TECHNICAL MEMORANDUM

DATE October 1, 2010 **PROJECT No.** 10-1427-0018

TO Mr. Justin Stockwell
Lorax Environmental Services Ltd.

CC Bjorn Weeks

FROM Fernando Junqueira and John Hull **EMAIL** fjunqueira@golder.com; jhull@golder.com

CONCEPTUAL ASSESSMENT OF LOW INFILTRATION COVER OPTIONS FOR THE MT. NANSEN PROJECT, YUKON

1.0 INTRODUCTION

Lorax Environmental Services Ltd. (Lorax) is currently assessing the viability of a closure option (referenced as Closure Option 4) for the Mt. Nansen project in the Yukon. The closure Option 4 involves relocation of tailings to an abandoned on-site open pit partially filled with waste rock, and installation of a low infiltration dry cover on top of the tailings, which are potentially acid generating. The purpose of the cover is to minimize water percolation into the tailings and to limit transport of possible acid mine drainage. Lorax has defined three scenarios for closure Option 4 as follows:

1) Place waste rock over the tailings, and then place an engineered cover on top of waste rock;

2) Place an engineered cover on top of the tailings, then place waste rock on top of the cover; and

3) A combination of 1 and 2 above.

Lorax requested that Golder Associates Ltd. (Golder) identify potential types of engineered low-infiltration covers and conduct a conceptual assessment of cover performance for cover options within the three scenarios listed above. In addition, it was requested that Golder conduct preliminary infiltration modeling for one of the identified cover options, and provide a range of infiltration that could be expected for the assessed options.

This Technical Memorandum outlines potential cover options identified that would suit the site conditions, includes typical range of infiltration rates expected for the different cover types, presents results of preliminary conceptual model for a chosen option, provides comments on aspects that can impact the long term performance of cover systems, and provides indication of future activities that should be completed for the detail design of the cover for closure Option 4 at Mt. Nansen.

2.0 COVER OBJECTIVE AND GUIDELINES

The objective of the cover system is to reduce the infiltration of precipitation and snow melt water into the tailings material, thereby reducing the potential for future impacts to the environment in the long term associated with the potential generation and leaching of acid mine drainage.

General criteria, guidelines and assumptions used for the conceptual cover assessment included:

- The site receives total precipitation averaging 283 mm per year, of which about 30% comes as snowfall between October and March. Evaporation occurs between May and September with an annual potential evaporation rate of approximately 369 mm over open water. Potential evaporation exceeds precipitation in the region and the climate is therefore classified as semi-arid.
- Materials available for cover construction include the following:
  - Waste rock with variable gradation (typically gravel with silt and sand);
  - Borrow material from the Victoria Creek pit that consists of relatively well-graded silty sand with gravel; and
  - A borrow material that is a poorly graded sand (this sand is reported to have been used to construct the tailings dam).
- Tailings that will be relocated to the on-site abandoned pit can potentially be included as a cover system component for specific cover configurations, either at natural conditions or amended with limestone.
- It has been assumed that it will be possible to sustain at least a poor quality cover of vegetation on top of the cover. Based on the local climate data, the growing season has been assumed to last between May and October, with peak growth occurring during the summer.

Note that the climate conditions considered in this evaluation are the same conditions as were detailed in the Golder Memorandum to Lorax dated August 27, 2010, which addressed the wet cover options.

3.0 CONCEPTUAL COVER OPTIONS

For the Mt. Nansen site, potential evaporation is reported to exceed precipitation by some 155 mm between May and September for a mean year as seen in Figure 1. This suggests that a store-and-release type of cover system could be used to minimize infiltration during this period. However, evaporation is practically nonexistent in April, when about 30% of average annual precipitation (snowfall) is expected to melt and flow during the freshet period. During this critical period with little or no evaporation, and with vegetation still in the early growing stages, freshet water will likely infiltrate into the cover. The cover system must be designed with sufficient storage capacity to retain water that infiltrates during this period, storing it for evaporation in the following months. Placement of waste rock on top of tailings will have a positive impact in the cover performance as it might create a capillary break effect that will minimize percolation of water through the bottom of the cover during the freshet period, promote storage and allow time for the evapo-transpiration process to remove water from the cover during the summer.

Installation of a low-permeability layer of geosynthetic at the bottom of the cover would also minimize water percolation to a large extent.

3.1 Potential Cover System Types

Based on the assumptions and criteria described above, five types of cover systems are conceptually envisaged that could suit the site conditions and meet the main objective of reducing overall infiltration rates to the tailings:

1) A single-layer, vegetated, store-and-release soil cover – This scenario would involve the placement of a growth media to establish vegetation over a layer of well-graded material (potentially from the Victoria Creek borrow pit). In this scenario, the well-graded material is placed directly over the tailings. A properly functioning cover with this type of design would store part of the infiltrating water in the well-graded material. This "stored" infiltration would be removed from storage during the summer by evaporation.

2) Vegetated, store-release-divert soil cover – This scenario is equivalent to scenario (1), but with a 1 m layer of waste rock under the Victoria Creek material, directly over the tailings. The design concept is that the waste rock layer could create a capillary break effect, which would limit the infiltration of water from the overlying Victoria Creek material to the waste rock. The upper portion of the cover would act as a store-and-release cover, while the infiltration that exceeds the storage capacity would be diverted laterally over the capillary break without being in contact with the tailings. This laterally diverted water could then be collected and discharged elsewhere. Proper functioning of the capillary break is dependant on the grain-size gradations of the waste rock and the Victoria Creek material being compatible in such a way as to meet design requirements.

3) Multi-layer vegetated, store-release-divert soil cover – This scenario would be similar to scenario (2), but would include a layer of fine tailings placed between the bottom layer of coarse waste rock and the storage layer of Victoria Creek material. The greater variation in the unsaturated hydraulic conductivity and soil-water characteristic curves between the coarse waste rock and fine tailings could improve the efficiency of the capillary break. Similar to scenario (2), part of the infiltration will be stored in the upper layer, while another portion would be diverted over the capillary break barrier for discharge elsewhere. For this option, it would be important to evaluate the potential impacts of using tailings in the cover, to ensure that discharge water quality is not impacted. Treatment of the portion of the tailings to be used in the cover with a limestone admixture would be one option to be evaluated in detailed design.

4) Synthetic barrier cover system – This option would involve the placement of a layer of well-graded Victoria Creek material over a drainage layer of sandy material placed on top of a low permeability (10^{-10} m/s) synthetic media (HDPE, GCL or Bitumen liner), which in turn would be underlain by a transition layer of sand and coarse waste rock. Water percolating the upper layer will reach the geomembrane and be drained away from the cover system through the sand drainage layer.

5) Multi-layer capillary break cover system – This scenario would involve the placement of waste rock over a layer of well-graded Victoria Creek material, underlain by a second layer of coarse waste rock material to create a capillary break effect. The top layer of waste rock will reduce the effect of freeze-thaw cycles in the storage layer of well-graded material. Part of the infiltration will be stored in the mid layer, while another portion would runoff over the capillary break barrier and be diverted for future evaporation. This option would require careful evaluation and design to ensure its applicability, as the presence of waste rock at the surface, while protective against freeze-thaw damage, would tend to limit evaporation from the storage layer and promote infiltration.

A conventional barrier cover which uses a layer of low-permeability compacted clayey material to prevent infiltration has not been considered. Local borrow sources for suitable clay have not been identified in the area of the site. Further, practical experience has shown that this type of cover tends to degrade and lose performance with time due to development of cracks associated with freeze/thawing and wet/drying cycles. Conventional covers with stiff compacted layers are also less resistant to deformations, and at this site deformations are to be expected due to differential long term consolidation of the tailings relocated to the pit.

Table 1 summarizes the alternative types of cover system designs that have been identified conceptually for installation on top of the tailings as part of Closure Option 4. The base geometries presented were defined to allow for sufficient water storage capacity and/or promote runoff of water during the freshet period, specifically, and year round, in general. Typical values of infiltration rates are mentioned as reference values based on common engineering practice and design target infiltration values. Accomplishment of these infiltration rates will largely depend on the cover geometry and material specifications that are defined during detailed design.

Table 1: Cover types assessed - Option summary for Mt. Nansen

Cover Option	Base Geometry (Top to Base)	Typical range of Infiltration rate (% of annual precipitation)	Remarks
1 – Single vegetated store-release	■ 0.3 m top soil [1] ■ 1.0 m well graded Victoria Creek material	10%-20%	Vegetation must be sustained on top. Cover performance is affected by vegetation condition.
2 - Vegetated, store-release-divert soil cover	■ 0.3 m top soil[1] ■ 1.0 m well graded Victoria Creek material [2] ■ 1.0 m coarse waste rock.	2-15%	Gradation and permeability of Victoria creek material and coarse waste rock must meet design requirements to generate the capillary break effect.
3 - Multi-layer vegetated, store-release-divert soil cover	■ 0.3 m top soil[1] ■ 1.0 m well graded Victoria Creek material ■ 0.5 m fine tailings ■ Geotextile filter ■ 1.0 m coarse waste rock	3%-10%	Fine tailings used to enhance the capillary break effect and minimize downward fluxes. Tailings layer might need to be amended with limestone to minimize acid generation potential.
4 - Synthetic barrier cover system	■ 0.5 m Victoria Creek material ■ 0.3 m drainage sand ■ Geosynthetic liner ■ 0.5 m transition sand ■ 1.0 m waste rock	1%-3%	Base layer of waste rock placed to provide a more stable base for the synthetic liner in an attempt to reduce overall deformation in the liner. Vegetation is not necessary, but can be added for aesthetic purposes without negative impact on cover performance and would help to minimize surface erosion.
5 - Multi-layer capillary break cover	■ 1.0 m Waste Rock ■ 1.0 m well graded Victoria Creek material ■ 1.0 m waste rock.	5%-20%	Top layer of waste rock placed to reduce the impact of freeze/thaw cycles in the long term. Evaporation might be limited by top layer of coarse waste rock.

1 If organic soils are not available, the Victoria Creek material might be tested as a growth media to establish vegetation

2 A layer of Geotextile might be needed to prevent migration of fines from the Victoria Creek material into the coarser waste rock.

3.2 Estimated Costs

A generic cost estimate is provided as reference to allow for preliminary cost comparison for base geometries of the different types of cover systems identified in Table 1. Material costs were based on mining projects developed in the Northwest Territories and should be taken as +/-35% accuracy. Average material costs used to make the cost estimates are summarized in Table 2, while Table 3 presents average unit costs for the different cover options.

The costs presented in Tables 2 and 3 are for reference only. Changes in the cover geometry during the detail design stage will affect actual cover costs.

Table 2: Summary of general material costs for mining projects in the NWT (+/- 35% up to summer 2010)

Material	Mt. Nansen equivalent	Average Unit Cost (+/- 35%)	Remarks
General cover fill	Victoria Creek borrow material	$20 / m^3	
General drainage sand	Poorly graded sand (tailings dam)	$28 / m^3	
Sub grade - general fill	Waste Rock	$2.5 / m^3	Average cost for re-use of on-site material
Tailings	Relocated Tailings	$4 / m^3	Estimated cost associated with haulage and spreading. Not including any tailings treatment.
Organic Soil	-	$30 / m^3	
Synthetic liner	-	$23 / m^2	Including installation
Geotextile filter	-	$3 / m^2	Including installation

Table 3: Estimated general costs for proposed cover options

Cover Option	Base Geometry (Top to Base)	Cost per material ($/m^2)	Total Cost ($/m^2)
1 – Single vegetated store-release	■ 0.3 m top soil [1] ■ 1.0 m well graded Victoria Creek material	■ $10 ■ $20	$30
2 - Vegetated, store-release-divert soil cover	■ 0.3 m top soil[1] ■ 1.0 m well graded Victoria Creek material [2] ■ 1.0 m coarse waste rock.	■ $10 ■ $20 ■ $2.5	$32.5
3 - Multi-layer vegetated, store-release-divert soil cover	■ 0.3 m top soil[1] ■ 1.0 m well graded Victoria Creek material ■ 0.5 m fine tailings ■ Geotextile filter layer ■ 1.0 m coarse waste rock	■ $10 ■ $20 ■ $2 ■ $3 ■ $2.5	$37.5
4 - Synthetic barrier cover system	■ 0.5 m Victoria Creek material ■ 0.3 m drainage sand ■ Geosynthetic liner ■ 0.5 m transition sand ■ 1.0 m waste rock	■ $10 ■ $9.5 ■ $23 ■ $10 ■ $2.5	$ 55

Cover Option	Base Geometry (Top to Base)	Cost per material ($/m^2)	Total Cost ($/m^2)
5 - Multi-layer capillary break cover	■ 1.0 m Waste Rock ■ 1.0 m well graded Victoria Creek material ■ 1.0 m waste rock.	■ $2.5 ■ $20 ■ $2.5	$ 25

4.0 BASE CASE MODEL

All the options listed in Table 1 have the potential to minimize water infiltration to the tailings and can be further investigated. The cover option 2 (Store-release-divert soil cover) was selected based on readily available materials at the site. This conceptual cover design is used as a base case for preliminary infiltration modeling as a means to understand the general infiltration pattern through this type of cover under the climatic conditions prevailing at Mt. Nansen, and to assess the predicted infiltration rates for this site compared to typical values reported for this type of cover.

The main objective of the conceptual modeling exercise is not to provide an accurate estimate of actual net infiltration through the cover, but to provide a measure of the applicability of this type of cover to the site's climatic conditions and readily available materials for cover construction.

4.1 Model Preparation

The modeled geometry consisted of 1.0 meter of Victoria Creek material underlain by 1.0 meter of coarse waste rock placed over 4.5 m of tailings.

Material properties were defined as follows:

Victoria Creek material: The hydraulic conductivity and soil-water characteristic curve of the Victoria Creek material were estimated based on a grain size distribution curve provided by Lorax and presented in Appendix I. The hydraulic conductivity was initially estimated based on Hazen's equation (Holtz 1981) as 2.3×10^{-5} m/s, using a Hazen's coefficient equal 10. Subsequently, this value was adjusted to 3×10^{-5} m/s based on measured values for materials with similar grain size distribution obtained from Golder's soil data base.

The soil-water characteristic curve was estimated using the method proposed by Fredlund et al (1997) as shown in Figure 2. The hydraulic conductivity function was estimated based on the SWCC using the method proposed by Fredlund and Xing (1994), and is shown in Figure 3.

Coarse Waste Rock: the properties estimated for coarse waste rock used to evaluate wet cover options for Mt. Nansen (Golder 2010) were used in the present study. The hydraulic conductivity was estimated as 1.4×10^{-4} m/s. The soil-water characteristic curve estimated based on waste rock grain size curves provided by Lorax (Appendix I) is shown in Figure 2, and the estimated hydraulic conductivity function is shown in Figure 3.

Tailings: The material properties defined for the tailings during evaluation of wet cover options (Golder 2010) were used in the present study. The average measured hydraulic conductivity of 1×10^{-8} m/s was used in the models. The SWCC and hydraulic conductivity functions were estimated using the same methods used for the waste rock and Victoria Creek.

A climate data set compiled for the year of 2003 on a daily basis was used as the upper boundary condition in the models. This data set consisted of maximum and minimum air temperature, precipitation, potential evaporation, and relative humidity. A constant head of 1182.3 m representing the average pit lake water level was applied as lower boundary condition.

For this conceptual model, vegetation was not considered on top of the cover and removal of water from the cover depended on the evaporation process and the ability of the capillary break layer to prevent bottom water percolation during periods of high infiltration periods (e.g., April freshet). This was used as a more conservative approach compatible with the purposes of this conceptual study, and the uncertainty regarding the amount and quality of the vegetation that could be maintained over the cover.

The models covered the period between April 15 and October 31 and extended for a period of 10 years. It was assumed that no flow occurs during the winter. Accumulated snow fall between November 1 and April 14 was considered in the models as additional water supply during the freshet period in April.

4.2 Model Results

The conceptual model showed that fluxes through the bottom of the capillary break layer would be very low (less than 1% of total precipitation) during the 10 year model period as shown in Figure 4. Fluxes through the top of the storage layer presented high fluctuation associated with periods of infiltration and evaporation. Infiltration occurred during the freshet season and sporadic periods of rainfall events during the year. Increased evaporation rates in the summer removed water from the cover and reduced water percolation through the bottom of the capillary break layer.

Table 4 summarizes computed cumulative fluxes through the top of the cover, bottom of the capillary break layer, and through the tailings at a depth of 4.5 m.

Table 4: Summary of computed cumulative fluxes through the Cover System and Tailings

Year	Cumulative Fluxes (m^3/m^2)		
	Top of Cover	Bottom of Cover	Tailings (4 m depth)
1	-0.0034	0.0005	0.0002
5	-0.0004	0.0016	0.0014
10	0.0033	0.0027	0.0026

Figure 5 shows computed daily flux rates through the top of the storage layer and at the bottom of the capillary break layer. The model showed that daily fluxes through the base of the cover also responded to seasonal precipitation; net percolation rates were much smaller than fluxes computed through the top of the cover system.

Figure 6 shows the evolution of the saturation profile within the cover system during a modelled year. It shows that the degree of saturation of the storage layer increased markedly during the first 30 days of high infiltration during spring freshet. Subsequently, evaporation exceeded precipitation during summer and water was progressively removed from the storage layer. The degree of saturation in the storage layer in the end of October was low, allowing storage capacity for the next freshet period in the subsequent year.

It can also be seen in Figure 6 that the degree of saturation in the capillary break layer remained low during all times, indicating that the capillary break effect was sustained and water percolation was minimized. Similarly, the degree of saturation of the tailings under the cover remained stable.

The very low percolation rates computed in this conceptual model are compatible with percolation rates reported for the Alternate Cover Assessment Program (ACAP) which was conducted by the United States Environmental Protection Agency (ACAP 2007). Different test areas involving store-and-release and capillary break covers were constructed in six arid and semi-arid climates in the southern and western regions of the United States. It has been reported that infiltration through the alternative covers is typically less than one percent of annual precipitation. However, the long term performance (more than 10 years) of the different covers is yet to be assessed.

We note that maintenance of the capillary break effect is very sensitive to the hydraulic properties of the cover materials, and additional studies would be required to confirm that these very low infiltration rates could in fact be achieved with the materials under consideration at site.

Additional laboratory testing will be required to confirm the suitability of combining the Victoria Creek material and waste rock to generate a capillary break effect. Maintenance of performance in the long term will depend on whether the materials properties will change with time subjected to freeze and thaw cycles. Additional studies are required to assess potential variations in the depth of the active layer, and to evaluate the need to increase the thickness of waste rock placed on top of the tailings.

As discussed above, the models developed for this conceptual study are based on general assumptions. The models have not been calibrated and did not include sensitivity analysis. It is therefore, recommended that, until the models are refined, a conservative approach be used to develop a site-wide water balance model. It is recommended that the upper bound of infiltration values in Table 1 be used in this pre-feasibility stage (e.g. 15% infiltration for cover option 2).

5.0 COMMENTS ON LONG TERM COVER INTEGRITY

5.1 General comments

Soil cover systems function at the interface between the atmosphere, biosphere and the geosphere. Fluctuations in temperature, soil moisture, and heat and mass transfer rates are the most extreme at this position within the soil–atmosphere profile. Engineered soil cover systems are designed to control these variables, but some aspects must be considered that will affect the performance of different types of cover systems in the long term.

Type of material:

Clays and silts are known as problematic soils for road construction, and the same can be said for the construction of cover systems as both are located within the active zone (i.e. the upper 0 - 3 m of the soil profile with seasonal variation in temperature and water content). Clay materials degrade rapidly in the active zone. Silt-rich soils are somewhat less susceptible to volume change, but are most susceptible to frost heave and erosion. Sand and gravel soils offer high strength and typically present low volume change compared to clay. However, granular materials have higher permeability with poor moisture retaining capacity and offer limited benefit with respect to barrier or store/release covers (Wilson et al 2003). Well-graded materials have proven to perform best for the construction of the base and sub-layers in pavement structures, and in general this rule is applied for the design of cover systems.

Type of cover

As mentioned before, barrier type covers that incorporate compacted layers of clay materials typically fail associated with the development of soil structures and cracking in the active zone. This type of cover is very susceptible to foundation deformation and variations in soil properties in portions located within the active zone. The design low permeability characteristic of this type of cover tends to degrade rapidly with consequent loss in cover performance (Benson 2007).

Failure of store-and-release cover systems occurs less frequently than for barrier-type (compacted) covers (Wilson et al 2003). In general, the primary mechanisms that affect the performance of store-release covers are lack of storage capacity and lack of vegetation. Wetting and drying may cause the soil structure to consolidate and/or become aggregated, leading to significant reduction in porosity that can cause reduction in storage capacity of up to 50 per cent.

Store-and-release covers have also been reported to reduce performance due to degradation of vegetation in the long term (Durham et al, 2000). The role of vegetation to continuously extract infiltration waters is of paramount importance, and vegetation condition must always be monitored when single-layer store-and-release cover systems are used.

One of the most important mechanisms that affects the performance of capillary-break cover systems is related to weathering of coarse material at the base of the cover. Weathering causes progressive increases in the amount of fines in the coarse layer. This process causes the hydraulic conductivity function of the coarse material to change with time and approach the hydraulic conductivity function of the fine material, greatly reducing the efficiency of the capillary break.

5.2 Context of Mt. Nansen

Specific maintenance needs for the cover system to be installed at Mt. Nansen will be defined upon detail design of the cover. However, preliminary models showed that a store-release-and-divert cover type composed of a storage layer underlain by a capillary break layer would be a viable option that could limit water percolation to the tailings.

If this type of cover is properly designed, and the cover construction follows a Quality Control / Quality Assurance (QC/QA) Plan prepared for the site, long term maintenance of the cover would be limited. The key maintenance activity would be related to sustaining at least a basic vegetation canopy on top of the cover, while preventing the growth of trees (tree roots can lead to the development of preferential flow paths through the cover).

Monitoring of the depth of the active zone will indicate whether, and to what extent, the active zone advances into the capillary break layer. The Monitoring Plan should be prepared during the detail design stage of the cover system.

The detail design of the cover should include additional seepage models, as well as thermal models to assess the extent of freeze and thaw cycles. The final monitoring plan shall be prepared under the light of the final cover geometry.

6.0 FUTURE WORKS

The conceptual study presented in this memorandum was mainly intended to provide general understanding of potential cover system types that could be installed on top of tailings at the Mt. Nansen site. Different cover alternatives were identified based on available construction materials and local climatic conditions. Preliminary infiltration models developed for a store-release-and-divert cover type showed that infiltration can be reduced to a great extent, but this tendency, as well as the final definition of the best type of cover system and cover geometry for the site should be further evaluated during the detail design stage. Activities that should be developed in the detail design phase include:

- Measurement of key geotechnical and hydraulic properties on multiple samples of potential cover construction materials to characterize both their properties and their variability;
- Run detailed numerical models for a range of scenarios to assess model sensitivity to design parameters and to refine cover geometry;
- Run of thermal models to assess the extent of the active zone within the cover system in the long term. Results from the thermal model will be used to refine the final cover geometry.
- Definition of specifications for the different construction materials;
- Preparation of a QC/QA Plan for cover construction; and
- Preparation of a staged monitoring plan to assess cover performance in the long term.

Consideration should also be give to pilot tests to evaluate alternative cover performance in-situ prior to design and construction of the final cover.

7.0 CLOSURE

We trust that the information presented in this document meets your expectation. Should you have any question or comment, please do not hesitate to contact one of the undersigned.

Yours very truly,

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED

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Attachments: Figures
Appendix I: Grain Size Distribution of Samples of Waste Rock and Victoria Creek Materials

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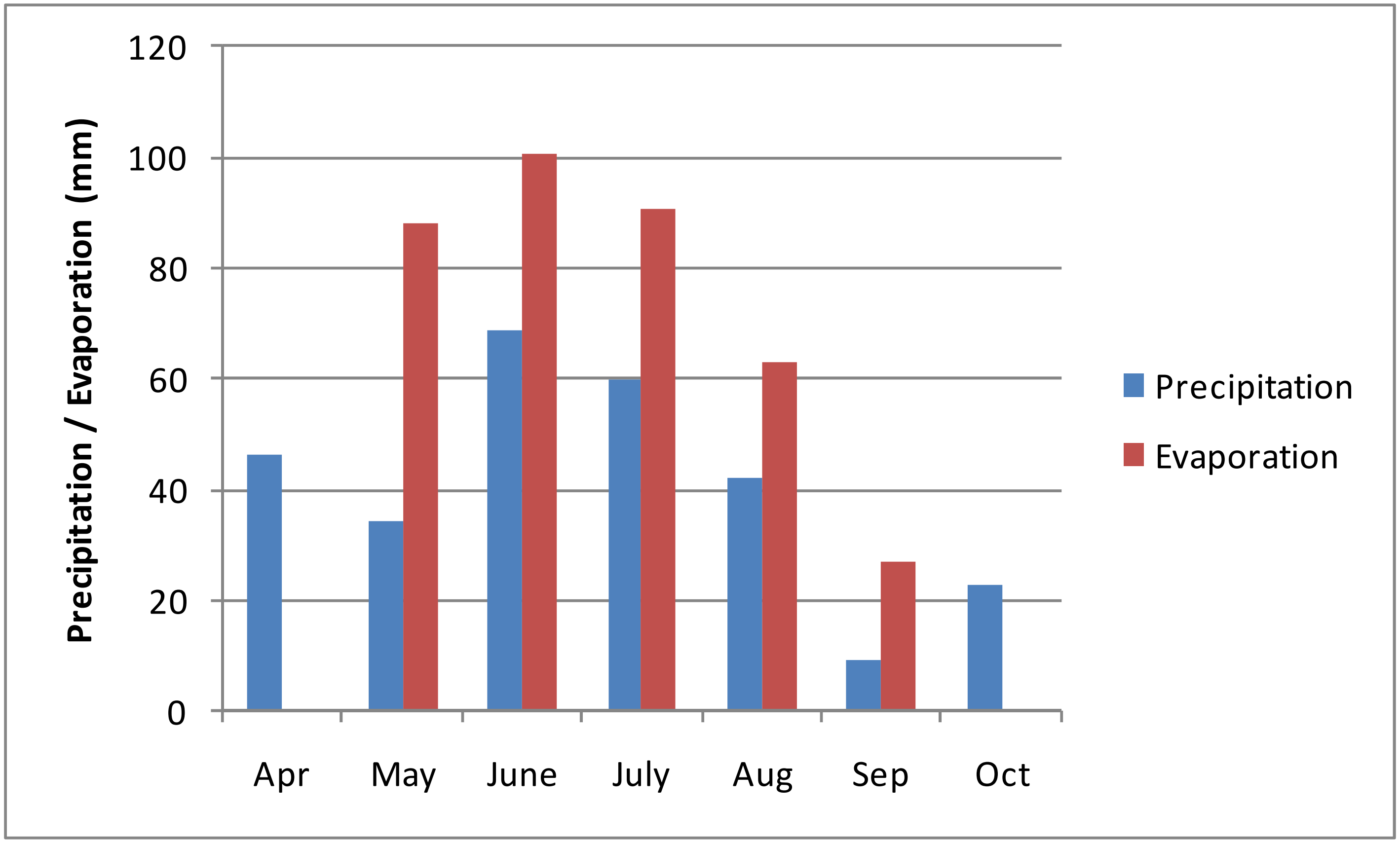

PROJECT	MT. NANSEN CLOSURE OPTIONS STUDY
TITLE	Average Monthly Precipitation (for mean years) vs. Monthly Evaporation

Golder Associates

PROJECT No. 10-1427-0018			FILE No. --	
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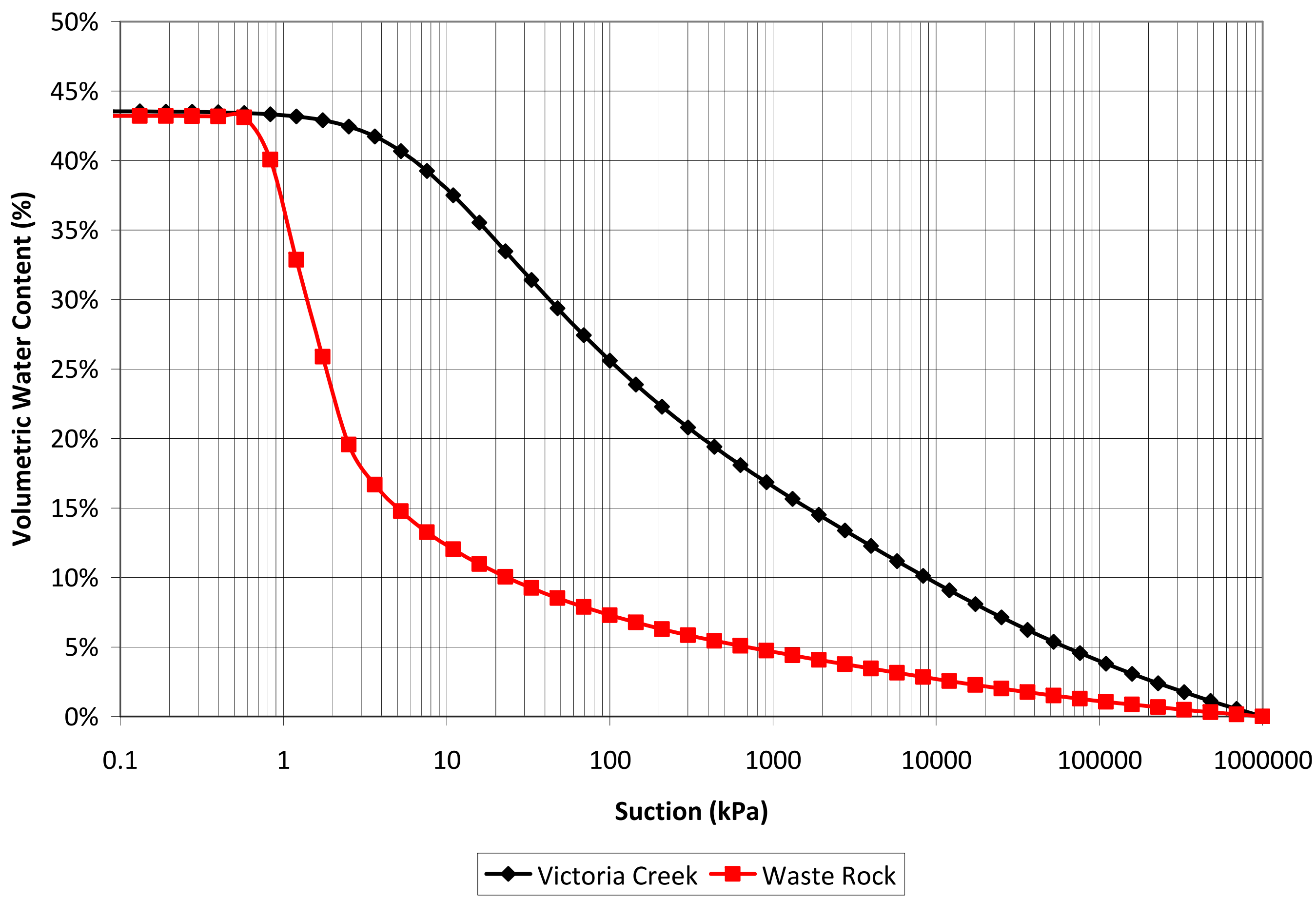
REVIEW				



PROJECT

MT. NANSEN CLOSURE OPTIONS STUDY

TITLE

Estimated SWCC for the Victoria Creek and Coarse Waste Rock Materials (Fredlund et al, 1997)

Golder Associates

PROJECT No.	10-1427-0018		FILE No. --	
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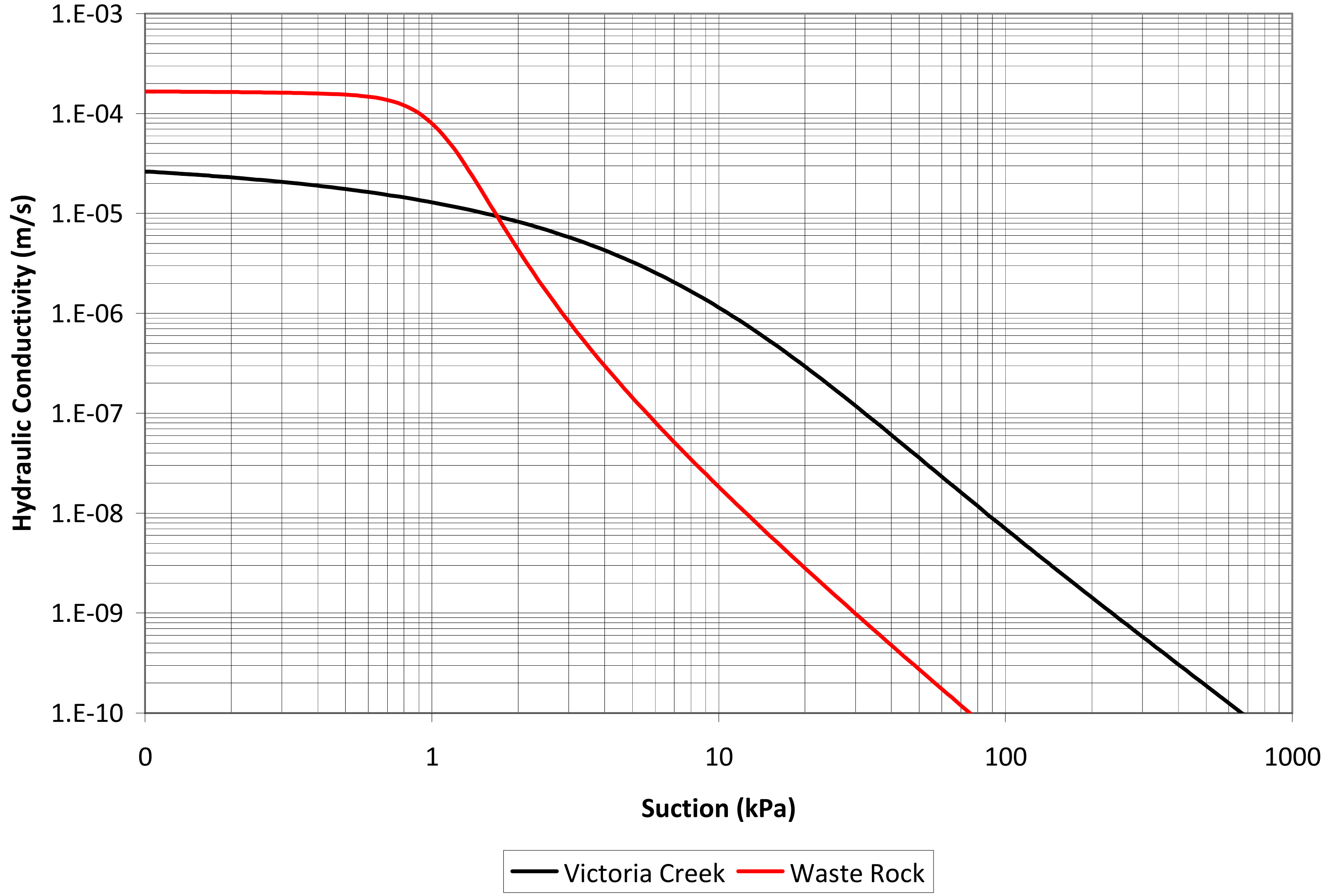

PROJECT

MT. NANSEN CLOSURE OPTIONS STUDY

TITLE

Estimated Hydraulic Conductivity Function for the Victoria Creek and Coarse Waste Rock Materials (Fredlund and Xing, 1994)

Golder Associates

PROJECT No.	10-1427-0018		FILE No. --
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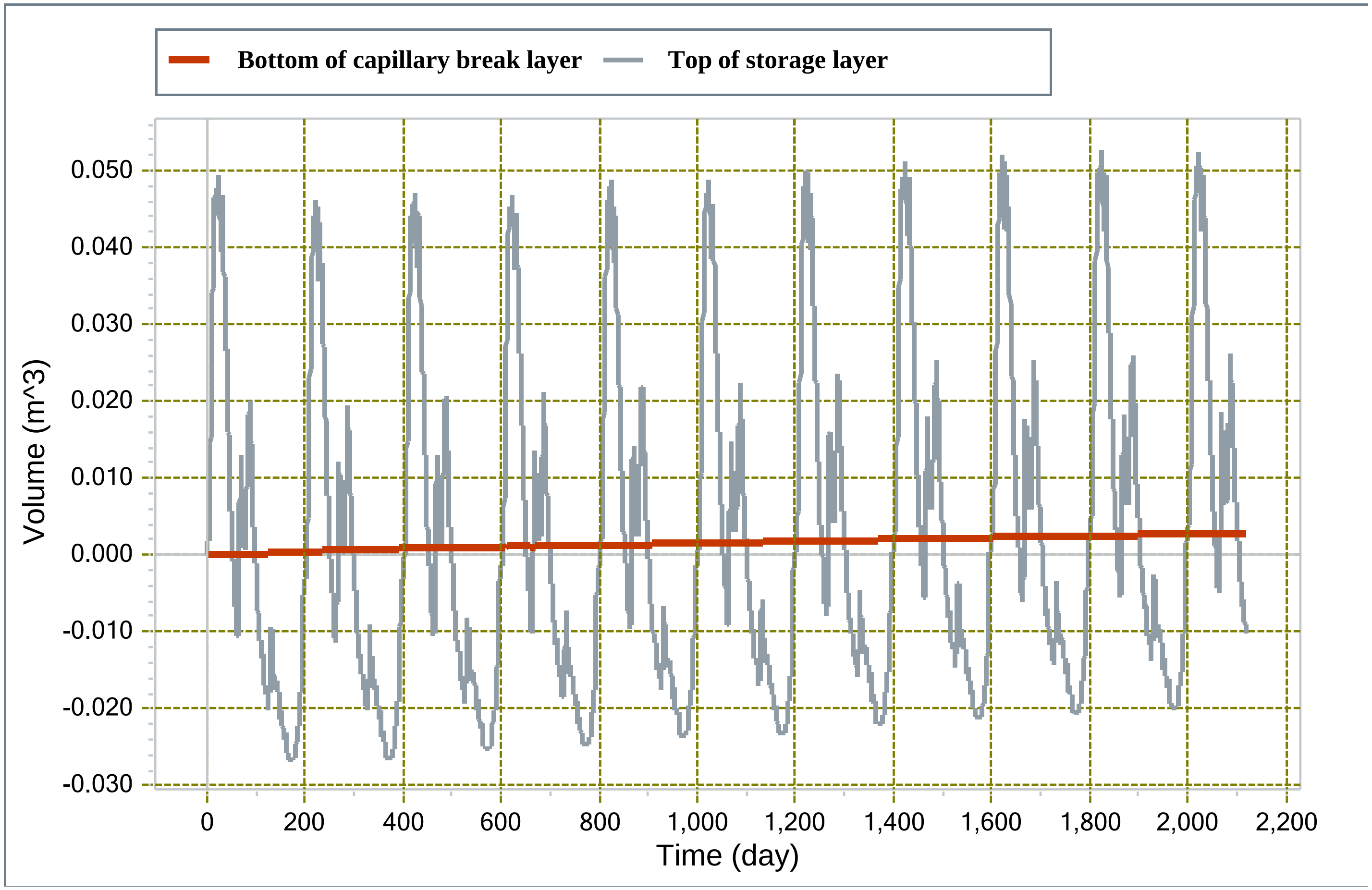

PROJECT

MT. NANSEN CLOSURE OPTIONS STUDY

TITLE

Evolution of Fluxes Through the Top of the Storage Layer and Bottom of the Capillary Break Layer

Golder Associates

PROJECT No. 10-1427-0018			FILE No. --
DESIGN	FJ	20-AUG-10	SCALE NTS REV.
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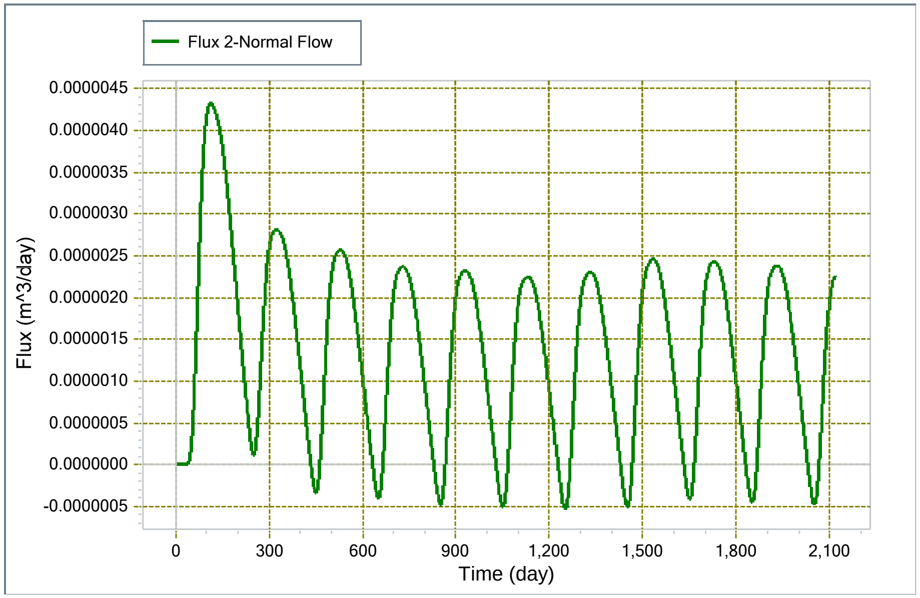
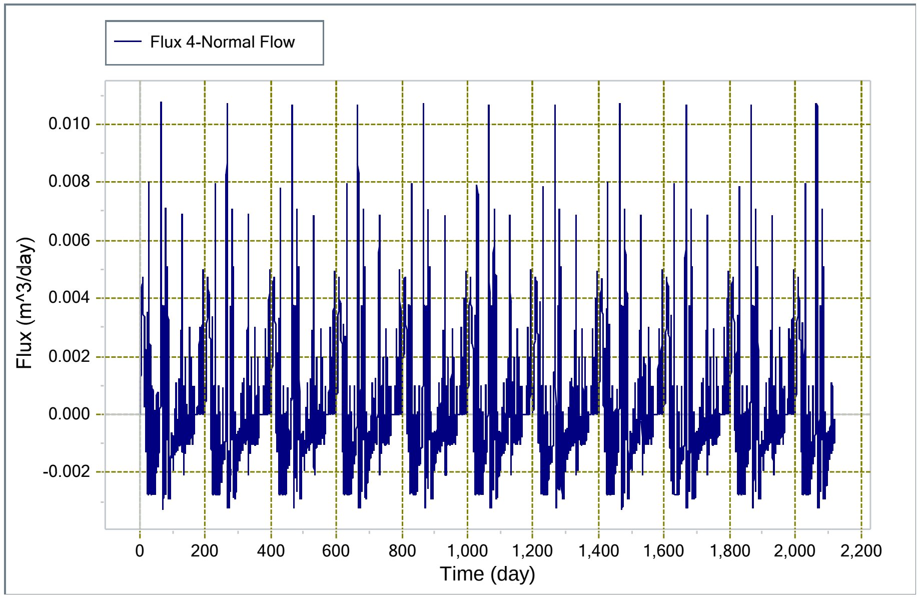


Daily flux rates through the bottom of capillary break layer.



Daily flux rates through the surface of storage layer.

PROJECT

MT. NANSEN CLOSURE OPTIONS STUDY

TITLE

Variation of Daily Fluxes Through the Top of the Storage Layer and Bottom of the Caplllary Break Layer.

Golder Associates

PROJECT No.	10-1427-0018		FILE No.	--
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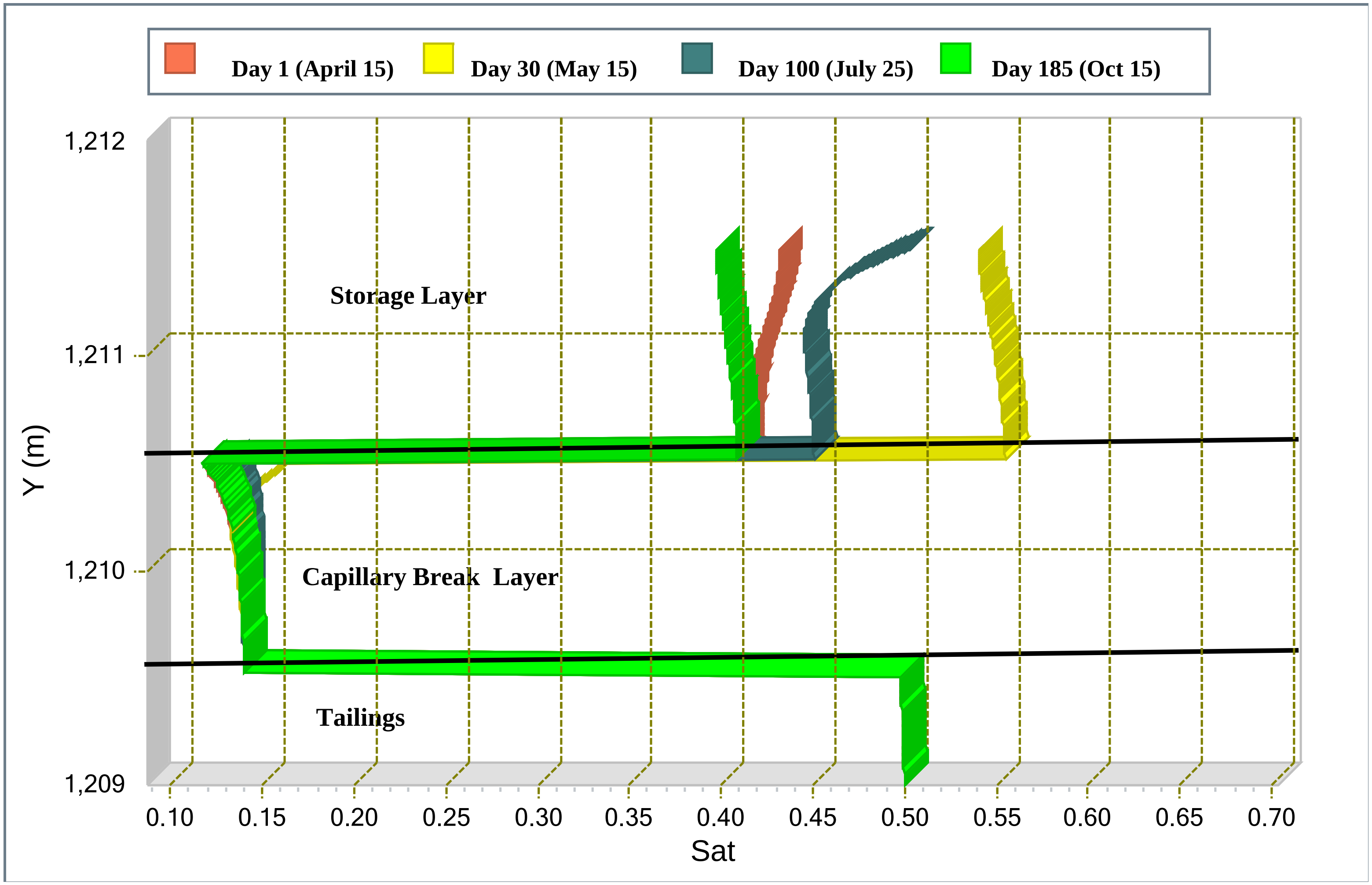
REVIEW				



PROJECT	MT. NANSEN CLOSURE OPTIONS STUDY			
TITLE	Evolution of Saturation within the Cover system for a Single Year.			
Golder Associates	PROJECT No. 10-1427-0018		FILE No. --	
	DESIGN FJ	20-AUG-10	SCALE NTS	REV.
	CADD	--	FIGURE 6	
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	REVIEW			

REFERENCES

Benson, C. H., Sawangsunya, A., Trzbiatowski, B. and Albrigth, W. (2007): Postconstruction Changes in the Hydraulic Properties of Water Balance Cover Soils. Journal of Geotechnical and Environmental Engineering. April 2007. pp 349-359

Durham, A, Wilson, G W and Currey, N, (2000). Field performance of two low infiltration cover systems at a semi-arid environment. 5th International Conference on Acid Rock Drainage (ICARD), pp 1319-1326. Denver, United States (2000).

Fredlund, M. D., Wilson, G. W., and Fredlund, D. G. (1997): Prediction of the Soil-Water Characteristic Curve from the Grain-Size Distribution Curve. 3rd Symposium on Unsaturated Soils. Rio de Janeiro, Brazil. April 20-22, pp. 13-23.

Fredlund, D.G., Xing, A., and Huang, S. (1994): Predicting the Permeability Function of Unsaturated Soils Using Soil-Water Characteristic Curve. Canadian Geotechnical Journal. Vol 31. No 3. pp 533-546.

Golder Associates Ltd (2010): Technical Memorandum on Assessment of Closure Options and Cover Water Balance for the Mt. Nansen Project, Yukon. August 27, 2010.

Holtz, R. D., and Kovacs, W. D. (1981): Introduction to Geotechnical Engineering. Prentice-Hall Inc. Englewood Cliffs, New Jersey.

G. W., Wilson, D. G. Williams, and Rykaart, E. M. (2003): The Integrity of Cover Systems – An Update. 6th International Conference on Acid Rock Drainage (ICARD). pp. 445-451. Caims, Australia (2003).

APPENDIX I
Grain Size Distribution of Samples of Waste Rock and Victoria Creek Materials

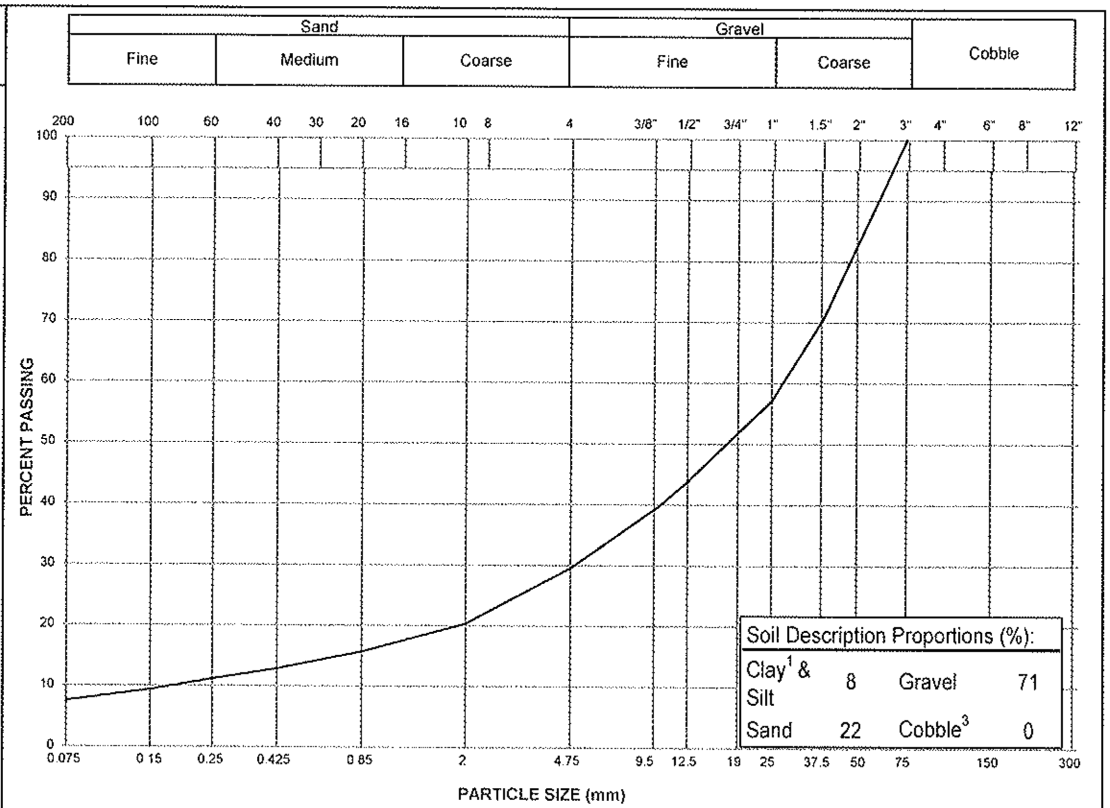
PARTICLE SIZE ANALYSIS TEST REPORT

ASTM D422 & C136

Project:	Mt. Nansen	Client:	AECOM
Project No.:	W14101299	Client Rep.:	Marc-Andre Lavigne
Site:	Mt. Nansen		

Material Type:		Date Tested:	By:
Sample No.:	Bulk 1	Soil Description[2]:	GRAVEL - sandy, trace silt
Sample Loc.:	NW Pile		
Sample Depth:		USC Classification: SM	Cu: 147.6
Sampling Method:			Cc: 4.8
Date sampled:	20-Jul-2009 By: NSP	Moisture Content:	4.1

Particle Size (mm)	Percent Passing
300	
200	
150	
100	
75	100
50	0
38	71
25	57
19	
12.5	44
10	40
4.75	30
2	20
0.85	16
0.425	13
0.25	11
0.15	9
0.075	8



Notes:

[1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

[3] If cobbles are present, sampling procedure may not meet ASTM C702 & D75

Specification: ______________________

Remarks: ______________________

Reviewed By: ______________________

EBA Engineering Consultants Ltd.

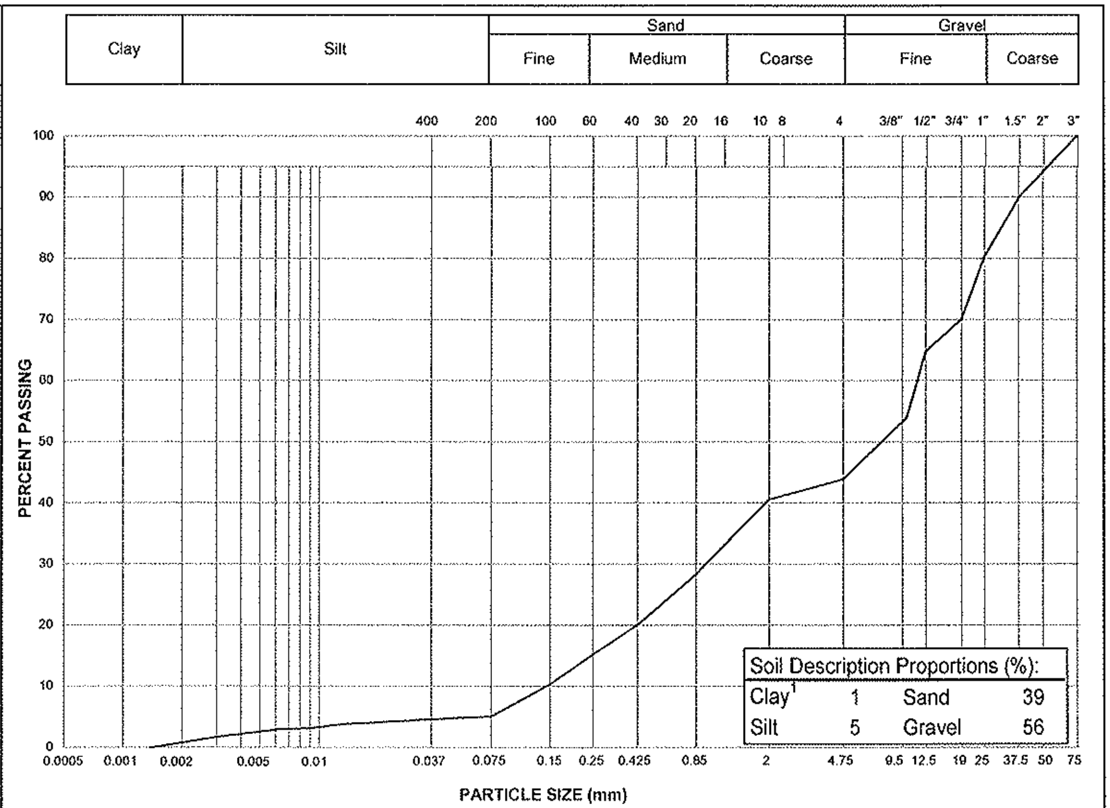
PARTICLE SIZE ANALYSIS TEST REPORT

ASTM D422 & C136

Project:	Mt. Nansen	Client:	AECOM
Project No.:	W14101299	Client Rep.:	Marc-Andre Lavigne
Site:	Mt. Nansen		

Material Type:		Date Tested:		By:	
Sample No.:	Bulk 2	Soil Description[2]:	GRAVEL and SAND - trace silt, trace clay		
Sample Loc.:	Ramp to Pit				
Sample Depth:		USC Classification:	SM	Cu:	78.4
Sampling Method:				Cc:	0.6
Date sampled:	28-Jul-2009 By: NSP	Moisture Content:	3.4		

Particle Size (mm)	Percent Passing
75	100
50	
38	90
25	80
19	70
12.5	65
10	54
4.75	44
2	41
0.85	28
0.425	20
0.25	15
0.15	10
0.075	5
0.0348	4.6
0.0222	4.2
0.0129	3.8
0.0092	3.2
0.0065	3.0
0.0032	1.8
0.0014	0.0



Soil Description Proportions (%):			
Clay[1]	1	Sand	39
Silt	5	Gravel	56

Notes:
[1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual
[2] The description is visually based & subject to EBA description protocols

Specification:

Remarks:

Reviewed By:

EBA Engineering Consultants Ltd.

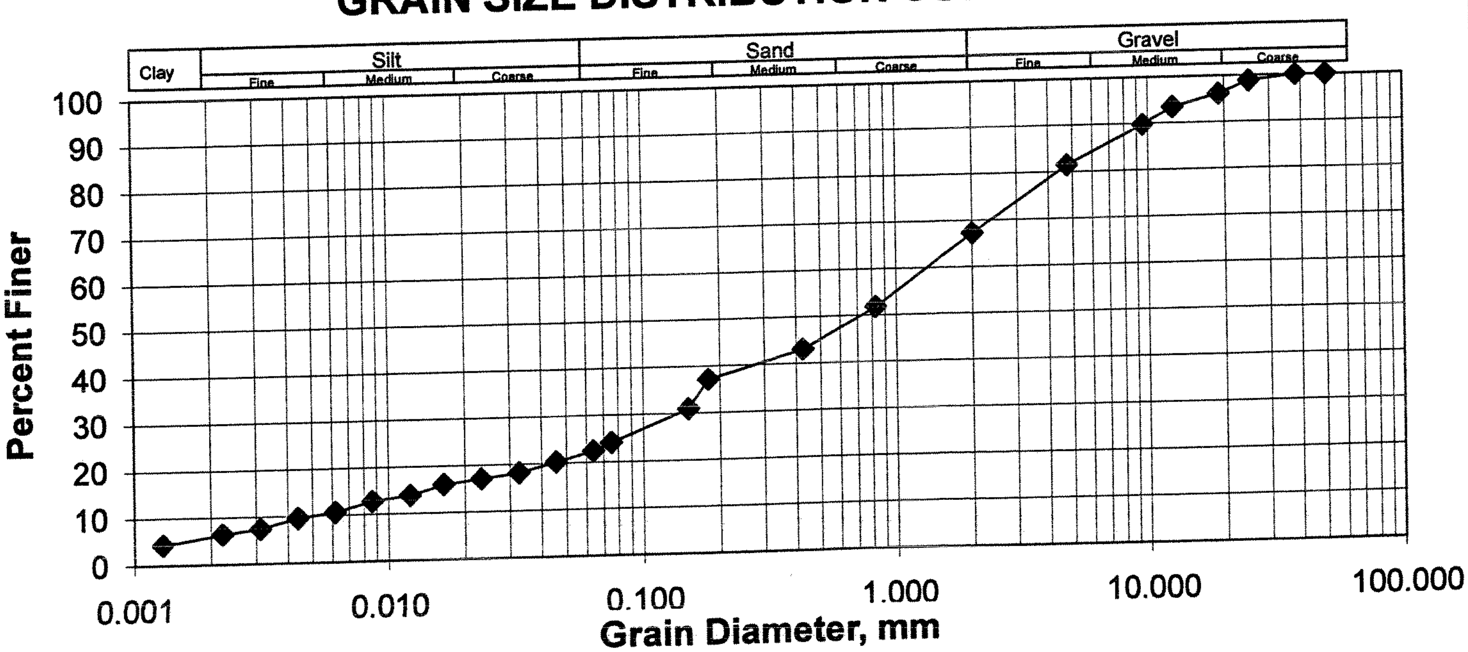
GRAIN SIZE DISTRIBUTION

MATERIALS LABORATORY
AECOM
99 Commerce Dr., Winnipeg, MB R3P 0Y7 Canada
tel (204) 477-5381 fax (204) 284-2040

Job No.:	60159089		Sample No.	
Client:	Government of Yukon		Hole No.	Victoria Creek Borrow Pit
Project :	MT Nansen Mine		Depth:	
Date Tested:	8-Jul-10		Date Sampled:	
Tested By:			Sampled By:	

GRAVEL SIZES		SAND SIZES		FINES	
Grain Size (mm.)	Total Percent Passing	Grain Size (mm.)	Total Percent Passing	Grain Size (mm.)	Total Percent Passing
50.0	100.0	2.00	67.2	0.0750	24.1
38.0	100.0	0.83	51.8	0.0638	22.4
25.0	98.8	0.43	43.0	0.0456	20.2
19.0	96.1	0.18	37.1	0.0325	18.1
12.5	93.5	0.15	30.9	0.0231	17.0
9.5	89.8	0.075	24.1	0.0164	16.0
4.75	81.4			0.0121	13.8
2.00	67.2			0.0086	12.8
				0.0061	10.6
				0.0044	9.6
				0.0031	7.4
				0.0022	6.4
				0.0013	4.2

GRAIN SIZE DISTRIBUTION CURVE



Gravel	32.8%	Silt	16.1%
Sand	45.3%	Clay	5.9%

** Note: Soil Classification based on Grain Size from Canadian Foundation Engineering Manual, 3rd edition (1992).