and cisco also captured. Species captured in Kirk Lake outlet stream included Arctic grayling, slimy sculpin, and ninespine stickleback, suggesting that these species are also likely present in the lake. Lake whitefish are not present in Kennady Lake, Lake N16, or Lake 410.

Streams

Eight species of fish have been captured in Stream K5, the Kennady Lake outlet stream (Table 10.3-6); these species are common to Kennady Lake. Six of these species have also been captured in Stream N16, the outlet stream of Lake N16. Table 10.3-6 also shows the fish species that have been recorded in the outlet streams of Lake 410 and Kirk Lake; however, sampling in these systems has not been as extensive as for the streams in the Kennady Lake watershed, and is likely not representative of all fish species present.

Based on spring fish fence data, Arctic grayling were the most abundant fish species captured in downstream of Kennady Lake. Arctic grayling was also the most abundant species captured in the outlet of Lake N16 in spring 2000. Lake trout are fall spawners and movement of these fish into outlet streams in spring was most likely to feed on spawning Arctic grayling and/or their newly laid eggs. Longnose sucker were also captured in the inlet and outlet streams of Lake N16, presumably using these streams for spawning.

Table 10.3-6 Fish Species Recorded in the Outlet Streams of Kennady Lake, Lake N16, Lake 410, and Kirk Lake

Common Name	Scientific Name	Stream K5 (Area 8 outlet)	Stream N16	Stream 410	Kirk Lake Outlet
Arctic grayling	*Thymallus arcticus*	√	√		√
Burbot	*Lota lota*	√	√	√	
Lake chub	*Couesius plumbeus*	√	√	√	
Lake trout	*Salvelinus namaycush*	√	√		
Lake whitefish	*Coregonus clupeaformis*				
Longnose sucker	*Catostomus catostomus*	√	√		
Ninespine stickleback	*Pungitius pungitius*				√
Northern pike	*Esox lucius*	√			
Round whitefish	*Prosopium cylindraceum*	√			
Slimy sculpin	*Cottus cognatus*	√	√	√	√

In summer sampling, Arctic grayling were typically the most abundant fish found in streams downstream of Kennady Lake and in the N watershed, often comprising over 80% of the total catch. Juvenile burbot, slimy sculpin, lake chub, and ninespine stickleback were also found in streams of both watersheds in summer, but in substantially lower numbers. In contrast, juvenile northern pike were common in streams downstream of Kennady Lake, but were not captured in the N watershed. Other species captured infrequently in summer sampling included lake trout, longnose sucker, and round whitefish. Young-of-the-year Arctic grayling were also captured in streams immediately downstream of Kennady Lake in summer, i.e., between Kennady Lake and Lake 410.

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

10.3.5 Wildlife

Baseline studies for wildlife were completed within the baseline regional study area (RSA) in order to assess wildlife seasonal distribution and movement in the area surrounding the Project. These studies are described in detail in Annex F (Wildlife Baseline). The wildlife baseline RSA (Figure 10.1-4) is approximately 5,600 km^2, with Kennady Lake at the centre.

Both traditional and scientific knowledge indicate that the Bathurst, Ahiak (Queen Maud), and Beverly caribou herds overlap with the RSA during the northern and post-calving migrations. The home ranges of these herds span from 282,000 km^2 to 345,000 km^2. Kennady Lake (8.15 km^2) makes up approximately 0.003% of their home range area (based on a home range area of approximately 300,000 km^2). Both traditional knowledge and aerial survey monitoring of herd sizes suggest that Bathurst caribou undergo natural, cyclical fluctuations in abundance over time. The RSA is also home to a number of other wildlife species, including barren-ground grizzly bears, wolves, foxes, wolverines, muskoxen, moose, upland breeding birds, waterfowl, and raptors. During the course of field surveys, no Arctic fox were observed within the RSA, as the study area is within the southernmost part of the species' home range. Red fox, in contrast, are relatively common year-round residents within the RSA. Wolves and wolverines generally are present and active in the RSA from March through October, coinciding with the caribou movements through the region. Studies suggest that wolves and wolverine are highly adaptable on the tundra and can alter their location and distribution over time.

The spatial extent of local populations of wildlife extends beyond the spatial scale of the RSA. For example, the grizzly bear and wolverine are characterized by large home ranges and likely have a population extending beyond the boundaries of the Slave Geological Province (SGP; an area of about 200,000 km^2). The barren-ground grizzly bears' annual home range is the largest reported for brown bears in North America. The mean annual range of adult male grizzly bears can span 7,245 km^2 and the mean annual range of females can extend over 2,000 km^2 in the SGP (McLoughlin et al. 2002). Populations of grizzly bear and wolverine generally exhibit low densities on the barrengrounds of the central Canadian Arctic.

Muskoxen occur mostly on Banks and Northwest Victoria Island, but continue to re-colonize the southern portions of their historic range (Fournier and Gunn 1998). During aerial surveys conducted for caribou between 1995 and 2005 in the RSA, small groups of muskoxen were observed. Traditional knowledge indicates that moose are not common to the RSA, although, moose have occasionally been observed.

A total of 28 species of songbirds, shorebirds, and ptarmigan have been detected within the RSA, along with 22 waterbird species. Traditional knowledge holders from Łutselk'e Dene First Nation have identified 35 bird species that are known to inhabit the Project area, 18 of which are edible. Since 1996, ten raptor species and ravens have been recorded within the RSA. In general, the topography within the RSA can be described as gentle undulating terrain; therefore, quality raptor nesting habitat is limited. Optimal nesting habitat is restricted to the northwest corner, in the region of Margaret Lake and along the western boundary of the RSA.

10.4 CLOSURE AND RECLAMATION

The following sub-section of this Key Line of Inquiry contains the Conceptual Closure and Reclamation Plan (Section 10.4.1) that has been developed for the Gahcho Kué Project (Project). It also includes an assessment of the long-term viability of the plan (Section 10.4.2) and a description of how public feedback and available traditional knowledge were used or considered when assembling the plan (Section 10.4.3).

10.4.1 Conceptual Closure and Reclamation Plan

10.4.1.1 Introduction

10.4.1.1.1 Objectives

Two important concepts for the Project are "progressive reclamation" and "design for closure". Closure and reclamation were considered during the selection of design alternatives. As such, closure and reclamation planning has been considered in all Project phases, including design. Progressive reclamation during operations, and closure and reclamation of the site at the end of mining will be consistent with the objectives outlined by INAC in the *Mine Site Reclamation Guidelines for the NWT* (INAC 2007).

The overall goal of the reclamation plan is to minimize the lasting environmental impacts of operations to the extent practical and allow disturbed areas to return to productive fish and wildlife habitat as quickly as possible.

Short-term reclamation objectives include the following:

- progressively reclaim disturbed areas during operations as soon as they are no longer required;
- minimize the risk of erosion and sediment loss as a result of on-site runoff;
- stabilize slopes on all structures to maintain safe working conditions and facilitate reclamation activities;
- restore natural drainage patterns where possible;
- cover ground to prevent soil drifting and dust production; and
- maintain an environmentally safe site.

Long-term objectives consist of the following:

- restore or replace the natural fish habitat that may have been lost, altered, or disturbed as a result of the Project;
- return the site to a state that is similar to other habitats in the same region and time period that are not affected by the Project; and
- create, to the extent practical, an aesthetically pleasing final landscape.

In line with the above-noted objectives, De Beers has made the following commitments for the Project:

- minimize, to the extent practical, the total amount of area disturbed by Project activities at any one time through the use of progressive reclamation;
- recover as much soil as practical for use in reclamation activities;
- develop a fish compensation plan that meets the "no-net-loss" guiding principle established by Fisheries and Oceans Canada (DFO);
- conduct reclamation trials throughout the life of the Project to determine what prescriptions work most effectively at the Project site; and
- liaise actively with other mine operators in the Canadian Arctic to understand the challenges and successes they have encountered with respect to reclamation.

Although closure and reclamation will be progressive and begin as soon as possible, it will extend years after mine closure. De Beers will use proven technology that is available at the time of reclamation, in accordance with the legal requirements at that time to facilitate reclamation as quickly as possible.

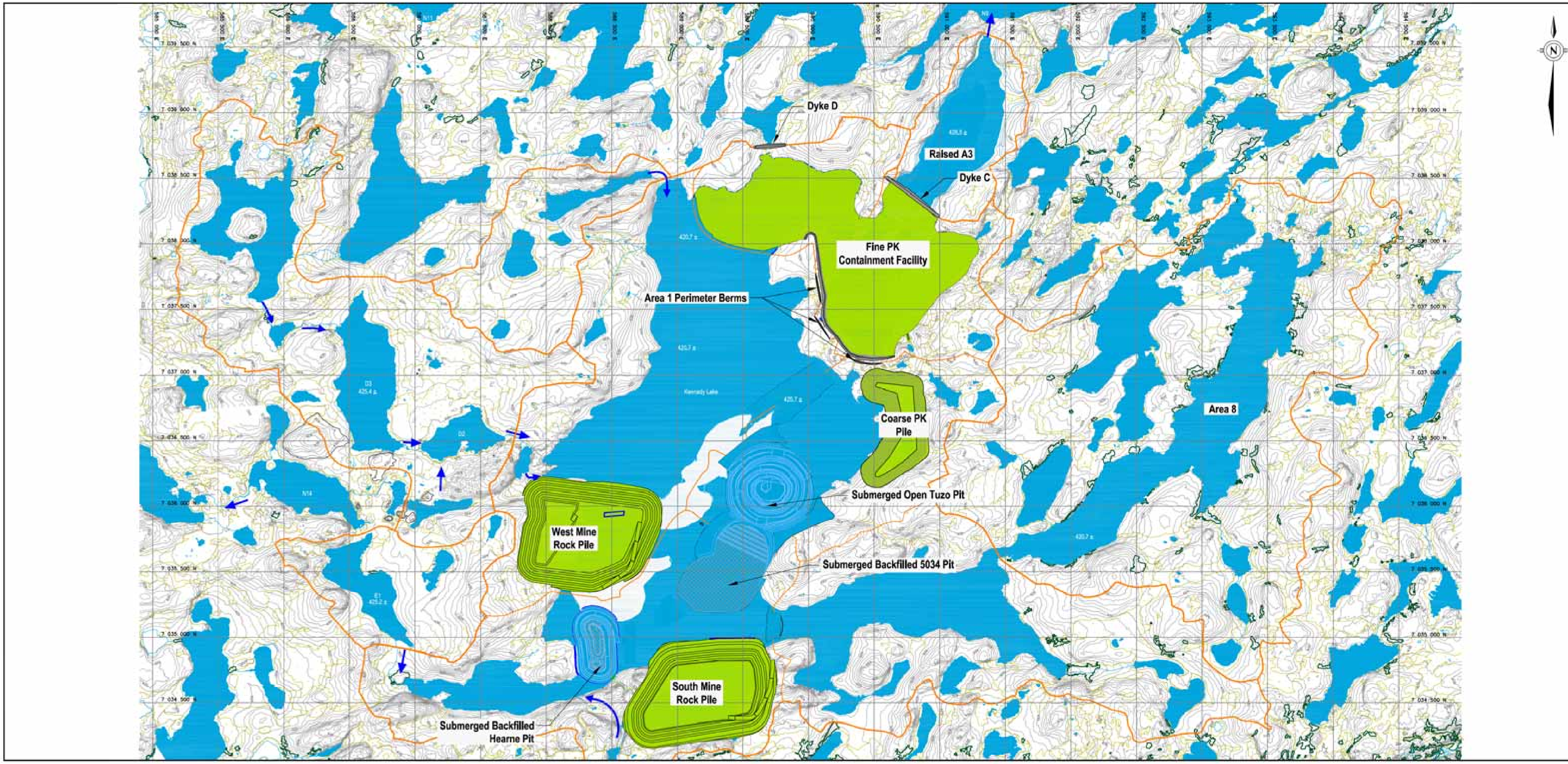
10.4.1.1.2 Overview of Key Closure and Reclamation Activities

The general components of the reclamation program are summarized briefly as follows:

- Salvage and stockpile soil, overburden, and lakebed sediments, to the extent practical, from areas of disturbance.
- Create new or expanded fish habitat areas during construction and operations phases.
- Progressively reclaim parts of the Area 1 and Area 2 portions of the Fine PKC Facility.
- Progressively reclaim portions of the South Mine Rock Pile.

- Progressively reclaim portions of the West Mine Rock Pile.
- Progressively backfill the 5034 Pit.
- Progressively backfill the Hearne Pit.
- At the end of operations:
  - remove all potentially hazardous materials from site;
  - dismantle and remove or demolish all buildings and related structures;
  - remove all above-grade (i.e., above ground level) concrete footings and foundations;
  - construct additional fish compensation habitat near Kennady Lake;
  - construct additional fish habitat enhancements structures, although most habitat enhancement structures will be constructed during operations;
  - refill Kennady Lake using natural runoff supplemented by water drawn from Lake N11;
  - cut channels in Dykes B, K, and N to begin filling the areas around Tuzo Pit and 5034 Pit and allow for lowering of all dykes below final planned lake elevation;
  - upon refilling the lake and achieving appropriate water quality, breach and/or partially remove Dyke A to connect the reclaimed portions of Kennady Lake with Area 8;
  - monitor conditions over time to evaluate the success of the Closure and Reclamation Plan and, using adaptive management and newer proven methods as available, adjust the plan, if necessary; and
  - comply with the legal requirements for closure and reclamation in effect at the end of operations.

An illustration of the Project site after reclamation is shown in Figure 10.4-1.



LEGEND

Existing Ground Contours 5m Index - 1m Intermediate

Marsh Area

Scrub

Sub-watershed Boundary

Drainage Flow Direction

Lake/Pond

Mine Rock

NOTES
Base data source: EBA Figure 8.2 - Final Reclamation

GAHCHO KUÉ PROJECT

Final Reclamation

PROJECTION: UTM Zone 12	DATUM: NAD83
SCALE 500 0 500 METRES	
FILE No: P-Other-021-CAD	DATE: December 22, 2010
JOB No: 09-1365-1004	REVISION No: 0
OFFICE: GOLD - SAS	DRAWN: TAH
CHECK: PT	

DE BEERS CANADA

Figure 10.4-1

10.4.1.1.3 Schedule of Key Activities

The cornerstone of the Project's Closure and Reclamation Plan is progressive reclamation, whereby any disturbed area that is no longer in use is reclaimed as soon as possible and practical. As a result, closure and reclamation activities will occur throughout the 11-year operational life of the Project. Key milestones in the closure and reclamation schedule are outlined in Table 10.4-1.

Table 10.14-1 Key Activities and Milestones in the Conceptual Closure and Reclamation Schedule

Activity / Milestone	Year
Begin progressive reclamation of Fine PKC Facility (Areas 1 and 2)	3
Begin progressive reclamation of South Mine Rock Pile	5
Begin progressive reclamation of West Mine Rock Pile	7
Begin progressive reclamation of the 5034 Pit	5
Begin progressive reclamation of the Hearne Pit	7
Begin progressive reclamation of Coarse PK Pile	6
Finish mining in the Tuzo Pit	11
Breach Dykes B, K, and N	11
Decommission explosives storage and manufacturing facilities	11
Complete construction of fish enhancements structures	11
Start to decommission processing plant and service shop	12
Complete decommissioning of processing plant and maintenance complex	12
Decommission main power plant	12
Remove main fuel storage tanks	12
Remove permanent accommodation complex	13
Achieve interim closure status	13
Reclaim site roads not required for reclamation monitoring	13
Breach Dyke A	19+
Complete the refilling of Kennady Lake	19+
Final demobilization from site	19+
Monitor post-closure conditions in Kennady Lake	20+

10.4.1.2 Overburden and Soil

During the development of the mine, overburden (including lakebed sediments) will be removed to expose the top of the kimberlite pipes contained within the Hearne, 5034, and Tuzo deposits and to allow surface mining of the deposits to proceed. To the extent possible and practical, these materials will be stockpiled as a portion of the South Mine Rock Pile and used for construction and/or reclamation activities, as part of the overriding “design for closure” philosophy that has been adopted for the Project. For example, overburden (including lakebed sediments) will be used to cover any areas in the core of the mine rock pile where potentially reactive mine rock (if present) is sequestered. The lakebed sediments and overburden, which consist mainly of till, will provide a low permeability barrier that will limit infiltration and encourage water to flow over the surface of the mine rock pile, rather than through it.

In a similar fashion, soils disturbed during the construction of the plant site, airstrip, and other on-land facilities will be, to the extent possible and practical, initially stockpiled in the South Mine Rock Pile. As progressive reclamation occurs, soils will be recovered from the stockpiles and spread over reclaimed areas that would benefit from additional soil.

10.4.1.3 Mine Rock Piles

Over the mine life, the Project is projected to produce approximately 226 Mt of mine rock. Of this total, approximately 143 Mt of mine rock will be placed in two designated mine rock piles during operations. 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. 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. The angle of the side slopes will provide stability against sliding, with flatter side slopes being constructed when the final slope is exposed to the shoreline. The mine rock piles are expected to be in permafrost conditions at the end of mine life (Year 11) since the piles are constructed in ambient conditions that average -10°C.

Geochemical testwork on the mine rock will be ongoing throughout the operational period, but results to date indicate that any PAG rock would comprise only a small proportion of the overall mine rock tonnage. Any potentially reactive rock will be identified by mine geologists and confirmed by blast hole sampling and testing, and will be sequestered within the central zone of the mine rock pile. Only non-reactive mine rock will be placed on the upper and outer surfaces of the mine rock pile. The thickness of the cover layer is predicted to be sufficient so that the active freeze-thaw layer remains within the non-reactive mine rock.

Based on available survey data, the mine rock piles will be constructed in Areas 5 and 6, and designed in such a way to allow both short- and long-term stability. A minimum thickness of 2 m of non-reactive mine rock will be placed prior to placement of any barren kimberlite, or mine rock mixed with barren kimberlite. This procedure will be used because experience at the Ekati Diamond Mine suggests that coarse kimberlite placed in direct contact with tundra soils can lead to low pH drainage due to the acidic nature of the tundra soils. Placing the initial layer of non-reactive mine rock at the bottom of the mine rock piles will separate barren kimberlite from the tundra soils.

Closure of the mine rock piles will involve contouring and re-grading, and will occur progressively, starting as early as Year 5 for the South Mine Rock Pile and Year 7 for the West Mine Rock Pile (Table 10.4-1). The piles will not be covered or vegetated, consistent with the approaches in place at the Ekati Diamond Mine and Diavik Diamond Mine. Thermistors will be installed within the mine rock piles to monitor the progression of permafrost development. The upper portion of the thick cover of clean mine rock over the waste repository will be subject to annual freeze and thaw cycles, but the PK and PAG rock sequestered below are predicted to remain permanently frozen.

10.4.1.4 Fine Processed Kimberlite Containment Facility

Reclamation of the Fine PKC Facility will be completed during mine 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 m to 2 m thick layer of non-acid generating (non-AG) 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 non-AG 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.

Permafrost development in the Fine PKC Facility and underlying talik is expected to occur over time. Thermistors will be installed in the Fine PKC Facility to monitor the formation of permafrost in the solids. The Fine PKC Facility is anticipated to take an appreciably longer time (i.e., to the end of the reclamation phase) than the mine rock piles to establish permafrost conditions, particularly Area 2 because a portion this area is located on the lake bed, under which a talik existed.

10.4.1.5 Coarse Processed Kimberlite Pile (Area 4)

The Coarse PK Pile is located on land adjacent to Area 4. It will be shaped and covered with a layer of mine rock of a minimum of 1 m to limit surface erosion. Runoff will be directed to Area 4.

10.4.1.6 Mine Pits

The Project will result in the creation of three mined-out pits: 5034, Hearne, and Tuzo. The closure and reclamation activity planned for each pit is described below.

10.4.1.6.1 5034 Pit

Mining within the 5034 Pit is scheduled to finish in Year 5 and the pit is expected to be about 305 m deep. Once mining in the pit has ceased, closure and reclamation activities, in the form of backfilling, will begin.

The 5034 Pit will be the primary storage area for mine rock from the Tuzo Pit, although PK might also be stored in the 5034 Pit. The 5034 Pit will be completely backfilled except for the northern quarter where it borders the Tuzo Pit; this shared boundary is lower than the bottom of Kennady Lake. The 5034 Pit will be backfilled to the extent possible with mine rock; the remaining space will be eventually filled with water once mining in the Tuzo Pit is complete.

10.4.1.6.2 Hearne Pit

Mining within the Hearne Pit is scheduled to finish in Year 7 of operations. Once mining in the pit has ceased, backfilling will begin. Hearne will be the repository for the fine PK stream as soon as mining of Hearne pit has ceased. The fine PK will be released via a pipeline into the pit. Runoff water, pit water, and decant water from the fine PK will cause a water layer above the settled fine PK in Hearne. The water will be left in place to allow for an accelerated filling schedule of the Hearne Pit. The top of the fine PK in the pit is anticipated to be approximately 120 m deep; in comparison, the total depth of the Hearne Pit is expected to be 205 m.

10.4.1.6.3 Tuzo Pit

The Tuzo Pit, which is the last pit to be mined, will not be backfilled with material and will be about 305 m deep. The pit will be allowed to flood following the completion of the operations phase. Natural watershed inflows will be supplemented by pumping water from Lake N11. Flooding of the pits and returning Kennady Lake to its original lake level is expected to take approximately eight to nine years after the end of operations.

10.4.1.7 Buildings, Machinery, and Other Infrastructure

After mining has ceased, closure and reclamation of the plant site and airstrip will begin. Gradually, all buildings, machinery, equipment, and other infrastructure established as part of the Project will be demolished, removed, or buried.

To support on-site personnel during the initial closure and reclamation phase of the Project, suitable site services, including potable water treatment, sewage treatment, and communications, will be maintained. Once they are no longer needed, they will be decommissioned, dismantled, and disposed of, as appropriate. They will be replaced, as appropriate, with smaller, temporary facilities in support of post-closure monitoring activities.

10.4.1.7.1 General Demolition and Disposal Procedures

Prior to demolition, buildings and equipment will be inspected so that potentially hazardous materials are correctly identified and flagged for appropriate removal and disposal. All equipment will be drained of fluids and cleaned so that potentially hazardous materials are not placed within the inert materials landfill.

Before beginning these activities, the appropriate authorizations for the non-hazardous waste disposal site will be obtained as required from the relevant regulatory agencies that deal with land leases and water use, such as the MVLWB and INAC.

Salvageable Materials

Structures, equipment, and materials deemed economically salvageable at the time of demolition will be dismantled and removed from site. Equipment will be cleaned, drained, and degreased as required before off-site transport.

Salvageable equipment is generally expected to include machinery and mobile equipment in working or repairable condition. Hazardous materials are generally expected to consist of waste oil, glycol, lubricants, solvents, paints, batteries, and miscellaneous chemicals. Some of these materials may be suitable for recycling, if appropriate facilities off-site are available.

Salvageable equipment to be shipped off-site will be prepared and stored in one of the site laydown areas. Hazardous materials will be stored in sealed containers and drums in a lined waste transfer area or temporary enclosure. The equipment and materials will be shipped to appropriate disposal, recycling, or salvage facilities (most likely in Edmonton) on the next available winter road.

Inert Solid Materials

Non-salvageable and non-hazardous components from demolition of the site buildings, structures, and equipment will be dismantled, washed and/or degreased (as necessary), and deposited in the inert materials landfill within the mine rock pile. The landfill will be above the water level of the re-filled Kennady Lake. The deposited materials will then be covered with a layer of non-reactive mine rock.

All above-grade concrete structures will be demolished, and any remaining below-ground footings/foundations covered with till or rock. Demolition concrete will be placed in the inert materials landfill.

Potentially Contaminated Soil and Hazardous Materials

The potential for ground contamination around the maintenance building and other structures will be assessed. Assessed areas will include the airstrip de-icing area and fuel storage pad, fuel tank farm, processing plant, power plant, accommodations complex, service complex, waste management facilities, and storage facilities. Soils in these areas will be sampled during decommissioning and analyzed for contaminants, such as hydrocarbons and glycol. Any contaminated soils will be excavated and either permanently encapsulated in a secure area, treated on-site to an acceptable standard, or stored in appropriate sealed containers for off-site shipment and disposal.

Hazardous materials will be stored in sealed containers and drums in a lined waste transfer area pending shipment to the appropriate off-site recycling, or disposal facility. Generally, hazardous materials will be retrieved directly by licensed companies specializing in the handling of these materials.

10.4.1.7.2 Process Facility

At the end of the operational life of the mine, all remaining ore stockpiles will be processed through the plant. The base of the stockpile will be scraped by bulldozers, and the scrapings run through the processing plant. Once all the ore has been processed, the various circuits within the processing plant will be flushed and cleaned.

When the milling circuit has been cleaned out, the interior of the building will be washed. All potentially hazardous materials, such as hydrocarbons, chemicals, and reagents, will be removed and prepared for off-site disposal. The process equipment will be drained of any potentially hazardous materials, such as lubricating oil and glycol. In addition, all utilities and services, including air, glycol, power, and water, will be shut off, de-energized, and drained as necessary to permit demolition.

Buildings and equipment with no salvageable value will be dismantled and buried in the inert materials landfill. Specific materials will be dealt with as follows:

- Concrete foundations and floor slabs will be broken down to original ground level and demolition rubble buried in the inert materials landfill.
- Surface piping will be flushed, if necessary, removed, and buried in the inert materials landfill.
- Buried electrical cables will be cut approximately 1 m below grade at surface terminations and left intact. The remaining above-ground cable will be removed and disposed of in the inert materials landfill.
- All other inert materials not suitable for re-use or salvage, such as metal cladding, wallboard, and insulation, will be buried in the inert materials landfill.

At closure, a 1 to 2 m cover of mine rock will be placed over the wastes in the inert demolition landfill.

10.4.1.7.3 Power Plant

One or more of the main generators will remain operational as long as necessary during the reclamation period to provide power. Once they are no longer needed, the generators will be decommissioned. The power plant will then be dismantled and salvaged or otherwise reclaimed using practices similar to those described for the processing plant.

After the power plant has been decommissioned, a small amount of power may still be required for accommodations, site services, and other activities. If such is the case, a small, skid-mounted diesel generator set will remain on-site; it will be demobilized when it is no longer required.

10.4.1.7.4 Explosives and Related Facilities

All explosives will be removed from the site by qualified contractors and handled only by certified employees in compliance with the federal *Explosives Act* and the *NWT Mine Health and Safety Act and Regulations*. Once the explosives and supporting infrastructure have been removed, the related buildings will be reclaimed as described above for other similar structures.

The remaining inventory of ammonium nitrate left on-site at the end of mining will either be returned to the supplier or transferred to another licensed user. The emulsion plant will be decommissioned, cleaned, and demolished in the same way as other buildings.

The remaining inventory of explosives caps left on-site at the end of mining will either be returned to the supplier or transferred to another licensed user. The cap magazines will then be decommissioned, cleaned and either removed from site for salvage or demolished.

10.4.1.7.5 Other Buildings

The shop complex will be decommissioned, cleaned, and demolished in a manner similar to the processing plant. The accommodations complex will remain in partial use after mine operations end until it is no longer required. Non-required portions of the camp will be decommissioned and reclaimed. Upon completion of the reclamation program, the remaining portion of the camp will be removed from site.

10.4.1.7.6 Transportation Corridors and Airstrip

Site roads not required for post-closure maintenance and monitoring will be decommissioned and reclaimed at the end of the closure phase; the rest will be reclaimed at the end of post-closure monitoring period. Post-closure access to the site will be achieved primarily by aircraft, with minimal vehicle traffic.

The airstrip will be reclaimed near the end of the site closure phase of the Project. It will be preferable to leave the airstrip until the end of monitoring requirements; this would be decided during the site closure phase. Lighting, navigation equipment, and culverts will be removed, and contouring will be done to eliminate potential hazards to wildlife. Reclamation will involve scarifying and loosening the surface to encourage natural re-vegetation. Where erosion or sedimentation is a concern, the surface will be re-contoured. Culverts or stream-crossing structures will be removed, and natural drainage re-established.

10.4.1.7.7 Fuel Storage Tanks

Before demobilization, the remaining diesel fuel inventory will be assessed for requirements for temporary power generation and construction equipment during the reclamation program. In the event of a shortfall, additional diesel fuel will be delivered to site and stored in the fuel tank farm. Smaller portable tanks with secondary containment will be used for fuel storage to allow the permanent tanks to be removed at the end of the closure program.

Before the permanent tanks are dismantled, any remaining inventory will be withdrawn. Steel plate sections and distribution system components will be washed and disposed of in the inert materials landfill, pursuant to regulatory approval. The containment berm and liner materials will be removed, and the area re-graded. Any additional fuel required for power generation and equipment for demobilization activities and post-closure monitoring will be drawn from the envirotanks.

10.4.1.7.8 Solid Waste Management Areas

The incinerators, waste handling equipment and associated structures will be dismantled. Salvageable equipment and structures will be demobilized from site. Non-salvageable equipment, materials, and structures will be disposed of in the inert materials landfill.

The potential for ground contamination in the immediate area of the incinerator and waste-handling facilities will be assessed, and any required remediation will be undertaken. A cover of non-reactive mine rock will then be placed over the site, and the area will be re-graded to blend with the surrounding topography.

Operation of the landfill will include the regular placement of a 2 m cover of non-reactive mine rock over the deposited wastes. Upon closure of the site, all remaining waste materials will be covered with a layer of non-reactive mine rock.

10.4.1.7.9 Conceptual Fish Habitat Compensation Plan

Construction and operation of the mine will cause harmful alteration, disruption, or destruction (HADD) of fish habitat in the Kennady Lake watershed. The affected habitat areas include portions of Kennady Lake and adjacent lakes within the Kennady Lake watershed that will be permanently lost, portions that will be physically altered after dewatering and later submerged in the refilled Kennady Lake, and portions that will be dewatered (or partially dewatered) but not otherwise physically altered before being submerged in the refilled Kennady Lake. During Project construction and operations, there will also be some alterations of flows within the Kennady Lake watershed and in areas downstream from the Kennady Lake watershed.

Compensation options have been developed and evaluated in step with the evolution of the Project. Additionally, meetings between De Beers and Fisheries and Oceans Canada (DFO) have occurred on several occasions, including site visits by DFO. The Conceptual Compensation Plan (Appendix 3.II) outlines anticipated Project effects on fish habitats, describes the various options considered for providing compensation, and presents a proposed fish habitat conceptual compensation plan to achieve no net loss of fish habitat according to DFO's Fish Habitat Management Policy (DFO 1986, 1998, 2006).

Proposed Conceptual Compensation Plan

The proposed fish habitat compensation plan consists of a combination of the compensation options (Section 3, Appendix 3.II). The preferred options for the proposed conceptual compensation plan include Options 1b and 1c (raising the water level in lakes to the east of Kennady Lake), Option 2 (raising the level of Lake A3), and Option 10 (widening the top bench of mine pits where they extend onto land). Also included in the proposed compensation plan are Options 3 and 4 (construction of habitat enhancement features in Areas 6, 7 and 8) and Option 8 (the Dyke B habitat structure).

The amount of compensation habitat, in terms of surface area, provided by the conceptual compensation plan is summarized in Table 10.4-2. Table 10.4-2 also shows the compensation habitat areas and compensation ratios (based on habitat surface area) during operations and after closure with compensation Options 1b, 1c, 2 and 10, and including altered areas of Kennady Lake that will be reclaimed and submerged at closure.

Quantification of habitat gains in terms of HUs, and determination of compensation ratios based on HUs, will be completed as part of the development of a detailed compensation plan to be completed in 2011.

Table 10.4-2 Summary of Fish Habitat Compensation Achieved with the Proposed Conceptual Compensation Plan

Compensation Description	Compensation Habitat Area (ha)	
	During Operations	After Closure
Newly Created Habitat		
Option 1b – Construction of Impounding Dykes F, G, E1 and N14 to the west of Kennady Lake to raise Lakes D2, D3, E1 and N14 to 428 masl elevation	149.7	–
Option 1c – After closure, further raise the water level in Lakes D2, D3, E1 and N14, and the surrounding area, to 429 masl and reconnect the flooded area to Kennady Lake through Lake D1	–	195.9
Option 2 – Construction of Impounding Dyke C between Area 1 and Lake A3, Dyke A3 to the north of Lake A3, and Dyke N10 between Lakes A3 and N10 to raise Lake A3 to 427.5 masl elevation	31.1	31.1
Option 10 – Widening the top bench of pits (to create shelf areas) where they extend onto land	–	13.7

Table 10.4-2 Summary of Fish Habitat Compensation Achieved with the Proposed Conceptual Compensation Plan (continued)

Compensation Description	Compensation Habitat Area (ha)	
	During Operations	After Closure
Altered Areas Reclaimed and Submerged at Closure		
Hearne Pit [(a)]	–	16.0
5034 Pit [(a)]	–	35.0
Tuzo Pit [(a)]	–	35.2
Dykes A, B, J, K and N	–	23.8
Road in Area 6	–	4.0
Water Collection Pond Berms CP3, CP4, CP5 and CP6	–	1.3
Mine rock areas [(b)]	–	25.3
Total	**180.8**	**381.3**
Compensation Ratios (gains:losses) [(c)]	**0.65**	**1.37**

(a) The areas for these options are the entire pit areas, including habitat features along the edges and the deep-water areas.

(b) The mine rock piles with final surface elevations between 410.0 and 418.0 masl are considered as compensation habitat.

(c) Calculated based on total area of permanently lost habitat and physically altered and re-submerged habitat (277.8 ha; Tables 3.II-2 and 3.II-11).

ha = hectares; masl = metres above sea level.

Monitoring Effectiveness of Compensation

Habitat created or enhanced to compensate for the loss of fish habitat will be monitored to assess effectiveness of compensation by evaluating the physical and biological characteristics of the habitats, as well as fish use of the habitats. Habitat improvements will be implemented, as part of an adaptive management approach in consultation with regulators, if new or enhanced habitats are not providing the required habitat components for the target fish species.

Monitoring results would be used, if necessary, to adjust mitigation and habitat compensation measures and make design improvements as required. Habitat monitoring will be vital to confirming the no net loss objective has been achieved. Details of the compensation monitoring will be included in the detailed compensation plan. The detailed monitoring plan will be designed to meet all fish and fish habitat monitoring requirements included as conditions attached to any regulatory authorizations, approvals or permits that may be issued for development of the Project. Should, for some reason, the proposed habitat compensation not be sufficient to achieve no net loss of the productive capacity of fish habitat, additional habitat compensation would be developed in consultation with the appropriate regulators.

10.4.1.8 Erosion Control and Revegetation

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 revegetation. Rock armouring will be done where revegetation is not possible and erosion control is required. The rock will be obtained by screening suitably sized inert material from the mine rock stockpile

An estimated 86 hectares (ha) will have soil replaced and will be revegetated (Section 11.7; Appendix 11.7.I), which includes the following facilities:

- plant site (31.5 ha);
- roads (34.5 ha);
- airstrip (9.6 ha); and
- dykes (10.3 ha).

Revegetation in northern areas is challenging, because of limitations associated with cool short summers, low precipitation levels, cold winters, permafrost, and other biotic and abiotic influences that are not always readily identifiable or controllable. Other challenging factors include the limited availability of soil, a less-than-comprehensive understanding of indigenous plant physiology and associated succession processes, and the general absence of endemic plant seeds or other propagules in sufficient quantities for use in large-scale planting or seeding. As a result, growth and establishment of vegetation in northern areas is often slow and patchy.

There are few examples of successful and well-documented revegetation programs in northern latitudes, especially for large-scale disturbances, that are instructive. Emerging technology and program techniques from southern locales are not directly relevant to northern areas. A revegetation plan that can fulfill the reclamation objectives will need to be flexible and developed through the operational life of the Project to take advantage of key findings obtained at other mine sites. At the Ekati and Diavik diamond mines, active reclamation research has been ongoing for several years with the goal of developing the best revegetation strategies for disturbed northern areas (HMA 2005; Naeth et. al. 2005). These research projects have involved the use of various combinations of amendments, soil materials, fertilizers, and vegetative species to maximize regrowth and develop a self-sustaining vegetative cover.

Some key results that will be considered at the Project include the following:

- The Ekati Diamond Mine has found that for selective mine units, including a diversion channel, a former exploration topsoil stockpile and a lake sediment stockpile, seedlings and willow cuttings have had some success.
- Similarly, a combination of dwarf birch, fireweed, and bluejoint were successfully established in esker areas at the Ekati Diamond Mine, whereas direct seeding of the tundra has not been successful.
- Care needs to be taken in stockpiling soil materials for reclamation, with free dumping proving to be more effective at maintaining soil physical properties than levelling the piles.
- Site recontouring and landscaping have improved moisture conditions, which in turn have improved vegetation success.
- Creating microhabitat, such as small boulder piles and mild depressions to trap moisture, has shown to be effective in enhancing plant growth opportunities, although boulder piles have only worked where vegetation is already established.
- The Ekati Diamond Mine has found that native plant cultivars applied at a low seeding rate have been the most successful in encouraging native plant recolonization.

- Sewage sludge has had mixed success at the Ekati Diamond Mine, but it has been a key part of plant establishment at the Diavik Diamond Mine (Naeth 2007, pers. comm.).
- Based on experience at the Ekati Diamond Mine, careful control of the application of sludge is required to prevent depressions from over-concentrating sludge and preventing plant establishment.
- Summer planting has not proven successful with seeds failing to germinate or seedlings dying from moisture stress; fall or spring planting shows the most promise.
- Grazing of newly established vegetation has been problematic at the Ekati Diamond Mine, and some method of discouraging grazers, such as Arctic hares, may be required.
- Salvaged glacial materials mixed with lake bed sediments containing a preponderance of till yield a soil with improved texture that has proved successful in promoting plant growth; however, the inclusion of too much lake sediments has led to soil compaction and the inhibition of plant growth.

Studies similar to those underway at the Ekati and Diavik diamond mines will be completed at the Project to develop a revegetation plan that is expected to help in the successful restoration of the site. Test plots will be prepared to evaluate the application and suitability of various reclamation techniques on the different ecological land classes disturbed as a result of Project activity. The evaluation will consider the physical aspects of revegetation, such as recontouring, erosion control techniques, seedbed preparation, surface roughening, and the use of soil amendments, which collectively promote natural secondary succession. Test plots will also be used to assess the effectiveness of various seed mixtures and their application on different growth media. In addition, the feasibility and practicality of collecting seeds from local species will be evaluated.

The overall objective of the revegetation management plan will be to create a stable landscape that encourages natural colonization, encroachment, and regeneration of endemic plant species. However, intermediate steps may be required to control soil and slope stability over a particular time period. Alternative reclamation methods, such as rock armouring, may also be used to provide long-term stability of rock slopes or other site features that may not be suitable for revegetation.

10.4.2 Long-term Viability of the Plan

The Terms of Reference issued for the Project called for an evaluation of the long-tem viability of the Closure and Reclamation Plan (Gahcho Kué Panel

2007). Particular emphasis was placed on the stability of the remaining structures left on-site and the propensity for permafrost to develop within these structures (see Table 10.1-1).

Following final closure of the site, the remaining large structures will include the following:

- South Mine Rock Pile;
- West Mine Rock Pile;
- Fine PKC Facility;
- Coarse PK Pile;
- backfilled and flooded 5034 Pit;
- partially backfilled and flooded Hearne Pit, and
- flooded Tuzo Pit.

The long-term viability of each of these structures is outlined below.

10.4.2.1 Mine Rock Piles

10.4.2.1.1 Geochemical Stability

Two key factors that affect geochemical stability are acid rock drainage and metal leaching (which may be a result of acid rock drainage). Based on the testing completed, less than 6% of the mine rock extracted through open pit mining will have to be managed as being PAG with metal leaching potential, even at very low levels of sulphur. Any PAG rock, as well as barren kimberlite, will be sequestered within the interior of the mine rock piles in areas that will allow permafrost to develop (i.e., areas on land) or will be underwater when Kennady Lake is re-filled. For the portions of the mine rock piles that are on land, PAG rock will be separated from the tundra by at least 2 m of non-PAG rock and till from ongoing pit stripping will be used to cover PAG rock placed within the interior of the structure to keep water from penetrating into that area of the structure. Permafrost is expected to develop within the mine rock piles.

10.4.2.1.2 Physical Stability

Stability analysis for typical sections along the mine rock piles have been completed (Section 3.7.3.3). The slope, height, and horizontal offset of each bench that makes up each pile are based on the results of the stability analysis. The overall slope of the mine rock piles is 2.4H:1V or flatter. Slope stability analysis indicates that the margin of stability (factor of safety) is greater than 1.5

at a maximum height of 95 m. Maximum height of the South Mine Rock Pile is currently estimated at 90 m, with the maximum height of the West Mine Rock Pile expected to be about 70 m.

Larger scale freezing within the mine rock pile is also expected to occur. Experience at the Ekati Diamond Mine indicates that permafrost develops rapidly within mine rock piles with an active freeze/thaw layer of about 8 m. Areas more than 8 m below the surface of the mine rock that are not in close contact with Kennady Lake water are likely to be permanently frozen; however, the two mine rock piles are constructed on the edge of Kennady Lake and parts of each pile will be inundated with lake water. A talik (permafrost free area) exists below Kennady Lake, which also makes the prediction of permafrost in these piles more complex.

Both above-ground structures will be subject to the stress of natural weathering and erosive forces. Chemical and mechanical weathering of exposed rock is ubiquitous on the earths' surface. In drier, arctic environments, such as those found in the Project area, the rate of chemical and physical weathering tends to be comparatively slow. Weathering of the mine rock pile and the mine rock covered PK is, therefore, expected to proceed at rates comparable to the weathering of natural geologic features in an arctic or temperate climate. Assuming that such climatic conditions persist, these structures will likely remain in place for thousands, if not tens of thousands, of years.

The potential occurrence of seismic events that could affect the physical viability of the mine rock piles in the long-term is also considered to be of low probability. Seismicity does not govern any design aspects of the structures. As such, the structures can withstand seismic events well in excess of those considered credible for the region. The central part of the NWT is generally considered to be seismically inactive without identifiable active faults. Further, it is quite distant from the active seismic zones in Canada and is located within the stable portion of the Canadian Shield.

No major earthquake has occurred in the past century in the vicinity of Kennady Lake. The closest earthquake event of notable magnitude occurred more than 1,000 km west of the site, and no substantial seismic activity has been recorded within a 500 km radius of the site. The site is located within the Stable Craton Area; hence, no probabilistic ground motion values could be calculated based on Appendix C, Table C-2 in the National Building Code of Canada (NRCC 2005). This does not mean that strong earthquake shaking will not happen; only that it is considered improbable.

10.4.2.2 Fine Processed Kimberlite Containment Facility

The Fine PKC Facility will be located in Areas 1 and 2; taking advantage of the physical stability of the existing basins. The fine PK will be covered by a 1 m layer of Coarse PK and then a 1 to 2 m thick layer of mine rock to isolate the tailings. Areas 1 and 2 will be linked into a contiguous facility, which will be contoured to achieve favourable drainage patterns so that water will flow toward Area 3 of Kennady Lake and not form ponds on the surface.

The Fine PKC Facility is constructed in lake areas that were covered with water and underlain by a talik. Since the Fine PKC Facility is only separated from the water in Area 3 of the re-flooded Kennady Lake by a filter dyke that allows water to flow through the dyke, the edge of the PKC will be in constant contact with unfrozen water. Development of permafrost in the fine PKC Facility is complex and currently uncertain.

Experience at the Ekati Diamond Mine indicates that permafrost develops rapidly within mine rock piles with an active freeze/thaw layer of about 8 m. The active layer may therefore likely extend below the 1 to 2 m layer of mine rock and into the 1 m layer of coarse PK and possibly fine PK. Runoff over the Fine PKC Facility may also have corresponding sub-surface flows within the active zone during the warmer months.

The material used to construct the mine rock cover will be fairly coarse, and air will be able to move through the cover layer relatively easily. The underlying PK will be finer and more impervious to the passage of air. Hence, complete permafrost development within the PK layer will take some time, and the time required will depend on the thickness of the PK layer, the salinity of the water contained therein, and the other factors mentioned above.

Weathering processes observed in temperate and Arctic environments on granitic materials suggest that the boulders and cobbles that constitute the active layers of both structures will very slowly reduce in size. This will result in the eventual development of a finer grained layer of rock replacing the granitic upper active layer on the Fine PKC Facility. The reduction in grain size will result in a more compacted surface layer, with a correspondingly reduced surface area exposed to further weathering. The net result will be a reduced active layer and an increased volume of frozen soil within each structure. Some of the finer grained material may be removed from the surface layer over time, due to snow melt or rainfall runoff.

10.4.2.3 Coarse Processed Kimberlite Pile

The coarse PK Pile will be shaped and covered with a layer of mine rock to a minimum depth of 1 m to limit surface erosion. Given that experience at the Ekati Diamond Mine indicates that permafrost develops rapidly within mine rock piles with an active freeze/thaw layer of about 8 m, the active layer is expected to extend into the coarse PK although possibly not to the same extent.

The Coarse PK Pile will be built entirely on land to a maximum height of 30 m and will have side slopes of 4H:1V. Permafrost conditions are expected to develop within the pile; however by the end of operations, the western edge of the pile will have reached the Area 4 of the re-flooded Kennady Lake and will likely be in contact with lake water.

10.4.2.4 Flooded Pits

In-pit disposal of PK represents greater physical and geochemical stability compared to on-land storage. The rock around the ore bodies consists generally of granite. Therefore, the resulting pit walls present greater physical stability than dams and dykes that would be used to contain PK on land. The PK and mine rock stored in the pits will be covered by water when the lake is re-filled, resulting in greater geotechnical stability.

Long-term changes to the shape or structure of the backfilled material contained within the Hearne and 5034 pits are considered unlikely. The deposited PK and mine rock will be physically stable within the pits, and natural sediments will accumulate over the surface of the backfilled material, as they would elsewhere in Kennady Lake. The low temperature and oxygen conditions expected to develop within the backfilled materials will effectively prevent the oxidation of sulphides or the occurrence of other chemical reactions within the backfill.

With respect to the Tuzo pit, some saline groundwater will accumulate in the bottom of the pit during the refilling process. Once the Tuzo pit and the adjoining 5034 pit have been completely filled, the active flow of groundwater into the Tuzo pit will notably decrease. However, as a result of passive diffusion and the small residual inflow that remains, salt levels in the lower portion of the Tuzo pit will continue to rise until they are in equilibrium with the surrounding groundwater.

10.4.2.5 Conclusion

The Terms of Reference specify the De Beers demonstrate the long-term maintenance of frozen conditions both within and under mine rock and PK storage facilities. Because these facilities extend across land and lake conditions, predictions of permafrost development cannot rely on experience with land-based containment facilities at other mines. It is expected that predictions of permafrost conditions at the Kennady lake site are more complex and will require additional study. De Beers will commit to an additional detailed study of permafrost development in the mine rock and PK storage facilities and its effect on long-term waste storage.

The Terms of Reference also identify an evaluation of the management options to deal with acid generating rock and its impacts. Because the PAG rock and kimberlite will be stored within the mine rock piles, which will be partly in water and partly on land, this evaluation is also related to the maintenance of frozen conditions.

Climate warming may also restrict the extent of permafrost development in all four facilities (i.e., the two mine rock piles, the Fine PKC Facility, and the Coarse PK Pile) and would be considered in the detailed study.

10.4.3 Consideration of Public Feedback and Traditional Knowledge in Developing the Plan

As noted in the *Terms of Reference for the Gahcho Kué Environmental Impact Statement* (Terms of Reference), the EIS is to provide:

> *"a summary of the use of public consultation, consultation with first nations, and traditional knowledge in determining standards and methods for reclamation".*

The Terms of Reference (Gahcho Kué Panel 2007) for this EIS was based on an extensive scoping exercise (MVEIRB 2006) that identified community concerns related to all aspects of the Project including closure and reclamation. The information arising from this process was used in developing the Closure and Reclamation Plan.

This section was developed to outline how additional community, and public feedback, as well as traditional knowledge, was initially solicited, what information was obtained, and how this information was used or how it influenced the design of the Closure and Reclamation Plan.

10.4.3.1 Overview of the Engagement Process

During the earliest phases of exploration at Kennady Lake, De Beers initiated contact with the Akaitcho, Tłı̨chǫ, and Métis communities (information gained from numerous meetings is compiled in Section 4, Table 4.3-1). De Beers participated in the MVEIRB scoping workshops in 2006, listening to the community participants and answering questions.

Following release of the Terms of Reference, De Beers contacted Chiefs and Councils, and other community leaders requesting permission to conduct a community engagement program to receive feedback on community concerns and priorities related to the Terms of Reference. These initial meetings resulted in a series of community meetings and open houses in the Akaitcho, Tłı̨chǫ, and Métis communities. The open houses were staged in seven communities: Behchokǫ̀, Gamètì, Wekweètì, Whatì, Yellowknife, Fort Resolution, and Łutselk'e. Attendance included Aboriginal leaders and members of the local communities, as outlined in Section 4.

The open house sessions were typically followed by a community supper and community meeting, open to all residents. The community meetings included a DVD presentation that described the Project from development through closure. The video presentation was followed by oral presentations on the environmental and socio-economic aspects of the Project. Members of the community were invited to share their opinions, questions, and feedback.

In the spring of 2010, De Beers invited the communities close to the Project to a site visit and an update of the Project. Communities that visited the site included the Deninu Kué First Nation, the Yellowknives Dene First Nation, the Łutselk'e Dene First Nation, and the Tłı̨chǫ Government. The participants' comments and questions, and De Beers' answers were recorded. The NWT Métis Nation and the North Slave Métis Alliance were invited, but did not visit the site.

De Beers and the Łutselk'e Dene Fist Nation worked together extensively to develop the methods for the Traditional Knowledge Study. The study was completed and verified; however, the TK study is not available as it has not been released by the Łutselk'e Dene First Nation. De Beers is continuing to discuss the potential for a Traditional Knowledge Study for Gahcho Kué with the Yellowknives Dene First Nation and the Tłı̨chǫ Government. Consequently, traditional knowledge was collected largely through secondary sources, as detailed in Section 5 and Annex M (Traditional Knowledge and Traditional Land Use Baseline).

10.4.3.2 Summary of Received or Identified Information

Feedback from community members, including Aboriginal attendees, was generally focused around broad concerns or objectives. Specific recommendations as to the standards and methods for reclamation were rarely discussed or brought forward. On a number of occasions, open house attendees voiced their desire for Kennady Lake to be restored as quickly as possible and that it should again support fish. Some community members were skeptical that such an outcome could be achieved, while others expressed a desire for all three mine pits to be backfilled.

Traditional knowledge identified through secondary sources that in some way touched on closure and reclamation issues included the following:

- When asked why the caribou might be attracted to the tailings [processed kimberlite] area, the elders gave three reasons. Some elders said that the caribou eat different kinds of mud and may be mistaking the tailings for the natural muds. Other elders simply said that the tailings area was on their migration route. Another elder qualified the statement about migration stating that not all the caribou pass through the tailings area. 'The caribou pass all over this area', she said (LKDFN et al. 1999: 11).
- As a possible solution, the Denesǫłıne recommended that these areas be fenced or blocked off, so that the caribou cannot access them (LKDFN et al. 1999).
- Concern was also voiced about the impact of small animals consuming unhealthy vegetation and the contaminants affecting the food chain (NSMA 1999: 141).
- "You should protect the areas and waterways that flow into the Lockhart River. Even as far as McKinley Point to MacKay Lake should be protected. At one time in the dry years –it may not seem like the water flows that way but in the spring you can see it –it all flows into Great Slave Lake" (PC in LKDFN 2001b:64, internet site).
- "Even if the ground is contaminated, it can be fixed. But if the water is contaminated, everything will be affected. We need to watch [monitor] even the smallest streams" (JBR in LKDFN 2001a:39).
- "There is going to be a lot of garbage and waste left on the snow during the winter. In springtime, it will flow down into Great Slave Lake and contaminate the water. Water has to be monitored carefully, especially runoff from the mine. The southern biologists don't know our traditional knowledge or our Dene way of life" (JB Rabesca in LKDFN et al. 1999: 17).

10.4.3.3 Incorporation of Feedback and Traditional Knowledge

Based on the feedback received during the open houses and the traditional knowledge available through secondary sources, De Beers recognized the following community desires for reclamation:

- restore Kennady Lake as quickly as possible;
- restore Kennady Lake so that the refilled lake can support fish;

- completely backfill all three mine pits;
- reclaim the Fine PKC Facility and Coarse PK Pile in such a way that they do not attract caribou;
- isolate process-affected materials, including PK, so that they are not accessible to wildlife;
- protect water quality in Kennady Lake and downstream systems so that it does not affect the health of caribou and other biota; and
- remove all buildings and materials, so that there is no garbage or waste left on-site that may wash downstream or blow around.

The Closure and Reclamation Plan was subsequently developed to address, to the extent possible, all of these desires. The relevant aspects of the Closure and Reclamation Plan that address each desired outcome are outlined below.

10.4.3.3.1 Restore Kennady Lake As Quickly As Possible

As outlined in Section 3.9.6, water will be diverted from Lake N11 to Kennady Lake to augment the restored natural flows from the watershed. Pumping additional water from Lake N11 will reduce the time required to fill Kennady Lake from 20 years to approximately eight or nine years. Although the filling time could be further reduced with a more aggressive diversion scheme, the current plan was designed to minimize filling times while maintaining adequate flow at the outlet of Lake N11 to protect downstream aquatic biota.

10.4.3.3.2 Refill Lake to Support Fish

Water quality in the refilled lake is expected to return to conditions suitable to support aquatic life, although nutrient concentrations in the water will be higher and the lake will be more productive. It is expected that a fish community will become re-established in Kennady Lake after closure; however, the fish community will be different than the community that exists currently. De Beers understands the importance of a sustainable fish community in Kennady Lake and is committed to do additional work to reduce the uncertainty around future conditions in the lake.

Closure and reclamation activity, as noted in Section 10.4.1.7.9, is going to include the construction of fish habitat enhancement features within and near Kennady Lake. Each feature will be designed to increase the amount of productive habitat.

10.4.3.3.3 Completely Backfill All Three Mine Pits

De Beers acknowledges that some members of the community indicated a desire for all three mine pits to be completely backfilled. Completing such an operation would, however, negatively affect other aspects of the Closure and Reclamation Plan. For example, Tuzo is the last ore body to be mined. Placing materials into the Tuzo Pit after the completion of mining would require extensive re-handling of the mine rock and PK. It would take several years to complete this activity, and the refilling of Kennady Lake would be delayed. As a result, the mined-out 5034 and Hearne pits will be partially backfilled, but backfilling of the Tuzo Pit was not included in the Closure and Reclamation Plan.

10.4.3.3.4 Reclaim Processed Kimberlite Facilities Not Attractive to Caribou

The Project results in two PK storage areas: the Fine PKC Facility and the Coarse PK Pile. Progressive reclamation of the Fine PKC Facility will occur in the operations phase. The facility will be filled with fine PK beginning in Area 1 and continuing into Area 2. As Area 1 is filled, the fine PK will be covered by a 1 m layer of coarse PK followed by a layer of mine rock 1 to 2 m in depth. This cover will be extended into Area 2 and the facility will be contoured and graded to enhance drainage towards Area 3 of Kennady Lake. The Fine PKC facility will not be revegetated and the mine rock cover is not expected to attract caribou. The Coarse PK Pile will also be covered by mine rock to a depth of 1 m and not revegetated.

The mine rock cover will prevent animals from becoming trapped in the fine PK which has been an ongoing concern. There is no record of injury or mortality to caribou from being trapped in fine PK in the PK containment areas at existing mines (Section 7.4.2.1.2); however, the proposed mine rock cover will remove this concern.

Fencing areas around PK containment areas was mentioned by Aboriginal People a number of times. These areas will not be fenced as the fences themselves cause problems. For example, six caribou have been entangled in the electric fence surrounding the airstrip at the Ekati Diamond Mine from 2001 to 2009, and four of these animals died. One caribou became entangled in an electric fence at the Diavik Diamond Mine and was then killed by a grizzly bear (Section 7.4.2.1.2). Fences can be used by predators to limit escape options of their prey. Covering the PK with mine rock presents less danger to caribou.

10.4.3.3.5 Isolate Process-affected Materials

The primary process-affected material is PK. As previously described, all PK will be covered by a 1 m layer of mine rock at closure. The remaining fine PK will deposited in the Hearne Pit and coarse PK may be deposited in the pits as well. Since the pits will be flooded at closure, these materials will be isolated by a layer of water.

The only accessible material remaining after the completion of site closure and reclamation will be non-reactive mine rock. The mine rock piles and the mine rock covered PK will not be revegetated and, therefore, will not encourage grazers (e.g., mice, caribou). This will reduce the potential for contaminants in the PK from entering a food chain through uptake in vegetation, grazers and eventually carnivores.

10.4.3.3.6 Protect the Quality of Water

To ensure that water quality in Kennady Lake and in downstream systems does not affect the health of fish, wildlife, or humans using this area in the future, the Project has been designed to prevent processes such as acid rock drainage, which may increase the concentrations of metals in seepage. Although most mine rock is non-reactive, rock that is PAG rock will be stored in the mine rock piles in a manner that reduces the potential for acid rock drainage as described in Section 10.4.2.1.1. Supplemental mitigation considered for the Fine PKC Facility will further reduce loading of geochemical constituents (e.g., phosphorus) associated with seepage that comes into contact with fine PK.

As outlined in Section 10.4.1.9, the refilled basins of Kennady Lake will only be reconnected to Area 8 (by breaching Dyke A) and, by extension, downstream waterbodies when the quality of the water contained in the refilled basins meets pre-determined regulatory requirements.

10.4.3.3.7 Remove All Buildings and Materials

As outlined in Section 10.4.1.7, all buildings, equipment, machinery, and other infrastructure associated with the Project will be decommissioned. All reactive or hazardous materials will be removed from site. Structures, equipment, and materials deemed economically salvageable at the time of demolition will be dismantled and removed from site. Non-salvageable and non-hazardous components from demolition of the site buildings, structures, and equipment will be dismantled, washed and/or degreased (as necessary), and deposited in the inert materials landfill within the mine rock pile. The landfill will be above the water level of the re-filled Kennady Lake. The deposited materials will then be covered with a layer of non-reactive mine rock. There will be no loose garbage or other waste material left on-site that could blow away or be washed downstream.

10.5 EFFECT OF PROJECT ACTIVITIES ON THE LONG-TERM RECOVERY OF KENNADY LAKE

10.5.1 Background

As noted in Section 10.1, connections exist between this key line of inquiry and that discussed in Section 8 (i.e., Key Line of Inquiry: Water Quality and Fish in Kennady Lake). To avoid undue repetition and to ensure that the EIS presents the information requested by the Gahcho Kué Panel (2007) in as efficient a manner as possible, a summary of the information presented in Section 8.11 (Recovery of Kennady Lake and its Watershed) related to long-term effects to downstream aquatic ecosystems has been provided below.

10.5.2 Long-Term Effects to Hydrology

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.

10.5.3 Long-Term Effects to Water Quality

Modelling of water quality in Kennady Lake was evaluated for the post-closure period (i.e., after removal of dyke A and flow will occur between Areas 3 through 7 and Area 8).

After refilling, Tuzo and Hearne pits represent new waterbody features within the restored Kennady Lake. The bottom of Tuzo pit will be about 295 m below the surface of Kennady Lake, and Hearne Pit will be approximately 120 m deep, creating deep depressions within the lake. During and after refilling of Tuzo pit, saline groundwater inflow will collect in the bottom of the pit forming a higher density, more saline (TDS concentration of up to 400 mg/L) layer, which is referred to as a monimolimnion layer. The monimolimnion layer will be separated from the overlying freshwater layer in what is referred to as meromictic conditions. A long-term analysis evaluated the stability of meromictic conditions for the long-term, and concluded that the saline bottom layer will remain stable and will not overturn. The water quality in Kennady Lake above Tuzo Pit will, therefore, will be primarily determined by the upper 20 m of fresh water, which will be subject to temperature and wind-driven summer seasonal stratification.

Hearne pit will be partially backfilled with fine PK and process water, but will not be initially filled with saline water as will occur for Tuzo pit. Therefore, meromixis is assumed not to occur in Hearne Pit, and water in this pit will be fully mixed with water in Area 6. This assumption is a conservative prediction, because if meromixis does occur in Hearne Pit, the deeper water in contact with the fine PK will be isolated and the input of the diffusive flux of metals and nutrients from the bottom of Hearne pit to the water quality in Area 6 will be unlikely.

After refilling is complete and the lake is restored to pre-mine levels, water quality in Kennady Lake will be influenced by:

- natural watershed runoff with a background surface water quality; and
- seepage from the Fine PKC Facility, and contact water from the Coarse PK Pile and the mine rock piles, and minor contribution from site runoff;
- contact water from the exposed pit walls during refilling of the Tuzo Pit basin and Hearne; and
- diffusion from PK material in the bottom of Hearne Pit.

Water quality in Area 8 during the post-closure phase will be driven by the water flowing from Kennady Lake after Dyke A is removed with additional dilution from the Area 8 sub-watershed. Concentrations of all modelled constituents are predicted to increase when Dyke A is removed. In nearly all cases, concentrations are predicted to peak within five years of Dyke A being removed, as water in Area 8 is replaced with water from the refilled Kennady Lake. Concentrations are generally predicted to decline with time. In a few cases, concentrations are predicted to increase during the post-closure period and reach a long-term steady state concentration within a few decades.

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 (200 years), the assessment was designed to represent potential future climatic conditions where there would be no permafrost.

Total Dissolved Solids and Major Ions

In the post-closure period, concentrations of TDS and major ions are predicted to continue to decline in Areas 3 to 7 as Kennady Lake receives fresh water inflows (i.e., natural drainage) from the basin and Dyke A is removed. In one to two decades of post-closure, concentrations are predicted to approach steady state at slightly less than 100 mg/L TDS. Calcium, chloride, magnesium and sodium are predicted to mirror the trends displayed by TDS.

Concentrations of TDS and major ions are predicted to remain elevated above background levels because loading of these constituents from the Fine PKC Facility, leaching from mine rock and diffusion from PK material in the bottom of Hearne Pit are assumed to continue in the long-term. The loading of TDS from this facility to Kennady Lake is expected to reduce with the establishment of permafrost through the fine PK material.

Concentrations of TDS and major ions in Area 8 are predicted to follow the general trends described for Kennady Lake. All major ions follow this trend, except potassium and sulphate, which are predicted to increase following closure.

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

Nutrients

By the time Dyke A is removed, modelled nitrogen and ammonia concentrations are expected to be at, or below, water quality guidelines and decline thereafter to near background levels. In Area 8, all forms of nitrogen are expected to peak in concentration in Area 8 within five years of breaching Dyke A, then return to near-background concentrations.

Concentrations of phosphorus are projected to increase to steady state concentrations in post-closure. The long-term phosphorus increases result from seepage through the mine rock piles, Coarse PK Pile, and the Fine PKC Facility, which eventually flows to Kennady Lake. More specifically, phosphorus is mobilized into seepage flows that come into contact with mine rock, coarse PK, and fine PK material as flows travel through the external structures, with fine PK in saturated conditions being the largest contributing source of phosphorus.

The modelled phosphorus projections were developed assuming contact of seepage flows with materials located in the mine rock piles, the Coarse PK Pile, and the Fine PKC Facility, including the supplemental mitigation associated with the fine PK deposit in the Fine PKC Facility. Long-term steady state water quality projections of total phosphorus of 0.018 mg/L were developed by setting water quality parameter concentrations based on ranked statistical measurements in the geochemical testing of mine rock, coarse PK, and fine PK completed in support of the EIS (Appendix 8.I, Attachment 8.I.3). As described in Section 8.8.2.1.1, water quality modelling did not include the aggradation of permafrost through the mine rock piles, the Coarse PK Pile, and the Fine PKC Facility.

Without supplemental mitigation (i.e., mitigation as described below), modelling has shown that the concentration of total phosphorus in Kennady Lake during post-closure would increase to approximately 0.030 mg/L. Baseline concentrations of total phosphorus are typically lower, with a range of <0.001 to 0.010 mg/L. This nutrient enrichment could increase the productivity of the lake by two trophic levels, from oligotrophic to meso-eutrophic. This is likely to have implications on habitat for cold-water fish species, such as lake trout. Nutrient enrichment effects would extend further downstream beyond Kennady Lake. For these reasons, supplemental mitigation will be added.

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

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

De Beers is committed to incorporating additional mitigation to achieve a long-term maximum steady state total phosphorus concentration of 0.018 mg/L in Kennady Lake. Pre-screening of the strategies listed above is underway and, where available, key information from this analysis, including the required reduction in flows through the fine PK needed to achieve the target phosphorus concentration, has been incorporated into the water quality modelling for Kennady Lake.

Based on the long-term steady state total phosphorus concentration of 0.018 mg/L projected in Kennady Lake for post-closure, the trophic status in Kennady Lake may shift from oligotrophic to mesotrophic. With this change in trophic status, increased growth of phytoplankton and algae within the lake is anticipated, which will result in a larger amount of total organic carbon remaining in the lake after senescence each fall. The decomposition of this organic carbon will exert an oxygen demand over winter after the ice has formed and atmospheric re-aeration has been cut off. The winter oxygen depletion rate for three depth zones in Kennady Lake and a dissolved oxygen balance for Kennady Lake at the end of winter were estimated. The results indicate that the surface zone of the water column (i.e., under ice to 6 m) should remain oxygenated over the winter period to concentrations that will likely remain in excess of the lower dissolved oxygen concentration guideline of 6.5 mg/L for cold-water fish. The mid-depth and bottom depth zones will likely be subject to lower oxygen levels, which may fall below guideline concentrations. The deeper epilimnetic zones of the open Tuzo and Hearne pits are not expected to be subject to the same winter oxygen demand as other shallower areas of Kennady Lake and are expected to remain well oxygenated. Under open-water conditions, Kennady Lake is expected to remain well mixed and near, or at, saturation with respect to dissolved oxygen (similar to existing conditions).

Trace Metals

Of the 23 trace metals that were modelled for this assessment, chromium, cobalt, iron, lead, manganese, mercury, selenium, silver, thallium, uranium, and zinc are predicted to increase in concentration during the operations phase, then steadily decline in concentration as the lake is flushed during the post-closure period. With the exception of thallium, the primary loading source of these metals to Kennady Lake is groundwater from the active mine pits, hence the decline once pit dewatering is finished. Because the concentrations of these metals will be mainly groundwater-driven, the dissolved fraction of these metals is predicted to comprise the majority of the total concentrations. Chromium and iron are projected to exceed water quality guidelines in the post-closure phase.

Aluminum, antimony, arsenic, cadmium, copper, nickel, and vanadium will be influenced by a combination of sources throughout the operations phase. These metals are predicted to increase mainly due to inputs from groundwater and mine rock runoff, with secondary loading sources through infiltration and contact with fine PK and process water. These metals are predicted to increase in concentration relatively steadily throughout the operations phase, rise or fall during the closure period, then remain fairly constant throughout the post-closure period. The lack of reduction in post-closure concentrations of these metals is due to the geochemical loading through seepage that will occur from the remaining mine rock and fine PK in and near Kennady Lake. Because the primary loading sources of these metals is groundwater and geochemical flux, the majority of these metals will be in the dissolved form. Cadmium and copper are projected to exceed water quality guidelines in the post-closure period.

Barium, beryllium, boron, molybdenum, and strontium are predicted to increase in the post-closure period. Concentrations of these metals will mainly be driven by loadings through infiltration and contact with mine rock, coarse PK and fine PK. Because these storage facilities will be present in the post-closure period, concentrations of these metals are predicted to increase after closure, reach steady state conditions in Kennady Lake within about 40 years. Because geochemical sources are the primary contributors of these metals, the majority of total concentrations will be in the dissolved form. None of these five metals are projected to exceed water quality guidelines in the post-closure phase.

Concentrations of trace metals in Area 8 are predicted to follow the general trends described above for Kennady Lake. After the initial period of approximately five years to approach Kennady Lake concentrations, trace metal concentrations are then predicted to decrease, remain relatively constant or decrease. Of the 23 modelled trace metals, cadmium, chromium, and copper are projected to exceed water quality guidelines in the post-closure period.

10.5.4 Long-Term Effects to Aquatic Health

As a result of Project activities, changes to water quality in Kennady Lake and Area 8 during post-closure are expected, i.e., after the removal of Dyke A. The potential effect of these changes on aquatic health was evaluated by considering both direct waterborne exposure and accumulation within fish tissues.

In regards to direct waterborne exposure, predicted maximum concentrations for most substances of potential concern (SOPCs) were lower than the corresponding chronic effects benchmark (CEB), with the exception of total copper, iron, and strontium.

Despite the predicted exceedances of the CEB, the potential for copper to cause adverse effects to aquatic life in Kennady Lake and Area 8 is considered to be low. The CEB for copper is based on the CCME guideline, which is intended to be conservative and protective of the most sensitive species. Predicted copper concentrations are only slightly greater than the CEB, indicating the possibility (but not necessarily the likelihood) of effects to the most sensitive species. However, the CCME guideline does not consider the potential for other water quality characteristics (e.g., dissolved organic carbon) to reduce bioavailability and ameliorate copper toxicity. Furthermore, the CCME guideline is based on toxicity tests with sensitive organisms, whereas organisms inhabiting Kennady Lake are unlikely to be highly sensitive to copper, given that baseline sediment copper concentrations exceed the CCME interim sediment quality guideline. Given the small magnitude by which predicted maximum concentrations exceed the CEB, and given the potential for ameliorating factors discussed above, the potential for adverse effects from copper is considered to be low. Follow-up monitoring will be undertaken to confirm this evaluation.

The potential for iron to cause adverse effects to aquatic life in Kennady Lake is considered to be low. Maximum total and dissolved iron concentrations in Kennady Lake after refilling and Dyke A is removed are predicted to be slightly above the corresponding CEB. The CEB for iron is based on the CCME guideline, which is intended to be conservative and protective of the most sensitive species. Iron concentrations similar to the CEB have been reported by some authors to elicit sublethal effects on cladocerans (Dave 1984). However, other authors have reported effects thresholds for the same species more than an order of magnitude higher than the CEB (Biesinger and Christensen 1972). Lethal effects on cladocerans and effects on fish and other taxa have only been reported at much higher iron concentrations, greater than the CEB and greater than all predicted iron concentrations in Kennady Lake. Thus, the predicted iron concentrations are not expected to result in adverse effects to aquatic life. Follow-up monitoring will be undertaken to confirm this evaluation.

Strontium is conservatively projected to be higher than the CEB in Kennady Lake during post-closure conditions. However, the CEB is highly conservative, and the actual likelihood of adverse effects to aquatic life is therefore highly uncertain. The CEB was based on a single study of rainbow trout embryos (Birge et al. 1979) that reported effects at strontium concentrations several orders of magnitude lower than any other study, including studies with rainbow trout and other fish species. Given the high level of uncertainty in the toxicity reported by Birge et al. (1979), and given that the maximum predicted strontium concentrations in Kennady Lake are orders of magnitude lower than all other effects concentrations in the toxicity dataset, the potential for adverse effects from strontium is considered likely to be low. Follow-up monitoring will be undertaken to confirm this evaluation.

Predicted fish tissue concentrations are below toxicological benchmarks for all substances considered in the assessment except silver. However, fish tissue silver concentrations are predicted to increase only marginally above baseline conditions as a result of the Project. Also, the selected silver tissue benchmark is based on a no-effect concentration, and thus is a highly conservative basis for assessing the potential for predicted silver concentrations to cause effects to fish. Given the modest predicted increase, and that both baseline and predicted tissue concentrations only marginally exceed the available no-effect concentration, the potential for predicted silver concentrations to cause effects to fish is concluded to be low.

Based on the above results, changes to concentrations of all substances considered in this assessment are predicted to result in negligible effects to aquatic health in Kennady Lake and downstream waters during post-closure.

10.5.5 Long-Term Effects to Fish and Fish Habitat

After reconnection of the refilled Kennady Lake to Area 8, concentrations of nutrients are predicted to be higher than during pre-development conditions. While Kennady Lake is oligotrophic under baseline conditions, the post-closure trophic status of Kennady Lake is predicted to be mesotrophic. The predicted change in the trophic status of Kennady Lake is expected to result in an increase in summer phytoplankton biomass and altered species composition of phytoplankton and shifts in dominance at the level of major phytoplankton group. The predicted increase in primary productivity in Kennady Lake is expected to result in increased secondary productivity and biomass of the zooplankton community, reflecting the increased amount of available food for zooplankton. The predicted increases in nutrient concentrations and primary productivity in Kennady Lake are likely to result an increase in benthic invertebrate abundance and biomass, reflecting the increased food supply. A shift in benthic invertebrate community composition is also likely during post-closure.

It is expected that there will be increases in the food base for fish (zooplankton and benthic invertebrates), as well as in the small-bodied forage fish community. Because of the increased food base, there may also be increased growth and production in the large-bodied fish species of Kennady Lake. However, due to the change in trophic status to mesotrophic, overwintering habitat in Kennady

Lake at post-closure may become more limited for cold-water fish species than under baseline conditions. The surface waters of Kennady Lake (i.e., under ice to 6 m depth) would be expected to retain sufficient levels of dissolved oxygen during winter to support fish; however, there may be reduced suitability and availability of overwintering habitat for cold-water fish species, such as lake trout and round whitefish.

The Project is expected to have low or negligible effects on aquatic health in Kennady Lake from changes in chemical constituents of water quality; therefore, no effects to fish populations or communities are expected to occur from changes in aquatic health.

10.5.6 Recovery of Kennady Lake

Some of the aquatic habitat in Kennady Lake disrupted or disturbed by Project activities will be replaced, and the long-term hydrology of Kennady Lake is expected to return to a stable state similar to current conditions. Water quality in the lake is similarly expected to return to existing conditions over time with the potential exception of nutrients and some components of total dissolved solids (TDS), with negligible effects predicted to aquatic health from predicted changes in the chemical constituents of water quality in the refilled Kennady Lake after mine closure. With the physical and chemical environment of Kennady Lake returning to stable conditions, it is reasonable to conclude that an aquatic ecosystem will develop within Kennady Lake. The uncertainty lies in how long the recovery may take and what the final aquatic ecosystem will consist of, taking into account colonization and trophic change.

Methods

As outlined in Section 8.11, a three step process was adopted to evaluate and assess how phytoplankton, zooplankton, benthic invertebrates, and fish may develop in Kennady Lake after refilling. The first step involved the completion of a literature review. The literature review was undertaken to develop a summary of the published information relevant to the recovery of lakes after flooding or refilling and to identify, to the extent possible, the main drivers that control the rate and direction of recovery. The second step in the assessment process involved evaluating how the results of the literature review applied to Kennady Lake, given its location and physical structure. The final step in the process consisted of taking the information obtained from the literature review and the evaluation of its suitability to Kennady Lake and using it to project how the aquatic ecosystem in Kennady Lake will likely recover. A more detailed discussion of the methods used to complete each step of the assessment process is outlined in Sections 8.11.1 and 8.11.2 of the Key Line of Inquiry: Water Quality and Fish in Kennady Lake.

Summary of Literature Review

Flooding terrestrial vegetation can result in a surge in nutrient concentrations, particularly of nitrogen, carbon, and phosphorus. However, the released phosphorus may be in a non-bioavailable form, which encourages the growth of bacteria over that of phytoplankton. Herbaceous vegetation generally decomposes faster than woody vegetation, and thus the type and amount of flooded vegetation affects the magnitude and duration of the nutrient surge.

Flooded soil can also be a source of nutrients to a newly created lake or reservoir. However, this input may not be as substantial as that originating from flooded vegetation. Removing terrestrial vegetation and soil prior to impoundment may limit the magnitude and duration of the nutrient surge, but the overall net benefits that result from this management option are dependent on site-specific conditions. Keeping the vegetation in place can enhance macrophyte growth, zooplankton abundance, and benthic invertebrate diversity. The removal of the terrestrial vegetation can also lead to increased shoreline erosion in the newly created lake or reservoir. Another management option available to limit or stabilize nutrient levels in a newly created system involves the repeated draining and refilling of the system.

Most of the reviewed studies did not discuss turbidity as a major driver for ecosystem recovery. Site-specific factors, however, can lead to erosion and increased levels of turbidity in newly created lakes and reservoirs. In a well-studied lake impoundment in northern Manitoba, extensive and ongoing erosion of fine-grained shorelines contributed to a sustained increase in turbidity levels, which has had a notable effect on the aquatic ecosystem.

With the exception of mercury, release of metals from sediment as a consequence of flooding was not observed or commented upon in the majority of the reviewed literature. Low oxygen conditions in flooded sediment, however, can result in the release of dissolved manganese and iron, as observed in a refilled reservoir in Germany (Nienhuser and Braches 1998).

In contrast to other substances, it is common for mercury concentrations in fish to increase following impoundment. This phenomenon is likely due to the inundation and subsequent decomposition of organic material that promotes the microbial methylation of inorganic mercury to organic methyl mercury. It has been well established that (1) mercury in pristine and flooded soils is predominately bound to organic matter, and (2) that mercury methylation is related to organic carbon content of the flooded soil/sediment. Methyl mercury is the most toxic form of mercury and readily accumulates in aquatic organisms.

To mitigate the effect of methyl mercury generation, bioaccumulation through the food chain and associated environmental and health risks, there are three processes that can be targeted: mercury methylation, mercury bioaccumulation, and fish consumption. Available mitigation options include partial or complete stripping or capping of organic materials and soils, high temperature burning of vegetation and leaf litter, liming, selenium additions to newly created reservoirs and lakes, intensive fishing, fish barriers (screens), restricted access, and/or fish consumption advisories. Of the options available, selenium addition and liming are not widely recommended, and consumption advisories serve only to protect human health without directly addressing mercury concentrations in fish.

The surge in nutrients that typically occurs following the creation of a new lake or reservoir generally leads to a brief increase in phytoplankton growth and photosynthesis, but bacterial growth quickly dominates. High bacterial growth coincides with low phytoplankton growth, suggesting that bacteria out-compete phytoplankton for nutrients.

As the source of organic matter switches from external to internal, a shift in dominance typically occurs, with phytoplankton replacing bacteria as the dominant planktonic organism. In other words, when an area is first flooded, the organic matter in the system or entering the system tends to originate primarily from external sources, such as flooded terrestrial vegetation or other materials entering the system through runoff or inflow. The characteristics of these materials tend to favour bacterial growth over phytoplankton; over time, the external material decays and is replaced with organic matter that originates primarily within the lake, from dead and decaying phytoplankton, zooplankton, fish, or other material (e.g., fish feces). The characteristics of the internal materials tend to favour growth of phytoplankton over that of bacteria, which leads to a shift in dominance between these groups of organisms. The period over which the shift from bacterial to phytoplankton dominance occurs is dependent on site-specific conditions. However, in some studies, plankton community structure returned to that characteristic of oligotrophic environments within three years of flooding.

Zooplankton biomass is generally high initially in new impoundments, with the possible exception of systems that experience notable shoreline erosion and turbidity. The high biomass is due to high food availability, in the form of abundant bacterial or phytoplankton growth, and low mortality rates, due to low fish densities and the availability of refugia in flooded vegetation. Initially, rotifers typically dominate the zooplankton community, because they are able to colonize new environments faster than cladocerans and copepods. Rotifers also benefit from the initial high level of bacterial production commonly observed following impoundment of new reservoirs.

Cladocerans typically become the dominant species of zooplankton after rotifers, possibly within two to three years of impoundment. Changes in the zooplankton community generally coincide with the shift from bacteria to phytoplankton dominance in the lowest trophic level. If persistent turbidity occurs following impoundment, then zooplankton biomass will likely decline and changes in species composition will be more strongly influenced by fish predation.

Similar to zooplankton, benthic invertebrates tend to be abundant in new impoundments, because the flooded terrestrial vegetation provides structural habitat and a food source. Generally, midges colonize new impoundments first, and they are usually more abundant than other benthic organisms. However, other groups of benthic invertebrates can initially dominate, depending on how the new lake or reservoir is formed. For example, early colonizers in a reservoir created by damming a river tend to originate from the river. They are then gradually replaced with species that prefer standing water. The rate at which succession within the benthic community occurs is dependent on the time required for flooded terrestrial vegetation to decay and dissipate, as well as the dispersal abilities of the local benthic populations. In general, succession will occur more quickly in systems where the flooded vegetation quickly dissipates and invertebrate drift from nearby standing waters occurs.

Key findings of the literature review for fish suggest that the net effect of reservoir/lake creation on the abundance and diversity of the resident fish population is dependent on the make-up of the fish community and the extent to which it can adapt to, or take advantage of, the new environment created within the lake. Flooded or refilled systems that are connected to surrounding waterbodies can experience rapid colonization and/or recovery, although the age-class structure post-impoundment tends to be biased towards a greater abundance of juvenile fish relative to older fish. Fish abundance also tends to be higher in lakes or reservoirs containing flooded vegetation, compared to that generally observed in lakes or reservoirs that were cleared prior to flooding or that contain little to no vegetation.

Fish abundance in new impoundments with increased concentrations of suspended sediments tends to be lower than those in systems without turbidity issues. High levels of turbidity can negatively affect fish through reduced feeding success. High levels of suspended sediment can also cause gill abrasions and the associated sedimentation can reduce egg survival rates. In addition, mercury levels in fish tissues tend to be higher in more turbid systems.

Applicability of Literature Review Findings to Kennady Lake

There are some important differences between Kennady Lake and the systems that have been reported in the available literature. Key areas of difference include the following:

- the potential influence of terrestrial vegetation on the refilled lake;
- the potential for erosion;
- the amount of organic matter present initially after refill that may influence methyl mercury production;
- increased nutrient concentrations in the refilled lake; and
- the rate at which recovery may occur.

These key areas of difference are summarized below. However, although some of the key findings from the literature review are not directly applicable to Kennady Lake, the overall trends documented in the reviewed studies provide evidence that an aquatic ecosystem will re-establish itself within Kennady Lake after refilling.

Terrestrial Vegetation

Unlike many of the studies, Kennady Lake refilling does not involve flooding of surrounding terrestrial vegetation. During refilling, the water level of Kennady Lake will return to its baseline elevation and not higher. During the operations phase, terrestrial vegetation could colonize the dewatered lake bed; however, given the physical characteristics of Kennady Lake and its geographical location, notable in-growth of terrestrial vegetation is unlikely.

Erosion and Turbidity

Extensive erosion of the shoreline is not expected to occur when Kennady Lake is refilled, because water levels are going to return to existing elevations. The surrounding tundra is not going to be inundated, and the existing shoreline consists almost entirely of rocky substrate, which is resistant to erosion. Consequently, effects associated with erosion are not expected to occur in Kennady Lake, such as prolonged periods of poor water clarity from turbidity and the associated limitations on phytoplankton development.

Methyl Mercury Production

The potential for methyl mercury production to occur in Kennady Lake after refilling is expected to be limited, because a new source of organic matter is unlikely to be present. Refilling activities will be limited to the lake itself. The surrounding soils will not be inundated, and the bed sediments in the refilled lake will effectively be the same as those that currently exist. The in-growth of terrestrial vegetation will likely be limited by the rocky substrate that dominates the shallow zones of Kennady Lake, and the organic materials contained in the existing bed sediments may experience a greater level of aerobic decay than currently occurs while the lake is dewatered. Conifer trees, needles, and boughs will not be present in Kennady Lake upon refilling. Terrestrial vegetation that may be present will likely consist of grasses and other weedy species, and the abundance of the terrestrial vegetation in Kennady Lake is expected to be limited. Without a large organic carbon source to support the process, it is unlikely that methyl mercury production will be of concern in Kennady Lake once refilled.

Increased Nutrient Levels

Following the creation of a new lake or reservoir, there is typically a surge in nutrients, which leads to a brief increase in phytoplankton growth and photosynthesis. The long-term increase in nutrient levels in the refilled lake is expected to increase lake trophic status to mesotrophic (Sections 8.8.4.1). This change in trophic status may influence the recovery of aquatic communities, and result in differences in lower trophic and fish community structure in the refilled lake relative to pre-development conditions.

Recovery Time

In several of the reviewed studies, recovery times for different components of the aquatic ecosystem were noted, with some being as short as two to three years. Most of the lakes described in the literature review are located at lower latitudes and have different species composition, greater species richness, higher productivity, and more complex food-webs than Kennady Lake under baseline conditions. These factors have a direct bearing on recovery rates and suggest a slower recovery in Kennady Lake. The rate of recovery in Kennady Lake will be influenced by increased nutrient concentrations following re-filling, which would increase the rate of recovery by providing an abundant supply of nutrients to primary producers.

Predicted Recovery of Kennady Lake

At the end of operations, some of the aquatic habitat in Kennady Lake physically altered during Project operations will be re-submerged. Habitat enhancement structures (e.g., finger reefs and habitat structures on the decommissioned mine pits/dykes) will be constructed. Refilling of Areas 3 through 7 will begin, using natural runoff from the upland watershed and waters diverted from Lake N11. During this time, Area 8 will continue to receive only natural runoff from the surrounding area. After approximately 8 to 9 years, Areas 3 to 7 of Kennady Lake will be full of water. Thereafter, once water quality meets regulatory requirements, dyke A will be removed. Kennady Lake will once again consist of five interconnected basins (i.e., Areas 3 and 5, Area 4, Area 6, Area 7, and Area 8).

The hydrology of the reconnected system is expected to be fairly similar to existing conditions as soon as dyke A is removed and pumping from Lake N11 ceases. The natural drainage of the B, D, and E watersheds to Kennady Lake will be restored; however, in the A watershed, Lake A3 will continue to flow to the N watershed. Water quality in the refilled lake is expected to return to conditions suitable to support aquatic life over time. The physical and chemical environment in Kennady Lake, therefore, will be in a state that will allow re-establishment of an aquatic ecosystem, although increases in nutrient concentrations indicate that the re-established communities may differ from pre-development communities.

The expected time frame for recovery of the phytoplankton community is estimated to be approximately five years after refilling is complete, taking into consideration that the phytoplankton community will begin to develop during the refilling period (approximately eight to nine years). The increase in nutrient levels in the refilled Kennady Lake will also facilitate community development and will result in a more productive phytoplankton community in the refilled lake compared to the pre-development community.

Zooplankton community development is predicted to follow recovery of the phytoplankton community. Colonization sources will be the same as those for phytoplankton and include the upstream watershed (i.e., the B, D, and E watersheds), Lake N11, and Areas 3 and 5. The zooplankton community of the refilled lake is also expected to be more productive than the existing community. The expected time frame for the development of the zooplankton community is longer than that of phytoplankton (i.e., likely within five to 10 years of Kennady Lake being completely refilled).

Recovery of the benthic invertebrate community is expected to be slower than that of the plankton communities. The estimated time to recovery for the benthic community in Kennady Lake is about 10 years after refilling is complete. At the end of the recovery period, the benthic invertebrate community in Kennady Lake will be different from the community that currently exists in Kennady Lake and in surrounding lakes. The community will likely be of higher abundance and biomass, reflecting the more productive nature of the lake, and will likely be dominated by midges and aquatic worms.

The re-establishment of the fish community within Kennady Lake, and the speed at which it will occur, will depend on the ability of fish to re-colonize the refilled lake, the habitat conditions within the lake, and how succession takes place within the refilled system after it has been fully connected to the surrounding environment. It is expected that a fish community will become re-established in Kennady Lake. However, due to changes in trophic status and associated habitat conditions, as well as predator/prey interactions during succession, the fish community structure may be different than exists currently.

Fish populations, including Arctic grayling, northern pike, burbot, lake chub, slimy sculpin, and ninespine stickleback, are expected to persist in the B, D, and E watersheds during Project operations. These watersheds are likely to be the primary source of initial migrants into Areas 3 to 7 of Kennady Lake. During refilling, exclusion measures will be used to limit the initial migration of large-bodied fish, such as northern pike, burbot, lake trout, and Arctic grayling, from entering the lake. It is anticipated that during the initial period of refilling, some mortality of the incoming small-bodied fish is likely to occur, because of insufficient water depths and possibly elevated levels of turbidity. As conditions improve, and water depths increase, the early migrants will become permanently established, feeding on the plankton and benthic invertebrate communities that are themselves becoming established in the refilled lake. Nutrient levels in the refilled Kennady Lake are predicted to be higher than under existing conditions. The increase in primary productivity from nutrient availability may also result in increased growth and production of these small-bodied forage fish species.

Following the removal of dyke A, migrant fish will also enter Areas 3 through 7 of Kennady Lake from Area 8, which is expected to contain residual populations of lake chub, slimy sculpin, ninespine stickleback, Arctic grayling, northern pike, and burbot. The migration of fish from Area 8 into the rest of Kennady Lake is expected to be rapid, due to proximity, and the increased productivity that is expected from higher nutrient levels in Kennady Lake and Area 8.

The final fish community of Kennady Lake will likely once again be characterized by low species richness (less than 10 species) consisting of a small-bodied forage fish community (e.g., lake chub, slimy sculpin, ninespine stickleback) and large-bodied species, such as Arctic grayling, northern pike, burbot, round whitefish, lake trout, and possibly longnose sucker. Total lake standing stock and annual production will be increased over what currently exists in the lake. It is expected that the fish species assemblage (i.e., fish species present) within Kennady Lake will be similar to pre-Project conditions, but that due to biotic and abiotic factors, the community structure (i.e., relative abundances of the species) may differ. Mesotrophic conditions are likely to be more favourable to northern pike, burbot and Arctic grayling, than cold-water species, such as lake trout and round whitefish. As such, the relative abundances of the large-bodied fish species are likely to change from baseline conditions; lake trout may not return as the most abundant predatory fish in the refilled Kennady Lake.

The estimated time to full recovery of fish populations is expected to fall between 50 to 60 years following the complete refilling of Kennady Lake, or 60 to 76 years from the end of Project operations.

10.6 LONG-TERM EFFECTS TO DOWNSTREAM AQUATIC ECOSYSTEMS

Background

As noted in Section 10.1, connections exist between this key line of inquiry and that discussed in Section 9 (i.e., Key Line of Inquiry: Downstream Water Effects). To avoid undue repetition and to ensure that the EIS presents the information requested by the Gahcho Kué Panel (2007) in as efficient a manner as possible, the relevant information presented in Section 9 related to long-term effects to downstream aquatic ecosystems has been summarized below.

The aquatic ecosystem, including fish populations, downstream of Kennady Lake is expected to reach a new equilibrium post-closure (i.e., when the flow path from Area 7 to Area 8 is reconnected after Kennady Lake has refilled). During post-closure, the long-term hydrology and water quality of Kennady Lake is expected to return to stable conditions; it is, therefore, reasonable to conclude that a stable, aquatic ecosystem will be present in the watershed downstream of Kennady Lake.

Long-Term Hydrology Downstream of Area 8

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. Watersheds downstream of Kennady Lake will be affected by the post closure hydrological regime of the Kennady Lake watershed, which includes a projected 3.8% increase in mean annual water yield and a slight increase in flood peak discharges. The effects of these changes to downstream watersheds will be approximately proportional, based on the ratio of the downstream watershed area to the Kennady Lake watershed area.

The post-closure hydrological regimes of the N11 and upstream watersheds will be identical to the baseline regimes. Changes to the post-closure regimes of the N2 and upstream watersheds will be negligible due to the permanent diversion of Lake A3 into Lake N9. Changes to the post-closure regime of the N1 watershed will similarly be negligible.

Long-Term Effects to Water Quality

At the end of the closure phase, the refilled Kennady Lake will be reconnected to Area 8, and mine-affected waters will flow through Area 8 and continue through to the downstream lake system (i.e., the post-closure period). The primary pathways for effects to water quality in downstream waterbodies during closure and post-closure include the following:

- seepage from mine rock and processed kimberlite storage facilities, and the open Tuzo Pit may change water quality in Kennady Lake, and affect water quality in downstream waterbodies;
- reclaimed project area may result in long-term changes to water quality in downstream watersheds; and
- reconnection of Kennady Lake with Area 8 may change the water quality of downstream waterbodies.

Projections of water quality in the downstream waterbodies 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 (200 years), the assessment was designed to represent potential future climatic conditions where there would be no permafrost.

Lake N11

In Lake N11, the operational discharge from the WMP will cease, and water quality within the N watershed will return to similar to baseline conditions over the long-term, including nutrient levels in Lake N11.

Interlakes (L and M watershed)

Water quality in the interlakes (the chain of lakes within the L and M watersheds) will be attenuated from that described for Area 8. Project activities that could potentially affect water quality in Area 8 will carry through to the series of lakes within the L and M watersheds, because Area 8 forms one of the upstream sources of water flowing through this system. However, as water moves downstream, effects will be progressively attenuated by dilution from the downstream sub-watersheds.

Following the removal of Dyke A and the reconnection of Areas 3 through 7 with Area 8, phosphorus is predicted to increase over the long-term in Kennady Lake during the post-closure period. Sources of phosphorus after closure will mainly be driven by long-term loadings to Kennady Lake from seepage through the Fine PKC Facility and contact with fine PK. These concentrations are anticipated to extend downstream but decline with distance as inflows from the L and M watersheds dilute the concentrations originating from Area 8. Average long-term steady state concentrations for lakes along the main flow path in the L and M watersheds are predicted to be 0.015 mg/L and 0.013 mg/L, respectively, resulting in a change in trophic status to mesotrophic. Increases in primary productivity may have some implications regarding water column oxygen dynamics; however, potential increases in winter oxygen depletion due to nutrient enrichment would not be expected to change the overwintering capability or suitability of these small lakes.

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

Lake 410

In Lake 410 during the post-closure period, TDS concentrations will increase slightly from 16 mg/L to 27 mg/L. Patterns of concentrations in Lake 410 will be similar to those predicted for Area 8, except that TDS will also be lower due to dilution and offset due to travel time. The long-term steady state TDS concentration will be approximately 27 mg/L. The main constituents of TDS include calcium and chloride, which is consistent with the background conditions.

The long-term results presented for the post-closure period reflect a reasonable degree of conservatism. Concentrations of TDS and major ions are predicted to remain elevated above background levels because loading of these constituents from the Fine PKC Facility, leaching from mine rock, and diffusion from PK material in the bottom of Hearne Pit are assumed to continue in the long-term. Most major ions will follow a similar trend to TDS, reaching peak concentrations in the operational and closure phases. Major ions, such as potassium and sulphate, which are driven more by geochemical loadings, are predicted to follow similar trends but remain higher in the post-closure phase than in the operational phase. There are no CCME guidelines for TDS or any of the major ions. To put the predicted concentrations into context, TDS and all major ions are predicted to remain above background conditions but below levels that would affect aquatic health.

In post-closure, nitrogen concentrations in Lake 410 increase several years after the removal of dyke A (i.e., 0.25 mg/L as nitrogen), and then decline to near background concentrations after blasting residue has been flushed from the mine rock and PK storage facilities. Concentrations of phosphorus are predicted to increase in Lake 410 from a background of 0.005 mg/L to 0.007 mg/L. The phosphorus increase in Lake 410 during operations and several years into closure will be associated with pumped discharge from the WMP to Lake N11. Increases several years into the post-closure period will follow the removal of Dyke A and the reconnection of Kennady Lake to the downstream lakes. Concentrations of phosphorus after closure will mainly be driven by long-term loadings to Kennady Lake from seepage through the Fine PKC Facility and contact with fine PK. A slight increase in primary productivity would be expected in Lake 410; however, the trophic status would remain oligotrophic (Environment Canada 2004; CCME 2004).

Most trace metals are predicted to return to near-background conditions in the long-term. However, antimony, arsenic, boron, molybdenum, silver, strontium, uranium, and vanadium are predicted to increase and reach long-term steady state concentrations more than double baseline concentrations. Concentrations of these metals will mainly be driven by long-term loadings to Kennady Lake from seepage contact with mine rock, coarse PK, and fine PK. Because these storage facilities will be present in the post-closure period, concentrations of these metals are predicted to increase after closure, and reach steady state conditions in Lake 410 within about 40 years. As these geochemical sources are the primary contributors of these metals, the majority of total concentrations will be in the dissolved form. None of these metals are predicted to exceed guidelines at any time.

Long-Term Effects to Aquatic Health

Negligible effects to aquatic health in waterbodies downstream of Kennady Lake were predicted from changes in the chemical constituents of water quality for the post-closure period.

Long-Term Effects to Fish and Fish Habitat

The aquatic ecosystem, including fish populations, downstream of Kennady Lake are expected to reach a new equilibrium post-closure. The recovery of the aquatic ecosystem downstream of Kennady Lake during post-closure is based on the following:

- flows and water levels will return to near baseline conditions between Kennady Lake and Lake 410, resulting in negligible effects to fish habitat;
- flows and water levels will return to near baseline conditions throughout the N watershed, resulting in negligible effects to fish habitat;
- Lake N11 will remain at an oligotrophic status but at a lower level of productivity, with lower trophic communities and fish productivity expected to return to those characteristic of baseline conditions;
- the increase in nutrient concentrations and primary productivity reflective of the gradient from Stream K5 to Lake 410 is expected to result in increased secondary productivity and biomass of the zooplankton community, as well as an increase in benthic invertebrate abundance and biomass;
- due to increases in the food base for fish (zooplankton and benthic invertebrates) and potentially in the small-bodied forage fish community (e.g., lake chub and slimy sculpin), there may also be increased growth and production in large-bodied fish species (e.g., Arctic grayling and northern pike), reflective of the gradient in predicted nutrient concentrations from Stream K5 to Lake 410;
- lakes downstream of Kennady Lake are expected to provide habitat similar to baseline conditions, although there may be some slight reductions in overwintering habitat suitability in some lakes, as well as some increased feeding and rearing opportunities during the open-water season;
- streams downstream of Kennady Lake are expected to continue to provide Arctic grayling spawning and rearing habitat, although there may be some increases in growth of attached algae in streams immediately downstream of Kennady Lake;
- although there may be some changes in the utilization of some habitats along the gradient of nutrient enrichment, it is expected that the fish species currently present in the downstream watershed will continue to persist during post-closure;
- the downstream extent of the effect of increased nutrient levels on fish and fish habitat is estimated as the lakes/streams between Area 8 and Lake 410; and
- the assessment of effects to aquatic health concluded that modelled changes in water chemistry will have a negligible effect on the health of aquatic life downstream waterbodies.

10.7 LONG-TERM EFFECTS TO WILDLIFE AND HUMAN USE

10.7.1 Overview

This section presents a summary of the long-term biophysical effects, and closure and reclamation, to wildlife and terrestrial habitat, and human health. The summary of residual effects is based on assessments presented in other sections of the environmental impact statement (EIS). The assessment of effects to wildlife for all pathways, including changes in water quantity, water quality, and fish are provided in the following other sections of the EIS:

- Key Line of Inquiry: Caribou (Section 7);
- Subject of Note: Carnivore Mortality (Section 11.10);
- Subject of Note: Other Ungulates (Section 11.11); and
- Subject of Note: Species at Risk and Birds (Section 11.12).

Potential pathways for effects to wildlife associated with changes in water quality, water quantity, and fish in the Kennady Lake watershed include:

- long-term effects to wildlife health;
- long-term effects to wildlife habitat; and
- long-term Effects in a decrease in open water area to wildlife habitat.

The only potential pathway for effects to human health relevant to Section 10 is associated with changes in water quality and fish tissue quality.

10.7.2 Summary of Residual Effects

10.7.2.1 Wildlife

10.7.2.1.1 Long-term Effects to Wildlife Health

An ecological risk assessment was completed to evaluate the potential for adverse effects to individual animal health associated with exposure to chemicals from the Project. Emission sources considered in the assessment included those outlined above (i.e., fugitive dust, air emissions, surface water runoff and seepage, leaching of PAG rock, and exposed sediments), and potential exposure pathways included changes in air, water, soil, and vegetation quality. The result of the assessment was that no impacts were predicted for caribou, carnivores, moose, and muskoxen health; however, potential effects to aquatic-dependant birds (i.e., waterfowl and shorebirds) were predicted as a result of boron levels in Kennady Lake after refilling. This potential effect is discussed below.

The ecological risk assessment was completed assuming that there was no isolation of the fine PKC material located at the base of the Fine PKC Facility, and that all waters travelling over the facility would come into contact with this material, which is the predominate source of boron to the refilled lake. Processes that would modify the degree of contact between the fine PK and the runoff waters were not considered, including the aggradation of permafrost and/or the application of cover material to limit infiltration. In addition, the risk predictions were developed by setting parameters concentrations in the seepage through the facility to statistically ranked concentrations observed in the geochemical investigations completed in support of the EIS. Consequently, the results of the risk assessment correspond to an extreme condition that has a low likelihood of occurring.

De Beers is committed to further assessment of this potential issue, and will incorporate mitigative strategies into the Project design to the extent required to maintain boron levels in Kennady Lake below those that may be of environmental concern. These strategies may include the reduction of the fine PK footprint within the Fine PKC facility, limiting infiltration through the Fine PKC Facility, and limiting seepage contact with fine PK material. Given these commitments and the low likelihood of the assessed situation actually occurring, overall potential effects to wildlife were deemed to be not environmentally significant in the long-term in the Kennady Lake watershed and in downstream systems. However, the predictions of environmental significance with respect to water birds are dependent on the execution of further study of the ingestion pathways discussed in Section 11.2 and the commitment that mitigative strategies will be incorporated into the Project design to the extent required to invalidate these pathways.

10.7.2.1.2 Long-term Effects to Wildlife Habitat

At closure, dykes will be removed to return drainage flows and water levels to baseline conditions. While most changes are predicted to revert back to natural conditions, it is anticipated that the drainage flows from Lake A3 to Lake N9 will remain permanently and the surface water elevation in Lake A3 will remain above baseline conditions (Section 3). 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.

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 the water level of Kennady Lake. This would be offset somewhat by void spaces in the South Mine Rock Pile and the West Mine Rock Pile. Changes to the Kennady Lake surface area will slightly increase post-closure flood peak discharges and water levels.

Expected changes to the post closure hydrological regime of the Kennady Lake watershed are minor and include a 3.8% increase in mean annual water yield and a slight increase in flood peak discharges. Because the changes are so small, effects to watersheds downstream of Kennady Lake will be proportionately small at Lake L1 and diminish with distance downstream.

The post-closure hydrological regimes of the N11 and upstream watersheds will be identical to the baseline regimes. The post-closure regimes of the N2 and upstream watersheds will be as discussed in Section 9.7.4.2, with negligible changes due to the permanent diversion of Lake A3 into Lake N9. Changes to the post-closure regime of the N1 watershed will similarly be negligible.

Progressive reclamation will be integrated into mine planning; however, not all the upland areas will be reclaimed. The mine rock piles, Coarse PK Pile, and Fine PKC Facility will be permanent features on the landscape, covering approximately 303 ha.

Overall, the long-term effects to wildlife habitat is localized and is expected to have a minor influence on habitat quantity and quality for wildlife relative to baseline conditions. For species with large home ranges (e.g., caribou, grizzly bear, wolverine), the change in habitat is likely not detectable (i.e., less than 0.01% change). For species with smaller home ranges (e.g., nesting songbirds and shorebirds), the changes are likely detectable but expected to have minor influence on reproduction in the populations. Therefore, the long-term residual effects to the persistence of wildlife populations are predicted to be negligible.

10.7.2.1.3 Long-term Effects of a Decrease in Open Water Area to Wildlife Habitat

After closure, a reduction in the surface area will persist due to the loss of Kennady Lake area through the development of the West and South Mine Rock Piles and Fine Processed Kimberlite Containment (PKC) Facility, and several small lakes (e.g., Lakes A1 and A2). This will be offset to a small degree by the permanent raising of Lake A3.

The overall decrease in the surface area of open water in the Kennady Lake watershed beyond closure will primarily affect habitat for water birds (e.g., waterfowl, loons, and grebes) and shore birds whose important habitats include vegetation communities with a wetter moisture regime including shallow and deep water, sedge wetlands, and riparian habitats. Long-term residual effects from the Project on water birds and shore birds are anticipated to be negligible in magnitude.

10.7.2.2 Human

10.7.2.2.1 Long-term Effects to Human Health

A human health risk assessment was completed to evaluate how the predicted changes to air and water quality in the Kennady Lake watershed could potentially affect human health. Emission sources considered in the assessment included fugitive dust, air emissions, site runoff and seepage and exposed lakebed sediments. Potential exposure pathways included changes in air, water, soil, vegetation and fish tissue quality.

The results of the assessment indicate that individuals living at the Project site could experience health issues should they consume fish, as predicted changes in metal levels in water could affect fish tissue quality. However, individuals working at the Project site will not be allowed to fish and, therefore, will not consume fish from the Kennady Lake watershed. In addition, individuals do not currently live at the Project site, and it is unlikely that non-workers would do so in the future. This exposure scenario was used to provide a conservative evaluation of potential effects to individuals using the area for traditional purposes, because traditional purposes typically involve a temporary presence on the land near the Project site. The human health assessment was also completed using the conservative water quality predictions described herein, which included contact between seepage and the materials contained in the mine rock piles, the Coarse PK Pile and the Fine PKC Facility.

De Beers is currently evaluating a variety of environmental design features and mitigation to limit contact between seepage and fine PK located within the Fine PKC Facility and other potential sources. De Beers is committed to implementing additional environmental design features and mitigation measures to the extent required to protect human health.

As a result, human health is not expected to be detrimentally affected by Project activities, in the Kennady Lake watershed or in downstream systems. However, this statement is contingent on the results of further study and the implementation of mitigation strategies to the extent required to maintain exposure levels below those that would be of concern.

10.8 RESIDUAL IMPACT CLASSIFICATION

Gahcho Kué Project (Project) activities will result in changes to the hydrology, water quality, and aquatic communities of the Kennady Lake watershed. These changes are projected to occur during construction, operations, closure, and post-closure. Over the long-term, there is expected to be a return to stable conditions after closure and reclamation activities are complete (i.e., the post-closure period), although conditions may be different than pre-Project. To assess the environmental significance of projected long-term effects, a residual impact classification system was developed and applied to aquatic VCs considered in the key line of inquiry: Long-term Biophysical Effects, Closure, and Reclamation. For this key line of inquiry, and to be consistent with Sections 8 and 9, the VCs consist of water quality, specific fish species, i.e., Arctic grayling, lake trout, and northern pike, and wildlife and human health (refer to Sections 8.5 and 9.5).

As long-term effects to wildlife (i.e., caribou, muskoxen, moose, grizzly bear and wolverine, vegetation) were not predicted as a result of the Project, the classification of residual effects for wildlife has not been presented. A summary of the effects to wildlife is presented in Section 10.7, and additional detail of the assessment of wildlife and terrestrial habitat is provided in Sections 7 (Caribou), 11.11 (other Ungulates), and 11.12 (Species at Risk and Birds).

In the EIS, the term “effect”, used in the effects analyses and residual effects summary, is regarded as an “impact” in the residual impact classification. Therefore, in the residual impact classification for this section, all residual effects are discussed and classified in terms of impacts to water quality and fish in the Kennady Lake watershed. The classification focused on long-term effects to be consistent with the scope of this key line of inquiry (i.e., during post-closure). The classification of projected effects that may occur during the construction, operations, and closure phases, and refilling of Kennady Lake are outlined in Sections 8 and 9.

The residual impact classification focused on VCs, because they represent the components of the aquatic ecosystems in the Kennady Lake watershed, that are of greatest interest or concern (as outlined in the Terms of Reference). Projected impacts to VCs also incorporate, or account for, changes to other important key components, such as groundwater quality, groundwater flow, hydrology, fish habitat, and aquatic life occupying lower trophic levels in the ecosystem (e.g., aquatic plants, plankton, zooplankton, benthic invertebrates, forage fish species). Notable changes in water flows, for example, will contribute to changes in water quality, and the quantity and quality of habitat available for Arctic grayling, lake trout, or northern pike. The classification of impacts to water quality and the three valued fish species, therefore, incorporates the classification of impacts to hydrology and key components, according to their influence on the VCs.

The classification was carried out on residual impacts (i.e., impacts with environmental design features and mitigation considered). The environmental design features and mitigation were incorporated in the engineering design or the management plans, and were incorporated in the Project as it evolved (i.e., as the engineers received input from various scientists and traditional knowledge holders, the design evolved).

10.8.1 Methods

The residual impact classification for long-term effects focuses on the assessment endpoints because these are statements of what is most important to future generations. The five assessment endpoints relevant to the Key Line of Inquiry: Long-term Biophysical Effects, Closure, and Reclamation and to be consistent with Sections 8 and 9, include the following:

- suitability of water quality to support a viable aquatic ecosystem within and downstream of Kennady Lake;
- persistence and abundance of desired population(s) of Arctic grayling within and downstream of Kennady Lake;
- persistence and abundance of desired population(s) of lake trout within and downstream of Kennady Lake; and
- persistence and abundance of desired population(s) of northern pike within and downstream of Kennady Lake.

For this key line of inquiry, the primary focus is on Kennady Lake and downstream watersheds to Lake 410 during the post-closure and recovery period. Therefore, the spatial boundary of the assessment is limited to the local study area for the Project. This approach was also adopted to achieve consistency in the scales used to evaluate geographic extent across the key lines of inquiry that focus on aquatic ecosystems. Residual impacts to each assessment endpoint were classified based on the results of the effects analyses and their linkage to these endpoints. For example, the results of the water quality, aquatic health, and productivity analyses in Sections 8 and 9 were used to classify residual impacts to the first assessment endpoint (i.e., suitability of water quality to support a viable aquatic ecosystem). Similarly, the results of the analysis of effects to fish and fish habitat in Sections 8 and 9 were used to classify residual impacts to the abundance and persistence of desired population(s) of key fish species.

The residual impact classification describes the residual impacts of the Project on water quality and fish using a scale of common words (rather than numbers and units). The use of common words or criteria is a requirement in the Terms of Reference for the Project. The following criteria are used to describe impacts of the Project on the VCs:

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

Generic definitions for each of the residual impact criteria are provided in Section 6.7.2.

The predicted scales for the impact criteria are also considered in the impact classification. The scales used to assign values (e.g., high, moderate, or low) to each of the classification criteria are outlined in Table 10.8-1. The rating system for magnitude is presented separately in Table 10.8-2, because the scales used to define magnitude are specific to each assessment endpoint, whereas the scales defined for the remaining classification criteria are common across all five assessment endpoints. Direction, duration, reversibility, frequency, likelihood, and ecological context are rated on the highest magnitude impact predicted to persist in the long-term. The results from this impact classification are then used to determine environmental significance of impacts from the Project on water quality and fish (Section 10.8.3).

To provide transparency in the EIS, the definitions for these scales were ecologically or logically based on aquatic environments. Although professional judgment is inevitable in some cases, a strong effort was made to classify impacts using scientific principles and supporting evidence. The scale for the residual impact criteria for classifying effects from the Project are specifically defined for water quality and fish, and definitions for each criterion are provided in Table 10.8-1.

Table 10.8-1 Definitions of Scales for Seven of the Eight Criteria Used in the Residual Impact Classification

Direction	Geographic Extent	Duration	Frequency	Reversibility[(a)]	Likelihood	Ecological Context
Neutral: no measurable change to a VC from existing conditions **Negative:** the Project will result in an adverse effect to a VC **Positive:** the Project will result in a beneficial effect to a VC	**Local:** projected impact is confined to watersheds upstream of the outlet of Lake 410; small scale direct and indirect impacts from the Project **Regional:** projected impact extends beyond Lake 410 to the inlet to Aylmer Lake; the predicted maximum spatial extent of combined direct and indirect impacts from the Project that exceed local scale effects **Beyond Regional:** projected impact extends into Aylmer Lake and beyond; cumulative local and regional impacts from the Project and other developments extend beyond the regional scale	**Short-term:** projected impact is reversible by the end of construction **Medium-term:** projected impact is reversible upon completion of refilling Kennady Lake (i.e., end of closure) **Long-term:** projected impact is reversible some time after the refilling of Kennady Lake is complete (i.e., beyond closure) or not reversible	**Isolated:** projected impact occurs once, with an associated short-term duration (i.e., is confined to a specific discrete period) **Periodic:** projected impact occurs intermittently, but repeatedly over the assessment period **Continuous:** projected impact occurs continually	**Reversible:** projected impact will not result in a permanent change from existing conditions or conditions compared to 'similar'[(a)] environments not influenced by the Project **Not reversible:** projected impact is not reversible (i.e., duration of impact is unknown or permanent)	**Unlikely:** projected impact is likely to occur less than one in 100 years **Possible:** projected impact will have at least one chance of occurring in the next 100 years **Likely:** projected impact will have at least one chance of occurring in the next 10 years **Highly Likely:** Projected impact is very probable (100% chance) within a year	**High:** projected impact relates to a highly valued component of the aquatic ecosystem

(a) "similar" implies a stream or waterbody that is similar in general characteristics and location to that affected by the Project (e.g., Kennady Lake, or streams and lakes downstream of Kennady Lake to Lake 410).

Table 10.8-2 Definitions Used to Rate the Magnitude of Projected Residual Impacts

Scale	Assessment Endpoint			
	Suitability of Water Quality to Support a Viable Aquatic Ecosystem	Abundance and Persistence of Desired Population(s) of Key Fish Species		
		Abundance of Lake Trout	Abundance of Arctic Grayling	Abundance of Northern Pike
Negligible	results of the aquatic health and productivity assessments indicate that no measurable change to the overall health of the aquatic ecosystem will occur	no measurable change to the abundance of lake trout, relative to existing conditions	no measurable change to the abundance of Arctic grayling, relative to existing conditions	no measurable change to the abundance of northern pike, relative to existing conditions
Low	results of the aquatic health and productivity assessments indicate that a measurable change to the aquatic community may occur, but no notable changes in community structure or overall health of the system are expected	no measurable change in the abundance of lake trout, but population statistics (such as, age-class structure) may differ from existing conditions	no measurable change in the abundance of Arctic grayling, but population statistics (such as, age-class structure) may differ from existing conditions	no measurable change in the abundance of northern pike, but population statistics (such as, age-class structure) may differ from existing conditions
Moderate	results of the aquatic health and productivity assessments indicate that a measurable change to the aquatic community, including a notable shift in community structure may occur, but no effect to the overall health of the system is expected	projected decrease in abundance of lake trout; however, the species is expected to persist	projected decrease in abundance of Arctic grayling; however, the species is expected to persist	projected decrease in abundance of northern pike; however, the species is expected to persist
High	results of the aquatic health and productivity assessments conclude that the overall health of the aquatic ecosystem could be affected	projected decrease in the abundance of lake trout is sufficient to result in a complete loss of the species in question (i.e., will not persist)	projected decrease in the abundance of Arctic grayling is sufficient to result in a complete loss of the species in question (i.e., will not persist)	projected decrease in the abundance of northern pike is sufficient to result in a complete loss of the species in question (i.e., will not persist)

(a) - = not applicable.

As existing and planned projects in the NWT are located outside of the Kennady Lake watershed, there is no opportunity for the releases of those projects to interact with those of the Project within the Kennady Lake watershed. Consequently, there is no potential for cumulative effects to fish or water quality in the Kennady Lake watershed.

10.8.1.1 Classification Time Periods

As previously noted, the classification completed as part of this key line of inquiry focuses on long-term impacts, those projected to occur after the initial recovery of Kennady Lake (i.e., effects projected to persist or occur 100 years after the initiation of the Project). It was completed taking into consideration the ability of the affected ecosystems to recover to a state comparable to other similar aquatic ecosystems in the area, rather than focusing on conditions that may occur at one particular point in time 100 years after the initiation of the Project.

The results of the application of the residual impact classification system to the projected impacts and the subsequent determination of environmental significance follow in Section 10.9.2.

10.8.2 Results

10.8.2.1 Long-term Suitability of Water Quality to Support Aquatic Life

Kennady Lake Watershed

In Section 8.8 and 8.9, the effects of the Project on water quality and aquatic health in the main basins of Kennady Lake and Area 8 resulting from the pathways of physical changes to Kennady Lake were assessed for closure (including post-closure).

Potential effects to aquatic health in the main basins of Kennady Lake and Area 8 were evaluated for closure and post-closure periods based on predicted changes in water quality. Predicted changes to concentrations of all substances considered were projected to result in negligible effects to fish tissue quality and, by association, aquatic health in Kennady Lake.

The projected long-term impacts of the Project on the suitability of water quality to support aquatic life were rated as negative in direction, low in magnitude, local in geographic extent, long-term in duration, and not reversible (Table 10.8-3). The low magnitude rating is based primarily on the long-term increases in the productivity of the main body of Kennady Lake and Area 8 as a result of increased nutrients. There are both positive and negative effects to aquatic life within Kennady Lake from the increased productivity. The increased nutrients will be reflected in increased biomass of lower trophic communities, and may also increase fish productivity, e.g., growth and production of large-bodied fish species, such as northern pike and burbot, compared to the present nutrient-limited system. However, due to the change in trophic status to mesotrophic, overwintering habitat in Kennady Lake at post-closure may become more limited for some fish species than pre-development conditions. Kennady Lake would be expected to retain sufficient levels of under-ice dissolved oxygen during winter to support fish; however, there may be reduced suitability and availability of overwintering habitat for cold-water fish species, such as lake trout and round whitefish. However, there are no predicted long-term effects to aquatic health that would impair the suitability of the water quality to support aquatic life. By this time period, it is expected that the lake would have reached its new equilibrium.

Downstream Watershed

In Section 9.8 and 9.9, the effects of the Project on water quality and aquatic health in waterbodies downstream of Kennady Lake were assessed for closure (including post-closure).

Potential effects to aquatic health were evaluated for downstream waterbodies for closure based on predicted changes in water quality (Section 9.8). Changes to water quality in waterbodies downstream of Kennady Lake are predicted to result in negligible long-term effects to aquatic health.

The projected long-term impacts of the Project on the suitability of water downstream of Kennady Lake to support a viable and self-sustaining aquatic ecosystem were rated as negative in direction and negligible in magnitude (Table 10.8-3). The rating is based on the projected shift in the trophic status downstream of Kennady Lake after reconnection, with predictions of a gradient in lake trophic status from mesotrophic in the L watershed to oligotrophic in Lake 410, with a corresponding gradient of both positive and negative effects. The increases in nutrients are expected to increase productivity in lower trophic levels, potentially leading to increased growth and productivity for fish, as well as rearing and feeding opportunities. However, there may be some small negative changes to fish habitat (i.e., potential for algal growth on streambed substrates and small reductions in the availability or suitability of overwintering habitat in downstream lakes). These projected impacts are local in geographic extent, long-term in duration, and not reversible.

10.8.2.2 Residual Impacts to the Abundance and Persistence of Desired Population(s) of Key Fish Species

An aquatic ecosystem will develop within Kennady Lake after refilling and reconnection of its basins. There will be some permanent losses of fish habitat in Kennady Lake due to mine rock piles, PK storage and mine pits; however, compensation habitats will be constructed within the Kennady Lake watershed to offset losses. The long-term hydrology of Kennady Lake is expected to return to a state similar to current conditions and water quality in the refilled lake is expected to return to conditions suitable to support aquatic life over time. The long-term flow regime in the N, L, and M watersheds through to Lake 410 will be similar to baseline conditions.

The classification of projected impacts of the Project on the abundance and persistence of the three valued fish species, namely Arctic grayling, lake trout and, northern pike, is outlined in more detail below. For the classification of long-term effects, the projected impacts on the abundance and persistence of the three key fish species were classified after the first 100 years.

10.8.2.2.1 Arctic Grayling

Kennady Lake Watershed
The projected long-term impacts on the abundance and persistence of Arctic grayling were rated as negative in direction, low in magnitude, local in geographic extent, long-term in duration, and not reversible (Table 10.8-3). Although increases in the growth and production of Arctic grayling in the refilled Kennady Lake may occur as a result of the increased planktonic and benthic food base, the re-established Arctic grayling population may take time to recover, or may not recover to existing conditions (i.e., in terms of standing stock and annual production rates) because of predicted changes in habitat conditions in the refilled Kennady Lake and downstream watershed.

Arctic grayling will likely establish a self-sustaining population in the refilled Kennady Lake earlier than northern pike. Arctic grayling will be able to access Kennady Lake from the downstream M watershed, as well as the upper B, D, and E watersheds. The recovery of the planktonic community will provide a stable food source for Arctic grayling rearing in Kennady Lake, which will likely be enhanced by nutrient enrichment. Spawning habitat will be available in streams in the reconnected B, D, and E watersheds and downstream of Area 8. It is expected that this species will be able to overwinter and form a self-sustaining population within the refilled Kennady Lake.

Arctic grayling begin to reach maturity in about four years and have a life expectancy of 6 to 10 years. A self-sustaining population of Arctic grayling reared in Kennady Lake should be present about 5 to 10 years after the exclusion measures are removed, or about 50 years after the start of construction. At that time, the abundance of Arctic grayling is expected to be substantially less than current abundance. However, given the relatively short time to maturity, the opportunities for immigration, and the reduction in predation by lake trout, the population is projected to increase in the next 50 years, which represents 5 to 10 generations. A precise prediction of fish abundance cannot be developed for an equilibrium state that will develop after 100 years; however, it is expected that a self-sustaining population of Arctic grayling will be present.

Downstream Watershed

The projected long-term impacts on the abundance and persistence of Arctic grayling in the downstream watersheds were rated as neutral in direction and negligible in magnitude (Table 10.8-3). The flow regime is expected to return to near baseline conditions. The increased productivity in streams and lakes downstream of Kennady Lake is likely to result in both positive and negative effects to Arctic grayling. Increased nutrients may cause increased growth and production in Arctic grayling from the increased food base. Arctic grayling feed mainly on zooplankton when young, and aquatic and terrestrial insects as adults, and will likely benefit from increased productivity at the lower trophic levels. As a result of the nutrient enrichment at post-closure, there may be increased algal growth on the streambed substrates in streams immediately downstream of Kennady Lake. However, ice scour and high flows during the time that Arctic grayling typically spawn (shortly after ice-out in streams) would likely limit the effects of algal accumulations on spawning habitat suitability, and it is expected that streams downstream of Kennady Lake will continue to provide spawning and rearing habitat for this fish species. Nutrient enrichment may also cause small reductions in overwintering habitat availability or suitability for Arctic grayling remaining in lakes in the M watershed throughout the winter. Arctic grayling show considerable low oxygen tolerance for salmonids, and they will likely be able to continue to overwinter successfully in most of the lakes currently used for overwintering, and the effect of reduced dissolved oxygen conditions is considered to be negligible.

10.8.2.2.2 Lake Trout

Kennady Lake Watershed

The projected long-term impacts of the Project on the abundance and persistence of lake trout in Kennady Lake are rated as negative in direction, moderate in magnitude, local in geographic extent, long-term in duration, and not reversible (Table 10.8-3). Although lake trout are expected to re-establish in the lake, recovery of the population abundance is partially influenced by the ability of lake trout to re-colonize Kennady Lake. Immigration of lake trout from downstream lakes is less likely to occur than for other large-bodied fish species. Furthermore, as lake trout are sensitive to low dissolved oxygen levels, this fish species may be affected by the reduced suitability and availability of overwintering habitat in Kennady Lake resulting from the change in trophic status. Although overwintering habitat conditions are expected to be suitable for lake trout in the refilled lake, overwintering habitat may be limiting, and the population may not recover to previous levels. Lake trout may not return as the most abundant predatory fish in the lake, due to overwintering habitat limitations, and the fact that conditions may be more favourable to other predatory fish species, such as northern pike and burbot. The geographic extent of any projected impact was determined to be local, as the impact would not extend to lake trout populations in downstream lakes (e.g., Lake 410).

Downstream Watershed

Projected long-term impacts on the abundance and persistence of lake trout in downstream waters were rated as neutral in direction and negligible in magnitude (Table 10.8-3). The flow regime is expected to return to near baseline conditions. The increased productivity in streams and lakes downstream of Kennady Lake may result in both positive and negative effects to lake trout. The increased productivity in streams and lakes downstream of Kennady Lake may cause increased growth and production in lake trout from the increased food base. Lake trout feed on a variety of food items, including smaller fish and macro-invertebrates, with YOY lake trout feeding almost exclusively on zooplankton. As a result, lake trout will likely benefit from the increased primary and secondary productivity due to nutrient enrichment, as well as increased density of forage fish. Lake trout from Lake 410 are likely to increase seasonal movements into the M lakes and streams to take advantage of the increased food base. Based on depth, Lake M4 is likely the only lake between Kennady Lake and Lake 410 that provides suitable overwintering habitat for lake trout. Cold-water fish species, such as lake trout, are less tolerant of low dissolved oxygen levels, and the other more shallow L and M lakes may not provide suitable overwintering habitat for this sensitive fish species. As a result of the nutrient enrichment at post-closure, there may be small reductions in overwintering habitat availability or suitability for lake trout remaining in Lake M4 throughout the winter.

10.8.2.2.3 Northern Pike

Kennady Lake Watershed

The projected long-term impacts on the abundance and persistence of northern pike in Kennady Lake were rated as neutral to positive in direction and negligible (Table 10.8-3). Increases in the growth and production of northern pike may occur in the refilled Kennady Lake as a result of the increased food base resulting from increased primary and secondary productivity. Spawning and rearing habitat in the refilled Kennady Lake is expected to be similar to, or better than, habitat that currently exists for this species. Northern pike are dependent on aquatic vegetation for spawning and rearing. The presence of aquatic vegetation in Kennady Lake is currently limited by physical factors, such as rocky substrates and wave action. However, existing macrophyte beds in sheltered areas may benefit from the increased nutrient concentrations, which would be reflected in increased plant abundance and productivity. The recovery of the population may also be enhanced by the lack of lake trout as the top predator at least initially in the recovery. Northern pike populations are expected to recover to similar levels to what currently exists by the second time period.

Table 10.8-3 Residual Impact Classification of Projected Long-Term Effects

Assessment Endpoint	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Likelihood	Ecological Context
Suitability of water to support a viable and self-sustaining aquatic ecosystem 100 years after the initiation of the Project								
Kennady Lake watershed	negative	low	local	long-term	continuous	not reversible	likely	high
Downstream systems	negative	negligible	-	-	-	-	-	-
Abundance and persistence of Arctic grayling 100 years after the initiation of the Project								
Kennady Lake watershed	negative	low	local	long-term	continuous	not reversible	likely	high
Downstream systems	neutral	negligible	-	-	-	-	-	-
Abundance and persistence of lake trout 100 years after the initiation of the Project								
Kennady Lake watershed	negative	moderate	local	long-term	continuous	not reversible	likely	high
Downstream systems	neutral	negligible	-	-	-	-	-	-
Abundance and persistence of northern pike 100 years after the initiation of the Project								
Kennady Lake watershed	neutral - positive	negligible	-	-	-	-	-	-
Downstream systems	neutral - positive	negligible	-	-	-	-	-	-

- = not applicable.

It is expected that northern pike will establish a self-sustaining population in the refilled Kennady Lake. Although migrants will be located in nearby systems, including the B, D, and E watersheds, northern pike are dependent on aquatic vegetation for spawning and rearing. Currently, the abundance of aquatic vegetation in Kennady Lake is limited to small isolated pockets where fine substrates accumulate within the lake. The pockets commonly occur at the mouths of the small tributaries that flow into Kennady Lake. Although aquatic vegetation is expected to eventually become re-established in the lake, re-colonization of aquatic vegetation is expected to be slow. With the exception of the younger juveniles, northern pike feed almost exclusively on fish and will rely on the recovery of the forage fish base; however, they will likely benefit from the increased density of forage fish due to higher biological productivity associated with nutrient enrichment. As northern pike are more tolerant of low dissolved oxygen concentrations than other large-bodied fish species, they will likely not be as influenced by the potential reduction in overwintering habitat in Kennady Lake and form a self-sustaining population within the refilled lake.

Northern pike mature relatively quickly, with an average age to maturity of about three years. Their life span ranges from about 10 to 26 years, generally averaging around 25 years. Even though northern pike reach maturity relatively quickly, northern pike is expected to re-establish self-sustaining populations in the refilled Kennady Lake later than Arctic grayling or burbot, due to the need for re-colonization of aquatic vegetation in the lake for spawning and rearing, and the development of a forage fish food base. As a result, recruitment of northern pike in Kennady Lake will occur for some time primarily through migration from lakes in the D and E sub-watersheds, and to a lesser extent from downstream of Area 8.

The re-establishment of a stable, self-sustaining northern pike population Kennady Lake during post-closure is expected to take a long time (i.e., approximately 50 to 60 years following the complete refilling of Kennady Lake) and it may take additional time (i.e., greater than 100 years) for the abundance of northern pike to recover to current levels. A precise prediction of fish abundance cannot be developed for an equilibrium state that will develop after 100 years; however, it is expected that a self-sustaining population of northern pike will be present at levels similar to existing conditions.

Downstream Watershed

The projected long-term impacts on the abundance and persistence of northern pike were rated as neutral to positive in direction and negligible in magnitude (Table 10.8-3). The flow regime is expected to return to near baseline conditions and the increased productivity in streams and lakes downstream of Kennady Lake is likely to result in positive effects to northern pike. The increased productivity in streams and lakes downstream of Kennady Lake likely will result in increased growth and production in northern pike from the increased food base. With the exception of the younger juveniles, northern pike feed almost exclusively on fish and will likely benefit from the increased density of forage fish due to nutrient enrichment. As a result of the nutrient enrichment at post-closure, there will likely be an increase in aquatic macrophyte growth, which would improve the availability of suitable spawning and rearing habitats in lakes and streams between Kennady Lake and Lake 410. As northern pike are fairly tolerant of low dissolved oxygen concentrations, they will continue to be able to overwinter successfully in downstream lakes.

10.8.3 Environmental Significance

Ultimately, significance will be determined by the Panel. In the Mackenzie Valley Environmental Impact Review Board (MVEIRB 2006) reference bulletin on interpretation of key terminology, the term “significant” means an impact that is, in the view of the MVEIRB, important to its decision. To determine significance, the MVEIRB (2006) “will use its own values and principles of good EIA. It will use its combined experience and knowledge”. Presumably the determination of significance will be made in a similar manner by the Gahcho Kué Panel. However, the Terms of Reference require that De Beers provide its views on the significance of impacts. To that end, projected impacts were evaluated to determine if they were environmentally significant.

The evaluation of significance for this key line of inquiry considers the entire set of primary pathways In Sections 8 and 9 that influence a particular assessment endpoint, but does not assign significance to each pathway. The relative contribution of each pathway is used to determine the significance of the Project on assessment endpoints, which represents a weight of evidence approach.

Environmental significance is used here to identify projected impacts that have sufficient magnitude, duration, and/or geographic extent that they could lead to fundamental changes to the VCs. For example, significance is determined by the risk to the persistence of fish populations within the aquatic ecosystem. The following definitions are used for assessing the significance of effects on the protection of surface water quality for aquatic and terrestrial ecosystems, and human use are as follows.

Not significant – impacts are measureable at the local scale, and may be strong enough to be detectable at the regional scale.

Significant – impacts are measurable at the regional scale and are irreversible. A number of high magnitude and irreversible effects (i.e., pathways) at the regional scale would be significant.

The following definitions are used for assessing the significance of impacts on the persistence of VC fish populations, and the associated continued opportunity for traditional and non-traditional use of these VCs.

Not significant – impacts are measurable at the individual level, and strong enough to be detectable at the population level, but are not likely to decrease resilience and increase the risk to population persistence.

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

Suitability of water to support a viable and self-sustaining aquatic ecosystem

The projected long-term impacts of the Project on the suitability of water to support a viable and self-sustaining aquatic ecosystem are considered to be not environmentally significant for both the Kennady Lake watershed, and its downstream watershed. Water quality is predicted to change; however, the potential for modelled substances to cause adverse effects to aquatic life in was considered to be low or negligible. Phosphorus is projected to increase in long-term steady state concentrations that may shift the trophic status of Kennady Lake up one trophic level (i.e., from oligotrophic to mesotrophic). In the downstream watershed, these increases are projected to be indicative of a gradient in trophic status from mesotrophic in the L watershed to oligotrophic in Lake 410. The projected increases in phosphorus will not pose a health risk to a viable and self-sustaining aquatic ecosystem, though it will likely be different from the pre-development ecosystem (e.g., a more productive aquatic ecosystem).

Abundance and persistence of Arctic grayling

The projected long-term impacts on the abundance and persistence of Arctic grayling are considered to be not environmentally significant for both the Kennady Lake watershed as well as its downstream watershed. It is expected that a self-sustaining population of Arctic grayling will become established in the refilled lake. During post-closure, flows return to near baseline conditions and the population and distribution of Arctic grayling are also expected to return to baseline conditions. Nutrient enrichment after closure may provide for improved productivity in the Arctic grayling population from the increased food base.

Abundance and persistence of lake trout

The projected long-term impacts on the abundance and persistence of lake trout are considered to be not environmentally significant for both the Kennady Lake watershed as well as its downstream watershed. It is expected that the refilled Kennady Lake will provide suitable habitat conditions for a self-sustaining lake trout population to become established, although the population may not recover to current levels of abundance, due to biotic and abiotic factors. In the downstream watershed, flows and lake levels return to near baseline conditions. Nutrient enrichment after closure may provide for improved productivity in the lake trout population from the increased food base. There may, however, be some small changes to overwintering availability and suitability for lake trout in lakes in the M watershed downstream of Kennady Lake.

Abundance and persistence of northern pike

The projected long-term impacts on the abundance and persistence of northern pike are considered to be not environmentally significant for both the Kennady Lake watershed as well as its downstream watershed. It is expected that a self-sustaining population will become established in the refilled Kennady Lake. In the downstream watershed, flows return to near baseline conditions and the population and distribution of northern pike are also expected to return to baseline conditions. Nutrient enrichment after closure may provide for improved productivity in the northern pike population from the increased food base.

10.9 UNCERTAINTY

Key areas of uncertainty related to long-term effects (i.e., post-closure period) for Kennady Lake watershed, and its downstream watershed, include the following:

- the Gahcho Kué Project (the Project) site water balance and associated uncertainty in downstream flows;
- water quality modelling and quality of assigned chemistry of source inputs, including the outflow from Area 8 to downstream lakes, Lake N11 and Lake 410;
- time to aquatic ecosystem recovery in Kennady Lake; and
- understanding ecosystems in the region of the Project.

The site water balance, quality and quantity of groundwater inflow to the mined-out pits, and water quality modelling, are also applicable to the construction, operations, and closure periods of the Project. However, the uncertainty with respect to these components remains relevant in the prediction of long-term impacts in the post-closure period for Kennady Lake and it watersheds, as well as the downstream watershed.

Each area of uncertainty is discussed in more detail below. The following discussion also includes a description of the approaches used to account for uncertainty in the effects analysis, so that potential effects were not underestimated. Where relevant, the inherent advantages of the design of the Project are also discussed, in terms of how they influence uncertainty in the assessment of effects.

10.9.1 Project Site Water Balance and Hydrology

The site water balance describes the movement of water through the Project site over the life of the Project. The water balance determines how much water will be discharged from the Project site to the receiving environment. The site water balance also identifies the sources of water entering and leaving the site.

The site water balance was developed through the use of a water balance model, and there is a high degree of confidence in the hydrological aspects of the project description that are considered in the water balance model. In most cases, the changes to the Kennady Lake watershed that will result from the Project are well-defined and subject to limits arising from environmental design features and mitigation. For example, the volume of Kennady Lake is well-defined, and discharges during dewatering will be managed within specified limits. Similarly, the drainage areas of the diverted A, B, D, and E watersheds are well-defined, and discharges to waterbodies downstream of Kennady Lake and to the N watershed will be managed within specified limits.

There is a corresponding high degree of confidence in the meteorological inputs to the water balance model inputs (e.g., temperature, precipitation) for median conditions, due to the quality of the available regional dataset. The length of the available datasets, which span from 46 years for the regional dataset to 2 to 7 years for more site-specific information, results in a lower level of confidence in the prediction of events with longer return periods, such as 1-in-50 or 1-in-100 year events. However, lake dynamics are driven to a greater extent by average or median conditions than by extreme events. As such, confidence levels are highest around those elements of the water balance model of most importance.

Uncertainty in predictions of flows and water levels in downstream waterbodies is lower than for the Kennady Lake watershed, because the model incorporates more assumptions with distance downstream from the project (e.g., lake outlet rating curves), as it would not have been practical to monitor and model each of the dozens of individual lakes in the Kirk Lake watershed. This greater uncertainty is somewhat offset by incorporating baseline data from downstream lakes including Kirk Lake, Lake 410 and Lake N1 in the water balance model calibration and validation.

10.9.2 Water Quality Modelling

Water quality in Kennady Lake, Area 8, Lake N11, the Interlakes and Lake 410 during closure will be dependent on the quality of the influent streams entering the each basin / lake. The predictions of water quality in these waterbodies after refill were completed using a dynamic, mass-balance model built within GoldSim™, which is widely used in environmental assessment. The GoldSim™ model was specifically used to simulate water quality outcomes in a receiving environment over time with multiple input variables.

The GoldSim™ water quality model was based on the site water balance within Kennady Lake and the hydrological model for the surrounding watersheds, and included inputs of material from the following sources:

- natural runoff within the Kennady Lake watershed, the N watershed, and the Lake 410 watershed, which were assigned average baseline water quality;
- water quality of the Kennady Lake after closure, which included:

- metals and other elements associated with the suspended solids in the WMP;
- seepage from Project areas to Kennady Lake, including the input of:
  - mine rock and coarse PK contact water and seepage from the Fine PKC Facility; and
  - blasting residue.

Baseline water quality data from the Project area provided the basis for estimation of the quality of natural runoff and inflows from unaffected areas. The prediction of water quality in Kennady Lake, Lake N11 and Lake 410, including the Interlakes, was based on modelling Project releases to average baseline water quality conditions. Some uncertainty around these predictions results from the use of an average baseline value assigned to each water quality parameter, when the dataset contains a naturally large degree of variability. The modelling was also focused on median climatic conditions. Although these areas of uncertainty exist, the selected approach is appropriate for lake systems, which are more strongly influenced by average conditions, rather than short-term extremes.

The water quality of Kennady Lake Areas 3 through 7 during refilling is an important input to the water quality model used to predict Area 8 and downstream water quality through the Interlakes in the post-closure and long-term post-closure periods. Combined, the water quality of the Lake N11 and the Interlakes are required to predict the water quality of Lake 410.

The modelled water quality parameters were also treated as conservative substances; no chemical transformations, biological uptake, degradation, or precipitation were assumed. When deriving means for baseline water quality, individual data that were below reporting limits were replaced with a value equal to half the detection limit.

A comprehensive description of the water quality modelling for Kennady Lake and downstream waters is described in Appendix 8.I. The uncertainty associated with the Project inputs, such as the runoff and seepage inputs from contact with the mine rock and PK material (i.e., phosphorus loading), groundwater inflows, and the open pits that will affect Kennady Lake and downstream waters, is also provided in detail in Section 8.15.3.

A description of the empirical modelling approaches used to estimate dissolved oxygen concentrations at the end of winter periods based on long-term steady state phosphorus concentrations in Kennady Lake is described in Appendix 8.V. The uncertainty associated with the projections, including variability of existing conditions, estimation of winter oxygen depletion rates and potential effects of the open mine pits is also provided in Section 8.15.3.

Projections of water quality in Kennady Lake and the downstream waterbodies 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 in these facilities and that permafrost will likely continue to develop following closure, which will result in lower rates of seepage through the facilities and geochemical loading to Kennady Lake during operations and closure than simulated in this assessment. However, as the assessment of impacts to the suitability of the water quality to support aquatic life includes time periods that extend into the long-term (200 years), the assessment was designed to represent potential future climatic conditions where there would be no permafrost.

In summary, the modelling approach is expected to yield a conservative estimate of the actual average concentrations that have been predicted for downstream waterbodies, with a high level of confidence that actual impacts to water quality are not underestimated.

De Beers is committed to undertake regular monitoring and testing using standard field and laboratory procedures during the Project operation to evaluate water quality of Kennady Lake, Area 8, Lake N11, and Lake 410. Where necessary, the water quality input profiles assigned to the loadings will be revised and Project effects will be re-assessed, as appropriate. Where required, adaptive management strategies will be adopted.

10.9.3 Time to Aquatic Ecosystem Recovery

A perfect analogue for Kennady Lake is not available, and the time required for the aquatic ecosystem in Kennady Lake to recover has been estimated from information presented in the available scientific literature. There is, as a result, some uncertainty in the estimated time for recovery (e.g., 50 to 60 years following the complete refilling of Kennady Lake for northern pike). Similarly, if habitat conditions are suitable for lake trout in the refilled lake, it is expected that this species will also require a long time to re-establish a stable, self-sustaining population (i.e., approximately 60 to 75 years following the complete refilling of Kennady Lake). The quoted range was developed using the longest recovery times noted in the literature (Section 8.11) and extending them further to account for the fact that Kennady Lake is located in the sub-arctic.

Arctic systems usually recover slower than temperate or tropical systems, because of colder temperatures, shorter growing seasons, and low nutrient availability. The longer recovery of Kennady Lake, compared to temperate zone lakes, remains likely due to Arctic climate-related factors. Because uncertainty is high, conservative assumptions were used in the estimation of the length of time for recovery, as described above. Consequently, there is a moderate degree of confidence that the length of time required for the ecosystem to recover is not underestimated. A moderate degree of confidence is the highest level that can be achieved in the assessment. The greatest uncertainty lies in the extent to which the abundance of each highly valued fish species returns to baseline values.

10.9.4 Understanding of Ecosystems in the Region of the Project

The main sources of uncertainty in the prediction of long-term impacts to fish and fish habitat include the following:

- incomplete knowledge of the relationship between changes in flow and changes in physical habitat of streams and lakes;
- incomplete knowledge of fish migrations and spawning habitat locations downstream of the Project area and if flow barriers will result in a reduction in spawning success; and
- incomplete knowledge of the flows at which barriers to migration persist, resulting in uncertainty in the flows required as part of the flow mitigation plan (magnitude, frequency and duration) to reduce population level effects on Arctic grayling.

The assessment on changes in wetted area and habitat suitability were based on results from single transects and may not be representative of the habitat available for the entire length of the stream. While reductions in habitat were noted, the same magnitude of change may or may not persist within other habitat types present within the stream.

Although extensive baseline studies were conducted in the local study area, some gaps remain in the understanding of spatial distribution of the fish VCs, and their annual migration patterns, particularly as it relates to movements to spawning habitats. For example, it is uncertain whether the B and D catchments support northern pike populations year-round and it is unclear whether upstream migrations of fish occur through stream N11 in spring. Although Arctic grayling have been captured moving between lakes downstream of Kennady Lake in the spring, presumably to access spawning habitat, the location of critical spawning habitats is unknown. When barriers to movement are present, it is unknown if suitable spawning habitat would still be available to Arctic grayling at points downstream of the barriers, or what the relative success of spawning would be during low flow years.

Although flows have been identified where barriers in stream downstream of Kennady Lake persist, and flows where barriers are not present, there is a fairly large gap in flow between these two known points. The development of a successful flow mitigation plan will need to better understand the flows required to allow for fish migrations and widespread spawning and rearing success. The timing, frequency and duration of flow augmentation must also be better understood when developing the flow mitigation plan.

The sources of uncertainty identified will be addressed during monitoring and through the development of a flow mitigation plan. Most of the uncertainty that remains is around changes to the flow regime downstream of Kennady Lake, and as a result, will only affect a few watercourses in the Project area. Based on the uncertainty identified, the assessment was conservative in evaluating long-term impacts to the fish VC's. However, since the scale of impacts is localized and reversible, the confidence level of the overall assessment of impacts to fish and fish habitat is considered to be moderate to high.

10.10 MONITORING AND FOLLOW-UP

10.10.1 Scope of Potential Monitoring Programs

Pursuant to the assessment approach outlined in environmental impact statement (EIS) Section 6, three types of monitoring are planned, and they include the following:

- compliance inspection;
- follow-up monitoring; and
- environmental monitoring.

Compliance inspection will consist of programs designed to confirm the implementation of approved design standards and the environmental design features described in the EIS.

Follow-up monitoring will consist of programs designed to verify key inputs to the effects analysis, as well as monitoring compensation habitat to confirm the no net loss objective has been achieved. Results of follow-up monitoring will be used to reduce the level of uncertainty related to impact predictions.

Effects monitoring will involve programs focused on the receiving environment, with the objectives of verifying the conclusions of the EIS, evaluating the short-term and long-term effects on the physical, chemical and biological components of the aquatic ecosystem of Kennady Lake, estimating the spatial extent of effects, and providing the necessary input to adaptive management.

Follow-up monitoring and compliance inspection programs will be focused on the Gahcho Kué Project (Project) site, with little to no work occurring beyond the immediate Project area. Effects monitoring programs will encompass a larger area; however, they are unlikely to extend beyond Kirk Lake. Anticipated monitoring activities in the Kennady Lake watershed and in the N lakes watershed and downstream of the Kennady Lake watershed are described in this section.

There is no requirement for a cumulative effects monitoring program for aquatics, because the projected impacts of the Project on aquatics do not extend beyond the local study area. They do not, as a result, overlap with other regional projects (e.g., Snap Lake Mine).

As this key line of inquiry: Long-term Biophysical Effects, Closure, and Reclamation, is focused on long-term effects, this section summarizes only the anticipated post-closure monitoring. The post-closure period is associated with the removal of dyke A and the reconnection of Areas 3 through 7 of Kennady Lake to Area 8 and downstream waterbodies. Details on anticipated monitoring programs for construction, operations, and closure are presented in Section 8.16 (Kennady Lake Watershed) and 9.15 (Downstream Watershed).

10.10.2 Potential Monitoring Activities

10.10.2.1 Compliance Inspection

Compliance inspection will verify that Project components are built to approved design standards and that environmental design features described in the EIS are incorporated. As each component of the Project is built, constructed features will be inspected to show that they comply with standard protocols, and that any variance from standard protocols has been completed with regulatory permission (as appropriate). A check list will also be developed to show that agreed-upon environmental design features are constructed as required.

Compliance monitoring will extend throughout the life of the Project, but will likely not be applicable to the post-closure period.

10.10.2.2 Follow-up Monitoring

Follow-up monitoring activities are relevant to verifying key inputs to the effects analysis. Follow-up monitoring activities are expected to include water sampling in and around the partially backfilled Hearne Pit and open Tuzo Pit basins, Areas 3 through 7, Area 8, and a reference lake to confirm the accuracy of the influent water quality profiles used to complete the effects assessment. Monitoring the progression of freezing within the external facilities will also be completed as part of this monitoring component. Only limited follow-up monitoring activities are anticipated in downstream waterbodies.

10.10.2.3 Effects Monitoring

Effects monitoring programs will include a Surveillance Network Program (SNP) that focuses primarily on Project site operations as well as a more broadly focused Aquatic Effects Monitoring Program (AEMP). De Beers will develop the scope of the SNP and AEMP in consultation with regulators and interested parties. It is anticipated, however, that the AEMP will include water flow, water quality and sediment quality components, along with components focused on lower trophic communities (i.e., plankton and benthic invertebrates), fish and fish habitat. Sampling areas are likely to be located in the Kennady Lake watershed, potentially affected areas of the N watershed and the A, B, D, and E watersheds, Lake 410, and Kirk Lake, and a suitable reference lake. Sampling stations in downstream waterbodies will be located in streams and lakes at varying distances downstream of Kennady Lake, likely extending to Kirk Lake. Components of the AEMP will be developed according to a common, statistically-based study design incorporating regulatory guidance and current scientific principles related to aquatic monitoring.

Monitoring will also be conducted to evaluate the effectiveness of habitat compensation, and will include evaluation of both physical and biological characteristics. This monitoring will be critical to confirming that the no net loss objective has been achieved. The detailed monitoring plan will be included in the detailed No Net Loss Plan, and will be designed to meet all fish and fish habitat monitoring requirements included as conditions attached to regulatory authorizations, approvals or permits that may be issued for development of the Project.

The scope of the AEMP is expected to change over the life of the Project. In particular, monitoring in adjacent and downstream watersheds is expected to decline when operations cease. However, monitoring of Kennady Lake and the reference lake will be maintained during all phases of the Project.

Monitoring and sampling techniques, and analysis procedures, will be consistent with methods used during the baseline survey period to the extent possible. The field and laboratory processes will include the implementation of quality assurance/quality control measures for data acquisition, water and biota sampling, and analysis and reporting.

The assessment of data and information collected during the monitoring programs will be compiled into annual AEMP reports that will be submitted to the appropriate parties for review. Where necessary and appropriate, the results of other monitoring programs (e.g., groundwater monitoring) will be integrated into the AEMP reports.

10.10.2.3.1 Kennady Lake Watershed

Post-closure

Hydrology

Hydrological monitoring of the reconnected watershed will occur at key locations in streams and lakes within and downstream of the Kennady Lake watersheds, i.e., similar sites selected during the baseline surveys. Monitoring is expected to be less frequent than during operations or closure, and will only persist for several years after the removal of Dyke A. The primary purpose of this monitoring will be to determine that the post-closure watershed hydrology is consistent with pre-development conditions, taking into account the modified watershed and lake areas.

Water Quality

Water quality monitoring will focus on parameters monitored during baseline surveys and used as input variables through the modelling process, including pH, hardness, alkalinity, total organic carbon, total suspended solids, total dissolved solids, major ions, metals, nutrients (e.g., phosphorus), and selected organic parameters. Sampling points in Kennady Lake during post-closure will include the partially backfilled Hearne Pit and open Tuzo Pit basins, Areas 3 through 7, Area 8, and a reference lake. Additional physico-chemical water column profile monitoring will be conducted seasonally in the Hearne and Tuzo pits to monitor the seasonal regime of meromictic conditions and the extent of chemocline development.

Sampling may occur on a less frequent basis than during operations and closure, but will maintain a seasonal basis (i.e., open water and under-ice conditions). Monitoring would be expected to continue, until water quality conditions are consistent with the surrounding environment or are on a predictable trajectory to that endpoint. Sampling will also be conducted in a reference lake to provide a comparison with background temporal trends.

Fish and Fish Habitat

Monitoring will include phytoplankton, zooplankton, benthic invertebrates, and fisheries sampling in the refilled Kennady Lake, the Kennady Lake watershed, and a reference lake. Monitoring in the refilled Kennady Lake will focus on changes to fish and fish habitat resulting from changes in nutrient levels and trophic change.

These monitoring programs will persist until it is determined that fish and lower trophic communities of the Kennady Lake watershed have reached applicable recovery thresholds as determined by Fisheries and Oceans Canada (DFO) and other interested parties, and that the compensation habitats are considered to be effective and habitat compensation targets are met. The monitoring programs will likely involve the following:

- Monitoring phytoplankton, zooplankton, benthic invertebrates, and fish populations in Kennady Lake will initially be conducted at two–year intervals, and then at five–year intervals after the removal of Dyke A, to provide an indication of the recovery and stability of the aquatic habitat.

- Monitoring the Kennady Lake pelagic and littoral fish communities (e.g., species composition, relative abundance) will be conducted annually after the removal of Dyke A, and then once every three years. This would provide an overall assessment of aquatic habitat and fish community recovery and the indication of potential need for fish stocking programs.
- If necessary, compensation habitats will continue to be monitored for fish habitat and fish presence and abundance at three–year intervals. It is anticipated that the effectiveness of the compensation habitats at meeting habitat compensation targets will be demonstrated before the end of the closure period. Therefore, post-closure monitoring of these locations is unlikely to be necessary.

10.10.2.3.2 Downstream Systems

Post-closure

Hydrology

Flow rates and water levels will be monitored at key locations in streams and lakes downstream of Kennady Lake. Monitoring will occur on a seasonal basis.

Water Quality

Water quality parameters, consistent with those monitored during Project operation, will be targeted. Likely sampling stations will include a subset of streams and lakes at varying distances downstream of Kennady Lake, likely extending to Kirk Lake, and in potentially affected areas of the N watershed, including a suitable reference lake.. Monitoring will be maintained on a seasonal basis (i.e., during open water and under-ice conditions).

Fish and Fish Habitat

Monitoring of phytoplankton, zooplankton, benthic invertebrates, and the fish community in selected streams and lakes downstream of Kennady Lake, the N watershed, and a reference lake will continue during post-closure (i.e., after the refilling of Kennady Lake and reconnection of upper drainages) to monitor changes to fish and fish habitat resulting from increased nutrient concentrations and trophic change as summarized below:

- Chlorophyll *a* concentrations in downstream lakes and a reference lake will be monitored through the open water season, in conjunction with plankton monitoring.

- Monitoring phytoplankton and zooplankton communities (e.g., species composition, biomass, community structure) in downstream lakes will be conducted through the open-water season, initially annually following reconnection, and then every three years.
- Benthic invertebrate communities will be monitored in downstream lakes and streams (e.g., species composition, community structure, compilation of assessment indices). This monitoring will be conducted in late summer, initially annually following reconnection, and then every three years.

It is expected that post-closure monitoring will cease once results demonstrate that the aquatic ecosystem in downstream waterbodies has reached a stable state.

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10.12 ACRONYMS AND ABBREVIATIONS

10.12.1 ACRONYMS

COMERN	Collaborative Mercury Research Network
DFO	Fisheries and Oceans Canada
DO	dissolved oxygen
DOC	dissolved organic compound
DOM	dissolved organic matter
e.g.	for example
EIS	environmental impact statement
El.	elevation
ELA	Experimental Lakes Area
Hg	mercury
i.e.	that is
INAC	Indian and Northern Affairs Canada
LSA	local study area
MVLWB	Mackenzie Valley Land and Water Board
NWT	Northwest Territories
PK	processed kimberlite
PKC	processed kimberlite containment
Project	Gahcho Kué Project
RSA	regional study area
SD	standard deviation
STP	sewage treatment plant
TDS	total dissolved solids
TSS	total suspended solids
WMP	water management pond
WTP	water treatment plant

10.12.2 Units of Measure

%	percent
<	less than
°C	degrees Celsius
µg Hg/g	milligram of mercury per gram
µg/g	micrograms per gram
µg/L	micrograms per litre
µm	micrometre
μm^3	cubic micrometre
dam^3	cubic decametre
ha	hectare

HUs	habitat units
km	kilometres
km^2	square kilometres
m	metres
m^3/d	cubic metre per day
m^3/s	cubic metres per second
masl	metres above sea level
$mE/m^{-2}/min^{-1}$	micro-Einsteins per square metre per minute
mg/L	milligrams per litre
Mm^3	million cubic metres
Mm^3/y	million cubic metres per year
Mt	million tonnes
$number/m^2$	number per cubic metre
TP	total phosphorus