REPORT

STUDIES RELATED TO WATER LICENCE REQUIREMENTS AND IN SUPPORT OF RECLAMATION PLANNING

Submitted to:

KINROSS GOLD CORPORATION

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1. INTRODUCTION

Echo Bay Mines Ltd., a subsidiary of Kinross Gold Corporation (Kinross), owns and operates the Lupin Mine, located on the west shore of Contwoyto Lake in Nunavut. Kinross retained Golder Associates Ltd. (Golder) to complete a series of geotechnical and other related studies to satisfy the water licence conditions and to support reclamation planning for the mine.

As provided in the April 2004 proposal to Kinross by Golder (P42-2178), the scope of the geotechnical and other related studies includes the following components:

- Studies of the potential for interaction between covered cells and flooded areas of the Lupin Tails Containment Area (TCA);
- An outline of methods to contain potential pore water expulsion from the TCA;
- A comprehensive assessment of material suitability, including geochemical and physical characterization of borrow materials, for the proposed TCA cover layer; and
- A climate and hydrology study to determine if an oxidation barrier could be maintained over the TCA.

As outlined in the Kinross letter dated March 16, 2004, the above studies were completed predominantly using existing information. Some laboratory tests were conducted on an esker sample, but no field investigation was carried out as a part of this program. The existing information that was used includes the following:

- Geocon Inc. (1982). As-built Tailings Containment Area, Lupin Project. Project Number A1207/01186-3. Submitted to Echo Bay Mines Ltd. in December 1982.
- Klohn Leonoff Ltd. (1992). Acid Rock Drainage Study, Lupin Mine, Northwest Territories. Project Number PE5684 0101. Submitted to Echo Bay Mines Ltd. in April 1992.

- Golder Associates Ltd. (1986). Tailings Impoundment Area, 1985 Divider Dyke Construction and Pond 1 Operation, Lupin Gold Mine, N.W.T. Project Number 842-2052. Submitted to Echo Bay Mines Ltd. in March 1986.
- Golder Associates Ltd. (1987). Tailings Impoundment Area, 1986 J Dyke Performance and Pond 1 Operation, Lupin Gold Mine, N.W.T. Project Number 842-2052. Submitted to Echo Bay Mines Ltd. in June 1987.
- Golder Associates Ltd. (1985). Tailings Impoundment Area Divider Dyke Design and Syphon Decant Design, Lupin Gold Mine, Contwoyto Lake, N.W.T. Project Number 842-2052. Submitted to Echo Bay Mines Ltd. in March 1985.
- Golder Associates Ltd. (1995). Assessment of the Potential to Place Uncemented Tailings Paste Backfill in Slopes. Project Number 932-1460. Submitted to Echo Bay Mines Ltd. in May 1995.
- Golder Associates Ltd. (1998). 1998 Geotechnical Inspection of the Tailings Containment Perimeter Embankments, Lupin Mine, Contwoyto Lake, N.W.T. Project Number 982-2427. Submitted to Echo Bay Mines Ltd. in October 1998.
- Golder Associates Ltd. (1997). 1997 Geotechnical Inspection of the Tailings Containment Perimeter Embankments, Lupin Mine, Contwoyto Lake, N.W.T. Project Number 972-2417. Submitted to Echo Bay Mines Ltd. in October 1997.
- Golder Associates Ltd. (1996). 1996 Geotechnical Inspection of the Tailings Containment Perimeter Embankments, Lupin Mine, Contwoyto Lake, N.W.T. Project Number 962-2422. Submitted to Echo Bay Mines Ltd. in September 1996.
- Golder Associates Ltd. (1997). Closure Cost Estimate and Scoping of Mine Closure Issues, Lupin Mine, N.W.T. Project Number 972-2414.8000. Submitted to Echo Bay Mines Ltd. in December 1997.
- B.G.C. Engineering Inc. (2001). 2001 Geotechnical Inspection of Perimeter Tailings Dams, Lupin Mine, N.W.T. Project Number 0256-003-02. Submitted to Echo Bay Mines Ltd. in September 2001.

- B.G.C. Engineering Inc. (2000). 2001 Geotechnical Inspection of Perimeter Tailings Dams, Lupin Mine, N.W.T. Project Number 0256-001-01. Submitted to Echo Bay Mines Ltd. in October 2000.
- B.G.C. Engineering Inc. (2000). Thermistor Installation Program, Dam 1A, Dam 2, M Dam, Cell 1 and Esker, Lupin Mine, N.W.T. Project Number 0256-002-01. Submitted to Echo Bay Mines Ltd. in December 2000.
- B.G.C. Engineering Inc. (2002). 2002 Geotechnical Inspection of Perimeter Tailings Dams, Lupin Mine, Nunavut. Project Number 0256-004-02. Submitted to Echo Bay Mines Ltd. in October 2002.
- B.G.C. Engineering Inc. (2003). 2003 Geotechnical Inspection of Perimeter Tailings Dams and Waste Containment Dikes, Lupin Mine, Nunavut. Project Number 0256-007-01. Submitted to Echo Bay Mines Ltd. in September 2003.
- Natural Resources Canada (1998). Mine Environment Neutral Drainage (M.E.N.D.) Project 1.62.2, Acid Mine Drainage Behaviour in Low Temperature Regimes, Thermal Properties of Tailings. Submitted to Echo Bay Mines Ltd. in July 1998.
- SEACOR Environmental Engineering Inc. (1995). 1995 Thermistor Installation, Lupin Mine, N.W.T. Project Number H0442-001. Submitted to Echo Bay Mines Ltd. in December 1995.
- Klohn-Crippen Consultants Ltd. (1995). Tailings Reclamation Test Cover Program, 1994 Report of Activities. Project Number PM 6698 02. Submitted to Echo Bay Mines Ltd. in August 1995.
- B.G.C. Engineering Inc. (2003). Dam 6 Site Investigation and Raise Design. Project Number 0256-006-01. Submitted to Kinross Gold Corporation. in July 2003.
- Electronic data supplied by Kinross Gold Corporation to Golder Associates Ltd. that included thermistor measurement histories, tailings deposition volume histories, pond water elevation histories, plan maps and cross-sections.

2. SITE DESCRIPTION

2.1 Location and Topography

Lupin Mine is located at 65°46'N, 111°14'W in the north-central District of Mackenzie, west of Contwoyto Lake, and approximately 380 km northeast of Yellowknife, N.W.T. The tailings containment area (TCA) is located approximately 5 km southwest of the mine.

The Lupin Mine is situated in an area of gently rolling topography that has an elevation generally between 480 m and 520 metres. Contwoyto Lake is on a divide between two watersheds and has two outlets. The southern outlet is Contwoyto River, which joins Back River and reports to Chantrey Inlet. The northern outlet drains into Kathawchaga Lake and reports to Bathurst Inlet via the Burnside River (Kerr et al 2000).

The location of the Lupin Mine is illustrated on Figure 1.

2.2 Geological Setting

The Lupin Mine and TCA are situated within the Canadian Shield in an area that is underlain by the Yellowknife Supergroup and intrusive granitoid rock. The Yellowknife Supergroup comprises metaturbidites and intermediate to felsic metavolcanic rock. An iron formation within the above metaturbidites hosts the Lupin gold deposit. The intrusive granitoid rock comprises granite, granodiorite, diorite, tonalite, and gneiss (Kerr et al 2000).

The surficial geology of the TCA comprises metaturbidite bedrock outcrops, glacial till and glaciofluvial (esker) deposits. The glacial till occurs predominantly as a silty sand veneer that is less than 2 m thick (Kerr et al 2000).

The surficial geology of the TCA is shown on Figure 2.

2.3 Regional Climate and Permafrost Conditions

Based on climate station data that has been obtained since 1982, the mean annual temperature at the Lupin Mine is -10.8°C. The mean annual precipitation at the Lupin Mine is 297 mm, of which 161 mm is rainfall and 136 mm is snowfall.

The Lupin Mine and TCA are situated within the zone of continuous permafrost. This area exhibits predominantly low (less than 10%) ground ice and the mean annual ground temperature at the depth of zero annual amplitude is approximately -7.5°C. Measured permafrost depths in this area are on the order of 500 m (National Atlas Information Service 1995).

Measurements at depths of approximately 20 m within the TCA indicate permafrost temperatures between -4°C and -6°C.

2.4 Tailings Containment Area

The Tailings Containment Area (TCA) is situated in an area of gently rolling topography with generally indistinct drainage patterns. Surface elevations generally vary from 480 m near Contwoyto Lake to 520 m with local relief generally less than 15 metres.

The perimeter of the TCA comprises areas of high topography and a number of dams or dykes that span low areas of distinct drainage paths. The perimeter of the TCA includes dams 1A, 1B, 1C, 2, 3, 4 and 6 and access roads across locally higher topography connect these perimeter dams. These dams and access roads are constructed to crest elevations of between 485 m and 490 metres.

The layout of the TCA is provided on Figure 3.

Perimeter dams 1A, 1B, 1C, 2 and 4A were initially used to contain a single deposition area at the commencement of mining operations in 1982. Additional internal dams were constructed between 1985 and 1990 to retain tailings solids and facilitate increased efficiency in handling decant tailings water. Additional perimeter dams 4, 5 and 6 were constructed between 1990 and 1992 to facilitate increased tailings management capacity.

The interior of the TCA is compartmentalised by dams 3C, 3D, 3E, J, K, L, M and N and comprises two ponds and five tailings deposition areas (cells). The ponds provide staged handling of the tailings decant water. Current practice is to pump excess water (spring melt-water and accumulated tailings decant water) from Cells 3 and 5 into Cell 4, where it is stored for one year. The water in Cell 4 is transferred via a gated culvert to Pond 1, where it is stored for another year. The water in Pond 1 is then pumped over J-Dam, where it is stored for one year before release over Dam 1A.

The water surface elevations in Pond 1 and Pond 2 are generally 481 m and 480 m, respectively, after release and are approximately 484 m prior to release.

Cells 1, 2, 3 and 5 comprise the tailings deposition areas. Cells 1 and 2 have been inactive and covered with esker material since approximately 1995. Since 2000, summer tailings deposition has been into Cell 3 and the N-Dam portion of Cell 5, and winter deposition has been into the main body of Cell 5.

The depositional history of the TCA is summarised in Table 1.

Table 1
Summary of TCA History

Period	Comments
1982 – 1984	• Tailings deposition to Cell 5
1985 – 1989	• Construction of Dam 3C and J-Dam • Tailings deposition to Cell 1
1990 – 1992	• Construction of perimeter dams 4, 5 and 6 and internal dams K, L and M • Tailings deposition to Cell 1 and Cell 2
1993 - 1997	• Gravelly sand esker material cover placed over Cell 1 and Cell 2 • Tailings deposition to Cell 3 and Cell 5
1998 - 1999	• Mine in Care and Maintenance mode • Tailings deposition to Cell 5
2000 – 2002	• M-Dam raised • Gravelly sand esker material cover placed over Cell 3A and 3B • Tailings deposition predominantly to Cell 3 and Cell 5 with less volumes of tailings deposited to Cell 2 • Mine in Care and Maintenance August 2002
2003 – present	• Tailings deposition to Cell 5 and Cell 3

2.5 Dam Geometry and Construction

The performance of the frozen tailings cells and the TCA dams depends upon factors including earth material composition and moisture content, thermal properties, ground and air temperature, and thermal boundary conditions such as pond elevations and their variations.

The TCA dams are constructed using various combinations of silty sand till, gravelly sand esker material, tailings sand, and run-of-mine rock. The run-of-mine rock was derived from shaft deepening during mining operations. The geometry and construction of the various dams are described in greater detail below.

2.5.1 Perimeter Dams

Construction information for perimeter dams 1A, 1B, 1C, 2 and 4A (later part of Dam 4) is provided in the Geocon (1982) report. These dams were initially constructed to a crest elevation of 485 m and were later raised to an elevation of 486.5 metres. Dam 4 was later raised to a crest elevation of 490 metres. These dams are constructed of silty sand till cores with gravely sand esker material and rip rap materials on the upstream faces. A geosynthetic liner, which is keyed into the underlying permafrost, separates the silty sand till from the gravely sand. A silty sand drainage blanket is provided at the downstream toe.

Construction information for perimeter dams 4, 5 and 6 is provided in the Golder (1992) report. These dams are constructed of gravelly sand esker material and incorporate a geosynthetic liner within the upstream portion and a downstream toe drain comprised of run-of-mine material. The Dam 4 liner extends 15 m upstream from the upstream toe. The liners are keyed into the permafrost below Dam 5 and Dam 6.

The perimeter dams incorporate frozen cores in addition to the geosynthetic liners. Dam core temperatures of less than 0°C have been measured by thermistors installed in Dam 1A, Dam 2, Dam 4, Dam 5 and Dam 6.

2.5.2 Internal Dams

Construction information for J-Dam, the internal dam that separates Pond 1 and Pond 2, is provided in the Golder (1984 and 1985) reports. The dam core is constructed of run-of-mine rock. On the upstream side, the run-of-mine rock is covered with gravely sand esker material, which underlies the tailings sand that forms the upstream face. The run-of-mine rock extends from the base of the dam to approximately elevation 485.5 metres. The upper portion of the dam, between elevation 485.5 m and approximate elevation 487.5 m, is constructed of gravely sand esker material and tailings sand. Tailings decant water is transferred from Pond 1 to Pond 2 using 5 siphon pipes that run over the top of J-Dam.

Construction information for internal dams 3C, 3D, 3E, K, L, M and N has been provided to Golder by Kinross Gold. These dams are constructed of run-of-mine waste with gravely sand esker material on the upstream face.

The internal dams were designed with no specific seepage control measures. Temperature measurements of thermistors that have been installed in Dam 3D and K-Dam indicate that the cores of these dams are frozen below depths of approximately 3 m to 5 m below the dam crests. It is understood that no thermistors were installed in the other internal dams.

3. INTERACTION BETWEEN FLOODED AREAS AND TAILINGS CONTAINMENT AREA

The Lupin Water Licence requires a "*study of the potential for interaction between covered cells and flooded areas of the Lupin Tails Containment Area (TCA), including thermal analyses and modelling of the interaction between the ponds, the frozen-core perimeter dykes, and frozen tailings within cells, as well as the thermal effects of proposed pond elevations*".

The objectives of this study included the following:

- Estimate of material geo-thermal properties;
- Selection of a typical cross-section for thermal analysis; and
- Parametric thermal analyses of the interaction between flooded areas, frozen-core perimeter dams, internal dams and frozen tailings deposits.

It is understood that the reclamation activities include plans to construct a spillway through Dam 1A and to breach J-Dam. It would, therefore, be unlikely that any water would be impounded against the internal and perimeter dams that comprise the TCA, with the possible exception of Dam 3D. The parametric thermal analysis, of interaction between flooded areas and the TCA dams is, therefore, intended to be conservative.

3.1 Material Geo-Thermal Properties

3.1.1 Materials

The following materials comprise the TCA:

- Esker gravely sand;
- Silty sand till;
- Bedrock;
- Run-of-mine rock; and
- Tailings.

Grain size distributions for the unclassified tailings, silty sand till and esker gravely sand are provided in the Golder (1985) report and recent laboratory testing and are reproduced on Figures A-1, A-2, A-3 and A-4 in Appendix A. The esker gravely sand was sampled from northwest of Dam 2. The silty sand till was sampled from a borrow area within the TCA between Dam 1A and Dam 4. Grain size distributions for the run-of-mine rock are unavailable.

3.1.2 Estimation of Thermal Properties

Readily available information regarding the thermal properties of the earth materials is relatively sparse. Thermal properties of fresh (i.e. unconsolidated) Lupin Mine tailings were measured as part of MEND Project 1.62.2, which was a study of acid rock drainage potential at low temperatures. However, the measured thermal properties are not considered representative of consolidated or partially drained tailings materials. It was necessary to estimate material thermal properties through analytical methods.

Available information of material characteristics was used to develop preliminary estimates of the material thermal properties within the TCA. The above estimates were then refined using measured thermistor data and thermal numerical modelling (back analyses).

The thermistor data comprised temperature from thermistors TC1-3 and D1A-00-1S. Thermistor TC1-3 was installed in 1995 and is situated in the northeast corner of Cell 1. The approximate stratigraphy at TC1-3 comprises 1 m of esker material, overlying 4 m of tailings, overlying bedrock. Thermistor D1A-00-1S was installed in 2000 and is situated on the crest of Dam 1A, south of the siphons. The approximate stratigraphy at D1A-00-1S comprises 16 m of run-of-mine rock overlying bedrock. It is noted that the thermistors within the TCA have been installed using air-track drilling equipment that produces highly disturbed samples during drilling. The reported stratigraphy at each location is considered to be approximate.

The initial estimates of material thermal properties were refined using the above thermistor data and thermal numerical modelling. The numerical modelling was completed using TEMP/W v.5.19, a commercially available finite element program that is produced by Geoslope International Ltd. One dimensional finite element models were constructed with geometries that were consistent with the estimated stratigraphy at the locations of TC1-3 and D1A-00-1S.

Measured temperature profiles on a single day at these thermistors were used to establish initial conditions within the finite element models. The measured fluctuations in ground surface temperature over a period of several years at these thermistors were then applied to the upper surface of the thermal models as the boundary conditions. After simulating the ground thermal response over several years, the predicted temperature profiles were compared to the measured temperature profiles and the estimated thermal properties were revised, as necessary.

Comparisons between measured and predicted temperature profiles at thermistors TC1-3 and D1A-00-1S are provided on Figures 4 and 5. The estimated thermal properties are provided in Table 2.

Table 2
Estimated Thermal Properties

Material Type	Material Property				
	k_f MJ/m·d·°C	k_u MJ/m·d·°C	c_{vf} MJ/m^3·°C	c_{vu} MJ/m^3·°C	θ
Gravely sand (esker)	0.2	0.2	2.0	3.0	0.3
Silty sand till	0.2	0.2	2.0	3.0	0.3
Run-of-mine rock	0.2	0.2	2.0	3.0	0.3
Tailings	0.2	0.2	3.0	4.0	0.4
Bedrock	0.2	0.2	2.4	2.4	0.1

k_f frozen thermal conductivity
k_u unfrozen thermal conductivity
c_{vf} frozen volumetric heat capacity
c_{vu} unfrozen volumetric heat capacity
θ volumetric water content (ratio of the volume of water per unit total volume of material)

It is observed on Figure 4 and 5 that the measured and predicted temperature profiles compare reasonably well. The thermal properties provided in Table 2 were used in subsequent thermal analysis.

3.2 Selection of Cross Section for Thermal Analyses

As described in Section 2.5, several dam geometries have been constructed within the TCA. The dams are constructed of various combinations of run-of-mine rock, gravely sand esker material and silty sand till. The estimated thermal properties of materials comprising the TCA, as shown in Table 2, were used to establish a cross-section for thermal analysis of the interaction between flooded areas and covered cells. In addition to the thermal properties, the embankment geometry and the presence (or absence) of impounded tailings were other variables that may impact the interaction between the flooded areas and TCA embankment structures.

It is observed in Table 2 that although the thermal conductivities of the materials are similar, the estimated volumetric heat capacity values of the gravely sand esker material, silty sand till and run-of-mine rock are less than the estimated volumetric heat capacity values of the tailings. Accordingly, it is expected that for a given embankment geometry the extent of thaw progression would be greater in embankments constructed of these materials than a geometrically equivalent embankment constructed of tailings. In other words, thermal analyses of a wide embankment of gravelly sand, silty sand or run-of-mine rock should provide a conservative (high) estimate of the extent of thaw penetration.

Based on the above discussion, K-dam was selected for parametric thermal analyses. K-Dam is a wide internal dam that is constructed of gravelly sand esker material and run-of-mine rock. This internal dam has a maximum height of approximately 11 m, a crest width of approximately 12 m, an upstream slope of approximately 3H:1V, and a downstream slope of approximately 1H:1V. The tailings impounded by K-Dam reach an elevation that is approximately 2 m below the dam crest. Pond 2 does not currently extent to the downstream toe of K-Dam. Based on the minimum existing crest elevation of the adjacent perimeter dams, the maximum depth of Pond 2 water that could exist adjacent to K-Dam is approximately 5.5 metres.

The geometry of K-Dam at the analysed cross-section is shown on Figure 6.

3.3 Analysis Methodology

The thermal analysis was completed using TEMP/W v.5.19 and two dimensional finite element models. The material thermal properties that are presented in Table 2 were used in the analysis.

3.3.1 Boundary Conditions

Bases on the existing geometry of the TCA, the maximum depth of Pond 2 water that could be impounded against the downstream face of K-Dam is approximately 5.5 metre. Impounded water depths of 5.0 m and 8.5 m were considered in the parametric thermal analysis.

Four sets of temperature boundary conditions were applied to the thermal models, at the following locations: The air-soil interface, the water-soil interface at the base of impounded water, the water-soil interface within the upper 2 m of impounded water, and at depth within the bedrock materials.

The temperature boundary condition at the air-soil interface was varied with time to reflect seasonal temperature variation. This temperature function was developed from measured surface temperatures at thermistor TC1-3 in Cell 1. The surface temperature measurements over the last 9 years, since this cell was covered with esker material, were used to derive the following ground surface temperature function:

$$T = -7.0 + 15.0 \cdot \sin\left(0.1 - \frac{2\pi\ t}{365}\right)$$

where T = ground surface temperature in °C and t = time in days, with $t = 0$ on November 5th.

The above temperature function is compared with measured surface temperatures at TC1-3 on Figure 7. It is seen on Figure 7 that the fitted temperature function compares well with the measured surface temperatures at TC1-3. The fitted temperature function on Figure 7 was used to approximate the variation in ground surface temperature with time during the numerical modelling.

A constant-temperature boundary condition was applied at the water-soil interface at the base of impounded water. The value of this boundary condition was determined using published sources. Studies of shallow Arctic lakes indicate that the temperature at depth reaches a nearly constant value of 3°C (Burn 2002). A more conservative value of 4°C was used as a constant temperature boundary condition at the water-soil interface at impounded water depths greater than 2 metres.

Studies of Arctic lakes indicate that the ice may reach a thickness of approximately 2 m each winter; consequently, temperatures within the upper 2 m of impounded water may reach subzero temperatures during the year (Burn 2002). A more conservative, constant-temperature boundary condition of 2°C was applied to the water-soil interface within the upper 2 m of impounded water in the numerical models discussed herein.

Published sources indicate that the permafrost temperature at a depth of 20 m near the Lupin Mine is between -4°C and -7°C. A more conservative, constant temperature boundary condition of -3.5°C was applied at a depth of 20 m below the original ground surface in the numerical models discussed herein. The value of this boundary condition is supported by measured values at a depth of 20 m within the TCA (e.g. thermistor D1A-00-02).

3.3.2 Initial Conditions

The initial temperatures at nodes of the finite element numerical models were estimated using steady state thermal analysis. The temperature of nodes at the uppermost soil boundary was set to -5°C as a constant-temperature boundary condition. The temperature at the base of the finite element models, at a depth of 20 m below the original ground surface, was assigned a constant temperature boundary condition of -3.5°C. Steady state thermal analysis was completed to determine the temperature variation with location under these boundary conditions. The calculated nodal temperatures were used to estimate the initial conditions within the finite element mesh during subsequent transient thermal analysis.

3.4 Results of Parametric Analysis

3.4.1 Interaction Between Flooded Areas and Covered Cells

Two scenarios were analysed to evaluate the interaction between flooded areas and covered cells. The first scenario considered water impounded to an elevation approximately half-way up the downstream face of K-Dam, with a water depth of 5 m at the downstream toe. The second scenario considered the maximum water depth that could be impounded against the downstream toe of K-Dam. Based on the lowest perimeter dam crest elevation adjacent to Pond 2, approximately 485.5 m, the maximum depth of water that could be impounded against the downstream face of K-Dam is approximately 8.5 metres.

The initial temperatures and boundary conditions that were described in Section 3.3 were used to evaluate both of the above scenarios. The thermal modelling determined the calculated maximum depth of the 0°C isotherm, i.e. the maximum yearly thaw depth, for each year over the simulated duration of 20 years.

The calculated progression of the 0°C isotherm over a period of 20 years with 5 m of impounded water adjacent to K-dam is shown on Figure 8. It is observed on Figure 8 that the slope of the talik (unfrozen zone) near the downstream toe is steep. The estimated talik reaches a depth of approximately 17 m below the original ground elevation after an elapsed time of 20 years. The estimated talik extends approximately 5 m into K-Dam, measured horizontally from the downstream toe, and it is observed that the calculated talik does not extend into the frozen tailings after an elapsed period of 20 years.

The calculated progression of the 0°C isotherm over a period of 20 years with 8.5 m of impounded water adjacent to K-dam is shown on Figure 9. It is observed on Figure 9 that the slope of the talik (unfrozen zone) near the downstream toe is steep. The estimated talik reaches a depth of approximately 18 m below the original ground elevation after an elapsed time of 20 years. The estimated talik extends approximately 8 m into K-Dam, measured horizontally from the downstream toe, and it is observed that the calculated talik does not extend into the frozen tailings after an elapsed period of 20 years.

3.4.2 Interaction Between Flooded Areas and Dam 1A

The cross-section used to assess the interaction between flooded areas and the perimeter dams (such as Dam 1A) is the same as shown in Figure 6 with the exception that tailings were not impounded by this model embankment. The initial temperatures and boundary conditions are the same as described in Section 3.3. An impounded water depth of 8.5 m above the dam toe was evaluated.

The calculated progression of the 0°C isotherm over a period of 20 years with 8.5 m of impounded water is shown on Figure 10. It is observed on Figure 10 that the slope of the talik (unfrozen zone) near the dam toe is steep. The estimated talik reaches a depth of approximately 19 m below the original ground elevation after an elapsed time of 20 years. The estimated talik extends approximately 8 m into the analysed cross section, measured horizontally from the dam toe, and it is observed that the calculated talik does not extend through the entire dam core after an elapsed period of 20 years.

3.5 Comments

The results of the thermal analyses indicate that, after an elapsed period of 20 years, the unfrozen zone does not extend to the frozen tailings when 8.5 m of water is impounded against the downstream face of K-Dam. As discussed in Section 3.2, the extent of thaw progression should be greater in gravely sand esker material, silty sand till and run-of-mine waste than in frozen tailings. In addition, the maximum depth of Pond 2 water that could be impounded against K-Dam is approximately 5.5 m, based on existing dam geometrics. The above results are, therefore, considered a reasonable and somewhat conservative representation of the interaction between flooded areas and other internal dams within the TCA.

M-Dam, N-Dam and Dam 3D are internal dams that could be exposed to impounded water within Pond 1 and Pond 2. Like K-Dam, the above dams are constructed of gravely sand esker material, silty sand till, and run-of-mine waste. These dams are constructed with crest elevations between 488 m and 491 m, crest widths of approximately 12 m, upstream faces sloped at approximately 1H:1V, and downstream faces sloped at between 1H:0.7V and 1H:1V. The construction of Dam 3D is slightly different from the above dams, in that approximately 300,000 m^3 of quarried riprap material was placed on the downstream face in 1995. The above riprap placement increased the crest width of the dam to 20 m and flattened the downstream face to slopes between 1.5H:1V and 2H:1V.

The geometries of the above dams are similar to that of K-Dam. It is considered that the results of thermal analysis of K-Dam are, therefore, applicable to M-Dam, N-Dam and Dam 3D.

4. METHODS TO CONTAIN POTENTIAL PORE WATER EXPULSION FROM TAILINGS CONTAINMENT AREA

It is understood that Condition I.3.b in the Water Licence requires Lupin Mine to provide "*an outline of methods to contain potential pore water expulsion from the TCA*" post closure/abandonment of the mine operation. In other words, it is necessary to evaluate potential release of pore water from the tailings and its long term impact to the surroundings of the TCA is of concerns.

The objectives of this study were as follows:

- Identify potential mechanisms of pore water expulsion;
- Estimate the timing and potential impact of pore water expulsion under each mechanism; and
- Assess measures to contain potential pore water expulsion.

4.1 Potential of Pore Water Expulsion

There are three main mechanisms that could potentially lead to expulsion of pore water from the TCA:

- Loss of pore water from the TCA via talik seepage at depth;
- Consolidation of unfrozen tailings situated against a perimeter dam (due to increased loading and/or thawing); and
- Leaching of pore water as a result of infiltration through the active layer within the tailings and cover.

The analysis of the above mechanisms comprised an evaluation of the thermal modelling results in Section 3 from the perspective of potential pore water expulsion.

4.1.1 Talik Seepage Mechanism

The talik seepage mechanism refers to seepage of pore fluid through an unfrozen zone beneath a frozen dam core, where the unfrozen zone is resulted of warming from adjacent impounded water.

The thermal analysis in Section 3.4 included an assessment of talik development adjacent to K-Dam and Dam 1A resulting from the maximum depth of impounded water adjacent to K-Dam in Pond 2. The results of the thermal analysis indicate that, after 20 years with a maximum depth of impounded water within Pond 2, the resulting talik would not form an unfrozen zone that would underlie the frozen core of K-Dam or Dam 1A. As discussed in Section 3.5, it is anticipated that the above results are also applicable to the remaining internal and perimeter dams that comprise the TCA. In other words, it is not anticipated that impounded water within the TCA would result in unfrozen zones that underlie the tailings impoundment structures. The potential mechanism of pore water expulsion from the TCA as a result of talik seepage is considered unlikely.

4.1.2 Consolidation Mechanism

The consolidation mechanism refers to pore water expulsion resulting from consolidation of unfrozen tailings, due to the loading from the proposed esker cover layer. As discussed earlier, based on the results of the thermal analyses, it appears that consolidation of the tailings is only limited to portion of the deposit within the active layer.

The thermal analysis results discussed in the previous section indicate that the depth of the active layer in the tailings is about 2 m, but reduces to approximately 1 m with the esker cover. This value is supported by thermistor measurements that have been obtained within Cell 1 and Cell 2, which have been covered with esker material since 1995.

It is necessary to assess both the volume and rate of expelled pore water, so as to evaluate the impact of the consolidation induced potential pore water release. The results of consolidation tests on Lupin tailings reported Golder (1995), as shown in Figures A-5 to A-7, Appendix A, were used in the consolidation assessment.

The following assumptions were incorporated into the consolidation analyses:

- Phreatic surface is located at the base of the esker cover (which provides an upper bound estimate of effectives stresses in the tailings);
- Esker cover is 1 m thick;
- Active layer extends 2 m below the tailings surface;
- Specific gravity of the tailings solids is 3.1;
- Saturated unit weight of the fresh tailings is 17 kN/m^3; and
- Bulk unit weight of the esker cover is 20 kN/m^3.

Based on the above assumptions and using consolidation properties shown in Figures A-5 to A-7, the release of tailings water from the pore voids due to consolidation is estimated to be approximately 0.03 m^3 of pore water for each 1 m^3 of tailings within the active layer. Since the maximum thickness of the tailings within the active layer is 2 m (assuming a summer placement of the cover), the above results correspond to a release of 0.06 m^3 of pore water for each 1 m^2 of tailings that are loaded by the placement of the esker cover layer. The amount of pore water release is estimated to be 0.03 m^3 per 1 m^2 of tailings area if the esker cover is place in the winter (reduced active layer thickness due to the cover).

Based on the consolidation curves shown on Figures A-6 and A-7, the time to consolidate the tailings materials within the active layer due to the loading of the esker cover is estimated to be less than 30 days. In other words, the pore water that is released by loading of unfrozen tailings by the esker cover is expected to be complete by the end of the first thaw season subsequent to the cover placement.

4.1.3 Leaching and Lateral Flow Mechanism

The thermal analyses that were discussed in Section 3 indicate that there is a potential of lateral pore water flow through the active layer. It is observed on Figures 8 and 9 that the active layer extends in the covered cell extends between 1 m and 3 m below the dam crest, from the top of the esker cover to 1 m below the top of the tailings . It is also observed on Figures 8 and 9 that the crest of the frozen dam core is approximately 3 m below the dam crest. It is, therefore, possible that pore water within the active layer could flow laterally, over the crest of the frozen dam core, through the downstream dam face materials.

The potential for lateral pore water flow and leaching is limited to the periphery of the tailings cells, adjacent to the impoundment dams. It is anticipated that this potential exists only when there is sufficient surface water infiltration (due to rainfall in the summer) that generates significant lateral hydraulic gradient within the active layer. The tailings pore water within the unfrozen portion of the deposit or in the bottom part of the esker cover may be “flushed out” under such lateral hydraulic gradient.

4.2 Reducing Potential Pore water Expulsion

As discussed above, the lateral flow and leaching mechanism is considered to potentially result in expulsion of pore water from the tailings containment area. Two conditions must be present for the lateral flow mechanism to be active. First, sufficient infiltration must occur into the esker cover material to provide a water table within the active layer. Second, the water table within the active layer must be higher than the frozen dam core. The probability of the above conditions being present at the same time depends upon the climate, the amount of rainfall and its timing.

Based on the results of climate and hydrology analysis that will be presented in Section 6, it is anticipated that the highest net precipitation levels will occur in the spring; however, the active layer is shallow (within the esker cover materials) during this period and the potential for pore water to leach into the active layer water is, therefore, low. The maximum depth to the frozen dam cores beneath the dam crests is expected to be in later summer/early fall; however, based on the results of the climate and hydrology studies, evaporation typically exceeds precipitation during this period. Consequently, the potential for a water table within the active layer that is higher than the elevation of the frozen dam core is relatively low. It is, therefore, anticipated that expulsion of pore water from the TCA via leaching and lateral flow would occur only with a combination of warm spring/summer and high precipitation events in the late summer/early fall. Again, the extent of the leaching would be limited to the periphery of the tailings cells adjacent to the dams.

Based on the above discussion, it is expected that the overall potential for expulsion of pore water from the TCA via the lateral flow and leaching mechanism is low. Where the potential for pore water expulsion by the lateral flow mechanism exists, two approaches may be considered to further reduce the potential for pore water flow. Both methods would involve modifying the thermal regime at the periphery of the covered tailings cells.

The first approach would involve limiting the active layer to within the esker cover at the periphery of the tailings cells. Additional esker cover would act as insulation that would raise the base elevation of the active layer and maintain the tailings in a frozen state. As a preliminary estimate, it appears that an additional 1 m to 1.5 m of esker cover (for a total thickness of 2 m to 2.5 m) may be sufficient to maintain the active layer within the cover materials. The second approach would involve raising the top elevation of the frozen dam cores through placement of additional insulating material upon the dam crest. Additional esker cover over the existing dams would raise the base of the active layer within the dam, thereby raising the elevation of the frozen dam core. Based on the results the thermal analyses, it is estimated that additional thickness of esker cover material would be required such that the new dam crest is 3 m higher than the top of the adjacent cell cover. It is noted that stability of the dams with the additional materials needs to be checked if this approach is implemented.

5. ASSESSMENT OF COVER MATERIAL SUITABILITY

It is understood that Lupin Mine is proposing to cover all exposed tailings with a 1-meter thickness of gravelly sand that will be obtained from an esker located several kilometres from the TCA. Condition I.1.d in the Water Licence requires "*a comprehensive assessment of material suitability, including geochemical and physical characterization and availability for restoration needs, with attention to top-dressing materials, including maps, where appropriate, showing sources and stockpile locations of all borrow materials*"

The objectives of this study were as follows:

- Identify gravel and other associated cover materials;
- Complete laboratory analysis of selected cover materials; and
- Assess the quantity and suitability, including potential environmental impacts, of these materials.

5.1 Identification of Cover Materials

It is understood that the gravely sand cover materials for Cell 1 and Cell 2 were obtained from the same esker sources that are proposed for use in covering Cell 3 and Cell 5. These esker borrow sources were examined by a Golder geotechnical engineer during the site visit in August 2004. Samples of the esker materials were provided to the Golder laboratory in Calgary by Echo Bay Mines.

5.2 Laboratory Analysis

The following laboratory tests were completed:

- Grain size distribution and maximum and minimum density to generally characterise the esker material;
- Cyclic wetting and drying to assess the physical stability of the esker material;
- Chemical analysis of the tailings decant water; and

- Chemical analysis of leachate fluid from a mixture of esker material and tailings decant water to assess the chemical stability of the esker material.

The grain size distribution and maximum and minimum density tests were completed as per ASTM D422, D4253 and D4254, respectively.

The cyclic wetting and drying test involved alternately soaking the esker material in water and drying the material at a temperature of 105°C. The above sequence was repeated 20 times using the same test specimen. Comparison of the initial dry mass to the final dry mass provides an estimate of the physical durability of the esker material.

Samples of tailings decant water from Cell 5 were provided to Golder by Kinross. Two sets of standard metals analysis results were obtained, the first for a specimen of Cell 5 tailings decant water and the second for a separate specimen of tailings decant water that was used in leachate testing of the esker cover material.

Tailings decant water was used as the leachate fluid for a leachate test that was completed as per the EPA 1311 Toxicity Leaching Procedure. This procedure is designed to determine the mobility of organic and inorganic analytes liquid, solid and multiphase waste materials. Pure (ASTM Type II) water or dilute acids are typically used as the reagent fluid during the EPA 1311 test. Tailings decant water was used as the reagent fluid for the results that are discussed herein.

The EPA 1311 test procedures for non-volatile compounds are summarised as follows:

- Reagent fluid (tailings decant water) and solid waste (esker material) were combined in a bottle extraction vessel (a borosilicate glass bottle);
- Bottle extraction vessel is rotated end-over-end at a rate of 30 ± 2 rpm for 18 ± 2 hours;
- Extract the fluid phase (leachate fluid) from the bottle extraction vessel using filtering methods; and
- Chemical analysis of the leachate fluid.

5.3 Results

Grain size distribution of the esker material that was provided to Golder by Echo Bay Mines is provided on Figure A-4 in Appendix A. The minimum and maximum dry densities of the gravely sand esker material, as per ASTM D4253 and D4254, were measured to be 1686 kg/m^3 and 1979 kg/m^3.

The initial dry mass of the specimen that was subjected to 20 cycles of wetting and drying was 963.29 grams. The final dry mass of the specimen was 960.35 grams. The calculated percentage decrease in specimen mass was 0.31 percent.

The results of chemical analysis of the tailings decant water and the tailings decant water after it was leached through the esker material are provided in Appendix A. The tailings decant water is labelled *Cell 5 Water* in Appendix A and the leachate fluid is labelled *Esker-SI*. The chemical analysis for specimens *Cell 5 Water* and *Esker-SI* are summarised in Table 3.

Table 3
Summary of Chemical Analysis Results

Component	Cell 5 Water (mg/L)	Esker-SI (mg/L)	Detection Limit (mg/L)
Total Trace Metals			
Silver	<0.0004	<0.0004	0.0004
Aluminum	0.02	<0.02	0.02
Arsenic	0.0769	0.0186	0.0004
Boron	0.21	0.21	0.02
Barium	0.0329	0.0370	0.0002
Beryllium	<0.001	<0.001	0.001
Bismuth	<0.0001	<0.0001	0.0001
Cadmium	<0.0002	0.0002	0.0002
Cobalt	0.0489	0.0591	0.0002
Chromium	<0.0008	<0.0008	0.0008
Copper	0.776	0.035	0.001
Molybdenum	0.0616	0.0573	0.0001
Nickel	0.296	0.237	0.0002
Lead	0.0002	0.0001	0.0001
Antimony	0.0018	0.0009	0.0004
Selenium	0.0005	0.0010	0.0004
Tin	<0.0004	<0.0004	0.0004
Strontium	2.45	2.33	0.0002
Titanium	<0.005	<0.005	0.005
Thallium	<0.0001	0.0002	0.0001
Uranium	0.0008	0.0006	0.0001
Vanadium	0.0011	0.0011	0.0002
Zinc	0.765	0.129	0.004
Total Major Metals			
Calcium	161	153	0.5
Potassium	21.7	21.5	0.1
Magnesium	8.0	8.5	0.1
Sodium	276	269	1
Iron	0.012	0.015	0.005
Manganese	0.072	0.172	0.001
Mercury	<0.0002	<0.0002	0.0002

5.4 Comments

It is observed on Figure A-4 that the esker material is classified as gravelly sand according to the Modified Unified Soil Classification System.

The results of 20 cycles of wetting and drying indicate that the percentage of mass lost by the specimen over the course of the test was 0.31 percent. This value is considered to be within the accuracy of the testing method; consequently, the results indicate that the esker material is physically stable.

It is observed in that the measured amounts in the specimens *Cell 5 Water* and *Esker-SI* were similar. There was relatively little difference between the specimen of tailings decant water and the specimen of tailings decant water that was leached through the esker material.

Based on the results presented above, it does not appear that the esker material will physically degrade on exposure to the tailings decant water. Further, it appears that the chemistry of the tailings decant water will change relatively little if this fluid leaches through the esker material. It is, therefore, concluded that the esker material is a suitable cover material for the tailings deposition cells.

6. CLIMATE AND HYDROLOGY STUDY

Lupin Mine plans to develop a partially saturated granular cover over the exposed tailings area to provide a barrier to oxidation. It is critical that a positive water balance is maintained within the cover system for the oxidation barrier to be effective.

The objectives of this study were as follows:

- Summarizes the climate conditions of the study area of the Lupin Mine Tailings Containment Area (TCA); and
- Estimate the probability of maintaining a positive water balance over the surface of the TCA.

6.1 Climatic Conditions

The water balance for the study area at the Lupin Mine TCA was assessed on the basis of regional as well as site-specific information on temperature, precipitation (rainfall and snowfall), evaporation and runoff.

6.1.1 Climate Data

A climate station has been in operation at Lupin since 1982. Table 4 summarizes the mean annual and mean monthly temperature and precipitation (including rainfall and snowfall) calculated from observed data at Lupin, as well as mean annual and mean monthly evaporation derived from data recorded at Norman Wells Airport.

Air temperature is the variable most commonly used to characterize the climate of northern regions. Air temperature is a key factor in determining snowmelt rate during the spring runoff period. Mean annual temperatures in the region, based on climate normal information published by Environment Canada, range from -6.0°C at Normal Wells Airport to -10.5^{o}C in the north at Tuktoyaktuk. The mean annual temperature, based on recorded data at Lupin, is -10.8^{o}C. The mean monthly temperatures range from -29.9^{o}C in January to 11.6^{o}C in July. Mean monthly temperatures are above the freezing mark from June (6.3^{o}C) to September (2.2^{o}C). The mean monthly temperature in August is 8.8^{o}C.

Precipitation (including rainfall and snowfall) and temperature data are available from 1982 to present at Lupin. Precipitation and temperature data from 1982 to 2003 were used in this assessment. The mean annual precipitation at Lupin, based on the recorded data, is 297 mm. The mean annual precipitation at Normal Wells, located about 700 km to the west of Lupin but at the same latitude, is comparable at 316 millimetres. For northern basins, snow storage is an important part of the water cycle. Regionally, snow contributes a large part of the annual precipitation for eight months of the year, with snowfall accounting for about 45% to 70% of total annual precipitation. Snowfall occurs mostly between October and April, although it is possible for snowfall to occur in any month. The mean annual rainfall and snowfall amounts, based on recorded data at Lupin, are 161 and 136 mm, or about 54% and 46% of total annual precipitation, respectively.

The recorded snowfall estimates at Lupin do not take into account snowfall under-catch and sublimation. Studies indicate that snowfall under-catch can be substantial at gauges where windy conditions hinder the collection of snow and where trace amounts are not recorded. Recommended correction factors range from about 1.15 to 1.30. Conversely, sublimation can significantly deplete end-of-winter snow accumulation, thus reducing spring runoff. The amount of snow lost to sublimation is dependent upon wind and humidity conditions and is not easily estimated. As well, water equivalent of snow can decrease from the time of deposition due to sublimation. Both events decrease the amount of runoff that would be available from the winter months. For the purposes of the water balance analysis at Lupin Mine, it was assumed that the amounts of snowfall “under-reported” and lost to sublimation were comparable and, thus, no adjustments to the recorded snowfall values were necessary.

Evaporation is a key factor in determining the amount of precipitation that appears as runoff from a watershed, however, it is also the least understood of the major hydrologic region components, especially in northern areas. In general, evaporation is greatest in the summer when days are long and solar radiation is greatest. Daily energy input controls the evaporation rate for shallow-water systems. The relative importance of evaporation in the water balance of watersheds tends to increase in the north because of the decrease in precipitation at higher latitudes. No direct measurements of evaporation were available for Lupin. Evaporation and temperature data from Norman Wells were used to assist in the water balance analysis. Both pan and lake evaporation data were available at Norman Wells from 1964 to 2003. Differences in mean temperature between Lupin and Norman Wells did not allow for direct transfer of evaporation data. A relationship between mean monthly temperature and total monthly evaporation was established for Norman Wells. The relationship was used to calculate pan and lake evaporation for Lupin using mean monthly temperatures. Evaporation was only calculated where the monthly mean temperatures were greater than zero.

Table 4
Climate Summary for Lupin

Month	Mean Temperature (°C)	Mean Rainfall (mm)	Mean Snowfall (cm)	Mean Precipitation (mm)	Mean Lake Evaporation (mm)
Jan	-29.9	0.0	8.9	8.9	0.0
Feb	-28.7	0.0	7.7	7.7	0.0
Mar	-24.9	0.0	12.1	12.1	0.0
Apr	-15.9	0.1	14.0	14.2	0.0
May	-5.7	5.8	13.2	19.0	0.0
Jun	6.3	24.1	3.9	28.0	53.0
Jul	11.6	43.9	0.4	44.3	97.1
Aug	8.8	58.5	2.9	61.4	73.7
Sep	2.2	26.7	17.2	43.9	18.4
Oct	-8.4	1.8	27.1	28.8	0.0
Nov	-20.5	0.0	16.0	16.0	0.0
Dec	-26.3	0.0	14.1	14.1	0.0
Annual	*-10.8*	*161*	*136*	*297*	*242*

6.1.2 Hydrological Data

The hydrologic regime of the region around the study area is dominated by snowmelt, with peak surface runoff occurring in late May and June. Flows in streams typically recede gradually over the summer. Water yield, estimated by dividing the mean annual discharge from a watershed by its area, represents a runoff depth of water. This provides a useful measure with which runoff can be compared with precipitation. There is no local long-term stream gauging station at Lupin. Annual water yield in the region of the study area can range between 70 and 120 millimetres.

Runoff during the months of May and June accounts for about 70% of the annual runoff, with the remaining 30% occurring over the summer and fall months between July and September.

The mean annual precipitation, based on recorded data at Lupin, is 297 millimetres. This suggests that between 25% and 40% of the annual precipitation, after losses to evaporation and transpiration, results in runoff that appears as flows in streams.

6.2 Methodology

A monthly water balance was conducted based on a 21-year series of monthly precipitation and evaporation data derived for the study area. The objective of the analysis was to characterize the availability of inflow into, or the runoff from the TCA. The assumptions in the analysis were as follows:

- The snow accumulated over the winter months, which on average amounts to approximately 46 % of the annual precipitation, is held in storage until the spring melt.
- The gravel layer is frozen during most of May and the snow cover does not completely disappear until after the end of May.
- About 50 mm of the snowmelt in late May and June is used to bring the moisture content of the esker gravel layer to about 10% throughout its entire 1-metre depth. Any excess moisture input from snowmelt and rain is lost through evaporation and surface runoff. Evaporation is assumed to be 70% of the potential lake evaporation value estimated from the monthly mean temperature. The relatively high value of evaporation, about 70% of the potential lake evaporation, is based on the moist and saturated surface during May and June.
- The top 10 cm (approximately) of the esker gravel layer, which is exposed to wind and solar radiation, is continually losing water. Hence, a minimum of about 10 mm of moisture input is necessary to “wet” or satisfy the “deficit” in the top layer at the beginning of a rainfall event.
- The moisture lost through evaporation is about 30% of the potential monthly mean lake evaporation calculated from the monthly mean temperature during

the summer and fall months from July to September. The value of 30% reflects the dryer and moisture-limited conditions of the top portion of the upper gravel layer during these months.

- Seepage losses from the TCA are assumed to be about 10 mm per month. About 30% of the annual runoff in watersheds in the region of the study area occurs from July to September. Most of the runoff during these months is through groundwater flow. Assuming an average annual runoff of 100 mm, of which 70% occurs during May and June, then about 30 mm of runoff occurs between July and September. The month runoff is then about 10 mm and sustained through infiltration.
- The water balance is conducted on a monthly basis, with no carry-over from month to month. While not strictly accurate, this assumption provides a conservative assessment because the effects of the variability in amount, frequency, duration and inter-event period of rainfall events during any month has not been factored in the analysis.
- A surplus of moisture is necessary after evaporation losses, satisfaction of surface moisture deficits and infiltration/seepage losses to maintain the gravel layer partially saturated and a positive water balance over the underlying tailings layer during the summer and fall months from July to September. It is assumed that a deficit of more than 25 mm can cause the upper gravel layer to start drying up.

6.3 Results

The results of the water balance analysis are presented in two sets: (1) the deficit is defined as a monthly moisture imbalance of less than zero; and (2) the deficit is defined as a monthly moisture imbalance of less than 25 millimetres. Based on the 21 years of data at Lupin, the probability of:

Deficit > 0 mm

- A year with no deficit in any given month = 19%
- A year with a deficit of greater than 0 mm during any one month between July and September = 57%

- A year with a deficit of greater than 0 mm during any two months between July and September = 24%

Deficit > 25 mm

- A year with no deficit in any given month = 67%
- A year with a deficit of greater than 25 mm during any one month between July and September = 33%
- A year with a deficit of greater than 25 mm during any two months between July and September = 0%

6.4 Comments

The water balance results indicate that there are relatively high probabilities of surface moisture deficit during any one summer month at the Lupin Mine TCA. However, the results also indicate that the probability of surface moisture deficits in two consecutive summer months is relatively low. More specifically, the results indicate that the cumulative surface moisture deficit in two consecutive summer months is unlikely to exceed 50 mm. Given the proposed cover thickness of 1 m, the probability of drying out the entire cover is considered low. In other words, it is considered likely that partial saturation can be maintained within the cover system for the given climate and hydrological conditions at the Lupin Mine area, and the cover layer is anticipated to perform as an oxidation barrier.

7. SUMMARY AND CONCLUSIONS

A series of studies have been completed to satisfy the water license requirements and to support the reclamation planning at the Lupin Mine. The components of the studies include:

- Geo-thermal analyses to assess the interaction between fluctuating pond elevations and performance of frozen cores in perimeter tailings containment structures within TCA;
- Geo-thermal modelling and consolidation analyses to assess the potential pore water expulsion from the tailings deposits due to various mechanism;
- Laboratory tests to evaluate the esker material on its suitability as a tailings cover; and
- Climate and hydrology analyses to address the suitability of esker cover as an oxidation barrier.

Based on the findings from the above studies, the following conclusions are derived:

- Impoundment of water within Pond 1 and Pond 2 to an elevation 3 m higher than the maximum elevations, as limited by the crest elevations of the adjacent TCA perimeter dams, over a 20 year period would most likely not lead to thawing of the frozen cores in the perimeter dams. In other words, the performance of the frozen core perimeter dams will not be negatively impacted by fluctuating pond elevations under the current dam configurations. It is noted that the geo-thermal analysis, upon which this conclusion is derived, represents a “worst case” scenario for the TCA configuration at present time.
- The overall probability of significant long term pore water expulsion from the tailings deposits is considered low, for the following reasons:
  - The results of thermal analyses indicate that elevated pond elevations will not cause thawing of frozen tailings below the active layer, even when the maximum pond elevations are maintained for a 20 year period.
  - Consolidation of the tailings deposits as a result of esker cover placement is limited within the active layer. The amount of water release is estimated to range

approximately from 0.03 m^3 to 0.06 m^3 per 1.0 m^2 of the tailings area. The pore water expulsion due to consolidation in the active layer is anticipated to complete by the end of the first thaw season after esker cover placement.

- The potential of tailings pore water expulsion due to lateral flow and leaching through the active layer would occur only with a combination of warm spring/summer and high precipitation events in the late summer/early fall. Furthermore it is limited to the periphery of the tailings cells, adjacent to the impoundment dams. Approaches to minimize the leaching through lateral flow include increased cover thickness on the dams or over the tailings area immediately adjacent to the dams.

- Laboratory testing results indicate that the proposed esker material (gravely sand) is physically and chemically stable, and suitable for being used as a tailings cover.
- The results of the climate and hydrology studies indicate that there are relatively high probabilities of surface moisture deficits during any one summer month at the Lupin Mine TCA. However, the cumulative surface moisture deficit in two consecutive summer months is unlikely to exceed 50 millimetres. Given the proposed cover thickness of 1 m, the probability of drying out the entire cover is low. In other words, it is considered likely that partial saturation can be maintained within the cover system for the given climate and hydrological conditions at the Lupin Mine area, and the cover layer is anticipated to perform as an oxidation barrier.

8. CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

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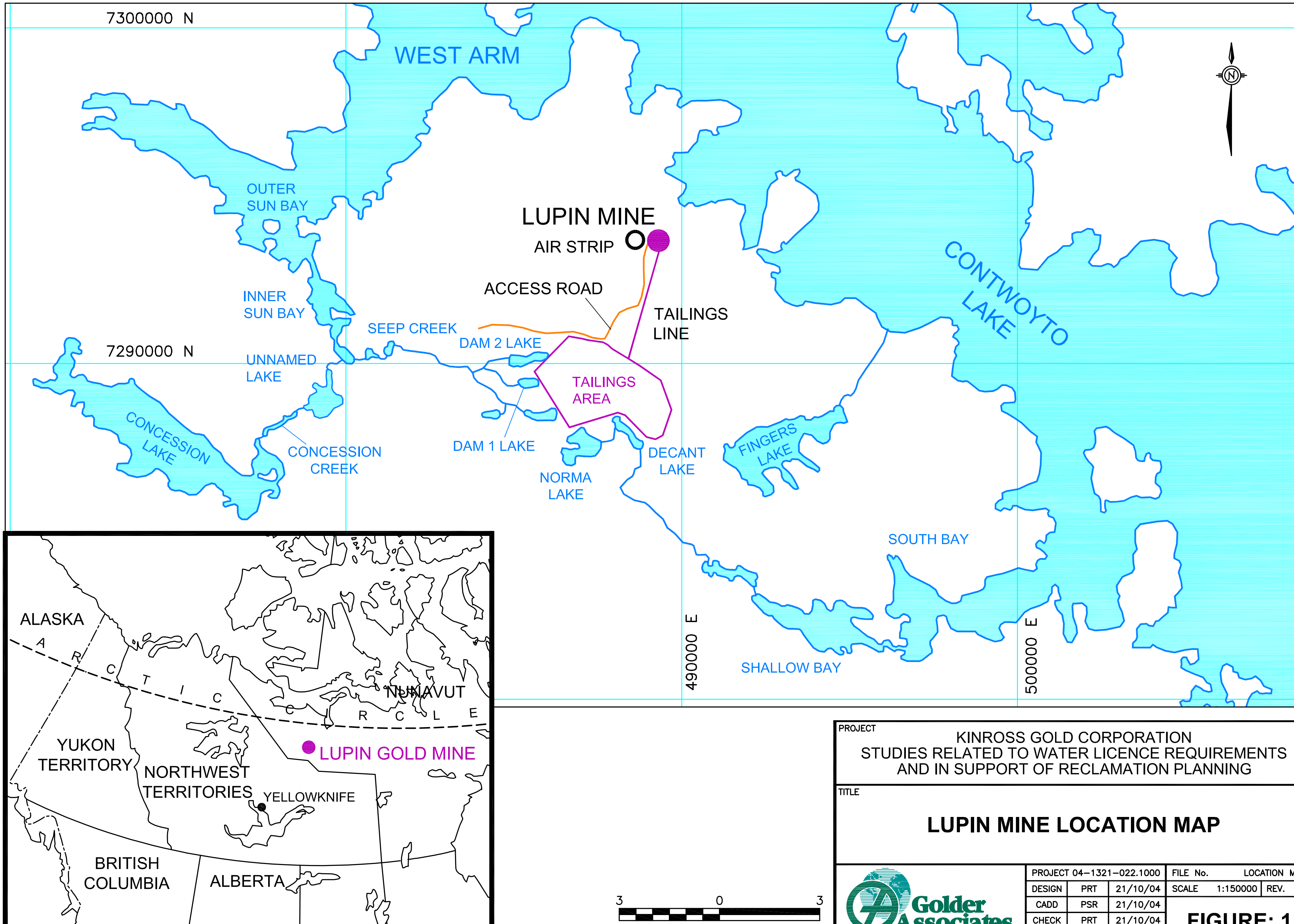
FIGURES

R:\CAD\2004\1330-Engin\1321\04-1321-022\1000\ Drawing file: Fig 1 LOCATION MAP.dwg Oct 29, 2004 - 10:37am



PROJECT

KINROSS GOLD CORPORATION
STUDIES RELATED TO WATER LICENCE REQUIREMENTS
AND IN SUPPORT OF RECLAMATION PLANNING

TITLE

LUPIN MINE LOCATION MAP

Golder Associates
Calgary, Alberta

PROJECT 04-1321-022.1000			FILE No. LOCATION MAP	
DESIGN	PRT	21/10/04	SCALE 1:150000	REV. 1
CADD	PSR	21/10/04		
CHECK	PRT	21/10/04	**FIGURE: 1**	
REVIEW				

LEGEND

QUATERNARY
HOLOCENE

NONGLACIAL ENVIRONMENT

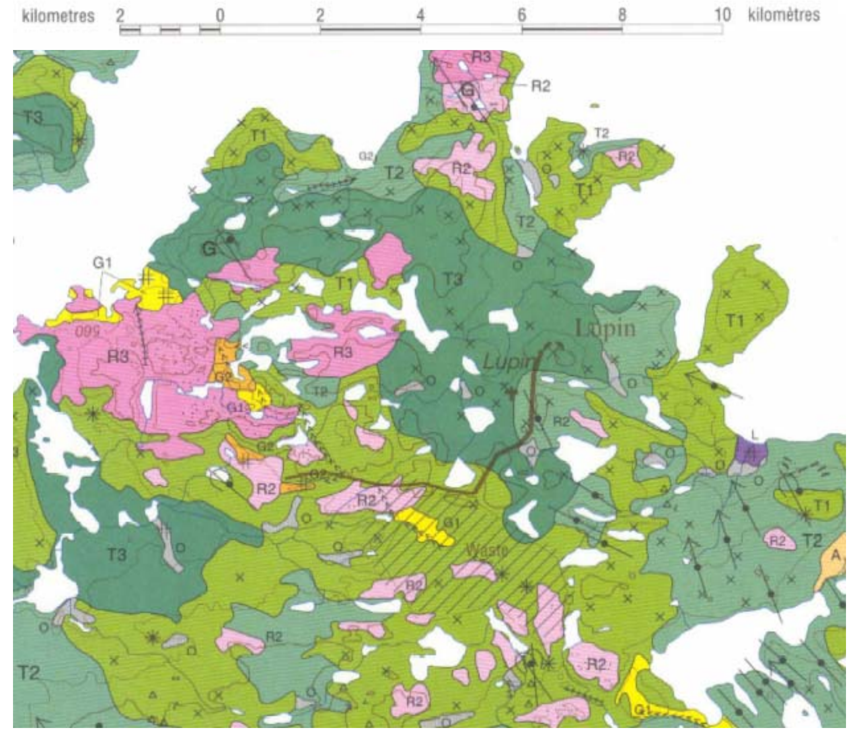
O	*ORGANIC DEPOSITS:* peat and muck up to 1 m thick; formed predominantly by the accumulation of vegetative material; occurs in depressions, along valley bottoms and in areas once submerged by glacial lakes where they may overlie fine-grained lacustrine sediments; may contain ice-wedge polygons. Small unmapped organic deposits occur in most terrain units
A	*ALLUVIAL DEPOSITS:* gravel to silt size sediment, 1 to 5 m thick, deposited by modern streams and rivers; deposits range from massive to well stratified; associated with meandering, braided, and floodplain environments

PLEISTOCENE (WISCONSIN GLACIATION)
GLACIAL ENVIRONMENT

L	*GLACIOLACUSTRINE DEPOSITS:* silt, sand, and gravel; 1 to 10 m thick; cross-stratified to planar bedded sands; deposited in temporary glacier-dammed lakes; associated with deltas and raised beaches indicated by symbols; may contain massive ground ice
	GLACIOFLUVIAL DEPOSITS: sand, gravel, and minor silt; 1 to 20 m thick; sorting ranges from good to poor, and stratification from massive or cross-stratified to planar bedded; deposited by water flowing from, or in contact with, glacier ice; may contain massive ground ice
G2	*Outwash:* rounded gravel and sand; massive to cross-stratified; probably less than 20 m thick; occurs as braided fans and outwash plains, commonly containing ice-wedge polygons
G1	*Esker sediments:* sand, silt, and gravel; in planar, cross-stratified, and massive beds; 1 to 20 m thick; forms ridges with both sharp-crested and flat-topped segments, mounds, and flanking aprons; deposited at or behind the ice margin; formed subglacially or in subaerially exposed ice-walled channels. Zones of washed bedrock (meltwater scours) between esker segments, isolated kame deposits, and boulder lags are shown by symbols between esker segments
	TILL DEPOSITS: unsorted glacial debris (diamicton), consisting of a silty sand matrix containing pebbles, cobbles, and boulders, with minor lenses of sorted sediments; deposited beneath or along the margin of glaciers as lodgment till, meltout till, and gravity flow deposits; may contain massive ground ice
T3	*Hummocky till:* greater than 2 m thick; forms irregular to rolling terrain with relief up to 15 m, locally forming hills and ridges up to 3 km long; some areas have abundant small meltwater channels and lag concentrations of boulders in depressions. Stabilized retrogressive thaw flow slides may be indicative of ice-rich till
T2	*Till blanket:* greater than 2 m thick; occurs as till plains or as drumlinoids. Small rock outcrops in this unit are shown by symbols
T1	*Till veneer:* less than 2 m thick; rock structure is generally visible on airphotos; unit includes patches of bedrock and till blanket

PRE-QUATERNARY

	BEDROCK: Archean metasedimentary, metavolcanic, granitic, and gneissic rocks; Proterozoic sedimentary rocks, mafic dykes and sills; may include patches of till veneer or glaciofluvial deposits; areas of shattered and frost-heaved rock are designated by symbols
R5	Gabbro sills
R4	Sedimentary rocks
R3	Granitic and gneissic rocks
R2	Metasedimentary rocks
R1	Metavolcanic rocks



Geological boundary
Retrogressive thaw flow slide
Solifluction lobe
Frost heaved and shattered rock
Thermokarst
Ice-wedge polygon
Raised beach
Area of meltwater scour
Lag concentration of glacially abraded boulders
Subglacial or proglacial meltwater channel
Esker (direction of flow known, unknown)
Kames
Moraine
Drumlinoid till form
Crag-and-tail landform
Roche moutonnée or whaleback
Striation (ice flow direction known, 1 = oldest)
Gossan G
Small rock outcrop
Sample site
Mine waste and settling ponds
(symbol overlies pre-development geology indicated on map)

Figure derived from:

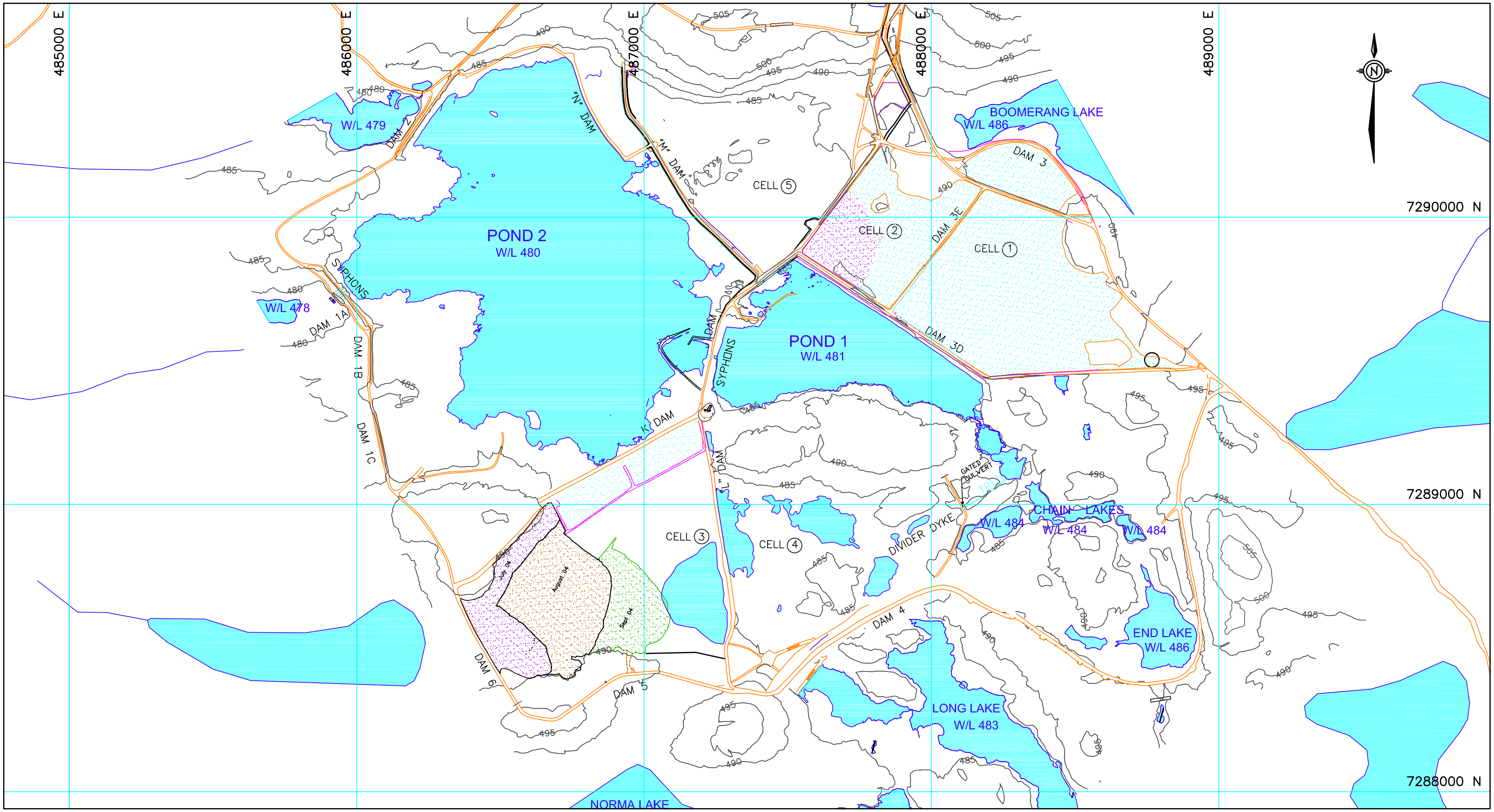
Kerr, D.E., Ward, B.C and Dredge, L.A. 2000. Surficial Geology, Contwoyto Lake, Northwest Territories-Nunavut. "A" Series Map 1978A. Geological Survey of Canada.

Golder Associates

Kinross Gold Corporation
Studies Related to Water License Requirements and in Support of Reclamation Planning

Surficial Geology

DRAWN: PRT	APPROVED:	DATE: 21 October 2004
PROJECT: 04-1321-022		FIGURE: 2



LEGEND

ESKER COVER

REFERENCE

BASE MAP PROVIDED BY KINROSS GOLD CORPORATION

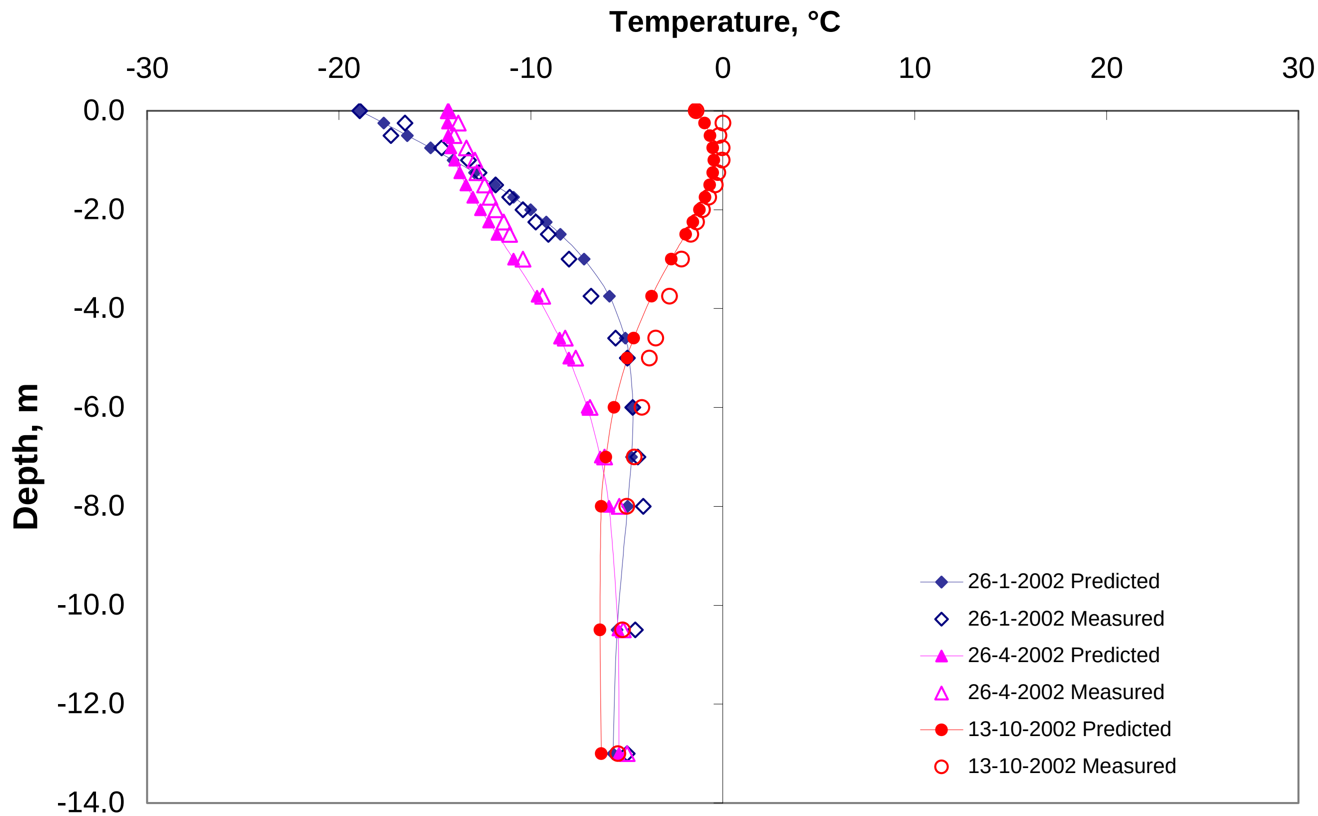
400 0 400
SCALE METRES

PROJECT
KINROSS GOLD CORPORATION
STUDIES RELATED TO WATER LICENCE REQUIREMENTS
AND IN SUPPORT OF RECLAMATION PLANNING

TITLE
LUPIN TAILINGS AREA

Golder Associates
Calgary, Alberta

PROJECT 04-1321-022.1000			FILE No. Lupin Tailings Area	
DESIGN	PRT	21/10/04	SCALE AS SHOWN	REV. 0
CADD	PSR	21/10/04	FIGURE: 3	
CHECK	PRT	21/10/04		
REVIEW				

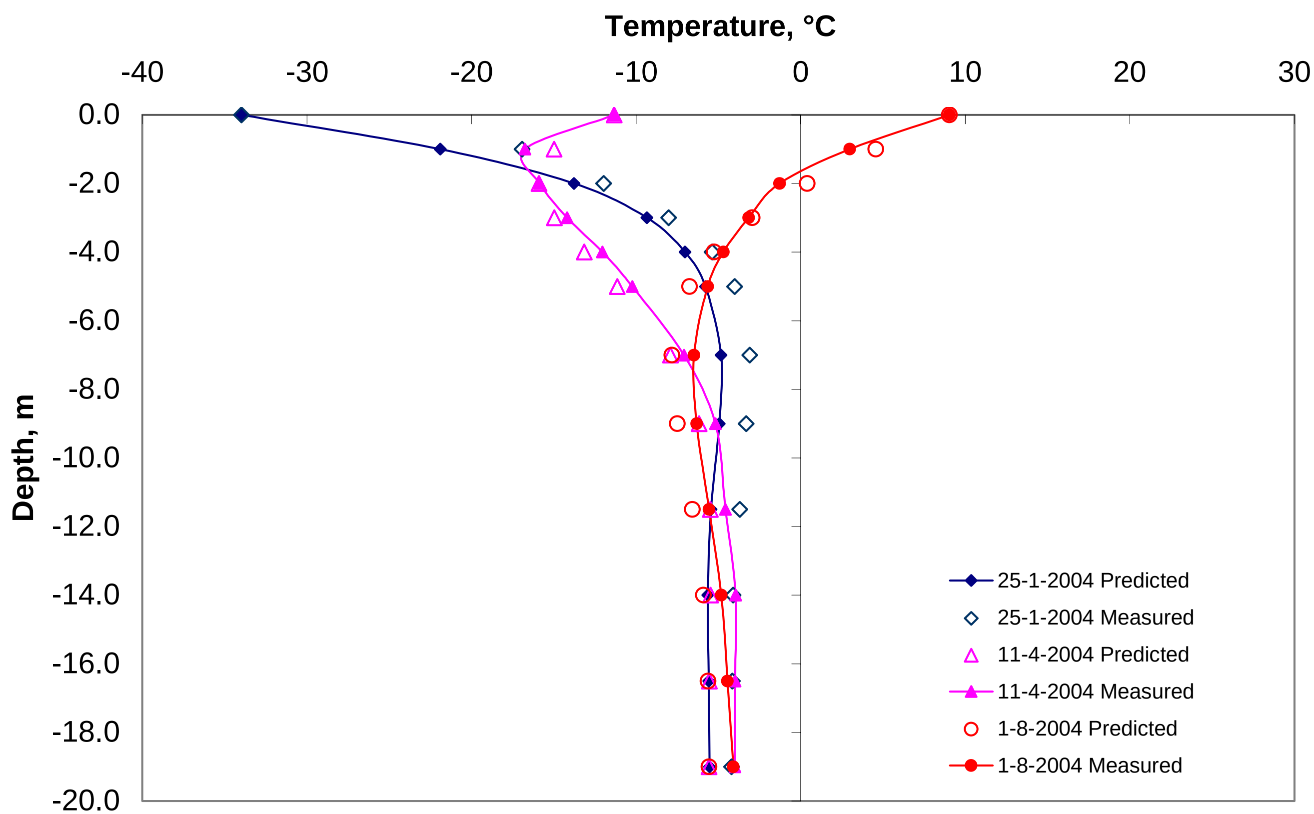


Golder Associates

Kinross Gold Corporation
Studies Related to Water License Requirements and in Support of Reclamation Planning

Predicted Behaviour of Thermistor TC1-3

DRAWN: PRT	APPROVED:	DATE: 21 October 2004
PROJECT: 04-1321-022		FIGURE: 4



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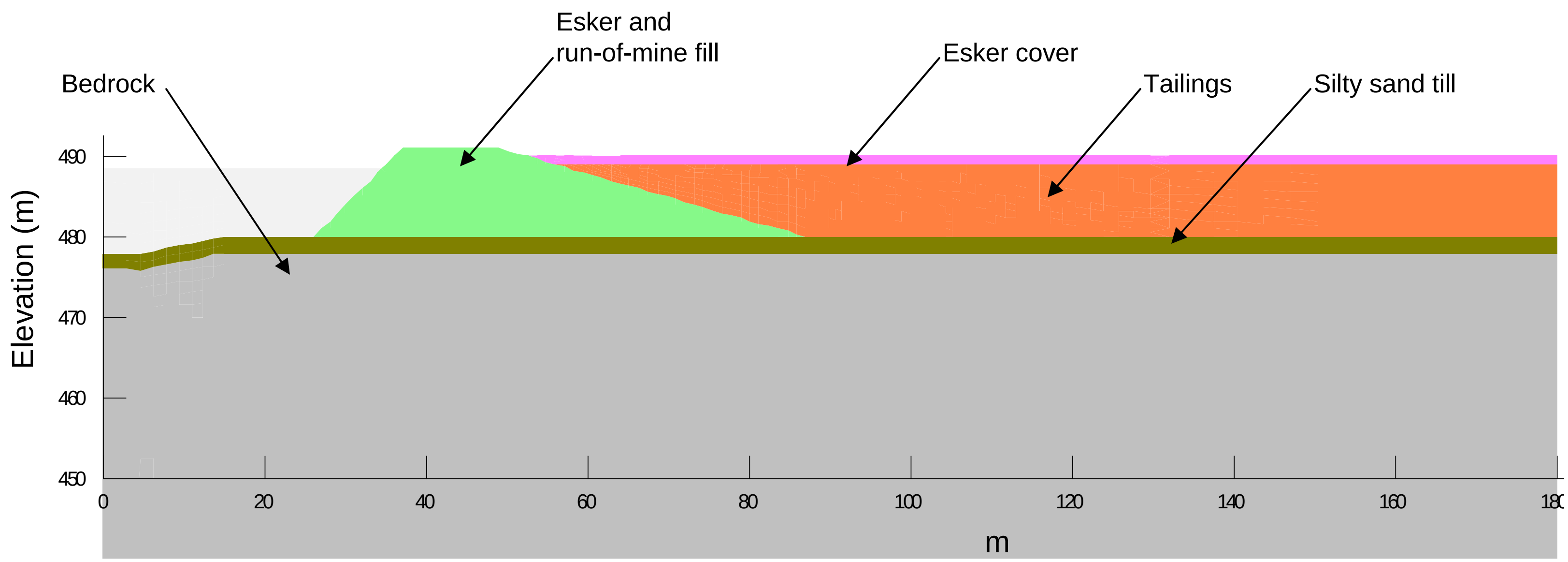
Studies Related to Water License Requirements and in Support of Reclamation Planning

Predicted Behaviour of Thermistor D1A-00-1S

DRAWN: PRT	APPROVED:	DATE: 21 October 2004
PROJECT: 04-1321-022		FIGURE: 5



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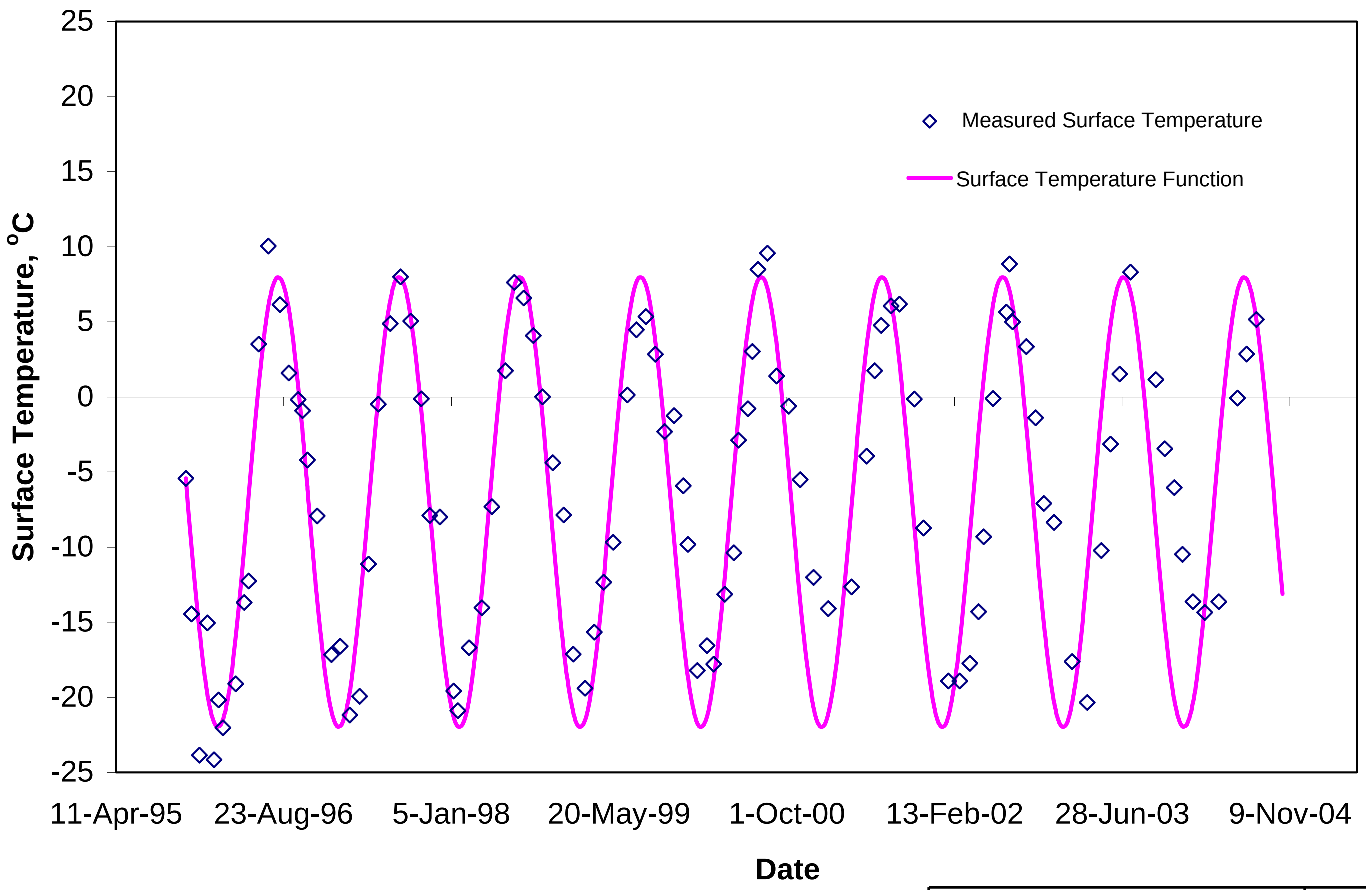
Studies Related to Water License Requirements and in Support of Reclamation Planning

Analysed Cross Section: K-Dam

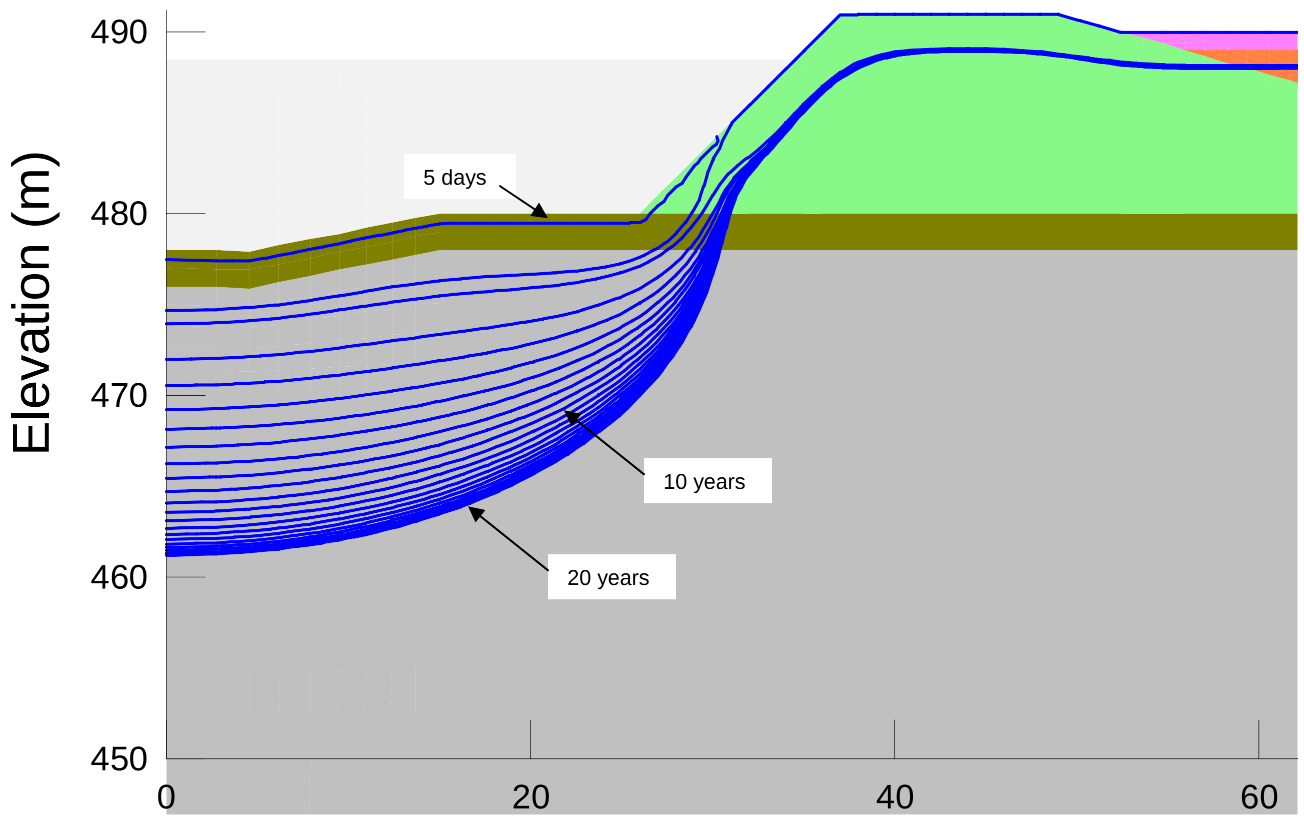
DRAWN: PRT	APPROVED:	DATE: 21 October 2004
PROJECT: 04-1321-022		FIGURE: 6



Golder Associates	Kinross Gold Corporation Studies Related to Water License Requirements and in Support of Reclamation Planning

Predicted Surface Temperature
Thermistor TC1-3

DRAWN: PRT	APPROVED:	DATE: 21 October 2004
PROJECT: 04-1321-022		FIGURE: 7



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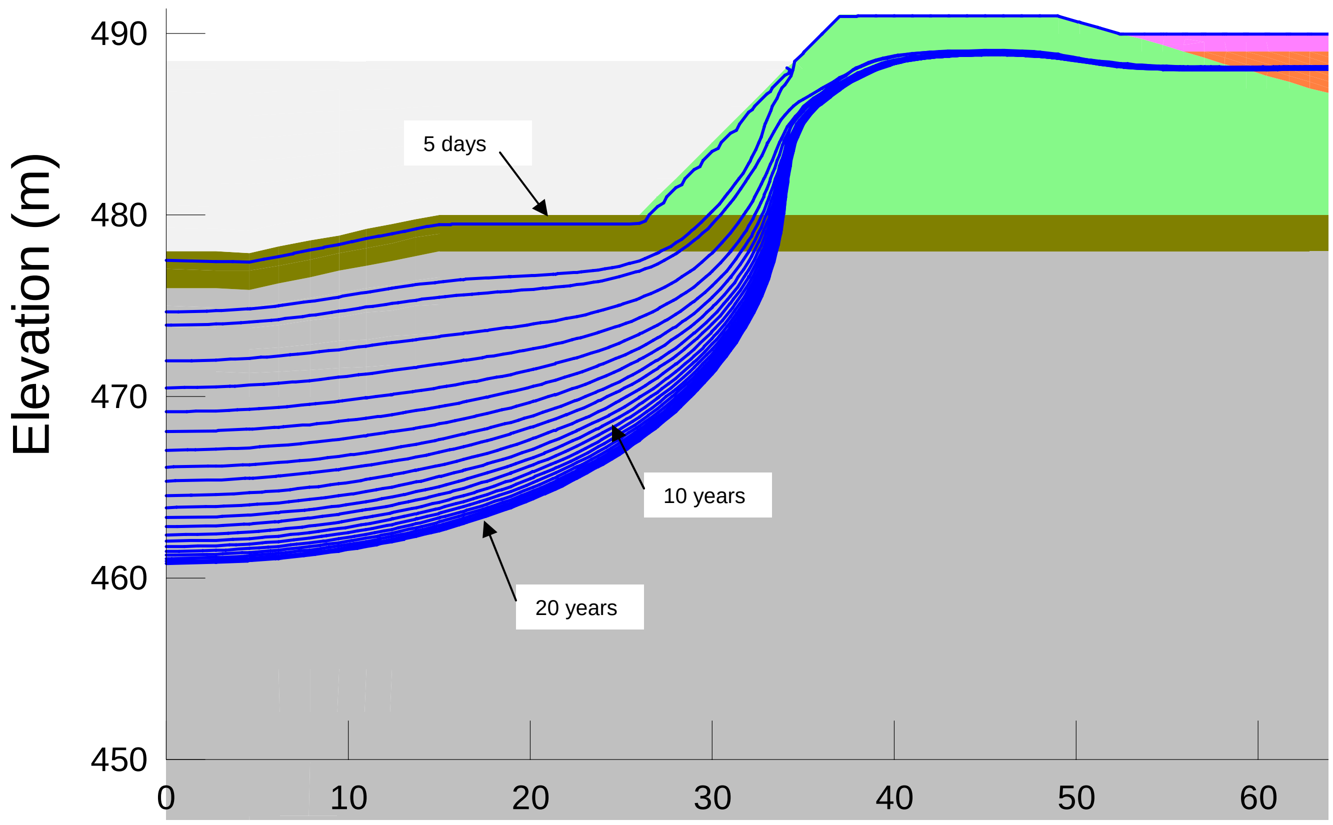
Studies Related to Water License Requirements and in Support of Reclamation Planning

Golder Associates

Progression of 0°C Isotherm
5 m of Water Downstream

DRAWN: PRT	APPROVED:	DATE: 21 October 2004
PROJECT: 04-1321-022		FIGURE: 8



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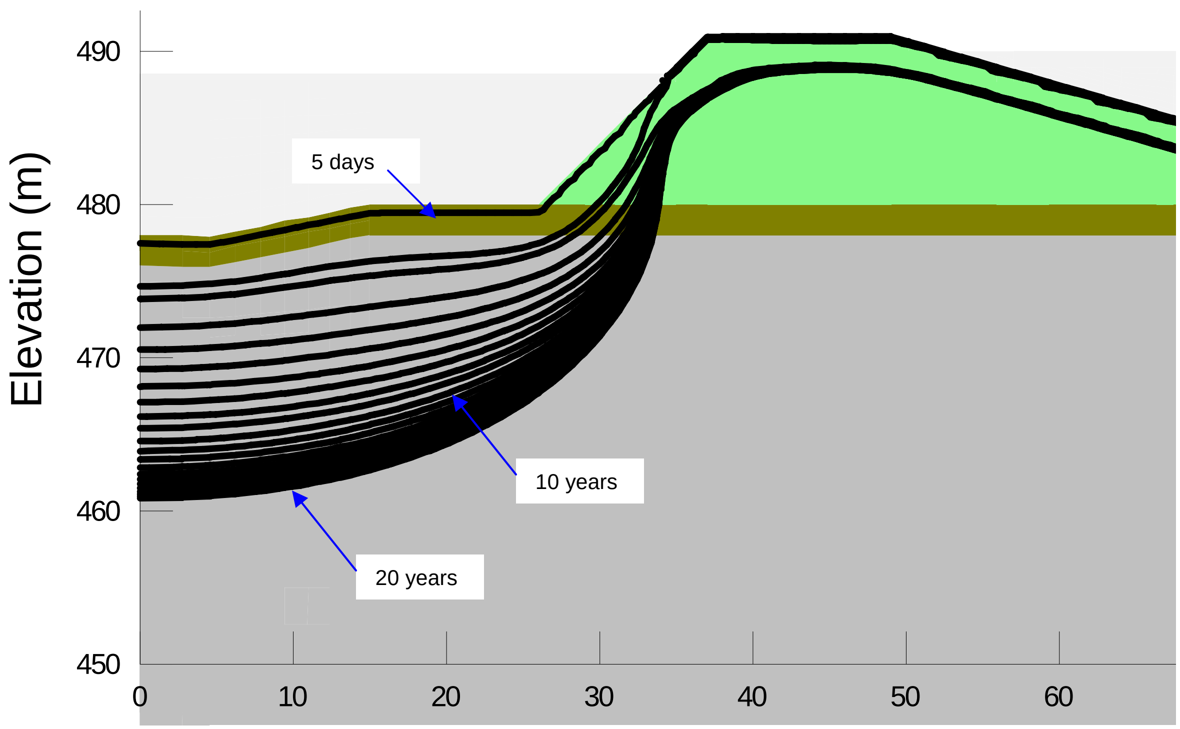
Kinross Gold Corporation
Studies Related to Water License Requirements and in Support of Reclamation Planning

Progression of 0°C Isotherm
8.5 m of Water Downstream

DRAWN: PRT	APPROVED:	DATE: 21 October 2004
PROJECT: 04-1321-022		FIGURE: 9



Kinross Gold Corporation
Studies Related to Water License Requirements and in Support of Reclamation Planning

Progression of 0°C Isotherm
8.5 m of Water Downstream
No Retained Tailings

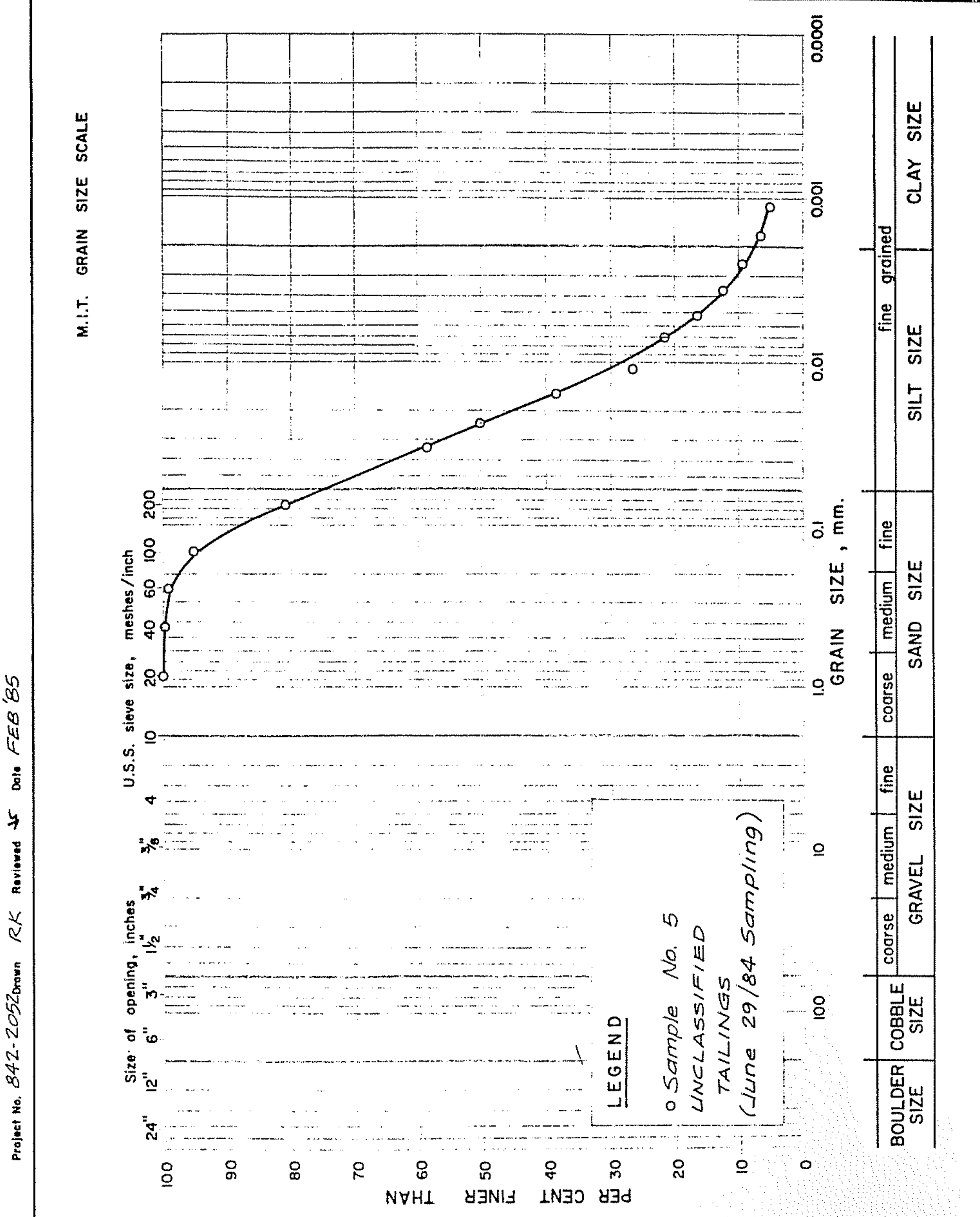
DRAWN: PRT	APPROVED:	DATE: 21 October 2004
PROJECT: 04-1321-022		FIGURE: 10

APPENDIX A

LABORATORY TEST RESULTS

GRAIN SIZE DISTRIBUTION
TAILINGS

Figure A-1



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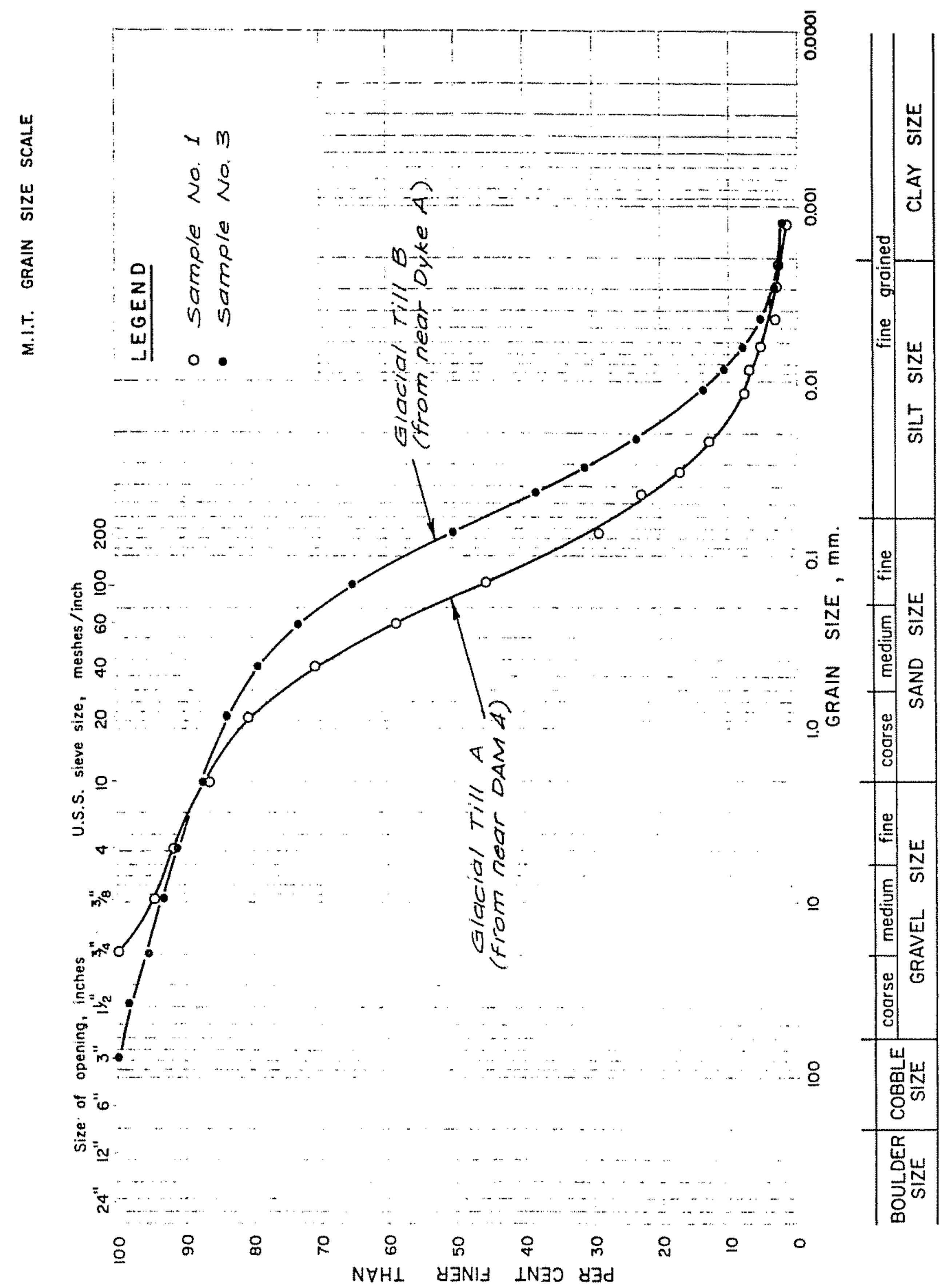
GRAIN SIZE DISTRIBUTION
GLACIAL TILL

Figure A-2

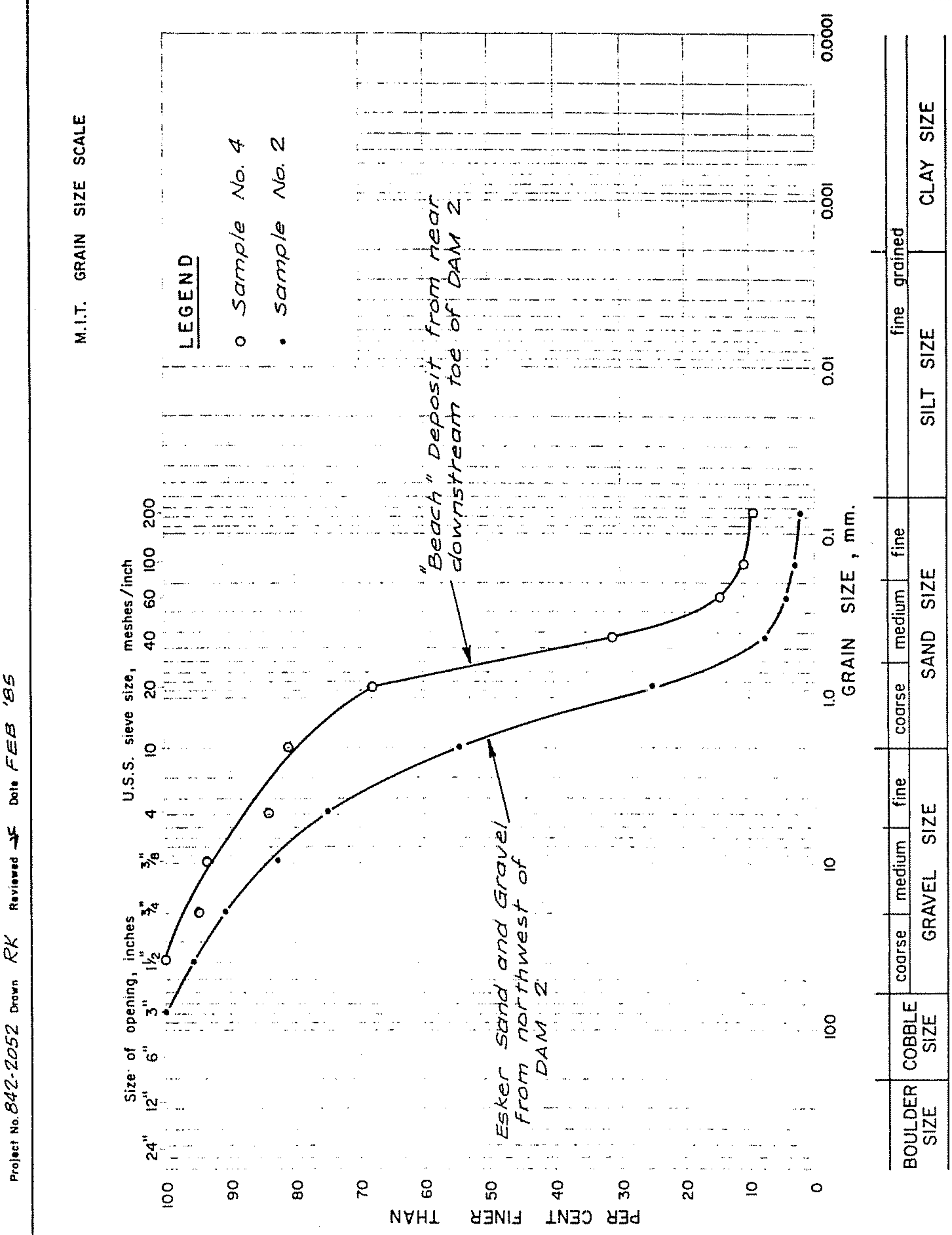


Project No. 842-2052 Drawn RK Reviewed Date FEB '85

Golder Associates

GRAIN SIZE DISTRIBUTION
ESKER SAND

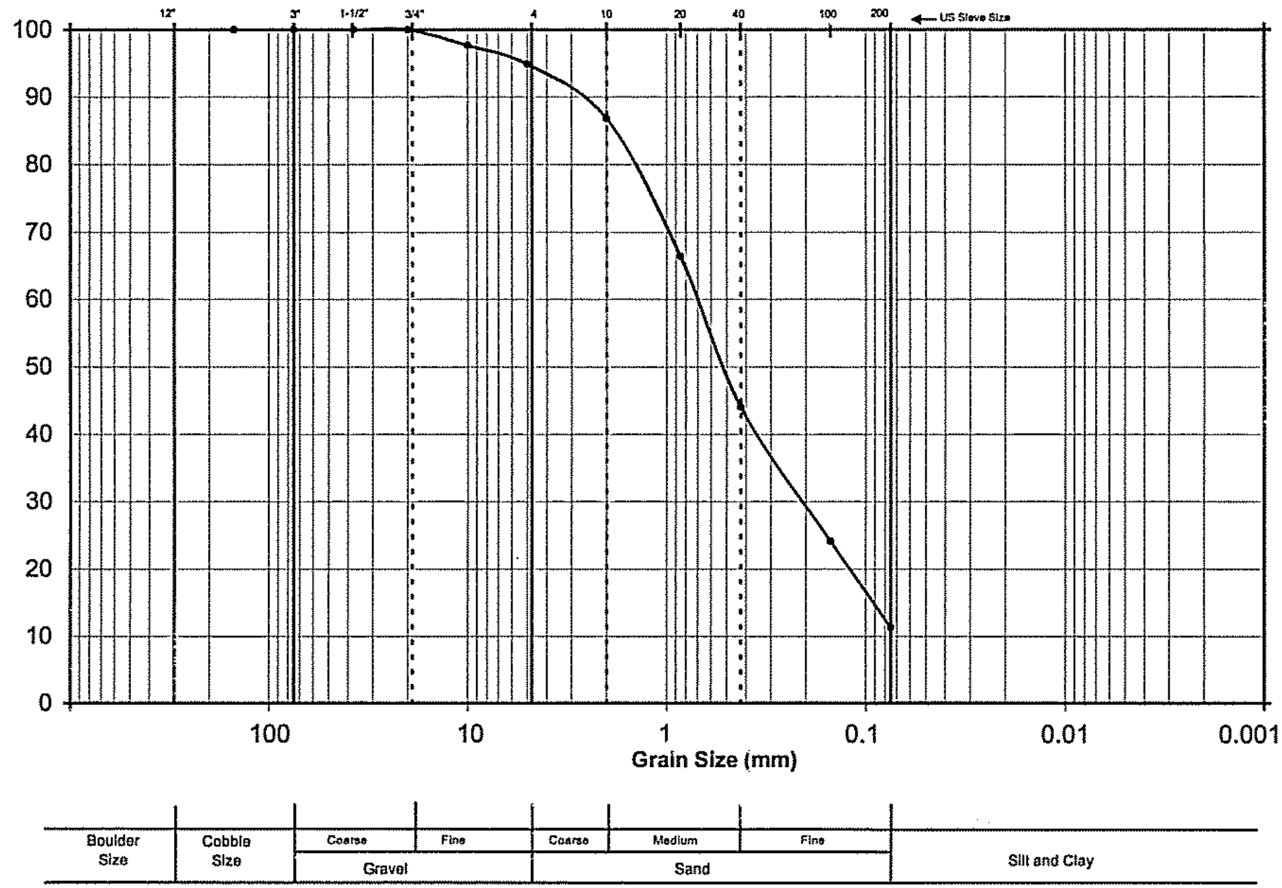
Figure A-3



Golder Associates

PARTICLE SIZE ANALYSIS OF SOIL
(ASTM D422)

Project No.: 04-1321-022 Lab No.: 560401
Project Title: Lupin
Borehole: - Sample No.: Esker sample
Depth: -
Date Tested: 21-Sep-04 By: LT

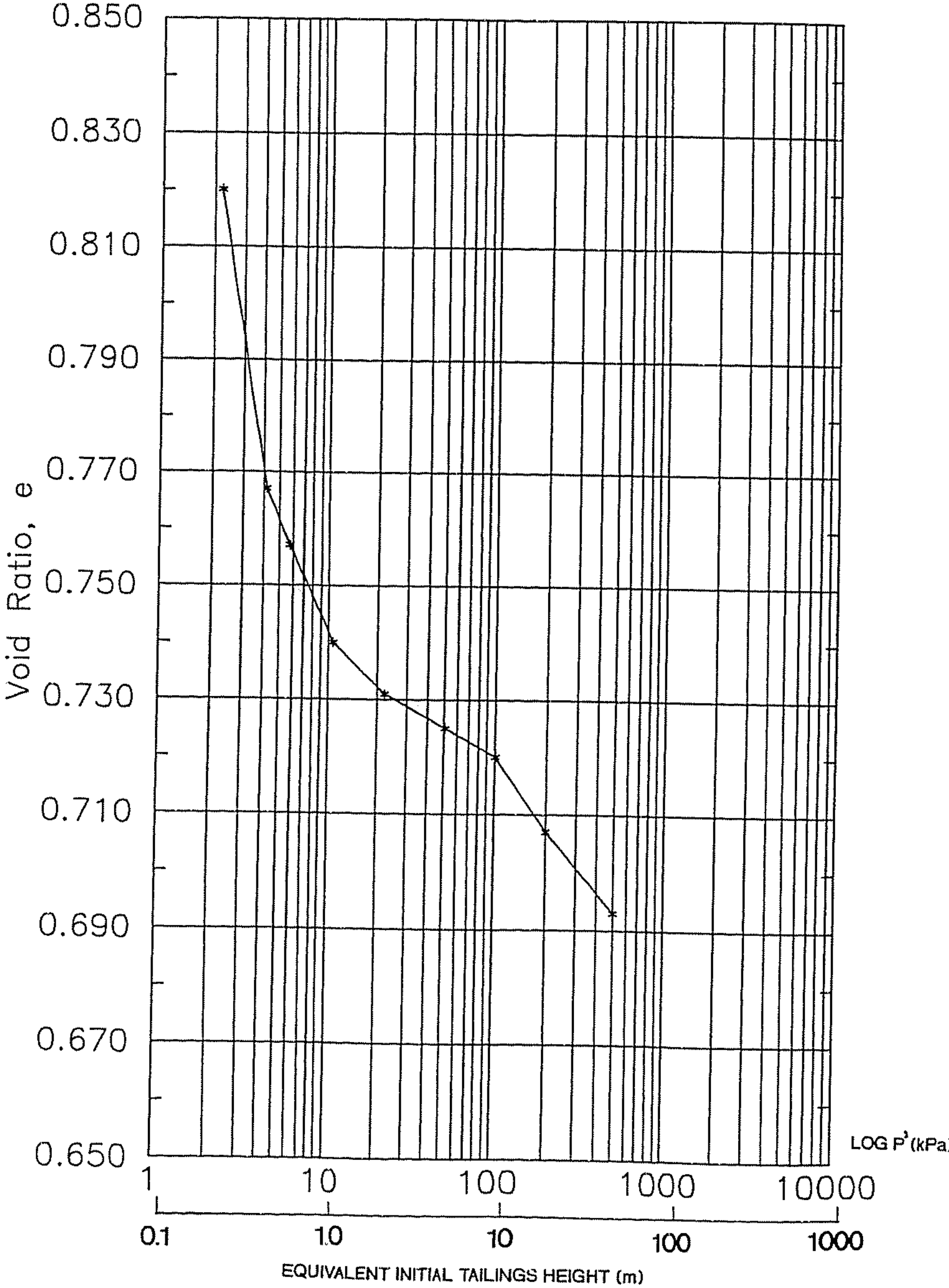


Diameter of Sieve (mm)	Percent Passing (%)
150.000	100.0
75.000	100.0
37.500	100.0
20.000	100.0
10.000	97.7
5.000	94.9
2.000	86.8
0.850	66.3
0.425	44.0
0.150	24.1
0.075	11.3

Comments/Limits:

OEDOMETER TEST RESULT SUMMARY
LUPIN TAILS TEST 3 (UNCEMENTED)
E LOG P

Figure A-5

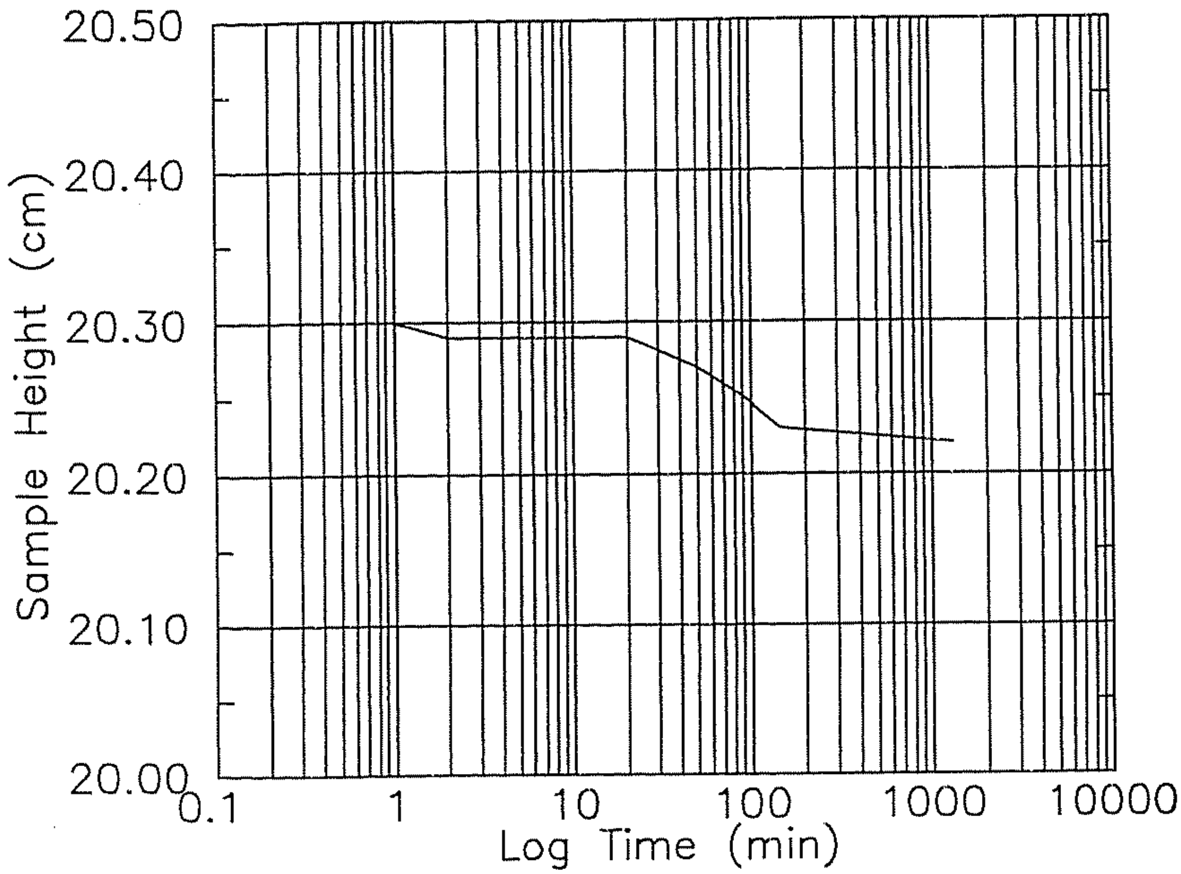


PROJECT No. 942-2436 DRAWN GCR REVIEWED ____ DATE 20 APR 1995

Golder Associates

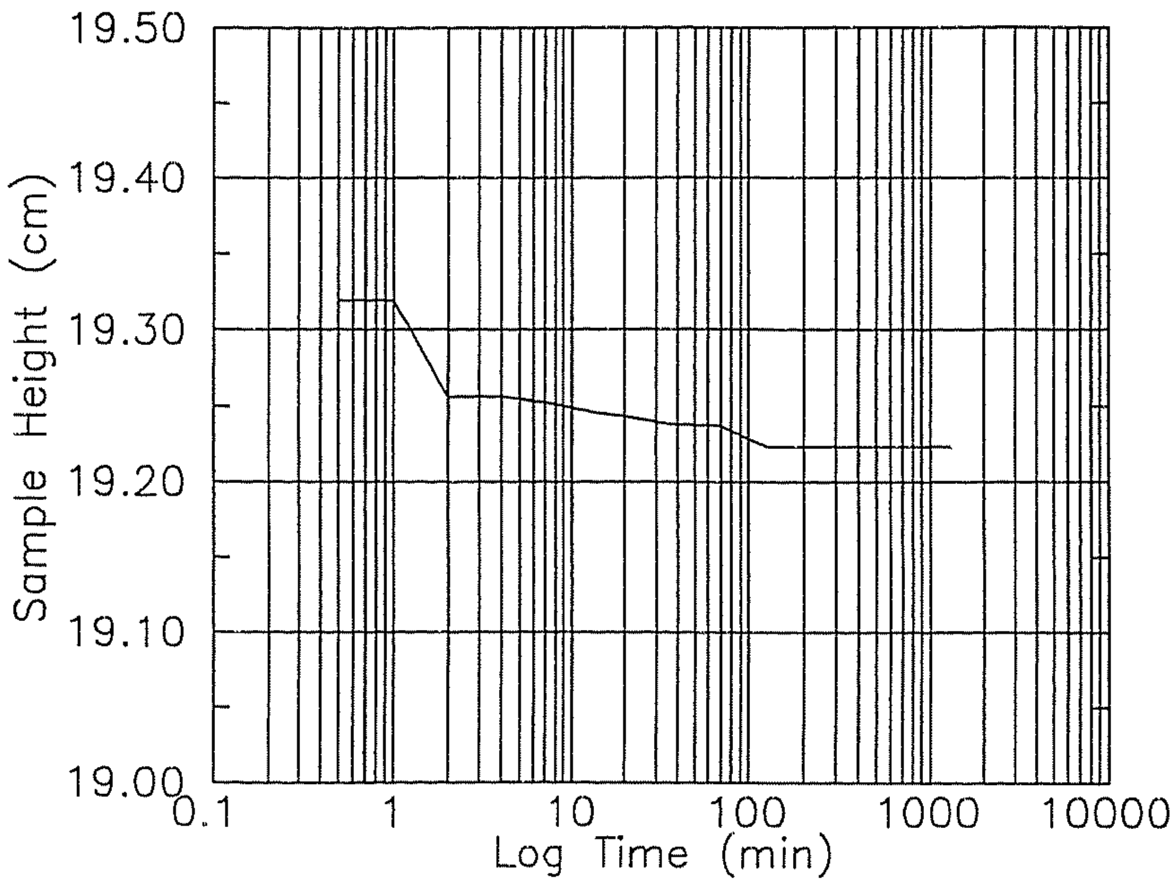
LUPIN TAILINGS TEST 3 (UNCEMENTED)
CONSOLIDATION TEST 2.20 kPa LOAD

Figure A-6



LUPIN TAILINGS TEST 3 (UNCEMENTED)
CONSOLIDATION TEST 22.12 kPa LOAD

Figure A-7



Golder Associates

ETL Enviro·Test
LABORATORIES
A DIVISION OF *ETL CHEMSPEC ANALYTICAL LIMITED*

ANALYTICAL REPORT

GOLDER ASSOCIATES LTD
ATTN: PETER THOMSON
9TH FLOOR 940 6 AVE SW
CALGARY AB T2P 3T1

DATE: 15-SEP-04 01:05 PM

Lab Work Order #: L201953 **Sampled By:** DJH **Date Received:** 30-AUG-04

Project P.O. #: NA

Project Reference: 04-1321-022

Comments: Method modification by client as follows: Sample -1 was extracted using -2 as the extraction fluid. Both samples were then run for Total Metals-Low Level.

RON MINKS
Director of Operations, Calgary

K. Robertson

KERRY ROBERTSON
Client Service Specialist

Bay 7, 1313 - 44 Avenue N.E., Calgary, Alberta T2E 6L5, Tel. (403) 291-9897, Fax (403) 291-0298
Canada Wide Tel. 1-800-668-9878 www.envirotest.com
(Edmonton, Calgary, Grande Prairie, Saskatoon, Winnipeg, Thunder Bay, Ottawa, Waterloo, Montreal)

ENVIRO-TEST ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier	D.L.	Units	Extracted	Analyzed	By	Batch
L201953-1 ESKER-SI								
Sample Date: 30-AUG-04								
Matrix: SOIL								
Total Metals								
Total Trace Metals (Low Level)								
Silver (Ag)	<0.0004	RAMB	0.0004	mg/L		08-SEP-04	MX	R216805
Aluminum (Al)	<0.02		0.02	mg/L		08-SEP-04	MX	R216805
Arsenic (As)	0.0186		0.0004	mg/L		08-SEP-04	MX	R216805
Boron (B)	0.21		0.02	mg/L		08-SEP-04	MX	R216805
Barium (Ba)	0.0370		0.0002	mg/L		08-SEP-04	MX	R216805
Beryllium (Be)	<0.001		0.001	mg/L		08-SEP-04	MX	R216805
Bismuth (Bi)	<0.0001		0.0001	mg/L		08-SEP-04	MX	R216805
Cadmium (Cd)	0.0002		0.0002	mg/L		08-SEP-04	MX	R216805
Cobalt (Co)	0.0591		0.0002	mg/L		08-SEP-04	MX	R216805
Chromium (Cr)	<0.0008		0.0008	mg/L		08-SEP-04	MX	R216805
Copper (Cu)	0.035		0.001	mg/L		08-SEP-04	MX	R216805
Molybdenum (Mo)	0.0573		0.0001	mg/L		08-SEP-04	MX	R216805
Nickel (Ni)	0.237		0.0002	mg/L		08-SEP-04	MX	R216805
Lead (Pb)	0.0001		0.0001	mg/L		08-SEP-04	MX	R216805
Antimony (Sb)	0.0009		0.0004	mg/L		08-SEP-04	MX	R216805
Selenium (Se)	0.0010		0.0004	mg/L		08-SEP-04	MX	R216805
Tin (Sn)	<0.0004		0.0004	mg/L		08-SEP-04	MX	R216805
Strontium (Sr)	2.33		0.0002	mg/L		08-SEP-04	MX	R216805
Titanium (Ti)	<0.005		0.005	mg/L		08-SEP-04	MX	R216805
Thallium (Tl)	0.0002		0.0001	mg/L		08-SEP-04	MX	R216805
Uranium (U)	0.0006		0.0001	mg/L		08-SEP-04	MX	R216805
Vanadium (V)	0.0011		0.0002	mg/L		08-SEP-04	MX	R216805
Zinc (Zn)	0.129		0.004	mg/L		08-SEP-04	MX	R216805
Total Major Metals								
Calcium (Ca)	153		0.5	mg/L		07-SEP-04	HAS	R216301
Potassium (K)	21.5		0.1	mg/L		07-SEP-04	HAS	R216301
Magnesium (Mg)	8.5		0.1	mg/L		07-SEP-04	HAS	R216301
Sodium (Na)	269		1	mg/L		07-SEP-04	HAS	R216301
Iron (Fe)	0.015		0.005	mg/L		07-SEP-04	HAS	R216301
Manganese (Mn)	0.172		0.001	mg/L		07-SEP-04	HAS	R216301
Mercury (Hg)-Total	<0.0002		0.0002	mg/L		08-SEP-04	MX	R216805
L201953-2 CELL 5 WATER								
Sample Date: 30-AUG-04								
Matrix: WATER								
Total Metals								
Total Trace Metals (Low Level)								
Silver (Ag)	<0.0004		0.0004	mg/L		08-SEP-04	MX	R216805
Aluminum (Al)	0.02		0.02	mg/L		08-SEP-04	MX	R216805
Arsenic (As)	0.0769		0.0004	mg/L		08-SEP-04	MX	R216805
Boron (B)	0.21		0.02	mg/L		08-SEP-04	MX	R216805
Barium (Ba)	0.0329		0.0002	mg/L		08-SEP-04	MX	R216805
Beryllium (Be)	<0.001		0.001	mg/L		08-SEP-04	MX	R216805
Bismuth (Bi)	<0.0001		0.0001	mg/L		08-SEP-04	MX	R216805
Cadmium (Cd)	<0.0002		0.0002	mg/L		08-SEP-04	MX	R216805
Cobalt (Co)	0.0489		0.0002	mg/L		08-SEP-04	MX	R216805
Chromium (Cr)	<0.0008		0.0008	mg/L		08-SEP-04	MX	R216805
Copper (Cu)	0.776		0.001	mg/L		08-SEP-04	MX	R216805
Molybdenum (Mo)	0.0616		0.0001	mg/L		08-SEP-04	MX	R216805
Nickel (Ni)	0.296		0.0002	mg/L		08-SEP-04	MX	R216805

ENVIRO-TEST ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier	D.L.	Units	Extracted	Analyzed	By	Batch
L201953-2 CELL 5 WATER								
Sample Date: 30-AUG-04								
Matrix: WATER								
Total Metals								
Total Trace Metals (Low Level)								
Lead (Pb)	0.0002		0.0001	mg/L		08-SEP-04	MX	R216805
Antimony (Sb)	0.0018		0.0004	mg/L		08-SEP-04	MX	R216805
Selenium (Se)	0.0005		0.0004	mg/L		08-SEP-04	MX	R216805
Tin (Sn)	<0.0004		0.0004	mg/L		08-SEP-04	MX	R216805
Strontium (Sr)	2.45		0.0002	mg/L		08-SEP-04	MX	R216805
Titanium (Ti)	<0.005		0.005	mg/L		08-SEP-04	MX	R216805
Thallium (Tl)	<0.0001		0.0001	mg/L		08-SEP-04	MX	R216805
Uranium (U)	0.0008		0.0001	mg/L		08-SEP-04	MX	R216805
Vanadium (V)	0.0011		0.0002	mg/L		08-SEP-04	MX	R216805
Zinc (Zn)	0.765		0.004	mg/L		08-SEP-04	MX	R216805
Total Major Metals								
Calcium (Ca)	161		0.5	mg/L		07-SEP-04	HAS	R216301
Potassium (K)	21.7		0.1	mg/L		07-SEP-04	HAS	R216301
Magnesium (Mg)	8.0		0.1	mg/L		07-SEP-04	HAS	R216301
Sodium (Na)	276		1	mg/L		07-SEP-04	HAS	R216301
Iron (Fe)	0.012		0.005	mg/L		07-SEP-04	HAS	R216301
Manganese (Mn)	0.072		0.001	mg/L		07-SEP-04	HAS	R216301
Mercury (Hg)-Total	<0.0002		0.0002	mg/L		08-SEP-04	MX	R216805

Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Sample Parameter Qualifier key listed:

Qualifier	Description
RAMB	Result Adjusted For Method Blank

Methods Listed (if applicable):

ETL Test Code	Matrix	Test Description	Preparation Method Reference(Based On)	Analytical Method Reference(Based On)
HG-TOT-LOW-ED	Water	Mercury, (Hg)-Total	EPA3015	EPA 6020
MET1-TOT-LOW-ED	Water	Total Trace Metals (Low Level)	EPA3015	EPA 6020
MET2-TOT-LOW-ED	Water	Total Major Metals	EPA3015	EPA 200.7

** Laboratory Methods employed follow in-house procedures, which are generally based on nationally or internationally accepted methodologies.

Chain of Custody numbers:

L201953

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location	Laboratory Definition Code	Laboratory Location
ED	Enviro-Test Laboratories - Edmonton, Alberta, Canada		

GLOSSARY OF REPORT TERMS
Surr - A surrogate is an organic compound that is similar to the target analyte(s) in chemical composition and behavior but not normally detected in enviromental samples. Prior to sample processing, samples are fortified with one or more surrogate compounds.
The reported surrogate recovery value provides a measure of method efficiency. The Laboratory warning units are determined under column heading D.L.
mg/kg (units) - unit of concentration based on mass, parts per million
mg/L (units) - unit of concentration based on volume, parts per million
< - Less than
D.L. - Detection Limit
N/A - Result not available. Refer to qualifier code and definition for explanation

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION
UNLESS OTHERWISE STATED, SAMPLES ARE NOT CORRECTED FOR CLIENT FIELD BLANKS
Although test results are generated under strict QA/QC protocols, any unsigned test reports, faxes, or emails are considered preliminary.

Enviro-Test Laboratories has an extensive QA/QC program where all analytical data reported is analyzed using approved referenced procedures followed by checks and reviews by senior managers and quality assurance personnel. However, since the results are obtained from chemical measurements and thus cannot be guaranteed, Enviro-Test Laboratories assumes no liability for the use or interpretation of the results.