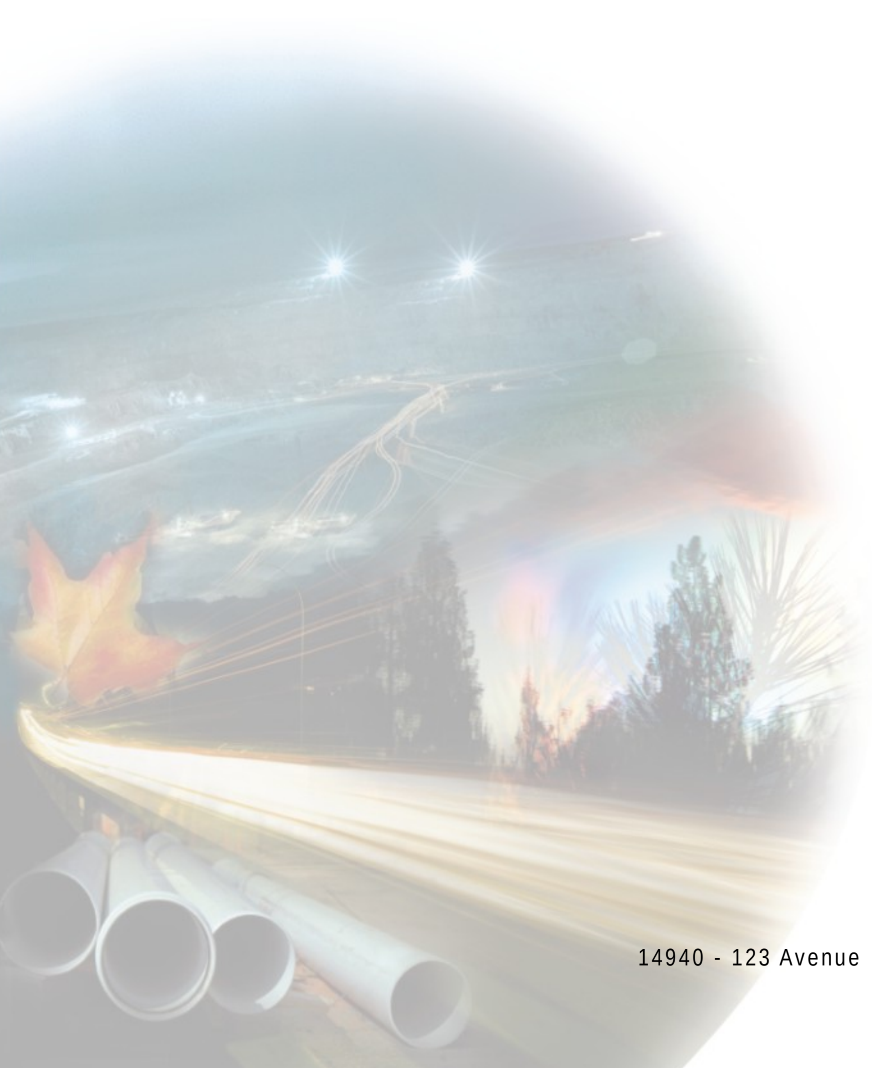
Tahera Diamond Corporation

JERICHO PROJECT
NORTH DAM
DESIGN REPORT

1100060.013

July 2007



EBA Engineering Consultants Ltd.
p. 780.451.2121 • f. 780.454.5688
14940 - 123 Avenue • Edmonton, Alberta T5V 1B4 • CANADA

EXECUTIVE SUMMARY

Tahera Diamond Corporation is operating the Jericho Diamond Mine, Nunavut. The fine processed kimberlite from the mine operation is deposited in the Processed Kimberlite Containment Area, which consists of several perimeter dams and cross-lake divider dykes. The proposed North Dam is one of the perimeter dams that are required based on the mine plan and tailings/water management plan. This report presents the design basis and construction considerations for the North Dam. Reduced-size construction drawings are also presented in this report. Construction specifications are presented in a separate companion document.

The original ground beneath the North Dam consists of 0.8 m to 3.8 m overburden till over granite bedrock. The measured ground temperatures at one borehole drilled in the valley of the North Dam area indicate that permafrost exists with a ground temperature of -2°C to -3°C at a depth of 10 m. Percolation tests conducted during the site investigation suggest that open joints or fractured zones in the bedrock are present beneath the north abutment.

The North Dam has been designed as a zoned rockfill, frozen core dam. It is approximately 10 m high, 103 m long, and will impound up to 5 m of water. A 20 mm minus processed granular material will be used to construct the core. The core is supported by 150 mm minus processed rockfill transition material and run-of-mine rockfill shell material.

An effective frozen core dam requires that the central core and underlying foundation remain frozen year-round to act as an impervious barrier against seepage. A key trench beneath the core will be excavated to ice-saturated soil or competent rock and backfilled with the core material to produce a well-bonded and impermeable mass. A secondary seepage barrier is provided by installing a geosynthetic clay liner against the upstream side of the core and over the critical portion of the key trench. A grout curtain will be installed in the bedrock beneath the key trench to cut off potential seepage paths through open joints or fractures.

The dam geometry and cross-sections have been designed to minimize material costs, protect the integrity of the frozen core, and satisfy thermal, stability, and settlement design criteria.

Thermal analysis results indicate that horizontal thermosyphon loops are required near the base of the core. With the operation of the thermosyphons, the dam will meet the design thermal criteria that the core should be perennially frozen and the temperatures in the critical zone of the core in the key trench should be colder than -2°C.

Stability analysis results indicate that the dam meets the stability requirements according to the Canadian Dam Safety Guidelines.

Thaw-induced settlements and creep-induced deformations are expected to be limited in magnitude and acceptable for the dam performance.

Ground temperature cables will be installed in the key trench backfill and the core to monitor the thermal regime in the dam and also monitor the thermal performance of the horizontal thermosyphons. Survey monitoring points will be installed along the crest of the dam to monitor settlement or horizontal movements of the dam through its service life.

TABLE OF CONTENTS

PAGE

TABLE OF CONTENTS

TABLE OF CONTENTS

PAGE

FIGURES

TABLE OF CONTENTS

APPENDICES

1.0 INTRODUCTION

Tahera Diamond Corporation (Tahera) is operating the Jericho Diamond Mine, Nunavut, located approximately 420 km northeast of Yellowknife. The mine produces crushed kimberlite as a by-product of the diamond extraction process. The crushed kimberlite is separated into "coarse processed kimberlite" (coarse PK) and a fine processed kimberlite (fine PK). The fine PK is deposited in a former lake basin (Long Lake) adjacent to the process plant. The fine PK and supernatant water is contained by the natural topography and low head dams that form the Processed Kimberlite Containment Area (PKCA). The PKCA consists of several perimeter dams and cross-lake divider dykes, as shown in Drawing ND-1.

The East Dam and Southeast Dam are geomembrane-lined dams at the east end of the PKCA. The East Dam was constructed to its design crest elevation during the 2005/2006 winter season. The majority of the Southeast Dam was constructed during the 2006/2007 winter. The Southeast Dam is expected to be completed in the summer of 2007. The West Dam is a frozen core dam at the west end of the PKCA. The dam was partially constructed during the winter of 2005/2006 and the winter of 2006/2007. The current minimum core elevation of the West Dam is approximately three metres below the design top core elevation of 524.0 m. It is planned to complete the West Dam construction during the winter of 2007/2008.

Divider Dyke A was partially constructed in the fall of 2005. The construction of Divider Dyke A is currently resumed and will be completed to its design crest elevation of 524.0 m this fall. Divider Dyke A divides the PKCA into two areas: Cell A and Cell B&C. The proposed Divider Dyke B has not been designed or constructed yet.

The fine PK solids (fine PK) is currently beached in the eastern portion of the PKCA between the East Dam/Southeast Dam and the Divider Dyke A. Water filters through the Divider Dyke A into the western portion of the PKCA. The western portion of the PKCA performs as a 'polishing pond' to facilitate the settlement of any remaining suspended solids so that excess water can be discharged from Cell B/C to Stream C3 (downstream of the West Dam) from June to September of each year. Further details of the PKCA operation have been described in the PKCA management plan (EBA, 2006).

The site investigation for the North Dam was carried out in February 2007. The site investigation details are presented in EBA (2007a).

This document describes the design basis, evaluations, and design and construction details of the North Dam. Reduced-size construction drawings are presented in Appendix A of this report. Construction specifications are presented in a separate companion document (EBA, 2007b).

EBA Engineering Consultants Ltd. (EBA) received approval from Tahera to proceed with the design of the North Dam under P.O. No. JDM-TS-11. EBA's scope of work was to:

- Develop the dam concept;
- Carry out thermal and stability analyses for the dam;
- Prepare a design report;
- Prepare construction drawings; and
- Prepare construction specifications.

2.0 DESIGN BASIS AND INTENT

2.1 PKCA MANAGEMENT AND PROJECTED WATER LEVELS

The natural water level in Long Lake was approximately 515.4 m prior to mine operation. The maximum allowable water level during operation of the PKCA has been defined as 523.0 m (EBA, 2006). The water level in the PKCA will be governed by the perimeter dams and regulated with regular water discharging to maintain the water level below the maximum level. The water level in Cell C is intended to be kept as close as possible to the natural level (515.4 m) by pumping the clean water out of the PKCA from June to September each year. Under planned normal annual discharge and assumed mean precipitation conditions, the water level in Cell C would be below 518.2 m during the mine life (2006 to 2012), as projected in EBA (2006).

Water level in Cell C would be higher if no discharge from the PKCA occurred. This is an "upset" condition and would only occur if the water in Cell C did not meet discharge criteria. Based on the input data for the water balance reported in EBA (2006), the projected water level in Cell C would be 515.4 m before the freshet of 2008 and 519.7 m at the end of summer 2008 under a mean precipitation year with an assumption of no discharge from the PKCA after October 2007. This water level is higher than the original ground elevation (approximately 518.2 m) in the valley along the North Dam centreline; therefore, if a no discharge condition occurs before the North Dam is constructed, water will flow downstream of the proposed North Dam.

Under the same assumptions as stated in the previous paragraph, the projected water level in Cell C would be 520.4 m before the freshet of 2009 and 523.0 m by the end of September of 2009 if water were not discharged from the PKCA.

For the current design of the North Dam, the water level in Cell C is conservatively assumed to be constant at 518.0 m before the freshet of 2008, 521.0 m after the freshet of 2008, and 523.0 m after the freshet of 2009 throughout the rest of the dam design life (end of 2014).

2.2 DAM CLASSIFICATION

Any potential failure of the North Dam could result in uncontrolled release of the water in Cell C of the PKCA to Lakes C2 and C1 and ultimately to Carat Lake through the C1 Diversion Channel. Depending on the volume of the water released, some of the water could overflow the right C1 Diversion Channel bank into the open pit. However, based on the general topographic information for the area downstream of the North Dam and overall geometry of the C1 Diversion Channel, the volume of potentially overflowed water into the pit would be limited and unlikely catastrophic in nature. Failure of the North Dam would result in none or some fatalities of life, some economic losses to the Owner's property, and potential damage to the environment from the uncontrolled release of water that may not meet discharge criteria. Therefore, the North Dam is classified as a low to high consequence structure, according to the Dam Safety Guidelines (CDA, 1999). The classification constitutes the basis for analyzing the dam's safety and setting appropriate levels of performance monitoring.

2.3 SITE GROUND CONDITIONS

The original ground along the proposed North Dam axis consists of a relatively steep slope at the north abutment, a narrow valley, and a gentle slope at the south abutment. The lowest original ground surface elevation along the dam axis is approximately 518.2 m. There is a pond immediately upstream of the North Dam. The water elevation in the pond was 517.3 m on June 12, 2007. The estimated surficial geology from air photos for the North Dam is shown in Drawing ND-2.

Four boreholes were cored using a diamond rotary drill rig in the North Dam area in February 2007 (EBA, 2007a). The borehole locations are shown in Drawings ND-2 and ND-3. Chilled brine was used as the drilling fluid to core the frozen ground. The soil profile in the North Dam area generally consists of overburden till overlying grey/pink, medium grained granite. The thickness of the overburden was 0.8 m to 1.5 m over the abutments and up to 3.8 m in the valley, as shown in Drawing ND-6. The overburden soils generally comprise sand till with varying quantities of gravel, cobbles and fines. The measured moisture contents for four samples ranged from 4% to 12% (average 7%). Trace amounts of excess ice were observed in Boreholes ND-BH-2 and ND-BH-3 during core logging. The estimated percentage of visible ice (by volume) was less than 5% (EBA, 2007a).

Pore water salinity values measured for three till samples ranged from 8 to 17.5 parts per thousand (ppt). These values are relatively high and were considered to be a result of brine contamination from drilling and therefore are not thought to be representative of the actual conditions. An additional four till samples were collected later from the stockpiled till that was originally produced from pit development to verify the till salinity at the mine site. The measured pore water salinity was 2 ppt for three sand samples and 8 ppt for one silty sand sample.

The bedrock was slightly weathered with closely to moderately spaced joints. Oxide staining was observed on most joint surfaces. Much of the jointing occurred along thin biotite laminations visible in the rock. Fractured zones were observed in Borehole ND-BH-1 at depths below 7.3 m. Four fractures zones were encountered in this borehole, typically less than 0.3 m in thickness. During drilling, all return water was lost when the first fractured zone at 7.3 m was encountered. Thin bands (0.1 m to 0.4 m) of coarse grained pegmatite were observed in all boreholes.

Percolation (falling head) tests were conducted for all the four boreholes during the site investigation. The water level in Borehole ND-BH-1 could not be raised above 7.5 m below the ground surface during the percolation test period and remained at this level on the following day after the test. The water levels at the end of each percolation test were 0.2 m, 0.8 m, and 0.0 m below the ground surface for Boreholes ND-BH-2, ND-BH-3, and ND-BH-4, respectively.

A ground temperature cable with multiple thermistor beads was installed in Borehole ND-BH-2 during the site investigation. The measured ground temperatures at a depth of 10 m below the original ground surface ranged from -2.2°C to -2.9°C in May to July 2007, as shown in Figure 1. Single bead thermistor cables were also installed in Borehole ND-BH-1. The measured ground temperature at a depth of 8.7 m below the ground surface on June 11, 2007 was -2.4°C.

2.4 CLIMATE CONDITIONS

There is no meteorological station at the Jericho Diamond Mine site. The climatic data used in the thermal design of the North Dam have therefore been based on historical data from the following nearby meteorological stations with long-term records: Lupin, Contwoyto Lake, and Norman Wells. Further details of the meteorological stations and available data are presented in Appendix B.

Climatic data used in thermal modeling of the North Dam include air temperature, wind speed, snow cover, and solar radiation. Appendix B presents a detailed description of the development of climatic parameters and scenarios (e.g., mean, warm-year, and climate change) used in the design of the North Dam. Table 1 summarizes the estimated long-term meteorological data at the Jericho Mine site and warm-year and climate change monthly air temperatures.

TABLE 1: CLIMATIC DATA AT JERICHO MINE SITE						
Month	Monthly Air Temperature (°C)			Monthly Wind Speed[d] (km/h)	Month-End Snow Cover[e] (m)	Daily Solar Radiation[f] (W/m^2)
	Long-Term Mean[a]	1 in 100 Warm Year[b]	Climate Change[c] (2014)			
January	-30.4	-25.2	-28.9	20.2	0.44	5.4
February	-28.5	-23.6	-27.0	13.3	0.52	31.6
March	-24.9	-20.6	-23.8	13.8	0.60	97.3
April	-15.9	-13.2	-14.8	14.3	0.65	179.2
May	-5.7	-4.7	-4.6	16.5	0.30	233.1
June	6.5	9.2	7.4	14.6	0	267.2
July	11.5	16.3	12.4	16.8	0	234.5
August	8.8	12.5	9.7	18.8	0	166.8
September	1.8	2.5	2.9	23.0	0.02	93.9
October	-8.6	-7.1	-7.5	19.8	0.15	32.5
November	-20.7	-17.1	-19.6	16.9	0.28	9.6
December	-26.8	-22.2	-25.3	16.3	0.37	2.0
Mean Annual	-11.1	-7.8	-9.9			
Freezing Index (°C-days)	4884	4044	4583			
Thawing Index (°C-days)	878	1243	997			

Notes:

(a) Climate Normals 1971-2000 at Lupin/Contwoyto Lake (website of Environment Canada).
(b) Estimated from monthly air temperatures measured from 1959 to 2005 at Lupin/Contwoyto Lake.
(c) Estimated from climate chnage trends of average of four Global Circulation Models (Appendix B).
(d) Climate Normals 1951-1981 at Contwoyto Lake (Environment Canada, 1982a).
(e) Climate Normals 1961-1991 at Contwoyto Lake (Environment Canada, 1993).
(f) Climate Normals 1951-1981 at Norman Wells (Environment Canada, 1982b)

2.5 DAM SITING AND ALIGNMENT SELECTION

The dam is located at the northwest side of Long Lake as shown in Drawing ND-1. The dam is on the northeast side of a shallow pond immediately north of Long Lake.

The North Dam is aligned to accommodate the topographic features around the North Dam area such that the proposed key trench for the dam is located on a relatively flatter slope on the north abutment while the overall dam length is minimized.

2.6 DAM CONCEPT

The nature of the foundation condition below the North Dam is such that it is desirable to maintain the foundation soils/rock frozen. Two types of dams have been successfully constructed over permafrost foundations in the Jericho Mine site and other northern mines to contain water or tailings while the permafrost foundations are preserved. They are a geomembrane-lined dam with a frozen key trench and a frozen core dam. Past experience suggests that a frozen core dam is more suitable for the North Dam for the following reasons:

- A frozen core dam is more robust and stable and will maintain the frozen foundation due to its massive frozen body serving as a heat sink.
- Installation of a geomembrane liner in winter is difficult, especially on a steep slope, such as the steep slope on the north abutment of the North Dam.
- Similar key trench excavation and backfilling will be required for both dam types; the required thickness of the fill cover over the key trench will also be similar on the abutments for both dam types. The cost savings from less fill materials placed over the valley portion for a lined dam is limited because the valley is narrow at the North Dam location.
- Risk of potential leakage through a lined dam is higher than that through a frozen core dam.

Therefore, the North Dam has been designed as a frozen core dam. The dam geometry and layout has been designed to minimize material costs, protect the integrity of the frozen core, and satisfy thermal, stability, and settlement design criteria. Elements of the dam design are presented in Section 3.2.

2.7 CONSTRUCTION CONSIDERATIONS

The North Dam should be constructed to limit the risk of uncontrolled release of water in the PKCA over the low saddle in the North Dam area. The requirements for construction of the frozen core dictate that fill placement should occur in cold weather conditions. Core and key trench construction (backfill, liner system) must take place during the months when air temperatures are below -15°C.

The construction of the till berm should take place in the fall prior to dam construction when the till can be placed, moisture-conditioned, and compacted in unfrozen conditions.

The grout curtain installation should take place in September and early October prior to dam construction when the bedrock is at its warmest and air temperatures are not too cold for construction. The key trench excavation should not begin until after the grout curtain has set up (approximately one month after grouting).

The local glacial till soils are generally not acceptable for embankment construction since they are variable with respect to both gradation and ice content. Abundant run-of-mine material from the mine site pit development is primarily hard non-acid-generating granite, which is an acceptable material for use in dam construction. This material was the primary source for the previous dams constructed at the mine site and will also be the primary source of construction material for the North Dam. Processing will be required to meet gradation requirements for some zones within the dam.

2.8 WATER LICENCE REQUIREMENTS

The design of the North Dam must adhere to the requirements of the Type "A" water licence for the Jericho Mine. The following excerpts are of particular importance to the design of the North Dam:

- Part F, Item 4(b) "A minimum freeboard limit of one (1) metre (for water management facilities) shall be maintained at all times or as recommended by a Geotechnical Engineer and as approved by the (Water) Board"; and
- Part F, Item 4(d) "Any runoff accumulated and/or seepage that does not meet the effluent quality criteria Part G, Item 6(a) shall be collected and directed to the PKCA and measures shall be employed to reduce seepage".

2.9 DAM DESIGN INTENT

The design criteria for the North Dam are as follows:

- The dam should retain water within the PKCA.
- The dam will remain physically stable during the operational life of the mine.
- The dam will not be required after mine abandonment.

3.0 DAM DESIGN

3.1 FREEBOARD DESIGN

The "maximum operating water level" for the PKCA has been defined as elevation 523 m. The water level may rise above this level while flood waters are discharged and will also be higher due to waves. The maximum wave height for the North Dam is estimated to be 0.3 m based on a method presented in Linsley and Franzini (1979). The "maximum water level" that includes waves and a temporary rise during flood routing has been defined as 524 m for the PKCA (EBA, 2005). The difference between the "maximum operating water level" and "maximum water level" is the freeboard. The freeboard also meets the freeboard requirement of 1.0 m for the Jericho Mine water licence. The water retention elements in the perimeter dams for the PKCA have been specified to be at elevation 524 m. The top of both the frozen core and the GCL liner of the North Dam is 524 m. Negligible settlement is expected at the frozen core crest based on observations at similar structures.

There is 4.0 m of rockfill over the top of the core. This is required for thermal protection of the frozen core. The rockfill also provides sufficient protection against remote overtopping risk from run-up of waves on the upstream slope of the North Dam.

3.2 DAM LAYOUT AND GEOMETRY

The North Dam is designed as a frozen core dam. The planned layout and typical cross-section of the North Dam are presented in Drawings ND-3 and ND-4. The dam geometry and layout are designed to minimize material costs, facilitate construction, protect the integrity of the frozen core, and satisfy thermal, stability, and settlement design criteria.

The North Dam will be approximately 103 m long. The maximum dam height is approximately 10 m. The crests of the dam and frozen core are at elevations 528.0 m and 524.0 m, respectively. The 4.0 m thick cover over the crest of the frozen core is required to prevent summer thaw of the frozen core. The crest width of 13 m is required for constructability and thermal protection of the frozen core.

The impervious core of the dam will be constructed of frozen, nearly-saturated crush (processed 20 mm minus). The core is positioned just downstream of the centre of the dam to increase the distance from the impounded water, which acts as a heat source. A key trench will be excavated to ice-saturated foundation soil or competent bedrock to produce a well-bonded and impermeable mass. The key trench will be backfilled with the same core material.

A geosynthetic clay liner (GCL) will be placed on the upstream face of the frozen core, extending into the key trench. The liner provides a secondary seepage barrier that will only function if the integrity of the core is jeopardized by thaw or crack formation. The upstream face of the GCL is covered with 0.5 m of coarse PK as a protective layer against the overlying 150 mm transition material.

Transition material (processed 150 mm minus rockfill) will be placed both upstream and downstream of the frozen core to provide protection of the core from thermal and mechanical degradation. The transition material downstream of the dam centreline is designed to act as a filter in the unlikely event of thaw of the core.

A till berm will be constructed within the upstream dam shell. The berm has a crest elevation of 521.0 m, a crest width of 3.0 m, and side slopes of 1.5H:1V. This berm may serve as an effective barrier to cut off potential convective heat transfer through large open voids in the saturated run-of-mine shell material and provide thermal protection to the core and foundation soils. This berm may also reduce potential seepage volume through the shell into the dam and its foundation in a remote case that leakage paths exist in the dam core or its underlying foundation when the water level in the PKCA is below the crest elevation of the till berm.

Shell material has been provided for stability and thermal protection of the frozen core. The shell will consist of run-of-mine granite rockfill with an upstream side slope of 3.5H:1V and a downstream side slope of 2.5H:1V.

Thermosyphons have been incorporated in the thermal design of the North Dam. The thermosyphon layout and details are shown in Drawings ND-10. Horizontal thermosyphons will be placed in four loops in the frozen core to maintain the frozen core and the foundation soil or bedrock below the key trench sufficiently cold to act as an impervious barrier. A design criterion of -2°C has been used as the maximum temperature in this zone. Each loop of the thermosyphons will be connected to a 39.0 m^2 radiator.

A grout curtain will be constructed in the bedrock beneath the key trench to seal off open cracks or fracture zones. The design details are presented in Section 3.3.2 and shown in Drawing ND-11.

3.3 DAM FOUNDATION TREATMENT

3.3.1 Key Trench

The planned key trench layout and a profile along the trench centerline of the North Dam are presented in Drawings ND-5 and ND-6, respectively. The key trench should be excavated to ice-saturated permafrost soil or competent rock with ice-saturated or grout-filled joints. Based on available information, the anticipated depth of the key trench will be 2.0 m over both the valley and the south abutment and 3.0 m over the south-facing north abutment. The final depth of the key trench will be determined by the Engineer during the construction based on actual foundation conditions and results from grouting program. Typical side slopes for the key trench will be approximately 0.5H:1V, perpendicular to the crest of the key trench.

3.3.2 Curtain Grouting

A percolation test conducted at the north abutment during the site investigation indicated that open joints and/or fracture zones exist in the bedrock at the north abutment. A grout curtain is proposed to cut off the potential seepage through these open cracks and/or fracture zones beneath the key trench. It is expected that any small open joints within the bedrock around the grout curtain, which are too small to be grouted, will eventually be filled with ice under the expected ground temperatures (-2 to -5°C).

Preliminary curtain grout hole locations and profile are shown in Drawing ND-11. Additional holes may be required based on actual ground conditions and grout takes during drilling, percolation testing and grouting of the proposed holes. All grout holes shall be 76 mm (3 inch) diameter and drilled using a percussion drill. A percolation test will be conducted for each grout hole prior to grouting to estimate the overall permeability of the bedrock.

A two-line grout curtain is proposed for the north abutment where both the cores and the percolation test results indicated the existence of open joints and/or fracture zones. The design spacing between the two grout lines is 2.6 m. Each line of the grout curtain will comprise primary and secondary grout holes at typical spacings of 6 m and 3 m respectively, as shown on Drawing ND-11.

A single-line grout curtain is proposed over the valley and south abutment to detect any major open joints and/or fracture zones similar to those found at Borehole ND-BH-1. A two-line grout curtain similar to that proposed for the north abutment may be required in some areas along the valley and south abutment if major open joints and/or fracture zones are detected in these areas during the percolation testing and grouting of the primary or secondary holes along the first grout curtain line. If the stabilized water level(s) in one or more grout hole(s) is more than 2.0 m below the original ground surface during the percolation testing, the second grout curtain line will be required within 6 m of the hole(s). This preliminary criterion for establishing the need for the second grout curtain line may be adjusted by the Engineer during the early stage of the grouting program based on site observations. The design team should be informed if the grout take in a particular hole is greater than twice the calculated volume of the drilled hole.

Tertiary grout holes will be drilled between the two grout curtain lines to verify the effectiveness of the grout curtain after the completion of the secondary grout holes. If the stabilized water level in a tertiary grout hole is more than 3.0 m (2.0 m for the valley and south abutment area) deep from the original ground surface during a percolation test, additional grout holes shall be drilled at split spacing around the hole(s) and then grouted to refusal. This preliminary criterion for the need for additional grouting may be adjusted by the Engineer during the early stage of the grouting program based on site observations. Other criteria, such as those based on grout take, may be adopted during the construction stage based on actual field behaviour.

The design depths of the grout curtain holes are 12.0 m below the original ground surface over the north abutment and 8.0 m over the valley and south abutment. The target zone for the curtain grouting is the bedrock from a depth of about 1.5 m below the original ground surface to the bottom of the grout holes. All grout holes will be oriented 20° to the vertical towards the north abutment along the dam axis to maximize the intersection of the holes with horizontal and vertical joint sets.

3.4 THERMAL EVALUATION

3.4.1 Thermal Design Criteria

The North Dam has been designed as a zoned dam with a frozen core and a frozen key trench over ice-saturated permafrost soil or competent rock. The design intent is to maintain the core, the key trench, and the underlying soil or rock in a perennially frozen condition throughout the mine life.

The North Dam has also been designed to maintain the core and permafrost foundation within a critical zone (where the GCL is keyed into the bottom of the key trench) sufficiently cold to maintain a water-tight bond along the interfaces between the core, GCL, and foundation. The temperatures in this zone should be colder than -2°C to reduce potential seepage through cracks that may develop in the foundation. This thermal design criterion has been shown to be appropriate for frozen core water-retention structures constructed at both the Jericho Mine site and EKATI Diamond Mine.

3.4.2 Analysis Methodology

Thermal analyses were carried out using EBA's proprietary finite element computer program, GEOTHERM. The model simulates transient, two-dimensional heat conduction. The program has been verified by comparison with closed-form solutions and numerous field observations. The model has been the design basis for a large number of projects in the arctic and sub-arctic, including the designs of the frozen core dams at the Jericho Mine site and EKATI Diamond Mine site.

Thermal analyses were carried out to predict the short and long-term thermal conditions of the North Dam under various assumed conditions for cases with and without thermosyphons. The thermal model was calibrated using the measured ground temperatures at the site. The initial ground temperatures in the dam foundation were estimated from thermal analyses considering the thermal impacts of the small lake upstream of the dam and snow drifting in the valley.

Thermal analyses were conducted for a typical dam cross-section through the valley. Subsurface conditions were estimated from the available information described in Section 2.3.

Thermal analyses were carried out to model key steps from dam construction through subsequent impoundment. The thermal analyses were conservatively analyzed assuming that the dam will impound water to 521.0 m at the onset of the first freshet after dam construction and to its maximum operating water level (523.0 m) after the onset of the second freshet, maintaining the water level throughout the rest of the dam design life (six years).

The North Dam has been designed to consider various air temperature conditions including mean, 1 in 100 warm, and a climate change scenario.

3.4.3 Input Parameters

Climatic conditions summarized in Table 1 were used in the thermal analyses.

The physical properties of the dam and foundation materials were based on past experience with similar materials and limited soil sample test results during the geotechnical site investigation. Thermal properties were determined indirectly from well-established correlations with soil index properties (Farouki, 1986; Johnston, 1981) or based on past experience. Table 2 summarizes the material properties used in the thermal analyses.

TABLE 2: MATERIAL PROPERTIES USED IN THERMAL ANALYSES							
Material	Water Content (%)	Bulk Density (Mg/m³)	Thermal Conductivity (W/m-K)		Specific Heat (kJ/kg°C)		Latent Heat (MJ/m³)
			Frozen	Unfrozen	Frozen	Unfrozen	
Shell - Run-of-Mine (unsaturated)	3	2.16	1.66	1.82	0.77	0.83	21
Core – 20 mm Minus	11	2.28	2.94	2.19	0.87	1.07	75
Till Fill (unsaturated)	7	2.14	1.69	1.66	0.82	0.96	47
Transition – 150 mm Minus (unsaturated)	4	2.18	1.84	1.93	0.79	0.87	28
Overburden Till	14	2.17	2.49	1.78	0.90	1.16	89
Bedrock	1	2.53	3.00	3.00	0.75	0.77	8
Shell – Run-of-Mine (saturated)	10	2.31	3.00	10.00[(a)] / 2.27	0.86	1.05	70
Till Fill (saturated)	13	2.26	2.77	94	0.89	1.13	87
Transition – 150 mm Minus (saturated)	10	2.31	3.00	2.27	0.80	1.05	70

Note:
(a) The thermal conductivity of the saturated shell was assumed to be 2.27 W/m-°C in the vertical direction and 10.0 W/m-°C in the horizontal direction. The larger horizontal thermal conductivity was used to account for potential heat transfer by convection through the water-filled voids of the saturated shell material.

3.4.4 Thermal Analysis Cases and Assumptions

A vertical cross-section perpendicular to the centre line of the North Dam through its lowest original ground surface was simulated in the thermal analyses. The foundation soil profile used in the thermal model consisted of 3.8 m of ice-poor till overlying bedrock.

Two cases were evaluated: Case 1 simulated the North Dam without thermosyphons, and Case 2 simulated the North Dam with normal operation of thermosyphons following the construction season. It was assumed for the thermal analyses that the construction of the North Dam will be completed on April 15, 2008. Table 3 summarizes thermal analysis runs and associated major assumptions. The assumed water elevation for each run was the highest possible level at the specified time period in Cell C of the PKCA. This is conservative, as it results in warmer predicted ground temperatures. The actual operation water levels are expected to be lower than those assumed.

TABLE 3: THERMAL ANALYSIS RUNS AND ASSOCIATED MAJOR ASSUMPTIONS				
Case	Run No.	Simulated Time Period	Upstream Water Elevation (m)	Air Temperature Assumed
1 (without Thermosyphons)	1	Apr. 15, 2008 to May 31, 2008	518.0	Mean
	2	Jun. 1, 2008 to May 31, 2009	521.0	
	3	Jun. 1, 2009 to Dec. 31, 2014	523.0	
2 (with Thermosyphons)	1	Jun. 1, 2008 to May 31, 2009	521.0	Mean
	2	Jun. 1, 2009 to Dec. 31, 2014	523.0	
	3	Jun. 1, 2009 to Dec. 31, 2014	523.0	GCM's Climate Change
	4	Jun. 1, 2009 to Dec. 31, 2010	523.0	1 in 100 Warm

3.4.5 Initial Conditions

A thermistor cable was installed in Borehole ND-BH-2 within the valley of the North Dam area on February 19, 2007. The ground temperatures at Borehole ND-BH-2 were measured on May 1, June 12, and July 9, 2007. Thermal analysis was conducted to simulate the original ground in the North Dam area considering the thermal effects of the pond upstream of the North Dam and snow drifting in the valley. Figure 1 compares the measured ground temperatures at Borehole ND-BH-2 with those predicted from the thermal analysis. A good agreement was obtained between the measured and predicted ground temperatures. Therefore, the initial ground temperatures prior to dam construction in the North Dam area were estimated from the calibration thermal analysis.

The initial temperatures of the dam and foundation at the end of dam construction (assumed April 15) were estimated in a separate thermal analysis based on the pre-construction ground temperatures and an assumed constant temperature of -2°C for the dam fill materials placed from January 1 to April 15.

The -2°C initial temperatures of the dam fill materials on April 15 were based on a range of measured frozen core temperatures for similar frozen core dams after construction. The actual fill temperatures will vary depending on the construction schedule, sequence, and climatic conditions during dam construction.

Prior to initial impoundment, the upstream shell (run-or-mine), till fill, and upstream transition zone (150 mm minus) materials are expected to be mostly frozen; however, water will infiltrate the upstream dam shell as water rises against the dam. It was assumed that impounded water will seep through the shell and till fill into the originally unsaturated transition zone in front of the frozen core, thereby raising the temperature of these materials. The temperatures of these materials upon initial submergence were assumed to be 0.5°C.

3.4.6 Boundary Conditions

A water/ice temperature boundary was applied on the upstream side of the original ground and dam surface below the assumed water elevation. The assumed water/ice temperature was based on measured lake water temperatures in northern lakes and past experience. Table 4 presents water temperatures assumed for shallow lakes (≤ 1.5 m deep) and deep lakes (> 1.5 m deep).

TABLE 4: ASSUMED WATER TEMPERATURES IN THERMAL ANALYSES

Lake Depth	Mid-Month Lake Water Temperature (°C)											
	J	F	M	A	M	J	J	A	S	O	N	D
≤ 1.5 m	0	-1	-1	-1	1	3	15	14	5	2	1	0.5
> 1.5 m	2	2	2	2	2	4	10	14	7	3	2	2

Climatic conditions were applied at the dam surfaces exposed to air and the original ground downstream of the dam. The snow cover on the dam was assumed to be affected by wind and snow drifting from the top of the nearby south-facing slope and estimated based on past experience. The assumed snow cover on the dam surface was 50% of the mean monthly snow cover at the dam crest and increased linearly to four times the mean monthly snow depth at the downstream toe and to three times the mean monthly snow depth on the upstream dam surface above the water level. Mean snow depth was assumed on the downstream original ground 20 m away from the downstream toe of the dam.

3.4.7 Thermosyphon Simulation

A thermosyphon is a passive heat transfer device that operates by convection through vaporization and condensation. It consists of a sealed vessel with an upper part working as a condenser and a buried part in the ground functioning as an evaporator. Heat transfer is driven by the temperature difference across the unit. For ground cooling applications, thermosyphons remove heat from the ground beneath a structure and release it to the outside ambient air, as long as the air is colder than the ground. A detailed description of thermosyphon technology is presented in Yarmak and Long (2002).

The thermosyphons were simulated as a convective heat flux boundary. The inside diameter of the evaporators was assumed to be 20 mm. The convective heat transfer characteristics of the thermosyphons were based on empirical expressions established from laboratory experiments of full-scale horizontal thermosyphons (Haynes and Zarling, 1988). A convective heat transfer coefficient of 15.8 W/(m^2.°C) was calculated based on an effective horizontal evaporator length of 150 m in the south abutment area, a radiator size of 39 m^2, and a design wind speed of 5 km/h. The evaporator length for the thermosyphons in the north abutment area is shorter, which may result in a higher value of the convective heat transfer coefficient and therefore colder ground temperatures. It was assumed that thermosyphons will be ready for normal operation on June 1 following construction.

3.4.8 Thermal Analysis Results

The thermal analyses indicate that the ground temperatures around the key trench are the warmest in January (nine months after dam construction) for Runs 1 to 3 of Case 1 (without thermosyphons). The predicted isotherms at this time (under mean climatic conditions) are shown in Figure 2. Figure 2 indicates that the predicted ground temperatures range from -1.0°C to -1.5°C within the key trench, which are warmer than the design ground temperature of -2.0°C, as specified in Section 3.4.1. This suggests that thermosyphons are required in the North Dam to lower the dam core and foundation temperatures.

Figure 3 illustrates that the predicted ground temperatures around the key trench in January (nine months after dam construction) are colder than -3.0°C with normal operation of the thermosyphons.

The thermal analyses indicate that the ground temperatures in the core and the foundation around the key trench are the warmest in early October for the Runs of Case 2 (with thermosyphons). Figures 4 and 5 present the predicted isotherms in early October after 1.5 years and 6.5 years following dam construction, respectively, under mean climatic conditions. The results in Figures 4 and 5 suggest that the predicted temperatures meet the design criteria and decrease with time.

Thermal analysis results indicate that the thaw depth below the dam surface will be deepest in early October. The predicted ground temperatures in early October after two consecutive 1:100 warm years following a mean climatic year after dam construction are shown in Figure 6. The top of the core remains frozen. The predicted maximum thaw depth below the dam surface at the core centerline is 3.1, 3.3, and 3.7 m under the air temperatures of mean, GCMs climate change, and 1:100 warm year conditions, respectively. The 4.0 m design thickness of the thermal cover over the core is sufficient to maintain the core in perennially frozen conditions.

Figure 7 presents the predicted temperatures in early October 6.5 years after construction under the assumed climate change trend following the average of the four GCMs. The predicted ground temperatures for the climate change case are slightly warmer than those for the mean climate case (comparing Figure 5 to Figure 7).

3.4.9 Discussion of Results

Preliminary thermal analyses and past experience suggest that the assumed initial temperatures of both the original ground and fill materials greatly affect their predicted temperatures in later years. In the current thermal analyses, the assumed initial temperatures are generally conservative for the following reasons:

- The section simulated has the warmest initial ground temperatures prior to the dam construction. The initial ground temperatures at other sections along the dam axis are expected to be colder.
- The initial ground temperature in the area adjacent to the open trench would be colder than assumed because of the extended period of time when the ground is exposed to cold air and snow is cleared after trench excavation but before the fill placement.
- The initial fill temperature can be colder than the assumed depending on the actual climatic conditions and specific construction sequence during the dam construction.

The water elevation assumptions in Table 3 are generally conservative. The actual upstream water elevation is expected to be lower than the assumed values. As a result, the actual ground temperatures for the upstream portion of the dam are expected to colder than predicted.

3.5 STABILITY EVALUATION

3.5.1 Analysis Methodology

Limit equilibrium stability analyses were carried out to evaluate the factors of safety for slope stability during construction and operation of the North Dam. The analyses were conducted using a commercial, two-dimensional, slope stability computer program, SLOPE/W (GeoSlope Office). The Morgenstern-Price method with a half-sine inter-slice force assumption was adopted in the analyses.

3.5.2 Design Criteria

The dam is designed to meet Canadian Dam Association guidelines (CDA, 1999). The design criteria for computed minimum factors of safety are given in Table 5.

TABLE 5: SLOPE STABILITY DESIGN CRITERIA

Loading Conditions	Minimum Factor of Safety	Slope
Static loading, full reservoir	1.5	Downstream and Upstream
Static loading, end of construction before reservoir filling	1.3	Downstream and Upstream
Full or partial rapid drawdown	1.2 to 1.3	Upstream
Earthquake, full reservoir	1.1	Downstream and Upstream

The stability analyses were carried out for the deepest dam cross-section, which is generally the worst case for evaluating dam stability. Stability analyses were also conducted for an abutment section, where the key trench is closest to the downstream shell.

3.5.3 Material Properties

The material properties chosen for the embankment and foundation materials in the stability analysis are presented in Table 6. The properties for granular materials were selected based on experience with similar materials used and encountered by EBA in dam designs at other sites across the Arctic. The analyses have been carried out assuming unfrozen embankment fill. The strength increase associated with frozen embankment fill has not been considered. This is a conservative assumption.

TABLE 6: MATERIAL PROPERTIES USED IN STABILITY ANALYSES

Material	Angle of Internal Friction (°)	Cohesion (kPa)	Unit Weight (kN/m³)
Run-of-Mine	42	0	20
150 mm Minus Material	35	0	21
Coarse PK	30	0	20
20 mm Minus Material	32	0	20
GCL Liner	8.7	11.3	15
Till – effective stress	32	0	20
Till - total stress (upstream)	0	50	19
Till - total stress (downstream)	0	63	19

The friction angle presented in Table 6 for the run-of-mine material is conservative for shallow depths where confining stresses are low.

The foundation till soils have been analyzed for both thawed, drained effective strength parameters and long-term frozen total stress parameters. The long-term frozen strength has been estimated by a relationship (Johnson, 1981) for the lower limit of the 50 year shear strength of an ice-rich soil. The relationship is as follows:

$C = 35 + 28T$ Where: T = Temperature in °C below freezing (with positive sign)
C = Long-term strength (kPa)

A temperature of –0.5°C has been assumed for the upstream conditions, and –1.0°C has been assumed for downstream conditions. The estimated strength from this relationship is considered to be conservative given that the foundation soils have relatively low excess ice contents.

The GCL liner has been analyzed assuming it has a "large-displacement" strength envelope. It has been assumed that the GCL liner is a needle-punched nonwoven product with strength parameters as listed and summarized by Zornberg et al. (2005). Designing with "large-displacement" strengths are conservative, as the liner must undergo movement which subjects the liner to a peak stress higher than its "large-displacement" strength.

3.5.4 Pore Water Pressure Conditions

The pore water pressures assigned to the rockfill on the upstream side of the core correspond to the maximum operating water elevation of 523.0 m for the static and seismic full reservoir stability analyses. The rockfill shell upstream of the till berm is expected to completely drain during rapid draw down situations. The phreatic surface in the rockfill between the till berm and the core was assumed to linearly decrease from the maximum operating water elevation at the core to the till berm crest elevation at the crest of the till berm during rapid draw down situations.

Pore water pressures assigned to the downstream rockfill equalled the original ground elevation. The dam core is not expected to leak significant volumes of water, and furthermore, the rockfill is free draining and will not sustain a significant water level within itself.

The pore water pressures assigned to the till berm corresponded to the maximum pond elevation for the static and seismic full reservoir stability analyses. It was conservatively assumed that the till berm will retain its pore water and also hold the water in the rockfill downstream of the till berm during rapid drawdown situations.

The pore water pressures assigned to the GCL liner correspond to the maximum pond levels for the static, seismic, and rapid drawdown stability analyses.

It was assumed that negligible excess pore water pressures would be generated due to thaw of the portion of the till under the upstream or downstream shell rockfill. This is considered to be appropriate for the following reasons:

- Thaw will progress relatively slowly into the foundation, and
- The till is non-plastic and has a significant sand and gravel content, which increases its permeability.

Given these conditions, excess pore water pressures generated in the till during thaw will be negligible based on Morgenstern and Nixon (1971). Furthermore, the permeability of the coarse-grained till is expected to prevent the build-up of excess pore water pressures during rapid drawdown.

3.5.5 Seismicity

The project area lies in a region of low seismicity, but magnitude 4+ earthquakes have recently occurred within a similar part of the shield. NRCan (2003a and 2003b) recommends that a probabilistic approach should be adopted to estimate the peak ground accelerations (PGA), particularly the new proposed National Building Code of Canada (NBCC) PGA values.

CDA (1999) requires that the minimum criterion for the design earthquake for a dam would be an earthquake with a return period from 100 to 1,000 years for the "low" consequence category and from 1,000 to 10,000 years for the "high" consequence category. NRCan

(2003a and 2003b) indicates that the peak horizontal acceleration is 0.016 g for a 1,000-year-return event and 0.06 g for a 2,475-year-return event at the mine site. An earthquake with a 2,475-year-return period has been adopted as the design earthquake for the North Dam, which is the same as the design earthquake for other dams at the mine site.

3.5.6 Stability Analysis Results

The stability analyses assumed drained strength parameters for the granular fill materials and both undrained and drained strength parameters for the foundation till.

Table 7 summarizes the minimum factors of safety under static, end of construction, rapid drawdown, and seismic conditions for the upstream and downstream slopes.

TABLE 7: SUMMARY OF STABILITY ANALYSIS RESULTS

Slip Surface	Case (Foundation Strength)	Minimum Factor of Safety			
		Static, Full Reservoir	Static, End of Construction	Static, Rapid Drawdown of Reservoir	Seismic, Full Reservoir
Upstream	Effective Stress	2.0	2.2	1.9	1.5
Upstream	Total Stress	2.0	2.0	1.9	1.6
Downstream	Effective Stress	1.9	1.9	--	1.6
Downstream	Total Stress	2.0	2.0	--	1.6

The computed minimum factors of safety exceed the design criteria listed in Table 5. The design geometry and cross-sections of the North Dam are determined by the thermal considerations.

Graphical representations for four selected slope stability analyses are shown in Figures 8 to 11.

Additional stability analyses were also conducted for an abutment section, where the key trench is closest to the downstream shell, to analyze the downstream stability. The calculated factor of safety is 2.1 under effective stress, static loading conditions, which is higher than the calculated factor of safety of 2.0 for the typical cross-section under the same loading conditions.

The analyses presented in Table 7 assumed drained strength parameters for the frozen core (20 mm minus material). Subsequently, the sensitivity of undrained strength parameters of the frozen core was evaluated. The undrained strength of the frozen core was based on Weaver and Morgenstern (1981) for long-term cohesion of an ice-poor sand. The undrained strength was assumed to be 200 kPa. The stability analyses indicated that the calculated factors of safety for slip surfaces through the frozen core with the undrained strength are higher than the corresponding values in Table 7 and the critical slip surfaces do not pass through the core.

An analysis was evaluated which considered the unlikely case that the frozen core is ice-rich. The long-term undrained shear strength was assumed to be 50 kPa for an assumed temperature of –0.5°C. The calculated minimum factor of safety for the downstream slope under static loading is 1.9, which also meets the stability design criteria.

3.5.7 Liquefaction Potential

The design peak horizontal ground acceleration for the area is very low at 0.06 g, and as a consequence, liquefaction of the thawed surface till layer due to earthquake loading is not expected to be a concern.

3.6 DEFORMATION EVALUATION

3.6.1 Thaw Settlement

A portion of the dam is founded on till that has low ice contents. A small amount of settlement would occur if the till thaws.

It is anticipated that the water level in the PKCA will be maintained at a low level thereby minimizing foundation thaw and settlement; however, if the water is maintained at a high elevation for an extended period, some foundation thaw and settlement may occur. Thaw settlements beneath the upstream dam shell should be less than 20 cm based on ice contents observed in the boreholes. The thaw settlements were estimated based on the predicted thaw penetration into the typical cross-section described in the thermal evaluation (Section 3.4.8). However, soil conditions vary along the dam alignment, and therefore, thaw settlements are expected to be non-uniform.

The small thaw settlements will not cause any slope instability in the relatively flat upstream dam slope.

Some settlements may also occur in the winter-placed fill materials after its initial thaw. The magnitude of the settlements will depend on the moisture contents and densities of the fill materials during the construction. All dam fill materials must be compacted in thin lifts to reduce post construction settlements. Given the expected low moisture content and high post-compaction density of the shell material, the post-construction thaw settlements of the shell material is expected to be minimal.

3.6.2 Creep-Induced Deformation

The foundation soils consist of sand till with none to low excess ice (less than 5% by volume), as discussed in Section 2.3. The frozen till in the foundation had moisture contents ranging from 4 to 12%. There is the possibility of some creep of the dam foundation; however it is difficult to accurately assess the creep magnitude due to lack of measured soil creep parameters. Creep movement that would have an adverse effect on the dam is not anticipated given the foundation conditions.

Creep is a slow, long-term process. It is recommended that the dam be monitored for any deformations, and remedial measures be employed should significant creep-induced deformations be observed.

3.7 WORST-CASE FAILURE SCENARIO

The combination of a frozen core and a GCL liner within a rockfill shell provides a low probability of a sudden release of impounded water due to slope instability or massive seepage loss. The North Dam would still be structurally stable should the entire core thaw. Nevertheless, the environmental impact of a hypothetical worst-case failure scenario must be considered in the event that the dam fails.

The core and underlying foundation are expected to be frozen from the end of construction to the end of the dam design life. The risk of seepage through the core and foundation is considered to be very low. There is a low risk of seepage through the bedrock abutments if the bedrock fracture zones are not fully ice-filled or grout-filled after curtain grouting. Further characterization of the bedrock abutments will be carried out during the grout program and visual observations in the key trench. If required, a deeper key trench will be excavated to meet the design intent.

In the remote event that seepage occurs through the dam or its foundation, the water level in the PKCA should be kept as low as practically possible. The dam safety would be then re-evaluated and remedial measures such as grouting or installing vertical thermosyphons would be considered. The seepage should be collected downstream of the North Dam and pumped back to the PKCA if necessary. If required, a small seepage collection dam could be constructed downstream of the North Dam to facilitate seepage collection.

4.0 DAM CONSTRUCTION PLAN

Construction of the dam will be conducted in accordance with the Construction Specifications and Construction Drawings. The Construction Specifications are presented in a separate document that accompanies this report. The Construction Drawings have also been issued as a separate document package. A set of construction drawings (reduced in size) are included, for ease of reference, with this report. The Construction Specifications and Construction Drawings must be among the governing documents used for construction planning and supervision, and ultimate construction of the dam.

The Construction Specifications present details regarding foundation preparation, fill materials, fill placement, the geosynthetic clay liner system, instrumentation, quality assurance program, and curtain grouting program. It is anticipated that the contractor chosen to conduct the work will develop a construction plan. The construction plan must satisfy the dam design intent and construction requirements.

4.1 CONSTRUCTION MATERIALS

The following provides a summary of the materials that will be used to construct the dam. Specifications for material gradations and placement requirements are presented in the North Dam Construction Specifications.

4.1.1 Slope Protection

The upstream slope of the North Dam may be subject to wave action. The fetch length is approximately 320 m when the water elevation in Cell C reaches 523.0 m. The calculated wave height is 0.3 m for the maximum sustained wind speed of 81 km/h for the design wind duration of 30 minutes. Rip-rap with a minimum average particle size (D50) of 300 mm is required to protect the dam against wave action.

It is proposed that the upstream dam shell will be run-of-mine rock with a maximum particle size of 700 mm. It is anticipated that the run-of-mine will have an average particle size larger than the minimum requirements for rip-rap and therefore will be suitable for slope protection.

4.1.2 Shell - Run-of-Mine Rockfill

The upstream and downstream shell materials will be run-of-mine granitic rock with a maximum particle size of 700 mm. The material shall be placed in lifts of a maximum of 700 mm thickness. Any boulder larger than 700 mm can be wasted to the outside dam slopes.

4.1.3 Till

A small till berm will be constructed within the upstream shell. The natural till deposits on site vary from sand and gravel with some cobbles and boulders to silty sand and gravel with cobbles and boulders. The till for the North Dam berm should be a silty sandy till with some gravel and cobbles. Particles larger than 250 mm should be removed from each lift of material to allow for compaction of the till. The large particles can be wasted on the outsides of the till berm.

4.1.4 20 mm Minus Core

A 20 mm minus crushed granite will be used to construct the frozen core and backfill the key trench. The material must have a minimum of 4% particle sizes smaller than 80 microns.

4.1.5 Geosynthetic Clay Liner

A geosynthetic clay liner (GCL) will be placed on the upstream side of the frozen core and within the key trench. The recommended GCL consists of two nonwoven geotextiles encapsulating a layer of bentonite. The GCL will be needle punched to provide adequate shear strength.

4.1.6 Liner Upstream Bedding

Upstream bedding material will be placed over the upper GCL above the key trench to protect the liner from damage during the construction and dam operation. The bedding material can consist of the coarse PK produced by the Jericho Process Plant. The coarse PK typically has a maximum particle size of 10 mm and less than 5% fines (smaller than 0.08 mm).

4.1.7 Transition Material

A 150 mm minus transition material is required between the upstream rockfill shell and the liner bedding material and also between the core and the downstream rockfill shell. The transition material must meet the following filter criteria:

- D15 of the transition < 5 * D85 of either the core or the bedding material
- D15 of the rockfill shell < 5 * D85 of the transition

The D15 size denotes that 15% of the particles are smaller than that size. The D85 size denotes that 85% of the particles are smaller than that size.

4.2 EXCAVATION AND MATERIAL QUANTITIES

Table 8 presents the in-place quantities of the major materials required for construction of the North Dam if constructed as per the design geometry. The quantities of material do not include any contingency for waste.

TABLE 8: NORTH DAM MATERIAL QUANTITIES	
Excavation/Material Type	Quantity[(a)]
Key Trench Excavation[(b)]	2,800 m^3
Run-of-Mine Shell Material (700 mm minus) (Material A)	18,600 m^3
Till Fill (250 mm minus) (Material B)	1,400 m^3
150 mm minus Transition Rockfill (Material C)	3,000 m^3
Coarse PK (20 mm minus) (Material D)	700 m^3
20 mm minus Core Material (Material E)	6,100 m^3
Geosynthetic Clay Liner (GCL)	2,600 m^2
Thermosyphon Evaporator Pipe	570 m
Thermosyphon Radiators (39 m^2 each)	4
Ground Temperature Cables[(c)]	8
Survey Monitoring Points[(d)]	6

Notes:

(a) Quantities are "in-place". Seaming allowance and contingencies must be added to GCL quantities to account for overlap, damaged sections, and/or waste during construction. It is recommended that 20% extra quantities be available on site. Bulking factors and contingencies must be added to fill quantities; 20% should be added to reported quantities for stockpile volumes. Quantities have been calculated based on 1 m contour data.

(b) The volume of key trench excavation has been calculated assuming a trench depth of 2 m over the valley and south abutment and 3 m over the north abutment. The depth and volume of key trench excavation depends on the conditions encountered. The required depth shall be determined during construction by the Geotechnical Engineer.

(c) See Drawing ND-8 for details.

(d) See Drawing ND-9 for details.

4.3 CONSTRUCTION SCHEDULE

The requirements for construction of the dam dictate that the majority of fill placement occurs in cold weather conditions. Core and key trench construction (backfill, liner system) must take place during the months when air temperatures are below -15ºC. The following generalized schedule for dam construction is suggested for construction planning purposes:

- August to October: Construction of Till Berm – Foundation preparation for the till berm; placement and compaction of the till in thin lifts under unfrozen conditions.
- September to October: Curtain Grouting – Grout hole drilling, water percolation tests, and grouting.
- October to November: Preparation for Construction – Development of material sources; construction of temporary warming shed at dam location; processing and stockpiling 20 mm minus and 150 mm minus material; preparation of the foundation upstream and downstream of key trench; key trench excavation.
- November to March: Dam Construction – GCL placement in the key trench, installation of ground temperature cables, placement of 20 mm minus in key trench, thermosyphon pipe installation, core construction, placement of downstream transition and shell materials.

- March to April: Ongoing Dam Construction – upstream GCL placement, upstream transition and run of mine placement, installation of thermosyphon radiators, vertical ground temperature cables and survey monitoring points, and demobilization and site cleanup.

4.4 CURTAIN GROUTING

The material and construction requirements for curtain grouting program are detailed in the Construction Specifications. It is required that the holes be grouted in September or early October when the annual thaw penetration is the deepest, the ground temperatures are warmer, and the air temperatures are still reasonably mild (not too cold) for grouting operations.

Preferably, the holes would be grouted to a pressure of 15 to 20 kPa per metre depth from the ground surface but not greater than the weight of overlying overburden/rock or lateral confining stresses at the abutments. Gravity grouting or tremie grouting is proposed for grouting the holes for this project for the following reasons:

- The target zone and hole depths are relatively shallow so that any benefit from increased grout pressures by using packers would be limited.
- Grouting using packers would make the grouting process much more complicated and time consuming.
- Sealing packers tightly in the overburden soil or shallow bedrock that is normally fractured would be challenging.
- The outside membrane surface of inflated packers may be frozen to the borehole wall due to sub-zero ground temperatures. Retrieving such packers would be difficult.

The gravity grouting method consists of drilling a hole to a final depth, washing the hole to clear cuttings, testing the overall hole water permeability, lowering a grout tremie pipe to the bottom of the hole, and pumping the grout through the pipe such that the grout is pushed from the hole bottom up to the ground surface. The maximum grouting pressure for this method is approximately equal to the total weight of the grout column above the location to be grouted. This grouting method is generally effective for cases where large, open voids exist and will take grout freely.

The purpose of the current curtain grouting program is to seal off any relatively large, open joints and fractures zones in the bedrock. Any small open joints that can not be grouted will be filled with water that will freeze, making them impermeable.

Cement grout mixes will be designed by the contractor and approved by the dam design team. The grout mixes should meet the requirements that the grout can be reasonably cured under ground temperatures of -2 to -5°C but without generating excess heat during the hydration stage. Excess heat may thaw existing ice-filled joints that could exist in the bedrock. An initial water-cement ratio of 3:1 by weight has been used in curtain grouting in bedrock for some dams in Canada and may be adopted as an initial water-cement ratio for the current grout program. In case of excess grout take under this initial ratio, the water-cement ratio can be lowered down to 2:1, 1:1, 0.8:1 or 0.5:1 by weight or a sanded grout mix used where viscosity in-place is desired.

4.5 FOUNDATION PREPARATION

The footprint under the upstream till berm, 20 mm minus and transition zones must be grubbed to remove loose or protruding boulders and loose, fractured bedrock fragments. Snow or ice or organic layers should also be removed prior to fill placement in the area.

The key trench will be excavated to ice-saturated frozen ground or competent bedrock so that the GCL liner system and core can be keyed into permanently frozen ground or competent bedrock to form an impermeable barrier. The width and depth of the key trench will vary along the axis of the dam. The key trench layout and proposed excavation depths are shown in Drawings ND-5 and ND-6. The actual required depth of the key trench will be determined prior to excavation based on the results and observations from the percolation tests and the grout program.

The key trench within till-covered areas can be excavated using conventional excavation methods. The key trench within bedrock areas will be excavated using controlled drill and blast techniques with removal of material by excavators and/or front end loaders. Blasting should be properly managed to limit damage to the bedrock outside and below the key trench. Loose frozen soil, fractured boulders and fractured bedrock, as well as protruding frozen ground, boulders or bedrock, must be removed to provide a relatively smooth key trench base. Additional excavation (blasting or mechanical) may be required to achieve a relatively smooth base.

Groundwater may be encountered during key trench excavation. Any inflow of ground water into the excavation must be controlled using sumps and pumps and be discharged into the PKCA upon approval from the Owner.

4.6 MOISTURE CONDITIONING OF EMBANKMENT MATERIALS

Granular material used for construction of the core, key trench, liner bedding and transition zones within the dam cross-sections will be processed from rock developed from mining operations. Processing will be required to achieve the specified gradations. Separate stockpiles of the different granular materials must be developed prior to the start of construction. The processed materials must be stockpiled as dry as possible to prevent any ice bonding of particles within the stockpile.

The 20 mm minus material used for the core and key trench must be placed in a nearly saturated condition. Water must be added to the 20 mm minus material to meet the target saturations, as specified in Section 4.7.2. The water must be heated to prevent freezing before placement in the key trench.

Moisture conditioning of the till fill may be required to achieve the specified density during the construction of the till berm within the upstream shell. The till fill should be placed and constructed in unfrozen conditions.

4.7 MATERIAL PLACEMENT

4.7.1 Till Fill

The till fill must be placed in lifts not exceeding 300 mm thickness and compacted with a smooth drum vibratory compactor weighing not less than 10 tonnes. Moisture conditioning may be required prior to compaction. The till material must be compacted with at least four passes of the compactor (back and forth being two passes). Rolling patterns must be used throughout construction to optimize the number of passes, amount of water added and vibration frequency for compacting the till material.

4.7.2 Core and Key Trench Backfill

Air temperatures during key trench and core construction shall be –15°C or colder. The moisture conditioned 20 mm minus material for the key trench and core must be trucked to the dam site and be placed and compacted before freezing occurs.

The 20 mm minus material shall have a minimum average degree of saturation of 85% with no results falling below 80%. The moisture content shall be adjusted so that the material shall become a nearly ice-saturated mass when frozen but no excessive water shall be available to form ice lenses. The established moisture content may be adjusted from time to time during construction based on results of the quality assurance tests. Compaction will be achieved by construction equipment traffic used to spread the material and a 10 tonne (minimum weight) vibratory, smooth drum compactor.

The first lift of 20 mm minus material placed in the key trench will serve as a bedding layer between the liner and the base of the key trench. The surface of the first lift should be levelled and smoothed to ensure the liner system has a level, even subgrade beneath it. Caution should be exercised to avoid damaging the liner and ground temperature cables during fill placement.

The core and key trench fill must be spread in lifts thin enough to freeze completely before the next lift is placed. Experience has shown that a typical lift thickness of 250 mm freezes in 24 hours when the air temperature is below -15°C. However, parameters such as mixing water content and temperature, surface cleaning and lift thickness should be optimized by controlled experimentation early in the construction season. These parameters may need to be periodically changed to suit varied weather conditions.

4.7.3 GCL Liner System

The GCL liner must be placed on smoothed core material and covered with bedding material. The liner panels must be overlapped a minimum of 0.5 m, and moisture conditioned bentonite paste placed along the seams.

4.7.4 Run-of-Mine Material

The run-of-mine rockfill material must be placed in lifts no thicker than 700 mm. Compaction of this material will be achieved by routing heavy equipment (bulldozers, haul trucks) evenly over each lift.

Run-of-mine material must be placed in a manner that will not cause segregation or nesting of coarse particles. The effectiveness of the construction technique will be evaluated in the field by the site engineer and changes to the construction procedure will be made as required. Boulders greater than 700 mm size should be bladed out of the fill and be wasted on the outside dam slopes.

4.7.5 150 mm Minus Transition Material

The 150 mm minus material must be placed in lifts not exceeding 400 mm in thickness. This material must be placed in a manner that will not cause segregation or nesting of coarse particles.

Compaction will be achieved by at least four passes with a smooth drum vibratory roller weighing 10 tonnes or more. It is anticipated that the number of passes, vibration frequency and volume of water required will be checked periodically throughout construction using a proof roll. The number of passes, vibration frequency and volume of water added should correspond to the point when deflection is not visible.

4.7.6 Liner Bedding Material

The coarse PK can be used as the upstream bedding material over the upper GCL above the key trench. Caution should be exercised to prevent damage to the GCL during the placement and compaction of the bedding material. The initial lift of the cover material shall be 300 mm in thickness and compacted to 90% of the maximum dry density (ASTM D698-91) or as specified by the Engineer to prevent damage to the GCL. The subsequent lifts should be placed in lifts not exceeding 300 mm in thickness and compacted to 95% of the maximum dry density (ASTM D698-91). The coarse PK should be placed and compacted in unfrozen conditions. Moisture conditioning may be required to achieve the specified level of compaction.

4.8 QUALITY ASSURANCE

The construction quality assurance program must be structured so that construction-sensitive features of the design are achieved. The elements of the program will include:

- Observation and approval of contractors' drilling, percolation testing and grouting operations for curtain grouting in the bedrock.
- Careful surveying to establish material quantities on a daily basis and allow preparation of as-built drawings.

- Specific quality control approvals at critical times such as key trench excavation, key trench backfill and superstructure fill placement.
- Monitoring and field testing of fill materials.
- Monitoring of fill mixing procedures.
- Specific approval of construction procedures for moisture conditioning and placement of all embankment materials.
- Daily field testing of the key trench and core fill to show complete lift freezeback and uniform distribution of moisture and density parameters.
- Observation and approval of contractors' proposed material placement sequences and preparation of surfaces below each lift placement.
- Periodic processing and evaluation of temperature data collected from ground temperature cables installed in the fill as part of long-term monitoring.
- Observation of GCL liner installation to ensure that design requirements are met.
- Defined procedures for reporting with identified responsibilities for decision-making during construction.
- Specific requirements and testing frequencies for the Quality Assurance process during construction are set out in the Construction Specifications.

5.0 LONG-TERM MONITORING

5.1 PURPOSE

Performance monitoring is an integral part of the operation of any water retention structure. This section describes a recommended monitoring program for the construction and operation for the North Dam.

The proposed monitoring program will serve the following three functions:

- Monitor the thermal regime of the dams,
- Monitor movements of the dam, and
- Satisfy regulatory requirements for dam performance monitoring.

Each of the components of the monitoring program is detailed in the following sections. The recommended instrumentation program for the North Dam is presented in the Construction Drawings.

5.2 THERMAL MONITORING

Six horizontal ground temperature cables will be installed in the key trench backfill and core of the dam to monitor the thermal regime in the core and key trench and thermal performance of the horizontal thermosyphons. Two vertical ground temperature cables will be installed through the centre of the core into the foundation bedrock to monitor the thermal regime of the core and its underlying foundation. The layouts and thermistor cable configurations of the horizontal and vertical ground temperature cables are presented in Drawing ND-8. The temperature cable installation requirements are presented in the Construction Specifications.

The ground temperature cables should be read on a monthly basis. The ground temperatures will be submitted to the NWB monthly and summarized in the annual geotechnical inspection report.

5.3 SURVEY MONITORING

Six survey monitoring points will be installed along the crest of the dam as shown in Construction Drawing ND-9. They will be used to monitor settlement or horizontal movements of the dam through its service life.

Each survey monitoring point shall consist of a steel rod with a steel plate attached to its bottom. The plate should be embedded 3.0 m in the shell material below the dam crest. The steel bar should be protected by a steel pipe buried in the shell material.

The survey monitoring points should be surveyed immediately upon completion of dam construction. The survey point elevations and coordinates should be surveyed on a monthly basis for the first two years of operation. Survey data should be reviewed by a geotechnical engineer until deformations are minor or at least until after the second filling of the reservoir. The monitoring schedule will be reviewed after that time to determine an appropriate schedule after that time. The settlement data will be reported in the annual geotechnical inspection report.

6.0 ANNUAL INSPECTION

An annual site inspection will be conducted by the design team to document the performance of each of the perimeter dams in the PKCA, including the North Dam. The Class "A" Water Licence requires at least one inspection be carried out annually in July by a Geotechnical Engineer. However, additional dam inspection may also be scheduled late September when the annual thaw depth is deepest and the water level in Cell C of the PKCA is low after the seasonal discharge, which permits inspection of the upstream slope and toe of the dams.

The specific tasks conducted during these visits include:

- Inspection of the upstream and downstream slopes for any sign of distress,
- Inspection of the dam crests for any sign of transverse cracking, and
- Inspection of the abutments and downstream toes for any evidence of seepage.

7.0 LIMITATIONS

The recommendations and design provided herein are based on the best available information at the time of their preparation. It is recommended that the construction of the North Dam be monitored by qualified personnel under the direction of an EBA geotechnical engineer. Construction changes which may or may not be required to field-fit the design should be approved by a qualified geotechnical engineer.

This report has been prepared in accordance with generally accepted geotechnical engineering practices for the exclusive use of the owner, Tahera Diamond Corporation, for their specific use at the Jericho Diamond Mine. No other warranty is made, either express or implied. Reference should be made to EBA's Geotechnical General Conditions (Appendix C) for further limitations.

8.0 CLOSURE

EBA trusts that this report satisfied your present requirements. Should you require any additional information, please contact us.

Respectfully submitted,
EBA Engineering Consultants Ltd.

REGISTERED PROFESSIONAL ENGINEER
G. ZHANG
LICENSEE
July 31, 07
NWT/NU

Guangwen (Gordon) Zhang, P.Eng.
Senior Project Engineer, Arctic Region
Direct Line: 780.451.2130 x501
gzhang@eba.ca

REGISTERED PROFESSIONAL ENGINEER
W. T. HORNE
LICENSEE
July 31, 2007
N.W.T.

THE ASSOCIATION OF
PROFESSIONAL ENGINEERS,
GEOLOGISTS and GEOPHYSICISTS
OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
July 31/07
P 018
EBA ENGINEERING
CONSULTANTS LTD.

Reviewed by:

Bill Horne, P.Eng.
Principal Consultant, Arctic Region
Direct Line: 780.451.2130 x276
bhorne@eba.ca

/jnc

REFERENCES

ACIA, 2004. Impacts of a Warming Arctic: Arctic Climate Impact Assessment. Cambridge University Press, 2004. 139 p., http://www.acia.uaf.edu.

CDA, 1999. Dam Safety Guidelines. Canadian Dam Association.

EBA, 2005. Jericho Project West Dam Design Report. Report submitted to Tahera Diamond Corporation by EBA Engineering Consultants Ltd., September 2005.

EBA, 2006. Jericho Project Processed Kimberlite Management Plan. Report submitted to Tahera Diamond Corporation by EBA Engineering Consultants Ltd., February 2006.

EBA, 2007a. North Dam Geotechnical Site Investigation, Jericho Diamond Mine, NU. Report submitted to Tahera Diamond Corporation by EBA Engineering Consultants Ltd., July 2007.

EBA, 2007b. Jericho Project North Dam Construction Specifications. Report submitted to Tahera Diamond Corporation by EBA Engineering Consultants Ltd., July 2007.

Environment Canada, 1982a. Canadian Climate Normals, Volume 5, Wind, 1951 - 1980, 283 pp.

Environment Canada, 1982b. Canadian Climate Normals, Volume 1, Solar Radiation, 1951 - 1980, 57 pp.

Environment Canada, 1993. Canadian Climate Normals, 1961-1990, Yukon and Northwest Territories, 58 pp.

Farouki, O.T., 1986. Thermal Properties of Soils. TransTech Publications, Germany, 136 p.

Haynes, F.D. and Zarling, J.P., 1988. Thermosyphons and foundation design in cold regions. Cold Regions Science and Technology, Vol. 15, pp. 251-259.

IPCC, 2000. Emissions Scenarios: A Special Report of the Intergovernmental Panel on Climate Change Working Group III, Nebojsa Nakicenovic and Rob Swart (eds.), Cambridge University Press, UK, 570 p.

Johnston, G.H. (Editor), 1981. Permafrost, Engineering Design and Construction. Wiley & Sons Toronto, 540 p.

Linsley, R.K. and Franzini, J.B., 1979. Water Resources Engineering, Third Ed., McGraw-Hill, Inc. 716 p.

Morgenstern, N.R., and Nixon, J.F., 1971. One Dimensional Thaw Consolidation of Thawing Soils. Can. Geotech. J. 10, pp. 25-40.

NRCan. 2003a. Natural Resource Canada's review of Tahera's Jericho Diamond Project Final Environmental Impact Statement, letter to Nunavut Impact Review Board dated May 12, 2003.a

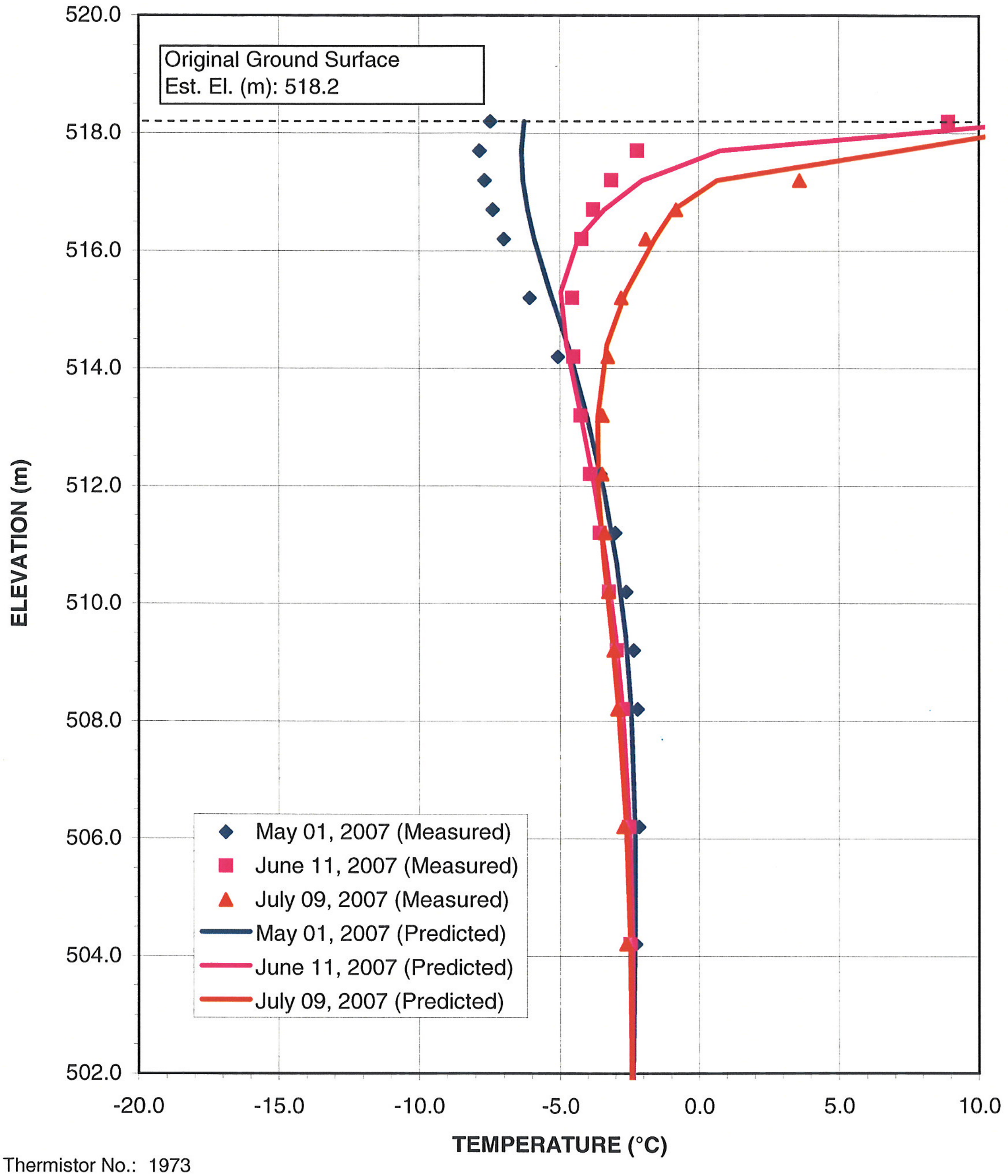
NRCan. 2003b. Seismic Hazard Analysis for Contwoyto Lake, Nunavut, prepared by Alison Bird.

Weaver, J.S., and Morgenstern, N.R. 1981. Pile Design in Permafrost. Canadian Geotechnical Journal, Vol. 18, pp. 357-370.

Yarmak, Jr., E., and Long, E.L., 2002. Recent developments in thermosyhon technology. Proceedings of the 11th International Conference on Cold Regions Engineering, Anchorage, Alaska, May 2002, pp. 656-662.

Zornberg, Jorge G., McCartney, S.M., Swan, Robert H., Jr.. 2005Analysis of a Large Database of GCL Internal Shear Strength Results. Journal of Geotechnical and Geoenvironmental Engineering © ASCE, March 2005, pp. 367-380.

FIGURES



Thermistor No.: 1973
Date Installed: 2007-02-19

Figure 1
Comparison of Measured and Predicted Ground Temperature Profiles at Borehole ND-BH-2 (GTC # 1973)
North Dam

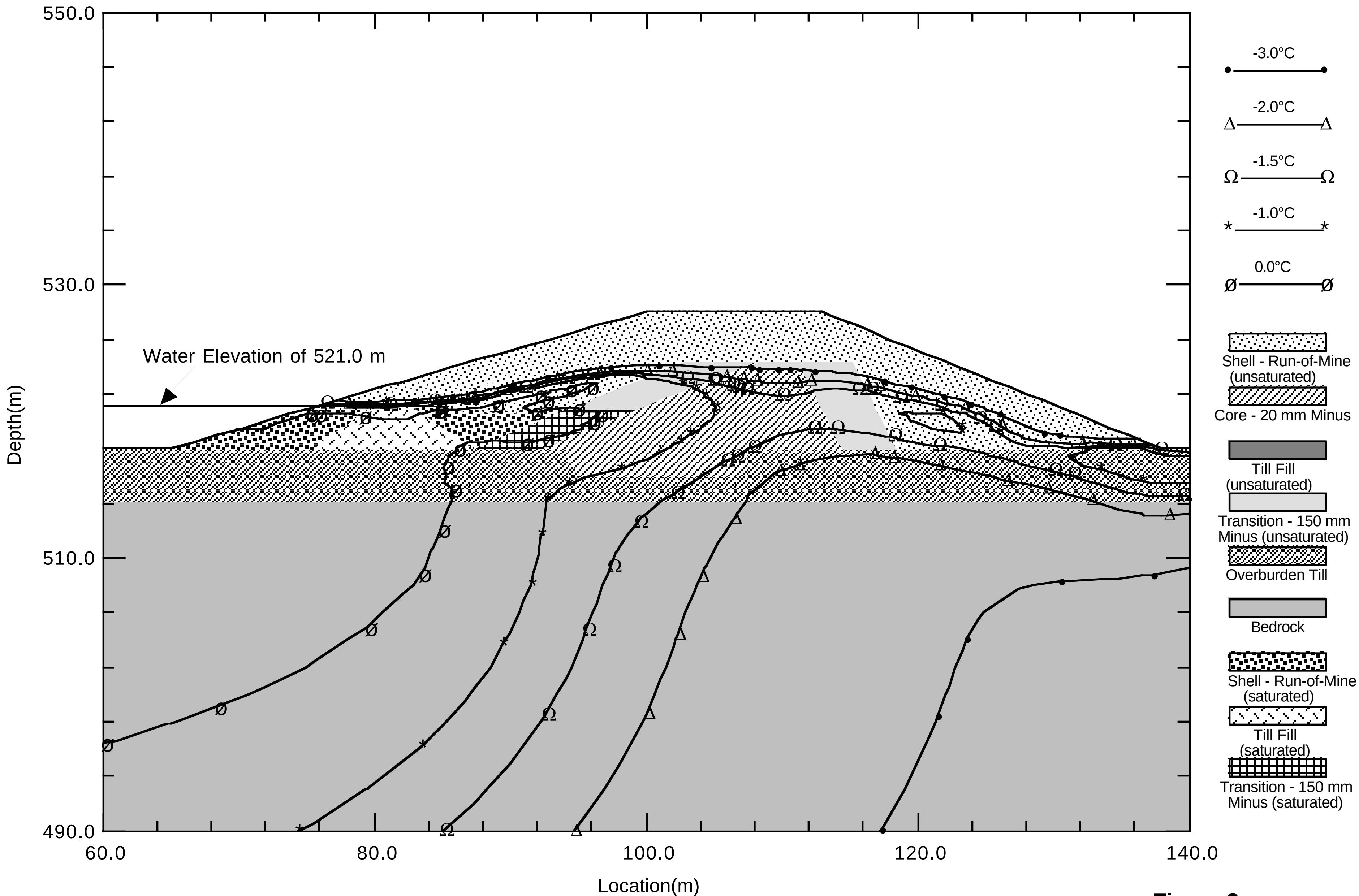


Figure 2

Predicted Isotherms in End January of 2009
North Dam without Thermosyphons under Mean Climatic Conditions

2D_ND_Jun01_2008 (Time Step 268)

Figure2_ND_1100060d013

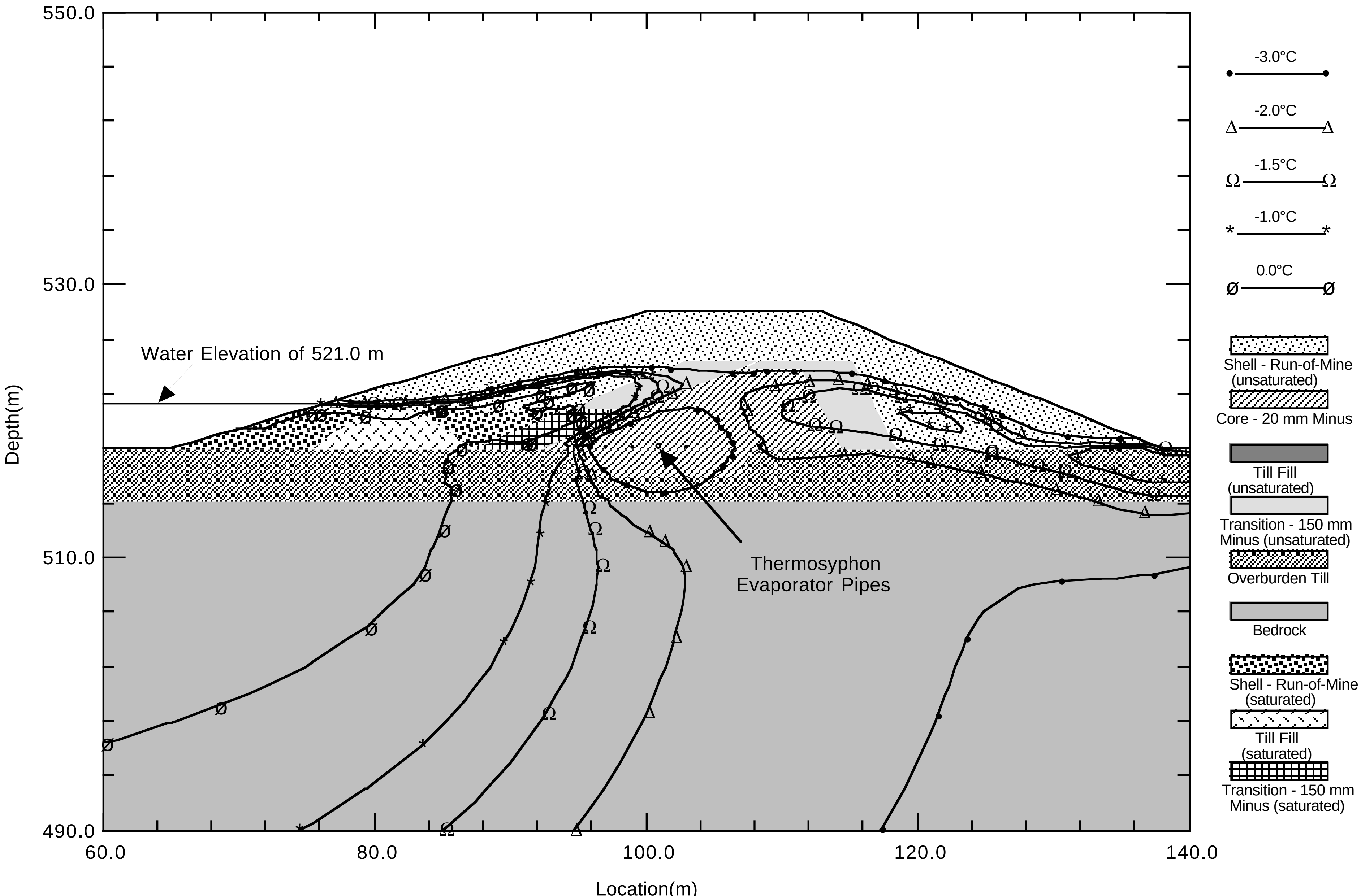


Figure 3

Predicted Isotherms in End January of 2009

North Dam with Operation of Thermosyphons after June 2008 under Mean Climatic Conditions

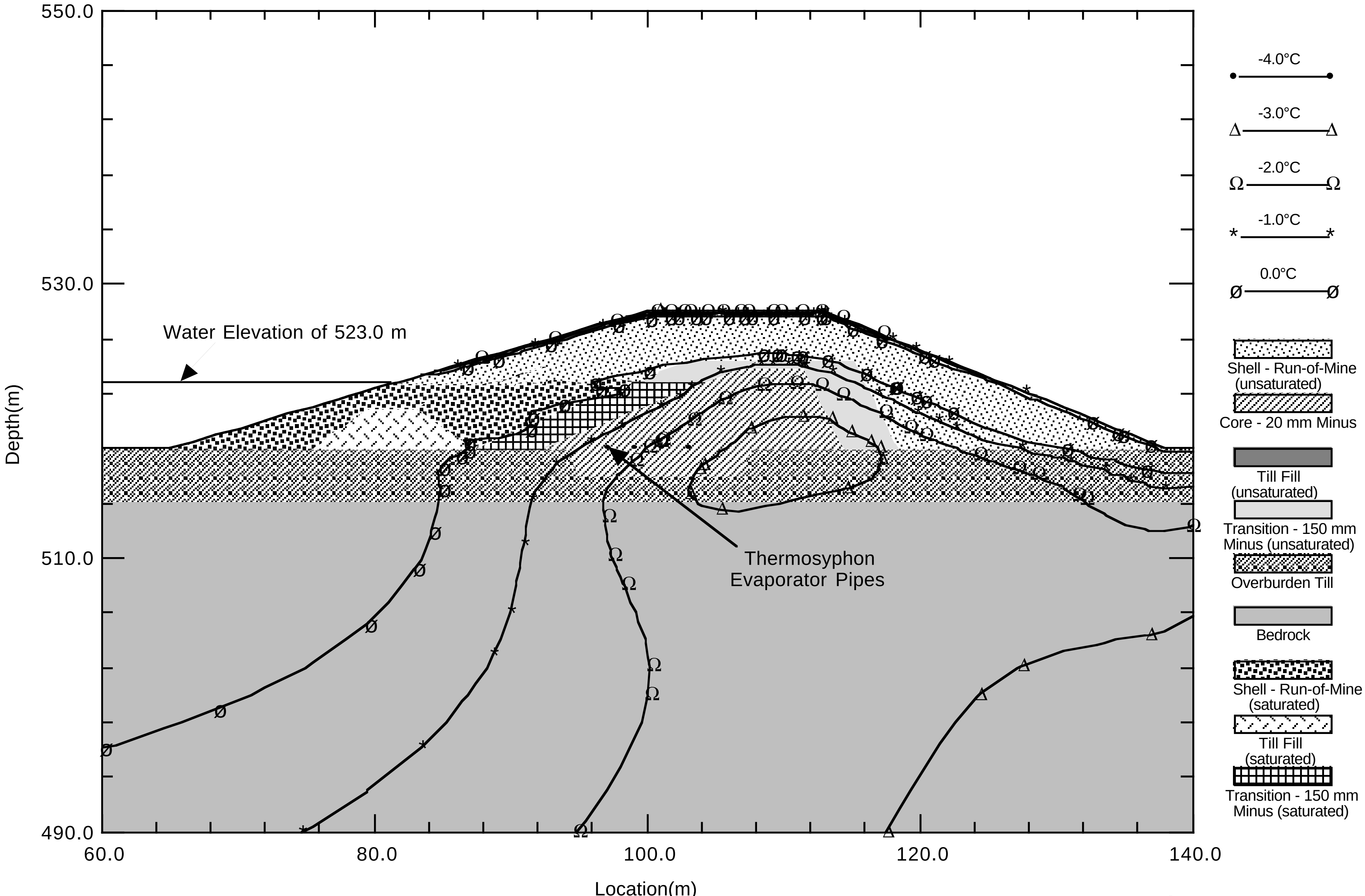


Figure 4

Predicted Isotherms in Early October of 2009
North Dam with Operation of Thermosyphons after June 2008 under Mean Climatic Conditions

2D_ND_Jun01_09_TS_M (Time Step 146)

Figure4_ND_1100060d013

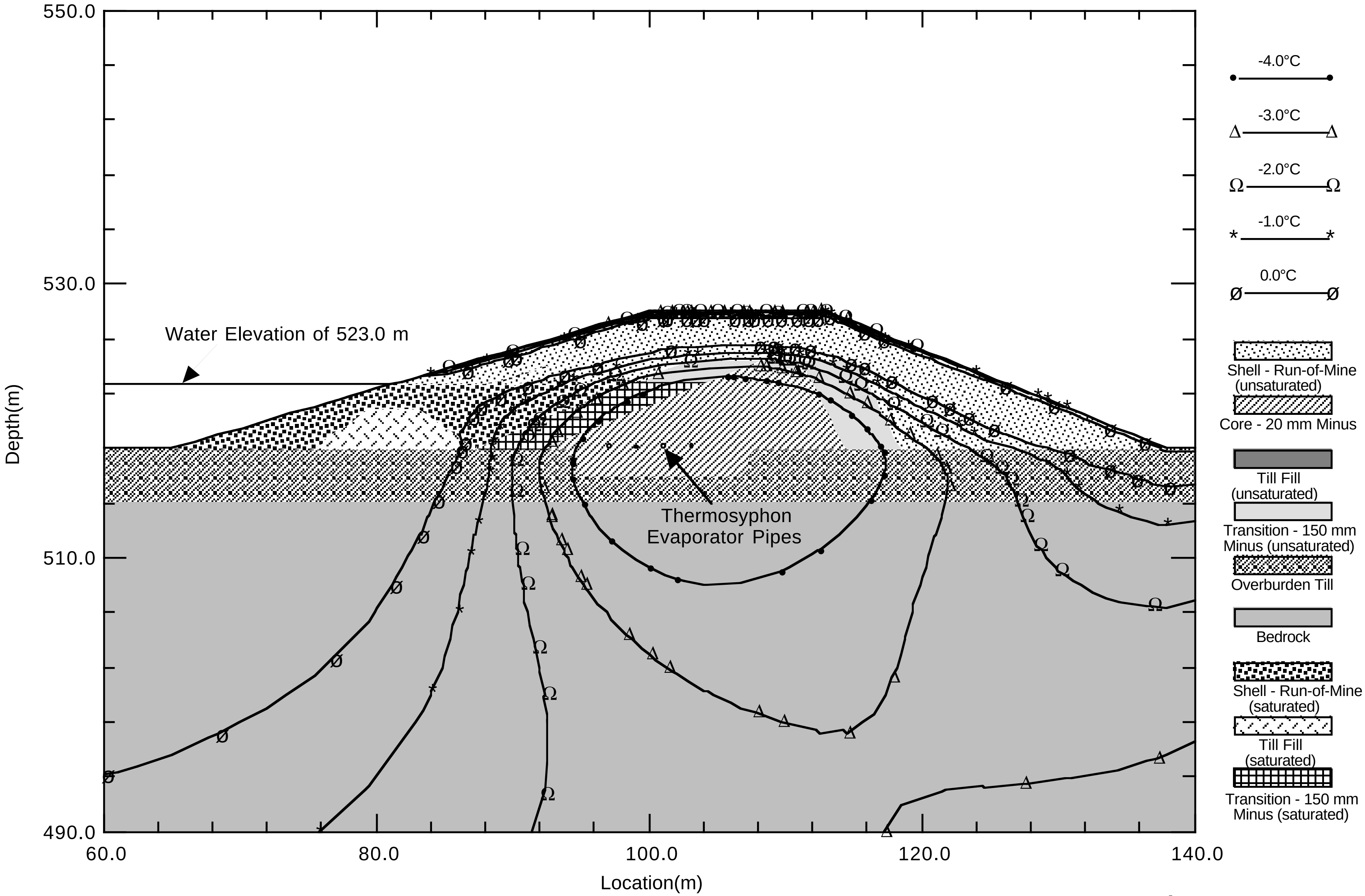


Figure 5

Predicted Isotherms in Early October of 2014

North Dam with Operation of Thermosyphons after June 2008 under Mean Climatic Conditions

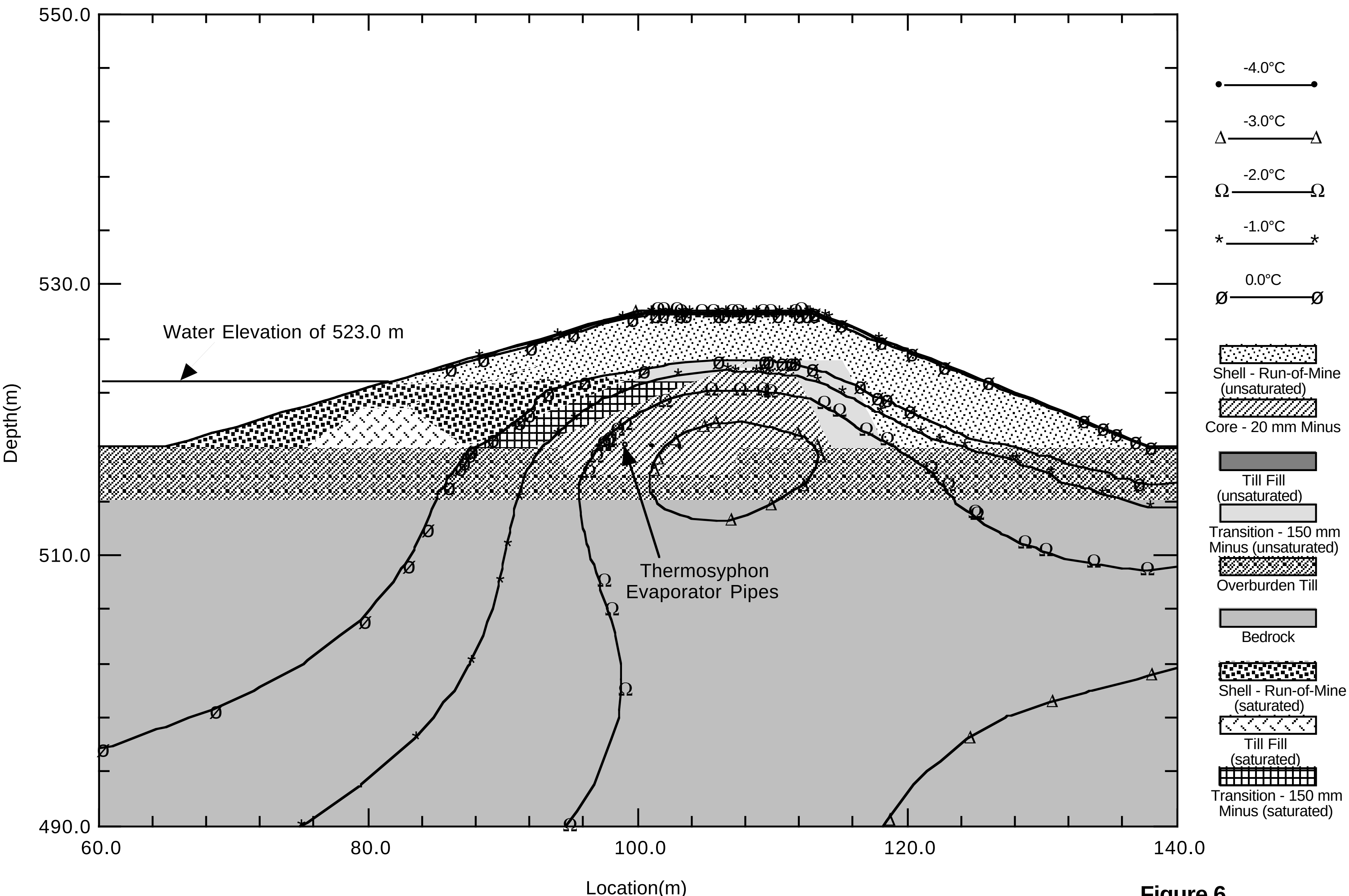


Figure 6

Predicted Isotherms in Early October of 2010
North Dam with Operation of Thermosyphons after June 2008 under Two Consecutive 1:100 Warm Years

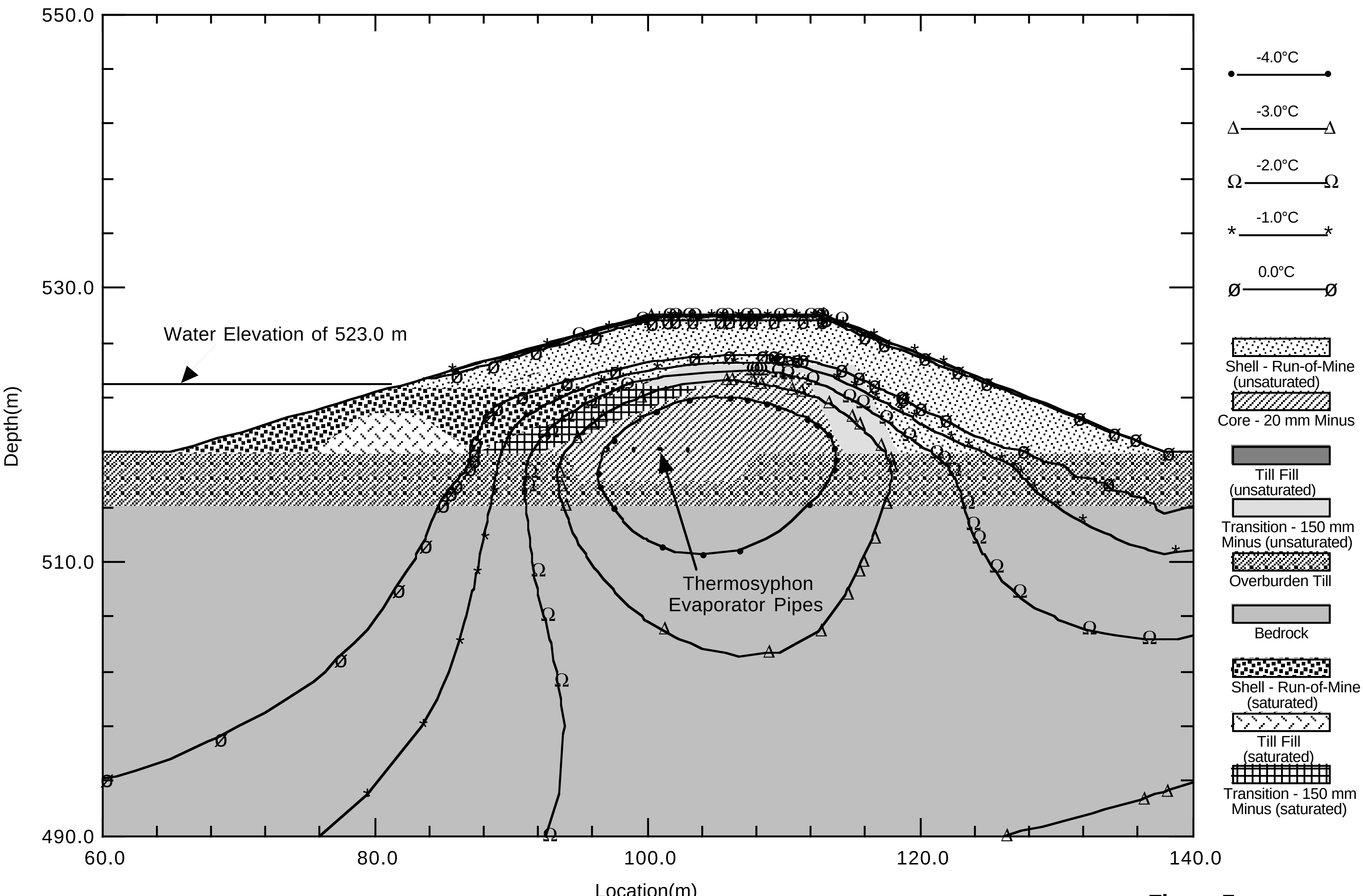


Figure 7

Predicted Isotherms in Early October of 2014
North Dam with Operation of Thermosyphons after June 2008 under GCM's Climate Change Trend

2D_ND_Jun01_09_TS_GW (Time Step 1974)

Figure7_ND_1100060d013

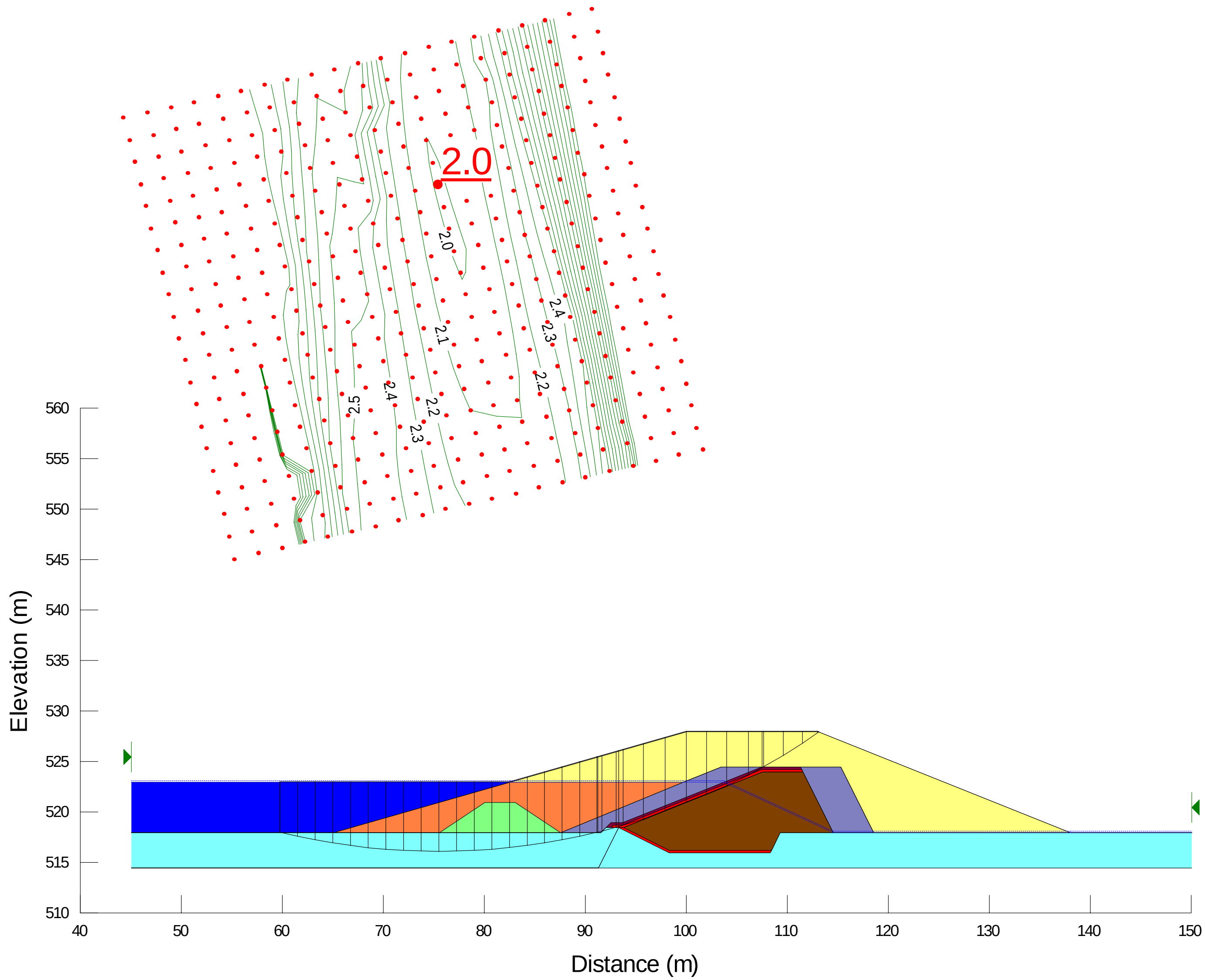


Figure 8

Stability Analysis - Upstream, Static, Effective Stress for Foundation Till

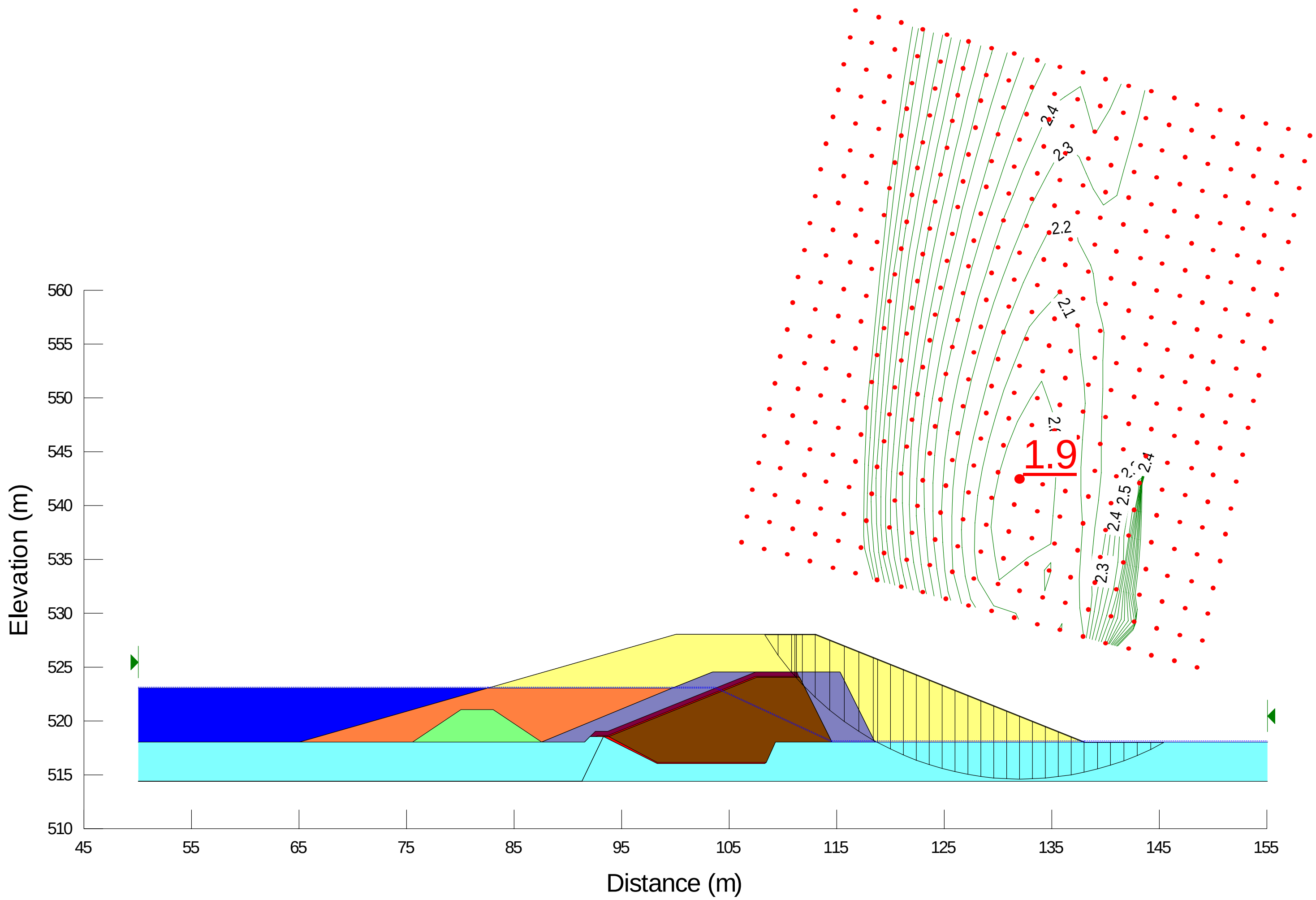


Figure 9

Stability Analysis - Downstream, Static, Effective Stress for Foundation Till

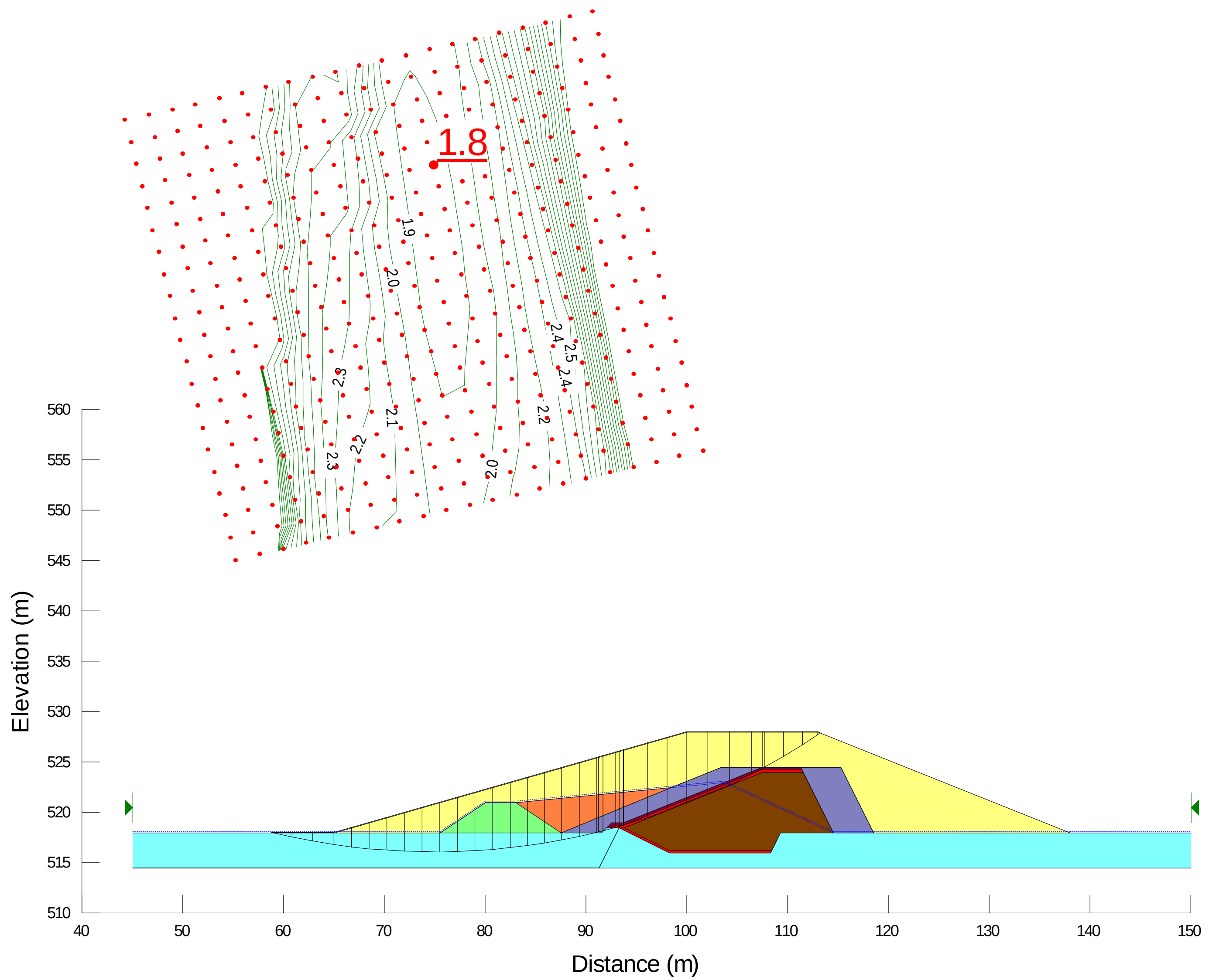


Figure 10

Stability Analysis - Upstream, Static, Rapid Drawdown of Reservoir, Effective Stress for Foundation Till

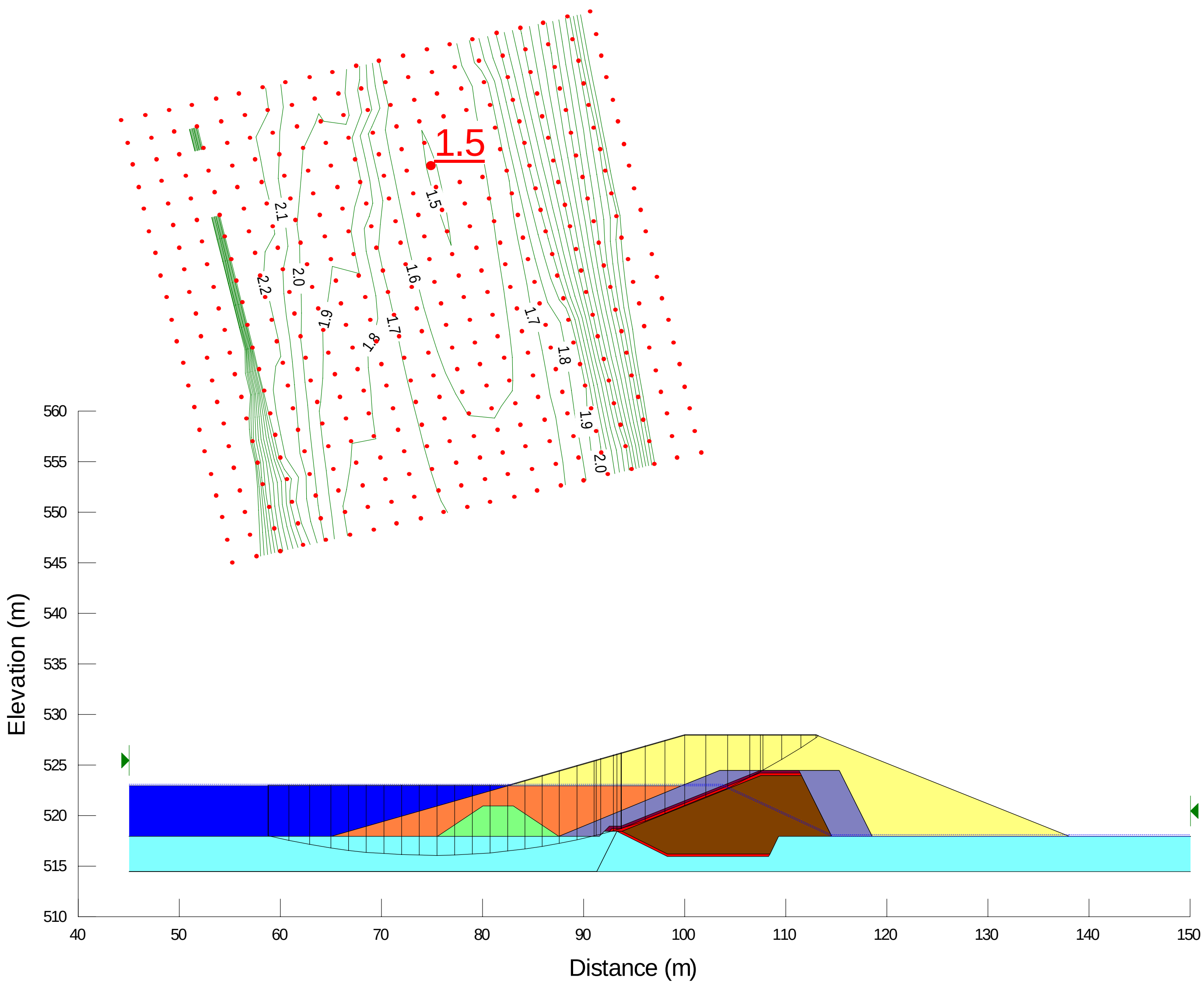


Figure 11

Stability Analysis - Upstream, Seismic, Effective Stress for Foundation Till

APPENDIX

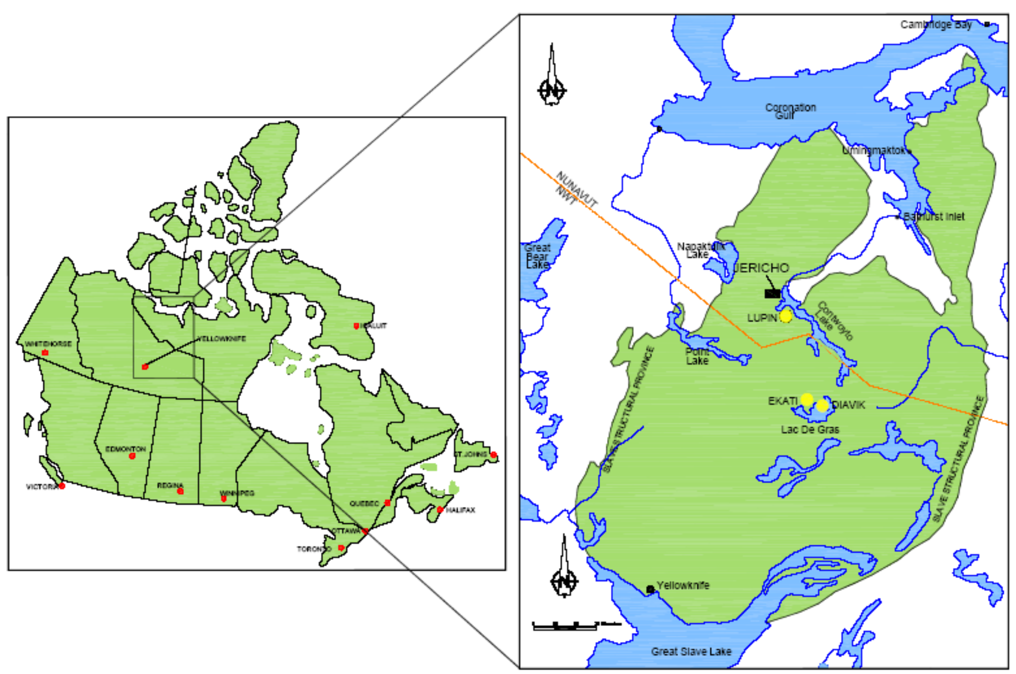
APPENDIX A CONSTRUCTION DRAWINGS

TAHERA Diamond Corporation

JERICHO PROJECT

NORTH DAM

CONSTRUCTION DRAWINGS



LOCATION PLAN

DRAWING LIST

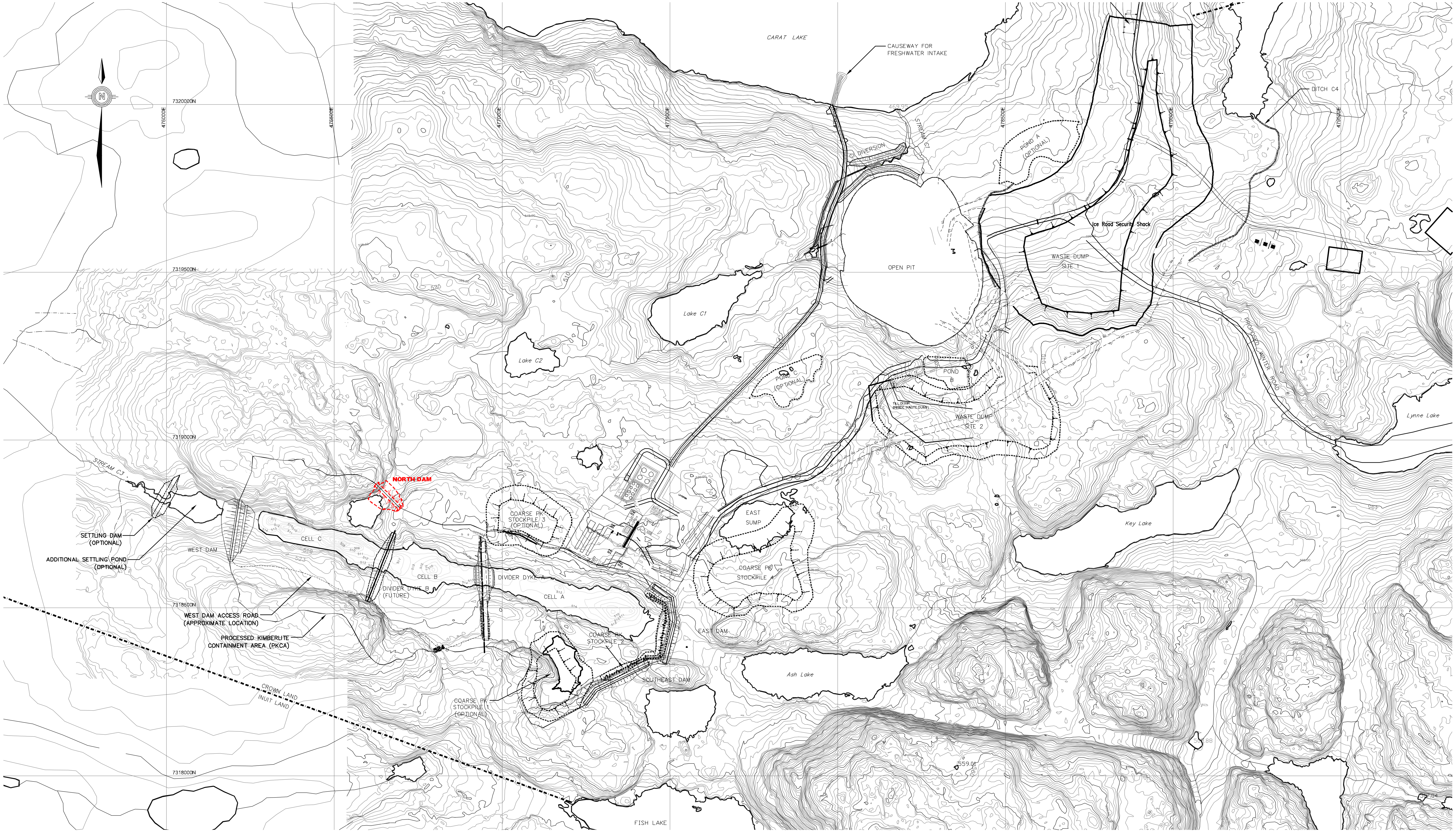
DRAWING	DRAWING TITLE
ND–1	JERICHO MINE REGIONAL PLAN
ND–2	NORTH DAM SURFICIAL GEOLOGY
ND–3	NORTH DAM PLAN VIEW
ND–4	NORTH DAM TYPICAL CROSS SECTIONS
ND–5	NORTH DAM KEY TRENCH LOCATION PLAN
ND–6	NORTH DAM PROFILES
ND–7	NORTH DAM SECTIONS
ND–8	NORTH DAM GROUND TEMPERATURE CABLE LAYOUT PLAN AND DETAILS
ND–9	NORTH DAM SURVEY MONITORING POINT LAYOUT PLAN AND DETAILS
ND–10	NORTH DAM THERMOSYPHON LAYOUT PLAN AND DETAILS
ND–11	NORTH DAM GROUT CURTAIN HOLE LOCATION PLAN AND PROFILE

JULY 2007

EBA ENGINEERING
CONSULTANTS LTD.

CONSULTANTS REFERENCE NO.: 1100060.013

ACAD FILENAME: 1100060013Q00a.dwg



REDUCED COPY

- Do Not Scale -

0 250

Scale: (metres)

DRAWING No.	DRAWING TITLE	DATE	REV
REFERENCE DRAWINGS			

No.	DESCRIPTION	DATE	APPROVED
0	ISSUED FOR CONSTRUCTION	JULY 31/07	GZ
A	ISSUED FOR REVIEW	JULY 24/07	GZ
REVISION			

CLIENT

TAHERA
Diamond Corporation

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 018
EBA ENGINEERING CONSULTANTS LTD.

PERMIT

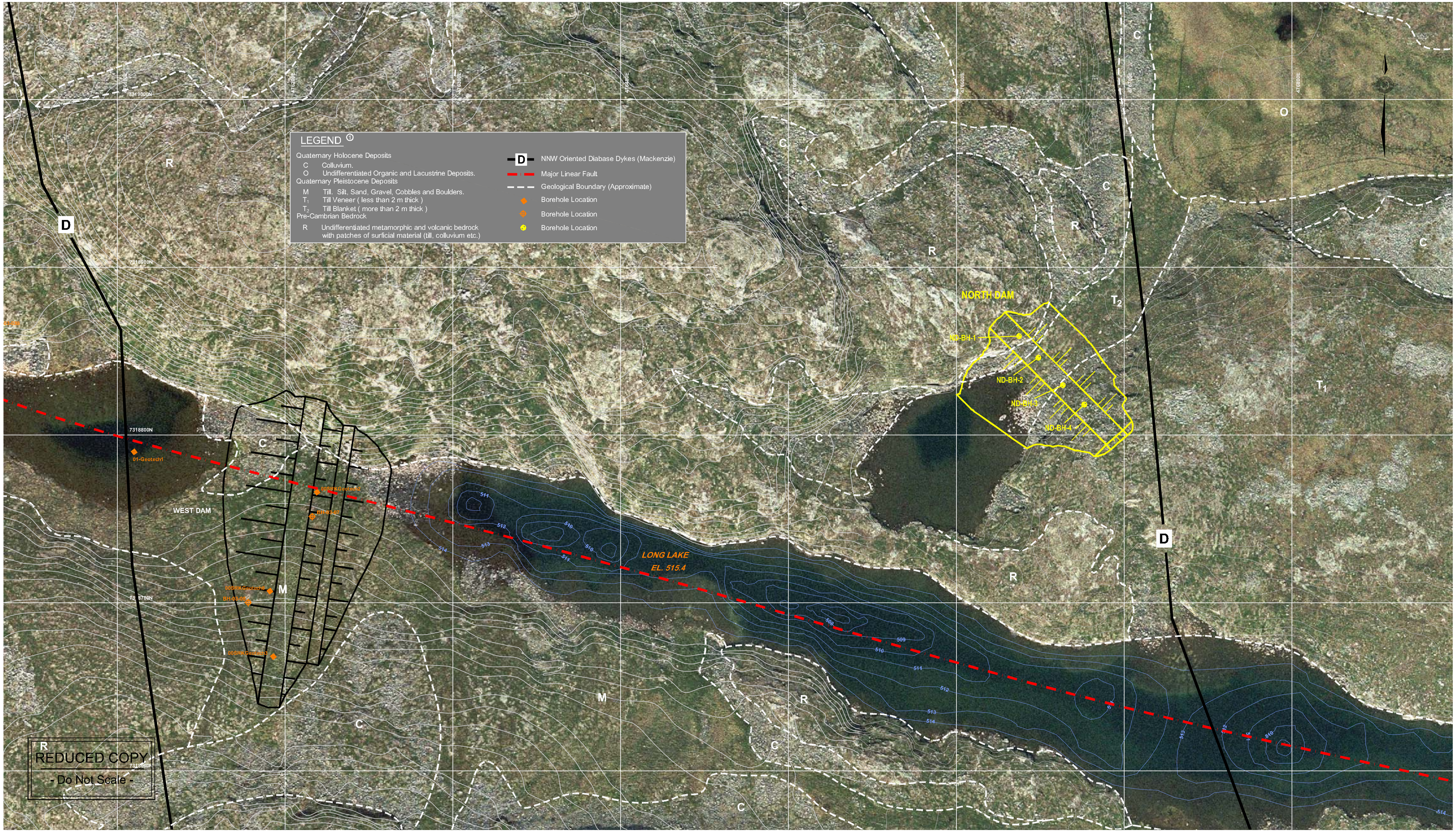
PROFESSIONAL SEAL

EBA Engineering Consultants Ltd.

Tahera Diamond Corporation
Jericho Project

Jericho Mine
Regional Plan

PROJECT NO./FILE NO.	DWN	CKD	REV	DRAWING NO.
1100060.013 1100060013Q01d.dwg	DBD	GZ	0	ND-1
OFFICE	DATE			
EBA-EDM	July, 2007			



① NOTE:
TILL THICKNESS BASED ON SURFACE EXPRESSIONS AND ARE ONLY APPROXIMATE. THICKNESSES NOT TO BE RELIED UPON FOR CONSTRUCTION.

0 50
Scale: 1: 1000 (metres)

DRAWING No.	DRAWING TITLE	DATE	REV

REFERENCE DRAWINGS

No.	DESCRIPTION	DATE	APPROVED
0	ISSUED FOR CONSTRUCTION	JULY 31/07	GZ
A	ISSUED FOR REVIEW	JULY 24/07	GZ

REVISION

CLIENT

TAHERA
Diamond Corporation

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 018
EBA ENGINEERING CONSULTANTS LTD.

PERMIT

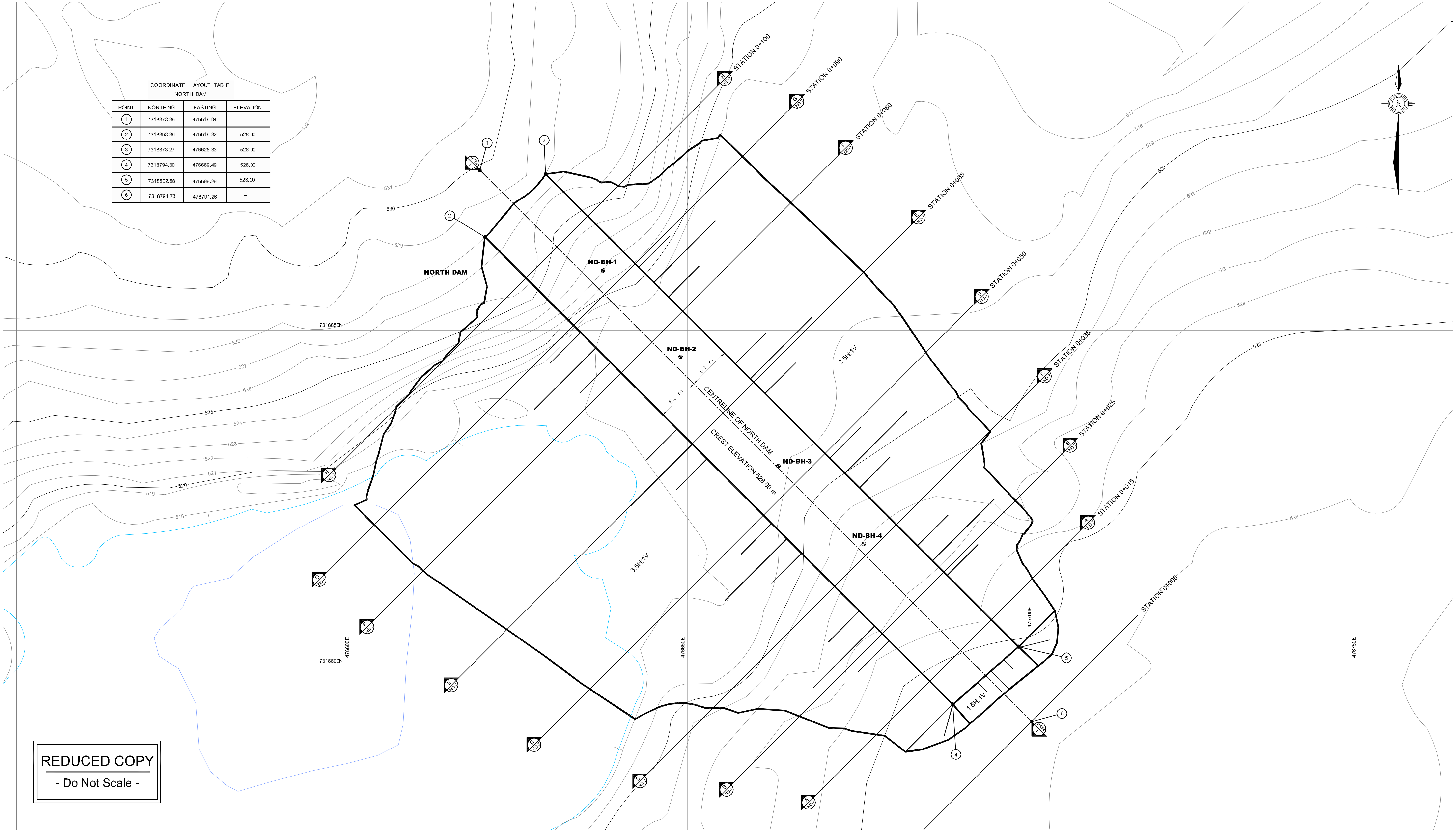
PROFESSIONAL SEAL

EBA Engineering Consultants Ltd.

TAHERA Diamond Corporation
Jericho Project

North Dam
Surficial Geology

PROJECT NO./FILE NO.	DWN	CKD	REV	DRAWING NO.
1100060.013 1100060013Q02d.dwg	DBD	GZ	0	ND-2
OFFICE	DATE			
EBA-EDM	July, 2007			



COORDINATE LAYOUT TABLE
NORTH DAM

POINT	NORTHING	EASTING	ELEVATION
1	7318873.86	476619.04	--
2	7318863.89	476619.82	528.00
3	7318873.27	476628.83	528.00
4	7318794.30	476689.49	528.00
5	7318802.88	476699.29	528.00
6	7318791.73	476701.26	--

REDUCED COPY
- Do Not Scale -

LEGEND:
– BOREHOLE LOCATION

Scale: 1: 250 (metres)

No.	DESCRIPTION	DATE	APPROVED
0	ISSUED FOR CONSTRUCTION	JULY 31/07	GZ
A	ISSUED FOR REVIEW	JULY 24/07	GZ

REVISION

DRAWING No.	DRAWING TITLE	DATE	REV

REFERENCE DRAWINGS

CLIENT
TAHERA
Diamond Corporation

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 018
EBA ENGINEERING CONSULTANTS LTD.

PERMIT

PROFESSIONAL SEAL

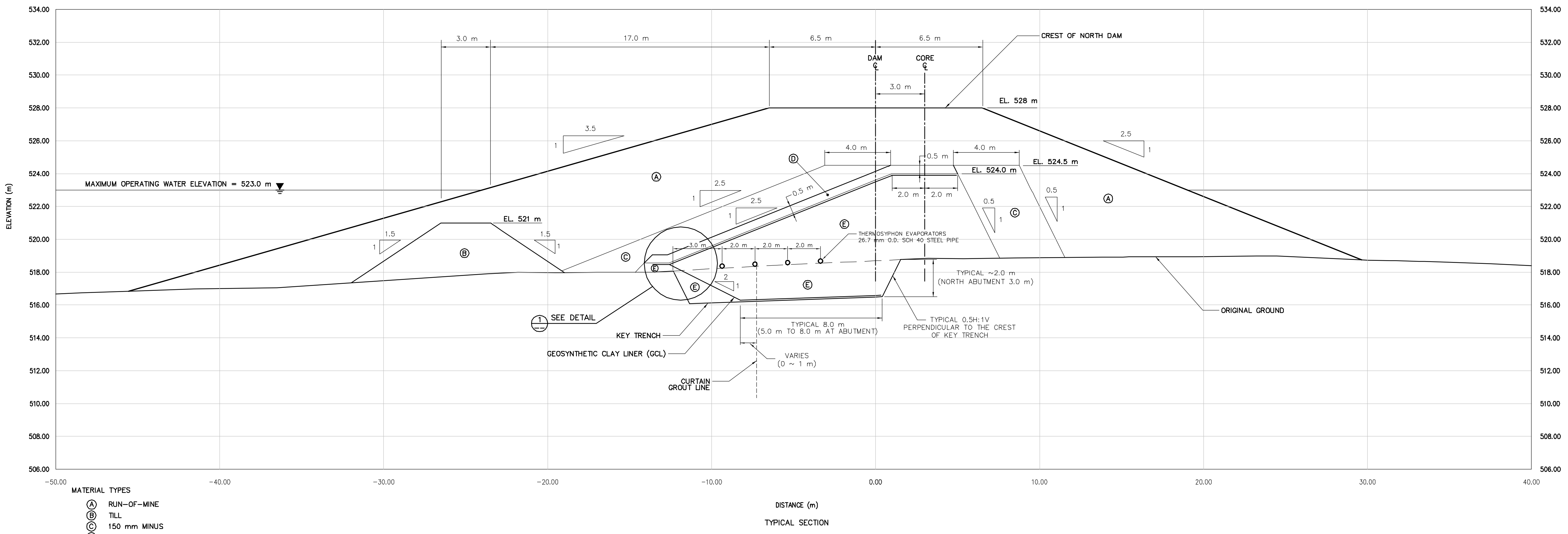
EBA Engineering Consultants Ltd.

TAHERA Diamond Corporation
Jericho Project

North Dam
Plan View

PROJECT NO./FILE NO.	DWN	CKD	REV	DRAWING NO.
1100060.013 1100060013Q03e.dwg	DBD	GZ	0	ND-3

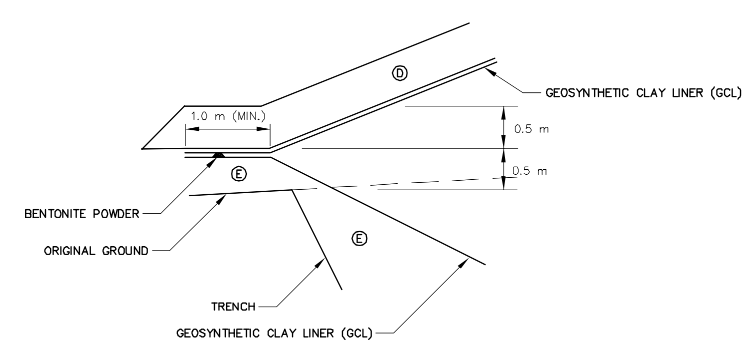
OFFICE	DATE
EBA-EDM	July, 2007



MATERIAL TYPES

- Ⓐ RUN-OF-MINE
- Ⓑ TILL
- Ⓒ 150 mm MINUS
- Ⓓ COARSE PK
- Ⓔ 20 mm MINUS

0 10
Scale (metres)



GEOSYNTHETIC CLAY LINER OVERLAP – DETAIL 1
N.T.S.

REDUCED COPY
- Do Not Scale -

DRAWING No.	DRAWING TITLE	DATE	REV

REFERENCE DRAWINGS

No.	DESCRIPTION	DATE	APPROVED
0	ISSUED FOR CONSTRUCTION	JULY 31/07	GZ
A	ISSUED FOR REVIEW	JULY 24/07	GZ

REVISION

CLIENT
TAHERA
Diamond Corporation

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 018
EBA ENGINEERING CONSULTANTS LTD.
PERMIT

PROFESSIONAL SEAL

EBA Engineering Consultants Ltd.

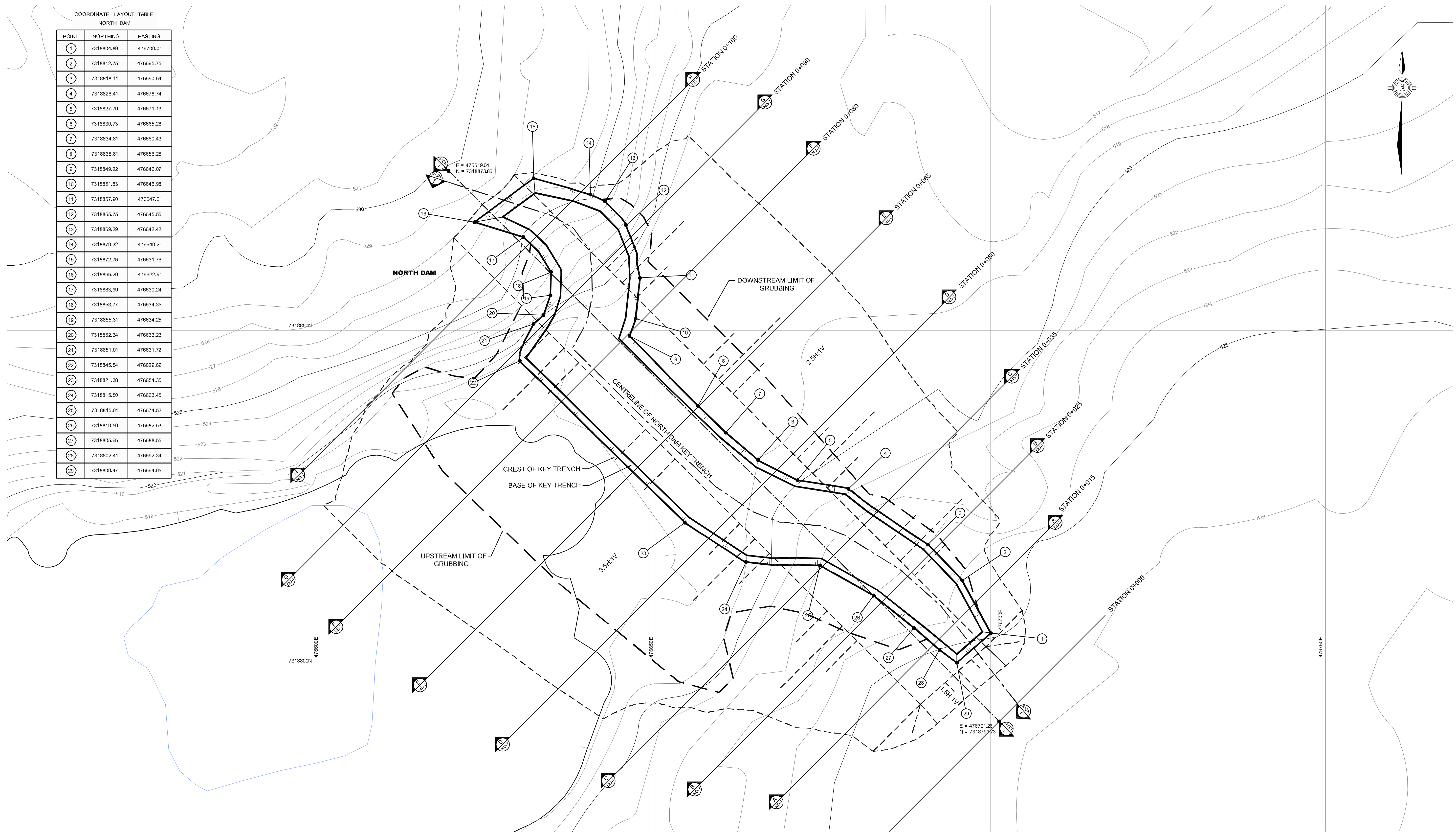
TAHERA Diamond Corporation
Jericho Project

North Dam
Typical Cross-Sections

PROJECT NO./FILE NO.	DWN	CKD	REV	DRAWING NO.
1100060.013 1100060013Q04e.dwg	DBD	GZ	0	ND-4
OFFICE: EBA-EDM	DATE: July, 2007			

COORDINATE LAYOUT TABLE
NORTH DAM

POINT	NORTHING	EASTING
1	7318804.89	476700.01
2	7318812.75	476695.75
3	7318818.11	476690.64
4	7318826.41	476678.74
5	7318827.70	476671.13
6	7318830.73	476665.26
7	7318834.81	476660.43
8	7318838.81	476656.28
9	7318849.22	476646.07
10	7318851.83	476646.98
11	7318857.90	476647.61
12	7318865.75	476645.55
13	7318869.29	476642.42
14	7318870.32	476640.21
15	7318872.76	476631.76
16	7318866.20	476622.91
17	7318863.99	476630.24
18	7318858.77	476634.35
19	7318855.31	476634.25
20	7318852.34	476633.23
21	7318851.01	476631.72
22	7318845.54	476629.69
23	7318821.38	476654.35
24	7318815.50	476663.45
25	7318815.01	476674.52
26	7318810.50	476682.53
27	7318805.66	476688.55
28	7318802.41	476692.34
29	7318800.47	476694.95



REDUCED COPY
- Do Not Scale -

Scale: 1: 250 (metres)

DRAWING No.	DRAWING TITLE	DATE	REV

REFERENCE DRAWINGS

No.	DESCRIPTION	DATE	APPROVED
0	ISSUED FOR CONSTRUCTION	JULY 31/07	GZ
A	ISSUED FOR REVIEW	JULY 24/07	GZ

REVISION

CLIENT

TAHERA
Diamond Corporation

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 018
EBA ENGINEERING CONSULTANTS LTD.

PERMIT

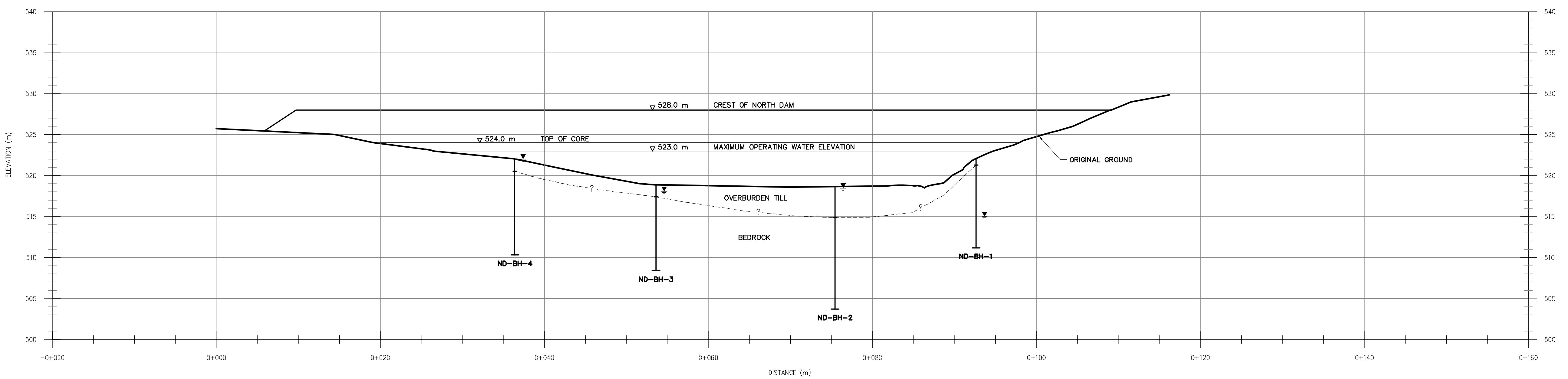
PROFESSIONAL SEAL

EBA Engineering Consultants Ltd.

TAHERA Diamond Corporation
Jericho Project

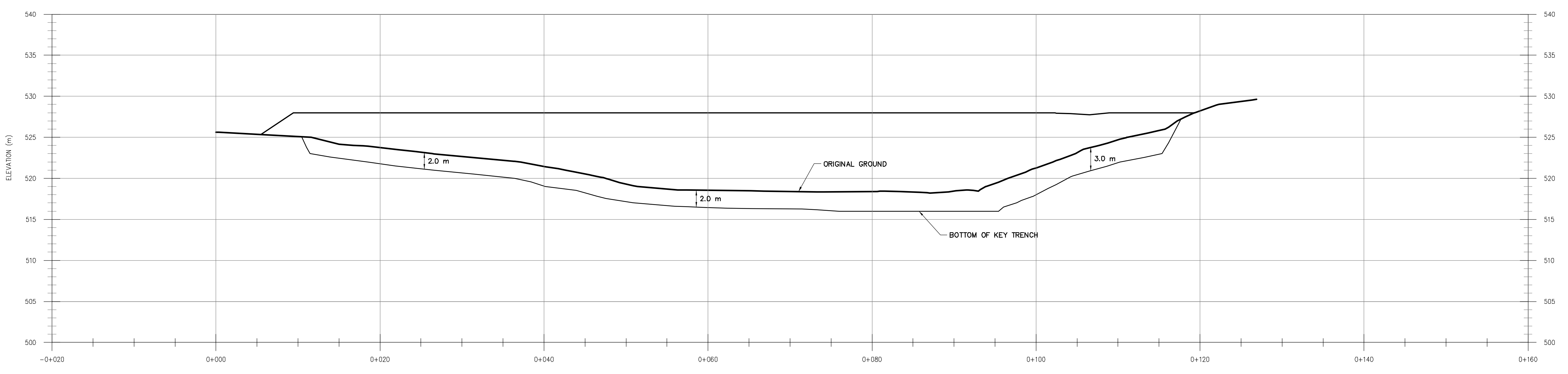
North Dam
Key Trench Location Plan

PROJECT NO./FILE NO.	DWN	CKD	REV	DRAWING NO.
1100060.013 1100060013Q05e.dwg	DBD	GZ	0	ND-5
OFFICE: EBA-EDM	DATE: July, 2007			



SECTION I / ND-3

DAM CENTRELINE PROFILE



SECTION J / ND-5

KEY TRENCH CENTRELINE PROFILE

LEGEND:
▼ – STABILIZED WATER ELEVATION DURING PERCOLATION TEST IN SITE INVESTIGATION

REDUCED COPY
- Do Not Scale -

DRAWING No.	DRAWING TITLE	DATE	REV
REFERENCE DRAWINGS			

No.	DESCRIPTION	DATE	APPROVED
0	ISSUED FOR CONSTRUCTION	JULY 31/07	GZ
A	ISSUED FOR REVIEW	JULY 24/07	GZ
REVISION			

CLIENT

TAHERA
Diamond Corporation

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 018
EBA ENGINEERING CONSULTANTS LTD.

PERMIT

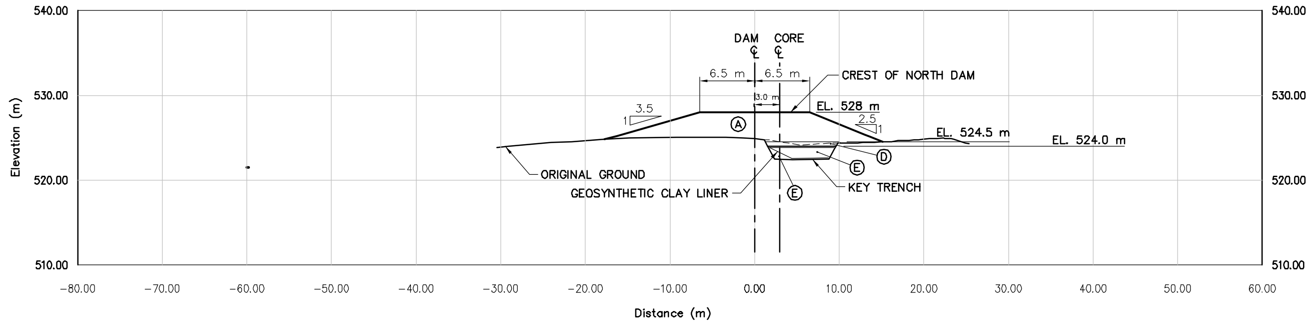
PROFESSIONAL SEAL

EBA Engineering Consultants Ltd.

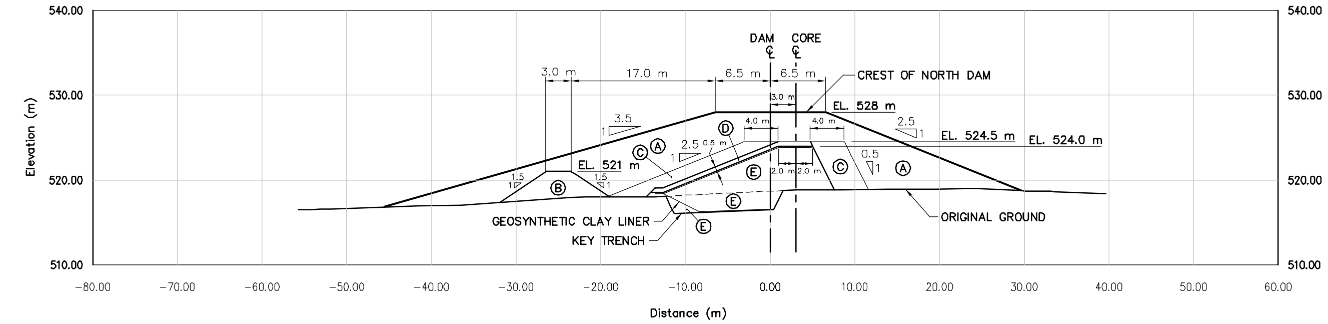
TAHERA Diamond Corporation
Jericho Project

North Dam
Profiles

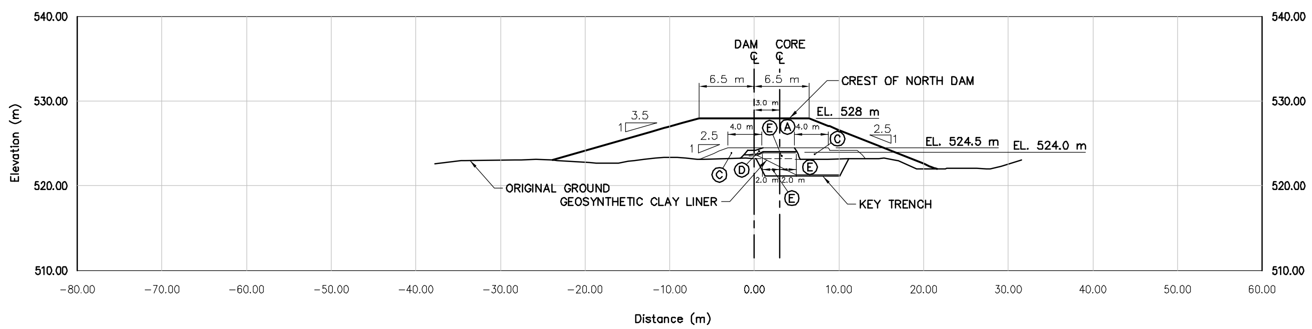
PROJECT NO./FILE NO.	DWN	CKD	REV	DRAWING NO.
1100060.013 1100060013Q06d.dwg	DBD	GZ	0	ND-6
OFFICE: EBA-EDM	DATE: July, 2007			



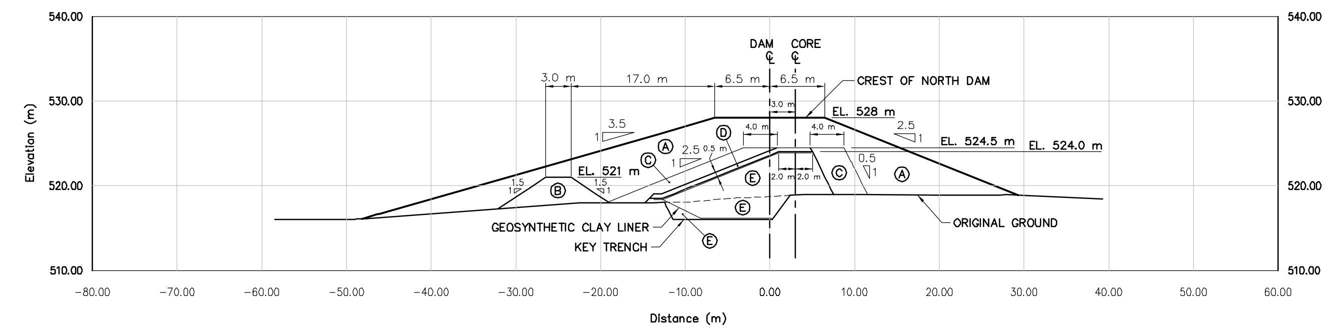
SECTION A ND-3



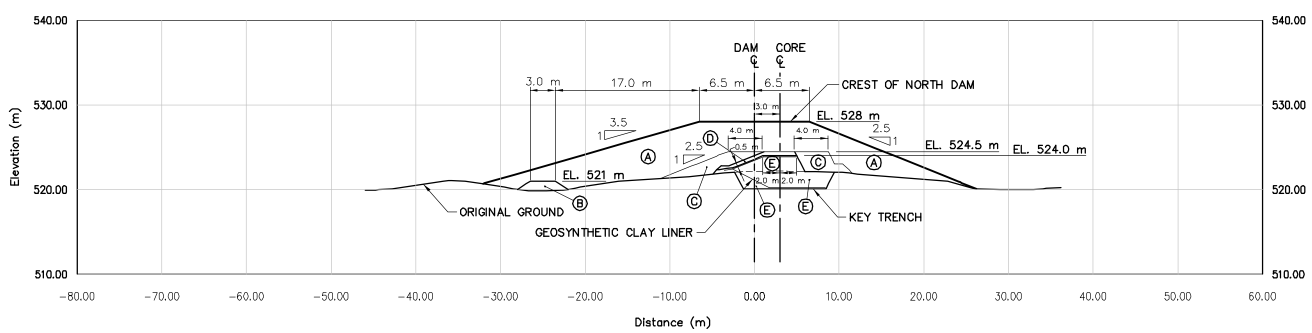
SECTION E ND-3



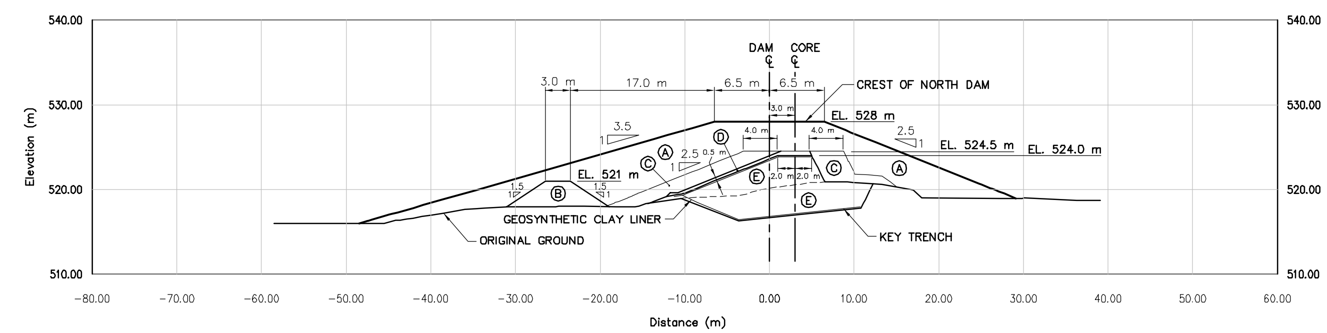
SECTION B ND-3



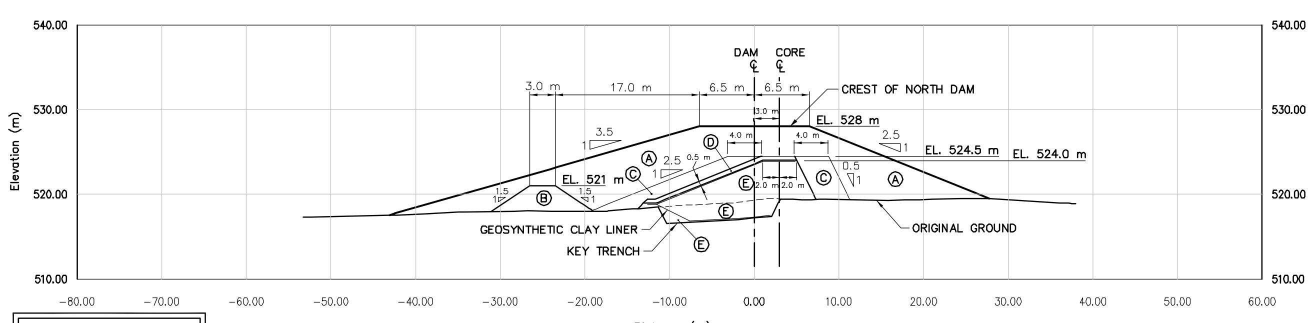
SECTION F ND-3



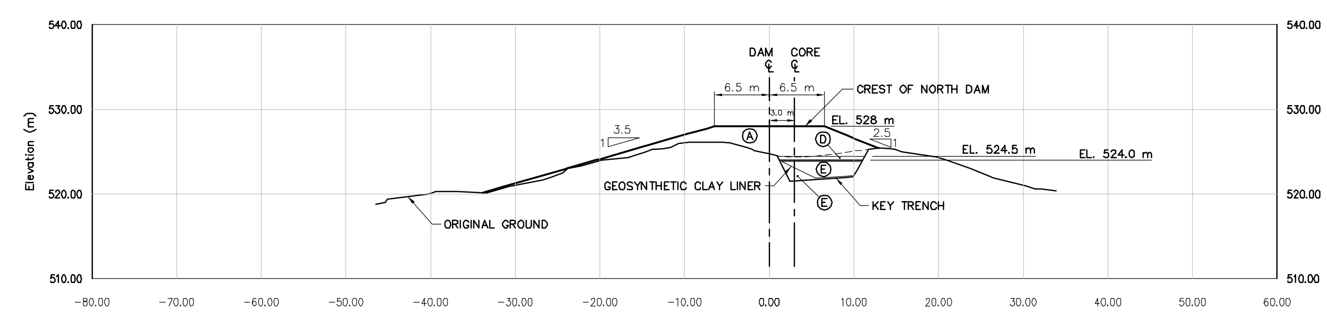
SECTION C ND-3



SECTION G ND-3



SECTION D ND-3



SECTION H ND-3

REDUCED COPY
- Do Not Scale -

MATERIAL TYPES

- Ⓐ RUN-OF-MINE
- Ⓑ TILL
- Ⓒ 150 mm MINUS
- Ⓓ COARSE PK
- Ⓔ 20 mm MINUS

NOTE:
GROUND TEMPERATURE CABLES, SURVEY MONITORING POINTS, THERMOSYPHONS, AND GROUT CURTAIN HOLES ARE NOT SHOWN FOR CLARITY. THE LAYOUTS AND DETAILS FOR THESE ELEMENTS ARE SHOWN ON CONSTRUCTION DRAWINGS ND-8 TO ND-11

REFERENCE DRAWINGS

DRAWING No.	DRAWING TITLE	DATE	REV

REVISION

No.	DESCRIPTION	DATE	APPROVED
0	ISSUED FOR CONSTRUCTION	JULY 31/07	GZ
A	ISSUED FOR REVIEW	JULY 24/07	GZ

CLIENT

TAHERA
Diamond Corporation

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 018
EBA ENGINEERING CONSULTANTS LTD.

PERMIT

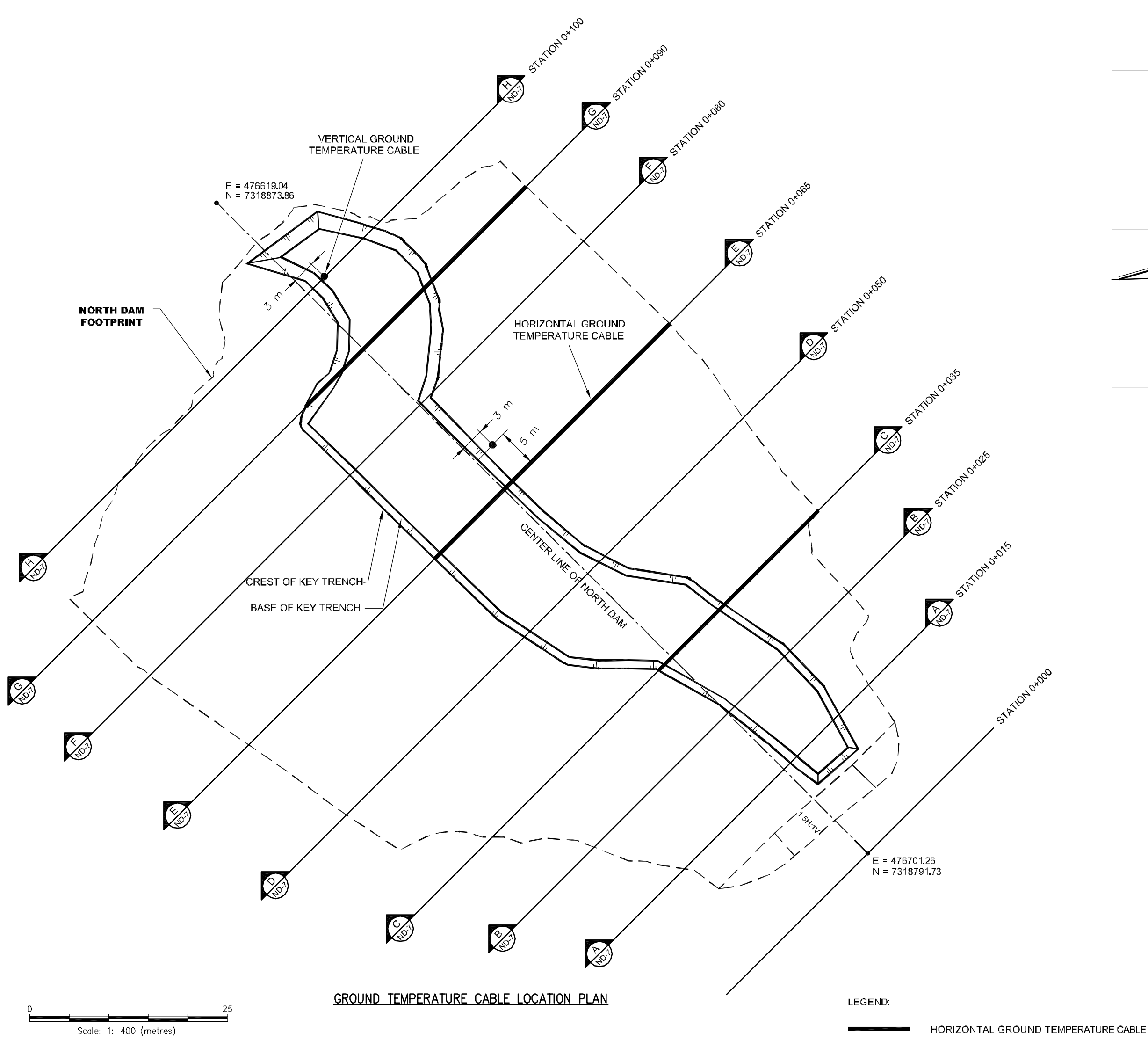
PROFESSIONAL SEAL

EBA Engineering Consultants Ltd.

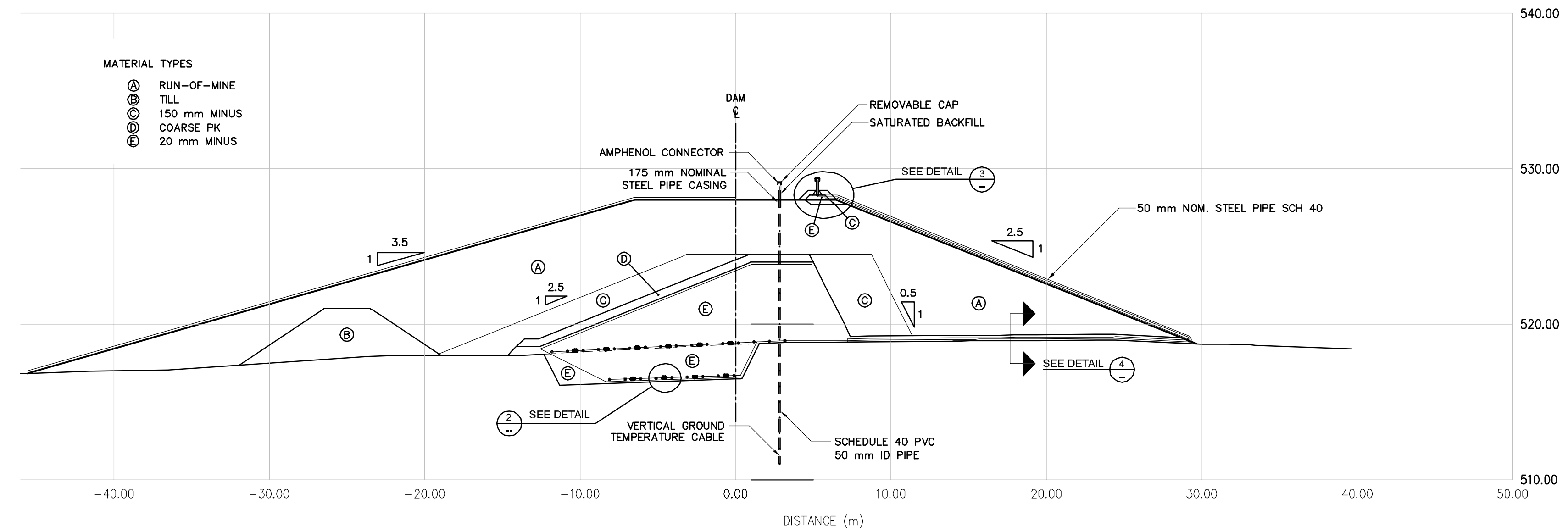
TAHERA Diamond Corporation
Jericho Project

North Dam
Sections

PROJECT NO./FILE NO.	DWN	CKD	REV	DRAWING NO.
1100060.013 1100060013Q07e.dwg	DBD	GZ	0	ND-7
OFFICE: EBA-EDM	DATE: July, 2007			

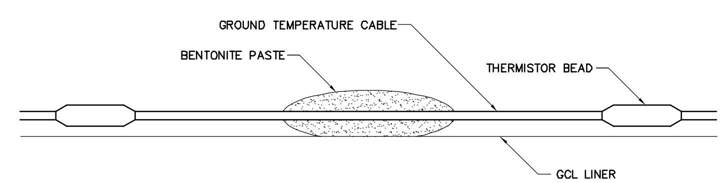


GROUND TEMPERATURE CABLE LOCATION PLAN



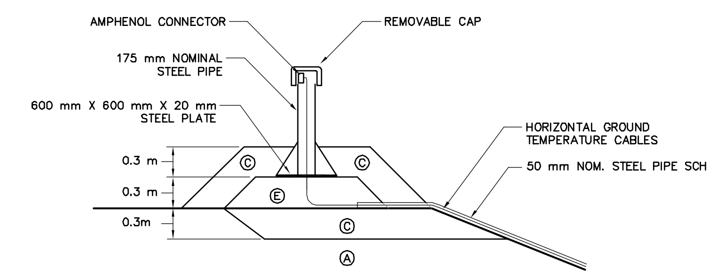
GROUND TEMPERATURE CABLE – STATION 0+065

SCALE 1: 200



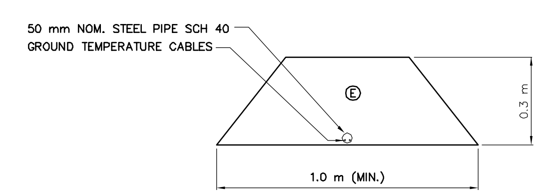
GROUND TEMPERATURE CABLE – WATERSTOP – DETAIL 2

N.T.S.



GROUND TEMPERATURE CABLE TERMINAL – DETAIL 3

N.T.S.



TEMPERATURE CABLE PROTECTIVE COVER –DETAIL 4

N.T.S.

NOTE:
GROUND TEMPERATURE CABLE TO BE PLACED IN STEEL PIPE WITHIN ZONE C, ZONE A AND DOWNSTREAM SLOPE OF DAM

GROUND TEMPERATURE CABLES
NORTH DAM

CABLE TYPE	STATION	BEAD ELEVATION	END BEAD LOCATION	BEAD SPACING (m)	TOTAL NUMBER OF BEADS	TOTAL CABLE LENGTH (m)
HORIZONTAL	0+035	Trench Bottom (~520.0 m)	IMMEDIATELY DOWNSTREAM OF GCL LINER	1.0	7	52
		Original Ground Surface (~522.0 m)		1.0	16	55
	0+065	Trench Bottom (~516.5 m)		1.0	9	70
		Original Ground Surface (~518.5 m)		1.0	16	72
	0+090	Trench Bottom (~517.5 m)		1.0	15	65
		Original Ground Surface (~520.5 m)		1.0	16	71
VERTICAL	0+070	511 m ~ 526 m	CENTRELINE OF CORE	1.0	16	22
	0+100	512 m ~ 527 m		1.0	16	21

REDUCED COPY
- Do Not Scale -

DRAWING No.	DRAWING TITLE	DATE	REV
REFERENCE DRAWINGS			

No.	DESCRIPTION	DATE	APPROVED
0	ISSUED FOR CONSTRUCTION	JULY 31/07	GZ
A	ISSUED FOR REVIEW	JULY 24/07	GZ

REVISION

CLIENT
TAHERA
Diamond Corporation

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 018
EBA ENGINEERING CONSULTANTS LTD.

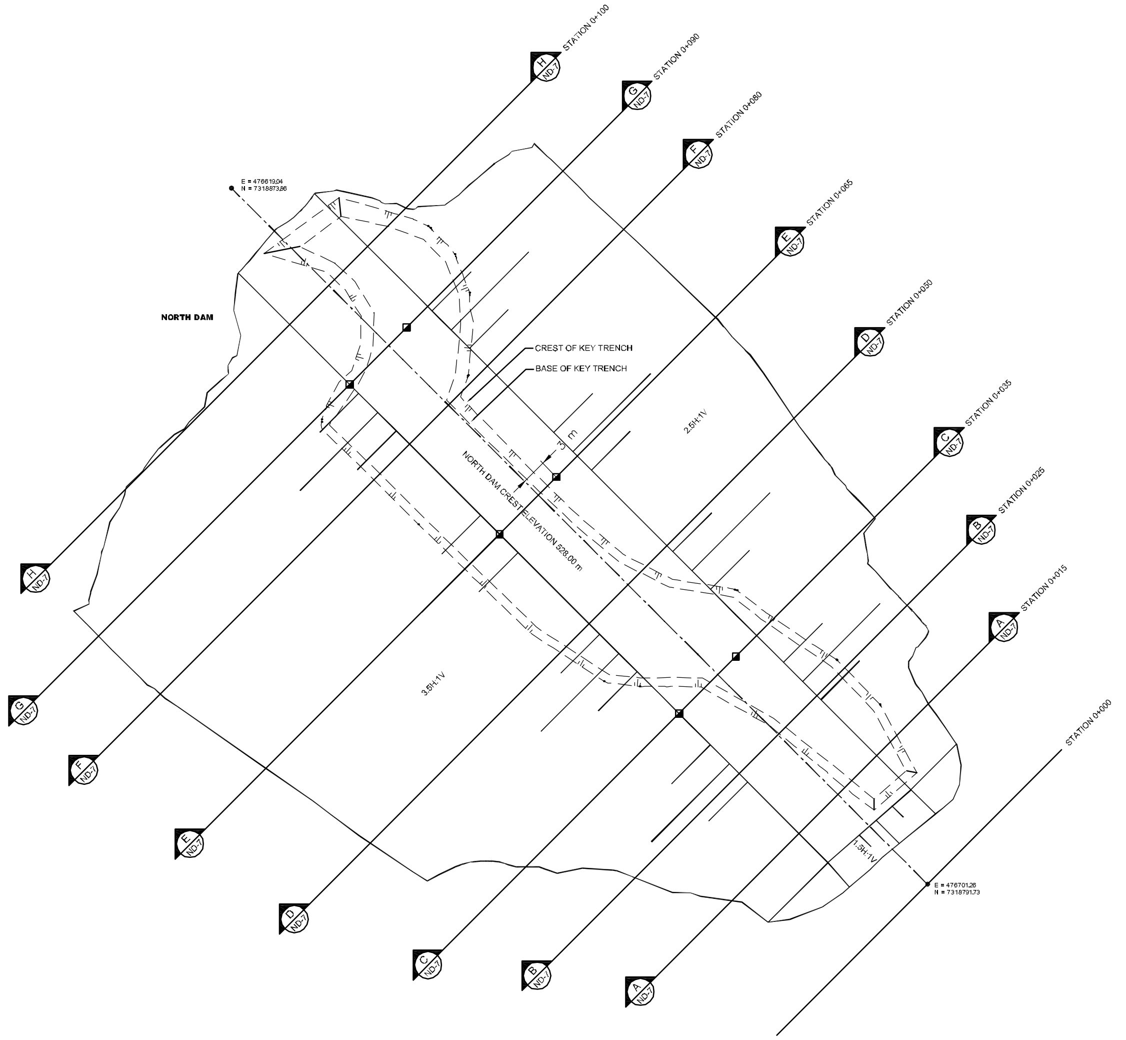
PERMIT
PROFESSIONAL SEAL

EBA Engineering Consultants Ltd.

TAHERA Diamond Corporation
Jericho Project

North Dam
Ground Temperature Cable
Layout Plan and Details

PROJECT NO./FILE NO.	DWN	CKD	REV	DRAWING NO.
1100060.013 1100060013Q08e.dwg	DBD	GZ	A	ND-8
OFFICE: EBA-EDM	DATE: July, 2007			

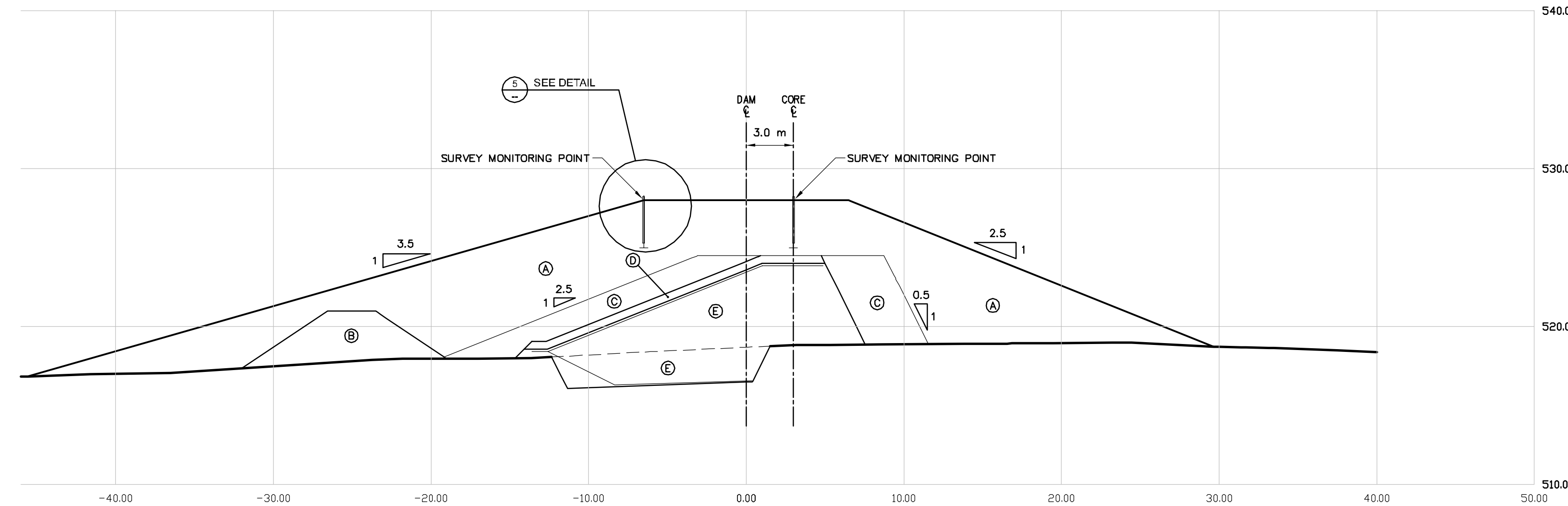


SURVEY MONITORING POINTS
NORTH DAM

STATION	NUMBER
0+035	2
0+065	2
0+090	2
TOTAL	6

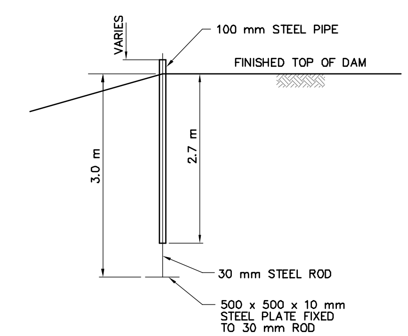
Scale: 1: 400 (metres)

LEGEND:
SURVEY MONITORING POINT



SURVEY MONITORING POINT – STATION 0+065

MATERIAL TYPES
- Ⓐ RUN-OF-MINE
- Ⓑ TILL
- Ⓒ 150 mm MINUS
- Ⓓ COARSE PK
- Ⓔ 20 mm Minus



SURVEY MONITORING POINT – DETAIL 5
SCALE 1:50

REDUCED COPY
- Do Not Scale -

DRAWING No.	DRAWING TITLE	DATE	REV

REFERENCE DRAWINGS

No.	DESCRIPTION	DATE	APPROVED
0	ISSUED FOR CONSTRUCTION	JULY 31/07	GZ
A	ISSUED FOR REVIEW	JULY 24/07	GZ

REVISION

CLIENT
TAHERA
Diamond Corporation

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 018
EBA ENGINEERING CONSULTANTS LTD.

PERMIT

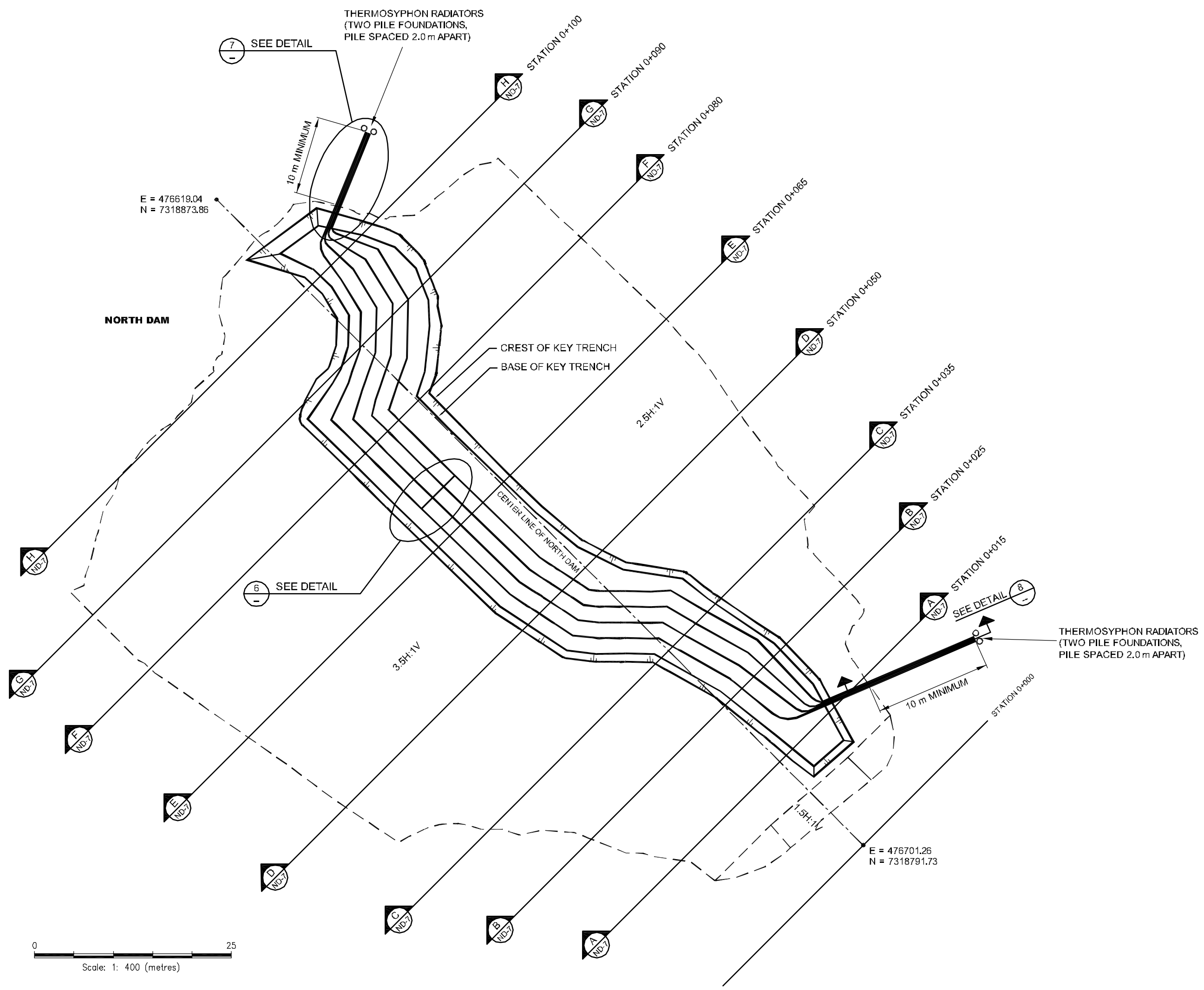
PROFESSIONAL SEAL

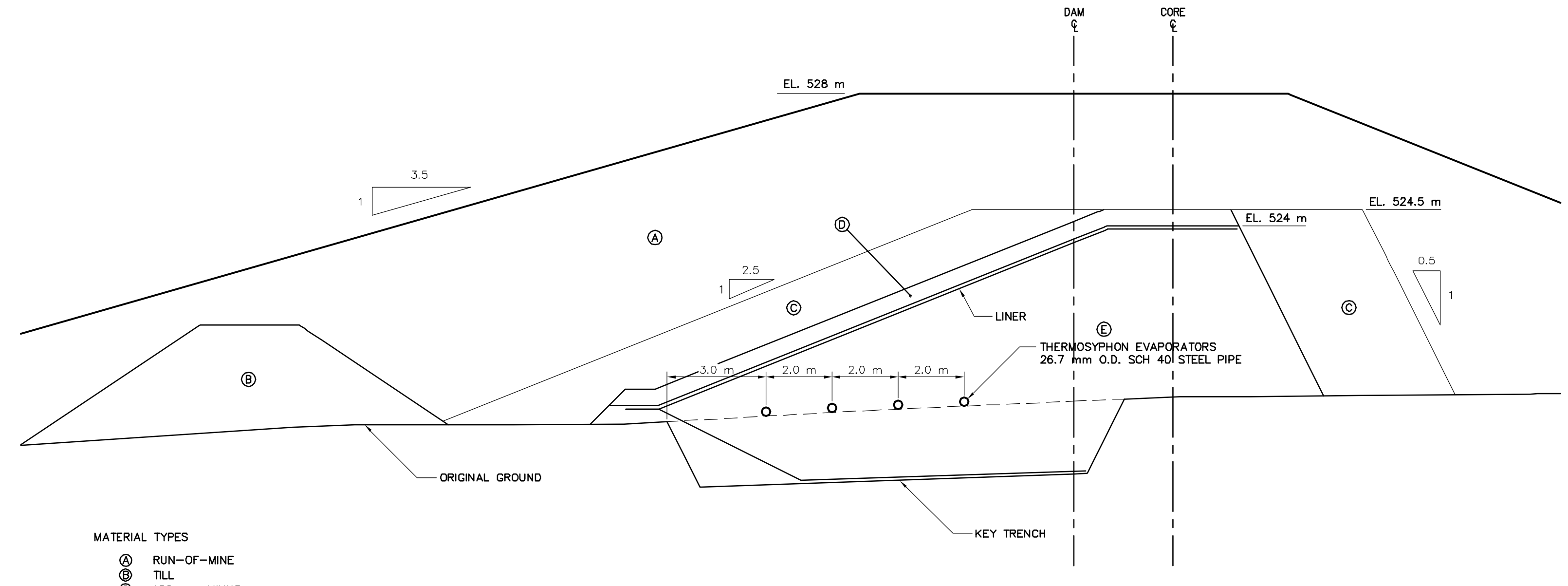
EBA Engineering Consultants Ltd.

TAHERA Diamond Corporation
Jericho Project

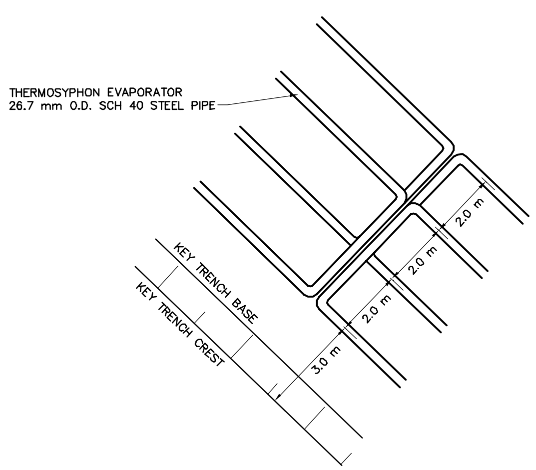
North Dam
Survey Monitoring Point
Layout Plan and Details

PROJECT NO./FILE NO.	DWN	CKD	REV	DRAWING NO.
1100060.013 1100060013Q09e.dwg	DBD	GZ	A	ND-9
OFFICE: EBA-EDM	DATE: July, 2007			

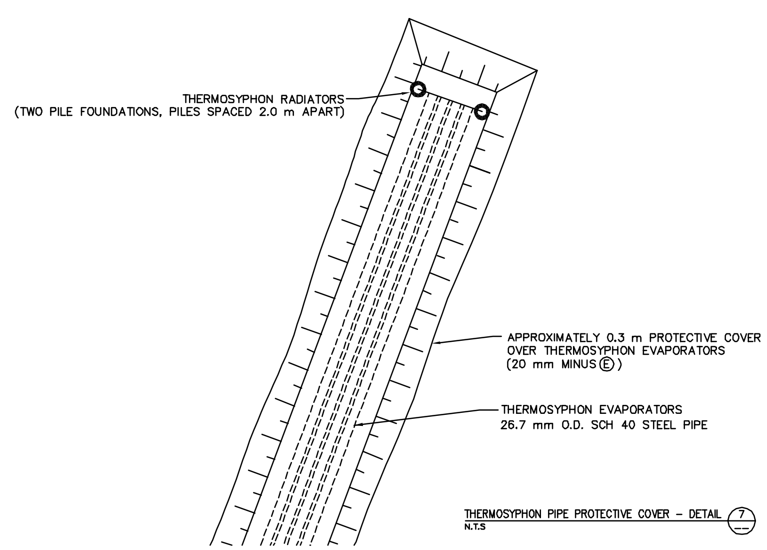




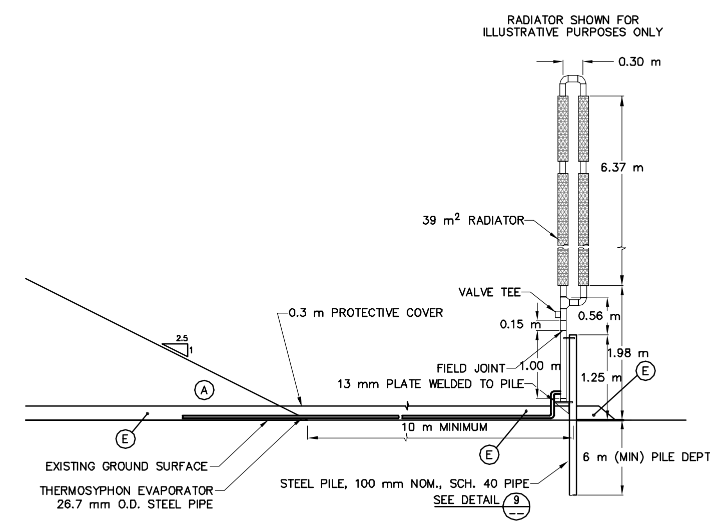
THERMOSYPHON EVAPORATOR LAYOUT – STATION 0+065



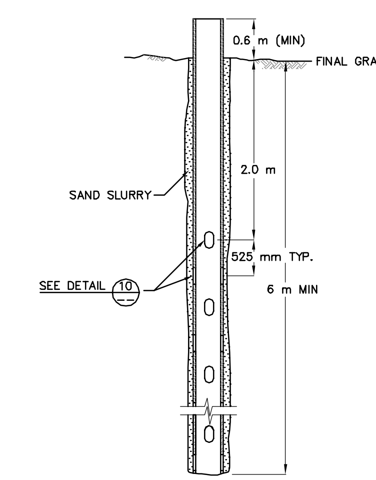
THERMOSYPHON EVAPORATORS – DETAIL 6
N.T.S



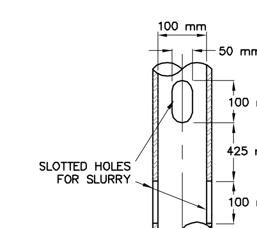
THERMOSYPHON PIPE PROTECTIVE COVER – DETAIL 7
N.T.S



RADIATOR INSTALLATION, DOWNSTREAM TOE – DETAIL 8
N.T.S



RADIATOR PILE SUPPORT AND SLURRY HOLES – DETAIL 9
N.T.S



SLURRY HOLES – DETAIL 10
N.T.S

REDUCED COPY
- Do Not Scale -

DRAWING No.	DRAWING TITLE	DATE	REV
REFERENCE DRAWINGS			

No.	DESCRIPTION	DATE	APPROVED
0	ISSUED FOR CONSTRUCTION	JULY 31/07	GZ
A	ISSUED FOR REVIEW	JULY 24/07	GZ

REVISION

CLIENT

TAHERA
Diamond Corporation

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 018
EBA ENGINEERING CONSULTANTS LTD.

PERMIT

PROFESSIONAL SEAL

EBA Engineering Consultants Ltd.

TAHERA Diamond Corporation
Jericho Project

North Dam
Thermosyphon
Layout Plan and Details

PROJECT NO./FILE NO.	DWN	CKD	REV	DRAWING NO.
1100060.013 1100060013Q10e.dwg	DBD	GZ	0	ND-10
OFFICE: EBA-EDM	DATE: July, 2007			

PRIMARY GROUT HOLES

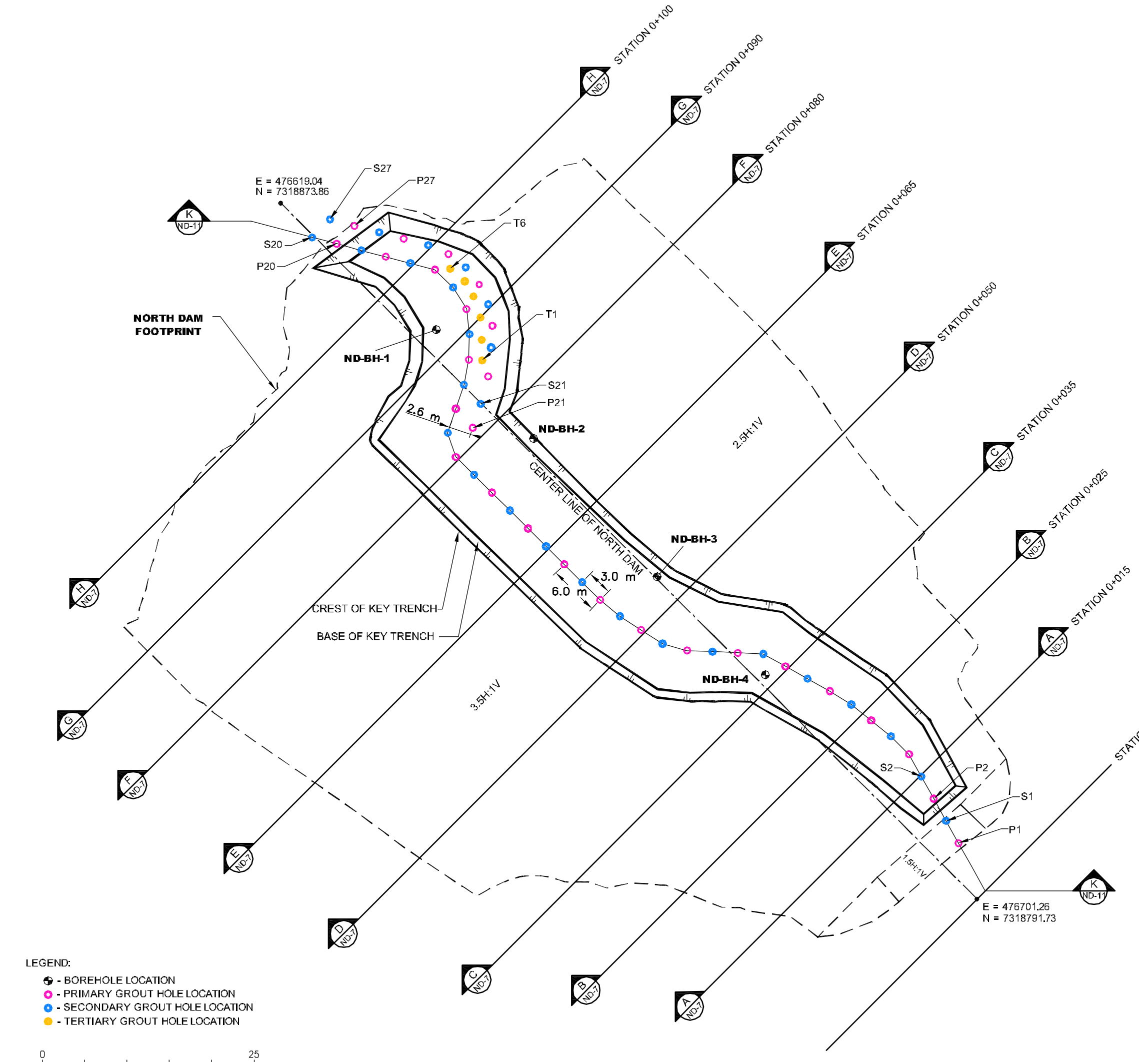
Grout Curtain Hole	Northing	Easting	Grout Curtain Hole	Northing	Easting
P1	7319715.73	487491.46	P15	7319767.00	487432.13
P2	7319720.98	487488.55	P16	7319772.79	487433.67
P3	7319726.22	487485.64	P17	7319778.76	487433.38
P4	7319730.21	487481.16	P18	7319783.41	487429.66
P5	7319733.68	487476.28	P19	7319784.94	487423.86
P6	7319736.59	487471.04	P20	7319786.47	487418.06
P7	7319738.19	487465.42	P21	7319764.75	487434.11
P8	7319738.46	487459.42	P22	7319770.81	487435.92
P9	7319740.89	487454.01	P23	7319776.80	487436.44
P10	7319744.42	487449.18	P24	7319781.67	487434.88
P11	7319748.65	487444.92	P25	7319785.27	487431.23
P12	7319752.87	487440.65	P26	7319787.07	487425.97
P13	7319757.10	487436.39	P27	7319788.60	487420.17
P14	7319761.32	487432.13			

SECONDARY GROUT HOLES

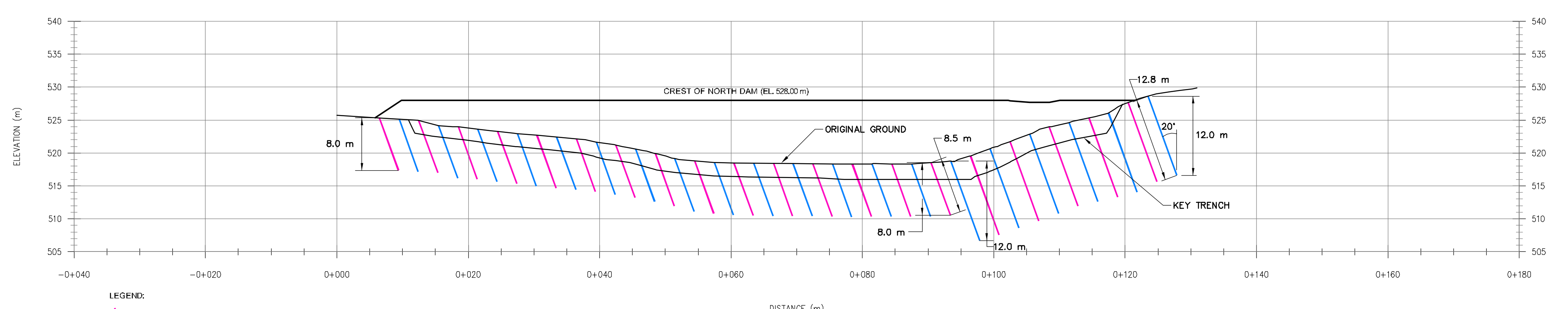
Grout Curtain Hole	Northing	Easting	Grout Curtain Hole	Northing	Easting
S1	7319718.35	487490.01	S15	7319769.84	487433.09
S2	7319723.60	487487.09	S16	7319775.79	487433.75
S3	7319728.33	487483.50	S17	7319781.32	487431.81
S4	7319732.09	487478.83	S18	7319784.18	487426.76
S5	7319735.14	487473.66	S19	7319785.71	487420.96
S6	7319738.05	487468.42	S20	7319787.23	487415.16
S7	7319738.32	487462.42	S21	7319767.59	487435.07
S8	7319739.26	487456.53	S22	7319774.22	487436.31
S9	7319742.52	487451.50	S23	7319779.33	487435.96
S10	7319746.53	487447.05	S24	7319783.69	487433.28
S11	7319750.76	487442.79	S25	7319786.31	487428.87
S12	7319754.98	487438.52	S26	7319787.84	487423.07
S13	7319759.21	487434.26	S27	7319789.36	487417.27
S14	7319764.16	487431.17			

TERTIARY GROUT HOLES

Grout Curtain Hole	Northing	Easting
T1	7319772.73	487435.24
T2	7319775.13	487435.17
T3	7319777.76	487435.01
T4	7319780.26	487434.22
T5	7319782.04	487433.19
T6	7319783.53	487431.45



GROUT CURTAIN HOLE LOCATION PLAN



GROUT CURTAIN HOLE LOCATION PLAN K ND-11

REDUCED COPY
- Do Not Scale -

DRAWING No.	DRAWING TITLE	DATE	REV

REFERENCE DRAWINGS

No.	DESCRIPTION	DATE	APPROVED
0	ISSUED FOR CONSTRUCTION	JULY 31/07	GZ
A	ISSUED FOR REVIEW	JULY 24/07	GZ

REVISION

CLIENT
TAHERA
Diamond Corporation

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 018
EBA ENGINEERING CONSULTANTS LTD.
PERMIT

PROFESSIONAL SEAL

EBA Engineering Consultants Ltd.

TAHERA Diamond Corporation
Jericho Project

North Dam
Grout Curtain Hole Location Plan and Profile

PROJECT NO./FILE NO.	DWN	CKD	REV	DRAWING NO.
1100060.013 1100060013Q12e.dwg	DBD	GZ	A	ND-11
OFFICE: EBA-EDM	DATE: July, 2007			

APPENDIX

APPENDIX B CLIMATIC DATA AND THERMAL CALIBRATION

B1.0 CLIMATIC DATA FOR THERMAL EVALUATIONS

B1.1 MEAN CLIMATIC CONDITIONS

Climatic data required for the thermal analyses includes monthly air temperature, wind speed, solar radiation, and snow cover. There has been no meteorological station at the Jericho Diamond Mine site. The closest meteorological station is at Lupin/Contwoyto Lake, which is approximately 30 km south of the mine site. The climatic data for air temperature, snow cover, and wind speed were obtained from Environment Canada's meteorological station at Lupin/Contwoyto Lake, which has been operating since 1959. Mean monthly air temperatures for the thermal analyses were based on the 1971–2000 climatic normals at Lupin/Contwoyto Lake (data from Environment Canada's webpage). Monthly wind speed data were based on the 1951-1981 climatic normals at Contwoyto Lake (Environment Canada, 1982a). Month end snow cover data were based on the 1961-1991 climatic normals at Contwoyto Lake (Environment Canada, 1993). The solar radiation data were obtained from the meteorological station at Norman Wells, which is at a similar latitude as that for the Jericho mine site. The solar radiation data were based on the 1951-1980 climatic normals at Norman Wells (Environment Canada, 1982b). Table 1 in Section 2.4 of this report summarizes the estimated long-term meteorological data at the Jericho Mine site. Warm-year and climate change monthly temperatures are also listed in Table 1.

B1.2 1 IN 100 WARM YEAR AIR TEMPERATURES

A probabilistic analysis was carried out to determine the mean monthly temperatures representative of a 1 in 100 warm year. The freezing index and thawing index for each year at Lupin/Contwoyto Lake from 1959 to 2004 were calculated. The freezing index for each winter was ranked in ascending order and plotted on probability paper. A "best-fit" line was drawn through the set of points to estimate the 1 in 100 warm year freezing index. A similar procedure was repeated for the summer temperatures to obtain the 1 in 100 warm year thawing index. Mean winter air temperatures were multiplied by the ratio of the 1 in 100 year freezing index to the mean freezing index to estimate the monthly winter air temperatures of a 1 in 100 warm year. Similarly, mean summer air temperatures were multiplied by the ratio of the 1 in 100 year thawing index to the mean thawing index to estimate the monthly summer air temperatures of a 1 in 100 warm year.

Monthly air temperatures for a 1 in 100 warm year are also listed in Table 1. As shown in Table 1, the 1 in 100 warm year annual air temperature is approximately 3.3°C warmer than the mean annual air temperature for the period of 1971 to 2000.

B1.3 AIR TEMPERATURES CONSIDERING CLIMATE CHANGE TRENDS

According to Environment Canada's "Climate Trends and Variations Bulletin" (http://www.msc-smc.ec.gc.ca/ccrm/bulletin/national_e.cfm), seven of the ten warmest years on record in northern Canada have occurred since 1994. There is an international scientific consensus that most of the warming observed over the last 50 years is attributable to human activities, namely in the emissions of greenhouse gases through the burning of fossil fuels (ACIA, 2004).

Global Circulation Models, or GCMs, are mathematical representation of the atmosphere, land surfaces, and oceans that have been developed to predict future climate behaviour in response to changes in the composition of the atmosphere. Several scenarios have been developed to estimate the likely range of future emissions that may affect climate (IPCC, 2000). Different GCMs have been developed, resulting in different degrees of projected global warming. In this study, using results from the Canadian Climate Impact Scenario project (http://www.cics.uvic.ca/scenarios/index.cgi), seasonal temperature changes for the Jericho Mine site area were estimated for the "B21 scenario" from four GCMs: a) CGCM2 (Canadian Centre for Climate Modelling and Analysis, Canada); b) GFDL-R30 (Geophysical Fluid Dynamics Laboratory, United States); c) ECHAM4 (Max-Planck Institute of Meteorology, Germany), and d) HadCM3 (Hadley Centre for Climate Prediction and Research, United Kingdom).

The average seasonal changes in temperatures over 110 years estimated from the four GCMs for the mine site area are 5.9°C, 4.1°C, 3.6°C, and 4.2°C during winter, spring, summer, and fall, respectively.

B2.0 CALIBRATION THERMAL ANALYSIS

B2.1 MODELLED SOIL PROFILE AND PROPERTIES

A thermistor cable was installed in borehole BH-03-08 at the south abutment of the West Dam during the 2003 geotechnical program conducted by SRK Consulting. This borehole was selected as a representative location for thermal model calibration since it was located relatively far away from water bodies. The subsurface soil profile for BH-03-08 consists of a thin (0.1 m) organics layer overlying 5.4 m thick till over granite bedrock. The till is silty sand and gravel with cobbles and boulders. The index properties for the soils were estimated based on the geotechnical data from the site investigation and past experience. Thermal properties of the soils were determined indirectly from well-established correlations with soil index properties (Farouki 1986; Johnston 1981). Table B1 summarizes the material properties used in the calibration thermal analysis.

TABLE B1: MATERIAL PROPERTIES USED IN CALIBRATION THERMAL ANALYSIS

Material	Water Content (%)	Bulk Density (Mg/m³)	Thermal Conductivity (W/m-K)		Specific Heat (kJ/kg°C)		Latent Heat (MJ/m³)
			Frozen	Unfrozen	Frozen	Unfrozen	
Moss/Organics	200	1.20	1.38	0.52	1.96	3.36	267
Till	12	2.24	2.59	1.90	0.88	1.10	80

Bedrock	1	2.53	3.00	3.00	0.75	0.77	8

B2.2 THERMAL MODEL CALIBRATION AND ANALYSIS RESULTS

One-dimensional calibration thermal analyses were carried out to calibrate the thermal model with the measured ground temperature at BH-03-08. Input data such as snow properties, ground surface conditions and evapotranspiration factor were modified in the calibration analyses to obtain a good agreement between the modelled and measured ground temperatures. Table B2 compares the calibrated ground temperatures with those measured on October 18, 2005 at BH-03-08.

TABLE B2: MEASURED AND MODELLED GROUND TEMPERATURES ON OCTOBER 18, 2005

Depth below Ground Surface (m)	Measured at BH-03-08 (°C)	Modelled at BH-03-08 (°C)
0.5	-0.7	-0.3
3.5	-2.3	-2.4
7.5	-4.9	-5.3
14.5	-6.0	-6.1

Table B2 indicates that there is generally a good agreement between the measured and calibrated ground temperatures for BH-03-08.

Two-dimensional calibration thermal analyses were also conducted to calibrate the thermal model with the measured ground temperatures at Borehole ND-BH-02 drilled within the valley of the North Dam area. The analyses are presented in Section 3.4.5 and the results are shown in Figure 1. A good agreement was obtained between the measured and predicted grout temperatures.

APPENDIX

APPENDIX C EBA GEOTECHNICAL GENERAL CONDITIONS

GEOTECHNICAL REPORT – GENERAL CONDITIONS

This report incorporates and is subject to these "General Conditions".

1.0 USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

This report and the recommendations contained in it are intended for the sole use of EBA's client. EBA does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than EBA's client unless otherwise authorized in writing by EBA. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of EBA. Additional copies of the report, if required, may be obtained upon request.

2.0 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

3.0 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

4.0 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

5.0 SURFACE WATER AND GROUNDWATER CONDITIONS

Surface and groundwater conditions mentioned in this report are those observed at the times recorded in the report. These conditions vary with geological detail between observation sites; annual, seasonal and special meteorologic conditions; and with development activity. Interpretation of water conditions from observations and records is judgmental and constitutes an evaluation of circumstances as influenced by geology, meteorology and development activity. Deviations from these observations may occur during the course of development activities.

6.0 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

7.0 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

8.0 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

9.0 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

10.0 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

11.0 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

12.0 SAMPLES

EBA will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the client's expense upon written request, otherwise samples will be discarded.

13.0 STANDARD OF CARE

Services performed by EBA for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practising under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

14.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, EBA has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

15.0 ALTERNATE REPORT FORMAT

Where EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed EBA's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by EBA shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by EBA shall be deemed to be the overall original for the Project.

The Client agrees that both electronic file and hard copy versions of EBA's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except EBA. The Client warrants that EBA's instruments of professional service will be used only and exactly as submitted by EBA.

The Client recognizes and agrees that electronic files submitted by EBA have been prepared and submitted using specific software and hardware systems. EBA makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.