FRACTURE ZONE CHARACTERIZATION AND HYDROGEOLOGICAL TEST WORK PLAN FOR THE A418 PIT AREA

Version # 1
Date: November 11, 2004
1.0 INTRODUCTION

This work plan has been prepared according to the requirements of the Water License for the Diavik Diamonds Project in NWT. The plan described in this document presents a work plan for collection of hydrogeological data in the A418 open pit area with focus on detailed characterization of the fractured rock zone identified in the project area, in support of the pit engineering design.

The work plan is based on a similar document that was developed by the Diavik Diamond Mines Inc. in 2001 for fracture zone characterization and hydrogeological testwork throughout the entire depth of proposed mine workings in the A154 pit area.

Because the proposed A418 open pit is located only about 900 m SW from the existing A154 pit, it can be expected that the groundwater conditions in that area will be similar to those encountered around the A154 open pit. Therefore, it is likely that the groundwater inflows into the proposed A418 open pit and underground mine workings will be controlled by the structural and tectonic discontinuities within the generally massive granitic rock. In order to properly evaluate the potential groundwater inflows it is necessary to determine the character of these features such as spacing, frequency, orientation, apertures, infill, length, and the hydraulic connectivity of the fracture network.

2.0 BACKGROUND

The background information presented below was summarized in the 2001 document.

Over the period of 1997 to 1999, Diavik completed several extensive geotechnical and hydrogeological drilling investigations of the rock mass in the A154 and A418 pit areas. A database consisting of in excess of 800 packer tests from over 9000 meters of drilling has been compiled. The deepest packer test was completed at a depth of 600 meters, or about 200 meters beneath the expected depth of underground mining. In addition, a limited program of borehole camera and flowmeter testing was undertaken in a few of the holes to help characterize the hydrogeology of the rock mass. Geotechnical mapping completed in the bulk sample decline and data derived from geotechnical core holes were used to characterize the nature of the fracturing in the rock mass.

Findings from the investigation programs indicated that the majority of the rock mass within the study area is relatively uniformly fractured with only occasional intervals of closely spaced discontinuities (highly broken intervals) in the core. If these fractured
rock zones are continuous and hydraulically connected over distances of hundreds of meters (i.e., hydrogeologically significant), they can potentially act as conduits for groundwater inflow, allowing higher localized inflow rates than the rest of the uniformly fractured rock mass. However, results of the in-situ hydraulic testing indicates that not all of the apparent “fractured rock zones” seen in the core are hydrogeologically significant. Most of them were found to be somewhat localized zones surrounded by the tighter rock. The test results were used to calculate a “bulk” hydraulic conductivity of the rock mass used in the hydrogeologic model of the project site developed to estimate pit inflows. The groundwater model was also used to determine the potential inflows into the proposed pits should the fractured zones hydraulically connected over large distances be present within the study area.

An additional program was designed in 2003 to further characterize the fractured rock zone identified in the area of the A154 pit because the data obtained from previous testing of individual drill holes did not allow an accurate determination of hydraulic inter-connectivity of these zones on a large scale, or how far they extend laterally or vertically in the rock mass. The program consisted of additional in-situ hydraulic testing, monitoring of total pit inflows, and mapping of the discontinuities exposed in the pit walls. The program was carried out over the period from October 2003 to August 2004, and the results, including groundwater chemistry, were used to calibrate the existing groundwater model for the A154 pit area.

3.0 DETAILED A418 GROUNDWATER CHARACTERIZATION PROGRAM

The new detailed groundwater characterization program is designed to provide further information on the fractured rock zone identified in the A418 area to allow accurate evaluation of the expected groundwater inflows into the proposed open pit and underground workings. Generally the program is based on the detailed work plan carried out in the area of the A154 pit, but also includes recommendations based on the deficiencies identified during the evaluation of the data obtained from that program.

Details of the individual tasks of the work plan are described below:

3.1 Groundwater Level Monitoring

One of the important issues identified during the A154 pit development was the ability to monitor any changes in groundwater levels across the project site as the mining works are being developed.

Due to well developed permafrost underneath even the small islands, the conventional standpipe piezometers do not provide the option for the required coverage across the site.
Vibrating wire piezometers were successfully used during the previous investigations and they will be incorporated in any of the drilling programs planned for the A418 area. It is important that some of the vibrating wire piezometers are installed in the area of the fractured rock zone.

3.2 Permafrost

Permafrost delineation has been conducted as part of the previous investigations across the project site. These investigations have concluded that the permafrost in the area of the A418 extends out into the lake to greater degrees than it did near the A154 pit. This has been attributed to the presence of an island located east of the A418 Pipe. However, it is important to confirm if the A418 open pit does extend past the frozen portion of the fractured rock zone thereby providing highly permeable pathway for flow of water from the lake to the pit. Also, it has to be determined if the existing permafrost in the fractured rock zone will melt during the pit excavation creating a permeable pathway for flow of water from the lake to the pit/underground workings. To obtain these data, thermistor strings will be installed in selected boreholes along the vibrating wire piezometers.

3.3 In-Situ Hydraulic Testing

A small number of in-situ hydraulic conductivity tests have been conducted in the proposed area of the A418 Pit. In order to confirm the bulk hydraulic conductivity values used in the groundwater model developed for the A418 area, additional hydraulic conductivity testing will be conducted as part of any delineation or geotechnical drilling investigations proposed for the study area.

As mining progresses, fractured rock zones identified within the project area will be assessed, and further characterization will be conducted as required. The characterization may include:

- Drilling of dedicated boreholes to examine the permeability of the fractured rock zone at all mining elevations.

- Use of an optical televiewer and heat flowmeter to identify specific zones that will be targeted for hydraulic conductivity testing.

- Geotechnical logging of the core to provide information on the conditions of the intercepted fractures.

- Packer testing of the selected intervals within each borehole.
This testing must be conducted in an area of the fractured rock zone that is not presently frozen.

If mitigation measures, such as horizontal drains are utilized during the development of the A418 open pit or underground mine workings, in-situ tests may be conducted to determine the hydraulic conductivity of the rock mass within the area being drained. Water inflow rates collected with these measures will also be monitored and recorded. When combined with responses seen in other nearby drains these response data will help assess the inter-connectivity of the fractured rock zones. Drilling done for horizontal drain installations will assist somewhat in defining the orientation and lateral extent of the fractured rock zones.

### 3.4 Groundwater Sampling

Groundwater chemistry data were part of the new information used for re-calibration of the original groundwater model developed for the A154 pit area. If required, a similar groundwater sampling and testing program shall be undertaken in the A418 Pit. The groundwater sampling program would be conducted in conjunction with any detailed hydraulic conductivity testing carried out in the area of the fractured rock zone.

### 3.5 Rock Face Mapping

As part of the geotechnical pit wall design process, an on-going program of rock face mapping will be undertaken throughout the life of the A418 pit. In the early stages of mining, this data will be used to verify assumptions used in pit slope design and can be used to predict rock mass conditions at greater depths. Specifically, the rock face mapping will provide statistical information on fracture and joint set orientations, and will highlight which joint sets tend to have larger apertures and greater continuity. Visual mapping of the pit walls will also indicate which joint sets tend to yield groundwater flows and which ones will likely to be tight.

Groundwater inflows from fractured rock zones or any other large-scale structural features that are identified along the pit walls will be estimated over time to assess sustained inflow rates and evaluate hydraulic connectivity of these features. They will be mapped in detail and plotted on geological pit plans. This will enable the geologists to interpret and predict their locations in advance of future mining activity. If the fractured rock zone is a significant water-bearing feature, then the geological interpretations will help determine the optimum type of mitigation to be implemented. Groundwater inflows from these features can be controlled using methods such as; horizontal drains, vertical pumping wells, or by grouting.
Rock face mapping will be done using either cell mapping or line mapping techniques. As each bench is mined, the entire pit perimeter will be visually examined for the presence of large-scale structural features, such as faults or fractured rock zones. A digital camera will be used to photograph the pit and to provide a visual record of significant features. The structural data will be entered into statistical databases that allow joint information to be analyzed by depth and by sector within the pit.

3.6 Monitoring of Total Pit Inflows

Total pit water inflows quantity and quality will be measured and recorded together with pertinent meteorological data. Such data will be reviewed together with the predicted mine inflows and differences between actual and predicted inflows documented.

3.7 Hydrogeological Modeling

The groundwater model that has been developed for the A418 area will be re-calibrated if there are any significant differences identified between the data collected during the new investigations and the modelling assumptions used for the model development that would likely result in an increase in mine inflows from the predicted values. If the field data is within reasonable limits of predicted values (<50%) and fractured rock zones are not present or if inflows through these zones are less than 500 m$^3$/day, then model revisions will not be necessary.

4.0 DISCUSSION

The planned detailed hydrogeological characterization program for the A418 area was prepared in corroboration with the Golder Associates Diavik Project team that has been involved in the hydrogeological site investigations conducted at the project site from the prefeasibility study stage until the recent investigations conducted in the A154 pit area. The program will be considered part of the on-going geological and geotechnical engineering activities. It may be necessary however, to modify the characterization program periodically depending on the findings and the trends seen within the rock mass.