials will be available in designated areas where fuel and chemicals are stored.

Employees will be trained in the transportation of dangerous goods, and domestic and recyclable waste dangerous goods will be stored in appropriate containers until shipped off site to an approved facility. Storage facilities for 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 is expected to result in no detectable change to surface water and sediment quality, and fish habitat and aquatic health relative to baseline conditions. Consequently, this pathway was determined to have no linkage to effects to fish.

8.6.2.3 Secondary Pathways

In some cases, both a source and a pathway exist, but the change caused by the Project is anticipated to result in a minor environmental change, and would have a negligible residual effect on water quality and fish in Kennady Lake relative to baseline or guideline values (e.g., a slight increase in a water quality parameter above Canadian Council of Ministers of the Environment [CCME] guidelines, but would not affect fish health). The following pathways are anticipated to be secondary, or minor, and will not be carried through the effects assessment.

Impingement and entrainment of fish in intake pumps during dewatering may cause injury and mortality to fish

Most fish will be removed from Kennady Lake during the fish salvage conducted before dewatering. The fish salvage will continue during dewatering; however, it is expected that some fish will still be remaining in Kennady Lake during dewatering and that some of these fish could become impinged or entrained in intake pumps. The intake pumps used for dewatering 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 Kennady Lake, as well as the swimming abilities of these species and the likely age classes of fish present at the water withdrawal location. Fish salvage will also occur in Lake A1 prior to it being partially dewatered to accommodate the Fine PKC Facility. Fish species captured in Lake A1 include Arctic grayling (*Thymallus arcticus*), burbot (*Lota lota*), and round whitefish (*Prosopium cylindraceum*). Forage fish species, such as slimy sculpin and ninespine stickleback, may also be present.

These screens, coupled with the ongoing fish salvage, should limit the number of large-bodied fish impinged on the intake pipe and should limit the fish entrained in the pumps to small-bodied fish (e.g., ninespine stickleback) and newly-hatched young-of-the-year of large-bodied fish (e.g., lake trout). While it is likely that any small fish that become impinged or entrained in the pumps may not survive, the goal of the fish salvage is to remove as many fish from Kennady Lake as possible. The screens will also be regularly maintained throughout the pumping period.

The implementation of environmental design features associated with dewatering, such as fish salvage and screening and maintenance of intake pumps, is expected to reduce fish mortality resulting from impingement or entrainment. Furthermore, the mortality of small species and young life stages are anticipated to be limited to a localized area. Therefore, residual effects to fish from the dewatering of Kennady Lake and Lake A1 are predicted to be negligible.

Release of sediment to Area 8 during the construction of Dyke A may change water and sediment water quality, and affect fish habitat and fish

Dyke A will be constructed in the narrows that separate Areas 7 and 8 in two stages. Initially, a temporary crossing structure will be placed in the narrows to provide access to the airstrip. The temporary dyke will become part of the permanent Dyke A, forming part of the dyke's shell.

During both stages of dyke construction, silt curtains will be used to minimize release of suspended sediments into Area 8. These curtains will be installed downstream of the dyke before construction and will be maintained until construction of the dyke is completed and TSS concentrations between the dyke and silt curtain have been reduced below required levels. With this measure in place, sediment re-suspension in the water column and sedimentation of fish habitat in Area 8 is expected to be minor.

The likelihood of silt curtains reducing the potential for increases in TSS in Area 8 is high because they are a well-established mitigation technique that has been demonstrated to be effective during dyke construction at the Diavik Diamond Mine (Diavik 1998). Use of silt curtains is also planned during construction of dykes for the Meadowbank Gold Project in Nunavut (Cumberland Resources

2005). Some general considerations in the use of silt curtains in dyke construction include:

- engage regulators in the decision process for the design and application of silt curtains;
- provide adequate anchoring of the curtains to maximize effectiveness;
- limit the distance between supports along the length of the curtains;
- tie the support anchors to topographic highs;
- construct wind blocks to limit wind fetch and wave action effects;
- establish the curtains at an appropriate distance from construction activities to maximize their effectiveness and to provide a settlement zone that does not become saturated with TSS;
- use double rows of silt curtains; and
- monitor TSS within and outside of the silt curtain area through construction.

Confidence in this assessment is further increased by the planned construction period, one to two months, and that very little fine sediment exists in the shallow waters at the narrows where the dyke will be built. In the event that TSS concentrations approach monitoring thresholds, construction activities will be curtailed.

The construction of Dyke A is expected to result in a minor change to the water quality through the increase in TSS in Area 8 from the disturbance of the lake bed. The use of silt curtains, and monitoring programs during construction, will minimize the amount of TSS that results in Area 8, which will be localized. Therefore, the residual effects to water and sediment quality, fish habitat and fish are predicted to be negligible.

Alteration of groundwater flows from dewatering Kennady Lake may change surface water levels in nearby lakes, and affect water quantity and quality, fish habitat, and fish

Dewatering of Kennady Lake will increase the hydraulic gradient in the active surface groundwater regime, which may extend 1 to 5 m below the ground surface of the Kennady Lake watershed depending on the topography. The groundwater discharge to the Kennady Lake areas will occur concurrently with the drawdown of the lake and will be a one-time release. The volume of groundwater ingress to the lake areas is expected to be negligible. Surficial groundwater is dilute water that contains substantial proportions of surface lake water and has low chloride concentration of about 100 mg/L or less

(Section 11.6, Subject of Note: Permafrost, Hydrogeology, and Groundwater) depending on the proportion of lake water.

The anticipated effects on the surface groundwater regime will be localized and short-term, and it is expected that dewatering will result in a minor change to the volume of surface groundwater in the Kennady Lake watershed relative to baseline conditions. The residual effects from the alteration of groundwater flows to water quality, fish habitat and fish are predicted to be negligible.

Reduction in upper watershed flow to Area 8 may change surface water levels, and affect surface water quality, fish habitat and fish

Area 8 is the easternmost basin of Kennady Lake and is just upstream of the L watershed. The area is approximately 4 kilometres (km) long, typically less than 500 m wide and contains several small bays and coves. Extensive areas in the northern part of this lake area are less than 4 to 5 m in depth with a mean depth of 3 m, and the deepest portion is located in one small region of the southern part of the lake area (greater than 9 m). The outlet of Kennady Lake to the L watershed is located at the northern end of Area 8.

The outflow channel of Kennady Lake to the downstream L watershed is a shallow, wide channel with a boulder bed and side channels present. Flows to the L watershed are limited to the open water season. In winter, Area 8 is isolated from the L watershed, with the outlet channel completely frozen during ice-covered months. Typically, ice thickness in Area 8 is less than 2.0 m.

With the construction of Dyke A in the early stages of the Project, Area 8 will become isolated from Areas 2 through 7 in Kennady Lake. During the construction and operations phase, Area 8 will receive limited inflows: natural runoff from the Area 8 sub-watershed and the G, H and I sub-watersheds, and dewatering discharge from Area 7.

After the cessation of discharge from Area 7, the reduction in inflows to Area 8 associated with the short-circuiting of the Kennady Lake watershed will result in an estimated annual average water level drop within Area 8 of 0.11 m, which will remain through the operations and closure phases of the Project. Once Kennady Lake is refilled and water quality conditions meet specific criteria, Dyke A will breached and removed to allow for the reconnection of the lake with Area 8.

The water level of Area 8 in the post-closure period is predicted to remain below baseline conditions. A lower water level, estimated to be -0.03 m compared to baseline, will be due to changes in Kennady Lake and the A sub-watershed, which will result in lower average annual discharge to Area 8. The A sub-watershed area will be reduced due to the diversion of Lake A3 to the N watershed and the alteration of the remaining sub-watershed due to the establishment of the Fine PKC Facility.

The average annual water level fluctuation in Area 8, modelled under normal flow conditions (i.e., 1960 to 2005), is 0.38 m. The predicted average annual reduction in water level due to the short-circuiting of Kennady Lake (construction of Dyke A and diversion of the A, B, D and E watersheds) is approximately 0.11 m, which represents approximately 30 percent (%) of the modeled average annual variation in water level under normal flow conditions. As the average depth of Area 8 is approximately 3 m and a maximum depth of up to 8 m, the reduction in water level due to the Project is considered minor.

During operations, Area 8 will still remain connected to the L watershed in open water conditions, although annual flows will be slightly reduced, and will remain isolated during winter conditions as a result of ice development. The predicted decrease in under-ice water levels in Area 8 relative to baseline is approximately 0.10 m, even under dry conditions.

The minor change in depth is not expected to alter water quality in Area 8. Compared to other areas in Kennady Lake, which are slightly deeper in average depth, physicochemical variability, particularly dissolved oxygen (DO) concentrations, are highly variable (see Annex I). Consistent with other areas in Kennady Lake, under-ice DO concentrations decrease rapidly with depth and during open water conditions DO concentrations are typically consistent throughout the water column. These characteristics are expected to remain consistent during the operation of the Project.

The close circuiting of Kennady Lake is anticipated to result in a minor change to water level in Area 8 during construction and operations. However, the small change in littoral area (approximately 2% of the surface area of Area 8) would have a negligible effect on the availability of fish and benthic invertebrate habitat. Changes to water quality, including under-ice DO levels, are expected to be negligible relative to baseline conditions. As a consequence, residual effects to fish habitat and fish (including the availability of overwintering habitat in Area 8) are predicted to be negligible.

Release of sediment during construction of dykes in the A, B, D and E watersheds may change water and sediment quality, and affect fish habitat and fish

During the construction of the water retention and water diversion dykes in the A, B, D, and E watersheds, silt curtains will be used to minimize the release of suspended sediment to the receiving waterbodies. These curtains will be located in lake areas adjacent to the dykes. They will be installed before construction of the dykes is initiated and will not be removed until TSS concentrations in water between the dyke and the silt curtains have been reduced below required levels. Water quality monitoring in lake areas outside of the silt curtains will be conducted throughout the construction period. Disturbance associated with the development of the dykes will also be minimized by avoiding construction during the spring freshet when the potential for erosion is highest and when spring spawning species, such as Arctic grayling (*Thymallus arcticus*), are using streams for spawning and migration.

As a result of the mitigation associated with the construction of the dykes, such as the use of silt curtains, avoiding construction activities during the spring freshet, and undertaking water quality monitoring programs during construction, changes to water and sediment quality from elevated suspended sediment associated with construction activities is expected to be minor and confined to the lake area bound by the silt curtains. As a result, residual effects to water quality and fish in the diverted upper watersheds are predicted to be negligible.

Changes to permafrost conditions in the flooded shoreline zone of the raised lakes due to increased water levels may lead to erosion and affect fish habitat

The raising of the lakes in the A, D and E watersheds after the construction of Dykes C, F, and G could alter permafrost conditions of the inundated terrain upstream from the dykes. Depending on water depth, permafrost will thaw beneath the inundated terrain, which may increase the extent of the taliks under the raised lakes. The inundated lake margins may be subject to higher erosion potential predominantly from wave action due to the saturation of the inundated surface soil material. The deposition of any disturbed material from these processes is expected to be deposited in close proximity to the shoreline. Surveys prior to the raising of the lakes will identify shoreline habitat that will be more prone to erosional processes when permafrost is lost (e.g., soils types, slope, bedrock) so that shoreline stabilization can be implemented where necessary. As Lakes D2, D3, and E1 will fill gradually changes to the inundated shoreline are also expected to be gradual.

Raised water levels in Lakes D2 and D3, and E2 will revert back to pre-development levels after closure allowing shoreline permafrost conditions to re-establish; however, Lake A3 will be raised permanently. Lowering the water levels in Lakes D2, D3, and E1 will allow permafrost to redevelop, which may lead to alterations in the surface topography (e.g., cracking), leading to increased potential of erosion, gullying and bank slumping along the exposed shoreline. Surveys to monitor the integrity of the lake shore environment during closure will identify these issues and allow for mitigation to be established.

Changes to permafrost along the shoreline of the lakes subject to raising and lowering throughout the life of the Project are predicted to be minor, which may result in erosional processes that may lead to elevated suspended sediment conditions in the nearshore lake areas. With monitoring and mitigation, erosion and sedimentation associated with changes to permafrost conditions in the lakeshore environments are expected to result in minor changes to fish habitat. As a result, residual effects to fish are expected to be negligible.

Release or generation of nutrients, mercury, or other substances into Lakes A3, D2, D3 and E1 from flooded sediments and vegetation may change water quality, and affect aquatic health and fish

Raising of lake levels also has the potential to cause the leaching of minerals and nutrients (i.e., phosphorus and nitrogen) from the soil and vegetation in the area to be inundated. This could cause an initial increase in primary (i.e., phytoplankton) and secondary (i.e., zooplankton and benthic invertebrate) production, and a subsequent increase in growth of fish.

Approximately 22.8 ha of riparian habitat around Lake A3 will be inundated permanently, with 53.1 ha and 6.8 ha of riparian habitat temporarily inundated as a result of raising Lakes D2 and D3, and E1, respectively. The riparian vegetation of the three lakes areas that will be flooded includes scrub birch (Labrador tea tundra and cloudberry low shrub bog), and water sedge (narrow-leaved cottongrass fen) over a low-gradient substrate that has a high proportion of boulder or cobble material. The larger surface area associated with the flooding of Lakes D2 and D3 has a predominance of sedges.

Changes to nutrient dynamics in the flooded lakes will be primarily driven by the inundation of the surrounding riparian vegetation and, to a more limited extent, soil. Nitrogen, phosphorus and carbon are likely to be released to the water column through decompositional processes and sediment-water interactions, but not all forms will be equally bioavailable (Paterson et al. 1997, Thouvenot et al. 2000). Phosphorus, for example, may be released in a non-bioavailable form (i.e., bound to particulates) which can lead to the preferential growth of bacteria over phytoplankton.

Following construction of the dykes, the lakes will fill to their new level through natural drainage. The time required to fill the lakes is predicted to take between one year (i.e., Lake 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. The gradual flooding of the riparian habitat associated with the raising of these lakes may result in a surge in nutrient concentrations, particularly in the nearshore region of the lakes. The period of time that the elevated nutrient concentrations will remain in the lakes will be dependent on site-specific conditions, such as the mass of inundated organic material, the hydrological regime (i.e., retention time and flushing rates) and rates of microbiological and biological activity (i.e., low temperatures may reduce the potential for decomposition and assimilation). Once the raised lakes are lowered at the end of operations (i.e., Lakes D2 and D3, and E1), nutrient dynamics are anticipated to return to a condition that is similar to baseline conditions. It is not expected that there will be any long term effect on the nutrient dynamics in these lakes, or in Lake A3, which will remain raised after operations.

The release of metals from the sediment of newly flooded areas is anticipated, either from the suspension of sediment (i.e., particulate metals associated with sediment particles) or during low oxygen conditions at the sediment water interface associated with under-ice conditions in the shallow lakes (i.e., dissolved metals). Total suspended sediment (TSS) concentrations will be elevated during spring freshet inflows through the lakes and as a result of wave action. However, any elevation in the concentration of metals associated with TSS from these sources is anticipated to be temporary. It is not expected that there will be any long term effect on the metals dynamics in these lakes.

Inundation of soils and vegetation surrounding lakes A3, D2 and D3, and E1 can also increase the concentration of methylmercury in fish. Methylmercury is the toxic form of mercury (Bloom 1992) and its availability to aquatic organisms increases when new sources of inorganic mercury are introduced to the water (i.e., inorganic mercury in the soil and vegetation) and microbial activity increases due to increased nutrient additions (Rudd 1995; Bodaly and Kidd 2004). Methylmercury tends to become more concentrated in higher trophic levels, particularly top-predatory fish such as lake trout (Wright and Hamilton 1982; Bodaly et al. 1984; Brouard et al. 1990; Hecky et al. 1987, 1991; Kidd et al. 1995).

There are several physical, chemical, and biological factors that increase the biomagnification of methylmercury in fish in a lake. These factors include the following:

- Small lake size (Bodaly et al. 1993). Smaller lakes tend to have fish with higher mercury concentrations.
- Larger upstream watershed size (Evans 1986).
- Location of the lake lower down in the watershed (McMurtry et al. 1989).
- Low pH and high dissolved organic carbon (McMurtry et al. 1989; Wiener et al. 1990; Driscoll et al. 1994).

- Longer food chain lengths (Cabana et al. 1994; Cabana and Rasmussen 1994; Power et al. 2002). Species connected to the benthic food chain (e.g., round whitefish) have lower mercury concentrations than species connected to the pelagic food chain (e.g., lake trout) (Power et al. 2002).
- Position of the fish at or near the top of the food chain (Kidd et al. 1995; Power et al. 2002).
- Age of the fish (Harris and Bodaly 1998). Larger, mature fish tend to be slower growing than younger fish and use most of their ingested energy for reproduction not growth. Therefore, older fish tend to retain most of the ingested mercury (Bodaly and Kidd 2004).

Mercury concentrations in fish in the raised lakes are not expected to increase high enough to impair the health of the fish or any wildlife that may eat these fish because of the following:

- The amount of inorganic mercury available for methylation will be minimized by preparing the area to be inundated before flooding.
- The number of lake trout, burbot, and northern pike (*Esox lucius*) expected to be present in the raised lakes during mine operations is low.
- Arctic grayling, slimy sculpin, and ninespine stickleback, (i.e., the fish species most likely to persist in the A, D and E watersheds during mining) are planktivores or benthivores and, therefore, are low on the food chain.
- The raised lakes are located in the headwaters of the Kennady Lake watershed.
- Mercury concentrations in non-piscivorous fish typically peak in 4 to 5 years and then return to pre-impoundment concentrations usually within 10 to 15 years after flooding (Schetagne et al. 1997, cited in Legault et al. 2004; Bodaly et al. 1997).

The effects of flooding on the riparian habitats around the small lakes to be raised are expected to be minor because of the following:

- Lake level increases will occur gradually and changes to water quality (i.e., increased turbidity) will be temporary.
- The riparian landscape surrounding Lakes D2, D3, E1, and A3 that will be inundated will be prepared to the extent possible. For example, some vegetation may be considered for removal during the construction of the diversion dykes, and prior to flooding. Surveys of the areas prior to flooding will identify vegetation that can be removed, and areas that should be avoided to minimize land disturbance.

- Shoreline areas that are susceptible to extensive erosion may be armoured by cobble and boulder to reduce erosion and associated resuspension of fine sediments.
- Physico-chemical water quality variations due to flooding are temporary, peak quickly (less than four years) and subside as time passes (Legault et al. 2004).
- Water quality monitoring in the lakes, and shoreline and riparian surveys will be conducted during operations and closure to monitor change and identify any requirement for mitigation.

Naturally low nutrient levels in the surface soils and cold temperatures throughout the year would limit bacterial production, resulting in much lower rates of processes such as decomposition (e.g., releasing nutrients) and methylation compared to warmer waterbodies where large increases in nutrient releases to the water column and mercury accumulation in fish have been documented. Although there is potential for temporary changes to surface water and sediment quality with the raising of lakes A3, D2 and D3, and E1, preparation of the areas to be flooded where necessary, and monitoring will limit the potential for long-term nutrient and metals releases to the lakes and mercury methylation. Changes in water and sediment quality are predicted to be minor relative to baseline conditions. As such, residual effects to fish are anticipated to be negligible.

Removal of bedrock and kimberlite material from the active mining of pits may change groundwater quantity in the Kennady Lake watershed, and affect the water level in small lakes in the watershed

Mining will remove approximately 270 million tonnes (Mt) of rock, primarily from the talik, but also from the deep groundwater system. This mass of rock occupies an approximate volume of 46 Mm^3. With an average porosity of 0.01, the groundwater within this volume is about 0.5 Mm^3. This volume of groundwater will be permanently removed and incorporated into the mine rock and coarse PK piles, the Fine PKC Facility, or managed through the WMP. Pore spaces of the mine rock and coarse and fine PK material used to backfill Hearne Pit and the backfilled portion of 5034 Pit will contain pore water that originates primarily as groundwater. This water will be augmented by fresh water during refilling. Therefore, the groundwater volume removed from the pits will be replaced by groundwater in the backfill material and fresh water. As such, the residual effect to groundwater quantity is expected to be negligible.

Alteration of the groundwater regime from groundwater flows to the mined out pits may change water quality and water quantity in other lakes in the watershed

Dewatering of the Kennady Lake bed and mine pits will induce groundwater to flow toward the pit 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 (Section 11.6, Subject of Note: Permafrost, Hydrogeology, and Groundwater Figure 11.6-2), 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 small lakes in the upper watershed of Kennady Lake, with the exception of Area 8, are not considered of sufficient surface area to have talik penetration to the deep groundwater regime. Based on the climatic conditions of the LSA, lakes with a surface area less than 1 km^2 are not expected to have fully penetrating taliks underneath except for some unusually shaped lakes (e.g., those that are long but very narrow) (Section 11.6; Subject of Note: Permafrost, Groundwater and Hydrogeology).

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 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 flow directions and intercepts are anticipated in the LSA surrounding the pit development, but no measureable effects are expected in reducing lake volumes, and therefore water levels, in the small lakes within the Kennady Lake watershed. As such this pathway was determined to have negligible residual effect on water quality.

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

The freshwater intake and pumphouse will be located on the north western 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 overlaid embankment will act as a secondary filtration screen, which will prevent fish from becoming entrained.

The implementation of fish screens on the intake and a buried intake under rock fill is anticipated to reduce fish mortality resulting from impingement or entrainment. Mortality of small species and young life stages are anticipated, but will be limited to a localized area and will have a minor influence on fish populations. Therefore, residual effects to fish from the pumping potable water from Area 8 are predicted to be negligible.

Extraction of potable water requirements for the Project may change surface water levels in Area 8, and affect fish habitat

The provision of potable water for the camp and plant will be from Area 8 has the potential to reduce surface water levels and outflows from Area 8. About 60,000 cubic metres per year (m^3/y) of fresh water will be required for potable water during construction. During operations, with a smaller workforce, the potable water required will decrease to about 27,000 m^3/y. The supply volumes are small in comparison to mean daily outflow volumes for median conditions predicted for Area 8 during construction and operations (Table 8.6-2).

Table 8.6-2 Mean Daily Outflow Volumes at the Outlet of Kennady Lake (Stream K5) – Construction and Operations

Condition	Return Period (years)	Snapshot	Monthly Mean Daily Outflow Volume (m^3)					
			May	June	July	August	September	October
Median	2	baseline	708	65,900	39,300	22,800	13,200	3,070
		construction	779	65,700	86,600	86,500	77,200	4,680
		operations	428	21,900	6,670	4,580	2,460	371

m^3 = cubic metres.

Potable water supply from Area 8 is a small annual supply volume compared to the volume of Area 8 and predicted outflows during construction and operations. The annual requirements of water from Area 8 to meet potable water demand is expected to result in a small change in water level to Area 8, and a minor change to available fish habitat. Consequently, residual effects to fish are expected to be negligible.

Close-circuiting of Areas 2 to 7 may change water quality in Area 8, and affect aquatic health and fish

Water quality in Area 8 during the operations and closure phases will be driven by dewatering of water from Area 7 and drainage flows from the H, I, J and Ke watersheds. Pumped discharge from Area 7 to Area 8 is expected to have similar water quality to Area 8, and will only be discharged if water in Area 8 meets specific discharge water quality criteria.

Concentrations of water quality constituents are predicted to increase slightly in Area 8 over the course of operations and closure, due to evapo-concentration.

The construction of Dyke A will result in a reduction in drainage area reporting to Area 8, thereby increasing the residence time and the rate of evaporation relative to recharge. Consequently, all water quality constituents are predicted to increase to slightly above background conditions by the time Dyke A is breached in Year 21.

The isolation of Area 8 from the upper areas of Kennady Lake will limit inflows to this area to dewatering discharge in the construction and early operations phase from Area 7, and sub-watershed drainage inputs. Minor changes to water quality are anticipated in Area 8 during operations and closure, but these changes are expected to be within the natural range of variability reported for Area 8. As such this pathway was determined to have negligible residual effect on fish.

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

Trucks travelling on winter roads or aircraft landing on an ice airstrip 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 (including helicopters, aircraft landing and takeoff, and ice-road traffic) measured in Kennady Lake 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, 2009).

The low level of truck traffic noise on winter roads or aircraft noise 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 be within their normal daily or day-to-day range.

Traffic activity on the winter road, and aircraft landing and taking-off on the ice airstrip on Kennady Lake, which will be used before the permanent airstrip is established, 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, and aircraft activity prior to the establishment of the on land airstrip, are expected to have negligible residual effects on fish.

8.6.2.4 Primary Pathways for Effects from Construction and Operations

The remaining pathways for water quality and fish in Kennady Lake and its watershed are classified as primary (listed below) and are carried forward as effects statements (Table 8.6-3) to be assessed in the effects analysis sections (Sections 8.7 to 8.12). 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).

8.6.2.5 Potential Pathways during Closure

Pathways for effects to water quality and fish during closure include direct impacts to fish and fish habitat (e.g., alteration of flows during the refilling of Kennady Lake), and indirect effects to fish through changes in water quality (e.g., change in concentrations of metals or nutrients in Area 8 when Dyke A is breached) (Table 8.6-4). The effects of the Project on fish populations in Kennady Lake and its watershed after Areas 3 to 7 are reconnected to Area 8 are addressed in this section. The discussion regarding the restoration processes of Kennady Lake is addressed in this key line of enquiry, and also more specifically in the Key Line of Inquiry: Long-term Biophysical Effects, Reclamation and Closure (Section 10).

Effects to downstream hydrological conditions, water quality, fish, and fish habitat and after closure are addressed in the Key Line of Inquiry: Downstream Water Effects (Section 9). Section 9 also includes assessment of downstream effects on fish during the refilling of Kennady Lake (i.e., downstream of Kennady Lake and downstream of Lake N11).

Table 8.6-3 Effects Statements for Water Quality and Fish during Construction and Operations

Discipline	Project Activity	Pathway	Effects Statement
Hydrology	Project footprint (e.g., dykes, mine rock and coarse PK piles, Fine PKC Facility, access roads, mine plant, airstrip)	reduction in watershed areas may change flows, water levels, and channel/bank stability in streams and small lakes in the Kennady Lake watershed	Effects of mine rock and coarse PK piles and Fine PKC Facility to flows, water levels and channel/bank stability in streams and smaller lakes in the Kennady Lake watershed
	Dewatering of Kennady Lake	dewatering of Area 7 to Area 8 may change flows, water levels, and channel/bank stability in Area 8	Effects of dewatering Kennady Lake to flows, water levels and channel/bank stability in Area 8
	Isolation and diversion of upper Kennady Lake watersheds	changes in A, B, D and E watershed areas and flow paths may change flows, water levels, and channel/bank stability in the Kennady Lake watershed	Effects of watershed diversions in watersheds A, B, D and E to flows, water levels and channel/bank stability in streams and smaller lakes in the Kennady Lake watershed
		shoreline erosion, re-suspension of sediments and sedimentation may change due to changes in water levels in Lakes A3, D2, D3, and E1	
Water Quality	Construction and mining activity during construction and operations	deposition of dust from fugitive dust sources may change to water quality and sediment quality	Effects of the deposition of dust and metals from air emissions to water quality and lake bed sediments in waterbodies within the Kennady Lake watershed
		air emission and deposition of sulphur dioxide [SO_2], nitrogen oxides [NOx], particulate matter [PM], and total suspended particulates [TSP] may change water and sediment quality	Effects of the acidifying air emissions to waterbodies within the Kennady Lake watershed
Aquatic Health	Construction and mining activity during construction and operations	deposition of dust in the Kennady Lake watershed may change aquatic health	Effects of air emissions to aquatic health in the Kennady Lake watershed
		deposition of acidifying substances in the Kennady Lake watershed may change aquatic health	
Fish and Fish Habitat	Project footprint (e.g., dykes, mine rock and coarse PK piles, Fine PKC Facility, access roads, mine plant, airstrip)	project development in the Kennady Lake watershed will result in the loss of fish habitat	Effects of Project activities to fish and fish habitat in Kennady Lake, and streams and lakes within the Kennady Lake watershed
	Dewatering of Kennady Lake	dewatering of Kennady Lake and other small lakes may cause mortality and spoiling of fish, temporary loss in productive capacity, and the alteration of flows, water levels, and channel/bank stability in Area 8	
	Isolation and diversion of upper Kennady Lake watersheds	change of flow paths and construction of retention and diversion dykes in the A, B, D and E watersheds may result in loss of stream habitat, alteration of water levels and lake areas, shoreline erosion, re-suspension of sediments and sedimentation, and changes to lower trophic levels, fish communities and migration	
	Construction and mining activity during construction and operations	deposition of dust and particulate matter may cause increases in suspended sediment, and changes to aquatic health	

Table 8.6-4 Potential Pathways for Effects to Water Quality and Fish during Closure

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Reclaimed Project footprint	• development of fish habitat compensation works to account for HADD associated with the Project	• fish habitat compensation developed in consultation with DFO and other regulatory agencies	Primary
	• removal of project infrastructure (e.g., roads, airstrip, dykes, buildings) may change flows, water levels, and channel/bank stability in streams and small lakes in the Kennady Lake watershed, and affect, water quality, fish habitat and fish	• to the extent possible, all disturbed areas will be reclaimed and the surface stabilized • surfaces will be re-graded and till or mine rock will be placed, as appropriate, to prevent dusting and water erosion, and stabilizing, as required, against thermokarst from freeze-thaw processes within the active layer • drainage patterns will be re-established as close to pre-operational conditions as possible, with drainage ditches contoured or backfilled as appropriate to remove any hazards to wildlife	No Linkage
	• the Project may change the long-term hydrology in the Kennady Lake watershed		Primary
Removal of the temporary diversion dykes in the B, D and E watersheds	• reduction of water levels in Lakes D2, D3, and E1 may change to permafrost conditions, and affect fish habitat	• none	Secondary
	• removal of dykes may change flows, water levels, and channel/bank stability in streams and small lakes in the B, D, and E watershed, and affect water quality, fish habitat and fish	• watershed will be reconnected to Kennady Lake along previous connecting streams where possible • any diversion channels will be designed to provide spawning and rearing habitat, and permit fish passage • monitoring of the new shorelines associated with the reduced lake levels	Primary
	• removal of the temporary dykes for the realignment of diverted B, D, and E watersheds to Kennady Lake may release sediment and change water and sediment quality, and affect fish habitat and fish	• watershed will be reconnected to Kennady Lake along previous connecting streams, but where necessary cobble and boulder placement will be used to reduce erosion potential • place erosion protection materials and processes over the natural downstream channels to limit erosion along the flow path to Kennady Lake • silt curtains will be placed upstream and downstream of the dykes to control the release of suspended sediments during their deconstruction/breaching • water levels in lakes will be drawn down by pumping or siphoning water to Kennady Lake prior to removal of dykes • dykes will be removed during low- or no-flow periods to allow work to be completed "in the dry"	Secondary
Removal of the temporary diversion dykes in the B, D and E watersheds (continued)	• removal of diversions and temporary dykes in B, D, and E watersheds may result in changes to fish migration	• watershed will be reconnected to Kennady Lake along previous connecting streams where possible • any diversion channels will be designed to provide spawning and rearing habitat, and permit fish passage • fish salvage will occur where appropriate prior to breaching and removing the dykes and constructed diversion channels	Primary

Table 8.6-4 Potential Pathways for Effects to Water Quality and Fish during Closure

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Refilling of Kennady Lake	• refilling dewatered areas of Kennady Lake may alter permafrost conditions, and affect fish habitat	• areas in Kennady Lake will not be completely dewatered for the duration of operations. Refilling of Areas 6 and 7 will be commenced in Year 6 when mining of 5034 is complete. Dewatering of Area 4 will start in Year 4	No Linkage
	• release of groundwater into the refilled Tuzo Pit may change groundwater quality in the pit, and affect water quality and fish in Kennady Lake	• Tuzo Pit will be refilled with surface water from Area 3 and 5 to minimize groundwater inflow.	Secondary
	• pumping water from Lake N11 to Kennady Lake to supplement refilling may change water and sediment quality in Kennady Lake, and affect aquatic health and fish	• use of supplemental inflow from Lake N11 using a pipeline and pumping system to divert water directly to Area 3 • water quality of supplemental inflow will be similar to water quality of Kennady Lake prior to dewatering	Secondary
	• realignment of B, D, and E watersheds for the refilling Kennady Lake may result in effects to fish	• exclusion measures will be used to limit the initial migration of large-bodied fish from the B, D, and E watersheds into Kennady Lake during refilling once the dykes have been removed	Primary
	• erosion of lake-bottom sediments in Area 3 from the pump discharge during the refilling of Kennady Lake may change water quality, and affect fish habitat and fish	• designing outfalls/diffusers so that they sit high in the water column and actively disperse piped discharge to prevent erosion of the lake-bed sediment • Areas 3 and 5 will remain part of the closed-circuited system until the lake is filled and water quality meets criteria for reconnection with Area 8	No Linkage
	• continued isolation of Area 8 during refilling and recovery period may change surface water flows, water levels in Area 8, and affect and water quality, fish habitat and fish	• refilling of Kennady Lake will be supplemented by pumping from Lake N11 to reduce the re-fill period to approximately 8 years	Primary
	• co-mingling of water in Tuzo Pit with water in Areas 3 to 7 during refilling may change water quality in Kennady Lake, and delay ecosystem recovery	• none	Primary
Refilling of Kennady Lake	• release or generation of mercury, nutrients, or other substances into Areas 3 to 7 from flooded sediments and vegetation during refilling of Kennady Lake may change water quality	• none	Primary
	• release of saline water from the Tuzo Pit to surface waters of Kennady Lake may change water quality	• none	Primary

Table 8.6-4 Potential Pathways for Effects to Water Quality and Fish during Closure

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Breaching Dyke A to reconnect Kennady Lake with Area 8	• release of sediment into Areas 7 and 8 during the removal of Dyke A may change water and sediment quality, and affect fish habitat and fish	• silt curtains will be placed upstream and downstream of the construction area to control the release of suspended sediments	Secondary
	• underwater noise and vibrations during the breaching and removal of Dyke A may affect fish	• use of machinery instead of explosives to reduce underwater noise and vibration • if explosives are required, DFO will be consulted, and their use will be in accordance with applicable standards and guidelines	Secondary
	• changes in B, D, and E watershed areas and flow paths may result in alteration of flows, water levels, and channel/bank stability in the Kennady Lake watershed, which can affect water and sediment quality, fish habitat and fish	• monitoring of the new shorelines associated with the reduced lake levels	Primary
	• changes to water levels in Lakes D2, D3, and E1 may lead to shoreline erosion, re-suspension of sediments and sedimentation, and affect water quality, fish habitat and fish		Primary
	• reconnection of Areas 3 to 7 to Area 8 may change water flows and water levels in Area 8, and affect fish habitat and fish	• breaching and removal activities will be limited to daylight hours to limit effects to fish and expected to be completed in one month • breaching and removal activities will be completed using heavy machinery, such as long-armed backhoes, to limit effects to fish, with explosives used only if necessary	Secondary
	• reconnection of Areas 3 to 7 with Area 8 may change water quality in Area 8, and affect aquatic health and fish	• Dyke A will be breached and removed when water quality in Kennady Lake meets specific criteria	Primary
	• removal of Dyke A will change fish migration through the Kennady Lake watershed	• none	Secondary

Table 8.6-4 Potential Pathways for Effects to Water Quality and Fish during Closure

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Mine rock and Coarse PK piles	• seepage from the mine rock and coarse PK piles may change water quality, and affect aquatic health and fish	• at closure, the mine rock piles will be re-shaped and a 1 m layer of non-acid generating mine rock will placed on the outer surface of the pile to prevent erosion. • PAG rock will comprise only a small proportion of the overall mine rock tonnage (<6%) and will be sequestered within the mine rock storage facilities within a till layer or will be underwater when Kennady Lake is re-filled. • the Coarse PK Pile, adjacent to Area 4, will be shaped and covered with a layer of mine rock of a minimum of 1 m to limit surface erosion. • runoff from the Coarse PK Pile and mine rock piles will be managed to mitigate downstream effects on flows, water levels and channel bank stability. Perimeter ditches will collect facility runoff, intercept upstream runoff and convey it to a discharge point. Natural receiving channels that convey water to Kennady Lake will be armoured to prevent erosion if necessary, or engineered channels will be constructed.	Primary
	• alteration of drainage patterns to Kennady Lake due to the mine rock and coarse PK piles may change water flows, water levels, and channel/bank stability in streams and small lakes, and can affect water and sediment quality, fish habitat and fish		No Linkage
Fine PKC Facility	• seepage through filter dyke L may change water quality in Kennady Lake, and affect aquatic health and fish	• At closure, the Fine PKC Facility (Areas 1 and 2) will be graded and 1 to 2 m of NAG mine rock will be placed on the outer surface of the pile to prevent erosion. • The final shaping of the facility will be designed to limit ponding of water over the mine rock. • Strategies being considered for the Fine PKC Facility include flexibility in the configuration of the facility to reduce the overall footprint area of the fine PK, reduce overall infiltration of water into the facility, and reduce seepage contact with materials that have the potential to contribute to elevated geochemical loadings. • Runoff from the Fine PKC Facility will be managed to mitigate downstream effects on flows, water levels and channel bank stability. Perimeter ditches will collect facility runoff, intercept upstream runoff and convey it to a discharge point. Natural receiving channels that convey water to Kennady Lake will be armoured to prevent erosion if necessary, or engineered channels will be constructed.	Primary
	• alteration of drainage patterns to Kennady Lake from the Fine PKC Facility may change water flows, water levels, and channel/bank stability in streams and small lakes, and affect water and sediment quality and fish		No Linkage
Partial backfilling of Hearne Pit with fine processed kimberlite	• seepage from backfilled PK material in pits may change water quality in Kennady Lake, and affect aquatic health and fish	• Hearne pit will be partially backfilled with fine PK. • after Year 7, the backfilled pit will be 120 m deep. • runoff water, pit water, and decant water from the fine PK will cause a high TDS water layer above the settled fine PK in the pit • the volume of high TDS water overlying the fine PK will allow for an accelerated refilling at closure and promote the development of a chemocline above the settled fine PK	Primary

Table 8.6-4 Potential Pathways for Effects to Water Quality and Fish during Closure

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Fish restocking to re-establish fish community structure	• restocking Kennady Lake with fish may change brood-stock fish population and affect genetics or parasites of fish in Kennady Lake	• maintain an annual sustainable harvest rate from each potential brood stock lake to reduce potential for fish mortality and maintain trophic stability • stocking of Kennady Lake with fish from lakes within the same watershed as Kennady Lake (i.e., the Kirk Lake watershed) will maintain similar genetic make-up and minimize susceptibility to disease and maximize adaptability to new environment • conduct pathology examinations of fish in potential source lakes to reduce the potential of transferring diseased or parasite-infested fish to Kennady Lake	Secondary

8.6.2.6 No Linkage Pathways

The following pathways are anticipated to have no linkage to water quality and fish in Kennady Lake during the closure phase, and will not be carried through the effects assessment. The following section lists all of the potential pathways that are classified with no linkage, and provides an explanation for the classification.

Removal of Project infrastructure (e.g., roads, airstrip, dykes, buildings) may change flows, water levels, and channel/bank stability in streams and small lakes in the Kennady Lake watershed, and affect water and sediment quality, fish habitat and fish

Mining is scheduled to end in Year 11, after which Project infrastructure removal will begin. This process is expected to take two years, and will require the demolition and removal of plant operations facilities (e.g., processing plant, power plant), storage facilities (e.g., explosive storage, fuel storage tanks), buildings, the airstrip, and roads.

To the extent possible, all disturbed areas will be reclaimed and the surface stabilized. This will include re-grading and placing till or mine rock, as appropriate to prevent dust generation and water erosion, and stabilizing, as required, against thermokarst from freeze-thaw processes within the active layer. Drainage patterns will also 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.

Erosion will be controlled principally by keeping slope angles of constructed facilities at less than the angle of repose or by rock armouring, as appropriate. Where feasible, long-term sediment control will be achieved by re-vegetation. Rock armouring will be done where re-vegetation is not possible and erosion control is required. The rock will be obtained by screening suitably sized inert material from the mine rock stockpile.

The removal of infrastructure from the Project is not anticipated to have a measurable influence on surface hydrology and bank/channel integrity within the Kennady Lake watershed. As such, drainage through the reclaimed areas of the Project is not expected to result in measurable changes to water and sediment quality in Kennady Lake. Consequently, this pathway was determined to have no linkage to effects to fish.

Refilling dewatered areas of Kennady Lake may change permafrost conditions, and affect fish habitat

A talik exists under most of Kennady Lake. During construction and operations, Areas 4, 6, and 7 of Kennady Lake will be dewatered for varying periods of time and exposed to cold air temperatures. This may result in the decrease in the extent of the talik under Kennady Lake and formation of permafrost in the dewatered lake-bed. The mean annual soil temperature in the dewatered lake-bed is estimated to cool after draining to approximately -2 to -3°C.

Based on the current Project schedule, Areas 4, 6 and 7 of Kennady Lake will be dewatered at stages during operations for extended periods while the pits are mined (i.e., up to a maximum of six years). Permafrost-related processes, such as frost cracking and thermoerosion may occur within the dewatered lake-bed. Frost cracking over the exposed lake-bed surface will also result in formation of a polygon landscape and thin ice wedges in the cracks. The exposed saturated material on the relatively flat slopes of the lake-bed surface will have sufficient time for pore water pressure dissipation and it is unlikely that major slope instability within the dewatered lake-bed will result. However, there may be a potential for a local slope failure/deformation in steeper slopes around the perimeter of the dewatered areas.

A talik is expected to reform under Kennady Lake after refilling. Disturbance of the lake-bed and any resulting earth processes that resulted during exposure of the lake bed following dewatering would be promptly levelled under the wave action after refilling in the shallow portions of Kennady Lake. In areas with deep water, the levelling of the bottom topography will occur more slowly, mainly by gravitational processes, but would return to pre-existing talik conditions.

The alteration of lake-bed topography due to changes in permafrost conditions within the areas of Kennady Lake is expected to have no measurable influence on the re-establishment of fish habitat [where it would be expected] after refilling. Consequently, this pathway was determined to have no linkage to effects to fish.

Erosion of lake-bottom sediments in Area 3 from the pump discharge point during the refilling of Kennady Lake may change water quality, and affect fish habitat and fish

The potential for erosion of lake-bottom sediments in Area 3 will be minimized during the pumping from Lake N11. Constructed channel outfalls or diffusers will be used to reduce the erosive energy of water pumped into Area 3 to supplement the natural refilling of Kennady Lake. Additionally, the water level in Areas 3 and 5 will be maintained to a minimum of 417.0 masl prior to refilling to minimize the risk of disturbing the entire lakebeds and increasing turbidity in the lake water during mine closure. It is anticipated that supplemental pumping from Lake N11 will be required for approximately 8 years for Kennady Lake to refill. The average annual volume of supplemental water required from Lake N11 will be 3.7 Mm3.

Outfalls will be constructed in Area 3 to diffuse the velocity of the pumped discharge. Diffusers, if required, will be placed as close to the surface as possible over the deepest portion of Area 3 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 be limited to the zone of turbulence immediately adjacent to the diffuser, and 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 Lake N11 to Area 3 during refilling is not expected to result in measurable changes to water and sediment quality or fish habitat in Area 3. Consequently, this pathway was determined to have no linkage to effects to fish.

Alteration of drainage patterns to Kennady Lake due to the mine rock and coarse PK piles may change water flows, water levels, and channel/bank stability in streams and small lakes, and affect water and sediment quality, fish habitat and fish

Runoff from the mine rock and coarse PK piles will be managed to mitigate downstream effects on flows, water levels and channel bank stability.

Mine rock will be placed in two designated mine rock piles during operations, which will be constructed in Areas 5 and 6: the South Mine Rock Pile final pile crest will be at a surface elevation of approximately 515 masl, giving the pile a maximum height of about 90 m, and the West Mine Rock Pile will have a final crest elevation of 474 masl and a height of 70 m. Both piles will be developed with 2.4H:1V overall side slopes, which provide stability. Flatter side slopes will be constructed when the final slope is exposed to the shoreline. Progressive reclamation of the mine rock piles, which will include contouring and re-grading, will start as early as Year 5 for the South Mine Rock Pile and Year 7 for the West Mine Rock Pile. The piles will not be covered or vegetated, consistent with the approaches in place at the Ekati Diamond Mine and Diavik Diamond Mine. Runoff from these piles will be directed to Areas 5 and 6.

The Coarse PK Pile is located on land adjacent to Area 4. The Coarse PK Pile will be progressively reclaimed during mine operations, and will be shaped and covered with a layer of mine rock of a minimum of 1 m to limit erosion and dust production. Runoff from this pile will be directed to Area 4.

Runoff rates from the South and West Mine Rock and Coarse PK Piles are expected to be equivalent to those from undisturbed surfaces after final mine rock and coarse PK placement is completed. Drainage courses from the piles to Kennady Lake will be monitored and evaluated to determine if flow rates exceed the capacity of natural channels. Alternatively, natural channels may be armoured to prevent erosion, or engineered channels may be used.

The alteration of drainage patterns in the Kennady Lake watershed from the construction of the mine rock and coarse PK piles is expected to have no measurable influence on water flows, water levels, and channel/bank stability in drainage streams to Kennady Lake. As a result, changes to water and sediment quality are not anticipated and this pathway was determined to have no linkage to effects to water quality or fish once Kennady Lake is reconnected with the upper watersheds and Area 8.

Alteration of drainage patterns to Kennady Lake from the Fine PKC Facility may change water flows, water levels, and channel/bank stability in streams and small lakes, and affect water quality, fish habitat and fish

Runoff from the Fine PKC Facility will be managed to mitigate downstream effects on flows, water levels and channel bank stability.

The Fine PKC Facility in Areas 1 and 2 will be progressively reclaimed during mine operations, as fine PK will be placed in the bottom of the mined-out Hearne Pit during the latter stages of operations. As the Area 1 portion of the facility becomes filled during the initial years of operations, it will be covered with a layer of coarse PK to prevent the fine PK from being windblown. This will allow subsequent vehicle traffic and placement of approximately a 1 to 2 m thick layer of NAG mine rock. The facility will be graded so that any surface runoff will flow towards Area 3.

The Area 2 portion of the Fine PKC Facility will be reclaimed in a similar fashion. Any remaining water impounded within Area 2 behind Dyke L will be backfilled with coarse PK or mine rock to provide runoff drainage patterns flowing into Area 3. As above, the closure scenario also involves a NAG mine rock covered terrain. For both Area 1 and Area 2, the final geometry of the cover layer will be graded to limit ponding of water over the mine rock covered areas.

Runoff rates from the Fine PKC Facility are expected to be less than those from undisturbed areas while they are being constructed, and equivalent to those from undisturbed surfaces after final mine rock placement is completed.

Drainage channels from these areas to Kennady Lake will be evaluated to ensure that flow rates do not exceed the capacity for stability in the drainage channels. These channels may be armoured to prevent erosion.

The alteration of drainage patterns in the Kennady Lake watershed from the construction of Fine PKC Facility is expected to have no measurable influence on water flows, water levels, and channel/bank stability in drainage streams to Kennady Lake. As a result, changes to water and sediment quality are not anticipated and this pathway was determined to have no linkage to effects to water quality and fish once Kennady Lake is reconnected with the upper watersheds and Area 8.

8.6.2.7 Secondary Pathways

The following pathways are anticipated to be secondary, or minor, and will not be carried through the effects assessment. The following section lists all of the potential pathways that are classified as minor, and provides an explanation for the classification.

Reduction of water levels in Lakes D2, D3 and E1 may change permafrost conditions, and affect fish habitat

At closure, the temporary dykes will be removed and the raised lakes that formed upstream of the diversion dykes will be allowed to drain back to pre-disturbance water levels to initiate the refilling of Kennady Lake. The background permafrost conditions will return to the drained shoreline areas, potentially resulting in the development of permafrost-related earth processes, such as frost cracking and thermoerosion. These alterations to the exposed shoreline may reduce the re-establishment of vegetation and increase erosion potential that may lead to localized fish habitat changes through increased suspended solids and sedimentation in the nearshore zone of the lakes. These changes are anticipated to be short-term.

The removal of the temporary dykes in the realignment of the D and E watersheds and lowering of water levels in lakes D2 and D3, and E1 will modify the permafrost conditions in the exposed shoreline areas. Increases in TSS and sedimentation in the nearshore zone of these lakes are anticipated, but will be localized and have a minor influence on shallow fish habitat. As a result, the residual effects to the fish are predicted to be negligible.

Removal of the temporary dykes for the realignment of diverted B, D and E watersheds to Kennady Lake may release sediment and change water and sediment quality, and affect fish habitat and fish

At the end of operations, diversion Dykes E, F, and G will be breached. Prior to breaching the dykes, the water levels in the raised lakes will be drawn down through pumping or siphoning. Silt curtains will also be installed within the drawn down lakes and downstream of the dykes before breaching activities are initiated. The silt curtains will minimize the release of suspended sediment to downstream channels. These curtains will remain in place until TSS concentrations between the dyke and the silt curtains have been reduced below required levels. Disturbance associated with the development of the dykes will also be minimized by avoiding construction during the spring freshet when the potential for erosion is highest.

Environmental design features and mitigation, such as silt curtains, restricting breaching activities to low or no-flow periods, and undertaking monitoring during breaching activities, will limit sediment resuspension and sedimentation. As a result, localized, minor changes to water and sediment quality are expected. Residual effects of dyke construction to fish and fish habitat in the diverted upper watersheds are predicted to be negligible.

Despite the realignment of the B, D and E watersheds to Kennady Lake, fish exclusion measures within the downstream channels will impede large-bodied fish migration from the upper watersheds into Kennady Lake until Kennady Lake is reconnected to Area 8.

Release of groundwater into the refilled Tuzo Pit may change groundwater quality in the pit, and affect water quality and fish in Kennady Lake

Flooding of the Tuzo Pit basin (Tuzo Pit and unfilled portion of the 5034 Pit) with fresh water will alter hydraulic gradients until new pressure and chemical equilibriums are established, which are predicted to take more than 1,000 years. The water quality within the talik that will reform directly under the refilled Kennady Lake will initially be more dilute due to fresh water from the pit flowing into the talik groundwater system. This will be expected to be a long-term effect.

Flooding of the backfilled and empty pit will be done in a controlled manner. Once the pits are refilled, groundwater, with a higher salinity and density than fresh water, may seep into the pit. The ingress of groundwater will be slow and as pit filling continues, density stratification will develop where the lower-density fresh water will float on top of the higher-density saline water. The hydrogeology modelling (Section 11.6) indicates that fluid density gradients will create very little flux and that reaching new equilibrium conditions with baseline groundwater chemistry will take a very long time. As a neutral hydraulic gradient is expected between the groundwater and refilled Tuzo Pit basin, it is expected that there will be no active movement of groundwater into Tuzo Pit.

The alteration to surface and deep groundwater regimes associated with Tuzo Pit and the development of a density gradient within Tuzo Pit is expected to have a negligible influence on groundwater quality in the pit, and surface water quality in Kennady Lake. The strong density gradients and potential for chemocline development will isolate the elevated TDS associated with deep groundwater in the deeper zones of the pit. Therefore, residual effects to fish after the reconnection of Kennady Lake to the upper watersheds and Area 8 are expected to be negligible.

The long-term stability of the saline water at the bottom of the Tuzo Pit basin was considered to be a primary effects pathway.

Pumping water from Lake N11 to Kennady Lake to supplement refilling may change water and sediment quality in Kennady Lake, and affect aquatic health, and fish

At the end of mine life, the water elevations in all water storage areas within Area 1 to 7 will be lowered to 417.0 m by siphoning the water from Areas 3 and 5, Area 6 and Area 7 to the mined-out Tuzo Pit. It is estimated that the total volume of water required to raise the water elevation in the entire lake area, including Areas 1 to 7 and the mined-out pits, to the original Kennady Lake elevation of 420.7 m will be 56.0 Mm^3. To reduce the time required to refill Kennady Lake, the closure Water Management Plan requires annual supplemental pumping of water from Lake N11 to Area 3. The average annual volume of water that can be pumped from Lake N11 has been estimated to be 3.7 Mm^3 per year, which represents no more than 20% of the normal annual flow from Lake N11. The required filling time is estimated to be approximately eight years of both pumping from Lake N11 and natural surface runoff accumulation. Natural surface runoff flows to Kennady Lake are much smaller in volume, such that it would take about 15 to 16 years to fill the lake using natural inflow alone. Groundwater inflow rates to the open pits will be small.

The water quality of the water pumped from Lake N11 to supplement the Kennady Lake refilling will be consistent with that measured in Kennady Lake during existing conditions. Any variability in water quality of the flows from Lake N11 will be within the natural range of variability reported for Kennady Lake.

The water quality in Kennady Lake at closure will possess a higher total dissolved solids concentration than the diverted inflows from Lake N11. The process of supplementing the natural refilling from watershed inflows will provide dilution potential to Kennady Lake.

During refilling, Kennady Lake will remain close circuited. Pumping water from Lake N11 to Kennady Lake to supplement refilling is expected to have a measurable influence on water quality because it will result in dilution of the water retained in Area 3, and Kennady Lake. This change is positive and as a result, residual effects to water quality from the pumping of supplemental water from Lake N11 are predicted to be negligible. Prior to the reconnection of Kennady Lake to Area 8, there will not be fish in the Areas 3 through 7.

The long-term water quality of Kennady Lake after refilling and effects to fish as a result of the Project is a primary effects pathway.

Release of sediment into Areas 7 and 8 during the removal of Dyke A may change water and sediment quality, and affect fish habitat and fish

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. As such residual effects to fish in Area 8 will be negligible.

Underwater noise and vibrations during the breaching and removal of Dyke A may affect fish

The noise and vibration disturbance from removing Dyke A in Area 8 will have a negligible effect on fish, as Dyke A will be breached and removed using heavy machinery, such as long-armed backhoes. Only if necessary will explosives be used.

Underwater noise will be generated by the removal of boulders and any crushing of rock or concrete by heavy machinery to facilitate the dyke breaching. However, noise levels and vibrations from these sources are expected to be low. Mann et al. (2009) found that activities associated with diamond exploration, such as under-water drilling (46 dB higher than ambient noise levels), helicopter hovering (60 dB higher than ambient), and walking on ice (30 dB higher than ambient) all produced noise in Kennady Lake greater than ambient at a control site. However, all anthropogenic (man-made) noises fell within the range of natural background noise (44 dB to greater than the 105 dB spectrum level in the

200 to 300 hertz [Hz] band) in Kennady Lake. Most of the anthropogenic sounds measured were considered to be only detectable by fish species with specialized hearing adaptations, such as chub and suckers (Mann et al. 2009). There is the potential impact that anthropogenic noise of this type may mask natural sounds for these species (Mann et al. 2009).

As a result, lake chub are likely to be the only fish species present in Area 8 able to hear noises generated by excavation of Dyke A. The masking of natural sounds could potentially make lake chub more susceptible to predation or reduce their feeding efficiency. However, this will have a negligible effect on lake chub in Area 8 because the breaching and removal of Dyke A will not be continuous (i.e., only occur during the day shift) and disturbance duration is not expected to extend beyond one month. Fish will also have the ability to move away from the noise and continue to seek cover in the boulders along the shoreline. The abundance of predators (i.e., lake trout, burbot, and northern pike) in Area 8 at closure is also likely to be lower than pre-disturbance conditions.

Noise disturbance as a result of the breaching and removal of Dyke A will be limited to fish present in Area 8, because fish are not expected in Kennady Lake upstream of the dyke before its removal. The disturbance to fish in Area 8 is anticipated to be minor, while being localized to the construction area and limited to the period of time to complete the breaching and removal activities. Consequently, residual effects to fish in Area 8 will be negligible.

Reconnection of Areas 3 to 7 with Area 8 may change water flows and water levels in Area 8, and affect fish habitat and fish

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

Removal of Dyke A will change fish migration through the Kennady Lake watershed

Once Kennady Lake is refilled and water quality conditions meet specific criteria, Dyke A will be breached and removed to allow for the reconnection of the lake with Area 8. It is expected that after removal of Dyke A, migrant fish will be enter the refilled portions of Kennady Lake from Area 8, which is expected to contain residual populations of lake chub, slimy sculpin, ninespine stickleback and burbot. Fish from the watershed downstream of Area 8, such as Arctic grayling, will also be able to migrate into Kennady Lake. Habitat under Dyke A will be replaced with similar large boulders, and the width and average depth of the narrows between Areas 7 and 8 will be similar to what currently exists in the lake (70 m and 2.5 m, respectively). As a result, fish will be able to migrate through the narrows between Areas 7 and 8 as they were before the Project. Consequently, residual effects to fish will be negligible.

Restocking Kennady Lake with fish from other local lakes may change brood-stock fish population in the Kennady Lake watershed and affect genetics or parasites of fish in Kennady Lake

After water quality in the refilled Kennady Lake is suitable for aquatic life, and a self-sustaining lower trophic community has established, including round whitefish, benthic invertebrates, phytoplankton, and zooplankton, lake trout may be transplanted into Kennady Lake from other lake sources. Potential donor lakes for lake trout for stocking Kennady Lake would be Lake 410 or Kirk Lake, which would maximize the likelihood of transferring fish with similar genetic composition as the lake trout in the Kennady Lake watershed. Stocking success is increased if the source population has genetic traits that have adapted it to similar habitat present in the lake to be stocked (Powell and Carl 2004).

A re-stocking plan for Kennady Lake will be required to include genetic analyses of lake trout in Kennady Lake before drawdown and from lake trout in candidate donor lakes to determine which lakes would provide the closest genetic match to lake trout in Kennady Lake. Genetic analyses of progeny from transplanted fish in Kennady Lake will also be conducted.

Fish will not be considered for transfer from any donor lake where the condition of lake trout is poor (e.g., low weight to length ratio, evidence of heavy parasite loading). This will ensure that potentially diseased or parasitized fish are not transferred to Kennady Lake.

Restocking Kennady Lake with fish from other lakes within the LSA is expected to result in minor changes to the genetic makeup of the lake trout population relative to baseline conditions. As a result of the upper watershed diversion and fish salvage prior to operations, lake trout would have been completely removed from Kennady Lake upstream of Area 8, and the assumption has been made that Area 8 would not support a self-sustaining population of lake trout during the mine operation. Lake trout that migrate to Kennady Lake after reconnection with the upper watershed and Area 8 (e.g., from Lake I1 and other lakes) may possess slightly different genetics from lake trout that were established in Kennady Lake prior to salvage, primarily because of the length of time between the initial fish salvage, isolation and reconnection of Kennady Lake (i.e., approximately 20 years). As a consequence, restocking of Kennady Lake with lake trout after reconnection with the upper watershed and Area 8 is predicted to result in negligible residual effects to fish.

Restocking Kennady Lake with fish to establish the fish community structure to aid in the recovery of the aquatic ecosystem in Kennady Lake is discussed in Section 8.11.

8.6.2.8 Primary Pathways for Effects from Closure

The remaining pathways for water quality and fish in Kennady Lake and its watershed during closure are classified as primary and are carried forward as effects statements (Table 8.6-5) to be assessed in the effects analysis sections (Sections 8.7 to 8.12).

Table 8.6-5 Effects Statements for Water Quality and Fish during Closure

Discipline	Project Activity	Pathway	Effects Statement
Hydrology	reclaimed Project footprint	the Project may change the long-term change hydrology in the Kennady Lake watershed	Long-term effects of mine development to hydrology of Kennady Lake
	removal of the temporary diversion dykes in the B, D, and E watersheds	removal of dykes may change flows, water levels, and channel/bank stability in streams and small lakes in the B, D, and E watersheds, changes to water levels in Lakes D2, D3, and E1 may lead to shoreline erosion, re-suspension of sediments and sedimentation	Effects of temporary dyke removal to flows, water levels and channel/bank stability in Kennady Lake
	refilling of Kennady Lake	continued isolation of Area 8 during refilling and recovery period may change surface water flows, water levels and water quality in Area 8, which may affect fish and fish habitat	Effects of diversion of flows, water levels and channel/bank stability in Area 8
			Effects of refilling activities on flows, water levels and channel/bank stability in Areas 3, 4, 5, 6 and 7
Water Quality	refilling of Kennady Lake	co-mingling of water in Tuzo Pit with water in Areas 3 to 7 during refilling may change water quality in Kennady Lake, and delay ecosystem recovery	Long-term effects of changes to pit water quality on the stability of meromictic conditions in the Tuzo Pit basin
		release or generation of mercury, nutrients, or other substances into Areas 3 to 7 from flooded sediments and vegetation during refilling of Kennady Lake may change water quality	Effects of Project activities to water quality in Kennady Lake and Area 8 during and after refilling
		release of saline water from the Tuzo Pit to surface waters of Kennady Lake may change water quality	
	breaching Dyke A to reconnect Kennady Lake with Area 8	reconnection of Areas 3 to 7 with Area 8 may change water quality in Area 8	
	mine rock and coarse PK piles	seepage and runoff from the mine rock and coarse PK piles may change water quality in Kennady Lake after refilling	
	Fine PKC Facility	seepage through filter dyke from the Fine PKC Facility after refilling may change water quality in Kennady Lake	
	full or partial backfilling of Hearne Pit with processed kimberlite	seepage from backfilled PK material in pits may change water quality in Kennady Lake	
Aquatic Health	breaching Dyke A to reconnect Kennady Lake with Area 8	altered water quality in Kennady Lake and Area 8 resulting in changes to aquatic health to waterbodies within the Kennady Lake watershed	Effects of water quality changes to aquatic health in waterbodies within the Kennady Lake watershed

Discipline	Project Activity	Pathway	Effects Statement
Fish and Fish Habitat	reclaimed Project Footprint	development of fish habitat compensation works to account for HADD associated with the Project	Effects of Project closure and post-closure activities to fish and fish habitat in Kennady Lake, and streams and lakes within the Kennady Lake watershed
	removal of the temporary diversion dykes in the B, D and E watersheds	changes to flow paths, water levels and lake areas in the B, D and E watersheds may change lower trophic levels, fish communities and migration	
	refilling of Kennady Lake	continued isolation of Area 8 during refilling may affect fish populations	
	post-closure activities	changes to water quality in Area 8 may change lower trophic communities, fish habitat, and fish communities	
		changes to aquatic health may affect fish populations and abundance	

8.7 EFFECTS TO WATER QUANTITY

The pathway analysis presented in Section 8.6 considered potential pathways for effects to hydrology in Kennady Lake and the Kennady Lake watershed. A summary of the primary pathways by which changes to water quantity could occur during construction and operations is presented in Table 8.7-1, and during closure in Table 8.7-2.

Section 8.7.1 provides an overview of the methodology used to develop the hydrology predictions within Kennady Lake and the Kennady Lake watershed during construction and operations, followed by a discussion of the results of the effects analysis in Section 8.7.3.

Table 8.7-1 Valid Pathways for Effects to Water Quantity in the Kennady Lake Watershed during Construction and Operations

Project Activity	Pathway	Effects Statement	Effects Addressed
Project footprint (e.g., dykes, mine pits, mine rock and coarse PK piles, Fine PKC Facility, access roads, mine plant, airstrip)	reduction in watershed areas may change flows, water levels, and channel/bank stability in streams and small lakes in the Kennady Lake watershed	Effects of mine rock and coarse PK piles and Fine PKC Facility to flows, water levels and channel/bank stability in streams and smaller lakes in the Kennady Lake watershed	Section 8.7.3.1
Dewatering of Kennady Lake	dewatering of Area 7 to Area 8 may change flows, water levels, and channel/bank stability in Area 8	Effects of dewatering Kennady Lake to flows, water levels and channel/bank stability in Area 8	Section 8.7.3.2
Isolation and diversion of upper Kennady Lake watersheds	changes in A, B, D and E watershed areas and flow paths may change flows, water levels, and channel/bank stability in the Kennady Lake watershed	Effects of watershed diversions in watersheds A, B, D and E to flows, water levels and channel/bank stability in streams and smaller lakes in the Kennady Lake watershed	Section 8.7.3.3
	shoreline erosion, re-suspension of sediments and sedimentation may change due to changes in water levels in Lakes A3, D2, D3, and E1		

PKC = processed kimberlite containment.

Table 8.7-2 Valid Pathways for Effects to Water Quantity in the Kennady Lake Watershed during Closure

Project Activity	Pathway	Effects Statement	Effects Addressed
Refilling of Kennady Lake	continued isolation of Area 8 during refilling and recovery period may change surface water flows, water levels and water quality in Area 8, which may affect fish and fish habitat	Effects of refilling activities on flows, water levels and channel/bank stability in Areas 3, 4, 5, 6, and 7	Section 8.7.4.1
		Effects of diversion of flows, water levels and channel/bank stability in Area 8	Section 8.7.4.2
Removal of the temporary diversion dykes in the B, D and E watersheds	removal of dykes may change flows, water levels, and channel/bank stability in streams and small lakes in the B, D, and E watersheds, changes to water levels in Lakes D2, D3, and E1 may lead to shoreline erosion, re-suspension of sediments and sedimentation	Effects of temporary dyke removal to flows, water levels and channel/bank stability in Kennady Lake	Section 8.7.4.3
Reclaimed Project footprint	the Project may change the long-term change hydrology in the Kennady Lake watershed	Long-term effects of mine development to hydrology of Kennady Lake	Section 8.7.4.4

Section 8.7.2 provides an overview of the methodology used to develop the hydrology predictions within Kennady Lake and the Kennady Lake watershed during closure, followed by a discussion of effects analysis results in Section 8.7.4.

8.7.1 Effects Analysis Methods – Construction and Operations

8.7.1.1 Water Balance Model

A water balance 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 watersheds, including Kennady Lake, its tributaries, and land area adjacent to the lake.

The water balance for each watershed considered rainfall and snowmelt runoff, inflow from upstream watersheds, changes in lake storage, lake evaporation, and outflow 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 watershed A, upstream of the Lake A3 outlet, was permanently diverted out of the Kennady Lake watershed due to the presence of Dyke C during Operations;
- watershed A, 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 watershed B was diverted out of the Kennady Lake watershed due to the presence of temporary Dyke E during Operations;
- runoff from watershed D, 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 watershed E, 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 (114,000 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 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).

8.7.1.2 Analysis

For each modelling scenario, the time series of temperature and precipitation was imposed on the water balance model for the entire 56-year modelling period. The resulting time series of flows at key nodes, including Area 8, were subject to frequency analysis to determine median flows and those for 5-, 10-, 20-, 50- and 100-year wet and dry conditions. Values were calculated for monthly mean daily outflow volumes as well as representative flows including 1-, 7-, and 14-day peak flows and 30-, 60-, and 90-day low flows. These simulated discharges are presented in figures and tables.

Effects on Kennady Lake tributary watersheds were evaluated by quantifying changes to watershed areas and using water balance components to determine the corresponding changes to mean annual water yields and lake water surface elevations.

Effects on channel and bank stability were evaluated qualitatively by identifying changes relative to baseline and the corresponding monitoring and mitigation methods to be applied.

8.7.2 Effects Analysis Methods – Closure

8.7.2.1 Water Balance Model

The baseline water balance model referred to in Section 8.7.1.1, and described in Annex H (Climate and Hydrology Baseline), was modified to represent changes to Area 8 of Kennady Lake and downstream watersheds during closure and refilling.

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 runoff to Areas 3 to 7 of Kennady Lake was restored.

Two refilling scenarios were modelled, to evaluate the Base Case scenario and one alternative:

- The Base Case scenario involved refilling Kennady Lake with runoff from the reconnected Kennady Lake watershed with supplemental diversion from Lake N11 to Kennady Lake Areas 3, 4, 5, 6 and 7 to reduce the refill time.
- The No Pumping scenario involved refilling Kennady Lake only with runoff from the Kennady Lake watershed, with no diversions from the adjacent watershed.

The Base Case is intended to represent conditions during refilling, including the effects of planned mitigation (pumped diversion from Lake N11). The No Pumping scenario is intended to demonstrate the positive effect of the mitigation provided in the Base Case scenario.

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 outflow equal to the 5-year dry flow condition (refer to Section 9.10). 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.

The No Pumping scenario was identical to the baseline water balance model, except Area 8 was separated from the other areas of Kennady Lake.

8.7.2.2 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 outflow 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.

8.7.2.3 Analysis

The analysis approach for closure is identical to that described in Section 8.7.1.2.

8.7.3 Effects Analysis Results – Construction and Operations

8.7.3.1 Effect of Project footprint (dykes, mine pits, mine rock and Coarse PK piles, Fine PKC Facility, access roads, mine plant and airstrip) on Flows, Water Levels and Channel/Bank Stability in Streams and Smaller Lakes in the Kennady Lake Watershed

8.7.3.1.1 Project Activities

Project Surface Infrastructure

Project surface infrastructure, aside from the Fine PKC Facility, Coarse PK Pile, South Mine Rock and West Mine Rock piles and watershed diversions, includes the camp and plant site, processing facilities, sewage treatment plant, explosives management facilities, airstrip and site roads.

The camp site will include an accommodations complex, administration offices, maintenance complex, warehouse, power plant and storage facilities for oil, fuel and de-icing fluid. The plant will include processing facilities for crushing, cleaning and screening, concentration, diamond recovery and disposal of fine and coarse PK. The camp, plant and sewage treatment plant will be located in Area 6 and Area 7.

Explosives management facilities will include explosives magazines, ammonium nitrate storage and an emulsion plant. These will be located in Area 1, to the east of the Fine PKC Facility.

The Airstrip will be located across Kennady Lake from the camp and plant facilities, in Area 7 and Area 8. It will be accessed via a causeway on top of Dyke A. The airstrip will include an aviation fuel storage tank incorporating spill prevention features and mobile de-icing equipment.

Site service and dedicated haul roads will be constructed throughout the Kennady Lake watershed to provide land access to mine infrastructure. These will be developed using compacted granular fill over general fill material. Road grades will generally be limited to 8%, and will provide for two 4 metre (m) wide lanes with 1 m wide shoulders, except for roads to outlying portions of the mine, which may be provided with one 4 m wide lane with 0.5 m shoulders.

Mine Rock Piles

The South Mine Rock Pile, with an ultimate footprint area of 0.778 square kilometres (km^2), will be developed starting in Year -2 on the south side of Kennady Lake. This will occupy portions of the bed of Area 6 and local tributary watersheds Kc and F.

The West Mine Rock Pile, with an ultimate footprint area of 0.789 km^2, will be developed starting in Year 3 on the west side of Kennady Lake. This will occupy portions of the bed of Kennady Lake Area 5 and local tributary watershed Ka.

Water from the mine rock piles will be managed to remain within the mine closed-circuited area and will be conveyed by constructed ditches or by natural drainage paths, where appropriate, to the WMP (Areas 3 and 5).

Coarse PK Pile

The Coarse PK Pile, with an ultimate footprint area of 0.323 km^2, will be developed starting in Year 1 on land in Area 4. During the latter part of

Operations, coarse PK will be used as reclamation cover for the Fine PKC Facility or placed in open pits.

Fine PKC Facility

The Fine PKC Facility, with an ultimate footprint area of 1.554 km^2, will be developed starting in Year -1 on the northeast side of Kennady Lake. This will occupy portions of the bed of Area 2 and local tributary watersheds Ka and A (Area 1). In Year 1 and 2, fine PK will be deposited in Area 1, followed by deposition in Area 2 in Years 3 to 8. After that time, fine PK will be deposited in the mined-out Hearne Pit. The Fine PKC Facility will ultimately be capped with coarse PK and mine rock.

8.7.3.1.2 Residual Effects

Project Surface Infrastructure

Plant and Camp

The camp and plant areas will have a footprint of approximately 0.333 km^2, and will be located primarily in Watersheds Kb (0.261 km^2) and Kd (0.047 km^2), with a small footprint in the upland area of Watershed I (0.024 km^2 or 3% of the watershed area of 0.746 km^2 Watershed I). Water flows will be managed within these areas, with natural drainage patterns used, where practical, to minimize the use of ditches or diversion berms. Runoff will be conveyed to the WMP (Areas 3 and 5).

Airstrip

The airstrip will be located about 1 km southeast of the plant site on the opposite side of Kennady Lake, in watersheds Kd, Ke, and H. It will have a total surface area of 0.15 km^2. Runoff from about 50% of the airstrip (eastern portion) will be conveyed to Area 8 via natural drainage paths. Runoff from the remainder (western portion) will be conveyed to Area 8 via natural and enhanced drainage paths. Sediment traps (e.g., filter cloth silt fences) will be installed to intercept sediment and will be cleaned out as required.

Explosives Management

Explosives management facilities have a footprint of approximately 0.025 km^2, and will be located in Watersheds Ka (0.023 km^2), Kb (0.019 km^2) and A (0.006 km^2). Water flows will be managed within these areas, with natural drainage patterns used, where practical, to minimize the use of ditches or diversion berms. Runoff will be conveyed to the WMP.

Access Roads

Runoff from access roads within the mine closed-circuited area will be conveyed to the WMP using natural drainage patterns, where practical, to minimize the use of ditches or diversion berms. Watercourse crossings will be constructed using culverts or rock drains to prevent upstream ponding and flows across the road surface.

A summary of effects on flows, water levels, and channel/bank stability is provided below:

- Effects on flows:
  - Tributaries to Areas 2 to 7 of Kennady Lake that include Project infrastructure and are not assessed elsewhere include watersheds A, Ka, Kb and Kd. All runoff from these watersheds will be conveyed to the WMP by the site water management system.
  - Tributaries to Area 8 that include Project infrastructure and are not assessed elsewhere include watersheds H, I, and Ke. All infrastructure within these watersheds will be free-draining and no measurable effect on the quantity of inflow to Area 8 of Kennady Lake is anticipated.
- Effects on water levels:
  - No measurable hydrological effects are anticipated on any waterbodies due to the Project infrastructure discussed in this section.
- Effects on channel/bank stability:
  - No effects on natural channel or bank stability are anticipated, as no natural lakes will be affected, and constructed ditches will incorporate erosion and sediment control measures.

Mine Rock Piles

The South Mine Rock Pile will be located in Area 6 of Kennady Lake, which is located within the closed-circuit site water management system. Besides land areas, the South Mine Rock Pile footprint of 0.778 km^2 will cover the existing Lake F1 outlet channel and a portion of the bed of Kennady Lake. Watersheds and basins affected, and the associated area of the South Mine Rock Pile, are summarized below and in Table 8.7-3:

- Area 6 of Kennady Lake: The South Mine Rock Pile will occupy 0.506 km^2 of the 1.778 km^2 land and lake area of Area 6.
- Watershed Kc: The South Mine Rock Pile will occupy 0.254 km^2 of the 1.695 km^2 land area in watershed Kc. All of the area occupied by the mine rock pile drains directly to Kennady Lake under baseline conditions, with no defined waterbodies.
- Watershed F: The South Mine Rock Pile will occupy 0.018 km^2 of the 0.300 km^2 watershed F. This includes the lower portion of the Lake F1

outlet channel, which drains directly to Kennady Lake under baseline conditions. Lake F1 (0.039 km^2) will not be disturbed, and its outflow will be diverted around the South Mine Rock Pile via a constructed diversion channel or natural watercourses with appropriate erosion control measures.

The West Mine Rock Pile will be located in Area 5 of Kennady Lake, which is located within the closed-circuit site water management system. Besides land areas, the South Mine Rock Pile footprint of 0.789 km^2 will cover the existing Lake Ka1 and its outlet channel, and a portion of the bed of Kennady Lake. Watersheds and basins affected, and the associated area of the South Mine Rock Pile, are summarized below and in Table 8.7-3:

- Area 5 of Kennady Lake: The West Mine Rock Pile will occupy 0.348 km^2 of the 2.448 km^2 watershed associated with the WMP (Areas 3 and 5).
- Watershed Ka: The West Mine Rock Pile will occupy 0.441 km^2 of the 1.695 km^2 Ka watershed area that drains to Kennady Lake. Some of this area drains directly to Kennady Lake under baseline conditions, with the remainder draining through Lake Ka1 (0.009 km^2) and its outlet channel. Lake Ka1 and its outlet channel will be completely covered by the West Mine Rock Pile and upstream flow will be diverted to Kennady Lake via a constructed diversion channel or natural watercourses with appropriate erosion control measures.

Mine rock will also be used to cap the Fine PKC Facility and the Coarse PK Pile, and effects are addressed in the discussion of those facilities in the following, sub-sections.

Table 8.7-3 Effects of Mine Rock Piles on Watershed Areas

Mine Rock Pile	Watershed/ Lake Area	Description	Watershed Area/ Lake Area (km^2)	Lake Area (%)
South	Kennady Lake Area 6	existing	1.778	100
		construction and operations	1.272	100[a]
	Kc	existing	1.695	0.0
		construction and operations	1.441	0.0
	F	existing	0.300	13.0
		construction and operations	0.282	13.8
West	Kennady Lake Area 3 and 5	existing	2.448	100
		construction and operations	2.100	100[b]
	Ka	existing	2.237	0.4
		construction and operations	1.796	0.0

(a) This portion of Kennady Lake will be dewatered during construction and operations.

(b) This portion of Kennady Lake will be partially dewatered and refilled during construction and operations.

km^2 = square kilometres; % = percent.

During construction and operations, it is estimated that direct precipitation to the mine rock piles will collect and freeze in interstices in the stored mine rock and that the mean annual water yield from the mine rock pile will be about 116 mm, or about half of that for natural vegetated land surfaces.

A summary of effects on flows, water levels and channel/bank stability is provided below:

- Effects on flows:
  - The mine rock piles will be located entirely within the mine closed-circuited area and all drainage will be managed as part of the closed-circuit site water management system.
- Effects on water levels:
  - Lake F1 will not be affected by the South Mine Rock Pile. A small portion (6%) of the tributary area to its outlet channel, downstream of Lake F1, will be occupied by the South Mine Rock Pile
  - Lake Ka1 and its outlet channel will be covered by the West Mine Rock Pile.
- Effects on channel/bank stability:
  - No effects on natural channel or bank stability are anticipated, because runoff around the mine rock pile perimeters and in the diverted Lake F1 outlet channel will be managed to prevent channel erosion.

Coarse PK Pile

The Coarse PK Pile will be located in Area 4 of Kennady Lake, which is located within the closed-circuit site water management system. Besides land areas, the Coarse PK Pile footprint of 0.323 km^2 will cover Lake Kb4 and its outlet channel, and a portion of the bed of Kennady Lake. Watersheds and lake areas affected, and the associated area of the Coarse PK Pile, are summarized below and in Table 8.7-4:

- Area 4 of Kennady Lake: The Coarse PK Pile will occupy 0.006 km^2 of the 0.762 km^2 Area 4 of Kennady Lake.
- Watershed Kb: The Coarse PK Pile will occupy 0.316 km^2 of the 1.375 km^2 Kb watershed area that drains to Kennady Lake. Some of this area drains directly to Kennady Lake under baseline conditions, with the remainder draining through Lake Kb4 (0.010 km^2) and its outlet channel. Lake Kb4 and its outlet channel will be completely covered by the Coarse PK Pile and flow from upstream will be diverted to Kennady Lake via a constructed diversion channel or natural watercourses with appropriate erosion control measures.

Table 8.7-4 Effects of Coarse PK Pile on Area 4

Watershed/ Lake Area	Description	Watershed/ Lake Area (km^2)	% Lake Area
Kennady Lake Area 4	baseline area	0.762	100.0
	Coarse PK Pile footprint	0.006	100.0
	area unaffected by Coarse PK Pile footprint	0.756	100.0
Watershed Kb	baseline area	1.375	4.1
	Coarse PK Pile footprint	0.316	3.1
	area unaffected by Coarse PK Pile footprint	1.059	4.4

km^2 = square kilometres; % = percent; PK = processed kimberlite.

A summary of effects on flows, water levels, and channel/bank stability is provided below:

- Effects on flows:
  - All runoff from the Coarse PK Pile will be located entirely within the mine closed-circuited area and all drainage will be managed as part of the closed-circuit site water management system.
- Effects on water levels:
  - Construction and operation of the Coarse PK Pile will result in the permanent loss of Lake Kb4 as a waterbody, with a lake area of approximately 0.010 km^2.
- Effects on channel/bank stability:
  - No effects on natural channel or bank stability are anticipated, due to construction of the Coarse PK Pile. Runoff from the facilities and upstream areas will be managed with internal and perimeter ditches to prevent channel erosion.

Fine PKC Facility

The Fine PKC Facility will be located in Areas 1 and 2 of Kennady Lake, which are located within the closed-circuit site water management system. Besides land areas, the Fine PKC Facility footprint of 1.554 km^2 will cover Lake A1 and its outlet channel, Lake A2 and its outlet channel, and a portion of the bed of Kennady Lake (Area 2). Watersheds and lake areas affected, and the associated footprint area of the Fine PKC Facility, are summarized below and in Table 8.7-5:

- Area 2 of Kennady Lake: The Fine PKC Facility will occupy 0.584 km^2 of Area 2 (0.626 km^2). Dyke L will occupy an additional 0.042 km^2 of Area 2 of Kennady Lake. The lake area of Area 2 will be completely filled.

- Watershed Ka: The Fine PKC Facility will occupy 0.100 km^2 of the 2.237 km^2 land area in watershed Ka. All of the area occupied by the Fine PKC Facility drains directly to Kennady Lake under baseline conditions, with no defined waterbodies. Dykes D, E and L will occupy an additional 0.028 km^2 of land area in watershed Ka.
- Watershed A: The Fine PKC Facility will occupy 0.492 km^2 of the 1.593 km^2 land area in watershed A, and will also completely cover Lakes A1, A2, A5 and A7, with a total lake area of 0.378 km^2, for a total footprint of 0.870 km^2. Dyke C will occupy an additional 0.019 km^2 of land area and 0.001 km^2 of lake area in Watershed A. The upper watershed, including Lake A3, will be diverted to the N lakes watershed, and this is discussed in Section 8.7.3.3.

Seepage water from the Fine PKC Facility will flow towards Area 2, where it will seep through the permeable Dyke L into the WMP. This will include runoff from undisturbed portions of the Area 2 (Watershed Ka) upland.

Table 8.7-5 Effects of Fine PKC Facility on Area 1 and Area 2

Watershed/ Lake Area	Description	Watershed/Lake Area (km^2)	% Lake Area
Kennady Lake Area 2	baseline area	0.626	100.0
	Fine PKC Facility footprint	0.584	100.0
	Dyke L footprint	0.042	100.0
	area unaffected by Fine PKC Facility footprint	0.000	100.0
Watershed Ka	baseline area	2.246	0.4
	Fine PKC Facility footprint	0.100	0.0
	Dyke D, E and L footprint	0.028	0.0
	area unaffected by Fine PKC Facility footprint	2.118	0.4
Watershed A	baseline area	2.237	28.8
	Fine PKC Facility footprint	0.870	43.4
	Dyke C footprint	0.020	5.0
	area unaffected by Fine PKC Facility footprint	0.840	28.7
	area diverted to L watershed	0.507	5.0

km^2 = square kilometres; % = percent; PKC = processed kimberlite containment.

A summary of effects on flows, water levels, and channel/bank stability is provided below:

- Effects on flows:
  - All runoff from the Fine PKC Facility will be located entirely within the mine closed-circuited area and all drainage will be managed as part of the closed-circuit site water management system.
- Effects on water levels:
  - Construction and operation of the Fine PKC Facility will result in the permanent loss of Kennady Lake Area 2 as a waterbody, with a lake area of approximately 0.626 km^2. It will also result in the permanent loss of lakes A1, A2, A5 and A7 and outlet channels, with a total lake area loss of approximately 0.379 km^2.
- Effects on channel/bank stability:
  - No effects on natural channel or bank stability are anticipated, due to construction of the Fine PKC Facility. Runoff from the facilities and upstream areas will be managed with internal and perimeter ditches to prevent channel erosion.

8.7.3.2 Effects of Dewatering of Kennady Lake to Flows, Water Levels and Channel/Bank Stability in Area 8

8.7.3.2.1 Project Activities

Kennady Lake Areas 2, 3, 4, 5, 6, and 7 will be partially or completely dewatered at stages during the construction and operation of the Project to allow mine pit development on the lake-bed. Key steps in this activity will include:

- Dyke A will be constructed across the narrows between Area 7 and Area 8;
- Areas 2 to 5 will be dewatered to Lake N11 through active pumping from Area 3, and Areas 6 and 7 will be dewatered to Area 8 through active pumping from Area 7. It is estimated that at a minimum 2 m drawdown will be achieved before bottom sediments have a significant impact on water quality. Active pumping from Area 7 will cease when the water quality in Area 7 approaches specific water quality criteria for discharge;
- Dewatering will expose sills on the lakebed. Dyke H will be constructed on the sill between Area 5 and Area 6, and Dyke J will be constructed on the sill between Area 4 and Area 6. These will separate Areas 2 to 5 from Areas 6 and 7, and allow Areas 3 and 5 to then serve as the WMP for the Project;

- The remaining water from Areas 6 and 7 will be dewatered to Area 5 of the WMP, to allow mining of the 5034 and Hearne pits. A pervious dyke may be constructed within Area 5 if required to control TSS concentrations in the WMP. As groundwater will be pumped to the WMP, active pumped discharge from Area 3 will continue as long as the water quality in Area 3 meets specific water quality criteria for discharge;
- Between Year 4 and Year 5, Dyke B will be constructed to separate Area 3 and Area 4 of Kennady Lake. Area 4 will then be dewatered to the WMP between Year 5 and 6 to allow mining of the Tuzo Pit;
- In Year 6, Dyke K will be constructed to its final height between Area 6 and Area 7 of Kennady Lake.

A summary of the Kennady Lake dewatering schedule is provided in Table 8.7-6. During the dewatering period, discharges will be limited so that flows at the outlet of Kennady Lake (stream K5) do not exceed the 1 in 2 year flood value of 114,000 m^3/d. During operations, natural flows from Areas 2 to 7 will no longer flow into Area 8 due to the construction of Dyke A, but runoff from undisturbed areas within the Area 8 watershed will still flow to Area 8.

Table 8.7-6 Kennady Lake Areas 2 to 7 Dewatering Schedule

Period	Kennady Lake Area	Project Activity	Water Surface Elevation at End of Period (masl)
Baseline	Areas 2 to 7	None.	420.7
Year -2 to Year -1	Areas 2, 3, 4 and 5	Dewater to Lake N11.	~418.7
	Areas 6 and 7	Dewater while meeting TSS criteria to Area 8; remaining water decanted to Area 5.	<414.5
Year 1 to Year 4	Areas 2, 3, 4 and 5	Annual discharge from Area 3 to Lake N11.	~418.7
	Areas 6 and 7	Maintain as dewatered.	<414.5
Year 5 to Year 6	Areas 2, 3 and 5	Operate as closed system, unless water quality permits discharge to Lake N11.	~420.7
	Area 4	Dewater to WMP (Areas 3 and 5) to allow mining.	405.0
	Areas 6 and 7	Maintain as dewatered.	<414.5
Year 6 to Year 8	Areas 2, 3 and 5	Allow to fill to ~2 m above original lake elevation. Allow overflow to Area 6 mined-out pits.	~422.1
	Area 4	Maintain.	405.0
	Area 6	Maintain. East portion allowed to refill after mining of Hearne Pit is complete.	404.0
	Area 7	Dyke off Area 7 and allow to refill.	<419.8
Year 9 to Year 11	Areas 2, 3 and 5	Maintain at ~2 m above original lake elevation.	~422.6
	Area 4	Maintain.	405.0
	Area 6	Maintain, with continued filling of east portion.	404.0
	Area 7	Allow to refill.	~420.7
End of Project	Areas 3 to 7	Begin flooding Tuzo Pit with water from Areas 3, 6 and 7. Begin supplemental pumping refill of Areas 2 to 7.	n/a

masl = metres above sea level; ~ = approximately; < = less than.

8.7.3.2.2 Residual Effects

Dewatering of Areas 2 to 7 will reduce the quantity of water in these lake areas to water stored in the WMP (Areas 3 and 5) and in local depression storages (collection ponds). All water in Areas 2 to 7 will be in the mine closed-circuit area and will be managed by the Project.

Dyke A will prevent water from flowing from Area 8 into Area 7 during construction and operations. Area 8 will be preserved as a free-draining waterbody throughout this period, though its hydrological regime will be changed.

During dewatering, discharges from Area 7 of Kennady Lake will be limited to ensure that 2-year flood conditions (1 in 2 year maximum daily discharge) are not exceeded within Area 8 or its outlet channel. During dewatering, no direct discharge will occur if snowmelt or rainfall runoff cause water levels to exceed the 2-year flood water level in Area 8.

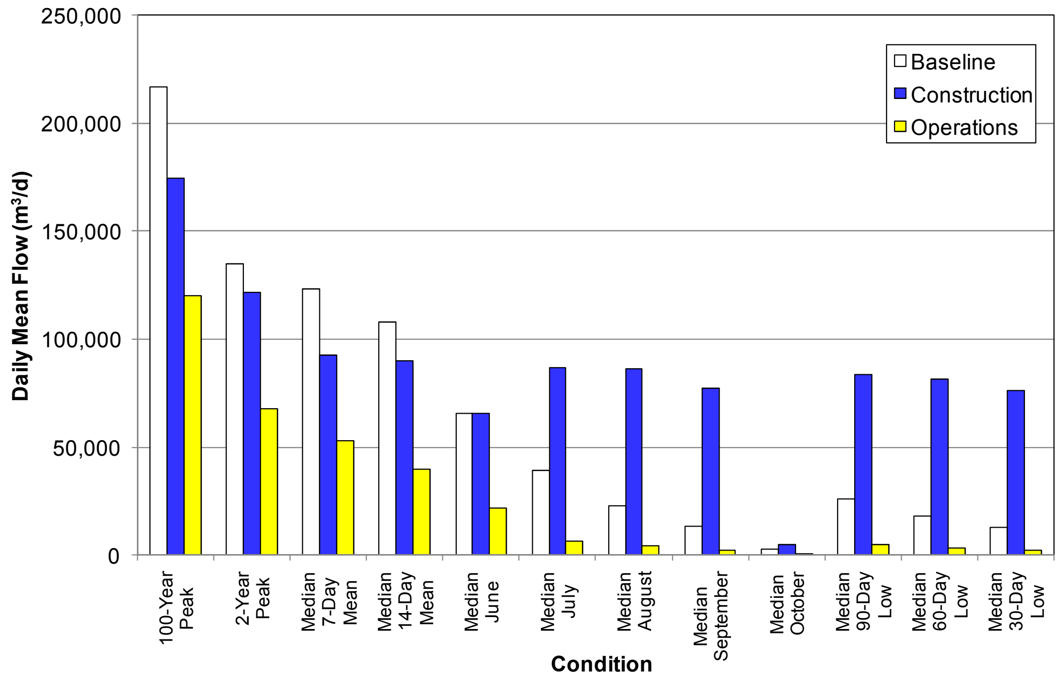
Diffusers will be used to dissipate the energy of water pumped into Area 8 during the dewatering. These diffusers will be placed as close to the surface as possible to increase the distance between the outfall and the bottom sediments. Although some sediment may be mobilized despite these measures, the extent of this effect is likely to be limited to the zone of turbulence immediately adjacent to the diffuser, and is likely to quickly diminish after sediments in the zone of turbulence are mobilized and become re-deposited further away from the outfall.

Discharges from Area 8 and water levels in Area 8 were modeled for dewatering during construction and operations. Project effects on Area 8 during construction and operations are shown in Figure 8.7-1 and Figure 8.7-2, and summarized in Table 8.7-7 to Table 8.7-10.

Construction: The water balance results for Area 8 show that monthly mean flows will be approximately equal to baseline during the natural high water month of June, and will be greater than baseline during the natural low water months of July to September. The 100-year and 2-year flood discharges will be lower than baseline due to the reduction in upstream drainage area and low pumping capacity relative to the natural flood discharges. Under median conditions, low flows will increase during construction.

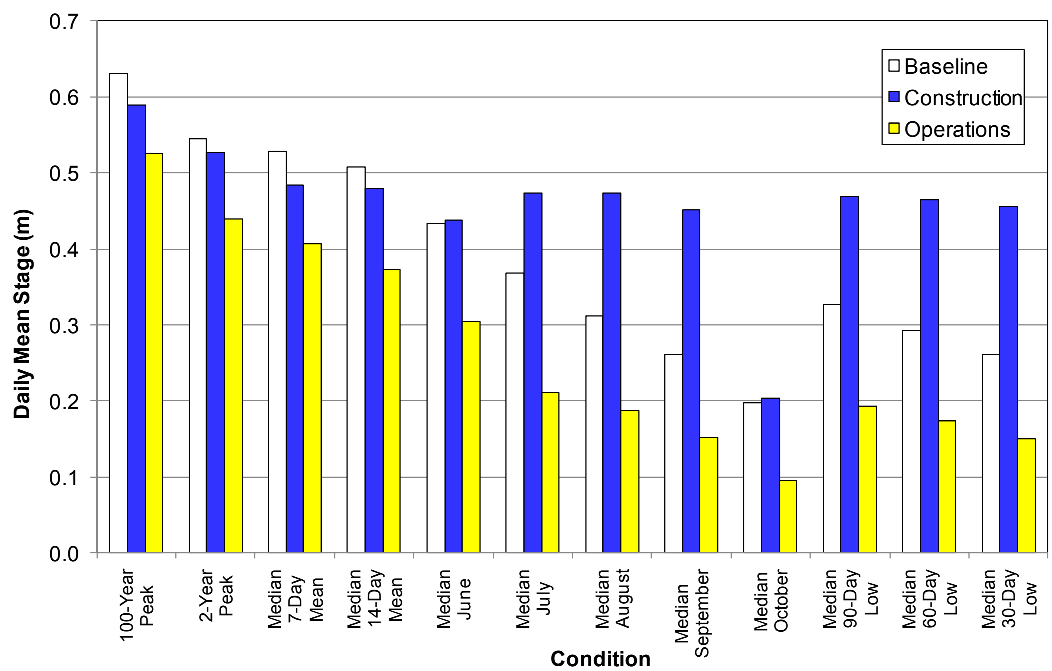
Operations: The water balance results for Area 8 show that when pumped discharge from Area 7 ceases, flows will be reduced from baseline. Results for the month of November are not shown because conditions during construction and operations for that month are expected to be similar to baseline, due to frozen conditions.

Figure 8.7-1 Comparison of Effects on the Outlet of Kennady Lake (Stream K5) Discharges during Construction and Operations



m^3/d = cubic metres per day.

Figure 8.7-2 Comparison of Effects on the Outlet of Kennady Lake (Stream K5) Water Level during Construction and Operations



m = metres.

Table 8.7-7 Mean Daily Outflow Volumes at the Outlet of Kennady Lake (Stream K5) – Construction and Operations

Condition	Return Period (years)	Snapshot	Monthly Mean Daily Outflow Volume (m^3)				
			June	July	August	September	October
Wet	100	baseline	121,000	86,500	59,600	68,600	13,500
		construction	91,500	92,800	93,300	90,800	18,400
		operations	35,500	19,600	14,700	16,900	2,030
	10	baseline	97,600	61,900	38,100	29,200	6,640
		construction	83,800	89,600	89,700	88,100	10,200
		operations	30,700	12,000	8,680	6,620	967
Median	2	baseline	65,900	39,300	22,800	13,200	3,070
		construction	65,700	86,600	86,500	77,200	4,680
		operations	21,900	6,670	4,580	2,460	371
Dry	10	baseline	36,900	23,100	13,900	6,880	1,430
		construction	41,000	85,500	85,400	57,300	1,880
		operations	12,000	3,570	2,310	892	91
	100	baseline	12,900	12,000	9,420	4,910	878
		construction	6,470	84,900	84,800	43,800	1,270
		operations	2,380	1,880	1,390	496	18

m^3 = cubic metres.

Table 8.7-8 Representative Discharges at the Outlet of Kennady Lake (Stream K5) – Construction and Operations

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
		construction	2.02	103,000	96,900	91,800	90,100	89,200
		operations	1.39	85,200	61,000	10,500	14,100	13,300
	10	baseline	2.14	166,000	145,000	26,200	32,300	41,000
		construction	1.68	97,600	93,100	88,100	87,500	87,700
		operations	1.11	71,700	52,600	5,070	7,200	8,450
Median	2	baseline	1.56	123,000	108,000	12,800	18,300	26,000
		construction	1.41	92,600	89,900	76,100	81,400	83,800
		operations	0.78	52,900	39,900	2,100	3,390	4,830
Dry	10	baseline	0.798	64,600	59,900	6,990	10,900	16,000
		construction	1.24	89,400	88,000	56,700	71,800	77,500
		operations	0.46	31,100	23,700	900	1,820	2,720
	100	baseline	0.0013	1,680	9,110	4,760	7,480	10,500
		construction	1.16	88,100	87,200	42,300	64,000	72,200
		operations	0.21	10,800	7,400	473	1,260	1,680

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

Table 8.7-9 Mean Daily Water Levels at the Outlet of Kennady Lake (Stream K5) – Construction and Operations

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			June	July	August	September	October
Wet	100	baseline	0.531	0.471	0.425	0.443	0.315
		construction	0.497	0.492	0.492	0.490	0.291
		operations	0.367	0.297	0.267	0.283	0.166
	10	baseline	0.498	0.430	0.370	0.341	0.256
		construction	0.479	0.484	0.484	0.483	0.254
		operations	0.348	0.257	0.231	0.214	0.137
Median	2	baseline	0.433	0.368	0.311	0.262	0.197
		construction	0.438	0.474	0.474	0.452	0.204
		operations	0.304	0.210	0.187	0.152	0.096
Dry	10	baseline	0.361	0.312	0.270	0.217	0.156
		construction	0.392	0.472	0.472	0.392	0.163
		operations	0.250	0.174	0.153	0.113	0.059
	100	baseline	0.299	0.269	0.246	0.197	0.136
		construction	0.356	0.472	0.472	0.343	0.139
		operations	0.203	0.149	0.133	0.095	0.039

m^3 = cubic metres.

Table 8.7-10 Representative Water Levels at the Outlet of Kennady Lake (Stream K5) – Construction and Operations

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	0.631	0.607	0.582	0.397	0.406	0.421
		construction	0.590	0.501	0.491	0.483	0.480	0.479
		operations	0.525	0.472	0.425	0.246	0.270	0.265
	10	baseline	0.600	0.581	0.557	0.327	0.349	0.376
		construction	0.557	0.492	0.485	0.477	0.476	0.476
		operations	0.490	0.447	0.406	0.197	0.219	0.230
Median	2	baseline	0.544	0.529	0.508	0.262	0.293	0.327
		construction	0.527	0.484	0.480	0.456	0.465	0.470
		operations	0.439	0.407	0.373	0.150	0.174	0.194
Dry	10	baseline	0.442	0.433	0.423	0.217	0.249	0.281
		construction	0.507	0.479	0.477	0.416	0.448	0.458
		operations	0.373	0.345	0.317	0.115	0.143	0.162
	100	baseline	0.060	0.140	0.236	0.193	0.222	0.246
		construction	0.496	0.477	0.475	0.380	0.432	0.448
		operations	0.290	0.249	0.221	0.094	0.128	0.140

m = metre.

A summary of effects on flows, water levels, and channel/bank stability is provided below:

- Effects on flows:
  - Construction of dyke A across the narrows will reduce the outflow from Area 7 into Area 8 to zero. All discharges from Area 7 to Area 8 during construction and operations will be by direct discharge during dewatering.
  - During dewatering, flows from Area 8 will generally be increased and the duration of the flood period will be extended through September; however, flows will be limited so that dewatering does not cause the total flow to exceed the 2-year flood discharge.
  - During Operations, when dewatering has ceased, flows from Area 8 will be reduced from baseline, because only the local tributary area (Watersheds I, J and Ke) will contribute runoff to Area 8.

- Effects on water levels:
  - Water levels in Areas 3 to 7 will be managed to allow mining and changes water levels will follow the schedule presented in Table 8.7-6.
  - Changes to water levels in Area 8 will correspond to changes in flows. For median conditions, the greatest changes in June to October mean monthly stage are expected to occur in September during construction (+0.190 m) and July for operations (-0.158 m).

- Effects on channel/bank stability:
  - No effects on channel stability in the Kennady Lake watershed are anticipated, as all dewatering flows will be pumped via pipeline to receiving waterbodies or pumped to receiving streams rather than conveyed by natural channels. No effects on bank stability are anticipated, due to the drop in water levels. Exposed lake-bed areas may be subject to erosion by runoff, depending on the type of substrate present. However, all water within Areas 3 to 7 will be managed to prevent the release of water to the natural receiving environment if TSS concentrations exceed specific water quality criteria.
  - Water levels in Area 8 and discharges from its outlet channel will be maintained below baseline 1 in 2 year flood levels throughout construction and operations, except where natural exceedences occur while pumped diversions are suspended. No adverse effects on channel or bank stability are anticipated.

8.7.3.3 Effect of Watershed Diversion in Watersheds A, B, D and E on Flows, Water Levels and Channel/Bank Stability in Streams and Smaller Lakes in the Kennady Lake Watershed

8.7.3.3.1 Project Activities

To reduce the amount of natural runoff into the dewatered Areas 2 to 7 of Kennady Lake, and the amount of water that must be managed by the site water management system, several upstream tributary watersheds will be diverted to the adjacent N watershed during operations. These diversions will remain in place until the start of Kennady Lake refilling.

Watershed A above Lake A2 will be diverted to Lake N9. Permanent Dyke C will be constructed across the existing Lake A3 outlet to Lake A2. The mean water level in Lake A3 will be raised by approximately 3.5 m. The new outlet channel from Lake A3 to Lake N9 will be approximately 150 m long at a bed slope of 2.6%. All diversion channels will be designed and constructed to prevent erosion and sedimentation and to incorporate lessons learned from the Ekati Diamond Mine (Jones et al. 2003).

Watershed B will be diverted to Lake N8. Temporary Dyke E will be constructed across the existing Lake B1 outlet to Kennady Lake. The mean water level in Lake B1 will not be raised, because the natural water surface is approximately 1.3 m above that in Lake N8. The new outlet channel from Lake B1 to Lake N8 will be approximately 275 m long at a bed slope of 0.5%.

Watershed D above Lake D1 will be diverted to Lake N14. Temporary Dyke F will be constructed across the existing Lake D2 outlet. The mean water level in Lake D2 will be raised by approximately 2.8 m and the mean water level in Lake D3 will be raised by approximately 1.6 m, as the area between the two lakes is flooded and they form a continuous waterbody. The new outlet channel from Lake D2/D3 to Lake N14 will be approximately 120 m long at a bed slope of 1.4%. Lake D1 is located downstream of the saddle dyke and will receive runoff from the local watershed only during the diversion period.

Watershed E will also be diverted to Lake N14. Temporary Dyke G will be constructed across the existing Lake E1 outlet. The mean water level in Lake E1 will be raised by approximately 0.8 m. The new outlet channel from Lake E1 to Lake N14 will be approximately 25 m long at a bed slope of 3.4%.

8.7.3.3.2 Residual Effects

Diversion of watersheds A, B, D and E will reduce the amount of runoff from undisturbed areas that must be managed by the site water management system.

Natural streams immediately downstream of the saddle dykes will be dry while the watershed diversions are in place, and flows to receiving streams will increase. The water level within the diverted lakes will also increase. A summary of hydrological changes to Lakes A3, B1, D2, D3 and E1 is provided in Table 8.7-11.

Table 8.7-11 Hydrological Effects on the Outflows from the A, B, D and E Watersheds during Operations

Lake	Condition	Local Lake Parameters			Watershed Parameters				
		Surface Area	Perimeter	Maximum Depth	Watershed Area	Lake Surface Area		Mean Annual Water Yield	
		(ha)	(m)	(m)	(km^2)	(km^2)	(%)	(mm)	(m^3)
A3[a]	Baseline	23.77	2,360	12.4	0.839	0.241	28.7	162	136,000
	Diverted	46.55	3,470	15.9	0.839	0.466	55.5	98	82,500
B1	Baseline	8.21	2,340	4.1	1.269	0.174	13.7	198	251,000
	Diverted	8.21	2,340	4.1	1.269	0.174	13.7	198	251,000
D1	Baseline	1.88	780	[b]	4.497	1.027	22.8	175	788,000
	Diverted	1.88	780	[b]	0.349	0.019	5.4	210	73,300
D2	Baseline	12.53	2,320	1.0	4.148	1.008	24.3	172	713,000
	Diverted	103.00	6,460	3.8	4.148	1.447	34.9	155	645,000
D3	Baseline	38.37	4,070	3.0	2.957	0.839	28.4	163	481,000
	Diverted	[c]	[c]	4.6	[c]	[c]	[c]	[c]	[c]
E1	Baseline	20.24	2,780	3.9	1.225	0.244	19.9	182	223,000
	Diverted	26.98	3,150	4.7	1.225	0.311	25.4	173	212,000

(a) Lake A4, with a pre-diversion lake area of 0.35 ha and an unknown depth, will also be inundated when Lake A3 is raised.

(b) Maximum depth unknown; no change anticipated due to Project.

(c) Included in values provided for raised Lake D2.

km^2 = square kilometre; % = percent; m = metre; mm = millimetre.

Diversion outlet structures will be designed and managed to provide an outflow rating curve that approximates the natural outflow rating curve, to the extent possible, during construction and operations. Because of the increase in proportion of lake water surface area for raised lakes, greater evaporative losses are expected and the mean annual water yield from the diverted portion of Lake A3 watershed will be reduced from 136,000 to 82,500 m^3 (a reduction of 39%), the mean annual water yield from the diverted portion of the D watershed will be reduced from 788,000 to 718,300 m^3 (a reduction of 10% from the watershed above the Lake D2 outlet and 9% from the entire watershed), and the mean annual water yield from the diverted portion of the E watershed will be reduced from 223,000 to 212,000 m^3 (a reduction of 5%). The D watershed below the Dyke F at the Lake D2 outlet will not be disturbed. The mean annual water yield from the local watershed is expected to be the same as baseline, though the inflow from Lake D2 will be interrupted while the diversion is in place. This will increase the residence time of water in the lake and reduce lake outflows.

The increase in lake storage in the Lake A3 watershed will be about 1,100,000 m^3, due to the increase in the water surface elevation of Lake A3. This volume is about 10 times the mean annual water yield from the diverted watershed, meaning that, for mean conditions, there will be no outflow from the diverted watershed as Lake A3 fills until the eleventh year of Operations. However, if water is transferred to Lake A3 during Area 1 dewatering, the time until outflow occurs would be reduced.

The increase in lake storage in the D2/D3 lakes watershed will be about 1,400,000 m^3, due to the increase in the water surface elevation of Lakes D2 and D3. This volume is about twice the mean annual water yield from the diverted watershed, meaning that, for mean conditions, there will be no outflow from the diverted watershed as these lakes fill until the third year of operations.

The increase in lake storage in the E1 watershed will be about 110,000 m^3, due to the increase in the water surface elevation of Lake E1. This volume is about half the mean annual water yield from the diverted watershed, meaning that, for mean conditions, outflow from the raised Lake E1 should commence in the first year of operations.

Raising of the water levels in Lakes A3, D2, D3 and E1 will create new shorelines at higher elevations than the existing shorelines. This will expose new soils, often on steeper slopes than the existing shorelines, to wave erosion and potential instability due to permafrost disturbance. A recent regulatory application (MHBL 2005) included a review of historical research and six case studies of lakes being raised in northern environments. Annual shoreline erosion for these case studies ranged from 0.14 m^3/m to 1.08 m^3/m, and a best estimate of 0.23 m^3/m was suggested for the lake that was the subject of the regulatory application. This lake had a fetch length of approximately 1 km, similar to those at Lakes A3, D2/D3 and E1, and shorelines comprising deposits of fine marine sediments including clay fractions.

Table 8.7-12 shows the approximate lengths of new shoreline that will be established at each raised lake, broken down by soil units corresponding to those described in Annex D (Bedrock Geology, Terrain, Soil and Permafrost Baseline). Surficial soils have the following Associations:

- Lobster Lake (moraine veneer, with till >1 m thick);
- Wolverine Lake (moraine veneer, with till <1 m thick);
- Sled Lake (shallow to deep bog and mixed fen and bog peat);
- Dragon Lake (shallow to deep fen peat); and

- Goodspeed (shallow organic soils derived from sedge, cottongrass, willow, birch and alder species.

Table 8.7-12 shows that of a total new shoreline length of 13 km:

- 3.7 km has a water erosion risk rating of Low;
- 5.7 km has a water erosion risk rating of Low (Moderate);
- 2.4 km has a water erosion risk rating of Low (High); and
- 0.4 km has a water erosion risk rating of Moderate.

The remaining 0.8 km of dyke face will be armoured appropriately to prevent erosion. These water erosion risk ratings were developed to assess the risk of erosion from flowing water, based on rainfall intensity, soil erodibility and terrain slope and length, so they are not directly applicable to erosion due to wave action at shorelines. However, they are indicative of the greater erosion resistance of organic soils (i.e., Dragon, Sled and Goodspeed Lake Associations) and morainal soils (i.e., Wolverine and Lobster Lake Associations) relative to more fine-grained lacustrine soils that are not present in the area. Approximately 8.1 km of the new shoreline will comprise morainal soils, and 4.1 km will comprise organic soils.

Furthermore, morainal soils, as described in Section D5.3.1.2 of Annex D, contain coarse fractions up to boulder size. These are erosion-resistant due to the natural armouring that occurs with these larger sized soil fractions; the fine fractions are eroded away and coarser fractions are left behind. The sand and larger fractions of morainal soils have high settling velocities relative to silts and clays, and are unlikely to contribute to persistent or non-localized increases in TSS concentrations.

Bog and fen peat soils are typically associated with low-slope terrain that is less susceptible to wave erosion and would similarly not contribute silt and clay sediment fractions that would result in elevated TSS concentrations.

Table 8.7-12 Characteristics of New Shorelines at Lakes A3, D2/D3 and E1

Lake	Shoreline Length (m)	Soil Unit	Description (From Table D6.3-3)	Erosion Risk (from Annex D Table D6.3-5)[(a)]
A3	180	W1u	Wolverine Lake Association dominant; minor inclusions of Bedrock and Sled Lake, Dragon Lake, and Goodspeed Lake unit, landforms are undulating in the W1u unit associations	M
	2,570	WS1	Wolverine Lake and Sled Lake associations are co-dominant; minor inclusions of Dragon Lake and Goodspeed Lake associations; the landform is undulating to hummocky with bog forms in the WS1 unit	L (M)
	370	SD1	Sled Lake and Dragon Lake associations co-dominant; minor inclusions of Goodspeed Lake Association; landforms are polygonal peat plateau, northern peat plateau and lowland polygon bogs, with level to gently inclined forms	L
	350	Dyke Face		n/a
	3,470	Total		
D2/D3	350	W2	Wolverine Lake Association dominant; inclusions of Sled Lake Association; minor inclusions of Bedrock, and of Goodspeed Lake and Dragon Lake associations; the landform is undulating to hummocky in the W2 unit	L (H)
	70	WS1u	See WS1 above	L (M)
	1,570	WS2u	Wolverine Lake and Sled Lake associations are co-dominant; inclusions of the Dragon Lake Association occur; landforms are undulating in the WS2u unit, with subdominant bog forms (plateau and polygonal)	L (M)
	310	S3u	Sled Lake Association dominant; inclusions of the Wolverine and Dragon Lake associations; landforms are polygonal peat plateau, northern peat plateau and lowland polygon bogs, with undulating upland in the S3u unit	L (M)
	510	SD1	See SD1 above	L
	110	SD2	the Sled Lake and Dragon Lake associations are co-dominant; inclusions of Wolverine Lake Association; landforms are polygonal peat plateau, northern peat plateau and lowland polygon bogs	L (M)
	230	Dyke Face		n/a
	3,150	Total		
E1	230	W1u	See W1u above	M
	990	W2	See W2 above	L (H)
	1,080	W3	Wolverine Lake Association dominant; inclusions of Sled Lake and Dragon Lake associations occur; the landform is undulating to hummocky, with inclusions of Bog and Fen forms	L (H)
	360	WS1	See WS1 above	L (M)
	730	WS2u	See WS2u above	L (M)
	1,440	SD1	See SD1 above	L
	1,380	D3	Dragon Lake Association dominant; inclusions of the Sled Lake Association; landforms are complexes of bog and fen forms, including horizontal and lowland polygon fens, with polygonal peat plateau, northern peat plateau and lowland polygon bogs	L
	250	Dyke Face		n/a
	6,460	Total		

[(a)] L = Low, L (M) = Low (Moderate), L (H) = Low (High), M = Moderate. The ratings Low (Moderate) and Low (High) indicate that there are some areas of soil complexes in which one of the soil components has a rating higher than Low. Generally, the Medium and High ratings apply to Wolverine Lake soils that occur on hummocky topography with slopes in the 6 to 15% or higher slope categories.

It is possible that shoreline erosion rates at the Project could be similar to those predicted for Tail Lake (MHBL 2005). However, the armouring action of morainal materials and the rapid settling of its coarse fractions from the water column, along with the location of organic soils in low-gradient locations, mean that increases in TSS concentrations during the lake level increases are expected to be low. It is expected that the lakes with the largest changes in elevation (A3 and D2/D3) will take three or more years to fill to an elevation that will result in discharge to the N watershed, leaving time to observe shoreline and TSS conditions and assess the need for specific mitigation.

A detailed survey of future shoreline areas to identify areas of significant erosion potential on a finer spatial scale will be performed during construction to establish a monitoring program baseline. The monitoring program will include visual inspection of shoreline characteristics and periodic TSS monitoring. Should areas of significant erosion be identified during construction and operations, mitigation measures, including placement of rock armour material to arrest erosion, will be undertaken.

A summary of effects on flows, water levels and channel/bank stability is provided below:

- Effects on flows:
  - Annual outflows from raised lakes (i.e., Lakes A3, D2/D3 and E1) will be reduced somewhat from baseline due to increased evaporation from the lake water surfaces. The annual outflow from Lake D1 into Kennady Lake will be greatly reduced, because of the upstream diversion. The annual outflow from Lake B1 will be unchanged.
  - Constructed diversion channels will convey water from the diverted areas to receiving waterbodies in the N watershed, once water surface elevations have increased to the spill elevation. The general shapes of the annual hydrographs in these diversion channels will be similar to that of the natural lake outflows, though peak and annual flows will be reduced due to increased evaporative losses.

- Effects on water levels:
  - The nominal water level of Lake A3 will increase by 3.5 m, the nominal water level of Lake D2 will increase by 1.6 m, the nominal water level of Lake D3 will increase by 2.8 m, and the nominal water level of Lake E1 will increase by 0.8 m. The nominal water level of Lake B1 will not be affected.
  - Annual variation in water levels in the raised lakes will be similar to pre-diversion values.

- Effects on channel/bank stability:
  - Diversions will consist of constructed channels designed to prevent erosion and to maintain stability in permafrost.
  - Raised lakes will be subject to erosion as new shorelines are established. Natural armoring of the 8.1 km of morainal soils is expected to limit erosion in these areas and persistent TSS generation is expected to be limited as coarse materials settle out on the lakebed near to where they are mobilized. Low slopes in new shoreline areas with organic (peat) soils are expected to minimize erosion and generation of TSS. A monitoring and mitigation program will be incorporated in an adaptive management plan for shoreline erosion.

8.7.4 Effects Analysis Results – Closure

8.7.4.1 Effect of Refilling Activities on Flows, Water Levels and Channel/Bank Stability in Areas 3, 4, 5, 6, and 7

8.7.4.1.1 Activity Description

Kennady Lake refilling will use natural runoff from Areas 2, 3, 4, 5, 6 and 7, including upstream tributary watersheds, plus a diversion of flow from Lake N11 to shorten the refill time.

Pumping of water from Lake N11 will be restricted to years where the annual runoff volume upstream of the N11 lake outlet will be greater than the 5-year dry annual runoff volume, to be protective of fisheries resources (refer to Section 9.10.4.1). This estimate will be based on measurements of snowpack and lake water surface elevation. When this criterion is met, the difference will be pumped to Area 3 of Kennady Lake. The diversion will occur within a 6-week period, centered between June and July. The difference between the 2-year median and 5-year dry annual runoff volume upstream of the Lake N11 outlet is estimated to be 3,715,000 m^3, or 88,550 m^3/d, over a 6-week period.

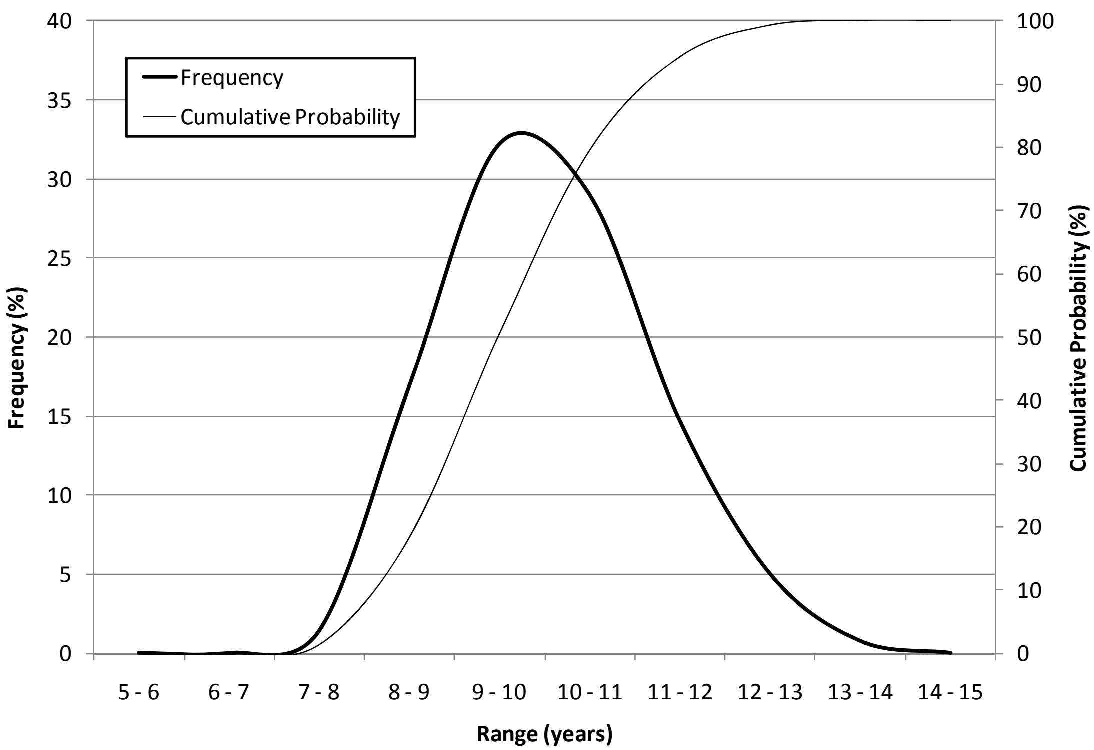
8.7.4.1.2 Residual Effects

To increase the rate of refilling and decrease the refilling time, flow will be diverted from Lake N11 to Area 3 of Kennady Lake.

The water balance model was used in conjunction with a Monte Carlo simulation to evaluate the probabilities of durations for Kennady Lake refilling. The simulations were based on a total lake refilling volume of 63.6 Mm^3, including mine pits and voids in mine rock placed below the final lake water level. The median refilling time for the Base Case scenario is about 8 to 9 years.

Detailed results for the Base Case scenario were placed in ranges along with the corresponding frequency of occurrence and cumulative probability. Results are presented in Figure 8.7-3 and Table 8.7-13. Corresponding lake water levels with time are shown in Figure 8.7-4 and Table 8.7-14. The median time to refill the mine pits is just over seven years, after which the lake proper will refill.

Figure 8.7-3 Kennady Lake Refilling Time Frequency and Cumulative Probability for Base Case Scenario



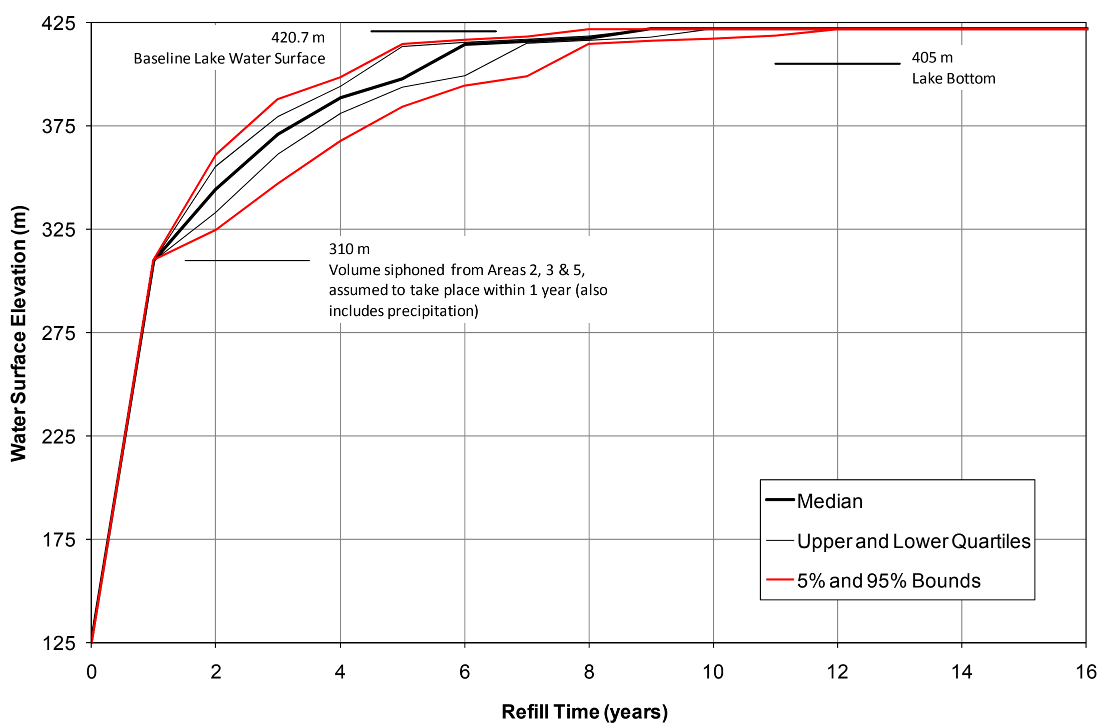
% = percent.

Table 8.7-13 Kennady Lake Refilling Time Frequency and Cumulative Probability for Base Case Scenario

Range (years)	Base Case Scenario		Range (years)	Base Case Scenario	
	Frequency (%)	Cumulative Probability (%)		Frequency (%)	Cumulative Probability (%)
5 to 6	0.00	0.00	10 to 11	29.00	79.56
6 to 7	0.00	0.00	11 to 12	14.68	94.24
7 to 8	1.40	1.40	12 to 13	5.00	99.24
8 to 9	16.92	18.32	13 to 14	0.76	100.00
9 to 10	32.24	50.56	14 to 15	0.00	100.00

% = percent.

Figure 8.7-4 Kennady Lake Water Levels with Time during Refilling – Base Case



m = metre.

Table 8.7-14 Kennady Lake Water Levels with Time during Refilling – Base Case, Median Conditions

Lake Depth (m)	Water Level (m)	Refilling Time (Years)
0	405.00	5.4
5	410.00	5.7
10	415.00	6.5
15	420.00	8.6
15.7	420.70	9.0

m = metre.

Areas of potential erosion during Kennady Lake refilling include direct discharge points and areas of unprotected sediment that are subject to wave action as the lake water level rises. The outfall of the pipeline in Area 3 from Lake N11 will be armoured to prevent local erosion, as will potentially erodible flow paths to lower elevations in the dewatered lake-bed and the Tuzo and Hearne mine pits. No water will be released downstream into Area 8 until the water level is equal to the water level in the upstream basins (about 420.7 m) and water quality in Area 7 meets specific water quality criteria. At that time, the shoreline will be at its naturally armoured baseline location and suspended sediment from prior wave action will have settled from the water column.

A summary of effects on flows, water levels, and channel/bank stability is provided below:

- Effects on flows:
  - During closure, all flow from Kennady Lake Areas 3, 4, 5, 6 and 7 tributary watersheds will contribute to lake refilling. Diversion of water from Lake N11 to Kennady Lake during refilling will reduce the median refilling time from 17 years to approximately 8 or 9 years.
- Effects on water levels:
  - Water levels in Kennady Lake will rise during refilling as a function of the cumulative inflow less lake evaporation.
- Effects on channel/bank stability:
  - The diversion pipeline outfall will be armoured to prevent erosion. No water will be released downstream from Kennady Lake Areas 3, 4, 5, 6 and 7 into Area 8 until the upstream water level is equal to that in Area 8 (and water quality in Area 7 meets specific water quality criteria). Water levels in the upstream Areas will not exceed the naturally armoured shoreline elevation. Therefore, no effects on channel or bank stability are anticipated.

8.7.4.2 Effect of Diversion on Flows, Water Levels and Channel/Bank Stability in Area 8

8.7.4.2.1 Activity Description

Refilling activities are described in detail in Section 8.7.4.1.1. During refilling, hydrological conditions at Area 8 will be similar to those during Operations. The only difference will be that potable water demand will likely be considerably reduced, but this will not have a significant effect on the water balance for the watershed.

8.7.4.2.2 Residual Effects

Discharges and water levels and associated residual effects during closure will be identical to those presented for operations in Section 8.7.3.2.2.

8.7.4.3 Effects of Temporary Dyke Removal to Flows, Water Levels and Channel/Bank Stability in Kennady Lake

8.7.4.3.1 Activity Description

During Closure, the temporary dykes involved in diversions of Lakes B1, D2/D3 and E1 to the N watershed will be removed to restore drainage of the upstream watersheds to Kennady Lake. Lake water levels will be drawn down to baseline levels prior to removal of the dykes. Lake outlets will be reconstructed to restore the baseline lake water level regime.

8.7.4.3.2 Residual Effects

Lake drawdown activities will require the transfer of approximately 1,400,000 m^3 of water from Lake D2/D3 (equal to approximately twice the natural annual water yield) and 110,000 m^3 of water from Lake E1 (equal to about half of the natural annual water yield) to Kennady Lake. This drawdown will be accomplished by pumping and/or siphoning flow over the dykes at the existing lake outlets. Flows in the natural outlet channels will be limited to the 2-year flood discharge, and dewatering could be accomplished in one year by maintaining this flow for an extended duration. Piping may be extended to discharge at armoured aprons on the shore of Kennady Lake if more rapid drawdown over a shorter duration is desired.

Lake B1 will not need to be drawn down, but the operational diversion will be decommissioned by constructing a permanent earthfill plug. Other operational diversions will be above the range of restored water levels and will not need to be blocked.

Temporary dykes at the natural lake outlets will be breached and the outlets restored to provide non-erodible control sections that restore the baseline water level and flow regimes of Lakes B1, D2, D3 and E1.

Baseline shorelines will be restored and it is expected that they will remain stable. Baseline water level and flow regimes in the lake outlet channels are expected to result in stable channels with natural rates of erosion. Shorelines will be monitored during and after the drawdown period for evidence of erosion or altered shoreline instability, including TSS monitoring in lakes. Mitigation in the form of armouring to prevent progressive erosion will be provided if required.

A summary of effects on flows, water levels, and channel/bank stability is provided below:

- Effects on flows:
  - Elevated flow rates during the drawdown of Lakes D2, D3 and E1 will be managed to ensure that flows do not exceed the baseline 2-year flood discharge.
  - During closure, natural flow regimes will be established in the outlet channels of Lakes B1, D2, D3 and E1.
- Effects on water levels:
  - The baseline lake water level regime in Lakes D2, D3 and E1 will be restored.
  - The baseline lake water level regime in Lake B1, maintained through construction and operations, will be maintained.
- Effects on channel/bank stability:
  - Drawdown flows will be managed to prevent erosion and instability in lake outlet channels.
  - Restoration of baseline lake outlet channel regimes will preserve channel stability with natural rates of erosion;
  - Restored baseline lake shorelines are expected to remain stable.

8.7.4.4 Long-term Effects of Mine Development on Hydrology of Kennady Lake

8.7.4.4.1 Activity Description

After Closure, the connection between Areas 3 to 7 and Area 8 of Kennady Lake will be restored, allowing unregulated downstream flow. Some changes to the land and water surfaces in the Kennady Lake watershed will remain, resulting in permanent reductions in the upstream watershed area and the proportion of lake area in the watershed.

8.7.4.4.2 Residual Effects

Changes to the Kennady Lake watershed will have a negligible effect on the post-closure (after refilling of Kennady Lake and removal of Dyke A) hydrological regime in the closure phase of the Project. Dyke A will be removed and all operational diversions within the watershed will be removed. Residual changes to the watershed will include:

- A net decrease in the total watershed area of Kennady Lake (from 32.46 km^2 to 31.62 km^2), due to the permanent diversion of the Lake A3 watershed to the adjacent N watershed.
- A net increase in the total land area (from 21.17 km^2 to 21.92 km^2) in the Kennady Lake watershed, due to the infilling of portions of Kennady Lake and some tributary lakes, partially offset by losses of land due to pit development.
- A net decrease in the total water surface area of Kennady Lake tributaries (from 3.14 km^2 to 2.51 km^2), due to the permanent diversion of Lake A3 to the adjacent N watershed, and infilling of Lakes A1 and A2, and some smaller tributary lakes by mine rock piles, the Coarse PK Pile and the Fine PKC facility. This will slightly increase the water yield of the Kennady Lake watershed, due to decreased lake evaporation.
- A net decrease in the water surface area of Kennady Lake (from 8.15 km^2 to 7.19 km^2), because the infill by the Fine PKC Facility, the Coarse PK Pile and the South Mine Rock and the West Mine Rock Piles will be greater than the removal of land area during excavation of the 5034, Tuzo and Hearne mine pits. This will change the area-elevation-storage relationship of Kennady Lake and cause less attenuation of flood flows.

A summary of changes to the land and lake areas within the Kennady Lake watershed is shown in Table 8.7-15.

Table 8.7-15 Post-closure Changes to Kennady Lake Watershed Land and Lake Areas

Area Description	Total Watershed (km^2)	Total Land (km^2)	Total Lake (km^2)	Kennady Lake (km^2)	Tributary Lake (km^2)	Lake Proportion (%)
Baseline Kennady Lake Watershed	**32.463**	**21.170**	**11.293**	**8.149**	**3.144**	**34.8%**
Diverted A3 Watershed	-0.839	-0.597	-0.241	-	-0.241	-
Kennady Lake less Lake A3 Watershed	**31.624**	**20.573**	**11.052**	**8.149**	**2.903**	**34.9%**
Infill - Mine Rock Covered Fine / Coarse PK	-	0.955	-0.955	-0.584	-0.371	-
Infill - Mine Rock Covered Coarse PK	-	0.016	-0.016	-0.006	-0.009	-
Infill - West Mine Rock Pile	-	0.348	-0.348	-0.339	-0.009	-
Infill - South Mine Rock Pile	-	0.506	-0.506	-0.506	-	-
Land Cut - 5034 Pit and Benches	-	-0.266	0.266	0.266	-	-
Land Cut - Tuzo Pit and Benches	-	-0.173	0.173	0.173	-	-
Land Cut - Hearne	-	-0.037	0.037	0.037	-	-
Kennady Lake Post-Closure	**31.624**	**21.922**	**9.703**	**7.190**	**2.513**	**30.7%**
Change	-0.839	0.752	-1.590	-0.959	-0.631	-

km^2 = square kilometres; PKC = processed kimberlite containment; % = percent; "-" = not applicable.

The reduced lake area will affect lake evaporation and evapotranspiration within the watershed and the annual outflow from Kennady Lake, while the increased land area will increase runoff to the lake. A water balance was completed using results from the baseline model simulation at the outlet of Area 8 (K5 Outlet). These calculations show that the mean annual water yield will increase by 8.9% at post-closure, from approximately 147 mm to 160 mm. Because the post-closure watershed area will be reduced by the permanent diversion of the Lake A3 watershed, the increase in mean annual discharge from Kennady Lake will increase by only 6.1%, from 4,760 cubic decametres (dam^3) to 5,050 dam^3.

Due to the post-closure decrease in Kennady Lake surface area by 11.8%, the runoff of a given quantity of water into the lake will result in a proportionally greater increase in lake water level. This would be offset somewhat by void spaces in the South and West Mine Rock piles, which will have a porosity of 23% and cover approximately 0.85 km^2. Changes to the Kennady Lake surface area will slightly increase post-closure flood peak discharges and water levels.

8.8 EFFECTS TO WATER QUALITY

The pathway analysis presented in Section 8.6 considered potential pathways for the Gahcho Kué Project (Project) activities to affect water quality in Kennady Lake and its watershed, including tributaries and small lakes. The implementation of environmental design features and mitigation into the Project eliminated potential pathways and reduced the number of potential effects that were carried forward to the detailed effect analysis. A summary of the valid pathways by which changes to water quality in Kennady Lake and the Kennady Lake watershed could occur during construction and operations is presented in Table 8.8-1.

Table 8.8-1 Effects to Water Quality in Kennady Lake and Streams and Smaller Lakes in the Kennady Lake Watershed – Construction and Operation

Project Component	Pathway	Effects Statement	Effects Addressed
Construction and mining activity during construction and operations	deposition of dust from fugitive dust sources may change water quality and sediment quality	Effects of the deposition of dust and metals from air emissions to water quality and lake bed sediments in waterbodies within the Kennady Lake watershed	Section 8.8.3.1
	air emission and deposition of sulphur dioxide, nitrogen oxides, particulate matter, and total suspended particulates may change water and sediment quality	Effects of acidifying air emissions to waterbodies within the Kennady Lake watershed	Section 8.8.3.2

A summary of the valid pathways by which changes to water quality in Kennady Lake and its watershed, including tributaries and small lakes, could occur during closure is presented in Table 8.8-2.

Table 8.8-2 Valid Pathways for Effects to Water Quality in Kennady Lake and the Kennady Lake Watershed – Closure

Project Component	Pathway	Effects Statement	Effects Addressed
Refilling of Kennady Lake	release or generation of mercury, nutrients, or other substances into Areas 3 to 7 from flooded sediments and vegetation during refilling of Kennady Lake may change water quality	Effects of Project activities to water quality in Kennady Lake and Area 8 during and after refilling	Section 8.8.4.1
	release of saline water from the Tuzo Pit basin to surface waters of Kennady Lake may change water quality		
Breaching Dyke A to reconnect Kennady Lake with Area 8	reconnection of Areas 3 to 7 with Area 8 may change water quality in Area 8		
Mine rock and Coarse PK piles	seepage and runoff from the mine rock and Coarse PK piles may change water quality in Kennady Lake after refilling		
Fine PKC Facility	seepage through filter dyke from the Fine PKC Facility after refilling may change water quality in Kennady Lake		
Refilling of Kennady Lake	co-mingling of water in Tuzo Pit with water in Areas 3 to 7 during refilling may change water quality in Kennady Lake, and delay ecosystem recovery	Long-term effects of changes to pit water quality on the stability of meromictic conditions in the Tuzo Pit basin	Section 8.8.4.2

PK = processed kimberlite; PKC = processed kimberlite containment.

Sections 8.8.1 and 8.8.2 provide an overview of the methods used to analyze the effects to water quality in Kennady Lake and its watershed during construction and operation, and closure, respectively. The discussion of analysis results is provided in Section 8.8.3 for construction and operations, and in Section 8.8.4 for closure.

8.8.1 Effects Analysis Methods – Construction and Operation

8.8.1.1 Deposition of Dust and Metals from Air Emissions to Water Quality and Lake Bed Sediments in Waterbodies within the Kennady Lake Watershed

8.8.1.1.1 Introduction

Windborne dust from Project facilities and exposed lake bed sediments, and air emissions from Project facilities may result in increased deposition of dust and associated metals in the surrounding area. The deposited dust may enter surface waters, particularly during spring freshet, and could result in increased concentrations of suspended sediments and associated metals in lake water.

This section evaluates potential changes in the concentrations of suspended sediments and metals from Project-related atmospheric deposition for lakes in the Kennady Lake watershed. Sections 8.8.1.1.2 and 8.8.1.1.3 describe the assessment approach and the study area, respectively. Section 8.8.1.1.4 summarizes the assessment methods. Section 8.8.3.1.1 provides the results of the analysis for baseline conditions, and during construction and operations.

8.8.1.1.2 Assessment Approach

A simple mass balance calculation was used to predict changes in total suspended solids (TSS) and metal concentrations in lake water from deposition on the lake surface and within the watershed, for selected lakes in the Kennady Lake watershed. Changes in TSS and metal concentrations were calculated based on total suspended particulate (TSP) deposition rate and individual metal deposition rates, respectively, as predicted by air quality dispersion modelling (Section 11.4 Subject of Note [SON]: Air Quality). The calculation was performed for baseline conditions and using maximum deposition rates during construction and operations. Predicted TSS concentrations are evaluated in Section 8.10 (Effects to Fish and Fish Habitat); predicted metal concentrations were compared to chronic water quality guidelines for the protection of aquatic life (CCME 1999) and background concentrations.

The approach used for this evaluation is highly conservative for the following reasons:

- It is based on air quality modelling, which incorporates conservative assumptions for emissions of dust and metals; in particular, modelling of dust emissions from roads did not account for reductions due to precipitation during summer or snow cover during winter (Section 11.4: Air Quality, Appendix 11.4.II).
- Predicted annual deposition rates were based on the maximum of the daily road dust emissions during summer and winter.
- No retention of particulates or metals was assumed in lake catchment areas.
- Settling of suspended sediments in lakes was not incorporated.
- Geochemistry data used to estimate metal concentrations in dust included a large proportion of concentrations below the analytical detection limit for cadmium, mercury, selenium, and silver.

Concentrations of these metals were set at the detection limit for air quality and deposition modelling.

As a result of these factors, predicted changes in TSS and metal concentrations in local lakes are considered to be conservative estimates of the maximum potential changes that could occur during construction and operations.

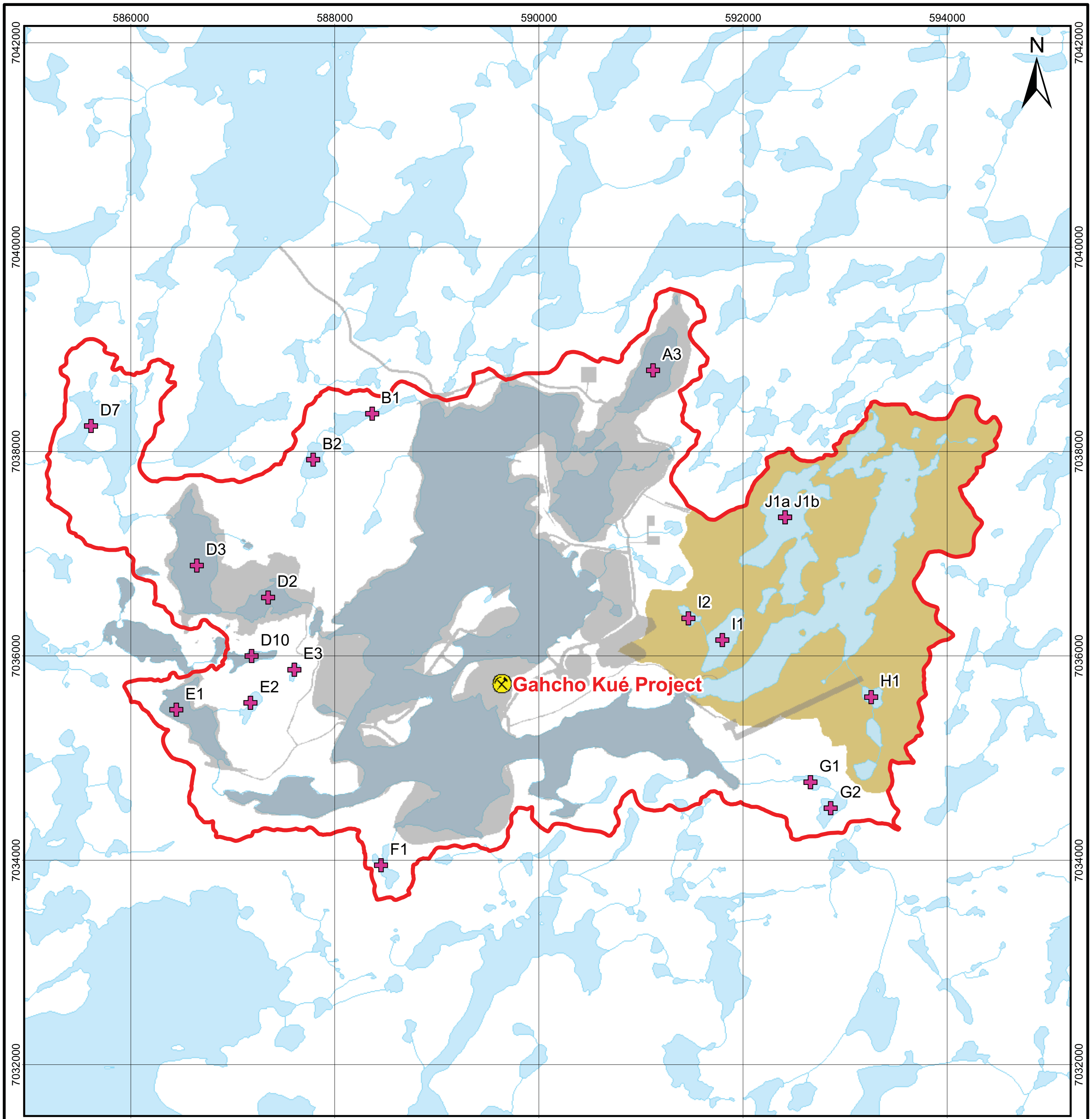
8.8.1.1.3 Study Area

The effects of atmospheric deposition of dust and metals were evaluated for 19 lakes within the Kennady Lake watershed (Figure 8.8-1). These lakes were selected on the basis of available water quality data and position relative to the Project footprint. Lakes that had available data and were located outside the Project footprint were included in the analysis. Lakes within the Project footprint were included if they were expected to remain largely undisturbed during construction and operations, and were not surrounded by Project infrastructure. Lakes excluded from the analysis are expected to be lost or modified during operations.

8.8.1.1.4 Assessment Methods

Modelled Parameters

Parameters included in the analysis and respective water quality guidelines are shown in Table 8.8-3. Parameters included a suite of metals and TSS, selected based on availability of chemistry data for particulate materials expected to contribute to dust released from roads and Project facilities.



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LEGEND

- Gahcho Kué Project
- Assessed Lake
- Project Footprint
- Watercourse
- Waterbody

Watershed Boundary

- Kennady Lake Watershed

Subwatershed Boundary

- Subwatershed Ke

NOTES

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

GAHCHO KUÉ PROJECT

Lakes in the Kennady Lake Watershed Assessed for Annual Deposition of Dust and Metals

PROJECTION: UTM Zone 12	DATUM: NAD83	DE BEERS CANADA
Scale: 1:55,000 1,000 500 0 1,000 Metres		
FILE No: KLOI-08-003-GIS		DATE: December 16, 2010
JOB NO: 09-1365-1004	REVISION NO: 1	Figure 8.8-1
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: JF

Table 8.8-3 Parameters Used to Evaluate Changes from Atmospheric Deposition of Dust and Metals in the Kennady Lake Watershed, and Water Quality Guidelines

Parameter	Chronic Aquatic Life Guideline[(a)] (mg/L)
Aluminum	0.1
Antimony	-
Arsenic	0.005
Barium	-
Beryllium	-
Boron	1.5
Cadmium	0.000039
Chromium	0.001
Cobalt	-
Copper	0.002
Iron	0.3
Lead	0.002
Manganese	-
Mercury	0.000026
Molybdenum	0.73
Nickel	0.065
Selenium	0.001
Silver	0.0001
Strontium	0.049
Uranium	-
Vanadium	-
Zinc	0.03
Total suspended solids	-

Source: CCME 1999.

mg/L = milligrams per litre; - = no data.

Mass Balance Calculation

Sources of metals and solids loading to lakes from atmospheric deposition are as follows:

- direct deposition on the lake surface;
- deposition to impervious surfaces within the watershed and subsequent runoff;
- deposition to pervious surfaces within the watershed followed by soil-water partitioning and subsequent runoff; and
- soil erosion and subsequent runoff from pervious surfaces.

A simple mass balance calculation was used to predict changes in TSS and metal concentrations for the selected lakes in the Kennady Lake watershed under baseline conditions, and during construction and operations. The calculation was based on the conservative assumption that the watershed consisted only of impervious surfaces and therefore all deposited material entered the lake. As noted above, this represents an upper-bound prediction, corresponding to the maximum potential change in concentrations of metals and TSS in lake water.

Hydrology and Lake Morphometry Data

Lake morphometry data and hydrology data are provided in Table 8.8-4. Mean annual water yield for lakes within the Kennady Lake watershed was calculated using the water balance model described in the Climate and Hydrology Baseline (Annex H).

Table 8.8-4 Hydrology and Morphometry Data for Lakes Included in the Evaluation of Atmospheric Deposition of Dust and Metals

Lake ID[(a)]	Site Name/ Original Identifier	Easting[(b)]	Northing[(b)]	Gross Catchment Area (km^2)	Lake Catchment Area (km^2)	Annual Water Yield (mm/y)	Net Annual Inflow (m^3/s)
30	Area 8	589341	7037350	7.56	4.33	143	0.0343
3	A3	591122	7038798	0.83	0.83	159	0.0042
5	B1	588368	7038371	1.27	0.17	195	0.0078
6	B2	587791	7037922	0.81	0.09	197	0.0051
11	D2	587349	7036574	4.15	0.95	169	0.0222
12	D3	586649	7036886	2.96	1.68	160	0.0150
13	D7	585613	7038252	1.41	1.41	157	0.0070
10	D10	587186	7036000	0.19	0.19	170	0.0010
14	E1	586448	7035474	1.23	0.23	182	0.0071
15	E2	587176	7035542	0.43	0.03	208	0.0028
16	E3	587605	7035867	0.04	0.01	167	0.0002
17	F1	588454	7033953	0.27	0.04	189	0.0016
18	G1	592663	7034766	0.66	0.09	195	0.0041
19	G2	592862	7034512	0.35	0.06	186	0.0021
20	H1	593258	7035599	0.78	0.08	196	0.0048
21	I1	591801	7036158	0.73	0.53	179	0.0041
22	I2	591468	7036370	0.25	0.02	206	0.0016
23	J1a	592415	7037357	1.65	0.53	161	0.0084
24	J1b	592415	7037357	1.23	1.23	155	0.0060

(a) Identifier used on map showing waterbody locations (Figure 8.8-1).

(b) Universal Transverse Mercator (UTM) co-ordinates, North American datum (NAD83), Zone 12.

km^2 = square kilometre; mm/y = millimetres per year; m^3/s = cubic metres per second.

Air Modelling

Change in metal deposition was estimated from air dispersion modelling for the Baseline and Application cases described in the Subject of Note: Air Quality (Section 11.4). The modelling results represent the highest predicted emissions near each lake and are therefore considered to be highly conservative. Total change in deposition for each parameter was estimated as a sum of both wet and dry deposition.

The modelled results do not include background emissions and represent only the change in deposition related to the Project. Emissions from other developments included only those from the De Beers Snap Lake Mine, because all other sources of emissions are located too far from the Project.

Emissions of metals and dust were modelled based on erosion sources (i.e., fugitive dust from lake beds) and Project-related industrial sources (i.e., power generators and vehicle traffic). A full list of emission sources included in the model is provided in the Air Quality SON (Section 11.4).

Data Sources

Background concentrations of metals and TSS were estimated from water quality data collected in the Kennady Lake watershed between 1995 and 2005 by various studies, and additional baseline water quality sampling in the Local Study Area by Golder in 2010 (Annex I, Addendum II, 2010 Additional Water Quality Information) (Table 8.8-5).

Available metal concentration data for each lake were pooled to calculate summary statistics for background concentrations. Data for which the detection limit was above the guideline were not included. Data below the detection limit were replaced with half the detection limit.

Table 8.8-5 Water Quality Studies Used to Characterize Background Metal Concentrations in the Kennady Lake Watershed, 1995 to 2010

Report Author(s)	Year Published	Report Title
Jacques Whitford Environment Ltd.	1998	Water Quality Assessment of Kennady Lake, 1998 Final Report. Project No. BCV50016 Submitted to Monopros Ltd., Yellowknife, NWT (Jacques Whitford 1998)
Jacques Whitford Environment Ltd.	1999	Results of Water Sampling Program For Kennady Lake, July 1999 Survey. Project No. 50091. Submitted to Monopros Ltd., Yellowknife, NWT (Jacques Whitford 1999a)
Jacques Whitford Environment Ltd.	2002	Baseline Limnology Program (2001), Gahcho Kué (Kennady Lake). Project No. ABC50254. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford 2002a)

Table 8.8-5 Water Quality Studies Used to Characterize Background Metal Concentrations in the Kennady Lake Watershed, 1995 to 2010 (continued)

Report Author(s)	Year Published	Report Title
Jacques Whitford Environment Ltd.	2002	Data Compilation (1995-2001) and Trends Analysis Gahcho Kué (Kennady Lake). Project No. ABC50310. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford 2002b)
Jacques Whitford Environment Ltd.	2003	Gahcho Kué (Kennady Lake) Limnological Survey of Potentially Affected Bodies of Water (2002). Project No. NTY71008. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford 2003a)
Jacques Whitford Environment Ltd.	2003	Baseline Limnology Program (2002), Gahcho Kué (Kennady Lake). Project No. NTY71008. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford 2003b)
Jacques Whitford Environment Ltd.	2004	Baseline Limnology Program (2003), Gahcho Kué (Kennady Lake). Project No. NTY71037. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford 2004)
Golder Associates Ltd.	2010	Annex I, Addendum II, 2010 Additional Water Quality Information
AMEC Earth & Environmental	n/a	Gahcho Kué Surface Water Quality Field Program (Unpublished Data) (AMEC 2004a)
AMEC Earth & Environmental	n/a	Gahcho Kué Surface Water Quality Field Program (Unpublished Data) (AMEC 2005a)

n/a = not applicable (not published).

8.8.1.2 Acidifying Air Emissions to Waterbodies within the Kennady Lake Watershed

8.8.1.2.1 Introduction

Mining activities have the potential to affect aquatic ecosystems through the release of air emissions that result in increased deposition rates of sulphate (SO_4^{2-}) and nitrate (NO_3^-). Deposition of SO_4^{2-} and NO_3^- can lead to a reduction in pH in acid-sensitive lakes, which in turn might alter other aspects of water chemistry (e.g., the solubility of aluminum), ultimately resulting in adverse effects on aquatic life.

This section evaluates the potential for acidification of local surface waters from Project-related air emissions. Sections 8.8.1.2.2 and 8.8.1.2.3 summarize the assessment approach and study area, respectively. Section 8.8.1.2.4 summarizes the assessment methods. Section 8.8.3.2.1 provides the results of the analysis for baseline conditions, and peak emissions during construction and operations.

8.8.1.2.2 Assessment Approach

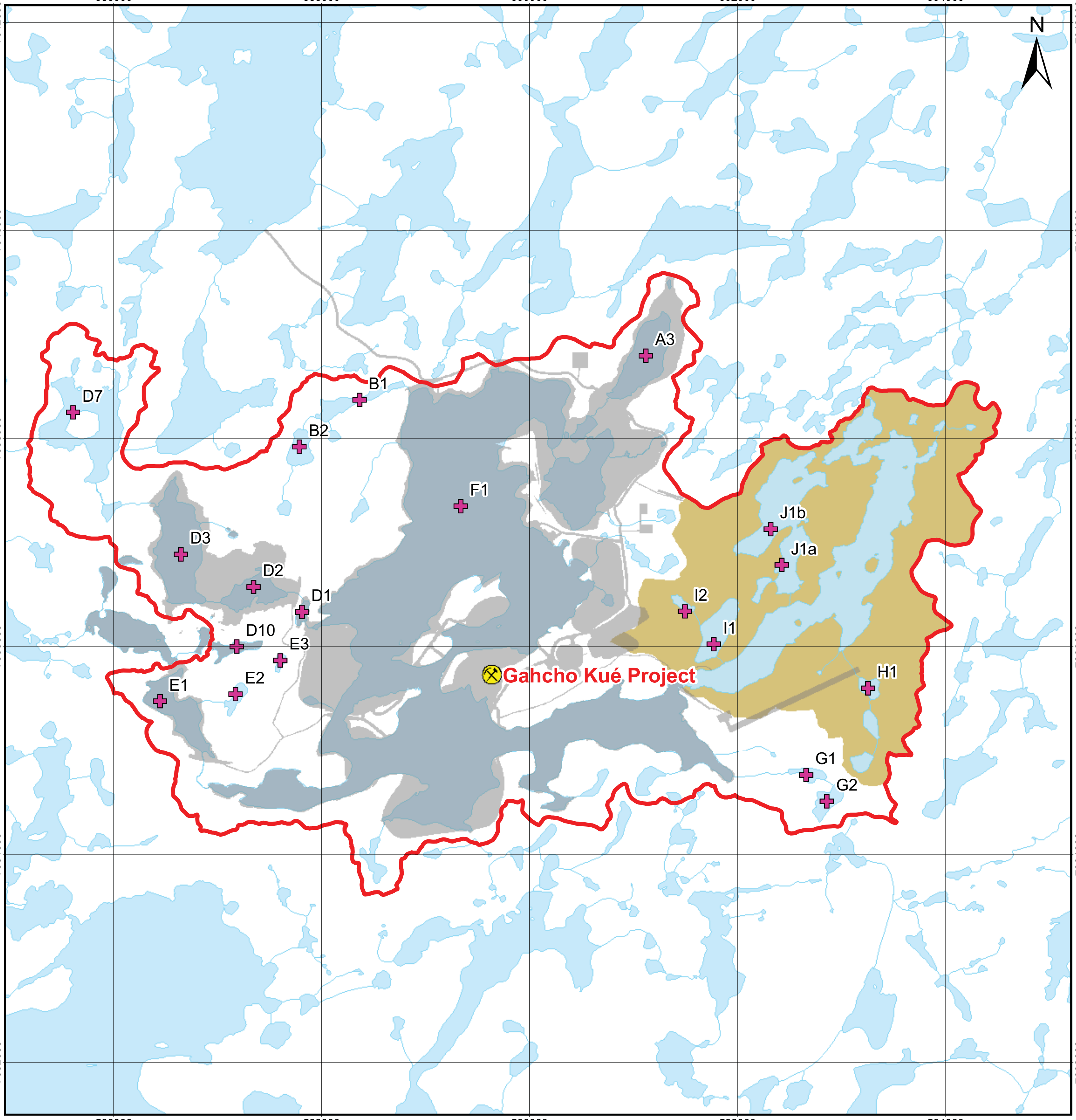
The effects of Project-related SO_4^{2-} and NO_3^- deposition on nearby surface waters were evaluated by comparing modelled acid deposition rates to lake-specific critical loads. Acid deposition was expressed as the Potential Acid Input (PAI). The critical load is an estimate of the amount of acidifying input above which a change in pH corresponding to adverse effects to aquatic life may occur. A PAI value above the critical load was considered an indication that a lake's buffering capacity may be exceeded, with a subsequent drop in pH below a specified threshold value.

PAI is usually calculated as the sum of SO_4^{2-} and NO_3^- deposition minus base cation deposition, as estimated by air dispersion modelling. This calculation includes deposition from all sources and is therefore referred to as the gross PAI. The gross PAI is commonly used to evaluate the effects of acid deposition on terrestrial ecosystems. A more refined estimate of the PAI was used in this assessment to evaluate aquatic effects, by incorporating retention of a portion of deposited nitrogen by the terrestrial ecosystem. The retained portion does not contribute to surface water acidification. The resulting PAI is referred to as the net PAI.

The net PAI does not incorporate the mitigating effect of base cation deposition. In the Steady-State Water Chemistry (SSWC) model (Henriksen and Posch 2001) used to estimate critical loads, the base cation component of the critical load is assumed to represent the current base cation flux to the waterbody from all sources, including base cation deposition from the atmosphere. Therefore, accounting for the neutralizing effect of base cation deposition, as done when using the gross PAI, would result in double-counting of base cations.

8.8.1.2.3 Study Area

The effects of acidifying emissions were assessed for 19 lakes in the Kennady Lake watershed (Figure 8.8-2). Although water quality data are available for a number of additional small lakes in the study area, they were not included in the evaluation because they are located within the Project footprint and will either be lost or modified during operations.



LEGEND

- Gahcho Kué Project
- Assessed Lake
- Project Footprint
- Watercourse
- Waterbody

Watershed Boundary

- Kennady Lake Watershed

Subwatershed Boundary

- Subwatershed Ke

NOTES

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

I:\CLIENTS\DE_BEERS\09-1365-1004\maps\09_water-quality\Baseline\KLOI-08-002-GIS.mxd

GAHCHO KUÉ PROJECT

Lakes in the Kennady Lake Watershed Surveyed for Effects of Acid Deposition

PROJECTION: UTM Zone 12	DATUM: NAD83	DE BEERS CANADA
Scale: 1:55,000 (1,000 500 0 1,000 Metres)		
FILE No: KLOI-08-002-GIS		DATE: December 16, 2010
JOB NO: 09-1365-1004	REVISION NO: 1	Figure 8.8-2
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: JF

8.8.1.2.4 Assessment Methods

Indicators of Acid Sensitivity

The sensitivity of surface waters to acid deposition can be evaluated based on alkalinity or acid neutralizing capacity (ANC). These terms are now used interchangeably and refer to the capacity of water to neutralize strong inorganic acids (Wetzel 2001). The term "alkalinity" is typically used when acid neutralizing capacity is estimated using titration, whereas "ANC" is usually used when it is calculated. Alkalinity is frequently expressed in units of mg/L as calcium carbonate ($CaCO_3$), assuming that alkalinity results only from calcium carbonate and bicarbonate, which may or may not be applicable to a given lake. Therefore, the clearest expression of alkalinity is in terms of microequivalents per litre (µeq/L) or milliequivalents per litre (meq/L). For comparative purposes, alkalinity of 1 mg/L as $CaCO_3$ = 20 µeq/L, or 50 mg/L as $CaCO_3$ = 1,000 µeq/L or 1 meq/L.

Saffran and Trew (1996) presented a scale of lake sensitivity to acidification based on alkalinity/ANC (Table 8.8-6).

Table 8.8-6 Acid Sensitivity Scale for Lakes Based on Alkalinity/ANC

Acid Sensitivity	Alkalinity/ANC	
	(mg/L as $CaCO_3$)	(µeq/L)
high	0 to 10	0 to 200
moderate	>10 to 20	>200 to 400
low	>20 to 40	>400 to 800
least	>40	>800

Source: Saffran and Trew (1996).

mg/L = milligrams per litre; $CaCO_3$ = calcium carbonate; µeq/L = microequivalents per litre;
> = greater than.

Acid sensitive lakes are situated in areas where soils have little or no capacity to reduce the acidity of the atmospheric deposition. Soil chemistry (i.e., particle size, texture, soil pH, cation exchange capacity), soil depth, drainage, vegetation cover and type, bedrock geology, and topographic relief are all factors that determine the sensitivity of the drainage basin to acid deposition (Lucas and Cowell 1984; Holowaychuk and Fessenden 1987; Sullivan 2000). Surface waters that are sensitive to acidification usually have the following characteristics, as summarized by Sullivan (2000):

- They are dilute, with low concentrations of major ions (i.e., specific conductance is less than 25 microSiemens per centimetre [µS/cm]).
- Alkalinity/ANC are low (i.e., less than 10 mg/L as $CaCO_3$ or less than 200 µeq/L).

- Base cation concentrations are low (i.e., in relatively pristine areas, the combined concentration of calcium, magnesium, potassium, and sodium in sensitive waters is generally less than 50 to 100 µeq/L).
- Organic acid concentrations are low (i.e., dissolved organic carbon [DOC] concentration is generally less than 3 to 5 mg/L).
- The pH is low (i.e., less than 6).
- Physical characteristics are as follows:
  - elevation is moderate to high;
  - lakes are located in areas of high relief;
  - lakes are subject to severe, short-term changes in hydrology;
  - there is minimal contact between drainage waters and soils or geologic material that may contribute weathering products to solution; and
  - sensitive lakes may have small drainage basins that derive much of their hydrologic input as direct precipitation to the lake surface.

Calculation of Critical Loads

General Application

The assessment approach was based on the application of critical loads according to the SSWC model. Critical loads of acidity can be used to evaluate the likelihood of lake acidification (Henriksen et al. 1992; Kämäri et al. 1992a, 1992b, 1992c; Posch et al. 1992; Rihm 1995; RMCC 1990; WHO 1994). The critical load has been defined in general terms as “a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge” (Nilsson and Grennfelt 1988). For evaluating the effects of acid deposition, the critical load can be thought of as an estimate of the amount of acidic deposition below which no significant harmful effects occur to a specified component of a lake’s ecosystem (e.g., a valued fish species) (Sullivan 2000).

The calculation of critical loads is based on a dose-response relationship between ANC and an aquatic organism considered important to the ecosystem. Many studies have shown that the effects of acidification on aquatic organisms are better correlated with ANC than with pH (as reviewed by Sullivan 2000) because pH measurements are sensitive to carbon dioxide (CO_2) effects (Stumm and Morgan 1981).

The following formula was used to calculate the critical load for each lake included in the analysis (Henriksen et al. 1992):

$$CL = ([BC^*]_0 – [ANC]_{lim}) \times Q$$

where:

CL = critical load (keq/ha/y);

$[BC^*]_0$ = pre-industrial non-marine base cation concentration (keq/L), assumed to correspond to the current values in lakes near the Project, because they are considered unaffected by acidification at the present;

$[ANC]_{lim}$ = critical value for acid neutralizing capacity (20 μeq/L = 2×10^{-8} keq/L) based on observed effects to brown trout (*Salmo trutta*), a European species; and

Q = mean annual runoff to the lake (L/ha/y).

Data used to calculate critical loads and resulting critical loads of acidity are provided in Table 8.8-7. Additional details related to the input data for calculating critical loads are provided in subsequent sections.

Table 8.8-7 Critical Loads of Acidity for the 19 Local Lakes Included in the Assessment

Lake ID[a]	Site Name/ Original Identifier	Easting[b]	Northing[b]	Distance[c] (km)	Direction[c]	Base Cations (μeq/L)	Annual Water Yield (mm/y)	Critical Load (keq/ha/y)
30	Area 8	589341	7037350	1	ESE	175	143	0.221
3	A3	591122	7038798	3	N	150	159	0.206
5	B1	588368	7038371	3	NW	130	195	0.215
6	B2	587791	7037922	3	WNW	262	197	0.477
11	D2	587349	7036574	3	W	131	169	0.188
12	D3	586649	7036886	4	W	89	160	0.110
13	D7	585613	7038252	6	WNW	185	157	0.259
10	D10	587186	7036000	4	W	191	170	0.291
14	E1	586448	7035474	4	W	168	182	0.269
15	E2	587176	7035542	4	W	478	208	0.952
16	E3	587605	7035867	3	W	251	167	0.386
17	F1	589341	7037350	2	NW	118	189	0.185
18	G1	592663	7034766	2	SE	242	195	0.434
19	G2	592862	7034512	3	SE	136	186	0.216
20	H1	593258	7035599	3	ESE	156	196	0.267
21	I1	591775	7036022	1	E	159	179	0.248
22	I2	591497	7036337	1	ENE	273	206	0.522
23	J1a	592428	7036785	2	ENE	633	161	0.988
24	J1b	592322	7037130	2	ENE	67	155	0.073

(a) Identifier used on map showing lake location (Figure 8.8-2).

(b) Universal transverse Mercator (UTM) co-ordinates; north American datum (NAD83), Zone 12.

(c) Distance and direction relative to the Project.

km = kilometre; μeq/L = microequivalents per litre; mm/y = millimetres per year; keq/ha/y = kiloequivalents per hectare per year.

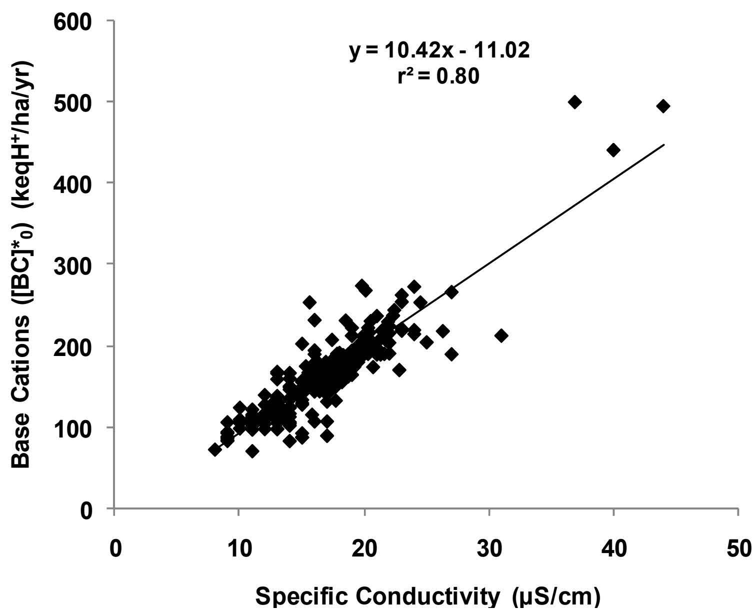
Base Cation Concentration

Henriksen and Posch (2001) and Henriksen et al. (2002) converted the present day base cation flux (i.e., the $[BC^*]_0$ term in the critical load equation) to a pre-acidification flux for European lakes and Ontario lakes, respectively. The procedure applied here assumed that the conditions before construction of the Project were representative of pre-industrial conditions.

The average concentration of each base cation was calculated for each lake based on available data shown in Table 8.8-8. This table also presents average concentrations of other indicators of acid sensitivity or modifying factors, such as pH, specific conductivity, total dissolved solids, alkalinity, dissolved organic carbon, colour, nitrate+nitrite, and sulphate.

Only field water quality measurements were available for three lakes in the Kennady Lake watershed (B2, G2, and H1). To allow estimating base cation concentrations in these lakes, a linear regression was run between specific conductivity and $[BC]^*_0$ using the data for all other lakes. The results of this analysis indicated a strong linear relationship between specific conductivity and $[BC]^*_0$ (r^2 = 0.80) (Figure 8.8-3). The regression equation was then used to estimate base cation concentrations for the three lakes with no base cation data.

Figure 8.8-3 Regression Analysis of Specific Conductivity vs. Base Cation Concentration



µS/cm = microSiemens per centimetre; $[BC]^*_0$ = base cation concentration; keq/ha/y = kiloequivalents per hectare per year.

Table 8.8-8 Summary of Water Chemistry Data for the 19 Local Lakes Included in the Assessment

Lake ID[(a)]	Site Name/ Original Identifier	Specific Conductivity (µS/cm)	TDS (mg/L)	DOC (mg/L)	Colour (TCU)	pH	Sulphate (mg/L)	Nitrate + Nitrite (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Alkalinity (mg/L as $CaCO_3$)	Alkalinity (µeq/L)	Critical Load (keq ha/y)	Acid Sensitivity[(b)]
30	Area 8	18	9	5	10	6.4	1.0	0.014	1.4	0.6	0.9	0.6	7	131	0.221	high
3	A3	18	24	4	8	6.4	1.1	0.002	1.1	0.4	1.2	0.4	15	308	0.206	moderate
5	B1	14	19	7	32	6.1	0.7	0.002	0.8	0.3	1.3	0.3	13	252	0.215	moderate
6	B2	26	-	-	-	6.5	-	-	-	-	-	-	-	-	0.477	-
11	D2	13	38	8	-	6.6	0.5	0.002	1.1	0.5	0.6	0.4	3	68	0.188	high
12	D3	9	20	6	15	6.0	0.4	0.002	0.7	0.3	0.5	0.3	6	128	0.110	high
13	D7	18	23	6	15	6.9	1.2	-	0.8	0.4	2.3	0.4	12	230	0.259	moderate
10	D10	18	20	8	23	6.6	0.7	0.003	1.3	0.5	1.6	0.5	12	237	0.291	moderate
14	E1	17	25	6	40	6.6	1.0	0.002	0.9	0.5	1.8	0.3	9	183	0.269	high
15	E2	40	71	28	150	6.9	2.3	0.003	3.4	1.6	3.4	1.1	10	197	0.952	high
16	E3	21	42	13	58	6.7	0.6	0.022	1.5	0.8	2.3	0.7	9	177	0.386	high
17	F1	13	20	6	-	6.7	0.5	0.002	0.9	0.5	0.5	0.4	4	74	0.185	high
18	G1	21	28	9	40	6.5	1.7	-	1.3	0.6	2.7	0.4	18	360	0.434	moderate
19	G2	14	-	-	-	9.4	-	-	-	-	-	-	-	-	0.216	-
20	H1	16	-	-	-	8.7	-	-	-	-	-	-	-	-	0.267	-
21	I1	17	21	5	18	6.2	1.1	-	0.8	0.4	1.7	0.4	15	291	0.248	moderate
22	I2	17	10	-	-	6.9	1.0	-	2.2	1.1	1.2	0.8	10	200	0.522	moderate
23	J1a	17	5	-	-	8.4	0.5	-	1.6	6.2	0.7	0.6	13	260	0.988	moderate
24	J1b	14	8	-	-	6.6	1.3	-	1.3	0.0	0.0	0.0	8	160	0.073	high

(a) Identifier used on map showing lake location (Figure 8.8-2).

(b) Acid sensitivity using categories as defined by Saffran and Trew (1996).

µS/cm = microSiemens per centimetre; mg/L = milligrams per litre; TCU = true colour unit; TDS = total dissolved solids; DOC = dissolved organic carbon; µeq/L = microequivalents per litre; keq/ha/y = kiloequivalents per hectare per year; "-"= no available data.

Verification of the ANC Threshold

The critical value for ANC (ANC_{lim}) is the value below which biological effects could occur. Based on the value used by Henriksen et al. (1992), an ANC_{lim} value of 20 μeq/L was used in this evaluation. To verify this value, an additional analysis was conducted using data for lakes in the Slave Geological Province, within which Kennady Lake is located.

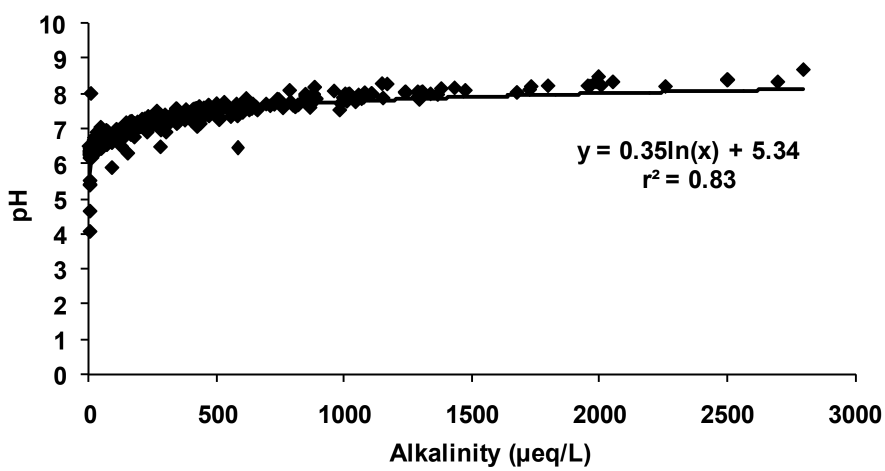
In the Henriksen model, ANC_{lim} was set to protect brown trout, the most common European salmonid, from toxic acidic episodes during the year. The ANC_{lim} was derived from water chemistry, critical load exceedances and fish population status data from 1000 Norwegian lakes (Henriksen et al. 1992; Lien et al. 1992). A value of 20 μeq/L was deemed most appropriate for Norwegian lakes and most Scandinavian countries have adopted this value (Henriksen et al. 1992). However, ANC_{lim} values have been set at 0, 20 and 50 μeq/L in various applications (e.g., Kämäri et al 1992c; Harriman et al. 1995). These values were intended to protect salmonid fisheries (Harriman et al. 1995), or correspond to the ANC where significant changes are expected to occur in a lake's diatom flora (Jenkins et al. 1997).

Brown trout is a European species that was introduced to North America, and as such, may not be an appropriate species for calculating critical loads outside Europe. In North America, there has not been a large-scale investigation of critical loads and ANC_{lim} values comparable to that done in Norway. One approach that has been used in North America involves relating ANC_{lim} to a pH effects threshold (WRS 2002). Numerous studies have shown that a pH of 6 is sufficient to maintain a healthy aquatic ecosystem, and protect fish and other aquatic organisms (based on reviews by RMCC 1990; Environment Canada 1997; Jeffries and Lam 1993; Sullivan 2000). This approach was also adopted in this assessment to verify the appropriateness of the chosen ANC_{lim} value.

To convert the pH threshold of 6 to an estimated ANC for the Kennady Lake watershed, the relationship between pH and ANC was analyzed using the results of a water quality survey (Puznicki 1996) of over 500 lakes in the Slave Geological Province. The Slave Geological Province includes the Kennady Lake watershed, as well as the Lockhart River and Hoarfrost River watersheds. A number of lakes outside these watersheds were also included in the analysis to incorporate a wider range of pH and alkalinity values (Puznicki 1996). Field measured alkalinity was used to estimate ANC. For this analysis, lakes with tea-stained, highly coloured water (>15 true colour units [TCU]) were omitted, as this colouration typically resulted from contact with humic or peaty materials and is generally indicative of elevated DOC concentration (Puznicki 1996).

Regression analysis showed that for lakes in the Slave Geological Province, a pH of 6 corresponds to an ANC value of about 7 μeq/L (Figure 8.8-4). This suggests that the ANC_{lim} value of 20 μeq/L is conservative, and is reasonably close to the level where pH may drop below a level where effects on aquatic biota would be expected to occur. The ANC_{lim} value of 20 μeq/L was also used in an assessment of nearby lakes for the Snap Lake Environmental Assessment Report (De Beers 2002).

Figure 8.8-4 Alkalinity versus pH for Lakes with Colour ≤15 TCU in the Slave Geological Province



Data source: Puznicki (1996).

TCU = true colour unit; μeq/L = microequivalents per litre.

Mean Annual Water Yield

The mean annual water yield (millimetres per year [mm/y]), which is required to calculate mean annual runoff (Q) to a lake, was calculated using baseline hydrologic data available for lakes in the Kennady Lake watershed. Values for lakes within the Kennady Lake watershed were calculated using the water balance model described in the climate section of the Climate and Hydrology Baseline (Annex H).

Acid Input Rates

Background Deposition Rate

A background deposition rate of 0.066 keq/ha/y was derived by combining dry deposition of 0.033 keq/ha/y from the Alberta Environment Regional Lagrangian Acid Deposition (AENV RELAD) model (0.020 keq/ha/y SO_4^{2-} and 0.013 keq/ha/y NO_3^-) for the extreme northeast portion of Alberta and the wet deposition rate of

0.033 keq/ha/y based on Environment Canada's monitoring data at Snare Rapids, NWT (0.019 keq/ha/y SO_4^{2-} and 0.015 keq/ha/y NO_3^-) (Section 11.4 SON: Air Quality).

Potential Acid Input

The net annual PAI was derived by taking into account changes in the seasonal retention pattern of deposited substances. Since winter (under-ice) conditions effectively prevent direct acid deposition to lakes for about seven months of the year, SO_4^{2-} and NO_3^- deposited during winter accumulates on the snow and ice. During spring freshet, the melting of snow and ice releases the SO_4^{2-} and NO_3^- accumulated over the winter in the watershed into lake water. Plants may not assimilate the NO_3^- during this period because the ground is still frozen and the snowmelt may run overland rather than infiltrating. Thus, it is assumed that the entire NO_3^- deposition accumulated over the winter enters the lake water. Therefore, net annual PAI was calculated using gross PAI for the winter period.

Nitrogen Retention

During open water conditions, when the short growing season occurs, plants completely assimilate NO_3^- deposition up to 5 to15 kg/ha/y (Gordon et al. 2001). Therefore, net NO_3^- deposition above 5 kg/ha/y and all SO_4^{2-} deposition were assumed to enter receiving waterbodies during open water conditions. When the modelled annual deposition of NO_3^- was below the threshold of 5 kg/ha/y, only the SO_4^{2-} deposition was included in the calculation of the net PAI for open water conditions. When NO_3^- deposition was above the threshold, both SO_4^{2-} and the load of NO_3^- over the threshold were included in the calculation of net PAI.

Data Sources

Background water quality data in the Kennady Lake watershed was collected between 1995 and 2005 by various studies during both open water and ice-covered conditions (Table 8.8-9). Additional baseline water quality data were collected in Kennady Lake and several small lakes in the Local Study Area by Golder in 2010 (Annex I, Addendum II, 2010 Additional Water Quality Information) during open water and ice-covered seasons. Data from both seasons were used to evaluate acid sensitivity and calculate critical loads.

Table 8.8-9 Water Quality Studies in the Kennady Lake Watershed, 1995 to 2010

Report Author(s)	Publication Year	Report Title
Jacques Whitford Environment Ltd.	1999	Results of Water Sampling Program For Kennady Lake, July 1999 Survey. Project No. 50091. Submitted to Monopros Ltd., Yellowknife, NWT (Jacques Whitford 1999a)
Jacques Whitford Environment Ltd. and EBA Engineering Consultants Ltd. (EBA)	2001	Gahcho Kué (Kennady Lake) Environmental Baseline Investigations (2000). Project No. 0701-99-13487. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford and EBA 2001)
Jacques Whitford Environment Ltd.	2002	Baseline Limnology Program (2001), Gahcho Kué (Kennady Lake). Project No. ABC50254. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford 2002a)
Jacques Whitford Environment Ltd.	2002	Data Compilation (1995-2001) and Trends Analysis Gahcho Kué (Kennady Lake). Project No. ABC50310. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford 2002b)
Jacques Whitford Environment Ltd.	2003	Gahcho Kué (Kennady Lake) Limnological Survey of Potentially Affected Bodies of Water (2002). Project No. NTY71008. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford 2003a)
Jacques Whitford Environment Ltd.	2003	Baseline Limnology Program (2002), Gahcho Kué (Kennady Lake). Project No. NTY71008. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford 2003b)
Jacques Whitford Environment Ltd.	2004	Baseline Limnology Program (2003), Gahcho Kué (Kennady Lake). Project No. NTY71037. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford 2004)
Golder Associates Ltd.	2010	Annex I, Addendum II, 2010 Water Quality Baseline
AMEC Earth & Environmental	n/a	Unpublished water chemistry data collected in Kennady Lake and surrounding watersheds (AMEC 2004a).
AMEC Earth & Environmental	n/a	Unpublished Aquatic Resources Field Data Collected in Kennady Lake and Surrounding Watersheds (AMEC 2004b).
AMEC Earth & Environmental	n/a	Unpublished water chemistry data collected in Kennady Lake and surrounding watersheds (AMEC. 2005a)
AMEC Earth & Environmental	n/a	Unpublished Aquatic Resources Field Data Collected in Kennady Lake and Surrounding Watersheds (AMEC. 2005b)

n/a = not applicable (not published).

8.8.2 Effects Analysis Methods – Closure

8.8.2.1 Water Quality in Kennady Lake during and after Refilling

8.8.2.1.1 Kennady Lake Closure Water Quality Model

To facilitate mining of the kimberlite pipes, Kennady Lake will be dewatered and divided into separate basins during the construction and operations phases of the Project. The remaining lake will function as a Water Management Pond (WMP). At closure, the lake will be refilled by importing water from nearby Lake N11. Details regarding water management during all phases of the Project are included in Section 8.4.

The Kennady Lake water quality model was developed to predict concentrations in Kennady Lake during the construction, operations, and closure phases. The model, developed in GoldSim^{TM}, is detailed briefly below and described fully in Appendix 8.I.

In general, the water quality model is a flow and mass-balance model that was set up to account for all inputs and processes described in Section 8.4.3. The spatial modelling domain includes the portion of Kennady Lake (i.e., Areas 2 to 7) that is planned to be hydraulically isolated from the surrounding environment during mining operations. Within the closed-circuited areas of Kennady Lake, the lake is planned to be divided by dykes into five basins (i.e., Area 2, Areas 3 and 5, Area 4, Area 6, and Area 7) during the operations phase (Section 8.4.3). Each of these basins was treated as a distinct reservoir within the model.

Within each reservoir, volumes and concentrations were calculated on a monthly time step from Year -2, which corresponds to the start of construction, to Year 121 which is 100 years after the reconnection of the upper areas of Kennady Lake with Area 8 and downstream watershed (i.e., post-closure). Inflow volumes and concentrations were included as inputs to each reservoir to account for loadings from natural areas, disturbed areas, mine rock runoff, fine and coarse processed kimberlite runoff and groundwater discharge.

The model assumed complete mixing within each basin at each timestep while the dykes are operational. At closure, when the dykes are planned to be breached, the model reports fully mixed conditions in Areas 3 to 7. No chemical reactions or sinks were assumed to occur in the model, except where volumes of water are sequestered in mine rock pore space.

The water quality model predicted concentrations for a range of water quality parameters at the following key nodes, for specific Project phases:

- Areas 3 and 5 (WMP) during operations, because this water is discharged to Lake N11 (Section 9.8);
- Kennady Lake Areas 3 to 7, at the end of closure; and
- Kennady Lake Areas 3 to 7, 100 years into post-closure.

Model predictions are made on a monthly basis (e.g., lowest stream flows combined with highest effluent flows during construction) and are restricted to relatively average climate conditions (i.e., 1:2 year wet [median] conditions). Model predictions were based on average climate conditions for three reasons. First, as a lake-dominated system, water quality is less susceptible to inter-annual fluctuations in precipitation and temperature. Second, the majority of changes in water quality parameter concentration due to the Project are large in terms of relative change compared to baseline conditions (see Section 8.8.4.1), so natural variability would be a relatively small contributor to overall change. Finally, using mean conditions allows for a straightforward assessment of incremental changes due to the Project.

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

Modelled changes in water quality resulting from the Project are the difference between the measured median background concentrations and the modelled water quality at the key nodes. The model uses median background concentrations and conservative estimates of mass loadings from the Project to simulate changes in water quality. The model results are projections that are suitable for the assessment of effects; however, the model does not account for natural variability, and therefore, model results should not be viewed as predictions or forecasts of future conditions.

8.8.2.1.2 Data Sources

Background water quality data in the Kennady Lake watershed was collected between 1995 and 2010. The data were collected by various consultants during open water and under-ice conditions (see Section 8.3). For the purposes of the Kennady Lake water quality assessment, data collected from the sources presented in Table 8.8-10 were used.

Table 8.8-10 Water Quality Studies Used in the Assessment of Kennady Lake, 1995 to 2010

Report Author(s)	Publication Date	Report Title
Jacques Whitford Environment Ltd.	July 1998	Water Quality Assessment of Kennady Lake, 1998 Final Report. Project No. BCV50016. Submitted to Monopros Limited, Yellowknife, NWT (Jacques Whitford 1998)
Jacques Whitford Environment Ltd.	October 14, 1999	Results of Water Sampling Program for Kennady Lake July 1999 Survey. Project 50091. Submitted to Monopros Limited, Yellowknife, NWT (Jacques Whitford 1999a)
Jacques Whitford Environment Ltd.	1999	Trip Report #1 and Data Assessment for Kennady Lake Water Quality - 1999 Survey Program. Submitted to Monopros Limited, Yellowknife, NWT (Jacques Whitford 1999b)
EBA Engineering Consultants Ltd. (EBA) & Jacques Whitford Environment Ltd.	2001	Gahcho Kué (Kennady Lake) Environmental Baseline Investigations (2000) Submitted to De Beers Canada Exploration Ltd., Yellowknife, NWT (EBA and Jacques Whitford Environment Ltd. 2001)
Jacques Whitford Environment Ltd.	March 4, 2002	Baseline Limnology Program (2001) Gahcho Kué (Kennady Lake). Project No. ABC50254. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford 2002a)
Jacques Whitford Environment Ltd.	April 29, 2002	Data Compilation (1995-2001) and Trends Analysis Gahcho Kué (Kennady Lake). Project No. ABC50310. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford 2002b)
EBA Engineering Consultants Ltd. (EBA)	2002	Gahcho Kué Winter 2001 Water Quality Sampling Program, Gahcho Kué, NWT. Project No. 0701-98-13487.028. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (EBA 2002)
EBA Engineering Consultants Ltd. (EBA)	2003	Kennady Lake Winter 2002 Water Quality Sampling Programme Kennady Lake, NWT. Project # 0701- 98-13487.035. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (EBA 2003)
Jacques Whitford Environment Ltd.	June 4, 2003	Gahcho Kué (Kennady Lake) Limnological Survey of Potentially Affected Bodies of Water (2002). Project No. NTY71008. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford 2003a)
Jacques Whitford Environment Ltd.	June 4, 2003	Baseline Limnology Program (2002) Gahcho Kue (Kennady Lake). Project No. NTY71008. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford 2003b)
Jacques Whitford Environment Ltd.	January 20, 2004	Baseline Limnology Program (2003) Gahcho Kué (Kennady Lake). Project No. NTY71037. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford 2004)

Table 8.8-10 Water Quality Studies Used in the Assessment of Kennady Lake, 1995 to 2010 (continued)

Report Author(s)	Publication Date	Report Title
EBA Engineering Consultants Ltd. (EBA)	2004	Kennady Lake Winter 2003 Water Quality Sampling Program, Project No. 0701-98-13487.048. Submitted to DeBeers Canada Exploration Inc., Yellowknife, NWT (EBA 2004a)
EBA Engineering Consultants Ltd. (EBA)	2004	Faraday Lake Winter 2003 Water Quality Sampling Program, Project No. 0701-98-13487.048. Submitted to DeBeers Canada Exploration Inc., Yellowknife, NWT (EBA 2004b)
EBA Engineering Consultants Ltd. (EBA)	2004	Kelvin Lake Winter 2003 Water Quality Sampling Program, Project No. 0701-98-13487-048. Submitted to DeBeers Canada Exploration Inc., Yellowknife, NWT (EBA 2004c)
EBA Engineering Consultants Ltd. (EBA)	2004	Kennady Lake (Winter 2004) Water Quality Sampling Program, Project # 1740071.001. Submitted to DeBeers Canada Exploration Inc., Yellowknife, NWT (EBA 2004d)
AMEC Earth & Environmental	N/A	Unpublished water chemistry data collected in Kennady Lake and surrounding watersheds (2004). Calgary, AB (AMEC 2004a)
AMEC Earth & Environmental	N/A	Unpublished Aquatic Resources Field Data Collected in Kennady Lake and Surrounding Watersheds (2004). Calgary, AB (AMEC 2004b)
AMEC Earth & Environmental	N/A	Unpublished water chemistry data collected in Kennady Lake and surrounding watersheds (2005). Calgary, AB (AMEC 2005a)
Section 8.3	2010	Additional baseline data collected in support of this application

8.8.2.2 Water Quality in Area 8 after Refilling

Although presently part of Kennady Lake, Area 8 is proposed to be hydraulically isolated from the rest of the lake during the construction, operations, and closure phases of the Project. During these phases, runoff from natural areas within the Area 8 sub-watershed are expected to be sufficient for maintaining water quality within this basin, as described in Section 8.6. Therefore, water quality was not modelled in Area 8 during these phases of the Project.

In post-closure (after Year 21), the original flow path of Kennady Lake will be re-established, and Area 8 will receive flows from the refilled portion of Kennady Lake. Therefore, Area 8 was included in the downstream water quality model. This model was developed to predict concentrations in Area 8, the L, M and N watersheds and Lake 410. The model, developed in GoldSim™, is detailed briefly below and fully described in Appendix 8.I.

The hydrology model (Sections 8.7.1 and 8.7.2) formed the basis of the downstream water quality model. Within each watershed, water quality profiles were assigned as baseline chemistry. Throughout the construction, operations, and closure phases of the Project, the downstream watershed was assumed to behave according to baseline conditions, with the following exceptions, which are included in the model:

- water will be discharged from the WMP to Lake N11 during the construction and operations phases;
- water will be drawn from Lake N11 to refill Kennady Lake during the closure phase;
- the flow path from Area 7 to Area 8 will be disconnected during the operations and closure phases; and
- the flow path from Area 7 to Area 8 will be reconnected after Kennady Lake has refilled (i.e., post-closure).

The water quality model predicted concentrations for a range of water quality parameters in Area 8 during post-closure (in addition to the downstream lake nodes and snapshots described in Section 9.8). The model assumed fully mixed conditions.

An upper-bounds estimate of oxygen demand during under-ice conditions was calculated based on long-term projected phosphorus concentrations in Kennady Lake. This estimate was used to determine potential end of winter dissolved oxygen concentrations in Kennady Lake following closure. Winter oxygen depletion rates (WODRs) for specific depth zones (i.e., surface [under-ice to 6 m], middle [7 to 12 m] and bottom [greater than 13 m]) were calculated based on measured baseline dissolved oxygen data for Kennady Lake (Section 8.3.6) and three empirical relationships available in published literature:

- Approach 1, which used total phosphorus concentrations and averaged lake morphometry (Babin and Prepas 1985);
- Approach 2, which used the annual rate of primary productivity based on total phosphorus concentrations (Vollenweider 1979; also cited in Wetzel 2001); and
- Approach 3, which used sediment oxygen demand based on trophic status (Mathias and Barica 1980).

These relationships are detailed in Appendix 8.V.

8.8.2.3 Stability Analysis of Meromictic Conditions in Tuzo Pit after Closure

The water quality in the Tuzo Pit basin (Tuzo Pit) and in the restored Kennady Lake will be influenced by several input sources. During the initial phase of refilling, water quality will be primarily influenced by groundwater influx and the sources used to fill the pit, namely, water from the WMP and Lake N11 (Section 8.4.3). After Kennady Lake is filled, water quality in Tuzo Pit will be determined by surface runoff to Kennady Lake and surface water– groundwater interaction in the Tuzo Pit.

The stability of stratification in Tuzo Pit was analyzed using two methods. These methods, detailed in Appendix 8.I, are as follows:

- hydrodynamic modelling of the first 100 years after refilling, using CE-QUAL-W2; and
- mass balance calculations over 15,000 years using a vertical slice spreadsheet model.

The CE-QUAL-W2 model was used to compute total dissolved solids (TDS), temperature and density at 1 to 3 metre (m) intervals in Tuzo Pit. The model was run iteratively to determine the long-term depth of the pycnocline (the layer of water with the highest density gradient between the two waters of varying density) to delineate the boundary between the low TDS surface water zone and deeper high TDS water zone in the pit. The water below the pycnocline represents the volume of water anticipated to be isolated from surface waters in the refilled Kennady Lake. The volumes of water above and below the pycnocline were then used as inputs to the Kennady Lake Goldsim model.

The vertical slice spreadsheet model was used to calculate long-term TDS concentrations over 15,000 years at 25 m vertical intervals in Tuzo Pit. This model included long-term inflows that were predicted by the hydrogeological model (Section 11.6 SON: Permafrost, Hydrogeology and Groundwater SON).

8.8.3 Effects Analysis Results – Construction and Operation

8.8.3.1 Effects of the Deposition of Dust and Metals from Air Emission to Water Quality and Lake-Bed Sediments in Waterbodies within the Kennady Lake Watershed

8.8.3.1.1 Results

The potential effects of dust and associated metal deposition on water quality were evaluated for 18 lakes within the Kennady Lake watershed.

Effects of Deposition of Dust and Metals and under Baseline Conditions

Under baseline conditions, predicted increases in TSS and metal concentrations relative to background were very small (i.e., <1% for most parameters). These results are consistent with the absence of development in the Project area at the time of start-up.

Effects of Deposition of Dust and Metals from the Project

Predicted maximum concentrations of seven metals during construction and operations are above water quality guidelines in two or more lakes, including aluminum, cadmium, chromium, copper, iron, mercury, and silver (Table 8.8-11). As noted above, predicted concentrations reflect the conservative assumptions used in the air quality modelling and mass balance analysis.

The spatial extent of dust and metal deposition is anticipated to be restricted to localized areas within and close to the Project footprint. Maximum deposition is expected to occur near haul roads along the southern, western, and eastern boundary of the development area, and primarily reflect winter fugitive road dust emissions (Section 11.4 SON: Air Quality). In general, elevated deposition of dust and metals is predicted to occur to a distance of approximately 2 km from the development area boundary.

Table 8.8-11 Predicted Concentrations of Metals and TSS in Lakes in the Kennady Lake Watershed under the Application Case

Parameter	Guideline[a]	Background Concentrations (mg/L)			Predicted Maximum Concentrations during Construction and Operations (mg/L)																		
		min	max	average	Area 8[b]	A3[b]	B1[b]	B2	D2[b]	D3[b]	D7[b]	D10	E1[b]	E2	E3	F1	G1[b]	G2[b]	H1[b]	I1[b]	I2	J1a[b]	J1b[b]
Aluminum	0.1	0.006	1.13	0.07	**0.22**	**0.16**	**0.17**	**0.19**	**0.40**	**0.23**	**0.13**	**0.42**	**0.20**	**0.37**	**0.89**	**0.41**	**0.18**	**0.17**	**0.15**	**0.32**	**0.37**	**0.19**	**0.20**
Antimony	-	0.00001	0.0021	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Arsenic	0.005	0.00005	0.0011	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Barium	-	0.002	0.0224	0.004	0.007	0.006	0.006	0.006	0.010	0.007	0.005	0.011	0.006	0.010	0.020	0.011	0.006	0.006	0.005	0.009	0.010	0.006	0.006
Beryllium	-	0.000005	0.0005	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Boron	1.5	0.001	0.01	0.005	0.005	0.005	0.005	0.005	0.006	0.005	0.005	0.006	0.005	0.006	0.006	0.006	0.005	0.005	0.005	0.006	0.006	0.005	0.005
Cadmium	0.000039	0.000001	0.0001	0.00002	**0.0004**	**0.0002**	**0.0002**	**0.0002**	**0.0005**	**0.0003**	**0.0001**	**0.0005**	**0.0002**	**0.0004**	**0.0008**	**0.0006**	**0.0003**	**0.0002**	**0.0002**	**0.0007**	**0.0008**	**0.0003**	**0.0003**
Chromium	0.001	0.00005	0.004	0.0006	**0.002**	**0.001**	**0.001**	**0.002**	**0.003**	**0.002**	**0.001**	**0.004**	**0.002**	**0.003**	**0.008**	**0.004**	**0.002**	**0.001**	**0.001**	**0.003**	**0.003**	**0.002**	**0.002**
Cobalt	-	0.00002	0.002	0.0002	0.0005	0.0004	0.0004	0.0004	0.0007	0.0005	0.0003	0.0008	0.0004	0.0007	0.0015	0.0008	0.0004	0.0004	0.0003	0.0007	0.0008	0.0004	0.0004
Copper	0.002	0.0005	0.012	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**	**0.004**	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**
Iron	0.3	0.005	1.28	0.2	**0.4**	**0.3**	**0.3**	**0.4**	**0.8**	**0.5**	0.3	**0.8**	**0.4**	**0.7**	**1.7**	**0.8**	**0.4**	**0.3**	**0.3**	**0.6**	**0.7**	**0.4**	**0.4**
Lead	0.002	0.000011	0.0008	0.0001	0.0003	0.0002	0.0002	0.0002	0.0004	0.0003	0.0002	0.0004	0.0002	0.0004	0.0007	0.0004	0.0002	0.0002	0.0002	0.0004	0.0004	0.0002	0.0002
Manganese	-	0.0011	0.0199	0.005	0.009	0.007	0.007	0.008	0.014	0.009	0.006	0.014	0.008	0.013	0.027	0.014	0.008	0.007	0.007	0.012	0.013	0.008	0.008
Mercury	0.000026	0.0000003	0.00001	0.000006	**0.000034**	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00002	0.00001	0.00002	**0.00006**	**0.00009**	0.00003	0.00002
Molybdenum	0.73	0.000025	0.0025	0.0006	0.0006	0.0006	0.0006	0.0006	0.0007	0.0006	0.0006	0.0007	0.0006	0.0007	0.0008	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
Nickel	0.065	0.0002	0.0132	0.002	0.004	0.003	0.003	0.003	0.006	0.004	0.003	0.006	0.003	0.006	0.012	0.006	0.003	0.003	0.003	0.006	0.0066	0.004	0.004
Selenium	0.001	0.00002	0.0005	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Silver	0.0001	0.0000003	0.0005	0.00005	**0.0001**	0.0001	0.0001	0.0001	**0.0001**	0.0001	0.0001	**0.0001**	0.0001	**0.0001**	**0.0002**	**0.0001**	0.0001	0.0001	0.0001	**0.0002**	**0.0002**	0.0001	**0.0001**
Strontium	0.049	0.004	0.026	0.008	0.009	0.008	0.008	0.009	0.010	0.009	0.008	0.010	0.009	0.009	0.012	0.010	0.009	0.009	0.008	0.010	0.010	0.009	0.009
Uranium	-	0.000005	0.0003	0.00003	0.00005	0.00004	0.00004	0.00005	0.00007	0.00005	0.00004	0.00007	0.00005	0.00006	0.00011	0.00007	0.00004	0.00004	0.00004	0.00006	0.00006	0.00005	0.00005
Vanadium	-	0.00005	0.0056	0.0007	0.0012	0.001	0.001	0.001	0.002	0.001	0.001	0.002	0.001	0.002	0.003	0.002	0.001	0.001	0.001	0.001	0.002	0.001	0.001
Zinc	0.03	0.0005	0.055	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.010	0.010	0.009	0.009	0.009	0.010	0.01	0.009	0.009
TSS	-	0.5	45	3	36	19	15	18	69	25	10	87	25	81	267	78	21	19	16	64	92	27	30

Note: **Bolding** identifies concentrations above chronic aquatic life guideline.

[a] Water quality guidelines for the protection of aquatic life (CCME 1999).

[b] Fish bearing lake.

TSS = total suspended solids; min = minimum; max = maximum; mg/L = milligrams per litre; "-" = not available or not applicable.

The period of elevated TSS and metal concentrations in affected lakes is expected to be relatively short. During construction and operations, the largest load of suspended sediments to surface waters during the year will occur during spring freshet, when dust deposited to snow during winter and eroded materials enter surface waters. Sediment inputs during other times of the year are anticipated to be sporadic and too small to result in measurable changes in TSS and metal concentrations in lakes, except in localized areas near stream mouths during and immediately after precipitation events.

The length of the freshet period is estimated to range from approximately two days for small lakes to a maximum of one to two weeks based on the length of the freshet for Kennady Lake (Section 8.3.5.2). This would be followed by a period of settling, estimated as less than a month based on observations at Snap Lake (De Beers 2010). Snap Lake is a small lake located adjacent an operating diamond mine in similar terrain as the Project. Post-freshet sampling of Snap Lake typically occurs in early to mid-July (i.e., less than a month after freshet), by which time TSS concentrations in lake water are typically below the analytical detection limit of 3 mg/L.

8.8.3.1.2 Summary

A conservative analysis was conducted to estimate maximum potential changes in TSS and metal concentrations in lakes within the Kennady Lake watershed, to evaluate potential effects of dust and air emissions during construction and operation of the Project. The results of this analysis indicate the concentrations of TSS and certain metals may be elevated during and after freshet, potentially to levels above water quality guidelines. Effects on TSS and metal concentrations are expected to be localized in the immediate vicinity of the Project and temporally restricted to the period during and after freshet.

Predictions of TSS and metal concentrations presented in this section are subject to a high degree of uncertainty, in the direction of predicting higher concentrations than can be realistically expected, based on the degree of conservatism incorporated in the evaluation and experience at operating diamond mines.

8.8.3.2 Effects of Acidifying Emissions to Waterbodies within the Kennady Lake Watershed

8.8.3.2.1 Results

The potential for acidification of lakes was evaluated by comparison of net PAI values to critical loads for baseline conditions, and during construction and operations. Peak emissions during operation were considered in the assessment, which represents a conservative, worst-case scenario as outlined in the Air Quality subject of note (Section 11.4).

Effects of Acidifying Emissions under Baseline Conditions

Predicted net PAI values for baseline conditions are below critical loads for the 19 local lakes included in the assessment (Table 8.8-11). Baseline net PAI values were only marginally above background values and the annual deposition of nitrogen was less than 5 kg/ha/y for all lakes included in the analysis. These results are consistent with the observed lack of acidified lakes in the Kennady Lake watershed.

Effects of Acidifying Emissions from the Project

Predicted net PAI values representing peak emissions during construction and operations are below the critical loads for the 19 lakes included in the evaluation of Project-related effects (Table 8.8-12). The annual deposition of nitrogen during construction and operations was less than 5 kg/ha/y for all lakes. Based on these results, Project-related deposition of SO_4^{2-} and NO_3^- in the Kennady Lake watershed is not predicted to result in lake acidification.

Table 8.8-12 Critical Loads and Predicted Acid Input Rates for the 19 Local Lakes Included in the Assessment

Lake ID[a]	Site Name/ Original Identifier	Distance[b] (km)	Direction[b]	Critical Load (keq/ha/y)	Baseline Conditions			Construction and Operations		
					SO_4^{2-} Deposition (keq/ha/y)	NO_3^- Deposition (keq/ha/y)	Net PAI (keq/ha/y)	SO_4^{2-} Deposition (keq/ha/y)	NO_3^- Deposition (keq/ha/y)	Net PAI (keq/ha/y)
30	Area 8	1	ESE	0.221	0.039	0.028	0.055	0.040	0.094	0.095
3	A3	3	N	0.206	0.039	0.028	0.055	0.039	0.065	0.077
5	B1	3	NW	0.215	0.039	0.028	0.055	0.040	0.066	0.078
6	B2	3	WNW	0.477	0.039	0.028	0.055	0.040	0.070	0.081
11	D2	3	W	0.188	0.039	0.028	0.055	0.040	0.093	0.094
12	D3	4	W	0.110	0.039	0.028	0.055	0.040	0.070	0.080
13	D7	6	WNW	0.259	0.039	0.028	0.055	0.039	0.052	0.070
10	D10	4	W	0.291	0.039	0.028	0.055	0.040	0.095	0.096
14	E1	4	W	0.269	0.039	0.028	0.055	0.040	0.073	0.082
15	E2	4	W	0.952	0.039	0.028	0.055	0.040	0.101	0.100
16	E3	3	W	0.386	0.039	0.028	0.055	0.041	0.132	0.118
17	F1	2	NW	0.185	0.039	0.028	0.055	0.041	0.116	0.108
18	G1	2	SE	0.434	0.039	0.028	0.055	0.040	0.079	0.086
19	G2	3	SE	0.216	0.039	0.028	0.055	0.040	0.071	0.081
20	H1	3	ESE	0.267	0.039	0.028	0.055	0.039	0.069	0.080
21	I1	1	E	0.248	0.039	0.028	0.055	0.040	0.159	0.133
22	I2	1	ENE	0.522	0.039	0.028	0.055	0.041	0.204	0.160
23	J1a	2	ENE	0.988	0.039	0.028	0.055	0.040	0.091	0.093
24	J1b	2	ENE	0.200	0.039	0.028	0.055	0.040	0.090	0.092

[a] Identifier used on map showing waterbody locations (Figure 8.8-2).

[b] Distance and direction relative to the Gahcho Kué Project.

km = kilometre; keq/ha/y = kiloequivalents per hectare per year; SO_4^{2-} = sulphate; NO_3^- = nitrate; PAI = Potential Acid input.

8.8.4 Effects Analysis Results – Closure

8.8.4.1 Effects of Project Activities to Water Quality in Kennady Lake and Area 8 during and After Refilling

At closure, the lake-bed of Kennady Lake will be modified by the three mine pits and portions of the remaining dykes. The Hearne Pit will be partially backfilled with fine PK, the 5034 Pit will be completely backfilled with mine rock, except for the northern quarter where it borders the Tuzo Pit, and the Tuzo Pit will not be backfilled.

Refilling of Kennady Lake will start by drawing down the water in Areas 3 to 7 and transferring this higher-salinity water to Tuzo Pit. Subsequently, Tuzo Pit and the remaining portions of Kennady Lake will be refilled. The water used to refill Kennady Lake will include natural watershed runoff and supplemental water pumped from the adjacent Lake N11 to expedite lake refilling.

After refilling, Tuzo Pit will represent a new waterbody feature within the restored Kennady Lake. The bottom of the Tuzo Pit will be about 300 metres (m) below the Kennady Lake surface and 285 m below the average bottom of the lake, creating a deep depression within the lake. During and after refilling of the Tuzo Pit, the saline groundwater collected in the bottom of the pit will form a higher density monimolimnion layer, which will be separated from the overlying fresh water by a pycnocline. The development of a pycnocline will create what is referred to as meromictic conditions in the Tuzo Pit, which if stable, will keep the monimolimnion layer isolated from the overlying fresh water indefinitely. A separate analysis of the long-term stability of meromictic conditions in the combined Tuzo Pit is provided in Section 8.8.4.2.

Water quality was modelled throughout closure and post-closure in Tuzo Pit and Kennady Lake, which includes all five basins (i.e., Areas 3 and 5, Area 4, Area 6, Area 7, and Area 8). The results of this modelling, which are presented in Section 8.8.4.1, assume that the fresh water in the Tuzo Pit will not interact with the underlying monimolimnion layer. The validity of this assumption is verified as a separate analysis in Section 8.8.4.2.

Because the lake will remain a managed system until it is refilled and Dyke A is breached, the effects analysis of Kennady Lake does not include the construction, operations or closure phases. Instead, it includes the post-closure period, when Kennady Lake is reconnected to the receiving environment, the natural flow path is restored and fish passage is resumed.