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Government of Yukon, Energy, Mines and Resources

Mount Nansen Tailings Dam
2008 Geotechnical Inspections

Prepared by:

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Project No.: 2940 040 00 (4.6.1)

Date: November, 2008

DRAFT

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November 20, 2008 Project No. 2940 040 00 (4.6.1)

Mr. Hugh Copeland, P.Eng., P.Geo.
Government of Yukon – Energy, Mines and Resources
Room 210 – 419 Range Road
Box 2703 (K-419)
Whitehorse, YT
Y1A 2C6

Dear Sir:

Re: Mount Nansen – 2008 Geotechnical Inspections

UMA Engineering Ltd., doing business as AECOM, is pleased to submit our revised Draft Report for the above referenced project. This report provides the results of our geotechnical inspection of the Tailings Management Area structures, provides recommendations on continued care and maintenance and an engineering assessment of closure options.

If you require further information or clarification, please contact Ken Skaftfeld, P.Eng. directly.

Sincerely,
UMA Engineering Ltd., doing business as AECOM

Ron Typliski, P.Eng.
Vice-President, Manitoba District
Canada West Region
KS/dh

Revision Log

Revision #	Revised By	Date	Issue / Revision Description
1	K. Skaftfeld	Oct. 27, 2008	Draft for Review
2	K. Skaftfeld	Nov. 20, 2008	Revised Draft for Review

Signature Page

Report Prepared By:	Report Reviewed By:
Ken Skaftfeld, P.Eng. Senior Geotechnical Engineer	Bill Wiesner, P.Eng. (MB)

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1. Introduction

1.1 Project Background

The Mount Nansen gold mine was operated by B.Y.G. Natural Resources Inc. from November 1997 to February 1999 at which time the owner went into bankruptcy. In March 1999, the mine was taken over by an interim receiver who abandoned the mine in July 1999 whereupon care and maintenance of the mine site was assumed by Indian and Northern Affairs Canada (INAC). The Yukon Government assumed responsibility of the Mount Nansen Mine site in April 2003 as part of the devolution of federal responsibilities in the Yukon. The Yukon Government currently maintains this responsibility but is interested in revisiting the cost for short and long term care and maintenance (status quo) and exploring alternatives for mine closure (walk-away solution).

Wastes associated with the mining of ore from the Brown McDade Open Pit were the generation of approximately 283,500 m^3 of arsenic and cyanide bearing tailings (EBA, 2002). The waste rock was deposited along the edge of the Dome Creek watershed immediately adjacent to the open pit. The tailings were deposited within an impoundment spanning the Dome Creek valley, about 1 km from the open pit. The tailings management area (TMA) consists of a main tailings dam and a downstream seepage dyke that impounds seepage water from the tailings pond and aquifer. The water level in the seepage pond is maintained at a relatively constant level by pumping water over the dyke and into the Dome Creek. Surface water is primarily diverted around the tailings pond via an interceptor ditch, creek diversion channel and associated drop structures.

1.2 Terms of Reference and Scope of Work

This report summarizes the results of our geotechnical inspection of the tailings dams and associated structures at the Mount Nansen, Yukon Territory, formerly operated by B.Y.G. Natural Resources Inc. The original terms of reference for the inspection were outlined in UMA's letter to Mr. Frank Patch of the Government of Yukon Energy, Mines and Resources dated June 27th, 2008. The purpose of the inspection was to carry out geotechnical inspections of the tailings dam and associated structures in order to provide comments on continued care and maintenance (status quo) and long term closure options. In order to achieve these objectives, the program was arranged into the following tasks, developed in consultation with the Government of Yukon's Project Manager during the course of the study:

1. Review background information provided by the Government of Yukon's Project Manager including: inspection and monitoring reports, dam safety reports, reports on tailings chemistry and hydrogeology.

2. Inspect the Tailings Management Area (TMA).

3. Prepare a site inspection report detailing the condition of the TMA structures, changes from the last inspection (based on the file review), required repairs and /or maintenance and other observed issues. Identify any immediate safety issues.

4. Assess the relative risk posed by the structures (dykes and diversion structures) and provide recommendations regarding the need for and frequency of follow-up site inspections.

5. Evaluate and prepare requirements and approximate (Class C) cost estimates for continued care and maintenance (status quo) and options to bring the structures up to a standard suitable for closure including upgrading the TMA, disposal of the tailings into the open pit and restoring the Dome Creek valley.

This inspection report is based on a cursory visual inspection and data provided in previous reports by others. Detailed investigations were not carried out and as such, this investigation was not intended to be detailed assessment of their condition. Several of the closure options described in this report have been evaluated in some detail by others. While we have reviewed information from previous reports, there has been no attempt made to corroborate or further analyze information or conclusions presented in past reports. In these cases, this report has focussed on providing new or anecdotal information relative to these options, constructability, and associated cost estimates.

2. Review of Background Information

A considerable amount of information was provided to AECOM for our use in preparing this report. Where applicable, the reports identified are referenced throughout this document as is anecdotal information provided by the Government of Yukon. The reader is encouraged to read these documents for more thorough discussions on previous engineering and environmental assessments and investigations. Background information provided by the Government of Yukon's Project Manager prior to the inspection included the following:

- Klohn-Crippen Consultants Ltd. – BYG Tailings Dam, Mount Nansen, YT – Site Visit report, October 19, 1999.
- EBA Engineering Consultants Ltd. – Geotechnical Data review Report, Mount Nansen Tailings Dam Safety Evaluation, December 1999.
- Klohn-Crippen Consultants Ltd., - BYG Tailings Dam, YT – Project Data Review Report, January 12, 2000.
- EBA Engineering Consultants Ltd., Dam Safety Assessment, Mount Nansen Tailings Facility near Carmacks, YT, May 2002.
- EBA Engineering Consultants Ltd., Dam Instrumentation Data and Assessment, Mount Nansen Tailings Dam NW of Carmacks, Yukon, February 2004.
- EBA Engineering Consultants Ltd., Instrumentation Data Review, Tailings and Seepage Collection Dams, Mount Nansen mine, Carmacks, YT, June 2006.

Subsequent to the inspection of the site, the following additional information was provided by the Government of Yukon's Project Manager:

- Canmet Mining and Mineral Sciences Laboratories - Assessment of Chemical Stability of Impounded Tailings at Mount Nansen, Yukon Territory, June 2002.
- J.L. Jambor, Leslie Investments ltd. – Minerology of Tailings From the Mount Nansen Site, Yukon.
- Gartner Lee Limited – 2005 Water Balance for the Mount Nansen Mine Tailings Pond, Yukon, February 2006.
- Gartner Lee Limited – Mt. Nansen Mine Site, Brown McDade Pit Desktop Hydrogeological Study, May 2007.
- Lorax Environmental – Mt Nansen Tailings Porewater Assessment, April 2008.

3. Site Description

3.1 Location and Mine Site Layout

The Mount Nansen Mine Site is located approximately 60 km west of Carmacks, YT as shown in Figure 01. The mine facility consists of a mill complex, mill camp, open pit (Brown McDade), waste rock dump and tailings management area (TMA). The general layout of the Mine Site is shown on Figure 02.

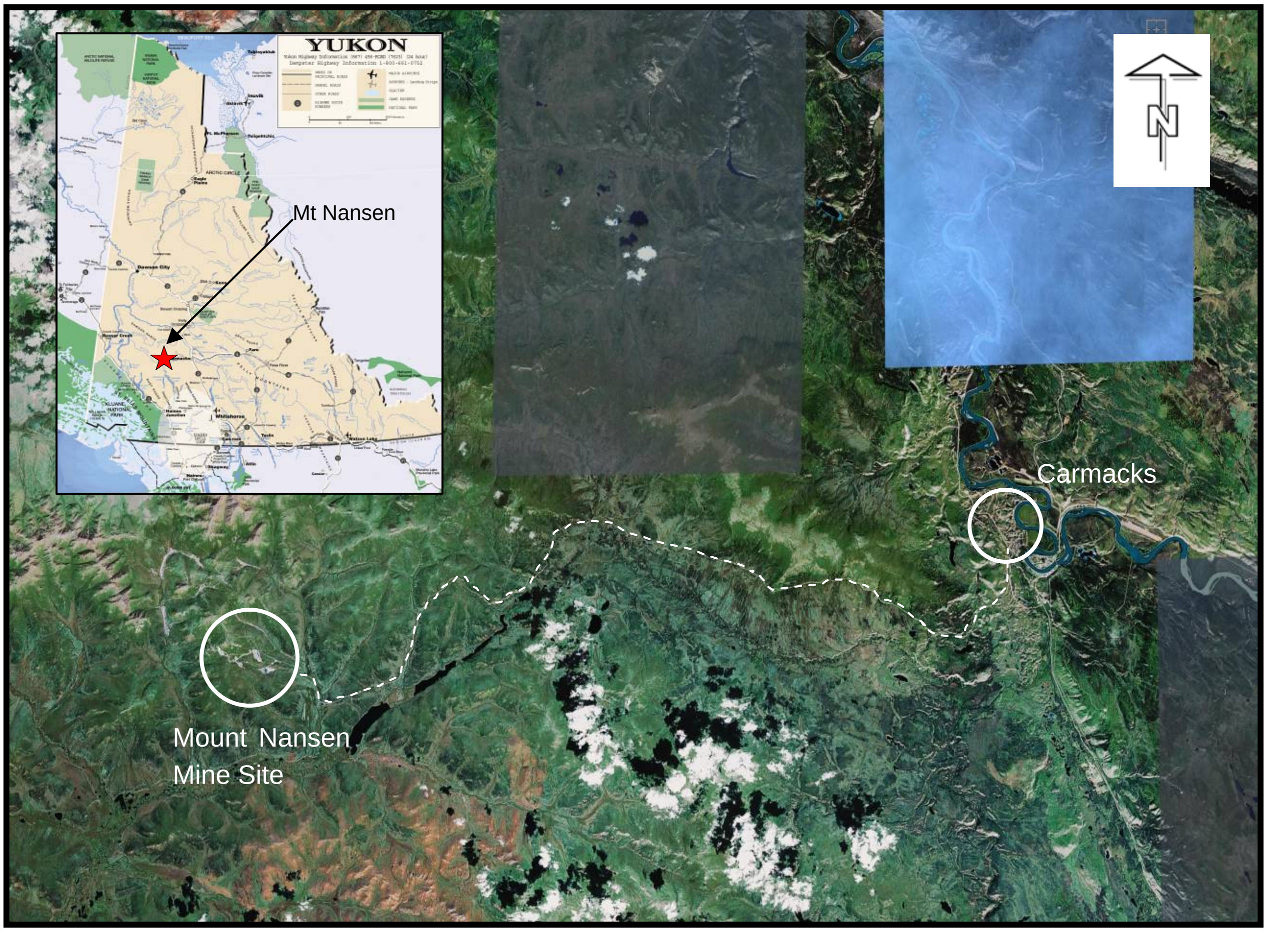


Figure 01 Location Plan

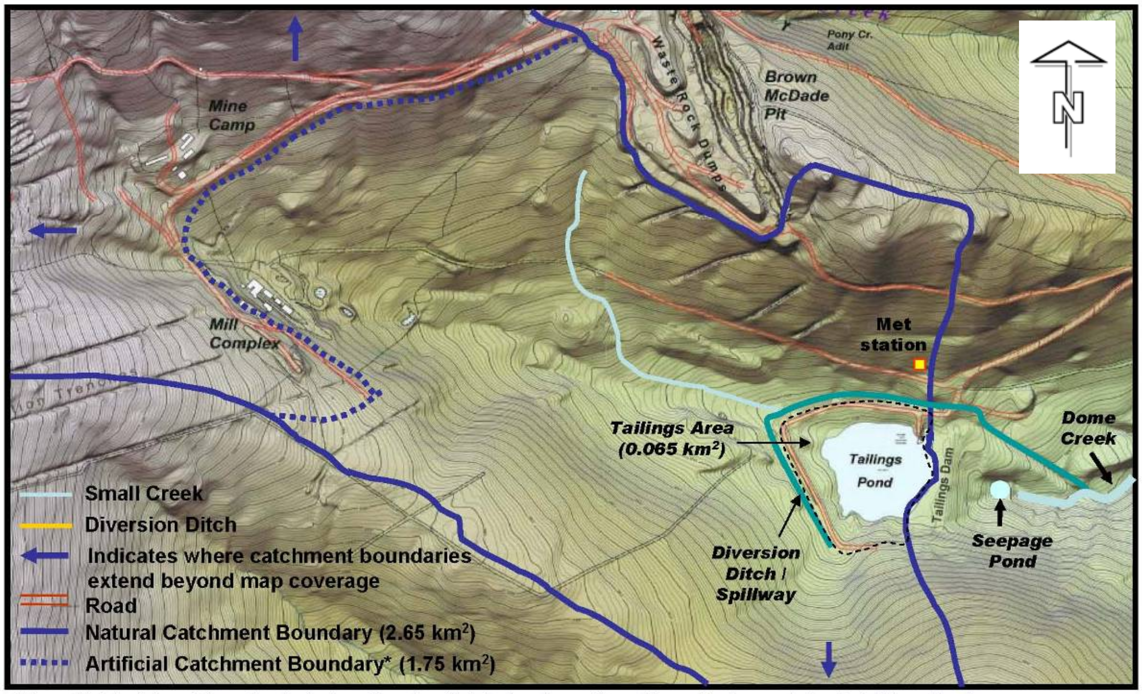


Figure 02 Mine Site Layout (GLL, 2005)

3.2 Components of Tailings Management Area

The TMA consists of a tailings impoundment dam (***tailings dam***), a seepage collection pond contained by a low height dam (***seepage dyke***), an ***interceptor ditch*** and creek diversion channel (***Dome Creek diversion channel***). The tailings dam, seepage dyke and diversion ditch were constructed in 1996 followed by construction of the interceptor ditch in 1997. A spillway from the tailings pond, also constructed in 1997, joins the creek diversion channel at the north abutment. The impoundment area is approximately 8 ha in size with an estimated 283,500 m^3 of tailings. The surface area of the tailings pond water has ranged in size from 4.5 ha (EBA, 2002) to approximately 1.5 to 2 ha at the time of AECOM's reconnaissance in 2008. The major components of the TMA are shown conceptually on Figure 03 and in detail on Drawing 01.

The tailings dam is about and 270 m long running north-south across the Dome Creek valley. The dam is an earthfill structure 21.5 m high for about 160 m from the south abutment to higher natural ground referred to in previous reports as the north terrace. The dam is 4 to 6 m high across the north terrace to the north abutment. Local sand was used to construct the dam which was founded on a layer of organic material underlain by permafrost soils (sand over till). Primary seepage control through the dam was intended to be provided by a 50 m wide beach of fine grained tailings within the impoundment. A geosynthetic clay liner (GCL) was installed into the upstream face of the dam as a means of secondary seepage control. An emergency stabilizing berm was constructed at the toe of the high dam section in 1997 to address piping and slope stability concerns.

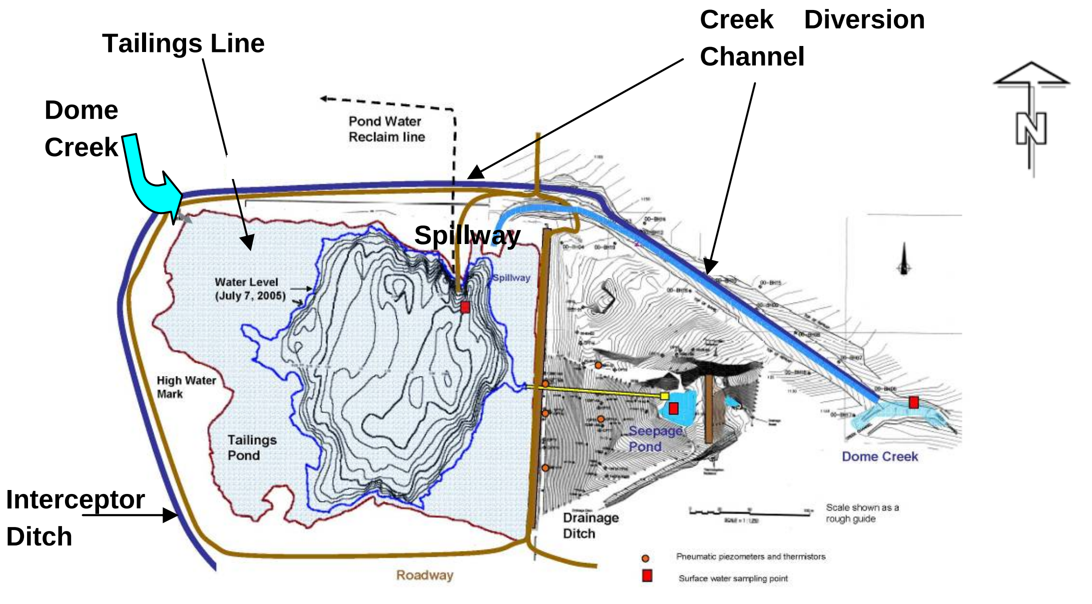


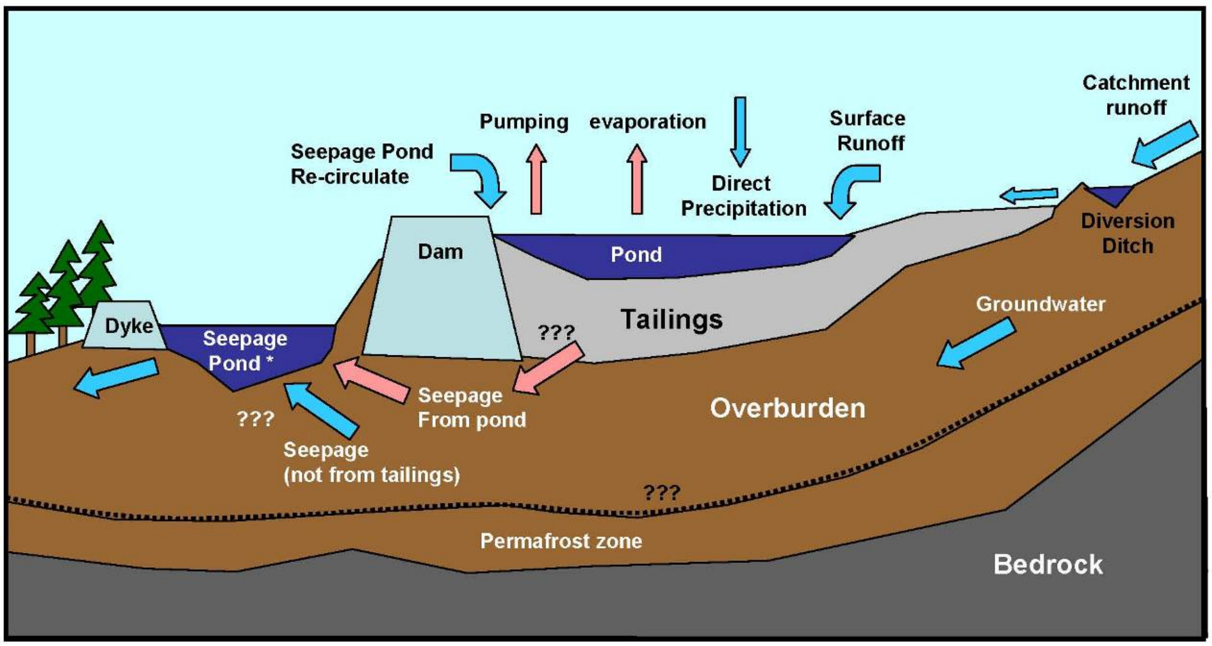
Figure 03 TMA Layout (GLL, 2005)

Dome Creek was rerouted around the TMA via a diversion channel along the northern edge of the tailings impoundment. An interceptor ditch extends along the western edge of the impoundment to collect intermittent stream flow and run off. The interceptor ditch joins the diversion channel at the northwest corner of the impoundment. Grades along the interceptor ditch and diversion channel are relatively gentle (about 0.5 to 1 percent) until reaching the north terrace where the diversion channel grade steepens to about 10 percent for about 315 m before joining the natural Dome Creek channel downstream of the TMA. An emergency spillway is located in the northeast corner of the tailings impoundment to divert water from the tailings pond into the Dome Creek diversion channel. The spillway was constructed with the intent to pass flows resulting from a breach of the Dome Creek diversion channel into the tailings pond (EBA, 2002).

A low height dam (seepage dyke) collects seepage water at the downstream toe of the tailings dam. The dyke is about 4 m high and 50 m long and incorporates a PVC liner keyed into permafrost and thermosyphons for freeze-back. Seepage from the main dam and its abutments is collected in a seepage pond between the toe of the tailings dam and seepage dyke. Major upgrades to the seepage dyke were carried out in 2000 at the same time as reconstruction of the emergency spillway (EBA, 2000).

Control of water from the TMA was originally handled by pumping water from the seepage pond over the tailings dam and back into the tailings pond. Water from the tailings pond was then pumped back to the mill via reclaim water lines for treatment. It is our understanding that this treatment consisted of SO_2 for cyanide destruction and lime addition for pH and facilitating metals precipitation out of the water (personal communication, Hugh Copeland). Treated water meeting discharge criteria was then pumped directly into Dome Creek at the mill complex and we hydroxide sludge was believed to have been disposed of in the tailings pond. Since 2005, water quality in the seepage pond has met the current license limits and has therefore been discharged directly over the seepage dyke and into Dome Creek.

The water balance in the TMA has been studied by Gartner Lee (Gartner Lee, 2005). In general, the main components include direct precipitation into the tailings pond, surface runoff from the catchment area, evaporation from the pond, and groundwater inflow/outflow as shown schematically in Figure 04. It should be noted that Figure 04 does not show seepage through the dam (thought to occur) and discharge of pond water over the seepage dyke. It is important to recognize that there were several limiting factors in determining the tailings pond water balance including the lack of groundwater monitoring wells in the vicinity of the tailings pond. The seepage collection pond captures a portion of the seepage through the tailings dam (tailings porewater) and groundwater flowing beneath and around the dam. It is recognized that the seepage pond does not capture all seepage losses. Pond levels are controlled by pumping year round from the seepage pond at a relatively constant rate of 2.8 L/s (GLL, 2005).



* Seepage pond also subject to surface runoff, precipitation and evaporation

Figure 04 Conceptual Tailings Pond Water Balance (GLL, 2005)

3.3 Surficial and Bedrock Geology

The surficial and bedrock geology are described in detail in Gartner Lee's Hydrogeological Study (GLL, 2007). In general, the surficial geology consists of glacial till overlying bedrock. The thickness of the till layer ranges from 1 m overlying upland bedrock outcrops to 20 m in the middle of the Dome Creek valley. Within the valley, the till is overlain by silty sand up to 15 m thick and up to about 1 m of moss and peat.

The Mount Nansen Mine is located in the eastern part of the Yukon Crystalline Terrane between the Coast Plutonic Complex to the south and the Yukon Cataclastic Terrane to the northeast. The oldest rocks in the area are Palaeozoic medisedimentary schists and gneisses that were in turn intruded by intermediate volcanic rocks of the Mount Nansen Volcanic Suite. Mineralization occurs in structurally controlled veins of quartz, carbonate and varying amounts of sulphides (most common), and simple vein systems. Gold and silver occur as inclusions in the mineralized rock (CANMET, 2002).

3.4 Permafrost

Previous drilling investigations revealed discontinuous permafrost in the area, in particular along north facing aspects. Natural depths to permafrost range from ground surface to 11 m below ground surface. The original designers predicted that the zone of foundation thawing (permafrost degradation) would be limited to an area underneath the tailings pond (up to 5 m) and the upstream embankment toe where the depth of thaw would be limited to 2 m (EBA, 2002). The permafrost table was then expected in the long term to rise into the dam by about 3 m at the centerline and return to natural permafrost levels (1.5 m) about 15 m beyond the downstream toe.

Since 1998, EBA Engineering has monitored thermistors which were installed in and downstream of the dam crest. The most recent monitoring was carried out in 2007 and 2008, however, no interpretation of this data was available at the time of preparing our report. Data up until 2006 has confirmed however, that the thawing of permafrost beneath the dam crest has exceeded the design predictions and there is no evidence to date that significant freeze-back (in the original predicted range) is occurring. There is no information with respect to the depth of thaw upstream of the dam as no instrumentation was installed beneath the tailings pond. A particular concern expressed by EBA however, is the potential for continued degradation of permafrost on the north abutment slope leading to the potential for increased seepage losses, settlement and piping (EBA, 2002).

3.5 Hydrogeology

The hydrogeology of the mine site area was evaluated in a desk top study by Gartner Lee in 2007 (GLL, 2007). The intent of the study was to assess the probable fate of seepage leaving the Brown McDade open pit via the groundwater pathway and comment on the potential flow regime changes to the pit by partially backfilling it with benign waste rock. It was concluded that seepage leaving the pit reports to a bedrock aquifer system, which eventually discharges downstream to talic under the tailings pond and/or the valley bottom aquifer system, located most likely in the Dome Creek drainage basin (Figure 05). It is therefore possible that a component of flow into the seepage pond downstream of the main tailings dam is associated with groundwater flow originating from the open pit. Closure options that involve infilling the open pit with tailings must therefore consider the possibility of a hydraulic connection between the open pit and downstream seepage pond, and the associated environmental considerations with respect to groundwater quality.

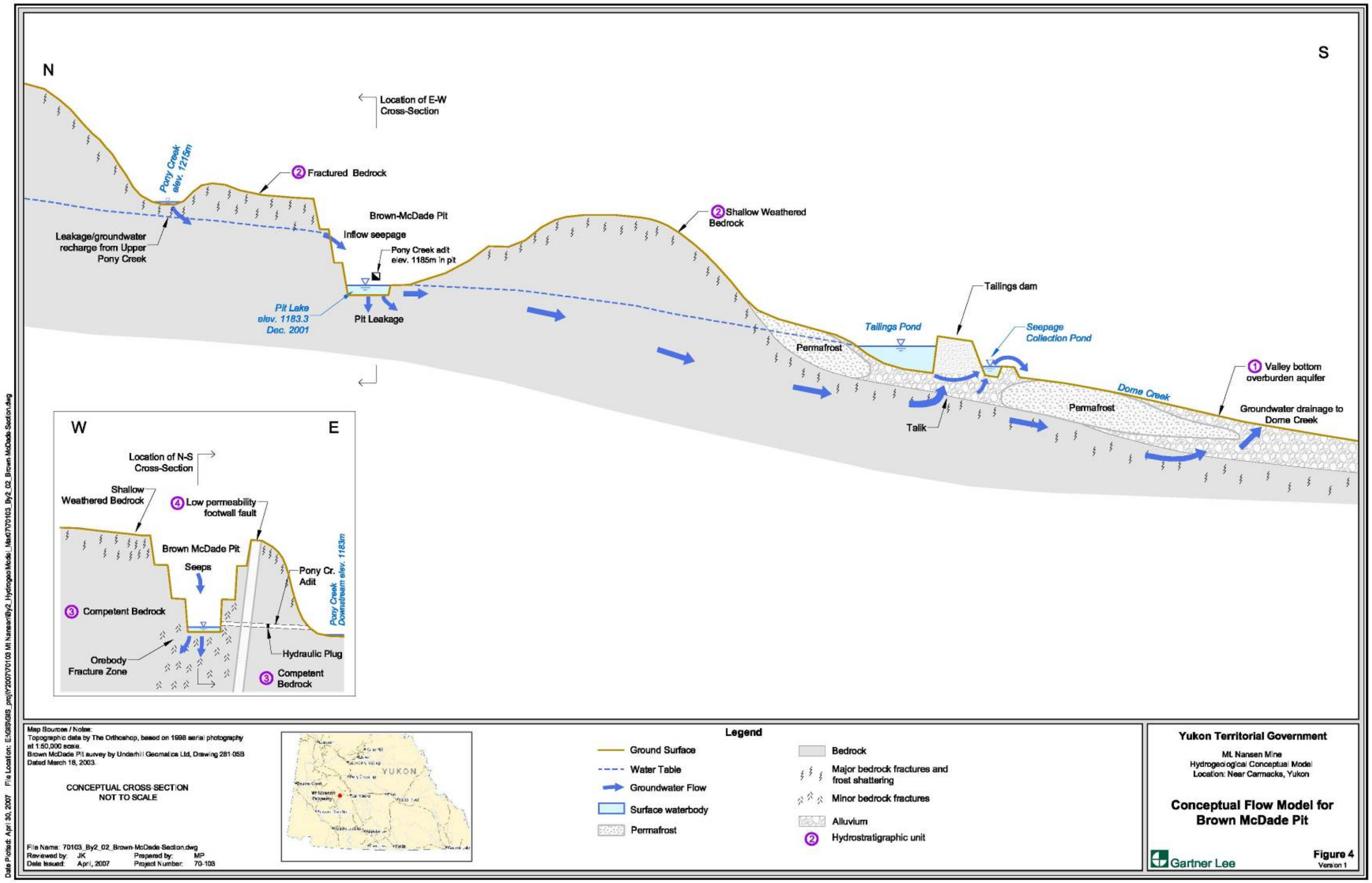


Figure 05 Conceptual Groundwater Flow Model (GLL, 2005)

4. Condition Assessment

The condition assessment was carried out on July 15th and 16th 2008 by Mr. Ken Skaftfeld of AECOM in the company of Hugh Copeland and Frank Patch from the Government of Yukon Energy, Mines and Resources and Glenn Ford from the Government of Yukon Water Resources Branch. Several photographs and a video were taken during the inspection. These have been included on the CD (photographs) and DVD (video) attached to this report as Appendix A. Select photographs from the photo set have been used throughout the report.

4.1 Tailings Dam and Pond

Overall, the tailings dam as shown in Figure 06 is in good condition. Also, seen in Figure 06 are piles of tailings sand that were pushed up in the winter of 2008 during additional investigations of the tailings by the Government of Yukon (personal communication, H. Copeland). The tailings pond elevation was surveyed at the time of our inspection and found to be 1096.3 m[1] (Figure 07). This level is considerably lower than previously reported and results in a freeboard of approximately 3 m. The exposed tailings beach is about 25 m wide at its closest point to the upstream edge of the dam (Figure 08) at which point it drops at about 1H:1V into the pond excavated to create the tailings piles at the north and south abutments. The crest is about 5 to 7 m wide with downstream side slopes estimated to be in the order of 3.5 H:1V as seen in Figures 09 and 10.

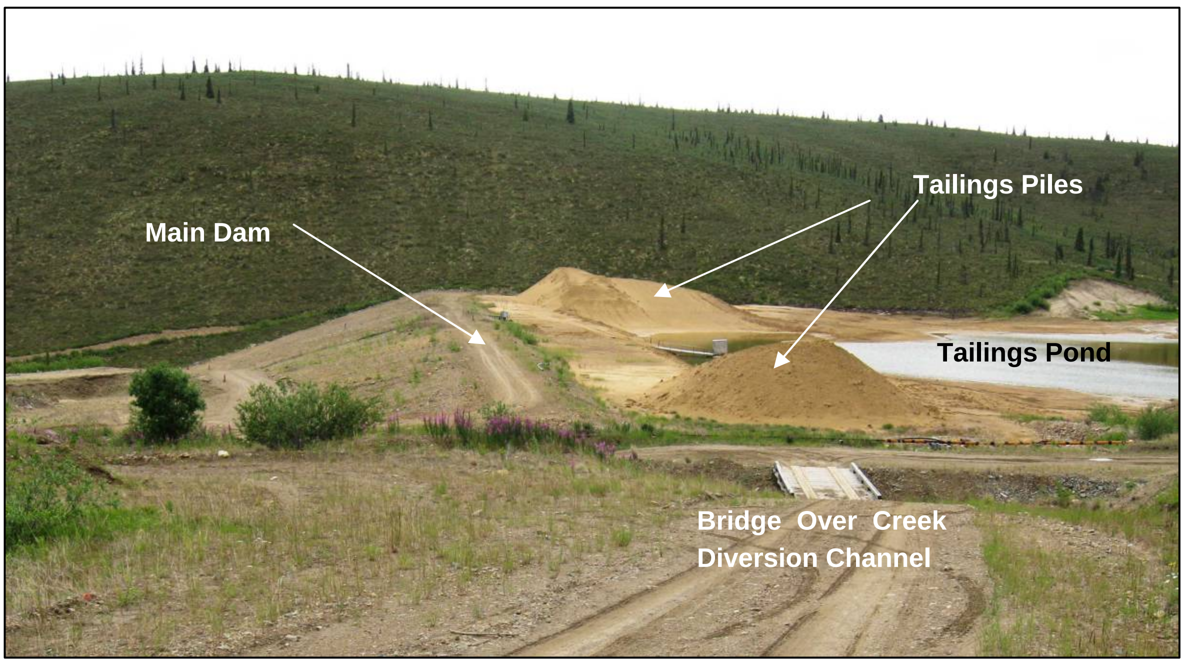


Figure 06 View S at Main tailings Dam From Access Road

[1] All elevations in this report are geodetic.

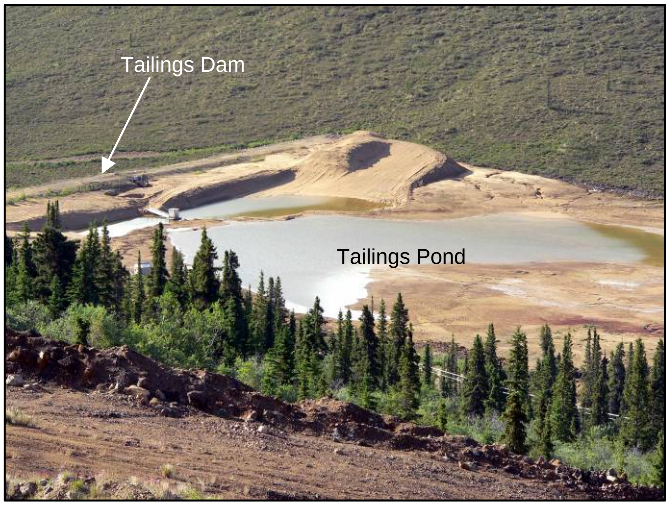


Figure 07 View SE at Tailings Pond

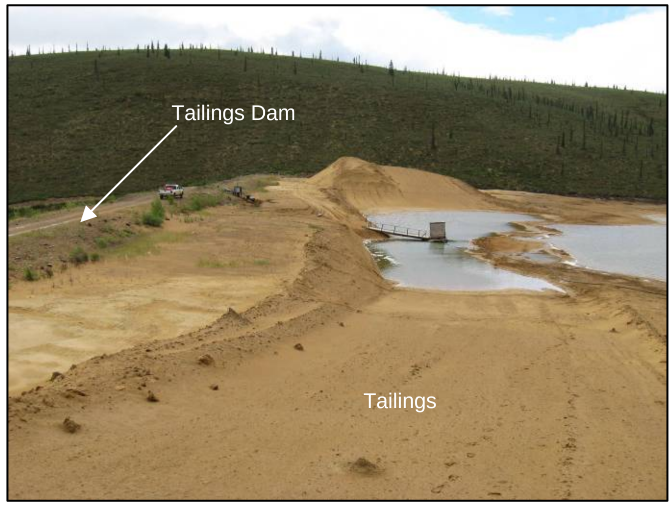


Figure 08 View S at W Edge of Tailings Pond

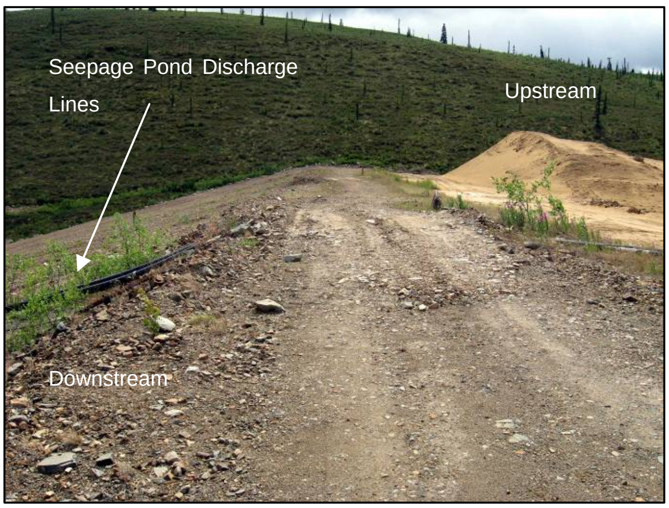


Figure 09 View S at Crest From Middle of Dam

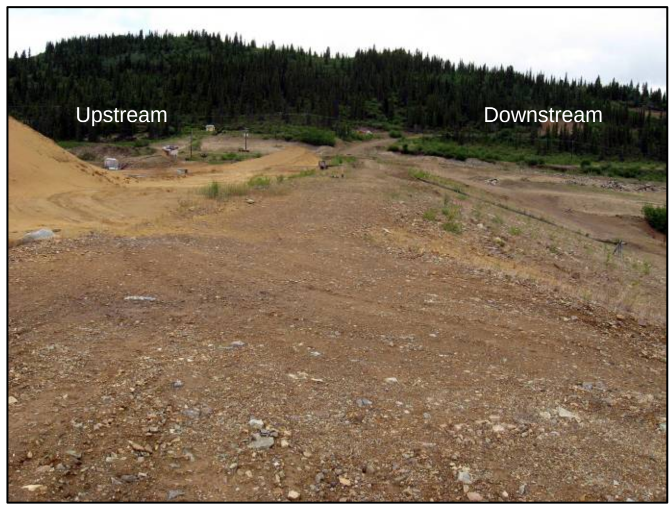


Figure 10 View N at Main Dam From S Abutment

The upstream slope from the crest to the tailings beach is about 2.5H:1V and about 1.2 m high (Figure 11). Vegetation is sparse consisting of occasional saplings and there are no signs of rodent burrowing. An erosion gully meanders through the tailings beach from the seepage pond discharge structure to the tailings pond, although this is of no consequence to the stability of the dam (Figure 12). The dam crest above the sand fill consists mainly of coarse gravel and small cobbles. The crest elevation is generally level until the mid point where fill has been added over the seepage pond return lines (Figure 09). The crest south of the line crossing is visibly lower than the north section.

Figure 11 View SE at Main Dam Upstream Slope

Figure 12 Erosion Gully in Tailings Beach

A stabilizing berm was constructed in 1997 to address stability and seepage (piping) concerns associated with higher than expected pond levels. It was reported that seepage was daylighting as high as elevation 1083 m on the downstream face of the dam. The berm was constructed along the toe of the southern half of the tailings dam to about elevation 1088 m. The top of the berm now serves as an access road from the south abutment to the seepage pond pumphouse (Figures 13 and 14).

Figure 13 View S at Stabilizing berm from WP 22

Figure 14 View N at Stabilizing berm from WP 22

Movement monitoring pins were installed in 1999 along the edge of the crest (11 pins) and downstream slope (16 pins) south of the north terrace to measure vertical and horizontal displacements (deformation) of the earth fill dam. Following the baseline survey in 1999, the pins were subsequently surveyed again in 2000 and 2001. These surveys were carried out using total station tied into the mine grid and datum. Data from the 2001 deformation survey indicated cumulative crest settlements ranging from 8 to 61 mm occurred with the most significant in the vicinity of the south abutment (EBA 2002). Over the same period, cumulative settlements on the downstream face of the dam ranged from 10 to 40 mm. No measurable cumulative horizontal displacements were measured on the dam crest. Cumulative displacements ranging from 6 to 64 mm were measured on the downstream face, generally in an easterly of south-easterly direction.

At the request of AECOM, the Government of Yukon retained YES to carry out additional topographic and deformation surveys again in 2008. The locations of the monitoring pins are shown on Drawing 02. The 2008 surveys were completed using global positioning system (GPS) surveys in UTM coordinates and a geodetic datum. A transformation between the mine grid/datum and UTM coordinates was successfully made using CP4001 as our control point to resolve the horizontal coordinates. The mine grid was then rotated around CP4001 and using Y4170 as a second control point. The final rotation from the mine grid to UTM grid was 1.914 degrees clockwise. The mine datum elevation was then converted to a geodetic elevation by subtracting 51.810 m. A centerline profile of the tailings dam and seepage dyke was also surveyed by YES in 2008.

Cumulative displacements up to the most recent (2008) survey have been determined by summing the displacements from 1999 to 2001 and from 2001 to 2008. Based on our experience on other projects where monitoring pin data is accumulated, we have found the most meaningful presentation of the data to be in the form of a vector plot that graphically shows the position of the pin for each survey relative to its baseline position. For simplicity, the baseline position is shown with Northing and Easting coordinates of 0,0 as shown in the example in Figure 15. The results of these plots for the surveyed pins are summarized in Appendix B.

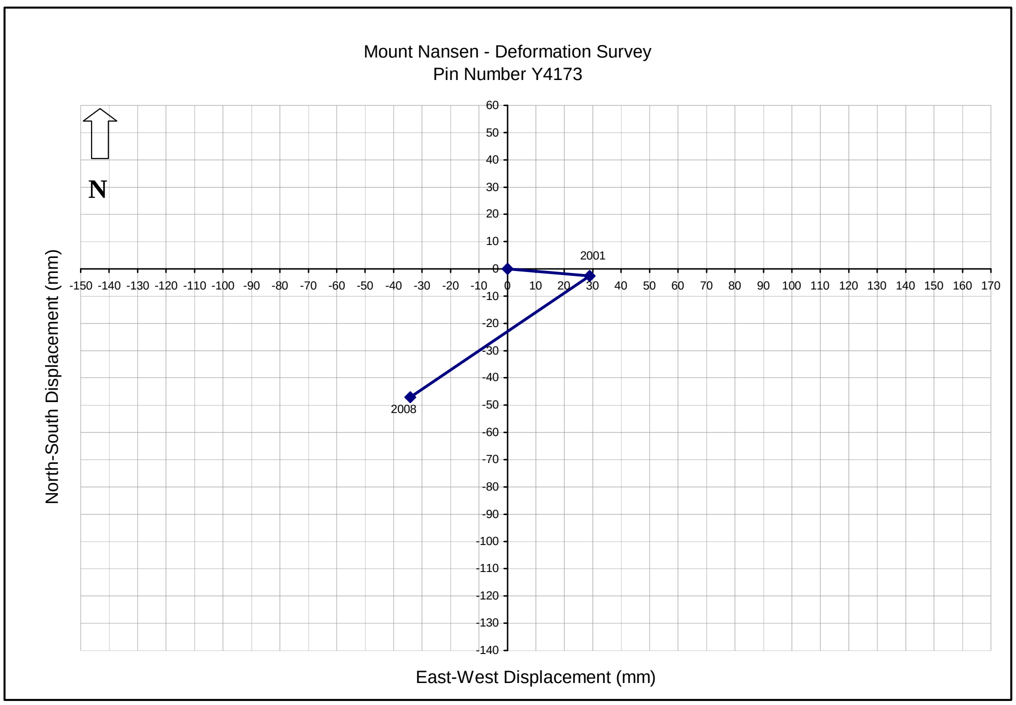


Figure 15 Example of Monitoring Pin Data Presentation

There are a number of sources of error, including systematic errors, equipment, etc., that must be considered when interpreting the deformation survey results. Any or a combination of these errors can affect the accuracy of the survey. For example, previous (total station) and the 2008 (GPS) surveys have different accuracies. The accuracy using GPS surveys is expected to be in the sub-centimetre range for both vertical and horizontal. Another potential source of error introduced into data reduction is the transformation between the mine grid and UTM coordinate surveys. With this in mind, it is difficult to conclusively determine the magnitude of deformations with the limited data set to date. In some cases, the reversal in movement direction is likely attributable to survey error rather than actual ground displacement. The data is meaningful however in identifying deformation trends e.g. areas of settlement or relatively large displacements. Incorporating data from future surveys will allow more meaningful interpretation of the results. In this regard, we recommend that all future surveys be done using GPS methods with UTM coordinates.

Figure 16 Spreading of Fill at WP 22 (View N)

Figure 17 View S From Pin Y4173 (WP 23)

The results from the 2008 deformation survey are presented on Drawing 02 which shows the direction of incremental movement and the magnitude of settlement at each pin (tabular). Settlements greater than 100 mm have been bolded. Overall, we have concluded that there is no clear indication that significant horizontal deformations of the dam have occurred since monitoring began. Consistent with EBA's observations in 2002 however, settlement of the southern portion of the dam crest appears to be continuing with up to 265 mm of cumulative settlement at Pin Y4159. The cause of continued settlement at this location is undetermined but could be related to seepage and/or permafrost degradation. Deformations along the downstream toe of the stabilizing berm coincide with visible settlement and spreading at this location (Figures 16 and 17). It is likely however, that these deformations are a result of lateral spreading of loosely placed fill material used to repair an erosion channel on the downstream side of the south abutment.

4.2 Seepage Dyke and Pond

The seepage dyke is in good condition with no evidence of settlement or instabilities (Figures 20 and 21). The dyke is about 3.5 to 4 m high with upstream and downstream slopes of about 3H:1V that are well armoured with coarse gravel and cobble sized material. There is no engineered spillway and if the pond level were to rise to the dyke crest, water would spill over the north end of the dyke based on a 2008 centerline profile survey (Drawing 03). At the time of our inspection, the freeboard was estimated to be in the order of 2 m although iron staining on the upstream face indicates that water levels may previously have been about 0.5 m higher (Figure 18). Seepage water is collected year round in the pond and pumped over the dyke by the pumphouse shown in Figures 19 and 20. There are no means to regulate pond levels other than pumping which is regulated to maintain a fairly constant water level in the pond. Typically these rates average to about 1.9 L/sec (30 USGPM) to 4.7 L/sec (75 USGPM) during periods of significant precipitation. It takes about two days worth of seepage to fill the pond if pumping is stopped (personal communication, H. Copeland).

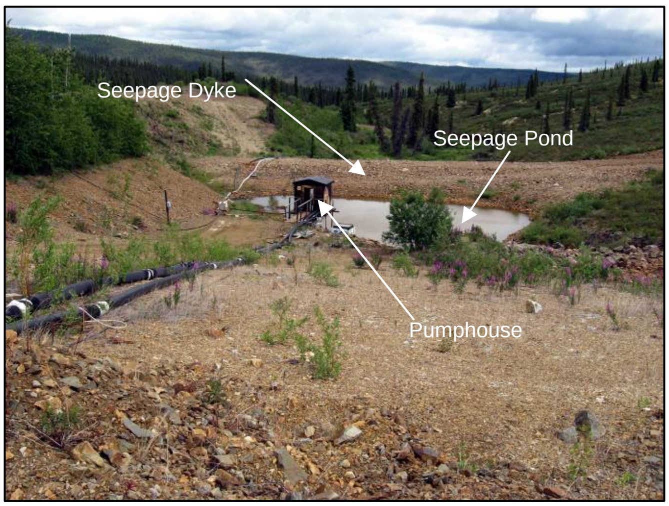


Figure 18 View at Seepage Dyke and Pond From WP 26

Figure 19 View W over Seepage Pond From Dyke

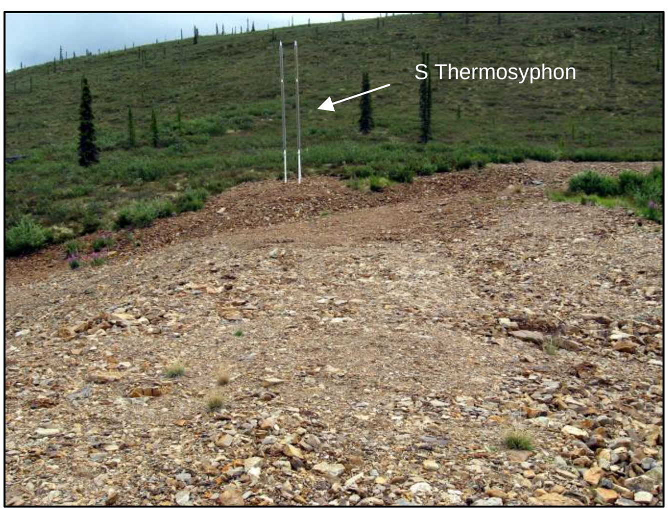


Figure 20 View S Along Seepage Dyke Crest

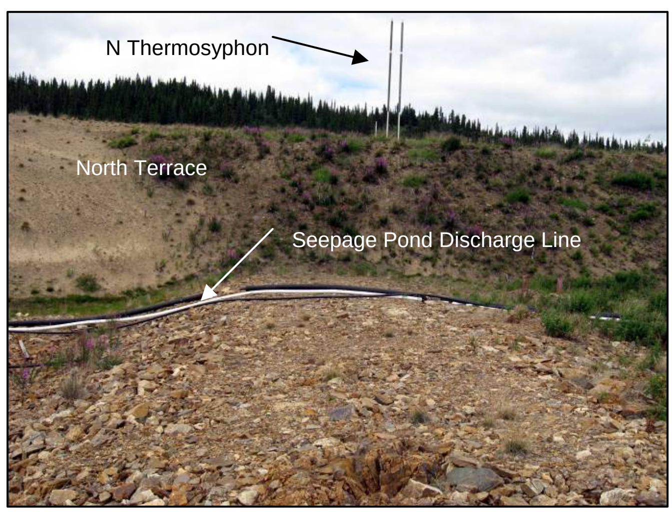


Figure 21 View N Along Seepage Dyke Crest

Seepage was observed entering the pond at two locations. The first is at the southwest corner of the pond where active seepage through the rock fill at the downstream edge of the stabilizing berm has caused iron staining of the rock (Figure 22). Seepage rates are estimated to be less than 4 L/min (<1 USGPM). The seepage water appears clear and the ground in the vicinity of the seepage is algae covered suggesting the flow at this location is nearly continuous throughout the year. The second location is at the northeast corner of the pond where flow is estimated to be in the order of 4 L/min (1 USGPM) at the toe of the north terrace slope (Figure 23). The seepage area is also covered in green algae. Subsequent examination of photos suggests that seepage may have been occurring in the past at a higher elevation at the top of the rock fill as evidenced by iron staining at this location (Figure 24). We are not aware of any water chemistry results associated with the individual seeps.

Figure 22 Seepage & Fe Staining at SW Corner of Pond

Figure 23 Seepage at NE Corner of Pond

Figure 24 View W at Seepage Pond and Tailings Dam

What appeared to be seepage was observed along the downstream toe of the seepage dyke, in particular along the southern half (Figure 25). No measurable flow was observed but the ground at the toe is very soft and wet with lush vegetation. A short distance downstream, water begins to collect in a meandering stream along what appears to be the original Dome Creek alignment (Figure 26). There is no visible seepage along the downstream toe of the northern half of the dyke where seepage pond water is pumped over the dyke where seepage pond water ii discharge sump as seen in Figure 27.

Figure 25 Soft ground at Toe of Seepage Dyke

Figure 26 Dome Creek Valley D/S of Seepage Dyke

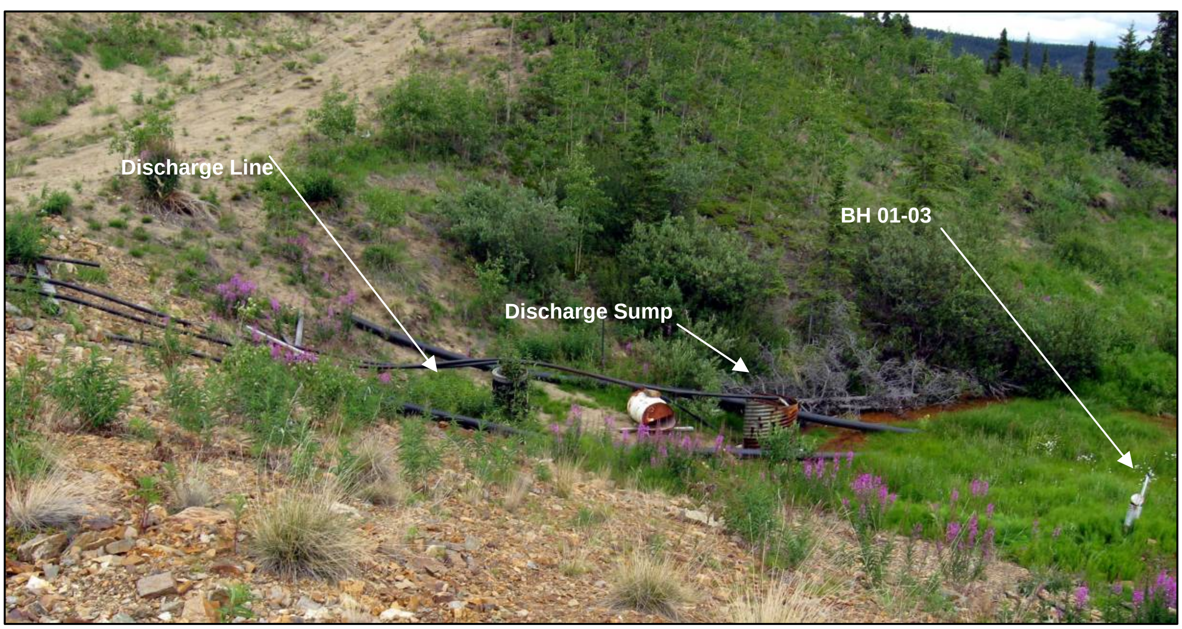


Figure 27 Discharge Sump Downstream of Seepage Dyke

4.3 Interceptor Ditch and Diversion Channel

The interceptor ditch collects surface water beginning at its south (upstream) end where a small creek enters the ditch. The grade on the channel is about 0.5 percent as shown on the profile on Drawing 04 (2008 survey). Along the upper reaches, the ditch meanders through a sand bedding and bank material with little to no armouring. The channel bottom width and bank heights are about 3 and 1.5 m respectively (see cross sections on Drawing 04). Vegetation is relatively well established along both banks although sloughing of the sand into the channel still occurs (Figure 28). Farther downstream, the bank heights gradually increase to about 2 m as does the amount of larger rock along both banks as shown in Figure 29. Vegetation is sparse on the east bank.

Figure 28 View D/S From S End of Ditch

Figure 29 View D/S From Station 0+150 (WP 76)

A secondary ditch branches out from the main interceptor ditch at Station 0+280. Water enters the south end of the secondary ditch via a creek channel to the west. The secondary ditch cuts through the edge of a former sand borrow area to its west. The channel is up to 6 m wide and almost flat with active erosion along the toe of both banks about 1 m above the bottom (Figures 30 and 31). There is no armouring along the banks which are primarily fine grained sand. A considerable amount of sediment in downstream stretches appears to originate from erosion of bank material along the secondary ditch. The interceptor ditch becomes very narrow with over-steepened un-armoured banks between the secondary ditch outlet and the confluence with the Dome Creek Diversion channel (Figure 32). The diversion channel widens out considerably at the bend to the east where it traverses the wide Dome Creek valley (Figure 33).

Figure 30 View U/S at Secondary Ditch at Sta 0+280

Figure 31 View U/S Along Secondary Ditch From WP 73

Figure 32 View D/S Along Ditch From Sta 0+285

Figure 33 E End of Diversion Channel at Confluence With Dome Creek (View D/S)

The diversion channel downstream of the confluence with Dome Creek is flanked on the south side by the road and the natural valley bottom and valley slope on the north side (Figures 34 and 35). The road is about 2 m above the channel bottom where a significant thickness of fine grained sediment is continually being deposited (at the observed flows). The channel slopes at about 0.5 percent as shown on Drawing 04. Sediment in the channel bottom has been excavated in the past with the castings windrowed along the south edge of the road. Sediment excavation is an ongoing maintenance item and it is our understanding that it is required at least annually. The road bank is over-steepened at about 1H:1V and shows signs of slumping and undercutting as seen in Figure 34. The channel cuts through the east Dome Creek valley slope as it heads to the east. The bank material is mainly sand with sparse vegetation (Figure 36). The channel narrows as it approaches the access road bridge although the slopes are flatter, at about 2H:1V (Figure 37).

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Figure 34 View U/S at Confluence With Dome Cr

Figure 35 View D/S from Sta 0+390 (WP 69)

Figure 36 View U/S From Sta 0+620 (WP 67)

Figure 37 View D/S From Sta 0+620 (WP 67)

The channel upstream and downstream of the bridge is narrow (1 to 2 m) with steep banks made up of sandy gravel (Figures 38 and 39). There is little armouring on the north bank along this relatively flat stretch before the confluence with the spillway. Armouring on the south bank is more extensive consisting of coarse gravel and small cobbles. The natural bank consists mainly of fine grained sand. An erosion gully is visible on the left hand side of Figure 39 enters the diversion channel immediately downstream of the bridge. The bank at the bridge crossing has over-steepened sideslopes of about 1H:1V.

Figure 38 View U/S from Bridge

Figure 39 View D/S from Bridge

The diversion channel steepens considerably just downstream of the confluence with the tailings pond spillway (Figure 40). This section is heavily armoured and contains 13 drop structures constructed with large boulders. There are no signs of bank erosion and the drop structures are in good condition (Figure 41). Flow is contained within the armoured section and although not significantly restricted by the boulders; at the flow rates observed, water tends to flow around (rather than over) individual boulders. It is likely however, that more evident steps in the hydraulic profile would occur at higher flows.

Figure 40 View D/S From Sta 0+810 (WP 51)

Figure 41 Drop Structure #2

The armouring on the upper portion of the channel banks appears to have been pulled back downstream of about Station 0+920 (Figures 42 and 43). Geotextile can be seen along both the north and south banks and the channel would be susceptible to erosion above the armouring at higher flow depths (Figure 44). Iron staining is also evident along the entire stretch of the diversion channel that has been lined with rock (Figure 45).

Figure 42 View D/S From Sta 0+950 (WP 59)

Figure 43 Drop Structure 8

Figure 44 Exposed Geotextile on N Bank at Sta 0+920 (WP 57)

Figure 45 Iron Staining (View U/S From WP 59)

The downstream end of the diversion channel widens out to about 25 m at the confluence with Dome Creek and channel flow becomes divided at the end of the road on the south side of the diversion channel. The channel is well armoured between the last drop structure (DS # 13) and the creek channel (Figures 46 and 47).

Figure 46 View D/S at Creek From DS # 13 (WP 64)

Figure 47 View D/S From DS # 13 (WP 64)

4.3.1 Spillway

The tailings pond spillway is in good condition although it does not appear to have been recently operational. The spillway entrance is formed by waste rock and gravel banks in the northeast corner of the tailings pond (Figure 48). Beyond the limits of the pond, the spillway channel has been cut into the north terrace and is flanked by the access road on the north side. The bend in the access road at the south bridge abutment has been widened into the spillway channel creating a constriction (Figure 49). A survey of the channel indicates that the high point of the spillway is just upstream of the road crossing at elevation 1098.5 m. Sideslopes are in the order of 2H:1V with the exception of steeper slopes where the road fill encroaches.

Figure 48 Spillway Entrance

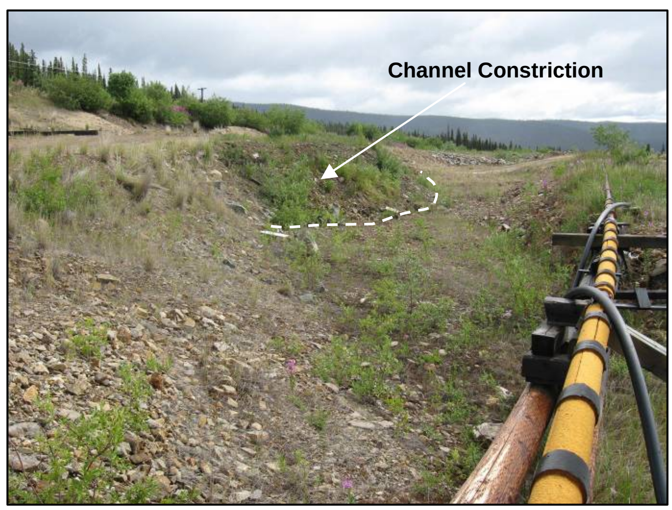

Figure 49 Spillway at Discharge Line Crossing

The material lining the spillway bed consists of coarse gravel (Figure 50). Coarser rock fill has been used to armour the banks as seen in Figure 51. The channel bedding material downstream of the road crossing consists of sand; however, it is possible that the sand has been deposited over the coarser bedding material. Vegetation consisting of saplings, shrubs and grasses are becoming established in the spillway, in particular in the section between the inlet and road crossing.

Figure 50 Channel U/S of Road Crossing

Figure 51 Channel D/S of Road Crossing

4.4 Summary

The overall condition of the tailings dam and seepage dyke at the time of our inspection was considered to be good. There do not appear to be any significant deformations of either structure that would indicate active instabilities. Seepage water at the toe of the rock fill at the edge of the seepage pond appears clean but it is important to recognize that this condition could worsen with increased water elevations in the tailings pond. Internal erosion of the earth fill dam associated with the toe seepage cannot be ruled out. Settlement of the south half of the tailings dam crest, as evidenced by surveys of monitoring pins and the centerline profile is of some concern and the cause should be investigated further, in particular to determine if it is associated with the observed toe seepage. Consideration should be given to restoring the design crest elevation in this area. The emergency spillway is in good condition although the constriction from widening the road approaching the south side of the bridge should be removed to restore full design hydraulic capacity.

The interceptor ditch and diversion channel are functioning although the banks upstream of the emergency spillway are typically over-steepened with active erosion and sloughing. Blockages associated with failures of the channel banks could lead to breaching of the adjacent road that separates the channels from the tailings pond. Excavation of sediment along flatter grades will continue to be required on an on-going basis until channel stabilization measures are undertaken. The diversion channel downstream of the emergency spillway is in good condition although some additional bank armouring and repairs to the drop structures should be considered in the downstream half of this portion of the channel.

5. Risk Assessment

5.1 Approach

A qualitative risk assessment was carried out for the tailings dam, the seepage dyke, the interceptor ditch and the Dome Creek diversion channel to assist in determining an appropriate risk management strategy for the TMA. The risk assessment has been developed by AECOM for use in abandoned and active mine sites. The consequence categories follow but are not necessarily consistent with those described in the CDA Dam Safety Guidelines. AECOM's approach considers a number of possible events (e.g. dam failure) for which a risk score can be determined. The risk score is the product of the likelihood, exposure and the possible consequences of the event. The risk scores are then used to determine the risk level for each structure. Recommendations for action (e.g. monitoring or repairs) are based on the risk level. The individual components used in determining the risk score are as follows:

Likelihood - Likelihood is the probability of the event occurring. The risk assessment approach for this study uses a ranking of likelihood that is directly related to a failure of the tailings pond dam or containment of the diversion channels (Table 5-1).

Table 5-1 Likelihood Categories

LIKELIHOOD OF DYKE FAILURE	DESCRIPTION	SCORE
Negligible **(N)**	Practically Impossible	**0.2**
Unlikely **(U)**	Conceivable But Very Unlikely	**0.5**
Low **(L)**	Remotely Possible	**1**
Moderate **(M)**	Unusual But Possible	**3**
Probable **(P)**	Quite Possibly Could Happen	**6**
Highly Probable **(HP)**	Might as Well Be Expected	**10**

Exposure - For each event in the risk assessment, there is a potential exposure to that risk. The exposure is the frequency that there is a likelihood of the event occurring (Table 5-2).

Table 5-2 Exposure Categories

EXPOSURE	DESCRIPTION	SCORE
Unlikely **(U)**	Very Rare (Yearly or Less)	**0.5**
Very Low **(VL)**	Rare (Few Times Per Year)	**1**
Low **(L)**	Unusual (Once Per Month)	**2**
Moderate **(M)**	Occasional (Once Per Week)	**3**
Probable **(P)**	Frequent (Daily)	**6**
Highly Probable **(HP)**	Continuous	**10**

Consequences - Each event may have a number of possible consequences as a result of the event in terms of an impact on operations of the TMA, for example, an injury or fatality or the cost of an environmental clean-up. The environmental impact has been combined with the overall economic consequence of a particular event. The possible consequences and associated scores are given in Table 5-3.

Table 5-3 Consequence Categories

CONSEQUENCES	CATEGORY	SCORE
Minor incident or inefficiency of little or no consequence. **Operations:** No impact on operations. **Health & Safety:** Near miss or recordable first aid to multiple employees. **Environmental and Economic:** <$10k	VERY LOW **(VL)**	**3**
Minor incident or inefficiency that may require review and is easily remediated. **Operations:** Operations delay of up to two weeks **Health & Safety:** Recordable case, minor injuries to multiple employees. **Environmental and Economic:** $10,000 to $100,000	LOW **(L)**	**7**
Moderate event that may need some physical attention and certainly review. **Operations:** Operations delay of up to a few months. **Health & Safety:** Serious lost time injuries to multiple employees. **Environmental and Economic:** $100,000 to $1,000,000	MODERATE **(M)**	**15**
Significant event that can be addressed but with great effort. **Operations:** Significant delay of six months to one year. **Health & Safety:** Serious injuries to multiple employees, possible fatality to an employee. **Environmental and Economic:** $1,000,000 to $10,000,000	HIGH **(H)**	**40**
Major uncontrolled event with uncertain and perhaps prohibitively costly remediation. **Operations:** Operations delay more than one year. **Health & Safety:** Multiple fatalities. **Environmental and Economic:** > $10,000,000.	EXTREME **(E)**	**100**

The risk level can then be assessed based on the risk score as shown in Table 5-4. Three categories, **I**, **II** and **III** are used for low, moderate and high levels of risk respectively. For example, the risk level associated with a risk score of 100 would be **II** or moderate.

Table 5-4 Risk Levels

RISK LEVEL	DESCRIPTION	RISK SCORE
I	Low Level of Risk	less than 70
II	Moderate Level of Risk	70 to 200
III	High Level of Risk	greater than 200

Finally, it is necessary to identify the degree of confidence and variability for the Risk Levels as shown in Table 5-5:

Table 5-5 Confidence Levels

CONFIDENCE LEVEL	DEGREE OF CONFIDENCE	DEGREE OF VARIABILITY
Low **(L)**	Low Confidence	Could Vary Significantly
Moderate **(M)**	Moderate Confidence	Moderate Variability
High **(H)**	Confident	Low Variability

5.2 Discussion

The risk assessment focuses on the issues and consequences associated with a potential failure of a component of the TMA resulting in the release of untreated water and/or tailings to the downstream environment. It must be recognized that this evaluation is based on the current condition and operation of the TMA and does not take into account any alterations to the method of operation or major modifications to structures to accommodate future tailings disposal. The consequences of such events include but may not be limited to environmental damage, property damage, injury or loss of life. The following sections provide a brief description of the pertinent structures which form the TMA and some of the potential events and resulting impacts that could occur in the event of slope instabilities and or overtopping (breach).

Tailings Dam

The tailings dam contains all of the contaminated mine tailings and pond water. Over the years, a number of repairs and modifications to the dam have been completed including the construction of a stabilizing toe berm, repairs to the south abutment and the construction (and repair) of an emergency spillway. A failure of the tailings dam possibly associated with seismic activity, internal erosion, or an overtopping event triggered by a failure of the emergency spillway would result in uncontrolled release of some portion of the tailings and pond water into the Dome Creek valley.

Seepage Dyke

The seepage dyke contains seepage water from the tailings dam and groundwater prior to direct discharge into Dome Creek by pumping over the dyke. There is no engineered spillway on the seepage dyke and if overtopped, it may breach. The necessity for the dyke in the overall operation of the TMA might be questioned since treatment of seepage pond water is no longer required (at least at this point in time). The dyke does however provide some control over the release of water in the event that discharge limits are exceeded in the future. A failure of the dyke at the present time would have minimal environmental consequence.

Interceptor Ditch

Failure of the interceptor ditch would likely involve a blockage from ice, sediment, or slumped bank material. Such an event could lead to rerouting creek and surface run-off from the west directly into the tailings pond. From a risk management perspective, the tailings dam spillway capacity must be sufficient to pass this flow should such an event occur. The contribution of flow from the interceptor ditch in terms of total flow in the Dome Creek Diversion Channel was estimated to be in the order of 25 percent, at the time of our inspection. Since the catchment area upstream of the interceptor ditch does not include Dome Creek, peak flows after heavy precipitation would more likely be of high intensity but of short duration (as compared with the diversion channel). Overall the interceptor ditch is functional although the banks are over-steepened in some cases and the channel width varies considerably. The channel bed and banks are poorly armoured. Erosion of sandy bank material is an ongoing concern with respect to loss of hydraulic capacity and subsequent maintenance work to remove the sediment load.

Dome Creek Diversion Channel

Failure of the diversion channel upstream of the emergency spillway would also likely involve a bank failure/channel blockage, possibly leading to a rerouting the combined flow of the interceptor ditch and Dome Creek into the tailings pond. From a risk management perspective, it is essential that the tailings dam spillway capacity be sufficient to safely pass this flow should such an event occur. Providing the inflow occurred when pond levels are low, the reservoir would help attenuate such an event. The worst case scenario would be an occurrence of high pond levels at the time of a breach of the diversion channel.

Previous evaluations have raised the concern that the material lining the channel and rock drop structures downstream of the spillway is insufficient for flows above what would be expected for the 20 year return period (EBA, 2002). Such a failure is most likely to occur in the stretch downstream of drop Structure 6 where armouring of the banks is sparse. It is anticipated that the damage associated with such an event could be repaired before any of the other TMA structures are compromised.

5.3 Risk Assessment Score

For each of the structures which form the TMA, a risk score has been calculated and is presented in Table 5-6. The risk score has been evaluated for failures that could result in the release of untreated water and/or tailings. The risk score is the matrix (product) of the likelihood of the event occurring, the exposure to the event occurring and consequences that may result from the event occurring.

Table 5-6 Risk Assessment Score

Structure	Likelihood	Exposure	Consequences	Risk Score	Risk Level	Confidence Level
Tailings Dam	3	1	40	120	II	Moderate
Seepage Dyke	1	1	7	7	I	Moderate
Interceptor Ditch	3	2	7	42	I	Moderate
Diversion Channel U/S of Tailings Pond Spillway	6	2	15*	180	II	Moderate
Diversion Channel D/S of Tailings Pond Spillway	6	1	7	42	I	Moderate

* Assumes worst case scenario where flow into the tailings pond exceeds the capacity of the emergency spillway.

6. Care and Maintenance (Status Quo)

General care and maintenance of the Mount Nansen TMA currently consists of year round discharge of water from the seepage pond into Dome Creek, excavation of sediment in the interceptor and diversion ditches around the tailings pond, instrumentation monitoring and general inspection and maintenance work of the TMA structures. The annual costs to maintain this status quo management practice are orders of magnitude less than those associated with mine closure options. These costs however, will carry forward into the foreseeable future and must be weighed against the one time capital costs for closure. It must also be recognized that the current care and maintenance costs are largely dependent on maintaining low levels of water quality elements such as arsenic that allow seepage water to be directly discharged without treatment. The potential environmental liability associated with the status quo option however, should consider the potential for future increases in concentrations of elements (and perhaps future decreased pH) in seepage water and/or more restrictive discharge limits that could trigger the requirement for water treatment.

The risk assessment identifies the need for maintenance or repairs to bring the physical condition of TMA structures up to an acceptable standard associated with the defined risk level. In this regard, there are likely to be capital expenditures that are not presently carried in current annual budgets for care and maintenance at the Mount Nansen Site. It may however be possible to stage some of these measures depending on their assigned priority (from a risk perspective) and available funding.

6.1 Physical Condition Considerations

The tailings dam has a risk score that falls within Risk Level II, primarily as a result of the consequences of a failure. The Dome Creek diversion channel also falls within a Risk Level II, primarily as a result of a breach that would potentially divert peak flows into the tailings pond leading to the failure of the emergency spillway and possible breach of the tailings dam. All other structures fall within a Risk Level I. The following guidelines for follow-up work are provided for the three levels associated with the risk assessment:

Risk Level I

- Upgrade deficiencies.
- Conduct an annual condition assessment.

Risk Level II

- Implement a comprehensive monitoring program.
- Prepare an Emergency Preparedness Plan (EPP).
- Develop an action plan for remedial works.
- Consider Implementation of remedial works to reduce risk.

Risk Level III

- Immediate action should take place to reduce/control risk.

Given that no structures have been assigned scores that would place them at a Risk Level of III, immediate action is not considered necessary. However, two components of the TMA have scores that fall within Risk Level II. Accordingly, it is recommended that a monitoring program be implemented for the tailings dam and Dome Creek diversion ditch. The program should consist of an annual condition assessment but include monthly monitoring during the spring, summer and fall by Mine Site staff. The monthly checks would act as an early warning system in the event that distress is identified at any of the TMA structures.

An Emergency Response Plan (ERP) should be prepared to identify the appropriate course of action should events occur that might lead to or be the direct cause of significant environmental consequence, loss of property or personal injury or death. This ERP should include but not be limited to actions that the dam owner should take in response to an unusual or emergency condition.

The 2002 Dam Safety Assessment completed by EBA identified deficiencies of the dam in its current (2002) state and provided recommendations for maintenance, surveillance and upgrading for the next 5 years (2002 – 2007). These should continue and in addition, the following recommendations should be considered if all of the components of the TMA are expected to operate in a similar (status quo) fashion for the long term:

- Classify the tailings dam following the Canadian Dam Safety Guidelines (2007) and identify appropriate improvements.
- Evaluate the need for the seepage dyke and construct an emergency spillway if the dyke remains operational.
- Evaluate condition and extent of armouring on upstream dam slopes and add material where necessary.
- Cut saplings on upstream and downstream dam slopes and emergency spillway.
- Fill low areas (below design crest elevation) on the tailings dam as required.
- Review hydraulic capacity and stability of the interceptor ditch and Dome Creek diversion channel. Continue with regular maintenance (sediment excavation) or reconstruct and armour as required.

6.2 Environmental Considerations

It is important to recognize that the measures recommended to improve the physical condition of the dam are not intended to reduce the environmental liability associated with continued seepage of tailings pond water. A geochemical study completed in 2002 also concluded that the tailings are potentially acid-generating, even with sulfide-sulfur contents not exceeding 4 wt%, (Kwong et al., 2002). Based on the available information, it is reasonable to assume that the water originating from the tailings area percolates through or beneath the existing tailings dam and ends up in part or in whole in the seepage pond. Measured concentrations of tailings porewater parameters of concern are highly variable ranging from 0.041 to 22.9 mg/L (arsenic), <0.030 to 36.6 mg/L (iron), 0.001 to 7.57 mg/L (copper) and <10 to 1750 mg/L (sulfates), (Lorax Environmental, 2008).

The concentrations in the seepage pond currently are acceptable for direct discharge, having met the discharge license limits in Table 6-1. However, any change in the current operation of the TMA, or the development of a closure plan may be subject to more stringent water quality guidelines.

Table 6-1 Discharge Limits

Parameter	License Limit (mg/L unless otherwise noted)
pH	6.0 – 8.5
Suspended Solids	50
Toxicity (LC50)	100 %
WAD Cyanide	0.1
Total Cyanide	0.3
Antimony (total)	0.15
Arsenic (dissolved)	0.15
Barium (total)	1.0
Cadmium (total)	0.02
Chromium (total)	0.04
Copper (total)	0.2
Iron (total)	1.0
Lead	0.1
Manganese	0.5
Mercury	5.0 micrograms/L
Nickel (total)	0.3
Silver	0.1
Zinc	0.3

There are several factors (other than dilution) that may explain the low contaminant concentrations in the seepage pond. The results of a study completed on the native sediment underlying the impoundment area (Lorax Environmental, 2008) show that the sediment appears to have some inherent acid buffering capacity, which would reduce the concentrations of contaminants breaking through to the downstream side of the tailings dam. In addition, the process waters at this site were initially basic resulting from cyanidation and lime addition (Kwong, 2002). The addition of lime in the system produces a basic environment, and consequently produces buffering reactions in the area.

At the Mt. Nansen site, the basic environment seems to be controlling the concentration of dissolved metals in the groundwater at low levels, from the tailings area to the seepage pond. Additionally, the conceptual model of tailings pond water balance presented by Gartner Lee Limited (2006) indicates that part of the water contributing to the formation of the seepage pond originates as natural aquifers not impacted by the tailings area. This may promote the dissolution of seepage waters from the tailings area, resulting in waters with low concentration of metals and buffered pH, consequently suitable for direct discharge (current operating condition).

It is anticipated that there is a time dependent behaviour of the contamination from the tailings area towards the seepage pond which is expected to influence the long-term seepage water quality. Due to an initial (current) basic environment, the transport of the contaminants through diffusion has possibly been significantly reduced (in terms of velocity). However, as the tailings release contamination during a long period of time, the concentration could eventually reach the point of compliance i.e. the buffering capacity is limited. High concentrations of some metals and cyanide may therefore be occurring at some location between the point of release (upstream side of tailings dam) and the point of compliance (seepage pond), traveling at an unknown velocity. The buffering capacity of the soil, groundwater and lime is limited and is likely to become exhausted at some point. Such an event will promote increased oxidation rates of the tailings and the eventual breakthrough of the contamination at the seepage pond. This hypothetical event, shown schematically in Figure 49, can only be verified by the installation and sampling of groundwater monitoring wells across the tailings dam.

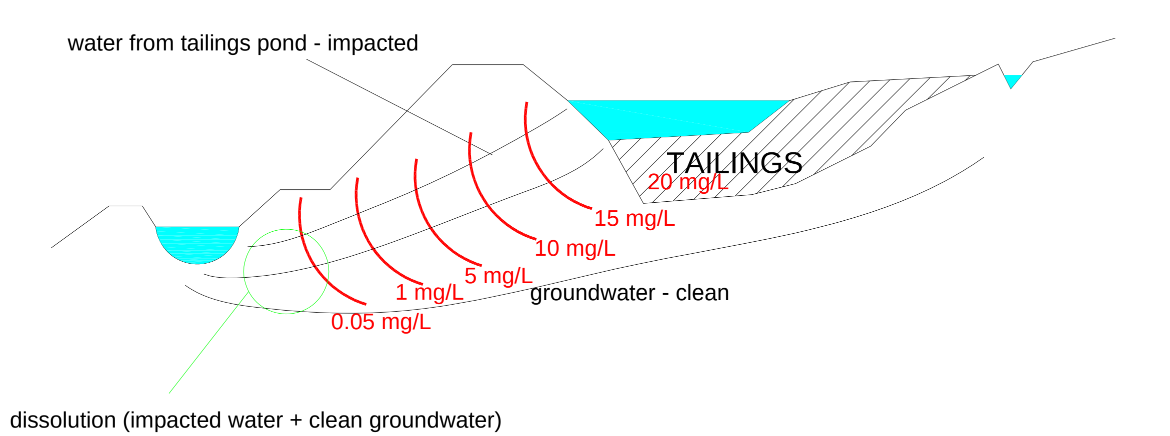

Figure 49 Hypothetical Contamination Concentrations

In summary, the following five scenarios (in no particular order) are presented with respect to the possible contamination transport mechanisms:

1. Contamination is propagating towards the seepage pond and the peak concentration is somewhere between the tailings and the seepage pond.
2. The peak concentration of contamination has already reached the seepage pond, but groundwater dilution is very high.
3. There is a preferred pathway for the majority contaminants around the pond and only a fraction of the contamination mixes with groundwater in the seepage pond.
4. The contamination has been largely immobilized in the tailings pond.
5. The majority of contamination from the tailings pond is downward into an underlying aquifer that does not report to the seepage pond.

7. Closure Options

7.1 Overview

Three conceptual closure options have been considered in this report:

1) Upgrade the existing TMA structures in accordance with the 2007 CDA Guideline and include a permanent long term closure plan for the tailings (soil cover);

2) Dispose of tailings in the open pit and breach the existing dams to restore Dome Creek valley; and

3) Excavate and redistribute a sufficient volume of tailings to allow the tailings dam to be breached and the Dome Creek valley restored.

Given the observation that the tailings are basic to this point in time, a water cover over the tailings has not been considered. It is also considered likely that the introduction of a water cover would exacerbate the mobilization of arsenic and increase seepage through the dam. Class C cost estimates have been provided for each of the concepts recognizing the limited information available. Where possible, we have estimated quantities for earthworks, liners, etc. The cost estimates are intended to assist in making policy decisions with respect to future capital expenditures. Additional field investigations and surveys will be required to advance any of these options to detailed design.

7.2 Option 1: Upgrade Existing TMA Facilities

This option involves upgrading the existing TMA structures to the accepted standard following the 2007 CDA Dam Safety Guidelines and placing an engineered cover over the tailings. A conceptual plan showing the major work components is shown on Drawing 05. Based on the dam classification, the facilities would be upgraded to withstand extreme surface water flows and seismic events. For the purpose of this study and to aid with cost estimating, the tailings dam classification has been set as high (2007 CDA) which is consistent with the high to very high classification used in EBA's Dam Safety Assessment (EBA, 2002).

7.2.1 Interceptor Ditch and Diversion Channel

Selected peak flow events for the 2002 Dam Safety Assessment were 1:20 and 1:200 year maximum instantaneous peak flows (IPF); which resulted in design flows of 1.2 and 3.7 m^3/s respectively (EBA, 2002). These returns periods were selected by the Regulating Authority at the time of the assessment based on a 5 year timeline to implement remedial repair works. It is our understanding the earlier studies by Klohn Crippen suggested that a flow of 6.4 m^3/sec should be assigned to the 1:20 year peak (EBA, 2002). For the purposes of the AECOM assessment of closure options, a conservative peak design flow of 10 m^3/sec has been used until such time as the design peak flows have been confirmed. The following criteria were considered for a conceptual channel design upstream of the emergency spillway:

- Minimum grade of 0.5% in diversion channel upstream of emergency spillway.
- Maximum flow depth of 1 m;
- Minimum freeboard depth of 1 m;
- Flow channel base width of 3 m; and side slopes of 3H:1V.

The resulting channel velocity for the design section under peak flow is about 3 m/s which would erode both the channel bottom and sideslopes in an unprotected channel. Channel erosion protection is therefore a requirement. Widening the diversion channel to the design geometry will require partial excavation of the adjacent access road (Drawings 06 and 07). In these circumstances the access road can be shifted towards the tailings pond. The road should be a minimum of 6 m wide with downstream sideslopes of 3H:1V. The road top should be graded away from the tailings pond and topped with traffic gravel. Exposed soil on both banks above the necessary armouring for channel flows should be revegetated.

The diversion channel downstream of the emergency spillway appears to be closer to the design cross section of the upstream stretch and it should therefore be possible to maintain a flow depth of approximately 1 m or less. Based on the observations from our inspection, additional armouring and upgrading of some of the drop structures should be considered, in particular downstream of Drop Structure 6. A more detailed hydraulic analysis, beyond the scope of this investigation, is required to determine if the drop structures are sufficient to achieve velocities in the steeper channel section that are acceptable for the size and thickness of bedding and bank armouring material. In lieu of this information, an allowance has been carried in our cost estimate for upgrading this section of the diversion channel. An allowance has also been carried to upgrade or replace the existing timber bridge.

Table 7-1 presents the estimated quantities and costs to upgrade the interceptor ditch and diversion channel.

Table 7-1 Interceptor Ditch and Diversion Channel Quantities and Costs

Description	Unit	Approximate Quantity	Unit Price	Amount
Mobilization & Demobilization	Allowance	1		$100,000
Interceptor Ditch and Diversion Channel U/S of Emergency Spillway				
Excavation	Cubic Metre	15,000	$10	$150,000
Geotextile	Square Metre	18,000	$5	$90,000
Armouring	Cubic Metre	5,000	$35*	$175,000
Road Construction – Fill	Cubic Metre	4,000	$10	$40,000
Road Construction - Gravel	Cubic Metre	1,500	$50*	$75,000
Bridge Upgrading/Replacement	Allowance	1		$500,000
Diversion Channel D/S of Emergency Spillway	Allowance	1		$500,000
Subtotal				$1,630,000
30% Contingency				$489,000
Total Estimated Cost				**$2,119,000**

*Note: Assume contractor will be able to crush and use existing waste rock.

7.2.2 Tailings Dam

To determine the necessary upgrades to the tailings dam, AECOM completed a review of information presented in previous reports supplemented with the results of the 2008 surveys and instrumentation monitoring. In particular, we have further considered the implications of seismic loading on the dam and the feasibility of upgrading options that could raise the factor of safety under various loading cases such as seismic events to acceptable levels. The capacity of the spillway and any necessary upgrades to pass the maximum design flood was also evaluated. For final design, the targets for improvement in stability and spillway capacity should be based in principle on the 2007 CDA Guidelines for the appropriate consequence classification.

Piezometric levels about 5 m (high) and 10 m (typical) below the dam crest were assumed for previous analysis. A review of piezometer monitoring data from 2008 (supplied by the Government of Yukon) indicates piezometric levels are currently lower than the typical values previously assumed. This is primarily a result of lower pond levels in 2008. Previous analyses adopted a peak (horizontal) ground acceleration (PGA) of 0.27g representing a predicted return period of 1:10,000. Based on the 2007 CDA Guidelines for high consequence dams, it may be acceptable to use a PGA of 0.11g associated with a return period of 1:2,500 in evaluating the need for and designing dam upgrading measures.

Based on the results of previous slope stability analysis and our experience, we would concur that the dam does not meet the design objectives identified in the 2007 CDA Dam Safety Guidelines for pseudo-static (min FS=1) and post earthquake conditions (min FS=1.2). In order to increase the theoretical FS to achieve the design objectives under earthquake loading, upgrading of the dam would be required. After considering viable options or combinations of options, we have concluded that a toe berm in conjunction with ground improvement techniques would be required to stabilize the dam under post-earthquake conditions. Ground improvement techniques would replace or modify the liquefiable soil using compaction grouting, permeation grouting, jet grouting or in situ soil mixing. Another possible approach could be ground freezing although this may be difficult to achieve under the active seepage conditions below the dam. This stabilization concept is shown on Drawing 05.

The estimated quantities and cost associated with upgrading the tailings dam are summarized in Table 7-4.

Table 7- 4 Tailings Dam Upgrading Quantities and Costs

Description	Unit	Approximate Quantity	Unit Price	Amount
Mobilization & Demobilization	Allowance	1		$100,000
Toe Berm	Cubic Metre	10,000	$35*	$350,000
Drainage Blanket	Allowance	1		$100,000
Ground Improvement	Allowance	1		$2,000,000
Subtotal				$2,550,000
30% Contingency				$765,000
Total Estimated Cost				**$3,315,000**

*Note: Assume contractor will be able to crush and use existing waste rock.

7.2.3 Tailings Dam Spillway Assessment

The current spillway flow capacity is believed to range between 0.6 and 1.2 m^3/s (EBA, 2002). At this capacity, the channel is only adequate to handle flows up to the 20 year return storm and its capacity should be increased as part of the overall TMA upgrading plan. The capacity of the spillway should be designed based on the dam classification under the 2007 CDA Guidelines. For the purpose of conceptual design, the capacity was based on the same flow rates assumed for the diversion channel (10 m^3/sec) although the base of the channel was arbitrarily increased to 4 m to account for the potential selection of a higher return period in final design (Drawing 08). The estimated quantities and costs to upgrade the spillway are summarized in Table 7-5.

Table 7- 5 Emergency Spillway Upgrading Quantities and Costs

Description	Unit	Approximate Quantity	Unit Price	Amount
Mobilization & Demobilization	Allowance	1		$20,000
Spillway - Excavation	Cubic Metre	2,000	$10	$20,000
Spillway - Geotextile	Square Metre	3,000	$10	$30,000
Spillway - Armouring	Cubic Metre	1,000	$50*	$50,000
Southside Berm – Fill	Cubic Metre	500	$10	$5,000
Southside Berm – Erosion Protection	Allowance			$15,000
Subtotal				$140,000
30% Contingency				$42,000
Total Estimated Cost				**$182,000**

*Note: Assume contractor will be able to crush and use existing waste rock.

7.2.4 Seepage Dyke

Although there does not appear to be any stability concerns with respect to the seepage dyke under current operating conditions, the construction of a spillway is recommended. A spillway located over the existing dam as shown on Drawing 05 would eliminate the need to pump water over the dam into the discharge sump. Based on the current operation of the TMA, there does not appear to be any need to upgrade this dyke to meet seismic loading conditions. If seismic upgrading is considered necessary, a plausible approach given the height of the dyke would be to flatten the slopes as required.

The estimated quantities and cost to upgrade the seepage dyke are summarized in table 7-6.

Table 7- 6 Seepage Dyke Upgrading Quantities and Costs

Description	Unit	Approximate Quantity	Unit Price	Amount
Mobilization & Demobilization	Allowance	1		$25,000
Fill For Slope Flattening	Cubic Metre	2,500	$20	$50,000
Spillway	Allowance	1		$50,000
Subtotal				$125,000
30% Contingency				$38,000
Total Estimated Cost				**$163,000**

*Note: Assume contractor will be able to crush and use existing waste rock.

7.2.5 Tailings Soil Cover

Even in the case of non-acid generating tailings, the presence of water can dissolve and mobilize some metals (e.g. arsenic) and minerals. At the Mount Nansen TMA, the contribution of the surface water in the migration of contaminants such as arsenic is not well understood; however, a soil cover could limit the volume of surface water that would potentially become contaminated. This would lead to a reduction in the dilution rate of contaminants (such as arsenic, zinc) in the water and decrease the potential for the tailings to generate acidic water (if the current buffering capacity was reduced). In terms of site restoration, a cover would allow for the establishment of a vegetated cover which would further reduce the chances of acid mine drainage. Placement of a cover will not eliminate, but only reduce the reactions that generate contamination. According to the literature, most of the reactions associated with surficial water are reduced by 70 to 90%, meaning 10 to 30% of reactions will continue to generate contamination.

In the case of the Mount Nansen TMA, the effectiveness of a soil cover must consider the contaminated tailings water and clean groundwater in the seepage pond. It is possible that the groundwater contribution is large enough to significantly dilute concentrations of metals in the seepage water leaving the tailings pond. If this is the case, reductions in the concentration of metals (for example) in the tailings water would lead to only small changes in the current quality of the water at the seepage pond.

Based on AECOM's experience at other tailings facilities, a one metre thick soil cover over the tailings areas (depending on the hydraulic and geologic condition of the site) is generally sufficient in reducing the oxidation of the tailings. It is reasonable to assume that suitable (sand) material is available a short distance from the TMA. The final thickness of the soil cover however, must be determined based on the infiltration rates of the soil cover material and the contribution of surface water in the system. The vegetation mat also helps reduce diffusion of oxygen and infiltration of water through the cover. A concept for surface water management on the cover is illustrated on Drawing 05. The final surface of the tailings would be graded to provide drainage paths or swales that would likely be lined with a seepage barrier such as a geosynthetic clay liner (GCL) and coarse armouring material (gravel).

The estimated quantities and costs for the tailings cover are summarized in Table 7-6.

Table 7- 6 Tailings Cover Quantities and Costs

Description	Unit	Approximate Quantity	Unit Price	Amount
Mobilization & Demobilization	Allowance	1		$100,000
Grade Tailings	Square Metre	85,000	$5	$425,000
Drainage Swales - Geotextile and Liner	Square Metre	15,000	$15	$225,000
Drainage Swales- Armouring	Cubic Metre	15,000	$40*	$600,000
Place and Compact Cover	Cubic Metre	70,000	$10	$700,000
Vegetate Cover	Square Metre	70,000	$3	$210,000
Subtotal				$2,260,000
30% Contingency				$678,000
Total Estimated Cost				**$2,938,000**

*Note: Assume contractor will be able to crush and use existing waste rock.

7.2.6 Inspection and Maintenance Costs

An allowance will also be required for long term monitoring and maintenance of completed works. In this regard, we recommend that an **annual allowance of $500,000** be carried for each of the first five years after construction is complete (total $2.5 million). This would be sufficient for monitoring and inspection at least twice a year and minor repairs to the completed works. If good performance of the structures is confirmed after the first five years, it is anticipated that the frequency of inspections and requirement for maintenance could be significantly reduced. For long term budgeting, **an annual allowance of say $100,000** is recommended for monitoring and inspection. This allowance should be sufficient to maintain and replace instrumentation if required. It may be prudent to recognize funding necessary for long term routine maintenance (brush clearing in spillway, etc.) say approximately every five years. In this regard, **an annual allowance of $50,000** should be considered.

7.2.7 Summary

The estimated construction component costs to upgrade the TMA are summarized in Table 7-7. The total estimated cost is approximately $9,000,000, excluding the cost of additional field investigations, engineering design, Contract Administration and annual inspections and maintenance.

Table 7-7 Construction Cost Summary – TMA Upgrading

Description	Estimated Construction Cost
Interceptor Ditch and Diversion Channel	$2,119,000
Tailings Dam	$3,315,000
Emergency Spillway	$182,000
Seepage Dyke Spillway	$163,000
Soil Cover	$2,938,000
Total Estimated Cost	**$8,717,000**

The implementation of this option at the Mount Nansen TMA requires the investigation of the current conditions of the site with regards to the groundwater and flow of contaminants towards the seepage pond. This would require installing monitoring wells between the tailings dam and the seepage pond, as well as downstream areas.

7.3 Option 2 – Open Pit Disposal

It has been estimated that there are approximately 283,500 m^3 of tailings upstream of the dam. These tailings could be relocated to the open pit using either conventional earth moving techniques (trucks, dozer, excavators, etc.) or they could be hydraulically moved back to the pit (similar to how they were deposited into the tailings pond). However, since arsenic can be easily remobilized into solution when water is introduced (required for the slurry process) hydraulic placement may not be advisable. It is assumed that removal and treatment of water in the tailings pond will be required prior to discharge and that a cover of clean soil or waste rock would be placed on the tailings deposited in the open pit.

Tailings could be hauled and disposed in the open pit either as sludge or in as dry a state as possible (drained). In terms of environmental impact, disposal in the form of sludge would relocate not only the solids, but also most of the contaminated tailings porewater. The discharge of the tailings as sludge in the pit lake would generate the immediate dissolution of some metals, due to agitation and turbulence. The main concern would be the mobilization of arsenic that would potentially be released to the pit lake and underlying soil/basal layer. If the tailings are transported as dry as possible, the impact would be reduced.

The ability to dewater the tailings will largely depend on the physical properties of the tailings, most notably grain size and permeability. While it is beyond the scope of this study to evaluate such options in detail, methods to dewater the tailings would fall into categories of either gravity drainage or mechanical dewatering. The decision as to the preferred method will likely depend on the capital cost and time frame required for each method.

Gravity drainage could be accomplished by methods such as excavating tailings and creating piles in areas where drainage water could be collected for treatment. This would most likely involve excavations during the winter similar to the work recently done by the Government of Yukon. This work indicated that excavation with conventional earth moving equipment is possible if a frozen crust can be used to support equipment. The tailings would then be piled and allowed to drain. Enhancements such as internal drains within or below the piles could be considered. Another possibility is using geo-bags to contain the solids and let the pore water seep out. Geo-bags have been used to dewater lagoon sludge and also to clean recreational beach areas.

Mechanical methods might include belt presses or hydro cyclones to produce a cake for disposal. Belt presses are often used by municipalities to dewater water treatment lime sludge. It is our understanding that some mining operations are using belt presses to dewater tailings. An alternative mechanical approach would be to install prefabricated wick drains into the tailings which would then be covered with a layer of permeable gravel and sealed. A vacuum would then be applied to the system to draw porewater from the tailings along the wicks where the water could be collected within the cover layer. The tailings would then be excavated for disposal. This method however, would require that external water entering the tailings could be limited or eliminated during the porewater extraction and tailings excavation processes.

The costs of dewatering could vary significantly with the most economical likely being gravity drainage. This method however, would likely require the most significant amount of time to complete (in the order of years). While mechanical means may be more rapid, the capital costs are likely to be significantly higher than those for gravity drainage options. For the purposes of economic comparisons, we have assumed allowances of $1,500,000 and $3,000,000 for gravity and mechanical methods respectively (including an allowance for water treatment). Research into tailings properties and available technologies would be required to determine more accurate cost estimates.

Once the tailings have been placed, the water table will once again become established, likely at or possibly higher than the current pit lake elevation. Depending on the final elevation of the tailings this will lead to either complete or partial saturation of the tailings. Redirection surface water once it enters the pit e.g. precipitation will not be feasible without pumping. Although the mobilization of arsenic is more likely occur within submerged tailings, it may also be problematic as water leaches through exposed tailings in particular if the water table fluctuates. There may be more advantages with keeping the tailings completely water covered and this would have to be taken into consideration when investigating placement methods and costs.

The feasibility of draining porewater from the tailings has not been investigated although the tailings piled up at the north and south abutments appear well drained. This may in large part be due to the sandy nature of the tailings in the piles. Excavation of the tailings and stockpiling the material was done in the winter, an operation that demonstrated the feasibility of mechanically moving the tailings. Excavation and draining of the finer grained tailings may be problematic and treatment of the extracted porewater from the tailings may be required.

The footprint of the former tailings will require restoration (including breaching the tailings dam and seepage dyke) that might include the remediation of impacted soil and groundwater. Without further investigation however, it is not possible to determine the level of contamination or the required treatment and as such only an allowance can be carried at this time for cost estimating. The estimated quantities and costs for the tailings cover are summarized in Table 7-8.

Table 7- 8 Open Pit Disposal Quantities and Costs

Description	Unit	Approximate Quantity	Unit Price	Amount
Mobilization & Demobilization	Allowance	1		$100,000
De-water Open Pit and Treat Water	Allowance	1		$1,000,000
De-water Tailings (assume mechanical dewatering) and Treat Surface & Pore Water	Allowance	1		$3,000,000
Excavate, Pace and Compact Tailings in Open Pit (assume 1.5 km haul distance)	Cubic Metre	283,500	$10	$2,835,000
Soil or Waste Rock Cover	Cubic Metre	50,000	$10	$500,000
Breach Tailings Dam and Restore TMA	Allowance	1		$1,500,000
Subtotal				$8,935,000
30% Contingency				$2,681,000
Total Estimated Cost				**$11,616,000**

7.4 Option 3 – Creek Valley Restoration

Creek valley restoration would involve the re-establishment of the Dome Creek along its former alignment through the tailings pond as shown in concept on Drawings 09 and 10. This option would involve the partial removal of tailings from within the tailings pond and relocating the excavated portion immediately downstream on the north side of the valley. Both the tailings dam and seepage dyke would also be breached. The tailings would be excavated at 5H:1V or flatter slope to maintain stability and allow the placement of a soil cover. The relocated tailings would also be placed at a 5H:1V slope, compacted, covered and revegetated. To maintain stability, benches would be incorporated and the finished slope would be graded towards the valley.

More detailed assessments on the impact of this option on the environment and permafrost would be required. As with the open pit disposal option, restoration and/or remediation of the footprint would be required, although over a smaller area. This would be offset however, by the requirement for additional undisturbed land for tailings placement. Porewater contained within the tailings would likely have to be collected and treated prior to placement. The mobilization of elements such as arsenic may be a chronic problem if water permeates through the tailings. More detailed investigations, thermal analysis and slope stability analysis would be required before the feasibility of this option could be evaluated further. One important consideration would be the potential liquefaction of the tailings under seismic loading and possible valley blockages from resulting instabilities.

The estimated quantities and costs for the tailings cover are summarized in Table 7-9.

Table 7- 9 Valley Restoration Quantities and Costs

Description	Unit	Approximate Quantity	Unit Price	Amount
Mobilization & Demobilization	Allowance	1		$100,000
Clearing and Grubbing	Square Metre	55,000	$5	$275,000
De-water Tailings and Treat Surface & Pore Water (assume mechanical dewatering)	Allowance	1		$3,000,000
Excavate, Place and Compact Tailings in the Valley	Cubic Metre	200,000	$10	$2,000,000
Soil Cover	Cubic Metre	100,000	$10	$1,000,000
Vegetate Cover	Square Metre	100,000	$3	$300,000
Breach Tailings Dam and Restore TMA	Allowance	1		$1,000,000
Subtotal				$7,675,000
30% Contingency				$2,303,000
Total Estimated Cost				**$9,978,000**

8. Conclusions and Recommendations

The overall condition of the tailings dam and seepage dyke at the time of our inspection was considered to be good. There do not appear to be any significant deformations of either structure that would indicate active instabilities. Seepage water at the toe of the rock fill at the edge of the seepage pond appears clean but it is important to recognize that this condition could worsen with increased water elevations in the tailings pond. Internal erosion of the earth fill dam associated with the toe seepage cannot be ruled out. Settlement of the south half of the tailings dam crest, as evidenced by surveys of monitoring pins and the centerline profile is of some concern and the cause should be investigated further, in particular to determine if it is associated with the observed toe seepage. Consideration should be given to restoring the design crest elevation in this area. The emergency spillway is in good condition although the constriction from widening the road approaching the south side of the bridge should be removed to restore full design hydraulic capacity.

The interceptor ditch and diversion channel are functioning although the banks upstream of the emergency spillway are typically over-steepened with active erosion and sloughing. Blockages associated with failures of the channel banks could lead to breaching of the adjacent road that separates the channels from the tailings pond. Excavation of sediment along flatter grades will continue to be required on an on-going basis until channel stabilization measures are undertaken. The diversion channel downstream of the emergency spillway is in good condition although some additional bank armouring and repairs to the drop structures should be considered in the downstream half of this portion of the channel.

The annual costs of continued care and maintenance are less than those associated with mine closure options. These costs however, will carry forward into the foreseeable future and must be weighed against the one time capital cost for closure. It must also be recognized that the current care and maintenance costs are largely dependent on the discharge limits under the current license that allow seepage water to be directly discharged without treatment. The potential environmental liability associated with the status quo option should however, consider the potential for future increases in concentrations of elements (such as arsenic) in seepage water or more restrictive discharge limits that could trigger the requirement for water treatment.

The 2002 Dam Safety Assessment completed by EBA identified deficiencies of the dam in its current (2002) state and provided recommendations for maintenance, surveillance and upgrading for the next 5 years (2002 – 2007). These should continue and in addition, the following recommendations should be considered if all of the components of the TMA are expected to operate in a similar (status quo) fashion for the long term:

- Classify the tailings dam following the Canadian Dam Safety Guidelines (2007) and identify appropriate improvements.
- Evaluate the need for the seepage dyke and construct an emergency spillway if the dyke remains operational.
- Evaluate condition and extent of armouring on upstream dam slopes and add material where necessary.

- Cut saplings on upstream and downstream dam slopes and emergency spillway.
- Fill low areas (below design crest elevation) on the tailings dam as required.
- Review hydraulic capacity and stability of the interceptor ditch and Dome Creek diversion channel. Continue with regular maintenance (sediment excavation) or reconstruct and armour as required.

The continued care and maintenance of the tailings management area at the abandoned Mount Nansen Mine Site is required until long term closure solutions are implemented. In comparison with long term care and maintenance, a mine site closure plan is a sustainable development strategy well worth considering. Considering the annual costs for care and maintenance, the Mount Nansen TMA could be an ideal candidate for a long term closure solution, perhaps as part of a closure plan for the entire mine site.

Three conceptual closure options considered in this report are:

1) Upgrade the existing TMA structures in accordance with the 2007 CDA Guideline and include a permanent long term closure plan for the tailings (soil cover);
2) Dispose of tailings in the open pit and breach the existing dams to restore Dome Creek valley; and
3) Excavate and redistribute a sufficient volume of tailings to allow the tailings dam to be breached and the Dome Creek valley restored.

Upgrading the TMA consists of major upgrades to the tailings dam, seepage dyke, interceptor ditch, diversion channel and placement of an engineered soil cover. ***Construction costs for upgrading the TMA are expected to be in the order $9,000,000.*** There is however, insufficient data at this time to confirm that upgrading the TMA is a viable long term closure plan due to the lack of information with regards to the migration of the contamination towards the seepage pond. In this regard, the following actions are recommended should this option be considered:

- Carry out detailed topographic survey of the mine site.
- Install monitoring wells between the tailings area and the seepage pond to monitor the movement and concentration of metals, cyanide and sulfates towards the seepage pond. This investigation should be expanded to also investigate the contribution of groundwater.
- Carry out additional investigations as to the nature of settlement of the tailings dam south abutment.
- Carry out additional field investigations to assess the permafrost and foundation soils in the vicinity of the tailings dam to determine appropriate ground improvement techniques.
- Carry out a hydro-geological/geochemical assessment of the tailings pond area to determine the groundwater flow regime and chemistry.

Open pit disposal and partial excavation of the tailings (valley restoration) have also been considered. These two options have in common, the ability to restore the Dome Creek valley by breaching the tailings dam and seepage dyke. In this regard, the following actions are recommended should this option be considered:

- Carry out assessment of possible geochemical implications associated with open pit disposal method.
- Carry out assessment of disposal methods in particular options for drying the tailings prior to disposal or relocation.
- Carry out an assessment of treatment options for extracted pore water.
- Determine the benefits of submerging the tailings after disposal in the open pit.
- Determine the environmental impacts and remediation alternatives/costs for restoring the ground beneath the tailings for both options.

Construction costs associated with open pit disposal and partial excavation and relocation of the tailings immediately downstream of the tailings pond are each estimated to be in the order of $12,000,000 and $10,000,000 respectively.

9. Closure

The findings and recommendations of this report are based on a review of the available information and the results of the 2008 inspection by AECOM. Interpretation and analysis of this information has been intended for the sole purpose of assessing stability for the dams and diversion channels within the TMA in order to determine risk. This approach is an engineering reliability technique to systematically identify, characterize and screen risks that derive from the failure to operate as intended.

This review has been based on current operating conditions for the Mount Nansen TMA. Should a revised operation plan for the TMA be considered, the risk assessment should be updated, beginning with any necessary reclassification of the structures. AECOM trusts that this information has been of value to the Government of Yukon. Should you have any questions regarding this report, please contact Mr. Ken Skaftfeld, P.Eng.

Appendix A
Site Photographs and Video

Appendix B
Monitoring Pin Survey Results