

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

Information Request Number: AANDC_16

Source: Aboriginal Affairs and Northern Development Canada (AANDC)

Subject: Site Drainage

EIS Section: Section 3: Project Description

Terms of Reference Section:

Preamble:

Reference 3 – 67 “If water quality of runoff from the mine rock piles to the west and south of Kennady Lake, the Coarse PK pile, or the Fine PKC Facility is unsuitable for direct discharge into Kennady Lake, this water will be collected and treated to achieve acceptable discharge quality”

Request

1. Please indicate the time over which water quality is going to be monitored, and the relation between this number and the expected time for permafrost establishment throughout these facilities, for both the Fine and Coarse PK facilities.
2. Please indicate how direct discharge is going to be monitored and the water quality levels that would initiate water collection.
3. Please indicate how unsatisfactory water is to be collected after mine closure.

Response

- 1) Seepage water quality and thermal conditions in the facilities will be monitored throughout all stages of the Project. De Beers Canada Inc. (DBCI) is committed to the development of a Mine Waste Management Plan.
- 2) All runoff and seepage from the mine rock piles and processed kimberlite will be collected in the control basin in a series of pit sumps and collection ponds during operations (see Figure 3.9-1 in 2012 EIS Supplement (De Beers 2012)). The water will be sampled on a regular basis during periods of flow.

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

- 3) Runoff and seepage from the mine rock piles and processed kimberlite facilities is expected to result in water quality that is suitable for entering directly to Kennady Lake during the closure and post closure periods for the following reasons:
- a. The water quality model input values for Kennady Lake during post closure assume that: 1) Runoff and seepage from mine rock piles and process kimberlite facilities occur in the absence of permafrost (completely thawed conditions); and 2) The higher-end (higher concentration) test results are observed throughout the Project. While these conservative assumptions were used in the assessment to demonstrate possible worst case scenarios in order to ensure adequate mitigation, operational conditions are such that permafrost is expected to aggrade into the piles and decrease contact and reactivity with water. This builds confidence that the runoff water quality will be suitable for Kennady Lake. .
 - b. Baseline data for the Project includes over 1,200 samples of mine rock tested (including 24 kinetic tests), and over 650 samples of kimberlite and processed kimberlite tested (including 48 kinetic tests). Mine rock is predominantly granite and testing shows very little sulfide minerals with small amounts of buffering capacity. The materials are generally non-acid generating, or without sufficient sulphide minerals to generate significant acidity. However, to further reduce the risk of potential acid rock drainage (ARD) and metal leaching, additional mitigation has been proposed. This includes identifying and sequestering potentially acid generating (PAG) mine rock in the central zones of the mine rock piles in which permafrost conditions are expected to develop. Material will be used to cover PAG rock to keep water from penetrating into that portion of the rock piles. Further, the coarse processed kimberlite pile will be capped with sufficient clean mine rock prior to refilling Kennady Lake, and the fine processed kimberlite facility will be progressively capped and reclaimed by Year 11.
 - c. De Beers is committed to the development of a monitoring program to verify the water quality predictions and the effectiveness of the above mitigation measures. As such, De Beers will be able to determine if additional mitigation is required well in advance of post closure.



April 2012

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

References

De Beers. 2012. Environmental Impact Statement Supplemental Information
Submission for the Gahcho Kué Project. Submitted to the Mackenzie Valley
Environmental Impact Review Board. April 2012.

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

Information Request Number: AANDC_17

Source: Aboriginal Affairs and Northern Development Canada (AANDC)

Subject: General Hydrogeology

EIS Section: Section 8: KLOI Water Quality and Fish in Kennady Lake

Terms of Reference Section:

Preamble:

Apparent Inconsistencies were identified during the review of EIS Sections 8.3 and 8.4.

Request

1. Please confirm the location of MPV-04-165 on Figure 8.3-7.
2. Please clarify the flow direction on Figure 8.4-5. This figure shows mine water flowing from 5034 pit to Hearne pit.
3. Please confirm whether Table 8.4-6 on p. 8-165 should be labelled Table 8.4-7.

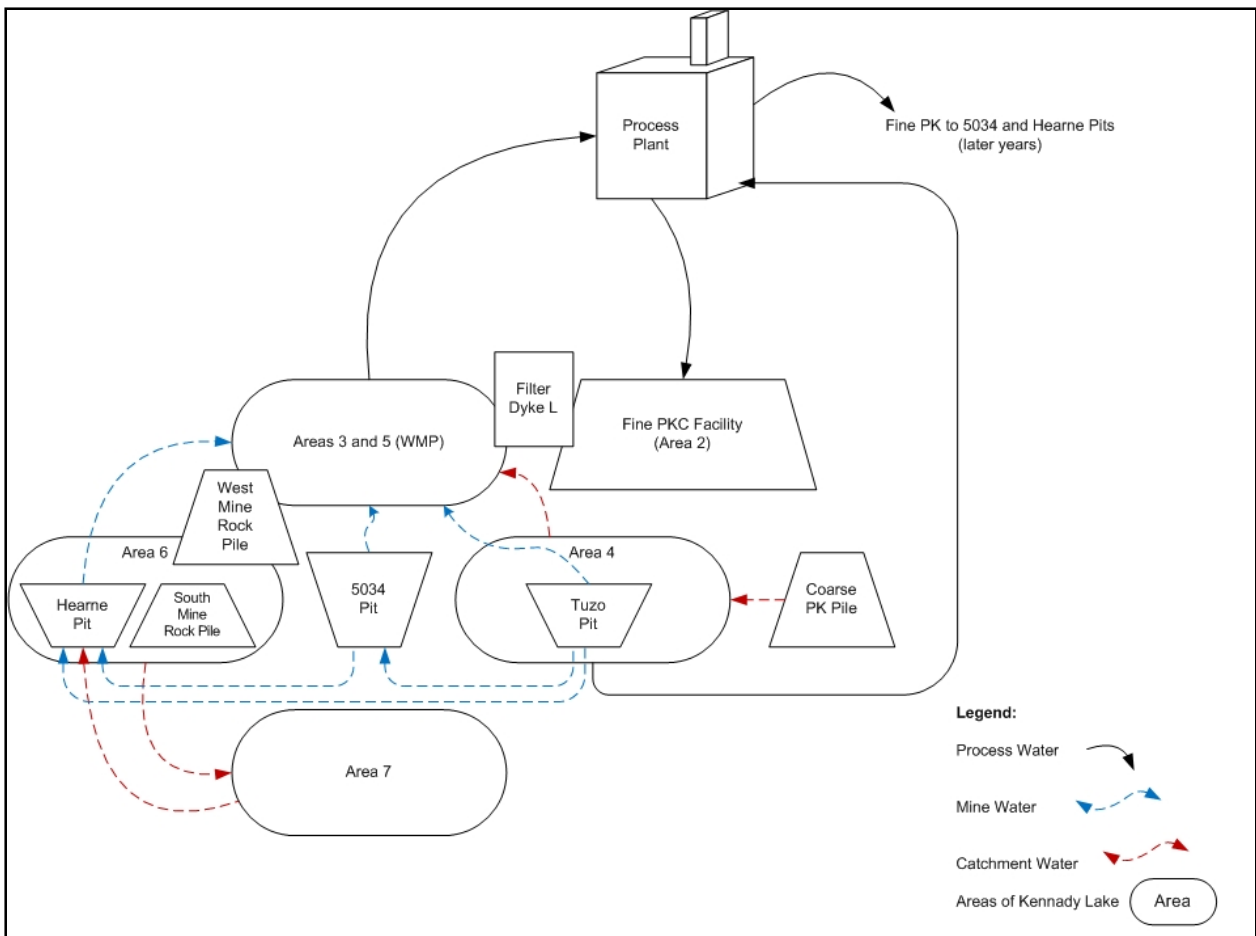
Responses

1. Figure 8.3-7 has been updated to show the location of MPV-04-165 (Figure AANDC_17-1).
2. The flow direction from the 5034 Pit to Hearne Pit is correct during operations. Once the 5034 Pit is mined out in Year 5, the groundwater entering the 5034 Pit and runoff water in the footprint of 5034 Pit will be retained in the pit. From mid-Year 7 to mid-Year 8, the excess water accumulated in the mined-out 5034 Pit may be pumped to the mined-out Hearne Pit. From mid Year 8 to the end of the mine life, the excess water accumulated in the mined-out 5034 Pit will be pumped to the process plant, Hearne Pit or Areas 3 and 5 to limit the water level in the mined-out 5034 Pit below 300 m elevation for safe mining in Tuzo Pit. Figure 8.4-5 has been

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

updated for the EIS Supplement (De Beers 2012), and has been included as Figure AANDC_17-2.

Figure AANDC_17-2 Diagram of Water Management in Operations Phase



Source: adapted from Figure 3.9-3 in De Beers (2010)

WMP = Water Management Pond; PKC = processed kimberlite containment; PK = processed kimberlite.

- Table 8.4-6 on page 165 of the EIS Update (De Beers 2011) is titled incorrectly, and should be, as the authors identified, Table 8.4-7.

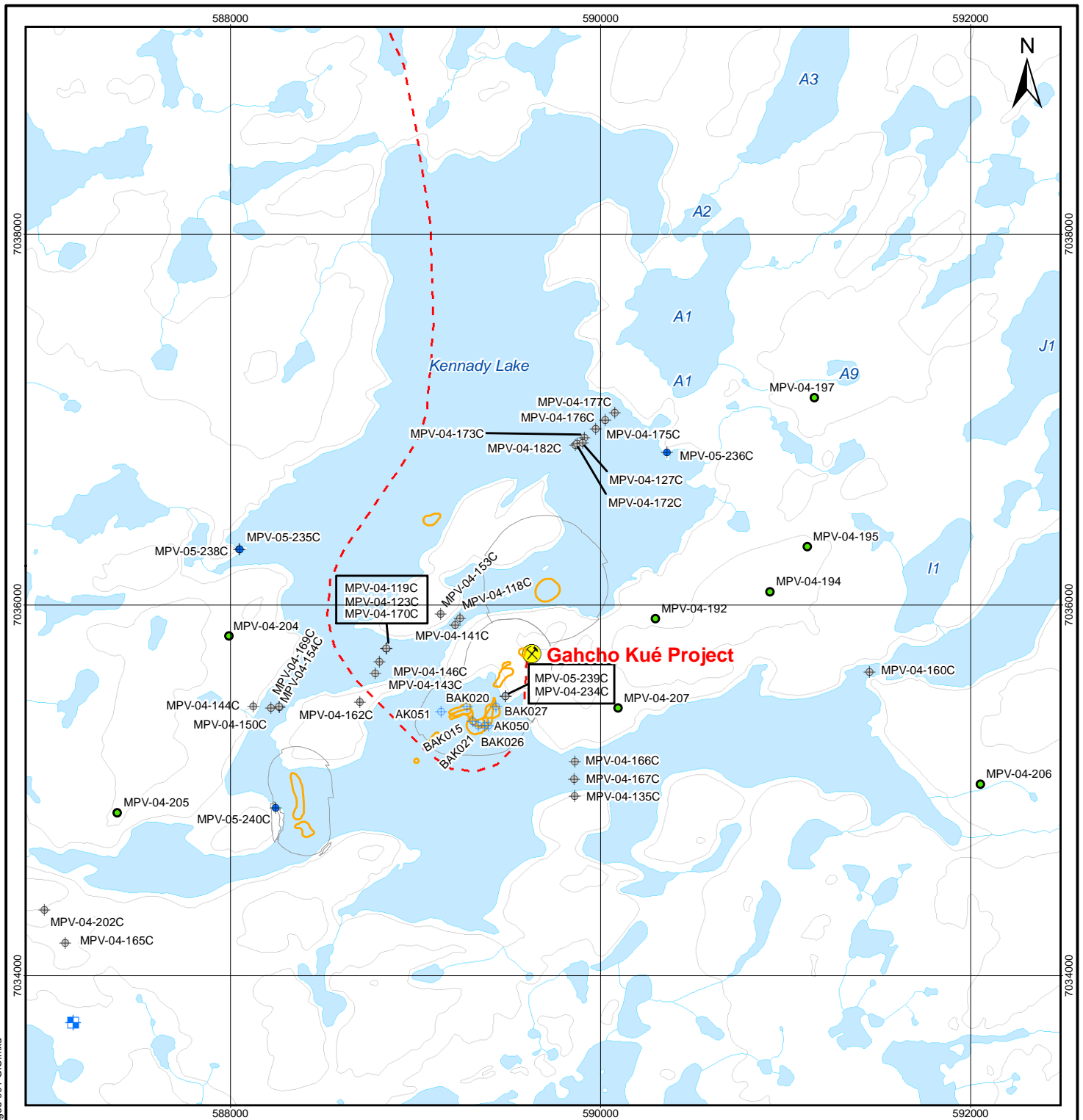
GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

References

De Beers (De Beers Canada Inc.). 2010. *Environmental Impact Statement for the Gahcho Kué Project. Volumes 1, 2, 3a, 3b, 4, 5, 6a, 6b, 7 and Annexes A through N.* Submitted to Mackenzie Valley Environmental Impact Review Board. December 2010.

De Beers. 2011. *Environmental Impact Statement for the Gahcho Kué Project. Volumes 3a Revision 2, 3b Revision 2, 4 Revision 2, and 5 Revision 2.* Submitted to the Mackenzie Valley Environmental Impact Review Board in Response to the Environmental Impact Statement Conformity Review. July 2011.

De Beers. 2012. Environmental Impact Statement Supplemental Information Submission for the Gahcho Kué Project. Submitted to the Mackenzie Valley Environmental Impact Review Board. April 2012.



I:\CLIENTS\DE_BEERS\11-1365-0001\Mapping\MXD\Hydrogeology\IR-Hydrogeo-001-GIS.mxd

LEGEND

- Gahcho Kué Project
- Winter Access Road
- Contour (10m interval)
- Watercourse
- Waterbody
- Shallow Groundwater Sampling Location
- Till Sampling Drillhole Location
- Borehole**
- 1996
- 2004
- 2005
- Kimberlite Outline
- Pit Outline

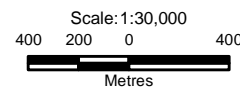
NOTES

- 1) Base Data Source: National Topographic Base Data (NTDB) 1:50,000
- 2) Borehole Data Sources:
 - Hydrological Consultants Inc. December 2005. Draft Predicted Hydrologic Effects of Developing Gahcho Kué Diamond Project. Prepared for SRK Ltd. HCI-1759.
 - Bruce Geotechnical Consultants. 1996. AK5034: Diamoniferous Kimberlite Pipe Geotechnical Studies, Permafrost and Ground Ice Conditions. A report prepared for Canamera Geological Ltd.

GAHCHO KUÉ PROJECT

Borehole Locations

PROJECTION: UTM Zone 12 DATUM: NAD83



FILE No: IR-Hydrogeo-001-GIS March 23, 2012

JOB NO: 11-1365-0001 REVISION NO: 4

OFFICE: GOLD-CAL DRAWN: CW CHECK: JF

Figure AANDC 17-1

DRAFT

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

Information Request Number: AANDC_18

Source: Aboriginal Affairs and Northern Development Canada (AANDC)

Subject: Case study results of Diavik and Snap Lake Hydrogeological Characterization Reports (Pre-mining and operational)

EIS Section: EIS and Conformity Responses

Terms of Reference Section:

Preamble:

Reference to Snap Lake and Diavik mine hydrogeological conditions and water management challenges during operations are made through the developer's EIS

Request

1. Provide copies of the pertinent sections related to hydrogeological characterization and water quality (groundwater and surface water) from the following reports:

De Beers (De Beers Canada Mining Inc.). 2002. Snap Lake Diamond Project Environmental Assessment Report. Prepared for De Beers Canada Mining Inc. by Golder Associates Ltd. Yellowknife, N.W.T. February 2002.

Diavik, EIS (Rio Tinto) Specifically the hydrogeological characterization components and groundwater management plans

2. Provide copies of the following paper:

Kuchling, K., D. Chorley and W. Zawadzki. 2000. Hydrogeological modelling of mining operations at the Diavik Diamonds Project. In Proceedings of the Sixth International Symposium on Environmental Issues and Waste Management in Energy and Mineral Production, University of Calgary, Calgary AB.

3. Provide copies of any publications relating to fracture flow within the regional study area.

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

Response

1. This Information Request asks for hydrogeology characterization sections of the Diavik EIS and the Snap Lake EIS. De Beers has confirmed from Diavik that the Wekeezhi Land and Water Board have a copy of the Diavik EIS, but not in electronic form. It is also not readily accessible on the public domain through the Wekeezhi Land and Water Board web site.

The link to the relevant sections of the Snap Lake EIS is:
http://reviewboard.ca/registry/project_detail.php?project_id=6&doc_stage=5

2. A copy of the Kuchling et al. (2000) paper is attached.
3. De Beers is not aware any other available documents in the public domain for the Regional Study Area of the Project that discusses fault permeability.

Hydrogeological Modeling of Mining Operations at the Diavik Diamonds Project

Ken Kuchling, P.Eng

Diavik Diamond Mines Inc., Calgary Alberta Canada

Don Chorley, P.Geo

Golder Associates Ltd. Vancouver, British Columbia, Canada

Willy Zawadzki

Golder Associates Ltd. Vancouver, British Columbia, Canada

ABSTRACT: Diavik Diamond Mines Inc. proposes to develop a diamond mining project at Lac de Gras in the Northwest Territories. As part of the Environmental Assessment, and mine design, estimates of mine water inflow quantity and quality were required. This paper describes the field investigations and numerical modelling studies that were completed in order to evaluate the groundwater conditions at site. The Diavik Diamonds Project is located in the Canadian Shield within the region of continuous permafrost, however mining operations will be located in unfrozen ground within the confines of a diked-off portion of Lac de Gras. Field investigations used to characterise the hydrogeological regime at site consist of extensive packer testing supplemented with a limited program of borehole flowmeter testing, borehole temperature logging and borehole camera imaging. This information was used to develop a conceptual hydrogeological model for the site, which in turn was modelled numerically using MODFLOW and MT3DMS to predict groundwater inflow volumes and water quality with time. Results indicate that the total mine inflows are expected to range up to 9,600 m³/day with TDS concentrations gradually increasing in time to maximum levels of about 440 mg/L. The modelling also showed that lake water circulating through the rock mass will eventually comprise more than 80% of the mine water handled.

1 INTRODUCTION

The Diavik Diamonds Project is located at Lac de Gras, 300 kilometres northeast of Yellowknife, N.W.T, shown in Figure 1. The project is a joint venture between two Canadian companies, Aber Resources Ltd. (40%) of Toronto and Diavik Diamond Mines Inc. (60%) of Yellowknife, a subsidiary of Rio Tinto plc of London, England.

The project will entail the mining of four diamondiferous kimberlite pipes, termed the A154S, A154N, A418, and A21 pipes. The total kimberlite resource stands at about 37 million tonnes with an average grade of 3.6 carats per tonne, for a total resource of about 133 million carats. The proposed mine plan consists of the initial development of three open pit mines after which underground mining operations will continue beneath two of the pits (A418 and A154 pits). The estimated mineable ore reserve is approximately 26 million tonnes yielding an estimated 102 million carats over the 20 year mine life. Twenty million tonnes of the reserve will be mined with open pit methods while the remaining 6 million tonnes will be recovered with underground methods. Mining operations will extend to a depth of 400 metres below the lake bottom.



Figure 1: Project Location

The Diavik project is located within the region of continuous permafrost, about 250 kilometres south of the Arctic Circle. The four kimberlite pipes are all located within the footprint of Lac de Gras, approximately 100 to 800 metres from the shoreline of east island. Therefore unfrozen ground conditions will be encountered in all the pits during mining.

Water retention dikes will be used to isolate the pit areas from the lake (Figure 2) with the consequence that groundwater will flow through the unfrozen rock. A key part of the project environmental assessment and mine design was prediction of the quantity and quality of mine water. The focus of this paper is on the hydrogeology of the A418 and A154 pit areas (Figure 2).

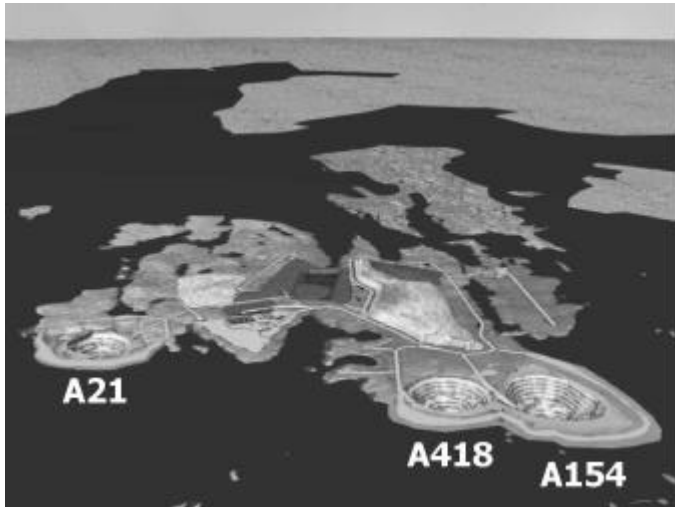


Figure 2: Project layout

2 GEOLOGICAL SETTING AND PERMAFROST CONDITIONS

The regional geologic setting for the Lac de Gras area is within syntectonic and post-tectonic intrusive rocks of the Slave Province. The main Archean rock units consist of sedimentary greywacke metaturbidites, biotite tonalite, 2-mica granite, and granodiorite. Proterozoic diabase dike swarms also appear regionally. The open pits will be developed in competent granitic country rocks with Rock Quality Designation (RQD) in the range of 95%. Existing fractures and local joint systems will therefore govern the hydrogeology of the country rock mass.

The formation of the kimberlite pipes are relatively recent geological events, having been emplaced approximately 50-60 million years ago. For comparison, the host rocks vary from 2.5 to 2.7 billion years in age and the younger diabase dikes at 1.3 to 2.6 billion years in age. The kimberlite pipes are cylindrically shaped and near vertical, with diameters of about 80-120 metres.

The pit areas are overlain with approximately 10 metres of overburden, consisting of an average of eight (8) metres of bouldery till and two (2) metres of lake bed sediments. The upper few metres of the bedrock can be weathered with some open joints being infilled with silty fines.

Permafrost develops in areas where the heat loss from the ground during winter exceeds the combined energy gain during the summer and energy radiated by the local geothermal gradient (i.e. heat radiating upwards from depth). Permafrost generally develops under dry land masses where the ground surface is exposed to prolonged cold air temperatures. The average annual air temperature at the Diavik site is -12°C . Beneath bodies of water which do not entirely freeze to depth (>1.5 metres deep at the Diavik site), taliks, or thawed zones, will be present. In these locations, the lake water and lakebed will only cool to temperatures in the range of 0°C to $+1^{\circ}\text{C}$ in winter and this relatively “warm” temperature will prevent the development of permafrost in the ground. At the Diavik site the permafrost depth has been measured to a vertical depth of about 380 metres below the east island and the ground temperatures are typically in the range of -5°C . Permafrost depths measured under the various small islands in the lake range from 100 metres to being non-existent, depending on the size of the island. Along the lake shoreline, permafrost has been shown to extend sub-vertically downwards from the lake edge contact forming a “bulb” shaped zone under the islands. Hydrogeologically, permafrost is considered to be impervious.

3 HYDROGEOLOGICAL INVESTIGATIONS

In order to characterize the hydrogeology of the site, three successive geotechnical/hydrogeological field programs were conducted between the years 1996 and 1998. The locations of these boreholes are shown in Figure 3.

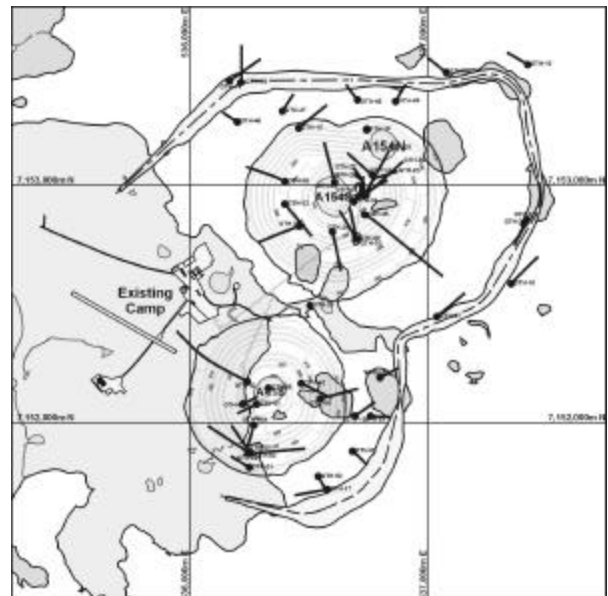


Figure 3: Geotechnical Borehole Locations

On average they were drilled at inclinations of -55° to vertical depths of 245 metres although two holes were extended down to 600 metres. Since the pit areas are under the lake, drilling was from the ice and restricted to the winter seasons only (February to mid-April). These core holes were logged geotechnically, including the collection of oriented core data. Packer testing was also undertaken in these holes. The goal of the hydrogeological investigations were to assess the hydraulic conductivity of the rock mass as a whole, and to determine the major factors controlling water flow, i.e. are the main flow paths along the natural jointing in the rock or mainly along major structures such as broken zones or faults. Knowledge of the groundwater flow system would help develop the conceptual hydrogeological model and aid in design of water collection or mitigation measures if needed. A 1000-metre long bulk sample decline was excavated to the A154S pipe (Figure 3) and this development also provided opportunity to assess hydrogeological conditions on a somewhat larger scale, although only 600 metres of the decline was actually in unfrozen rock beneath the lake. The length could be extended to 800 metres if boreholes drilled out from the face are included.

Four types of hydrogeological field investigation methods were used at site. They consisted of; (i) packer testing, (ii) borehole flowmeter testing, (iii) borehole temperature logging, and (iv) borehole video imaging.

Packer testing: Approximately two hundred shallow and deep HQ and NQ sized core holes were drilled as part of the geotechnical and hydrogeological investigations for the pit walls and the water retention dikes (pit wall holes only are shown in Figure 3). Most of the geotechnical holes were packer tested using constant head tests although some falling head tests were also conducted. In total approximately 600 packer tests were completed in the country rock over packer intervals ranging from 40 metres down to 3 metres. Packer testing intervals associated with the water retention dike design were generally short, in the range of 3 to 10 metres in both the bedrock and overburden. Packer tests associated with the pit investigations were done over 40 metre intervals in the bedrock only. The deepest packer test at site was done at a vertical depth of 570 metres below lake bottom.

Heat pulse flowmeter logging: This geophysical technique utilizes a down-the-hole probe that can measure water flow rates along a borehole. A small diameter submersible pump is used to lower the head

in the borehole in order to induce upward water flow from depth. The flowmeter tool is lowered to various locations in the hole in order to take flow rate measurements. As cumulative flows are measured at various points in the hole, water-bearing zones can be identified by changes in borehole flow quantity. The water-bearing zone would be somewhere between a “high flow” reading and the previous “low flow” reading. Several boreholes were tested with this method however only one provided good results. In the unsuccessful holes, extremely permeable zones near the top of the hole yielded almost all of the water influx and consequently very little upward flow could be induced. Figure 4 shows a typical plot from the flowmeter log. The maximum and minimum values were determined by taking several readings at each depth increment.

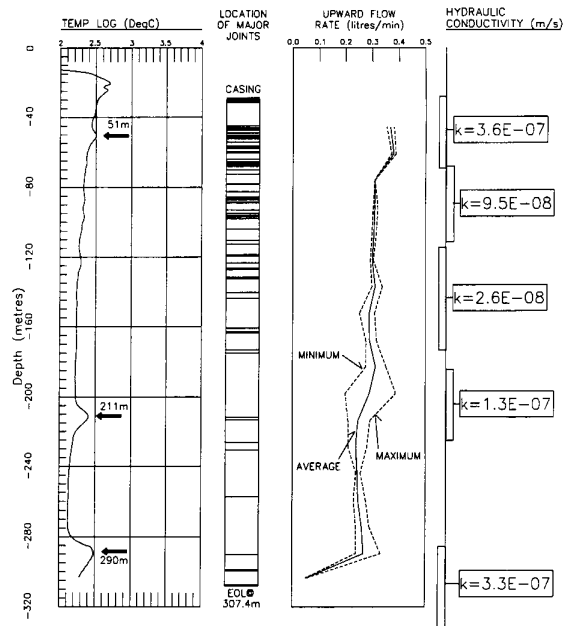


Figure 4: Example borehole geophysical log

Resistivity/temperature logging: This geophysical technique also utilizes a down-the-hole probe that measures both water temperature and fluid resistivity. Changes in water temperature along the borehole are signs of natural seepage or diffusion of groundwater into the hole. No flow is induced in the hole for this test in order to prevent mixing of water and the smearing of temperature signatures. The geophysical probe is lowered down the hole at a constant rate of about three metres per minute with a reading automatically taken every 3-cm. Due to the low Total Dissolved Solids (TDS) in the lake water and groundwater at the site, resistivity values were too low to be measured and therefore did not provide any useful information. Temperature readings generally measured borehole fluid temperatures of between

2°C to 3°C, with the water bearing zones showing a slight temperature increase, in the range of 0.1°C to 0.5°C. Figure 4 shows a typical plot of a temperature log. Four boreholes were tested with this tool.

Borehole video imaging: This technique utilizes a SeeSnake down-the-hole camera. The self-illuminating camera provided black and white images along hole lengths in the range of 300 metres. After a 3 to 6 hour hole flushing period, the camera was lowered down the hole at a rate of about three metres per minute. Elapsed time and depth along hole are tracked with a pulley wheel equipped with an encoder and are displayed on the video image and recorded on videotape. At 300 metres the depth accuracy was usually to within 40 cm and was never off more than 70 cm. Five holes were examined with the camera. The goal of the video imaging was to examine water bearing zones identified by the packer tests and temperature logs. This was to determine whether the flow was from a highly broken zone or from an area with widely spaced single fractures. The images also helped to compare the in-situ rock mass with geotechnical core logs. It became apparent that in some instances, broken zones in the core appeared in-situ as tight fractures. Conversely several single fractures were encountered with centimeter wide joint apertures, something that would not be determined by examining core.

4 HYDROGEOLOGICAL CHARACTERIZATION

For hydrogeological characterization purposes, the country rock at Diavik was initially considered to consist of two domains, fractured rock zones and weakly fractured rocks, that can be differentiated based on the frequency, spacing and connectivity of the fractures. This differentiation is similar to the approach used by researchers at the Whiteshell Research Area (Stevenson et. al., 1996). A fractured rock zone was defined as a zone with enhanced fracture density and permeability relative to the background, that is spatially continuous over the scale of hundreds of metres or more. These zones are significant hydrogeological features that are important to groundwater flow because of their size, hydraulic conductivity, and connectivity. A zone of broken rock that is not significantly permeable due to sealing or a limited lateral extent would not be classified as a fractured rock zone. Highly permeable single fractures, on an individual basis, are not considered to be significant hydrogeological features, as they are not expected to extend over such large dis-

tances. Weakly fractured rock is defined as a volume of rock that contains relatively infrequent open fractures that are generally poorly connected. Weakly fractured rock is, on average, significantly less permeable than the fractured rock zones. By comparing the drill core logs and core photographs with packer tests and geophysical data, it was readily apparent the some of the highly permeable zones in the rock mass consisted of open, single joints. Broken rock zones identified in the core were not necessarily significantly water bearing. Possibly the broken zones consisted of random joints that happen to be closely spaced rather than being associated with a major fault structure. In fact very few fault zones were ever identified in the drill core or during construction of the bulk sample decline. Major water inflows encountered in the decline were mainly associated with single open joints. Figure 5 is a photo of a 1-cm wide vertical open joint that was encountered in cover drill hole in the decline. This joint was by far the most significant water bearing structure intercepted over the 600-metre decline length and resulted in temporary flooding at the decline face. Grouting eventually sealed off the uncontrolled water flow (grout can be seen in the lower portion of the fracture). Most of the rock domain at Diavik is therefore comprised of weakly fractured rock. Fractured rock zones appear to be rare and widely spaced.



Figure 5: In-situ open fracture

From a hydrogeological modeling perspective, the conclusions from the field investigations confirmed that the most reasonable approach would be to model

the rock mass as a single hydrostratigraphic unit using an average hydraulic conductivity rather than try to interpret distinct major water bearing horizons within the country rock. The next step in the hydrogeological characterization was to determine the average hydraulic conductivity and evaluate spatial trends in the data.

Figure 6 provides a histogram of the hydraulic conductivity (K) data derived from packer tests in the granitic country rock. The data appears to follow a lognormal distribution and range over several orders of magnitude, from 10^{-3} m/s to 10^{-9} m/s, with a mean of 2×10^{-7} m/s. Table 1 provides a summary of the measured hydrogeological parameters in the various stratigraphic units.

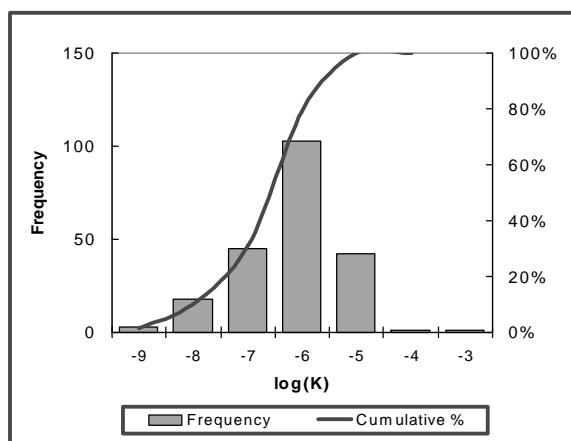


Figure 6: Packer test results

Researchers have shown that at various sites in the Canadian Shield and at other locations worldwide, rock mass permeability decreases with increasing depth. (Davison et al., 1994 a & b; Stevenson et al., 1996 a & b; Ophori et al., 1994 & 1996; Raven et al., 1987; and Burgess, 1979).

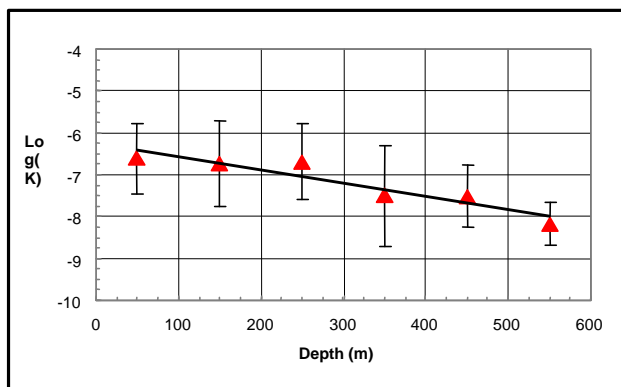


Figure 7: Hydraulic conductivity with depth

In order to assess whether there is a similar depth dependent trend at the Diavik site, average K values were calculated for successive 100 metre vertical in-

Table 1: Hydraulic Conductivity (K) Summary

Hydrogeological Unit	Average Measured K Values	Calibrated K
Lakebed sediments & till	4×10^{-5} m/s	<i>Not modeled</i>
Country Rock	2×10^{-7} m/s	5×10^{-7} m/s
Kimberlite	4×10^{-7} m/s	3×10^{-6} m/s
Diabase Dike	5×10^{-8} m/s	5×10^{-8} m/s

tervals. The results are shown in Figure 7. The error bars show the maximum and minimum values over that interval. A general trend of decreasing K with depth is apparent in the data.

Hydraulic conductivity data in the kimberlite was collected mainly from cover holes in the bulk sample. Packer tests were not completed vertically down the kimberlite pipe due to difficulties with borehole collapse. The average K in the kimberlite was measured at 4×10^{-7} m/s.

In the lakebed overburden soils, the range of K values measured was between 7×10^{-3} and 2×10^{-8} m/s, with an average of 4×10^{-5} m/s. Since the K for the overburden soils was greater than that of the underlying bedrock, it would not be a controlling factor in groundwater recharge. Consequently, for simplification purposes, the overburden layer was excluded from the groundwater model.

Typically in the Canadian Shield, the concentration of Total Dissolved Solids (TDS) in the groundwater increases with depth. As part of the environmental baseline study, water quality sampling was conducted in the upper 350 metres of the rock mass at the Diavik site. Attempts to take deeper water samples were unsuccessful. Consequently the site data was supplemented with water quality samples collected at the Echo Bay Lupin Mine at depths in the range of 800-1300 metres. The Lupin Mine is about 100 kilometres north of the Diavik site. The combined water quality results (TDS) are plotted in Figure 8, which also presents water quality results collected by researchers elsewhere in the Canadian Shield. Two TDS versus depth profiles were developed; ① a profile based on the Canadian Shield data, and ② the Diavik profile based on the local and Lupin data. The Diavik profile estimates that at 500 metres depth the TDS concentration is 1000 mg/L and at 1000 metre depth the TDS concentration would be 6,400 mg/L. At 1600 metres the concentration would be 100,000 mg/L. Since mining operations are only planned to a depth of about 400 metres, a significant amount of groundwater upwell-

ing could introduce quantities of high TDS water into the mine, which could affect the environmental impacts of the operation as well as capacity of the project water treatment plant.

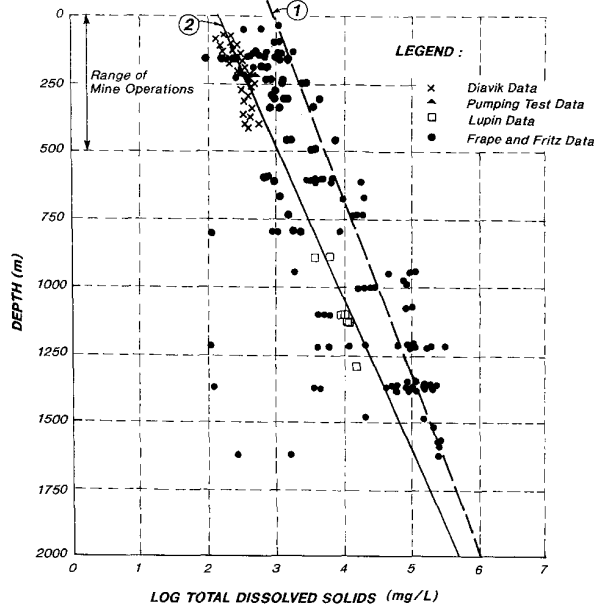


Figure 8: TDS vs. depth profile

5 GROUNDWATER MODELLING

Initially a preliminary modeling study was done to evaluate the type of model that should be used. Due to increasing TDS concentrations with depth it was possible that variable fluid densities could potentially influence the modeling results. A two-dimensional numerical model representing a vertical cross-section through A418 mine was used to compare flow and transport predictions that included variable density with predictions based on constant density. The model was constructed using FEFLOW (Diersch, 1998), which is a finite element code capable of simulating density and viscosity coupled groundwater flow, transport of solutes, and heat flow in three-dimensional porous media under a variety of boundary conditions. Due to the relatively low TDS concentrations and because of the relatively high hydraulic gradients that will be induced by mining, density effects were deemed to be negligible. Consequently the decision was made to use a single fluid density approach.

A detailed three-dimensional flow and transport model was constructed using Visual ModflowTM (Waterloo Hydrogeologic, 1999), which is a graphical pre- and post-processor for MODFLOW and MT3DMS model codes. MODFLOW is a finite dif-

ference code that was developed by the United States Geological Survey (McDonald and Harbaugh, 1988) to simulate transient groundwater in three-dimensional porous medium. MT3DMS is a MODFLOW companion code developed for the United States Environmental Protection Agency ((Zheng and Wang, 1998) which is capable of simulating three-dimensional, transient transport of dissolved chemicals in groundwater, using the grid and hydraulic heads calculated by MODFLOW. Both models assume that changes in the densities of a solute have insignificant effects on groundwater flow and solute transport.

The MODFLOW model grid for the A418/A154 pit area, shown in Figure 9, encompassed an area of 4.8 km by 5.3 km to a depth of about 1500 metres. It consisted of 108 columns, 125 rows, and 26 layers for a total of approximately 350,000 grid blocks. To provide sufficient resolution for model predictions and to ensure the stability of numerical solution, the grid block size is about 30 meters in the vicinity of the mines and increases towards the model boundaries. A separate, similar sized model was created for the A21 pit area.

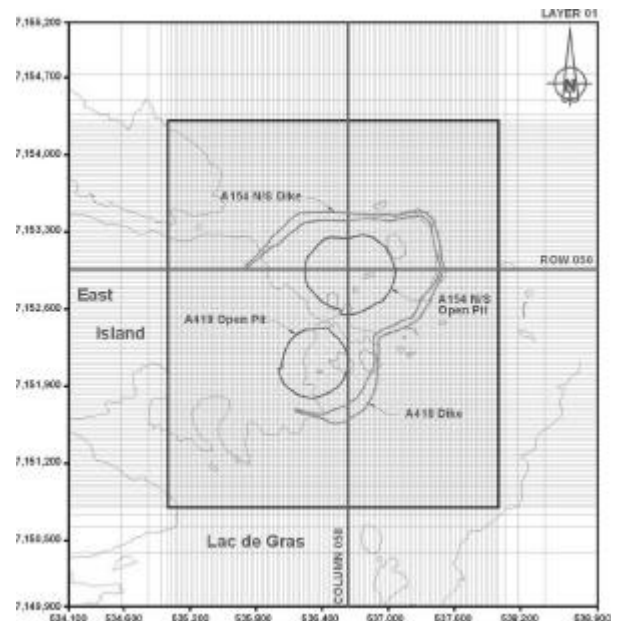


Figure 9: MODFLOW grid layout

Model calibration was completed by comparing actual inflows measured in cover holes drilled ahead of the bulk sample decline with inflows predicted by the model. The model could not be calibrated to the total water inflow recorded in the decline since grouting was regularly used to control inflows. The calibration process resulted in some minor changes to the

initial hydrogeological parameters. Calibrated parameters are summarized in Table 1.

The groundwater model simulated the project development sequence, including construction of the water retention dikes and the staged excavation of the open pits and underground mines. Changes in the extent of mine components were incorporated in the model by automatically adjusting model boundaries every two years during the twenty-year mine life.

The predicted A418/A154 groundwater inflow quantities are shown in Figure 10, illustrating how inflow quantities increase with time as the pits and underground mines are deepened. The plot also shows corresponding TDS concentration in the mine water. Due to the lower permeability at depth, the amount of deep-seated brackish groundwater welling up is relatively minor. The TDS concentrations are averaged over the entire mine, combining lower TDS water from the upper portions of the pit with higher TDS water ingress near the pit bottom. The peak groundwater flows into the A154 and A418 open pit and underground workings is about 9,600 m³/day with an average TDS concentration of 440 mg/L.

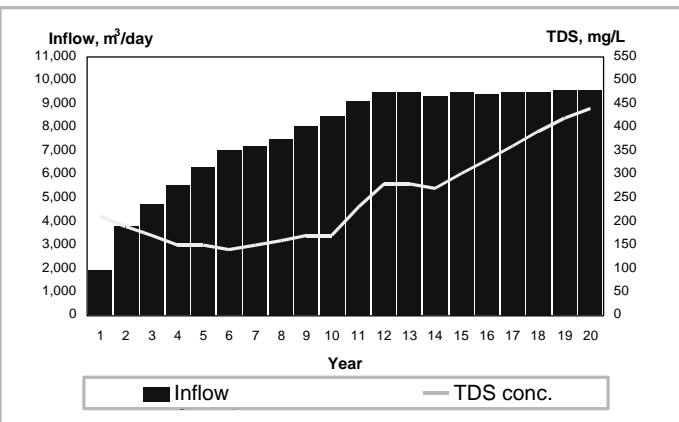


Figure 10: Mine inflow quantity and TDS concentration

Figures 11 and 12 provide MODFLOW cross-sections through the A418/A154 pit areas showing hydraulic head and TDS concentration contours at Year 10 and Year 20 of the mine life.

In order to observe to what extent lake water migrates into the pit, an MT3D model run was done whereby the groundwater TDS concentrations were set to 0 mg/L and the lake water was arbitrarily set to 100 mg/L. By determining the mine inflow water quality with time, one is able to see how the percent lake water reporting to the pit increases with time. Figure 13 shows that the contribution of lake water to

the total mine inflow increases rapidly in the first 5 years, and then levels off at about 85%

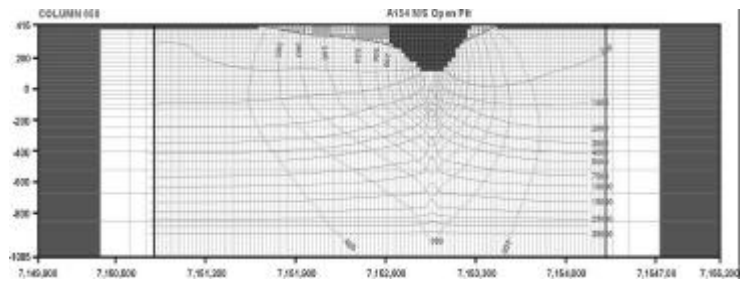


Figure 11: Hydraulic heads at Year 10

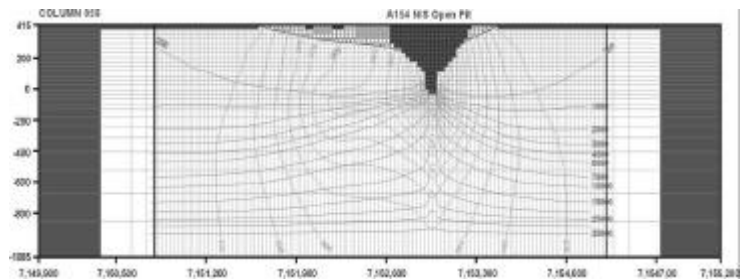


Figure 12: Hydraulic heads at Year 20

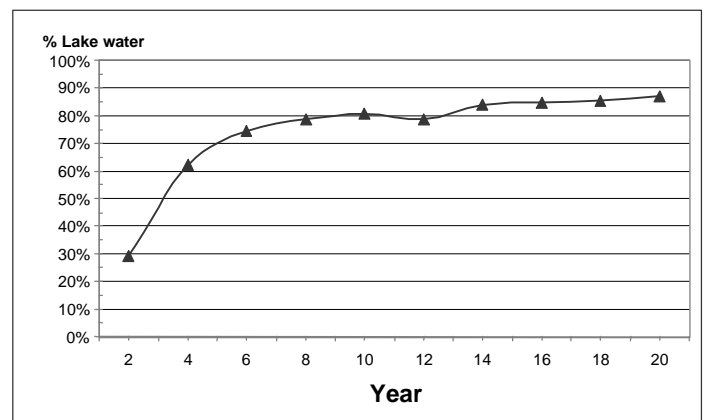


Figure 13: Percent lake water infiltration

6 CONCLUSIONS

Based on the hydrogeological investigations conducted at the Diavik site, it is reasonable to model the large scale rock mass as a single, hydrostratigraphic. A single fluid density approach is also valid even though the groundwater exhibits increasing TDS concentrations with depth.

Borehole temperature logging provides a relatively quick and simple way to assess the frequency and position of potential water bearing zones.

The current plan is to install a few deep Westbay type water sampling wells at site to monitor for upwelling of groundwater from depth. These will provide water quality data long before actually encountering higher TDS water in the mine workings.

The groundwater model will continue to be used as a predictive tool over the operating life of the mine. The hydraulic regime at site will be closely monitored and on-going model calibration will take place.

7 REFERENCES

Burgess, A.A. 1979. Pluton Hydrogeology. Atomic Energy of Canada, Ltd. TR-73.

Davison, C.C., A. Brown, R.A. Everitt, M. Gascoyne, E.T. Kozak, G.S. Lodha, C.D. Martin, N.M. Soonawala, D.R. Stevenson, G.A. Thorne, and S.H. Whitaker. 1994a. The Disposal of Canada's Nuclear Fuel Waste: Site Screening and Site Evaluation Technology. AECL-10713, Whiteshell Laboratories, Pinawa, Manitoba.

Davison, C.C., Chan, T., Brown, A., Gascoyne, M., Kamineni, D.C., Lodha, G.S., Melnyk, T.W., Nakka, B.W., O'Connor, P.A., Ophori, D.U., Scheier, N.W., Soonawalla, N.M., Stanchell, F.W., Stevenson, D.R., Thorne, G.A., Vandergraaf, T.T., Vilks, P., and Whitaker, S.H. 1994b. The Disposal of Canada's Nuclear Fuel Waste: The Geosphere Model for Postclosure Assessment. AECL-10719, Whiteshell Laboratories, Pinawa, Manitoba.

Diersch, H.G. 1998. FEFLOW Interactive, Graphics-Based Finite-Element Simulation System for Modeling Groundwater Flow, Contaminant Mass and Heat Transport Processes. WASY Institute for Water Resources Planning and System Research Ltd., Berlin, Germany.

Frape, S. K. and Fritz, P. 1997. Geochemical trends for groundwaters from the Canadian Shield; in Saline Water and Gases in Crystalline Rocks. Editors: Fritz, P. and Frape, S. K. Geological Association of Canada Special Paper 33, p. 19-38.

McDonald, M.G., and A.W. Harbaugh. 1988. A modular three-dimensional finite difference groundwater flow model. Techniques of Water-Resources Investigations, 06-A1, U.S. Geol. Surv., 528 p.

Stevenson, D.R., A. Brown, C.C. Davison, M. Gascoyne, R.G. McGregor, D.U. Ophori, N.W. Scheier, F.W. Stanchell, G.A. Thorne and D.K. Tomsons. 1996a. A Revised Conceptual Hydrogeologic Model of a Crystalline Rock Environment, Whiteshell Research Area, Southeastern Manitoba, Canada. AECL-11331, Whiteshell Laboratories, Pinawa, Manitoba.

Stevenson, D.R., E.T. Kozak, M. Gascoyne and R.A. Broadfoot. 1996b. Hydrogeologic Characteristics of Domains of Sparsely Fractured Rock in the Granitic Lac du Bonnet Batholith, Southeastern Manitoba, Canada. AECL-11558, Whiteshell Laboratories, Pinawa, Manitoba.

Ophori, D.U. and T.Chan. 1994. Regional Groundwater Flow in the Atikokan Research Area; Simulation of 18O and 3H Distributions. AECL-11083. Manitoba.

Ophori, D.U., Brown, A., Chan, T., Davison, C.C., Gascoyne, M., Scheier, N.W., Stanchell, F.W., and Stevenson, D.R., 1996. Revised Model of Regional Groundwater Flow in the Whiteshell Research Area. AECL Whiteshell Laboratories, Pinawa, Manitoba.

Waterloo Hydrogeologic Inc. 1999. Users Manual for Visual MODFLOW v. 2.8.1 – The Fully Integrated, Three-Dimensional, Graphical Modeling Environment for Professional Groundwater Flow and Contaminant Transport Modeling. Waterloo Hydrogeologic Inc., Waterloo, ON.

Zheng, C. and P.P. Wang. 1998. MT3DMS, a Modular Three-Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion and Chemical Reactions of Contaminants in Groundwater Systems, Documentation and User's Guide. University of Alabama. prepared for U.S. Army Corps of Engineers.

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

Information Request Number: AANDC_19

Source: Aboriginal Affairs and Northern Development Canada (AANDC)

Subject: Water Quality

EIS Section: Section 11.6: SON: Permafrost, Groundwater and Hydrogeology

Terms of Reference Section:

Preamble:

This request deals with the uncertainty in predicted inflows during dewatering operations.

The groundwater model described in Section APPENDIX 11.6.I HYDROGEOLOGICAL MODELS PRE-MINING, DURING MINING AND CLOSURE utilizes specified head boundaries (Layer 1 of the model) to represent all lakes assumed to have open taliks connected to the deep groundwater flow regime. Each of these boundaries was set to the surveyed lake elevation shown in Figure 11.6.I-1. Simulations show drawdown of these water levels during dewatering; however Areas 3 and 5 will remain flooded as part of the WMP. A constant head boundary equal to the operational level of the WMP should have been set as the boundary condition. As the combined surface area of Areas 3 and 5 is substantial and the water level in this pond managed, an endless supply of water to the open pit through the shallow sediments and underlying exfoliated bed rock toward dewater pits will occur. This will result in higher than anticipated inflow rates, and lead to transport of constituents in WMP water deeper into the underlying lake bed.

Further, the sensitivity analysis conducted on the model is not clearly understood with respect to how it demonstrates that the physical parameters in the base case scenario are a reasonable upper bound. Throughout the EIS, the developer states that a conservative estimate of permeability should be applied to the fault zones, lessons learned from operations at Snap Lake and Diavik.

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

Request

1. With the presence of the WMP overlying the open talik during operational phases of the project how much of an increase in inflow would be expected?
2. What is the range of permeability observed at Snap Lake and Diavik for the major faults?
3. What would be the inflow rate to the pits if the maximum observed permeability of faults at Diavik or Snap Lake were realized at Gahcho Kué, and how would DBCMI manage this increase in flow and TDS loadings?

Response

1. The projected groundwater inflows to the mined pits, including the percentage of lake water, to the open pits are presented in Table AANDC 19_1.

The presence of the water management pond is simulated in the numerical hydrogeological model. The extent and the changes in the water levels in the water management pond over time are simulated using specified head boundaries set at the elevation of the water management pond. Therefore, the expected inflow from the water management pond overlying the open talik are taken into account and included in the predictions of groundwater inflow to the pits.

2. The range of permeability observed at Snap Lake and Diavik for the major faults do not apply directly to the Gahcho Kué Project since the relevant parameters to assess the effects of enhanced permeability zones associated with faults on groundwater inflow are the hydraulic conductivity (K) and the width of the zone. These parameters are site-specific and related to the genesis or formation of the individual kimberlite pipe.

At DDMI (Diavik), based on observations of inflows and numerical hydrogeological model calibration, there is an enhanced permeability zone through the A154 Pipes that was initially estimated to be about 90 metres (m) wide (now thought to be about 30 m wide) with an estimated hydraulic conductivity of 3×10^{-5} metres per second (m/s) down to a depth of about 360 m, then 5×10^{-6} m/s and less at greater depths. On the other hand, the enhanced permeability zone through A418 is only about 10 m wide with a K of about 5×10^{-5} m/s down to 360 m and then 5×10^{-6} and less at greater

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

depths and the enhanced permeability zone associated with the A21 is estimated to be about 100 m wide with a K of about 3×10^{-6} m/s down to a depth of about 450 m and then less at a greater depth.

At Snap Lake the kimberlite is within a shallow dipping dyke (kimberlite sheet). It is not a kimberlite pipe and therefore is not considered relevant to the Project.

At the proposed Project site several of the primary structures have been tested and were found to have similar hydraulic conductivity values as the adjacent relatively un-fractured rock. Nevertheless, in the model simulations it was conservatively assumed that an enhanced permeability zone:

- intersects each of the pipes;
 - is aligned along the primary structures identified by geophysics;
 - is 30 m wide; and
 - continuous over long distances with an arithmetic average hydraulic conductivity of 3×10^{-6} m/s (the arithmetic average of tests conducted in three boreholes that may have encountered an enhanced permeable zone near the 5034 pipe) down to a depth of 500 m, then 3×10^{-7} m/s at greater depths in the model domain.
3. As mentioned in Part 2 of this response, permeabilities are site specific and observed conditions at Diavik and Snap Lake are not applicable to the Project. Application of data from these mine sites would provide meaningless results. The groundwater model developed for the Project is based on several conservative assumptions. These include the following:
- a. Drilling and testing of primary structures identified during geophysical surveys.
 - b. Assuming a 30 m wide enhanced permeability zone with a K of 3×10^{-6} m/s, through each of the pipes aligned along these primary structures, even though the testing of the structures found that they appeared to have similar K values to that of the adjacent relatively competent rock.
 - c. Assuming that the K of this enhanced permeability zone is the same to a depth of 500 m and throughout the lateral model domain.

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT INFORMATION REQUEST RESPONSES

In addition to the assumptions applied to potential enhanced permeability zones, the hydraulic conductivity values determined from the hydrogeologic testing at the Project have been increased. All of these conservative assumptions were built into the assessment to provide a high degree of confidence that the effects on groundwater (quantity and quality), and surface water quality as a result of changes to the groundwater, have not been underestimated. Any additional increase in hydraulic conductivity and/or width of the enhanced permeability zone is thought to be unwarranted based on site specific data and these conservative assumptions.

It is important to note that predictive modeling is based on several inputs all of which have inherent variability and uncertainty. As such, it is suggested that groundwater inflow and quality predictions should not be used to predict absolute concentrations, but rather as a planning tool and to develop water quality monitoring plans (Appendix 8.1.5; De Beers 2011). It is anticipated that groundwater inflow rates and Total Dissolved Solids (TDS) loadings will be monitored during operations to compare to Environmental Impact Statement (EIS) predictions. If it is identified that the inflow rates or TDS concentrations are worse than predictions, adaptive management strategies will be triggered.

References

- De Beers. 2011. *Environmental Impact Statement for the Gahcho Kué Project*. Volumes 3a Revision 2, 3b Revision 2, 4 Revision 2, and 5 Revision 2. Submitted to the Mackenzie Valley Environmental Impact Review Board in Response to the Environmental Impact Statement Conformity Review. July 2011.

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

Table AANDC 19_1. Predicted Open Pit Groundwater Inflows

Mine Year	Predicted Inflow (m ³ /d)			Percent Contribution from Area 3/5			Percent Contribution from Area 4			Percent Contribution from Area 7		
				From Area 3/5			From Area 4			From Area 7		
	5034	Hearne	Tuzo	5034	Hearne	Tuzo	5034	Hearne	Tuzo	5034	Hearne	Tuzo
-1	2100	0	0	0	-	-	59	-	-	8	-	-
1	2300	0	0	1	-	-	22	-	-	6	-	-
2	2100	0	0	3	-	-	12	-	-	9	-	-
3	2400	0	0	8	-	-	9	-	-	15	-	-
4	2600	400	0	12	2	-	8	64	-	19	17	-
5	2500	800	600	15	11	0	6	22	57	24	10	16
6	2200	1200	800	21	26	4	4	2	24	28	6	10
7	1200	1400	1100	27	38	12	9	1	15	34	3	6
8	1400	700	1800	28	66	20	5	2	6	36	2	4
9	1400	300	2100	29	87	29	3	0	4	40	2	2
10	1400	100	2200	31	90	35	2	0	3	41	0	2
11	1400	50	2400	31	90	39	2	0	3	42	0	1

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

Information Request Number: AANDC_20

Source: Aboriginal Affairs and Northern Development Canada (AANDC)

Subject: Water Quality

EIS Section: Section 11.6: SON: Permafrost, Groundwater and Hydrogeology

Terms of Reference Section:

Preamble:

This request deals with the uncertainty in predicted inflows during dewatering operations.

DBCMI developed a three-dimensional groundwater flow model of the site using MODFLOW and a solute transport model using MT3D. Calibration results of the model were not provided in the write up (Section 11.6 Subject of Note: Permafrost, Groundwater and Hydrogeology, specifically Appendix 11.6.I Hydrogeological models pre-mining, during mining and closure).

Furthermore, sensitivity analyses conducted on the model does not include an evaluation of enhanced permeability. The authors conclude that the base case scenario provides a reasonable upper bound of mass loading to the pits over the mine life. Throughout the EIS, the developer states that a conservative estimate of permeability should be applied to the fault zones, lessons learned from operations at Snap Lake and Diavik.

Request

1. Provide calibration results and supporting discussion.
2. Run simulations on a calibrated model that includes best, worst and likely scenarios using the range of TDS concentrations in groundwater observed at the site, and using the range of permeability observed for faulting in the regional study area (i.e., values from Diavik and Snap Lake mines).

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

3. The model should also incorporate a constant head boundary condition overlying the WMP.

Response

1. The purpose of the hydrogeological model is to predict the groundwater inflows to each of the pits and provide an estimate of the inflow TDS concentrations based on the proposed Project Description. As such, no site specific flow data for developed project is available for model calibration.

It is important to note that the groundwater inflows and TDS concentrations to the pits will be monitored during operations. If the concentrations vary from the projections, the site specific information can be used to calibrate and refine the model predictions once sufficient monitoring data is available.

2. Three sensitivity cases are presented in the 2010 EIS (De Beers 2010) that incorporate conservative assumptions, which are considered to adequately bracket the range of conditions that could occur at the Gahcho Kué Project. The sensitivity analyses conducted as part of the hydrogeological study are presented in Section 11.6.1.3.6 of the Subject of Note: Permafrost, Groundwater and Hydrogeology (De Beers 2010), and discussed further in Section 11.6.4.3. They include:
 - Base Case: Enhanced Permeability Zones are present and associated with the geologic faults that intersect the proposed open pits
 - Sensitivity Case 1: The enhanced permeability zones were removed from the model and all other parameters including the TDS/depth profile, remained the same as the Base Case.
 - Sensitivity Case 2: The enhance permeability zones were removed but a conservative TDS/depth profile, where TDS concentrations were doubled compared to the base case were used.

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

As mentioned in the response to AANDC_19, permeabilities are site specific and observed conditions at Diavik and Snap Lake are not applicable to the Project. However, it is recognized that predictive modeling is based on several inputs all of which have inherent variability and uncertainty. It is suggested that groundwater inflow and quality predictions should not be used to predict absolute concentrations, but rather as a planning tool and to develop monitoring plans (Appendix 8.1.5; De Beers 2011).

It is anticipated that groundwater inflow rates and TDS loadings will be monitored during operations to compare to EIS predictions. If it is identified that the inflow rates or TDS concentrations are higher than predicted, adaptive management strategies will be triggered.

3. The head boundary in the water management pond was considered as part of the EIS assessment. As presented in Section 11.6.1.3.4 of the 2010 EIS (De Beers 2010), specified head boundaries were applied to represent all lakes assumed to have open taliks connected to the deep groundwater flow regime. This includes the water management pond.

Based on these head boundaries, the proportion of lake water entering the open pits is projected. In the water quality assessment in the 2011 EIS Update (De Beers 2011), it was assumed that all of the lake water flowing to the open pits originated from the water management pond. These projections have been refined to evaluate the percentage of lake water originating from all standing water bodies in the controlled area. These results are provided in Table AANDC 20_1. Updated site water quality modelling results based on these predictions are presented in the 2012 EIS Supplement (De Beers 2012).

References

- De Beers (De Beers Canada Inc.). 2010. *Environmental Impact Statement for the Gahcho Kué Project. Volumes 1, 2, 3a, 3b, 4, 5, 6a, 6b, 7 and Annexes A through N*. Submitted to Mackenzie Valley Environmental Impact Review Board. December 2010.

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

De Beers. 2011. *Environmental Impact Statement for the Gahcho Kué Project. Volumes 3a Revision 2, 3b Revision 2, 4 Revision 2, and 5 Revision 2.* Submitted to the Mackenzie Valley Environmental Impact Review Board in Response to the Environmental Impact Statement Conformity Review. July 2011.

De Beers. 2012. *Environmental Impact Statement Supplemental Information Submission for the Gahcho Kué Project.* Submitted to the Mackenzie Valley Environmental Impact Review Board. April 2012.

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

Table AANDC 20_1. Predicted Open Pit Groundwater Inflows

Mine Year	Predicted Inflow (m ³ /d)			Percent Contribution from Area 3/5			Percent Contribution from Area 4			Percent Contribution from Area 7		
				From Area 3/5			From Area 4			From Area 7		
	5034	Hearne	Tuzo	5034	Hearne	Tuzo	5034	Hearne	Tuzo	5034	Hearne	Tuzo
-1	2100	0	0	0	-	-	59	-	-	8	-	-
1	2300	0	0	1	-	-	22	-	-	6	-	-
2	2100	0	0	3	-	-	12	-	-	9	-	-
3	2400	0	0	8	-	-	9	-	-	15	-	-
4	2600	400	0	12	2	-	8	64	-	19	17	-
5	2500	800	600	15	11	0	6	22	57	24	10	16
6	2200	1200	800	21	26	4	4	2	24	28	6	10
7	1200	1400	1100	27	38	12	9	1	15	34	3	6
8	1400	700	1800	28	66	20	5	2	6	36	2	4
9	1400	300	2100	29	87	29	3	0	4	40	2	2
10	1400	100	2200	31	90	35	2	0	3	41	0	2
11	1400	50	2400	31	90	39	2	0	3	42	0	1

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

Information Request Number: AANDC_21

Source: Aboriginal Affairs and Northern Development Canada (AANDC)

Subject: Water Quality – Taliks

EIS Section: EIS and Conformity Responses

Terms of Reference Section:

Preamble:

The open pits (TDS during dewatering), WMP, the fine PK and the western edge of the coarse PK of the pile will be situated over the talik and in contact with water and all three are considered point sources of contaminants

Request

1. If groundwater conditions with respect to TDS concentrations have been underestimated how will DCI deal with managing the increase in loadings?
2. How would treatment of TDS take place to meet discharge objectives?
3. If discharge criteria (with respect to TDS) are not achieved and discharge to Lake N11 is not permitted how will DBCMI manage water on site?
4. With respect to the presence of the WMP lying over an open talik:
 - a) How will the water quality of the WMP vary during operations and at closure?
 - b) With the WMP being situated over a talik in connection with an active dewatering system during operations, what will be the predicted short term and long term concentrations in lake bed sediments and the underlying exfoliated bedrock, and what would be the potential impacts to benthic community and water column quality?
5. Permafrost establishment within 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, particularly Area 2 because a portion of this area is located on the lake bed, under which a talik existed. If this pile is not covered and

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

rinsing of the material occurs then metal leaching from this pile could be an issue. Please provide the following information related to this issue:

- a) Will there be a loading to the underlying groundwater system?
 - b) If so can you predict the magnitude of the impact to groundwater quality and potentially down gradient receptors (groundwater discharge sites)?
6. 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. This scenario could act as a source for metal leaching. Please provide the following information related to this scenario:
- a) As with the fine PK scenario will there be a loading to the underlying groundwater system or Kennady Lake considering the western edge will lie over an open talik?
 - b) If so can you predict the magnitude of the impact to groundwater quality and potentially down gradient receptors (groundwater discharge sites)?

Response

1. *If groundwater conditions with respect to TDS concentrations have been underestimated how will DCI deal with managing the increase in loadings?*

Results of groundwater quality monitoring and conservative modelling assumptions were used to estimate the composition of groundwater that could flow into the open pits during operations. A summary of the groundwater quality assessment is presented in Section 11.6 of the EIS (De Beers 2010), and a description of the integration of the modelled groundwater chemistry into the water quality modelling of Kennady Lake is provided in Appendix 8.II, Section 8 of the 2011 EIS Update (De Beers 2011). Depth profiles were developed to evaluate the variability of groundwater composition with depth. Total dissolved solids (TDS) are known to vary with depth, and regression analysis was used to derive concentrations for parameters which correlated with TDS. Non-correlated

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

parameters were set equal to the 75th percentile concentration measured in samples from each pit.

Since the submission of the 2011 EIS Update, water quality modelling has been updated based on supplemental mitigation associated with the deposition of fine PK and updated geochemistry testing data. Based on the updated water quality projections for the water management pond (De Beers 2012), it is expected that TDS loadings from groundwater will not result in concentrations that would prohibit discharge from the water management pond during the dewatering and early operational periods.

However, it is anticipated that water quality in locations within the controlled area (e.g., the water management pond) will be monitored during operations, and, if required, adaptive management strategies can be developed and triggered should an increase in groundwater loadings beyond predictions be reported.

For example, flexibility exists in the water management plan to store additional water in Kennady Lake. At the end of operations, this water can be directed to the bottom of the Tuzo pit. This would improve the long-term water quality in Kennady Lake since higher TDS concentrations could increase the stability of meromixis in the pit isolating additional TDS mass from mixing with the overlying water.

2. How would treatment of TDS take place to meet discharge objectives?

Current water quality modelling indicates that water quality in Kennady Lake will be suitable for discharge according to the proposed water management plan presented in Section 3 of the 2012 EIS Supplement (De Beers 2012). Water quality modelling projections, based on no treatment of TDS, indicate that residual effects to aquatic communities are predicted to be negligible in Kennady Lake following closure and in downstream watersheds throughout the life of mine and into post-closure. As a result TDS water quality treatment is not required. Water quality will be monitored during operations, and, if required, adaptive management strategies can be developed and implemented.

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

3. *If discharge criteria (with respect to TDS) are not achieved and discharge to Lake N11 is not permitted how will DBCMI manage water on site?*

De Beers will be monitoring the water quality throughout the project operations. If the water quality during the dewatering or planned operational dewatering phases of the Project becomes unsuitable for discharge, adaptive water management strategies will be triggered. This may include storing additional water in Kennady Lake until closure, until the Tuzo pit becomes available for water storage.

4. *With respect to the presence of the WMP lying over an open talik:*

- a) *How will the water quality of the WMP vary during operations and at closure?*

Water quality results simulated for the water management pond during operations and at closure are provided in the 2012 EIS Supplement (De Beers 2012) and in Figures AANDC-21_1 and AANDC-21_2.

- b) *With the WMP being situated over a talik in connection with an active dewatering system during operations, what will be the predicted short term and long term concentrations in lake bed sediments and the underlying exfoliated bedrock, and what would be the potential impacts to benthic community and water column quality?*

Changes to sediment quality in the water management pond (i.e., Areas 3 and 5) were not modelled. The 2010 EIS (De Beers 2010) does not assess the conditions in the water management pond, as this area is not considered to have water quality conditions suitable for fish during operations. In fact, these areas would be a component of the controlled area, which represents the isolated region of Kennady Lake from which the Project operations will be conducted. As per Section 8.10.3.2 of the 2010 EIS, although Areas 2 to 5 will only be partially dewatered, conditions in these areas will not be suitable to support a fish community. Fish will also be removed during the fish salvage, and will not be

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

present during mine operations. As a result, the potential effects on fish and fish habitat in the isolated and partially dewatered areas of Kennady Lake were not included in the EIS.

However, the simulated water quality in Kennady Lake in post-closure was used to assess the potential for effects to aquatic life, including benthic and pelagic invertebrates in Section 8.9 in the 2012 EIS Supplement (De Beers 2012). Based on maximum predicted concentrations, the potential for toxicity due to the predicted increase in TDS and its constituent ions was considered to be low, and residual effects to aquatic communities were expected to be negligible.

5. *Permafrost establishment within 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, particularly Area 2 because a portion of this area is located on the lake bed, under which a talik existed. If this pile is not covered and rinsing of the material occurs then metal leaching from this pile could be an issue. Please provide the following information related to this issue:*

a) *Will there be a loading to the underlying groundwater system?*

b) *If so can you predict the magnitude of the impact to groundwater quality and potentially down gradient receptors (groundwater discharge sites)?*

The fine PK facility will be covered by at least two metre of coarse PK and Mine Rock. Seepage modeling of the Fine PKC Facility (EBA 2012) indicates seepage from the facility will drain into Kennady Lake. The permeability of the surface cover of this facility and its grading will promote precipitation as runoff towards the open water of Area 2 through Dyke L, rather than into the underlying groundwater system.

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 will

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

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 the EIS assessment. However, as the assessment of impacts to the suitability of the water quality to support aquatic life includes time periods that extend into the long-term (i.e., 200 years), the assessment was designed to represent potential future climatic conditions where there would be no permafrost.

6. *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. This scenario could act as a source for metal leaching. Please provide the following information related to this scenario:*

a) *As with the fine PK scenario will there be a loading to the underlying groundwater system or Kennady Lake considering the western edge will lie over an open talik?*

b) *If so can you predict the magnitude of the impact to groundwater quality and potentially down gradient receptors (groundwater discharge sites)?*

Based on the design of the Coarse PK Pile, loading from the facility is expected to enter Kennady Lake and not the underlying groundwater system. The final surface area of the Coarse PK Pile, which will possess a mine rock cover, will be graded to promote precipitation as runoff, rather than seepage penetrating into the piles. Additionally, the placement of both the Coarse PK Pile adjacent to Kennady Lake will promote a seepage gradient towards the lake, rather than into the underlying taliks. Therefore, significant seepage from this pile, or the mine rock piles, that could result in changes to groundwater quality is not expected. As stated in Section 11.6 of the 2010 EIS (De Beers 2010):

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

“Seepage rates into the underlying groundwater system are expected to be small, with no measureable effect beyond the boundaries of the facilities themselves.”

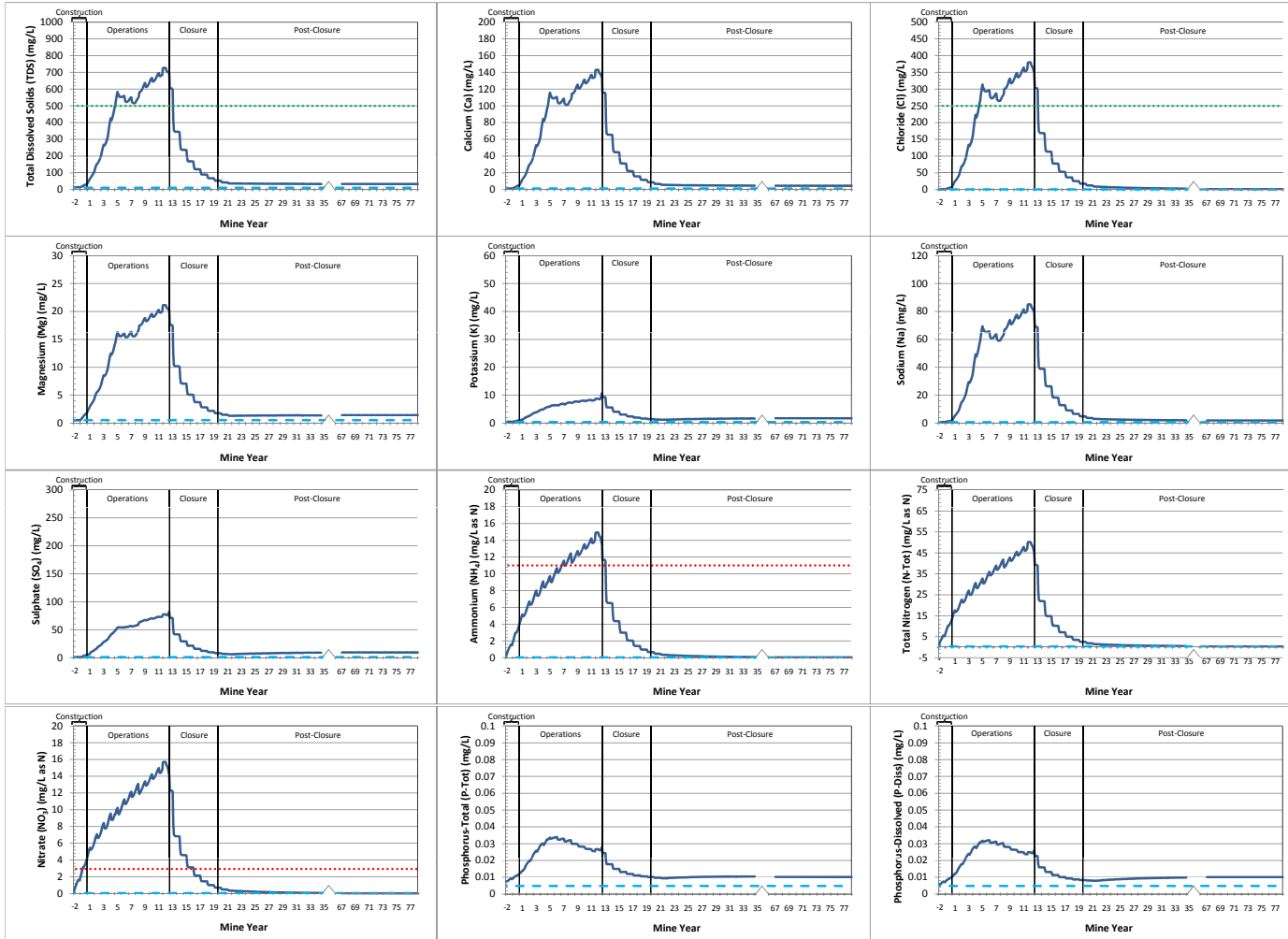
In addition, permafrost conditions are expected to develop rapidly within the Coarse PK Pile, with an active freeze thaw layer of about 8 m (Section 11.6 of the 2010 EIS). Material below this 8 m is expected to be permanently frozen, preventing penetration to the underlying taliks. Loadings from the Coarse PK Facility were accounted for in the Kennady Lake water quality evaluation. The simulated results are presented in Section 8.8 of the 2012 EIS Update (De Beers 2012).

References

- De Beers (De Beers Canada Inc.). 2010. *Environmental Impact Statement for the Gahcho Kué Project. Volumes 1, 2, 3a, 3b, 4, 5, 6a, 6b, 7 and Annexes A through N.* Submitted to Mackenzie Valley Environmental Impact Review Board. December 2010.
- De Beers. 2011. *Environmental Impact Statement for the Gahcho Kué Project. Volumes 3a Revision 2, 3b Revision 2, 4 Revision 2, and 5 Revision 2.* Submitted to the Mackenzie Valley Environmental Impact Review Board in Response to the Environmental Impact Statement Conformity Review. July 2011.
- De Beers. 2012. *Environmental Impact Statement Supplemental Information Submission for the Gahcho Kué Project.* Submitted to the Mackenzie Valley Environmental Impact Review Board. April 2012.
- EBA. 2012. Seepage Analysis for Fine PK in Area 2 (Updated Fine PK Management Plan – Option 2) Gahcho Kué Diamond Project. EBA File: E14101143.

Figure AANDC-21-1: Nutrient and anion concentrations in the Water Management Pond (Areas 3 and 5)

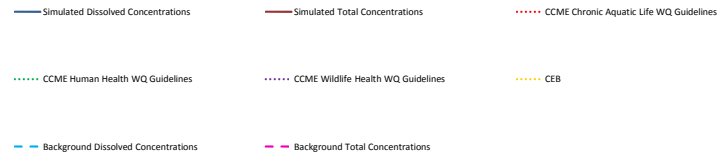
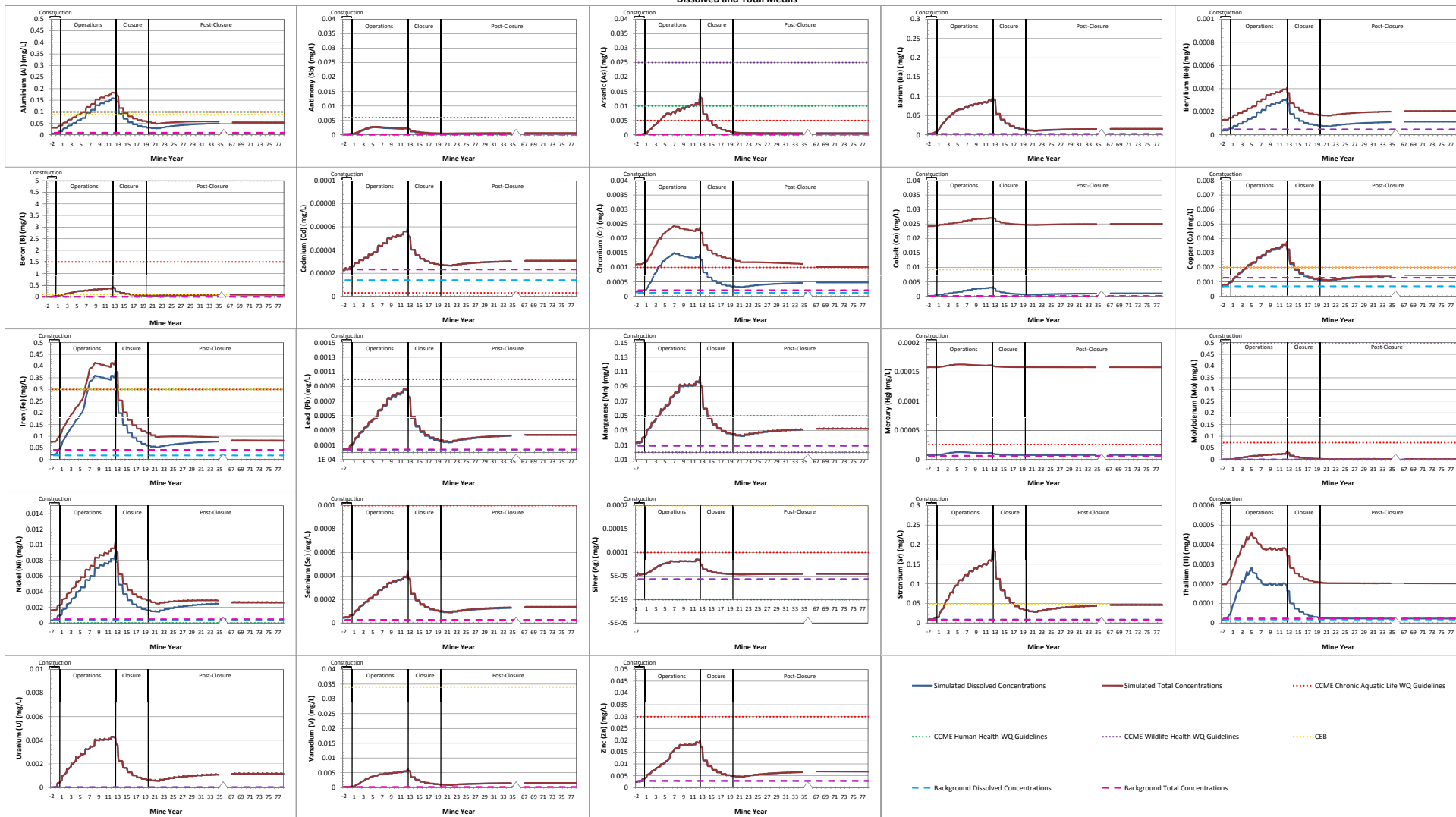
Nutrients and Anions



— Simulated Concentrations - - - - CCME Chronic Aquatic Life WQ Guidelines - · - · - CCME Human Health WQ Guidelines - · - · - CCME Wildlife Health WQ Guidelines - - - - Background Concentrations

Note: mg/L as N = milligrams per litre as Nitrogen

Dissolved and Total Metals



GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

Information Request Number: AANDC_22

Source: Aboriginal Affairs and Northern Development Canada (AANDC)

Subject: Adequacy of Permafrost Baseline Information

EIS Section: Section 11.6: SON: Permafrost, Groundwater and Hydrogeology,
Annex D.

Terms of Reference Section:

Preamble:

One of the stated objectives of the baseline program was “... to describe nearsurface permafrost conditions as part of the terrain survey ...” (De Beers 2010c, pg. D1-2) “Permafrost investigations ... were carried out ... in 2004 and 2005. The objective ... was to obtain and provide baseline permafrost data for the design and operation of the Project facilities, and for predicting effects from the project.” (De Beers 2010c, pg. D7-1,) However, the thermistors installed in the winter of 2004 were only read between April and August 2004, between 1 and 6 times (De Beers 2010c, Appendices D.II, D.III and D.IV). The monitoring period is far short of that needed to interpret the baseline ground thermal regime. Indeed, the data reported indicate ongoing stabilization of ground temperatures in response to drilling disturbance.

Attempts to probe the active layer thickness were hampered by the coarse soil texture, with success limited to areas of organic soil (De Beers 2010c, pg. D7-17).

Further, “Due to the absence of actual data on the mean annual soil temperatures for the majority of the identified terrain units, this important permafrost parameter was calculated ...” (De Beers 2010c, pg. D7-10, Tables D7.3-2 and D7.3-3)

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

The Proponent concludes: *“Results suggest that the calculated mean annual permafrost temperatures are generally in close agreement with the measured mean annual permafrost temperatures in moraine blanket and organic veneer. This suggests also that the input parameters for calculating mean annual permafrost temperatures correspond to actual climate and vegetation conditions within the study area.”* (De Beers 2010c, pg. D7-27; also EBA 2011b, pg. 6)

AANDC considers the reported permafrost data are minimal. If the field data are sparse and potentially not in equilibrium, then the confidence in any assumptions made using this data base is low.

Request

1. Please describe and evaluate the risks to the project assumptions due to using calculated data and data collected over a short monitoring period.
2. Please provide an evaluation of additional data sources that could be used to supplement the existing ground thermal regime database
3. Please describe any uncertainties in the geothermal modelling outputs resulting from use of the existing ground thermal regime database.

Response

1. The geothermal data obtained and used in the 2010 EIS (Annex G; De Beers 2010) provides a baseline for the Project area and generally confirms the expected permafrost conditions in the Project area.

The Project design in general does not rely on permafrost performance, with the exception of specific engineered structures (e.g dykes), which will be the subject of site specific field investigations prior to detailed design and construction. Please refer to Appendix AANDC_15-1 for more details on the inputs used for the thermal analysis.

Areas of deep sediments and fractured and weathered rock zones are limited within the Project area, and the current thermal condition of the permafrost in the area is not expected to change significantly, if at all. The existing ground

GAHCHO KUÉ PROJECT ENVIRONMENTAL IMPACT STATEMENT
INFORMATION REQUEST RESPONSES

temperature data provides the necessary information for hydrologic studies since the specific geometry of the permafrost masses is likely not as significant as it could be if the site were underlain by deep saturated sediments. Permafrost is essentially an impermeable mass within another mass of very low permeability in this Project area. Low ground permeability would limit the groundwater flow velocities and thus limit the permafrost deterioration as a result of convective heat removal due to flowing water or air.

2. In combination with the geothermal data that has been collected to date, and the data that will be collected as part of the site specific investigations that will form part of the final design phase, the thermal aspects of the Project are considered to be well defined for the Project requirements.
3. De Beers will provide a technical memorandum that describes the risks and uncertainties pertaining to the geothermal regime based on the available data.

References

De Beers (De Beers Canada Inc.). 2010. Environmental Impact Statement for the Gahcho Kué Project. Volumes 1, 2, 3a, 3b, 4, 5, 6a, 6b, 7 and Annexes A through N. Submitted to Mackenzie Valley Environmental Impact Review Board. December 2010.