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Written Submission from Orano Canada Inc.

Mémoire d' Orano Canada Inc.

In the matter of

À l'égard d'

Orano Canada Inc.

Orano Canada Inc.

Application to renew the McClean Lake Operating Licence for 2-year term

Demande pour le renouvellement du permis d'exploitation de McClean Lake pour une période de deux ans

Hearing in writing based on written submissions

Audience par écrit fondée sur des mémoires

September 2026

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Canada

Appendix B

Section A: Overburden Stability Analysis

Appendix H1

Overburden Stability Analysis

JEB Open Pit Mine

McClean Lake Project

COGEMA Resources Inc.

November 29, 1997

Page No.

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1.0 INTRODUCTION

This appendix provides an assessment of the stability of the overburden slopes at the JEB open pit for both short and long term slope stability. Analyses considers additional work conducted in the vicinity of JEB pit.

2.0 STRATIGRAPHY

An investigation of the drift stratigraphy in the JEB pit area was conducted as part of this study by EA. Christiansen Consulting Ltd. Quaternary deposits in the JEB pit area range in thickness from about 10 m to 30 m. The deposits, in ascending order, are designated informally as units 1, 2 and 3. Unit 1 is composed of less than 1 m to 15 m of sandy till and sand interbeds. Unit 2 is composed of less than 1 m to 15 m of silty till with a more sandy interbed in the pit area. Unit 3 is composed of less than 1 m to 20 m of sandy till and probably sandy interbeds. The drumlins in the JEB pit area appear to be composed mainly of Unit 3. The three stratigraphic units are thought to represent three separate and distinct glaciations.

A geotechnical investigation for the McClean Lake mill facilities (AGRA, 1993) drilled bore holes in the mill and pit area with numerous standard penetration tests conducted at various levels throughout the drift stratum. Standard penetration test results are summarized in Table 3.1.

3.0 STABILITY ANALYSIS

Stability analyses conducted for this study were done using SLOPE/W software by GEOSlope International Inc. for two-dimensional analysis. Analyses were conducted using the Morgenstern Price method with a half sine interslice force function.

Pit slope designs presented Section 3.3.2 of the McClean Lake Project Environmental Impact Statement, 1991 with drift slopes maintained at 27° (2 horizontal: 1 vertical) were analyzed for both short and long term stability. Short term stability was analyzed to assess stability of the drift slopes soon after excavation with piezometric conditions near the surface of the slope and long term slope stability was analyzed with piezometric conditions drawn down to the base of the drift unit. A section of the stability sections analyzed is presented in Drawing No. S765.11-H1.

The effective friction angle of the drift was estimated from standard penetration testing results (de Mello, V.F.B. (1967)). Table 3.1 provides a summary of standard penetration testing conducted in the JEB pit area and the estimated effective friction angle.

Table 3.1
Summary of Standard Penetration Testing in Mill Area (AGRA, 1993)

Depth (m)	Vertical Stress (kPa)	Average SPT No.	Effective Friction Angle*
1	20	45.2	50
2.5	50	50.0	50
4.5	90	30.2	45
5.5	110	19.0	40
7.5	150	24.8	40
8.5	170	17.3	35

* after Apud de Mello (1967)

Material properties used in the stability analyses are summarized in Table 3.2.

Table 3.2
Soil Parameters Used in Stability Analysis

	Unit Weight (kN/m^3)	Effective Cohesion (kPa)	Effective Friction Angle (_)
Drift	20	10.0	40.0
Sandstone	Impenetrable	-	-

The estimated factor of safety of the drift slope for the short term case is 1.5. For the fully softened condition with the effective cohesion equal to 0 kPa the estimated factor of safety is 1.22 in the short term. Drawing S765.11-H2 illustrates the calculated circle failure plane. The estimated factor of safety with an effective cohesion of 30 kPa is greater than 2.

The estimated factor of safety of the drift slope for the long term drained case is in excess of 2.

4.0 CONCLUSIONS

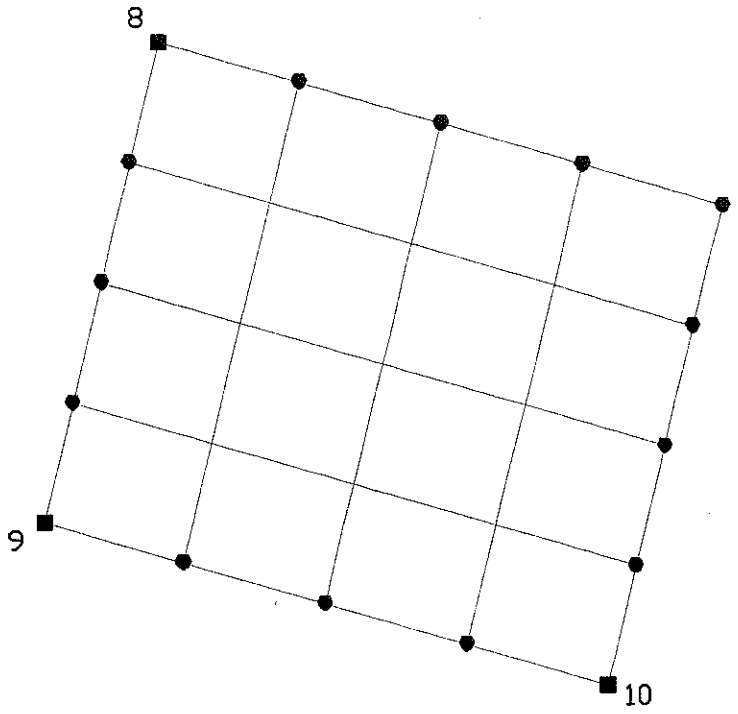
The design drift slope angles of 27° (2 horizontal:1 vertical) will be more than sufficient to meet the criteria set out in the Basis of Design report dated 24 May 1996 of 1.25 for long term slope stability of the drift portion of the pit wall.

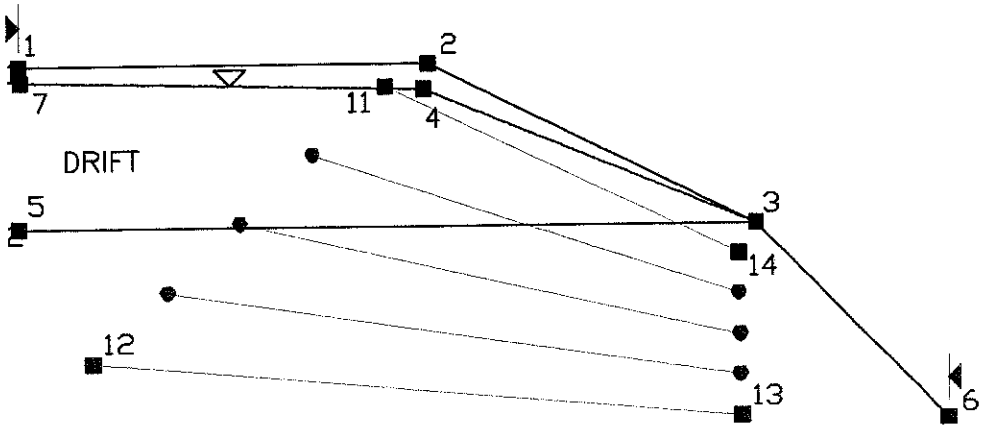
The geometry of the excavated slopes in the overburden was controlled to a substantial degree by construction conditions. The overburden was excavated in an undrained condition, resulting in limitations on trafficability and some minor deviations in overburden slope geometry. Locally, the slopes were oversteepened to 45° by sloughing and ravelling, and while slumping did occur over a short length (less than 50 m) of the highwall, the remainder of the overburden slopes are stable even at the steeper angles. The safety of the slopes is reinforced by the wide (22 m) safety berm at the top of the bedrock that will safely contain any sloughing or slumped material.

5.0 REFERENCES

HBT AGRA Limited (1993). Geotechnical Report Proposed Mill, Campsite, and Sink Lake Control Structure, McClean Lake Uranium Mine.

de Mello, V.F.B. (1967) - "Consideracoes sobre os ensaios de pentracao e sua aplicacao a problemas de fundacoes rasas', Sao Paulo University Professorship Thesis. Results published in the Fourth Pan American Conference on Soil Mechanics.





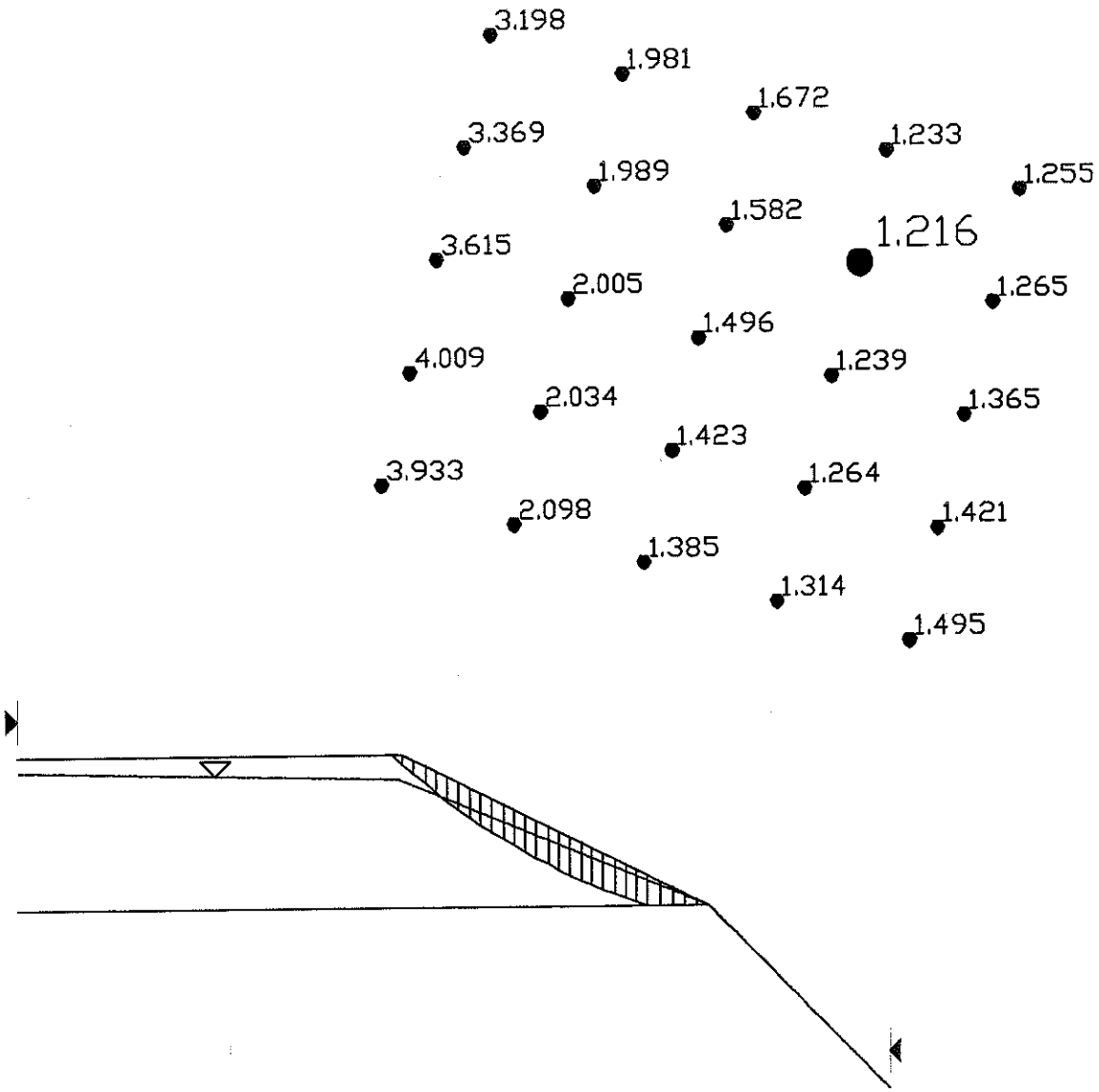
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COGEMA Resources Inc.

CLIENT: COGEMA RESOURCES INC.

PROJECT: McCLEAN LAKE PROJECT
JEB TAILINGS MANAGEMENT FACILITY

TITLE: INPUT STABILITY SECTION



DATE	DRAWN BY	APPROVED BY	SCALE	FILE NO.	DRAWING NO.
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COGEMA Resources Inc.

CLIENT: COGEMA RESOURCES INC.

PROJECT: McCLEAN LAKE PROJECT
JEB TAILINGS MANAGEMENT FACILITY

TITLE: ESTIMATED CRITICAL CIRCLE

Appendix B

Section B: JEB Tailings Management Facility Structural Mapping

McClean Lake Project

JEB Pit Tailings Management Facility
Structural Mapping
June - July 1997

November 1997 Version 1997.1

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1.0 INTRODUCTION

The JEB pit is located in the northeast part of the Athabasca basin at the boundary of two major geological domains of the Trans-Hudsonian Orogeny: the Wollaston domain to the southeast and the Mudjatik domain to the northwest. At the property scale, it is situated at the southwest tip of the Rainbow granitoid dome on the west extension of the E-W Rainbow geophysical trend. Bore holes campaigns carried out in the JEB zone showed that about 74.5m of Middle Proterozoic sandstone (Athabasca group), covered by on average 18m of glacial overburden, overlies a Lower Proterozoic basement. This basement consists of graphitic para gneisses, calcosilicate gneisses, and pegmatite. Mineralization is closely associated with graphitic units. The basement foliation dips steeply to the south.

Previous geological studies recognized three principle fault systems in the basement in the vicinity of the ore body: NE-SW, NE-SE and E-W (parallel to the foliation) steeply dipping sets. Structural mapping of the JEB Pit at the 421m level indicates the presence the same three trends of fractures in the overlying Athabasca sandstone (N40-70°, N140-160° and N80-90°). The mapping of the pit showed the absence of major structures in the sandstone and instead a uniform fractured sandstone rock mass. It also led to the reinterpretion of the hydrogeological model with four hydrostratigraphic units corresponding, from the bottom to the top, to the regolith basement, the altered sandstone, the unaltered silicified sandstone and the overburden.

Structural mapping extended to the lower benches of the sandstone and in the basement in order to improve the geological model. A geotechnical mapping of 421m, 397m, 373m and 359m benches and a detailed structural and lithological mapping of the basement at the bottom of the pit (below 360m) was carried out.

2.0 METHODOLOGY

2.1 Geotechnical Mapping

In order to complete a thorough analysis of the fracture distribution, systematic measurements were taken in the sandstone on four different benches (or levels) of the pit at the 421m, 397m, 373m and 359m elevation. All fractures crossing through at least two sandstone beds were measured. The 421m bench was remapped as only fractures. Overall the spatial distribution of measurement station gives a homogeneous data sampling. The entire circumference of the upper bench (421m) has been covered and 85% of the 397m bench and 2/3 of the 359m bench was accessible. On the 373m bench, only the northwest quarter has been studied.

Fractures and bedding joints have been measured along 10 meter-wide stations. Randomly oriented fracture sets due to blasting and subsequent stress release were disregarded. For each station, structures crosscutting a subhorizontal line (traverse; made evident by a tight string) have been systematically collected. Station locations have been marked on pit walls with paint and surveyed.

Along each traverse, the following parameters have been recorded:

- azimuth and exact plunge of the traverse (subhorizontal line)
- strike and dip (right-hand rule) of every set of structures crosscutting the traverse
- number of structures of that orientation per traverse
- alteration
- roughness
- presence of limonite coating
- type of structure (bedding joint: JN, fracture: FC, fault with evidence of significant movement: FT)
- comments: hydraulic breccia size and shape, type of filling, wet fractures
- Numerical codes used for alteration and roughness corresponds to international geotechnical norms defined by the Norwegian Geotechnic Institute (NGI).

For the alteration the code is as follows:

1 = clean joint
2 = fine coating
4 = hard clay < 5 mm
5 = soft clay < 5 mm
6 = sandy clay < 5mm
8 = sand < 5mm
14 = hard clay > 5mm
15 = soft clay > 5mm
16 = sandy clay > 5mm
17 = sand > 5mm
20 = hydraulic breccia

Roughness:

1 = smooth plane (irregularities at metric scale)
2 = undulated plane (irregularities at decimetric scale)
3 = rough plane (irregularities at centimetric scale)

For the data processing, the geotechnical DIPS 4.03 software designed by the Department of Rock Mechanics at the University of Toronto was used. This program takes the Terzaghi correction into account for the calculation of a fracture frequency weighted plot.

The Terzaghi correction is a coefficient applied to the frequency of each set of fractures according to the orientation of the studied wall (represented here by the traverse). It allows to correct the fact that, on a E-W oriented traverse for instance, an observer will meet more N-S (perpendicular to the traverse) E-W structures than structures subparallel to parallel to the wall. A total of 184 stations were established (fig. 1). and 3300 structures were measured.

2.2 Structural Mapping

In addition to the geotechnical mapping, main structural features such as main fracture planes, fracturing corridors and hydraulic breccia zones, have been mapped. Hydraulic breccia are zones of strong delithification and fracturing of the rock forming permeable and sandy bodies.

In the basement lithological units, brittle structures (fractures, faults) as well as more ductile older structures (foliation, shear zones, fold, etc.) mapped. The lithology variation have been also noticed.

This structural mapping and the rosette map of fig. 7 permitted us to produce structural maps for the basement (fig. 10) and for all the pit (fig. 11).

3.0 RESULTS

3.1 Sandstone Fracturing

3.1.1 Sandstone Generality

The sandstone bedding is globally flat-lying (fig. 3). Local tilting occurs notably between A37 and A41 due to a south-dipping WNW-ESE normal fault. In the upper benches (421m and 409m) the sandstone is weakly altered and silicified. The rock has a massive appearance. It is still purple (weak bleaching of the primary hematite) on 421m bench and moderately bleached on bench 409. Bleached zones are parallel to the bedding. From 397m bench, sandstone matrix is increasingly argilized and bleaching becomes strong. Primary hematite is locally preserved, especially in coarser beds.

3.1.2 General Description of Fractures

Fractures are steep: 88% of all measured fractures have a dip greater than 70° (fig. 2). No significant displacement is visible on fault plane except a for a normal fault zone (dip-slip striae) identified in the southern part of the pit as well as a sinistral fault (strike-slip striae) on the west wall of the 359m bench.

The size of fracture planes are variable: biggest plan can cut across at least two benches (24m), smallest across two sedimentary beds (around 20 cm).

Limonite coating on fracture planes is very frequent throughout the pit and equally affects the different sets of fractures. Most often, strongest limonite coating (several mm thick) occurs on large straight planes. Druzy quartz coating was found occasionally.

The alteration of wall fractures produced most often a dry sand or sandy clay filling (desilicified and argilized sandstone), a few millimeters to several centimeters thick. An other type of alteration observable in JEB pit is the hydraulic breccia. It corresponds to the delithification of sandstone due to flowing fluid under pressure at the time of mineralization. It produces generally lenses or pockets of dry strongly friable and porous sand or sandy clay associated with limonitization, hematization, argilization or chloritization. It can be a few centimeters to several meters wide with typically no vertical and horizontal continuity along the fracture plane or at the intersection with two fractures (column). Hydraulic fracturing can also affect a broad area, such as the west wall of benches 385 and 373 (see below), producing large breccia and 'zone à boules' without well-defined trend.

The general appearance of fracturing changes vertically. In the upper 421m and 409m benches where sandstone are less altered and more competent fractures seem more regularly organized and straighter than in the lower benches.

3.1.3 Fractures Distribution

The fracture density (number of fractures per 10 m) decreases slightly downwards (Table 1). However variations are weak and the fracturing seems to be homogenous throughout the pit.

A the scale of the pit fractures are distributed along three trends: NW-SE (N130-160°), NE-SW (N40-70°) and E-W (70-100°) [fig. 4a].

The NW-SE trend is the predominant one (peak at N140-150°; fig. 4a). It is represented often by large straight limonitic plane which stands out in the pit. Fractures are vertical to steeply dipping to the south-west (fig. 3). The NW-SE trend is particularly strong on the 421m, 373m and 359m benches (fig. 4b, d, e) with an average density of 8 (Table 2) but less abundant on the 397m bench (density of 4). It is the predominant trend on 421m and 359m benches. On the 373m bench, the NW-SE trending fractures are divided in two distinct sets: N130-140° and N150-160° (fig. 4d).

The NE-SW trending fractures are mostly dipping steeply to the southeast (fig. 3). The peak is at N50-70° (fig. 4a). They are particularly abundant on the 373m bench (fig. 4d). It is due to the presence of N50° fractured corridor (fig. 11). They are also predominant on the 397m bench (fig. 4c) but are almost absent on the 359 m bench where N10-30° trending fractures dominate.

E-W trending fractures are generally subvertical. They are not the principal set on any bench and are more abundant on lower benches (373 and 359). Fracture orientation varies within a 30° wide range from N70-80° on the 373m bench to N80-100° on the 359m and 397m benches.

On the bench 359, an other minor trend at N110-120° was identified.

3.1.4 Altered Fractures

Fractures are considered altered when they show a sand or sandy clay alteration thicker than 5mm (NGI code 14, 15, 16 and 17) as well as hydraulic breccia development (20).

The density and percentage of altered fractures progressively increase downwards (Table 1) to the 359m bench where it drops significantly. This variation is comparable to changes in hydraulic breccia density and percentage. It shows that the presence of hydraulic breccia implies a greater density of altered fractures.

At the scale of the pit altered fractured are distributed homogeneously among the three main fracture trends (fig. 5a). The N50-60° trending altered fractures are slightly dominant. On each bench, orientation rosette of altered fractures is similar to the rosette for altered and unaltered fractures.
Most hydraulic breccia-filled fractures belongs to a wide N120-170° orientation range (fig. 6a). They are more abundant on the 373m bench (4 per 10 meters, Table 1).

3.2 Main Fracturing Corridor Repartition and Altered Zone Location

The plot of the hydraulic breccia-filled fractures on a pit map shows that hydraulic breccia exists throughout the pit (fig. 8). However they are less frequent on the northeast part of the pit. Combining this map with the rosette map (fig. 7) for every three traverse, we can define main fracturing corridors surrounding the ore body (fig. 8). Those corridor corresponds to more dense or altered (hydraulic breccia) fracturing. The following trends were identified:

- Two NW-SE fracturing corridor to the west and east of the ore deposit zone.
- Two NE-SW fracturing corridor to the north and southeast.
- A N80° fracturing corridor on the northwest face of the pit.
- A N80-90° fractured zone on the western face of the pit.
- A WNW-ENE normal fault zone to the south.

The two NW-SE trending corridors are wrapping around the ore body and orientation refraction occurs (cf. fig. 4d). That suggests a genetic link between ore deposit process and NW-SE trending fractures.

In the southeast part of the pit, the eastern NW-SE corridor intercepts a NE-SW trending corridor producing a strong development of hydraulic breccia. This NE-SW corridor dips to the southeast making all the lower southeast wall unstable up to the 421m bench.

Similarly, a WNW-ESE fracturing corridor dips to the south in the southern part of the pit. It corresponds to a normal fault zone particularly obvious on the 397m bench (slickensides). The western NW-SE trending corridor bends toward the ESE meeting this fault zone (fig. 11). The latter seems to crosscut and interrupt to the west a N80-90° fracturing zone which exhibits thick hydraulic breccia running along straight fracture planes. This EW fractured corridor is not visible above the 385m bench (photo 7). Towards the east it limits the ore zone to the south and meets at this point NW-SE and south dipping NE-SW fractures making this zone unstable. This E-W fracturing does not appear on the east face of the 397m and 421m benches.

Northward, on the west face of JEB pit a broad zone of hydraulic breccia with 'zones à boules' is visible in the lower benches (385 and 373). A strong alteration is associated (argilization and hematization). No fracturing trend is obvious. However, above on the bench 397 local hydraulic

breccia indicate that this zone could correspond to the meeting point of the west NW-SE corridor and of a N70-80° fracturing corridor. Upwards on the 421m bench between station F73 to F77, a large hydraulic breccia zone ('zone à boules') with strong clay alteration was identified, however associate fractures trends NW-SE and NNE-SSW (N26-30°) and no E-W trending fractures were visible.

Northward, on the 373m bench south of station B1, N70-80° trending fractures controlled the development of a large hydraulic breccia. It disappears rapidly upward in the uppermost benches and fractures turn to NE-SW (around N50-60°) when intersecting the southwest continuation of a NE-SW fracturing corridor on the NE face of the pit at the 373m (B10-B14), 385 and 397bench. This NE-SW corridor vanishes upward on 409m bench.

3.3 Discussion on the Sandstone Fracturing

Hydraulic breccia in JEB pit are linked to the hydrothermal activity contemporary to the formation of the ore deposit. It is noted that they are controlled by the three main fracturing trends and that they follow the same distribution variation as the altered fractures. This suggests that the global fracturing in JEB is related to ore deposit process.

Whereas the NW-SE and NE-SW trending fractures are widespread throughout the pit and seems homogenous, the E-W trending fracturing is concentrated along a fractured corridor. These zones are located in the southern part of the pit (fig. 7) and on the west wall of 373m and 385m benches. The latter corresponds to the most altered and tectonized area of the pit. It is important to notice that the E-W hydraulic breccia fracture do not extend to the east side and appears to stop above the ore zone when meeting NE-SW less altered fractures. Similarly on the west wall E-W fractures are rare and NE-SW trending fractures predominate.

On the 359m bench, the closest from the ore body, the geotechnical mapping showed that sandstone are less fractured, and the large hydraulic breccia zone encountered on the 373-385m benches is not present. It leads us to propose a fan geometry for the hydraulic fracturing (fig. 12): the fracturing is localized at the base in narrow hydraulic breccia zone (359m bench) and spreads out upward in larger hydraulic breccia corridors (373 and 385m benches). In the more silicified zone, as the density of fracturing increases, the brecciation scatters in local hydraulic breccia-filled fractures (397m bench) and then declines (409 and 421m benches). The result is that in the upper benches density of fractures is higher but the alteration lower.

3.4 Basement Fracturing (fig. 10)

3.4.1 Lithology

At the bottom of the pit, unconformity elevation varies from 362 m to the east to 358 m to the west. The basement is overlain by a discontinuous basal conglomerate or directly by sandstone.

The basement consists mainly of graphitic gneiss and pegmatite. Gneiss composition is variable (calcosilicate gneiss, feldspar-biotite gneiss, quartz-rich gneiss...). Main pegmatite bodies bracket the graphitic rocks.

Some anatectic gneiss showing segregation give evidence that gneiss reached high-grade metamorphism conditions, certainly during Hudsonian events. They were affected by a widespread chloritization most probably as they were exhumed. The hydrothermalism associated with the ore deposit process removed most of the paleoregolith hematization. Nevertheless it is still possible to observe it locally. Hydrothermal activity also caused argilization (illitization or kaolinitization), chloritization (sudoite?) and local silicification of the basement. Chloritization is especially strong near the mineralized zones.

3.4.2 Basement Structures

Gneisses generally exhibit a tight foliation attesting of a strong old ductile deformation (mylonite to ultramylonite). This foliation trends around N100° vertical to steeply dipping north (fig. 9a). On the southern wall it dips locally to the south. Pole stereogram (fig. 8) shows that foliation dip locally moderately to the north. It is mainly due to drag folding by shallow to moderately dipping fractures (cf. below) or bending at the unconformity caused by the Athabasca sandstone loading.

Fracturing in the basement trends mainly parallel to the foliation as shown by the fractures rosette (fig. 9b). NW-SE and NE-SW fractures are also present. Similarly NW-SE fractures, mostly trending N130-140°, are represented mainly by big straight steep planes (west wall). Nevertheless they are not as frequent. They locally induce brecciation of basement rocks indicating movement along the fault plane. A dextral sense of movement was recognized on a 132° trending fault.

The NE-SW trending fractures play a more important part in the basement structures. They locally induce reorientation of the foliation and of pegmatite-gneiss contacts (fig 9a). A N60° trending fault seems to produce an significant sinistral offset. However, its northeast extension shows evidence of reverse movement. NE-SW fractures (N40-60°) have often a shallow to moderate dip to the southeast.

North-South trending fractures has been observed but they seems to be restricted to the south-east of the pit (G15). One shows a dextral displacement.

Faulting running parallel or sub-parallel to foliation is the most widespread. On the west wall, foliation planes trending around N100°, bear a strong dip-slip chlorite-carbonate striation. The most fractured zone is situated between the points G10 and G19, and correspond to the main graphitic zone. Here, graphite lenses developed steep ENE-WSW trending brittle shear zones. Large cryptocrystalline quartz veins are associated. Weak brecciation occurs. Drag folding of the mylonitic foliation is common. Nevertheless the kinematics of shear zones is ambiguous. As some graphitic planes exhibit dip-slip striation, others bear subhorizontal ones and contradictory senses of movement have been observed. Secondary narrow shear zones, trending east-west and slightly oblique to the foliation, can be sinistral or dextral.

A major mineralized strike-slip fault limits this tectonized zone to the north from a wide boudin of anatectic gneiss and pegmatite. To the south, mylonitic gneiss are separated from a pegmatitic zone by a big irregular ESE-WNW trending reverse fault. The pegmatite-rich zones to north and to the south seems to have played a important part in JEB basement tectonic. They acted like two resistant blocks between which the well foliated softer graphitic gneiss slid. This could explain the complexity of the graphite gneiss tectonic.

An other feature of the basement tectonic is the presence of shallow to moderately dipping fractures cross-cutting the structures mentioned above. Some of these fractures show evidence of reverse or normal movement and induce a drag-folding of the foliation. They trends generally ESE-WNW or NE-SW.

The two main fracture trends NW-SE and NE-SW observed in the basement are present in the sandstone. Nevertheless the N100-110° major fracturing trends in the basement is not well developed in the sandstone. The E-W sandstone fractures run at N80-90° which corresponds rather to a secondary fracturing trend in the basement. The ESE-WNW normal fault observed in the southern part of the pit could be related to the basement major trend. A N96° local sinistral fault have been noticed at the point C8 which is at the continuation of the main basement fractured zone. Globally few basement fractures crosscut the unconformity.

3.4.3 Water Circulation

Very few seeping fracture have been noticed and they are restricted to the south of the pit. The hydraulic breccia sand is always dry. Nevertheless the widespread limonite coating on fracture planes indicate that water has circulated along the fractures. Limonite coating is equally developed along all fracture set and therefore does not show evidence of a preferential water drainage system. Currently the ground water come from the base of the sandstone and notably from the contact basal conglomerate-sandstone. When the conglomerate is missing (mostly

above pegmatite) the unconformity acts as a drain. The alteration of bedding joints throughout the pit shows how important they are for the ground water circulation. In the lower benches (373, 359) it is frequent to see thick recent clay sealing the bedding. No evidences of water seepage have been noticed in the basement. Therefore the unconformity seems to be a important hydrogeologic interface.

Bench	Stations	Fractures Nb			Fracture Density (/10m)			Fracture %	
	Nb	totality	altered	hyd. br.	totality	altered	hyd. br.	altered	hyd. br.
421	89	2925	619	87	32.9	7	1	21.1	3
397	66	1895	589	168	28.7	8.9	2.5	31.1	9
373	13	372	143	49	28.6	11	3.8	38.4	13.1
359	16	406	79	4	25.4	4.9	0.25	19.5	1
All	184	5598	1429	309	30.4	7.8	1.7	25.5	5.5

Table 1

Density (/10m) and percentage of totality, altered and hydraulic breccia fractures (weighted)

Bench	130-160°		40-70°		70-100°	
	Nb	Density	Nb	Density	Nb	Density
421	777	8.7	519	5.8	296	3.3
397	280	4.2	347	5.3	264	4.0
373	97	7.5	116	8.9	81	6.2
359	124	7.7	21	1.3	74	4.6

Table 2

Density (/10m) of the three main trends of fractures (weighted)

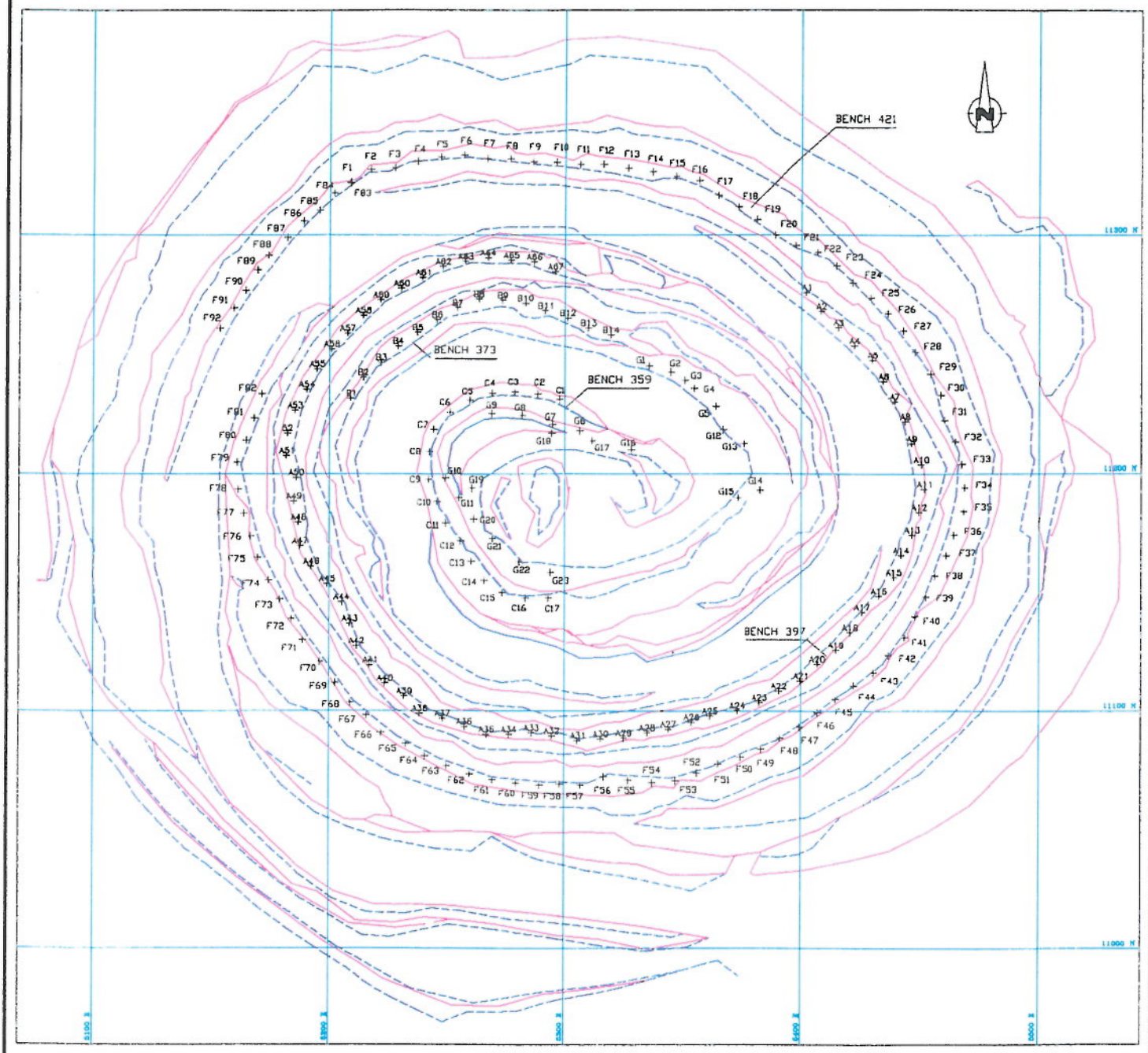
4.0 CONCLUSION

This study confirms the presence of the three groups of fractures trending N130-160°, N40-70° and N70-90°. In the basement NW-SE and NE-SW fractures have been observed but the main fracturing occurred along N100-110° trending corridors and graphite shear zone. This direction is not well reflected in the sandstone. The rheologic contrast between marginal pegmatite-rich zones and the central graphitic mylonitic gneiss played a important part for the structures of the JEB ore deposit.

The sandstone fracturing in JEB pit is in large way related to the ore deposit event. The vertical distribution of the fractures and alteration fits with an hydraulic fracturing model. The alteration is distributed uniformly throughout the different fracture groups.

The main altered zone (broad hydraulic breccia) is located on the west wall of JEB pit. It seems that it is restricted to the vicinity of the ore body.

Porous hydraulic breccia are a potential drain for ground water but they have no vertical or horizontal continuity. The control of the water circulation is rather stratigraphic through bedding joints and major stratigraphic discontinuity like the basal conglomerate-sandstone contact or the unconformity. The altered sandstone (~397-370m) which is characterized by a broader development of subvertical breccia and altered fractures as well as stronger alteration of bedding joints will certainly represent the main drainage unit. No potential vertical hydrogeologic barrier could be identified as clay-rich hydraulic breccia developing above the unconformity show a poor lateral and vertical continuity. Nevertheless NE fractures on the eastern wall limits the eastern extension of the major hydraulic breccia (lower sandstones) and might therefore create a permeability contrast between the NW and SE part of the pit.



0 50 100m

Scale 1:2500

LEGEND

A, B, C, F points: sandstone stations

G points: basement stations

Crest

Toe

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McCLEAN LAKE PROJECT

Jeb Pit
Station Locations

By: R. Moriceau	Date: Aug, '97
Report: 97-CND-99-01	Fig.: 1

9799-806

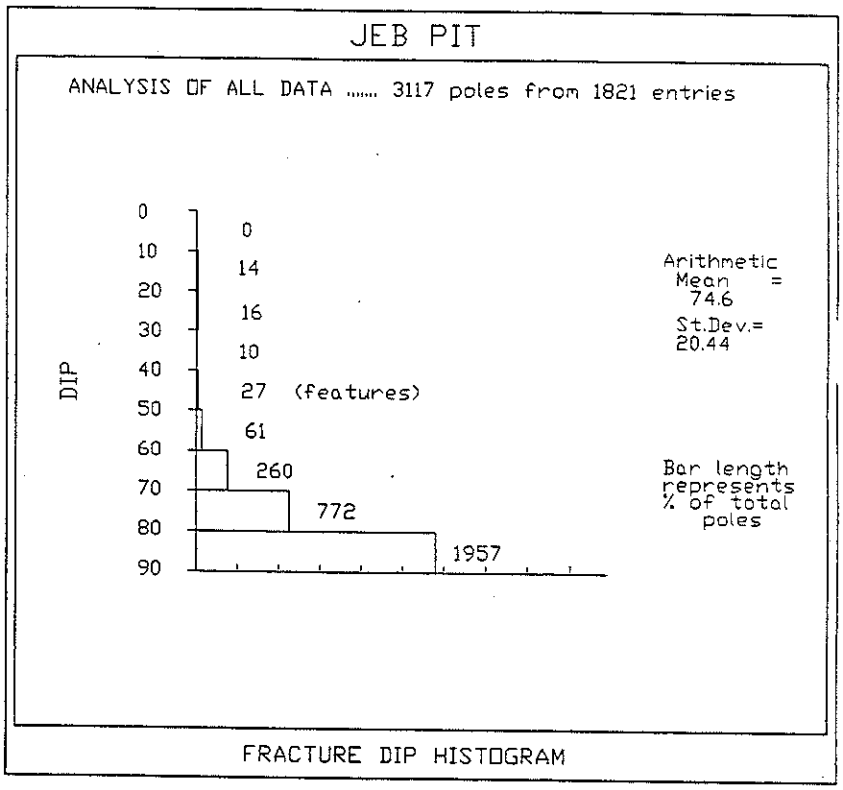


Fig. 2:Histogram of fracture dips.

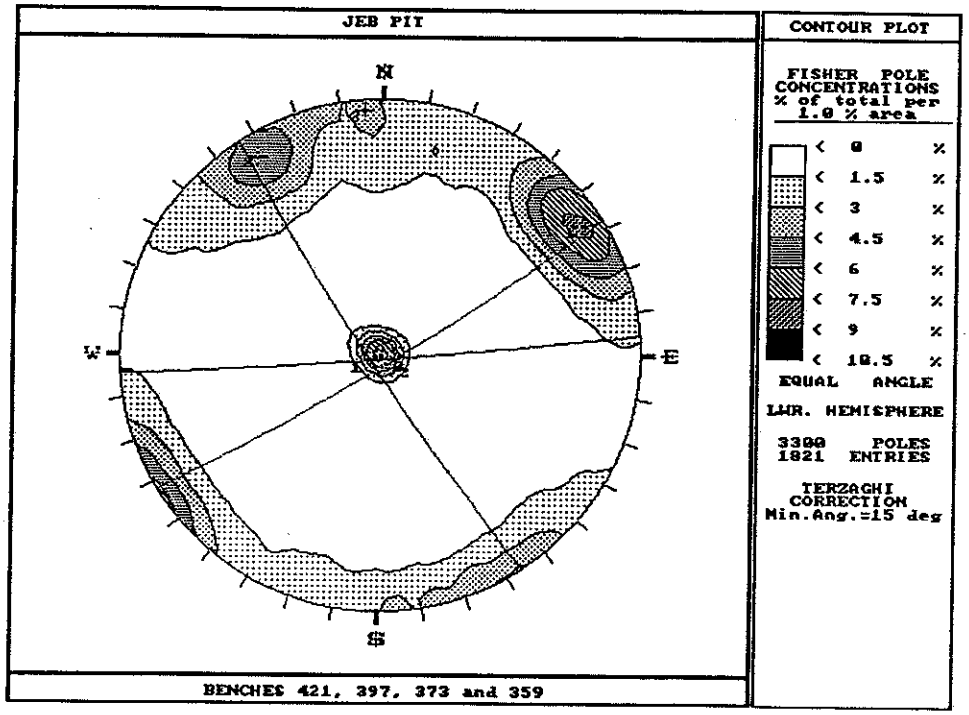


Fig. 3: Fracture and bedding pole contour plot for all the data (weighted).

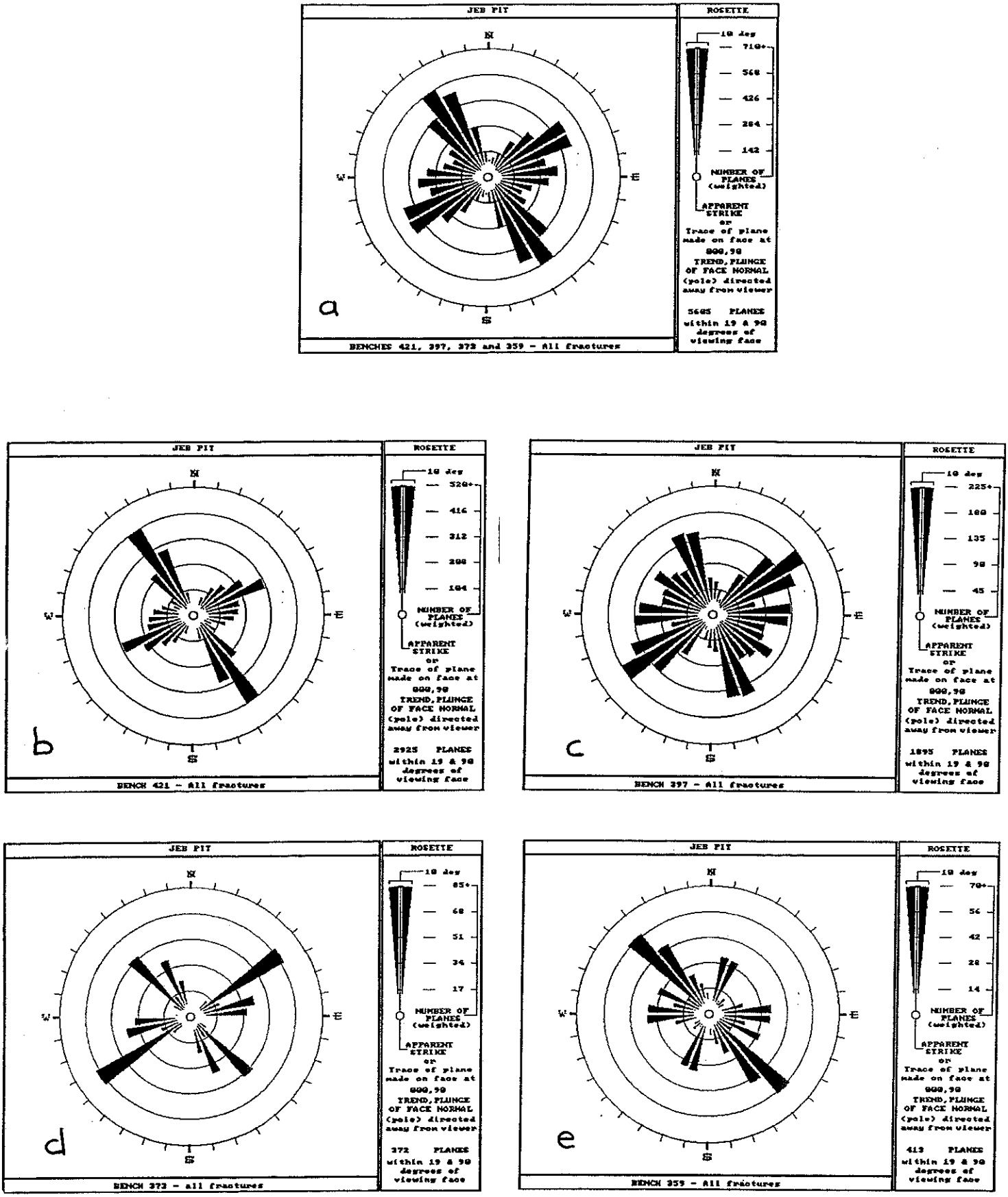
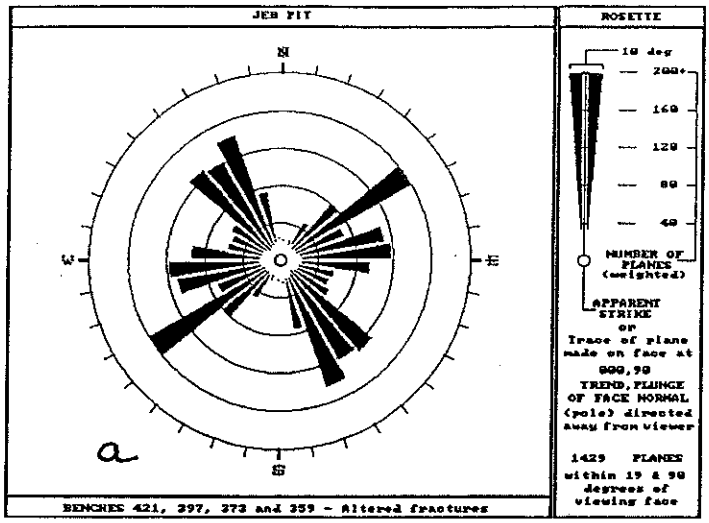
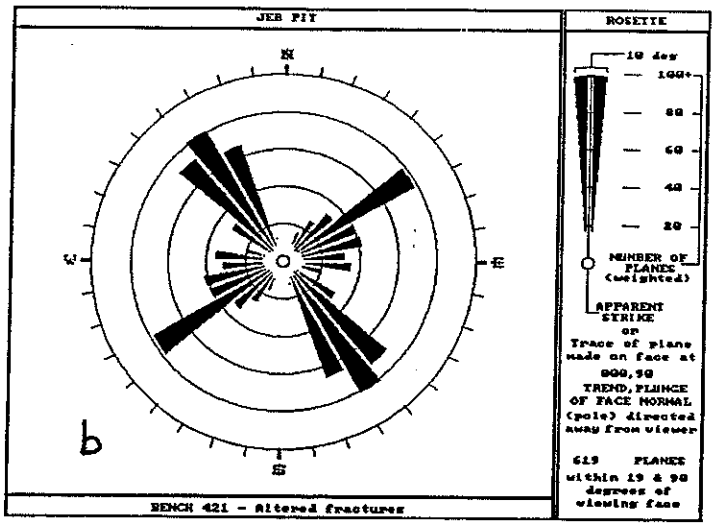
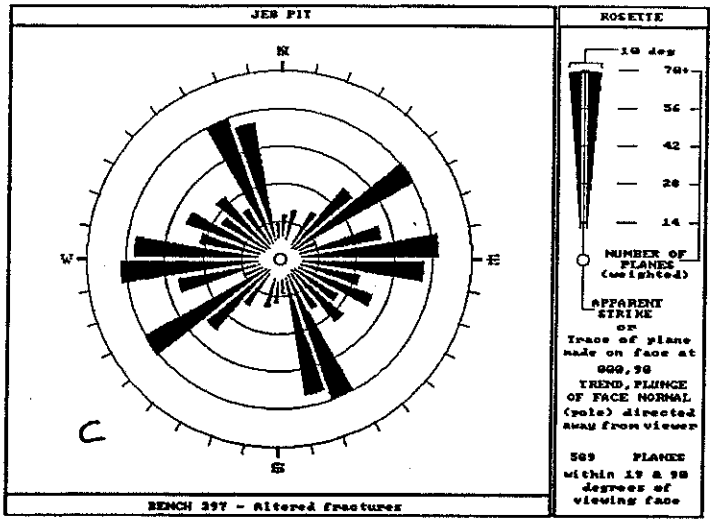
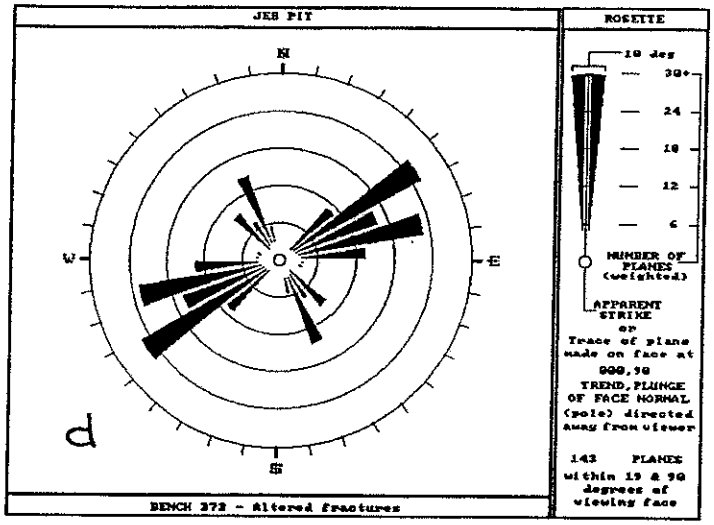


Fig.4: Weighted rosette plot for the totality of fractures,
[a] totality of benches, [b] 421m bench, [c] 397m bench, [d] 373m bench, [e] 359m bench.









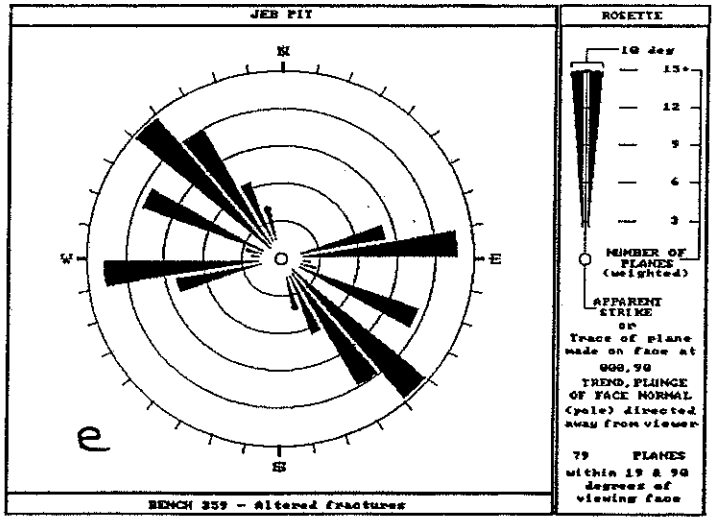


Fig.5: Weighted rosette plot for altered fractures,
[a] totality of benches, [b] 421m bench, [c] 397m bench, [d] 373m bench, [e] 359m bench.

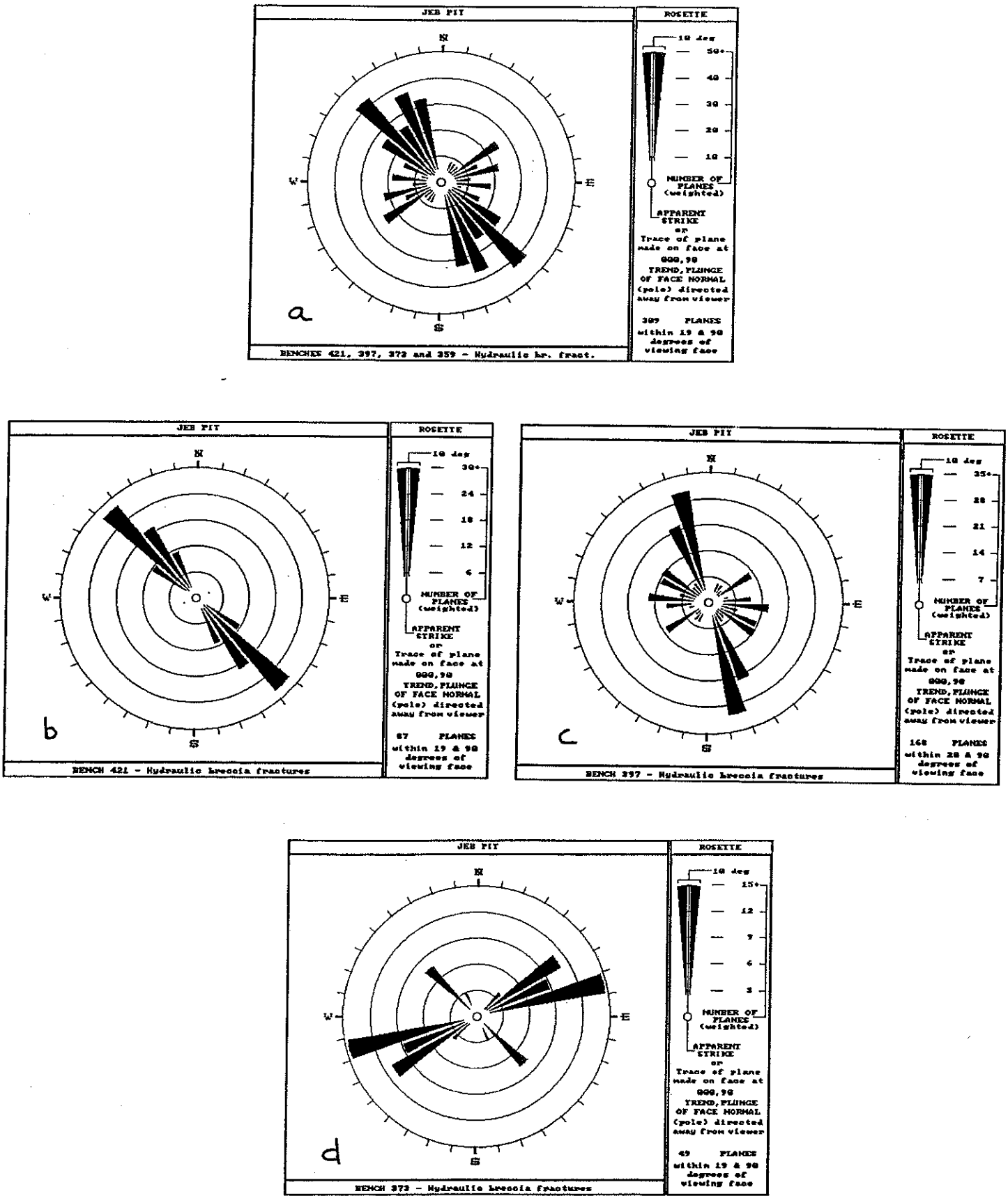
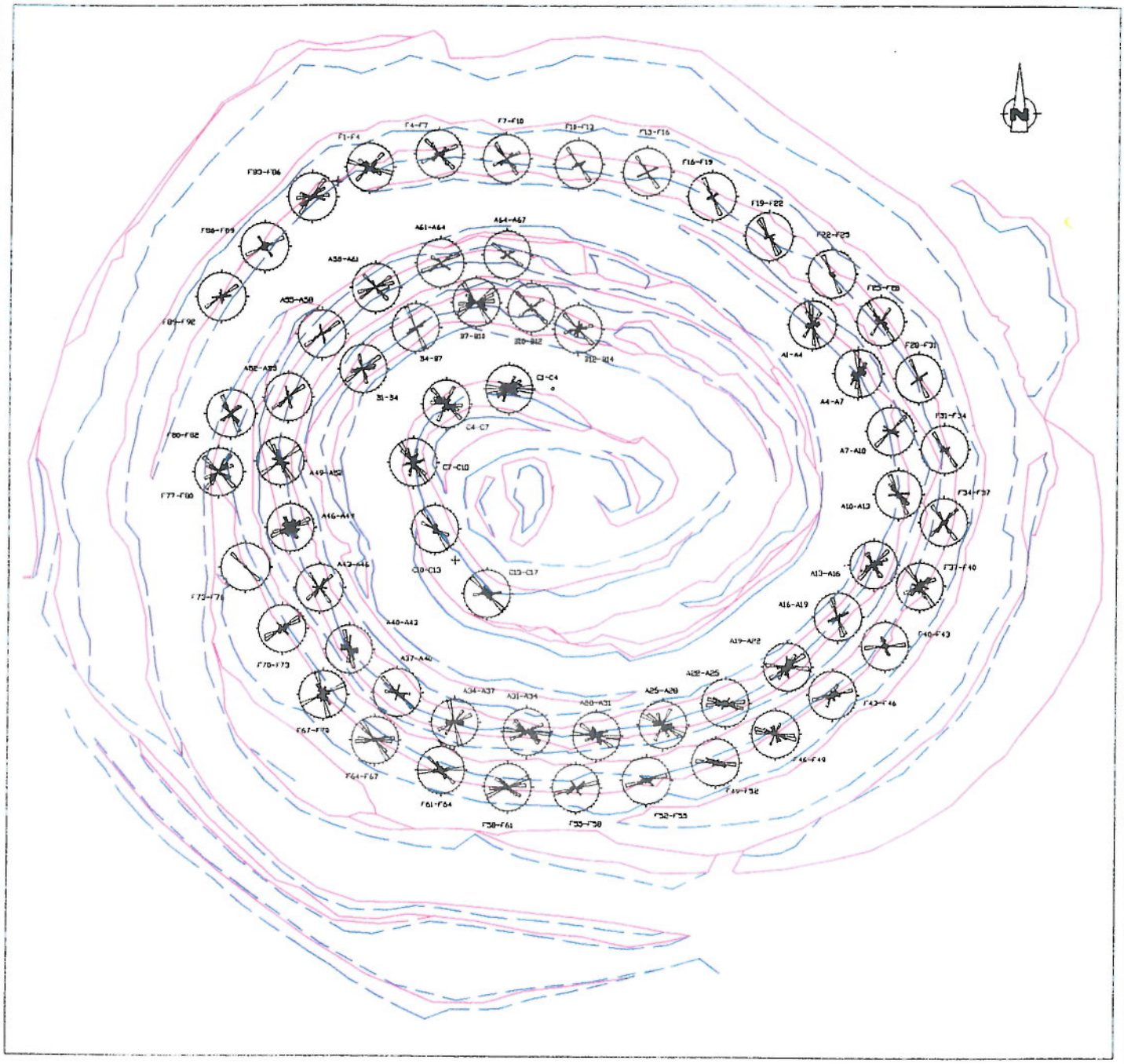


Fig.6: Weighted rosette plot for hydraulic breccia-filled fractures,
[a] totality of benches, [b] 421m bench, [c] 397m bench, [d] 373m bench.



LEGEND

Crest

Toe

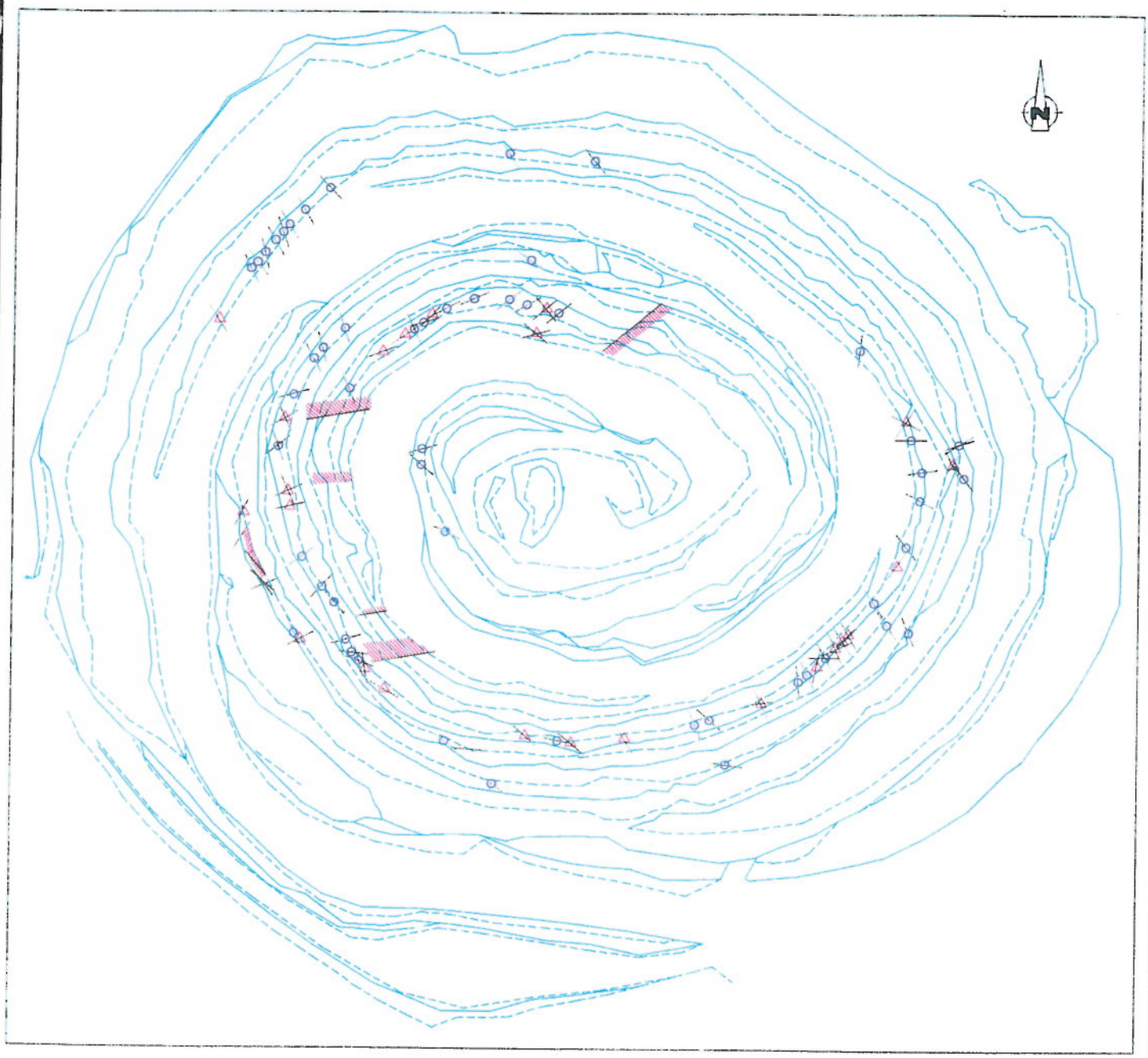
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McCLEAN LAKE PROJECT

Jeb Pit
Rosette Map
Every 3 Traverses

By: R. Moriceau	Date: Aug./97
Report: 97-CND-99-01	Fig.: 7

9799-808



0 50 100m

Scale 1:2500

LEGEND

- Main hydraulic breccia zone
- Fractures with hydraulic breccia >50cm
- Fractures with hydraulic breccia <50cm

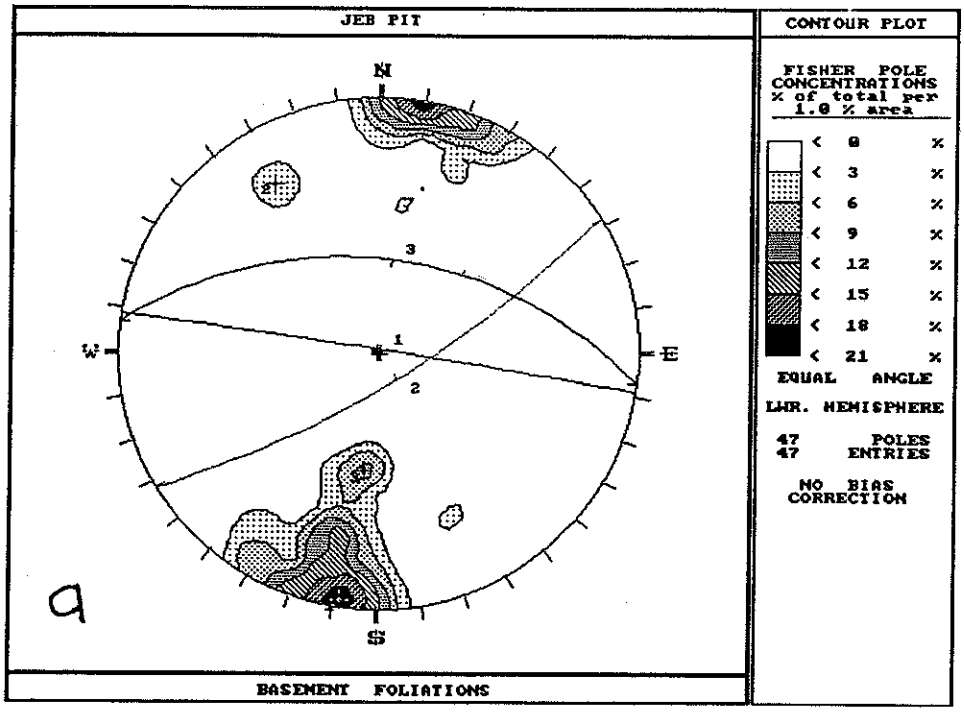
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Jeb Pit Hydraulic Breccia Distribution

By: R. Moriceau	Date: Aug./97
Report: 97-CND-99-01	Fig.: 8

5769-005



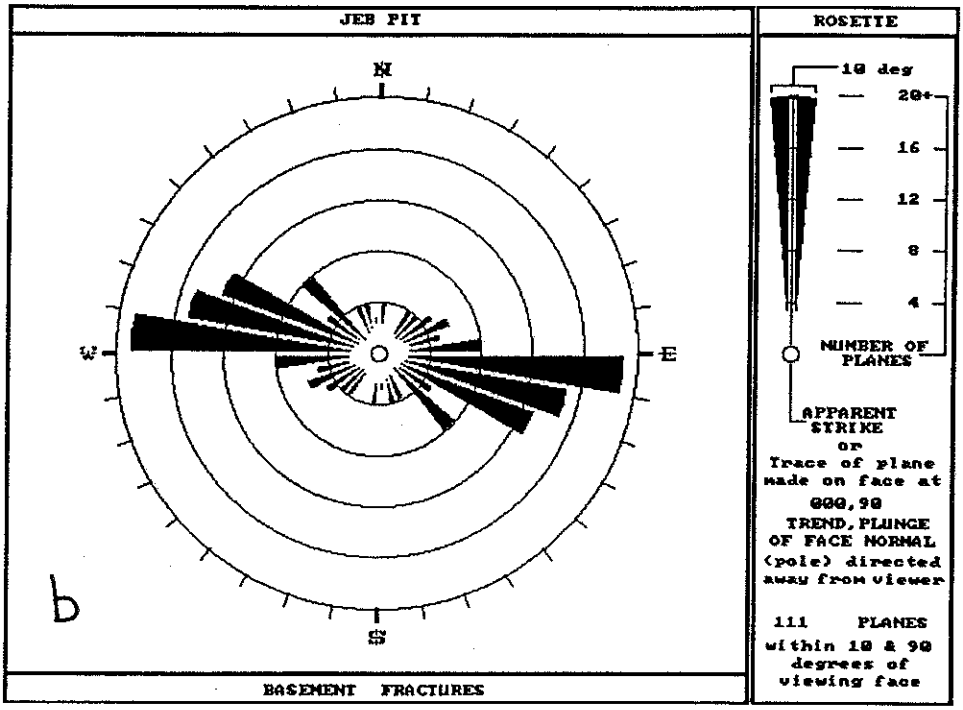
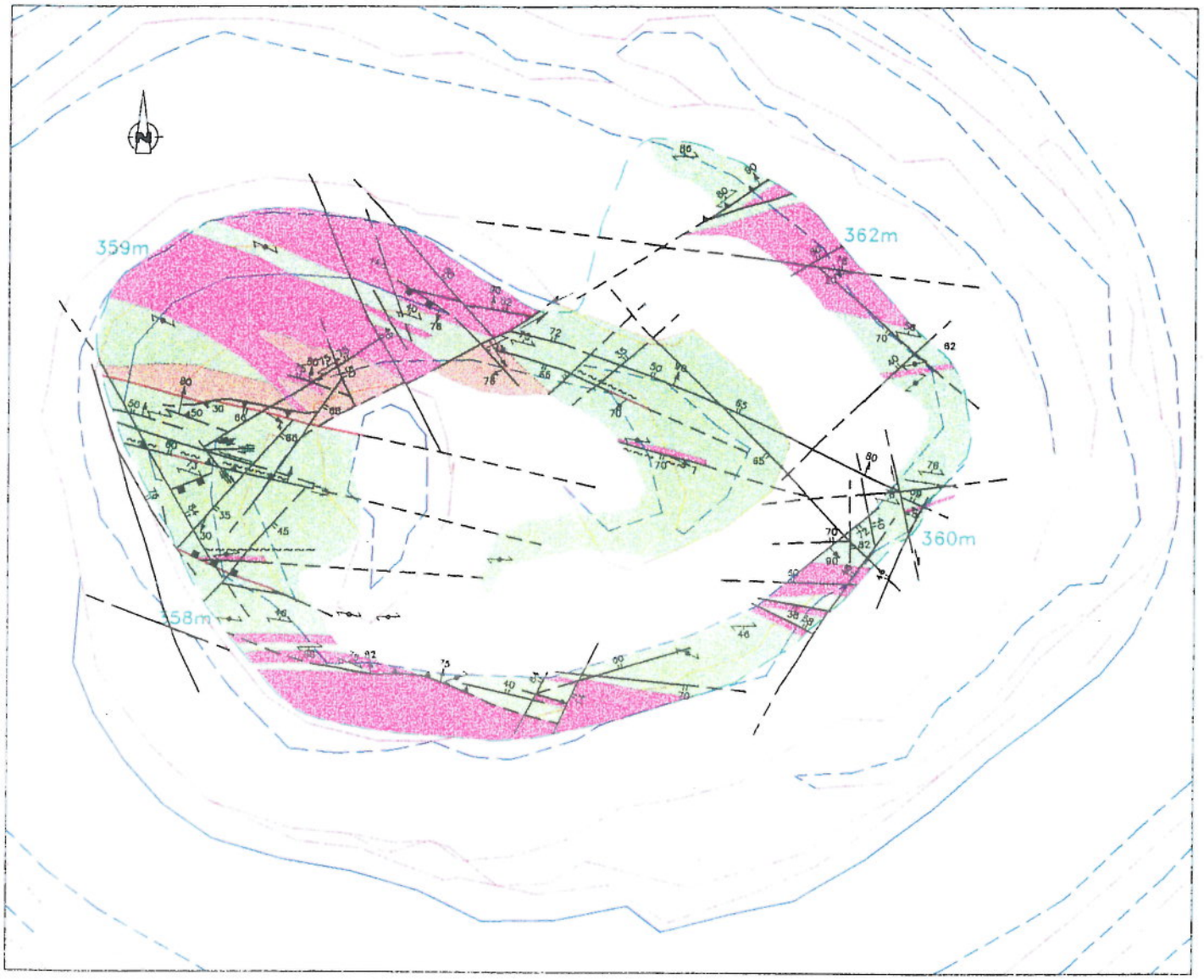


Fig.9: Basement structures,
[a] Foliation pole contour plot, [b] Fracture rosette plot



LEGEND

- Graphitic mylonitic gneiss (moderately to strongly chloritized)
- Anatectic graphitic gneiss ±pegmatite veins
- Pegmatite
- Mineralization
- Fractures (40 ° dip)
- Reverse fault
- Normal fault
- Striction pitch
- Main graphitic shear zone or fracture
- Foliation (46 ° dip)
- Quartz vein
- 359m Unconformity (359: average elevation)
- Crest
- Toe

0 20 40m

Scale 1:1000

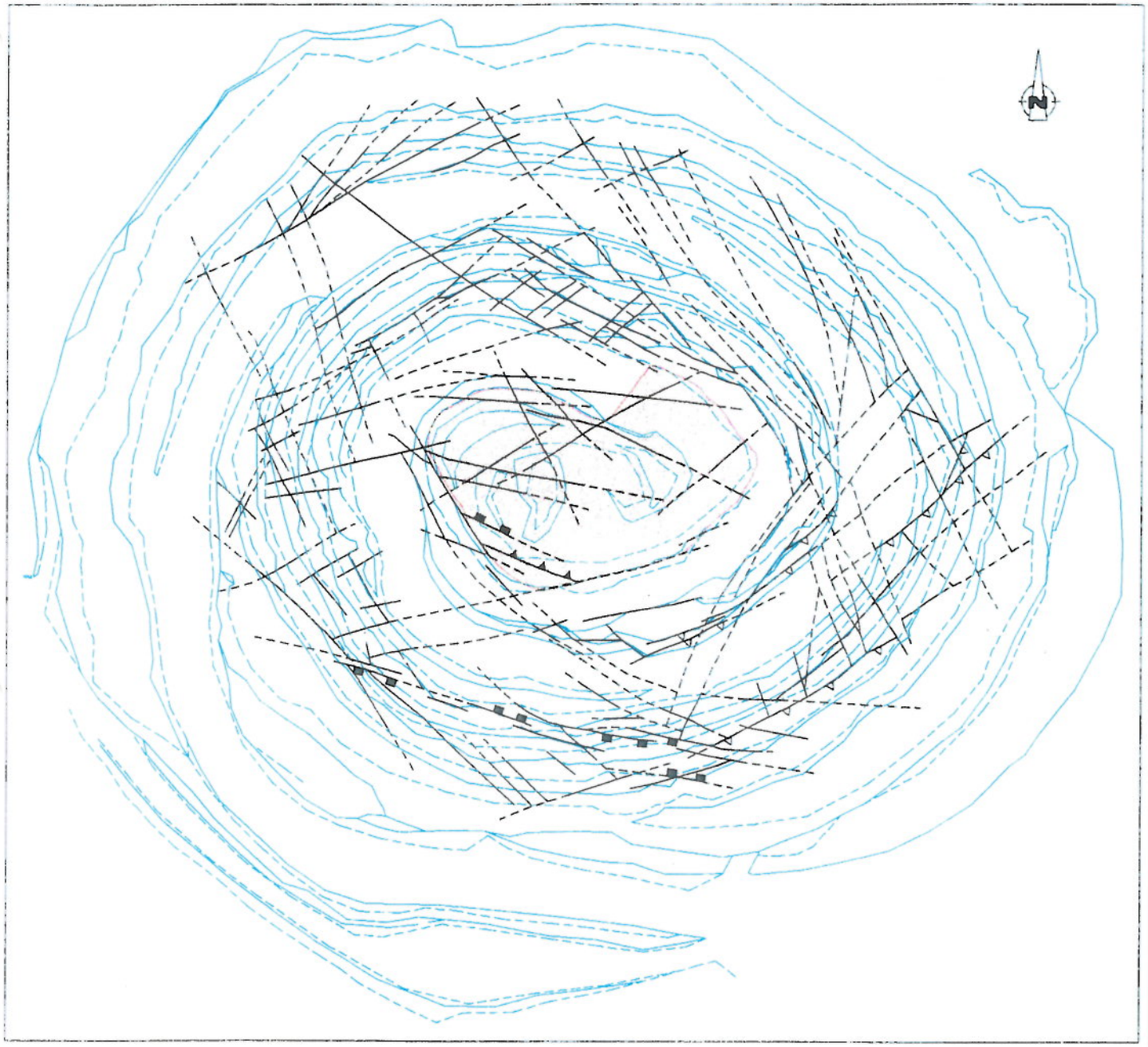
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McCLEAN LAKE PROJECT

Jeb Pit Basement Structural Map

By: R. Moriceau	Date: Aug. '97
Report: 97-CND-99-01	Fig.: 10

9759-603



0 50 100m

Scale 1:2500

LEGEND

- Main fractures or fracture zone
- NE-SW fractures dipping to SE
- Normal fault
- Reverse fault
- Basement

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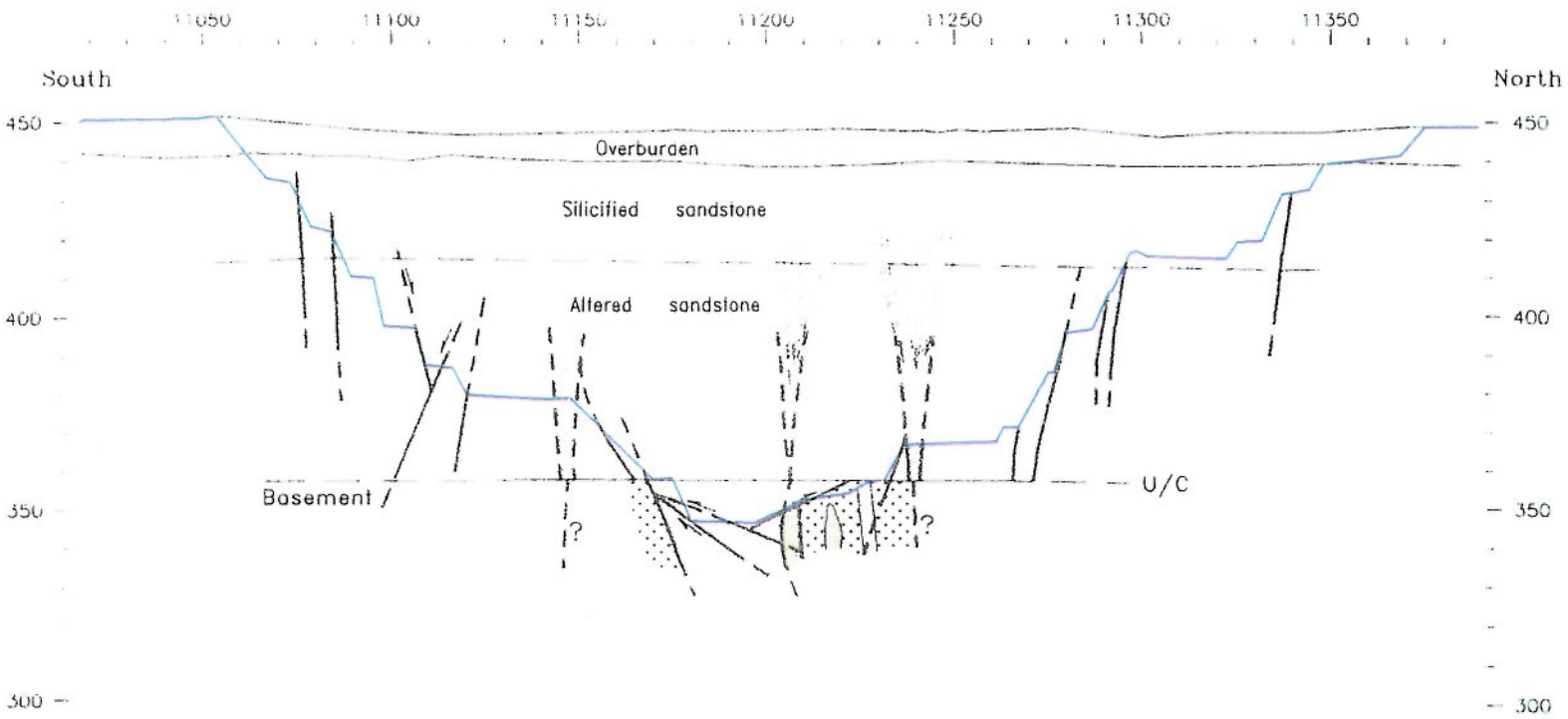
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Jeb Pit Structural Map

By: R. Moriceau	Date: Aug/97
Report: 97-CND-99-01	Fig.: 11

9799-804

9799-807



Legend

- Hydraulic breccia
- Fractures
- Gneiss foliation
- Anatectic gneiss
- Pegmatite

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McCLEAN LAKE PROJECT

Simplified North-South Cross-Section Through Jeb Pit (X=5270.77)

By: R. Moriceau	Date: Aug/97
Report: 97-CHD-99-01	Fig.: 12

- PHOTOGRAPHS -



Photo 1: NW-SE and NE-SW trending fractures on bench 421. Note the limonite coating on a NE-SW plane.

Photo 2: Limonite coating on a big straight N63° trending fracture, bench 373 (B6-B8).





Photo 3. Hydraulic breccia column at the intersection between N177° (left) and N32° (right) trending fracture, bench 397 (A8).

Photo 4. Hydraulic breccia pocket along N130° trending fracture, bench 359, below B11.

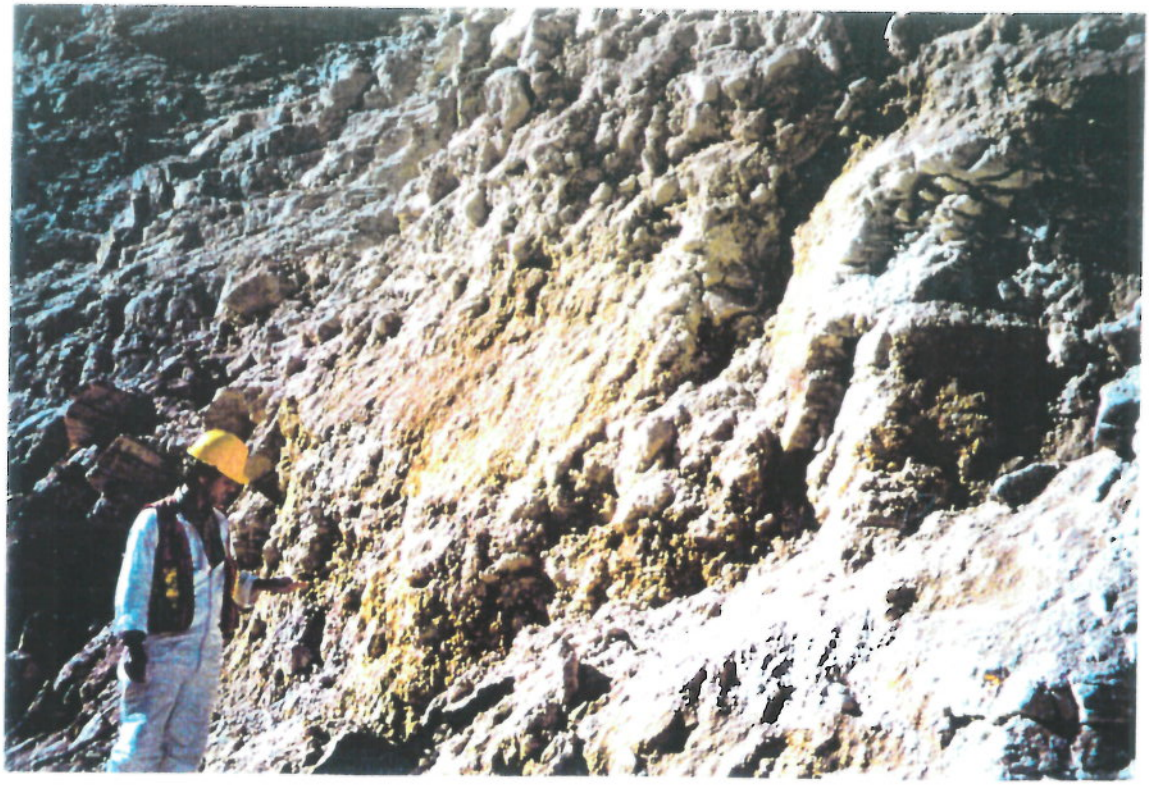




Photo 5: limonitic Hydraulic breccia along NW-SE trending fracture. Note that it closes up upward, bench 409, above A18.

Photo 6: 'Zone à boule' in clay hydraulic breccia, bench 421 (F75), south at the left.



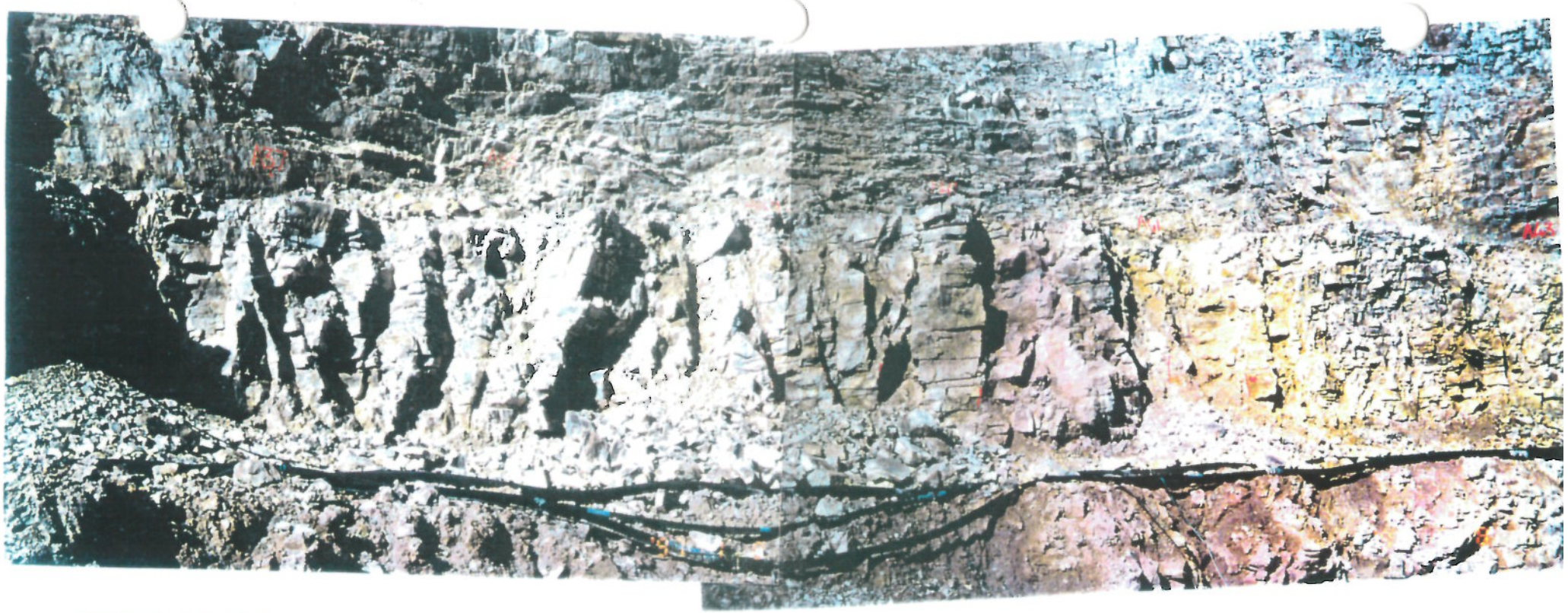


Photo 7. N80° trending fracturing corridor with hydraulic breccia, bench 385, southwest wall, south at the left. Note the abrupt interruption upward (bench 397) on a WNW-ESE fractured zone.



Photo 8. N102° trending Normal fault, dipping south, bench 397 (A27), west at the left.



Photo 9: Strong sandy clay alteration along a bedding joint, bench 359, north wall.



Photo 10: Ground water seepage at the contact between the sandstone and the basal conglomerate, bench 359 (C5).



Photo 11. Thick clay sealing at the sandstone-conglomerate bedding joint, bench 359, southeast wall (above G15). Nnortheast at the left.



Photo 12. Unconformity between flat-lying Athabasca sandstone and strongly argilized mylonitic gneiss, bench 359, northeast wall. Note the thin basal conglomerate bed wich disappears toward the southeast (right)

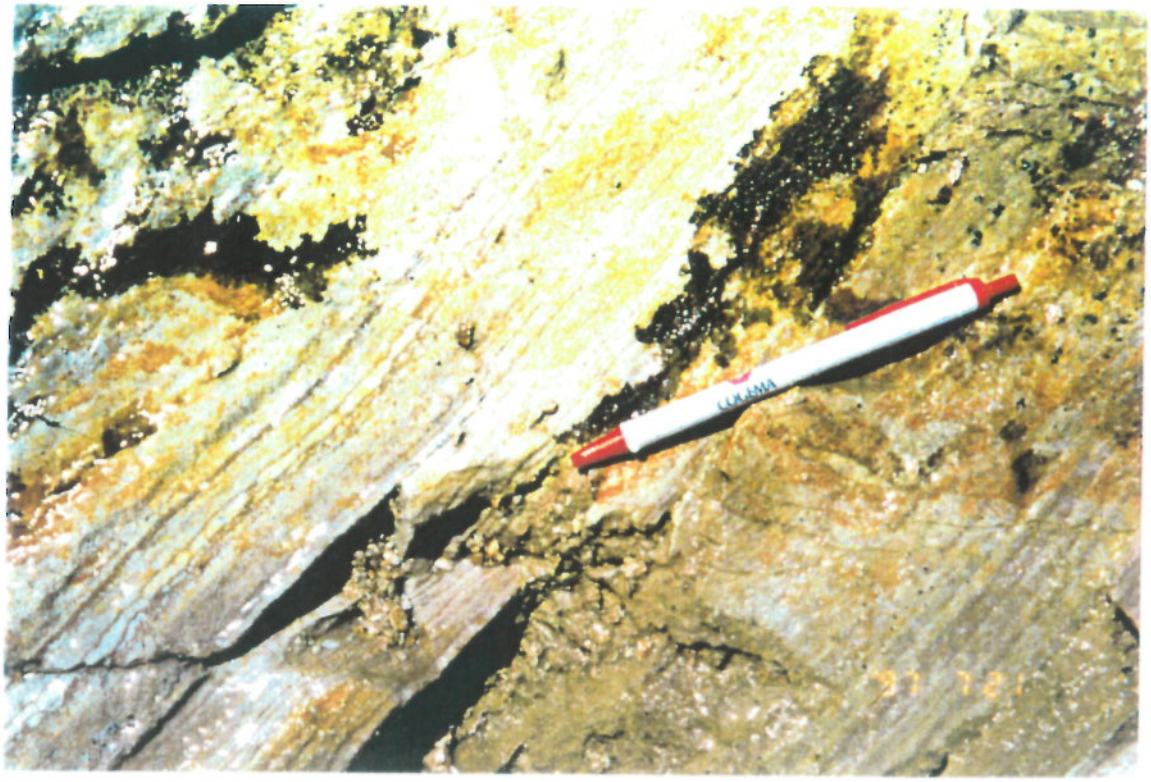


Photo 13: north-dipping tight foliation in bleached argilized gneiss, bench 359, northeast wall, north at th left. Note the microfracturing offsetting the foliation.



Photo 14. Vertical N118° trending contact between altered mylonitic gneiss (left) and pegmatite (right), bench 355 (G8).

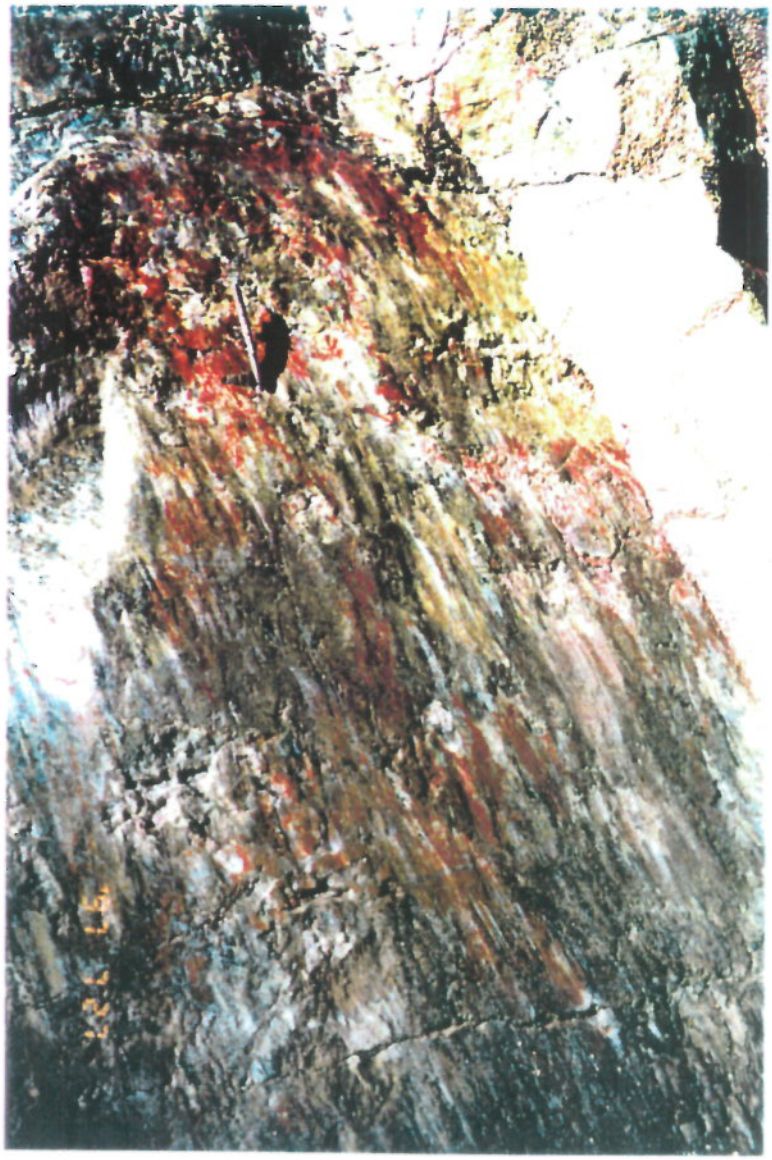


Photo 15: Dip-slip hematite-chlorite-carbonate striation on a north-dipping N96° trending foliation plane, bench 351, west wall (G21).

Photo 16: Strike-slip graphite-chlorite striation on a N110° trending plane parallel to the contact with a pegmatite boudin (in the background), bench 351, east wall, east at the right.

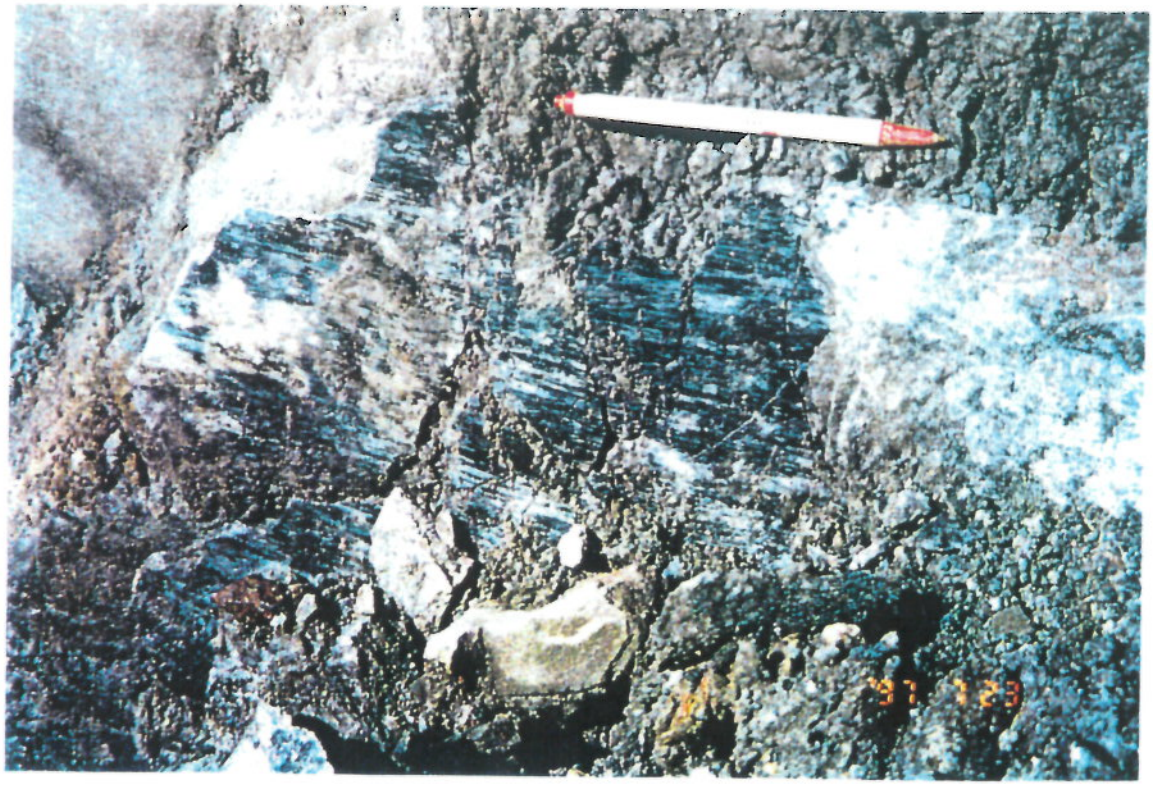


Photo 17: N110° trending fold in altered mylonitic gneiss, bench 355, north wall (G8), southwest at the left.



Photo 18 N90° trending sinistral graphite fracture, bench 351, west wall (G19).





Photo 19: Thick chloritized basal conglomerate on fractured gneiss. Note that fractures, mainly parallel to the foliation, become steeper in the conglomerate. Some do not cross the unconformity, bench 355, west wall (G10), south is at the left.

Photo 20: N118° trending graphite-chlorite fracture, dipping north, with dip-slip striations. The drag folding of the foliation indicates a normal movement, bench 351, west wall, south is at the left.





Photo 21: Quartz vein along N110° graphite shear zone, bench 351, west wall (G19), south is at the left.

Photo 22: N110° trending graphite shear zone. Note the dip-slip striation and the drag folding of the foliation. A late subhorizontal fracture crosscuts the shear zone, same place as photo 21, south at the left.



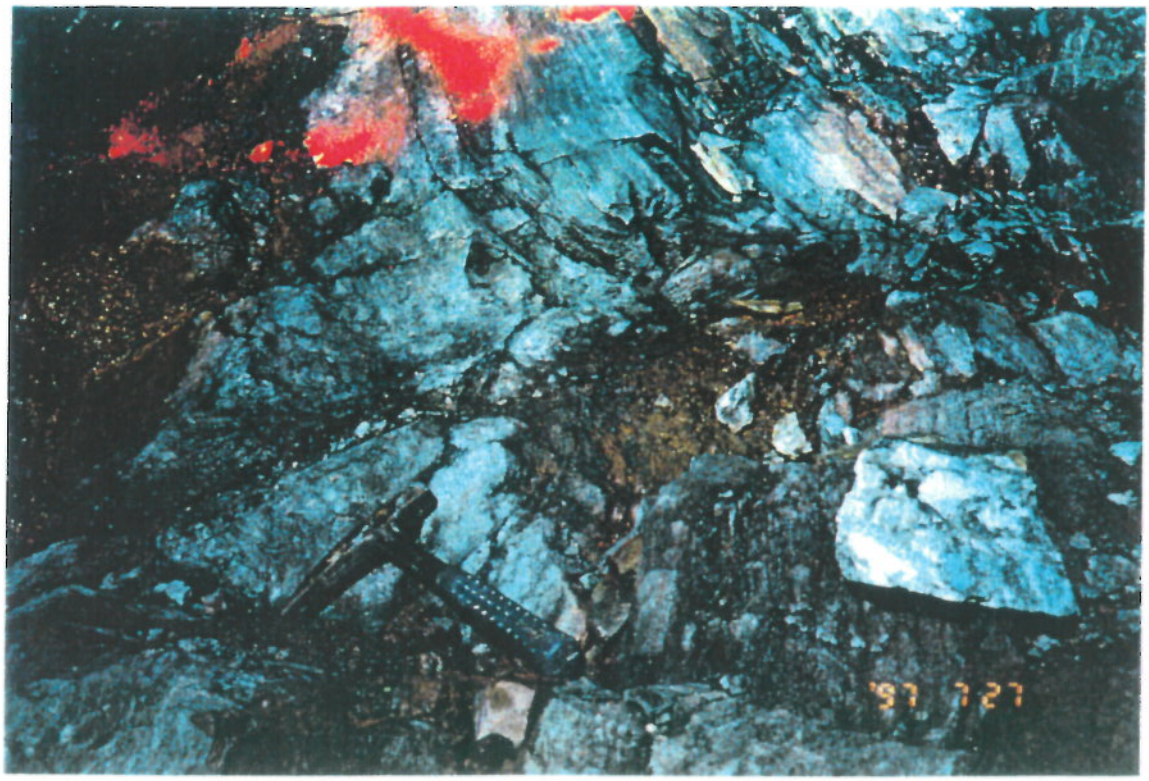


Photo 23: Shallow dipping ESE trending normal fracture, bench 351 (G19)



Photo 24 Drag folding of the foliation by a medium north dipping normal fracture
Note the bending of the foliation below the unconformity (right), bench 355-351, between G22 (left) and G20 (right)



Photo 25: West and North faces of JEB pit from point F40.

- ANNEX -

GEOTECHNICAL MAPPING DATA

Bench	Traverse name	Traverse orientation	Azimuth	Dip	Number /traverse	Alteration	Limonite	Roughn.	Structure	Comments
BENCH 397	A1-A2	170-04	40	6	2	6		1	JN	
			40	6	1	16		2	JN	
			35	70	1	16	L	2	FC	
			158	80	1	2	L	2	FC	
			35	70	3	2		1	FC	
	A2-A3	126-06	40	6	2	6		1	JN	
			160	78	2	17	L	2	FC	
			55	80	1	8		2	FC	
			280	70	1	2		2	FC	
			154	90	1	2		2	FC	
	A3-A4	142-05	40	6	1	16		1	JN	
			40	6	1	6		1	JN	
			40	6	1	2		1	JN	
			180	76	1	17	L	1	FC	
			85	54	2	8		1	FC	
			170	82	4	2		2	FC	
			164	80	3	8	L	2	FC	
			64	89	3	2		1	FC	
			94	90	2	2	L	2	FC	
	A4-A5	045-00	40	6	1	17		1	JN	
			28	15	2	8		1	FC	
			186	86	1	20		1	FC	
			265	68	1	17	L	1	FC	
			186	86	2	2		1	FC	
			265	69	3	2		1	FC	
			75	38	2	17	L	1	FC	
			42	90	2	17	L	2	FC	
			122	90	1	8	L	2	FC	
	A5-A6	175-08	232	84	3	8		2	FC	
			112	40	1	17		1	FC	
			40	6	1	2		1	JN	
			22	22	1	8		1	FC	
			244	84	1	6	L	1	FC	
			15	62	1	16	L	2	FC	
			60	90	3	1		2	FC	
			5	78	1	2		2	FC	
			353	88	2	2		1	FC	
			174	78	1	2	L	2	FC	
			170	80	1	2	L	1	FC	
			92	90	3	2	L	2	FC	
	A6-A7	005-03	40	6	1	17		2	JN	
			40	6	1	2		1	JN	
			132	62	1	2	L	2	FC	
			174	76	1	17	L	2	FC	
			32	70	1	16	L	2	FC	
			28	78	1	1		1	FC	
			100	90	4	1		2	FC	
			10	53	1	17	L	2	FC	
			188	70	1	2	L	2	FC	
			218	84	3	8		2	FC	
	A7-A8	155-02	137	74	1	17	L	1	FC	
			90	68	9	2		1	FC	
			224	80	2	1		1	FC	
			117	73	4	20	L	1	FC	hyd. br. column, 2m
	A8-A9	003-16	32	68	2	20	L	1	FC	sandy clay
			40	6	1	17		1	JN	
			79	78	1	6		1	FC	
			355	12	1	1		1	FC	
			40	80	8	6		1	FC	
			40	52	1	17	L	1	FC	
			40	60	1	2		1	FC	
			225	75	3	2		2	FC	
			80	66	3	8	L	1	FC	
			73	70	3	6		1	FC	
			48	62	1	2		2	FC	
			63	78	1	8		2	FC	
			70	78	1	8		1	FC	
			62	76	2	8		1	FC	
			225	82	4	2		2	FC	
			96	64	1	1		2	FC	
			67	63	1	17	L	2	FC	
			67	75	2	2		2	FC	
			90	68	2	20		1	FC	
			146	68	1	8		2	FC	
	A9-A10	135-00	45	85	4	17	L	1	FC	
			120	82	4	2	L	1	FC	
			330	85	1	17		1	FC	
			88	76	1	17		2	FC	
			50	76	8	17		2	FC	

Bench	Traverse name	Traverse orientation	Azimuth	Dip	Number /traverse	Alteration	Limonite	Rougth.	Structure	Comments
397	**A10-A11**	180-06	10	6	1	17		1	JN	
			82	80	1	20	L	1	FC	15 cm wide
			70	80	2	17	L	1	FC	
			172	88	1	17		1	FC	
			40	19	5	8		1	FC	
			152	65	2	8	L	1	FC	
			144	80	1	16	L	2	FC	
	A11-A12	017-03	87	7	1	2		1	JN	
			87	7	1	8		1	JN	
			83	68	3	2	L	2	FC	
			137	80	3	8		2	FC	
			300	83	4	2		2	FC	
			132	85	4	2	L	1	FC	
			317	88	1	17	L	1	FC	
			330	89	2	2		2	FC	
			318	82	1	2	L	2	FC	
			87	80	1	17	L	2	FC	
			250	88	2	2		1	FC	
			308	80	2	17	L	2	FC	
			165	78	1	2	L	2	FC	
			160	84	1	17	L	2	FC	
			85	87	1	17	L	2	FC	
	A12-A13	196-04	37	10	1	2		1	JN	
			150	80	10	2	L	2	FC	
			40	10	1	2		1	JN	
			135	90	4	2		2	FC	
			64	80	3	2	L	1	FC	
			128	80	3	20	L	2	FC	20 cm wide
			50	77	1	2	L	1	FC	
			83	81	1	6	L	2	FC	
			82	79	1	15	L	2	FC	
			80	70	2	16	L	2	FC	
	A13-A14	040-00	48	18	1	6		1	FC	
			176	90	1	8	L	2	FC	
			32	10	1	8		1	JN	
			140	85	1	2		1	FC	
			180	90	1	2	L	2	FC	
			68	77	1	2		1	FC	
			152	72	6	2	L	2	FC	
			140	90	1	2	L	1	FC	
			152	86	1	20	L	1	FC	5 cm wide
			125	90	1	17	L	1	FC	
			315	77	4	8	L	1	FC	
			68	90	1	1		2	FC	
			68	72	1	2	L	1	FC	
			64	68	2	2	L	2	FC	
			112	85	3	2		1	FC	
			315	80	1	2	L	2	FC	
	A14-A15	020-02	70	12	3	17	L	1	JN	
			40	76	3	2		2	FC	
			35	12	3	20	L	1	JN	hyd. br. lens, 1 m
			188	88	1	2	L	2	FC	
			300	68	1	1		1	FC	
			150	90	4	2	L	2	FC	
			325	85	4	2		2	FC	
			82	70	1	2		2	FC	
			248	60	2	1		2	FC	
			45	73	2	2		2	FC	
			92	72	2	8	L	2	FC	
	A15-A16	226-06	40	6	1	17		1	JN	
			44	62	2	2	L	2	FC	
			84	24	1	8		2	FC	
			168	84	2	2		2	FC	
			84	64	2	8		2	FC	
			142	82	3	2	L	2	FC	
			148	90	5	8		1	FC	
			336	84	1	20		1	FC	20 cm wide
	A16-A17	228-04	40	6	1	16	L	1	JN	
			54	76	1	2	L	1	FC	
			36	78	1	16	L	1	FC	
			160	82	7	17	L	1	FC	
			154	90	1	16	L	1	FC	
			338	84	1	2	L	2	FC	
	A17-A18	028-04	40	6	2	17		1	JN	
			40	6	1	8		2	JN	
			160	90	4	2	L	1	FC	
			330	79	2	17	L	1	FC	
			240	86	6	1		1	FC	
			150	84	3	17	L	1	FC	
			342	80	3	20		2	FC	hyd. br. column, 1m
			58	80	2	20		2	FC	
			142	90	2	20	L	2	FC	hyd. br. column, 50 cm

Bench	Traverse name	Traverse orientation	Azimuth	Dip	Number /traverse	Alteration	Limonite	Rougth.	Structure	Comments
397	**A18-A19**	037-08	208	76	1	20	L	1	FC	
			110	88	2	17	L	2	FC	
			146	90	1	1		2	FC	
			252	88	3	2	L	2	FC	
			158	82	10	20	L	1	FC	1.5 m wide
			109	74	2	20	L	2	FC	hyd. br. column, 15 cm
			164	60	1	17		2	FC	
			172	90	1	8		2	FC	
			163	90	1	20	L	1	FC	hyd. br. column, 1m
			75	90	1	20	L	2	FC	
			342	86	1	20		1	FC	sandy clay
			80	6	1	6		1	JN	
			80	6	1	8		1	JN	
			80	6	1	17		1	JN	
	A19-A20	236-10	246	10	1	16		1	JN	
			246	10	3	8		2	JN	
			246	10	2	17	L	1	JN	
			114	64	2	20		2	FC	
			334	70	1	17	L	1	FC	
			355	85	1	17		1	FC	
			148	66	1	8	L	1	FC	
			10	82	1	8	L	2	FC	
			92	72	6	20	L	2	FC	hyd. br. column,30-50 cm
			340	88	1	20		1	FC	sandy clay
			0	80	1	17	L	2	FC	
			62	76	1	17		1	FC	
			192	80	4	8		2	FC	
			202	80	1	2	L	2	FC	
			202	80	1	20	L	1	FC	2m wide, curve
			284	85	3	2	L	2	FC	
			359	76	2	2	L	2	FC	
	A20-A21	045-08	230	20	1	16		1	FC	wet sandy clay
			92	6	1	8		2	JN	
			92	6	1	16		1	JN	
			259	76	1	2	L	2	FC	
			85	66	3	2	L	2	FC	
			8	86	2	2	L	2	FC	
			34	44	4	8	L	2	FC	
			46	48	1	17	L	2	FC	
			162	68	1	17	L	2	FC	
			268	40	2	17	L	2	FC	
			68	60	1	8	L	2	FC	
			335	86	1	20	L	2	FC	
			288	84	1	2	L	2	FC	
			176	74	3	2	L	2	FC	
			94	72	1	2	L	2	FC	
			350	76	1	8	L	2	FC	
			120	62	2	8		2	FC	
			56	66	1	8	L	1	FC	
			174	78	1	20	L	2	FC	10 cm wide
			132	66	1	8	L	2	FC	
	A21-A22	250-05	0	0	2	8		1	JN	
			93	66	2	8	L	1	FC	
			93	66	1	16	L	1	FC	
			168	84	1	8		2	FC	
			50	68	5	2	L	1	FC	
			12	64	1	2	L	2	FC	
			176	74	1	1		1	FC	
			148	82	3	17	L	1	FC	
	A22-A23	242-04	210	24	1	8		2	FC	
			352	82	2	1		2	FC	
			99	75	3	8	L	1	FC	
			334	80	1	17	L	2	FC	
			86	25	1	17	L	1	FC	
			82	54	2	2	L	1	FC	
			84	52	2	17		1	FC	
			155	72	1	8		2	FC	
			79	60	1	8	L	2	FC	
			79	60	2	17		1	FC	
			162	61	2	6	L	1	FC	
			212	80	1	2	L	2	FC	
			110	70	2	8	L	2	FC	
			83	66	3	20	L	1	FC	hyd. br. column, sandy clay
			154	69	1	20		1	FC	
			110	64	1	16		1	FC	
	A23-A24	254-02	332	6	1	6		1	JN	wet
			130	3	1	16		1	JN	wet
			198	70	3	17	L	1	FC	wet
			288	55	3	17	L	1	FC	
			268	60	1	16	L	1	FC	
			165	64	1	8		1	FC	
			89	62	1	16	L	1	FC	
			142	78	5	2		1	FC	

Bench	Traverse name	Traverse orientation	Azimuth	Dip	Number /traverse	Alteration	Limonite	Rougth.	Structure	Comments
397	**A23-A24**	254-02	186	60	2	16		1	FC	
			139	78	1	8		2	FC	
			92	80	2	2		2	FC	
			197	72	2	8		1	FC	
			118	68	3	17		1	FC	
			118	68	1	16	L	1	FC	
			323	79	1	2	L	1	FC	
			161	80	3	2	L	2	FC	
			110	68	1	16		1	FC	
			215	80	4	2	L	2	FC	
			132	74	4	2	L	2	FC	
			154	76	2	8		2	FC	
			154	76	1	16	L	2	FC	
	A24-A25	257-04	273	2	1	15		1	JN	wet, brownish clay
			120	62	1	17	L	1	FC	
			120	62	1	8	L	1	FC	
			188	74	1	17		2	FC	
			114	76	7	8		2	FC	
			180	80	2	2	L	2	FC	
			254	83	1	2	L	2	FC	
			108	68	2	16	L	1	FC	
			108	68	3	2	L	2	FC	
			307	78	1	5		1	FC	
			100	56	5	6		2	FC	
			132	76	1	20		1	FC	
	A25-A26	263-02	311	5	1	6		2	JN	
			110	68	3	8		2	FC	
			328	55	1	2		2	FC	
			207	80	2	8		2	FC	
			142	68	1	17	L	1	FC	
			158	90	2	20	L	1	FC	
			120	76	2	8		1	FC	
			120	76	1	5		1	FC	
	A26-A27	264-02	187	4	1	8		1	JN	
			104	90	1	8	L	1	FC	
			82	52	1	14		1	FC	brown clay, 2 cm
			188	64	2	1		2	FC	
			112	83	2	2	L	1	FC	
	A27-A28	067-08	0	0	1	16		1	JN	
			2	7	2	8		1	FC	
			102	73	1	6	L	1	NFT	dip-slip striae, quartz, clay
			303	80	2	6	L	2	FC	
			27	82	3	8		2	FC	
			335	72	3	1		2	FC	
	A28-A29	58-02	292	66	1	17	L	1	NFT	striae pitch 82W, quartz, clay
			3	4	1	6		1	JN	
			334	84	3	2	L	1	FC	
			224	86	1	1		2	FC	
			62	72	1	8		2	FC	
			152	80	2	17		1	FC	
			122	74	1	17	L	1	FT	striae pitch 85W, clay, wet sand
			127	80	1	1		2	FC	
			325	84	4	20	L	1	FC	1m wide
			126	84	2	8		1	FC	
	A29-A30	261-00	24	10	1	16		1	FC	
			24	10	1	1		1	FC	
			302	88	4	1		1	FC	
			37	48	1	1		2	FC	
			65	72	1	2	L	2	FC	
			320	82	1	8		2	FC	
			103	70	1	6	L	2	FC	
			258	68	1	8	L	1	FC	
	A30-A31	266-06	41	8	1	8		1	FC	
			162	85	2	2	L	1	FC	
			306	85	1	8	L	2	FC	
			82	78	1	2	L	2	FC	
			235	88	2	8		2	FC	
			330	82	1	1		2	FC	
			160	70	2	8		2	FC	
			312	82	2	17	L	1	FC	
			91	90	3	8		1	FC	
			91	90	1	17	L	1	FC	
	A31-A32	113-02	308	82	1	20	L	1	FC	50 cm wide
			312	85	1	8	L	1	FC	
			281	78	1	20		1	FC	sandy clay
			136	88	1	8	L	1	FC	
			299	78	2	16	L	1	FC	
			83	90	2	6		1	FC	
			233	88	2	1		2	FC	

Bench	Traverse name	Traverse orientation	Azimuth	Dip	Number /traverse	Alteration	Limonite	Rougth.	Structure	Comments
397	**A32-A33**	096-02	312	10	1	17		1	JN	
			128	85	4	1		1	FC	
			207	90	3	6		2	FC	
			270	72	5	17	L	2	FC	
			245	70	2	8	L	2	FC	
			138	80	1	8		1	FC	
			122	74	1	20	L	1	FC	
	A33-A34	083-00	168	8	3	8		2	JN	
			130	67	1	20	L	1	FC	1m wide
			237	88	2	1		2	FC	
			133	80	1	17	L	1	FC	
			133	80	3	8	L	1	FC	
			67	77	3	2	L	2	FC	
			30	82	2	1		2	FC	
			293	80	1	1		2	FC	
			172	85	1	8		1	FC	
			321	60	1	6		2	FC	
			127	15	2	16	L	1	FC	wet sandy clay, 5 cm
	A34-A35	265-04	55	5	2	8		1	JN	
			362	88	1	1		1	FC	
			121	85	2	8		1	FC	
			64	78	1	8		2	FC	
			322	77	1	8		2	FC	
			370	88	1	17	L	2	FC	
			217	82	5	1		2	FC	
			217	82	1	17		2	FC	
			217	82	1	8		2	FC	
			350	80	2	2	L	2	FC	
			260	68	2	2	L	2	FC	
			35	60	2	16	L	1	FC	
	A35-A36	296-02	150	2	1	8		1	JN	
			161	74	5	2	L	2	FC	
			64	80	1	6	L	2	FC	
			24	72	1	17	L	2	FC	
			62	80	1	1		1	FC	
			347	86	9	2	L	2	FC	
			68	85	1	16	L	1	FC	
			63	82	7	6	L	1	FC	
			76	86	1	17	L	1	FC	
	A36-A37	112-02	160	6	1	17		1	JN	
			286	81	2	17	L	1	FC	curve
	A37-A38	104-12	312	12	1	8		1	JN	
			4	85	1	17	L	1	FC	
			358	73	1	8		1	FC	
	A38-A39	322-10	136	25	4	17		1	FC	
			190	82	7	2	L	2	FC	
			112	90	3	2	L	1	FC	
			131	70	3	8	L	1	FC	
	A39-A40	123-10	158	54	2	8		2	FC	
			94	82	5	17	L	1	FC	
			90	65	2	8		2	FC	
			118	64	1	20	L	1	FC	50 cm wide
			260	74	1	8	L	2	FC	
	A40-A41	321-09	154	48	2	8	L	1	FC	
			92	90	2	8	L	2	FC	
			138	88	1	8	L	2	FC	
			168	38	4	8		2	FC	
			289	81	2	17	L	2	FC	
			181	55	1	8	L	2	FC	
			181	55	2	17	L	1	FC	
			279	86	3	8	L	1	FC	
			266	45	1	16		1	FC	
			169	68	4	20	L	1	FC	1m wide, clay
			256	70	2	2	L	2	FC	
	A41-A42	319-08	17	20	1	17		1	JN	
			17	20	2	8	L	1	JN	
			265	56	2	17	L	1	FC	
			265	56	2	2	L	1	FC	
			162	68	2	20	L	1	FC	sandy clay
			108	86	1	20	L	1	FC	
			108	86	3	1		2	FC	
			182	82	4	2	L	1	FC	
			270	49	3	2		1	FT	dip-slip striae.,quartz
			274	67	1	20	L	1	FT	10 cm wide
			297	72	5	8		1	FC	
			322	54	1	2		1	FT	striae pitch 70E, quartz
			122	90	2	6	L	1	FT	striae pitch 84W, quartz
			265	76	4	8		1	FC	
			317	12	1	17		1	JN	
			145	17	2	8	L	1	FC	

Bench	Traverse name	Traverse orientation	Azimuth	Dip	Number /traverse	Alteration	Limonite	Rougth.	Structure	Comments
397	**A42-A43**	346-02	5	74	2	2	L	1	FC	
			251	74	1	20	L	1	FC	discontinuous lenses, 10 cm
			4	84	1	17	L	2	FC	
			230	76	2	17	L	1	FC	
			50	80	2	17	L	1	FC	
			156	85	3	8	L	1	FC	
			214	82	4	8	L	1	FC	
			0	0	1	16		1	JN	
			0	0	1	6		1	JN	
	A43-A44	157-02	0	0	1	6		1	JN	
			23	86	3	8	L	1	FC	
			140	72	2	8	L	1	FC	
			137	85	1	20	L	1	FC	
			78	82	1	2	L	1	FC	
	A44-A45	142-00	141	1	1	17	L	1	JN	
			226	75	5	17	L	1	FC	
			266	90	1	1	L	1	FC	
			221	72	2	20		1	FC	
			98	82	1	8	L	1	FC	
	A45-A46	136-05	141	1	2	17	L	1	JN	
			276	80	1	6	L	2	FC	
			230	80	2	17	L	1	FC	
			34	86	2	8		1	FC	
			141	3	1	8	L	1	JN	
	A46-A47	352-02	57	90	1	8		2	FC	
			140	84	2	8	L	1	FC	
			191	76	1	17		1	FC	
			65	80	1	2	L	2	FC	
			233	84	1	20	L	1	FC	
			94	63	3	8	L	2	FC	
			141	3	1	8		1	JN	
			106	70	5	6	L	2	FC	
			229	82	1	17		1	FC	
			32	50	1	16	L	2	FC	
			144	85	2	8	L	1	FC	
			260	12	1	17	L	1	JN	
			260	12	1	6		1	JN	
	A47-A48	108-02	162	13	2	16	L	1	JN	
			56	78	1	8		2	FC	
			53	78	1	8	L	2	FC	
			152	90	5	17	L	1	FC	
			233	78	2	17	L	1	FC	
			75	82	1	17		1	FC	
			141	2	1	16		1	JN	
			73	88	2	1		1	FC	
			248	89	2	16	L	1	FC	
			248	89	1	17	L	1	FC	
			204	80	1	6	L	1	FC	
	A48-A49	175-03	60	86	3	8		1	FC	
			85	76	1	8		2	FC	
			34	67	1	17	L	1	FC	
			34	67	1	8		1	FC	
			306	80	4	8		1	FC	
			241	81	1	6		1	FC	
			199	88	1	17		1	FC	
			76	80	5	17		1	FC	
			76	80	1	20		1	FC	hyd. br. pocket, 3m
			132	90	1	17	L	1	FC	
			244	79	2	8		1	FC	
			350	85	1	1		1	FC	
			243	86	1	17	L	1	FC	
			181	8	1	17		1	JN	
	A49-A50	011-08	226	86	1	17	L	1	FC	
			334	74	5	17		1	FC	
			334	74	1	20	L	1	FC	hyd. br. column, 1m/30 cm
			64	72	2	20	L	1	FC	
			344	85	2	17		1	FC	
			248	87	1	8		2	FC	
			208	4	2	8	L	1	JN	
			44	86	1	2	L	2	FC	
			320	59	2	2	L	1	FC	
	A50-A51	321-02	17	74	2	2	L	2	FC	
			326	72	1	2	L	1	FC	
			122	90	1	1		2	FC	
			50	88	2	8		1	FC	
			50	88	1	17		1	FC	
			236	82	1	17	L	1	FC	
			57	80	2	8		1	FC	
			288	80	3	8	L	1	FC	
			89	87	1	17	L	1	FC	

Bench	Traverse name	orientation	Azimuth	Dip	Number /traverse	Alteration	Limonite	Rougth.	Structure	Comments
397	**A51-A52**	184-08	0	0	1	17		1	JN	
			238	88	2	8		1	FC	
			322	40	4	17		1	FC	
			342	69	1	8	L	1	FC	
			230	81	3	17		1	FC	
			230	81	1	20		1	FC	10 cm wide
			216	6	1	6		1	JN	
			35	82	1	20		1	FC	
			55	85	1	20		1	FC	
			303	90	1	20		1	FC	hyd. br. column
	A52-A53	022-05	44	84	1	20		1	FC	
			44	84	2	17		1	FC	
			169	90	4	8		1	FC	
			83	77	2	17	L	1	FC	
			83	77	2	8		1	FC	
			154	80	1	20	L	1	FC	hyd. br. column, 1m
			59	70	4	20	L	1	FC	
			59	70	1	6	L	1	FC	
			59	70	6	2	L	1	FC	
			59	70	1	8	L	1	FC	
			163	76	6	2	L	1	FC	
			142	72	2	8		1	FC	
			54	82	1	6	L	1	FC	
			209	7	1	8		1	JN	
	A53-A54	209-02	50	77	2	1		2	FC	
			232	80	1	17	L	1	FC	
			150	68	4	1		1	FC	
			58	74	2	17	L	1	FC	
			179	80	1	2	L	1	FC	
			179	80	2	17	L	1	FC	
			162	84	2	2	L	2	FC	
			162	84	1	17	L	1	FC	
			55	90	1	8		2	FC	
			76	70	1	20	L	1	FC	
			180	5	1	8		1	JN	
			175	87	3	1		1	FC	
			226	84	3	8		1	FC	
			155	75	1	8		1	FC	
	A54-A55	021-00	227	86	3	2	L	1	FC	
			141	84	1	17	L	1	FC	
			141	84	1	8	L	1	FC	
			152	76	1	6		2	FC	
			147	80	1	17	L	1	FC	
			64	85	1	2	L	1	FC	
			180	85	1	1		2	FC	
			86	77	2	2	L	1	FC	
			222	4	1	6	L	1	JN	
	A55-A56	048-04	337	87	1	1		2	FC	
			152	83	2	2	L	1	FC	
			68	75	1	2	L	1	FC	
			332	74	1	20	L	1	FC	10 cm wide
			57	80	1	1		2	FC	
			155	90	1	1		1	FC	
			80	70	2	6	L	2	FC	
			150	76	2	2	L	2	FC	
			344	79	1	20	L	1	FC	
			150	82	1	6	L	1	FC	
			160	86	1	20	L	1	FC	30 cm wide
			314	86	1	6	L	1	FC	
			82	86	1	8	L	2	FC	
			222	4	1	8		1	JN	
	A56-A57	047-05	69	90	2	8		2	FC	
			150	84	1	6	L	1	FC	
			68	85	1	8	L	1	FC	
			156	90	1	17		2	FC	
			151	86	1	1		2	FC	
			59	82	2	2	L	1	FC	
			319	87	1	8	L	1	FC	
	A57-A58	050-02	61	81	1	2	L	2	FC	
			343	82	3	20	L	1	FC	
			53	84	3	8	L	1	FC	
			53	84	1	17	L	1	FC	
			343	82	8	2	L	1	FC	
			343	82	2	8	L	1	FC	
			53	84	2	2	L	1	FC	
	A58-A59	055-02	59	87	2	1		1	FC	
			138	78	4	6	L	1	FC	
			138	78	1	8	L	1	FC	
	A59-A60	066-02	70	76	2	17	L	1	FC	
			139	82	2	8	L	2	FC	

Bench	Traverse name	Traverse orientation	Azimuth	Dip	Number /traverse	Alteration	Limonite	Rougth.	Structure	Comments
373	**B5-B6**	060-05	170	80	1	17	L	1	FC	
			112	81	1	2	L	2	FC	
			72	67	1	17	L	1	FC	
			159	88	6	2	L	2	FC	
			155	88	5	17	L	1	FC	
			155	88	7	8	L	1	FC	
			74	88	1	20	L	1	FC	
			44	86	1	20	L	1	FC	50 cm wide
	B6-B7	245-08	150	90	1	2	L	2	FC	
			136	82	2	17	L	1	FC	
			63	70	1	20	L	1	FC	
			148	77	1	8	L	1	FC	
			88	78	1	16	L	1	FC	
			210	4	2	8	L	1	JN	
	B7-B8	243-03	127	80	1	2	L	1	FC	
			152	85	1	2	L	1	FC	
			121	76	1	8	L	1	FC	
			66	74	1	20	L	1	FC	
	B8-B9	099-06	210	4	3	8		1	JN	
			210	4	1	17		1	JN	
			105	76	1	17		1	FC	
			68	82	2	17	L	1	FC	
			145	83	4	8	L	1	FC	
			147	79	2	17	L	1	FC	
			265	83	2	17	L	1	FC	
			140	75	1	2	L	1	FC	
	B9-B10	103-04	236	85	2	8	L	2	FC	
			132	76	1	8		1	FC	
			233	88	1	20	L	1	FC	
			233	88	3	8		2	FC	
			122	73	1	17		1	FC	
			58	83	1	8	L	1	FC	
	B10-B11	125-12	136	79	2	8	L	1	FC	
			44	86	4	17		1	FC	
			62	88	1	20	L	1	FC	
			62	88	1	8		1	FC	
			41	73	1	17	L	1	FC	
			53	83	2	8	L	1	FC	
			53	83	2	17	L	1	FC	
			132	84	1	8	L	1	FC	
			252	2	1	16		1	JN	
			252	2	1	8		1	JN	
	B11-B12	150-03	125	76	3	8	L	1	FC	
			240	87	2	17	L	1	FC	
			51	82	4	17	L	1	FC	
			51	82	1	20	L	1	FC	hyd. br. column, 2m
			139	78	2	20	L	1	FC	
			52	88	8	17	L	1	FC	
			52	88	1	20	L	1	FC	
			175	86	2	8	L	1	FC	
			136	79	2	8	L	1	FC	
			63	85	3	8		1	FC	
			252	2	1	8		1	JN	
	B12-B13	121-03	162	81	2	8	L	1	FC	
			72	90	1	8	L	1	FC	
			183	89	2	8		2	FC	
			142	74	1	17	L	1	FC	
			79	77	1	8		2	FC	
			352	80	1	8		1	FC	
			42	82	2	17	L	1	FC	
			137	87	1	8		1	FC	
			70	81	1	8	L	2	FC	
			135	78	3	8	L	1	FC	
			89	76	1	8		1	FC	
			79	75	1	17	L	1	FC	
			254	2	1	8		1	JN	
	B13-B14	105-05	156	90	2	1		2	FC	
			75	90	5	1		2	FC	
			81	86	3	1		1	FC	
			181	85	4	2	L	1	FC	
			131	81	3	1		1	FC	
			46	82	3	2	L	1	FC	
			360	85	2	17	L	2	FC	
			61	88	1	17	L	2	FC	
			34	81	5	6		1	FC	
			34	81	1	16		1	FC	
			254	2	1	17	L	1	JN	

Bench	Traverse name	Traverse orientation	Azimuth	Dip	Number /traverse	Alteration	Limonite	Rougth.	Structure	Comments
359	**C8-C9**	184-03	48	76	1	8	L	1	FC	
			130	81	1	20	L	1	FC	10 cm wide, sandy clay
			262	88	1	16	L	1	FC	
			127	90	1	16	L	1	FC	
			64	90	1	8	L	1	FC	
			142	82	2	16	L	1	FC	
			335	88	2	8	L	1	FC	
			247	90	1	2	L	1	FC	
			72	80	1	2	L	1	FC	
			286	86	2	2	L	1	FC	
	C9-C10	160-00	290	85	2	17		1	FC	
			314	70	1	16	L	1	FC	
			314	70	2	8	L	1	FC	
			203	83	1	2	L	1	FC	
			131	90	1	2	L	1	FC	
			83	82	1	1		1	FC	
			323	90	2	2	L	1	FC	
			22	78	2	8	L	1	FC	
	C10-C11	156-04	38	76	1	1		2	FC	
			326	85	3	2	L	1	FC	
			320	82	1	17	L	1	FC	
			68	90	1	8	L	2	FC	
			113	83	1	17	L	1	FC	
			30	90	1	2	L	2	FC	
	C11-C12	327-04	23	82	1	2	L	2	FC	
			291	88	4	8	L	1	FC	
			5	76	1	1		2	FC	
			107	90	1	16	L	1	FC	
			116	78	1	20	L	1	FC	30 cm wide
			26	82	1	2	L	2	FC	
			299	76	1	6	L	1	FC	
			151	7	1	8	L	1	JN	
	C12-C13	334-12	15	88	1	1		1	FC	
			19	90	1	8	L	2	FC	
			40	88	2	8	L	1	FC	
			142	90	1	2	L	1	FC	
			186	80	1	8	L	2	FC	
			274	74	1	16	L	1	FC	
			166	90	1	8	L	2	FC	
			35	80	1	8	L	2	FC	
			314	81	1	8	L	2	FC	
			96	58	1	8	L	2	FC	
			16	85	1	8	L	1	FC	
			262	84	1	17	L	1	FC	
			104	88	1	17	L	1	FC	
			146	4	2	8	L	1	JN	
			146	4	1	16	L	1	JN	
	C13-C14	140-02	88	78	4	2	L	2	FC	
			10	81	1	2	L	2	FC	
			342	80	1	8	L	1	FC	
			270	88	2	8	L	2	FC	
			313	76	1	8	L	1	FC	
			16	85	1	8		2	FC	
			313	76	1	17	L	1	FC	
			263	79	1	8	L	1	FC	
			167	80	1	2	L	1	FC	
			0	15	1	8		1	JN	
	C14-C15	124-10	354	90	3	8	L	1	FC	
			270	80	2	8	L	1	FC	
			24	76	1	2	L	2	FC	
			317	81	1	2	L	2	FC	
			192	86	1	1		2	FC	
			297	76	1	8	L	1	FC	
			268	84	1	8	L	1	FC	
			150	76	2	1		2	FC	
			270	72	1	2	L	1	FC	
			357	84	1	1		2	FC	
			338	79	2	8		1	FC	
			83	90	2	8		1	FC	
			110	6	1	17	L	1	JN	
	C15-C16	111-06	244	80	1	8	L	1	FC	
			130	85	2	17	L	1	FC	
			141	90	1	8	L	2	FC	
			142	5	1	17	L	1	JN	
			245	88	1	8	L	1	FC	
	C16-C17	270-06	75	82	1	2	L	1	FC	
			200	86	1	1		2	FC	
			102	88	1	8	L	1	FC	
			134	90	1	1		2	FC	
			119	76	1	8	L	1	FC	
			35	79	2	8	L	2	FC	

Bench	Traverse name	Traverse orientation	Azimuth	Dip	Number /traverse	Alteration	Limonite	Rougth.	Structure	Comments
421	**F10-F11**	108-02	190	84	1	2	L	2	FC	
			306	76	1	8	L	1	FC	
			102	90	1	2	L	1	FC	
			102	90	1	17	L	1	FC	
			42	78	2	8	L	1	FC	
			42	78	2	17	L	1	FC	
			42	78	2	2		2	FC	
			298	6	1	17	L	1	JN	
			242	5	1	8		1	JN	
	F11-F12	274-08	320	83	3	2	L	1	FC	
			320	83	1	8	L	1	FC	
			66	82	1	2	L	2	FC	
			85	87	1	2	L	1	FC	
			68	85	2	2	L	1	FC	
			140	87	2	8	L	1	FC	
			140	87	2	1		1	FC	
			140	87	1	20	L	1	FC	discontinuous hyd. br., 15 cm
			138	70	1	17	L	1	FC	
			281	5	1	8		1	JN	
			281	5	2	1		1	JN	
	F12-F13	107-00	175	85	2	8	L	1	FC	
			175	85	1	1		1	FC	
			70	71	1	17	L	1	FC	
			86	80	2	8	L	1	FC	
			57	61	3	1		1	FC	
			57	61	1	2	L	1	FC	
			140	82	2	8	L	1	FC	
			140	82	5	2	L	1	FC	
			69	71	5	2	L	1	FC	
			281	5	2	8	L	1	JN	
	F13-F14	108-01	155	80	1	1		1	FC	
			155	80	2	8	L	1	FC	
			184	80	1	8	L	2	FC	
			76	75	1	2	L	1	FC	
			147	86	2	8	L	1	FC	
			147	86	1	17	L	1	FC	
			63	70	2	8	L	1	FC	
			148	80	6	8		1	FC	
			148	80	2	2	L	1	FC	
			68	65	4	2	L	1	FC	
			201	5	2	8		1	JN	
	F14-F15	106-03	305	81	1	17	L	1	FC	
			142	86	4	8	L	1	FC	
			142	86	1	17	L	1	FC	
			49	80	2	2	L	1	FC	
			49	80	1	1		1	FC	
			54	75	1	8	L	1	FC	
			54	75	1	17	L	1	FC	
			167	30	2	8	L	1	FC	
			153	24	4	6		1	FC	
			146	58	2	8	L	2	FC	
	F15-F16	112-02	145	84	3	17		1	FC	
			145	84	3	1		1	FC	
			60	79	3	17	L	1	FC	
			60	79	4	1		1	FC	
			60	79	3	8	L	1	FC	
			15	81	1	8		2	FC	
	F16-F17	135-02	57	63	3	17	L	1	FC	
			57	63	6	8	L	1	FC	
			57	63	2	1		1	FC	
			152	86	5	17		1	FC	
			152	86	1	17	L	1	FC	
			152	86	4	8		1	FC	
			165	85	3	8		2	FC	
			34	80	1	1		2	FC	
			327	3	1	8		1	JN	
	F17-F18	305-02	160	86	1	17	L	1	FC	
			160	86	2	8	L	1	FC	
			140	88	5	8	L	1	FC	
			140	88	1	17	L	1	FC	
			64	64	6	2	L	1	FC	
			64	64	2	8	L	1	FC	
			84	86	1	2	L	1	FC	
			72	32	1	17	L	1	FC	
	F18-F19	301-04	150	82	5	8	L	1	FC	
			150	82	1	17	L	1	FC	
			150	82	2	1		2	FC	
			275	85	1	1		2	FC	
			94	77	1	1		2	FC	
			85	75	3	8		1	FC	
			66	85	1	1		1	FC	

Bench	Traverse name	Traverse orientation	Azimuth	Dip	Number /traverse	Alteration	Limonite	Rougth.	Structure	Comments
421	F25-F26	135-02	130	75	1	1		1	FC	
			277	88	1	8		1	FC	
			165	77	1	2	L	2	FC	
			171	54	1	2	L	1	FC	
			65	64	1	8	L	1	FC	
			291	81	1	8	L	2	FC	
			71	63	1	8	L	2	FC	
			274	64	1	17		2	FC	
			274	64	1	1		2	FC	
			146	90	2	1		1	FC	
			284	81	1	6		1	FC	
			36	45	1	6		1	FC	
			102	74	1	1		1	FC	
			49	4	1	1		1	JN	
	F26-F27	329-03	155	84	1	2	L	1	FC	
			38	73	1	17	L	1	FC	
			38	73	1	8	L	1	FC	
			114	89	1	2	L	1	FC	
			106	85	2	1		1	FC	
			154	89	1	8		2	FC	
			45	73	1	1		1	FC	
			37	59	1	8		1	FC	
			49	4	1	8		1	JN	
	F27-F28	160-02	55	62	1	17	L	1	FC	
			55	62	2	8		1	FC	
			154	82	1	8	L	1	FC	
			136	86	2	2	L	1	FC	
			214	56	1	2	L	1	FC	
			130	90	1	2	L	1	FC	
			148	81	3	2	L	1	FC	
			34	46	3	8	L	1	FC	
			148	83	1	2	L	1	FC	
			99	4	1	6		1	JN	
	F28-F29	330-02	51	68	1	8	L	1	FC	
			42	3	4	8	L	1	JN	
			44	52	1	17	L	1	FC	
	F29-F30	161-00	241	74	1	1		2	FC	
			234	64	1	2	L	1	FC	
			46	70	1	17	L	1	FC	
			310	86	1	8	L	1	FC	
			54	76	1	2	L	1	FC	
	F30-F31	000-06	52	76	1	1		1	FC	
			52	76	2	8	L	1	FC	
			333	89	2	1		1	FC	
			333	89	3	2	L	1	FC	
			268	86	2	2	L	1	FC	
			301	87	1	2	L	1	FC	
			59	66	1	17		2	FC	
			308	83	1	17		1	FC	
			45	86	1	8	L	1	FC	
			330	87	3	2	L	1	FC	
			106	90	2	8	L	1	FC	
			290	84	2	2	L	2	FC	
			330	3	1	17	L	1	JN	
			280	84	1	2	L	1	FC	
	F31-F32	156-02	287	78	1	17	L	1	FC	
			287	78	2	8		1	FC	
			60	80	1	8	L	1	FC	
			275	84	1	17	L	1	FC	
			47	78	1	8	L	1	FC	
			144	84	2	17	L	1	FC	
			144	84	1	8	L	1	FC	
			65	82	1	8	L	1	FC	
			47	62	1	16	L	1	FC	
			72	79	2	17	L	1	FC	
			72	79	2	8	L	1	FC	
			138	85	1	6	L	1	FC	
			42	86	1	17	L	1	FC	
			166	90	1	8	L	1	FC	
	F32-F33	345-04	72	73	1	20	L	2	FC	
			59	80	1	20	L	2	FC	10 cm wide
			136	75	1	2	L	2	FC	
			58	78	1	8		1	FC	
			69	78	1	17	L	1	FC	
			69	78	1	8		1	FC	
			131	88	2	2	L	2	FC	
			38	90	1	1		2	FC	
			114	90	1	8	L	1	FC	
			72	89	1	2	L	1	FC	
			110	90	1	2	L	1	FC	
			63	86	1	8	L	1	FC	
			227	86	2	1		2	FC	

Bench	Traverse name	Traverse orientation	Azimuth	Dip	Number /traverse	Alteration	Limonite	Rougth.	Structure	Comments
421	**F40-F41**	020-12	162	82	1	8		1	FC	
			86	90	1	2		1	FC	
			159	77	3	17	L	1	FC	
			282	87	1	2	L	1	FC	
			218	86	1	2	L	1	FC	
			336	88	1	8	L	1	FC	
			158	82	3	8	L	1	FC	
			158	82	1	20	L	1	FC	5-10 cm wide
			280	84	1	8	L	1	FC	
			262	80	3	8	L	1	FC	
			262	80	1	17	L	1	FC	
			166	80	1	2	L	1	FC	
			112	5	2	8		1	JN	
	F41-F42	228-03	276	76	1	2	L	1	FC	
			268	85	1	17	L	1	FC	
			348	80	1	17	L	1	FC	
			348	80	2	2	L	1	FC	
			54	77	1	17	L	1	FC	
			274	80	1	8	L	1	FC	
			354	89	1	2	L	1	FC	
			354	89	1	17	L	1	FC	
			284	80	1	17	L	1	FC	
			158	88	1	8	L	1	FC	
			307	85	1	8		1	FC	
			307	85	1	17	L	1	FC	
			344	80	1	8	L	1	FC	
			266	82	1	17	L	1	FC	
			266	82	1	1		1	FC	
			165	90	1	2	L	1	FC	
	F42-F43	044-05	345	88	2	2	L	2	FC	
			312	86	1	17	L	1	FC	
			263	85	3	2	L	1	FC	
			263	85	1	17	L	1	FC	
			353	80	2	17	L	1	FC	
			353	80	1	8	L	2	FC	
			353	80	1	2	L	2	FC	
			308	80	1	2	L	1	FC	
			303	86	1	8		2	FC	
			272	74	1	2	L	2	FC	
			266	79	4	2	L	1	FC	
			324	84	1	8	L	1	FC	
			23	86	1	1		1	FC	
			259	77	2	17	L	1	FC	
			47	4	1	8	L	1	JN	
	F43-F44	239-08	259	87	3	2	L	1	FC	
			166	83	2	1		2	FC	
			264	86	1	2		2	FC	
			293	79	1	8		2	FC	
			223	90	1	2	L	2	FC	
			156	80	1	17	L	1	FC	
			253	81	2	2	L	1	FC	
			159	87	1	2	L	2	FC	
			159	87	1	17	L	1	FC	
			29	72	2	1		2	FC	
			110	64	1	8		1	FC	
	F44-F45	230-02	133	52	1	2		2	FC	
			25	86	4	8		2	FC	
			88	60	1	8	L	1	FC	
			61	84	1	2	L	2	FC	
			98	68	1	2		1	FC	
			230	84	1	1		1	FC	
			164	76	1	1		2	FC	
			334	88	2	2	L	1	FC	
			346	82	1	2	L	2	FC	
			70	90	1	2	L	1	FC	
			170	76	1	1		2	FC	
			93	90	1	2	L	2	FC	
			348	82	1	8	L	1	FC	
			348	82	1	1		2	FC	
			254	9	1	1		1	JN	
	F45-F46	233-03	60	86	1	2	L	1	FC	
			224	86	1	2	L	2	FC	
			193	89	1	2		2	FC	
			174	85	1	8	L	1	FC	
			90	90	1	1		2	FC	
			72	83	2	2	L	1	FC	
			175	88	1	2	L	2	FC	
			150	90	1	8		2	FC	
			86	64	1	2	L	2	FC	
			115	68	1	8		2	FC	
			158	84	1	8	L	2	FC	
			141	78	1	17	L	1	FC	
			94	70	2	17	L	1	FC	

Bench	Traverse name	Traverse orientation	Azimuth	Dip	Number /traverse	Alteration	Limonite	Rougth.	Structure	Comments
421	**F53-F54**	078-15	285	80	1	17	L	1	FC	
			327	85	1	8	L	2	FC	
			57	86	1	2	L	1	FC	
			311	80	2	17	L	1	FC	
			311	80	2	8	L	1	FC	
			253	78	1	2	L	1	FC	
			154	90	2	17		1	FC	
			279	68	1	2	L	1	FC	
			131	3	1	8	L	1	JN	
	F54-F55	284-14	169	77	3	2	L	2	FC	
			169	77	1	8		1	FC	
			259	66	8	8	L	1	FC	
			127	90	4	2	L	2	FC	
			254	82	3	17		1	FC	
			128	90	2	17	L	2	FC	
			244	60	4	8	L	1	FC	
			244	60	2	17	L	1	FC	
			113	12	1	16	L	1	JN	
	F55-F56	281-02	136	70	1	17		2	FC	
			255	48	1	8	L	1	FC	
			276	58	1	17	L	1	FC	
			276	58	1	8	L	1	FC	
			186	78	1	8	L	1	FC	
			324	90	1	8	L	1	FC	
			142	86	1	17	L	1	FC	
			142	86	1	8	L	1	FC	
			281	82	1	2	L	1	FC	
			121	75	1	17	L	1	FC	
			320	84	1	2	L	1	FC	
			84	73	1	2	L	1	FC	
	F56-F57	255-01	135	74	3	17	L	1	FC	
			52	79	1	8	L	1	FC	
			288	82	1	2	L	1	FC	
			320	86	1	8		1	FC	
			150	88	1	8		2	FC	
			156	87	5	17		1	FC	
			54	90	4	17		2	FC	
			140	82	1	1		2	FC	
			62	6	1	17		1	JN	
	F57-F58	095-03	251	89	7	8	L	1	FC	
			251	89	3	17	L	1	FC	
			141	90	1	6		1	FC	
			141	90	1	2	L	1	FC	
			62	3	1	6	L	1	JN	
	F58-F59	096-02	49	87	1	17	L	1	FC	
			307	85	3	2	L	2	FC	
			70	90	1	17	L	1	FC	
			70	90	2	8	L	1	FC	
			161	90	2	17		1	FC	
	F59-F60	027-02	134	81	2	17	L	1	FC	
			242	87	4	8	L	1	FC	
			134	81	3	1		2	FC	
			331	78	2	17	L	1	FC	
	F60-F61	293-05	262	89	2	1		2	FC	
			262	89	1	2	L	1	FC	
			262	89	2	8	L	1	FC	
			262	89	1	17	L	1	FC	
			272	85	1	2	L	2	FC	
			247	75	3	8	L	1	FC	
			247	75	1	17	L	1	FC	
			305	88	1	20	L	1	FC	10-15 cm wide
			320	81	1	2	L	1	FC	
			320	81	1	8	L	2	FC	
			78	90	1	2	L	1	FC	
	F61-F62	286-03	351	81	2	17	L	1	FC	
			335	86	2	17	L	1	FC	
			208	82	1	17		2	FC	
			324	80	1	17	L	1	FC	
			53	88	1	8		1	FC	
			344	78	1	8	L	1	FC	
			90	83	1	17	L	1	FC	
			137	90	1	8	L	1	FC	
			74	90	2	8		1	FC	
			74	90	1	17	L	1	FC	
			330	82	1	1		2	FC	
			260	88	1	2	L	1	FC	
			260	88	2	8	L	1	FC	
			73	84	1	17	L	1	FC	
			133	90	2	2	L	2	FC	

Bench	Traverse name	orientation	Azimuth	Dip	Number /traverse	Alteration	Limonite	Rougth.	Structure	Comments
421	**F62-F63**	106-02	305	84	1	17	L	1	FC	
			47	85	2	17		2	FC	
			316	85	1	8	L	1	FC	
			86	90	1	8	L	1	FC	
			88	76	1	2	L	2	FC	
			146	80	1	2	L	2	FC	
			88	85	1	8	L	1	FC	
			96	4	1	8		1	JN	
	F63-F64	120-00	134	90	1	8	L	1	FC	
			274	85	1	17	L	1	FC	
			316	88	1	8	L	1	FC	
			282	80	1	8	L	1	FC	
			150	70	1	8		2	FC	
			333	90	1	8	L	1	FC	
			80	90	2	17	L	1	FC	
			187	90	3	17	L	2	FC	
			96	4	1	17		1	JN	
			96	4	1	1		1	JN	
	F64-F65	292-02	254	88	1	17	L	1	FC	
			254	88	2	8	L	1	FC	
			131	80	1	17	L	1	FC	
			84	86	2	2	L	1	FC	
			322	90	1	2	L	2	FC	
	F65-F66	294-03	84	90	1	2	L	1	FC	
			84	90	1	17	L	1	FC	
			381	76	1	17	L	1	FC	
			279	84	1	1		2	FC	
			144	90	1	1		1	FC	
			96	90	1	2	L	1	FC	
			140	70	1	17	L	1	FC	
			132	65	1	17	L	1	FC	
	F66-F67	133-04	140	70	1	17	L	1	FC	
			59	84	1	8	L	1	FC	
			0	0	1	17	L	1	JN	
	F67-F68	136-00	247	75	1	2	L	2	FC	
			223	80	2	2	L	2	FC	
			300	85	1	2	L	2	FC	
			88	83	2	17	L	2	FC	
			161	84	1	8	L	1	FC	
			80	75	1	2	L	2	FC	
			130	90	1	2	L	1	FC	
			93	90	1	2	L	1	FC	
			96	4	1	17	L	1	JN	
	F68-F69	138-10	71	76	1	2	L	1	FC	
			146	86	1	8	L	1	FC	
			208	70	3	2	L	1	FC	
			162	74	2	8	L	1	FC	
			324	93	1	8	L	1	FC	
			242	72	1	8	L	1	FC	
			185	66	1	2	L	1	FC	
			42	60	1	2	L	2	FC	
			292	80	1	2	L	2	FC	
	F69-F70	134-03	190	80	2	1		2	FC	
			370	90	1	2	L	1	FC	
			370	90	1	8	L	1	FC	
			237	76	4	17	L	2	FC	
			247	78	12	2	L	2	FC	
			167	84	4	2	L	2	FC	
			152	8	1	8		1	JN	
			152	8	1	1		1	JN	
	F70-F71	346-09	242	88	1	17	L	1	FC	
			271	85	4	17	L	1	FC	
			281	69	2	2	L	2	FC	
			29	70	3	2	L	2	FC	
			262	90	1	17		1	FC	
			321	81	1	8	L	2	FC	
			44	74	4	2	L	1	FC	
			139	80	2	8		2	FC	
			29	79	1	2	L	1	FC	
			7	85	1	1	L	2	FC	
			215	82	1	2	L	1	FC	
			274	76	1	2	L	1	FC	
			153	90	1	2	L	1	FC	
			230	66	1	2		2	FC	
			243	87	1	2	L	1	FC	
			243	87	20	17	L	1	FC	
			243	87	1	20	L	1	FC	1.5m wide
			311	78	1	17	L	1	FC	
			154	90	1	20	L	1	FC	10 cm wide
			86	4	3	8		1	JN	

Bench	Traverse name	Traverse orientation	Azimuth	Dip	Number /traverse	Alteration	Limonite	Rougth.	Structure	Comments
421	F71-F72	329-02	230	83	1	16	L	2	FC	kaolinite
			230	83	1	8	L	2	FC	
			240	82	3	8	L	1	FC	
			289	83	1	8	L	2	FC	
			235	61	4	8	L	2	FC	
			57	86	1	16	L	1	FC	kaolinite
			322	86	1	16		1	FC	kaolinite
			50	90	5	17	L	1	FC	
			242	86	1	16	L	1	FC	kaolinite
			218	50	2	16	L	1	FC	kaolinite
			48	90	1	17	L	1	FC	
			209	64	1	16	L	1	FC	kaolinite
			30	90	2	17	L	1	FC	
			134	50	1	8	L	1	FC	
			260	88	2	2	L	2	FC	
			86	4	1	16	L	1	JN	
	F72-F73	143-02	205	79	2	8	L	1	FC	
			286	86	1	17	L	1	FC	
			317	72	2	17	L	1	FC	
			220	76	1	17	L	1	FC	
			290	77	1	17		2	FC	
			275	85	1	2	L	2	FC	
			235	85	1	8		1	FC	
			162	90	1	16	L	1	FC	
			59	75	1	16	L	1	FC	
	F73-F74	152-02	149	76	1	17	L	1	FC	
			119	77	1	16	L	1	FC	
			70	78	2	17	L	1	FC	
			70	90	1	17	L	2	FC	
			43	70	2	8	L	2	FC	
			77	85	3	17	L	1	FC	
			323	72	1	20	L	1	FC	25 m of hyd.fracturing
			66	72	2	20	L	2	FC	
			311	80	1	20	L	2	FC	
	F74-F75	152-09	120	83	4	20	L	2	FC	
			208	62	2	17	L	2	FC	
			93	90	2	2	L	2	FC	
			136	85	2	20	L	1	FC	
			209	65	2	16	L	1	FC	
			139	90	4	20	L	2	FC	
	F75-F76	159-06	289	85	5	8	L	1	FC	
			315	67	1	8	L	2	FC	
			215	72	1	8	L	1	FC	
			25	90	1	2	L	1	FC	
			98	70	2	16	L	1	FC	
			2	75	1	2	L	1	FC	
			30	65	1	20		2	FC	
			30	80	1	20		1	FC	
	F77-F78	346-04	26	83	1	20	L	1	FC	2m wide
			29	83	1	20		1	FC	
			154	72	1	16	L	1	FC	
			219	70	2	17	L	1	FC	
			39	74	5	8	L	1	FC	
			229	80	1	17	L	1	FC	
			229	80	4	8	L	1	FC	
			227	70	5	17	L	1	FC	
			134	82	1	8	L	1	FC	
			134	82	4	2	L	1	FC	
			217	82	2	17	L	1	FC	
			217	82	2	8	L	1	FC	
			193	82	1	8	L	1	FC	
	F78-F79	002-04	35	90	4	8	L	1	FC	
			114	90	4	8	L	1	FC	
			110	90	2	1		2	FC	
			314	86	1	2	L	1	FC	
			137	90	3	2	L	2	FC	
			300	85	4	2	L	1	FC	
			27	82	5	2	L	1	FC	
			184	2	2	8		1	JN	
	F79-F80	026-02	308	90	1	2	L	2	FC	
			317	88	7	8		1	FC	
			60	82	9	2	L	1	FC	
			116	84	6	8		1	FC	
			116	84	1	17		2	FC	
			226	4	1	8		1	JN	
	F80-F81	203-02	130	80	1	8		1	FC	
			120	81	1	17		2	FC	
			209	74	1	8	L	1	FC	
			312	88	1	2	L	1	FC	
			315	78	1	17	L	1	FC	
			52	90	5	2	L	1	FC	

Bench	Traverse name	Traverse orientation	Azimuth	Dip	Number /traverse	Alteration	Limonite	Rougth.	Structure	Comments
421	**F80-F81**	203-02	130	80	2	2	L	1	FC	
			328	70	3	1		2	FC	
			327	74	3	1		2	FC	
			65	90	2	2	L	1	FC	
			132	90	2	2	L	2	FC	
			170	78	1	17	L	1	FC	
			130	84	2	8		1	FC	
			226	7	1	8	L	1	JN	
	F81-F82	198-02	156	90	2	8	L	1	FC	
			224	86	2	2	L	2	FC	
			144	84	2	8	L	1	FC	
			45	90	2	17	L	1	FC	
			150	80	8	8		1	FC	
			150	80	2	17	L	1	FC	
	F83-F84	234-01	26	90	2	1		1	FC	
			106	70	4	8	L	1	FC	
			106	70	1	17	L	1	FC	
			98	90	1	17	L	1	FC	
			354	82	2	17		1	FC	
			85	90	1	17	L	1	FC	
			214	88	1	8	L	1	FC	
			88	90	1	17		1	FC	
			284	77	2	17		1	FC	
			211	78	2	8		2	FC	
			82	80	2	8		1	FC	
			82	80	1	17		1	FC	
			93	90	1	8		2	FC	
			50	83	3	1		1	FC	
			59	90	1	17		1	FC	
			80	90	2	8		1	FC	
			80	90	1	17	L	1	FC	
			38	90	1	8		1	FC	
			208	5	1	8		1	JN	
			208	5	1	17		1	JN	
	F84-F85	041-03	136	90	2	20	L	1	FC	10 cm wide
			34	75	1	17	L	1	FC	
			164	13	3	8		1	JN	
	F85-F86	234-02	36	90	1	2	L	1	FC	
			36	90	1	1		1	FC	
			286	85	3	1		2	FC	
			329	86	1	20	L	1	FC	10 cm wide
			155	85	1	20	L	1	FC	10 cm wide
			150	90	1	8	L	1	FC	
			270	90	2	1		2	FC	
			160	50	1	8	L	1	FC	
	F86-F87	040-10	170	84	1	2	L	2	FC	
			63	76	2	1		2	FC	
			321	80	2	8	L	1	FC	
			321	88	2	8	L	1	FC	
			61	82	1	8		1	FC	
			36	90	1	1		2	FC	
			30	87	1	8		1	FC	
			148	90	5	8	L	1	FC	
			148	90	1	20	L		FC	10 cm wide
			257	83	3	8		1	FC	
			162	80	1	17		1	FC	
			135	79	4	1		2	FC	
			162	90	1	20	L	1	FC	10 cm wide
			94	80	3	8		1	FC	
			194	84	1	8		1	FC	
			140	90	1	1		2	FC	
			70	90	1	1		2	FC	
			164	13	1	8		1	JN	
	F87-88	050-03	151	86	2	20	L	1	FC	10 cm wide
			79	89	1	1		2	FC	
			324	78	1	20	L	1	FC	10 cm wide
			324	78	3	8		1	FC	
			324	78	2	17		1	FC	
			150	90	1	20	L	1	FC	10 cm wide
			150	90	2	8		1	FC	
			238	61	1	17	L	1	FC	
			150	70	1	8		1	FC	
			167	90	1	20	L	1	FC	10 cm wide
			97	90	1	1		2	FC	
			258	76	1	1		2	FC	
	F88-F89	048-02	196	88	2	8	L	1	FC	
			50	75	1	1		2	FC	
			82	84	1	1		2	FC	
			120	62	2	8	L	1	FC	
			144	72	1	20	L	1	FC	10 cm wide
			170	88	2	1		1	FC	

Bench	Traverse name	orientation	Azimuth	Dip	Number /traverse	Alteration	Limonite	Rougth.	Structure	Comments
421	**F88-F89**	048-02	154	80	2	20	L	1	FC	10 cm wide
			69	90	6	1		1	FC	
			162	79	1	8		1	FC	
			180	90	1	2	L	1	FC	
			172	87	3	2		1	FC	
			65	85	3	1		1	FC	
			85	76	1	8	L	1	FC	
			145	82	1	8		2	FC	
			211	5	2	8		1	JN	
	F89-F90	041-04	269	80	1	8		1	FC	
			155	83	2	8	L	2	FC	
			0	76	2	2		1	FC	
			75	75	3	1		2	FC	
			84	86	1	2	L	2	FC	
			77	98	2	1		2	FC	
			90	72	2	1		2	FC	
			12	80	1	8	L	1	FC	
			90	85	2	17	L	1	FC	
			80	83	2	2	L	1	FC	
			132	90	2	8	L	1	FC	
			88	80	1	8		1	FC	
			237	70	2	8	L	1	FC	
	F90-F91	034-04	244	70	2	8	L	1	FC	
			331	83	1	2	L	1	FC	
			4	90	1	2	L	1	FC	
			340	90	1	2		2	FC	
			89	87	3	2	L	1	FC	
			178	90	8	2	L	1	FC	
			82	90	4	1		2	FC	
			74	75	2	17		1	FC	
			270	90	1	2	L	1	FC	
			281	82	1	2	L	1	FC	
			235	72	1	2	L	1	FC	
			83	90	3	2	L	1	FC	
	F91-F92	220-03	350	80	2	1		1	FC	
			100	82	1	6		2	FC	
			50	71	2	16	L	1	FC	
			50	71	4	8		1	FC	
			144	90	1	8	L	1	FC	
			337	76	2	2	L	1	FC	
			89	80	1	8	L	1	FC	
			150	90	2	2	L	1	FC	
			66	70	1	2	L	1	FC	
			148	74	1	2	L	1	FC	
			148	74	4	20	L	1	FC	80 cm wide
			163	82	2	8		1	FC	
			66	82	1	6		1	FC	
			144	85	4	1		1	FC	
			91	86	2	1		1	FC	
			58	81	2	2	L	1	FC	
			58	81	1	17	L	1	FC	

Appendix B

Section C: Rock Stability Analysis – JEB Open Pit Mine

Appendix H2

Rock Stability Analysis

JEB Open Pit Mine

McClean Lake Project

COGEMA Resources Inc.

November 29, 1997

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Drawing S765.11H2-5 Contour Plot Poles of Joint Orientations - Top of Rock to 409 Bench
Drawing S765.11H2-6 Kinematic Analysis
Drawing S765.11H2-7 JEB Pit - Hydraulic Breccia Distribution
Drawing S765.11H2-8 Input Stability Section
Drawing S765.11H2-9 Estimated Critical Circle
Drawing S765.11H2-10 JEB Pit Wall - July 13, 1997 Rock Slide
Drawing S765.11H2-11 Cross Section through Slide Area

SUMMARY

Structural measurements of the major joints, over 3,000 measurements, have been collected over the full depth of the mined out JEB pit and are reported in Appendix A3. The structures were variously identified as joints or faults with the vast majority dipping at more than 70°. Most had limonitic stains on them. A few of the structures were described as chloritic or clay coated. Details of the data collection and analysis of the rock slopes is included in Appendix H2.

The poles of all structural measurements were plotted on stereonets in order to group the data into major joint sets. The concentrations of the poles were then contoured to define the more statistically prominent features. The contoured concentrations of the poles from the 421 to the 359 Bench identified four structural features. They are northwest-southeast set ranging between 130° and 160°, a northeast-southwest set ranging between 050° and 070°, a less prominent east-west set ranging between 080° and 090° and a prominent horizontal partings parallel to bedding planes. The pit was subdivided into six zones and each was subject to a kinematic analysis to identify potential failure modes incuding plane failures, toppling failure, wedge failures, stepped path failure, circular slip failure and ravelling.

Given the abundance of subvertical structure evidenced in the measurements taken within the JEB pit, the relatively shallow overall design pit slope and the foregoing analysis there is a low potential for major slope failures within the pit.

There is a higher potential for minor plane failures when shallow dipping structures daylight on the backwalls. This is evidenced in the failure that occurred in July 1997. The proportion of shallow dipping structures is low, (2% of measured structures), therefore it is not likely that large plane failures will occur.

1.0 INTRODUCTION

The following provides an analysis of newly obtained structural geologic data from the mined out JEB open pit. The pit is presently developed to full depth and the data represents measurements from the 433 to the 359 bench backwalls. Preliminary slope stability analysis of potential wedge failures identified by the kinematic analysis is presented. A limit equilibrium analysis of a plane striking 069 degrees and dipping 74 degrees is also presented to demonstrate the conditions required for a slope failure along the shallowest dipping joints identified from the field data in combination with the assumed horizontal unconformity at the top of the basement rocks.

This analysis represents the major joint sets in the sandstone only.

In July 1997 a small rock slide occurred between the 387 level and the 359 level. This slide is also documented and discussed.

2.0 PREVIOUS WORK

Preliminary work carried out for Minatco in 1989 used a limited amount of data from 3 oriented bore holes. This data indicated 2 dominant joint sets in the sandstone; one striking northwesterly and dipping subvertical and the second striking northwesterly and dipping approximately 70 degrees to the southeast. This work identified 3 main lithostructural units; cemented sandstone, weakly cemented, friable sandstone and basement gneiss.

Limit equilibrium analysis showed that planar failures up to 45 degrees on slopes of up to 50 degrees have factors of safety greater than 1.1 if either the hydraulic head is less than 2/3 of the height of the tension crack; or the persistence of the sliding surface is less than 88 percent. Analysis showed that neither of these conditions hold true (in the un-dewatered state) and that slope angles of less than 35 degrees would be required to provide a factor of safety of 1.1.

Kinematic analysis showed that for slope angles of 50 degrees, only the northwest quadrant is subject to kinematically admissible wedge failure. Limit equilibrium analysis also showed that all kinematically admissible wedge failures are stable with no pore water pressure.

Minor failures of all types were identified as possible along bench walls. Toppling failure along bench walls was identified as possible due to the steeply dipping nature of the joints identified. Interbench backwalls of 70 degrees were recommended to reduce the potential for small scale failures along backwalls.

Structural data was collected from the northwest quadrant of the 433 and 421 benches during initial development in 1996. Interpretation and analysis of this data is reported in the *07 April 1997 "Confirmation of the Environmental Acceptability of the JEB Pit TMF" (Appendix E).* The dominant joint sets, identified in this report were; northwest trending dipping subvertically and northeast to east trending and dipping subvertically. The kinematic analysis indicated that given the proposed design slopes of 45 degrees and the predominant subvertical dips, the potential for major slope failures is very low.

3.0 DESCRIPTION OF DATA

COGEMA geologists have mapped the entire pit between June 1996 and July 1997. The majority of the fractures are either filled with limonite, sandy grit or drusy quartz. A minority of the structures are described as slickensided, chloritic or clayey. No significant displacement is visible on fracture planes. The size of the structures measured ranges from 24m (two benches) to 20 cm (smallest measured structures that cross two sedimentary beds).

One significant type of feature is termed a hydraulic breccia. These are delithified zones in the sandstone formed due to fluid flow under pressure, presumably at the time of mineralization. These zones are characterized by lenses or pockets of dry, friable and porous sand or sandy clay associated with limonitization, hematization, argilization or chloritization. These zones can range from a few centimeters to several meters wide, typically with no vertical or horizontal continuity along fracture planes. These zones are prominent on the west wall between the 385 and 373 benches.

Structural measurements of the major joints have been collected over the entire pit. Over 3,300 structural measurements were made by COGEMA geologists. Drawing S765.11H2-1 shows the pit plan and locations of the structural measurement stations. The structures are described variously as joints, faults and zones of hydraulic breccia. The vast majority of the structures are steep. Drawing S765.11H2-2 shows a histogram of fracture dips. Eighty eight percent of the fractures are steeper than 70 degrees. Only 67 fractures out of the 3,117 measurements have dips between 10 and 50 degrees. Subhorizontal partings associated with the bedding are not included in this total.

The poles of all structural measurements were plotted on stereonets in order to group the data into major joint sets. The concentrations of the poles were then contoured to define the more statistically prominent features. Drawing S765.11H2-3 shows the contoured concentrations of the poles from the 421 to the 359 Bench, four structural features were identified. They are:

- A prominent northwest-southeast set ranging between 130° and 160°.
- A prominent northeast-southwest set ranging between 050° and 070°.
- A less prominent east-west set ranging between 080° and 090°.
- Prominent horizontal partings parallel to bedding planes.

The mean planes for each of the dipping joint sets identified were calculated to be:

- Strike 147°/dip 85°
- Strike 060°/dip 84°
- Strike 084°/dip 89°

Drawing S765.11H2-4 shows weighted rosette plots of all the fractures. These joint sets correlate well with those defined on the 433 bench early in the development of the pit (July 1996) and reported in the *07 April 1997 "Confirmation of the Environmental Acceptability of the JEB Pit TMF" (Appendix E).* Drawing S765.11H2-5 shows the joint sets defined early in the pit development. The dominant joint sets, identified in this report were; northwest trending dipping subvertically and northeast to east trending and dipping subvertically. The stability assessment provided in the earlier report has therefore been reviewed and extended to the data collected from the 421, 397, 373 and 359 benches.

4.0 KINEMATIC ANALYSIS

Kinematic analysis was carried out by dividing the pit into six structural sectors as shown on Drawing S765.11H2-6. The average backwall orientation of each sector was plotted on a stereonet to evaluate the potential for failure. An overall backwall slope of 50 degrees was used in the analysis, the actual slopes vary between 40 and 50 degrees. The following analysis is therefore conservative.

The mean orientations of the major joint sets defined in the updated mapping are within 10 degrees of those used in the earlier analysis as shown in Table 4.1.

Table 4.1
Mean Orientations of Joint Sets

Joint Set	April 1997 (°)	Joint Set	November 1997 (°)
1 & 2	138/89 and 157/89	1	147/85
3	069/74	2	060/84
4	083/89	3	084/89

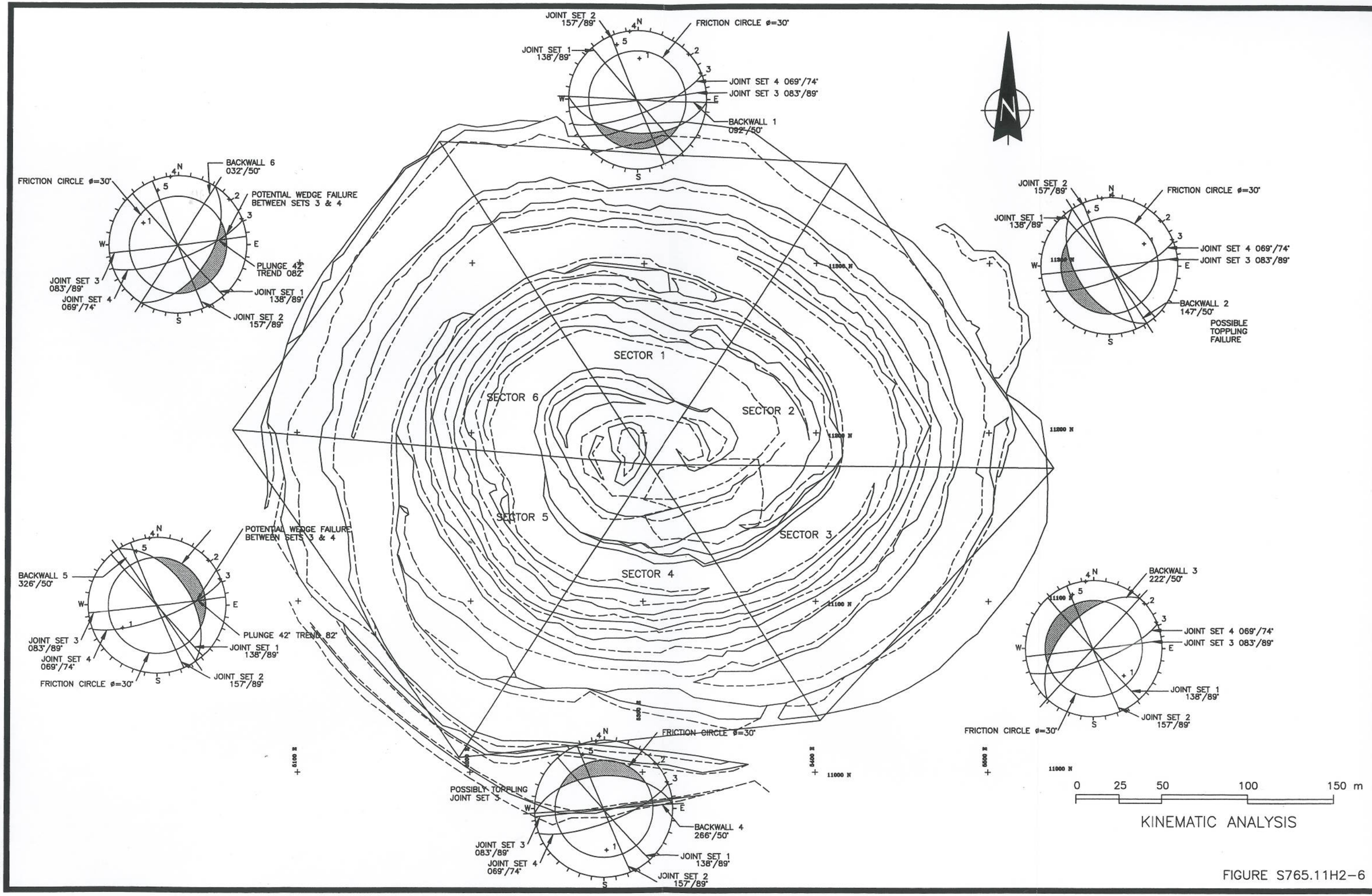
Therefore the analysis completed in the April 1997 report is considered valid for the entire pit. Small changes in orientation do not affect the geometric analysis particularly because the vast majority of the dips are steeper than 70 degrees and subhorizontal partings. The subhorizontal and subvertical nature of the rock mass results in "cubic" rock mass that, although it may be highly fractured in places, maintains high overall stability. It is the 2% of the fractures that dip between 10 and 50 degrees that could result in local instability.

Drawing S765.11H2-6 shows the stereonets associated with each sector of the pit. Each of the mean planes associated with joint sets identified from the pole plot in Drawing S765.11H2-5 are plotted on each stereonet. A plane representing the backwall orientation of each sector and a small circle representing a friction angle of 30 degrees is also plotted on each stereonet.

Geometric analysis was used to identify potential failure modes. Potential plane failures can occur when the strike of a fault or joint set is subparallel to the orientation of the backwall and the dip of the joint set is shallower than the overall backwall slope (i.e. 50 degrees). Potential toppling failure can occur when a joint set strikes subparallel to a bench backwall and dips subparallel to the dip of the bench backwall.

The Markland Test was used to identify potential wedge failures where the line of intersection of two joint sets plunges at an angle less than the overall slope and greater than the assumed friction angle of 30 degrees.

Stepped path failure can occur when one joint set intersects another set such as a subhorizontal plane.



KINEMATIC ANALYSIS

JEBGEOL2

FIGURE S765.11H2–6

5.0 POTENTIAL MODES OF FAILURE

5.1 Plane Failure

Structural measurements indicate a low potential for major plane failures. Two percent of the 3,117 measurements have dips between 10 and 50 degrees. The northwest and northeast orientations of the two main fracture systems suggests the possibility for minor joints with shallow dips would be higher in either of these directions. The potential for local plane failures therefore can be expected to be higher in sectors 2, 3, 5 and 6 because the backwalls are approximately subparallel to the major joint trends in these sectors.

5.2 Wedge Failure

Kinematic analysis using the Markland Test suggests the potential for wedge failure to occur in Sectors 5 and 6. The line of intersection of Joint Sets 3 and 4 (April 1997 joint sets) plunges at 42 degrees and trends at 082 degrees. This line daylights on the 45 to 50 degree overall slope and exceeds the assigned friction angle of 30 degrees. The strikes of the intersecting joint sets are 069 and 083 degrees. The steep dips and similarity in the strike suggests that should a pure wedge failure occur it would not be large in scale. The potential for stepped wedge failure on a larger scale also exists in Sectors 5 and 6. As the overall pit slope barely exceeds the plunge of this intersection and pit dewatering will reduce pore water pressures a mechanical analysis was used to determine the factor of safety of this failure mechanism. See Section 6.

5.3 Stepped Path Failure

This mode of failure is possible in Sectors 1 and 6 where backwalls parallel Joint Set 4 (strike 069 degrees, dip 74 degrees). A special case is considered for large block sliding along a joint or fault plane of the above orientation which intersects a horizontal parting along the unconformity. This case is analyzed in Section 7.

5.4 Toppling Failure

The majority of the joints measured are subvertical (70 to 90 degrees). This suggests potential for minor toppling failures along essentially all bench backwalls. The design interbench backwall angle is 70 degrees. The safety berms in the pit design will catch loose material resulting from this type of failure and allow access for cleanup.

5.5 Circular Slip Failure

Previous work (Geocon, 1989) identified a zone of weak, friable to uncemented sandstone in a single bore hole on the east side of the pit. This material was identified as having potential for circular slides and is correlated with the hydraulic breccia unit identified in the pit. Limiting equilibrium analysis were carried out using PC-SLOPE. The analyses suggested that with overall pit slopes of 35 to 40 degrees and by lowering the groundwater table to 75 m below the

ground surface a factor of safety of 1.1 can be achieved. These units are not widespread and during mapping were noted as small zones (the largest is less than 10 m in wide) on the west backwalls. Mappable zones occur on the 421, 397 and 385 backwalls as shown in Drawing S765.11H2-7. The small and discontinuous nature of this unit indicates the potential for a large scale failure of this type is low. Therefore this type of failure has not been analyzed further.

5.6 Ravelling

The sandstone in the pit walls will almost certainly be subject to weathering deterioration and erosion. Locally, the zones of hydraulic breccia are particularly subject to ravelling. These zones are not continuous on a large scale. Ravelling needs to be controlled, the safety berms in the JEB TMF are designed to catch loose material and provide access for cleanup.

6.0 STABILITY ANALYSIS - WEDGE FAILURE

The stability analysis of potential wedge failures in Sectors 5 and 6 was performed using two methods developed by Hoek and Bray (1981). Both methods assume sliding is resisted by friction only and that ϕ is the same for both planes. The first method is a geometric solution utilizing the angle between the two intersecting planes (ξ=18 degrees), the angle between the horizontal and 1/2ξ or β = 80.5 degrees, plunge of the line of intersection (ψ_j = 42 degrees) and friction angle (ϕ = 30 degrees).

In this method the factor of safety is calculated as follows:

$F = \text{Sin}\beta/\text{Sin}0.5\xi \times \text{Tan}\phi/\text{Tan}\psi_j = 4.2$

A second, "chart" method also defined by Hoek and Bray was used to verify the magnitude of the above factor of safety. This method uses the difference in dip between planes A and B and the difference in dip direction between planes A and B to calculate the factor of safety. By this method a factor of safety of 2.9 is estimated.

Based on the above calculations and geometric relationships between the two intersecting planes as discussed previously, the potential for wedge failure or stepped wedge failure does not exist in Sectors 1 to 4. The potential for this type of failure in Sectors 5 and 6 is very low.

7.0 STABILITY ANALYSIS - STEPPED PATH FAILURE ON UNCONFORMITY

A special case was analyzed for a large block sliding along a joint or fault plane of the following orientation (strike 069 degrees, dip 74 degrees) which intersects a horizontal parting along the unconformity. The stability analysis of potential step path failure in Sectors 5 and 6 was analyzed using the limit equilibrium Bishop's Simplified method assuming a failure plane of uniform strength along the joint or fault plane and the unconformity.

The sliding block was assigned strength properties (ϕ'=55_, effective cohesion= 2,000 kPa, unit weight of 22 kN/m^3) sufficiently high to ensure the failure remained along the fault plane and unconformity, as shown in Drawing S765.11H2-8. Table 7.1 provides a summary of estimated factors of safety for a stepped path failure on the unconformity for various friction angles along the joint or fault plane and the unconformity. The estimated critical circle is presented in Drawing S765.11H2-9.

Table 7.1
Summary Estimated Factor of Safety

Failure Plane Effective Friction Angle (_)	Estimated Factor of Safety
25	1.00
30	1.25
35	1.51
40	1.80

8.0 PLANE FAILURE ON SHALLOW SPLAY - JULY 1997

On 14 July 1997, a portion of the lower southeast wall of the JEB pit collapsed onto the pit floor. The slide involved a section of loose sandstone bedrock between the 387 and 359 benches. The slide started from near the edge of the ramp and covered a portion of the ramp at the pit floor level.

Mapping of the pit walls indicated that a series of east-west (80-100°) and northeast-southwest (40-60°) structures cut across the southeast corner of the pit as shown in Drawing S765.11-10. These fractures are steeply dipping to vertical and intersect in the southeast corner, just below the ramp on the 387 bench. There are two main northeast trending structures, oriented roughly parallel to the wall and dipping at 80° to the north. A lower angle, (about 50°) fracture splay joins the two main vertical fractures.

The wall failure was due to the undercutting of the hanging wall along the splay above the 359 bench as shown in Drawing S765.11H2-11. The splay daylighted at the northernmost fracture face causing the entire block to slide. These low angle structures are not common in the pit but demonstrate the potential for local plane failures, particularly in sectors 3 and 6 which parallel the northeast trending joint sets and in sectors 2 and 5 which parallel the northwest trending joint set.

9.0 CONCLUSIONS

Given the abundance of subvertical structure evidenced in the measurements taken within the JEB pit, the relatively shallow overall design pit slope and the foregoing analysis, there is a low potential for major slope failures within the pit.

There is a higher potential for minor plane failures when shallow dipping structures daylight on the backwalls. This is evidenced in the failure that occurred in July 1997. The proportion of shallow dipping structures is low, (2% of measured structures), therefore it is not likely that large plane failures will occur.

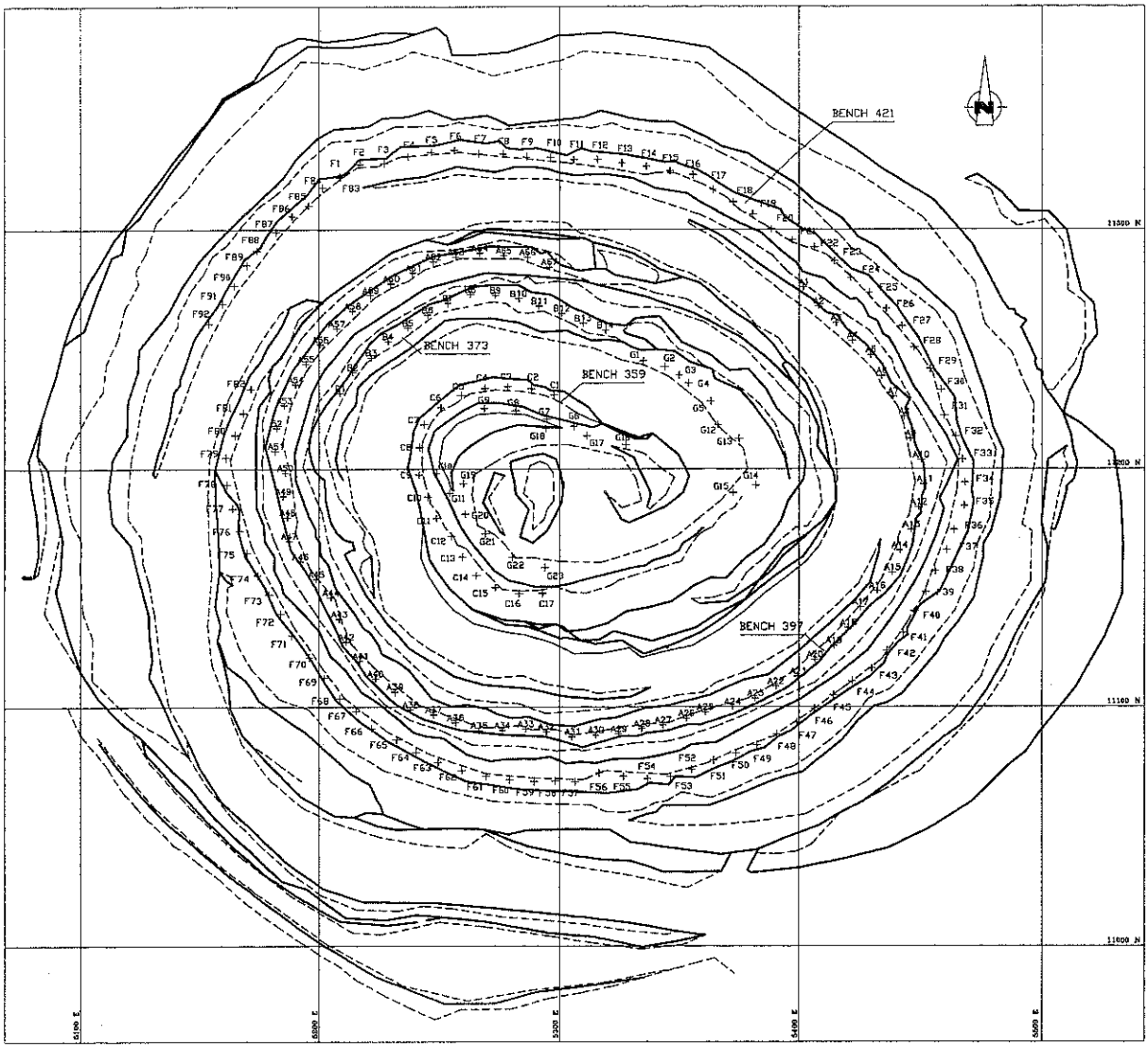
10.0 REFERENCES

Clifton Associates Ltd., Backwall Stability, JEB Open Pit, report completed for COGEMA and submitted to Saskatchewan Energy and Mines, 2 April 1997.

Clifton Associates Ltd., Appendix E2, Rock Stability Analysis, JEB Open Pit, part of the Confirmation of the Environmental Acceptability of the JEB Pit TMF submitted to AECB, 07 April 1997.

Hoek, E. and Bray, J.W., Rock Slope Engineering; Institution of Mining and Metallurgy, London, 3rd edition, 1981.

Geocon Inc., Preliminary Pit Slope Design, JEB Open Pit Mine, report to Minatco Limited, 1989.



0 50 100m

Scale 1:2500

LEGEND

A, B, C, F points: sandstone stations

G points: basement stations

Crest

Toe

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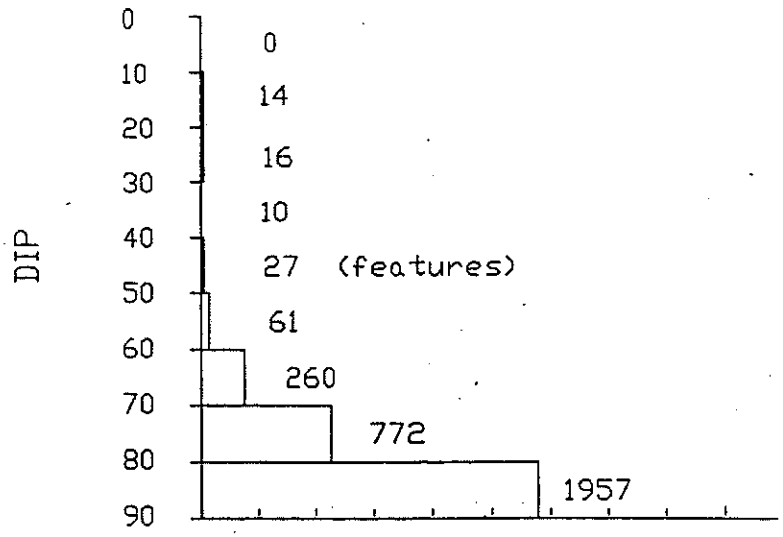
COGEMA Resources Inc.

CLIENT COGEMA RESOURCES INC.

PROJECT McCLEAN LAKE PROJECT
JEB TAILINGS MANAGEMENT FACILITY

TITLE JEB PIT STATION LOCATIONS

ANALYSIS OF ALL DATA ..... 3117 poles from 1821 entries



Arithmetic Mean = 74.6

St.Dev.= 20.44

Bar length represents % of total poles

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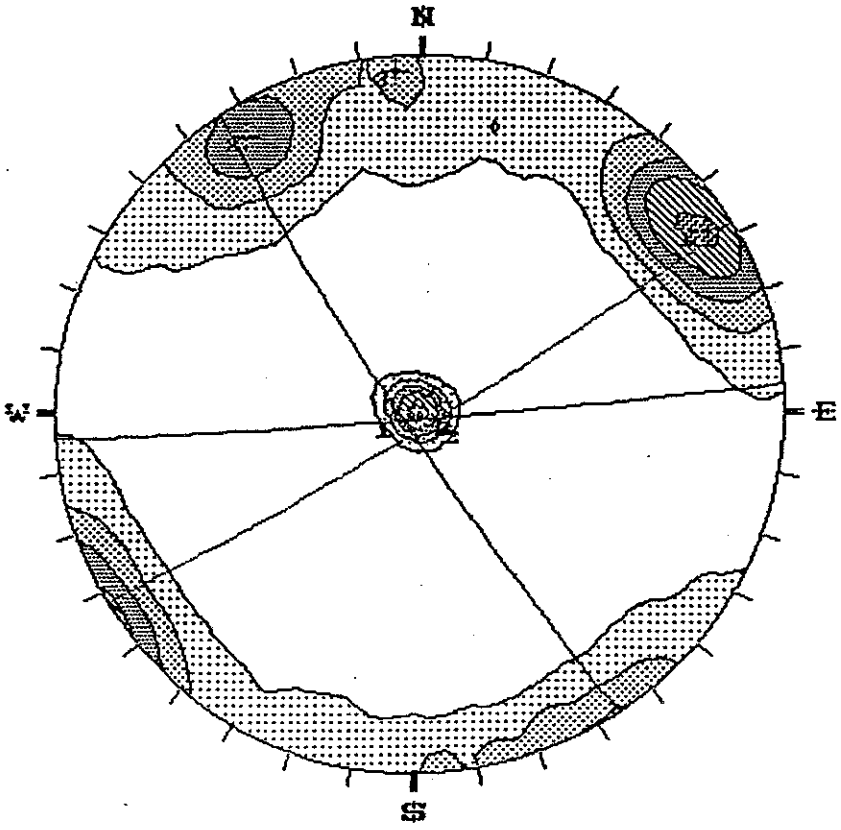
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PROJECT McCLEAN LAKE PROJECT
JEB TAILINGS MANAGEMENT FACILITY

TITLE HISTOGRAM OF FRACTURE DIPS

JEB PIT



BENCHES 421, 397, 373 and 359

CONTOUR PLOT

FISHER POLE CONCENTRATIONS
% of total per 1.0 % area

< 0	%
< 1.5	%
< 3	%
< 4.5	%
< 6	%
< 7.5	%
< 9	%
< 10.5	%

EQUAL ANGLE

LWR. HEMISPHERE

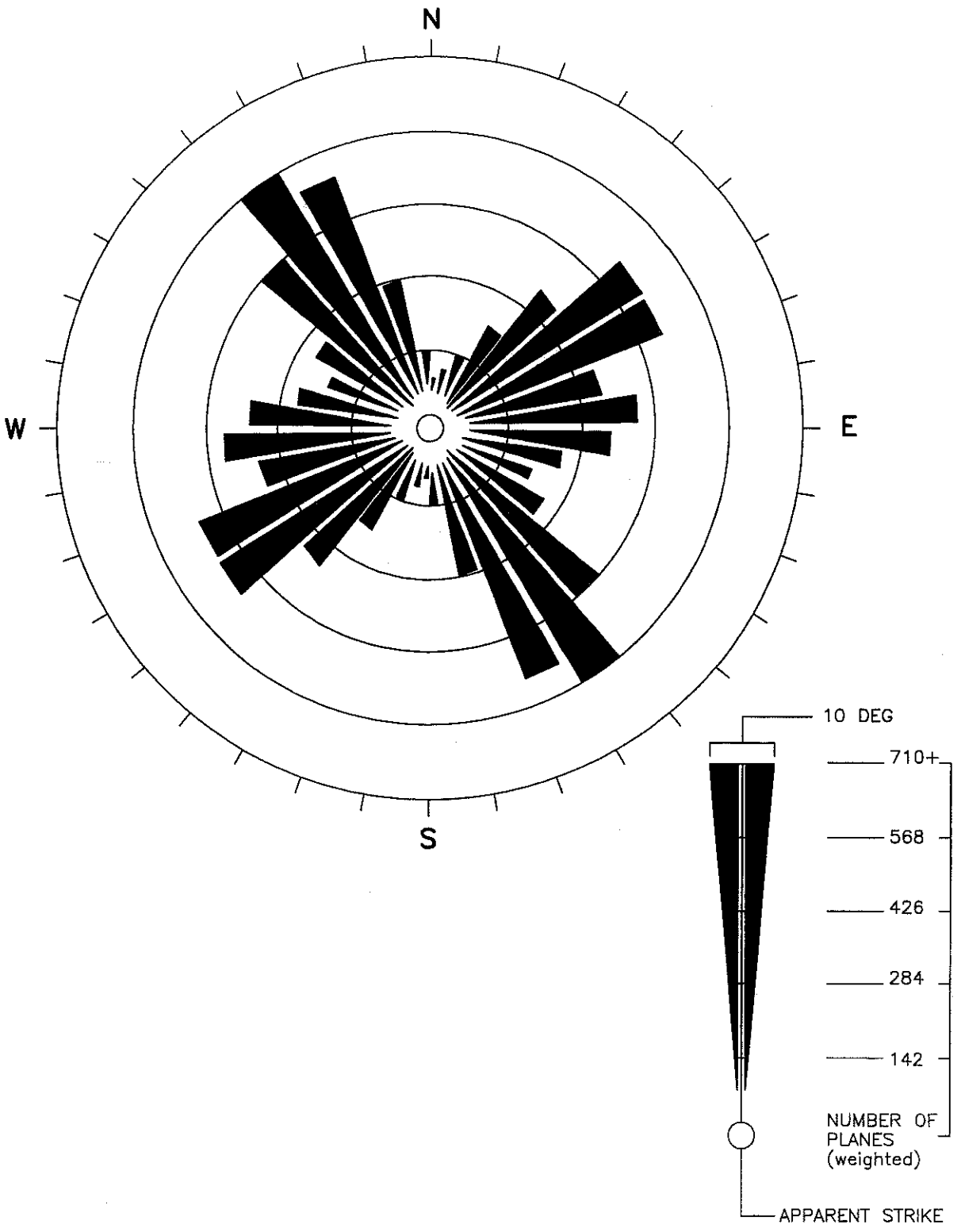
3300 POLES
1821 ENTRIES

TERZAGHI CORRECTION
Min.Ang.=15 deg

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COGEMA Resources Inc.

CLIENT COGEMA RESOURCES INC.
PROJECT McCLEAN LAKE PROJECT
JEB TAILINGS MANAGEMENT FACILITY
TITLE CONTOUR PLOT POLES OF JOINT ORIENTATIONS – 421 TO 359 BENCH



DATE	DRAWN BY	APPROVED BY	SCALE	FILE NO.	DRAWING NO.
97/11/18	DWW			APPH2_4	S765.11H2-4

COGEMA Resources Inc.

CLIENT: COGEMA RESOURCES INC.

PROJECT: McCLEAN LAKE PROJECT
JEB TAILINGS MANAGEMENT FACILITY

TITLE: FRACTURE ROSETTE

EQUAL AREA
LOWER HEMISPHERE

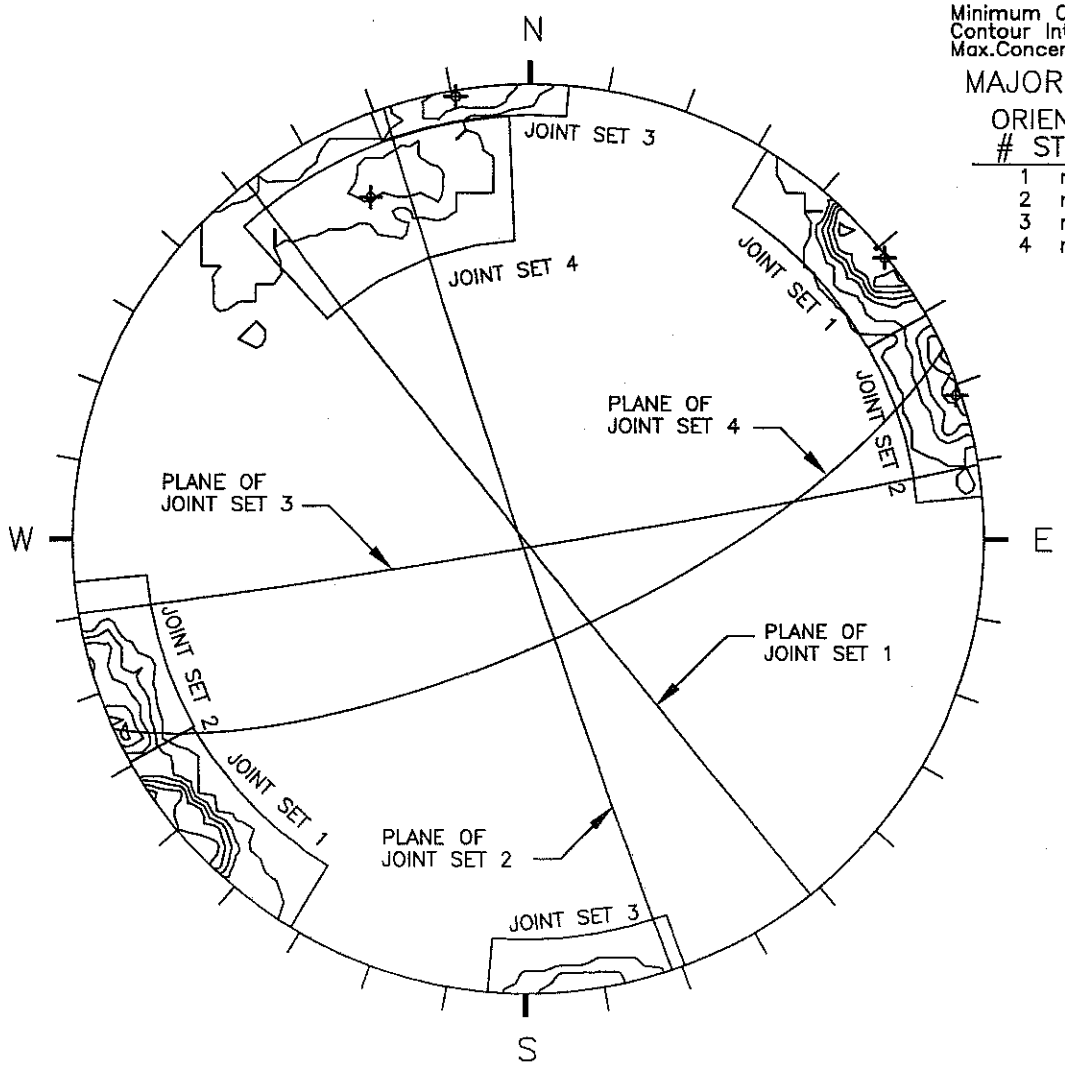
CONTOUR LEGEND

SCHMIDT POLE CONCENTRATIONS
% of total per 1.0 % area

Minimum Contour =	3
Contour Interval =	3
Max.Concentration =	20.8

MAJOR PLANES ORIENTATIONS

#	STRIKE/DIP
1	m 138°/89°
2	m 157°/89°
3	m 083°/89°
4	m 069°/74°

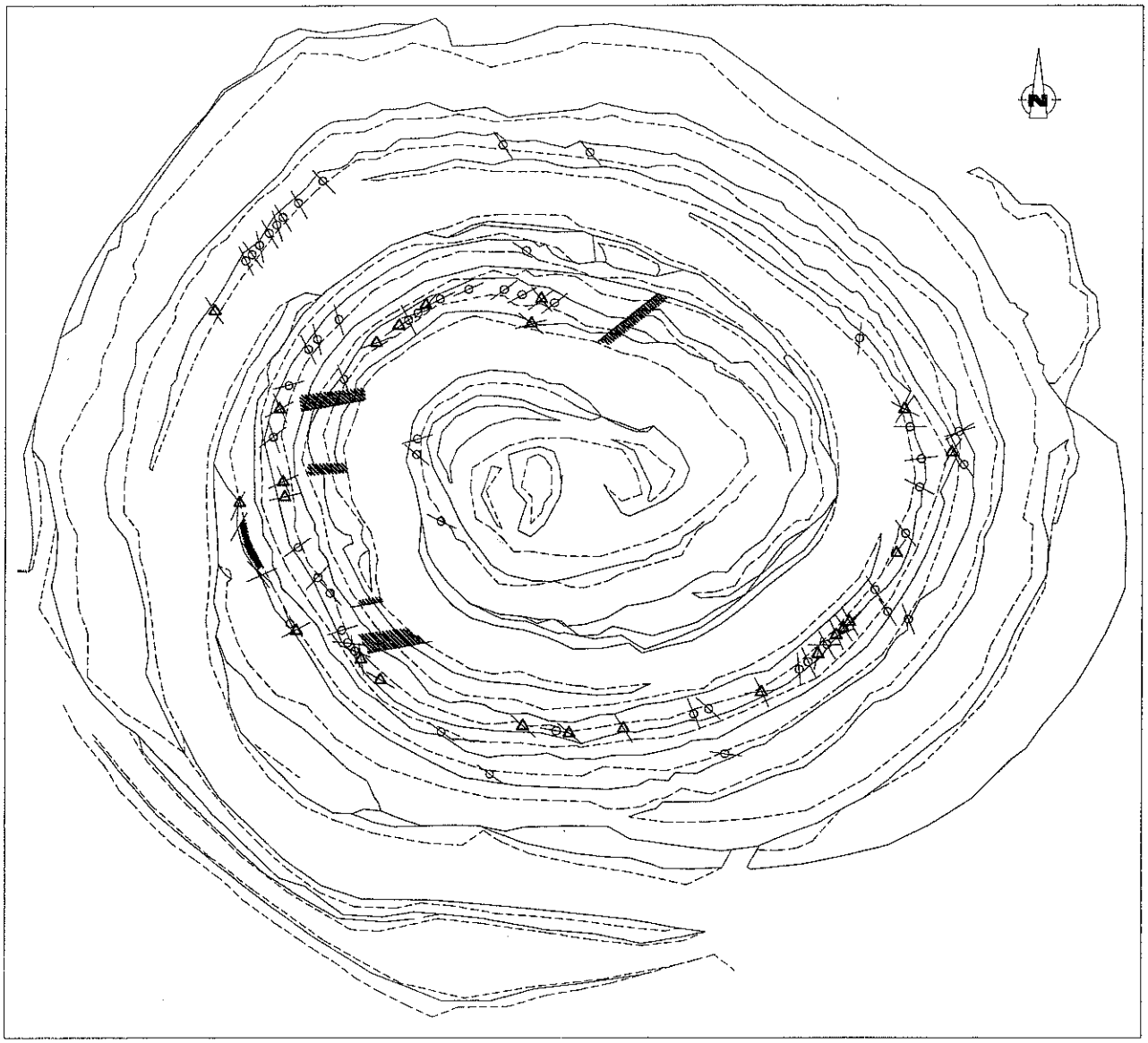


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97/11/10	DWW			APPH2_5	S765.11H2-5

COGEMA Resources Inc.

CLIENT: COGEMA RESOURCES INC.
PROJECT: McCLEAN LAKE PROJECT
JEB TAILINGS MANAGEMENT FACILITY

TITLE: CONTOUR PLOT POLES OF JOINT ORIENTATIONS–TOP OF ROCK TO 409 BENCH



0 50 100m

Scale 1:2500

LEGEND

- Main hydraulic breccia zone
- Fractures with hydraulic breccia >50cm
- Fractures with hydraulic breccia <50cm

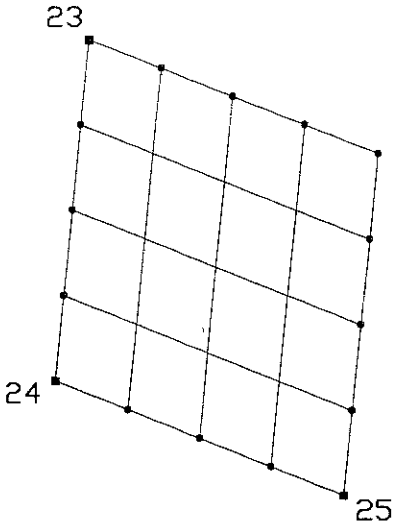
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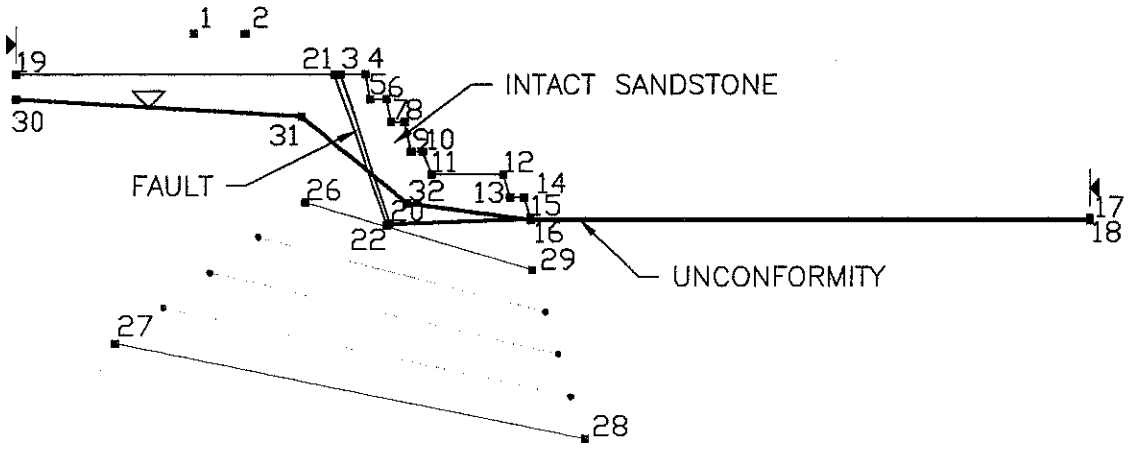
COGEMA Resources Inc.

CLIENT COGEMA RESOURCES INC.

PROJECT McCLEAN LAKE PROJECT
JEB TAILINGS MANAGEMENT FACILITY

TITLE JEB PIT HYDRAULIC BRECCIA DISTRIBUTION

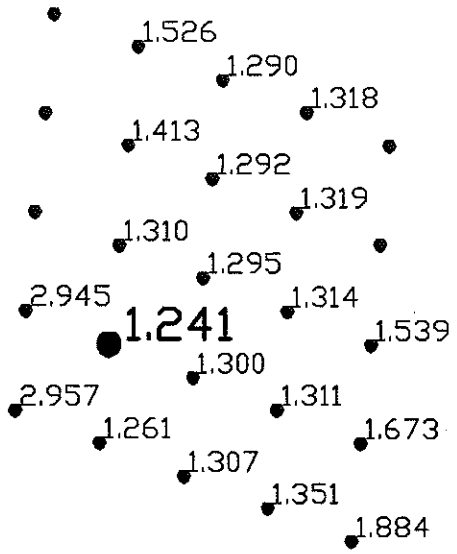


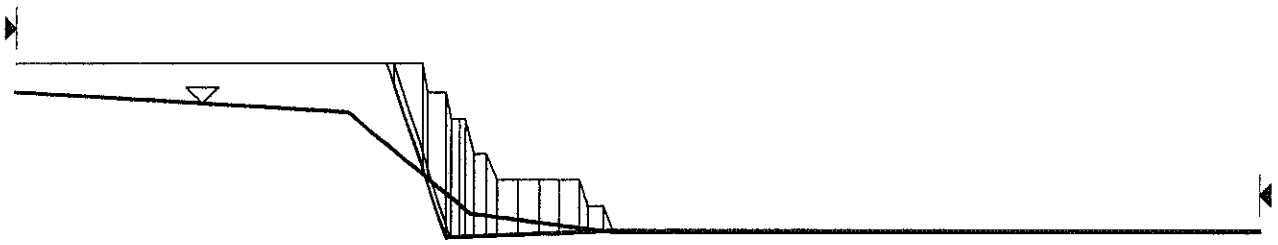


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97/11/25	DWW		1:50	APPH2_8	S765.11H2-8

COGEMA Resources Inc.

CLIENT	COGEMA RESOURCES INC.
PROJECT	McCLEAN LAKE PROJECT JEB TAILINGS MANAGEMENT FACILITY
TITLE	INPUT STABILITY SECTION





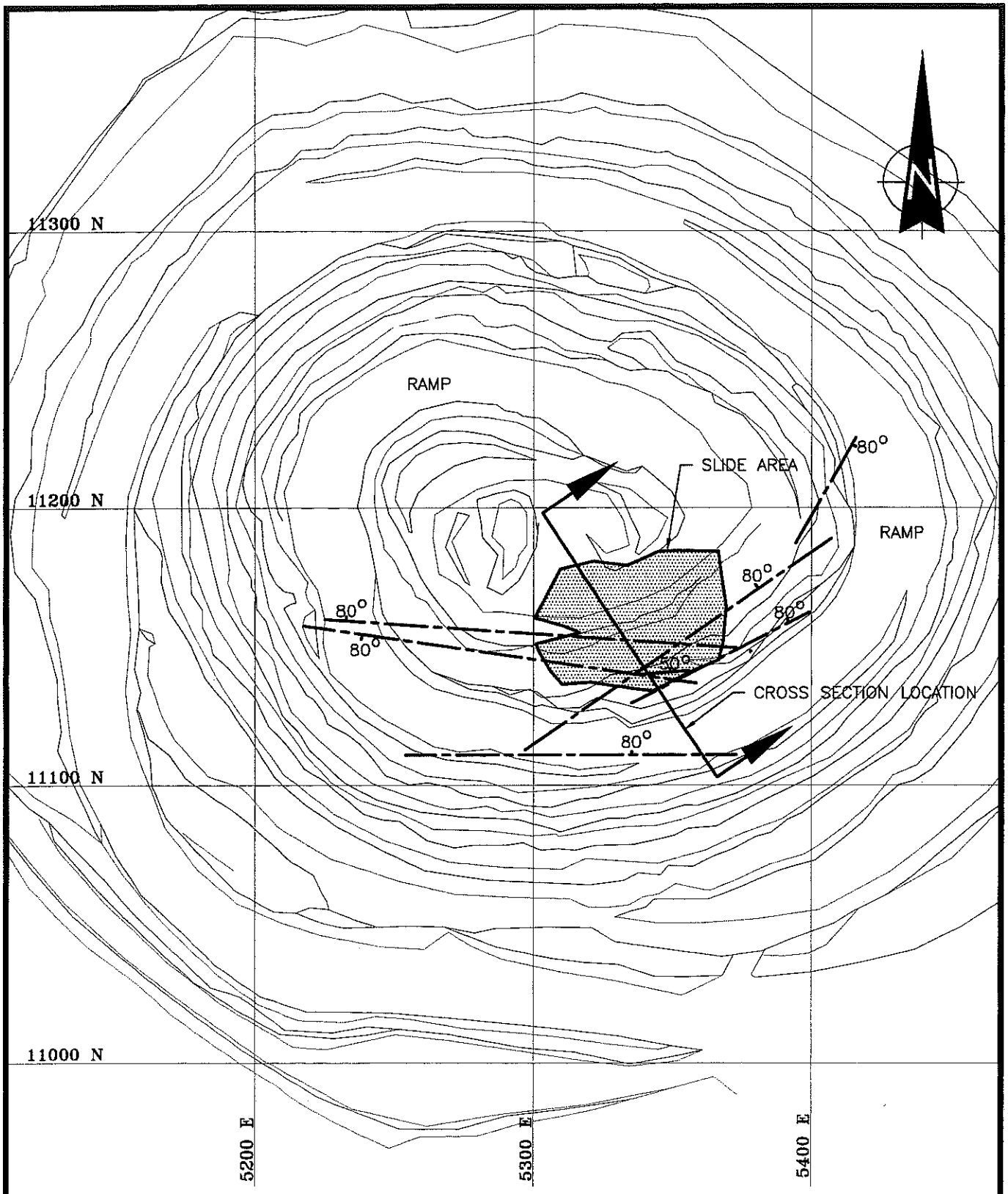
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CLIENT: COGEMA RESOURCES INC.

PROJECT: McCLEAN LAKE PROJECT
JEB TAILINGS MANAGEMENT FACILITY

TITLE: ESTIMATED CRITICAL CIRCLE



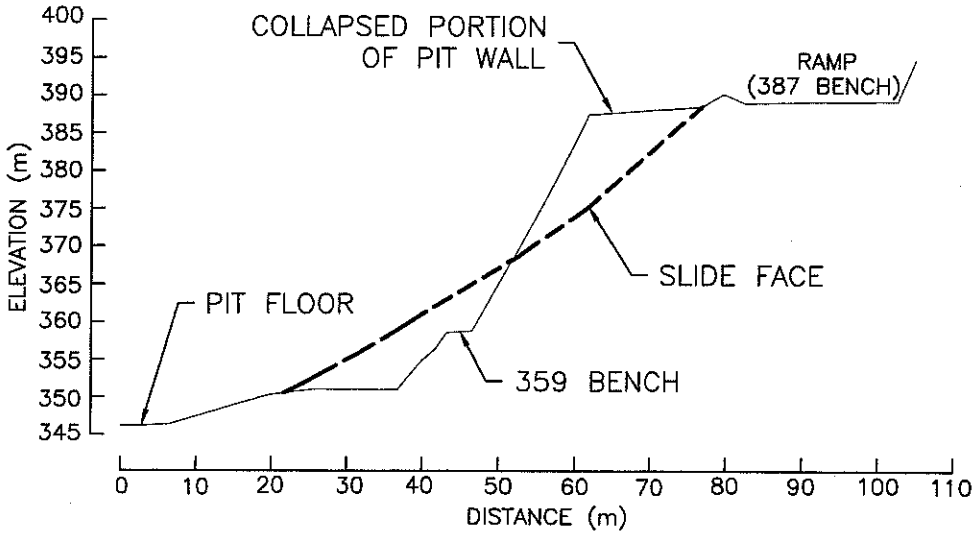
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97/11/10	DWW		1:2000	APPH2_10	S765.11H2-10

COGEMA Resources Inc.

CLIENT: COGEMA RESOURCES INC.

PROJECT: McCLEAN LAKE PROJECT
JEB TAILINGS MANAGEMENT FACILITY

TITLE: JEB PIT WALL
JULY 13, 1997 ROCK SLIDE



DATE	DRAWN BY	APPROVED BY	SCALE	FILE NO.	DRAWING NO.
97/11/10	DWW		1:1000	APPH2_11	S765.11H2-11

COGEMA Resources Inc.

CLIENT COGEMA RESOURCES INC.

PROJECT McCLEAN LAKE PROJECT
JEB TAILINGS MANAGEMENT FACILITY

TITLE CROSS SECTION THROUGH SLIDE AREA

From:	Akhter, Salman (CNSC/CCSN)
To:	LANIECE Vincent (ORN-MN)
Cc:	OC-McCleanRegulatory; SEARCY Tina (ORN-MN); UMMD / DMUCU (CNSC/CCSN); Su, Grant (CNSC/CCSN)
Subject:	Orano - McClean Lake - Construction details for the previous JEB TMF expansion to 457 m ASL
Date:	Thursday, January 07, 2021 12:25:42 PM
Attachments:	E-DOCS-#5223402-v2B-CNSC_staff_Review_of_JEB_TMF_Expansion_Project.DOCX E-DOCS-#5200656-v1-McClean_Lake_-_Response_to_CNSC_Follow-up_on_JEB_TMF_Expansion_Project.PDF SITE CHARACTERIZATION FOR DAM FOUNDATIONS IN BC.pdf

Security Notice: Please be aware that this email was sent by an external sender.

Hi Vincent,

Thanks for the telephonic discussion yesterday including previous JEB TMF expansion approval up to 457 meter ASL. One of the approval condition was (see attached CNSC approval letter):

"As required by CNSC staff, AREVA has committed to provide construction details for CNSC staff review and acceptance prior to initiating any construction activities."

You mentioned that Orano is currently working on the construction details and will be submitted to CNSC in coming weeks. Also in your letter dated February 28, 2017 (see attached), Orano committed to undertake several activities before the construction of the TMF expansion to 457 m ASL, in particular for CNSC comment below:

"*AREVA shall verify the foundation condition of the TMF embankment and characterize the foundation condition of the proposed storm water storage pond prior to construction of the embankment and the dyke."*

Please note that this is very important for both expansions. Basically, Orano needs to drill boreholes to fill the large borehole spacing sections along the embankment axis to verify the foundation condition. Please include this information when submitting construction details for the previous JEB TMF expansion.

Also attached is the APRGBC guidance document for Site Characterization for Dam Foundations in BC for your information, which is considered best practice in Canada.

Please let me know if you have any questions or need clarification.

Thanks,
Salman

VIA EMAIL

February 28, 2017

Mr. Salman Akhter
Senior Project Officer
Uranium Mines & Mills Division
Canadian Nuclear Safety Commission
#520, 101-22nd Street East
Saskatoon, SK S7K 0E1

Dear Mr. Akhter:

Re: McClean Lake Operation – Response to CNSC Follow-up on JEB TMF Expansion Project

Please find enclosed AREVA's responses to CNSC follow-up comments (Akhter to Huffman, February 21, 2017) resulting from CNSC staff review of AREVA's JEB Tailings Management Facility - Expansion Project.

Should you have any questions, please contact me at (306) 343-4058 or dale.huffman@areva.com.

Sincerely,



Dale Huffman
Vice President
Health, Safety, Environment & Regulatory Relations

enclosure

cc: Greg Adilman, SMoE
UMMD Distribution
ARC Distribution

AREVA Response to CNSC Follow-Up

McClean Lake Operation

JEB Tailings Management Facility Expansion Project

February 2017

CNSC Follow-up to Comment 3: *Should the project be accepted to proceed with TMF Optimization Stage 2 and Expansion 1, a vast area of liner will be installed. The hydraulic containment of the JEB TMF will be provided during the operations phase by the liner and pumping from the raise wells. Therefore, the liner integrity will be very important for the TMF performance and for preventing the outward migration of constituents of potential concern (COPCs) from the JEB TMF. Although a steady state seepage and slope stability analysis conducted for cross-section A-A' at end of operation condition with no liner present shown no significant effect on the calculated factor of safety for the downstream slope, the leakage would increase under this condition. Depending on the scale of a liner failure, the resulting leakage and potential environmental impact would not be negligible.*

Therefore, contingency measures should be identified in the event of a liner failure.

AREVA Response:

Contingency Measures

In the unlikely event of a failure of a portion of the liner contingency options available to AREVA include:

- Placement of a geo-synthetic, clay, geo-net (to stabilize the area) and/or a geomembrane (e.g. HDPE or bitumus liner) to patch degrade portion of liner. These types of liners would need to sealed against the remaining liner by securing in place with either replacement rip rap or other anchoring system (e.g. soil anchors);

- Placement of bentonite or soil-bentonite mixture to reinforce, stabilize and limit the flow of water through the area where the liner is damaged. Bentonite could be placed in the area of liner failure to quickly stabilize the area, acting both to limit the migration of water out of the TMF and also to stabilize the area; or,

- Grout injection into the embankment of overburden in the immediate vicinity of the liner failure. Grout injection would limit flow through the embankment in the area of liner damage or degradation.

In the unlikely event that liner failure covered a larger surface area, other potential contingence options would also include:

- Construction of a bentonite-soil slurry wall or barrier system through the embankment as close as possible to area of liner damage. A vertical slurry wall could be constructed using a single pass trencher (e.g. Dewind One Pass Trenching) or using standard excavating equipment. A barrier wall could be designed such that it would have a suitably low hydraulic permeability to act as a replacement liner until the tails covered and sealed the area of concern.

- Installation of a cut-off trench or cut-off well(s) to collect any water that migrates out of the TMF and pump it back into the TMF pond. This type of collection system would ensure that there was no effect on the stability of the embankment and it would only have to operate until the tailings covered and sealed the area of concern.

Environmental Risk Assessment

The environmental consequence assessment of a complete failure of the JEB TMF Expansion embankment is presented in the Appendix J – Environmental Consequence Assessment of the Unlikely Embankment Failure of the JEB Tailings Management Facility Expansion of Attachment A – Project Description (AREVA, June 2016). This assessment evaluated the implications of two hypothetical failure scenarios of the JEB TMF embankment on the receiving environment (namely, Fox Lake, Pat Lake, and Nadia Lake). The two scenarios represent bounding conditions for the amount of water and tailings solids that could potentially be released during a failure event. The recovery of water quality in the watershed was considered on a monthly basis, with clean run-off flushing COPC out of Fox Lake, but impacting the water quality in downstream waterbodies. The conclusion of this screening level assessment is that the consequences of an embankment failure at the JEB TMF would not have catastrophic effects on the Collins Creek watershed downstream of the facility. While water and sediment quality and the health of aquatic biota in Fox Lake would be affected and the recovery of the lake could take many months or years, it is not anticipated that water bodies downstream of Fox Lake would be negatively impacted over the short- or long-term. Only cadmium, molybdenum and radium-226 were predicted to be greater than water quality guidelines in Pat Lake in the short-term; however, the peak levels of all COPC in Pat Lake were below criteria considered protective of 95% of aquatic species.

CNSC Follow-up to Comment 8: *CNSC staff understood that a total of seven boreholes were drilled around the pit slope and a total of 13 test pits were excavated along the JEB pit slope in the till varying in depth from 1.5 m to 3.4 m below ground surface plus boreholes drilled previously to characterize the foundation conditions of the proposed embankment of the TMF. However, there is large borehole spacing within the footprint of the embankment foundation and the absence of site investigation in the area of the proposed storm water storage pond.*

- *AREVA shall verify the foundation condition of the TMF embankment and characterize the foundation condition of the proposed storm water storage pond prior to construction of the embankment and the dyke.*

An existing temporary contaminated material landfill will require relocation under a separate approval prior to the construction of the embankment and no further information is provided. The excavation of the contaminated materials might have impacts on both Optimization Stage 2 and expansion of the TMF and should be assessed.

- *AREVA should assess the impact of the excavation of the contaminated materials to the TMF Optimization Stage 2 and the expansion, and confirm if any remediation measures such as foundation improvements are needed.*

The collapse potential tests of till were conducted for three composite Unit 2 samples and three composite Unit 3 samples. The test results presented in Table 2 and the field SPT results obtained during the field investigation indicates that Unit 2 and Unit 3 are "compact" to "dense" (Golder 2009a). Therefore, the licensee concluded that instability of the slopes due to collapse is not a concern. However, the field investigation data were not provided in the report and no test was done on Unit 1 till. There are also high uncertainties for the SPT data obtained from tills due to some coarse materials in the tills. When looking at the test results of Unit 3 samples, one can infer that if the initial dry density of the Unit 3 till is below 1,646 kg/m3, significant collapse could occur.

AREVA should verify the collapse potential of all three till units located under the proposed embankment prior to construction of the embankment.

Visual observation of the tailings embankment and various field instrumentations will be conducted for stability monitoring of the JEB TMF Expansion embankment. The proposed slope inclinometer casing will be keyed a minimum of 3.0 m into the till below the embankment. While CNSC concurs with installation of a slope inclinometer, its key-in depth of 3m might not be deep enough to capture potential deep seated deformation.

AREVA should justify the key-in depth of the proposed inclinometer casing at Cross Section F-F.

AREVA Response:

Removal of the temporary contaminated landfill and subsequent backfilling and compaction is described in a notification (Huffman to Akhter, February 24, 2017).

The remainder of this comment will be fully undertaken as part of the detailed design phase of the TMF Expansion Project and submitted for CNSC acceptance.

CNSC Follow-up to Comment 9: *CNSC staff understand that stability analysis of the embankment surrounding the TMF has been conducted and presented in Appendix A and the factors of safety are acceptable for the embankment stability. However, no stability analysis was conducted to support the design of the containment dyke for both the storm water storage pond and the expanded waste rock run off pond.*

AREVA shall conduct a stability analysis of the dykes for both the storm water storage pond and the expanded waste rock run off pond with the projected highest pond water level and the characterized foundation condition to support the dyke design.

AREVA Response:

The comment will be fully undertaken as part of the detailed design phase for the storm water management features and submitted for CNSC acceptance.

Directorate of Nuclear Cycle and Facilities Regulation

File No.: 4.04.02 ML-A
e-Doc 5223402

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April 19, 2017

Mr. Dale Huffman, Vice-President
Health, Safety, Environment &
Regulatory Relations
AREVA Resources Canada Inc.
817- 45th Street West
P.O. Box 9204
Saskatoon, SK S7K 3X5

Subject: **McClean Lake Operation**
Modification to the JEB Tailings Management Facility Expansion Project

Dear Mr. Huffman**:**

AREVA Resources Canada Inc. (AREVA) submitted a letter notification request dated June 10, 2016 titled *"McClean Lake Operation – Notification of Modification to the JEB Tailings Management Facility Expansion Project."* The proposed expansion would provide additional tailings capacity of 1.7 million cubic metres. Canadian Nuclear Safety Commission (CNSC) staff asked AREVA to provide clarity and additional information related to the source term, the robustness of the cover, engineering controls and other design features. AREVA provided acceptable responses to the requested information.

Based on the submission and additional information provided, CNSC staff conclude that the increase of consolidated tailings elevation remains within the licensing basis and will continue to achieve the operational and post-closure objectives developed to ensure safety and protection of the environment. CNSC staff have also completed an Environmental Assessment for the JEB TMF expansion under the *Nuclear Safety and Control Act* and concluded that AREVA has made, and will continue to make, adequate provision for the protection of the environment and health of persons.

As required by CNSC staff, AREVA has committed to provide construction details for CNSC staff review and acceptance prior to initiating any construction activities. AREVA has confirmed that the Environmental Assessment Branch, Saskatchewan Ministry of Environment

(SMOE) has completed an environmental screening of the JEB tailings management facility expansion project and confirmed that no further environmental assessment would be required.

CNSC staff, as part of their ongoing compliance verification process, will carry out the following activities to ensure safety and protection of the environment:

- verify annually that hydrodynamic containment of the JEB TMF is being maintained
- review tailings consolidation studies which are on a five-year cycle
- confirm the timely implementation of any mitigation measures necessary to ensure that the aquatic ecosystem in nearby Fox and Pat lakes is protected

In view of CNSC staff review, the following change to the LCH will be made:

Section	**Change from**	**Change to**
Part I, Section 2.4	Disposal of tailings in the JEB Tailings Management Facility (JEB TMF) up to a consolidated tailings elevation of 434 Meters Above Sea level (MASL), which is the approximate low point of the sandstone-till contact.	Disposal of tailings in the JEB Tailings Management Facility (JEB TMF) up to a consolidated tailings elevation of 448 Meters Above Sea level (MASL), which is the approximate low point of natural ground elevation.

This change will be incorporated during the next revision of the LCH.

CNSC staff understand that the following licensing documents will require a revision:

- Mining Facility Licensing Manual (MFLM)
- Facility Description Manual (FDM)

The changes to these documents will be incorporated and submitted by AREVA during the next revision of these referenced documents.

If you have any questions or concerns, please do not hesitate to contact Mr. Salman Akhter by e-mail at salman.akhter@canada.ca or by phone at 306-975-6385.

Sincerely,

Robert Lojk
Director
Uranium Mines and Mills Division

Enclosure (1)

c.c.: T. Searcy, V. Laniece, Regulatory Records – AREVA
G. Adilman – Sask. Ministry of Environment
D. Thomas – Northern Engagement
M. Langdon, S. Akhter, D. Humphreys, R. Goulet – CNSC

References

1- Correspondence from D. Huffman, AREVA Resources Canada Inc. to S. Akhter, CNSC, dated June 10, 2016 *McClean Lake – Notification of Mofiidcation to the JEB Tailings Managmenet Facility Expansion Project*, (e-Doc 5020837)

2- Correspondence from T. Searcy, AREVA Resources Canada Inc. to S. Akhter, CNSC, dated September 8, 2016 *McClean Lake – JEB TMF Expansion – Provincial Extension to Construction Dates,* (e-Doc 5082353)

3- Corespondence to D. Huffman, AREVA from S. Akhter, CNSC dated December 22, 2016 Staff Review of Modification to the JEB Tailings Management Facility Expansion Project (e-Doc 5149299)

4- Correspondence from D. Huffman, AREVA to S. Akhter, CNSC dated February 8, 2016 AREVA's Response to CNSC Comments on Tailings Management Facility Expansion Project (e-doc 5186303)

5- Email from D. Huffman, AREVA to S. Akhter, CNSC, dated February 13, 2017 AREVA's Response to CNSC Staff Comments on TMF Expansion Project (e-doc 5189839)

6- Email from S. Akhter, CNSC to D. Huffman, AREVA dated February 21, 2017 CNSC Staff Review of AREVA's Responses (e-doc 5195424)

7- Correspondence from D. Huffman, AREVA to S. Akhter, CNSC dated February 28, 2017 AREVA's Response to CNSC Follow-up on JEB TMF Expansion Project e-doc 5200656)

SITE CHARACTERIZATION FOR DAM FOUNDATIONS IN BC

APEGBC PROFESSIONAL PRACTICE GUIDELINES

V1.2

Professional Engineers and Geoscientists of BC

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PREFACE

The Professional Practice Guidelines – Site Characterization for Dam Foundations in BC have been developed in response to Recommendation 6 in the *Report on Mount Polley Tailings Storage Facility Breach* prepared by the Independent Expert Engineering Investigation and Review Panel (Panel Report). On August 4, 2014, a 40-metre-high section of the Mount Polley tailings dam failed along a weak soil layer in the dam's foundation, releasing over 20 million cubic metres of tailings and process water ("Mount Polley incident"). The Province of British Columbia appointed the Independent Expert Engineering Investigation and Review Panel ("Review Panel") to assess the failure and provide recommendations for improved practice.

Recommendation 6 of the Panel Report reads as follows:

> 6. To improve professional practice
>
>   Encourage the Association of Professional Engineers and Geoscientists of British Columbia (APEGBC) to develop guidelines that would lead to improved site characterization for tailings dams with respect to the geological, geomorphological, hydrogeological and possibly seismotectonic characteristics.

The Panel Report also noted that the development of these professional practice guidelines is one of the best applicable practices that should be implemented.

The Professional Practice Guidelines – Site Characterization for Dam Foundations in BC have been developed in response to Recommendation 6.

The Mount Polley incident demonstrated that when a dam's foundation is not sufficiently characterized or accounted for in the design, failure can result. The nature of the Mount Polley incident is relevant to a range of other types of dams, such as water reservoir dams and other types of storage dams (e.g., storage facilities used at oil and gas exploration or production facilities and sewerage facilities). It follows that the application of an appropriate standard of practice when carrying out site characterization for foundations is equally important for all types of dams, and fundamental to their safe construction and ongoing operation. Consequently, these guidelines have been developed to be applicable to all types of dams and, where appropriate, the differences between dam types have been noted.

The application of the appropriate standard of practice when carrying out site characterization for dam foundations is fundamental to the safe construction and ongoing operation of *any type of dam*. On this basis, the appropriate standard of practice identified in these guidelines has been developed so the guidelines apply to *all* dam types.

In the context of improving professional practice involving dam-related activities, these guidelines will complement the existing *APEGBC Professional Practice Guidelines – Legislated Dam Safety Reviews in BC*, which also applies to dams in the mining industry and to water storage dams.

The development of these guidelines is consistent with one of the primary objectives of APEGBC, which is to establish, maintain, and enforce standards for the professional practice of practitioners regulated by APEGBC.

These guidelines apply to site characterization for dam foundations during the various phases of development, from conceptual through to design, construction, design updates, and closure.

These guidelines have been written for the information of APEGBC professionals, statutory decision-makers, regulators, dam owners (including utilities, mining companies, municipalities, farmers, and others), First Nations, the public at large, and a range of other stakeholders who might be involved in, or have an interest in, carrying out site characterization for dam foundations in British Columbia. These guidelines provide a common level of expectation for these various stakeholders with respect to the level of effort, due diligence, and standard of practice to be followed when carrying out the site characterization.

These guidelines outline the appropriate standard of practice at the time they were prepared. However, this is a living document that is to be revised and updated, as required, in the future, to reflect the developing state of practice.

Although these guidelines are applicable to dams in British Columbia, the guidance provided can also be considered by APEGBC professionals while working in other jurisdictions in Canada or any other global jurisdiction.

DEFINITIONS

The explanations of the terms below are specific to these guidelines. All of these terms are italicized the first time they appear in the text.

APEGBC
The Association of Professional Engineers and Geoscientists of British Columbia.

APEGBC professionals
Professional engineers, professional geoscientists, and licensees who are members or licensees of APEGBC.

Assurance Statement
The Design Engineer Site Characterization Assurance Statement, Appendix A-1 of these guidelines.

British Columbia Dam Safety Regulation
British Columbia Regulation 44/2000, including revised amendments B.C. Reg. 108/2011 (June 2011) and B.C. Reg. 163/2011 (September 2011).

Client
An individual or company that engages an APEGBC professional to carry out work related to the design, inspection, or review of a dam. The client is typically the dam owner. The client might also be a third party that has been contracted to operate and maintain the dam on behalf of the dam owner. Multiple holders of water licences, and therefore multiple owners, are common for small dams.

Consequence classification
The dam failure consequence classification of a dam as determined by Schedule 1 of the *British Columbia Dam Safety Regulation* (for water dams) or Table 2-1 of the *Canadian Dam Association Dam Safety Guidelines* (for dams under the Mines Act).

Dam
A structure that allows storage of water or saturated solids.

Design Engineer
The professional engineer having overall responsibility for the design of the dam, which includes responsibility for developing and overseeing the site characterization of the dam's foundation. The Design Engineer signs the Design Engineer's Site Characterization Assurance Statement (see Appendix A-1 of these guidelines) required in support of the feasibility study. The Design Engineer would normally transition into the Engineer of Record.

Engineers and Geoscientists Act
Engineers and Geoscientists Act, RSBC 1996, Chapter 116, as amended.

Engineer of Record
The professional engineer responsible for assuring that the dam is safe, in that it is designed and constructed in accordance with the current state of practice and applicable regulations, statutes, guidelines, codes, and standards.

Field reviews
Reviews of the work at a dam site or, where applicable, at fabrication sites where components are fabricated for use at the dam site, considered necessary by an APEGBC professional in his/her professional discretion to ascertain whether the work substantially complies in all material respects with the documents that he/she has prepared.

Geologic Strength Index
A system for estimating the reduction in rock mass strength for different geological conditions as identified by field observations.

InSAR
A radar technique used in geodesy and remote sensing.

Lidar
A surveying technology that measures distance by illuminating a target with a laser light.

Mines Act
Mines Act, RSBC 1996, c. 293 (updated to 2007).

Owner / dam owner

A person or legal entity that, with respect to a dam, is any or all of the following:

1. The person or legal entity that holds the current licence or is required to hold the licence for the dam
2. The person or legal entity that last held a licence for the dam, including a licence that has been suspended, cancelled, abandoned, or terminated
3. If there is no person or legal entity to whom paragraph (1) or (2) above applies, the owner of the land on which the dam is located or the person or legal entity that had the dam constructed.

Phases
Phases of the project are design, construction, operation, decommissioning, and closure (in the case of tailings dams).

Professional engineer
An engineer who is a member or licensee in good standing with APEGBC and, in relation to dam foundation work, is typically registered in one of the following disciplines: geological engineering, mining engineering, or civil engineering, all of which are designated disciplines of professional engineering.

Professional geoscientist
A geoscientist who is a member or licensee in good standing with APEGBC and, in relation to dam foundation work, is typically registered in the discipline of geology or of environmental geoscience, each of which is a designated discipline of professional geoscience.

Regulatory authority
The regulatory authority tasked with managing the regulatory requirements of a dam project, as decreed by statutes and regulations of British Columbia. Regulatory authorities may include the Ministry of Energy and Mines; Ministry of Environment; Ministry of Forests, Lands and Natural Resource Operations; Parks Canada Agency; Canadian Nuclear Safety Commission; or International Joint Commission.

Site characterization
The process of defining a dam's subsurface conditions with respect to geology, geomorphology, and hydrogeology. Site characterization involves data collection, field investigations, and interpretation.

Site characterization program
The combination of activities that are undertaken to define a dam's subsurface conditions (e.g., field mapping, drilling, geophysics, testing).

Site characterization report
A report produced by the Design Engineer that documents the site characterization data and the interpretation of the data.

Site geological model
A model that includes the bedrock and surficial geology, with integration of geomorphology, geotechnical and hydrogeological conditions, and relevant seismotectonic characteristics.

Stages
Stages of project design are as follows: scoping-level, pre-feasibility, feasibility and detailed design.

Supporting registered professional (SRP)
An APEGBC professional engineer, professional geoscientist, or licensee engaged by the Design Engineer to carry out professional activities related to the site characterization of the dam foundation.

ABBREVIATIONS USED IN THESE GUIDELINES

APEGBC	Association of Professional Engineers and Geoscientists of British Columbia
ASTM	American Society for Testing and Materials
DSCR	dam site characterization report
FMEA	failure modes and effects analysis
InSAR	interferometric synthetic aperture radar
lidar	light detection and ranging
SGM	site geological model
SRP	supporting registered professional

INTRODUCTION

1.1 INTRODUCTION TO THESE GUIDELINES

The foundation of a *dam* is a critical structural component and requires special attention. A dam foundation has a twofold function: (1) structural stability (to provide stability and sufficient stiffness to limit deformations to within acceptable behaviour patterns under the weight of the dam and the forces acting on it and to maintain this integrity under the conditions that exist and/or can be expected to develop over time); and (2) seepage control (to control seepage with respect to flow quantity and quality, uplift pressures, and erosive stresses). If one of these functions is not sufficiently addressed, the dam's performance may be impaired to the point that the dam is unsafe.

The foundation conditions at a site are also a determining factor in the selection of the type of dam; *site characterization* is therefore important for the design of the dam and its safe operation. In the context of dam safety, the design and supporting *site characterization program* are important "critical controls" – elements that reduce risks. Accordingly, the site characterization program could be considered a "critical control" for dam safety and should be treated as such.

Whereas the dam itself is "engineered" and quality control can be exercised through design and construction specifications, the foundation conditions are "natural" and are subject to the inherent heterogeneities and potentially complex conditions between investigated locations. Because it is impractical to achieve a full definition of the geologic domain in a dam's foundation, the challenge is to keep the uncertainties within acceptable limits and to balance the uncertainties with design provisions. This balance is part of the ongoing review of cost/benefit considerations of incremental investigations.

It should always be assumed that a given site is both geologically and geomorphologically complex. Therefore, the site characterization program should be carried out to confirm either that the site is one of those rare locations that is not complex and that conditions and parameters are understood, or that the program has appropriately assessed the site's complexity and variability, allowing determination of representative conditions and parameters.

Tailings dams have unique characteristics that are different from those of water dams and industrial dams, as discussed in Section 2.1. The most significant differences are the staging of tailings dam construction over the life of the mine (steady state is typically reached only at mine closure or when an alternative tailings storage facility is commissioned for an operation), the impoundment of both tailings solids and mine process/contact water, and the fact that the dam will be required in perpetuity. These conditions provide for a unique set of considerations that must be addressed where tailings dams are involved.

The role of the *Design Engineer*, as described in these guidelines, is to develop a site characterization program that considers the geological complexity, the dam design, and factors influencing the program. The Design Engineer is responsible for assuring that adequate and appropriate site characterization has been carried out for the dam's foundations, and commonly transitions into the *Engineer of Record*.

1.2 BACKGROUND TO THESE GUIDELINES

The investigation carried out by the Chief Inspector of Mines into the Mount Polley incident ("Chief Inspector's Report") concluded that the incident occurred because the dam's embankment failed as a result of an unidentified weak soil layer (upper glaciolacustrine unit) in the foundation of the dam. Insufficient freeboard relative to the embankment deformation then led to a dam breach.

The main findings of the Chief Inspector's Report with respect to site characterization of the dam foundation included:

* The spacing between deep sampled drill holes in the dam foundation was over 400 metres, which was considered to be too far apart for the nature of the site's geology and geomorphology.
* The depth of drilling (typically less than 10 metres) was not enough to characterize the foundation for the height of the dam (40 metres) and the nature of the foundation materials.
* The drilling and sampling methodology for the one deep drill hole located in the breach area was not adequate for characterization of the soils (rotary diamond drill hole with observation of cuttings).
* The geological model for the site did not recognize the more than three stages of glaciation and the complexity of the surficial geology.

The Chief Inspector's Report identified additional factors that did not appear to have been adequately characterized, although they may not have contributed directly to the incident:

* The foundation bedrock beneath the breach included high-plastic, low-strength mudstone, which could influence stability at higher dam heights.
* The undrained strength response of the foundation glaciolacustrine layers was not clearly identified in the design reports.
* Artesian pressures in the foundational glaciofluvial soils were not explicitly recognized or accounted for in stability analyses.

1.3 PURPOSE AND OBJECTIVES OF THESE GUIDELINES

The *Professional Practice Guidelines – Site Characterization for Dam Foundations in BC* have been developed in response to Recommendation 6 of the Independent Expert Engineering Investigation and Review Panel's *Report on Mount Polley Tailings Storage Facility Breach*. The purpose of these guidelines is to identify an appropriate standard of professional practice for site characterization. This standard of practice provides a framework for adequate site characterization for dam foundations, to improve dam safety and ensure that incidents such as the one at Mount Polley will not be repeated.

These guidelines provide direction on good practice for site characterization and on the level of detail required.

The guidelines are intended to lead to a common level of expectation for Association of Professional Engineers and Geoscientists of British Columbia (*APEGBC*) professionals, *owners*, regulatory authorities, First Nations, and other stakeholders. For First Nations, this common level of expectation should include issues related to Aboriginal title, rights, and traditional land use being reviewed with the relevant authorities and stakeholders. This review is normally undertaken by the owner(s) during the project's scoping stage.

[1] *APEGBC*'s Code of Ethics is at https://www.apeg.bc.ca/APEGBC/media/APEGBC/Governance/APEGBC-Code-of-Ethics.pdf. The Code of Ethics, along with accompanying Guidelines and Commentary, are published in the current (1994) *edition of APEGBC's Guidelines for Professional Excellence.*

These guidelines should be considered within the context of guidance provided by the Canadian Dam Association and the Mining Association of Canada with respect to dams.

The specific objectives of these guidelines are to:

1. Describe the types of dams that these guidelines apply to, the *stages* of dam design, and the *phases* of a dam project/life
2. Describe the roles and responsibilities of the various participants and stakeholders, including regulatory authorities, that are involved in the site characterization for dam foundations
3. Outline the professional services to be provided by APEGBC professionals in conducting site characterization for dams in British Columbia
4. Describe the standard of practice to be followed by APEGBC professionals in providing professional services related to conducting site characterization for dams in British Columbia. The standard of practice is set in the context of the complexity of the site, dam design, and other factors.
5. Specify the tasks and the technical components to be considered by APEGBC professionals in order to meet an appropriate standard of practice and the intent of these guidelines while fulfilling APEGBC professionals' obligations under the *Engineers and Geoscientists Act*. These obligations include a primary duty to protect the safety, health, and welfare of the public and the environment.
6. Describe the quality management practices to be followed by APEGBC professionals in carrying out site characterization, in order to meet their professional obligations
7. Provide consistency in site characterization and reporting
8. Describe the appropriate knowledge, skill sets, and experience that APEGBC professionals must have when providing professional services related to site characterization

These guidelines provide a framework for the standard of practice to be applied to site characterization of foundation conditions for dams in British Columbia. They are an important tool for managing the uncertainties associated with the outcome of a site characterization program.

In particular, Section 4.6 of these guidelines outlines the documentation outcomes of a site characterization. These include a *site characterization* report and *Site Characterization Assurance Statement* that are to be submitted to the *dam owner* and the *regulatory authority*, if applicable, by the Design Engineer and supporting APEGBC professionals.

A Site Characterization Assurance Statement is required at the feasibility and detailed design stages of a project, as described in Section 2.2.2. A Site Characterization Assurance Statement provides a standardized statement confirming that the objectives of the site characterization program have been met in obtaining an appropriate understanding of the following five site characterization components and that the level of investigation carried out was sufficient:

- Bedrock and structural geology
- Surficial geology and geomorphology
- Geotechnical conditions
- Hydrogeology
- Seismotectonic conditions

These characterization components are addressed in Section 4.4. A template for the Site Characterization Assurance Statement is included in Appendix A-1.

1.4 ROLE OF APEGBC

These guidelines have been formally adopted by the APEGBC Council and reflect APEGBC's ongoing commitment to maintaining the quality of services APEGBC professionals provide to their clients and the general public. APEGBC professionals are professionally accountable for their work under the *Engineers and Geoscientists Act*, which is enforced by APEGBC.

An APEGBC professional must exercise professional judgment when providing professional services; as a result, application of these guidelines will vary depending on the circumstances. APEGBC supports the principle that, in order to comply with the standard of practice provided in these guidelines, the Design Engineer responsible for carrying out the site characterization of the dam foundation should be provided with appropriate financial, human, and technical services. These guidelines should be used to assist in establishing the objectives, type of dam site characterization, level of service, and terms of reference for an APEGBC professional's scope of work and agreement with the client.

By following these guidelines, APEGBC professionals will fulfill their professional obligations, especially with regard to APEGBC's Code of Ethics Principle 1 ("Hold paramount the safety, health, and welfare of the public, the protection of the environment and promote health and safety in the workplace" 1). Failure of an APEGBC professional to meet the intent of these guidelines could be evidence of unprofessional conduct and lead to disciplinary proceedings by APEGBC.

1.5 SCOPE OF THE GUIDELINES

These guidelines apply to site characterization conducted for dam foundations regulated under the *British Columbia Dam Safety Regulation* and/or permit conditions under the *Mines Act* and other relevant provincial or federal legislation. These guidelines apply to all stages of design, as described in Section 2.2.

Dam site characterization may be carried out for dams other than those regulated under the legislation referenced above. The information contained in these guidelines is likely relevant to dam site characterization for the construction of dams that are not regulated by legislation in British Columbia.

Furthermore, dam site characterization methods documented in these guidelines are not intended to address any occupational health and safety requirements in relation to the site characterization activities to be carried out. However, where a serious concern is identified, it must be brought to the attention of the constructor / dam owner / client.

1.6 APPLICABILITY OF THESE GUIDELINES AND APEGBC

These guidelines provide guidance on professional practice for APEGBC professionals carrying out site characterization assessments for dams in British Columbia. These dams may be owned by diverse parties, including utilities, mining companies, pulp and paper companies, companies working in the oil and gas sector, various levels of government, First Nations, or private owners. The application of these guidelines provides a consistent and comprehensive standard of professional practice to be applied to site characterization for dams in British Columbia.

An APEGBC professional's decision not to follow one or more aspects of these guidelines does not necessarily mean that he/she has failed to meet his/her

1).APEGBC's Code of Ethics is at https://www.apeg.bc.ca/APEGBC/media/APEGBC/Governance/APEGBC-Code-of-Ethics.pdf. The Code of Ethics, along with accompanying guidelines and commentary, is published in the current (1994) edition of APEGBC's *Guidelines for Professional Excellence*.

professional obligations. Such judgments and decisions depend on considering the facts and circumstances for a specific site to determine whether another reasonable and prudent APEGBC professional, in a similar situation and during the same time frame, would have conducted himself or herself similarly.

These guidelines outline the appropriate standard of practice at the time they were prepared; this is a living document that is to be revised and updated, as required, to reflect the developing state of practice. These guidelines are influenced by current provincial legislation, advances in knowledge, and the evolution of general professional practices in British Columbia.

With respect to the use of these guidelines in other jurisdictions in Canada (provinces and territories) or internationally, the practitioner wishing to apply them in another jurisdiction should confirm this with the relevant regulatory body. APEGBC supports the development of a common standard of care in professional practice in the carrying out of professional engineering/geoscience activities across Canada and, as practical, internationally. This includes site characterization for dam foundations.

1.7 ACKNOWLEDGMENTS

These guidelines were prepared on behalf of APEGBC by a committee of APEGBC professionals and were reviewed by several individuals as members of a review task force. The authors and reviewers are listed in Appendix C. The authors thank the reviewers for their constructive suggestions. A review of this document does not necessarily indicate that reviewers and/or their employer / agency / affiliated association endorse everything in these guidelines.

APEGBC thanks the BC Ministry of Energy and Mines and BC Ministry of Forests, Lands and Natural Resource Operations for providing technical support in the preparation of these guidelines. APEGBC also thanks the Canadian Dam Association, Mining Association of British Columbia, and BC First Nations Energy & Mining Council for providing support and peer review of these guidelines.

CONTEXT FOR SITE CHARACTERIZATION FOR DAM FOUNDATIONS

2.1 TYPES OF DAMS

These guidelines are intended for dams that are constructed for any one of a variety of purposes ranging from, for example, small water storage dams for irrigation to very high dams for hydroelectric power generation and mine tailings storage. In addition, dam ownership and uses can vary widely. Table 2-1 summarizes three general dam types and purposes—water dam, industrial dam, and tailings dam—and the key differences between them.

Earth or rockfill dams (embankment dams) can be constructed for each of the types shown in Table 2-1. Concrete dams are often constructed for water dams and industrial dams, but rarely for tailings dams.

Table 2-1. Characteristics of Water Dams, Industrial Dams, and Tailings Dams

Characteristic	Water Dam	Industrial Dam	Tailings Dam
Purpose and stored material	Water supply; hydroelectric; flood control; water and stream diversions; run-of-river hydroelectric; recreational; land improvement	Storage of process and waste water, sludge, and sediment	Storage of tailings solids and process/ mine contact water
Operating life	Typically designated as 100 years, but "as long as required by society"	As long as the industrial operation remains (can be multiple decades)	As long as the mine remains operating (can be multiple decades)
Construction period	Usually 1 to 5 years	Usually less than 1 year	Initial starter dam, then staged over the operating life (can be multiple decades)
Closure	Facility may be decommissioned, with the dam removed or breached	Often decommissioned and/or covered	Commonly a perpetual closure period. If there is water retention, then the dam may have to be treated the same way as it was during operation. Modifications to the dam may allow redesign to become a "landform."
Continuity of engineering	Typically one engineering firm for design and construction	Varies and can change frequently during operating life	Varies: engineering firm may change during the operating life and most certainly will change over the closure period
Owner	Public utilities and municipalities; individual landowners	Mining, forestry, and oil and gas companies; municipalities	Mining companies and government
Consequences of failure	Water inundation	Release of water and/or sludge that has been affected by the process	Water inundation and tailings solids debris flow
Dam section	Usually a consistent section; upgrades, including raising and downstream berms, are possible	Usually a consistent section	Can vary and evolve during the development of the facility

Special Considerations for Tailings Dams

The three dam types shown in Table 2-1 perform different functions, and each type has unique characteristics. For example, tailings dams have three unique characteristics:

- The progressive raising of the dam during the operating life of the mine results in ongoing changes to the stability of the dam.
- Unlike most water retention dams, which can be breached at the end of their intended life, a tailings dam is required in perpetuity, although its function may change according to the water retention characteristics on closure.
- The storage of mine tailings and process water increases the potential environmental consequences associated with seepage, water release, or dam failure. Industrial dams may also have additional public safety and environmental concerns.

Considerations for tailings dams include the following:

- Tailings dams are fundamentally different from other types of dams in that they are typically raised successively over time as a mine develops. As a result, the static loading conditions are continually changing, and stability and seepage considerations therefore also continue to change.
- The progressive dam raises typically involve additional site characterization and detailed designs for the stages and/or dam modifications over time.
- Most, or at least a significant portion, of a dam is constructed over the operating life of a mine, which in some cases can be multiple decades. As a result, changes can be expected in the Design Engineer, potentially in the ownership, and even in regulatory requirements over this extended time frame. Transitions between the responsible parties can represent a challenge and must be carefully planned and implemented to maintain the integrity of institutional knowledge, including the site characterization studies.
- Permitting requirements for a tailings dam may be tailored to the periodic raises that may occur over the life of the facility or to a specific dam elevation, which may change. As a result, the regulatory review process may also be subject to changing regulatory requirements over time.
- The nature of tailings solids and process water may limit the allowable quantity of seepage water to the receiving environment, which places additional emphasis on the need for hydrogeological assessment.
- As noted above, tailings dams cannot be removed on closure. As a result, they have to be maintained in perpetuity and engineered to function as a dam in that manner or engineered to be able to transition to performing as a natural landform while maintaining physical and chemical containment for the tailings.

2.2 LIFE PHASES AND DESIGN STAGES OF DAMS

2.2.1 Life Phases

There can be several life phases for a dam, as follows:

- Concept development— the general location, configuration, and type of dam is considered
- Planning and site selection—involves a comprehensive review of potential sites and dam configurations
- Design of the dam
- Construction of the dam— for a tailings dam, this would be the starter dam
- Operation—for a water dam or industrial dam, operation involves first filling the reservoir, and after that, ongoing operation; for a tailings dam, construction typically occurs in stages during the operational life of the dam
- Closure—for many dams can include breaching or removal of the dam (decommissioning); however, for many tailings dams, the dams may have to remain in perpetuity, unless they can be closed as a natural landform; tailings dams requiring storage of water for permanent submergence of reactive tailings must function as both tailings and water retention structures in perpetuity

Figure 2-1 shows a generalized timeline for water or industrial dams, which starts with concept development and ends with breaching or removal of the dam. Figure 2-2 is a similar timeline for a tailings dam that cannot be transitioned to a "landform" after mine operations cease and may require treatment as a dam in perpetuity.

Figure 2-1. Life Phases of Conventional Dams (Water or Industrial Dams)



Figure 2-2. Life Phases of Tailings Dams



2.2.2 DESIGN STAGES

There are typically a number of stages of design for a dam, and different conventions are used for naming and defining them. Table 2-2 presents the naming conventions that are used in these guidelines and, for comparison, provides examples of naming conventions used by others.

The design stages and life phases of a water dam and an industrial dam are the same.

Table 2-2. Naming Conventions for Typical Design Stages

Terms Used in These Guidelines	Other Common Terms	
Scoping-level design	Conceptual design	Preliminary economic assessment
Pre-feasibility design	Feasibility design	Preliminary design
Feasibility design	Preliminary design	Basic engineering design
Detailed design	Detailed design	Final engineering design

As shown in Table 2-2, design stages for dams typically include:

- **Scoping-level design** – this design stage develops the initial concept for the dam, including site selection and possible options for the dam configuration, location, size, and so on. The study typically focuses on identifying major features that could have a bearing on the dam siting, configuration, and operation. Major cost items and risks are identified. In some cases, the scope level may advance far enough to decide on the site and location for the dam. Cost estimates are typically developed to an accuracy of +/– 50% or greater and should be consistent with the owner's needs. The key objective of this stage is to determine whether the project should move forward.
- **Pre-feasibility design** – this stage typically considers multiple options and possibly multiple sites for the dam. The preferred site and location for the dam will typically be defined during this stage. The site characterization program is undertaken to provide information for the advancement of the dam concepts and should identify the preferred configuration of the dam. Cost estimates for the dam construction are typically developed to an accuracy of +/– 25% to 35% and should be consistent with the owner's needs.

- **Feasibility design** – this stage advances the design to support a +/– 15% to 25% cost estimate, consistent with the owner's needs. The feasibility design for the dam may also be required to support financing, environmental assessments, and other regulatory requirements for approval of the project.
- **Detailed design (tender stage)** – this stage occurs just prior to construction and is when the scope of work, specifications, and construction drawings are prepared. It is typically used to support a +/– 10% to 15% cost estimate, consistent with the owner's needs. Additional regulatory approvals may be required after the detailed design has been completed and prior to construction commencing. It may also be necessary to conduct additional site characterization to support aspects of the detailed design.

For smaller projects, the design stages are often combined (e.g., scoping and pre-feasibility are combined, followed by the feasibility design and detailed design stages).

Section 4.1 provides information on the typical site characterization activities for each design stage. During construction and operation, conditions may develop that had not been anticipated during the feasibility and detailed design stages, and additional site investigations and/or modifications to the design and construction plans may be required.

For a new tailings dam, the dam design and site characterization at the feasibility stage should be based on the planned ultimate configuration of the dam, with consideration of the future construction sequencing and raises. A detailed design will typically be prepared for the starter dam and/or the permitted dam elevation. Additional detailed design updates throughout the operation life phase are typically required for each successive raise of the tailings dam for construction control and, in some cases, to meet permit requirements. To support the design of the raises, additional site characterization may be required.

For many mining projects, as the mine develops there is an increase in the tailings quantity above the originally planned amount, which requires an increase in the size of the tailings storage facility. There may also be modifications to the mine plan that require a reduction in the size of the facility or other modifications, such as a new spillway. These design modifications may move directly into the feasibility stage required to support amendments to the previously granted regulatory approvals, and in this case would be followed by detailed design to support additional permitting and the construction. There will typically be additional site characterization activities to support these design modifications.

The design of a dam depends on site characterization at any phase of the dam's life. Therefore, these guidelines for site characterization are organized, in large part, by design stage.

ROLES AND RESPONSIBILITIES

This section describes the roles and responsibilities of the parties that are involved in a dam site characterization program.

3.1 OWNER

The owner is responsible for assigning a Design Engineer who will take responsibility for the dam site characterization. On rare occasions, the owner may have an internal team with a Design Engineer as part of the team. However, in many cases and almost always for tailings dams, the owner requires the services of an external professional (consulting firm) to carry out the design, which includes the site characterization.

The use of external professionals (consultants) typically starts during the scoping or pre-feasibility study, and a contractual arrangement to be used throughout the design stages may be established. The arrangement is most often established through a request for proposals process that allows an owner to assess the relative merits and core competencies of the candidates and, as appropriate, their proposed supporting APEGBC professionals. Typically, the request for proposals is for some portion of the design, of which the site characterization program is a component.

Other typical roles and responsibilities of the owner include the following:

- Provides safe work guidelines
- Establishes the general objectives for the project
- Documents who the Design Engineer is
- Instructs the Design Engineer to develop a work plan specific to the envisioned investigation works
- Interacts with First Nations and other stakeholders as required to communicate the extent of the site characterization program
- Obtains authorization for investigations to proceed on the property
- Finances the investigations
- Obtains, or assigns responsibility to the Design Engineer to obtain, clearances for underground infrastructure, road closures, working near power lines, and so on
- Participates in the development of the site characterization scope and monitoring during the execution of the program
- Provides relevant documentation to the Design Engineer
- Obtains, or assigns responsibility to the Design Engineer to obtain, regulatory approvals for site characterization activities that require such approvals
- In the event of a change in ownership, provides for an effective transfer of information related to the investigation program, including previous investigations
- Establishes contracts with firms undertaking the site characterization programs directly, or instructs the Design Engineer to act in this capacity
- Reviews changes that the Design Engineer recommends for consideration during the site characterization program and acts accordingly

For tailings dams, where construction and design services commonly are required over decades, changes in the Design Engineer are common. During the engagement process, provisions for full transference of salient information from previous design and investigation work need to be ensured, and the transfer should be formally documented. Furthermore, through all stages of the project, the owner should document the identity of the Design Engineer for the relevant regulatory authorities and stakeholders.

3.2 DESIGN ENGINEER

A Design Engineer must be identified who will be responsible for the design of the dam and for overall oversight, development, and execution of the site characterization program. The Design Engineer is typically an external professional (consultant) but may also be someone within the owner's organization.

The Design Engineer, through interaction with the owner, will establish the overall objectives and scope of the site characterization program. The Design Engineer will lead the program (actively in the field) and/or provide oversight of the program to determine whether the objectives of the investigation with respect to the design requirements are being met. The Design Engineer is responsible for ensuring that the site investigation program is sufficient to support the design stage for the dam. However, portions of that responsibility may be officially transferred to a supporting APEGBC professional (as described in Section 3.3).

The fieldwork for the site characterization program may be supervised by the Design Engineer or may be undertaken by an individual or individuals with sufficient experience as a qualified engineer, geologist, or technician, under the direction supervision of the Design Engineer. Supporting APEGBC professionals may also be engaged to provide specialist support in key technical areas.

The contracted entities that conduct the site characterization activities (e.g., reconnaissance, pitting, soundings, drilling, geophysics, surveying) may be contracted directly to the owner or, as directed by the owner, to the Design Engineer.

The Design Engineer must be a *professional engineer* experienced in dam design and site characterization programs. It is expected that the Design Engineer will understand the benefits, limitations, and risks of each of the investigation methods being considered for the site characterization program. (The education and training requirements for the Design Engineer are addressed in Section 6.2.)

Other typical roles and responsibilities of the Design Engineer include the following:

- In consultation with the owner, develops the site characterization program, consistent with project objectives
- Takes on responsibility for the site characterization program
- As requested by the owner, may take on specific roles that are normally carried out by the owner
- Develops a safe work plan that is submitted to the owner for approval
- Develops scope of work and methodology for the site characterization program that is submitted to the owner for approval
- Leads and/or monitors the implementation of the program
- Reports to the owner on progress and deviations from the plan
- Supervises the supporting APEGBC professionals who may be involved in support of the program
- If required by the owner, establishes contracts with firms undertaking the site characterization program
- Confirms with the owner that regulatory approvals and clearances for powerlines, roads, and so on have been obtained
- Reviews the results of the site characterization program as they are obtained from the field and identifies modifications that may be required to meet the objectives of the program
- Documents limitations on site access due to regulatory, land-ownership, or other factors
- Prepares reports describing the site characterization program results and implications for the design of the dam

- With the owner, develops a database and document control system that will allow the results of site characterizations programs to be properly catalogued
- Prepares the Site Characterization Assurance Statement(s)

3.3 SUPPORTING REGISTERED APEGBC PROFESSIONAL

A Design Engineer may require supplementary supporting professional engineering or professional geoscience services for a particular professional activity or component or sub-component of a professional activity related to the site characterization program in support of the design and construction of a dam. This would be provided by an APEGBC-registered *supporting registered professional (SRP)*. The SRP carries out duties for the site characterization as assigned by the Design Engineer (e.g., geological, geophysical, geotechnical, geochemical, hydrogeological, hydrological studies).

In instances where supporting professional engineering or professional geoscience services are required, site characterization assurance statements should be obtained by the Design Engineer from the SRP. All of the SRPs engaged to carry out professional activities related to the site characterization of the dam foundation must submit site characterization assurance statements that the professional activity that they are responsible for has been carried out in a manner that meets the intent of these guidelines and good professional practice.

The use of SRPs is appropriate for the site characterization program because the Design Engineer should draw on the experience and knowledge of professionals who specialize in the required disciplines when undertaking a site characterization program. SRPs include:

- Geologists
- Geomorphologists
- Geophysicists
- Geotechnical engineers
- Geochemists
- Hydrogeologists
- Hydrologists
- Seismologists

For a small site characterization program without complexity, the Design Engineer may draw on published information that has been prepared by such specialists. For a large program or a complex site, the Design Engineer must involve specialized professionals as required. Additional specialists may also be required to address land and water use issues, such as anthropologists, archaeologists, and biologists.

3.4 REVIEWERS

Both internal and external reviewers may be used for a site characterization program (see Sections 4.3 and 4.4). Specialist technical experts may be used in areas where the Design Engineer requires a higher level of investigation and assessment to support the design. An owner might also request that an external review of the designs be conducted, or the regulatory authority may have requirements regarding external review.

A site characterization program should include a review process as part of the APEGBC professional's quality assurance program. This review process is often provided by another APEGBC professional within the firm that employs the Design Engineer. In addition to this review, different types of external review of the site characterization program may be undertaken. These include:

- External peer review, whereby a specialist external to the owner's company and the Design Engineer's company is invited by the owner to conduct a review of the site characterization program. Such a review may be done during the development of the site characterization program,

after it is completed, or as part of a review of the overall dam design. The review would consider, for example, the appropriateness of the investigation tools and methods, location, quality control programs during the work, findings, and interpretations. This would typically occur at the feasibility design stage or later.

- Review boards can be established by the owner to review the design and performance of a dam—in particular, a tailings dam or large water dam. A review of the site characterization program should be included in the review board's scope.

3.5 REGULATORY AUTHORITY

The regulatory authority may be involved in the site characterization to review applications for permits to support the site characterization program (e.g., water crossings, working near water, or working near sensitive habitat). As required, the regulatory authority can work with the Design Engineer and owner to address constraints with respect to obtaining adequate site access for specified site investigation contractors and associated equipment and to manage potential environmental effects of the work.

3.6 OTHER PARTIES

Table 3-1 shows the roles of other parties that may be involved in a site characterization program.

Table 3-1. Roles of Other Parties Involved in a Site Characterization Program

Party	Role
Field team supervising the site characterization program	• Reports to the Design Engineer on progress and deviations from the plan • Prepares documents describing the site characterization program that can be used in the reports being prepared by the Design Engineer
Site investigation contractors/firms (e.g., drilling, geophysics, laboratory)	• Undertake work in accordance with the work plan developed by the Design Engineer • Advise the Design Engineer of challenges that may be encountered, as well as opportunities to obtain information in a more effective manner
Communities of interest	• Participate in community meetings or similar communication vehicles and in the permitting review process
First Nations	• Participate in consultation for possible site investigation on traditional lands

GUIDELINES FOR PROFESSIONAL PRACTICE

This section of these guidelines provides guidance on the standard of practice and due diligence associated with carrying out a site characterization for a dam, given the complexity of the site, the scale of the project, the life phase of the project, and the design stage (see Section 2.2). This section reinforces the requirement that a systematic assessment be carried out and describes what is involved in doing so from a professional practice perspective.

Section 4.1 provides an overview of a site characterization program, including a general description of the activities that should be undertaken for each design stage. Section 4.2 describes the elements that should be considered in a work plan for a site characterization program. Section 4.3 introduces the Site Characterization Assurance Statement. Section 4.4 provides details on the subject areas that should be investigated during the site characterization program (e.g., geology, hydrogeology); it describes "what" should be done, and not so much "how" it should be done. (References are provided for the "how.") Sections 4.5 to 4.7 describe other aspects of site characterization, including reporting.

The Design Engineer has overall responsibility for the site characterization program, including integration of the components described in this section.

4.1 OVERVIEW OF SITE CHARACTERIZATION

4.1.1 Site Characterization Activities

Characterization of the dam foundation most commonly begins during the scoping-level site selection studies. Figure 4-1 shows the typical activities that are undertaken during the site characterization.

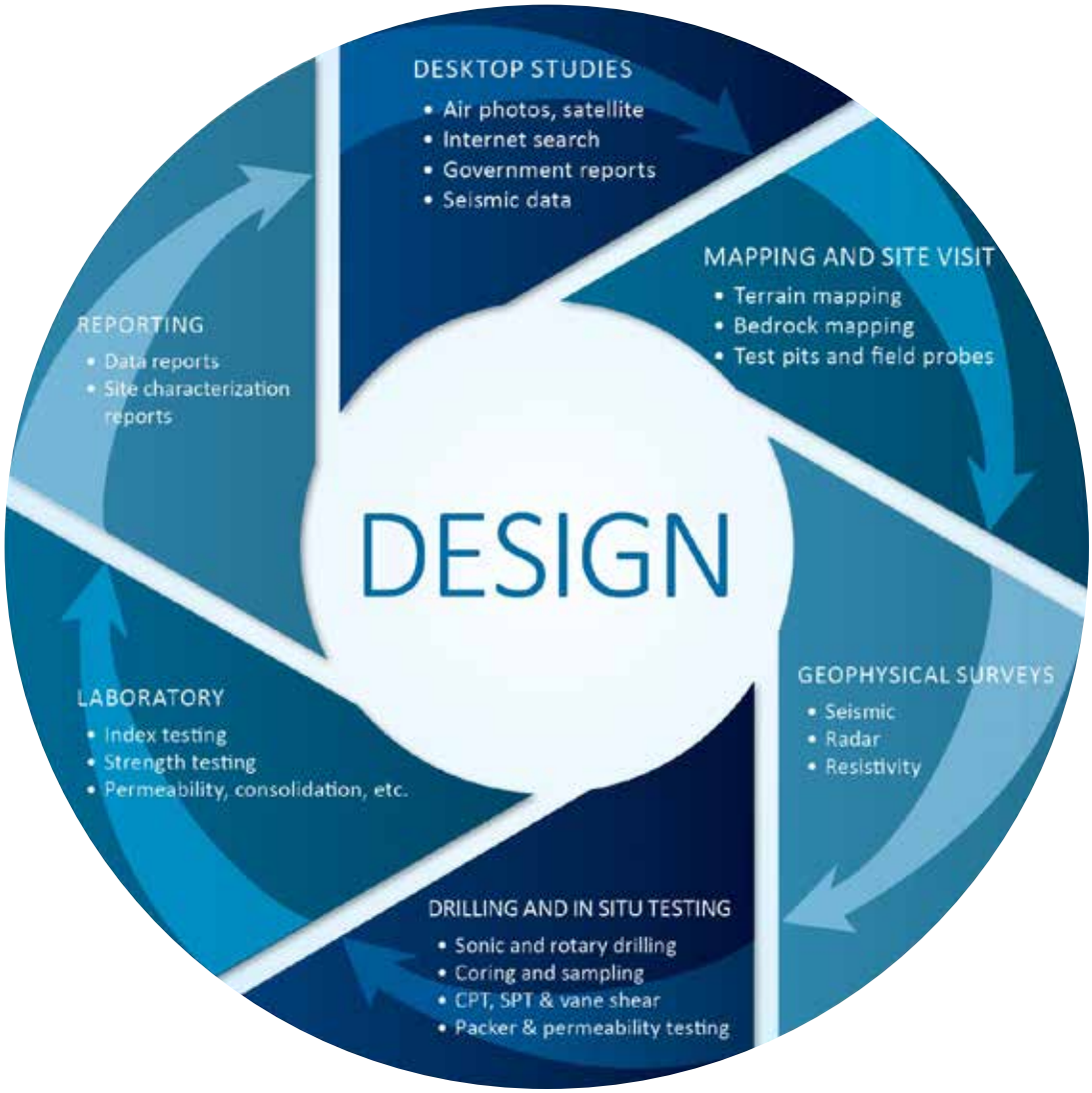
During scoping-level design, the concept for the dam may be partially or completely developed, and some level of site characterization work is required. The concept for the dam could require changes as a result of the site characterization, and these developments are often iterative processes. The questions that are asked about the site's geological, geomorphological, geotechnical, hydrogeological, and environmental characteristics are a function of the concept for the dam and the anticipated foundation conditions.

As the dam design develops through the pre-feasibility, feasibility, and detailed design stages, the site characterization will typically become increasingly detailed. It is typical to have ongoing site characterization work associated with each of these project stages, and for it to become more intensive as the project proceeds.

Site characterization is not a one-time event (as shown in Figure 4-1) and, in fact, continues from design into construction, operation, and closure. In addition, technologies for site characterization continue to evolve over time. Monitoring is used during construction and operation to confirm expected conditions and, if changes are observed, additional site characterization and design may be required.

For a water-retaining dam, site characterization activities are most active during planning and design; however, additional site characterization should take place when surveillance and monitoring indicate changing conditions or provide better knowledge. For tailings dams, the site characterization will continue through the years of construction and operation as the dam is raised.

Figure 4-1. Typical Site Characterization Activities to Support Design



Notes: CPT = cone penetration test; SPT = standard penetration test.

A range of APEGBC professionals may participate in site characterization for a dam foundation. They may include technical specialists such as structural geologists, Quaternary geologists, and geomorphologists. The requirements for various APEGBC professionals are determined by the scale and complexity of the dam. Other specialists, such as anthropologists and archaeologists, may be required to address land and water use issues.

Section 2.2.2 describes the design stages for a dam and how the site characterization program fits into those design stages. Table 4-1 outlines the typical site characterization activities for each of the design stages.

Table 4-1. Typical Site Characterization Activities by Design Stage

Design Stage	General Objectives of Design Stage	Typical Site Characterization Activities
Scoping-level design	Develop options for siting and dam configuration	Work is primarily based on existing information and table-top evaluations, but it typically includes a site visit for general reconnaissance of site conditions and mapping. Site geologic and other public information is used to develop an initial characterization of the potential site foundation conditions.
Pre-feasibility design	Compare options to select the preferred site and design for the dam	Work typically includes terrain and bedrock mapping, some site-specific intrusive investigations, *lidar*, test pits, and geophysics.
Feasibility design	Support financing and environmental assessment estimates	Work includes a wide range of investigation methods, including intrusive investigations, in situ testing, geophysics, and laboratory testing. Extent of site investigations is increased to the level required for the complexity of the site.
Detailed design	Issue for construction drawings and specifications Address permitting requirements	It may be necessary to conduct additional site characterization to support aspects of the detailed design.

For a new tailings dam, the design stages and site characterization activities will be similar to those shown in Table 4-1. For a tailings dam that is being raised in accordance with an existing approved design, additional site characterization may be required to check that the design basis that was used during the feasibility design stage remains valid and determine whether or not modifications need to be made to the design to accommodate information gained during construction and operation. For a tailings dam that is being raised beyond an existing approved design, the site characterization activities are similar to those described above for the pre-feasibility, feasibility, and detailed design stages, depending on the extent of the raise.

As far as is practical, if the potential tailings facility is near areas of exploration interest, it may be possible to integrate geotechnical investigations with the exploration holes that are being advanced for the mine. Regardless, any tailings facility should have some economic geological evaluation to confirm mineral value. If mineral exploration work can potentially be integrated into the dam site investigation for dams to be built at the site, it is essential the Design Engineer ensure that the exploration personnel are sufficiently trained to obtain the information expected to come from that program.

Permitting for fieldwork locations and access to sensitive areas can be a challenge. As the dam design advances through successively detailed stages, from pre-feasibility to detailed design, the need for more intensive site characterization typically increases. Permitting requirements (e.g., to clear a site of archaeology, to cut a tree to work in and near a stream) affect timelines, budgets, access to critical sites, and, ultimately, the quality of site characterization. Good site investigations cannot be conducted if they are impeded by competing constraints, such as limited access when more intensive site investigations are needed. For example, if it is impractical to get appropriate drilling equipment into a site until construction is underway, an appropriately detailed stratigraphic record to detect potentially thin, isolated, and shear-strength-deficient stratigraphic units cannot be produced. Planning, foresight, and early permit applications can minimize the potential for this to occur.

If the regulatory process is at odds with sufficient site characterization, it is the Design Engineer's responsibility to make that clear and to and to state his or her concerns about deficiencies in the supporting investigation work accordingly for the design stage involved. Further, it is important for the regulatory authority to understand its role in the site investigation process and how that role can influence the effectiveness of the program.

4.1.2 Site Geological Model

The general objective of site characterization is to develop a clear, three-dimensional understanding of a dam's foundation. As noted above, site characterization begins with a broad appreciation of the site with respect to the overall landscape and geology in the region, then progresses with more site-specific information and details until a sufficient three-dimensional picture of the dam's foundation conditions has been developed. The degree of refinement of the three-dimensional picture is commensurate with the nature of the dam to be constructed.

Depending on the nature of the dam, the format of the three-dimensional picture can range from basic plan views and cross-sections to a fully integrated three-dimensional model containing the available information. In these guidelines, this three-dimensional picture, based on an understanding of the geological and geomorphological processes, is referred to as the *site geological model* (SGM).

- The SGM has several components, including:
- Bedrock and structural geology
- Surficial geology and geomorphology
- Geotechnical conditions
- Hydrogeology
- Seismotectonic conditions

These components are addressed in detail in Section 4.4.

4.2 WORK PLAN FOR SITE CHARACTERIZATION PROGRAM

For each design stage, the Design Engineer should develop a work plan that describes the information that is available, the objectives of the site characterization program, and the methodology to be undertaken to meet those objectives (including the activities noted in Figure 4-1). The program work plan developed by the Design Engineer is to be reviewed according to the Design Engineer's applicable quality control procedures.

The work plan should take into account the considerations listed below.

General

- The general planned configuration of the dam or modification, including the areal extent, height, seepage control requirements, and so on – These aspects set the context for the investigation program. At the early design stages, this will be in general terms, but in later design stages, it will become better defined.
- Purpose of the dam (water control, tailings disposal, or other)
- Anticipated design loads of the dam during construction and operation
- Design basis and design criteria – In the early design stages, these will be general, but they will be better defined in later stages.
- Background to the site characterization investigation program, including known existing information and nature of such information, to set the context of the program and the objectives of the program
- Documentation that is expected to be produced
- Budget and schedule
- Health, safety, and environmental protection plan
- Potential risks associated with the program
- How the results are to be integrated into the SGM

Investigation Programs

- Description of locations for the site characterization investigations (field mapping, geophysics, subsurface exploration, and other), including the reasoning behind establishing the locations – This should also include anticipated depths for subsurface explorations and instrumentation.
- Plans for access to the required locations
- Description of investigation methodologies to be employed
- Quality control program
- Permitting requirements
- Location of underground utilities and infrastructure that need to be protected from damage during an intrusive investigation
- Location of above-ground power lines that could limit access for some drilling and excavation equipment
- Method of soil classification (such as Unified Soil Classification System) and technical standards and/or guidelines to be used for investigation and testing (such as American Society for Testing of Materials [ASTM] International)
- Method for logging the investigations
- Method for naming the investigation locations so that they can easily be tracked in a database over many years
- Laboratory testing plan (which may be modified as the investigation program proceeds)
- Plan to survey the investigation locations in terms of laying them out and then locating them after completed

"Data worth" is an important consideration in developing the work plan for site characterization (Freeze *et al*. 1992): "Data worth is established by comparing the cost of data collection and interpretation against the expected value that the data provides." This can also be considered the value of risk reduction. The decision to collect further data must therefore be weighed against the cost of the data collection and the value of that data in improving the performance of a dam, including improved stability of a structure and improved control of seepage losses. The information can also be evaluated by comparing the risks prior to the data collection with the remaining risks after incorporating the expected value of the additional data into the analyses. Reducing the uncertainties through data collection will add value to a project.

4.3 SITE CHARACTERIZATION ASSURANCE STATEMENT

The Design Engineer must provide a Site Characterization Assur ance Statement based on the dam site characterization, stating that the Design Engineer is an APEGBC professional; the dam site characterization report was completed in accordance with these guidelines; and either the dam site characterization report is reasonably comprehensive and supports the design of the dam, or the dam site characterization report is not sufficiently comprehensive and additional investigation is required. The Design Engineers Site Characterization Assurance Statement supports the feasibility design and the detailed design stages.

Leading up to the feasibility design stage, there are a wide range of variables, configurations, sites, and so on, that are considered when undertaking a site characterization program. It is the Design Engineer's judgment, in concert with the owner's requirements, the regulatory authority's requirements, and input from First Nations and other stakeholders, that determines the requirements for these earlier design stages.

However, for the feasibility design stage, where the design has to be advanced sufficiently to demonstrate that the dam can safely be constructed and to support regulatory requirements for permitting, the site characterization has to be thorough enough to support the design. While

these guidelines provide information that is applicable to all design stages, a Site Characterization Assurance Statement is required only for the feasibility design and detailed design stages.

As noted in Section 3.2, the Design Engineer may require supporting APEGBC professional services for a particular professional activity or component related to the site characterization program. These services would be provided by an APEGBC-registered supporting registered professional (SRP).

All of the SRPs engaged to carry out professional activities related to the site characterization of the dam foundation must submit separate assurance statements to the Design Engineer in the form set out in Appendix A-2 of these guidelines. The SRP Assurance Statement declares that the professional activity and the supporting documents prepared by the SRP have been carried out and produced in a manner that meets the objectives of these guidelines and reflects good professional practice. The Design Engineer will review the SRP assurance statements as part of his/her acceptance and sign off on the Site Characterization Assurance Statement.

4.4 SITE CHARACTERIZATION COMPONENTS

A preliminary site geological model (SGM) is developed on the basis of published reports, aerial photographs / lidar, site reconnaissance, and so on, and it informs planning for the site investigation. Much of the larger-scale information, such as satellite images, aerial photographs, and regional and smaller-scale geological and topographical maps, is publicly available. There may also be published papers about the area, as well as research reports. If there are any other development projects or mines in the area, it is possible that other site characterization reports for the area may be available.

The SGM should focus not just on the dam and the impoundment but also on the surrounding region. The preliminary SGM should also provide some initial idea as to the degree of variability expected, which then informs the conduct and sequence of the site investigation. An iterative process ensues.

4.4.1 Bedrock Geology

Bedrock in BC varies from strong massive intrusive rocks to weak hydrothermally altered volcanic rocks and fissile sedimentary sequences. Weak rock can adversely affect siting conditions, and landslides could affect a dam or impoundment. Existing bedrock geologic information will provide valuable input to the initial SGM, which can then be used for considerations such as drilling density. Publications related to bedrock geology are available from the Geological Survey of Canada and the BC Geological Survey, and full references are listed in Appendix B to these guidelines (Bibliography).

Table 4-2 lists documents that are particularly relevant. The information provided by these sources may be too limited for siting considerations but is vital for regional overview. For tailings and other mine-related dams, more detailed information about local bedrock geology should be available from the mining company, as a result of extensive drilling and ground traverses that would have also identified outcrop locations. However, the objectives of the mining company's investigation would have been more focused on proving the ore deposit and not necessarily on geotechnical characteristics. At least some fieldwork will be required to proof the bedrock map and the SGM.

Table 4-2. Key Information Sources for Bedrock Geology

Reference	Items of Interest
GEOSCAN—Natural Resources Canada (Earth Sciences Sector) publications database.	Geological Survey of Canada publications, including maps
BC Geological Survey publications.	BC Geological Survey publications
Geologic Maps of BC.	Geologic maps of BC
Geological Survey of Canada maps.	Geological Survey of Canada maps

A bedrock mapping program should emphasize features that affect the geotechnical properties of the rocks: faults, fractures, joints, and types of weathering. A competent bedrock mapper with experience with structural geology should do the mapping and evaluation, likely in conjunction with a geotechnical specialist. Having a good understanding of the regional tectonic history of the area from previous studies will assist in the mapping of structural features.

Faults are problematic because rocks adjacent to the fault can be highly fractured, and the fault itself could contain fault gouge (finely crushed rock), both of which serve to lower the *Geologic Strength Index*. Other potential planes of weakness, such as joints and bedding, should be measured and evaluated with respect to continuity, daylighting, general foundation conditions, and overall joint fabric orientations of major joint sets. Stress relief from isostatic rebound after glaciation causes unloading and can also affect jointing patterns. Glaciotectonic considerations are discussed in Section 4.4.2.

Although remote sensing is generally of less utility in bedrock mapping than in surficial mapping, satellite images, aerial photographs, and especially lidar images are useful for locating structural elements such as lineaments. Ground-based lidar and photogrammetry can be useful for discontinuity analysis if suitable outcrops exist.

To support the SGM, geophysics and drilling must be considered. The drilling program and ongoing site observations will be used to improve the SGM in an iterative manner. Surface geophysics, as discussed in Section 4.4.2, may be useful. The selection of appropriate drilling equipment, such as triple-tube diamond drilling with oriented core, should be considered.

Groundwater well databases should also be consulted to provide input to the hydrogeological component of the SGM (discussed further in Section 4.4.4).

Special care is required in areas of calcareous rock because of the possibility of karst features. Dissolution can cause cavities that provide conduits for groundwater and may collapse. Although calcareous rocks occur throughout BC, they are most common on Vancouver Island and in the Rocky Mountains. Geophysical surveys may be considered to determine whether larger cavities exist in the area. A related issue is old underground workings that can have similar issues of collapse and groundwater diversion.

For a mining project, the mining company will have an understanding of the local bedrock geology, gained from its exploration drilling and mapping. However, as mentioned above, geological work associated with mine development is typically more focused on identifying and confirming the ore-body characteristics, with potentially limited information gathered about the geotechnical characteristics of the bedrock and surficial (non-consolidated) material. There is commonly little information on the stratigraphy of the surficial material. The mining company's drilling program and mapping programs should therefore be

used to improve the SGM in an iterative manner, once the initial SGM has been created.

For a greenfield non-mining dam project, there may be little drill-hole information available prior to commencing the site characterization program, but records of nearby groundwater wells and examination of rock exposures in the area can assist in the development of the preliminary SGM.

4.4.2 Surficial Geology

Glacial stratigraphy and history of an area can have important implications for the terrain mapping and the presence of subsurface and rare sediment types.[2] BC has a glacial history that spans the Quaternary period (Clague and Ward 2011). The Pleistocene epoch is characterized by periods of cooler temperatures during which glaciers covered large portions of the northern hemisphere. These periods are termed glaciations. Periods of warm or warmer-than-present temperatures are termed interglaciations. Due to differential preservation caused by erosion and burial, sediments from the last glacial cycle dominate the record. Care must be taken when assessing the surficial geology, however, as sediments from older glaciations and interglaciations can exist in the subsurface in areas of BC, and these can affect siting considerations and the design of the site characterization program. Of particular concern are buried organic-bearing soils (paleosols), advance or retreat glaciolacustrine sediments, and glaciomarine sediments.

The availability of information on the Quaternary history and terrain maps is variable across BC. While some publications discuss BC as a whole, most are more regional and local in nature. See Appendix B and Table 4-3 for a list of relevant publications. If no local surficial geologic history has been developed, it will have to be constructed for the area under consideration. This work should be done by someone with experience and training in Quaternary geology and terrain analysis.

It is important to be able to view the surface expression of the area for the Quaternary history and for the terrain and geomorphic analysis. There are three main choices: aerial photographs, satellite imagery, and *lidar*. Interferometric synthetic aperture radar (*InSAR*) also has potential for certain applications. Another relatively inexpensive possibility is the use of unmanned aerial vehicles or drones to create a three-dimensional image of a small area using photogrammetry software. Aerial photograph flight lines can be viewed through Google Earth and then ordered through the Internet.

Table 4-3. Key Information Sources for Surficial Geology

Reference	Items of Interest
Clague and Ward. 2011. Pleistocene Glaciation of British Columbia.	Overview of Quaternary history of BC. Contains numerous references
Fulton. 1991. A Conceptual Model for the Growth and Decay of the Cordilleran Ice Sheet.	Summary of the style of glaciation and deglaciation in the Canadian Cordillera
Fookes *et al.* 2015. Geomodels in Engineering Geology: An Introduction.	Engineering geology, geologic environments, geophysics, ground investigations

2). The Mount Polley incident highlighted the importance of understanding the glacial stratigraphy and carrying out site characterization studies commensurate with the complexity of the site.

Light detection and ranging (lidar), satellite data, and InSAR are usually available only from private companies. Aerial photographs are black and white or colour images taken from an airplane. Satellite data can be useful for recent changes/events (e.g., roads, landslides) but cannot be viewed in stereo. As well, resolution can be lacking on satellite images for the type of detailed work required. Light detection and ranging, if available, is the best option. Processing allows the stripping off of the vegetation to get a "bare earth" image. The detail provided by lidar is the best of the three options, but the acquisition and processing can be expensive. There are both ground-based and aerial-based lidar systems.

It is important to develop a regional glacial history through examination and interpretation of the glacial and non-glacial sediments and the literature. An understanding of the nature of glaciation and deglaciation of the Cordilleran Ice Sheet (Fulton 1991), the regional stratigraphic framework (e.g., Ryder *et al.* 1991), the potential antiquity of sediments (e.g., Nichol *et al.* 2015), and the potential complexity of sediments (Ward and Thomson 2004) is vital for anticipating the types and ranges of sediments that may be present. This knowledge, combined with examining natural exposures and drilling, should allow for the appropriate determination of the local glacial history. Although there may be insufficient exposures at the actual site, the Quaternary history can be reconstructed by examining exposures in the vicinity of the dam site. These can be identified through aerial photographs, lidar, and so on, and then combined with the site drilling information.

A drilling method that results in undisturbed samples and continuous core that can be examined for sedimentary structures is preferred. Obviously, sediment types that are susceptible to lateral shearing are of concern; these include fine-grained alluvial, lacustrine, glaciolacustrine, glaciomarine, marine, peat, and organic-rich paleosols. An understanding of the lateral variability of these environments is vital. A good example is glaciolacustrine, which, although commonly thought just to be rhythmically bedded clay and silt, may contain ice-contact glaciolacustrine sediments that can have sand, gravel, and diamicton (that can look like a till) interstratified at various scales and expressing rapid lateral variability. If the site is close to the present coastline, or to historic coastlines, care must be taken to determine whether glaciomarine sediments are possible, based on the geologic history and elevation of marine limit (McCuaig and Roberts 2006). Quick clays, or sensitive clays, may be present and are prone to landslides if disturbed (e.g., Geertsema and Torrance 2005).

As glaciers moved over the landscape, they not only eroded and deposited sediments, but they may also have sheared, folded, and fractured sediments and bedrock. This glaciotectonism can form thrust sheets that could repeat units, complicating the stratigraphy recorded in drill holes. The faults themselves can also form planes of weakness and/or conduits for groundwater.

Terrain mapping must be carried out for all sites. It is a way of portraying the landscape of surficial materials, surface expression, and geomorphological processes, such as landslides, snow avalanches, and gullying. Terrain mapping provides information on topography and slope steepness, texture, porosity, permeability, moisture content, thickness, and present-day geomorphic processes. It portrays the landscape as a mosaic of irregularly shaped areas that are referred to as terrain units or polygons. It has a flexible (open) legend, in contrast to the closed legend of a surficial geology map. An open legend provides the most information because the mapper selects the symbols that most represent the particular conditions in a given polygon. Each polygon therefore ends up with unique polygon descriptors; however, untrained users can have difficulty interpreting the map.

Production of applied terrain maps, such as terrain stability, terrain hazard and risk, sediment erosion potential and delivery, and earthquake hazard maps, may be required for siting. These maps all have a specialized terrain base where the polygons are subdivided on the basis of the end product. The polygons are then interpreted for the final objective of the map; for example, terrain stability classes are added. A general terrain map base cannot be used for creating applied maps, and the mappers doing this work require specialized training.

In areas of steep relief (especially in close association with glaciers), avalanches and all types of landslides should be considered during dam site characterization. These geohazards must be recognized and mitigated as part of the design and development plan. Recognition should be part of the terrain-mapping portion of the assessment. For example, snow avalanches are common in areas of high relief and significant snowfall, and they may be recognized by vertical swaths that contain low trees such as alder, birch, and willow—but no conifers—below steep terrain that has few if any trees.

Permafrost is ground that stays below 0°C year-round. It occurs in many alpine areas and in northeastern BC (Smith 2011). Disturbance of the surficial organic layer in permafrost terrain results in melting and degradation of the terrain. If there is a high content of frozen soil and ice, the potential for degradation (melting) can be significant. If permafrost is suspected in the area, the objectives of the drilling program must include its characterization and distribution.

Surface geophysics (also referred to as geophysical surveys) can play an important role in defining the surficial geology and bedrock geology and in identifying anomalies and spatial continuity of foundation materials.

Geophysical surveys have the following benefits:

- They are non-intrusive and have limited impact on the site conditions.
- They provide a continual spatial quantification of potential ground conditions.
- They can identify anomalous areas that can be targeted with a drilling program.
- They can identify bedrock contacts and support better definition of the extent of the site investigation program, including depth and spacing of drill holes.

Typical geophysical surveys include, for example:

- Seismic refraction/reflection – measures velocity and can be used to identify bedrock and groundwater levels and indicate the density of materials
- Electrical and electromagnetic surveys measuring resistivity/conductance – can be used to identify saturated and/or clay rich materials
- Ground-penetrating radar – can be used in shallow investigations to identify permafrost or anomalies in layering and materials
- Magnetic and gravity surveys – may be useful in identifying low-strength rock or natural or human-made cavities

However, geophysical surveys do not provide quantitative information in all situations and should be used in conjunction with ground proofing and calibration with known information.

4.4.3 Geotechnical

The objective of the geotechnical component of the site characterization program is to develop parameters that can be used in the dam design. The geotechnical component may include, for example, investigations related to stability, deformation, settlement, seismic response, seepage, and piping potential.

Geotechnical characterization of the bedrock foundations should assess the spatial distribution of the lithological rock units, as well as the orientation and distribution of the main joint sets within each lithological unit. Additionally, it is important to identify major geological structural features, such as faults, shears, and intrusive dykes. The strength of bedrock will be influenced by its structure (e.g., unfavourably dipping sedimentary rock), degree of weathering, degree of fracturing (rock quality designation, joints, and faults), rock hardness, and the Geologic Strength Index. The hydraulic conductivity of bedrock is typically controlled by the degree of fracturing and rock quality. The stress state of the rock should consider the potential for valley rebound and regional stresses. For high dams, the deformation properties of the rock may be determined with geophysical methods and correlations with rock strength and rock properties.

Geotechnical characterization of the foundation soils should delineate representative geotechnical units. The geotechnical units would consider, for example, the surficial geologic history and geotechnical properties. Index testing of soils is used for general characterization and generally includes, for example, moisture contents, grain size, Atterberg limits, and density and pocket penetration shear strength indices. Undisturbed samples of cohesive soils are required for strength and consolidation testing. Strength testing should consider drained and undrained strength response and peak and residual/large strain strength, as well as the stress state of the soils and the stress conditions that will be imposed by the dam. Deformation properties of the materials should consider the stress history; pre-consolidation stress state; degree of over-consolidation; and coefficients of compression, recompression, and consolidation. In determining the potential for liquefaction of the materials during static or dynamic loading, the degree of saturation, density, stress state, and drainage properties should be considered.

In considering the SGM, the site investigation program should focus on obtaining representative geotechnical properties for each of the identified geotechnical units in the dam foundation. A range of methods are available for conducting intrusive investigations, such as test pits, drill holes, standard penetration tests, and cone penetration tests. These methods include obtaining disturbed and undisturbed samples, conducting in situ testing, downhole examination, and instrument installation. They are described in many sources, a selection of which is included in Appendix B. Particularly relevant references are indicated in Table 4-4. The Design Engineer is responsible for determining the most appropriate methods for the dam and site being considered.

Table 4-4. Key Information Sources for Geotechnical Field and Laboratory Work

Reference	Items of Interest
Fell *et al*. 2005. Geotechnical Engineering of Dams.	Chapters 1–7, covering geology, site investigations, geotechnical properties, and clay properties
International Commission on Large Dams. 2005. ICOLD Bulletin 129, Dam Foundations: Geologic Considerations, Investigation Methods, Treatment, Monitoring.	Foundation investigations and case histories
Federal Energy Regulatory Commission. Various dates. Engineering Guidelines for the Evaluation of Hydropower Projects.	Chapter V: Geotechnical Investigations and Studies (Dams, Dam Sites or Appurtenant Structures)
US Army Corps of Engineers. 2004. Engineering and Design: General Design and Construction Considerations for Earth and Rock-Fill Dams.	Chapter 3: Field and Laboratory Testing
US Army Corps of Engineers. 1995. Engineering and Design: Geophysical Exploration for Engineering and Environmental Investigations.	Geophysical Exploration for Engineering and Environmental Investigations
US Army Corps of Engineers. 2001. Engineering and Design: Geotechnical Investigations.	Geotechnical Investigations
US Department of the Interior, Bureau of Reclamation. 2012. Design Standards No. 13: Embankment Dams.	Chapter 12: Foundations and Earth Materials Investigation, Phase 4.
US Department of the Interior, Bureau of Reclamation. 1987. Design of Small Dams, 3rd edition.	Chapter 5: Foundations and Construction Materials

For the feasibility design stage and the detailed design stage, a detailed work plan should be developed for the geotechnical site investigation program that clearly describes the basis for the work plan, the drill hole spacing and depth, and so on. This work plan should be included in the dam site characterization report to document how the geotechnical site investigation program was developed. Site characterization programs (including the laboratory testing and instrumentation aspects) are typically modified during the execution of the program to address conditions that are encountered in the field that are different from what was expected (e.g., access challenges, poor weather, unexpected results).

Other considerations with respect to developing the geotechnical parameters include, for example:

- Clay mineralogy and potential for dispersive soils
- Potential effects of glacial rebound/drag – damage to fabric, reduction of strength, change of orientation
- Hydrogeological properties (as discussed in Section 4.4.4)
- Permafrost and ground temperatures and the potential for thermal influences from the dam and reservoir/impoundment
- For dams in the mining industry, the mine plan (underground workings below a dam, or an open pit near a dam)
- Effect of other subsurface activities that could affect a dam design

As noted in Section 4.4.2, surficial geophysical methods (or geophysical surveys) can be used to provide spatial coverage that, in concert with intrusive investigations, can supplement the SGM. These surveys may precede the geotechnical investigation, or additional surveys may be done to address specific areas in parallel with the geotechnical site investigation. Downhole geophysics may also be employed to obtain additional information on the properties of the soil and rock units.

Some general guidance for intrusive geotechnical site investigations includes the following:

- The depth of the geotechnical investigation should be to the expected height of the final dam or to a depth sufficient to confirm competent strata for the proposed dam. Deeper investigations may be required if conditions at depth could influence the design and function of the dam.
- The spacing between investigative locations along the proposed dam axis should be determined within the context of the variability of the foundation conditions and height of the dam. Spacing could, for example, range from a few metres apart for complex foundation conditions to 100 metres for sites with simple foundation conditions.
- The investigations should be strategically located to cover the areal extent of the dam structure and the anticipated stratigraphy.
- The number of investigative locations must be sufficient to support representative profiles along the dam axis and representative design cross-sections (upstream to downstream) along the dam alignment. The number of investigative locations must be sufficient to adequately characterize all the different soil and bedrock units that are present in the proposed dam foundation.
- Undisturbed sampling of cohesive soils should be conducted to obtain samples for laboratory testing.
- Appropriate in situ testing should be considered to establish and confirm in situ properties.

Laboratory testing is assigned based on field observations, and the results of laboratory testing can be an important input in the design of further field investigations. This interaction is an important part of the refinement of the site characterization throughout the development of increasingly detailed site characterization and refinements of the dam design.

Instrumentation (e.g., standpipes, piezometers, slope indicators, thermistors) is an important component of a site characterization program. Instrumentation will ordinarily be installed during the foundation site characterization program and also during the construction of the dam.

Site characterization programs (including the lab testing and instrumentation aspects) are typically modified during the execution of the program to address conditions that are encountered in the field that are different from what was anticipated. The work plan for the site characterization program should include a process for managing these modifications that will allow for response during the execution of the program. The owner must be advised to set aside a budget contingency allowance to respond effectively to these modifications (typically 20% to 50%). The contingency allowance will vary by design stage.

4.4.4 Hydrogeology

Hydrogeological assessments are carried out to support both the engineering design and the environmental permitting of dams. The understanding of the bedrock and surficial geology and the geotechnical conditions is intimately related to, and complementary to, the development of the hydrogeological component of the SGM. Hydrogeological assessments are therefore commonly integrated with the bedrock, surficial geology, and geotechnical investigations.

The hydrogeological assessment is used to develop a conceptual hydrogeological model, which is developed within the framework of, and is complementary to, the SGM. The SGM, however, typically extends from within the reservoir/impoundment area to downstream from the dam. The interpretation of site data defines the foundation conditions and

associated groundwater occurrence. Factors influencing groundwater levels, quality, flows, and seepage are also described in the SGM. Prediction of seepage through the dam foundation and from the reservoir/impoundment area is used to support design of seepage control, conveyance, collection, and mitigation systems, and the assessment of potential downstream impacts on the receiving environment. Prediction of seepage is also used to support design of filters and piping controls and to assess the potential for artesian uplift pressures within the dam foundation.

Appendix B includes references for hydrogeological investigations, and Table 4-5 lists references that are particularly relevant.

Table 4-5. Key Information Sources for Hydrogeology

Reference	Items of Interest
BC Ministry of Environment. Water Protection and Sustainability Branch. 2012. Guidelines for Groundwater Modelling to Assess Impacts of Proposed Natural Resource Development Activities.	Modelling for contaminant transport assessment
BC Ministry of Environment. 2012. Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators.	Monitoring guidelines
Province of British Columbia. 2014. *Water Sustainability Act.*	Entire document
Province of British Columbia. 2004. *Water Act—Ground Water Protection Regulation.*	Entire document

The hydrogeological components of site characterization typically include the following:

- Distribution and significance of hydrogeologic units (aquifers, aquitards, and aquicludes) associated with bedrock and overburden
- Hydraulic characteristics (hydraulic conductivity, anisotropy, transmissivity, storage characteristics) of bedrock and overburden, including structural features (e.g., faults)
- Groundwater levels, flow directions, and groundwater gradients
- Groundwater quality and factors that may influence that quality, including temporal and seasonal variability (e.g., response to freshet)
- Groundwater quality with respect to baseline quality and geochemistry of groundwater water types
- Groundwater–surface water interconnectivity (e.g., baseflow), and recharge and discharge mechanisms and locations
- Location and characteristics of nearby groundwater receptors (e.g., groundwater-fed wetlands/springs), users (e.g., existing wells), and existing infrastructure that may influence groundwater (e.g., sources of contamination)
- Hydraulic gradients indicating flow direction

Investigative methods used as part of hydrogeological characterizations include:

- Site walk/fly overs and mapping
- Overburden/bedrock drilling and logging (the methodology should be selected with consideration to site conditions, testing requirements, and access)

- Installation of monitoring and pumping wells, and monitoring instrumentation
- "Point" hydraulic tests (e.g., packer and slug tests)
- Pumping tests (which measure aquifer response to pumping)
- Unsaturated zone testing (e.g., double ring infiltrometer testing, permeameter testing)
- Groundwater level measurement (including instrumented), surface water flow gauging and groundwater/surface water quality sampling
- Geophysical surveys (downhole and regional)

Hydrogeological site investigations are often performed in conjunction with exploration, geological, geotechnical, and other investigations (e.g., surface water) to reduce costs and maximize data acquisition.

The conceptual hydrogeological sub-model of the SGM should include:

- Details of the SGM extents/boundaries) and how these were selected
- Baseline geochemical conditions, if groundwater quality is a potential issue
- A simple visual representation of the groundwater system (e.g., cross-sections, "cartoon"-type figures, zone maps for recharge/discharge)
- A description of key hydrostratigraphic units and processes influencing groundwater
- Quantitative components – a groundwater flow balance, ranges of hydraulic data for key overburden/bedrock units
- Details of how dam development may affect the groundwater system

Baseline hydrogeological conditions are established for comparison as the dam project proceeds into construction and operation. The hydrogeology information is used in seepage analyses, in concert with assumptions made about the dam materials, to develop estimates of the seepage patterns that will be present through the dam and dam foundation when the dam is in operation.

4.4.5 Site Characterization of Seismotectonic Conditions

The objective of the seismotectonic assessment is to develop an understanding of the regional tectonic conditions at the dam site and to carry out site characterization studies to develop parameters that can be used to support a seismic hazard assessment for the site. These parameters would include the design ground-motion events/parameters and the foundation response parameters that will be used for the seismic response assessment for the dam, foundations, and reservoir or impoundment slopes.

Appendix B contains references for seismic investigations, and Table 4-6 lists references that are particularly relevant.

Table 4-6. Key Information Sources for Seismotectonics

Reference	Items of Interest
Natural Resources Canada. Seismic Hazard Maps and Seismic Hazard Calculator.	For location in question
Canadian Dam Association. 2007. Seismic Hazard Considerations for Dam Safety.	Overview of seismic hazard assessment
Idriss and Archuleta. 2007. Evaluation of Earthquake Ground Motions.	Section 3: Geologic and Seismologic Considerations
American Society of Civil Engineers. 2005. Minimum Design Loads for Buildings and Other Structures.	Chapter 20: Site Classification Procedure for Seismic Design Chapter 21: Site-Specific Ground Motion Procedures for Seismic Design

Seismic hazard analysis considers two approaches, the probabilistic (determines events for various annual exceedance probabilities) and the deterministic (determines seismic hazard due to identified faults), and consideration of both may be important for dam design.

Assessment of the seismotectonic setting should consider the regional area (up to a 500-kilometre radius) and include the following considerations:

- Plate tectonic setting with respect to potential subduction zones and tectonostratigraphic terranes that may have associated active faults
- Regional faults identified in geologic and seismic hazard maps and from aerial photograph, satellite, and lidar imagery
- Evidence of potential Holocene fault movements (e.g., scarps displacing glacial or recent soil deposits)
- Human-induced seismicity (e.g., hydrofracking, gas/oil extraction subsidence, mine operational blasting)

Seismic hazard evaluation in Canada continues to be developed in support of the *National Building Code of Canada 2015* (Canadian Commission on Building and Fire Codes 2015). Improvements to the seismic hazard assessment incorporate ongoing refinement of our understanding of the seismic source zones and developments in both probabilistic and deterministic influences on the hazard classification. Seismic hazard maps and a seismic hazard calculator (for the specific location) are available online via http://www.earthquakescanada.nrcan.gc.ca/index-en.php (Natural Resources Canada; see Appendix B). Use of these sources provides a preliminary estimate of the seismic hazard up to the 1:2500 ground motion annual exceedance level and is appropriate in cases of firm ground conditions (i.e., non-liquefiable or non-strain softening) for low-, medium-, or high-consequence dams.

For very-high-consequence and extreme-consequence dams and for sites with complex geological conditions, it is appropriate to carry out site-specific probabilistic and/or deterministic hazard evaluations. The probabilistic evaluations allow for determination of parameters for various exceedance probabilities, whereas the deterministic assessment is typically used in simple but rare cases where the concept of a maximum credible earthquake that could be generated by one or more known faults can be used.

The determination of earthquake ground motions generally assumes "firm ground" or "rock" conditions, which would be an input to the analytical model for the dam that would consider the foundation soil and rock conditions. Consequently, an understanding of the foundation conditions is an important consideration in seismic analysis. The depth of soils under the dam and the shear wave velocity of the soils are important inputs to that analysis and must be determined. Low-strain shear wave (see Chapter 21, American Society of Civil Engineers 2005) velocities can be determined from field measurements using downhole or linear seismic surveys or from similar soils in the site vicinity. Non-linear or linear shear stress-strain relationships and unit weights can be selected on the basis of laboratory tests or published relationships for similar soils. The uncertainties in the soil properties must be estimated. Where very deep soil profiles make the determination of the model impractical, adjustments to the seismic hazard assessment need to be made to accommodate that uncertainty.

The seismotectonic components of the site characterization study are typically used to support a more detailed seismic hazard assessment, which would include both the probabilistic and deterministic hazard assessment.

4.5 EVOLVING UNDERSTANDING OF PROJECT AND SITE CONDITIONS

Site characterization for a dam foundation is an ongoing process that yields a better and better understanding of the site as the project proceeds through design stages. This gradual increase in understanding can develop with additional site investigations, observations from construction and monitoring, and additional studies such as geohazard assessment and a refined assessment of Quaternary geology. In addition, as the design of the dam proceeds, the relative influence and importance of specific site conditions—for example, the influence of foundation soil behaviour under dynamic loading conditions, and changes in allowable seepage release—to different dam components will evolve, as will site characterization technologies.

Other changes may also influence the requirements for understanding of the site conditions. For example, an increase in land or water use downstream from the dam may increase the consequence of failure or impose limitations on seepage or on dam footprint in the case of expanding dam height or requirements for flatter slopes. Natural geohazard events such as landslides or debris flows could influence the dam foundation or the dam.

The Design Engineer should continue to monitor the ongoing information and understanding of the site characterization and consider the effect of the most up-to-date understanding on dam design, through all stages of a project. As the results of additional site investigations, observations, and monitoring continue to inform the Design Engineer, and as data are collected from ongoing recommended site investigations or studies, the data need to be incorporated into ongoing updates to the dam site characterization report.

For tailings dams that are developed over a long period of time, consideration should be given to updating the design record and dam site characterization report (discussed in Section 4.6) at appropriate intervals to ensure that the evolving understanding of the site is integrated into the evolving design of the dam.

4.6 DAM SITE CHARACTERIZATION AND DATA RECORD REPORTS

Reports will be prepared to document the ongoing site characterization data (the data record report, discussed in Section 4.6.2) and the interpretation of the data (dam site characterization report, discussed in Section 4.6.1).

4.6.1 Dam Site Characterization Report

A dam site characterization report (DSCR) must be produced by the Design Engineer to allow his/her work to be replicable and to make it transparent for report reviewers, so they can understand how the APEGBC professionals involved arrived at their conclusions.

The DSCR may be a stand-alone report or form part of a dam design report. There may be several DSCRs issued for a dam project as the design and site characterization evolve.

The purpose of the DSCR is to present the data and relevant supporting information used by the Design Engineer (e.g., empirical correlation, reference reports) and document his/her interpretation of them. Representative geological and hydrogeological plans and cross-sections should be developed to communicate the extent of site investigation data, geological and geotechnical units, and groundwater conditions. The report should also include summaries of physiographic, climatic, and hydrological conditions that provide context for the site characterization. The interpretation of the data is intimately integrated with the design of the project, and the report therefore needs to be considered within the context of the design.

The DSCR should summarize the objectives of the site investigation plan and document the outcomes. All data and reports must be documented and kept on file, in accordance with APEGBC quality management bylaws.

Internal peer review must be carried out in accordance with APEGBC quality management bylaws. External peer review specialists should be considered for specialist technical areas where the Design Engineer or the SRPs may not have the appropriate level of experience. The use of an independent technical review board should be considered for projects with greater potential consequences and/or complexity.

4.6.2 Data Record Report

The data record report may be a separate document or an appendix to the DSCR or the dam design report. The data record report must include all relevant data acquired or produced as part of the site characterization (e.g., mapping, results of site investigations and laboratory testing). The data record report should summarize the extent of the site characterization studies, with appropriate summaries to guide reviewers. Interpretation of data should be kept at a "high level," with a focus on areas relevant to the data collection and veracity of data.

4.6.3 Limitations and Qualifications—Dam Site Characterization Report

The DSCR must include a section on limitations and qualifications. Site investigations and site characterizations provide a snapshot in time at various stages of the design of the project. A degree of professional judgment is required to understand site conditions and some natural events, such as ancient landslides, that may not be readily interpreted. As the project proceeds, additional information on the site conditions is produced, and understanding grows, through ongoing studies, construction observations, monitoring observations, and so on. Additionally, the dam design can change in response to site characterization results, economic conditions, dam height changes, and other factors. Consequently, it is important for the Design Engineer to document the limitations and qualifications of the DSCR, as described in Section 4.7.3. The Design Engineer's signing of the Site Characterization Assurance Statement is limited to the stage of the project at the time of signing (i.e., it is time-variable) and should include reference to the limitations and qualifications identified in the DSCR.

The DSCR should identify limitations or qualifications relevant to the assessment (e.g., areas of uncertainty and requirements for further investigation, context with respect to spatial limitations and dam height). Qualifications with respect to assumptions and reliance on existing or third-party reports should also be documented.

The DSCR should document the minimum requirements for additional site characterization studies. As the project proceeds, the owner must document completion of the recommended work or provide written assurance that the recommendations have been amended or that their implementation can be appropriately delayed, as approved by the Design Engineer. When transitioning from one Design Engineer to another, the new Design Engineer will be required to provide that approval.

Data Record Report
The data record report must identify significant limitations or qualifications relevant to data collection (e.g., access to project area and drill pads, drilling or sampling problems, equipment reliability, budget or scope limitations, laboratory data quality).

4.6.4 Reviewing and Updating the DSCR

Follow-up to the DSCR will normally be required at various stages of the project. Follow-up could be required in response to the execution of recommendations, or in response to a Site Characterization Assurance Statement that indicates that the level of site characterization is not appropriate or identifies areas of risk. Follow-up could also be triggered by

advancement to the next stage of the project or in recognition of other factors discussed in Section 4.7. A review of the DSCR will also be triggered by an unusual event, such as excessive slope deformation, or in response to a major earthquake.

Advancement to the next stage of the project could require more-detailed investigations or additional laboratory testing to confirm empirical relationships that may have been used previously. Areas of identified risk could also warrant additional appropriate site characterization to reduce the level of risk. The Design Engineer must review the DSCR at each project stage and at appropriate intervals during construction and operations. Site visits and review of construction and monitoring data are important components of these ongoing DSCR reviews.

The data record report and the SGM should continue to be populated with new data. Existing and new data may be stored in a database or electronic files that contain all site characterization data and associated reports. The new data will include data developed during construction of the dam when the foundation conditions are exposed, or additional information developed through instrumentation and performance.

The DSCR will be updated either with highlighted revisions to the original report or with DSCR amendment reports. Updates to the DSCR will include a Site Characterization Assurance Statement that documents the areas of change and the current status of the relevant provincial legislation as it relates to the use of APEGBC professionals in carrying out this type of work.

4.7 OTHER SITE CHARACTERIZATION CONSIDERATIONS

4.7.1 First Nations and Communities of Interest

Site characterization activities may be initiated in the early stages of the potential development of a dam and, consequently, the owner's discussions with the relevant First Nations and communities of interest may also take place at an early stage. The Design Engineer will confirm with the owner that the site characterization activities have been discussed with the relevant First Nations and communities of interest.

4.7.2 Hydrology and Climate

Both hydrology and climate influence the surficial geology, hydrogeology, and geotechnical conditions around the dam foundation, as well as the dam's sizing and design requirements. For example, the influences of hydrology and climate are apparent in the geological deposition of materials, as well as on groundwater conditions:

- Precipitation can lead to erosional deposition of soils, and infiltration of precipitation can lead to slope instability and colluvial processes.
- Freeze/thaw cycles over time can lead to erosion and colluvial processes.
- Historic extreme hydrological events in mountainous terrain may lead to deposition of significant debris-flow deposits over time. Depending on the energy of the debris flows and the origin of the soils, the deposits may vary considerably, from loose silty soils to dense granular soils.

The dam site characterization report (DSCR) should therefore include summaries of these conditions and their effect on the dam.

Hydrology is a key component of the hydrogeology site characterization, because the amount of precipitation and the climatic cycle influence the rate of infiltration into the ground and, additionally, could introduce artesian pressures in both confined and unconfined pervious layers in the foundation of the dam.

The presence of permafrost and permafrost-influenced soils and bedrock is directly influenced by the temperature, both past and future. Thermal-induced influences

on the foundation can lead to changes in the permafrost, which may affect the dam's foundation soils and bedrock.

4.7.3 Risk Management and Uncertainty in Site Characterization

As noted in Section 1.1, site characterization is a "critical control" for the safe design and operation of a dam. Identification of risk and uncertainty is an important component of site characterization and directly influences the intensity of site investigations and the level of detail required to understand the site conditions. When undertaking a site characterization program, the key risk factors to consider include:

- Complexity of the site conditions – that is, multiple periods of glaciation and interglacial depositions, variability in clay origin and strength, spatially diverse conditions, artesian pressures. The Design Engineer must start with the assumption that the geologic conditions at the site are complex and could present risks to the dam.
- The *consequence classification* of the dam as determined by BC and Canadian dam safety regulations/guidelines
- The consequences to the owner of not properly characterizing the different geologic units
- Site access issues (e.g., high water levels, landowner issues)
- Climate changes that were not planned for in the development of the program
- Equipment issues, such as breakdowns
- Inadequate tools to address findings as they develop

These factors, as well as others defined by the Design Engineer and owner, must be considered throughout all design stages and in each step of a site characterization program.

Risk assessments are routinely carried out at numerous stages of a project. For example, for mining dams, the *Mining Association of Canada Guidelines* recommends carrying out risk assessment at all phases of a mining project. The failure modes and effects analysis (FMEA) is an industry-accepted methodology for identifying risks and developing risk management plans. The FMEA is a semi-quantitative, practical tool for identifying potential risks, and an FMEA risk workshop would typically include key APEGBC professionals involved as specialists in the site characterization and dam design. An FMEA carried out for the feasibility design stage of a project could identify potential risks associated with the foundation, and the risk assessment must be updated throughout the life of the project to reflect ongoing changes.

Risk assessment can be integrated within the framework of a site characterization program with, for example, identification of critical failure modes that include the foundation soils or rock. These potential failure modes can then be examined with respect to the adequacy of the information being collected to appropriately assess the risk.

On completion of the site characterization program, there will still be uncertainty associated with the foundation conditions. The Design Engineer must identify where those uncertainties are and plan to deal with them in the design, construction, and operation of the dam—for example, through additional investigations, instrumentation, and contingency plans.

5.0 PROFESSIONAL PRACTICE—QUALITY ASSURANCE/QUALITY CONTROL

An APEGBC professional must carry out quality assurance / quality control during all phases of site characterization for a dam foundation. This includes the preparation of a data record report and dam site characterization report (DSCR).

5.1 APEGBC Quality Management Requirements

APEGBC professionals are obligated to abide by the quality management requirements set out in the APEGBC Bylaws. In order to meet the intent of those requirements, APEGBC professionals must establish and maintain documented quality management processes for their practices, including as a minimum:

- The application of the relevant APEGBC Professional Practice *Guidelines*, the *Engineers and Geoscientists Act*, s. 4(1) and Bylaw 11(e)(4)(h):
  - When carrying out site characterization for dam foundations, an APEGBC professional must have sufficient broad-based knowledge of and competence in applying these guidelines.
- Retention of complete project documentation—Bylaw 14(b)(1):
  - When carrying out site characterization for dam foundations, an APEGBC professional must comply with the *APEGBC Quality Management Guidelines – Retention of Project Documentation.*
- Regular, documented checks using a written quality control process—Bylaw 14(b)(2):
  - When carrying out site characterization for dam foundations, an APEGBC professional must comply with the *APEGBC Quality Management Guidelines – Documented Checks of Engineering and Geoscience Work.*
- Documented field reviews of engineering/geoscience designs/ recommendations during implementation or construction—Bylaw 14(b)(3):
  - When carrying out site characterization for dam foundations, an APEGBC professional must comply with the *APEGBC Quality Management Guidelines – Documented Field Reviews During Implementation or Construction*. For example, if the Design Engineer makes specific technical recommendations related to the site characterization of the dam's foundation, which can include the carrying out of engineering/ geoscience investigations, the Design Engineer must be able to demonstrate that he/she carried out field reviews or that field reviews were carried out under his/her direct supervision. Field reviews are required to ensure that the documentation prepared by the Design Engineer supporting his/her technical recommendations are followed in a matter which is consistent with his/her recommendations.

Authentication of professional documents by the application of the APEGBC professional's professional seal—*Engineers and Geoscientists Act,* s. 20(9):

- The Design Engineer must apply his/her professional seal to the data record report and the DSCR prepared in his/her professional capacity or under his/her direct supervision and the Design Engineer must apply his/her seal to the Site Characterization Assurance Statement. The APEGBC professional must meet the intent of the *APEGBC Quality Management Guidelines – Use of the APEGBC Seal.*

- Professional engineering/geoscience activities can only be delegated to subordinates under direct supervision—*Engineers and Geoscientists Act*, s. 1(1) and 20(9):
  - If certain aspects of the dam site characterization, such as field reviews, are delegated to non-professionals or other subordinate engineers/geoscientists, they must be carried out under direct supervision of the APEGBC professional. Where such delegation occurs it must be carried out in a fashion which meets the intent of the APEGBC Quality *Management Guidelines – Use of the APEGBC Seal*. The APEGBC professional assumes full responsibility for all work so delegated.

5.2 Direct Supervision

Section 1(1) of the *Engineers and Geoscientists Act* states that direct supervision means taking responsibility for the control and conduct of the engineering or geoscience work of a subordinate. With regard to direct supervision of delegated responsibilities, the APEGBC professional having overall responsibility should consider:

- The complex nature of the dam site characterization and the nature of the values/elements at risk
- Which aspects of the dam site characterization can be delegated and how much of those aspects can be delegated
- The training and experience of individuals to whom work is delegated
- The amount of instruction, supervision, and review of the subordinate required

Field review work is one of the most critical aspects of dam site characterization. This is especially the case in the geotechnical investigations being carried out and laboratory tests and analysis resulting from the geotechnical investigation. Therefore, careful consideration must be given to delegating field review work. Because of the complexities and subtleties of dam site characterization, direct supervision of field review work is difficult, and care must be taken to see that delegated work meets the standard expected of the APEGBC professional. Direct supervision could typically take the form of specific instructions on what to observe, check, confirm, test, record, and report back to the APEGBC professional. The APEGBC professional must exercise judgment when relying on delegated field review observations by conducting a sufficient level of review to be satisfied with the quality and accuracy of those observations.

5.3 Internal Checking and Review

As referenced in Section 4.6.1 of these guidelines and consistent with the requirements of APEGBC Quality Management Bylaw 14(b)(2), as a minimum, a DSCR must undergo a documented checking and review process before being finalized and delivered. This process would normally involve an internal review by another APEGBC professional within the same firm. Where an appropriate internal reviewer is not available, an external reviewer (i.e., outside the firm) must be engaged. Where an internal or external review has been carried out, this must be documented in the DSCR. The level of review is to be based on the professional judgment of the APEGBC professional (the reviewer). Considerations should include the complexity of the site and of the underlying geological conditions; the consequence classification and the nature of the dam; loading conditions; elements at risk; availability, quality, and reliability of background information and geotechnical data; the degree of judgment on which the dam site characterization is based; and the APEGBC professional's training and experience.

5.4 External Review

An external review is an additional level of review beyond the minimum requirements of APEGBC Bylaw 14(b)(2) that may be

undertaken for a variety of reasons by an independent APEGBC professional not previously involved in the project. At the discretion of the Design Engineer, in consultation with the reviewer(s) involved in the regular checking/review process outlined above, this additional level of review may be deemed appropriate. Alternatively, a regulatory authority or the owner may request an independent external review to support project approval. An independent external review may be undertaken by another APEGBC professional employed by another firm, independent from the firm that carried out the initial DSCR for the dam's foundation.

An independent external review process should be more formal than the checking/review process carried out under Bylaw 14(b)(2). An independent external reviewer should submit a signed, sealed, and dated letter or report, to be either included with the DSCR or included in the Design Engineer's file. The letter or report should include the limitations and qualifications with regard to the independent external review and the results of the independent external review.

When an independent external review is carried out, the APEGBC professional who sealed the DSCR remains the designer of record (Design Engineer) for the dam site characterization.

The independent external review discussed above is not the same as an independent review or advisory service provided by an APEGBC professional who is retained by the regulatory authority or sometimes by the client.

6.0 PROFESSIONAL REGISTRATION, EDUCATION, TRAINING, AND EXPERIENCE

6.1 Professional Registration

It is the responsibility of the professional engineer or *professional geoscientist* to determine whether he/she is qualified by training and/or experience to undertake and accept responsibility for the carrying out of site characterization for dams in British Columbia (APEGBC Code of Ethics Principle 2).

With regard to the distinction between professional engineering and professional geoscience, the following is an excerpt under Principle 2 of the Code of Ethics guidelines (APEGBC 1994, amended in 1997):

> The professions are distinct and registration in one does not give a member the right to practice in the other; however, the Association recognizes that there is some overlap of the practices of engineering and geoscience.
>
> Nothing in this principle authorizes a professional engineer to carry on an activity within the area of professional geoscience which goes beyond the practice of professional engineering and nothing in this principle authorizes a professional geoscientist to carry on an activity within the area of professional engineering which goes beyond the practice of professional geoscience.

On this basis, the APEGBC professional who leads site characterization for a dam requires registration with APEGBC as a professional engineer.

The Design Engineer must be registered and in good standing with APEGBC as a professional engineer under the *Engineers and Geoscientists Act*.

A professional engineer acting as a Design Engineer for dams in British Columbia is typically registered with APEGBC within the discipline of civil, geological, or mining engineering.

The Design Engineer can take professional responsibility only for design and field review activities related to the design and construction of the dam that are consistent with his/her training and experience. This would include responsibility for development and oversight of the site characterization of the dam's foundation. As such, a Design Engineer may require supplementary supporting professional engineering and/or professional geoscience services for a particular professional activity, or component or sub-component of a professional activity, related to the design and construction of the dam, including aspects related to the development and oversight of the dam site characterization. The APEGBC professional acting in such a supporting capacity is engaged as a supporting registered professional (SRP). It is the responsibility of the professional engineer acting as the Design Engineer to determine which professional activities he/she can take personal responsibility for as well as those professional activities that will require the services of an SRP with the relevant training and experience.

The APEGBC professional who investigates or interprets complex geological conditions, geomorphic processes, and geochronology in support of dam site characterization is typically registered with APEGBC as a professional geoscientist in the discipline of geology or environmental geoscience, or as a professional engineer in the discipline of geological or geotechnical engineering.

A professional geoscientist is typically registered with APEGBC in the discipline of geology, environmental geoscience, or geophysics.

6.2 Education, Training, and Experience

The professional engineer acting as the Design Engineer having overall responsibility for the design of a dam, which includes responsibility for developing and overseeing the site characterization of the dam's foundation, as described in these guidelines, requires minimum levels of education, training, and experience in many overlapping areas of engineering and geoscience. The Design Engineer must adhere to APEGBC Code of Ethics Principle 2 (to undertake and accept responsibility for professional assignments only when qualified by training or experience) and, therefore, must evaluate his/her qualifications and must possess the appropriate education, training, and experience to provide the services.

The level of education, training, and experience required of a professional engineer acting as a Design Engineer should be commensurate with the complexity of a dam, the dam site, and the dam's consequence classification. The qualifications of the Design Engineer should be supplemented by training and experience in additional subject areas, depending on the dam's consequence classification and as required by any increased complexity of a dam and its site conditions.

The recommended qualifications that an individual must hold prior to acting in the capacity of Design Engineer include the following:

- Be currently registered as a professional engineer with APEGBC
- Have previous extensive involvement with the design of at least two dams of similar nature and complexity (e.g., if a concrete dam, then of that nature)
- Have at least 10 years of experience related to the design of dams, including responsibility for developing and overseeing the site characterization of dam foundations
- For water dams, have current knowledge of industry best practices in the assessment, design, and construction of dam foundations for water reservoir dams, the *British Columbia Dam Safety Regulation, Canadian Dam Association Dam Safety Guidelines,* and international dam safety guidelines
- For tailings dams, have current knowledge of industry best practices in the assessment, design, and construction of dam foundations for tailings dams, the regulations applicable to the *Mines Act* and the *Health, Safety and Reclamation Code for Mines in British Columbia,* the guidelines provided by the Mining Association of Canada, and, if relevant, portions of the *Canadian Dam Association Dam Safety Guidelines* that may apply to tailings dams
- When a multidisciplinary team approach is utilized, the Design Engineer is also required to have extensive experience in coordinating the work of a variety of SRPs. In such instances, the Design Engineer would be required to identify:
  - All of the types of professional activities for which SRPs need to be engaged
  - The engineering/geoscience and other disciplines required, as well as the background, experience, and expertise required of individual SRPs in order to carry out a particular professional activity (that is, determine that each SRP has the appropriate skills and competencies required to complete the activity he/she is engaged to carry out)
- Be knowledgeable about site characterization for dams and the design, construction, and operation of dams

- Confirm that he/she has the appropriate training and experience to oversee the dam site characterization for the particular type of dam, complexity of the site, and associated overall system of containment for the reservoir; if not, involve the required specialists to provide assistance in the relevant areas

The level of experience required for a Design Engineer, as identified above, can only be obtained by working under the direct supervision of a suitably knowledgeable and experienced professional engineer.

Supporting registered professionals acting as specialists in a particular field of practice offering specialized services (e.g., seismic determination and response) usually require specialized education, training, and experience in addition to the recommended qualifications to act in the capacity of Design Engineer (discussed above).

In addition to the above-listed qualifications, the relevant technical skill sets can be acquired through formal university or college courses, or through continuing professional development. There may be some overlap in courses, and specific courses may not correlate to specific technical skill sets.

An APEGBC professional acting in the capacity of a Design Engineer or an SRP must also remain current, through continuing professional development, with evolving topics related to their field of practice as it relates to the design of dams (see APEGBC Code of Ethics, Principle 6). Continuing professional development can include taking formal courses; attending conferences, workshops, seminars, and technical talks; reading new texts and periodicals; searching the web; and participating in field trips.

APPENDIX A-1: DESIGN ENGINEER'S SITE CHARACTERIZATION ASSURANCE STATEMENT

To: The Owner(s) Date: _____

Name: _____

Address: _____

_____

For the dam:

UTM (Location): _____

Located at (Description): _____

Name of dam or description: _____

Provincial dam number: _____

Dam function: _____

Current *project stage* is:

Check one

☐ Feasibility design
☐ Detailed design
☐ Construction/operations

The undersigned hereby gives assurance that he/she is a qualified APEGBC-registered professional and is a professional engineer and is the **Design Engineer** for the dam project identified above.

I have signed, sealed, and dated the attached dam site characterization report in accordance with the *APEGBC Professional Practice Guidelines – Site Characterization for Dam Foundations in BC*. The report must be read in conjunction with this Assurance Statement.

In preparing the dam site characterization report, I have completed the following activities:

(Check the applicable items)

Completed by the Design Engineer	Activity
	Collected and reviewed available and relevant background information, documentation, and data
	Visited the site and reviewed the conditions in the field that may be relevant for site characterization
	Developed and executed a site characterization program that provides information to support the design of the dam, subject to the qualifications noted
	Reviewed previous site characterization studies and data and updated the dam site characterization assessment report to include all data and, where appropriate, revised interpretations of data
	Assessed potential areas of risk identified during site characterization programs to date and, as far as is practical, addressed the risks
	Evaluated the level of complexity of the site and documented how it was assessed and supported by the site characterization program(s)
	Reviewed and accepted all assurance statements submitted by the supporting registered professionals (SRPs)
	Prepared a data record report
	Prepared the dam site characterization report, which interprets the site conditions

In preparing the dam site characterization report, I have completed the following activities or reviewed and accepted such activities completed by a supporting registered professional (SRP):

(Check the applicable items)

Completed by the Design Engineer	Completed by the SRP, and reviewed and accepted by the Design Engineer	Activity
		Assessed the surficial and bedrock geological models to confirm that they adequately support the understanding of the spatial variability of the geotechnical properties of the foundation materials
		Carried out sufficient in situ and laboratory testing to quantify the geotechnical properties of the foundation materials
		Assessed the strength properties of the foundation materials with consideration of stress state and response to loadings
		Assessed the hydrogeological properties of the foundation materials with consideration of potential hydraulic gradients, artesian pressures, and seepage flow paths
		Assessed the seismotectonic conditions to provide a basis for the seismic hazard analysis of the dam
		Evaluated the level of complexity of the site and documented how it was assessed and supported by the site characterization program(s)
		Reviewed and accepted all assurance statements submitted by the supporting registered professionals (SRPs)
		Prepared a data record report
		Prepared the dam site characterization report, which interprets the site conditions

I hereby give my assurance that based on the attached dam site characterization report, at this point in time:

Check one

☐ The dam site characterization report is reasonably comprehensive and supports the design of the dam.

☐ The dam site characterization report is not sufficiently comprehensive to support the design of the dam, in that the dam site characterization report identifies areas of potential concern that require additional investigation as set out in section(s) _____ of the attached dam site characterization report

Name: (print) _____

Signature:_____ Date:_____

Address: _____

_____

_____ (Affix professional seal here)

Telephone: _____

Email: _____

(If the APEGBC professional is a member of a firm, complete the following)

I am a member of the firm _____
(Print name of firm)

and I sign this letter on behalf of the firm.

APPENDIX A-2: SUPPORTING REGISTERED PROFESSIONAL'S ASSURANCE STATEMENT OF PROFESSIONAL SERVICES

To: The Design Engineer Date: _____

Name: (print) _____

Address: (print) _____

_____

For the dam:

UTM (Location): _____

Located at (Description): _____

Name of dam or description: _____

Dam function: _____

Owned by: _____

Current project stage is:

Check one

☐ Feasibility design
☐ Detailed design
☐ Construction/operations

This is to advise that the undersigned is a **supporting registered professional** (SRP) retained by _____to carry out supporting professional services for the dam.

I undertook supporting professional services in the following:

(Check applicable sections)

☐ Bedrock/structural geology
☐ Surficial geology
☐ Geotechnical investigations
☐ Hydrogeology
☐ Seismotectonic investigations
☐ Other

The undersigned hereby gives assurance that the_____

_____

_____(Insert here the specific professional services carried out) and the documents prepared by this supporting registered professional for the project have been carried out in a manner that meets the intent of the applicable APEGBC guidelines and good professional practice.

These professional services are described, and the results of them reported on in the documents prepared by me, or under my direct supervision, which bear my professional seal.

(With respect to field reviews, initial the following statements, as applicable. Leave blank those that are not applicable.)

_____ Field review(s) are not applicable

_____ Field review(s) are applicable:

_____ I have performed field review(s) for the services identified above.

_____ Field review(s) have been performed by_____.

I confirm that I have communicated and liaised as required with the appropriate APEGBC professionals for the purposes of my services.

I hereby give my assurance that I am an APEGBC-registered professional.

Name: (print) _____

Signature:_____ Date:_____

Address: _____

_____

_____ (Affix professional seal here)

Telephone: _____

Email: _____

(If the APEGBC professional is a member of a firm, complete the following)

I am a member of the firm _____
(Print name of firm)

and I sign this letter on behalf of the firm.

APPENDIX B: BIBLIOGRAPHY

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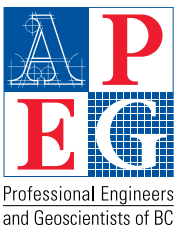
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Date:	Friday, January 7, 2022 1:14:33 PM
Attachments:	image001.png 2022 01 07 Embankment Record of Construction Expansion 457.5.pdf

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Dear Mr. Akhter,

Please see attached, *2022 01 07 Embankment Record of Construction Expansion 457.5*

2nd attachment sent through Open Trust large file transfer

Regards,

Betsy Laliberte
Management Systems Technician
Phone: 306-633-1554



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January 7, 2022

Mr. Salman Akhter
Senior Project Officer
Uranium Mines and Mills Division
Canadian Nuclear Safety Commission
101 – 22nd Street East, Suite 520
Saskatoon, SK, S7K 0E1

Dear Mr. Akhter,

Re: McClean Lake Operation – Submission of Record of Construction for 2021 JEB TMF Expansion (457.5 mASL)

Orano Canada Inc.

100-833 45th Street West
Saskatoon SK S7L 5X2
Tel.: +1 (306) 343-4500

Please find attached the Record of Construction for JEB TMF Expansion Project (457.5 mASL) for work carried out between April and October 2021. The Record of Construction provides a summary of the construction works including the as-constructed drawings, test pad construction report and QA/QC results. The record of construction also includes a summary of the monitoring well decommissioning in the embankment footprint.

During construction, modifications to the design were required to accommodate construction conditions. These modifications are summarized in Table 1 and shown on the attached drawings. The construction and the modifications identified in Table 1 met the intention of the design.

Table 1: Modification to Design

Modification	Description
Fill Outside Embankment Toe	Fill was placed outside the embankment toe between Station 0+950 and Station 1+125 to control surface water.
Organics Excavation Under Soil – Bentonite Liner	Organics were excavated from under the soil-bentonite liner between Station 0+650 and Station 0+700. The affected liner portion was removed and replaced.
Organics Excavation Under TMF Access Road	Buried organics continued under a portion of the TMF access road which necessitated excavation of a portion of the road
Exclusion of Granular Filter Layer	Following waste rock fill test pad construction, based on preliminary analysis for the compatibility of the compacted fill with the soil-bentonite liner, a filter layer would not be required to separate the compacted fill from the soil-bentonite liner. The compacted waste rock fill was constructed to the lines and grades of the base of the soil-bentonite liner, replacing the 0.5 m granular filter. An assessment will be completed to determine

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To: Mr. Salman Akhter
Re: Submission of Record of Construction for 2021 JEB TMF Expansion (457.5 mASL)
January 7, 2022

Modification	Description
	whether a filter layer is needed between the compacted fills and the soil-bentonite liner prior to construction of the clay liner for the 457.5 mASL expansion. The assessment will be submitted separately prior to soil-bentonite liner construction.
Trail Between South Stockpile and Embankment	Buried organics continued under the south till stockpile. The trail between the stockpile and embankment was constructed with fill to avoid additional excavation of the stockpile.
Fill in Erosion Control Swale	Fill was required in the base of the erosion control swale to promote drainage to the sediment traps.
Modifications to Sediment Trap at Station 0+200	The orientation of the berms in the sediment trap at Station 0+200 were modified to allow vehicle access to the 95-03 series of monitoring wells.

Should you have any questions, please contact me or Mark Neal, P. Eng at (306) 633-2177.

Sincerely,

DocuSigned by:
Dale Huffman
A0EC0C80244B42B...

Dale Huffman
Vice President
McClean Lake Operation

Attach.: Record of Construction

cc: UMMD
Orano distribution

TS/DH

Appendix B

Section D

Subsection A: Construction Reports TMF Optimization Stage 1

December 2012

RECORD OF CONSTRUCTION

JEB TAILINGS MANAGEMENT FACILITY OPTIMIZATION STAGE 1/PHASE 1 2012 CONSTRUCTION

Submitted to:
AREVA Resources Canada Inc.
P.O. Box 9024
817-45th Street West
Saskatoon, Saskatchewan
S7K 3X5

REPORT

Report **Number:** 12-1362-0022
Distribution:

1 Copy - AREVA Resources Canada Inc.
2 Copies - Golder Associates Ltd.

Golder Associates

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1.0 INTRODUCTION

1.1 General

AREVA Resources Canada Inc. (AREVA) conducted a study to optimize tailings storage within the JEB Tailings Management Facility (TMF) at the McClean Lake Operation mine site. The optimization of tailings storage within the JEB TMF involves re-sloping of the existing till slopes, construction of a bentonite amended liner, and placement of riprap on the liner for erosion protection. It will be constructed in two stages: Stage 1 and Stage 2. Stage 1 will be split into Phase 1 (constructed in the summer of 2012) and Phase 2 (constructed in the summer of 2013).

Stage 1/Phase 1 began during the summer of 2012. Work completed for Stage 1/Phase 1 during the 2012 construction season included the following components:

- preparation of a site office and laydown area;
- preparation of two stockpiling areas: the South Stockpile Area and the North Stockpile Area;
- re-sloping the existing till slopes within the JEB TMF;
- construction of two access ramps into the JEB TMF; and
- processing of riprap and liner granular materials for the construction of the bentonite amended liner in the summer of 2013.

The work completed during 2012 for Stage 1 was constructed under the Saskatchewan Ministry of Environment Approval to Construct No. PC10-165 (File No. S25020-50/ML/03) dated November 18, 2010 and the Canadian Nuclear Safety Commission letter (File No. 2.04 ML-A) dated September 30, 2010. The two stockpiling areas were prepared under the Ministry of Environment Aquatic Habitat Protection Permit #12PA040 dated May 14, 2012 and Forest Product Permit #2821H dated May 14, 2012. The documents are provided in Appendix D.

This report contains a summary of the Stage 1/Phase 1 work carried out by Broda Construction Ltd. of Prince Albert, Saskatchewan. The work occurred between July 11, 2012 and September 28, 2012.

Details of the work completed are shown on the record drawings provided in Appendix A.

1.2 Report Objectives

The objective of this report is to document construction activities and report results of quality assurance and construction monitoring activities conducted by Golder Associates Ltd. (Golder). In addition, modifications to the design are specifically discussed.

Details of the 2012 construction are shown on the record drawings included in Appendix A.

1.3 Division of Responsibilities

The responsibilities for each company involved in the 2012 construction are shown in Table 1.

Table 1: Division of Responsibilities

Company	Responsibilities
AREVA Resources Canada Inc. (Saskatoon, Saskatchewan)	Owner: contract administration
Golder Associates Ltd. (Saskatoon, Saskatchewan)	Owner's Representative: assistance with contract administration; design engineers; quality assurance testing; on-site monitoring during construction; construction, quantity and record surveying; preparation of record drawings and Record of Construction report
Broda Construction Ltd. (Prince Albert, Saskatchewan)	Contractor: re-sloping of till slopes and stockpiling of excavated material; construction of access ramps; construction of safety berm; production of riprap and liner granular material for the Stage 1/Phase 2 bentonite amended liner construction

1.4 Survey Control Datum

Survey control utilized during the construction was referenced to the local mine grid co-ordinate system. Localization to the local mine grid control was performed using co-ordinates provided to Golder by AREVA. Golder's site control network was established in reference to Golder-MLO-CP1 using the localization created. The co-ordinates for Golder-MLO-CP1, in the local mine grid, are as follows:

- Northing – 11,109.63 metres (m);
- Easting – 5,040.22 m; and
- Elevation – 453.18 m.

Details of the survey control datum are provided in the survey control report in Appendix E.

1.5 Location of Field Records

The locations of field records of construction are summarized in Table 2.

Table 2: Field Records and Filing Locations

Record Type	Description	On File With
Field Report	Field Books Daily Golder Field Reports	Golder/AREVA Golder/AREVA
Field Report	Daily Broda Field Reports	Golder/Broda/AREVA
Meeting Minutes	Daily Toolbox Safety Minutes Weekly Contractor Safety Minutes	Broda/AREVA Broda/AREVA
Quality Assurance Testing	Standard Proctor Curves Nuclear Density Test Reports Grain Size Analysis Hydrometers Hydraulic Conductivity Testing	Golder Golder Golder Golder Golder
Surveying	Field Books Plan/Profiles	Golder Golder
Construction Photographs	Photographs	Golder

1.6 Photo Log

Photographs were taken by Golder during construction as part of the monitoring program. Select photographs are included in Appendix B.

2.0 MODIFICATIONS TO DESIGN

During construction modifications to the design were required to accommodate construction conditions. These modifications are summarized in Table 3 and shown on the record drawings provided in Appendix A.

Table 3: Modifications to Design

Modification	Description
Shift of design toe of slope location: Station 0+335 to 0+375	Runoff between Station 0+335 and Station 0+375 resulted in erosion of the slope and a shift of the design toe was required to maintain a 3H:1V slope below elevation 440.6 masl.
Increased liner quantities	The exposed sandstone surface below the liner was found to be below the design sandstone surface in some areas. This increased the quantity of material necessary to construct the liner during Phase 2 by approximately 1,907 m^3.
Riprap gradation specification	The riprap gradation specification was altered to contain a larger coarse fraction. Table 5 in Section 6.1.1 provides a comparison of the original and modified riprap specification.
Safety Berm	The dimensions of the Safety Berm were changed to a minimum height of 1.35 m with a minimum top width of 0.15 m and 1H:1V sideslopes.

m = metre

3.0 BLAST ROCK INVESTIGATION

During construction a material similar in appearance to blast rock was observed at the exposed sandstone contact elevation along the south side of the TMF (approximately Station 0+950 to Station 0+050). A test pitting program was undertaken to assess the competency of this material as a foundation for the Phase 2 liner construction.

Four test pits were excavated within the JEB TMF. The test pits were excavated using a Cat 330 excavator with a smooth edge bucket owned and operated by Broda Construction. Upon completion the test pits were backfilled with excavated materials and compacted using the bucket of the excavator.

Three test pits were excavated along the southern edge of the TMF between approximately Station 0+950 and Station 1+030. Silty sand (till) overlying intact sandstone was encountered in all three test pits. The sandstone contact was encountered between 0 m and 2.7 m below ground surface (Elevation 438.14 masl to 435.17 masl) which corresponded well to the design sandstone contact.

An access ramp existed between approximately Station 1+030 and Station 0+025 at the time of test pitting. Silty sand (till) overburden through this section was too thick to excavate test pits to the sandstone contact and therefore no test pits were excavated through this section.

A fourth test pit was excavated at approximately Station 0+040 (within the South Turnaround Area). The surface of the test pit was at Elevation 434.65 masl. This elevation corresponds to the design sandstone contact elevation at this location. The material encountered in this test pit was blocky, angular sandstone. The sandstone

blocks ranged in size from approximately 0.1 m to approximately 1.5 m. Fractures between the blocks were thin and filled with silty sand. No evidence of voids being present between the blocks was observed. The excavator had difficulty to excavate through this material and excavation was stopped at a depth of 0.9 m.

The four test pits indicated no major change in the sandstone contact from the design drawings. The test pit at Station 0+040 indicated that blast rock may be present but based on visual observation there appeared to be no voids visible at the sandstone contact elevation. Based on the observations during excavation of the test pits the surface below the liner appears to be a competent surface for which to found the liner on.

4.0 EXCAVATION

4.1 General

Stage 1 included re-sloping the existing till slopes above the till/sandstone contact within the JEB TMF.

Details of the excavation geometry, materials and finishing are provided below.

The original till slopes and slope armouring were left in place as erosion protection below two culvert outlets at approximately Station 0+850 (Photo 12). Re-sloping of this section of the TMF will occur in the summer of 2013.

4.2 Excavation Geometry

Re-sloping of the existing till slopes occurred above the till/sandstone contact. The till was re-sloped, beginning at 14.0 m horizontally from the crest of the till/sandstone contact, at a slope of 3H:1V up to about elevation 440.9 metres above sea level (masl), then at 1.5H:1V until the slope day-lighted with existing ground (Photo 5).

Details of the excavation geometry are provided on the record drawings in Appendix A.

4.3 Excavation Materials

Excavated till from the re-sloping was used in the following areas:

- blending with granular materials for the bentonite amended liner;
- common fill for the south and north access ramps;
- common fill for the safety berm; and
- placed in one of two stockpile areas: the South Stockpile Area (Photo 3) or the North Stockpile Area (Photo 7).

Clearing and grubbing of 1.2 hectares (ha) of brush was required for the South Stockpile Area (Photo 1), while the North Stockpile Area required clearing and grubbing of 0.8 ha.

Approximately 48,820 cubic metres (m^3) of excavated till was placed in the South Stockpile Area. Approximately 49,840 m^3 of excavated till was placed in the North Stockpile Area. Both stockpiles were graded to drain upon completion (Photo 9).

Details of the stockpile locations are provided on the record drawings in Appendix A.

4.4 Excavation Finishing

Upon completion of excavation the slopes were trimmed to an even surface.

Details of the finishing are provided on the record drawings in Appendix A.

5.0 EMBANKMENT CONSTRUCTION

5.1 General

Embankment construction for Stage 1 consisted of the construction of the South Access Ramp (Photo 14) and North Access Ramp (Photo 15), filling over-excavated areas of the 3H:1V till slope, and construction of the Safety Berm.

Details of the embankment geometry, materials, and finishing are provided below.

5.2 Embankment Geometry

The South Access Ramp was constructed along the south edge of the JEB TMF. It is approximately 380 m in length. The North Access Ramp was constructed along the northwest edge of the JEB TMF. It is approximately 120 m in length. Both ramps were constructed with top width of 15.0 m. Side-slopes of the ramps were constructed at 1.5H:1V in areas of excavation (cut) and at 3H:1V in areas of fill. A 2 percent (%) cross-slope was constructed to allow the ramps to drain. The South Access Ramp was constructed with a slope of between 0.7% and 9.5%, while the North Access Ramp was constructed with a 10% slope on the driving surface.

Over-excavation of the till slopes occurred between approximately Station 0+350 and Station 0+415 and between approximately Station 0+810 and Station 0+830 within the 3H:1V portion of the slope. Till material was placed and compacted to bring the slope back up to the design grade.

The Safety Berm was constructed along the South Access Ramp, North Access Ramp, and along the sandstone crest below the till re-sloping. It was constructed with a minimum height of 1.35 m with 1H:1V sideslopes and a crest width between approximately 0.5 m and 1.0 m.

Details of the embankment construction are shown on the record drawings provided in Appendix A.

5.3 Embankment Materials

5.3.1 Till

Till was excavated from the re-sloping of the slopes within the JEB TMF. Samples of the till were taken to Golder's Saskatoon laboratory for Standard Proctor Maximum Dry Density (SPMDD) (ASTM D698) testing. The results of the SPMDD testing are summarized in Table 4.

Table 4: Till Standard Proctor Maximum Dry Density Test Results

Proctor Number	Description	Optimum Moisture Content (%)	Standard Proctor Maximum Dry Density (kg/m^3)
2012-MLO-001	Till	6.9	2,086
2012-MLO-001 (corrected for oversize material)	Till	5.5	2,177
2012-MLO-005	Till	7.1	2,032
2012-MLO-007	Till	7.8	2,052
2012-MLO-007 (corrected for oversize material)	Till	7.1	2,093

% = percent; kg/m^3 = kilograms per cubic metre

Details of the SPMDD testing performed on the till are provided in Appendix C.

5.3.2 Nuclear Density Testing

Compaction specification for the embankment material required a minimum of 95% of SPMDD. To check compliance with specification, Golder performed quality assurance testing on the material using the nuclear densometer method (ASTM D6938) to determine the percentage SPMDD of the material after compaction. A summary of the results for each embankment are provided in the following sections.

5.3.2.1 South Access Ramp

The South Access Ramp was constructed of till placed in lifts not exceeding a thickness of 300 millimetres (mm) after compaction. Each lift was compacted using a Cat CS-583 smooth-drum roller.

The average % SPMDD of the South Access Ramp material was determined to be 99.8%. The minimum and maximum % SPMDD of the material was determined to be 95.3% and 103.0%, respectively.

5.3.2.2 North Access Ramp

The North Access Ramp was constructed of till placed without compaction. The material placed within the North Access Ramp is planned to be removed when the slopes are flattened to 3H:1V above elevation 440.94 m in the future.

5.3.2.3 3H:1V Slope

At locations where over-excavation of the 3H:1V slope occurred, till was used to build the slope back up to the design grade. The till was placed in lifts not exceeding 300 mm after compaction and compacted using smooth-drum rollers.

The average % SPMDD of the till was determined to be 98.2%. The minimum and maximum % SPMDD of the material was determined to be 95.2% and 102.3%, respectively.

5.3.2.4 Safety Berm

The safety berm was constructed of nominally compacted till. No nuclear density testing was conducted on the Safety Berm.

6.0 PROCESSING OF GRANULAR MATERIALS FOR LINER CONSTRUCTION

Processing of granular materials which will be used in the construction of the bentonite amended liner during the summer of 2013 occurred between August 4, 2012 and September 16, 2012. Riprap and liner granular material were produced. Processing occurred on top of the waste rock pile at the McClean Lake mine site. Sandstone excavated from the waste rock pile and till excavated from the re-sloping of the TMF till slopes were blended to produce the final product.

6.1 Granular Materials

6.1.1 Riprap

Approximately 7,870 m^3 (measured in stockpile) of riprap was produced by crushing and screening sandstone obtained from the waste rock pile between August 4, 2012 and August 16, 2012 (Photo 16). Grain size analysis testing of the riprap was not conducted; rather, visual assessments were performed by Golder during production. The visual assessments were performed with the objective of assessing that the top particle size was around 300 mm, the median particle size was around 200 mm, and that the processed material contained a sufficient

fine grained component. Based on the visual assessments, the riprap was determined to meet the specification, and was accepted for use.

The riprap gradation specification was modified on August 10, 2012 as indicated in Section 2.0. Table 5 provides the original and modified riprap gradation specification.

Table 5: Riprap Gradation Specification

Sieve Size (mm)	Original Specification – Percent Passing (%) (By Weight)	Alternate Specification – Percent Passing (%) (By Weight)
400	100	100
300	--	100
200	--	40 – 60
100	75 – 100	--
4.5	30 – 70	10 – 30
0.074	--	0 - 15

mm = millimetre; % = percent

Riprap material produced prior to August 10, 2012 was stockpiled in two separate stockpiles; one consisting of material smaller than 75 mm and one consisting of material larger than 75 mm. This material will be considered part of the overall riprap quantity for protection of the liner, and will be placed on the liner during Stage 2 construction in 2013 as follows:

- all riprap material produced prior to August 10, 2012 will be placed on top of the liner (on the 5% slope);
- the fraction smaller than 75 mm will be placed directly on top of the liner, to a thickness of approximately 200 mm;
- the fraction larger than 75 mm will be placed above the smaller fraction, to a thickness of approximately 300 mm; and
- the resulting thickness of riprap will be 500 mm, which is consistent with the Drawings.

6.1.2 Liner Granular Material

6.1.2.1 General

Approximately 10,687 m^3 (measured in stockpile) of granular material for use as the base material for the bentonite amended liner was produced. The liner granular material was produced between August 17, 2012 and September 16, 2012. The liner granular material was produced by blending sandstone and till.

6.1.2.2 Grain Size Analysis

Grain size analysis testing (ASTM D422) was performed by Golder on the granular liner material during production. The results of the grain size analysis testing are summarized in Table 6.

Table 6: Liner Base Material Grain Size Analysis Test Results

Sieve Size (mm)	Specification (% Passing)	Average Percent Passing (%)
60	100	100
1.0	40 - 100	68
0.075	15 - 35	19

mm = millimetre; % = percent

A detailed summary of the grain size analysis results is included in Appendix C.

6.1.2.3 Excavated Till Hydrometers

Hydrometers were conducted on select samples of the excavated till in Golder's Saskatoon laboratory. Table 7 provides a summary of the hydrometer testing results.

Table 7: Liner Base Material Hydrometer Results

Sieve Size (mm)	Average Percent Passing (%)
152	100
76	100
38	100
19	96
9.5	93
4.75	90
2.00	85
0.850	76
0.425	64
0.250	48
0.150	35
0.075	26
0.045	18
0.027	14
0.018	11
0.012	9
0.009	7
0.006	5
0.005	4
0.003	3
0.002	2
0.001	2

mm = millimetres; % = percent

A detailed summary of the hydrometer testing is provided in Appendix C.

6.1.2.4 Hydraulic Conductivity

Hydraulic conductivity testing included a sampling program to retrieve representative samples of liner granular material from the crusher belt. A sample of the crushed sandstone and till blend was first retrieved. The crusher was then modified to exclude the till feed and crushed sandstone with no till blend (pure crushed sandstone) was sampled. Both samples were delivered to Golder's Saskatoon laboratory.

Grain size testing was completed on both samples of granular material (Figure 1). Both samples were then amended with 5% bentonite (by weight of dry aggregate) and tested at a dry density of about 98% SPMDD in a tri-axial hydraulic conductivity apparatus. The objective of the hydraulic conductivity testing of the crushed sandstone and till blend was to provide an indication of the expected in-situ hydraulic conductivity of the finished liner prior to Stage 1/Phase 2 construction (test strips of the finished liner are also planned prior to construction). The objective of testing the pure crushed sandstone was to assess if the hydraulic conductivity of pure crushed

sandstone without blending till would meet the design intentions for future construction projects beyond the JEB TMF Optimization project.

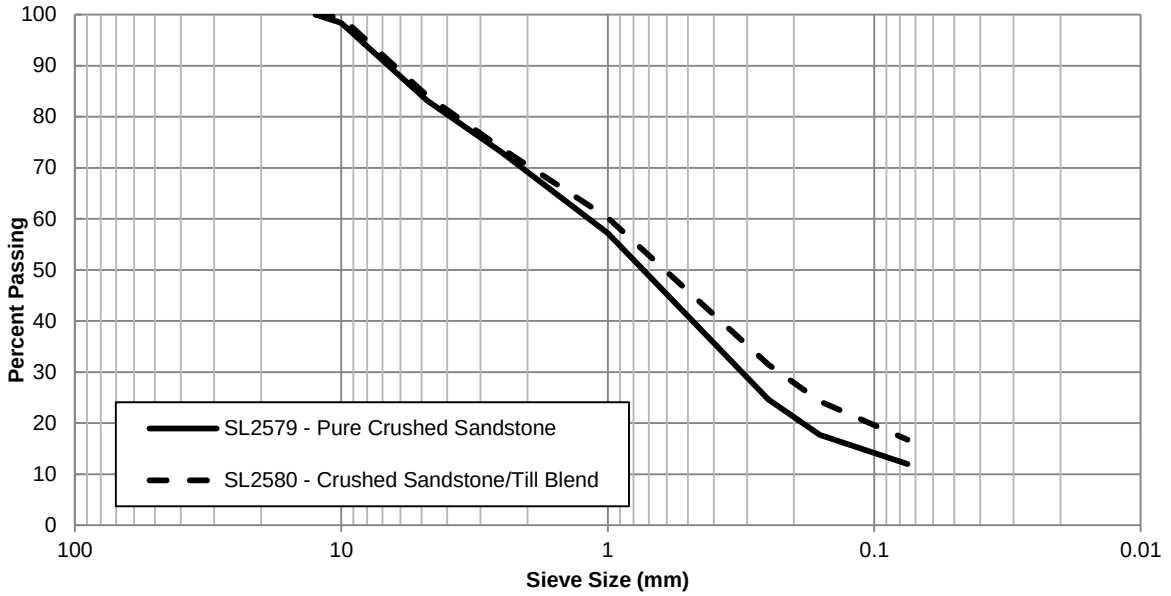


Figure 1: Grain size of samples tested for hydraulic conductivity

Table 8 provides the results of the hydraulic conductivity tests completed on bentonite amended granular materials. Pure crushed sandstone tested at two dry densities to assess the effect of density on hydraulic conductivity.

Table 8: Bentonite Amended Granular Material Hydraulic Conductivity Test Results

Description	Prepared Specimen Initial Dry Density (kg/m^3)	Hydraulic Conductivity (m/s)
Pure Crushed Sandstone (unblended with till) with 5% Bara-Kade SP Bentonite (Lower Initial Dry Density)	1,747	2.1×10^{-10}
Pure Crushed Sandstone (unblended with till) with 5% Bara-Kade SP Bentonite (Higher Initial Dry Density)	1,911	1.1×10^{-10}
Crushed Sandstone/Till Blend with 5% Bara-Kade SP Bentonite	1,851	9.4×10^{-11}

m/s = metres per second; % = percent; kg/m^3 = kilograms per cubic metre

The hydraulic conductivity tests completed in the laboratory indicate that the 5% bentonite amended granular materials meet the intentions of the design. Details of the hydraulic conductivity testing are provided in Appendix C.

7.0 OUTSTANDING WORK

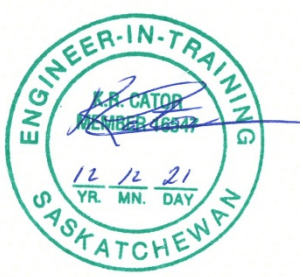
At the time of writing, the following work was outstanding for the Stage 1 construction:

- grading of the 3H:1V slope between approximately Station 0+850 and Station 0+900;
- re-sloping of the existing till slope below the culverts at approximately Station 0+850;
- cross-slope grading on the South Access Ramp; and
- completion of the liner granular material processing (approximately 1,956 m^3 left to produce)

8.0 CLOSURE

This report presents a summary of the construction of Stage 1/Phase 1 of the JEB TMF Optimization at the AREVA McClean Lake mine site between July 11, 2012 and September 28, 2012. The information presented in this report is based on daily reporting by Golder personnel, laboratory testing conducted by Golder and communications between Golder, Broda and AREVA.

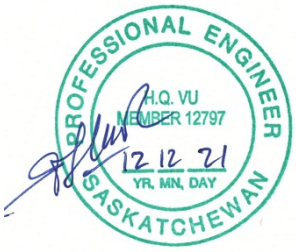
We trust that this report contains the information you presently require. Should you have any comments or questions, please do not hesitate to contact the undersigned.



Kyle Cator
Engineer-in-Training



Chris Fortier, P.Eng.
Geotechnical Engineer



Hung Vu, Ph.D., P.Eng.
Senior Geotechnical Engineer



Greg Misfeldt, M.Sc., P.Eng.
Principal, Senior Geotechnical Engineer

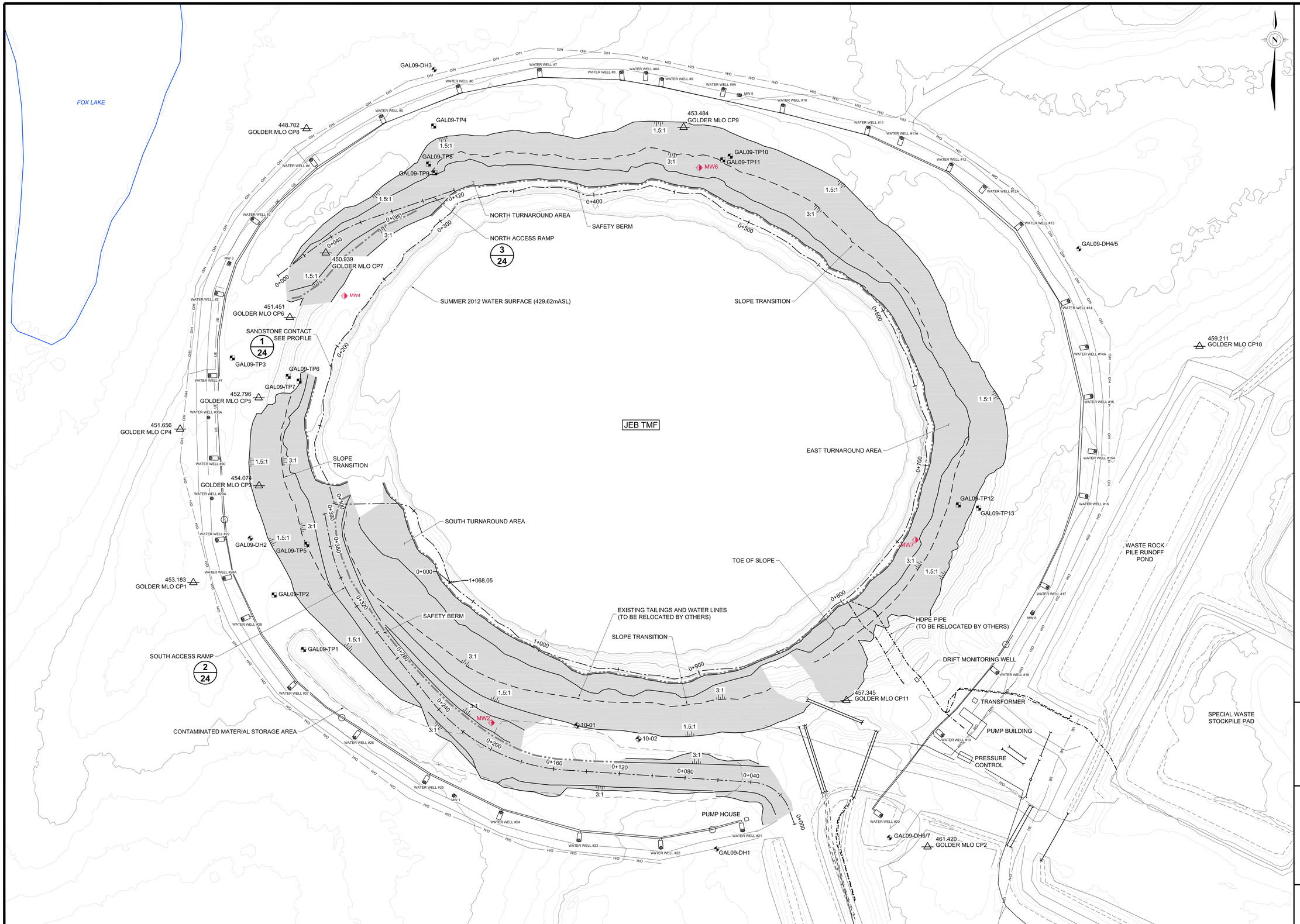
KRC/CSF/HV/pls

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APPENDIX A

Record Drawings



NOTES

1. CONTOURS GENERATED FROM LIDAR SURVEY (2009).
2. CONTOURS SHOWN AT 1m INTERVAL.
3. ELEVATIONS ARE REFERENCED TO GEODETIC DATUM: NAD83, ZONE 13.
4. NORTHINGS AND EASTINGS REFERENCED TO LOCAL MINE COORDINATE SYSTEM.

LEGEND

- ORIGINAL GROUND CONTOURS
- BOREHOLE LOCATION
- TEST PIT LOCATION
- MONITORING WELLS TO BE DECOMMISSIONED OR EXTENDED THROUGH FILL BY OTHERS
- SAFETY BERM LOCATION
- OVERHEAD POWERLINE
- POWER POLE
- EXISTING CSP CULVERT
- CONTROL POINT

CONTROL POINTS

DESCRIPTION	NORTHING	EASTING	ELEVATION
GOLDER MLO CP1	11109.626	5040.221	453.183
GOLDER MLO CP2	10949.172	5485.630	461.420
GOLDER MLO CP3	11168.406	5080.049	454.074
GOLDER MLO CP4	11202.765	5032.194	451.656
GOLDER MLO CP5	11221.790	5079.850	452.796
GOLDER MLO CP6	11270.627	5098.761	451.451
GOLDER MLO CP7	11309.745	5120.554	450.939
GOLDER MLO CP8	11385.195	5108.893	448.702
GOLDER MLO CP9	11385.978	5337.661	453.484
GOLDER MLO CP10	11253.050	5650.665	459.211
GOLDER MLO CP11	11038.026	5436.444	457.345

20 0 20
SCALE 1:1000 METRES

THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc) ARE BASED ON 24"X36" FORMAT DRAWINGS

PROFESSIONAL ENGINEER SASKATCHEWAN
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Association of Professional Engineers & Geoscientists of Saskatchewan
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Golder Associates Ltd.
Number C0230
Permission to Consult held by:

Discipline	Sk. Reg. No.	Signature
Geotechnical	6128	

Golder Associates
Saskatoon, Saskatchewan

REFERENCE

REVISIONS

No.	BY	DATE	APPROVED	DESCRIPTION

REVISIONS

No.	BY	DATE	APPROVED	DESCRIPTION
01	JDS	17/12/12	CSF GAM	RECORD OF 2012 CONSTRUCTION
00	JDS	13/06/12	CSF GAM	ISSUED FOR CONSTRUCTION
B	JDS	22/04/10	TPCP GAM	ISSUED FOR TENDER
A	JDS	23/12/09	TPCP GAM	ISSUED FOR REVIEW

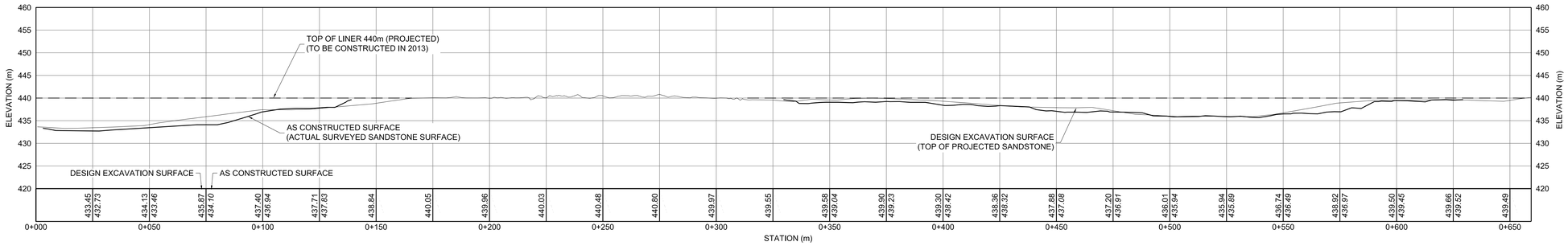
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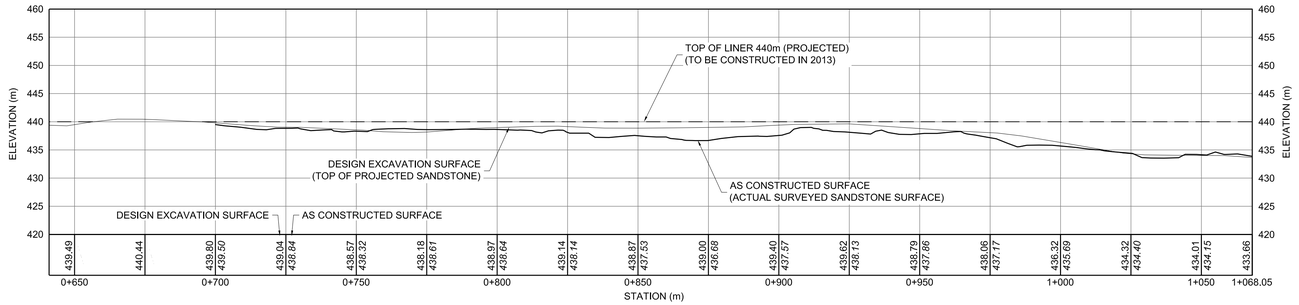
AREVA

FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN
	EXCAVATION PLAN
JOB	JEB TMF OPTIMIZATION STAGE 1

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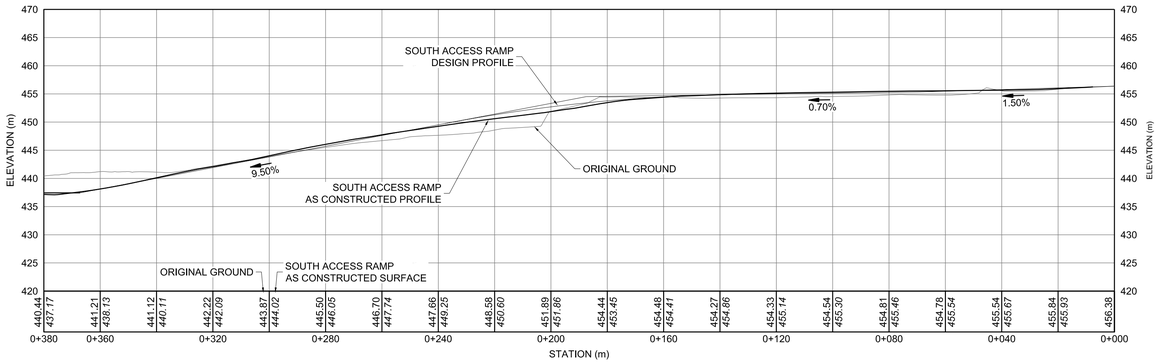
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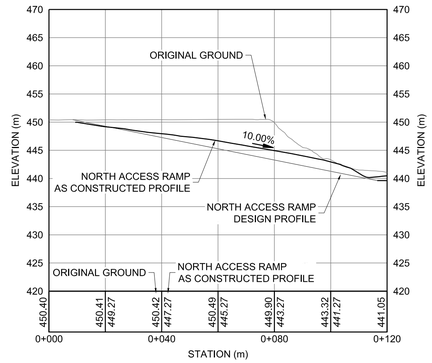
1 / 22 SANDSTONE CONTACT PROFILE

SCALE 1:500 METRES — VERTICAL
SCALE 1:1000 METRES — HORIZONTAL



2 / 22 SOUTH ACCESS RAMP PROFILE

SCALE 1:500 METRES — VERTICAL
SCALE 1:1000 METRES — HORIZONTAL



3 / 22 NORTH ACCESS RAMP PROFILE

SCALE 1:500 METRES — VERTICAL
SCALE 1:1000 METRES — HORIZONTAL

NOTES

1. ELEVATIONS ARE REFERENCED TO GEODETIC DATUM: NAD83, ZONE 13.
2. NORTHINGS AND EASTINGS REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
3. SANDSTONE CONTACT ALIGNMENT AND ELEVATIONS PROVIDED BY AREVA.

THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc) ARE BASED ON 24"X36" FORMAT DRAWINGS

PROFESSIONAL ENGINEER SASKATCHEWAN — C.S. FORTIER — MEMBER 14129 — 12 12 21 YR. MN. DAY

PROFESSIONAL ENGINEER SASKATCHEWAN — G.A. MCKAY — MEMBER 6128 — 12 12 21 YR. MN. DAY

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Discipline	Sk. Reg. No.	Signature
Geotechnical	6128	

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Saskatoon, Saskatchewan

REVISIONS						
No.	BY	DATE	APPROVED			DESCRIPTION
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00	JDS	13/06/12	CSF	GAM		ISSUED FOR CONSTRUCTION
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A	JDS	23/12/09	TPCP	GAM		ISSUED FOR REVIEW

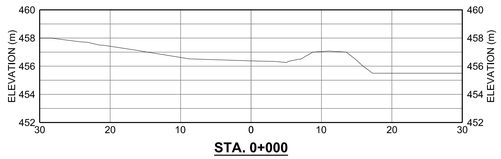
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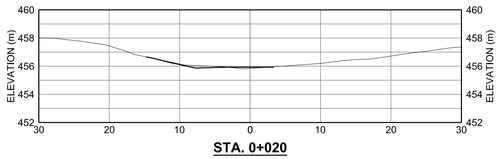
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ACTIVITY	CIVIL DESIGN
	PROFILES
JOB	JEB TMF OPTIMIZATION STAGE 1

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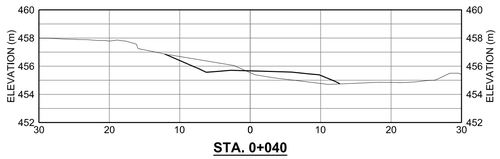
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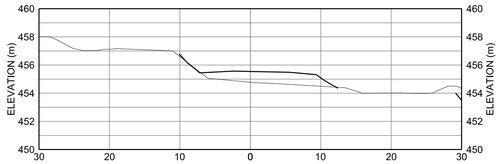
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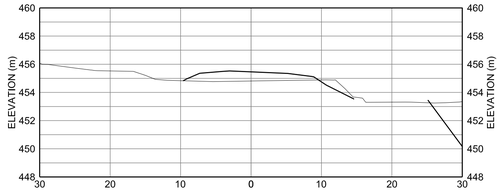
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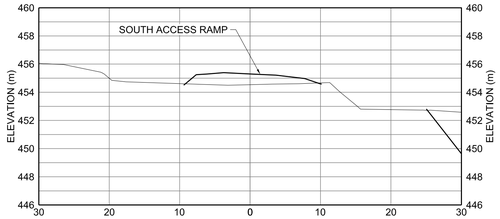
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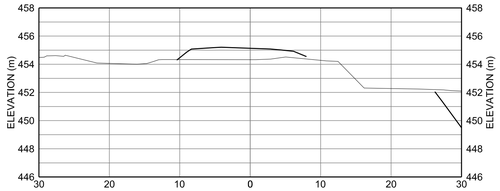
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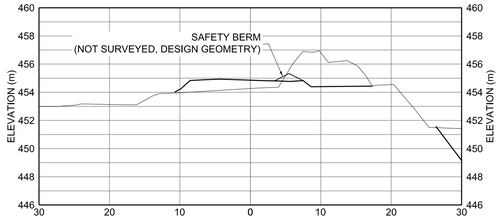
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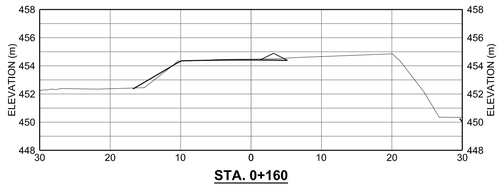
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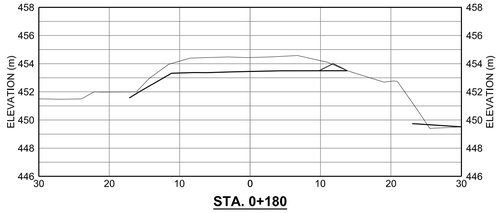
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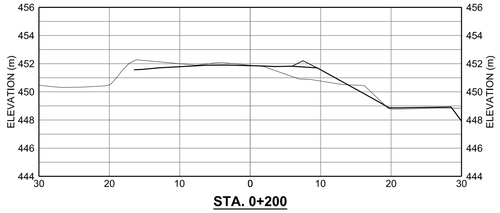
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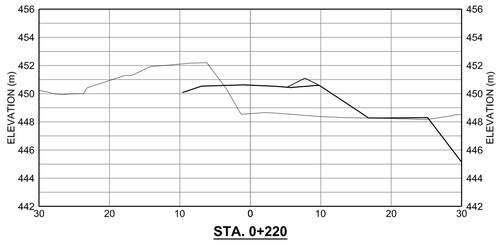
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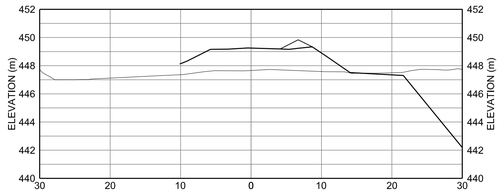
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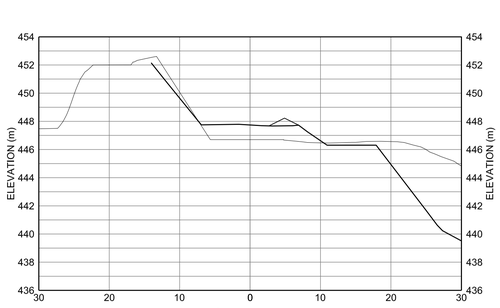
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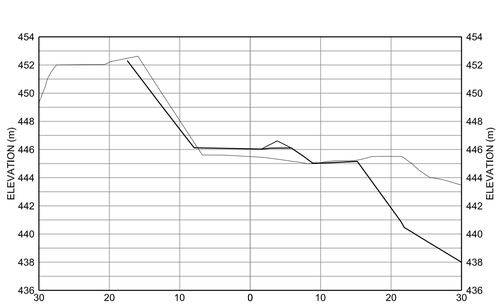
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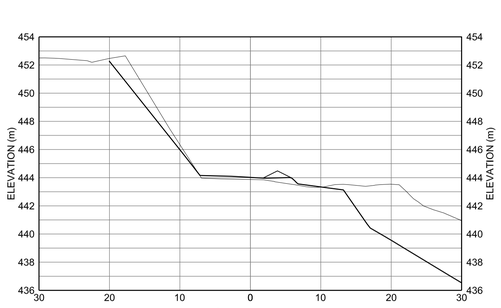
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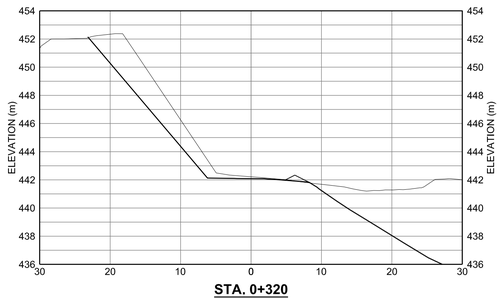
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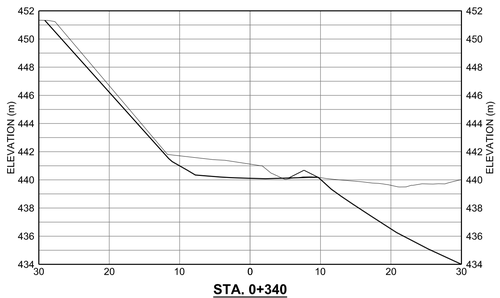
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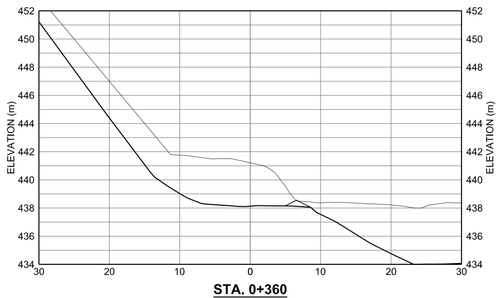
STA. 0+300



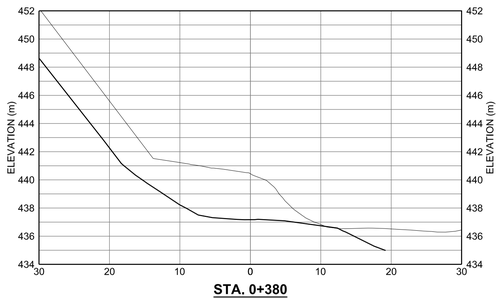
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STA. 0+340

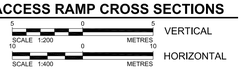


STA. 0+360



STA. 0+380

SOUTH ACCESS RAMP CROSS SECTIONS



NOTES

1. ELEVATIONS ARE REFERENCED TO GEODETIC DATUM; NAD83, ZONE 13.
2. NORTHINGS AND EASTINGS REFERENCED TO LOCAL MINE COORDINATE SYSTEM.

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REFERENCE

REVISIONS

No.	BY	DATE	APPROVED	DESCRIPTION

REVISIONS

No.	BY	DATE	APPROVED	DESCRIPTION
01	JDS	17/12/12	CSF	GAM	RECORD OF 2012 CONSTRUCTION
00	JDS	13/06/12	CSF	GAM	ISSUED FOR CONSTRUCTION

SCALE:	AS SHOWN	
DRAWN:	JDS	12/06/12
CHD:	CSF	13/06/12
APP'D:	GAM	13/06/12
DATE ISSUED		DATE

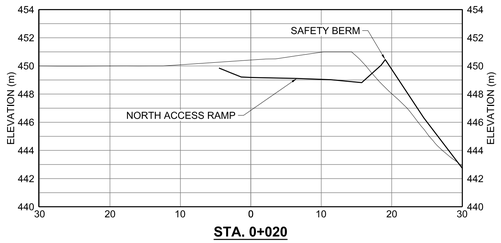
AREVA

FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN
	SOUTH ACCESS RAMP CROSS SECTIONS
JOB	JEB TMF OPTIMIZATION STAGE 1

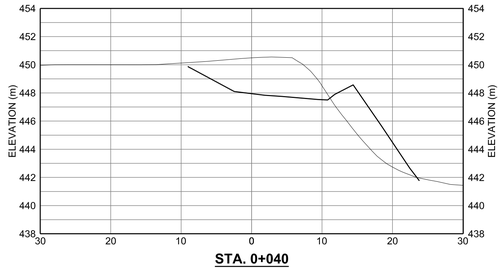
PROJECT NO. 12-1362-0022

FILE NAME. 12-1362-0022_Excavation Plan.dwg

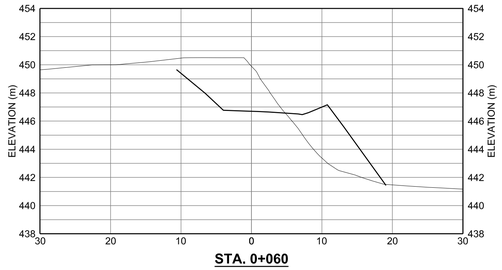
DRAWING NO. GA0024.1



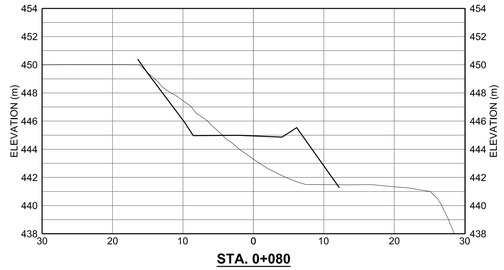
STA. 0+020



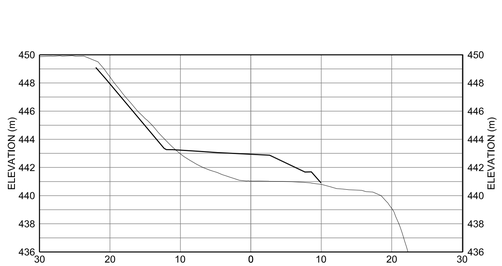
STA. 0+040



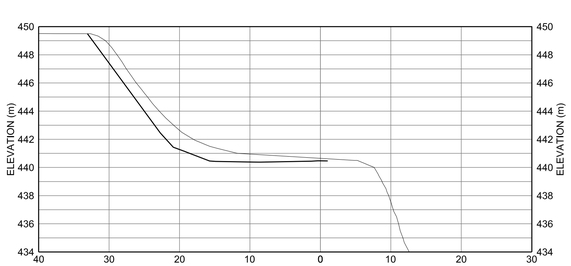
STA. 0+060



STA. 0+080



STA. 0+100



STA. 0+120

NORTH ACCESS RAMP CROSS SECTIONS

5 0 5 METRES
SCALE 1:200 VERTICAL

10 0 10 METRES
SCALE 1:400 HORIZONTAL

NOTES

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Geotechnical	6028	

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SCALE:	AS SHOWN	
DRAWN:	JDS	12/06/12
CHD:	CSF	13/06/12
APP'D:	GAM	13/06/12
DATE ISSUED		DATE

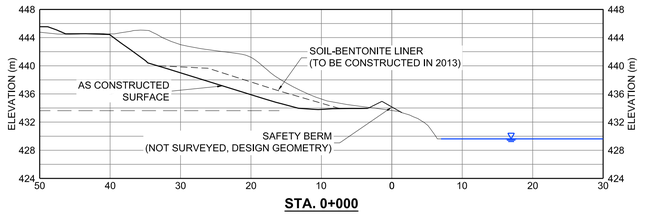
AREVA

FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN
	NORTH ACCESS RAMP CROSS SECTIONS
JOB	JEB TMF OPTIMIZATION STAGE 1

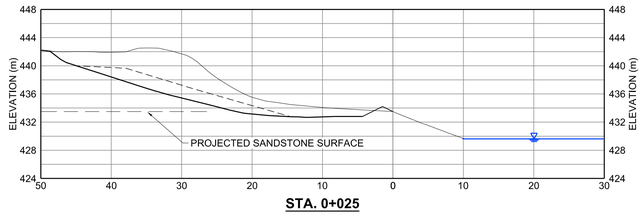
PROJECT NO. 12-1362-0022

FILE NAME. 12-1362-0022_Excavation Plan.dwg

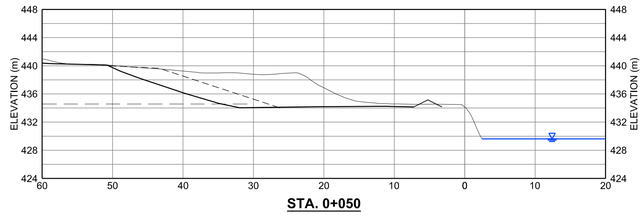
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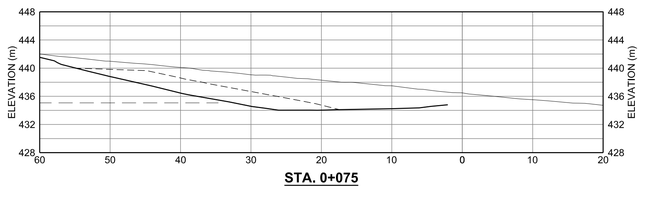
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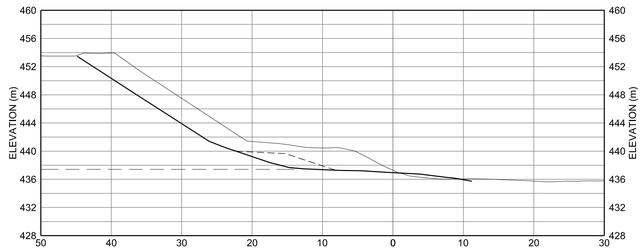
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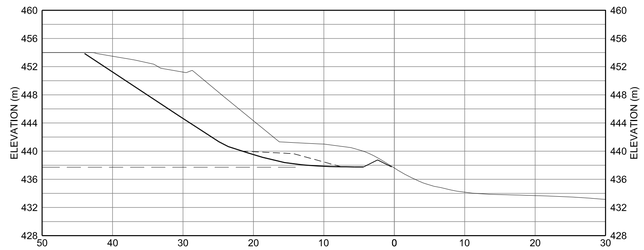
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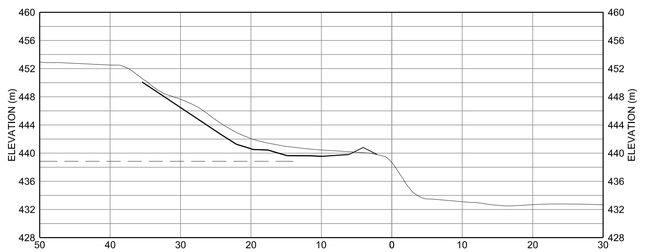
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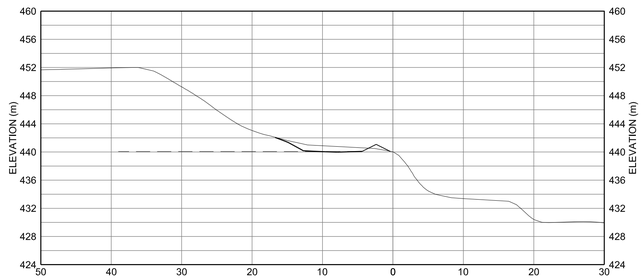
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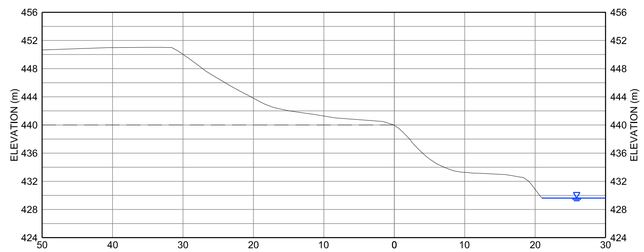
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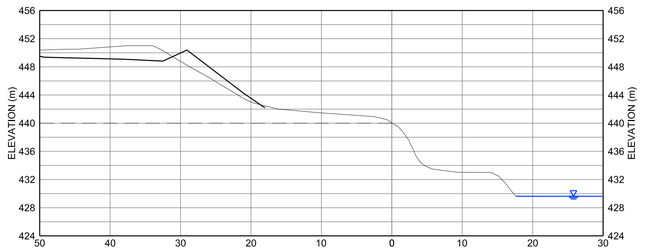
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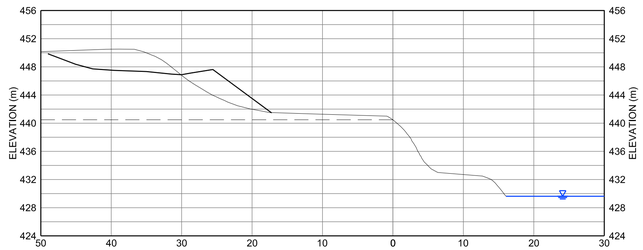
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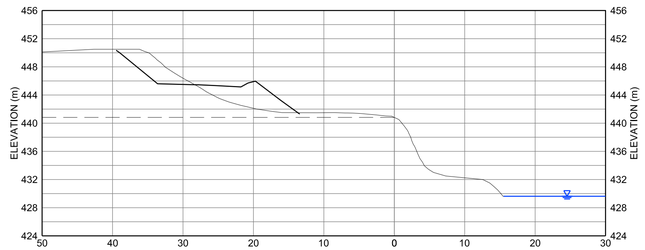
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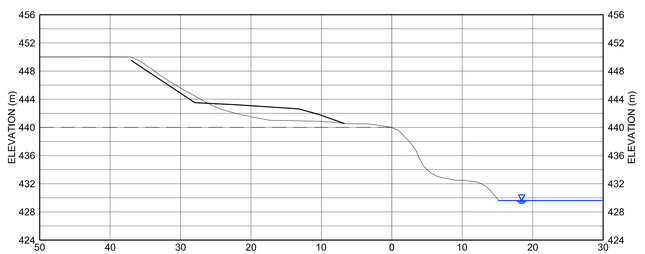
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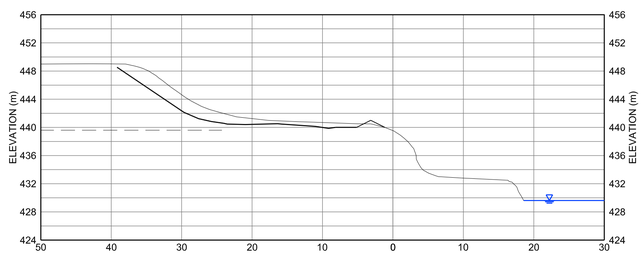
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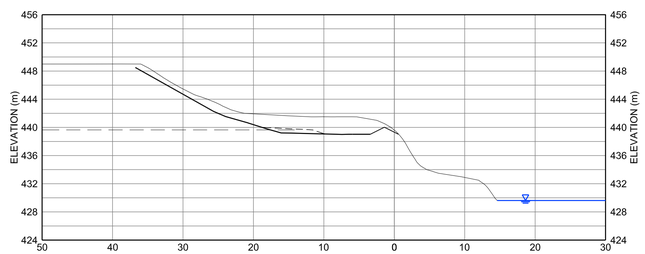
STA. 0+275



STA. 0+300



STA. 0+325



STA. 0+350

CROSS SECTIONS

VERTICAL SCALE 1:200

HORIZONTAL SCALE 1:400

NOTES

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REFERENCE

REVISIONS

No.	BY	DATE	APPROVED	DESCRIPTION
01	JDS	17/12/12	CSF	GAM	RECORD OF 2012 CONSTRUCTION
00	JDS	13/06/12	CSF	GAM	ISSUED FOR CONSTRUCTION
B	JDS	22/04/10	TPCP	GAM	ISSUED FOR TENDER
A	JDS	23/12/09	TPCP	GAM	ISSUED FOR REVIEW

SCALE:	AS SHOWN	
DRAWN:	JDS	23/12/09
CH'D:	TPCP	23/12/09
APP'D:	GAM	23/12/09
DATE ISSUED		DATE

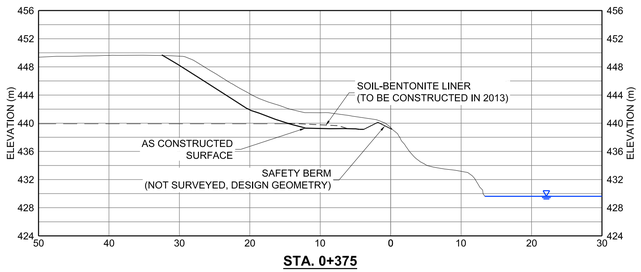
AREVA

FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN
	CROSS SECTIONS - EXCAVATION AND LINER PLACEMENT
JOB	JEB TMF OPTIMIZATION STAGE 1

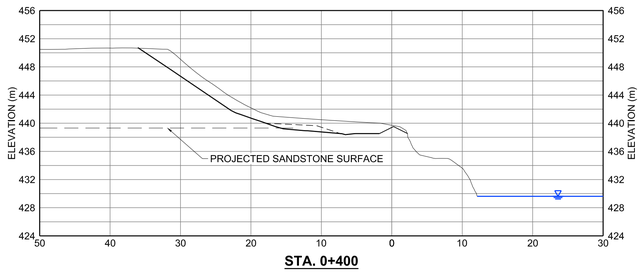
PROJECT NO. 12-1362-0022

FILE NAME. 12-1362-0022_Cross Sections.dwg

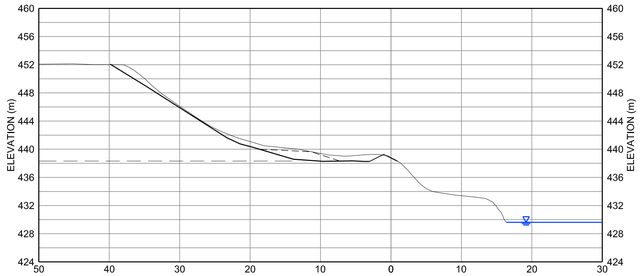
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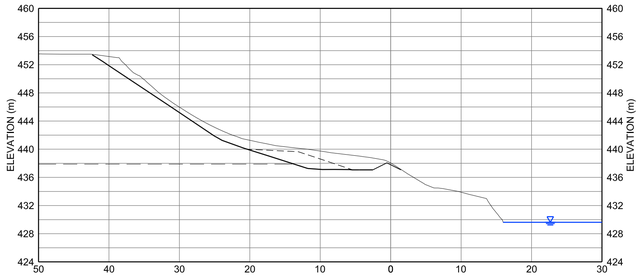
STA. 0+375



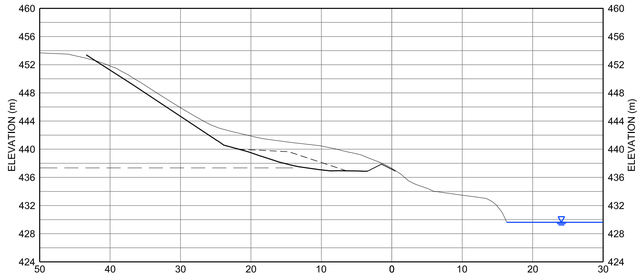
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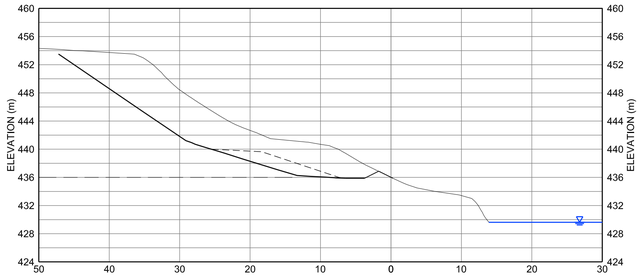
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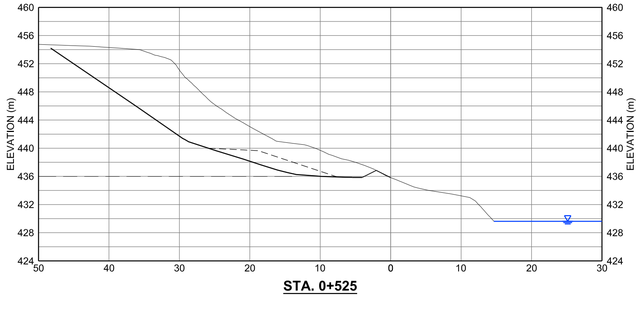
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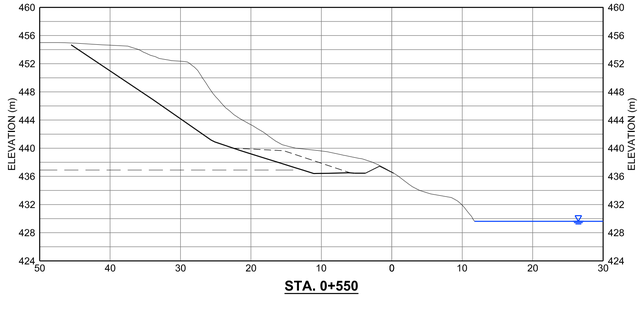
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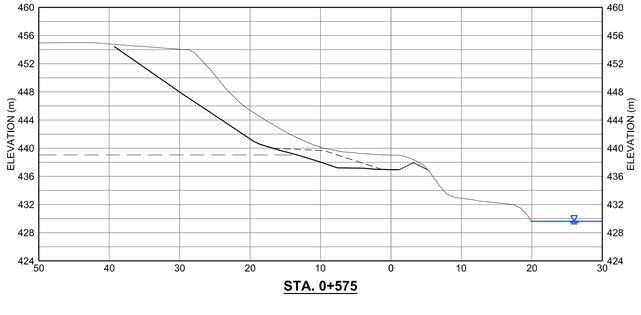
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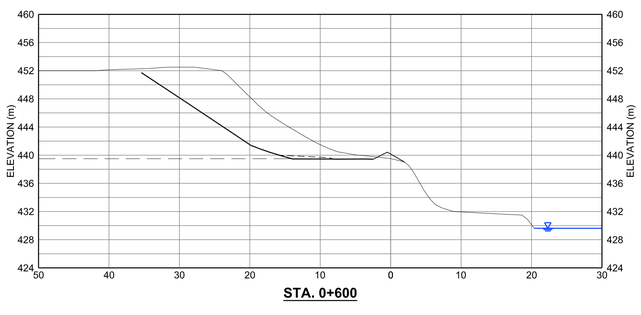
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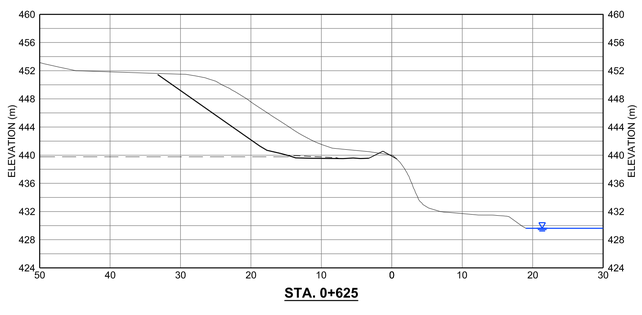
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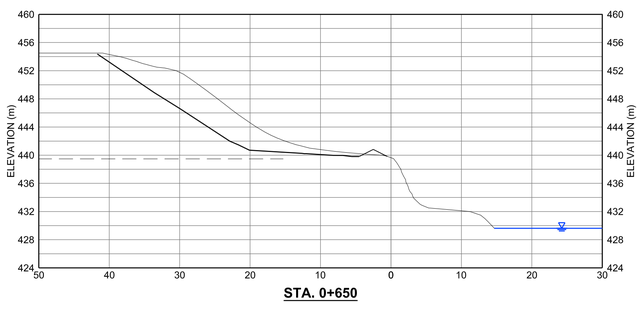
STA. 0+575



STA. 0+600



STA. 0+625



STA. 0+650

CROSS SECTIONS



NOTES

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Golder Associates Ltd.
Number C0230
Permission to Consult held by:

Discipline	Sk. Reg. No.	Signature
Geotechnical	6028	

Golder Associates
Saskatoon, Saskatchewan

REFERENCE

REVISIONS

No.	BY	DATE	APPROVED	DESCRIPTION

REVISIONS

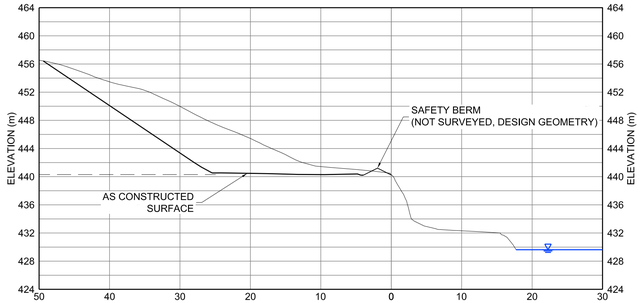
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00	JDS	13/06/12	CSF	GAM	ISSUED FOR CONSTRUCTION

SCALE:	AS SHOWN	
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CH'D:	CSF	13/06/12
APP'D:	GAM	13/06/12
DATE ISSUED		DATE

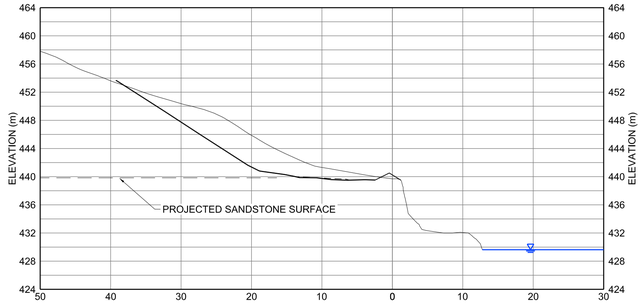
AREVA

FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN CROSS SECTIONS - EXCAVATION AND LINER PLACEMENT
JOB	JEB TMF OPTIMIZATION STAGE 1

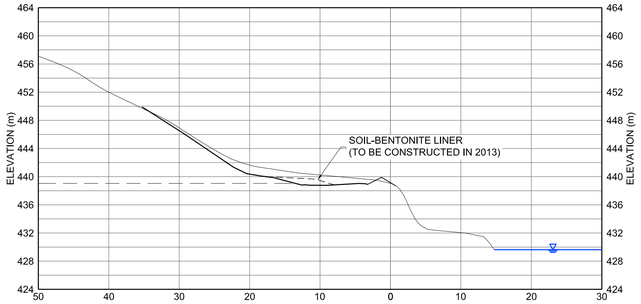
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FILE NAME.	12-1362-0022_Cross Sections.dwg
DRAWING NO.	GA0025.1



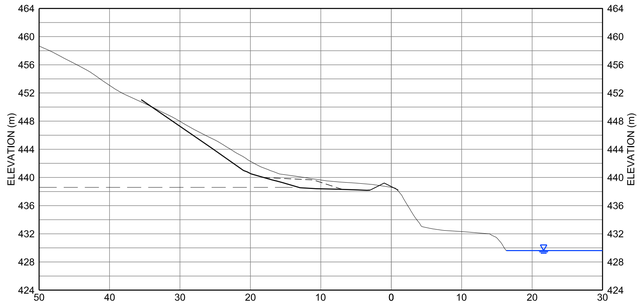
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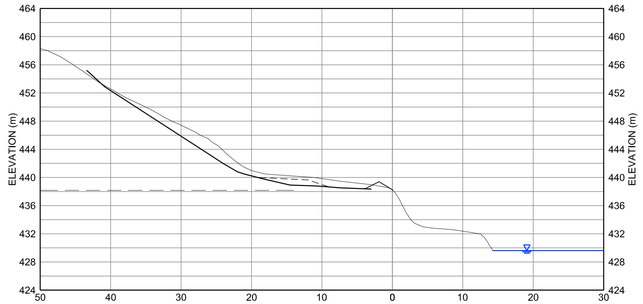
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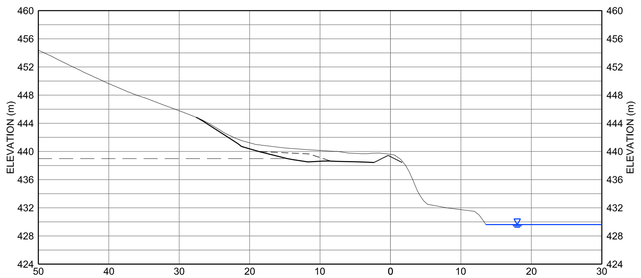
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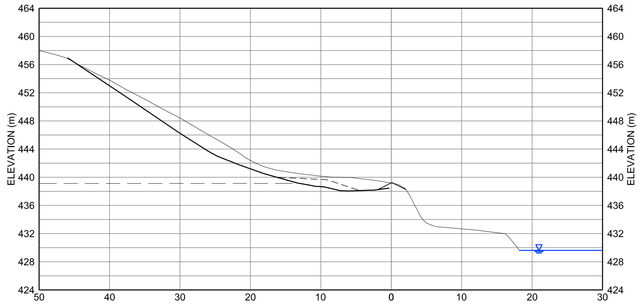
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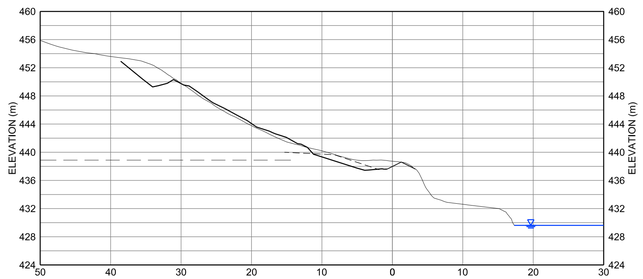
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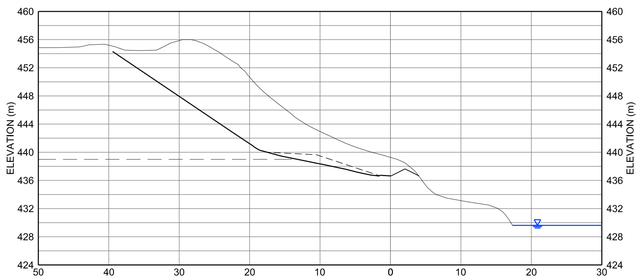
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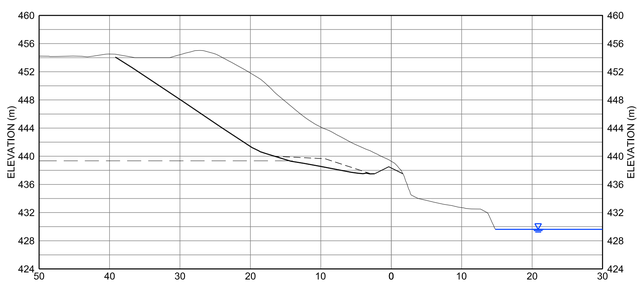
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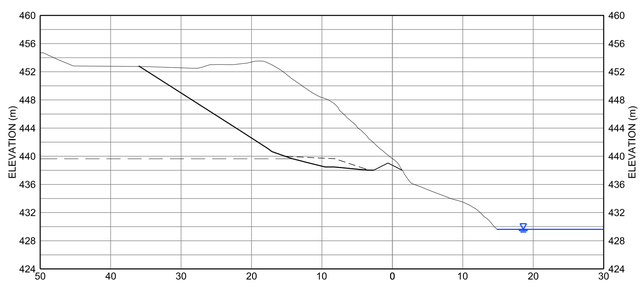
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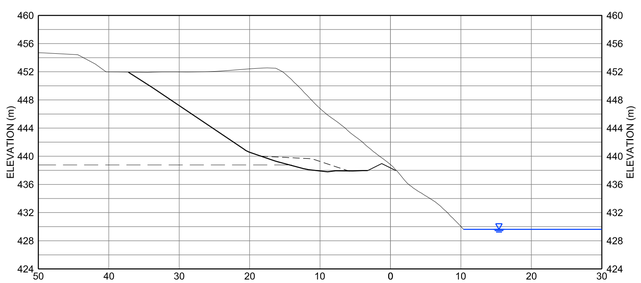
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STA. 0+900



STA. 0+925



STA. 0+950

CROSS SECTIONS

VERTICAL
SCALE 1:200 METRES

HORIZONTAL
SCALE 1:400 METRES

NOTES

1. ELEVATIONS ARE REFERENCED TO GEODETIC DATUM; NAD83, ZONE 13.
2. NORTHINGS AND EASTINGS REFERENCED TO LOCAL MINE COORDINATE SYSTEM.

THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc) ARE BASED ON 24"X36" FORMAT DRAWINGS

PROFESSIONAL ENGINEER SASKATCHEWAN C.S. FORTIER MEMBER 14128 12 12 21 YR. MN. DAY

PROFESSIONAL ENGINEER SASKATCHEWAN G.A. MEMBER 12 12 21 YR. MN. DAY

Association of Professional Engineers & Geoscientists of Saskatchewan
CERTIFICATE OF AUTHORIZATION
Golder Associates Ltd.
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Discipline	Sk. Reg. No.	Signature
Geotechnical	6128	

Golder Associates
Saskatoon, Saskatchewan

REFERENCE

REVISIONS

No.	BY	DATE	APPROVED	DESCRIPTION

REVISIONS

No.	BY	DATE	APPROVED	DESCRIPTION
01	JDS	17/12/12	CSF GAM	RECORD OF 2012 CONSTRUCTION
00	JDS	13/06/12	CSF GAM	ISSUED FOR CONSTRUCTION

SCALE:	AS SHOWN	
DRAWN:	JDS	12/06/12
CHD:	CSF	13/06/12
APP'D:	GAM	13/06/12
DATE ISSUED		DATE

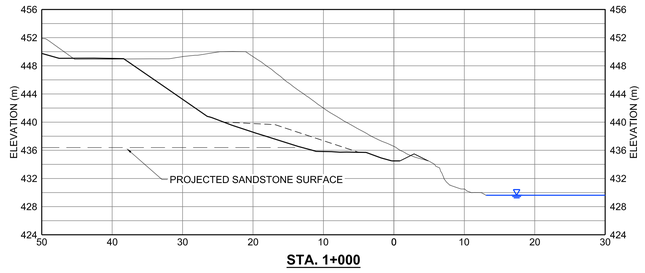
AREVA

FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN CROSS SECTIONS - EXCAVATION AND LINER PLACEMENT
JOB	JEB TMF OPTIMIZATION STAGE 1

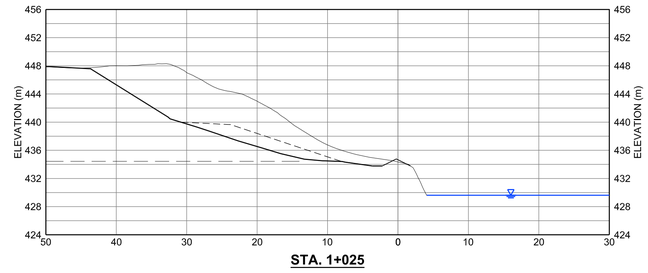
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FILE NAME.	12-1362-0022_Cross Sections.dwg
DRAWING NO.	GA0025.2



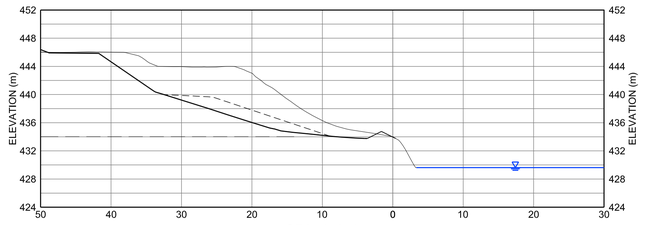
STA. 0+975



STA. 1+000



STA. 1+025



STA. 1+050

CROSS SECTIONS

5 0 5
SCALE 1:200 METRES — VERTICAL

10 0 10
SCALE 1:400 METRES — HORIZONTAL

NOTES

1. ELEVATIONS ARE REFERENCED TO GEODETIC DATUM; NAD83, ZONE 13.
2. NORTHINGS AND EASTINGS REFERENCED TO LOCAL MINE COORDINATE SYSTEM.

THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc) ARE BASED ON 24"X36" FORMAT DRAWINGS

PROFESSIONAL ENGINEER — C.S. FORTIER — MEMBER 14129 — SASKATCHEWAN — 12. 12. 21 YR. MN. DAY

PROFESSIONAL ENGINEER — G.A. [illegible] — MEMBER [illegible] — SASKATCHEWAN — 12 12 21 YR., MN., DAY

Association of Professional Engineers & Geoscientists of Saskatchewan
CERTIFICATE OF AUTHORIZATION
Golder Associates Ltd.
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Discipline	Sk. Reg. No.	Signature
Geotechnical	6128	

Golder Associates
Saskatoon, Saskatchewan

REFERENCE

REVISIONS

No.	BY	DATE	APPROVED	DESCRIPTION

No.	BY	DATE	APPROVED	DESCRIPTION
01	JDS	17/12/12	CSF	GAM	RECORD OF 2012 CONSTRUCTION
00	JDS	13/06/12	CSF	GAM	ISSUED FOR CONSTRUCTION

SCALE:	AS SHOWN	
DRAWN:	JDS	12/06/12
CHD:	CSF	13/06/12
APP'D:	GAM	13/06/12
DATE ISSUED		DATE

AREVA

FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY	PROJECT NO.	12-1362-0022
ACTIVITY	CIVIL DESIGN CROSS SECTIONS - EXCAVATION AND LINER PLACEMENT	FILE NAME.	12-1362-0022_Cross Sections.dwg
JOB	JEB TMF OPTIMIZATION STAGE 1	DRAWING NO.	GA0025.3

APPENDIX B

Photo Log



Photo 01 – Clearing and grubbing of South Stockpile Area (July 18, 2012).



Photo 02 – Overview of south slope of TMF prior to construction (July 15, 2012).



Photo 03 – Placing excavation material in South Stockpile Area (July 20, 2012).



Photo 04 – Excavation of 1.5H:1V slope on south slope of TMF (August 4, 2012).

Golder Associates	DATE: 16-NOV-12 PROJECT NO.: 12-1362-0022 DRAWN BY: KRC CHECKED BY: HV	PHOTO LOG 2012 CONSTRUCTION JEB TAILINGS MANAGEMENT FACILITY AREVA McCLEAN LAKE OPERATION



Photo 05 – Excavation of south slope of TMF (August 12, 2012).



Photo 06 – Construction of South Access Ramp (August 13, 2012).



Photo 07 – North Stockpile Area (September 3, 2012).



Photo 08 – Overview of excavation (September 10, 2012).

Golder Associates	DATE: 16-NOV-12	PHOTO LOG
	PROJECT NO.: 12-1362-0022	2012 CONSTRUCTION
	DRAWN BY: KRC	JEB TAILINGS MANAGEMENT FACILITY
	CHECKED BY: HV	AREVA McCLEAN LAKE OPERATION



Photo 09 – Final grading of North Stockpile Area (September 28, 2012).



Photo 08 – Overview of TMF after construction – Northwest Slope (September 29, 2012).



Photo 09 – Overview of TMF after construction – Southwest Slope (September 29, 2012).



Photo 10 – Overview of TMF after construction – North Slope (September 29, 2012).

Golder Associates	DATE: 16-NOV-12	PHOTO LOG
	PROJECT NO.: 12-1362-0022	2012 CONSTRUCTION
	DRAWN BY: KRC	JEB TAILINGS MANAGEMENT FACILITY
	CHECKED BY: HV	AREVA McCLEAN LAKE OPERATION



Photo 011 – Overview of TMF after construction – East Slope (September 29, 2012).



Photo 012 – Overview of TMF after construction – Southeast Slope (September 29, 2012).



Photo 013 – Overview of TMF after construction – South Slope (September 29, 2012).



Photo 014 – South Access Ramp at end of construction (September 29, 2012).

Golder Associates	DATE: 16-NOV-12	PHOTO LOG
	PROJECT NO.: 12-1362-0022	2012 CONSTRUCTION
	DRAWN BY: KRC	JEB TAILINGS MANAGEMENT FACILITY
	CHECKED BY: HV	AREVA McCLEAN LAKE OPERATION



Photo 015 – North Access Ramp at end of construction (September 29, 2012).



Photo 016 – Rip rap processing (August 11, 2012).

Golder Associates	DATE: 16-NOV-12	PHOTO LOG
	PROJECT NO.: 12-1362-0022	2012 CONSTRUCTION
	DRAWN BY: KRC	JEB TAILINGS MANAGEMENT FACILITY
	CHECKED BY: HV	AREVA McCLEAN LAKE OPERATION

APPENDIX C

Quality Assurance Results

STANDARD PROCTOR - ASTM D698

Project #:	12-1362-0022	Phase:	2000
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested by:	K.N.	Date:	July 20, 2011

Sample #: 2012-MLO-001
Source:
Visual Description of Sample:
Date Sample Received:

Compaction Test Results:

water content (%)	dry density (kg/m^3)
4.7	2026
6.8	2085
8.2	2050
9.8	1997

Maximum dry density: ***2086*** ***kg/m^3***
Corrected for oversize material: ***2177*** ***kg/m^3***

Optimum water content: ***6.9*** ***%***
Corrected for oversize material: ***5.5*** ***%***

Test Summary:

Method used:	C		
Material used passing:	19.0 mm	sieve	
Preparation method:	dry		
Rammer type:	manual		

Oversize Correction Data (if applicable):

Oversize fraction:	21.2	%	
Bulk Specific Gravity	2.6	value:	assumed
Water content	0.28	value:	assumed

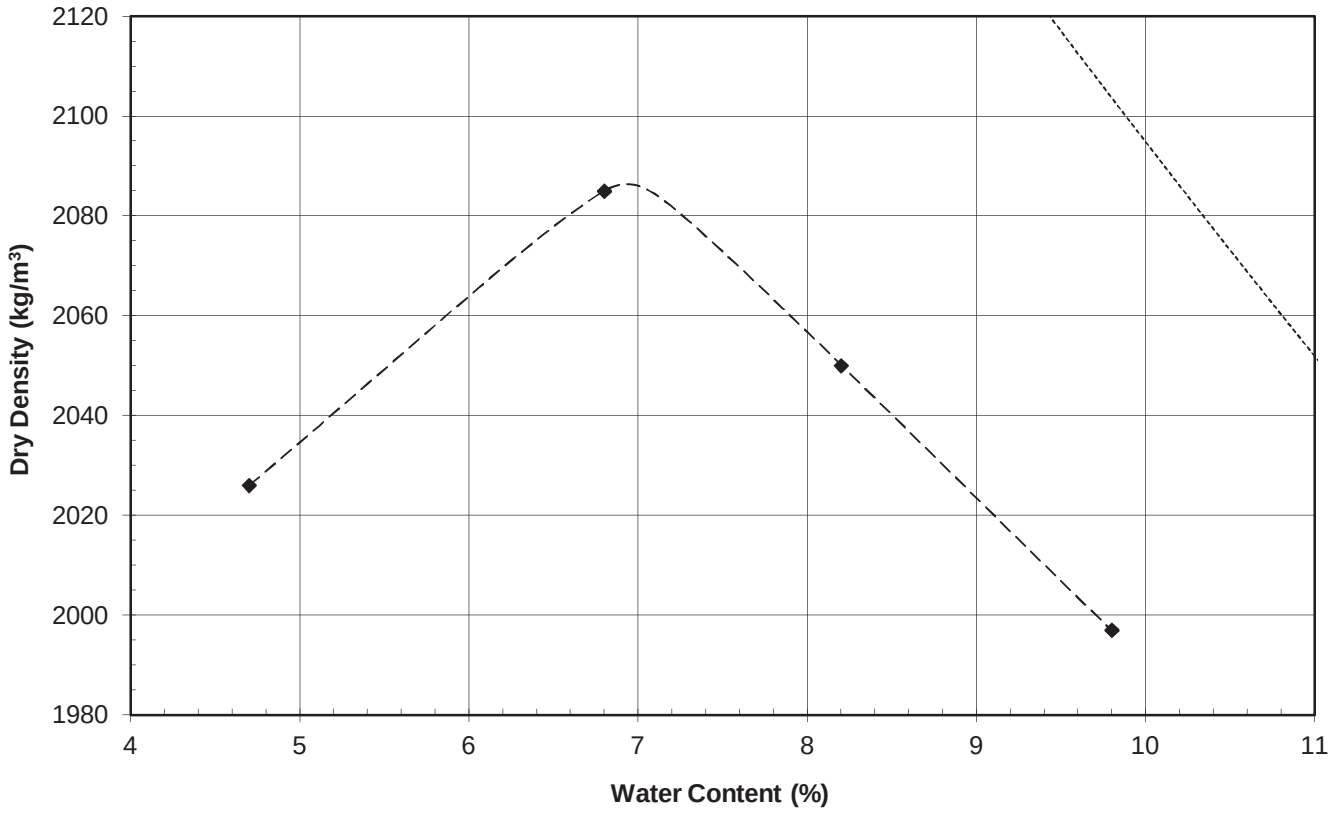
100% Saturation Curve Data:

Specific Gravity:	2.65	value:	assumed

Comments:

Water content of sample as received in lab: 4.4 %

Graphical Analysis - Uncorrected for Oversize Material



The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client. This report constitutes a testing service only and does not represent any results interpretation or opinion regarding specification compliance or material suitability. Engineering interpretation can be provided by Golder Associates Ltd. upon request.

1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:_____

STANDARD PROCTOR - ASTM D698

Project #: 12-1362-0022 Phase: 2000
Short Title: AREVA / JEB Stage 1 Optimization / McClean Lake
Tested by: K.N. Date: July 24, 2011

Sample #: 2012-MLO-005
Source:
Visual Description of Sample:
Date Sample Received:

Compaction Test Results:

water content (%)	dry density (kg/m^3)
3.3	1943
5.1	1989
9.1	1990
11.1	1941

Maximum dry density: ***2032*** ***kg/m^3***
Corrected for oversize material: ***N/A*** ***kg/m^3***

Optimum water content: ***7.1*** ***%***
Corrected for oversize material: ***N/A*** ***%***

Test Summary:
Method used: C
Material used passing: 19.0 mm sieve
Preparation method: dry
Rammer type: manual

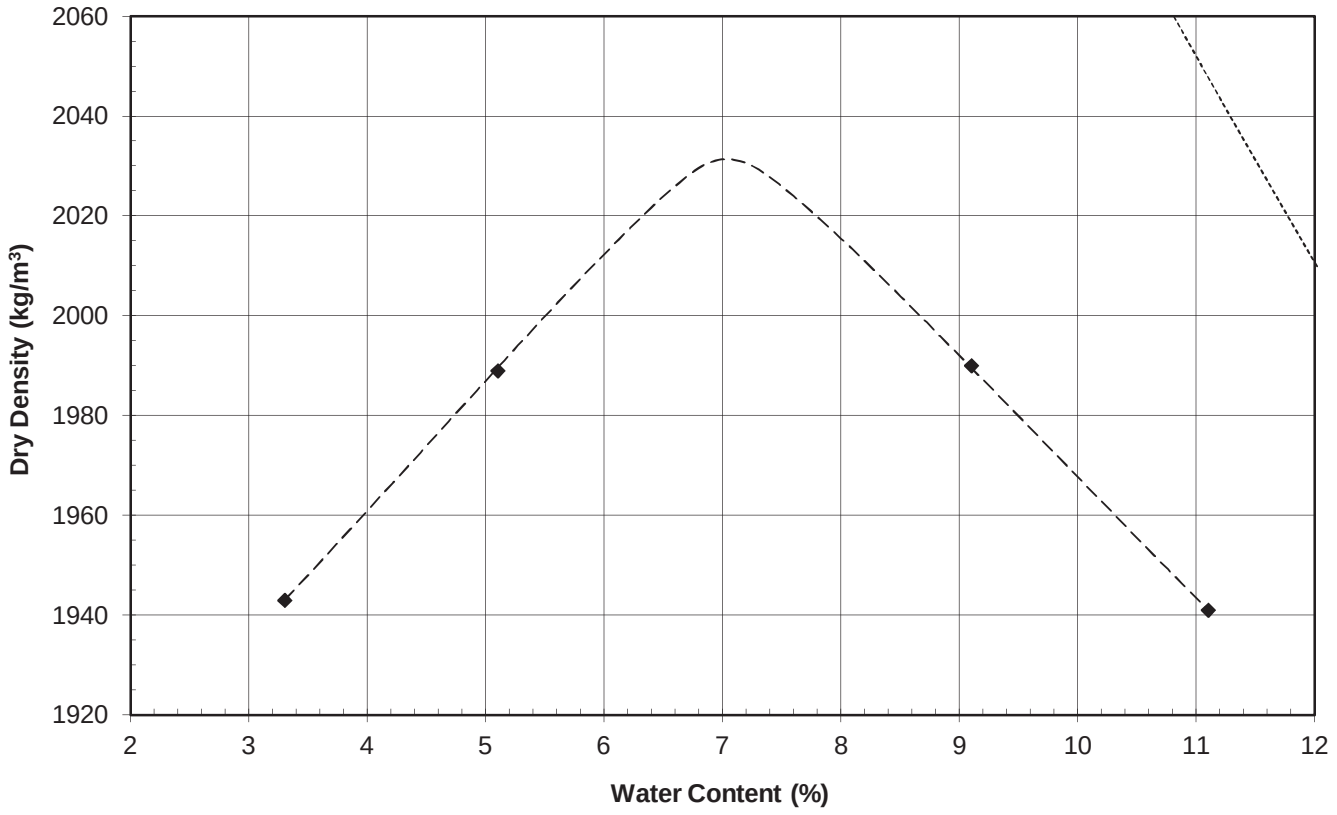
Oversize Correction Data (if applicable):
Oversize fraction: N/A
Bulk Specific Gravity N/A
Water content N/A

100% Saturation Curve Data:
Specific Gravity: 2.65 value: assumed

Comments:

Water content of sample as received in lab:

Graphical Analysis



The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client. This report constitutes a testing service only and does not represent any results interpretation or opinion regarding specification compliance or material suitability. Engineering interpretation can be provided by Golder Associates Ltd. upon request.

1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:_____

STANDARD PROCTOR - ASTM D698

Project #: 12-1362-0022 Phase: 2000
Short Title: AREVA / JEB Stage 1 Optimization / McClean Lake
Tested by: K.M. Date: August 9, 2012

Sample #: 2012-MLO-007
Source:
Visual Description of Sample:
Date Sample Received: August 7, 2012

Compaction Test Results:

water content (%)	dry density (kg/m^3)
5.3	1991
7.5	2049
8.4	2041
9.9	1995

Maximum dry density: ***2052*** ***kg/m^3***
Corrected for oversize material: ***2093*** ***kg/m^3***

Optimum water content: ***7.8*** ***%***
Corrected for oversize material: ***7.1*** ***%***

Test Summary:

Method used: C
Material used passing: 19.0 mm sieve
Preparation method: dry
Rammer type: manual

Oversize Correction Data (if applicable):

Oversize fraction: 9.2 %
Bulk Specific Gravity 2.6 value: assumed
Water content 0.31 value: assumed

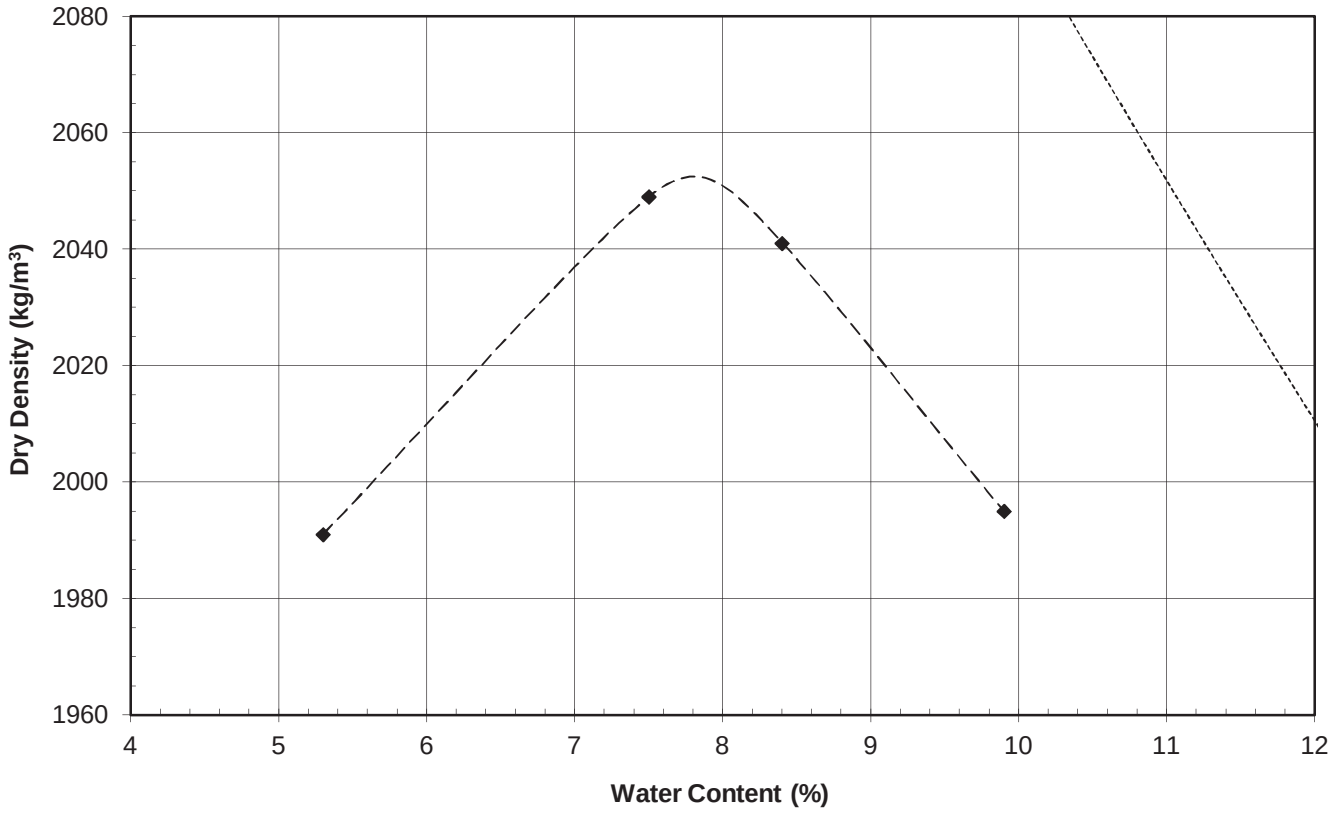
100% Saturation Curve Data:

Specific Gravity: 2.65 value: assumed

Comments:

Water content of sample as received in lab: 4.9 %

Graphical Analysis - Uncorrected for Oversize Material



The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client. This report constitutes a testing service only and does not represent any results interpretation or opinion regarding specification compliance or material suitability. Engineering interpretation can be provided by Golder Associates Ltd. upon request.

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Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:_____

FIELD NUCLEAR DENSITY TEST REPORT
SOUTH RAMP

Project #: 12-1362-0022 Phase: 2000
Short Title: AREVA / JEB Stage 1 Opt / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 1338
Tested by: K.N. / D.T. / K.M. Test Date: July 22, 2012 - August 15, 2012

Test No.	Date	Tested by:	Northing	Easting	Test Elev.	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
1	22-Jul-12	K.N.	10988	5366	0.3m B.G.	300	2,015	2.6	2012-MLO-001	2,086	6.9	96.6
2	22-Jul-12	K.N.	10996	5337	0.3m B.G.	300	2,148	3.6	2012-MLO-001	2,086	6.9	103.0
3	23-Jul-12	K.N.	10996	5342	0.15m B.G.	200	2,081	7.0	2012-MLO-001	2,086	6.9	99.8
4	23-Jul-12	K.N.	10990	5280	0.6m B.G.	200	2,074	5.9	2012-MLO-001	2,086	6.9	99.4
5	25-Jul-12	K.N.	10988	5327	0.15m B.G.	300	2,063	5.4	2012-MLO-005	2,032	7.1	101.5
6	25-Jul-12	K.N.	10997	5297	0.15m B.G.	300	2,042	5.3	2012-MLO-005	2,032	7.1	100.5
7	26-Jul-12	K.N.	11010	5212	3.0m B.G.	300	2,071	5.9	2012-MLO-005	2,032	7.1	101.9
8	4-Aug-12	D.D.T.	10995	5352	0.2m B.G.	250	2,013	4.8	2012-MLO-005	2,032	7.1	99.1
9	4-Aug-12	D.D.T.	10995	5316	0.2m B.G.	250	2,063	4.6	2012-MLO-005	2,032	7.1	101.5
10	4-Aug-12	D.D.T.	11000	5265	Grade	250	2,057	4.4	2012-MLO-005	2,032	7.1	101.2
11	4-Aug-12	D.D.T.	11015	5215	2.3m B.G.	250	2,041	5.3	2012-MLO-005	2,032	7.1	100.4
12	6-Aug-12	D.D.T.	10997	5346	Grade	300	2,068	4.5	2012-MLO-005	2,032	7.1	101.8
13	6-Aug-12	D.D.T.	10999	5307	Grade	300	2,014	4.2	2012-MLO-005	2,032	7.1	99.1
14	6-Aug-12	D.D.T.	11011	5261	Grade	300	2,067	4.4	2012-MLO-005	2,032	7.1	101.7
15	7-Aug-12	D.D.T.	11014	5218	1.6m B.G.	300	2,036	4.9	2012-MLO-005	2,032	7.1	100.2

Reviewed By: _____CSF_____

FIELD NUCLEAR DENSITY TEST REPORT
SOUTH RAMP

Project #: 12-1362-0022 Phase: 2000
Short Title: AREVA / JEB Stage 1 Opt / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 1338
Tested by: K.N. / D.T. / K.M. Test Date: July 22, 2012 - August 15, 2012

Test No.	Date	Tested by:	Northing	Easting	Test Elev.	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
16	7-Aug-12	D.D.T.	11039	5189	1.2m B.G.	300	1,992	4.3	2012-MLO-005	2,032	7.1	98.0
17	7-Aug-12	D.D.T.	11066	5165	Grade	300	1,997	4.5	2012-MLO-005	2,032	7.1	98.3
18	8-Aug-12	K.N.	11015	5215	1.2m B.G.	300	1,988	3.1	2012-MLO-001	2,086	6.9	95.3
19	8-Aug-12	K.N.	11035	5183	0.9m B.G.	300	2,110	4.5	2012-MLO-001	2,086	6.9	101.2
20	8-Aug-12	K.N.	11061	5171	0.15m B.G.	300	2,075	4.8	2012-MLO-001	2,086	6.9	99.5
21	12-Aug-12	K.M.	11022	5209	0.4m B.G.	300	2,073	3.3	2012-MLO-007	2,093	7.1	99.0
22	12-Aug-12	K.M.	11032	5187	0.4m B.G.	300	2,111	4.0	2012-MLO-007	2,093	7.1	100.9
23	12-Aug-12	K.M.	11050	5180	0.4m B.G.	300	2,103	3.5	2012-MLO-007	2,093	7.1	100.5
24	15-Aug-12	K.N.	10997	5228	0.2m B.G.	300	2,025	6.3	2012-MLO-007	2,093	7.1	96.8
25	15-Aug-12	K.N.	11028	5197	0.3m B.G.	300	2,023	4.5	2012-MLO-007	2,093	7.1	96.7
26	15-Aug-12	K.N.	11060	5167	Grade	300	2,098	5.8	2012-MLO-007	2,093	7.1	100.2
											MIN	95.3
											AVG	99.8
											MAX	103.0

Remarks:

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Reviewed By: _____CSF_____

FIELD NUCLEAR DENSITY TEST REPORT
3H:1V SLOPE

Project #: 12-1362-0022 Phase: 2000
Short Title: AREVA / JEB Stage 1 Opt / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 1338
Tested by: K.N. / D.T. / K.M. Test Date: Sept. 16 - Sept. 25, 2012

Test No.	Date	Tested by:	Northing	Easting	Test Elev.	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
27	16-Sep-12	D.D.T.	10992	5380	0.4m B.G.	300	2,108	7.4	2012-MLO-007	2,093	7.1	100.7
28	16-Sep-12	D.D.T.	11121	5121	0.4 m B.G.	300	2,076	7.0	2012-MLO-007	2,093	7.1	99.2
29	17-Sep-12	D.D.T.	11364	5297	Grade	250	2,070	4.7	2012-MLO-007	2,093	7.1	98.9
30	17-Sep-12	D.D.T.	11363	5285	0.25 m B.G.	250	1,994	4.5	2012-MLO-007	2,093	7.1	95.3
31	17-Sep-12	D.D.T.	11360	5266	0.25 m B.G.	250	2,141	4.6	2012-MLO-007	2,093	7.1	102.3
32	17-Sep-12	D.D.T.	11363	5290	Grade	250	1,993	4.1	2012-MLO-007	2,093	7.1	95.2
33	17-Sep-12	D.D.T.	11362	5277	Grade	250	2,083	5.0	2012-MLO-007	2,093	7.1	99.5
34	18-Sep-12	D.D.T.	11366	5236	Grade	250	2,037	5.0	2012-MLO-007	2,093	7.1	97.3
35	18-Sep-12	D.D.T.	11359	5292	Grade	250	2,021	4.3	2012-MLO-007	2,093	7.1	96.6
36	18-Sep-12	D.D.T.	11361	5270	Grade	250	2,108	4.7	2012-MLO-007	2,093	7.1	100.7
37	18-Sep-12	D.D.T.	11368	5247	Grade	250	2,015	7.0	2012-MLO-007	2,093	7.1	96.3
38	18-Sep-12	D.D.T.	11365	5266	Grade	250	2,115	4.3	2012-MLO-007	2,093	7.1	101.1
39	18-Sep-12	D.D.T.	11362	5288	Grade	250	2,040	5.5	2012-MLO-007	2,093	7.1	97.5
40	24-Sep-12	K.N.	11070	5433	0.15m B.G.	300	2,053	5.0	2012-MLO-001	2,086	6.9	98.4
41	24-Sep-12	K.N.	11062	5428	0.15m B.G.	300	1,989	4.5	2012-MLO-001	2,086	6.9	95.3
43	25-Sep-12	K.N.	11065	5425	Grade	300	2,104	5.1	2012-MLO-001 (RC)	2,177	5.5	96.6
44	25-Sep-12	K.N.	11074	5435	Grade	300	2,156	4.7	2012-MLO-001 (RC)	2,177	5.5	99.0

Reviewed By: CSF

FIELD NUCLEAR DENSITY TEST REPORT
3H:1V SLOPE

Project #: 12-1362-0022 Phase: 2000

Short Title: AREVA / JEB Stage 1 Opt / McClean Lake, Sk

Contractor: Broda Construction

Gauge No.: 1338

Tested by: K.N. / D.T. / K.M. Test Date: Sept. 16 - Sept. 25, 2012

Test No.	Date	Tested by:	Northing	Easting	Test Elev.	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
Remarks:											**MIN**	95.2
Test No. 42 did not meet compaction specification. Test No. 44 was completed as a re-test for Test No. 42.											**AVG**	98.2
											MAX	102.3

The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client. This report constitutes a testing service only and does not represent any results interpretation or opinion regarding specification compliance or material suitability. Engineering interpretation can be provided by Golder Associates Ltd. upon request.

Reviewed By: CSF

Golder Associates

SUMMARY OF MECHANICAL SIEVE RESULTS
LINER GRANULAR MATERIAL

Project #: 12-1362-0022 **Phase:** 2000
Short Title: AREVA / JEB Stage 1 Opt / McClean Lake, Sk
Contractor: Broda Construction
Tested by: K.M. / P.J. **Test Date:** Aug. 17 - Sept. 16, 2012

Sample Number	Date	Time	Percent Passing Sieve Size (mm)								
			60	12.5	10	4.75	2.5	1.00	0.250	0.160	0.075
2012-MLO-0015	17-Aug-12	6:30 AM	100	100	100	89	N/A	65	34	27	18.2
2012-MLO-0016	17-Aug-12	9:20 AM	100	100	99	86	N/A	62	32	25	17.5
2012-MLO-0017	17-Aug-12	11:30 AM	100	100	99	88	N/A	64	33	26	18.1
2012-MLO-0018	17-Aug-12	11:30 AM	100	100	100	91	N/A	72	47	39	26.8
2012-MLO-0019	18-Aug-12	8:30 AM	100	100	99	88	N/A	69	35	26	16.6
2012-MLO-0020	18-Aug-12	1:15 PM	100	100	100	90	N/A	71	37	27	16.9
2012-MLO-0021	18-Aug-12	4:30 PM	100	100	100	90	N/A	69	36	26	17.0
2012-MLO-0022	19-Aug-12	7:30 AM	100	100	99	87	N/A	67	33	25	15.5
2012-MLO-0023	19-Aug-12	10:30 AM	100	100	99	88	N/A	68	35	26	16.3
2012-MLO-0024	19-Aug-12	3:15 PM	100	100	99	88	N/A	66	33	25	16.0
2012-MLO-0025	20-Aug-12	8:00 AM	100	100	99	88	N/A	70	42	33	21.7
2012-MLO-0026	20-Aug-12	10:15 AM	100	100	100	89	N/A	69	40	31	20.2
2012-MLO-0027	20-Aug-12	2:00 PM	100	100	99	85	N/A	64	35	26	17.0
2012-MLO-0028	21-Aug-12	11:00 AM	100	100	100	90	N/A	70	40	31	20.8
2012-MLO-0029	21-Aug-12	1:50 PM	100	100	100	89	N/A	68	38	29	19.5
2012-MLO-0030	21-Aug-12	3:50 PM	100	100	100	90	N/A	70	39	29	19.1
2012-MLO-0031	1-Sep-12	7:15AM	100	100	99.8	87.6	79.4	68.2	38.7	29.5	19.3
2012-MLO-0032	1-Sep-12	12:45PM	100	100	99.7	90.6	81.5	68.6	38.3	29.6	19.8
2012-MLO-0033	1-Sep-12	4:15PM	100	99.6	99.2	85.7	75.8	61.8	33.2	25.8	17.6
2012-MLO-0034	10-Sep-12	7:30AM	100	100	99.7	88	80	67.6	38.3	29.5	20.2
2012-MLO-0035	10-Sep-12	2:30PM	100	100	100	89.4	79.9	66.8	36.3	27.4	17.9
2012-MLO-0036	12-Sep-12	10:30AM	100	100	99.4	90.8	83.4	70.7	39.1	30.8	21.4
2012-MLO-0037	12-Sep-12	1:30PM	100	100	100	88.7	80.9	69.6	36.5	26.8	17.6
2012-MLO-0038	13-Sep-12	7:30AM	100	100	99.4	84.7	73.4	57.6	27.4	20.4	13.1
2012-MLO-0039	13-Sep-12	1:30PM	100	100	100	89.3	80.6	70.1	37.4	27.3	17.9
2012-MLO-0040	14-Sep-12	7:00AM	100	100	99.1	87.6	80.5	71.2	40.1	30.1	20.0
2012-MLO-0041	14-Sep-12	10:30AM	100	100	100	88.6	80.4	70.9	42.9	33.1	21.7
2012-MLO-0042	14-Sep-12	2:00PM	100	100	99.4	89.4	81.8	72.9	43.8	33.3	22.2
2012-MLO-0043	15-Sep-12	8:30AM	100	100	100	88.5	80.8	71.3	43.4	34	22.8
2012-MLO-0044	15-Sep-12	11:30AM	100	100	99.5	89.5	83	73.3	43.4	33.4	22.5
2012-MLO-0045	16-Sep-12	7:00AM	100	100	98.8	87.2	79.6	70.2	42.3	32.7	21.8
2012-MLO-0046	16-Sep-12	10:30AM	100	99.6	98.8	86.7	79	69.3	38.8	29.2	19.5
Specification			**100**	**--**	**--**	**--**	**--**	**40-100**	**--**	**--**	**15 - 35**
Average			**100.0**	**100.0**	**99.5**	**88.3**	**80.0**	**68.2**	**37.8**	**28.8**	**19.1**

Remarks:
Test No. 2012-MLO-0001 through Test No. 2012-MLO-0014 represent material that was not included in the final liner granular material stockpile, and therefore the test results are not reported in this summary.

The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client.

Reviewed By: CSF

SUMMARY OF HYDROMETER RESULTS
EXCAVATED TILL MATERIAL

Project #: 12-1362-0022 **Phase:** 2000
Short Title: AREVA / JEB Stage 1 Opt / McClean Lake, Sk
Contractor: Broda Construction
Tested by: K.M. / P.J. **Test Date:** Aug. 17 - Sept. 16, 2012

Sample Number		2012-MLO-002	2012-MLO-003	2012-MLO-004	2012-MLO-006	Average
Date		1-Aug-12	1-Aug-12	1-Aug-12	3-Aug-12	
Percent Passing Sieve Size (mm)	152	100	100	100	100	100
	76	100	100	100	100	100
	38	100	100	100	100	100
	19	100	94	100	91	96
	9.5	99	93	97	82	93
	4.75	95	92	95	78	90
	2.00	89	87	90	72	85
	0.850	79	77	83	66	76
	0.425	66	64	70	56	64
	0.250	49	48	54	42	48
	0.150	36	35	40	30	35
	0.075	27	26	30	21	26
	0.045	19	17	20	15	18
	0.027	14	13	16	12	14
	0.018	12	10	13	9.3	11
	0.012	8.8	7.9	11	7.9	8.9
	0.009	7.1	6.5	8.4	6.5	7.1
	0.006	5.5	4.7	6.4	5.1	5.4
	0.005	3.8	3.6	4.9	4.2	4.1
	0.003	2.8	2.5	3.6	3.2	3.0
	0.002	1.8	1.7	2.3	2.4	2.1
	0.001	1.7	1.9	1.7	1.0	1.6

Remarks:

The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client.

Reviewed By: CSF

TRIAXIAL HYDRAULIC CONDUCTIVITY TEST

Project #:	12-1362-0022	Phase:	2000
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	D.B.	Date:	September 7, 2012
Sample:	SL2579 - Pure Sandstone with 5% Bara-Kade SP bentonite		

Final Hydraulic Conductivity:

k = 2.1E-10 m/s @ 17,229 minutes

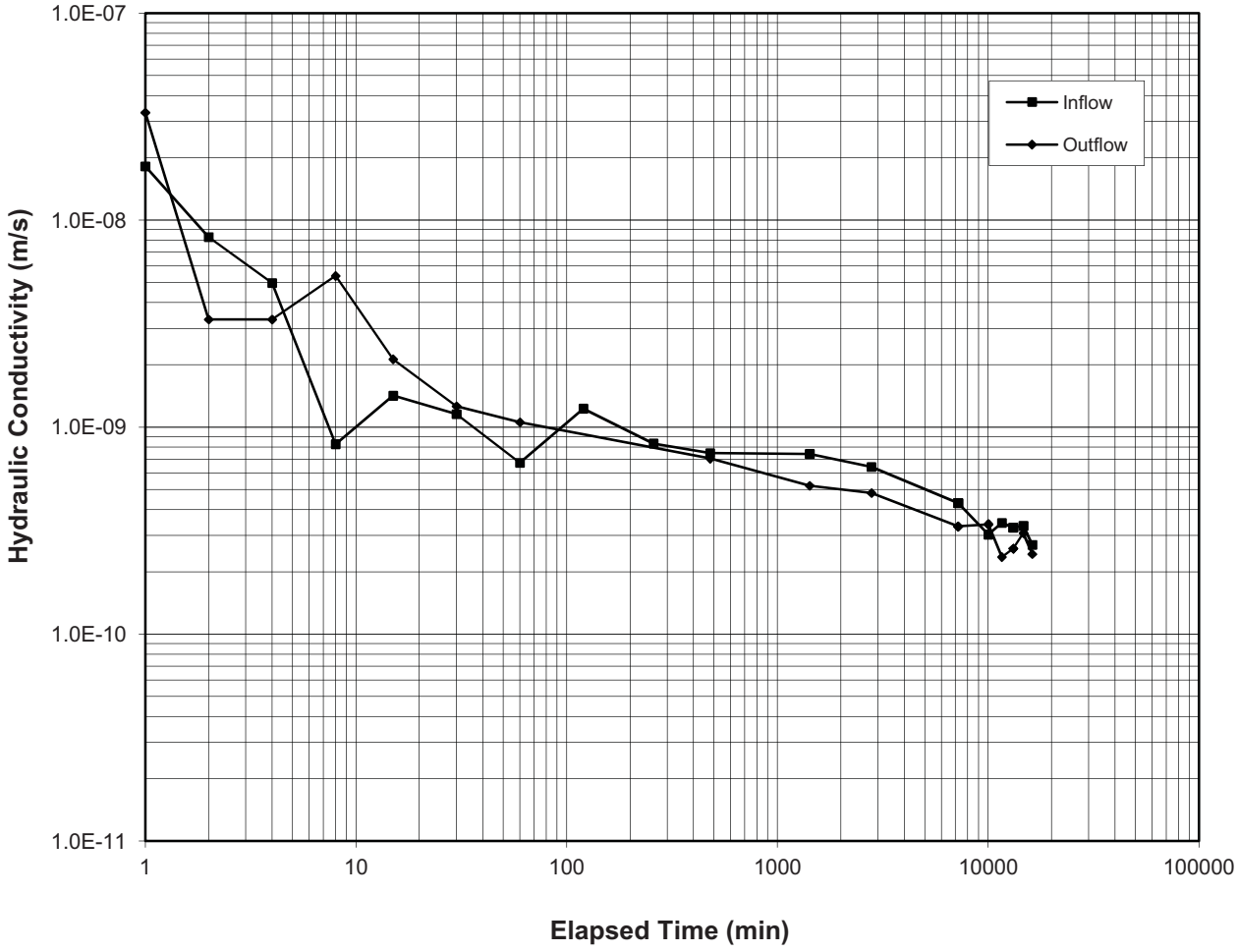
Test Summary:

Initial Dry Density:	1747	kg/m^3
Initial Water Content:	9.1	%
Final Dry Density:	1694	kg/m^3
Final Water Content:	17.4	%
Sample Diameter:	101.77	mm
Sample Height:	56.89	mm
Average Effective Stress:	17	kPa
Hydraulic Gradient:	6 to 16	

Comments:

Permeant Liquid: tap water

Graph of Hydraulic Conductivity versus Time



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1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

TRIAXIAL HYDRAULIC CONDUCTIVITY TEST

Project #:	12-1362-0022	Phase:	2000
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	D.B.	Date:	October 10, 2012
Sample:	SL2579 - Pure Sandstone with 5% Bara-Kade SP bentonite		

Final Hydraulic Conductivity:

k = 1.1E-10 m/s @ 18,662 minutes

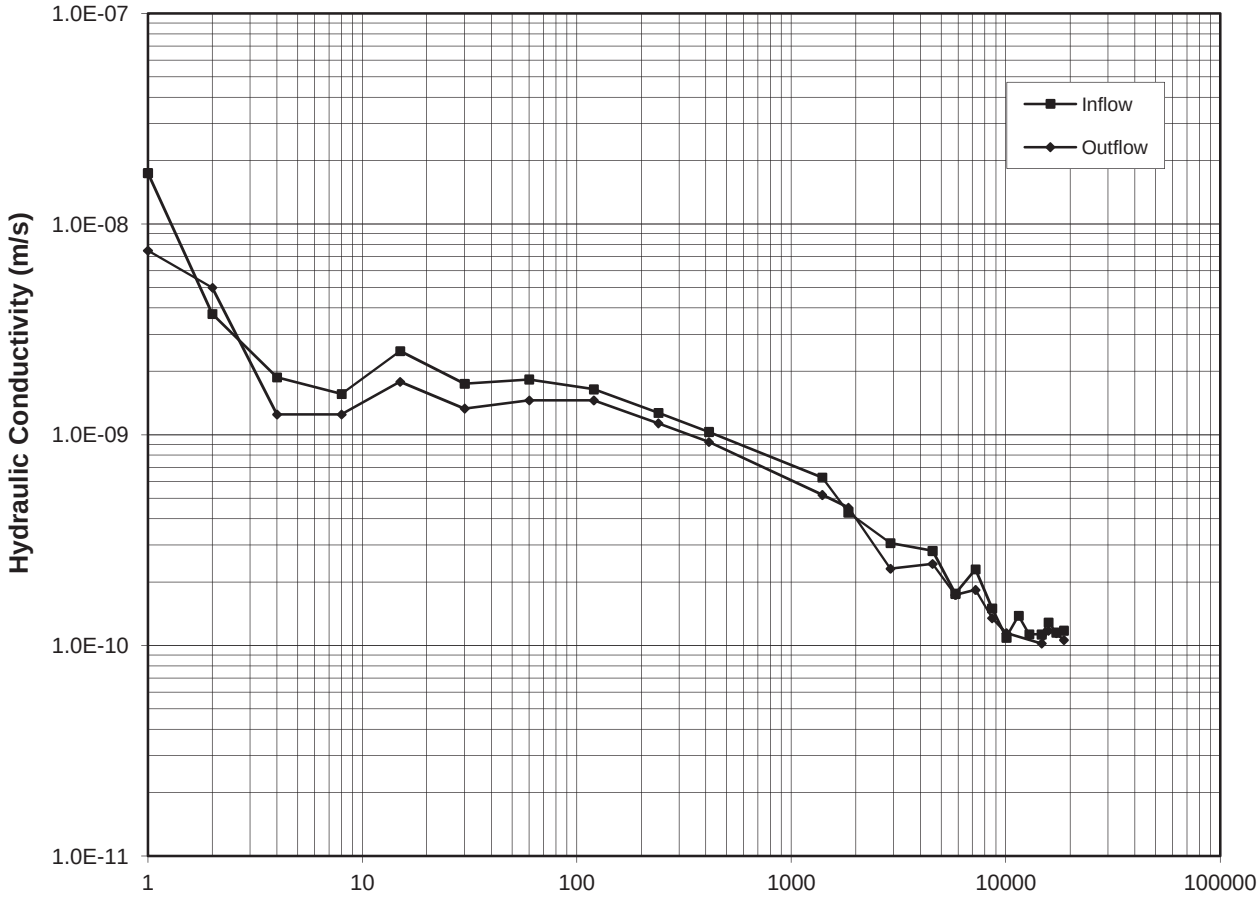
Test Summary:

Initial Dry Density:	1911	kg/m^3
Initial Water Content:	11.1	%
Final Dry Density:	1858	kg/m^3
Final Water Content:	16.0	%
Sample Diameter:	100.77	mm
Sample Height:	42.06	mm
Average Effective Stress:	17	kPa
Hydraulic Gradient:	13 to 22	

Comments:

Permeant Liquid: tap water

Graph of Hydraulic Conductivity versus Time



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1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

TRIAXIAL HYDRAULIC CONDUCTIVITY TEST

Project #:	12-1362-0022	Phase:	2000
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	D.B.	Date:	September 11, 2012
Sample:	SL2580 - Till Blend with 5% Bara-Kade SP bentonite		

Final Hydraulic Conductivity:

k = 9.4E-11 m/s @ 20,169 minutes

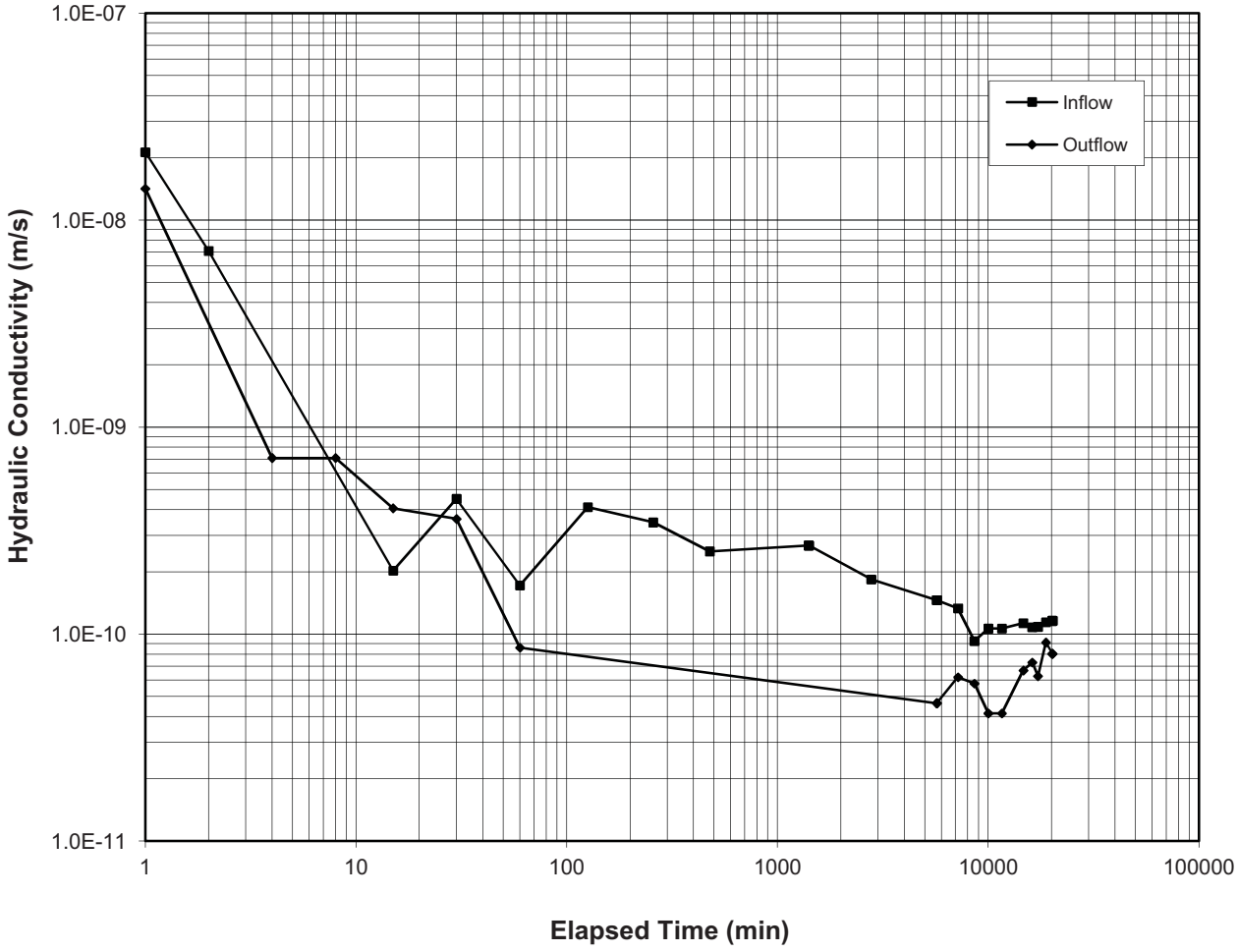
Test Summary:

Initial Dry Density:	1851	kg/m^3
Initial Water Content:	10.5	%
Final Dry Density:	1827	kg/m^3
Final Water Content:	16.1	%
Sample Diameter:	102.49	mm
Sample Height:	49.45	mm
Average Effective Stress:	17	kPa
Hydraulic Gradient:	10 to 17	

Comments:

Permeant Liquid: tap water

Graph of Hydraulic Conductivity versus Time



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1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

APPENDIX D

Permits

Saskatchewan

Ministry of Environment

Industrial Branch
Uranium and Northern Operations

112 Research Drive
Saskatoon, SK
S7N 3R3
Phone: (306)933-7274
Fax: (306)933-5773

November 18, 2010

File: S25020-50/ML/03
McClean Lake

S1-005

Ms. Tammy Van Lambalgen
VP Regulatory Affairs & General Counsel
AREVA Resources Canada Inc.
P.O. Box 9204
817 – 45th Street West
Saskatoon, SK S7K 3X5

Re: Request for Review and Approval: JEB TMF Optimization Application

Dear Ms. Van Lambalgen,

Ministry of Environment (Ministry) staff have received and reviewed AREVA Resources Canada Inc.'s (AREVA) October 29, 2010 submission "TMF Optimization – AREVA response to MOE comments on application."

AREVA has proposed to develop the existing JEB tailings management facility (TMF) to the approved capacity. The Ministry has the following understanding based on the submission, previous submissions, and discussions with AREVA.

- The proposed work will be conducted in two stages. AREVA has applied for approval to implement Stage 1 in 2011. Stage 2 work will be subject to separate application.
- Stage 1 involves re-sloping the till to 440 masl at 3H:1V from 438.1 masl as noted in Cross Section A, 435.7 masl as noted in Cross Section B, and 439.0 masl as noted in Cross Section C, liner construction to 440 masl, tailings placement to 436 masl, and pond water cap to 439 masl.
- Stage 2 will involve re-sloping the till to 1.5H:1V from 440 masl to 443 masl, liner construction to 443 masl, tailings placement to 439 masl, and pond water cap to 442 masl.
- A liner consisting of till, crushed sandstone, and 5% bentonite (by mass) will be constructed over the sandstone/till contact and is expected to have a hydraulic conductivity of approximately $5x10^{-11}$ m/s.
- The liner will have a crest width of 6.0 m.
- A rip rap layer 0.5 m thick will be used to protect the liner from erosion.
- A 1.0 m freeboard will be maintained above the pond water elevation throughout operations.
- The proposed work will require relocation of the tailings and reclaim lines, construction of a laydown area, stockpile areas, and access ramps.

- During Stage 1, material will be placed over the contaminated landfill to construct an access ramp. During Stage 2, the portion of the ramp covering the contaminated landfill will be removed so the contaminated waste can be removed and relocated to another storage location. This other storage location will be subject to a separate application and approval.
- AREVA McClean Lake's Approval to Operate Pollutant Control Facilities PO10-110 will need to be amended to reflect changes associated with monitoring wells MW#2, 6, 7, and 4 that will be required as work progresses.
- No changes to the preliminary decommissioning plan or financial assurance cost estimates are expected as a result of the proposed work.

Please find the enclosed Approval PC10-165 authorizing AREVA to proceed with alterations to the existing JEB TMF at the McClean Lake Operation. Please review the conditions of this Approval and ensure that all conditions are met.

Should any changes to the proposed work be contemplated, including changes to scheduling, AREVA shall provide information on the changes to the Ministry for approval before the changes are undertaken.

AREVA shall submit an application to amend the McClean Lake Approval to Operate Pollutant Control Facilities PO10- 110 prior to monitoring wells MW#2, 6, 7, and 4 being modified, as described in the submission.

If you have any questions or comments, you may contact the undersigned at 306-933-7274.

Sincerely,

Jana Lung, P.Eng.
Environmental Project Officer
Ministry of Environment

Enclosure:
PC10-165

cc:
T. Searcy (email) / J. Richards (email) / McClean Regulatory Mailbox (email) – AREVA
T. Gates (email) – Canadian Nuclear Safety Commission
A. Merkowsky (email) / T. Moulding (email) / File – Ministry of Environment

Saskatchewan Ministry of Environment

APPROVAL TO CONSTRUCT, ALTER, OR EXTEND A POLLUTANT CONTROL FACILITY

Issued pursuant to *The Mineral Industry Environmental Protection Regulations, 1996*

APPROVAL NO. PC10-165

AREVA Resources Canada Inc. of Saskatoon, Saskatchewan is hereinafter called "the Company." Saskatchewan Ministry of Environment is hereinafter called "Ministry."

AUTHORIZED ACTIVITY:

The Company is hereby authorized to conduct the following work and activities associated with the alterations to the McClean Lake Operation JEB Tailings Management Facility (TMF) as described in the following Company submissions to the Ministry:

- April 30, 2010 submission "Request for Review and Approval: JEB TMF Optimization Application."
- October 29, 2010 submission "TMF Optimization – AREVA response to MOE comments on Application."
- November 10, 2010 email correspondence (T. Searcy to J. Lung)

With the following conditions:

1. Prior to Stage 2 commencing, the Company shall submit an application with design drawings signed and stamped by a Qualified Person and information regarding potential changes to the preliminary decommissioning plan and financial assurance cost estimates associated with Stage 2.
2. For each stage, the Company shall notify the Ministry when work commences and when work is completed.
3. For each stage, the Company shall submit "as constructed" plans, signed and stamped by a Qualified Person, to the Ministry within 90 days of the completion of construction as per Section 9.3 of the McClean Lake Operation – Approval to Operate PO10-110.
4. The Company shall ensure that a copy of this Approval is on site during all construction activities and is available for presentation upon demand by the local authorities or an authority having jurisdiction.

Any changes to the work proposed by the Company will require the prior written approval of the Ministry. The Company shall ensure that the requirements of all previous approvals and operating limits not described in this authorization are met. The appropriate changes to the Company operating manuals and other documentation shall be made where required.

Dated at Saskatoon, Saskatchewan this 18th day of November, 2010

Recommended

Tim Moulding – Manager, Uranium and Northern Operations, For and on Behalf of the Minister of Environment

…1

Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

101 – 22nd Street East, Suite 520
Saskatoon, SK S7K 0E1
Tel: 306-975-6372
Fax: 306-975-6387

Your file Votre référence

Our file Notre référence
2.04 ML-A

Directorate of Nuclear Cycle
and Facilities Regulation

Telephone: 306-975-6384

September 30, 2010 OCT 0 4 2010

Ms. Tammy Van Lambalgen, Vice President
Regulatory Affairs and General Counsel
AREVA Resources Canada Inc.
817 - 45th Street West
Saskatoon, SK S7K 3X5

Subject: McClean Lake Operation
Request for Review and Approval
JEB TMF Optimization Application

Dear Ms. Van Lambalgen:

Canadian Nuclear Safety Commission (CNSC) staff has reviewed AREVA's McClean Lake Operation's *Request for Review and Approval: JEB TMF Optimization Application* dated April 30, 2010 (T. Van Lambalgen, AREVA to T. Gates, CNSC) and *TMF Optimization Application - Reference Documents* (T. Searcy. AREVA to T. Gates dated June 2, 2010).

The application with supporting documents (modeling and risk assessment) requests review and approval of optimization of 'approved' tailings storage capacity in the JEB Tailings Management Faciltiy (TMF). CNSC staff finds the proposed work acceptable and within the scope of approved activities. No changes to the Mine Facility Licensing Manual are required. Accordingly the TMF optimization is approved per Licence UMOL-MINEMILL-McCLEAN.00/2017 condition 3.1. AREVA's McClean Lake Operation should ensure that on commencement of construction activities that detailed construction schedules are provided to the CNSC Project Officer for inspection planning purposes.

If you have any questions, please do not hesitate to contact myself or the McClean Lake Project Officer, Mr. T. Gates, at 306-975-6362.

Sincerely,

Kevin H. Scissons, Director
Uranium Mines and Mills Division

E-Docs #3614899

c.c.: J. Lung, Sask. Ministry of Environment
C. Morrish, Sask. Ministry of Labour Relations & Workplace Safety

Canada

P004
FPP#2821h
AHPP#12PA040

Saskatchewan

Saskatchewan
Ministry of
Environment

P.O. Box 3003,
6th Floor, 800 Central Avenue
Prince Albert, SK S6V 6G1
Phone: 1-306-953-2423
Cell: 1-306-980-8603
Fax: 1-306-953-2502

May 14, 2012

PERMIT CONDITIONS FOR AREVA RESOURCES CANADA INC'S MCCLEAN LAKE OPERATION PROJECT. PERMIT# 12PA040, AQUATIC HABITAT PROTECTION PERMIT AND FOREST PRODUCT PERMIT 2821H.

Under authority of the Environmental Management and Protection Act (EMPA) 2002, Section 36 (1), The Water Regulations, 2002, Sections 8 and 9, The Forest Resources Management Act and The Provincial Lands Act and Regulations, permission is hereby granted to **Areva Resources Canada Inc** to complete the following:

- Clear approximately 2 hectares of forest/organic materials from the north stockpile area.
- Clear approximately 1 hectare of forest/organic materials from the south stockpile area.

Proponent to contact either Warner Carlson or Scott Andrew at Southend Saskatchewan Ministry of Environment office 306-758-6255 or fax a notice to 306-758-6250 or email Warner.Carlson@gov.sk.ca or Scott.Andrew@gov.sk.ca prior to work commencing and immediately upon completion.

1) The contractor completing the work must be given a copy of this permit to ensure all conditions are met.

2) This permit does not replace or super cede any approvals, licenses or authorizations, which may be required from municipal, provincial or federal legislation. The permit holder will maintain in force all such approvals, licenses or authorizations that may be required.

3) Saskatchewan Environment must be notified of any changes to this project and must approve these changes prior to their implementation.

4) A closure report is required to be submitted to Andy Cook of Saskatchewan Environment within one month following expiry of this permit.

5) This permit may be suspended by Saskatchewan Environment where spring breakup or other conditions warrant.

6) Weather permitting; all reclamation work is to be completed within 30 days of completion of this project.

7) Condition to meet OH&S concerns in respect to transportation of injured workers.
   a. Under the *Occupational Health and Safety Act, 1993 & Occupational Health and Safety Regulations, 1996* it is the responsibility of the employer to ensure that

there are adequate means to transport injured workers to a medical facility or hospital. Please ensure that contractors are familiar with this legislation. Please call Neal Crocker of Saskatchewan Labour (306) 933-5106 for clarification of this requirement.

b. It is further suggested that employers contact the local Regional Health Authority to research the emergency procedures for the area where work is being carried out. What is available in the area may directly affect employers planning for *Occupational Health and Safety Act* requirements.

8) Prior to entry of equipment on forested Crown land, all equipment must be washed and clear of any non-indigenous plants or seeds.

9) The proponent must ensure that upon abandonment of any site, all man made items are removed and disposed of properly. This includes, but is not limited to, flagging tape, nails, petroleum products and dimensional lumber. Haul out what you hauled in.

10) Forest operations are to be conducted as per the Forest Resources Management Act and Regulations unless otherwise stated.

11) Low impact and avoidance cutting techniques shall be used when clearing. This should include such techniques as cutting the path of least resistance, removing branches from trees rather than cutting the tree, avoiding the cutting of standing merchantable trees where possible.

12) No material is to be pushed into standing timber. All leaning trees are to be removed from standing timber. All trees not salvaged are to be utilized in the reclamation of access trails and any other disturbances.

13) **Clearing of vegetation within 100 meters of any watercourse/body must be hand cleared.**

14) Unless otherwise approved, any clearing of vegetation shall be minimized and follow the construction plan outlined in the program proposal. Stripping of the site shall be limited to vegetation removal and, **if required**, topsoil removal (vegetation and topsoil are to be stripped and stored separately for final reclamation).

15) All spoiled materials resulting from the clearing operations must be placed in a location where it will not be subject to erosion into any water body or watercourse.

16) Once operations are completed, sites must be re-contoured, topsoil is to be re-spread, and woody species are to be rolled back and spread on the sites. Sites will be allowed to naturally regenerate. If supplemental planting is required, approval for seeding and/or tree planting is required prior to completing any reclamation work. Contact the local Ecological Protection Specialist.

17) All activities are to occur during dry ground conditions. During overly wet conditions, work must be stopped for any activity that could potentially cause undue rutting of the ground surface (other than permanent roadways). Rutting is defined as an area 5 meters in length and greater than 15 cm in depth.

18) Any (new) Stream crossings will be identified on a 1:50,000 scale map and a description of the method to be used to cross the stream will be provided to S.E. for approval before construction of these crossings takes place.

19) Within bogs, muskegs or possible wet areas, the ground must be frozen enough to support equipment. If frozen ground conditions do not exist, alternate **approved** methods must be used to prohibit rutting of the ground surface (i.e. timber matting, planks, etc.).

20) No debris is to be deposited in any water body or watercourse or on the ice of any frozen water body or watercourse. Any debris accidentally deposited is to be removed immediately.

21) Until re-vegetation is sufficient to control sediment erosion, the proponent shall ensure that effective sediment and erosion control measures are in place and that they are functioning properly and are maintained and/or upgraded as required to prevent sediment from entering the water body or water course.

22) Felling and yarding of trees shall be away from any water body. Trees are not to be yarded across any watercourse. No cut brush or trees may be left in or on any water body during this project.

23) The bank or boundary of any water body or watercourse disturbed by construction activities will be recontoured to the natural slope and will be stabilized immediately to prevent erosion by revegetation or other means (eg. using clean riprap and/or erosion control blankets).

24) **All** spills of hazardous substances or waste dangerous goods are to be reported as per thresholds amounts identified in the *Environmental Spill Control Regulations* and handled according to the regulations.

25) All stationary fuel tanks, pumps, motors and hydraulic lines must have secondary containment. (E.g. If a pump is used to pump water, the pump and it's fuel supply must be placed in a container that is capable of holding 110% of the pump fuels and oils).

26) A spill kit must be on site during operations and all members of the crew must be properly trained in the operation of the spill kits.

27) Work operations, from April 1 to October 31, within the Provincial Forest or within 4.5 km of the Provincial Forest, work crews must have fire-fighting equipment on hand, as per Best Management Practice 006 of the Mineral Exploration Guidelines of Saskatchewan.

This permit expires on December 31, 2012.

Signature

Andy Cook
Senior Ecological Protection Specialist

Saskatchewan

Ministry of
Environment

6th Floor, 800 Central Avenue
P.O. Box 3003, Prince Albert
Saskatchewan, S6V 6G1
Phone: 1-306-953-2423
Cell: 1-306-980-8603
Fax: 1-306-953-2502
andy.cook@gov.sk.ca

May 14, 2012

AQUATIC HABITAT PROTECTION PERMIT #12PA040

Under authority of the Environmental Management and Protection Act (EMPA) 2002, Section 36 (1), The Water Regulations, 2002, Sections 8 and 9, permission is hereby granted to **AREVA Resources Canada Inc.** to;

1. Work in or in the proximity of Aquatic Habitat to complete their forest clearing proposal at McClean Lake Mine Site as submitted to the Ministry of Environment March 21, 2012.
2. As per attached conditions.

This permit expires December 31, 2012.

Andy Cook
Senior Ecological Protection Specialist

Saskatchewan Ministry of Environment

Forest Product Permit

02/2009

2821 H

Pursuant to the Forest Resource Management Act and Regulation permission is granted to the Permittee for: (check one)

☒ Timber ☐ Haying ☐ Grazing ☐ Special Products ☐ Oil & Gas Exploration ☐ Mineral Exploration ☐ Right of Way ☐ Science Projects

Effective Date: 14 / 05 / 12 (dd mm yy) Expiry Date: 31 / 12 / 12 (dd mm yy)

Method of Payment
☐ monthly returns by permittee
☐ monthly returns by other (list)

☐ equal installments ($/due date)
1st _____ / application date
2nd _____
3rd _____ / 90 days after first remittance

Company/Individual Name: Areva Resources Canada Inc (Last / First)

Date of Birth _____ (dd mm yy) Drivers License _____ or SHSC# _____

Address: P.O. Box 9204 - 817 - 45th Street West

City: Saskatoon Prov.: SK Postal Code: S7K-3X5 Telephone #: 343-4551

Operator Name: Blondeel (Last) Christopher (First)

Inspecting Officer Name: Cook (Last) Andy (First)

Application date: 21 / 03 / 12 (dd mm yy)

Received by (please print): Andy Cook

Operating Office Name: Prince Albert

Fire Year _____

Fire Name _____

*U - forest products must be used for own non-commercial use *S - authorizes permittee to offer for sale, sell, exchange, barter, deal, solicit or trade the forest products legally obtained with this permit

*U/*S	Zone	Easting	Northing	Quantity	Units	Species	Product Class	Salvage Type	Land Type	Crown Dues rate	Dues Total	Fund Code	Management Fee Rate	Fee Total	Bonus Bid Crown rate	Bid Crown Total	Bonus Bid Fee rate	Bid Fee Total
S	13	568	646									CF						
McClean Lake Operation Project																		
Permit # 12PA040																		

Allocation Holders only: Maximum annual allowable harvest from operating plans

Green	Salvage
_____ m³ SW	_____ m³ SW
_____ m³ HW	_____ m³ HW (gA, wB, wE & mM)
_____ m³ HW	_____ m³ HW (tA, bP)

Dues Subtotal + Fees Subtotal + Bid Dues Sub + Bid Fee Sub = Subtotals

Or 1st installment (2 or 3 installments): Dues + Fees + Bid Dues + Bid Fees = Installment total

(Commercial permit fee $50.00 Own Use permit fee $10.00) + 50.00 Permit Fee

GST Registrant # _____ or + 2.50 GST

Less: Credit from Permit # _____ - Credit Total

Total Paid = 52.50

Pd Chq #12641o

Permittee Signature (Individual/Company representative) _____

If representative please print name _____

Approved by _____

This license is subject to the Forest Resources Management Act and Regulations, officer's instructions and terms and conditions as stated in the following attachments:

☐ Operating Plan ☐ Scaling Plan ☐ Payment Schedule ☐ Range Management Plan ☐ Agreement Letter ☐ Access Letter (Ag & Food) ☐ Special Products Ledger ☒ Conditions

Permittee

APPENDIX E

Survey Control Report

SURVEY REPORT FOR CONTROL NETWORK

Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

1.0 EQUIPMENT

GPS BASE STATION

- Sokkia GRX1 base station receiver with integrated with GPS and GLONASS tracking in conjunction with Satel differential correction external radio.

RTK GPS ROVER

- Sokkia GRX1 RTK rover receiver with integrated with GPS and GLONASS tracking in conjunction with Satel differential correction internal radio mounted to a fixed height carbon fibre range pole.

2.0 SURVEY PROCEDURE

ESTABLISHED CONTROL

- Localization to local mine grid control was performed using coordinates provided by Areva.
- Golder Associates' site control network was established in reference to Golder MLO CP1 using the localization created.
- Coordinates established by averaging 100 fixed readings at each occupied station.

CONTROL POINT DEFINITIONS

- Golder MLO CP1, Golder MLO CP3, Golder MLO CP4, Golder MLO CP5, Golder MLO CP6, Golder MLO CP7, Golder MLO CP8, Golder MLO CP9, Golder MLO CP10 and Golder MLO CP11, are iron bars set in concrete. Specifics of the iron bar and concrete are unknown.
- Golder MLO CP2 is an iron bar driven in the ground to an unknown depth.
- All control points identified with three lathe and blue and pink flagging.

ACCURACY

- The horizontal error when establishing control did not exceed 8mm.
- The vertical error to when establishing control did not exceed 12mm.

Client: Areva – McClean Lake Operation
Crew Chief: Kyle Nontell
Date: June 05, 2012
Project/Phase No: 12-1362-0022
Survey Assistant: N/A

3.0 CONTROL DATA

Coordinates Established By Golder Associates				Coordinates Provided By Areva MLO			
STATION	NORTHING	EASTING	ELEVATION	STATION	NORTHING	EASTING	ELEVATION
Golder MLO CP1	11109.626	5040.221	453.183	1995004	11109.641	5040.221	453.183
Golder MLO CP2	10949.172	5485.630	461.420	1995002	10949.179	5485.625	461.424
Golder MLO CP3	11168.406	5080.049	454.074	1995010	11168.416	5080.053	454.076
Golder MLO CP4	11202.765	5032.194	451.656	1995005	11202.785	5032.195	451.656
Golder MLO CP5	11221.790	5079.850	452.796	1995011	11221.808	5079.992	452.699
Golder MLO CP6	11270.627	5098.761	451.451	1995012	11270.672	5098.774	451.468
Golder MLO CP7	11309.745	5120.554	450.939	1995013	11309.720	5120.568	450.955
Golder MLO CP8	11385.195	5108.893	448.702	1995006	11385.199	5108.891	448.700
Golder MLO CP9	11385.978	5337.661	453.484	1996001	11385.996	5337.650	453.503
Golder MLO CP10	11253.050	5650.665	459.211	1995008	11253.039	5650.665	459.217
Golder MLO CP11	11038.026	5436.444	457.345	1995014	11037.971	5436.440	457.359

Variance Between Given And Established Coordinates

STATION	NORTHING	EASTING	ELEVATION
Golder MLO CP1	-0.015	0.000	0.000
Golder MLO CP2	-0.007	0.005	-0.004
Golder MLO CP3	-0.010	-0.004	-0.002
Golder MLO CP4	-0.020	-0.001	0.000
Golder MLO CP5	-0.018	-0.142	0.097
Golder MLO CP6	-0.045	-0.013	-0.017
Golder MLO CP7	0.025	-0.014	-0.016
Golder MLO CP8	-0.004	0.002	0.002
Golder MLO CP9	-0.018	0.011	-0.019
Golder MLO CP10	0.011	0.000	-0.006
Golder MLO CP11	0.055	0.004	-0.014

NOTE: COORDINATES SHOWN ARE CONSIDERED ACCURATE IN REFERENCE TO *GOLDER MLO CP1* USING LOCALIZATION TO THE MINE GRID CONTROL NETWORK WITH COORDINATES PROVIDED BY AREVA. CONTROL POINTS ARE SUBJECT MOVEMENT AND DAMAGE AND ARE TO BE CONFIRMED PRIOR TO USE.

Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

4.0 PICTURES

Golder MLO CP1



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Base Station set up at Golder MLO CP1



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP2



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP3



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP4



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP5



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP6



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP7



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP8



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP9



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP10



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP11



At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.

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Golder Associates

December 2013

RECORD OF CONSTRUCTION

JEB TAILINGS MANAGEMENT FACILITY OPTIMIZATION STAGE 1/PHASE 2 2013 CONSTRUCTION

Submitted to:
AREVA Resources Canada Inc.
P.O. Box 9024
817-45th Street West
Saskatoon, Saskatchewan
S7K 3X5

REPORT

Report **Number:** 12-1362-0022/4000
Distribution:

1 Copy - AREVA Resources Canada Inc.
2 Copies - Golder Associates Ltd.

Golder Associates

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1.0 INTRODUCTION

1.1 General

AREVA Resources Canada Inc. (AREVA) conducted a study to optimize tailings storage within the JEB Tailings Management Facility (TMF) at the McClean Lake Operation mine site. The optimization of tailings storage within the JEB TMF involves re-sloping of the existing till slopes, construction of a soil bentonite liner, and placement of rip rap on the liner for erosion protection. It will be constructed in two stages: Stage 1 and Stage 2. Stage 1 was split into Phase 1 (constructed in the summer of 2012) and Phase 2 (constructed in the summer of 2013). This record of construction report summarizes the work completed for the Phase 2 portion of the Stage 1 Optimization. Details of the design of Stage 1/Phase 2 of the Optimization project can be found on the Issued for Construction drawings (Drawing No. GA0023 through GA0029) and the technical specifications.

Stage 1/Phase 2 began during the summer of 2013. Work completed for Stage 1/Phase 2 during the 2013 construction season included the following components:

- completion of till slope excavation;
- production of additional liner base material;
- construction of a soil bentonite liner;
- removal and replacement of the South Access Ramp over the soil bentonite liner;
- placement of rip rap on completed sections of the liner; and
- installation of a half round culvert.

The work completed during 2013 for Stage 1/Phase 2 was constructed under the Saskatchewan Ministry of Environment Approval to Construct No. PC10-165 (File No. S25020-50/ML/03) dated November 18, 2010 and the Canadian Nuclear Safety Commission letter (File No. 2.04 ML-A) dated September 30, 2010. The two stockpiling areas were prepared under the Ministry of Environment Aquatic Habitat Protection Permit #12PA040 dated May 14, 2012 and Forest Product Permit #2821H dated May 14, 2012. The documents are provided in Appendix D.

This report contains a summary of the Stage 1/Phase 2 work carried out by Broda Construction Ltd. of Prince Albert, Saskatchewan. The work occurred between May 22, 2013 and September 24, 2013.

Details of the work completed are shown on the record drawings provided in Appendix A.

This report should be read in conjunction with the Record of Construction report for the Stage 1/Phase 1 construction completed in 2012, titled “JEB Tailings Management Facility Optimization Stage 1/Phase 1 2012 Construction”. Relevant background information is listed in Table 1.

Table 1: Relevant Background Information

Project No.	Title	Description	Date Issued	By
12-1362-0022	JEB Tailings Management Facility Optimization Stage 1/Phase 1 2012 Construction	Report	December 2012	Golder Associates Ltd.
08-1362-0590	Quality Assurance / Quality Control Plan	Report	January 2010	Golder Associates Ltd.
12-1362-0022	Summary of Test Pad Construction	Memo	December 2013	Golder Associates Ltd

1.2 Report Objectives

The objective of this report is to document construction activities and report results of quality assurance and construction monitoring activities conducted by Golder Associates Ltd. (Golder). In addition, modifications to the design are specifically discussed.

1.3 Division of Responsibilities

The responsibilities for each company involved in the 2013 construction are shown in Table 2.

Table 2: Division of Responsibilities

Company	Responsibilities
AREVA Resources Canada Inc. (Saskatoon, Saskatchewan)	Owner: contract administration.
Golder Associates Ltd. (Saskatoon, Saskatchewan)	Owner's Representative: design engineers; engineering support during the construction; quality assurance testing; on-site monitoring during construction; construction, quantity and record surveying; preparation of record drawings and Record of Construction report.
Broda Construction Ltd. (Prince Albert, Saskatchewan)	Contractor: re-sloping of till slopes and stockpiling of excavated material; production of additional liner base material; construction of soil bentonite liner; removal and replacement of South Access Ramp over soil bentonite liner; placement of rip rap over soil bentonite liner; installation of half round culvert.

1.4 Survey Control Datum

Survey control utilized during the construction was referenced to the local mine grid coordinate system. Localization to the local mine grid control was performed using coordinates provided to Golder by AREVA. Golder's site control network was established in reference to Golder-MLO-CP1 using the localization created. The co-ordinates for Golder-MLO-CP1, in the local mine grid, are as follows:

- Northing – 11,109.626 metres (m);
- Easting – 5,040.221 m; and
- Elevation – 453.183 m.

Details of the survey control datum are provided in the survey control report in Appendix E.

1.5 Location of Field Records

The locations of field records of construction are summarized in Table 3.

Table 3: Field Records and Filing Locations

Record Type	Description	On File With
Field Report	Field Books Daily Golder Field Reports	Golder/AREVA Golder/AREVA
Field Report	Daily Broda Field Reports	Golder/Broda/AREVA
Meeting Minutes	Daily Toolbox Safety Minutes Weekly Contractor Safety Minutes	Broda/AREVA Broda/AREVA
Quality Assurance Testing	Standard Proctor Curves Nuclear Density Test Reports Grain Size Analysis Hydraulic Conductivity Lab Testing Hydraulic Conductivity Field Testing Water Content Testing Direct Shear Testing	Golder Golder Golder Golder Golder Golder Golder
Surveying	Field Books Plan/Profiles	Golder Golder
Construction Photographs	Photographs	Golder

1.6 Photo Log

Photographs were taken by Golder during construction as part of the monitoring program. Select photographs are included in Appendix B.

2.0 ADDITIONS AND MODIFICATIONS TO DESIGN

During construction modifications to the design were required to accommodate construction conditions. These modifications are summarized in Table 4 and shown on the record drawings provided in Appendix A.

Table 4: Modifications to Design

Modification	Description
Liner construction beneath the South Access Ramp.	The section of soil bentonite liner beneath the South Access Ramp was originally designed to be constructed at a 10H:1V slope over the top of the South Access Ramp. To ease construction and reduce the quantity of soil bentonite liner required it was constructed at a 3H:1V slope beneath the South Access Ramp. This also resulted in the liner having more contact with the sandstone. This required excavating a portion of the existing South Access Ramp to expose the sandstone surface and construct the liner. The South Access Ramp was then re-constructed over the soil bentonite liner using common fill.

3.0 CALIBRATION OF TESTING EQUIPMENT

All testing equipment and nuclear densometers used during the Stage 1/Phase 2 construction have been calibrated annually, at a minimum, according to industry accepted standards. Calibration records and certificates are on file with Golder.

4.0 EXCAVATION

4.1 General

Stage 1/Phase 2 included completion of re-sloping the existing till slopes, above the till/sandstone contact, within the JEB TMF (Photos 5 and 6).

A portion of the original till slope and slope armouring was left in place during the winter of 2012/2013 for erosion protection beneath two existing culverts at approximately Station 0+850. This material was removed as part of the completion of the till re-sloping during Phase 2 (Photo 5). In addition, sediments resulting from erosion of the till slopes during spring melt were excavated and hauled to the North and South stockpiles.

4.2 Excavation Geometry

Re-sloping of the existing till slopes occurred above the till/sandstone contact. The till was re-sloped, beginning at about 14 m horizontally from the crest of the till/sandstone contact, at a slope of 3H:1V up to about elevation 440.9 m, then at 1.5H:1V until the slope day-lighted with existing ground.

Details of the excavation geometry are provided on the record drawings in Appendix A (Drawing No.'s GA0022, GA0025, GA0025.1, GA0025.2, GA0025.3 and GA0026).

4.3 Excavation Materials

Excavated till from the re-sloping was hauled to the North and South stockpiles. Approximately 5,548 cubic metres (m^3) of till was removed from the slopes and hauled to stockpile to complete the re-sloping of the existing slopes.

Details of the stockpile locations can be found on the record drawings in Appendix A (Drawing No. GA0021).

4.4 Excavation Finishing

Upon completion of excavation, the slopes were trimmed to an even surface (Photo 6).

Details of the finishing are provided on the record drawings in Appendix A (Drawing No.'s GA0025, GA0025.1, GA0025.2 and GA0025.3).

5.0 COMMON FILL PLACEMENT

5.1 General

Common fill placement for Stage 1/Phase 2 consisted of the removal and replacement of the South Access Ramp during liner construction, filling of erosion which occurred during spring melt on the 3H:1V till slope and completion of the safety berm.

5.2 Common Fill Geometry

Removal of the bottom portion of the South Access Ramp was required during construction to facilitate the construction of the soil bentonite liner in that area (Photo 23 and 24). The existing South Access Ramp was excavated and hauled to the South stockpile. Upon completion of the liner construction (Photo 34), the South Access Ramp was re-constructed over the soil bentonite liner (Photo 35). Approximately 2,114 m^3 of till was used to re-construct the South Ramp. The re-constructed South Access Ramp was built with a top width of 15.0 m, a cross slope of 2%, sides slopes of 3H:1V and a slope of 9.5%. The driving surface of the South

Access Ramp was reconstructed by placing a lift of till over the rip rap placed on the soil bentonite liner (Drawing No. GA0026).

The safety berm was re-constructed along the re-constructed South Access Ramp. It was constructed to a minimum height of 1.35 m with 1H:1V side-slopes and a crest width between approximately 0.5 and 1.0 m.

Localized areas of erosion caused by spring melt and groundwater within the till slopes were filled with compacted till prior to the construction of the soil bentonite liner. Approximately 237 m^3 of till was used to fill the erosion.

Details of the common fill placement are shown on the record drawings provided in Appendix A (Drawing No.'s GA0022, GA0024, GA0024.1, GA0024.2 and GA0026).

5.3 Common Fill Materials

5.3.1 Till

Till material was used to re-construct the South Access Ramp over the liner, fill the localized erosion on the till slopes, and re-construct the safety berm. This till material was imported from the North stockpile area.

Standard Proctor Maximum Dry Density (SPMDD) (ASTM D698) testing was completed on the till material at a rate of approximately one (1) test per 1,000 m^3 of material placed. This rate met the required minimum of one (1) test per 1,000 m^3 placed. A total of two (2) SPMDD tests were completed for the till material. Samples of the till were sent to Golder's Saskatoon laboratory for SPMDD testing. The results of the SPMDD testing are summarized in Table 5.

Table 5: Till SPMDD Test Results

Proctor Number	Optimum Moisture Content (%)	Standard Proctor Maximum Dry Density (kg/m^3)
2013-MLO-001	6.9	2,086
2013-MLO-005	7.1	2,032

kg/m^3 = kilogram per cubic metre; % = percent

Details of the SPMDD testing performed can be found in Appendix C.

5.3.2 Nuclear Density Testing

Compaction specification for the common fill material required a minimum of 95% of SPMDD. To check compliance with specification, Golder performed quality assurance testing on the material using the nuclear densometer method (ASTM D6938) to determine the percentage SPMDD of the material after compaction. A summary of the results for each area are provided in the following sections.

5.3.2.1 South Access Ramp

The South Access Ramp was re-constructed over the soil bentonite liner with till placed in lifts of about 300 millimetres (mm) thickness after compaction. Each lift was compacted using a Cat CS-563 smooth-drum roller (Photo 35).

Nominal compaction was specified for the re-construction of the South Access Ramp. Nuclear densometer testing was not performed on the re-constructed South Access Ramp.

5.3.2.2 3H:1V Slope

Till was used to build the slope back up to the design grade where localized erosion had occurred on the till slopes due to spring runoff. The till was placed in lifts not exceeding 300 mm after compaction and compacted using a Cat CS-563 smooth-drum roller.

Nuclear densometer testing was completed on the till at a rate of approximately one (1) test per 3 m^3 of material placed. This testing rate exceeded the required minimum of one (1) test per 100 m^3 of material placed. A total of 76 nuclear densometer tests were completed on the till. The average placed dry density of the till was determined to be 98.4% of SPMDD. The minimum and maximum placed dry densities of the material were determined to be 95.3% and 102.0% of SPMDD, respectively. These test results met the specification for common fill placement.

5.3.2.3 Safety Berm

The safety berm was constructed of nominally compacted till. Nuclear densometer testing was not required on the safety berm.

6.0 PROCESSING OF LINER BASE MATERIAL

Processing of granular material used as the base material for the construction of the soil bentonite liner occurred between August 17, 2012 and September 16, 2012. During construction it was found that the sandstone contact was lower than anticipated. Therefore additional liner material was required to complete the liner. Additional liner base material was produced from crushed sandstone blended with till between May 22, 2013 and May 30, 2013 and from screened till between August 26, 2013 and August 29, 2013 (Photos 29, 41, 42, 43).

Processing occurred on top of the waste rock pile at the McClean Lake Operation. Sandstone excavated from the waste rock pile and till excavated from the re-sloping of the TMF till slopes was used to produce the liner base material.

Details of the liner base material produced during 2012 can be found in the Record of Construction report for the Stage 1/Phase 1 construction titled “JEB Tailings Management Facility Optimization Stage 1/Phase 1 2012 Construction”. Details of the production of riprap used during Stage 1/Phase 2 can also be found in that report.

6.1 Granular Materials

6.1.1 Liner Base Material

6.1.1.1 General

Approximately 12,895 m^3 (measured in-place) of liner base material for the soil bentonite liner was produced. Of that quantity 10,687 m^3 consisted of crushed sandstone blended with till produced in 2012, 1,260 m^3 was crushed sandstone blended with till produced in 2013, and 948 m^3 consisted of screened till produced in 2013 (Photo 30).

6.1.1.2 Grain Size Analysis

Grain size analysis testing (ASTM D422) was performed by Golder on the liner base material during production. The grain size analysis testing was completed at a rate of approximately one (1) test per 60 m^3 of material produced. This rate exceeded the required minimum of one (1) test per 500 cubic metres produced.

A total of 28 grain size analysis tests were completed on the liner base material produced by blending crushed sandstone and till. The results of the grain size analysis testing for the base material produced by blending crushed sandstone with till in 2013 are summarized in Table 6.

Table 6: Liner Base Material Grain Size Analysis Test Results: Crushed Sandstone Blended with Till

Sieve Size (mm)	Specification (% Passing)	Average Percent Passing Crushed Sandstone (% Passing)
60	100	100
1.0	40 - 100	72.6
0.074	15 - 35	19.5

mm = millimetre; % = percent

A total of 11 grain size analysis tests were completed on the liner base material produced by screening till. Table 7 summarizes the grain size analysis testing for the base material produced by screening till in 2013.

Table 7: Liner Base Material Grain Size Analysis: Screened Till

Sieve Size (mm)	Specification (% Passing)	Average Percent Passing Screened Till (% Passing)
60	100	100
1.0	40 - 100	70.9
0.074	15 - 35	26.3

mm = millimetre; % = percent

The results of the grain size analysis testing completed for the liner base material produced by blending crushed sandstone and till in 2012 can be found in the Record of Construction report for the Stage 1/Phase 1 construction titled “JEB Tailings Management Facility Optimization Stage 1/Phase 1 2012 Construction”.

These results were found to meet the requirements of the specification. A detailed summary of the grain size analysis results is included in Appendix C.

7.0 SOIL BENTONITE LINER CONSTRUCTION

7.1 General

A soil bentonite liner was constructed above the sandstone contact on the 3H:1V portion of the re-sloped till slopes around the interior of the JEB TMF. The soil bentonite liner material was produced by blending the liner base material with bentonite and water in a pugmill (Photos 1 to 4). A minimum of 5% bentonite content (by dry weight of liner material) was used in the soil bentonite mixture. The bentonite used was BARA-KADE SP produced by Bentonite Performance Minerals LLC, which is an untreated Wyoming sodium bentonite which meets the requirements of API 13A Section 10. Water was also added to the mixture in the pugmill to meet the specified water content for liner construction. Upon start-up the pugmill was calibrated to produce the desired percentage of bentonite and water content in the liner material (Photos 1, 2 and 3).

A test pad was constructed (June 26, 2013) on the top of the waste rock pile prior to the start of liner construction to determine the methodology to be used to construct the liner in the JEB TMF. Hydraulic conductivity results were conducted on the test pad material to demonstrate that the required hydraulic conductivity could be achieved. Details of the test pad construction can be found in the record of construction memorandum “Summary of Test Pad Construction” issued by Golder in December 2013.

The sandstone contact was cleaned prior to construction of the soil bentonite liner to provide a good contact between the liner and the sandstone. The sandstone contact was cleaned by first sweeping with a mechanical broom attached to a skid steer (Photo 7 and 8) and then by hand cleaning with shovels and brooms (Photo 15). The sandstone contact was cleaned across the full width of the base of the soil bentonite liner (Photo 11, 17, 19, 20, 21, 24 and 31). Golder visually inspected and approved each section of cleaned sandstone prior to the placement of liner material (Photo 10).

The soil bentonite liner material was loaded into haul trucks and hauled down into the JEB TMF where it was dumped and then end dozed into position by a dozer (Photo 12 and 18). The liner was constructed using a method consistent with the construction methodology determined during the test pad construction. The liner material was typically placed in lifts of 150 mm after compaction and compacted using a Cat CS-563 smooth-drum roller and hand operated tampers (Photo 13, 14 and 32). Construction conditions in some localized areas required the material be placed in lifts thicker than 150 mm (such as low spots and cracks in the sandstone contact); however no lifts exceeded 300 mm after compaction. The top of each compacted lift was scarified (using either a saw toothed bucket attached to a tracked skid-steer or a bucket equipped with grader blade bolts attached to a loader) prior to placement of the next lift (Photo 16 and 33).

7.2 Liner Geometry

The soil bentonite liner was constructed in two (2) sections. The north section was constructed from approximately Station 0+325 to Station 0+640. The south section was constructed from approximately Station 0+700 to Station 1+068 and Station 0+000 to Station 0+140.

The final crest elevation of the liner was not constructed to the intended final elevation of 440.0 metres above sea level (m ASL) due to a shortage of liner base material caused by the lower sandstone contact. The minimum elevation of the completed liner was 438.94 m and the maximum elevation of the completed liner was 439.79 m (measured to the interior shoulder of the liner).

The liner was constructed to a minimum thickness of 1.92 m (measured perpendicular to the 3H:1V slope).

Details of the soil bentonite liner construction are shown on the record drawings provided in Appendix A (Drawing No.'s GA0023, GA0025, GA0025.1, GA0025.2, GA0025.3 and GA0026).

7.3 Soil Bentonite Liner Materials

7.3.1 Grain Size Analysis

Grain size analysis testing (ASTM D422) was performed by Golder on the liner material during placement. The grain size analysis testing was completed at a rate of approximately one (1) test per 240 m^3 of material placed. This rate exceeded the required minimum of one (1) test per 500 m^3 of material placed. A total of 54 grain size analysis tests were completed on the liner material during placement. No grain size distribution was specified for the placed liner material. The results of the grain size analysis testing are summarized in Table 8.

Table 8: In-place Liner Material Grain Size Analysis Test Results

Sieve Size (mm)	Average Percent Passing (% Passing)
60	100
1.0	73.0
0.074	25.2

mm = millimetre; % = percent

A detailed summary of the grain size analysis results is included in Appendix C.

7.3.2 Standard Proctor Maximum Dry Density

Samples of the soil bentonite liner material were taken to Golder's Saskatoon laboratory for Standard Proctor Maximum Dry Density (SPMDD) (ASTM D698) testing. SPMDD testing was completed on the liner material at a rate of approximately one (1) test per 6,500 m^3 of material placed. No minimum rate was specified for SPMDD testing on the liner material. A total of two (2) SPMDD tests were completed on the placed liner material. The results of the SPMDD testing are summarized in Table 9.

Table 9: Soil Bentonite Liner SPMDD Test Results

Proctor Number	Optimum Moisture Content (%)	Standard Proctor Maximum Dry Density (kg/m^3)
SL3104	8.9	2,035
2013-MLO-186	7.3	2,057

kg/m^3 = kilogram per cubic metre; % = percent]

Details of the SPMDD testing performed can be found in Appendix C.

7.3.3 Nuclear Density and Water Content Testing

Compaction specification for the soil bentonite liner material required a minimum of 98% of SPMDD within -1% to +2% of the optimum moisture content (refer to Table 9 for optimum moisture contents). To check compliance with specification, Golder performed quality assurance testing on the material using the nuclear densometer method (ASTM D6938) to determine the percentage SPMDD and water content of the material after compaction. Acceptance of the material in the field was based on the results of the nuclear densometer testing.

The liner material was typically placed in lifts of 150 mm after compaction and compacted using a Cat CS-563 smooth-drum roller and hand operated tampers (Photo 13, 14 and 32). Construction conditions in some localized areas required the material be placed in lifts thicker than 150 mm (such as low spots and cracks in the sandstone contact); however no lifts exceeded 300 mm after compaction.

Nuclear densometer testing was completed on the placed liner material at a rate of approximately one (1) test per 45 m^3 of material placed. This rate exceeded the required minimum of one (1) test per 100 m^3 of material placed. A total of 289 nuclear densometer tests were completed on the placed liner material.

The average placed dry density of the soil bentonite liner material was determined to be 99.9% of SPMDD. The minimum and maximum values were determined to be 98.0% and 102.7%, respectively. The average moisture content was determined to be 9.3%. The minimum and maximum moisture content was determined to be 6.4% and 10.9%, respectively.

Laboratory water content testing (ASTM D2216) was performed in Golder's Saskatoon laboratory on the liner material during placement as a check of the water content results obtained using the nuclear densometer method. The laboratory water content testing was completed at a rate of approximately one (1) test per eight (8) nuclear densometer tests performed. This rate exceeded the required minimum of one (1) test per ten (10) nuclear densometer tests performed. A total of 28 laboratory water content tests were performed. Table 10 below provides a comparison of the nuclear densometer test results and the laboratory water content test results.

Table 10: Comparison of Nuclear Densometer Test Results and Laboratory Water Content Test Results

Nuclear Densometer Test Number	Nuclear Densometer Moisture Content Result (%)	Laboratory Water Content Test Number	Laboratory Water Content Result (%)	Difference (Field - Lab) (%)
29	9.9	13-MLO-127	10.5	-0.6
42	10.1	13-MLO-129	10.7	-0.6
56	9.1	13-MLO-131	10.2	-1.1
82	9.5	13-MLO-139	9.3	0.2
87	9.1	13-MLO-140	10.1	-1.0
90	9.0	13-MLO-141	10	-1.0
98	8.9	13-MLO-142	10.1	-1.2
103	9.6	13-MLO-144	11.6	-2.0
110	9.9	13-MLO-145	9.3	0.6
122	9.0	13-MLO-146	9.8	-0.8
131	9.5	13-MLO-147	10.3	-0.8
140	9.8	13-MLO-148	11.3	-1.5
155	10.1	13-MLO-156	10	0.1
165	10.6	13-MLO-157	10.9	-0.3
179	9.8	13-MLO-159	9.6	0.2
180	9.7	13-MLO-160	9.3	0.4
181	9.2	13-MLO-161	10.8	-1.6
192	8.9	13-MLO-162	11	-2.1
193	9.7	13-MLO-163	10.5	-0.8
194	9.7	13-MLO-164	9.9	-0.2
246	9.1	13-MLO-176	9.7	-0.6
259	9.5	13-MLO-178	11.1	-1.6
269A	7.7	13-MLO-198	9.1	-1.4
285	7.4	13-MLO-202	8.3	-0.9
295	7.1	13-MLO-204	8.2	-1.1
MAX	**11.2**	-	**11.6**	**2.1**
MIN	**7.1**	-	**8.2**	**0.1**
AVERAGE	**9.4**	-	**10.0**	**0.9**

[1] – corresponds to a nuclear densometer test which was performed at the location of air-entry permeameter test no. 5

The results of the laboratory water content tests agreed well with the results obtained with the nuclear densometer method. The average difference between the results was 0.9%. The maximum and minimum difference between the results was 2.1% and 0.1%, respectively. These results are within the expected range of variance for water content determination by the nuclear densometer method.

Two (2) of the laboratory water content results (13-MLO-165 and 13-MLO-200) (not shown in Table 9) did not agree well with the results obtained with the nuclear densometer. The results returned were higher than the nuclear densometer results by 4.2% and 3.2 %, respectively. The nuclear densometer results for these two locations were within the specification and were accepted in the field. This difference between the results was considered to be a result of the sampling method (i.e., the small size of the laboratory water content sample

compared to the larger sample volume covered by the nuclear densometer). For this reason, the results were considered to be outliers and were not included in the data set.

Details of the nuclear densometer testing and laboratory water content testing are provided in Appendix C.

7.3.4 Hydraulic Conductivity

Hydraulic conductivity testing was conducted both directly on the as-built liner and in Golder's Saskatoon laboratory to check that a hydraulic conductivity less than the specified maximum of 1.0×10^{-9} metres per second (m/s) had been achieved.

Hydraulic conductivity testing was conducted directly on the as-built liner using an air entry permeameter. Samples of the liner material were also brought back to Golder's Saskatoon laboratory for hydraulic conductivity testing at a dry density of about 98% SPMDD in a tri-axial hydraulic conductivity apparatus.

Hydraulic conductivity testing was completed on the placed liner material at a rate of approximately one (1) test per 860 m^3 of liner material placed. This rate exceeded the required minimum of one (1) test per 1,000 m^3 of material placed.

A total of five (5) air entry permeameter tests were completed on the liner in the field. Table 11 provides the results of the hydraulic conductivity tests completed directly on the soil bentonite liner material in the field.

Table 11: Soil Bentonite Liner Material Hydraulic Conductivity Test Results - Field

Location (Station; Elevation [m])	Hydraulic Conductivity (m/s)
0+760; 439.64	3×10^{-10}
0+965; 439.65	1×10^{-10}
0+854; 439.50	7×10^{-11}
0+025; 439.12	6×10^{-10}
0+100; 439.26	7×10^{-10}

m/s = metres per second; m = metre

A total of ten (10) hydraulic conductivity tests were completed on the liner material in Golder's Saskatoon laboratory. Table 12 provides the results of the hydraulic conductivity tests completed in Golder's Saskatoon laboratory.

Table 12: Soil bentonite Liner Material Hydraulic Conductivity Test Results - Lab

Sample Number	Location (Station; Elevation [m])	Hydraulic Conductivity (m/s)
2013-MLO-123	0+972; 436	9.6×10^{-11}
2013-MLO-126	0+977; 437	1.2×10^{-10}
2013-MLO-134	0+950; 438.27	6.6×10^{-11}
2013-MLO-141	0+025; 439	5.0×10^{-11}
2013-MLO-146	0+415; 439.02	5.5×10^{-11}
2013-MLO-156	0+785; 438.89	4.0×10^{-11}
2013-MLO-161	0+460; 439.47	2.9×10^{-11}
2013-MLO-167	1+025; 435.89	2.2×10^{-11}
2013-MLO-177	0+070; 432.21	6.0×10^{-11}
2013-MLO-198	0+095; 436.45	6.4×10^{-11}

m/s = metres per second; m = metre

These results indicate that the hydraulic conductivity of the soil bentonite liner is less than the specified maximum hydraulic conductivity of 1.0 x 10^{-9} m/s. These results were found to meet the requirements of the specification. Details of the hydraulic conductivity testing are provided in Appendix C.

7.3.5 Direct Shear Testing

Direct shear testing (ASTM D3080) was completed on select samples of the liner material in Golder's Saskatoon laboratory. The direct shear testing was completed at a rate of approximately one (1) test per 2,000 m^3 of material placed. This rate met the required minimum specified rate of one (1) test per 2,000 m^3 of material placed. A total of six (6) direct shear tests were completed on the liner material. Table 13 summarizes the results of the direct shear testing.

Table 13: Direct Shear Testing Results

Sample Number	Peak		Residual	
	Friction Angle (degrees)	Cohesion (kPa)	Friction Angle (degrees)	Cohesion (kPa)
2013-MLO-87	32.9	18	32.9	0
2013-MLO-123	34.4	28	34.4	0
2013-MLO-141	37.2	13	37.2	0
2013-MLO-146	35.3	20	33.3	0
2013-MLO-167	33.4	25	32.8	0
2013-MLO-198	33.5	16	33.5	0

kPa = kiloPascals

Details of the direct shear testing completed can be found in Appendix C.

7.4 Finishing

Upon completion of the soil bentonite liner, rip rap was placed on the surface of the liner to a nominal thickness of 0.5 m. Compaction of the rip rap was not required. The rip rap was placed by end dozing with a CAT D6 Dozer equipped with a GPS guidance system (Photo 36, 37, 38 and 39).

Details of the finishing are provided on the record drawings in Appendix A (Drawing No.'s GA0025, GA0025.1, GA0025.2, GA0025.3 and GA0026).

8.0 HALF ROUND CULVERT

8.1 General

A 1,200 mm diameter half round culvert was installed at the southeast corner of the JEB TMF to replace the two existing culverts at approximately Station 0+850. The two existing culverts were removed and the excavation backfilled with till. The half round culvert drains the area to the southeast of the JEB TMF, between the JEB TMF and the mill terrace.

The culvert was installed by excavating the JEB TMF slope to the final 3H:1V slope for a width of 5.2 m at approximately Station 0+830 (Photo 9 and 25). The culvert was installed down the slope in sections, from the top of the slope, over the soil bentonite liner and past the edge of the sandstone contact (Photo 26, 27 and 28). A full round section of culvert was installed within an embankment constructed at the top of the slope and connected to the half round culvert via a header plate. The full round culvert connects the drainage ditch for the two original culverts to the half round culvert. The sections of the half round culvert were anchored to the slope

using 1.0 m long pieces of rebar, and secured against sliding by attaching concrete anchor blocks to the half round culvert at various locations at the base of the slope.

Details of the construction of the half round culvert are shown on the record drawings provided in Appendix A (Drawing No.'s GA0027, GA0028 and GA0029).

8.2 Nuclear Density Testing

Till was used to construct the embankment and backfill the full round culvert at the top of the slope. Compaction specification required a minimum of 95% of SPMDD. To check compliance with specification, Golder performed quality assurance testing on the material using the nuclear densometer method (ASTM D6938) to determine the percentage SPMDD of the material after compaction.

The nuclear densometer testing was completed at a rate of approximately one (1) test per 15 m^3 of till placed. This rate exceeded the specified minimum rate of one (1) test per 100 m^3 of material placed.

A total of 14 nuclear densometer tests were completed on the till used to backfill the full round culvert. The average placed dry density of the till was determined to be 97.2% of SPMDD. The minimum and maximum values were determined to be 95.3% and 99.6%, respectively.

These results were found to meet the requirements of the specification. Details of the nuclear density testing are provided in Appendix C.

8.3 Finishing

Upon completion of installation, rip rap was placed to provide erosion protection at the inlet of the full round culvert at the top of the slope (Photo 40).

Details of the finishing are provided on the record drawings in Appendix A (Drawing No. GA0027).

9.0 OUTSTANDING WORK

No outstanding work remains for the JEB TMF Optimization Stage 1/Phase 2 project.

10.0 CLOSURE

This report presents a summary of the construction of Stage 1/Phase 2 of the JEB TMF Optimization at the AREVA McClean Lake mine site between May 22, 2013 and September 24, 2013. The information presented in this report is based on daily reporting by Golder personnel, laboratory testing conducted by Golder and communications between Golder, Broda and AREVA.

We trust that this report contains the information you presently require. Should you have any comments or questions, please do not hesitate to contact the undersigned.

Kyle Bruce
Engineer-In-Training

Kyle Cator
Engineer-In-Training



Hung Vu, Ph.D., P.Eng.
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KLB/KRC/HV/jlb

Association of Professional Engineers & Geoscientists of Saskatchewan

CERTIFICATE OF AUTHORIZATION

Golder Associates Ltd.
Number C0230

Permission to Consult held by:

Discipline	Sk. Reg. No.	Signature
Geotechnical	6128	

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APPENDIX A

Record Drawings

AREVA

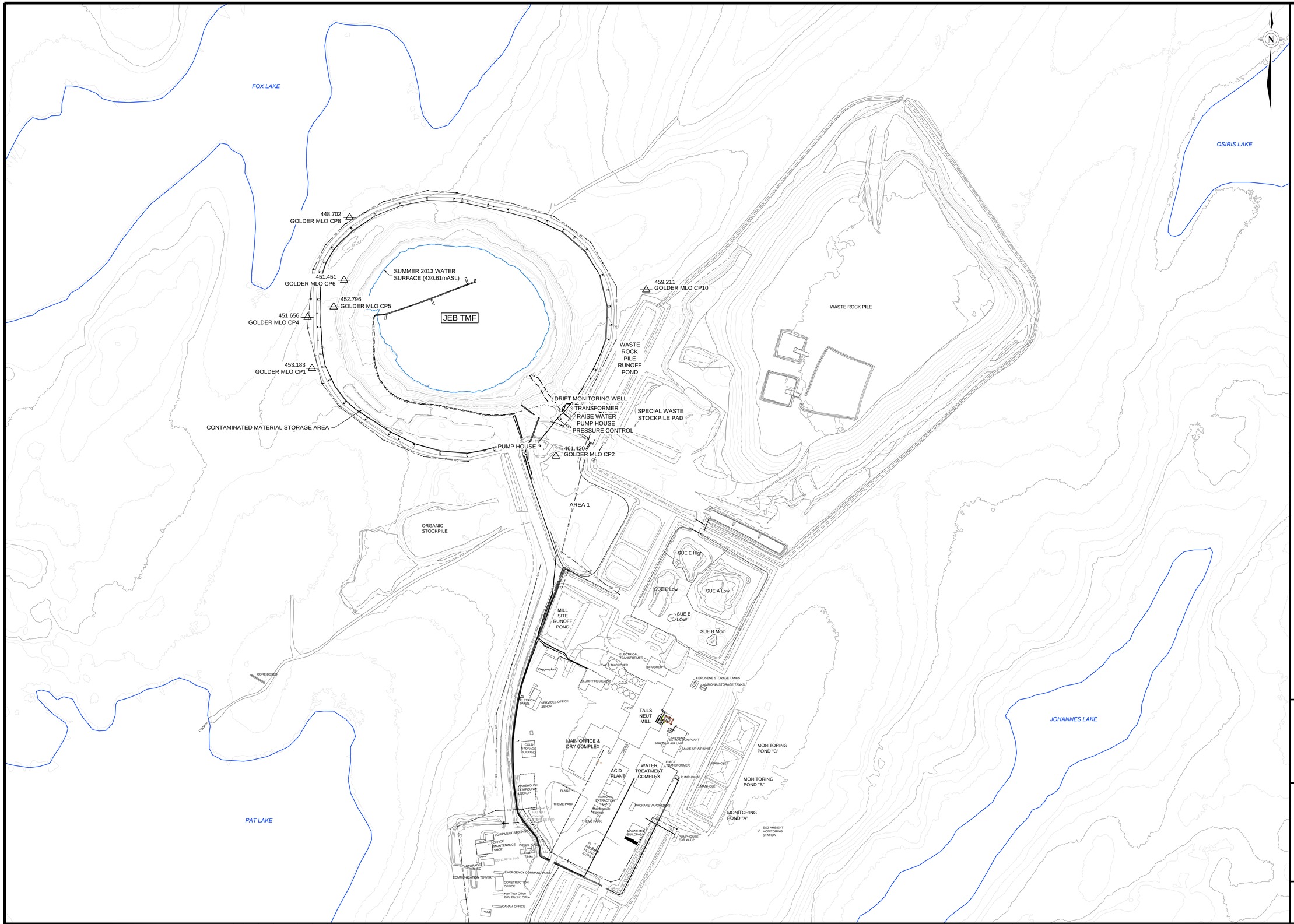
McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
JEB TMF OPTIMIZATION STAGE 1
RECORD DRAWINGS

DRAWING NO.	DRAWING SHEET TITLE	REVISION NO.
GA0020	SITE GENERAL ARRANGEMENT PLAN	01
GA0021	PROJECT LOCATION PLAN	01
GA0022	EXCAVATION PLAN	02
GA0024	PROFILES	02
GA0024.1	SOUTH ACCESS RAMP CROSS SECTIONS	02
GA0024.2	NORTH ACCESS RAMP CROSS SECTIONS	02
GA0023	LINER CONSTRUCTION PLAN	01
GA0025	CROSS SECTIONS - EXCAVATION AND LINER PLACEMENT	03
GA0025.1	CROSS SECTIONS - EXCAVATION AND LINER PLACEMENT	03
GA0025.2	CROSS SECTIONS - EXCAVATION AND LINER PLACEMENT	03
GA0025.3	CROSS SECTIONS - EXCAVATION AND LINER PLACEMENT	03
GA0026	TYPICAL CROSS SECTIONS	03



Golder Associates
Saskatoon, Saskatchewan

G:\CLIENTS\AREVA\McClean Lake Operation\Figures\12-1362-0022 AREVA - JEB Stage 1 Optimization - McClean Lake\1000 - 2012 Preconstruction Preparation\1100 - Finalize Construction Drawings\Stage 1
2012 Record Drawings\12-1362-0022_Title Sheet.dwg, 01/15/2013 10:52:21 AM



NOTES

1. CONTOURS GENERATED FROM LIDAR SURVEY (2009).
2. CONTOURS SHOWN AT 2m INTERVAL.
3. ELEVATIONS ARE REFERENCED TO GEODETIC DATUM: NAD83, ZONE 13.
4. LOCAL MINE COORDINATE SYSTEM.
5. AS-BUILT SURFACES SHOWN WERE OBTAINED FROM AS-BUILT SURVEYS COMPLETED BY GOLDER ASSOCIATES IN 2013 (VARIOUS DATES).

LEGEND

437 EXISTING GROUND CONTOURS

CONTROL POINT

CONTROL POINTS

DESCRIPTION	NORTHING	EASTING	ELEVATION
GOLDER MLO CP1	11109.626	5040.221	453.183
GOLDER MLO CP2	10949.172	5485.630	461.420
GOLDER MLO CP4	11202.765	5032.194	451.656
GOLDER MLO CP5	11221.790	5079.850	452.796
GOLDER MLO CP6	11270.627	5098.761	451.451
GOLDER MLO CP8	11385.195	5108.893	448.702
GOLDER MLO CP10	11253.050	5650.665	459.211

50 0 50
SCALE 1:3,000 METRES

THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc) ARE BASED ON 24"X36" FORMAT DRAWINGS

PROFESSIONAL ENGINEER
G.A. MISFELDT
MEMBER 6128
SASKATCHEWAN

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Golder Associates Ltd.
Number C0230
Permission to Consult held by:

Discipline	Sk. Reg. No.	Signature
Geotechnical	6128	

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Saskatoon, Saskatchewan

REVISIONS						
No.	BY	DATE	APPROVED	DESCRIPTION		
01	JDS	16/12/13	KRC	GAM	RECORD DRAWINGS	
00	JDS	13/06/12	CSF	GAM	ISSUED FOR CONSTRUCTION	
B	JDS	22/04/10	TPCP	GAM	ISSUED FOR TENDER	
A	JDS	23/12/09	TPCP	GAM	ISSUED FOR REVIEW	

REFERENCE

SCALE: AS SHOWN

DRAWN:	JDS	23/12/09
CHD:	TPCP	23/12/09
APP'D:	GAM	23/12/09
DATE ISSUED		DATE

AREVA

FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN SITE GENERAL ARRANGEMENT PLAN
JOB	JEB TMF OPTIMIZATION STAGE 1
PROJECT NO.	12-1362-0022
FILE NAME.	12-1362-0022_General Arrangement.dwg
DRAWING NO.	GA0020

G:\CLIENTS\AREVA\McClean Lake Operation\Figures\12-1362-0022 AREVA - JEB Stage 1 Optimization - McClean Lake\1000 - 2012 Preconstruction Preparation\1100 - Finalize Construction Drawings\Stage 1 2013 Record Dwgs\12-1362-0022_General Arrangement.dwg 12/16/2013 10:37 AM

FOX LAKE

OSIRIS LAKE

JOHANNES LAKE

PAT LAKE

NORTH STOCKPILE AREA

SANDSTONE WASTE ROCK EXCAVATION AREA

448.702
GOLDER MLO CP8

STAGE 1 EXCAVATION EXTENT

SUMMER 2013 WATER SURFACE (430.61mASL)

451.451
GOLDER MLO CP6

459.211
GOLDER MLO CP10

452.796
GOLDER MLO CP5

451.656
GOLDER MLO CP4

JEB TMF

WASTE ROCK PILE

453.183
GOLDER MLO CP1

WASTE ROCK PILE RUNOFF POND

AGGREGATE PROCESSING AREA

DRIFT MONITORING WELL

TRANSFORMER

RAISE WATER PUMP HOUSE

PRESSURE CONTROL

SPECIAL WASTE STOCKPILE PAD

CONTAMINATED MATERIAL STORAGE AREA

PUMP HOUSE

461.420
GOLDER MLO CP2

SOUTH STOCKPILE AREA

AREA 1

ORGANIC STOCKPILE

SUE E High

SUE E Low

SUE A Low

SUE B LOW

SUE B Main

MILL SITE RUNOFF POND

ELECTRICAL TRANSFORMER

TAILS THICKENER

CRUSHER

Oxygen plant

KEROSENE STORAGE TANKS

AMMONIA STORAGE TANKS

SLURRY RECIRC. PUMPS

C.C.C.

ELECTRICAL PANEL

SERVICES OFFICE &SHOP

TAILS NEUT MILL

MAIN OFFICE & DRY COMPLEX

COLD STORAGE BUILDING

SOLVENT EXTRACTION PLANT

MAKE-UP AIR UNIT

ELECT. TRANSFORMER

MANHOLE

WATER TREATMENT COMPLEX

ACID PLANT

PUMPHOUSE

MONITORING POND "C"

MONITORING POND "B"

MONITORING POND "A"

WAREHOUSE COMPOUND LOCKUP

FLAGS

THEME PARK

AMMONIA EXTRACTION PLANT

Maintenance access

PROPANE VAPORIZERS

MAGNETITE BUILDING

PUMPHOUSE FOR WTP

SO2 AMBIENT MONITORING STATION

CONCRETE PAD

EQUIPMENT STORAGE

OFFICE MAINTENANCE SHOP

DIESEL Fuel Tanks

STORAGE Bins

COMMUNICATION TOWER

EMERGENCY COMMAND POST

CONSTRUCTION OFFICE

Kam Tack Office
Bill's Electric Office

CANAM OFFICE

PACI

CORE BOXES

DOCK

NOTES

1. CONTOURS GENERATED FROM LIDAR SURVEY (2009).
2. CONTOURS SHOWN AT 2m INTERVAL.
3. ELEVATIONS ARE REFERENCED TO GEODETIC DATUM: NAD83, ZONE 13.
4. LOCAL MINE COORDINATE SYSTEM.
5. AS-BUILT SURFACES SHOWN WERE OBTAINED FROM AS-BUILT SURVEYS COMPLETED BY GOLDER ASSOCIATES IN 2013 (VARIOUS DATES).

LEGEND

- EXISTING GROUND CONTOURS
- CONTROL POINT
- PROCESSING AREA
- STOCKPILE AREA
- EXCAVATION AREA

CONTROL POINTS

DESCRIPTION	NORTHING	EASTING	ELEVATION
GOLDER MLO CP1	11109.626	5040.221	453.183
GOLDER MLO CP2	10949.172	5485.630	461.420
GOLDER MLO CP4	11202.765	5032.194	451.656
GOLDER MLO CP5	11221.790	5079.850	452.796
GOLDER MLO CP6	11270.627	5098.761	451.451
GOLDER MLO CP8	11385.195	5108.893	448.702
GOLDER MLO CP10	11253.050	5650.665	459.211

SCALE 1:3,000
50 0 50 METRES

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Association of Professional Engineers & Geoscientists of Saskatchewan
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Discipline	Sk. Reg. No.	Signature
Geotechnical	6128	

Golder Associates
Saskatoon, Saskatchewan

REFERENCE

REVISIONS

No.	BY	DATE	APPROVED	DESCRIPTION
01	JDS	16/12/13	KRC	GAM	RECORD DRAWINGS
00	JDS	13/06/12	CSF	GAM	ISSUED FOR CONSTRUCTION
B	JDS	22/04/10	TPCP	GAM	ISSUED FOR TENDER
A	JDS	23/12/09	TPCP	GAM	ISSUED FOR REVIEW

SCALE:	AS SHOWN	
DRAWN:	JDS	23/12/09
CHD:	TPCP	23/12/09
APPD:	GAM	23/12/09
DATE ISSUED		DATE

AREVA

FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN PROJECT LOCATION PLAN
JOB	JEB TMF OPTIMIZATION STAGE 1
PROJECT NO.	12-1362-0022
FILE NAME.	12-1362-0022_Project Location Plan.dwg
DRAWING NO.	GA0021

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FOX LAKE

GAL09-DH3

448.702
GOLDER MLO CP8

GAL09-TP4

GAL09-TP8

GAL09-TP9

GAL09-TP10

GAL09-TP11

TW06

NORTH TURNAROUND AREA

NORTH ACCESS RAMP

3
24

SAFETY BERM

SUMMER 2013 WATER SURFACE (430.61mASL)

SLOPE TRANSITION

TW04

451.451
GOLDER MLO CP6

SANDSTONE CONTACT
SEE PROFILE

1
24

GAL09-TP3

GAL09-TP6

GAL09-TP7

452.796
GOLDER MLO CP5

451.656
GOLDER MLO CP4

JEB TMF

EAST TURNAROUND AREA

SLOPE
TRANSITION

SOUTH TURNAROUND AREA

GAL09-DH2

GAL09-TP5

453.183
GOLDER MLO CP1

GAL09-TP2

0+000

1+068.05

TOE OF SLOPE

TWO EXISTING CSP CULVERTS
DECOMMISSIONED

EXISTING CULVERTS
COVERED WITH COMMON
FILL (BOTH ENDS)

SAFETY BERM

TAILINGS PIPELINES

SLOPE TRANSITION

HDPE PIPE

SOUTH ACCESS RAMP

2
24

GAL09-TP1

RECLAIM LINE

DRIFT MONITORING WELL

TRANSFORMER

RAISE WATER
PUMP HOUSE

PRESSURE
CONTROL

CONTAMINATED MATERIAL STORAGE AREA

TW02

10-01

10-02

PUMP HOUSE

GAL09-DH1

GAL09-DH6/7

461.420
GOLDER MLO CP2

TW07

GAL09-TP12

GAL09-TP13

WASTE ROCK
PILE RUNOFF
POND

SPECIAL WASTE
STOCKPILE PAD

GAL09-DH4/5

459.211
GOLDER MLO CP10

WATER WELL #1
WATER WELL #2
WATER WELL #3
WATER WELL #4
WATER WELL #5
WATER WELL #6
WATER WELL #7
WATER WELL #8
WATER WELL #8A
WATER WELL #9
WATER WELL #9A
WATER WELL #10
WATER WELL #11
WATER WELL #11A
WATER WELL #12
WATER WELL #12A
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WATER WELL #25
WATER WELL #26
WATER WELL #27
WATER WELL #28
WATER WELL #29
WATER WELL #29A
WATER WELL #30
WATER WELL #30A
MW 1
MW 3
MW 5
MW 8

0+000 0+040 0+080 0+120 0+160 0+200 0+240 0+280 0+300 0+320 0+360 0+380 0+400 0+500 0+600 0+700 0+800 0+900 1+000 1+100

1.5:1 3:1

NOTES

1. CONTOURS GENERATED FROM LIDAR SURVEY (2009).
2. CONTOURS SHOWN AT 1m INTERVAL.
3. ELEVATIONS ARE REFERENCED TO GEODETIC DATUM: NAD83, ZONE 13.
4. NORTHINGS AND EASTINGS REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
5. AS-BUILT SURFACES SHOWN WERE OBTAINED FROM AS-BUILT SURVEYS COMPLETED BY GOLDER ASSOCIATES IN 2013 (VARIOUS DATES).

LEGEND

- 437 — ORIGINAL GROUND CONTOURS
- BOREHOLE LOCATION
- TEST PIT LOCATION
- INNER TREND WELLS
- SAFETY BERM LOCATION
- OH — OVERHEAD POWERLINE
- POWER POLE
- EXISTING CSP CULVERT
- CONTROL POINT

CONTROL POINTS

DESCRIPTION	NORTHING	EASTING	ELEVATION
GOLDER MLO CP1	11109.626	5040.221	453.183
GOLDER MLO CP2	10949.172	5485.630	461.420
GOLDER MLO CP4	11202.765	5032.194	451.656
GOLDER MLO CP5	11221.790	5079.850	452.796
GOLDER MLO CP6	11270.627	5098.761	451.451
GOLDER MLO CP8	11385.195	5108.893	448.702
GOLDER MLO CP10	11253.050	5650.665	459.211

20 0 20
SCALE 1:1000 METRES

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REVISIONS

No.	BY	DATE	APPROVED	DESCRIPTION

REVISIONS

No.	BY	DATE	APPROVED	DESCRIPTION
02	JDS	16/12/13	KRC	GAM	RECORD DRAWINGS
01	JDS	17/12/12	CSF	GAM	RECORD OF 2012 CONSTRUCTION
00	JDS	13/06/12	CSF	GAM	ISSUED FOR CONSTRUCTION
B	JDS	22/04/10	TPCP	GAM	ISSUED FOR TENDER
A	JDS	23/12/09	TPCP	GAM	ISSUED FOR REVIEW

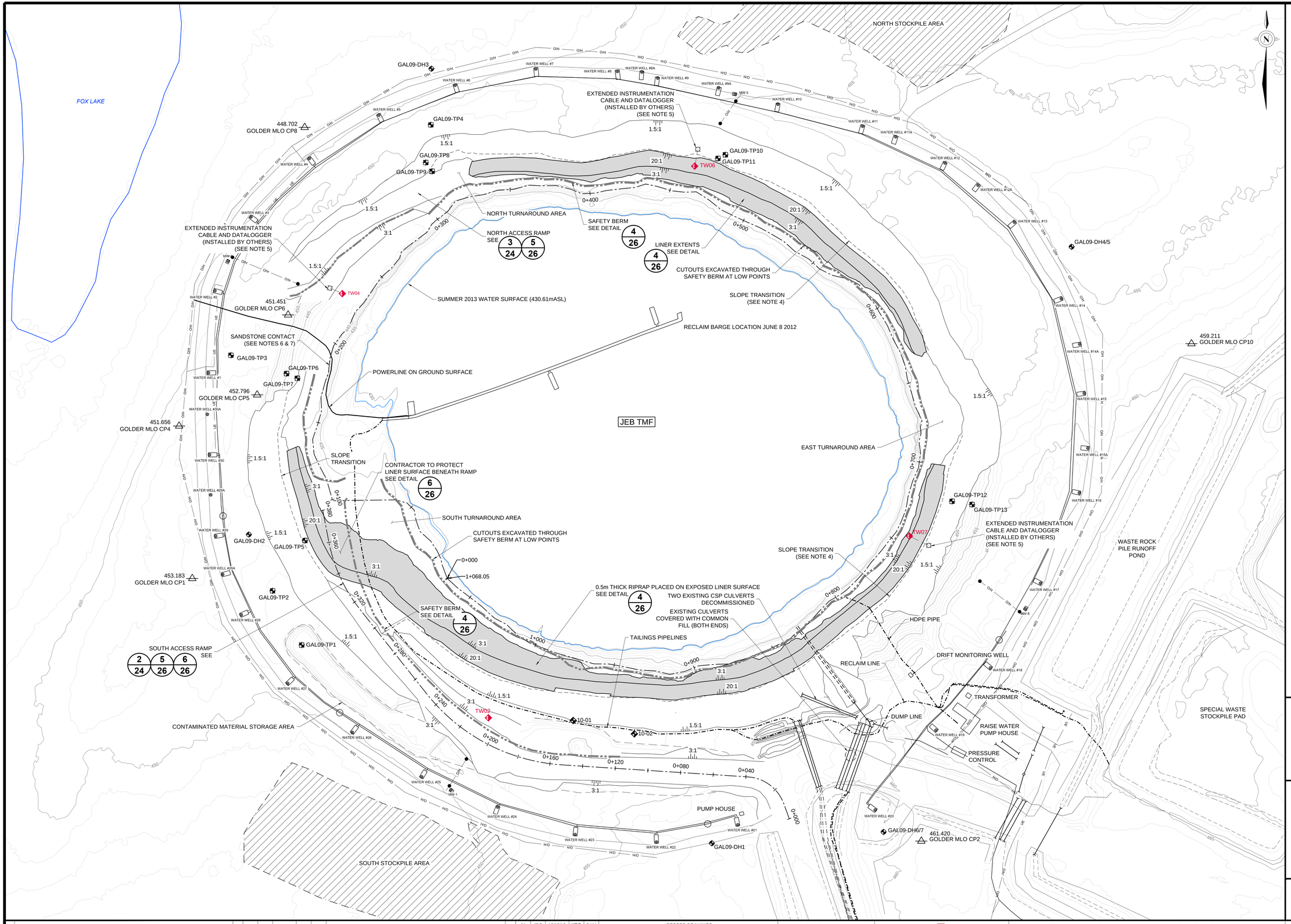
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DRAWN:	JDS	23/12/09
CH'D:	TPCP	23/12/09
APP'D:	GAM	23/12/09
DATE ISSUED		DATE

AREVA

FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN
	EXCAVATION PLAN
JOB	JEB TMF OPTIMIZATION STAGE 1

PROJECT NO.	12-1362-0022
FILE NAME.	12-1362-0022_Excavation Plan.dwg
DRAWING NO.	GA0022

G:\CLIENT\SAREVA\McClean Lake Operation\Figures\12-1362-0022 AREVA - JEB Stage 1 Optimization - McClean Lake\1000 - 2012 Preconstruction Preparation\1100 - Finalize Construction Drawings\Stage 1 2013 Record Dwgs\12-1362-0022_Excavation Plan.dwg 12/18/2013 2:28 PM



NOTES

1. CONTOURS GENERATED FROM LIDAR SURVEY (2009).
2. CONTOURS SHOWN AT 1m INTERVAL.
3. ELEVATIONS AND COORDINATES ARE REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
4. NORTHINGS AND EASTINGS REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
5. INNER TREND WELLS (TW04, TW06, TW07) GROUTED BY OTHERS.
6. AS-BUILT SURFACES SHOWN WERE OBTAINED FROM AS-BUILT SURVEYS COMPLETED BY GOLDER ASSOCIATES IN 2013 (VARIOUS DATES).

LEGEND

- EXISTING GROUND CONTOURS
- BOREHOLE LOCATION
- TEST PIT LOCATION
- INNER TREND WELLS
- SAFETY BERM LOCATION
- OVERHEAD POWERLINE
- POWER POLE
- EXISTING CSP CULVERT
- CONTROL POINT

CONTROL POINTS

DESCRIPTION	NORTHING	EASTING	ELEVATION
GOLDER MLO CP1	11109.626	5040.221	453.183
GOLDER MLO CP2	10949.172	5485.630	461.420
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GOLDER MLO CP10	11253.050	5660.665	459.211

20 0 20
SCALE 1:1000 METRES

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Saskatoon, Saskatchewan

REFERENCE

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REVISIONS	No.	BY	DATE	APPROVED	DESCRIPTION
	01	JDS	16/12/13	KRC GAM	RECORD DRAWINGS
	00	JDS	12/04/13	HV GAM	ISSUED FOR CONSTRUCTION
	C	JDS	14/02/13	CSF GAM	ISSUED FOR REVIEW
	B	JDS	22/04/10	TPCP GAM	ISSUED FOR TENDER
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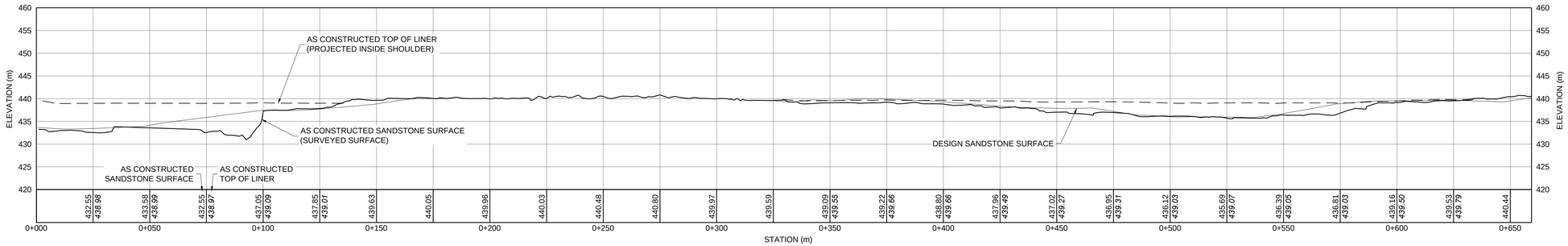
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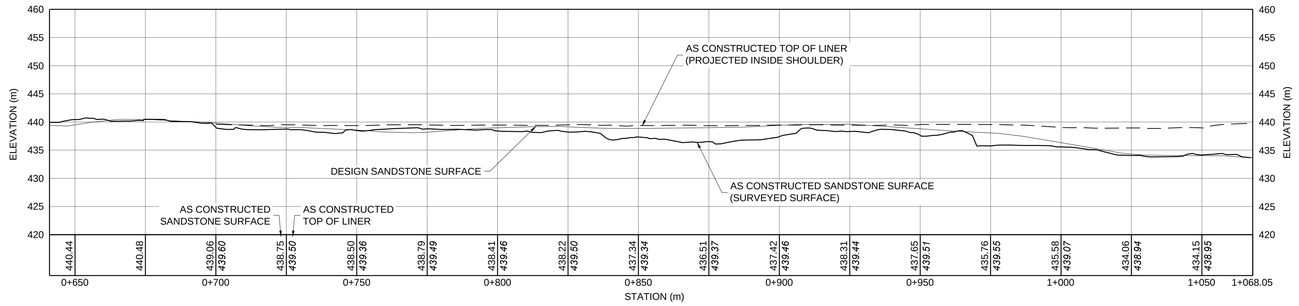
AREVA

FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN LINER CONSTRUCTION PLAN
JOB	JEB TMF OPTIMIZATION STAGE 1

PROJECT NO.	JEB TMF OPTIMIZATION STAGES 1 & 2 (229ML)
FILE NAME.	12-1362-0022_Liner Construction Plan.dwg
DRAWING NO.	GA0023

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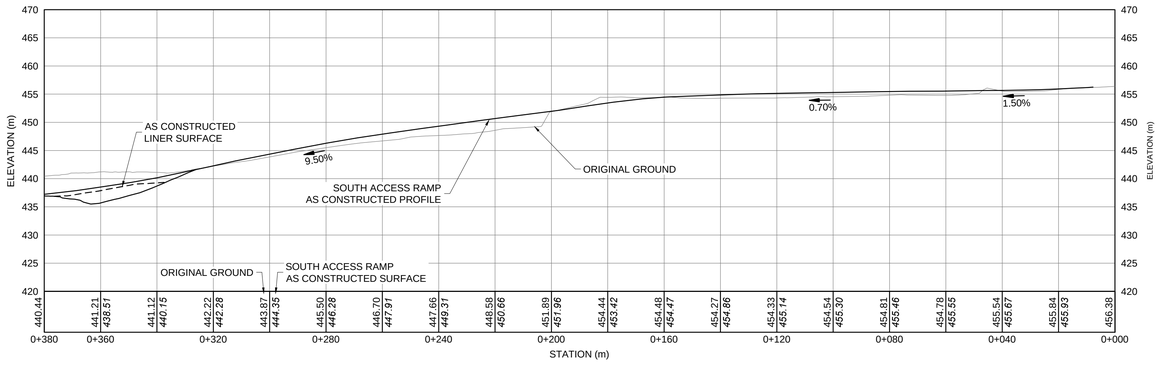




1/22 SANDSTONE CONTACT PROFILE

VERTICAL SCALE 1:500

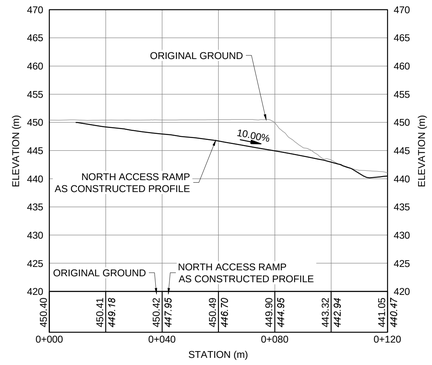
HORIZONTAL SCALE 1:1000



2/22 SOUTH ACCESS RAMP PROFILE

VERTICAL SCALE 1:500

HORIZONTAL SCALE 1:1000



3/22 NORTH ACCESS RAMP PROFILE

VERTICAL SCALE 1:500

HORIZONTAL SCALE 1:1000

NOTES

1. ELEVATIONS ARE REFERENCED TO GEODETIC DATUM: NAD83, ZONE 13.
2. NORTHINGS AND EASTINGS REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
3. SANDSTONE CONTACT ALIGNMENT AND ELEVATIONS PROVIDED BY AREVA.
4. AS-BUILT SURFACES SHOWN WERE OBTAINED FROM AS-BUILT SURVEYS COMPLETED BY GOLDER ASSOCIATES IN 2013 (VARIOUS DATES).

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02	JDS	16/12/13	KRC	GAM		RECORD DRAWINGS
01	JDS	17/12/12	CSF	GAM		RECORD OF 2012 CONSTRUCTION
00	JDS	13/06/12	CSF	GAM		ISSUED FOR CONSTRUCTION
B	JDS	22/04/10	TPCP	GAM		ISSUED FOR TENDER
A	JDS	23/12/09	TPCP	GAM		ISSUED FOR REVIEW

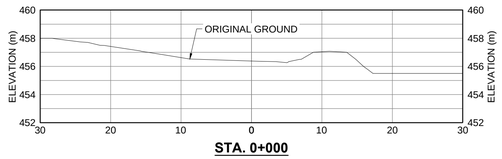
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AREVA

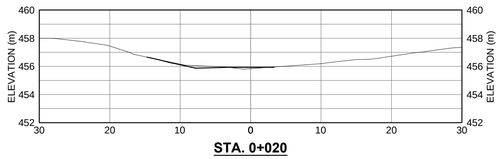
FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN
	PROFILES
JOB	JEB TMF OPTIMIZATION STAGE 1

PROJECT NO.	12-1362-0022
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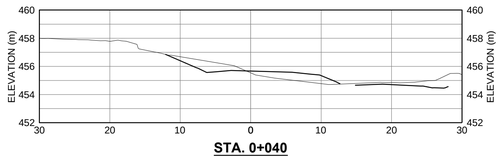
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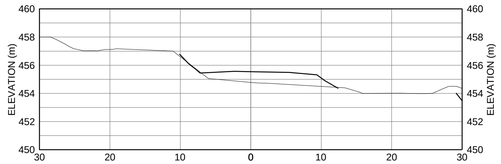
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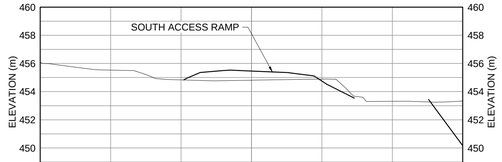
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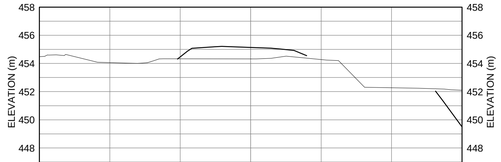
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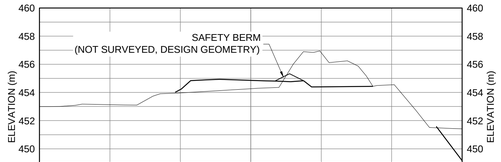
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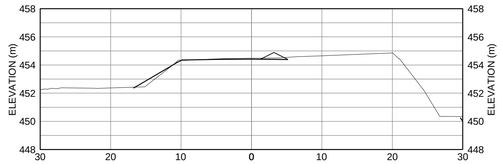
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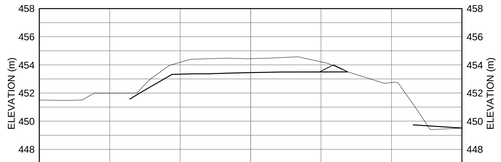
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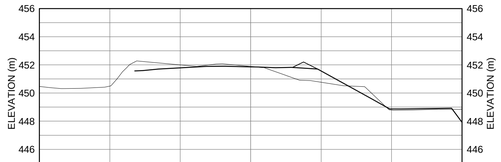
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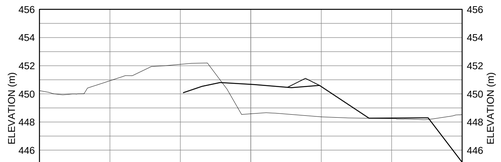
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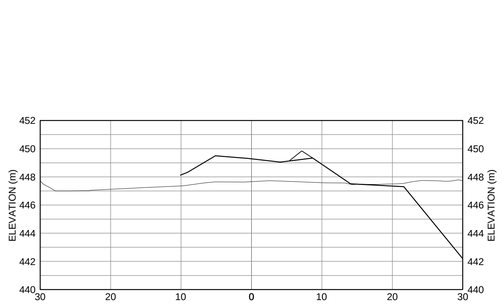
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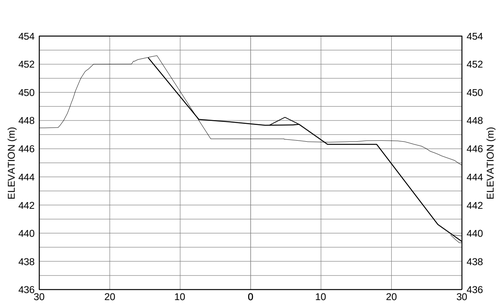
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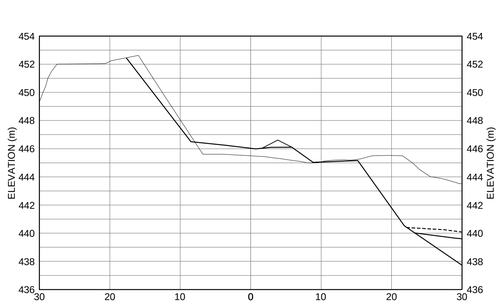
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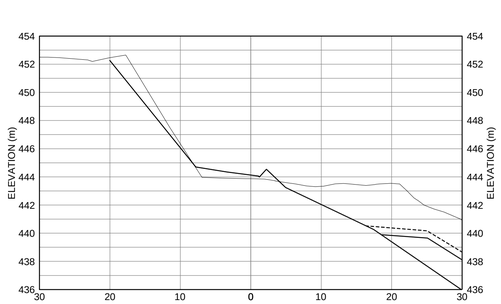
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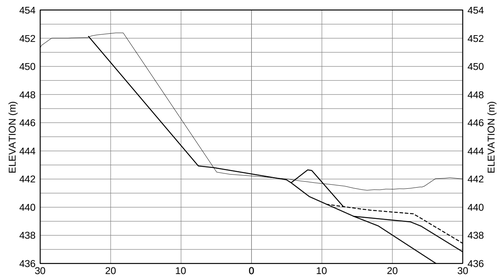
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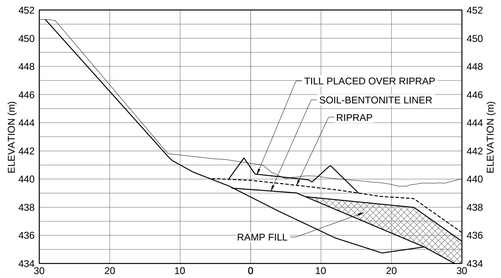
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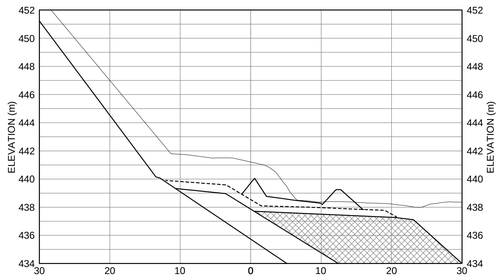
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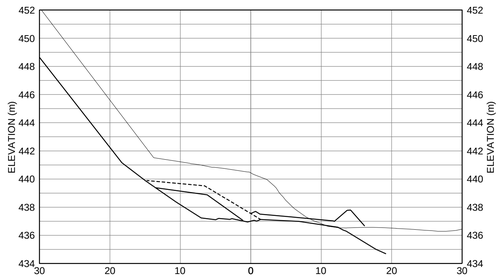
STA. 0+320



STA. 0+340

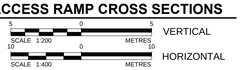


STA. 0+360



STA. 0+380

SOUTH ACCESS RAMP CROSS SECTIONS



NOTES

1. ELEVATIONS ARE REFERENCED TO GEODETIC DATUM: NAD83, ZONE 13.
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PROFESSIONAL ENGINEER
G.A. MISFELDT
MEMBER #6128
SASKATCHEWAN

Association of Professional Engineers & Geoscientists of Saskatchewan
CERTIFICATE OF AUTHORIZATION
Golder Associates Ltd.
Number C0230
Permission to Consult held by:

Discipline	Sk. Reg. No.	Signature
Geotechnical	6128	

Golder Associates
Saskatoon, Saskatchewan

REFERENCE

REVISIONS

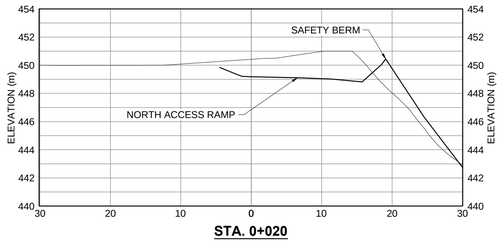
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01	JDS	17/12/12	CSF	GAM	RECORD OF 2012 CONSTRUCTION
00	JDS	13/06/12	CSF	GAM	ISSUED FOR CONSTRUCTION

SCALE:	AS SHOWN	
DRAWN:	JDS	12/06/12
CHD:	CSF	13/06/12
APP'D:	GAM	13/06/12
DATE ISSUED		DATE

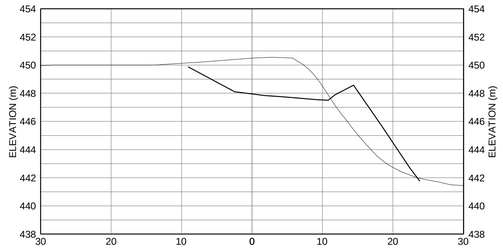
AREVA

FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN SOUTH ACCESS RAMP CROSS SECTIONS
JOB	JEB TMF OPTIMIZATION STAGE 1

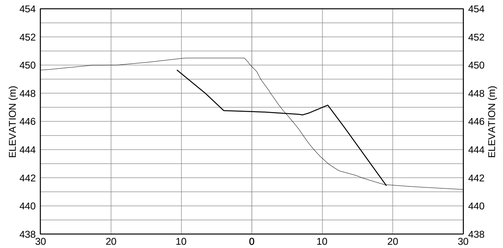
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FILE NAME.	12-1362-0022_Excavation Plan.dwg
DRAWING NO.	GA0024.1



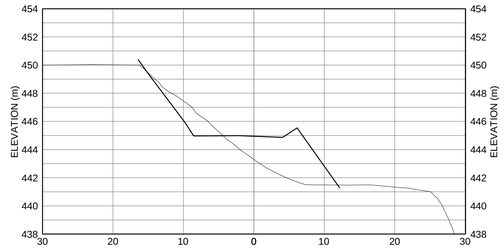
STA. 0+020



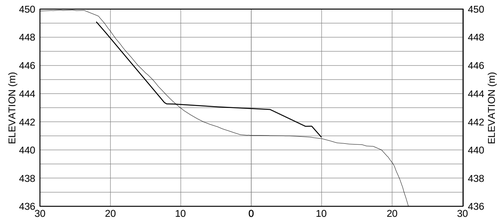
STA. 0+040



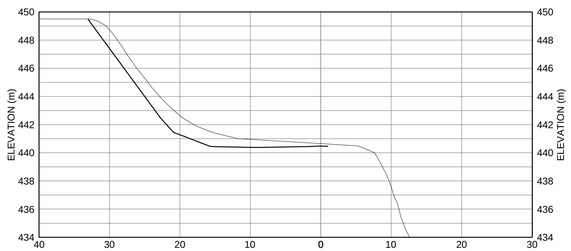
STA. 0+060



STA. 0+080



STA. 0+100



STA. 0+120

NORTH ACCESS RAMP CROSS SECTIONS

5 0 5
SCALE 1:200 METRES
VERTICAL

10 0 10
SCALE 1:400 METRES
HORIZONTAL

NOTES

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G.A. MISFELDT
MEMBER 6128
SASKATCHEWAN
YR. MO. DAY.

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Golder Associates Ltd.
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Discipline	Sk. Reg. No.	Signature
Geotechnical	6128	

Golder Associates
Saskatoon, Saskatchewan

REFERENCE

REVISIONS

No.	BY	DATE	APPROVED	DESCRIPTION

REVISIONS

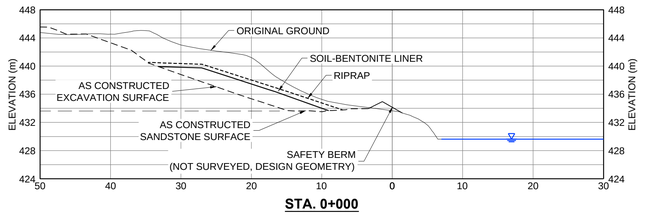
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01	JDS	17/12/12	CSF GAM	RECORD OF 2012 CONSTRUCTION
00	JDS	13/06/12	CSF GAM	ISSUED FOR CONSTRUCTION

SCALE:	AS SHOWN	
DRAWN:	JDS	12/06/12
CHD:	CSF	13/06/12
APPD:	GAM	13/06/12
DATE ISSUED		DATE

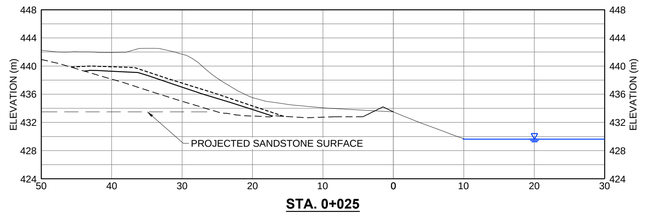
AREVA

FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN
	NORTH ACCESS RAMP CROSS SECTIONS
JOB	JEB TMF OPTIMIZATION STAGE 1

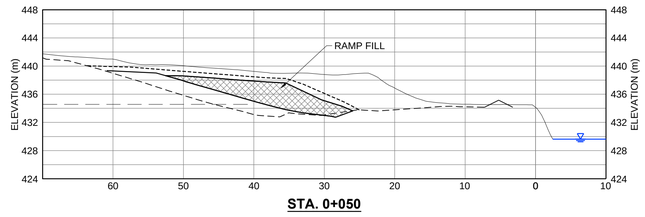
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FILE NAME.	12-1362-0022_Excavation Plan.dwg
DRAWING NO.	GA0024.2



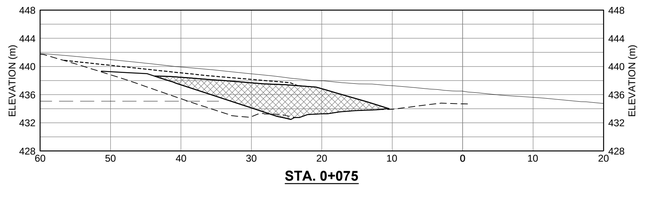
STA. 0+000



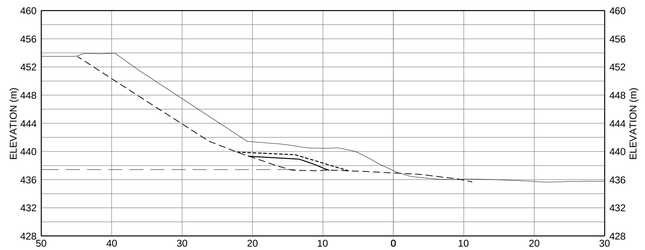
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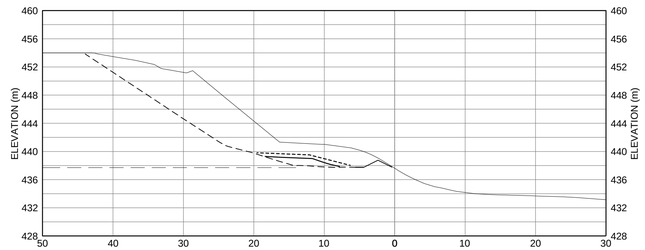
STA. 0+050



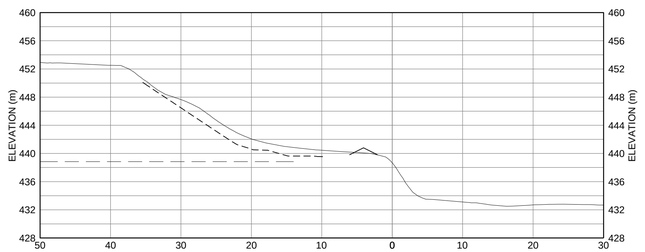
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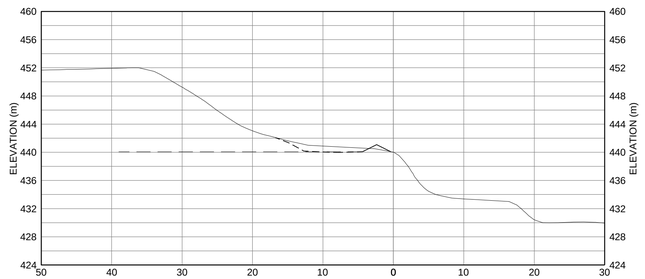
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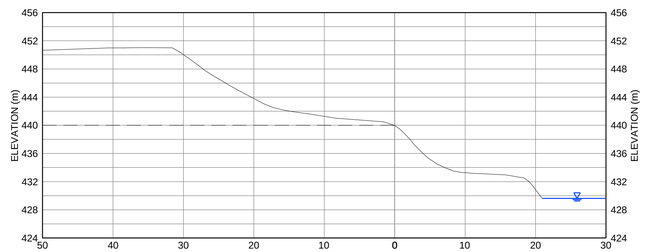
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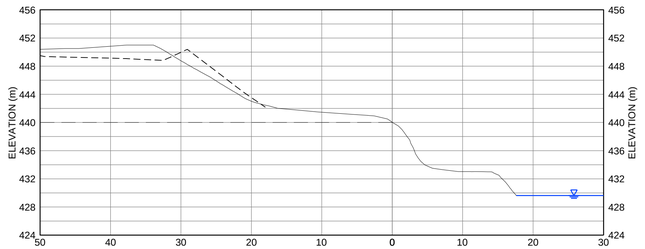
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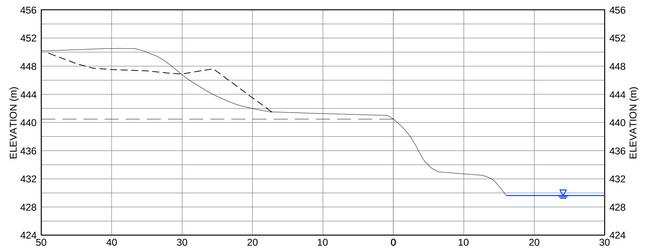
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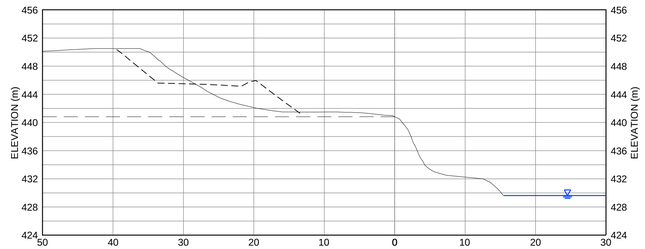
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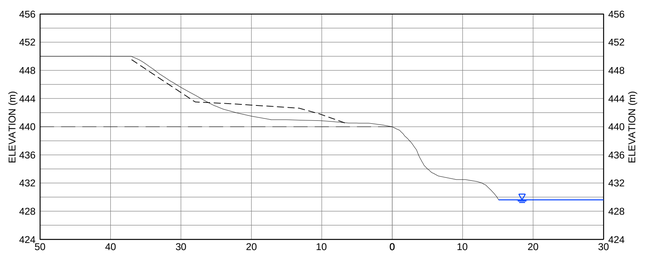
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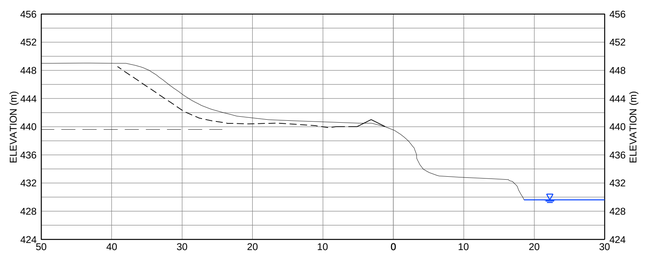
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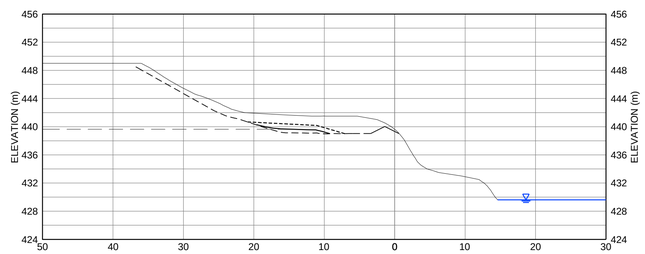
STA. 0+275



STA. 0+300



STA. 0+325



STA. 0+350

CROSS SECTIONS

VERTICAL SCALE 1:200

HORIZONTAL SCALE 1:400

NOTES

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PROFESSIONAL ENGINEER SASKATCHEWAN G. A. MISFELDT MEMBER 6128 TR, MN, DAY 13.12.18

Association of Professional Engineers & Geoscientists of Saskatchewan
CERTIFICATE OF AUTHORIZATION
Golder Associates Ltd.
Number C0230
Permission to Consult held by:

Discipline	Sk. Reg. No.	Signature
Geotech'l	6128	

Golder Associates Saskatoon, Saskatchewan

REFERENCE

REVISIONS						
No.	BY	DATE	APPROVED			DESCRIPTION
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02	JDS	12/04/13	HV	GAM		ISSUED FOR CONSTRUCTION

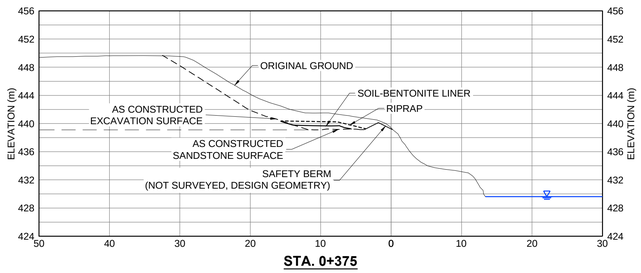
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00	JDS	13/06/12	CSF	GAM		ISSUED FOR CONSTRUCTION
B	JDS	22/04/10	TPCP	GAM		ISSUED FOR TENDER
A	JDS	23/12/09	TPCP	GAM		ISSUED FOR REVIEW

SCALE: AS SHOWN
DRAWN: JDS 23/12/09
CHD: TPCP 23/12/09
APP'D: GAM 23/12/09
DATE ISSUED DATE

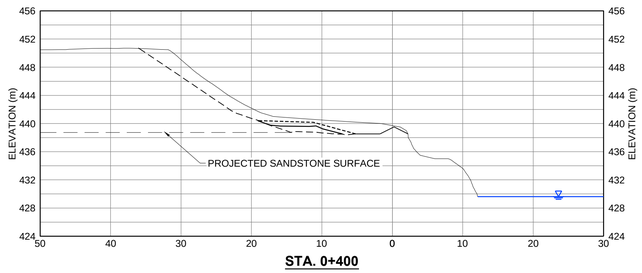
AREVA

FUNCTION McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY CIVIL DESIGN
CROSS SECTIONS - EXCAVATION AND LINER PLACEMENT
JOB JEB TMF OPTIMIZATION STAGE 1

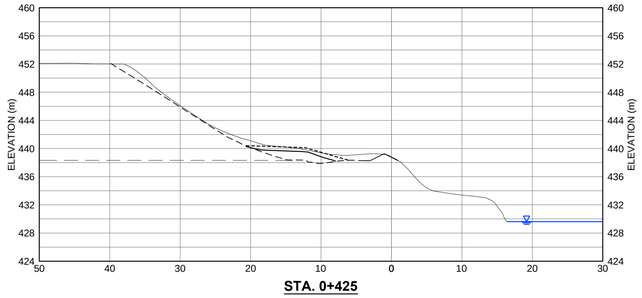
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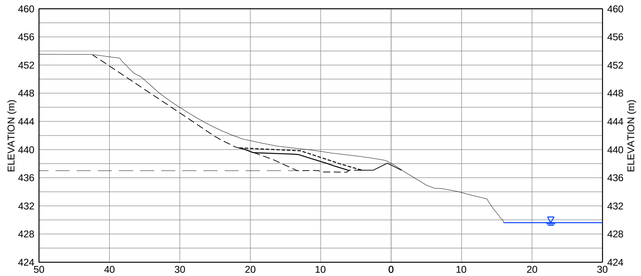
STA. 0+375



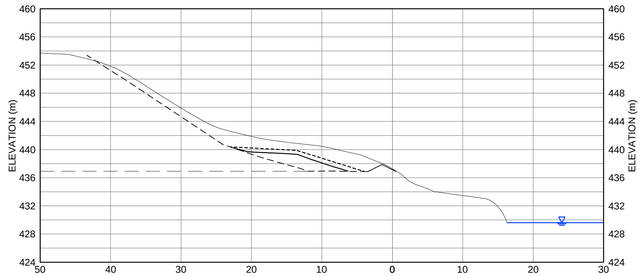
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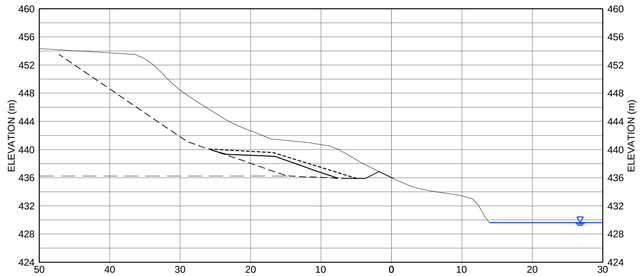
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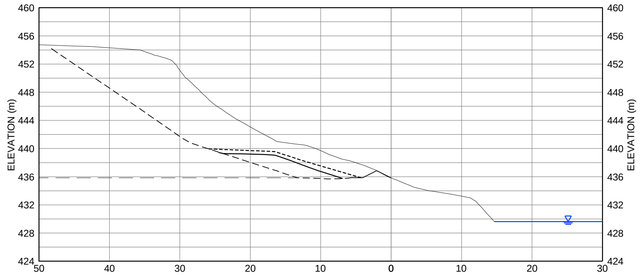
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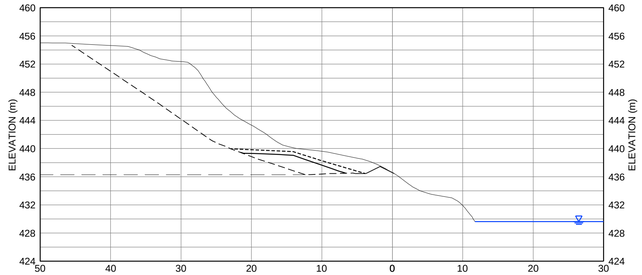
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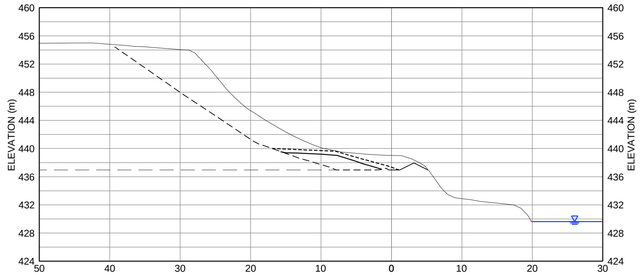
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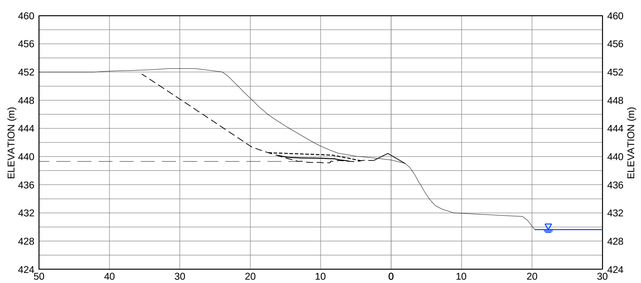
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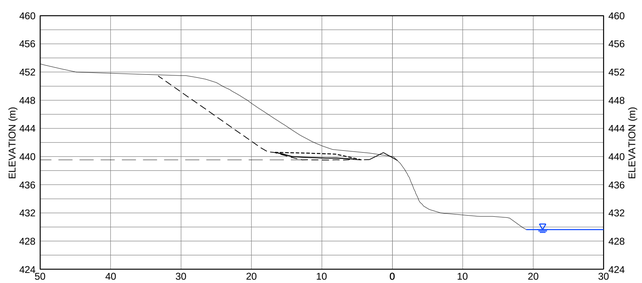
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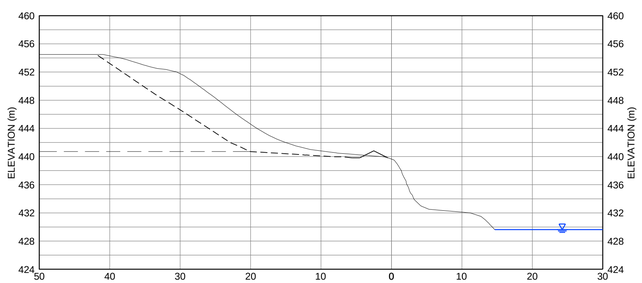
STA. 0+575



STA. 0+600



STA. 0+625



STA. 0+650

CROSS SECTIONS

VERTICAL SCALE 1:200 METRES

HORIZONTAL SCALE 1:400 METRES

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PROFESSIONAL ENGINEER — G.A. MISFELDT — MEMBER 6128 — SASKATCHEWAN — 13 12 12 YR, MN, DAY

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Geotechnical	6128	

Golder Associates
Saskatoon, Saskatchewan

REFERENCE

REVISIONS

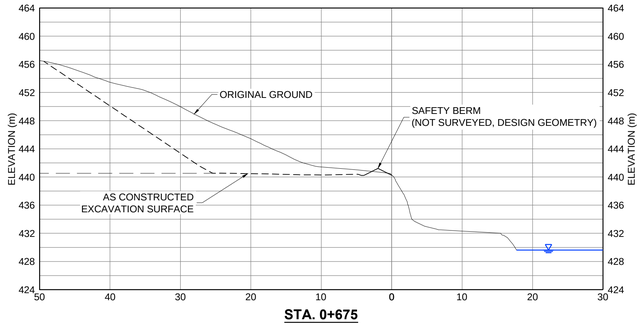
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A	JDS	14/02/13	CSF	GAM	ISSUED FOR REVIEW
01	JDS	17/12/12	CSF	GAM	RECORD OF 2012 CONSTRUCTION
00	JDS	13/06/12	CSF	GAM	ISSUED FOR CONSTRUCTION

SCALE:	AS SHOWN	
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CH'D:	CSF	13/06/12
APP'D:	GAM	13/06/12
DATE ISSUED		DATE

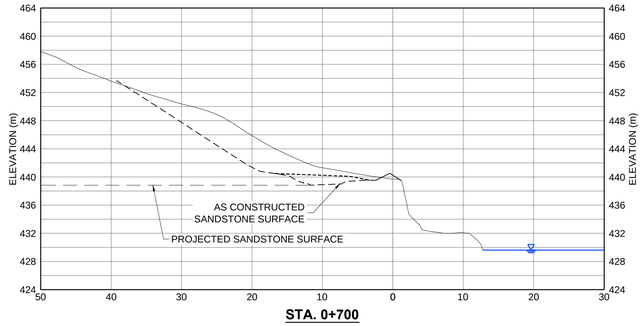
AREVA

FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN CROSS SECTIONS - EXCAVATION AND LINER PLACEMENT
JOB	JEB TMF OPTIMIZATION STAGE 1

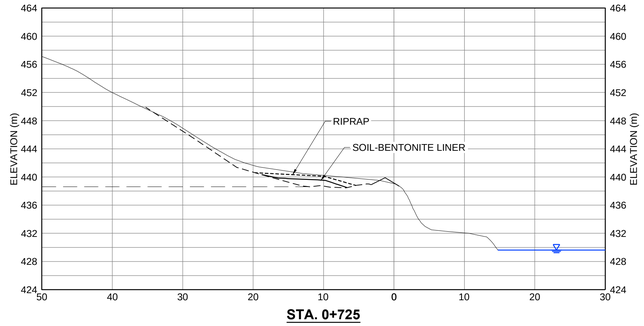
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FILE NAME.	12-1362-0022_Liner Construction Sections.dwg
DRAWING NO.	GA0025.1



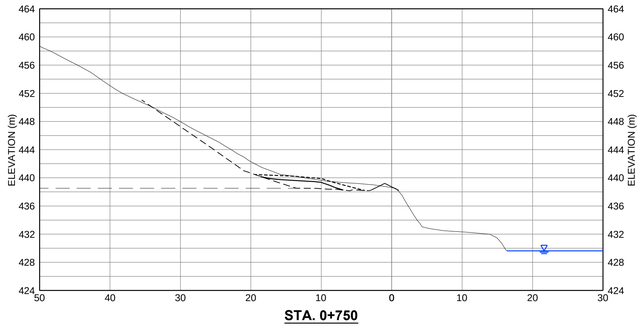
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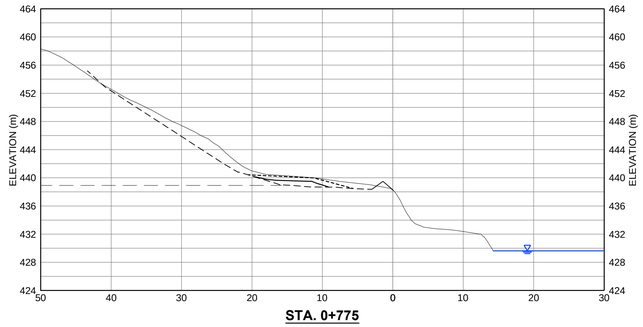
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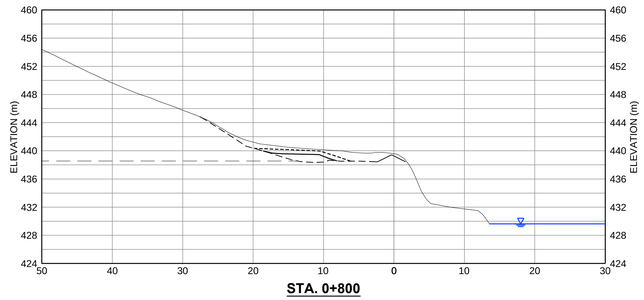
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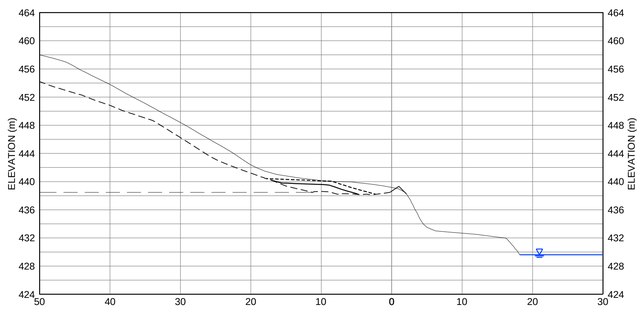
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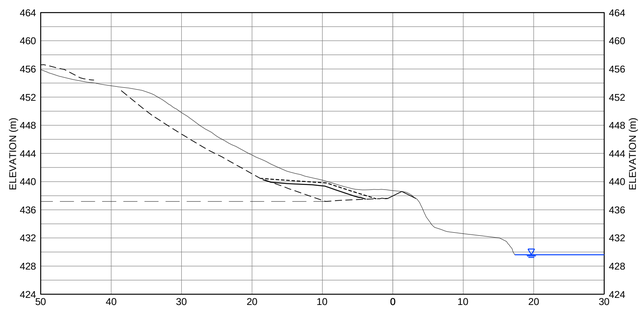
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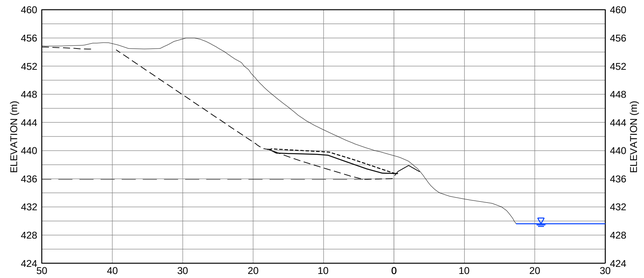
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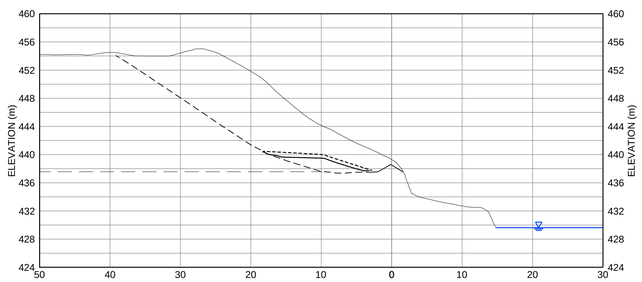
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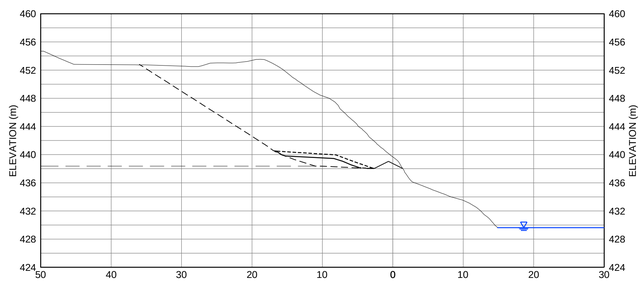
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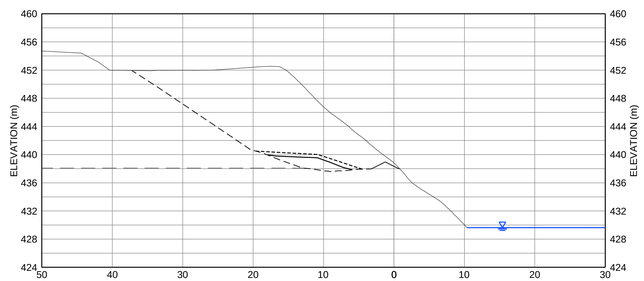
STA. 0+875



STA. 0+900



STA. 0+925



STA. 0+950

CROSS SECTIONS



NOTES

1. ELEVATIONS ARE REFERENCED TO GEODETIC DATUM: NAD83, ZONE 13.
2. NORTHINGS AND EASTINGS REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
3. AS-BUILT SURFACES SHOWN WERE OBTAINED FROM AS-BUILT SURVEYS COMPLETED BY GOLDER ASSOCIATES IN 2013 (VARIOUS DATES).

THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc) ARE BASED ON 24"X36" FORMAT DRAWINGS

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Geotechnical	6128	

Golder Associates
Saskatoon, Saskatchewan

REFERENCE

REVISIONS

No.	BY	DATE	APPROVED	DESCRIPTION

REVISIONS

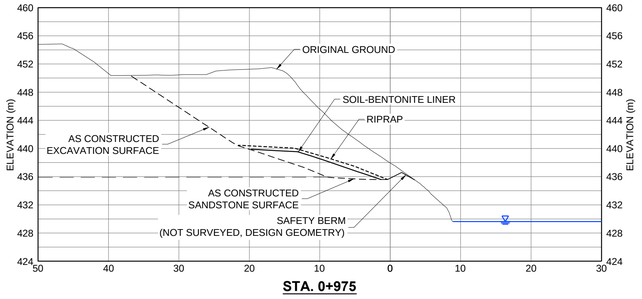
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02	JDS	12/04/13	HV GAM	ISSUED FOR CONSTRUCTION
A	JDS	14/02/13	CSF GAM	ISSUED FOR REVIEW
01	JDS	17/12/12	CSF GAM	RECORD OF 2012 CONSTRUCTION
00	JDS	13/06/12	CSF GAM	ISSUED FOR CONSTRUCTION

SCALE: AS SHOWN
DRAWN: JDS 12/06/12
CHD: CSF 13/06/12
APPD: GAM 13/06/12
DATE ISSUED DATE

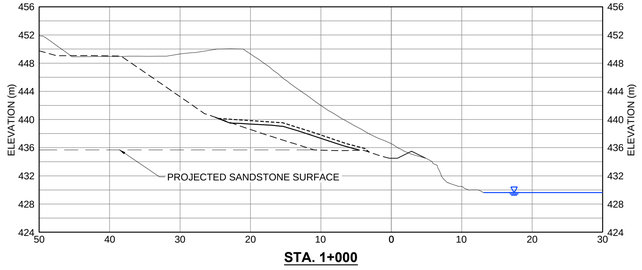
AREVA

FUNCTION McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY CIVIL DESIGN
CROSS SECTIONS - EXCAVATION AND LINER PLACEMENT
JOB JEB TMF OPTIMIZATION STAGE 1

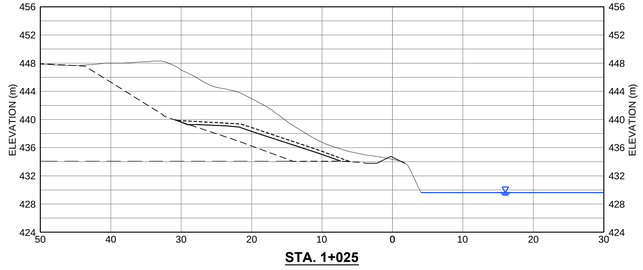
PROJECT NO. JEB TMF OPTIMIZATION STAGES 1 & 2 (229ML)
FILE NAME. 12-1362-0022_Liner Construction Sections.dwg
DRAWING NO. GA0025.2



STA. 0+975



STA. 1+000



STA. 1+025

STA. 1+050

CROSS SECTIONS

5 0 5
SCALE 1:200 METRES VERTICAL

10 0 10
SCALE 1:400 METRES HORIZONTAL

NOTES

1. ELEVATIONS ARE REFERENCED TO GEODETIC DATUM: NAD83, ZONE 13.
2. NORTHINGS AND EASTINGS REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
3. AS-BUILT SURFACES SHOWN WERE OBTAINED FROM AS-BUILT SURVEYS COMPLETED BY GOLDER ASSOCIATES IN 2013 (VARIOUS DATES).

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Geotechnical	6128	

Golder Associates
Saskatoon, Saskatchewan

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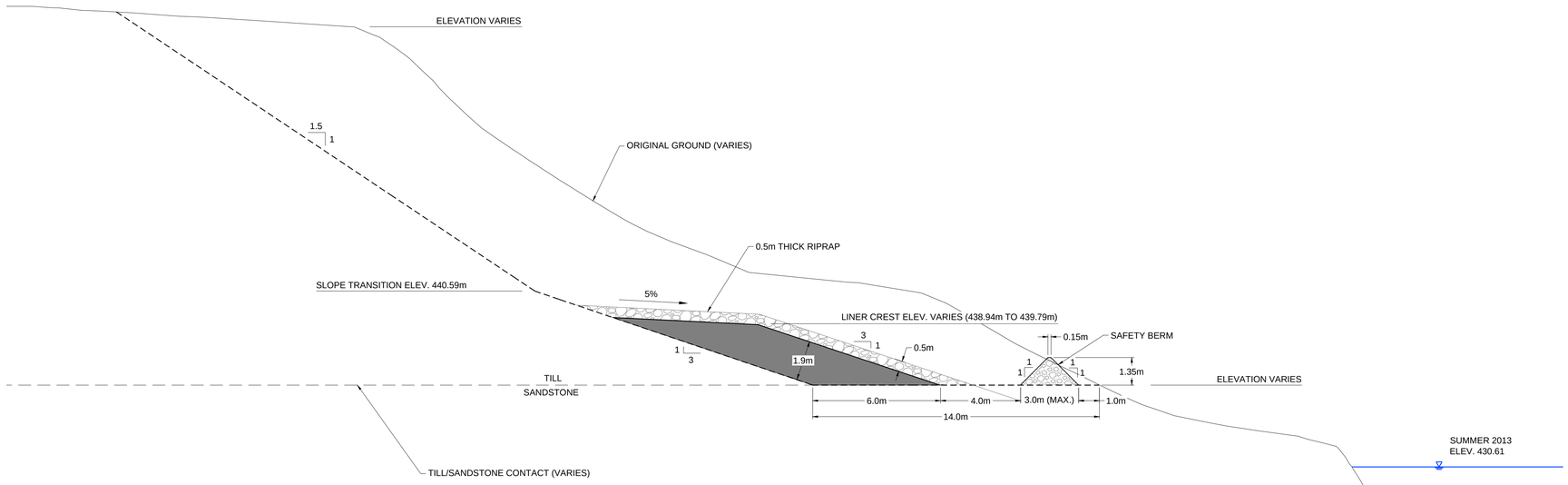
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No.	BY	DATE	APPROVED		DESCRIPTION	

REVISIONS						
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02	JDS	12/04/13	HV	GAM	ISSUED FOR CONSTRUCTION	
A	JDS	14/02/13	CSF	GAM	ISSUED FOR REVIEW	
01	JDS	17/12/12	CSF	GAM	RECORD OF 2012 CONSTRUCTION	
00	JDS	13/06/12	CSF	GAM	ISSUED FOR CONSTRUCTION	

SCALE:	AS SHOWN	
DRAWN:	JDS	12/06/12
CHD:	CSF	13/06/12
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DATE ISSUED		DATE

AREVA

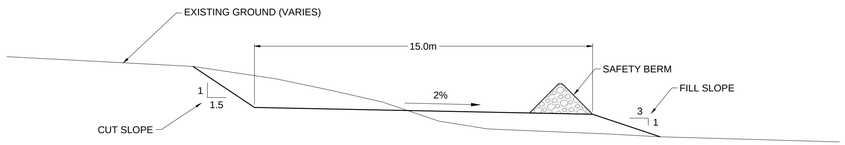
FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN CROSS SECTIONS - EXCAVATION AND LINER PLACEMENT
JOB	JEB TMF OPTIMIZATION STAGE 1
PROJECT NO.	JEB TMF OPTIMIZATION STAGES 1 & 2 (229ML)
FILE NAME.	12-1362-0022_Liner Construction Sections.dwg
DRAWING NO.	GA0025.3



TYPICAL CROSS SECTION
JEB TMF STAGE 1 OPTIMIZATION

4 / 22 / 23

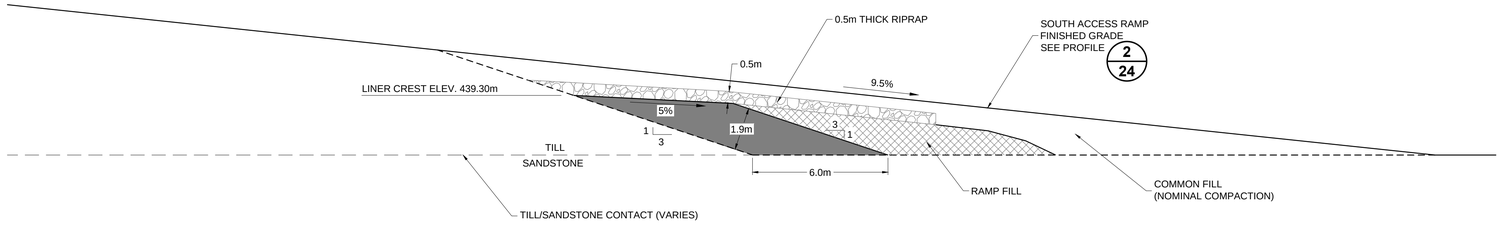
2.5 0 2.5
SCALE 1:125 METRES



TYPICAL CROSS SECTION
NORTH AND SOUTH ACCESS RAMP

5 / 22 / 23

2.5 0 2.5
SCALE 1:125 METRES



SOUTH RAMP LINER DETAIL
JEB TMF STAGE 1 OPTIMIZATION

6 / 23

2.5 0 2.5
SCALE 1:125 METRES

NOTES

1. ELEVATIONS AND COORDINATES ARE REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
2. AS-BUILT SURFACES SHOWN WERE OBTAINED FROM AS-BUILT SURVEYS COMPLETED BY GOLDER ASSOCIATES IN 2013 (VARIOUS DATES).

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No.	BY	DATE	APPROVED	DESCRIPTION
03	JDS	16/12/13	KRC	GAM	RECORD DRAWINGS
02	JDS	12/04/13	HV	GAM	ISSUED FOR CONSTRUCTION
A	JDS	14/02/13	CSF	GAM	ISSUED FOR REVIEW
01	JDS	23/07/12	CSF	GAM	ISSUED FOR CONSTRUCTION
00	JDS	13/06/12	CSF	GAM	ISSUED FOR CONSTRUCTION

REVISIONS

SCALE:	AS SHOWN	
DRAWN:	JDS	23/07/12
CH'D:	CSF	23/07/12
APP'D:	GAM	23/07/12
DATE ISSUED		DATE

AREVA

FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN TYPICAL CROSS SECTIONS
JOB	JEB TMF OPTIMIZATION STAGE 1
PROJECT NO.	JEB TMF OPTIMIZATION STAGES 1 & 2 (229ML)
FILE NAME.	12-1362-0022_Liner Construction Plan.dwg
DRAWING NO.	GA0026

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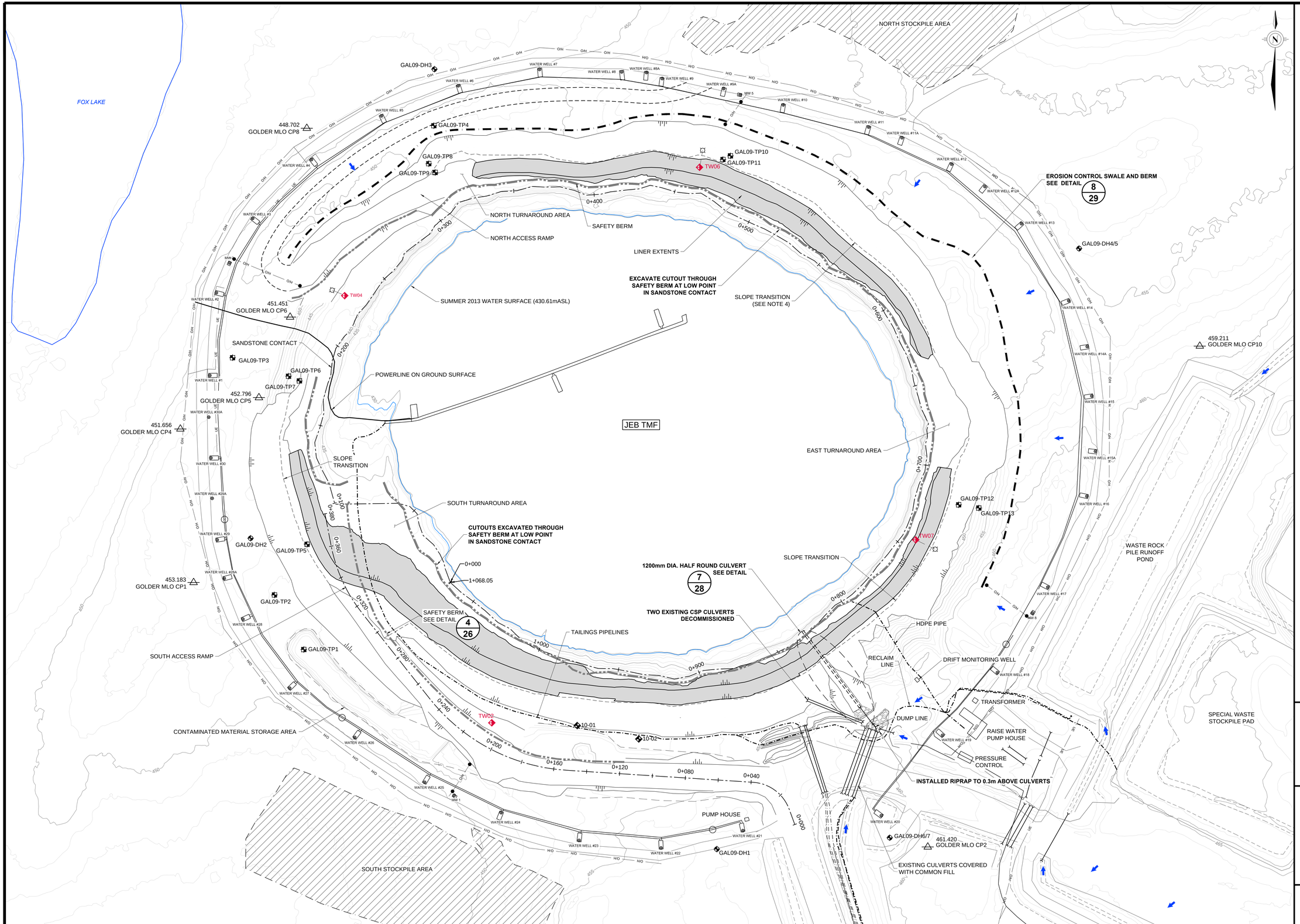
McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
JEB TMF OPTIMIZATION STAGE 1
EROSION CONTROL PLAN
RECORD DRAWINGS

DRAWING NO.	DRAWING SHEET TITLE	REVISION NO.
GA0027	EROSION CONTROL PLAN	1
GA0028	EROSION CONTROL DETAILS	1
GA0029	EROSION CONTROL DETAILS	1



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Erosion Control\12-1362-0022-Erosion_Control_Plan_Sheet.dwg, 10/29/2012 2:36:41 PM



NOTES

1. CONTOURS GENERATED FROM LIDAR SURVEY (2009).
2. CONTOURS SHOWN AT 1m INTERVAL.
3. ELEVATIONS AND COORDINATES ARE REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
4. NORTHINGS AND EASTINGS REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
5. INNER TREND WELLS (TW04, TW06, TW07) GROUTED BY OTHERS.
6. AS-BUILT SURFACES SHOWN WERE OBTAINED FROM AS-BUILT SURVEYS COMPLETED BY GOLDER IN 2013 (VARIOUS DATES).

LEGEND

- EXISTING GROUND CONTOURS
- BOREHOLE LOCATION
- TEST PIT LOCATION
- INNER TREND WELLS
- SAFETY BERM LOCATION
- OVERHEAD POWERLINE
- POWER POLE
- EXISTING CSP CULVERT
- CONTROL POINT
- EROSION CONTROL SWALE AND BERM
- APPROXIMATE SURFACE RUNOFF DIRECTION

CONTROL POINTS

DESCRIPTION	NORTHING	EASTING	ELEVATION
GOLDER MLO CP1	11109.626	5040.221	453.183
GOLDER MLO CP2	10949.172	5485.630	461.420
GOLDER MLO CP4	11202.765	5032.194	451.656
GOLDER MLO CP5	11221.790	5079.850	452.796
GOLDER MLO CP6	11270.627	5098.761	451.451
GOLDER MLO CP8	11385.195	5108.893	448.702
GOLDER MLO CP10	11253.050	5650.665	459.211

20 0 20
SCALE 1:1000 METRES

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Discipline	Sk. Reg. No.	Signature
Geotechnical	6128	

Golder Associates
Saskatoon, Saskatchewan

REVISIONS					
No.	BY	DATE	APPROVED	DESCRIPTION	
1	JDS	16/12/13	KRC	GAM	RECORD DRAWINGS
0	JDS	10/05/13	HV	GAM	ISSUED FOR CONSTRUCTION
C	JDS	26/04/13	KRC	HV	ISSUED FOR DISCUSSION
B	JDS	17/04/13	KRC	HV	ISSUED FOR DISCUSSION
A	JDS	01/03/13	KRC	GAM	ISSUED FOR REVIEW

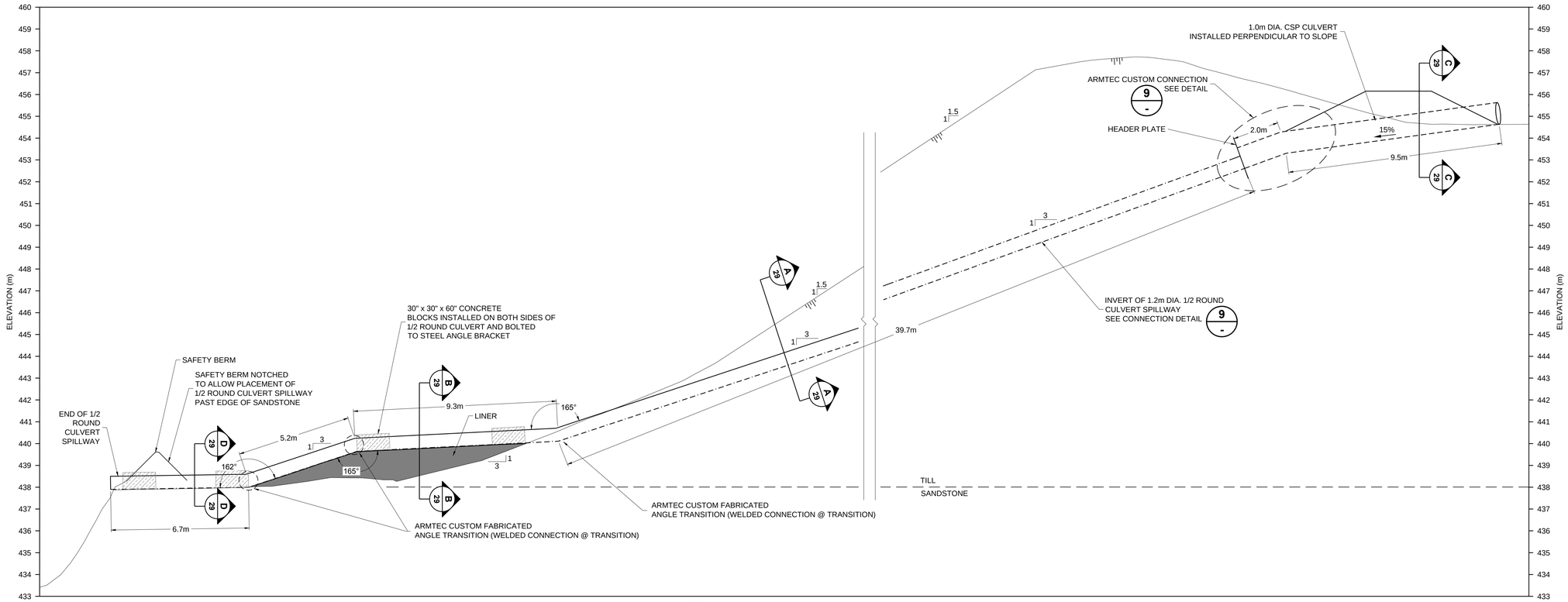
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APP'D:	HV	17/04/13
DATE ISSUED		DATE

AREVA

FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN EROSION CONTROL PLAN
JOB	JEB TMF OPTIMIZATION STAGE 1

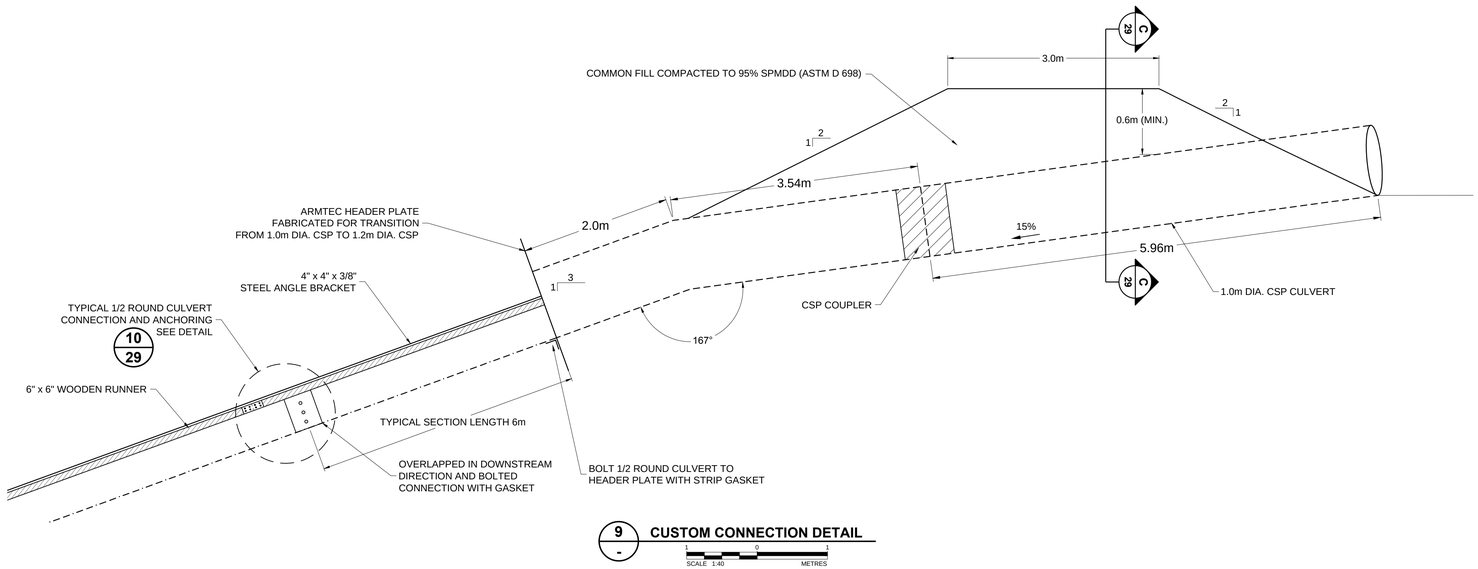
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FILE NAME.	12-1362-0022_Erosion Control Plan.dwg
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7/27 1/2 ROUND CULVERT DETAIL

SCALE 1:100 METRES



9/- CUSTOM CONNECTION DETAIL

SCALE 1:40 METRES

NOTES

1. ELEVATIONS AND COORDINATES REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
2. AS-BUILT SURFACES SHOWN WERE OBTAINED FROM GOLDER ASSOCIATES AS-BUILT SURVEY COMPLETED IN 2013 AND ARMTEC DESIGN DRAWINGS FOR HALF ROUND CULVERT.

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13 Feb 18
YR, MN, DAY

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Saskatoon, Saskatchewan

REFERENCE

REVISIONS

No.	BY	DATE	APPROVED	DESCRIPTION

REVISIONS

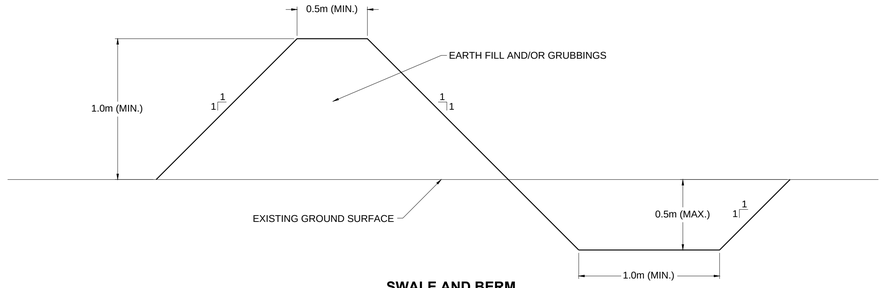
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C	JDS	26/04/13	KRC	HV	ISSUED FOR DISCUSSION
B	JDS	17/04/13	KRC	HV	ISSUED FOR DISCUSSION
A	JDS	01/03/13	KRC	GAM	ISSUED FOR REVIEW

SCALE:	AS SHOWN	
DRAWN:	JDS	17/04/13
CHD:	KRC	17/04/13
APP'D:	HV	17/04/13
DATE ISSUED		DATE

AREVA

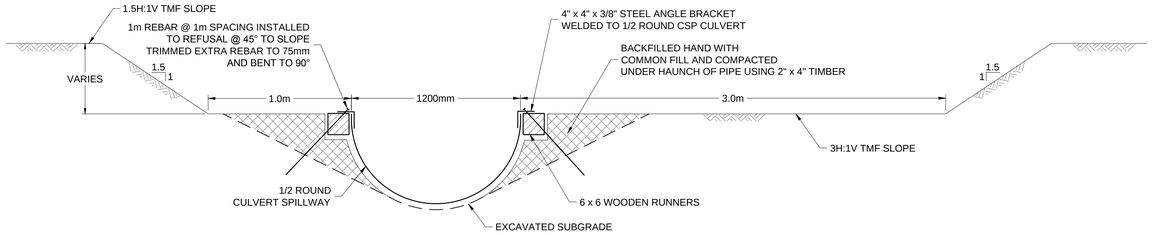
FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN EROSION CONTROL DETAILS
JOB	JEB TMF OPTIMIZATION STAGE 1
PROJECT NO.	JEB TMF OPTIMIZATION STAGES 1 & 2 (229ML)
FILE NAME.	12-1362-0022_Erosion Control Plan.dwg
DRAWING NO.	GA0028

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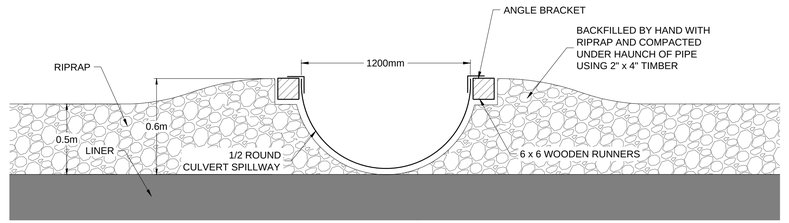
SWALE AND BERM TYPICAL CROSS SECTION

8/27 — SCALE 1:20 — 0.5 0 0.5 METRES



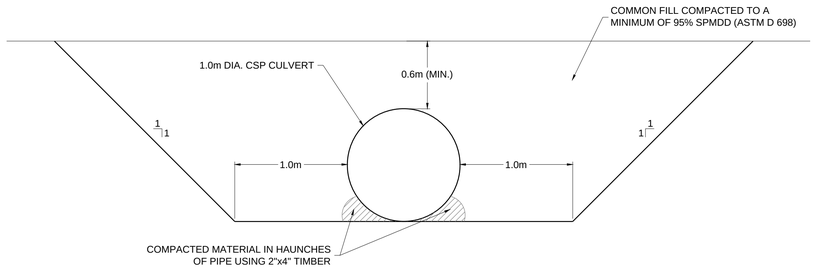
CROSS SECTION 1/2 ROUND SPILLWAY ON TILL SLOPE

A/28 — SCALE 1:20 — 0.5 0 0.5 METRES



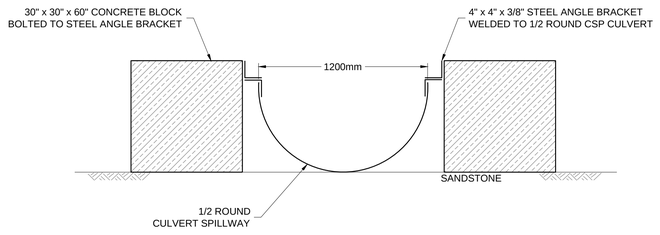
CROSS SECTION 1/2 ROUND SPILLWAY ON LINER

B/28 — SCALE 1:20 — 0.5 0 0.5 METRES



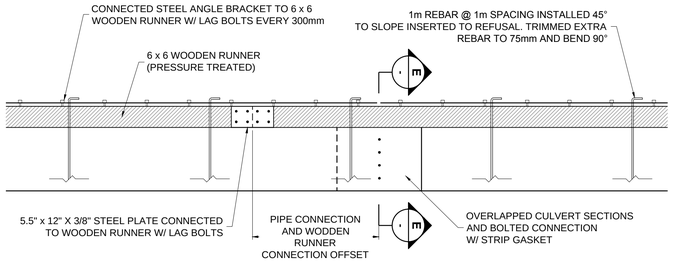
CROSS SECTION C-C - TYPICAL CULVERT BACKFILL PLAN

C/28 — SCALE 1:25 — 0.5 0 0.5 METRES



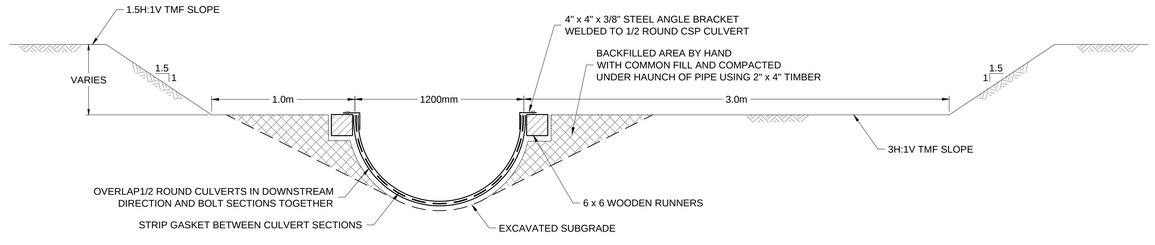
CROSS SECTION 1/2 ROUND SPILLWAY ON SANDSTONE

D/28 — SCALE 1:20 — 0.5 0 0.5 METRES



TYPICAL PROFILE THROUGH 1/2 ROUND CULVERT PIPE CONNECTION

10/28 — SCALE 1:20 — 0.5 0 0.5 METRES



TYPICAL CROSS SECTION THROUGH 1/2 ROUND CULVERT PIPE CONNECTION

E/- — SCALE 1:20 — 0.5 0 0.5 METRES

NOTES

1. ELEVATIONS AND COORDINATES REFERENCED TO LOCAL MINE COORDINATE SYSTEM.
2. AS-BUILT SURFACES SHOWN WERE OBTAINED FROM GOLDER ASSOCIATES AS-BUILT SURVEY COMPLETED IN 2013 AND ARMTEC DESIGN DRAWINGS FOR HALF ROUND CULVERT.

THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc) ARE BASED ON 24"X36" FORMAT DRAWINGS

PROFESSIONAL ENGINEER — G.A. MISFELDT — MEMBER 14122 — SASKATCHEWAN — YR, MN, DAY

Association of Professional Engineers & Geoscientists of Saskatchewan
CERTIFICATE OF AUTHORIZATION
Golder Associates Ltd.
Number C0230
Permission to Consult held by:

Discipline	Sk. Reg. No.	Signature
Geotechnical	6128	

Golder Associates — Saskatoon, Saskatchewan

REFERENCE

No.	BY	DATE	APPROVED	DESCRIPTION

REVISIONS

No.	BY	DATE	APPROVED	DESCRIPTION
1	JDS	16/12/13	KRC	GAM	RECORD DRAWINGS
0	JDS	10/05/13	HV	GAM	ISSUED FOR CONSTRUCTION
C	JDS	26/04/13	KRC	HV	ISSUED FOR DISCUSSION
B	JDS	17/04/13	KRC	HV	ISSUED FOR DISCUSSION
A	JDS	01/03/13	KRC	GAM	ISSUED FOR REVIEW

SCALE:	AS SHOWN	
DRAWN:	JDS	17/04/13
CHD:	KRC	17/04/13
APP'D:	HV	17/04/13
DATE ISSUED		DATE

AREVA

FUNCTION	McCLEAN LAKE TAILINGS MANAGEMENT FACILITY
ACTIVITY	CIVIL DESIGN EROSION CONTROL DETAILS
JOB	JEB TMF OPTIMIZATION STAGE 1

PROJECT NO.	JEB TMF OPTIMIZATION STAGES 1 & 2 (229ML)
FILE NAME.	12-1362-0022_Erosion Control Plan.dwg
DRAWING NO.	GA0029

G:\CLIENT\SAREVA\McClean Lake Operation\Figures\12-1362-0022 AREVA - JEB Stage 1 Optimization - McClean Lake\1000 - 2012 Preconstruction Preparation\1100 - Finalize Construction Drawings\Stg 1 Erosion Record Dwgs\12-1362-0022_Erosion Control Plan.dwg 12/16/2013 11:14 AM

APPENDIX B

Photo Log



Photo 1 - Pugmill calibration of bentonite content (2013-06-20)



Photo 2 - Pugmill calibration of liner base material content (2013-06-21)



Photo 3 - Calibrate water content of soil bentonite liner from pugmill (2013-06-21)



Photo 4 - Pugmill mixing shafts and water nozzles (2013-06-21)



Photo 5 - 3H-IV till slope grading (2013-06-23)



Photo 6 - 3H-IV till slope grading (2013-07-05)



Photo 7 - Cleaning sandstone with skid steer and mechanical broom (2013-06-28)



Photo 8 - Cleaning sandstone with skid steer and mechanical broom (2013-06-28)



Photo 9 - Excavation for half round culvert (2013-07-01)



Photo 10 - Inspection of sandstone contact by Golder Associates QAQC technician (2013-07-03)



Photo 11 - Cleaned sandstone surface (2013-07-07)



Photo 12 - Placing soil bentonite liner (2013-07-07)



Photo 13 - Compacting Soil Bentonite liner (2013-07-07)



Photo 14 - Compacted soil bentonite liner (2013-07-10)



Photo 15 - Cleaning sandstone surface (2013-07-12)



Photo 16 - Scarification of soil bentonite liner required prior to the next lift (2013-07-14)



Photo 17 - Cleaning Sandstone surface- Soil bentonite liner in-place in background (2013-07-15)



Photo 18 - Placing soil bentonite liner (2013-07-20)



Photo 19 - Cleaned sandstone surface (2013-07-24)



Photo 20 - Cleaned sandstone surface (2013-07-25)



Photo 21 - Cleaned sandstone surface (2013-07-27)



Photo 22 - Scarification of soil bentonite liner required prior to the next lift (2013-08-02)



Photo 23 - Excavation of south access ramp prior to liner placement (2013-08-07)



Photo 24 - Cleaning sandstone contact at south access ramp (2013-08-08)



Photo 25 - Excavation for half round culvert (2013-08-11)



Photo 26 - Installation of half round culvert (2013-08-14)



Photo 27 - Installation of half round culvert (2013-08-15)



Photo 28 - Compacting the haunches of the half round culvert (2013-08-15)



Photo 29 - Screening till to produce liner base material (2013-08-26)



Photo 30 - Stock pile of liner base material produced from screening till (2013-08-30)



Photo 31 - Cleaned sandstone surface (2013-08-23)



Photo 32 - Compacting soil bentonite liner (2013-08-25)



Photo 33 - Placing soil bentonite liner (2013-09-05)



Photo 34 - Soil bentonite liner in-place at south access ramp- Air entry permeameter testing is visible in background (2013-09-08)



Photo 35 - Placing and compacting till at south access ramp following completion of soil bentonite liner construction (2013-09-10)



Photo 36 - Placing rip rap on soil bentonite liner (2013-08-11)



Photo 37 - Placing rip rap on soil bentonite liner- GPS equipped dozer assisted by on-site surveyor (2013-09-09)



Photo 38 - Placing rip rap on soil bentonite liner (2013-09-16)



Photo 39 - Finished rip rap placement (2013-09-22)



Photo 40 - Rip rap placed at the inlet to the half round culvert (2013-09-11)



Photo 41 - Pugmill setup (2013-06-19)



Photo 42 - Pugmill setup (2013-06-19)



Photo 43 - Pugmill setup (2013-06-19)

APPENDIX C

Quality Assurance Results

STANDARD PROCTOR - ASTM D698

Project #:	12-1362-0022	Phase:	2000
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested by:	K.N.	Date:	July 20, 2012

Sample #: 2012-MLO-001
Source: N 11015 E 5215 1.2m below grade.
Visual Description of Sample: (SM) Gravelly SITLY SAND, light brown, non-cohesive.
Date Sample Received:

Compaction Test Results:

water content (%)	dry density (kg/m^3)
4.7	2026
6.8	2085
8.2	2050
9.8	1997

Maximum dry density: ***2086*** ***kg/m^3***
Corrected for oversize material: ***2177*** ***kg/m^3***

Optimum water content: ***6.9*** ***%***
Corrected for oversize material: ***5.5*** ***%***

Test Summary:

Method used:	C		
Material used passing:	19.0 mm	sieve	
Preparation method:	dry		
Rammer type:	manual		

Oversize Correction Data (if applicable):

Oversize fraction:	21.2	%	
Bulk Specific Gravity	2.6	value:	assumed
Water content	0.28	value:	assumed

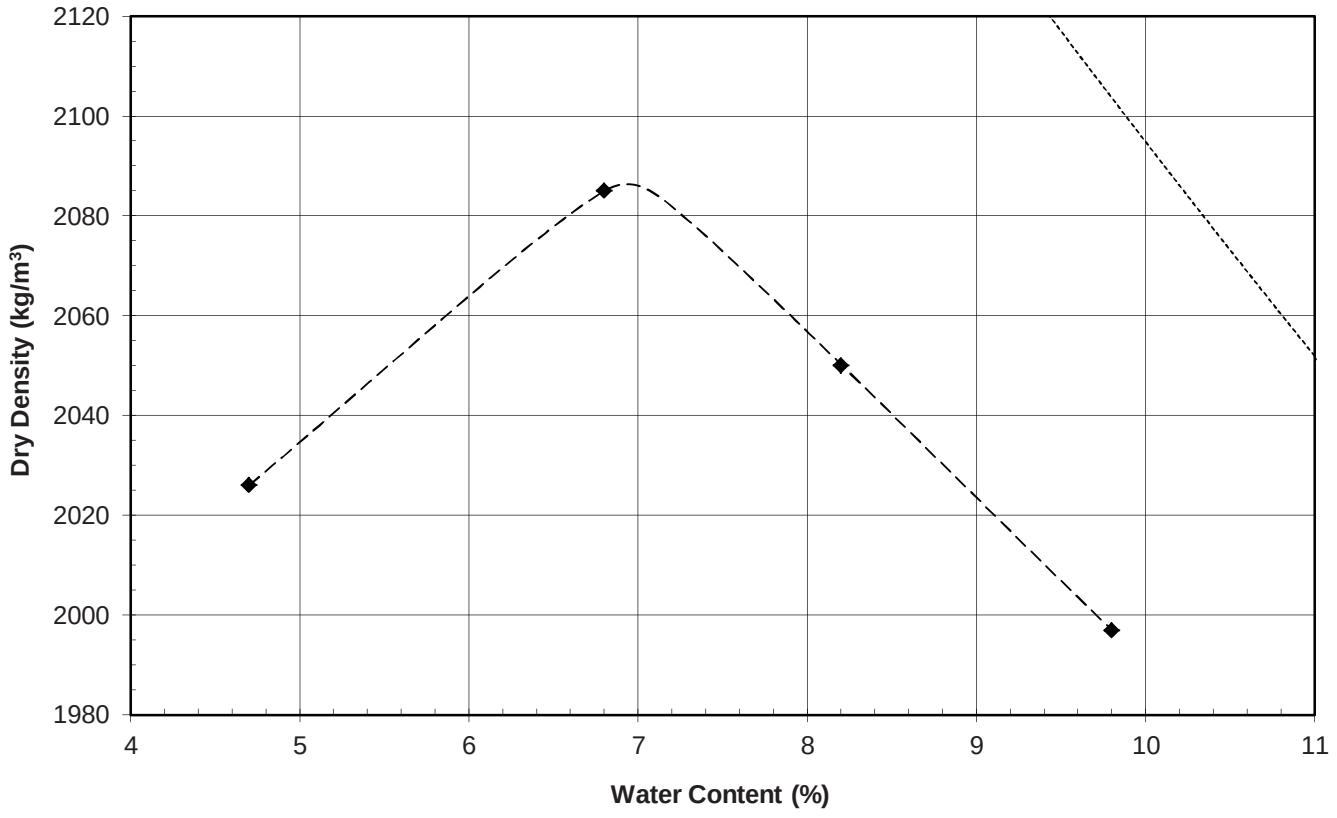
100% Saturation Curve Data:

Specific Gravity:	2.65	value:	assumed

Comments:

Water content of sample as received in lab: 4.4 %

Graphical Analysis - Uncorrected for Oversize Material



The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client. This report constitutes a testing service only and does not represent any results interpretation or opinion regarding specification compliance or material suitability. Engineering interpretation can be provided by Golder Associates Ltd. upon request.

1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:_____

STANDARD PROCTOR - ASTM D698

Project #: 12-1362-0022 Phase: 2000
Short Title: AREVA / JEB Stage 1 Optimization / McClean Lake
Tested by: S.C. Date: August 4, 2012

Sample #: 2012-MLO-005 (SL2541 - Check Test)
Source: N 22025 E 5218 1.5m below grade.
Visual Description of Sample: (SM) SILTY SAND, trace gravel, light brown, non-cohesive.
Date Sample Received:

Compaction Test Results:

water content (%)	dry density (kg/m^3)
6.1	1985
7.4	2034
9.6	1997
10.6	1969

Maximum dry density: ***2043*** ***kg/m^3***
Corrected for oversize material: ***2077*** ***kg/m^3***

Optimum water content: ***7.8*** ***%***
Corrected for oversize material: ***7.2*** ***%***

Test Summary:

Method used: A
Material used passing: 4.75 mm sieve
Preparation method: dry
Rammer type: manual

Oversize Correction Data (if applicable):

Oversize fraction: 7.7 %
Bulk Specific Gravity 2.6 value: assumed
Water content 0.31 value: assumed

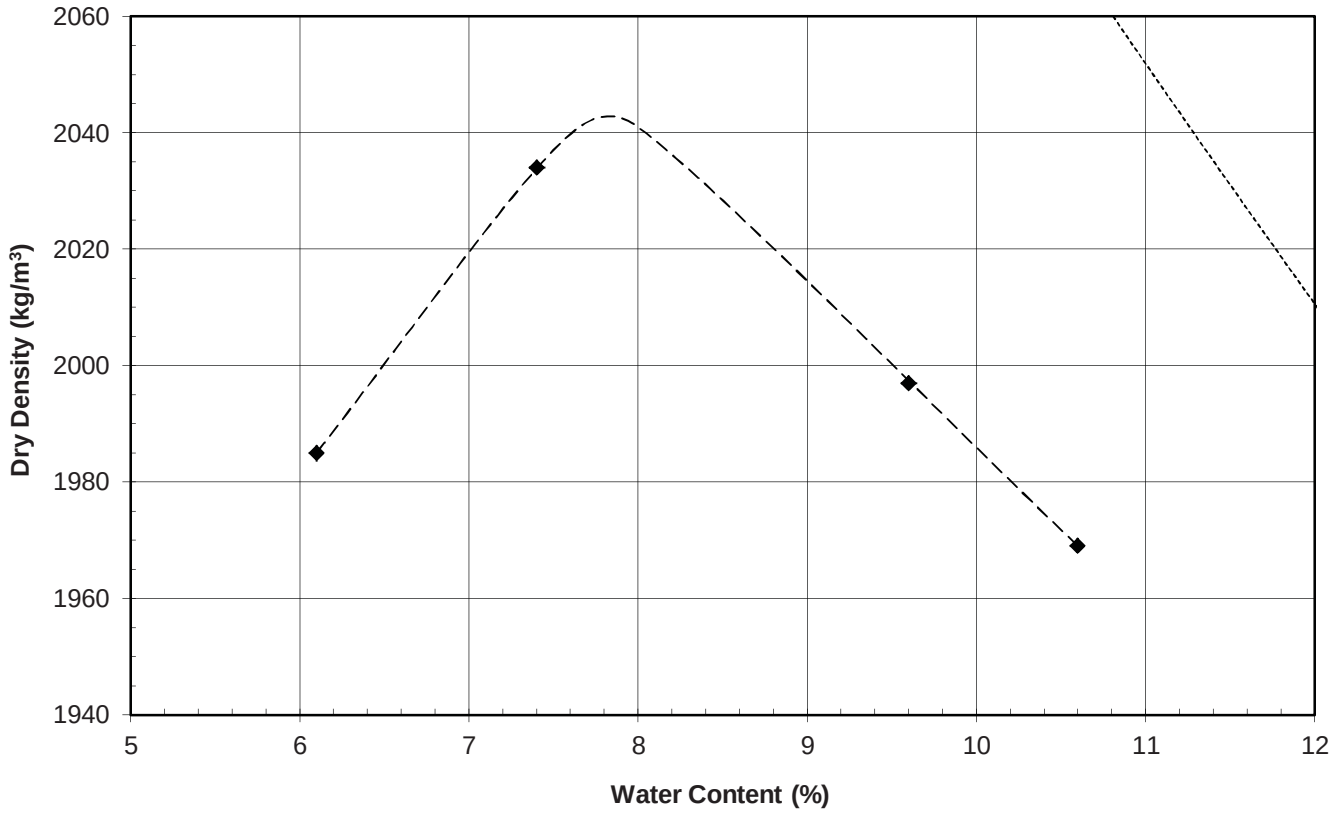
100% Saturation Curve Data:

Specific Gravity: 2.65 value: assumed

Comments:

Water content of sample as received in lab:

Graphical Analysis - Uncorrected for Oversize Material



The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client. This report constitutes a testing service only and does not represent any results interpretation or opinion regarding specification compliance or material suitability. Engineering interpretation can be provided by Golder Associates Ltd. upon request.

1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:_____

STANDARD PROCTOR - ASTM D698

Project #: 12-1362-0022 Phase: 4000
Short Title: AREVA / JEB Stage 1 Optimization / McClean Lake
Tested by: G.D.P. Date: June 27, 2013

Sample #: SL3104 (2013-MLO-087A)
Source:
Visual Description of Sample: Soil Bentonite Liner Material
Date Sample Received: June 27, 2013

Compaction Test Results:

water content (%)	dry density (kg/m^3)
5.9	1939
8.2	1964
10.4	1975
11.7	1953
12.4	1937

Maximum dry density: ***1976*** ***kg/m^3***
Corrected for oversize material: ***2035*** ***kg/m^3***

Optimum water content: ***10.1*** ***%***
Corrected for oversize material: ***8.9*** ***%***

Test Summary:

Method used: A
Material used passing: 4.75 mm sieve
Preparation method: dry
Rammer type: manual

Oversize Correction Data (if applicable):

Oversize fraction: 12.0 %
Bulk Specific Gravity 2.6 value: assumed
Water content 0.40 value: assumed

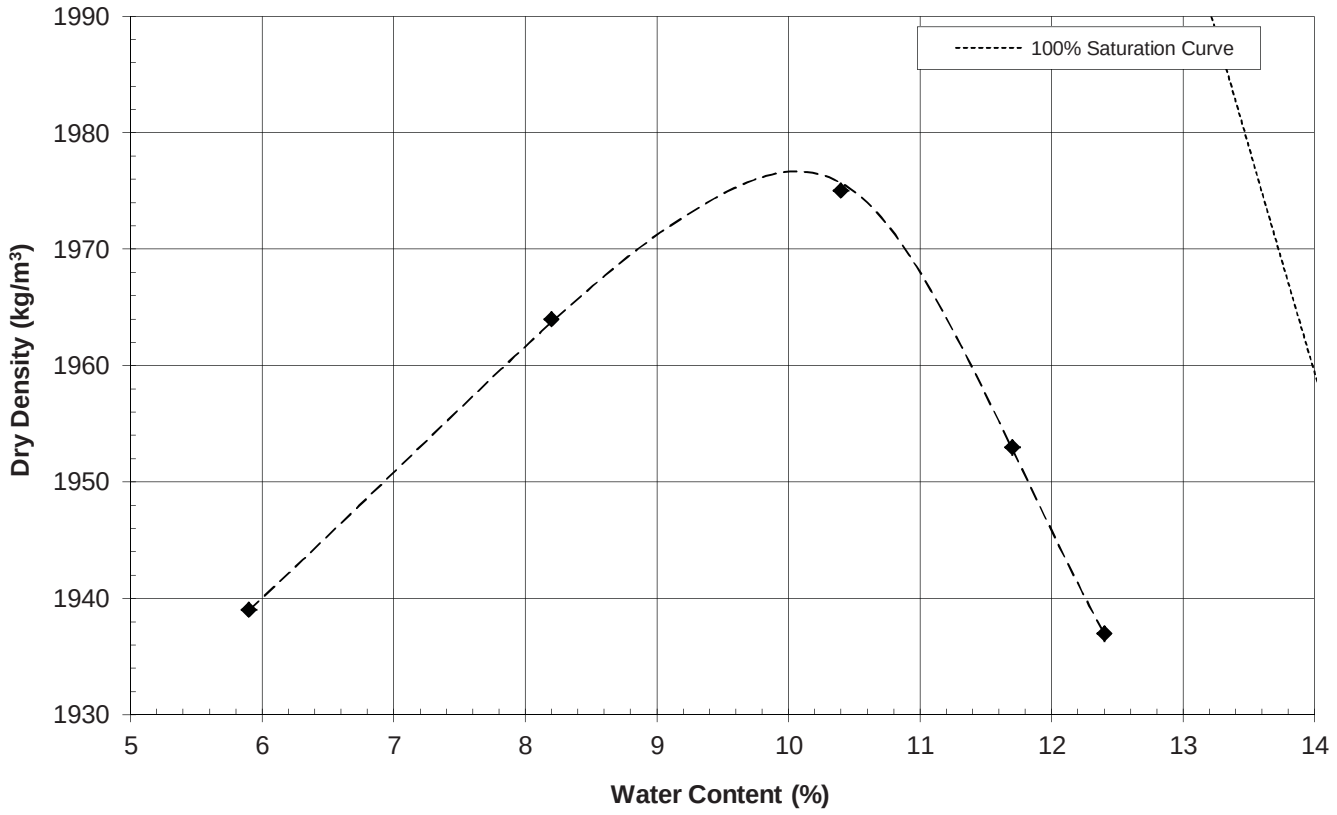
100% Saturation Curve Data:

Specific Gravity: 2.7 value: assumed

Comments:

Water content of sample as received in lab: 10.8 %

Graphical Analysis - Uncorrected for Oversize Material



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1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:_____

STANDARD PROCTOR - ASTM D698

Project #: 12-1362-0022 Phase: 4000 / 4200
Short Title: AREVA / JEB Stage 1 Optimization / McClean Lake
Tested by: J.C. / J.B. Date: August 29, 2013

Sample #: 2013-MLO-186
Source: Screened stockpile.
Visual Description of Sample: Liner material.
Date Sample Received: August 28, 2013

Compaction Test Results:

water content (%)	dry density (kg/m^3)
6.4	1954
7.6	2005
10.4	1981
12.0	1956

Maximum dry density: ***2012*** ***kg/m^3***
Corrected for oversize material: ***2057*** ***kg/m^3***

Optimum water content: ***8.1*** ***%***
Corrected for oversize material: ***7.3*** ***%***

Test Summary:

Method used: A
Material used passing: 4.75 mm sieve
Preparation method: dry
Rammer type: manual

Oversize Correction Data (if applicable):

Oversize fraction: 9.7 %
Bulk Specific Gravity 2.6 value: assumed
Water content 0.32 value: assumed

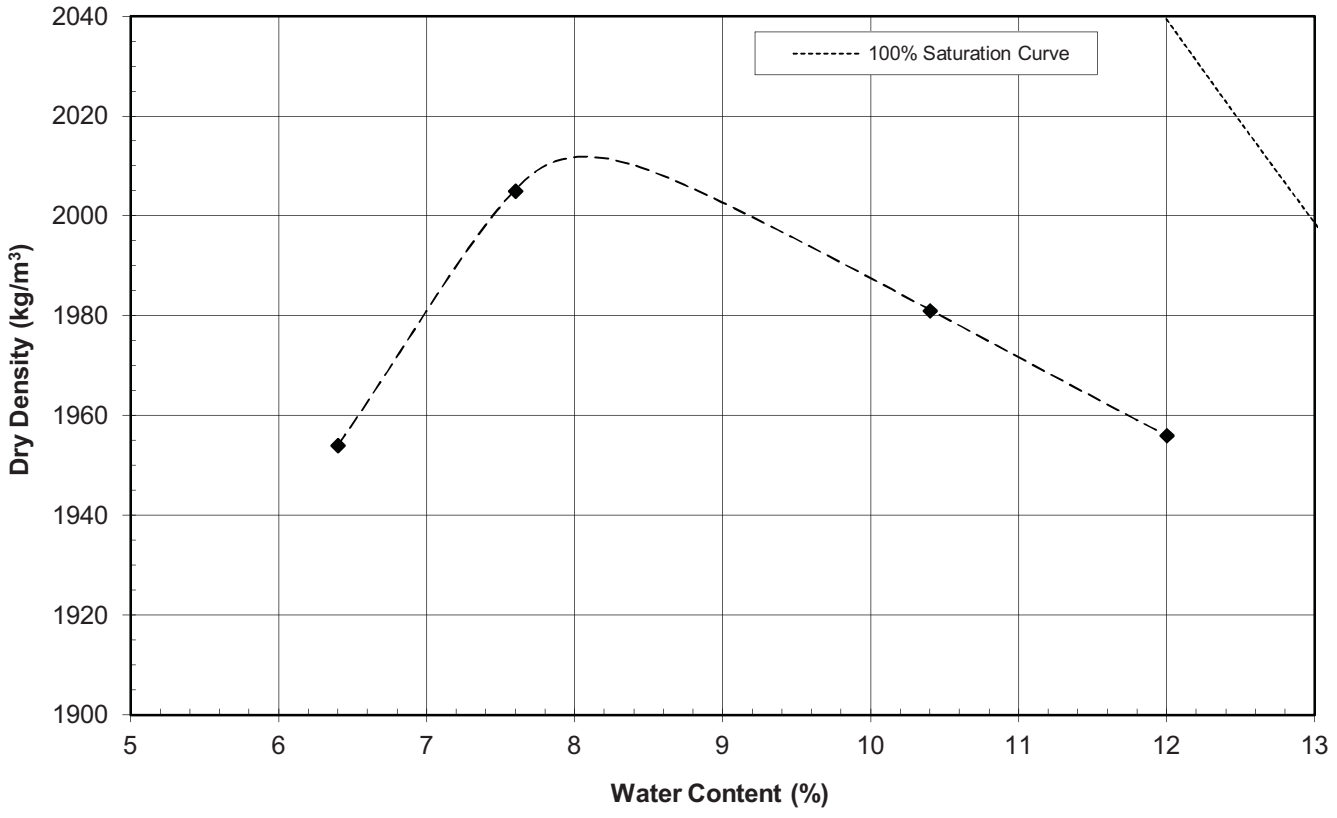
100% Saturation Curve Data:

Specific Gravity: 2.7 value: assumed

Comments:

Water content of sample as received in lab:

Graphical Analysis - Uncorrected for Oversize Material



The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client. This report constitutes a testing service only and does not represent any results interpretation or opinion regarding specification compliance or material suitability. Engineering interpretation can be provided by Golder Associates Ltd. upon request.

1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

FIELD NUCLEAR DENSITY TEST REPORT
Common Fill

Project #: 12-1362-0022 Phase: 4000
Short Title: AREVA / JEB Stage 1 Optimization Stage 1 / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 32355
Tested by: K.J./K.N. Test Date: June 16 - September 13, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
45	16-Jun-13	K.N.	11020	5463	456.00	300	2058	3.8	2013-MLO-005	2032	7.1	101.3
46	16-Jun-13	K.N.	11017	5461	456.00	300	1985	4.0	2013-MLO-005	2032	7.1	97.7
47	16-Jun-13	K.N.	11021	5461	456.30	300	2030	3.6	2013-MLO-005	2032	7.1	99.9
48	16-Jun-13	K.N.	11018	5462	456.30	300	1979	3.9	2013-MLO-005	2032	7.1	97.4
49	16-Jun-13	K.N.	11021	5460	456.60	300	1936	2.3	2013-MLO-005	2032	7.1	95.3
50	16-Jun-13	K.N.	11017	5463	456.60	300	1972	2.8	2013-MLO-005	2032	7.1	97.0
51	16-Jun-13	K.N.	11021	5462	456.90	300	1944	3.1	2013-MLO-005	2032	7.1	95.7
52	16-Jun-13	K.N.	11016	5461	456.90	300	1958	2.9	2013-MLO-005	2032	7.1	96.4
53	16-Jun-13	K.N.	11022	5460	457.20	300	2021	3.1	2013-MLO-005	2032	7.1	99.5
54	16-Jun-13	K.N.	11017	5459	457.20	300	2027	2.9	2013-MLO-005	2032	7.1	99.8
55	17-Jun-13	K.N.	11023	5461	457.50	300	2050	2.9	2013-MLO-005	2032	7.1	100.9
56	17-Jun-13	K.N.	11016	5461	457.50	300	2064	3.3	2013-MLO-005	2032	7.1	101.6
57	21-Jun-13	K.N.	11042	5382	439.90	300	1934	3.9	2013-MLO-005	2032	7.1	95.2
58	21-Jun-13	K.N.	11050	5388	438.50	300	2092	4.0	2013-MLO-001	2086	6.9	100.3
59	21-Jun-13	K.N.	11044	5386	440.20	300	2124	6.2	2013-MLO-001	2086	6.9	101.8
60	21-Jun-13	K.N.	11049	5384	438.80	300	1983	4.7	2013-MLO-001	2086	6.9	95.1
61	21-Jun-13	K.N.	11044	5387	440.50	300	2086	4.0	2013-MLO-001	2086	6.9	100.0
62	30-Jun-13	K.N.	11056	5227	436.50	200	2099	3.9	2013-MLO-001	2086	6.9	100.6
63	30-Jun-13	K.N.	11052	5250	436.50	200	2061	5.1	2013-MLO-001	2086	6.9	98.8
64	30-Jun-13	K.N.	11054	5222	436.70	200	2128	4.8	2013-MLO-001	2086	6.9	102.0
65	30-Jun-13	K.N.	11053	5246	436.70	200	2111	3.7	2013-MLO-001	2086	6.9	101.2
66	30-Jun-13	K.N.	11055	5229	436.90	200	2061	4.6	2013-MLO-001	2086	6.9	98.8
67	30-Jun-13	K.N.	11052	5240	436.90	200	2042	4.9	2013-MLO-001	2086	6.9	97.9

Reviewed By: KRC

Golder Associates

FIELD NUCLEAR DENSITY TEST REPORT
Common Fill

Project #: 12-1362-0022 Phase: 4000
Short Title: AREVA / JEB Stage 1 Optimization Stage 1 / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 32355
Tested by: K.J./K.N. Test Date: June 16 - September 13, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
68	30-Jun-13	K.N.	11054	5227	437.10	200	2082	4.5	2013-MLO-001	2086	6.9	99.8
69	30-Jun-13	K.N.	11053	5248	437.10	200	2090	4.3	2013-MLO-001	2086	6.9	100.2
70	30-Jun-13	K.N.	11051	5230	437.40	250	2032	4.6	2013-MLO-001	2086	6.9	97.4
71	30-Jun-13	K.N.	11055	5242	437.40	250	2055	4.2	2013-MLO-001	2086	6.9	98.5
72	30-Jun-13	K.N.	11053	5223	437.70	250	2036	4.8	2013-MLO-001	2086	6.9	97.6
73	30-Jun-13	K.N.	11054	5247	437.70	250	2000	4.9	2013-MLO-001	2086	6.9	95.9
74	30-Jun-13	K.N.	11056	5231	437.90	200	2005	4.3	2013-MLO-001	2086	6.9	96.1
75	30-Jun-13	K.N.	11055	5243	437.90	200	2009	4.2	2013-MLO-001	2086	6.9	96.3
76	18-Jul-13	K.J.	11366	5239	439.4	100	2050	4.4	2013-MLO-001	2085	6.5	98.3
77	18-Jul-13	K.J.	11367	5241	439.5	100	2020	4.7	2013-MLO-001	2085	6.5	96.9
78	18-Jul-13	K.J.	11366	5242	439.85	200	2085	4.1	2013-MLO-001	2085	6.5	100.0
79	18-Jul-13	K.J.	11367	4222	490.12	150	2121	3.5	2013-MLO-001	2085	6.5	101.7
80	18-Jul-13	K.J.	11366	5240	439.94	150	2052	4.0	2013-MLO-001	2085	6.5	98.4
81	18-Jul-13	K.J.	11367	5240	440.15	200	1997	2.9	2013-MLO-001	2085	6.5	95.8
82	25-Jul-13	K.J.	11163	5494	439.22	250	2006	3.5	2013-MLO-001	2086	6.9	96.2
83	25-Jul-13	K.J.	11143	5488	438.88	250	2022	3.2	2013-MLO-001	2086	6.9	96.9
84	25-Jul-13	K.J.	11161	5492	439.68	200	1991	3.5	2013-MLO-001	2086	6.9	95.4
85	25-Jul-13	K.J.	11142	5479	439.47	200	1997	3.4	2013-MLO-001	2086	6.9	95.7
86	25-Jul-13	K.J.	11157	5498	439.65	250	2056	3.2	2013-MLO-001	2086	6.9	98.6
87	25-Jul-13	K.J.	11154	5494	439.95	200	2050	3.7	2013-MLO-001	2086	6.9	98.3
88	25-Jul-13	K.J.	11159	5497	440.25	250	2073	3.2	2013-MLO-001	2086	6.9	99.4
89	25-Jul-13	K.J.	11158	5497	440.45	200	2075	3.4	2013-MLO-001	2086	6.9	99.5
90	26-Jul-13	K.J.	11146	5492	439.41	200	2120	3.7	2013-MLO-001	2085	6.9	101.7

Reviewed By: KRC

FIELD NUCLEAR DENSITY TEST REPORT
Common Fill

Project #: 12-1362-0022 Phase: 4000
Short Title: AREVA / JEB Stage 1 Optimization Stage 1 / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 32355
Tested by: K.J./K.N. Test Date: June 16 - September 13, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
91	26-Jul-13	K.J.	11150	5498	441.1	200	2079	4.4	2013-MLO-001	2085	6.9	99.7
92	26-Jul-13	K.J.	11140	5491	439.98	200	2012	4.0	2013-MLO-001	2085	6.9	96.5
93	31-Jul-13	K.J.	11064	5218	436.72	250	2085	5.7	2013-MLO-001	2086	6.9	100.0
94	31-Jul-13	K.J.	11061	5224	436.62	250	2090	5.3	2013-MLO-001	2086	6.9	100.2
95	31-Jul-13	K.J.	11065	5211	437.38	250	2018	4.6	2013-MLO-001	2086	6.9	96.7
96	31-Jul-13	K.J.	11058	5221	438.13	250	2084	4.9	2013-MLO-001	2086	6.9	99.9
97	16-Aug-13	K.N.	11026	5449	453.98	150	1989	4.4	2013-MLO-001	2086	6.9	95.3
98	16-Aug-13	K.N.	11029	5449	454.32	150	1992	4.5	2013-MLO-001	2086	6.9	95.5
99	16-Aug-13	K.N.	11028	5448	454.27	300	2043	6.0	2013-MLO-001	2086	6.9	97.9
100	16-Aug-13	K.N.	11026	5451	454.59	300	2077	5.2	2013-MLO-001	2086	6.9	99.6
101	16-Aug-13	K.N.	11026	5450	454.87	300	1997	6.9	2013-MLO-001	2086	6.9	95.7
102	16-Aug-13	K.N.	11030	5449	454.42	300	2069	6.1	2013-MLO-001	2086	6.9	99.2
103	16-Aug-13	K.N.	11028	5450	454.86	300	2050	3.2	2013-MLO-001	2086	6.9	98.3
104	16-Aug-13	K.N.	11029	5447	454.58	300	1988	3.9	2013-MLO-001	2086	6.9	95.3
105	16-Aug-13	K.N.	11026	5449	455.21	300	2019	3.8	2013-MLO-001	2086	6.9	96.8
106	16-Aug-13	K.N.	11030	5449	454.88	300	1988	4.2	2013-MLO-001	2086	6.9	95.3
107	17-Aug-13	K.N.	11027	5447	455.56	300	2060	3.2	2013-MLO-001	2086	6.9	98.8
108	17-Aug-13	K.N.	11030	5452	455.26	300	2001	4.9	2013-MLO-001	2086	6.9	95.9
109	17-Aug-13	K.N.	11027	5450	455.83	300	2074	5.6	2013-MLO-001	2086	6.9	99.4
110	17-Aug-13	K.N.	11029	5446	455.57	300	2029	3.9	2013-MLO-001	2086	6.9	97.3
111	19-Aug-13	K.N.	11123	5140	433.22	300	2188	4.1	2013-MLO-001(RC)	2177	5.5	100.5
112	19-Aug-13	K.N.	11120	5141	433.64	300	2086	4.4	2013-MLO-001	2086	6.9	100.0
113	19-Aug-13	K.N.	11130	5126	434.83	300	2105	5.2	2013-MLO-001	2086	6.9	100.9

Reviewed By: KRC

FIELD NUCLEAR DENSITY TEST REPORT
Common Fill

Project #: 12-1362-0022 Phase: 4000

Short Title: AREVA / JEB Stage 1 Optimization Stage 1 / McClean Lake, Sk

Contractor: Broda Construction

Gauge No.: 32355

Tested by: K.J./K.N. Test Date: June 16 - September 13, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
114	19-Aug-13	K.N.	11123	5137	433.84	300	2127	4.3	2013-MLO-001	2086	6.9	102.0
115	19-Aug-13	K.N.	11129	5128	434.67	300	2086	5.4	2013-MLO-001	2086	6.9	100.0
116	19-Aug-13	K.N.	11124	5145	433.43	300	2079	5.3	2013-MLO-001	2086	6.9	99.7
117	19-Aug-13	K.N.	11129	5127	435.15	300	2083	5.1	2013-MLO-001	2086	6.9	99.9
118	19-Aug-13	K.N.	11121	5140	434.47	300	2095	5.0	2013-MLO-001	2086	6.9	100.4
119	12-Sep-13	K.N.	11100	5146	441.85	300	2076	4.1	2013-MLO-001	2086	6.9	99.5
120	13-Sep-13	K.N.	11101	5139	441.67	300	1998	4.2	2013-MLO-001	2086	6.9	95.8

Remarks: Results communicated verbally to Dale Bruce (Broda).

MIN 95.3

AVG 98.4

MAX 102.0

The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client. This report constitutes a testing service only and does not represent any results interpretation or opinion regarding specification compliance or material suitability. Engineering interpretation can be provided by Golder Associates Ltd. upon request.

Reviewed By: KRC

FIELD NUCLEAR DENSITY TEST REPORT
Full Round Culvert

Project #: 12-1362-0022 Phase: 4000
Short Title: AREVA / JEB Stage 1 Opt / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 32355
Tested by: K.N. Test Date: Aug. 16 - Aug. 17, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
97	16-Aug-13	K.N.	11026	5449	453.98	150	1989	4.4	2013-MLO-001	2086	6.9	95.3
98	16-Aug-13	K.N.	11029	5449	454.32	150	1992	4.5	2013-MLO-001	2086	6.9	95.5
99	16-Aug-13	K.N.	11028	5448	454.27	300	2043	6	2013-MLO-001	2086	6.9	97.9
100	16-Aug-13	K.N.	11026	5451	454.59	300	2077	5.2	2013-MLO-001	2086	6.9	99.6
101	16-Aug-13	K.N.	11026	5450	454.87	300	1997	6.9	2013-MLO-001	2086	6.9	95.7
102	16-Aug-13	K.N.	11030	5449	454.42	300	2069	6.1	2013-MLO-001	2086	6.9	99.2
103	16-Aug-13	K.N.	11028	5450	454.86	300	2050	3.2	2013-MLO-001	2086	6.9	98.3
104	16-Aug-13	K.N.	11029	5447	454.58	300	1988	3.9	2013-MLO-001	2086	6.9	95.3
105	16-Aug-13	K.N.	11026	5449	455.21	300	2019	3.8	2013-MLO-001	2086	6.9	96.8
106	16-Aug-13	K.N.	11030	5449	454.88	300	1988	4.2	2013-MLO-001	2086	6.9	95.3
107	17-Aug-13	K.N.	11027	5447	455.56	300	2060	3.2	2013-MLO-001	2086	6.9	98.8
108	17-Aug-13	K.N.	11030	5452	455.26	300	2001	4.9	2013-MLO-001	2086	6.9	95.9
109	17-Aug-13	K.N.	11027	5450	455.83	300	2074	5.6	2013-MLO-001	2086	6.9	99.4
110	17-Aug-13	K.N.	11029	5446	455.57	300	2029	3.9	2013-MLO-001	2086	6.9	97.3
											MIN	95.3
											AVG	97.2
											MAX	99.6

Remarks: Results communicated verbally to Dale Bruce (Broda).

The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client. This report constitutes a testing service only and does not represent any results interpretation or opinion regarding specification compliance or material suitability. Engineering interpretation can be provided by Golder Associates Ltd. upon request.

Reviewed By: KRC

Golder Associates

FIELD NUCLEAR DENSITY TEST REPORT
Soil Bentonite Liner

Project #: 12-1362-0022 Phase: 4000
Short Title: AREVA / JEB Stage 1 Optimization Stage 1 / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 32355
Tested by: K.J./K.B./K.N./J.C/J.B. Test Date: July 7, 2013 - Sept. 7, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
1	7-Jul-13	K.J.	11111	5177	433.23	150	2043	9.4	SL3104	2035	8.9	100.4
2	7-Jul-13	K.J.	11098	5189	433.77	100	2029	10.0	SL3104	2035	8.9	99.7
3	7-Jul-13	K.J.	11103	5185	433.60	100	2029	9.7	SL3104	2035	8.9	99.7
4	7-Jul-13	K.J.	11096	5191	433.85	150	2024	10.3	SL3104	2035	8.9	99.5
5	7-Jul-13	K.J.	11101	5187	433.82	200	2054	9.5	SL3104	2035	8.9	100.9
6	7-Jul-13	K.J.	11097	5191	434.15	150	2032	10.1	SL3104	2035	8.9	99.9
7	7-Jul-13	K.J.	11098	5190	434.25	150	2017	10.2	SL3104	2035	8.9	99.1
8	7-Jul-13	K.J.	11093	5195	434.51	150	2027	10.5	SL3104	2035	8.9	99.6
9	9-Jul-13	K.J.	11109	5177	433.67	150	2007	10.5	SL3104	2035	8.9	98.6
10	9-Jul-13	K.J.	11099	5188	434.17	150	2016	9.9	SL3104	2035	8.9	99.1
11	9-Jul-13	K.J.	11105	5178	434.35	150	2007	10.4	SL3104	2035	8.9	98.6
12	9-Jul-13	K.J.	11094	5190	434.65	150	2009	10.2	SL3104	2035	8.9	98.7
13	9-Jul-13	K.J.	11100	5184	434.75	150	2022	9.9	SL3104	2035	8.9	99.4
14	9-Jul-13	K.J.	11088	5196	435.27	150	2002	10.2	SL3104	2035	8.9	98.4
15	9-Jul-13	K.J.	11059	5249	436.11	150	2033	10.5	SL3104	2035	8.9	99.9
16	10-Jul-13	K.J./K.B.	11052	5274	436.10	150	2035	10.7	SL3104	2035	8.9	100.0
17	10-Jul-13	K.J./K.B.	11051	5275	436.10	150	2043	9.9	SL3104	2035	8.9	100.4
18	10-Jul-13	K.J./K.B.	11097	5184	435.16	150	2036	9.1	SL3104	2035	8.9	100.0
19	10-Jul-13	K.J./K.B.	11056	5251	436.68	150	2004	10.5	SL3104	2035	8.9	98.5
20	10-Jul-13	K.J./K.B.	11054	5274	436.20	150	2012	10.3	SL3104	2035	8.9	98.9
21	10-Jul-13	K.J./K.B.	11088	5195	435.73	150	2047	9.5	SL3104	2035	8.9	100.6
22	10-Jul-13	K.J./K.B.	11052	5272	436.46	150	2012	9.9	SL3104	2035	8.9	98.9

Reviewed By: KRC

Golder Associates

FIELD NUCLEAR DENSITY TEST REPORT
Soil Bentonite Liner

Project #: 12-1362-0022 Phase: 4000
Short Title: AREVA / JEB Stage 1 Optimization Stage 1 / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 32355
Tested by: K.J./K.B./K.N./J.C/J.B. Test Date: July 7, 2013 - Sept. 7, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
23	10-Jul-13	K.J./K.B.	11055	5251	437.00	150	2057	9.1	SL3104	2035	8.9	101.1
24	10-Jul-13	K.J./K.B.	11108	5173	435.15	150	2081	9.2	SL3104	2035	8.9	102.3
25	10-Jul-13	K.J./K.B.	11059	5243	436.65	150	2036	10.1	SL3104	2035	8.9	100.0
26	10-Jul-13	K.J./K.B.	11056	5275	436.47	150	2051	9.3	SL3104	2035	8.9	100.8
27	11-Jul-13	K.B.	11118	5159	435.00	150	2039	9.3	SL3104	2035	8.9	100.2
28	11-Jul-13	K.B.	11059	5243	436.85	150	2045	9.2	SL3104	2035	8.9	100.5
29	11-Jul-13	K.B.	11056	5275	436.67	150	2015	9.9	SL3104	2035	8.9	99.0
30	11-Jul-13	K.B.	11083	5202	435.78	150	2009	10.3	SL3104	2035	8.9	98.7
31	11-Jul-13	K.B.	11055	5261	437.44	150	2065	9.5	SL3104	2035	8.9	101.5
32	11-Jul-13	K.B.	11052	5275	436.79	150	2033	9.8	SL3104	2035	8.9	99.9
33	11-Jul-13	K.B.	11080	5193	436.30	150	1995	11.1	SL3104	2035	8.9	98.0
34	11-Jul-13	K.B.	11082	5194	436.30	150	2055	9.4	SL3104	2035	8.9	101.0
35	11-Jul-13	K.B.	11055	5276	436.87	150	2026	9.5	SL3104	2035	8.9	99.6
36	11-Jul-13	K.B.	11055	5247	437.52	150	2040	9.5	SL3104	2035	8.9	100.2
37	11-Jul-13	K.B.	11083	5200	436.15	150	1998	10.0	SL3104	2035	8.9	98.2
38	11-Jul-13	K.B.	11084	5195	436.60	150	2026	10.0	SL3104	2035	8.9	99.6
39	11-Jul-13	K.B.	11059	5243	435.18	150	2057	9.2	SL3104	2035	8.9	101.1
40	11-Jul-13	K.B.	11050	5272	435.46	150	2052	9.5	SL3104	2035	8.9	100.8
41	11-Jul-13	K.B.	11100	5172	436.72	150	2029	9.8	SL3104	2035	8.9	99.7
42	11-Jul-13	K.B.	11053	5277	437.40	150	2021	10.1	SL3104	2035	8.9	99.3
43	11-Jul-13	K.B.	11054	5257	437.93	150	2011	10.1	SL3104	2035	8.9	98.8
44	11-Jul-13	K.B.	11084	5195	436.65	150	2043	9.5	SL3104	2035	8.9	100.4

Reviewed By: KRC

Golder Associates

FIELD NUCLEAR DENSITY TEST REPORT
Soil Bentonite Liner

Project #: 12-1362-0022 Phase: 4000
Short Title: AREVA / JEB Stage 1 Optimization Stage 1 / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 32355
Tested by: K.J./K.B./K.N./J.C/J.B. Test Date: July 7, 2013 - Sept. 7, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
45	14-Jul-13	K.B.	11103	5168	437.08	150	2027	10.6	SL3104	2035	8.9	99.6
46	14-Jul-13	K.B.	11050	5275	348.35	150	2026	10.2	SL3104	2035	8.9	99.6
47	14-Jul-13	K.B.	11050	5278	438.30	300	1995	10.9	SL3104	2035	8.9	98.0
48	14-Jul-13	K.B.	11046	5275	438.40	150	2034	10.2	SL3104	2035	8.9	100.0
49	14-Jul-13	K.B.	11049	5205	438.41	150	2051	9.9	SL3104	2035	8.9	100.8
50	14-Jul-13	K.B.	11048	5295	437.05	150	2004	11.2	SL3104	2035	8.9	98.5
51	14-Jul-13	K.B.	11048	5295	437.12	150	2017	9.7	SL3104	2035	8.9	99.1
52	14-Jul-13	K.B.	11048	5295	437.12	150	2045	9.6	SL3104	2035	8.9	100.5
53	14-Jul-13	K.B.	11082	5195	437.06	150	2015	9.9	SL3104	2035	8.9	99.0
54	14-Jul-13	K.B.	11048	5295	437.22	150	2057	9.4	SL3104	2035	8.9	101.1
55	14-Jul-13	K.B.	11048	5295	437.34	150	2004	10.3	SL3104	2035	8.9	98.5
56	14-Jul-13	K.B.	11046	5287	438.45	150	2046	9.1	SL3104	2035	8.9	100.5
57	14-Jul-13	K.B.	11050	5296	437.60	150	2009	10.1	SL3104	2035	8.9	98.7
58	14-Jul-13	K.B.	11049	5256	438.50	150	2009	10.1	SL3104	2035	8.9	98.7
59	15-Jul-13	K.B.	11103	5165	437.40	150	2066	9.0	SL3104	2035	8.9	101.5
60	15-Jul-13	K.B.	11047	5292	438.05	150	2047	9.1	SL3104	2035	8.9	100.6
61	15-Jul-13	K.B.	11048	5299	437.91	150	2032	9.6	SL3104	2035	8.9	99.9
62	15-Jul-13	K.B.	11049	5256	438.73	150	2022	10.1	SL3104	2035	8.9	99.4
63	15-Jul-13	K.B.	11108	5164	437.26	150	2013	10.5	SL3104	2035	8.9	98.9
64	15-Jul-13	K.B.	11108	5297	438.20	150	2067	9.8	SL3104	2035	8.9	101.6
65	15-Jul-13	K.B.	11051	5254	438.90	150	1998	9.6	SL3104	2035	8.9	98.2
66	15-Jul-13	K.B.	11086	5182	438.25	150	2007	10.0	SL3104	2035	8.9	98.6

Reviewed By: KRC

Golder Associates

FIELD NUCLEAR DENSITY TEST REPORT
Soil Bentonite Liner

Project #: 12-1362-0022 Phase: 4000
Short Title: AREVA / JEB Stage 1 Optimization Stage 1 / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 32355
Tested by: K.J./K.B./K.N./J.C/J.B. Test Date: July 7, 2013 - Sept. 7, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
67	16-Jul-13	K.B.	11048	5250	439.12	150	2010	9.7	SL3104	2035	8.9	98.8
68	16-Jul-13	K.B.	11045	5298	438.55	150	2033	9.6	SL3104	2035	8.9	99.9
69	16-Jul-13	K.B.	11042	5307	438.75	150	2031	9.8	SL3104	2035	8.9	99.8
70	16-Jul-13	K.B.	11052	5247	439.05	150	1998	9.4	SL3104	2035	8.9	98.2
71	16-Jul-13	K.B.	11042	5299	438.95	150	2006	9.6	SL3104	2035	8.9	98.6
72	16-Jul-13	K.B.	11102	5167	437.98	150	2010	9.3	SL3104	2035	8.9	98.8
73	16-Jul-13	K.B.	11044	5276	439.68	150	2043	9.2	SL3104	2035	8.9	100.4
74	16-Jul-13	K.B.	11043	5311	438.67	150	2051	9.7	SL3104	2035	8.9	100.8
75	16-Jul-13	K.B.	11088	5176	438.71	150	2029	9.9	SL3104	2035	8.9	99.7
76	17-Jul-13	K.B./K.J.	11044	5326	438.55	150	2040	9.2	SL3104	2035	8.9	100.2
77	17-Jul-13	K.B./K.J.	11078	5182	439.88	150	2087	9.2	SL3104	2035	8.9	102.6
78	17-Jul-13	K.B./K.J.	11046	5343	438.35	150	2010	9.8	SL3104	2035	8.9	98.8
79	17-Jul-13	K.B./K.J.	11041	5304	439.77	150	2020	10.2	SL3104	2035	8.9	99.3
80	17-Jul-13	K.B./K.J.	11102	5160	438.57	150	2034	9.1	SL3104	2035	8.9	100.0
81	17-Jul-13	K.B./K.J.	11089	5191	439.07	150	2036	9.5	SL3104	2035	8.9	100.0
82	17-Jul-13	K.B./K.J.	11042	5327	438.88	150	2055	9.5	SL3104	2035	8.9	101.0
83	17-Jul-13	K.B./K.J.	11050	5355	436.86	100	2055	9.1	SL3104	2035	8.9	101.0
84	17-Jul-13	K.B./K.J.	11048	5355	437.84	100	2002	9.3	SL3104	2035	8.9	98.4
85	17-Jul-13	K.B./K.J.	11082	5183	439.31	150	2053	8.7	SL3104	2035	8.9	100.9
86	17-Jul-13	K.B./K.J.	11040	5315	439.68	150	2037	9.4	SL3104	2035	8.9	100.1
87	17-Jul-13	K.B./K.J.	11099	5162	439.16	150	2017	9.1	SL3104	2035	8.9	99.1
88	17-Jul-13	K.B./K.J.	11057	5379	435.66	100	2011	10.0	SL3104	2035	8.9	98.8

Reviewed By: KRC

Golder Associates

FIELD NUCLEAR DENSITY TEST REPORT
Soil Bentonite Liner

Project #: 12-1362-0022 Phase: 4000
Short Title: AREVA / JEB Stage 1 Optimization Stage 1 / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 32355
Tested by: K.J./K.B./K.N./J.C/J.B. Test Date: July 7, 2013 - Sept. 7, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
89	17-Jul-13	K.B./K.J.	11054	5367	436.06	100	2027	10.2	SL3104	2035	8.9	99.6
90	17-Jul-13	K.B./K.J.	11104	5161	438.98	150	2002	9.0	SL3104	2035	8.9	98.4
91	17-Jul-13	K.B./K.J.	11041	5302	439.85	150	2009	10.0	SL3104	2035	8.9	98.7
92	18-Jul-13	K.J.	11059	5382	435.79	100	2035	9.7	SL3104	2035	8.9	100.0
93	18-Jul-13	K.J.	11055	5371	436.08	100	1997	9.4	SL3104	2035	8.9	98.1
94	18-Jul-13	K.J.	11075	5192	439.52	150	2000	8.6	SL3104	2035	8.9	98.3
95	18-Jul-13	K.J.	11058	5391	435.87	150	1998	10.4	SL3104	2035	8.9	98.2
96	18-Jul-13	K.J.	11087	5177	439.93	150	2009	9.5	SL3104	2035	8.9	98.7
97	18-Jul-13	K.J.	11054	5368	436.61	150	2017	9.1	SL3104	2035	8.9	99.1
98	19-Jul-13	K.J.	11053	5367	436.60	150	2028	8.9	SL3104	2035	8.9	99.7
99	19-Jul-13	K.J.	11054	5364	437.00	150	2027	9.8	SL3104	2035	8.9	99.6
100	19-Jul-13	K.J.	11055	5374	436.30	150	1998	9.9	SL3104	2035	8.9	98.2
101	19-Jul-13	K.J.	11057	5381	436.13	150	2024	9.7	SL3104	2035	8.9	99.5
102	19-Jul-13	K.J.	11045	5356	438.83	150	1999	10.0	SL3104	2035	8.9	98.2
103	19-Jul-13	K.J.	11045	5360	438.81	150	2004	9.6	SL3104	2035	8.9	98.5
104	19-Jul-13	K.J.	11057	5382	436.25	150	2040	9.9	SL3104	2035	8.9	100.2
105	19-Jul-13	K.J.	11057	5381	436.36	150	2032	10.1	SL3104	2035	8.9	99.9
106	19-Jul-13	K.J.	11059	5381	436.39	150	2030	10.0	SL3104	2035	8.9	99.8
107	19-Jul-13	K.J.	11057	5380	436.53	150	2022	9.5	SL3104	2035	8.9	99.4
108	20-Jul-13	K.J.	11056	5381	436.60	150	2004	9.4	SL3104	2035	8.9	98.5
109	20-Jul-13	K.J.	11055	5384	437.07	150	2020	9.5	SL3104	2035	8.9	99.3
110	20-Jul-13	K.J.	11051	5372	437.97	150	2031	9.9	SL3104	2035	8.9	99.8

Reviewed By: KRC

Golder Associates

FIELD NUCLEAR DENSITY TEST REPORT
Soil Bentonite Liner

Project #: 12-1362-0022 Phase: 4000
Short Title: AREVA / JEB Stage 1 Optimization Stage 1 / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 32355
Tested by: K.J./K.B./K.N./J.C/J.B. Test Date: July 7, 2013 - Sept. 7, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
111	20-Jul-13	K.J.	11360	5242	438.61	100	2047	9.1	SL3104	2035	8.9	100.6
112	20-Jul-13	K.J.	11362	5237	439.28	100	2005	9.9	SL3104	2035	8.9	98.5
113	20-Jul-13	K.J.	11358	5253	439.19	150	2039	10.2	SL3104	2035	8.9	100.2
114	20-Jul-13	K.J.	11363	5238	439.61	150	2017	10.5	SL3104	2035	8.9	99.1
115	20-Jul-13	K.J.	11362	5249	439.76	150	2003	8.4	SL3104	2035	8.9	98.4
116	20-Jul-13	K.J.	11359	5265	439.70	150	2048	9.4	SL3104	2035	8.9	100.6
117	20-Jul-13	K.J.	11363	5228	439.76	150	2061	9.2	SL3104	2035	8.9	101.3
118	20-Jul-13	K.J.	11358	5283	439.28	150	2056	9.4	SL3104	2035	8.9	101.0
119	21-Jul-13	K.J.	11357	5282	439.37	150	2017	9.7	SL3104	2035	8.9	99.1
120	21-Jul-13	K.J.	11360	5311	438.33	150	2033	9.6	SL3104	2035	8.9	99.9
121	21-Jul-13	K.J.	11360	5319	438.04	50	1998	9.1	SL3104	2035	8.9	98.2
122	21-Jul-13	K.J.	11359	5298	439.02	150	2069	9.0	SL3104	2035	8.9	101.7
123	21-Jul-13	K.J.	11041	5351	439.94	150	2090	8.2	SL3104	2035	8.9	102.7
124	21-Jul-13	K.J.	11363	5315	438.62	150	2066	9.8	SL3104	2035	8.9	101.5
125	21-Jul-13	K.J.	11062	5401	437.33	100	2035	8.2	SL3104	2035	8.9	100.0
126	21-Jul-13	K.J.	11362	5311	438.93	150	2000	8.9	SL3104	2035	8.9	98.3
127	21-Jul-13	K.J.	11356	5342	437.03	100	2006	9.9	SL3104	2035	8.9	98.6
128	21-Jul-13	K.J.	11361	5317	438.69	150	2047	8.9	SL3104	2035	8.9	100.6
129	21-Jul-13	K.J.	11357	5332	437.54	150	2020	9.2	SL3104	2035	8.9	99.3
130	22-Jul-13	K.J.	11358	5283	439.67	150	2037	9.1	SL3104	2035	8.9	100.1
131	22-Jul-13	K.J.	11363	5303	439.72	150	2036	9.5	SL3104	2035	8.9	100.0
132	22-Jul-13	K.J.	11354	5344	437.02	150	2046	9.2	SL3104	2035	8.9	100.5

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Golder Associates

FIELD NUCLEAR DENSITY TEST REPORT
Soil Bentonite Liner

Project #: 12-1362-0022 Phase: 4000
Short Title: AREVA / JEB Stage 1 Optimization Stage 1 / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 32355
Tested by: K.J./K.B./K.N./J.C/J.B. Test Date: July 7, 2013 - Sept. 7, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
133	22-Jul-13	K.J.	11061	5399	437.62	150	2013	9.1	SL3104	2035	8.9	98.9
134	22-Jul-13	K.J.	11052	5383	437.99	150	2076	9.2	SL3104	2035	8.9	102.0
135	22-Jul-13	K.J.	11356	5341	437.66	150	2059	9.5	SL3104	2035	8.9	101.2
136	22-Jul-13	K.J.	11050	5386	438.15	150	2033	9.2	SL3104	2035	8.9	99.9
137	22-Jul-13	K.J.	11350	5360	437.42	150	2011	10.4	SL3104	2035	8.9	98.8
138	22-Jul-13	K.J.	11338	5382	437.98	150	1998	9.2	SL3104	2035	8.9	98.2
139	22-Jul-13	K.J.	11354	5353	437.76	150	2074	9.6	SL3104	2035	8.9	101.9
140	22-Jul-13	K.J.	11357	5344	438.19	150	2039	9.8	SL3104	2035	8.9	100.2
141	22-Jul-13	K.J.	11051	5383	438.35	150	2027	9.2	SL3104	2035	8.9	99.6
142	22-Jul-13	K.J.	11331	5398	436.23	150	2042	9.6	SL3104	2035	8.9	100.3
143	22-Jul-13	K.J.	11053	5387	438.29	150	2070	9.5	SL3104	2035	8.9	101.7
144	22-Jul-13	K.J.	11356	5351	438.12	150	2049	9.3	SL3104	2035	8.9	100.7
145	23-Jul-13	K.J.	11355	5350	438.16	150	2039	9.2	SL3104	2035	8.9	100.2
146	23-Jul-13	K.J.	11362	5279	439.89	150	2068	9.2	SL3104	2035	8.9	101.6
147	23-Jul-13	K.J.	11334	5393	436.51	150	2060	8.8	SL3104	2035	8.9	101.2
148	23-Jul-13	K.J.	11064	5403	437.77	150	1997	9.7	SL3104	2035	8.9	98.1
149	23-Jul-13	K.J.	11052	5387	438.51	150	2068	9.4	SL3104	2035	8.9	101.6
150	23-Jul-13	K.J.	11343	5382	437.27	150	2001	10.3	SL3104	2035	8.9	98.3
151	23-Jul-13	K.J.	11355	5355	438.31	150	1999	10.4	SL3104	2035	8.9	98.2
152	23-Jul-13	K.J.	11062	5402	438.05	150	2026	9.5	SL3104	2035	8.9	99.6
153	23-Jul-13	K.J.	11053	5386	438.77	150	2036	9.7	SL3104	2035	8.9	100.0
154	24-Jul-13	K.J.	11059	5401	438.27	150	2027	10.8	SL3104	2035	8.9	99.6

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FIELD NUCLEAR DENSITY TEST REPORT
Soil Bentonite Liner

Project #: 12-1362-0022 Phase: 4000
Short Title: AREVA / JEB Stage 1 Optimization Stage 1 / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 32355
Tested by: K.J./K.B./K.N./J.C/J.B. Test Date: July 7, 2013 - Sept. 7, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
155	24-Jul-13	K.J.	11098	5452	428.89	150	2035	10.1	SL3104	2035	8.9	100.0
156	24-Jul-13	K.J.	11050	5389	439.13	300	2022	10.6	SL3104	2035	8.9	99.4
157	24-Jul-13	K.J.	11050	5389	439.13	200	2006	10.8	SL3104	2035	8.9	98.6
158	24-Jul-13	K.J.	11050	5389	439.13	150	2011	10.9	SL3104	2035	8.9	98.8
159	24-Jul-13	K.J.	11059	5890	439.22	150	2076	9.4	SL3104	2035	8.9	102.0
160	24-Jul-13	K.J.	11098	5454	439.17	200	2035	10.2	SL3104	2035	8.9	100.0
161	24-Jul-13	K.J.	11112	5477	439.14	150	1998	10.8	SL3104	2035	8.9	98.2
162	24-Jul-13	K.J.	11118	5470	439.28	150	2001	10.6	SL3104	2035	8.9	98.3
163	24-Jul-13	K.J.	11341	5386	437.10	150	2076	8.9	SL3104	2035	8.9	102.0
164	24-Jul-13	K.J.	11352	5367	438.14	150	2027	9.7	SL3104	2035	8.9	99.6
165	24-Jul-13	K.J.	11103	5459	439.48	150	2033	10.6	SL3104	2035	8.9	99.9
166	24-Jul-13	K.J.	11113	5467	439.96	150	2019	9.7	SL3104	2035	8.9	99.2
167	24-Jul-13	K.J.	11091	5446	439.54	150	2018	10.2	SL3104	2035	8.9	99.2
168	24-Jul-13	K.J.	11326	5407	436.20	150	2031	9.6	SL3104	2035	8.9	99.8
169	24-Jul-13	K.J.	11351	5368	438.18	150	2039	9.5	SL3104	2035	8.9	100.2
170	25-Jul-13	K.J.	11113	5470	439.76	150	2046	9.9	SL3104	2035	8.9	100.5
171	25-Jul-13	K.J.	11075	5427	439.38	150	2032	9.7	SL3104	2035	8.9	99.9
172	25-Jul-13	K.J.	11315	5418	436.29	150	2044	9.6	SL3104	2035	8.9	100.4
173	25-Jul-13	K.J.	11316	5421	436.68	150	1997	9.1	SL3104	2035	8.9	98.1
174	25-Jul-13	K.J.	11324	5409	436.62	150	2013	10.5	SL3104	2035	8.9	98.9
175	25-Jul-13	K.J.	11345	5383	437.59	150	2025	9.2	SL3104	2035	8.9	99.5
176	25-Jul-13	K.J.	11348	5376	438.10	150	2072	9.4	SL3104	2035	8.9	101.8

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FIELD NUCLEAR DENSITY TEST REPORT
Soil Bentonite Liner

Project #: 12-1362-0022 Phase: 4000
Short Title: AREVA / JEB Stage 1 Optimization Stage 1 / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 32355
Tested by: K.J./K.B./K.N./J.C/J.B. Test Date: July 7, 2013 - Sept. 7, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
177	25-Jul-13	K.J.	11315	5424	436.97	150	1999	10.9	SL3104	2035	8.9	98.2
178	26-Jul-13	K.J.	11300	5440	437.28	100	2044	8.5	SL3104	2035	8.9	100.4
179	26-Jul-13	K.J.	11346	5383	438.19	200	2060	9.8	SL3104	2035	8.9	101.2
180	27-Jul-13	K.J.	11302	5438	437.30	150	2008	9.7	SL3104	2035	8.9	98.7
181	27-Jul-13	K.J.	11361	5347	439.47	150	2035	9.2	SL3104	2035	8.9	100.0
182	27-Jul-13	K.J.	11327	5412	437.00	150	2031	9.4	SL3104	2035	8.9	99.8
183	27-Jul-13	K.J.	11336	5397	437.49	150	2007	8.4	SL3104	2035	8.9	98.6
184	27-Jul-13	K.J.	11133	5479	438.32	100	2012	10.2	SL3104	2035	8.9	98.9
185	27-Jul-13	K.J.	11069	5424	439.59	150	2033	9.0	SL3104	2035	8.9	99.9
186	27-Jul-13	K.J.	11360	5351	439.35	200	2007	10.2	SL3104	2035	8.9	98.6
187	27-Jul-13	K.J.	11124	5477	439.59	150	2035	9.6	SL3104	2035	8.9	100.0
188	27-Jul-13	K.J.	11316	5245	437.47	150	2037	10.9	SL3104	2035	8.9	100.1
189	27-Jul-13	K.J.	11321	5422	437.98	150	2070	9.6	SL3104	2035	8.9	101.7
190	27-Jul-13	K.J.	11146	5487	439.38	150	2020	10.1	SL3104	2035	8.9	99.3
191	27-Jul-13	K.J.	11317	5426	437.78	150	2010	9.4	SL3104	2035	8.9	98.8
192	27-Jul-13	K.J.	11309	5436	437.87	150	2082	8.9	SL3104	2035	8.9	102.3
193	27-Jul-13	K.J.	11133	5484	499.74	150	2030	9.7	SL3104	2035	8.9	99.8
194	28-Jul-13	K.J.	11308	5439	437.78	150	1999	9.7	SL3104	2035	8.9	98.2
195	28-Jul-13	K.J.	11361	5358	439.56	150	2047	9.8	SL3104	2035	8.9	100.6
196	28-Jul-13	K.J.	11312	5430	437.75	150	2036	9.5	SL3104	2035	8.9	100.0
197	28-Jul-13	K.J.	11172	5493	438.92	150	2072	9.0	SL3104	2035	8.9	101.8
198	28-Jul-13	K.J.	11163	5492	439.27	150	2040	10.2	SL3104	2035	8.9	100.2

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FIELD NUCLEAR DENSITY TEST REPORT
Soil Bentonite Liner

Project #: 12-1362-0022 Phase: 4000
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Contractor: Broda Construction
Gauge No.: 32355
Tested by: K.J./K.B./K.N./J.C/J.B. Test Date: July 7, 2013 - Sept. 7, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
199	28-Jul-13	K.J.	11171	5493	439.22	150	1994	10.0	SL3104	2035	8.9	98.0
200	28-Jul-13	K.J.	11325	5419	437.96	150	2047	9.6	SL3104	2035	8.9	100.6
201	28-Jul-13	K.J.	11274	5475	439.92	150	2068	9.1	SL3104	2035	8.9	101.6
202	28-Jul-13	K.J.	11168	5495	439.74	150	2054	9.8	SL3104	2035	8.9	100.9
203	28-Jul-13	K.J.	11155	5492	440.17	150	2008	9.4	SL3104	2035	8.9	98.7
204	28-Jul-13	K.J.	11345	5393	438.93	150	2042	10.0	SL3104	2035	8.9	100.3
205	1-Aug-13	K.J.	11071	5221	434.87	150	2045	10.0	SL3104	2035	8.9	100.5
206	1-Aug-13	K.J.	11066	5220	434.67	150	2039	10.2	SL3104	2035	8.9	100.2
207	1-Aug-13	K.J.	11068	5225	435.08	150	2054	9.9	SL3104	2035	8.9	100.9
208	1-Aug-13	K.J.	11074	5215	435.11	150	2035	9.3	SL3104	2035	8.9	100.0
209	1-Aug-13	K.J.	11067	5223	435.63	150	2019	9.7	SL3104	2035	8.9	99.2
210	1-Aug-13	K.J.	11075	5223	435.89	150	2047	9.9	SL3104	2035	8.9	100.6
211	1-Aug-13	K.J.	11071	5219	435.76	150	2033	9.1	SL3104	2035	8.9	99.9
212	2-Aug-13	K.J.	11070	5223	436.04	150	2066	8.9	SL3104	2035	8.9	101.5
213	2-Aug-13	K.J.	11071	5210	436.47	150	2071	9.1	SL3104	2035	8.9	101.8
214	2-Aug-13	K.J.	11067	5220	436.76	150	2059	9.3	SL3104	2035	8.9	101.2
215	2-Aug-13	K.J.	11064	5226	436.62	150	2079	8.9	SL3104	2035	8.9	102.2
216	2-Aug-13	K.J.	11066	5216	436.97	150	2051	9.4	SL3104	2035	8.9	100.8
217	2-Aug-13	K.J.	11071	5206	437.39	150	2036	7.9	SL3104	2035	8.9	100.0
218	2-Aug-13	K.J.	11062	5228	437.01	150	2023	9.4	SL3104	2035	8.9	99.4
219	2-Aug-13	K.J.	11068	5210	437.66	150	2030	9.5	SL3104	2035	8.9	99.8
220	2-Aug-13	K.J.	11063	5222	437.91	150	1998	10.9	SL3104	2035	8.9	98.2

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FIELD NUCLEAR DENSITY TEST REPORT
Soil Bentonite Liner

Project #: 12-1362-0022 Phase: 4000
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Contractor: Broda Construction
Gauge No.: 32355
Tested by: K.J./K.B./K.N./J.C/J.B. Test Date: July 7, 2013 - Sept. 7, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
221	2-Aug-13	K.J.	11069	5218	438.09	150	2045	8.2	SL3104	2035	8.9	100.5
222	3-Aug-13	K.N.	11068	5212	438.34	150	2042	8.8	SL3104	2035	8.9	100.3
223	3-Aug-13	K.N.	11067	5210	438.60	150	2069	8.0	SL3104	2035	8.9	101.7
224	3-Aug-13	K.N.	11060	5230	438.30	150	2011	8.6	SL3104	2035	8.9	98.8
225	3-Aug-13	K.N.	11061	5215	438.85	150	2001	8.6	SL3104	2035	8.9	98.3
226	3-Aug-13	K.N.	11059	5223	439.99	150	2036	8.3	SL3104	2035	8.9	100.0
227	14-Aug-13	K.N.	11068	5417	439.77	250	2078	7.9	SL3104	2035	8.9	102.1
228	15-Aug-13	K.N.	11052	5389	439.52	200	2072	8.2	SL3104	2035	8.9	101.8
229	15-Aug-13	K.N.	11042	5359	439.62	200	2063	9.1	SL3104	2035	8.9	101.4
230	20-Aug-13	K.N.	11139	5133	430.94	300	2064	9.2	SL3104	2035	8.9	101.4
231	22-Aug-13	J.C.	11140	5134	431.20	150	2051	8.8	SL3104	2035	8.9	100.8
232	22-Aug-13	J.C.	11139	5134	431.37	150	2039	8.7	SL3104	2035	8.9	100.2
233	22-Aug-13	J.C.	11139	5134	431.56	150	2066	8.9	SL3104	2035	8.9	101.5
234	22-Aug-13	J.C.	11139	5133	431.79	200	2004	7.9	SL3104	2035	8.9	98.5
235	22-Aug-13	J.C.	11133	5138	432.15	200	2065	8.5	SL3104	2035	8.9	101.5
236	22-Aug-13	J.C.	11138	5133	431.92	150	2008	9.2	SL3104	2035	8.9	98.7
237	22-Aug-13	J.C.	11137	5136	432.18	150	2060	10.1	SL3104	2035	8.9	101.2
238	22-Aug-13	J.C.	11154	5113	437.77	300	2033	8.9	SL3104	2035	8.9	99.9
239	22-Aug-13	J.C.	11137	5134	432.39	200	2025	8.5	SL3104	2035	8.9	99.5
240	22-Aug-13	J.C.	11137	5134	432.59	150	2018	10.0	SL3104	2035	8.9	99.2
241	22-Aug-13	J.C.	11153	5113	437.96	150	2024	9.8	SL3104	2035	8.9	99.5
242	22-Aug-13	J.C.	11137	5133	432.90	250	2045	9.5	SL3104	2035	8.9	100.5

Reviewed By: KRC

Golder Associates

FIELD NUCLEAR DENSITY TEST REPORT
Soil Bentonite Liner

Project #: 12-1362-0022 Phase: 4000
Short Title: AREVA / JEB Stage 1 Optimization Stage 1 / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 32355
Tested by: K.J./K.B./K.N./J.C/J.B. Test Date: July 7, 2013 - Sept. 7, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
243	23-Aug-13	J.C.	11162	5109	438.18	200	2051	9.7	SL3104	2035	8.9	100.8
244	23-Aug-13	J.C.	11135	5133	433.28	200	2009	10.3	SL3104	2035	8.9	98.7
245	23-Aug-13	J.C.	11155	5111	438.33	150	2073	9.3	SL3104	2035	8.9	101.9
246	23-Aug-13	J.C.	11129	5150	432.21	250	2043	9.1	SL3104	2035	8.9	100.4
247	23-Aug-13	J.C.	11156	5108	438.60	250	2051	9.3	SL3104	2035	8.9	100.8
248	23-Aug-13	J.C.	11132	5137	433.26	200	2042	8.9	SL3104	2035	8.9	100.3
249	23-Aug-13	J.C.	11158	5109	438.63	200	1997	10.6	SL3104	2035	8.9	98.1
250	23-Aug-13	J.C.	11132	5136	433.55	150	2057	9.5	SL3104	2035	8.9	101.1
251	23-Aug-13	J.C.	11157	5109	438.82	150	2018	9.7	SL3104	2035	8.9	99.2
252	23-Aug-13	J.C.	11129	5136	433.72	150	2039	10.4	SL3104	2035	8.9	100.2
253	23-Aug-13	J.C.	11158	5109	438.82	150	2027	9.6	SL3104	2035	8.9	99.6
254	24-Aug-13	J.C.	11127	5138	433.88	200	1999	9.7	SL3104	2035	8.9	98.2
255	24-Aug-13	J.C.	11172	5105	439.00	150	2032	9.2	SL3104	2035	8.9	99.9
256	24-Aug-13	J.C.	11169	5104	493.15	150	2049	9.7	SL3104	2035	8.9	100.7
257	24-Aug-13	J.C.	11126	5140	434.00	150	2044	9.4	SL3104	2035	8.9	100.4
258	24-Aug-13	J.C.	11127	5138	434.32	200	2081	8.3	SL3104	2035	8.9	102.3
259	24-Aug-13	J.C.	11131	5131	434.76	200	2036	9.5	SL3104	2035	8.9	100.0
260	24-Aug-13	J.C.	11126	5135	434.92	150	2009	8.7	SL3104	2035	8.9	98.7
261	25-Aug-13	J.C.	11127	5134	435.06	150	2075	8.7	SL3104	2035	8.9	102.0
262	25-Aug-13	J.C.	11124	5137	435.14	200	2065	9.3	SL3104	2035	8.9	101.5
263	25-Aug-13	J.C.	11128	5129	435.82	150	2016	8.0	SL3104	2035	8.9	99.1
264	30-Aug-13	K.J.	11138	5117	437.90	150	2069	7.4	2013-MLO-186	2057	7.3	100.6

Reviewed By: KRC

Golder Associates

FIELD NUCLEAR DENSITY TEST REPORT
Soil Bentonite Liner

Project #: 12-1362-0022 Phase: 4000
Short Title: AREVA / JEB Stage 1 Optimization Stage 1 / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 32355
Tested by: K.J./K.B./K.N./J.C/J.B. Test Date: July 7, 2013 - Sept. 7, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
265	30-Aug-13	K.J.	11123	5139	435.61	150	2080	7.8	2013-MLO-186	2057	7.3	101.1
266	30-Aug-13	K.J.	11121	5150	435.28	150	2057	7.6	2013-MLO-186	2057	7.3	100.0
267	30-Aug-13	K.J.	11120	5146	435.39	150	2090	7.3	2013-MLO-186	2057	7.3	101.6
268	30-Aug-13	K.J.	11119	5140	436.01	150	2067	8.4	2013-MLO-186	2057	7.3	100.5
269	30-Aug-13	K.J.	11127	5130	436.45	150	2090	7.7	2013-MLO-186	2057	7.3	101.6
270	31-Aug-13	K.J.	11118	5140	436.48	150	2024	7.8	2013-MLO-186	2057	7.3	98.4
271	31-Aug-13	K.J.	11130	5124	437.02	150	2061	8.5	2013-MLO-186	2057	7.3	100.2
272	31-Aug-13	K.J.	11127	5123	437.23	150	2071	8.3	2013-MLO-186	2057	7.3	100.7
273	31-Aug-13	K.J.	11119	5145	436.36	150	2098	7.4	2013-MLO-186	2057	7.3	102.0
274	31-Aug-13	K.J.	11117	5134	437.06	150	2051	7.9	2013-MLO-186	2057	7.3	99.7
275	31-Aug-13	K.J.	11129	5120	436.39	150	2076	7.3	2013-MLO-186	2057	7.3	100.9
276	31-Aug-13	K.J.	11116	5143	436.92	150	2057	7.7	2013-MLO-186	2057	7.3	100.0
277	31-Aug-13	K.J.	11115	5146	437.06	150	2049	8.0	2013-MLO-186	2057	7.3	99.6
278	1-Sep-13	K.J.	11130	5119	437.37	150	2073	7.9	2013-MLO-186	2057	7.3	100.8
279	1-Sep-13	K.J.	11129	5121	437.50	150	2065	7.7	2013-MLO-186	2057	7.3	100.4
280	1-Sep-13	K.J.	11118	5144	437.31	150	2078	7.8	2013-MLO-186	2057	7.3	101.0
281	1-Sep-13	K.J.	11115	5145	437.62	150	2092	7.7	2013-MLO-186	2057	7.3	101.7
282	1-Sep-13	K.J.	11130	5117	438.51	150	2080	7.7	2013-MLO-186	2057	7.3	101.1
283	1-Sep-13	K.J.	11133	5115	438.65	150	2071	8.3	2013-MLO-186	2057	7.3	100.7
284	1-Sep-13	K.J.	11115	5142	437.81	150	2045	8.0	2013-MLO-186	2057	7.3	99.4
285	5-Sep-13	K.J.	11135	5115	438.66	150	2073	7.4	2013-MLO-186	2057	7.3	100.8
286	5-Sep-13	K.J.	11148	5109	439.13	150	2016	9.9	2013-MLO-186	2057	7.3	98.0

Reviewed By: KRC

FIELD NUCLEAR DENSITY TEST REPORT
Soil Bentonite Liner

Project #: 12-1362-0022 Phase: 4000
Short Title: AREVA / JEB Stage 1 Optimization Stage 1 / McClean Lake, Sk
Contractor: Broda Construction
Gauge No.: 32355
Tested by: K.J./K.B./K.N./J.C/J.B. Test Date: July 7, 2013 - Sept. 7, 2013

Test No.	Date	Tested by:	Northing (m)	Easting (m)	Test Elev. (m)	Probe Depth (mm)	Dry Density (kg/m^3)	% Moisture	Proctor No.	Max. Dry Density (kg/m^3)	Opt. W/C	% Proctor
288	5-Sep-13	K.J.	11140	5112	439.06	150	2038	7.9	2013-MLO-186	2057	7.3	99.1
289	5-Sep-13	K.J.	11113	5138	438.20	150	2055	7.6	2013-MLO-186	2057	7.3	99.9
290	5-Sep-13	K.J.	11121	5120	438.94	150	2088	8.5	2013-MLO-186	2057	7.3	101.5
291	5-Sep-13	K.J.	11114	5127	439.19	150	2052	8.6	2013-MLO-186	2057	7.3	99.8
292	5-Sep-13	K.J.	11112	5138	439.02	150	2028	9.3	2013-MLO-186	2057	7.3	98.6
293	5-Sep-13	K.J.	11136	5112	439.25	150	2088	8.9	2013-MLO-186	2057	7.3	101.5
294	5-Sep-13	K.J.	11108	5144	439.23	150	2032	7.3	2013-MLO-186	2057	7.3	98.8
295	6-Sep-13	K.J.	11155	5107	439.23	150	2082	7.1	2016-MLO-186	2057	7.3	101.2
296	6-Sep-13	K.J.	11331	5410	438.47	150	2063	7.6	2016-MLO-186	2057	7.3	100.3
297	6-Sep-13	K.J.	11296	5452	439.19	150	2049	7.6	2016-MLO-186	2057	7.3	99.6
298	6-Sep-13	K.J.	11327	5418	438.92	150	2036	7.1	2016-MLO-186	2057	7.3	99.0
299	6-Sep-13	K.J.	11336	5402	438.99	150	2073	7.0	2016-MLO-186	2057	7.3	100.8
300	6-Sep-13	K.J.	11302	5450	439.39	150	2049	7.0	2016-MLO-186	2057	7.3	99.6
301	6-Sep-13	K.J.	11323	5425	439.16	150	2041	7.6	2016-MLO-186	2057	7.3	99.2
302	7-Sep-13	J.B	11332	5410	439.17	150	2029	6.4	2013-MLO-186	2057	7.3	98.6
Remarks:	Results communicated verbally to Dale Bruce (Broda)						**MIN**	6.4			**MIN**	98.0
							AVG	9.4			**AVG**	99.9
							MAX	11.2			**MAX**	102.7

The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client. This report constitutes a testing service only and does not represent any results interpretation or opinion regarding specification compliance or material suitability. Engineering interpretation can be provided by Golder Associates Ltd. upon request.

Reviewed By: KRC

SUMMARY OF MECHANICAL SIEVE RESULTS
LINER BASE MATERIAL - CRUSHED SANDSTONE

Project #: 12-1362-0022 **Phase:** 4000/4200
Short Title: AREVA / JEB Stage 1 Optimization Stage 1 / McClean Lake, Sk
Contractor: Snake Lake
Tested by: K.M. **Test Date:** May 22 - May 30, 2013

Sample Number	Date	Time	Percent Passing Sieve Size (mm)							
			60	12.5	10	4.75	1.00	0.250	0.160	0.075
2013-MLO-047	22-May-13	6:00 PM	100.0	100.0	100.0	93.1	71.6	40.9	31.1	20.9
2013-MLO-048	22-May-13	6:00 PM	100.0	100.0	100.0	97.5	76.4	42.9	32.5	21.8
2013-MLO-049	23-May-13	9:40 AM	100.0	100.0	100.0	94.9	69.9	37.3	27.7	18.2
2013-MLO-050	23-May-13	12:30 PM	100.0	100.0	100.0	96.5	70.9	35.9	26.6	17.6
2013-MLO-051	23-May-13	3:45 PM	100.0	100.0	100.0	97.6	74.5	39.5	29.1	18.9
2013-MLO-052	24-May-13	6:45 AM	100.0	100.0	100.0	91.1	63.6	31.8	23.3	15.2
2013-MLO-053	24-May-13	10:15 AM	100.0	100.0	100.0	96.4	72.1	39.4	29.3	19.1
2013-MLO-054	24-May-13	1:15 PM	100.0	100.0	100.0	97.4	73.7	40.9	30.7	20.1
2013-MLO-055	24-May-13	3:50 PM	100.0	100.0	100.0	96.1	72.0	40.1	30.1	19.9
2013-MLO-056	25-May-13	6:45 AM	100.0	100.0	100.0	91.7	66.1	33.9	24.4	15.8
2013-MLO-057	25-May-13	10:00 AM	100.0	100.0	100.0	94.0	69.9	37.5	27.4	17.8
2013-MLO-058	25-May-13	1:30 PM	100.0	100.0	100.0	95.7	73.6	42.3	31.8	21.2
2013-MLO-059	25-May-13	4:15 PM	100.0	100.0	100.0	92.3	70.9	39.0	29.4	19.9
2013-MLO-060	26-May-13	6:50 AM	100.0	100.0	100.0	93.7	72.4	37.7	27.4	18.4
2013-MLO-061	26-May-13	10:15 AM	100.0	100.0	100.0	95.2	73.9	43.8	33.7	22.9
2013-MLO-062	26-May-13	1:15 PM	100.0	100.0	100.0	94.4	72.3	41.2	30.8	20.2
2013-MLO-063	26-May-13	4:15 PM	100.0	100.0	100.0	96.5	75.1	36.7	25.3	16.2
2013-MLO-064	27-May-13	7:30 AM	100.0	100.0	100.0	93.2	69.5	32.9	23.3	15.3
2013-MLO-065	27-May-13	10:20 AM	100.0	100.0	100.0	94.2	70.9	33.9	24.0	15.5
2013-MLO-066	27-May-13	3:50 PM	100.0	100.0	100.0	96.6	73.8	36.4	26.0	17.0
2013-MLO-067	28-May-13	6:45 AM	100.0	100.0	100.0	95.2	70.9	35.0	25.3	16.8
2013-MLO-068	28-May-13	10:10 AM	100.0	100.0	100.0	98.6	75.6	40.9	30.5	20.3
2013-MLO-069	28-May-13	1:30 PM	100.0	100.0	100.0	97.3	78.0	47.3	36.2	24.2
2013-MLO-070	28-May-13	4:30 PM	100.0	100.0	100.0	97.0	75.9	43.8	33.2	22.0
2013-MLO-071	29-May-13	7:00 AM	100.0	100.0	100.0	96.1	73.9	44.3	34.4	23.2
2013-MLO-072	29-May-13	10:15 AM	100.0	100.0	100.0	97.1	74.0	43.7	35.5	22.3
2013-MLO-073	29-May-13	2:00 PM	100.0	100.0	100.0	96.1	74.7	43.8	33.3	22.1
2013-MLO-074	30-May-13	7:00 AM	100.0	100.0	100.0	96.1	75.5	45.0	34.5	23.3
Specification			**100**	**--**	**--**	**--**	**40-100**	**--**	**--**	**15 - 35**
Average			**100.0**	**100.0**	**100.0**	**95.4**	**72.6**	**39.6**	**29.5**	**19.5**

Remarks:

The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client.

Reviewed By: KRC

SUMMARY OF MECHANICAL SIEVE RESULTS
LINER BASE MATERIAL - SCREENED TILL

Project #: 12-1362-0022 **Phase:** 4000/4200
Short Title: AREVA / JEB Stage 1 Optimization Stage 1 / McClean Lake, Sk
Contractor: Broda Construction
Tested by: J.B./K.J. **Test Date:** August 26, 2013 - August 29, 2013

Sample Number	Date	Percent Passing Sieve Size (mm)								
		60	56	12.5	10	4.75	1.00	0.250	0.160	0.075
2013-MLO-183	26-Aug-13	100.0	100.0	90.0	88.0	84.0	74.0	49.0	40.0	27.0
2013-MLO-184	27-Aug-13	100.0	100.0	87.0	86.0	83.0	72.0	49.0	40.0	27.0
2013-MLO-185	27-Aug-13	100.0	100.0	86.0	85.0	81.0	70.0	47.0	38.0	26.0
2013-MLO-187	27-Aug-13	100.0	100.0	82.0	80.0	76.0	67.0	45.0	37.0	26.0
2013-MLO-188	28-Aug-13	100.0	100.0	85.0	85.0	82.0	71.0	48.0	38.0	27.0
2013-MLO-189	28-Aug-13	100.0	100.0	78.0	76.0	73.0	63.0	43.0	35.0	25.0
2013-MLO-190	28-Aug-13	100.0	100.0	89.0	87.0	84.0	72.0	48.0	39.0	27.0
2013-MLO-191	29-Aug-13	100.0	100.0	79.0	79.0	75.0	65.0	42.0	34.0	23.0
2013-MLO-192	29-Aug-13	100.0	100.0	91.0	89.0	85.0	75.0	48.0	38.0	26.0
2013-MLO-193	29-Aug-13	100.0	100.0	91.0	90.0	87.0	76.0	50.0	40.0	27.0
2013-MLO-194	29-Aug-13	100.0	100.0	89.0	88.0	85.0	75.0	50.0	40.0	28.0
Specification		**100**		**--**	**--**	**--**	**40-100**	**--**	**--**	**15 - 35**
Average		**100.0**	**100.0**	**86.1**	**84.8**	**81.4**	**70.9**	**47.2**	**38.1**	**26.3**

Remarks:

The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client.

Reviewed By: KRC

SUMMARY OF MECHANICAL SIEVE RESULTS
In-Place Soil Bentonite Liner

Project #: 12-1362-0022 **Phase:** 4000/4200
Short Title: AREVA / JEB Stage 1 Opt / McClean Lake, Sk
Contractor: Broda
Tested by: G.P.D./K.N./J.B./K.J. **Test Date:** July 7, 2013 - September 6, 2013

Sample Number	Date	Percent Passing Sieve Size (mm)								
		60	56	12.5	10	4.75	1.00	0.250	0.160	0.075
2013-MLO-119	7-Jul-13	100.0	100.0	100.0	100.0	93.0	74.0	44.0	34.0	25.0
2013-MLO-121	9-Jul-13	100.0	100.0	100.0	100.0	96.0	74.0	43.0	33.0	24.0
2013-MLO-122	10-Jul-13	100.0	100.0	99.0	99.0	92.0	74.0	43.0	33.0	24.0
2013-MLO-125	10-Jul-13	100.0	100.0	100.0	100.0	95.0	75.0	44.0	34.0	25.0
2013-MLO-127	11-Jul-13	100.0	100.0	100.0	100.0	95.0	76.0	46.0	36.0	26.0
2013-MLO-128	11-Jul-13	100.0	100.0	100.0	99.0	92.0	74.0	44.0	34.0	25.0
2013-MLO-129	11-Jul-13	100.0	100.0	100.0	100.0	93.0	75.0	45.0	35.0	26.0
2013-MLO-131	14-Jul-13	100.0	100.0	100.0	100.0	96.0	76.0	44.0	34.0	24.0
2013-MLO-132	14-Jul-13	100.0	100.0	100.0	100.0	96.0	76.0	45.0	35.0	25.0
2013-MLO-133	15-Jul-13	100.0	100.0	100.0	100.0	96.0	75.0	44.0	34.0	24.0
2013-MLO-134	15-Jul-13	100.0	100.0	100.0	100.0	97.0	75.0	44.0	34.0	25.0
2013-MLO-136	16-Jul-13	100.0	100.0	100.0	100.0	93.0	72.0	41.0	32.0	23.0
2013-MLO-138	16-Jul-13	100.0	100.0	100.0	100.0	94.0	74.0	41.0	32.0	23.0
2013-MLO-139	17-Jul-13	100.0	100.0	100.0	100.0	92.0	74.0	41.0	32.0	23.0
2013-MLO-141	17-Jul-13	100.0	100.0	100.0	100.0	95.0	75.0	43.0	33.0	24.0
2013-MLO-142	18-Jul-13	100.0	100.0	100.0	100.0	90.0	72.0	42.0	33.0	24.0
2013-MLO-143	24-Jul-13	100.0	100.0	100.0	100.0	88	70	42	32	24.0
2013-MLO-144	22-Jul-13	100.0	100.0	100.0	99.0	90.0	73.0	43.0	34.0	24.0
2013-MLO-145	21-Jul-13	100.0	100.0	100.0	100.0	91.0	72.0	42.0	33.0	24.0
2013-MLO-146	21-Jul-13	100.0	100.0	100.0	100.0	91.0	74.0	44.0	34.0	24.0
2013-MLO-147	22-Jul-13	100.0	100.0	100.0	99.0	93.0	75.0	44.0	34.0	25.0
2013-MLO-148	22-Jul-13	100.0	100.0	100.0	99.0	91.0	73.0	43.0	33.0	24.0
2013-MLO-150	23-Jul-13	100.0	100.0	100.0	100.0	89.0	72.0	43.0	33.0	24.0
2013-MLO-152	24-Jul-13	100.0	100.0	100.0	99.0	88.0	69.0	39.0	30.0	20.0
2013-MLO-153	24-Jul-13	100.0	100.0	100.0	100.0	91.0	72.0	40.0	30.0	20.0
2013-MLO-154	24-Jul-13	100.0	100.0	100.0	100.0	90.0	73.0	43.0	34.0	24.0
2013-MLO-155	24-Jul-13	100.0	100.0	100.0	100.0	89.0	72.0	42.0	33.0	24.0
2013-MLO-156	24-Jul-13	100.0	100.0	100.0	99.0	89.0	71.0	42.0	33.0	24.0
2013-MLO-157	24-Jul-13	100.0	100.0	100.0	99.0	90.0	72.0	42.0	33.0	24.0
2013-MLO-161	27-Jul-13	100.0	100.0	100.0	100.0	90.0	70.0	40.0	31.0	23.0
2013-MLO-162	27-Jul-13	100.0	100.0	100.0	100.0	91.0	73.0	43.0	34.0	24.0
2013-MLO-165	28-Jul-13	100.0	100.0	100.0	100.0	88.0	70.0	41.0	33.0	24.0
2013-MLO-166	1-Aug-13	100.0	100.0	100.0	99.0	89.0	72.0	43.0	34.0	24.0
2013-MLO-167	1-Aug-13	100.0	100.0	100.0	100.0	93.0	74.0	43.0	34.0	25.0
2013-MLO-170	2-Aug-13	100.0	100.0	100.0	100.0	92.0	75.0	44.0	34.0	25.0
2013-MLO-173	24-Aug-13	100.0	100.0	100.0	100.0	89.0	70.0	41.0	32.0	23.0
2013-MLO-176	24-Aug-13	100.0	100.0	100.0	100.0	91.0	71.0	41.0	32.0	23.0
2013-MLO-183	26-Aug-13	100.0	100.0	90.0	88.0	84.0	74.0	49.0	40.0	27.0
2013-MLO-184	27-Aug-13	100.0	100.0	87.0	86.0	83.0	72.0	49.0	40.0	27.0
2013-MLO-185	27-Aug-13	100.0	100.0	86.0	85.0	81.0	70.0	47.0	38.0	26.0
2013-MLO-187	27-Aug-13	100.0	100.0	82.0	80.0	76.0	67.0	45.0	37.0	26.0
2013-MLO-188	28-Aug-13	100.0	100.0	85.0	85.0	82.0	71.0	48.0	38.0	27.0

Reviewed By: KRC

SUMMARY OF MECHANICAL SIEVE RESULTS
In-Place Soil Bentonite Liner

Project #: 12-1362-0022 **Phase:** 4000/4200
Short Title: AREVA / JEB Stage 1 Opt / McClean Lake, Sk
Contractor: Broda
Tested by: G.P.D./K.N./J.B./K.J. **Test Date:** July 7, 2013 - September 6, 2013

Sample Number	Date	Percent Passing Sieve Size (mm)								
		60	56	12.5	10	4.75	1.00	0.250	0.160	0.075
2013-MLO-189	28-Aug-13	100.0	100.0	78.0	76.0	73.0	63.0	43.0	35.0	25.0
2013-MLO-190	28-Aug-13	100.0	100.0	89.0	87.0	84.0	72.0	48.0	39.0	27.0
2013-MLO-191	29-Aug-13	100.0	100.0	79.0	79.0	75.0	65.0	42.0	34.0	23.0
2013-MLO-192	29-Aug-13	100.0	100.0	91.0	89.0	85.0	75.0	48.0	38.0	26.0
2013-MLO-193	29-Aug-13	100.0	100.0	91.0	90.0	87.0	76.0	50.0	40.0	27.0
2013-MLO-194	29-Aug-13	100.0	100.0	89.0	88.0	85.0	75.0	50.0	40.0	28.0
2013-MLO-195	30-Aug-13	100.0	100.0	98.0	95.0	90.0	78.0	52.0	41.0	28.0
2013-MLO-196	30-Aug-13	100.0	100.0	90.0	88.0	85.0	75.0	51.0	42.0	31.0
2013-MLO-198	30-Aug-13	100.0	100.0	84.0	82.0	78.0	70.0	50.0	41.0	30.0
2013-MLO-199	31-Aug-13	100.0	100.0	95.0	94.0	90.0	79.0	55.0	45.0	33.0
2013-MLO-203	5-Sep-13	100.0	100.0	93.0	92.0	88.0	77.0	52.0	42.0	30.0
2013-MLO-205	6-Sep-13	100.0	100.0	96.0	95.0	91.0	80.0	55.0	45.0	33.0
Average		**100.0**	**100.0**	**96.3**	**95.7**	**89.2**	**73.0**	**44.7**	**35.2**	**25.2**

Remarks:

The testing services reported herein have been performed in accordance with the indicated recognized standard, or in accordance with local industry practice. This report is for the sole use of the designated client.

Reviewed By: KRC

Golder Associates

GENERAL TESTING RESULTS

Project #: 12-1362-0022 Phase : 4000 / 4200

Short Title: AREVA / JEB Stage 1 Optimization / McClean Lake, SK

Tested by: G.D.P. / J.B. Date: September 12, 2013

Sample Identification		Laboratory Test Results							
Sample #	Sample Type	Water Content (%)							
13-MLO-127		10.5							
13-MLO-129		10.7							
13-MLO-131		10.2							
13-MLO-132		9.6							
13-MLO-139		9.3							
13-MLO-140		10.1							
13-MLO-141		10.0							
13-MLO-142		10.1							
13-MLO-144		11.6							
13-MLO-145		9.3							
13-MLO-146		9.8							
13-MLO-147		10.3							
13-MLO-148		11.3							
13-MLO-156		10.0							
13-MLO-157		10.9							
13-MLO-159		9.6							
13-MLO-160		9.3							
13-MLO-161		10.8							
13-MLO-162		11.0							
13-MLO-163		10.5							
13-MLO-164		9.9							
13-MLO-165		13.3							
13-MLO-176		9.7							
13-MLO-178		11.1							
13-MLO-198		9.1							
13-MLO-200		12.2							
13-MLO-202		8.3							
13-MLO-204		8.2							

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1721 8th Street E.
Saskatoon, SK S7H 0T4

Reviewed by:_____

IN SITU HYDRAULIC CONDUCTIVITY TEST

Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	D.B. / B.Y.	Date:	August 15, 2013
Location:	N: 11116 E: 5470 Elev. 439.64 m In place liner.		

Final Hydraulic Conductivity:

k = 3E-10 m/s

Test Summary:

Dry Density: 2035 kg/m^3

Initial Water Content: 9.5 %

(both measured with nuclear densometer)

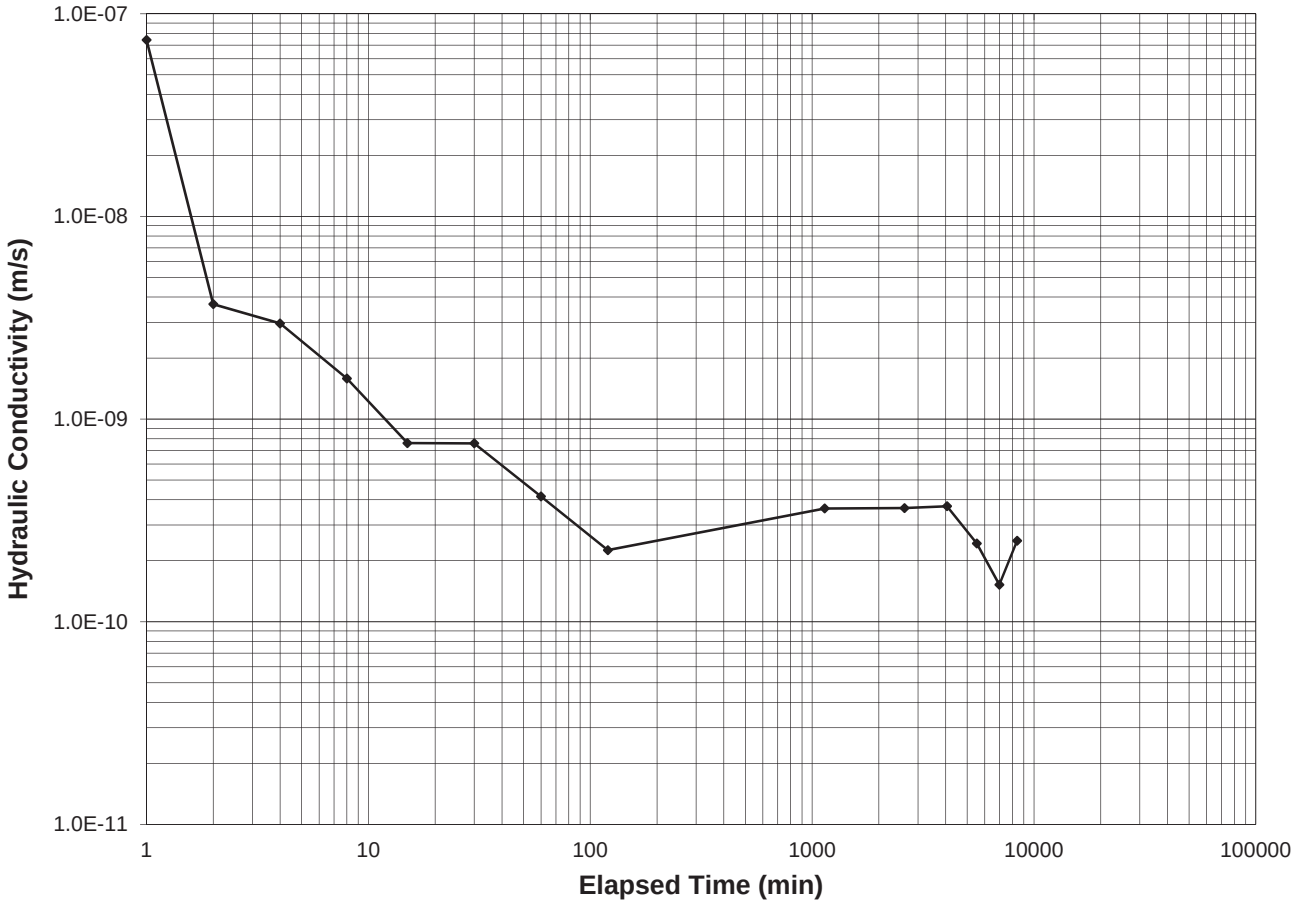
Sample Diameter: 217 mm

Comments:

Test started August 4, 2013

Permeant Liquid: tap water

Graph of Hydraulic Conductivity versus Time



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1721 8th Street E.,
Saskatoon, Saskatchwan, S7H 0T4

Reviewed by:

IN SITU HYDRAULIC CONDUCTIVITY TEST

Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	D.B. / B.Y.	Date:	August 15, 2013
Location:	N: 11046 E: 5278 Elev. 439.65 m In place liner.		

Final Hydraulic Conductivity:

k = 1E-10 m/s

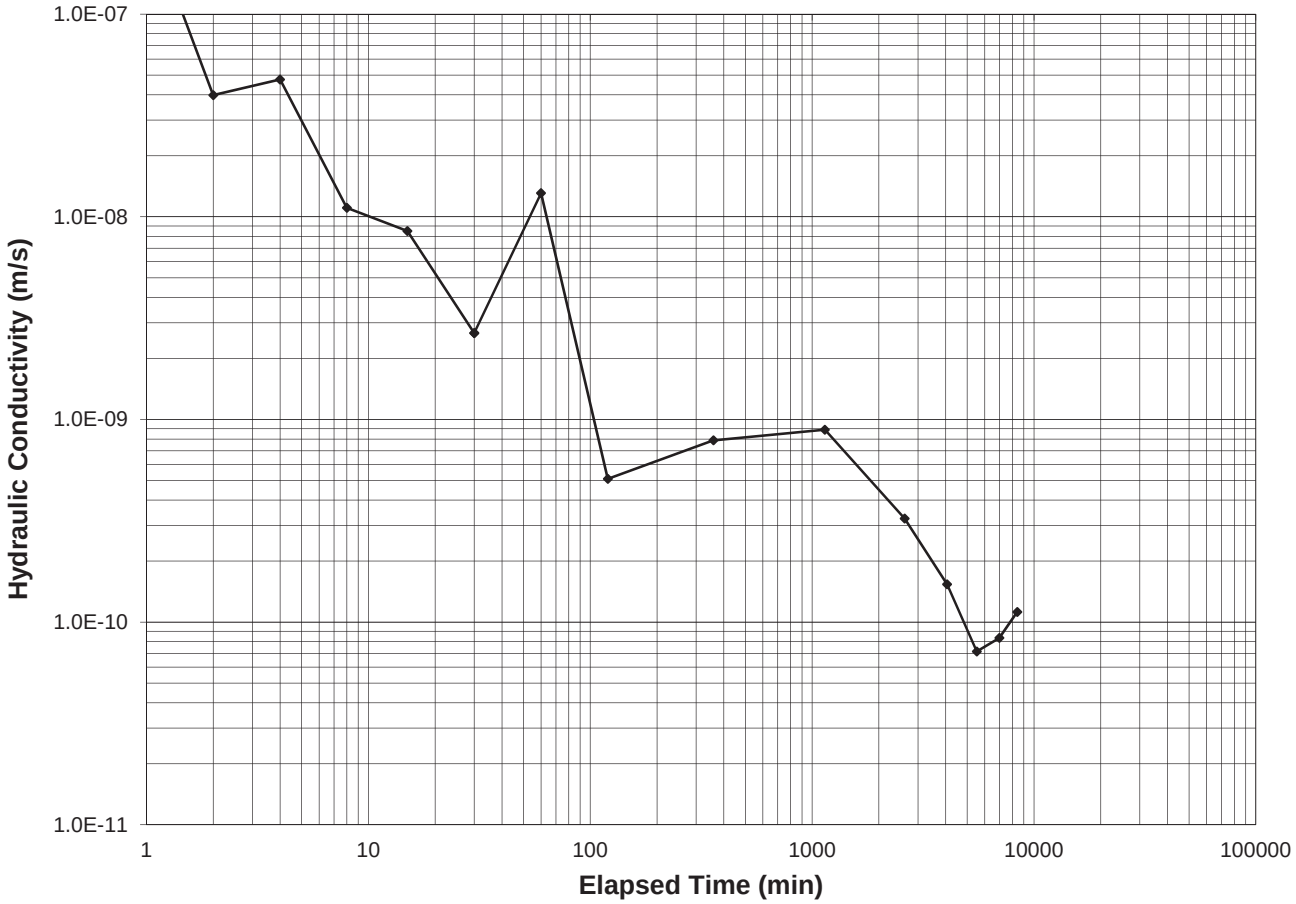
Test Summary:

Dry Density:	2043	kg/m^3
Initial Water Content:	9.4	%
(both measured with nuclear densometer)		
Sample Diameter:	229	mm

Comments:
Test started August 4, 2013

Permeant Liquid: tap water

Graph of Hydraulic Conductivity versus Time



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1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

IN SITU HYDRAULIC CONDUCTIVITY TEST

Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	D.B. / B.Y.	Date:	September 10, 2013
Location:	N: 11055 E: 5395 Elev. 439.5 m In place liner.		

Final Hydraulic Conductivity:

k = 7E-11 m/s

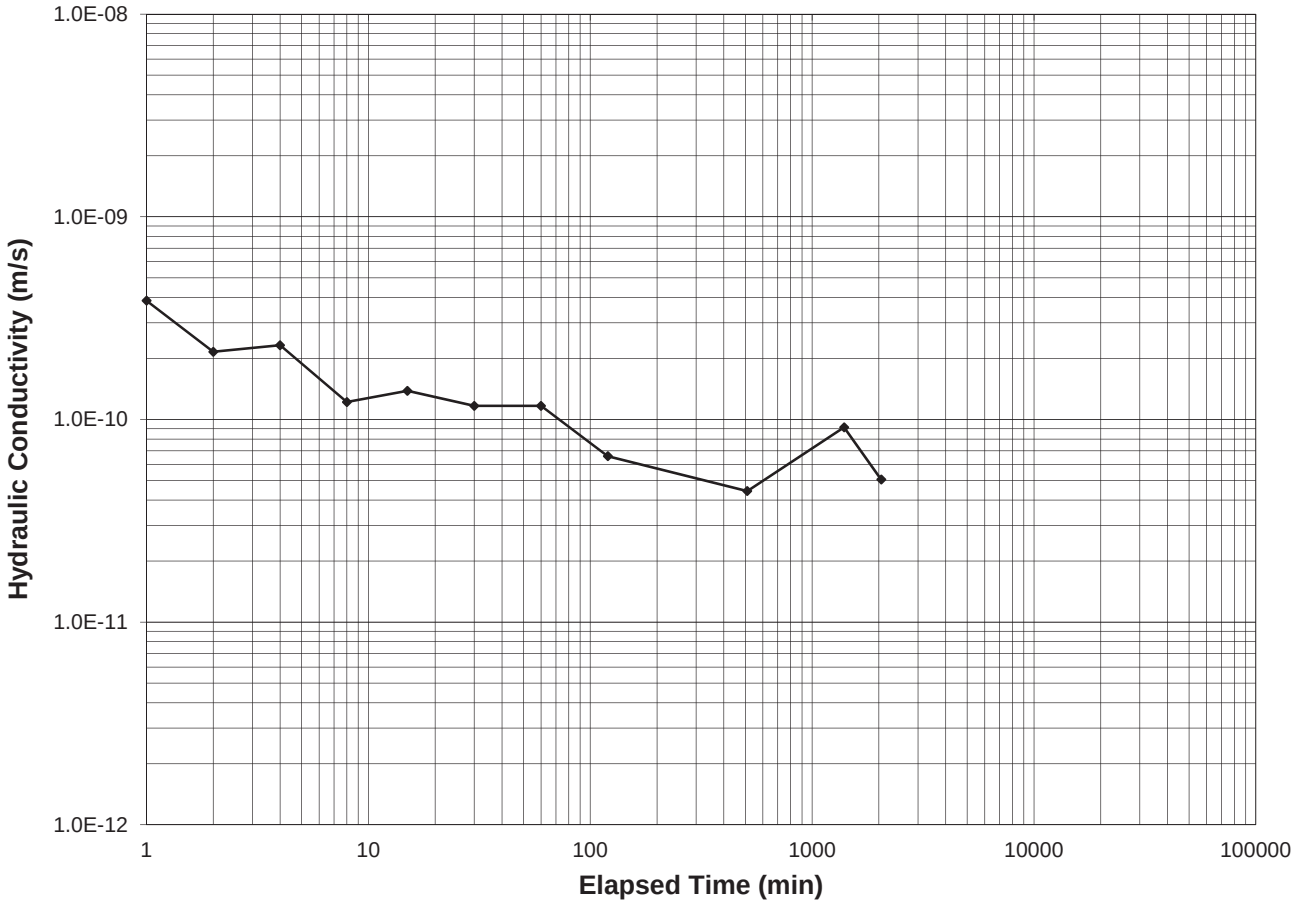
Test Summary:

Dry Density:	2062	kg/m^3
Initial Water Content:	9.0	%
(both measured with nuclear densometer)		
Sample Diameter:	239	mm

Comments:
Test started September 1, 2013

Permeant Liquid: tap water

Graph of Hydraulic Conductivity versus Time



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Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

IN SITU HYDRAULIC CONDUCTIVITY TEST

Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	K.J. / J.C.	Date:	October 24, 2013
Location:	N: 11107.8 E: 5155.6 Elev. 439.12 m In place liner.		

Final Hydraulic Conductivity:

k = 6E-10 m/s

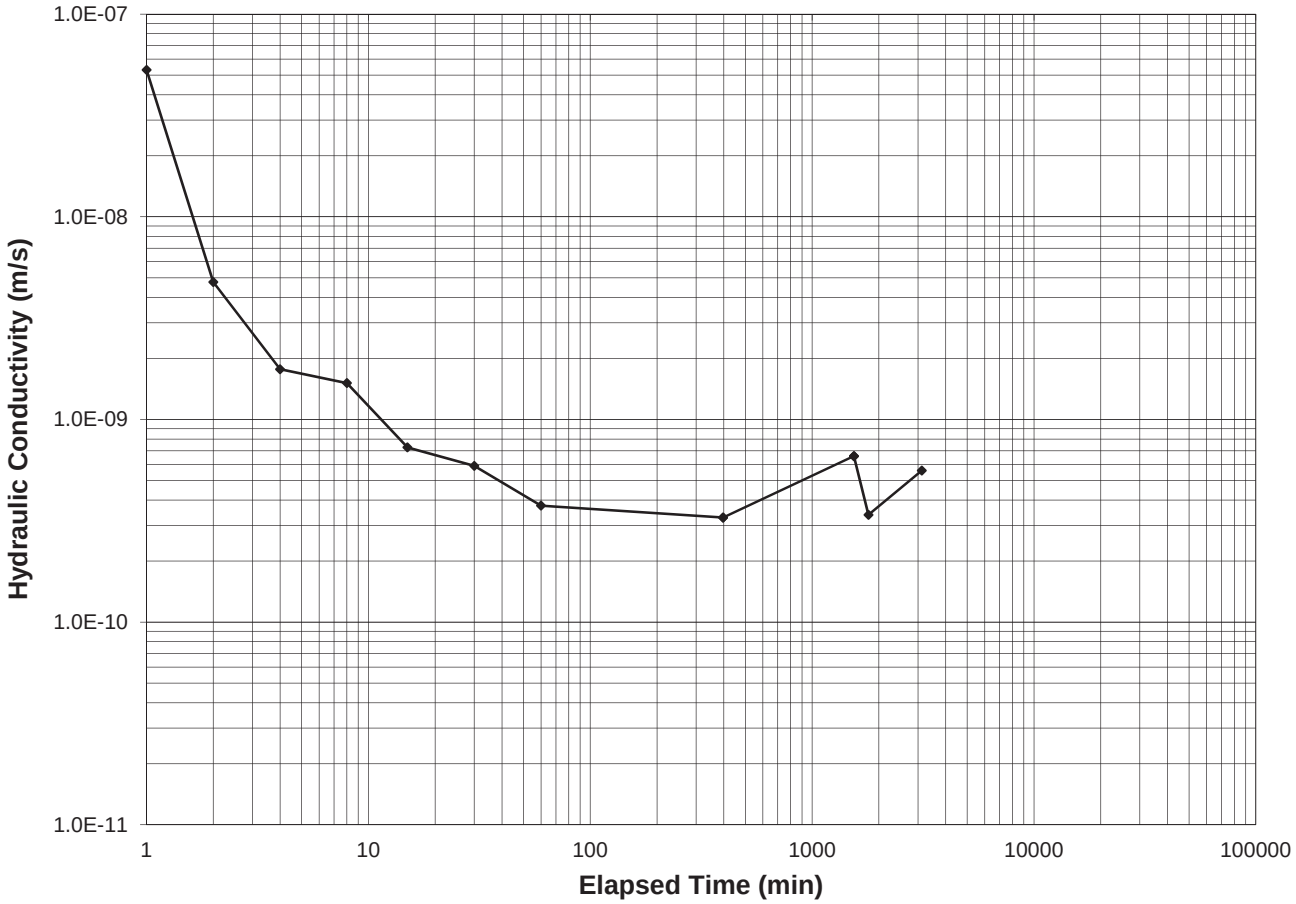
Test Summary:

Dry Density:	2057	kg/m^3
Initial Water Content:	7.3	%
(both measured with nuclear densometer)		
Sample Diameter:	218	mm

Comments:
Test started September 7, 2013
"Closest to ramp"

Permeant Liquid: tap water

Graph of Hydraulic Conductivity versus Time



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Reviewed by:

IN SITU HYDRAULIC CONDUCTIVITY TEST

Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	K.J. / J.C.	Date:	October 24, 2013
Location:	N: 11126.9 E: 5116.9 Elev. 439.26 m In place liner.		

Final Hydraulic Conductivity:

k = 7E-10 m/s

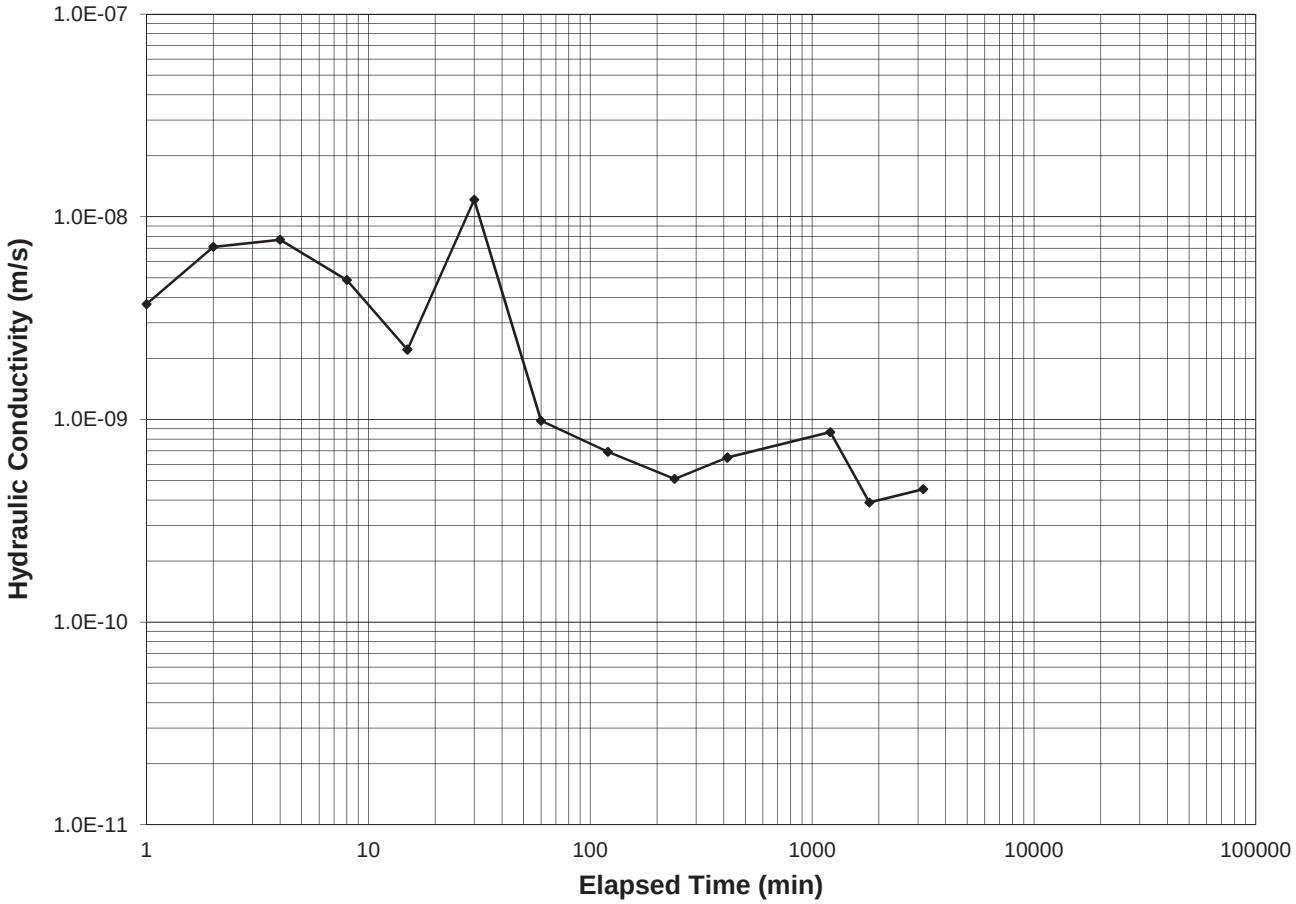
Test Summary:

Dry Density:	2073	kg/m^3
Initial Water Content:	7.9	%
(both measured with nuclear densometer)		
Sample Diameter:	251	mm

Comments:
Test started September 7, 2013

Permeant Liquid: tap water

Graph of Hydraulic Conductivity versus Time



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Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

TRIAXIAL HYDRAULIC CONDUCTIVITY TEST

Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	August 13, 2013
Sample:	2013-MLO-123		
	In place liner. N: 11052 E: 5274 Elev. 436		

Final Hydraulic Conductivity:

k = 9.6E-11 m/s @ 18,713 minutes

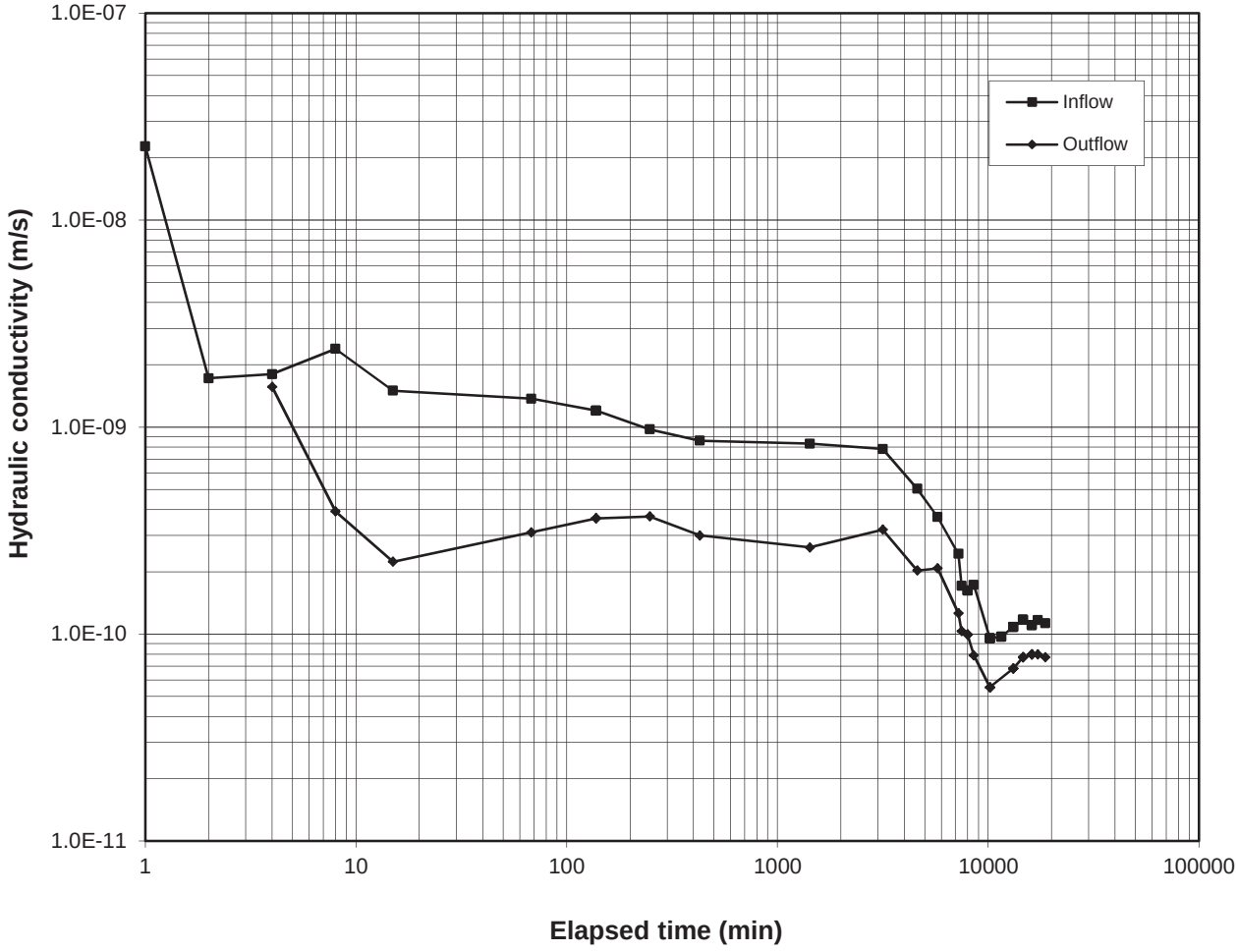
Test Summary:

Initial Dry Density:	1935	kg/m^3
Initial Water Content:	10.6	%
Final Dry Density:	1886	kg/m^3
Final Water Content:	14.6	%
Sample Diameter:	102.51	mm
Sample Height:	56.59	mm
Average Effective Stress:	17	kPa
Hydraulic Gradient:	6 to 29	

Comments:

Permeant Liquid: tap water

Graph of Hydraulic Conductivity versus Time



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Reviewed by:

TRIAXIAL HYDRAULIC CONDUCTIVITY TEST

Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	August 16, 2013
Sample:	2013-MLO-126		
	In place liner. N: 11052 E: 5268 Elev. 437		

Final Hydraulic Conductivity:

k = 1.2E-10 m/s @ 19,348 minutes

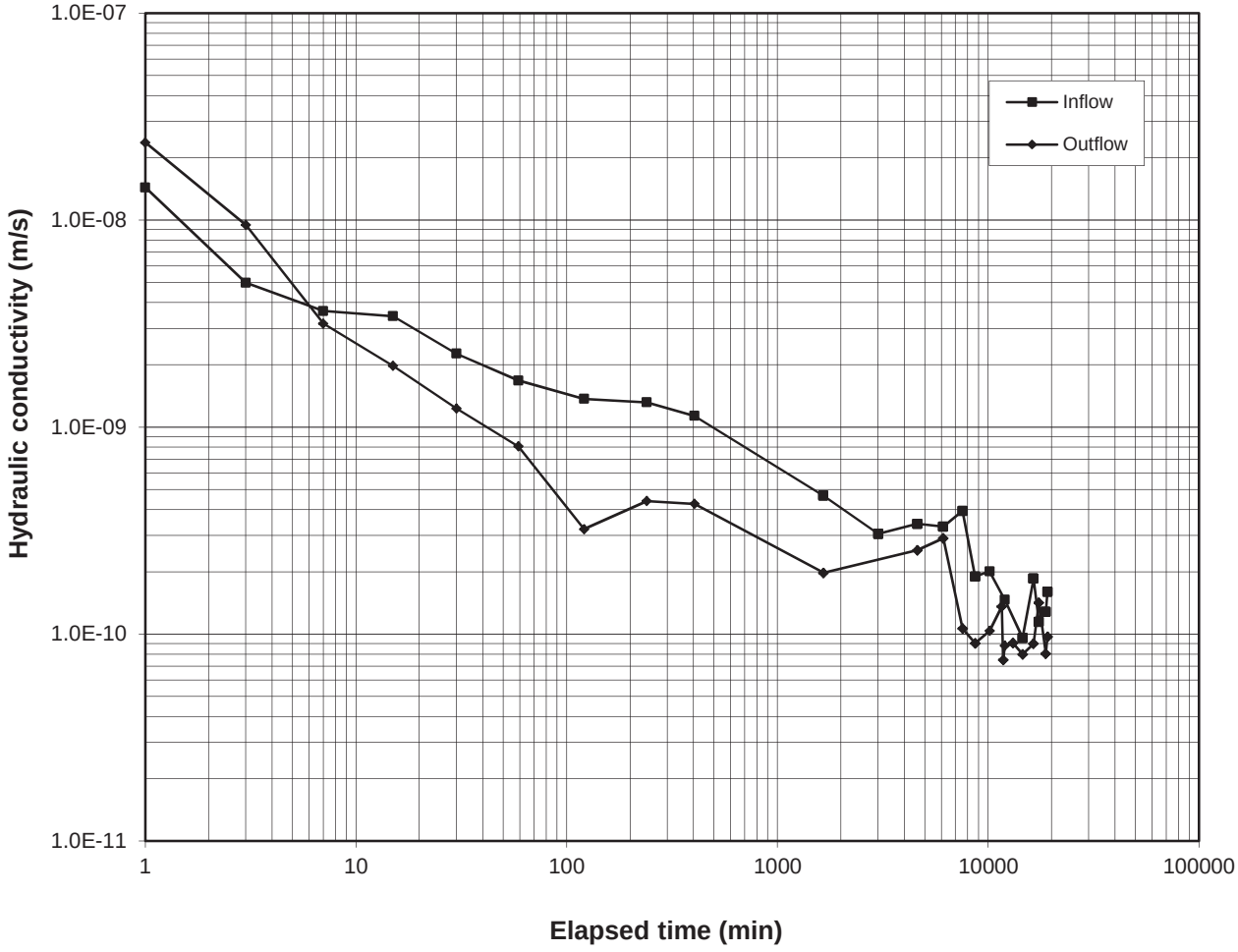
Test Summary:

Initial Dry Density:	1951	kg/m^3
Initial Water Content:	9.7	%
Final Dry Density:	1881	kg/m^3
Final Water Content:	14.5	%
Sample Diameter:	101.66	mm
Sample Height:	54.22	mm
Average Effective Stress:	17	kPa
Hydraulic Gradient:	5 to 26	

Comments:

Permeant Liquid: tap water

Graph of Hydraulic Conductivity versus Time



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Reviewed by:

TRIAXIAL HYDRAULIC CONDUCTIVITY TEST

Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	October 23, 2013
Sample:	2013-MLO-134		
	In place liner. N: 11045 E: 5297 Elev. 438.27 m		

Final Hydraulic Conductivity:

k = 6.6E-11 m/s @ 20,080 minutes

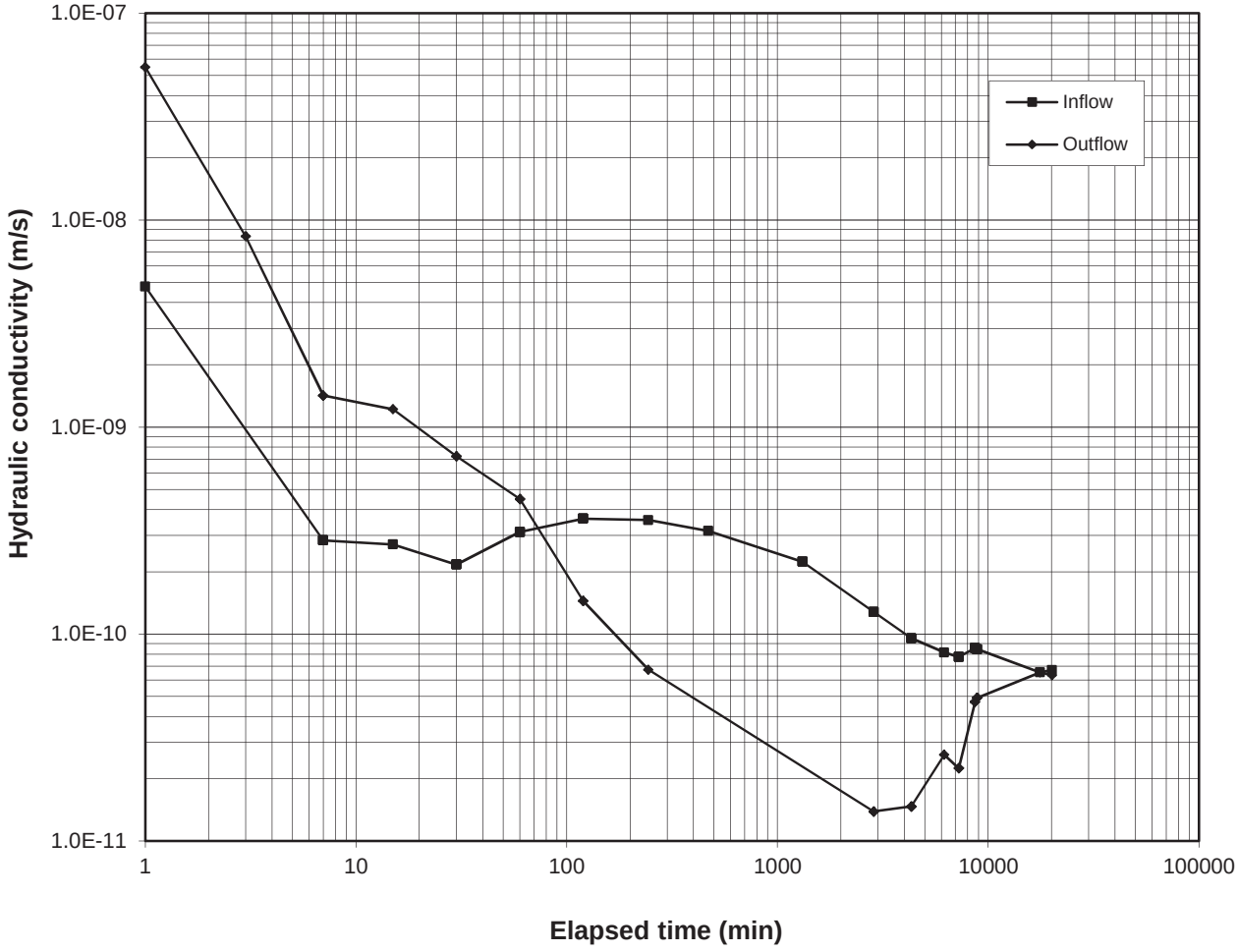
Test Summary:

Initial Dry Density:	1934	kg/m^3
Initial Water Content:	9.3	%
Final Dry Density:	1887	kg/m^3
Final Water Content:	15.1	%
Sample Diameter:	101.93	mm
Sample Height:	41.10	mm
Average Effective Stress:	17	kPa
Hydraulic Gradient:	14 to 21	

Comments:

Permeant Liquid: tap water

Graph of Hydraulic Conductivity versus Time



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Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

TRIAXIAL HYDRAULIC CONDUCTIVITY TEST

Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	D.B. / B.Y.	Date:	September 10, 2013
Sample:	2013-MLO-141		
	In place liner. N: 11104 E: 5161 Elev. 439.0 m		

Final Hydraulic Conductivity:

k = 5.0E-11 m/s @ 20,457 minutes

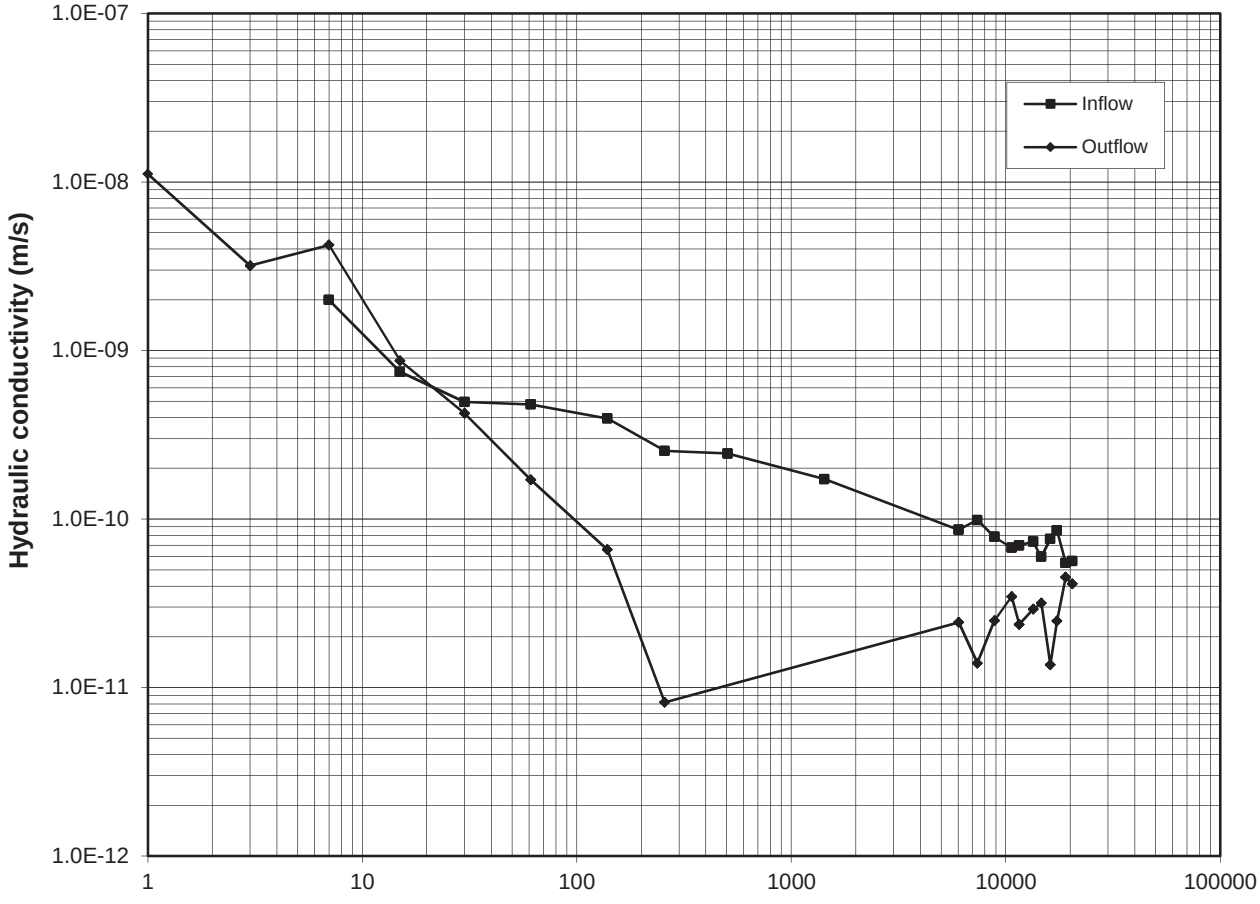
Test Summary:

Initial Dry Density:	1919	kg/m^3
Initial Water Content:	10.1	%
Final Dry Density:	1864	kg/m^3
Final Water Content:	14.9	%
Sample Diameter:	102.24	mm
Sample Height:	55.18	mm
Average Effective Stress:	17	kPa
Hydraulic Gradient:	10 to 22	

Comments:

Permeant Liquid: tap water

Graph of Hydraulic Conductivity versus Time



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1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

TRIAXIAL HYDRAULIC CONDUCTIVITY TEST

Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	October 24, 2013
Sample:	2013-MLO-146		
	In place liner. N: 11359 E: 5298 Elev. 439.02 m		

Final Hydraulic Conductivity:

k = 5.5E-11 m/s @ 27,371 minutes

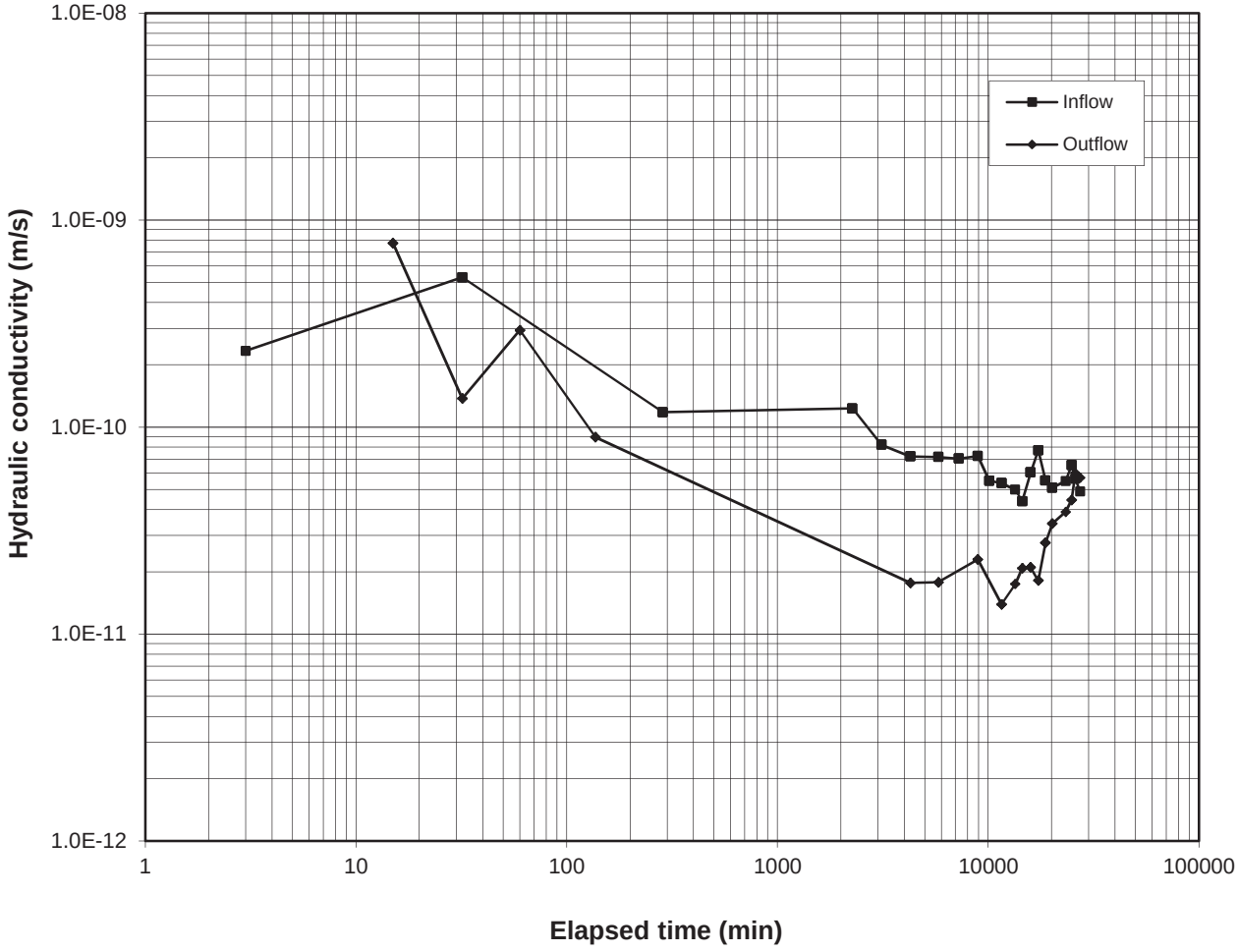
Test Summary:

Initial Dry Density:	1929	kg/m^3
Initial Water Content:	8.5	%
Final Dry Density:	1854	kg/m^3
Final Water Content:	15.4	%
Sample Diameter:	101.70	mm
Sample Height:	40.06	mm
Average Effective Stress:	17	kPa
Hydraulic Gradient:	9 to 23	

Comments:

Permeant Liquid: tap water

Graph of Hydraulic Conductivity versus Time



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Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

TRIAXIAL HYDRAULIC CONDUCTIVITY TEST

Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	September 26, 2013
Sample:	2013-MLO-161		
	In place liner. N: 11361 E: 5347 Elev. 439.47 m		

Final Hydraulic Conductivity:

k = 2.9E-11 m/s @ 30,185 minutes

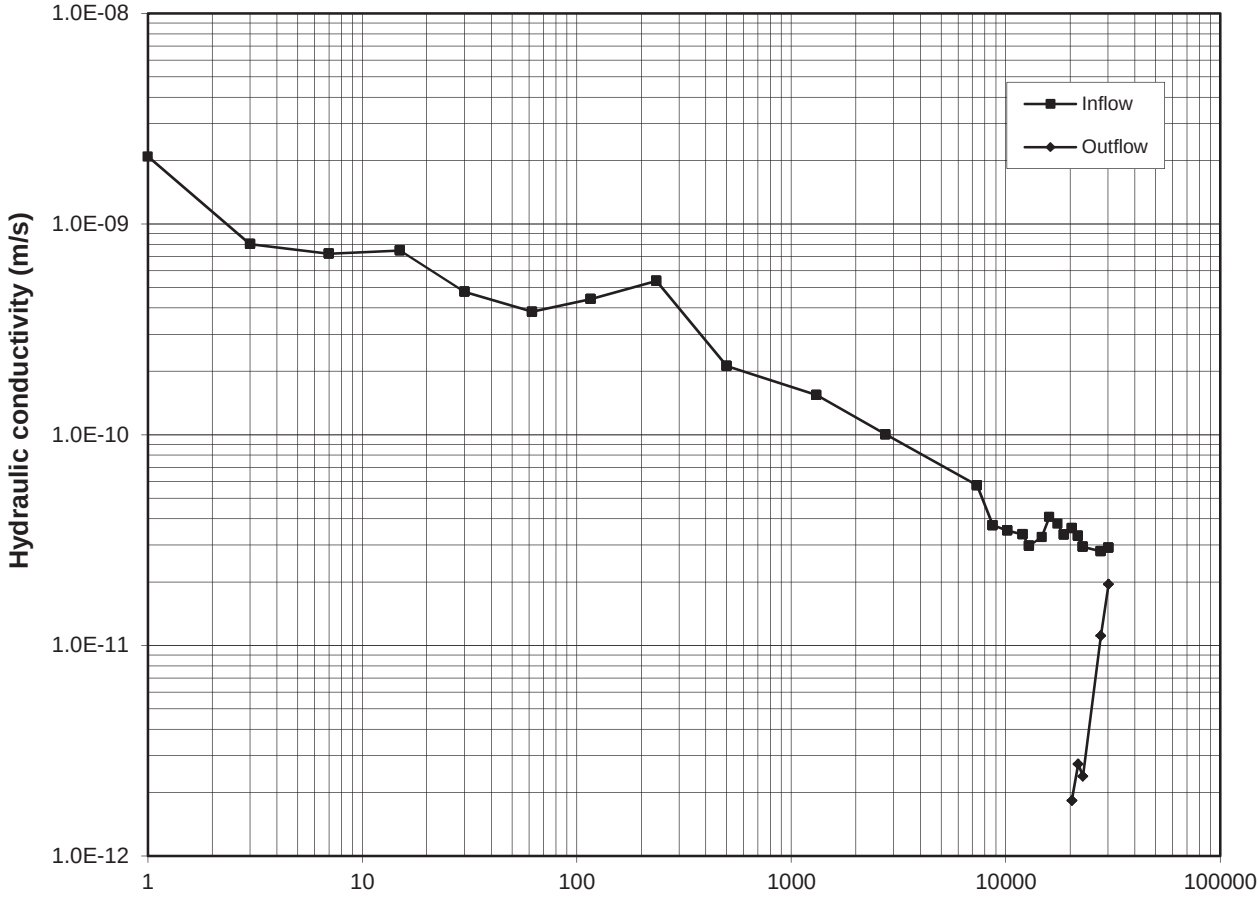
Test Summary:

Initial Dry Density:	1899	kg/m^3
Initial Water Content:	11.7	%
Final Dry Density:	1843	kg/m^3
Final Water Content:	14.3	%
Sample Diameter:	101.81	mm
Sample Height:	55.29	mm
Average Effective Stress:	17	kPa
Hydraulic Gradient:	10 to 21	

Comments:

Permeant Liquid: tap water

Graph of Hydraulic Conductivity versus Time



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Reviewed by:

TRIAXIAL HYDRAULIC CONDUCTIVITY TEST

Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	October 24, 2013
Sample:	2013-MLO-167		
	In place liner. N: 11075 E: 5223 Elev. 435.89 m		

Final Hydraulic Conductivity:

k = 2.2E-11 m/s @ 33,116 minutes

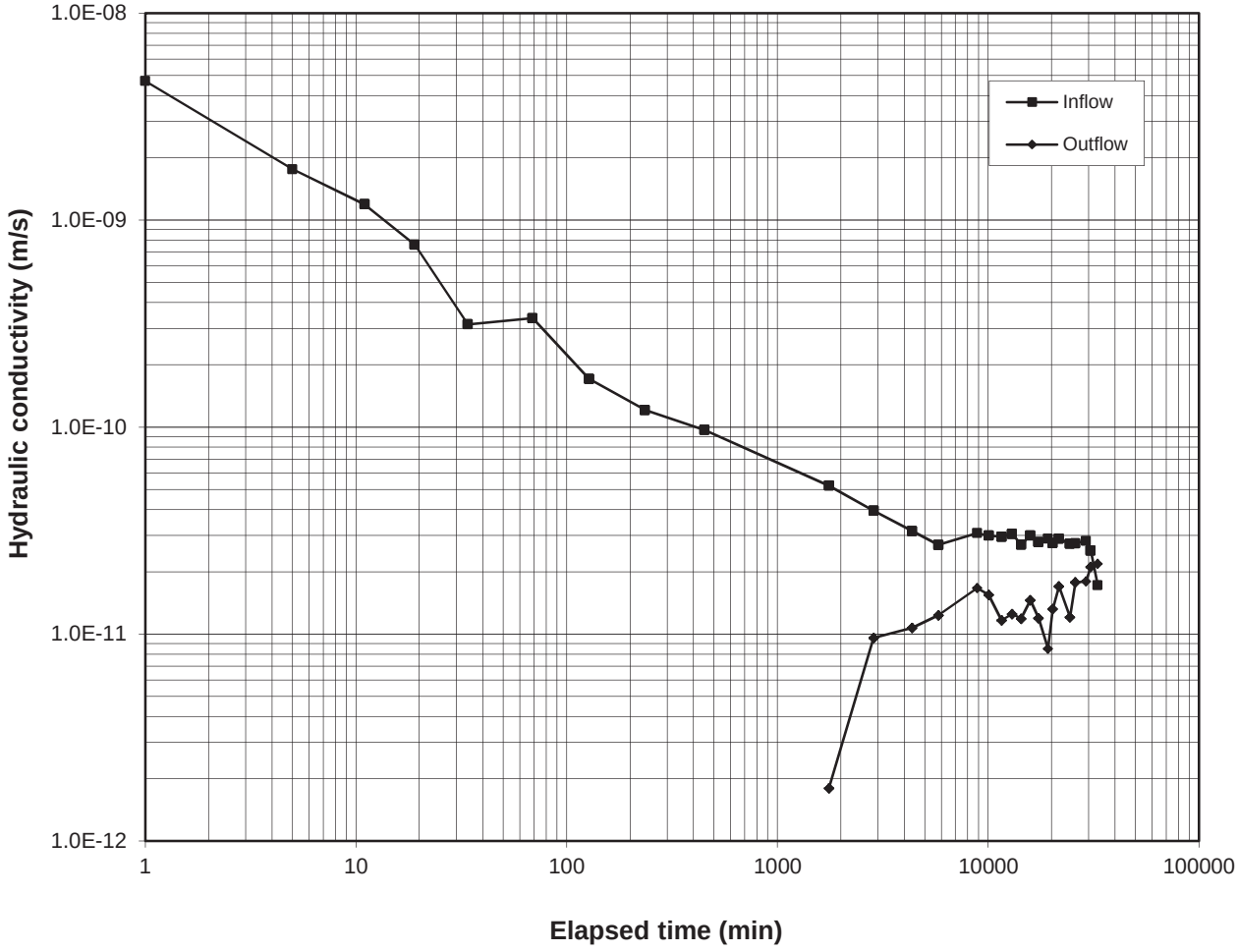
Test Summary:

Initial Dry Density:	1945	kg/m^3
Initial Water Content:	9.6	%
Final Dry Density:	1928	kg/m^3
Final Water Content:	14.4	%
Sample Diameter:	102.17	mm
Sample Height:	40.70	mm
Average Effective Stress:	17	kPa
Hydraulic Gradient:	15 to 24	

Comments:

Permeant Liquid: tap water

Graph of Hydraulic Conductivity versus Time



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1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

TRIAXIAL HYDRAULIC CONDUCTIVITY TEST

Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / Mclean Lake		
Tested By:	B.Y. / D.B.	Date:	September 26, 2013
Sample:	2013-MLO-198		
	In place liner. N: 11127 E: 5130 Elev. 436.45 m		

Final Hydraulic Conductivity:

k = 6.4E-11 m/s @ 14,438 minutes

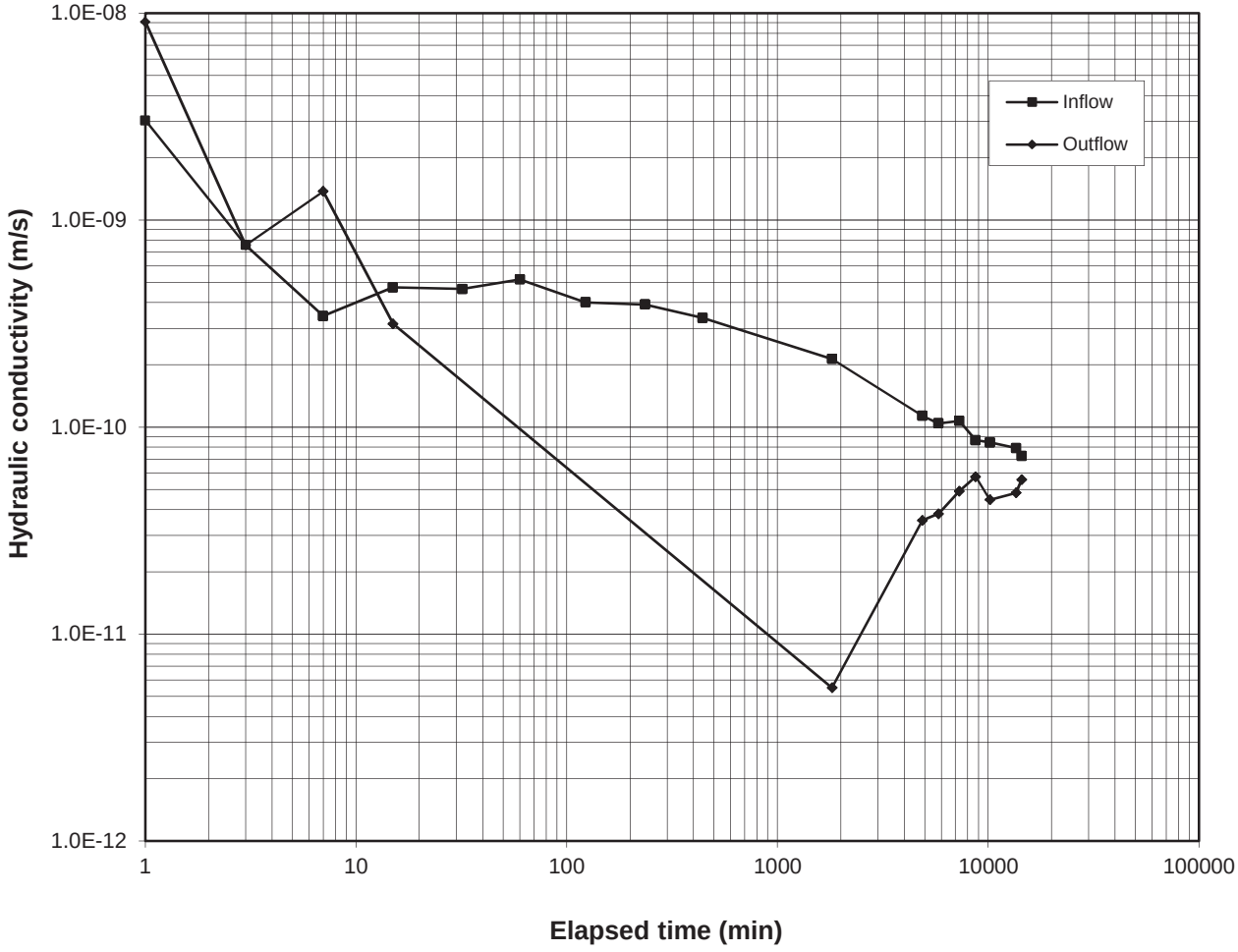
Test Summary:

Initial Dry Density:	1943	kg/m^3
Initial Water Content:	8.8	%
Final Dry Density:	1853	kg/m^3
Final Water Content:	14.5	%
Sample Diameter:	101.68	mm
Sample Height:	51.93	mm
Average Effective Stress:	17	kPa
Hydraulic Gradient:	14 to 20	

Comments:

Permeant Liquid: tap water

Graph of Hydraulic Conductivity versus Time



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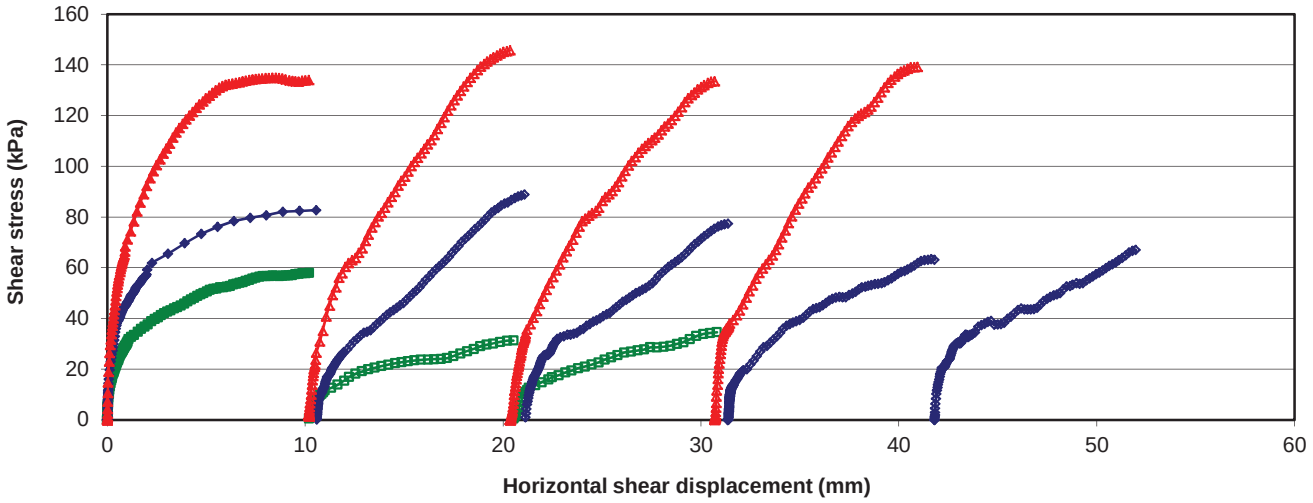
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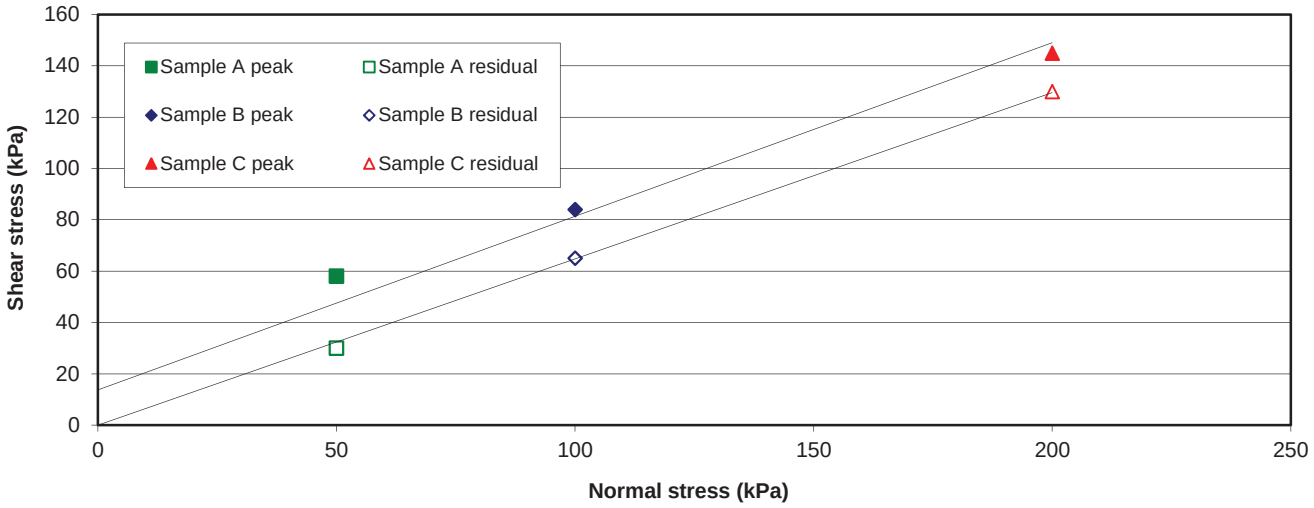
CONSOLIDATED DRAINED DIRECT SHEAR TEST-SUMMARY

Project #: 12-1362-0022 Phase: 4000 / 4200
Short Title: AREVA / JEB Stage 1 Optimization / McClean Lake
Tested By: B.Y. / D.B. Date: November 8, 2013

Sample	Normal Stress (kPa)	Shear Stress Peak (kPa)	Shear Stress Residual (kPa)
2013-MLO-87A (test pad material)	50	58	30
	100	84	65
	200	145	130

	Peak	Residual
Friction angle (degrees):	32.9	32.9
cohesion (kPa):	18	0





Comments:

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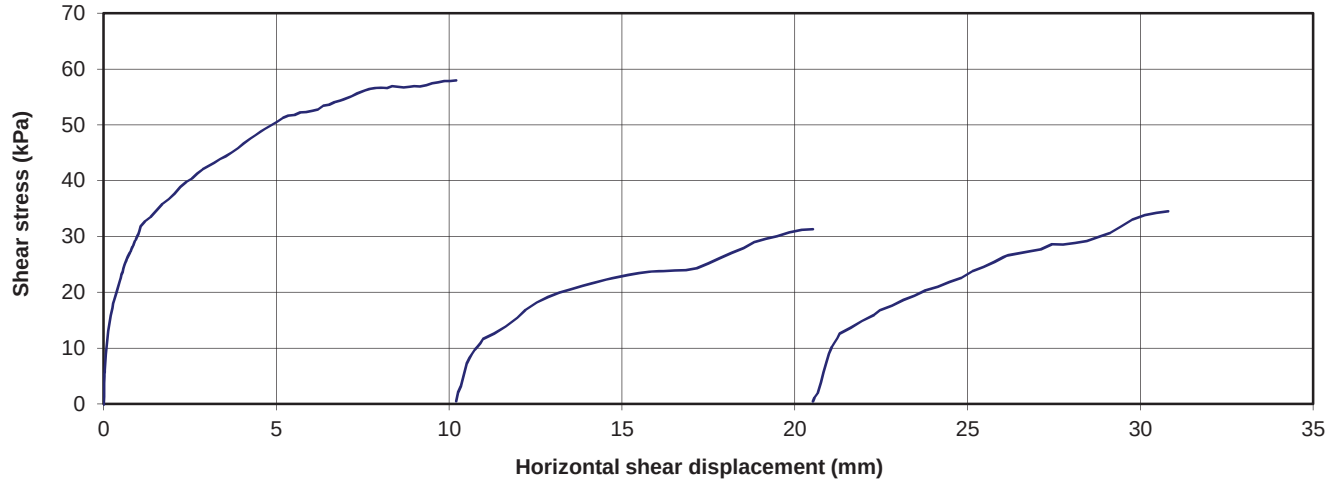
CONSOLIDATED DRAINED DIRECT SHEAR TEST

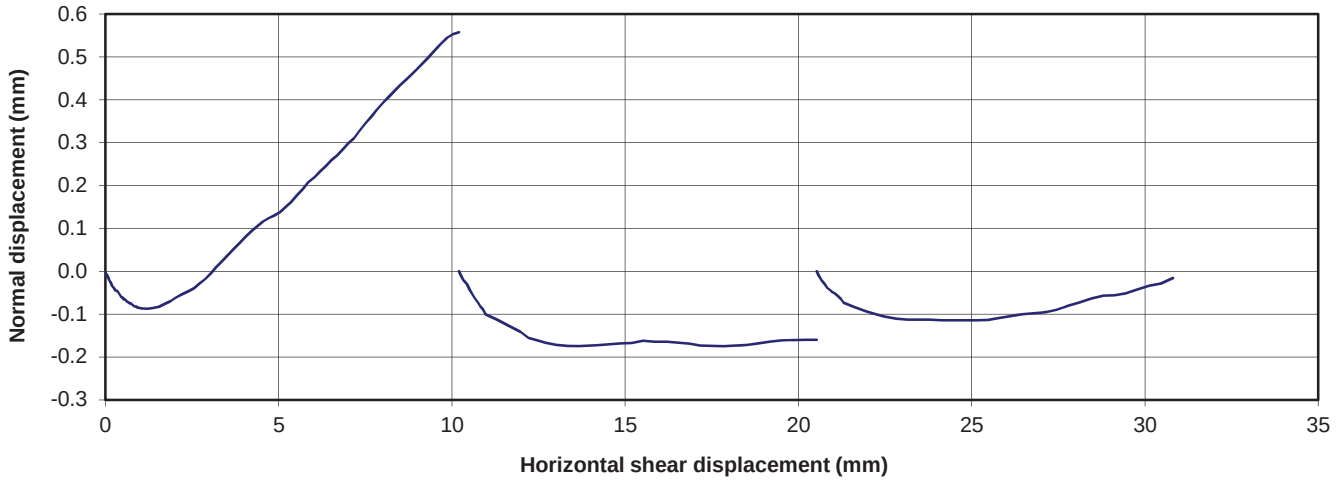
Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	November 8, 2013
Sample:	2013-MLO-87A (test pad material)		

Effective Stress:	50	kPa
Sample Data:		
Sample Length:	60.0	mm
Initial Height:	20.0	mm
Initial Water Content:	9.4	%
Initial Dry Density:	1938	kg/m^3
Final Water Content:	17.7	%

Peak Shear Stress:	58	kPa
Residual Shear Stress	30	kPa

Comments:





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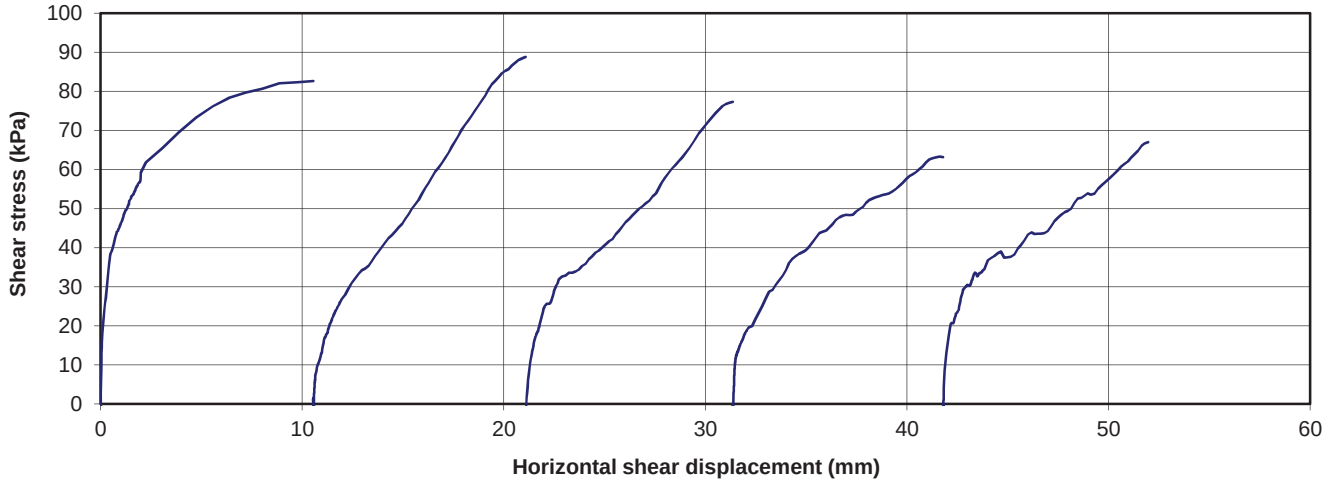
CONSOLIDATED DRAINED DIRECT SHEAR TEST

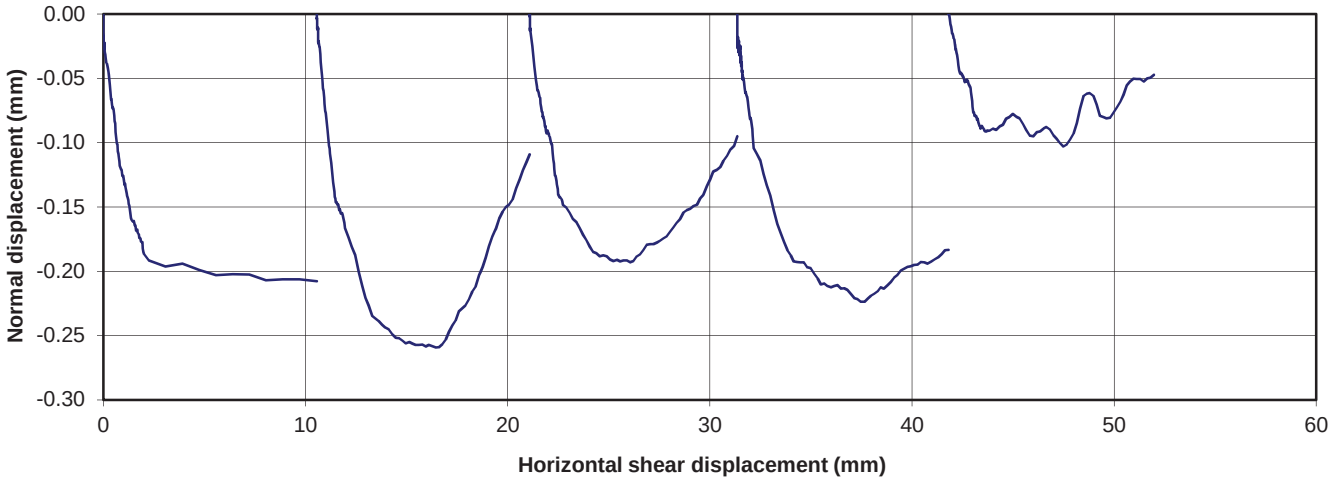
Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	November 8, 2013
Sample:	2013-MLO-87A (test pad material)		

Effective Stress:	100	kPa
Sample Data:		
Sample Length:	60.0	mm
Initial Height:	20.0	mm
Initial Water Content:	9.8	%
Initial Dry Density:	1937	kg/m^3
Final Water Content:	15.0	%

Peak Shear Stress:	84	kPa
Residual Shear Stress	65	kPa

Comments:





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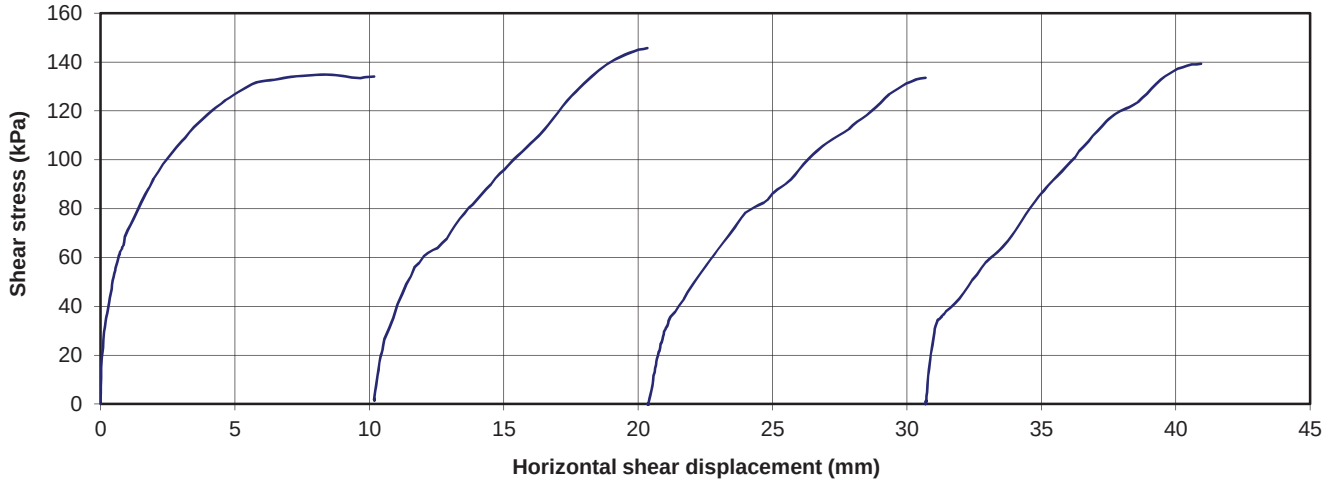
CONSOLIDATED DRAINED DIRECT SHEAR TEST

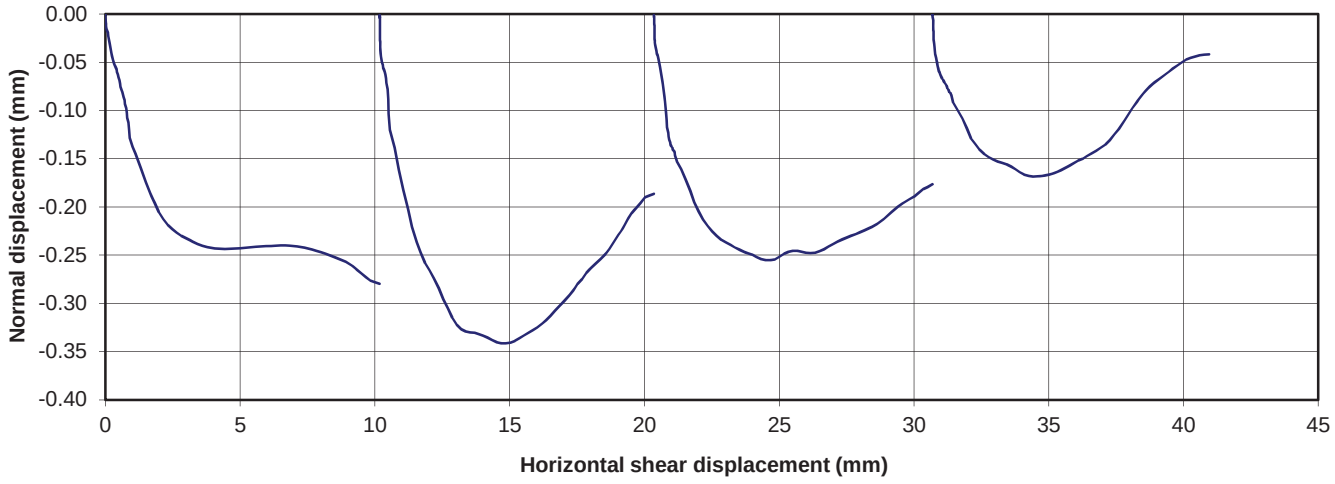
Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	November 8, 2013
Sample:	2013-MLO-87A (test pad material)		

Effective Stress:	200	kPa
Sample Data:		
Sample Length:	60.0	mm
Initial Height:	20.0	mm
Initial Water Content:	9.8	%
Initial Dry Density:	1937	kg/m^3
Final Water Content:	13.9	%

Peak Shear Stress:	145	kPa
Residual Shear Stress	130	kPa

Comments:





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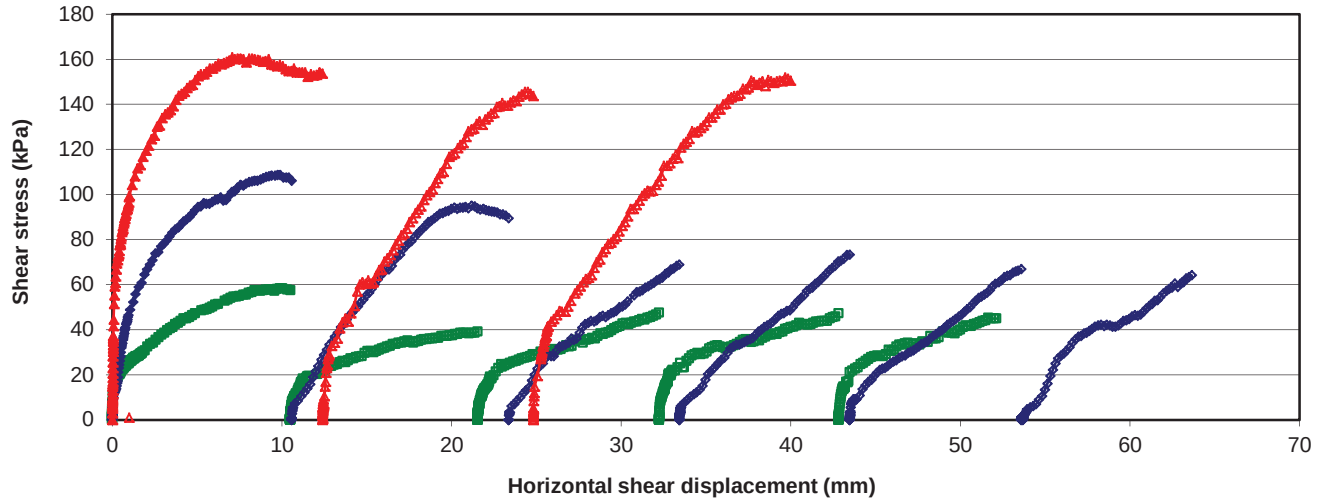
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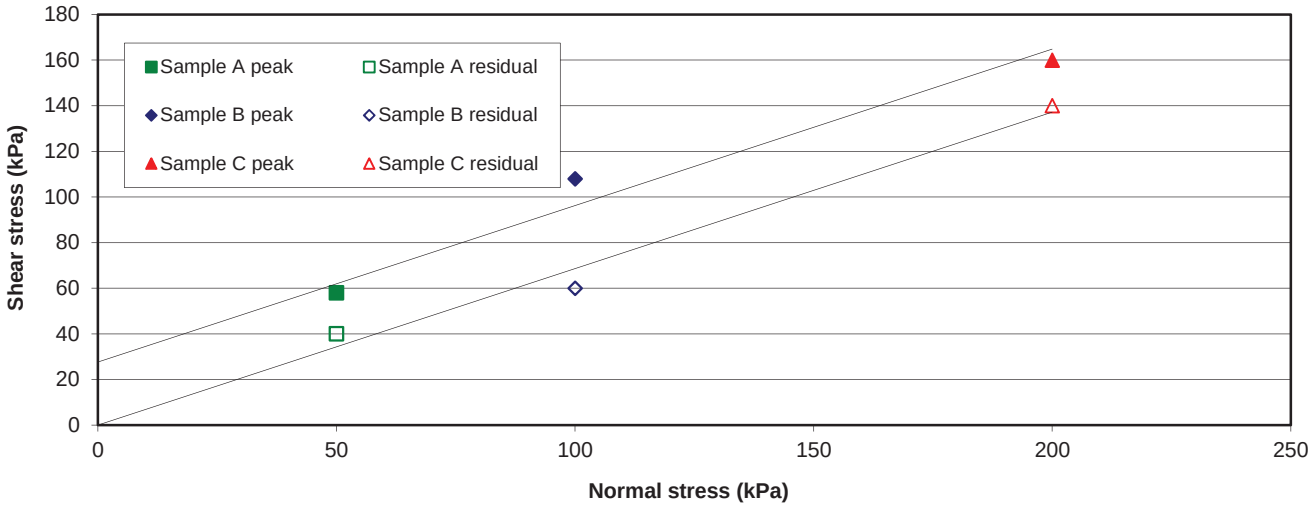
CONSOLIDATED DRAINED DIRECT SHEAR TEST-SUMMARY

Project #: 12-1362-0022 Phase: 4000 / 4200
Short Title: AREVA / JEB Stage 1 Optimization / McClean Lake
Tested By: B.Y. / D.B. Date: September 26, 2013

Sample	Normal Stress (kPa)	Shear Stress Peak (kPa)	Shear Stress Residual (kPa)
2013-MLO-123 In place liner. N: 11052 E: 5274 Elev. 436	50	58	40
	100	108	60
	200	160	140

	Peak	Residual
Friction angle (degrees):	34.4	34.4
cohesion (kPa):	28	0





Comments:

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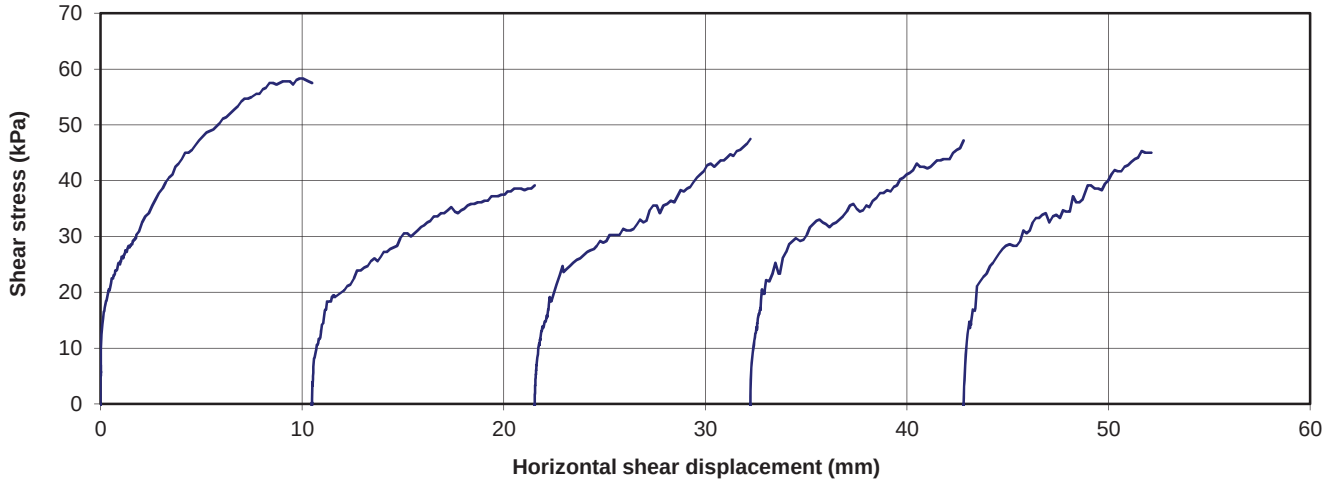
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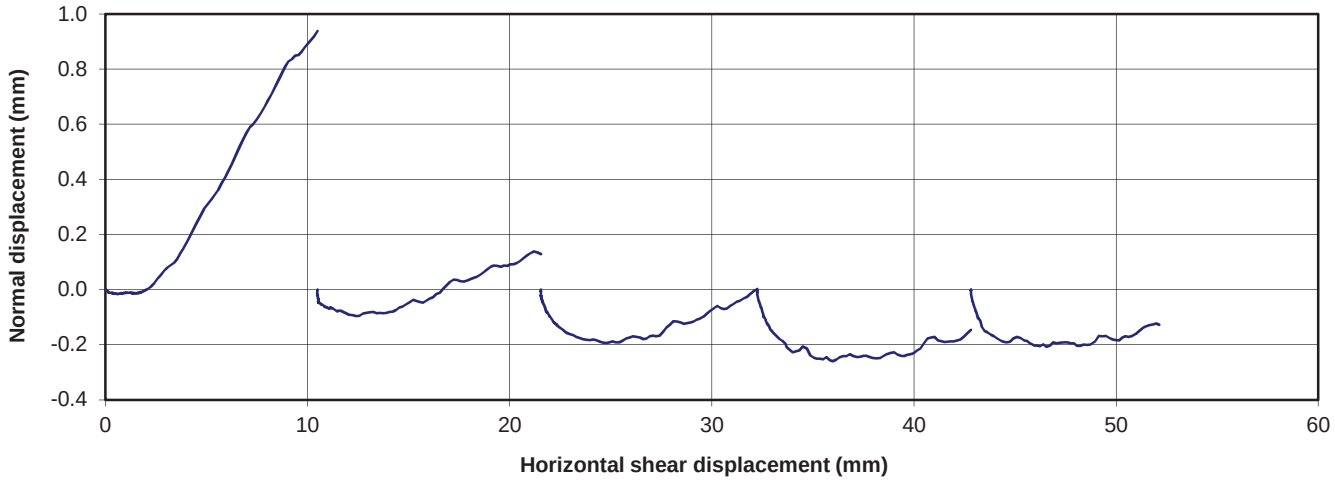
Reviewed by:

CONSOLIDATED DRAINED DIRECT SHEAR TEST

Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	September 26, 2013
Sample:	2013-MLO-123		
	In place liner. N: 11052 E: 5274 Elev. 436		

Effective Stress:	50	kPa	Peak Shear Stress:	58	kPa
			Residual Shear Stress	40	kPa
Sample Data:			Comments:		
Sample Length:	60.0	mm			
Initial Height:	20.0	mm			
Initial Water Content:	9.5	%			
Initial Dry Density:	1950	kg/m^3			
Final Water Content:	16.5	%			





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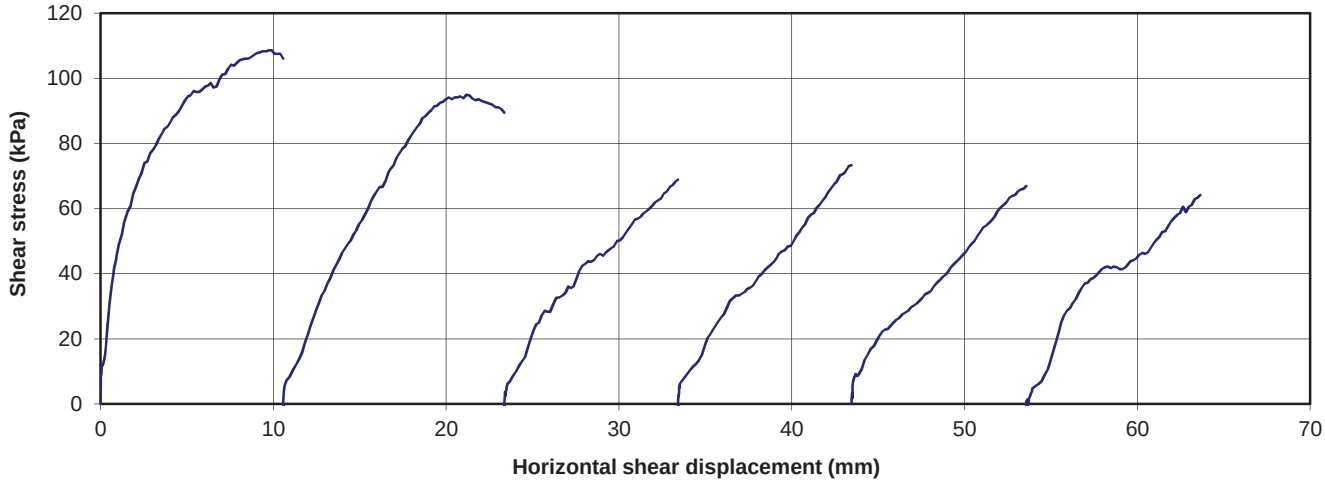
CONSOLIDATED DRAINED DIRECT SHEAR TEST

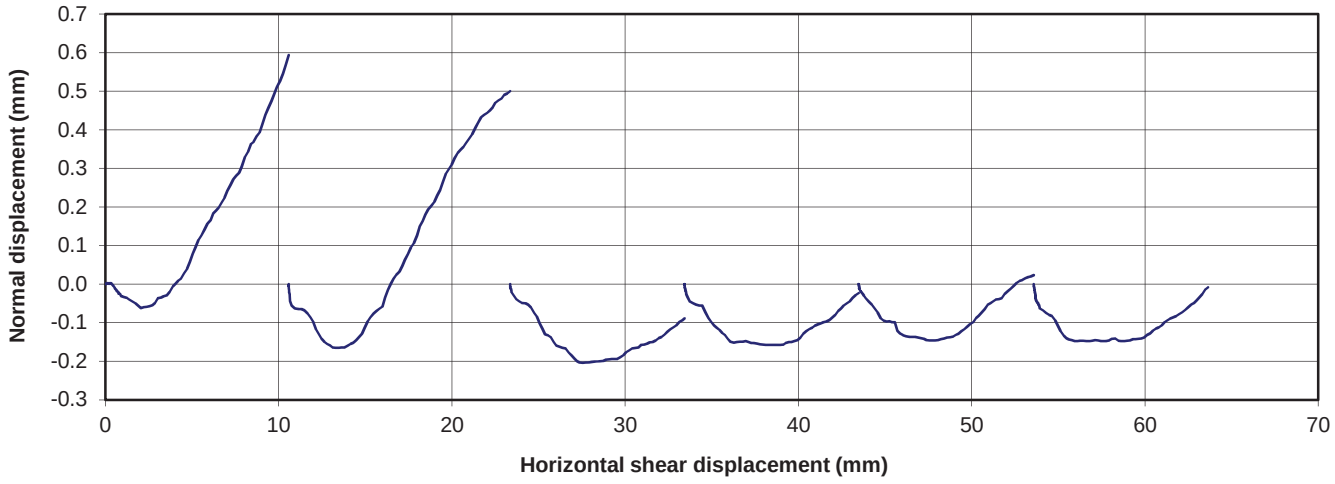
Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	September 26, 2013
Sample:	2013-MLO-123		
	In place liner. N: 11052 E: 5274 Elev. 436		

Effective Stress:	100	kPa
Sample Data:		
Sample Length:	60.0	mm
Initial Height:	20.0	mm
Initial Water Content:	9.1	%
Initial Dry Density:	1957	kg/m^3
Final Water Content:	15.9	%

Peak Shear Stress:	108	kPa
Residual Shear Stress	60	kPa

Comments:





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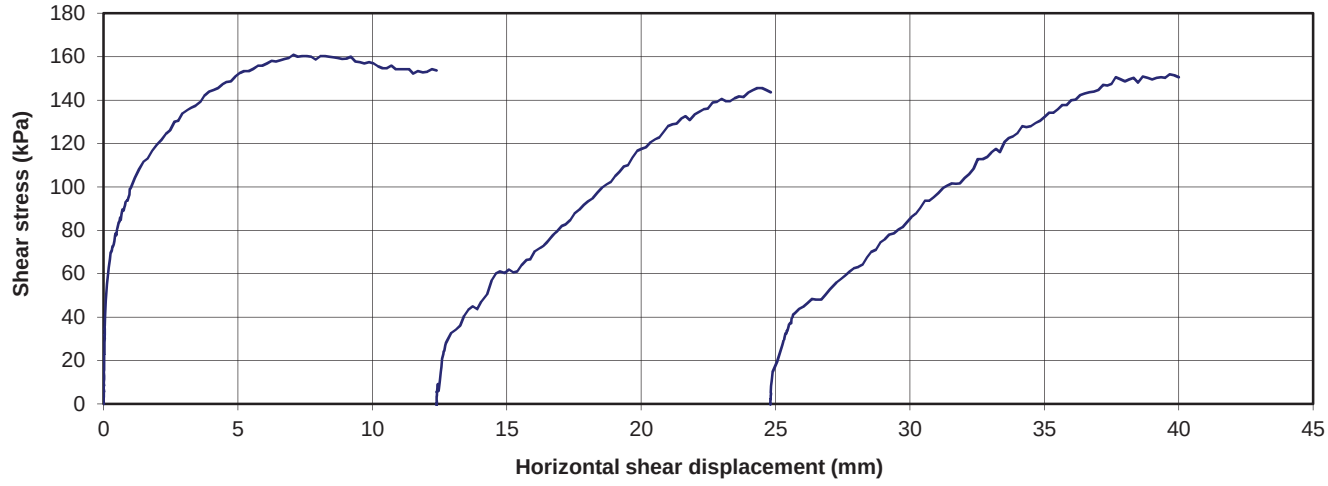
CONSOLIDATED DRAINED DIRECT SHEAR TEST

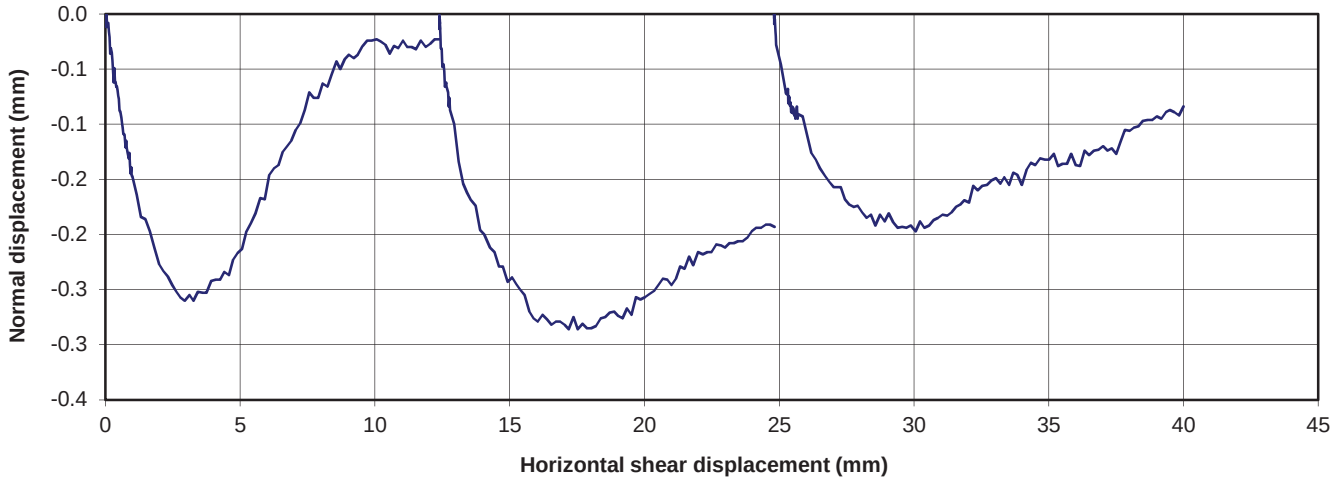
Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	September 26, 2013
Sample:	2013-MLO-123		
	In place liner. N: 11052 E: 5274 Elev. 436		

Effective Stress:	200	kPa
Sample Data:		
Sample Length:	60.0	mm
Initial Height:	20.0	mm
Initial Water Content:	10.1	%
Initial Dry Density:	1938	kg/m^3
Final Water Content:	13.9	%

Peak Shear Stress:	160	kPa
Residual Shear Stress	140	kPa

Comments:





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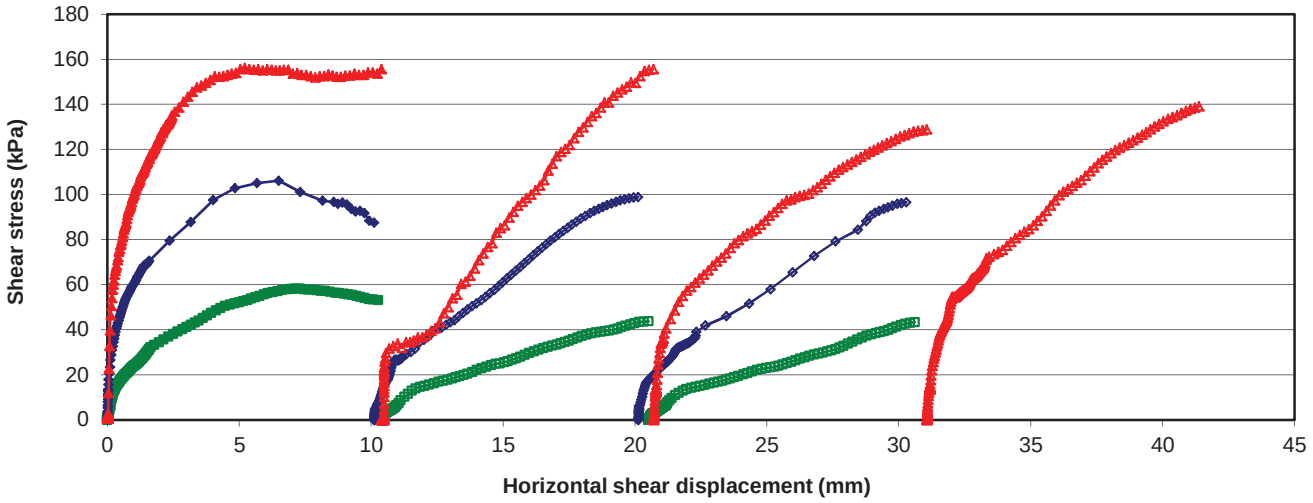
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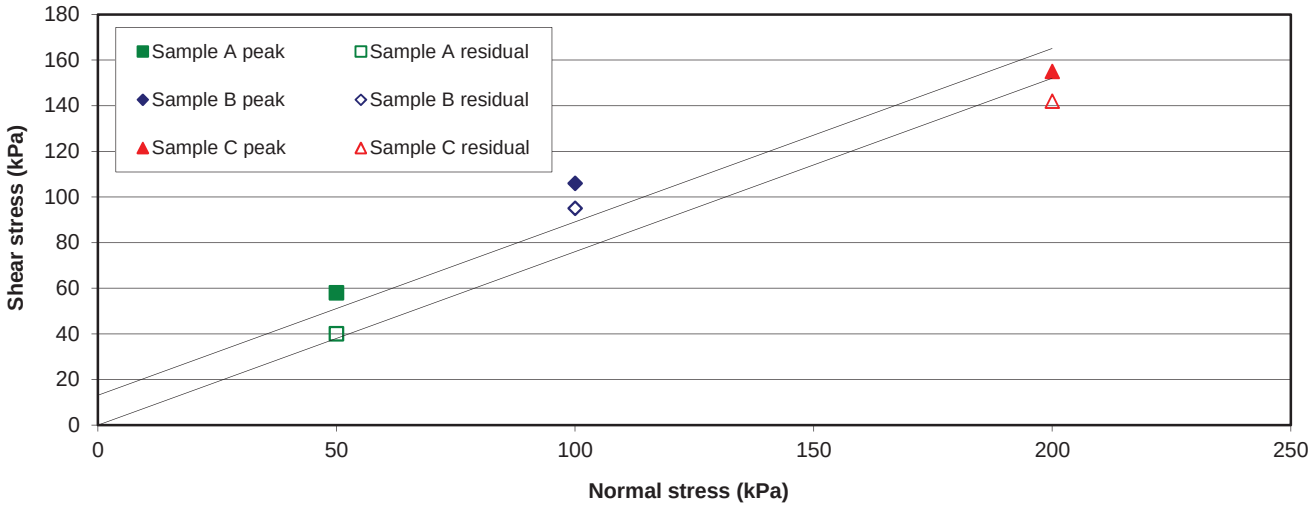
CONSOLIDATED DRAINED DIRECT SHEAR TEST-SUMMARY

Project #: 12-1362-0022 Phase: 4000 / 4200
Short Title: AREVA / JEB Stage 1 Optimization / McClean Lake
Tested By: D.B. / B.Y. Date: November 8, 2013

Sample	Normal Stress (kPa)	Shear Stress Peak (kPa)	Shear Stress Residual (kPa)
2013-MLO-141 In place liner. N: 11104 E: 5161 Elev. 439.0 m	50	58	40
	100	106	95
	200	155	142

	Peak	Residual
Friction angle (degrees):	37.2	37.2
cohesion (kPa):	13	0





Comments:

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CONSOLIDATED DRAINED DIRECT SHEAR TEST

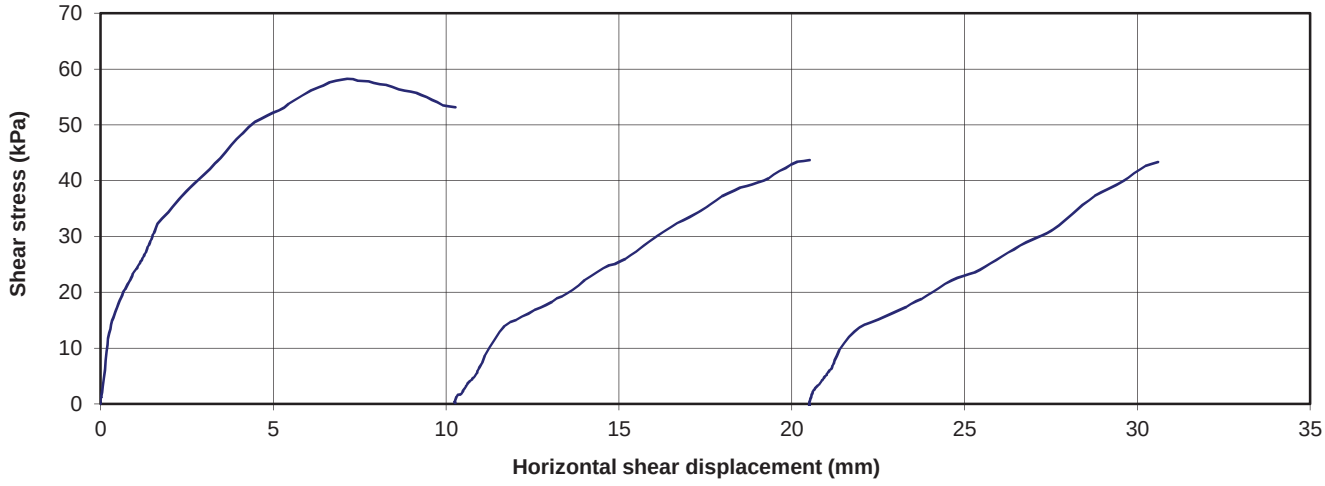
Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	D.B. / B.Y.	Date:	November 8, 2013

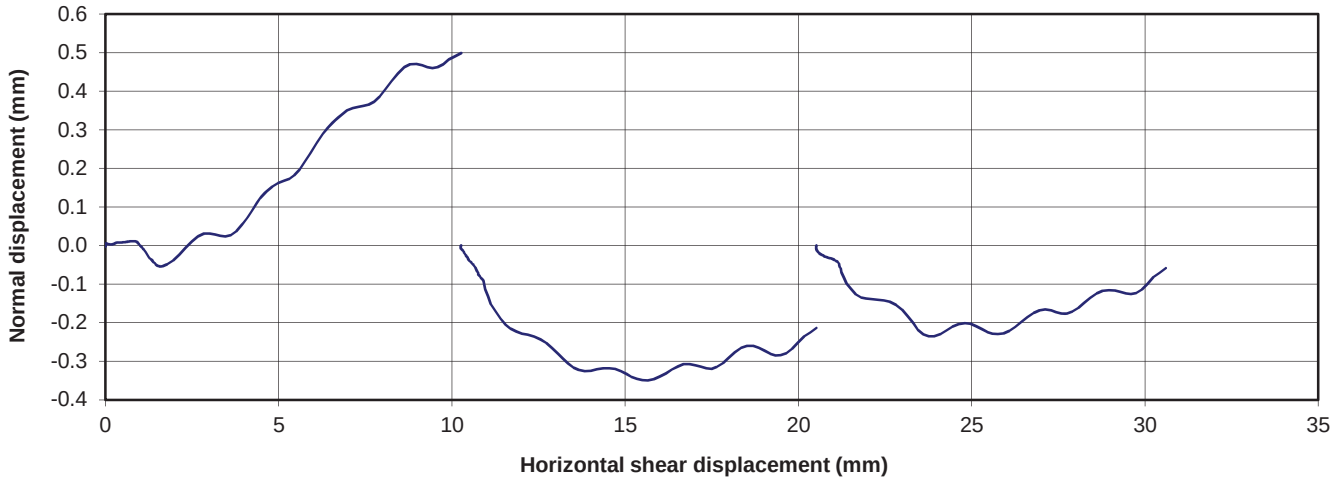
Sample: 2013-MLO-141
In place liner. N: 11104 E: 5161 Elev. 439.0 m

Effective Stress:	50	kPa
Sample Data:		
Sample Length:	60.0	mm
Initial Height:	20.0	mm
Initial Water Content:	8.7	%
Initial Dry Density:	1939	kg/m^3
Final Water Content:	17.2	%

Peak Shear Stress:	58	kPa
Residual Shear Stress	40	kPa

Comments:





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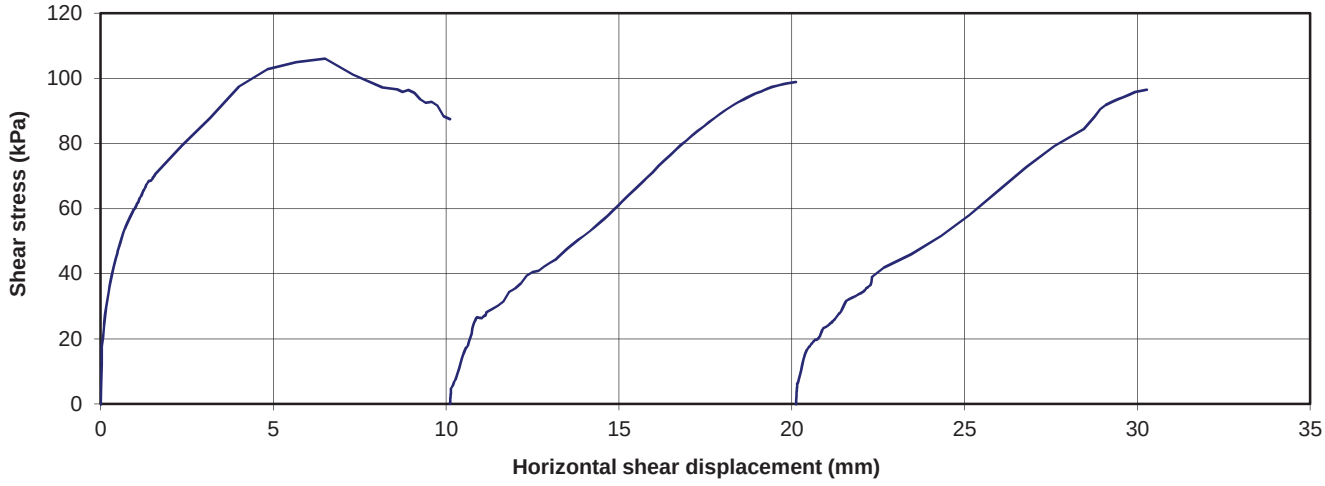
Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	D.B. / B.Y.	Date:	November 8, 2013

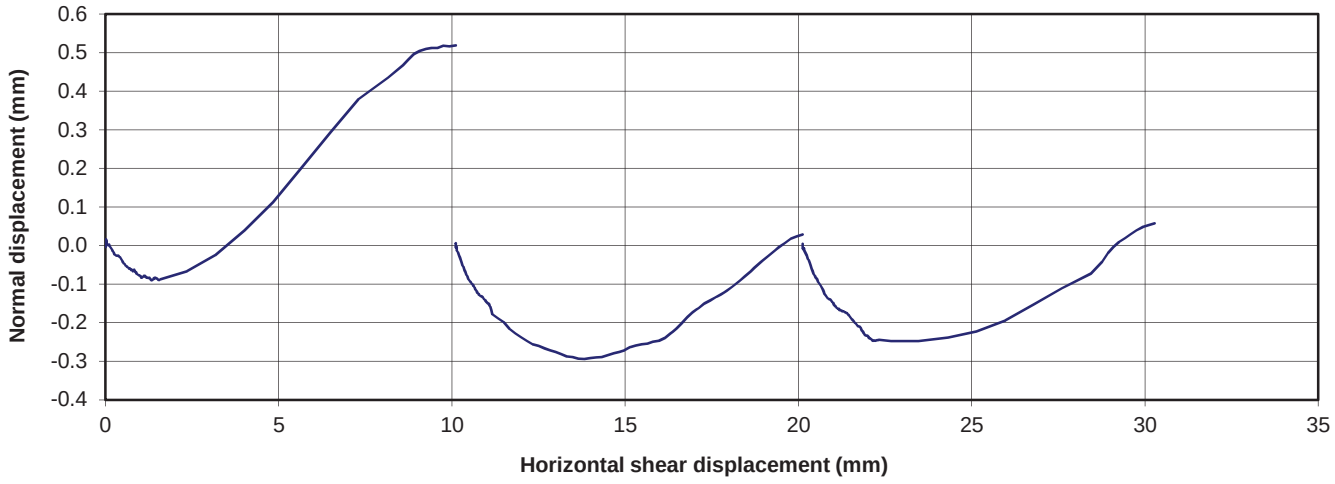
Sample: 2013-MLO-141
In place liner. N: 11104 E: 5161 Elev. 439.0 m

Effective Stress:	100	kPa
Sample Data:		
Sample Length:	60.0	mm
Initial Height:	20.0	mm
Initial Water Content:	8.7	%
Initial Dry Density:	1937	kg/m^3
Final Water Content:	15.2	%

Peak Shear Stress:	106	kPa
Residual Shear Stress	95	kPa

Comments:





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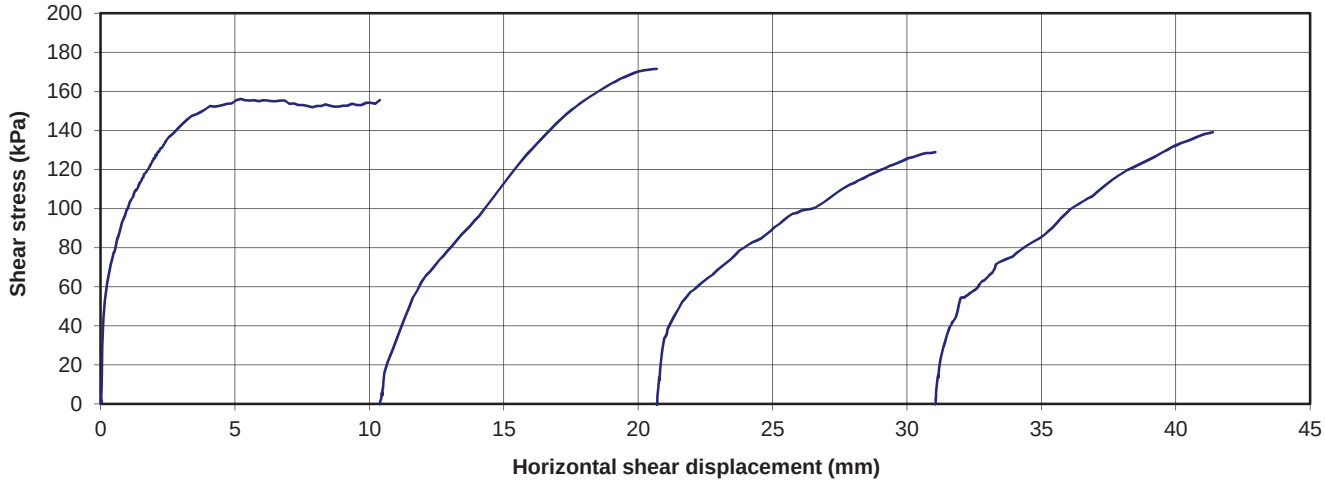
CONSOLIDATED DRAINED DIRECT SHEAR TEST

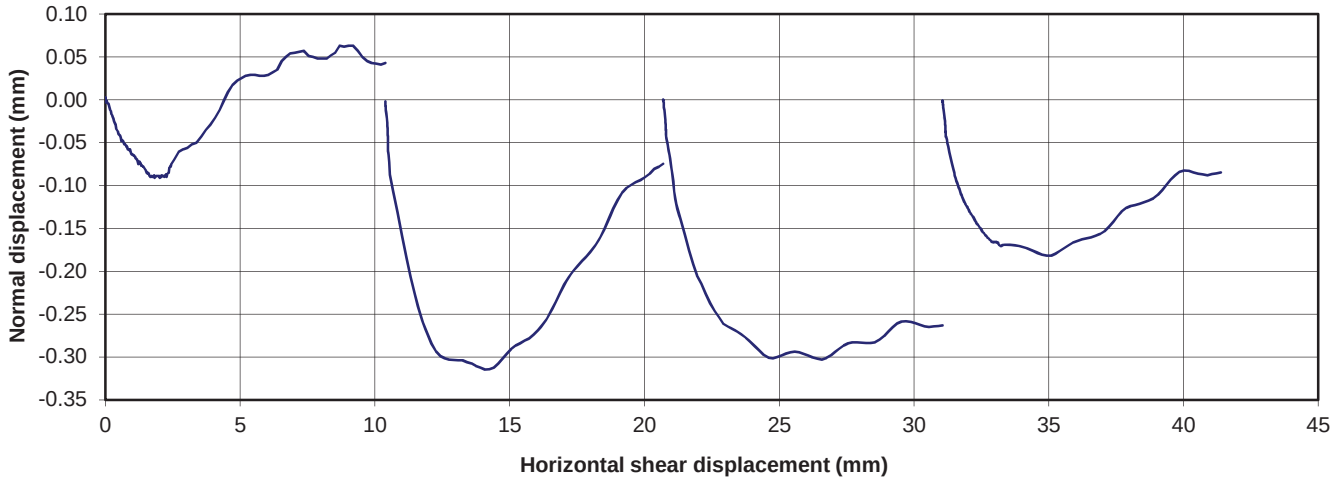
Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	D.B. / B.Y.	Date:	November 8, 2013
Sample:	2013-MLO-141		
	In place liner. N: 11104 E: 5161 Elev. 439.0 m		

Effective Stress:	200	kPa
Sample Data:		
Sample Length:	60.0	mm
Initial Height:	20.0	mm
Initial Water Content:	8.7	%
Initial Dry Density:	1939	kg/m^3
Final Water Content:	14.2	%

Peak Shear Stress:	155	kPa
Residual Shear Stress	142	kPa

Comments:





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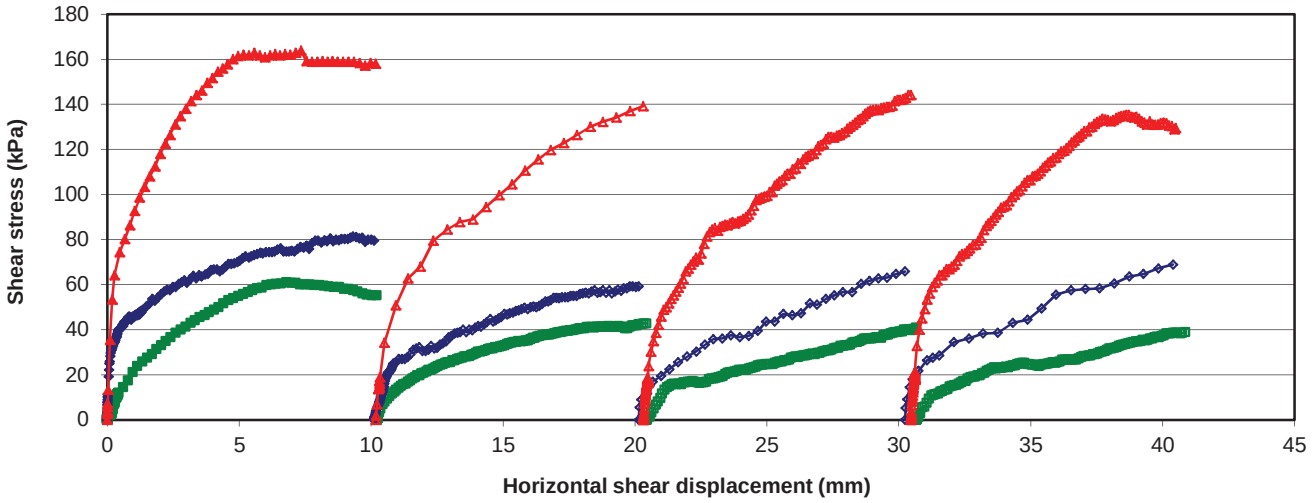
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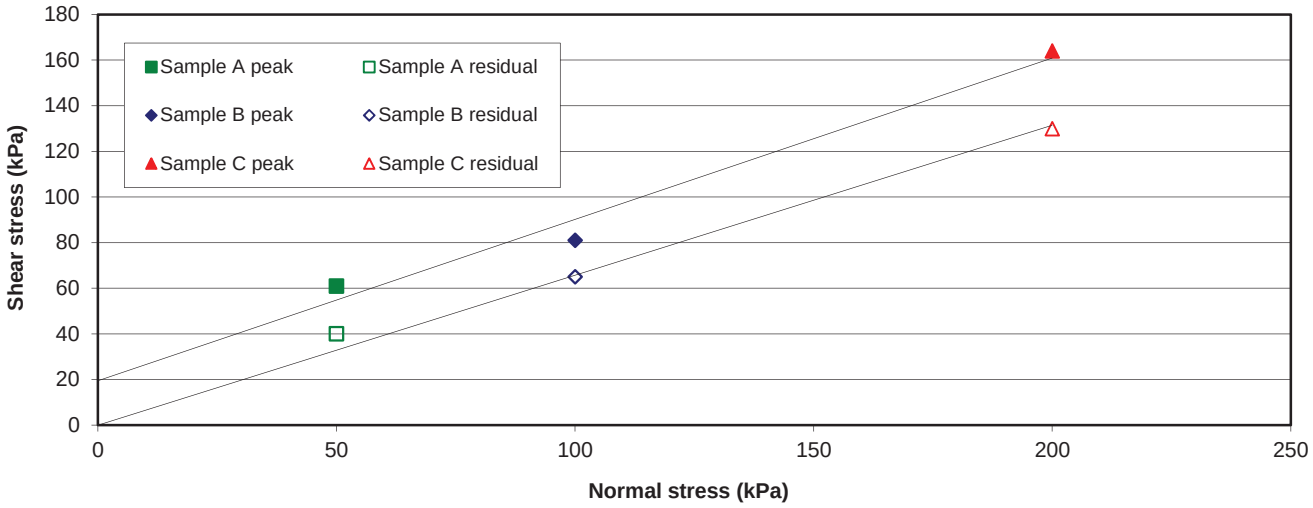
CONSOLIDATED DRAINED DIRECT SHEAR TEST-SUMMARY

Project #: 12-1362-0022 Phase: 4000 / 4200
Short Title: AREVA / JEB Stage 1 Optimization / McClean Lake
Tested By: B.Y. / D.B. Date: October 25, 2013

Sample	Normal Stress (kPa)	Shear Stress Peak (kPa)	Shear Stress Residual (kPa)
2013-MLO-146	50	61	40
In place liner. N: 11359 E: 5298	100	81	65
Elev. 439.02 m	200	164	130

	Peak	Residual
Friction angle (degrees):	35.3	33.3
cohesion (kPa):	20	0





Comments:

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1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

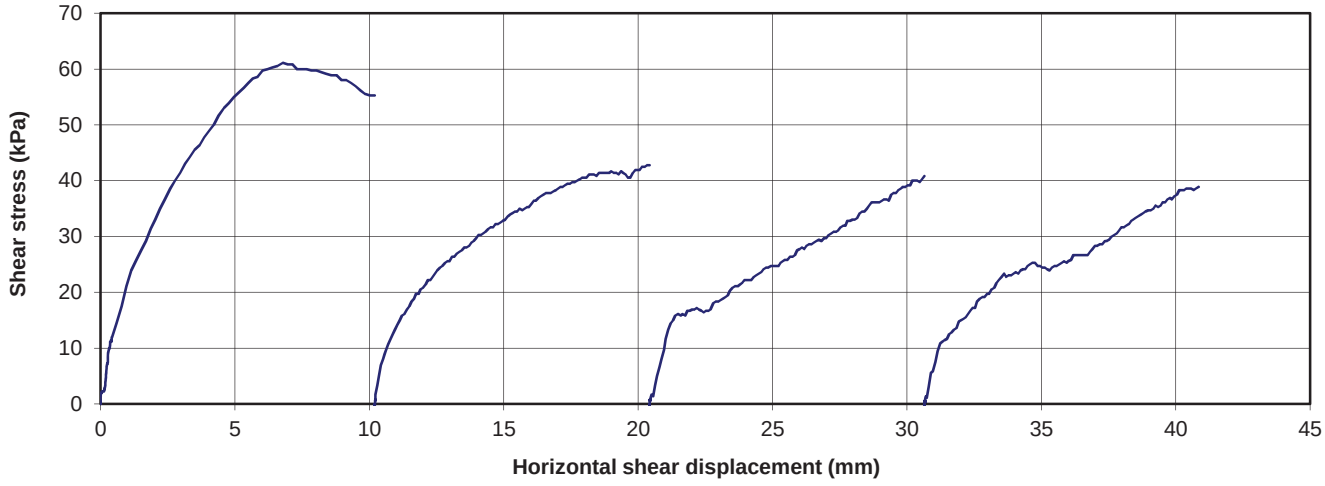
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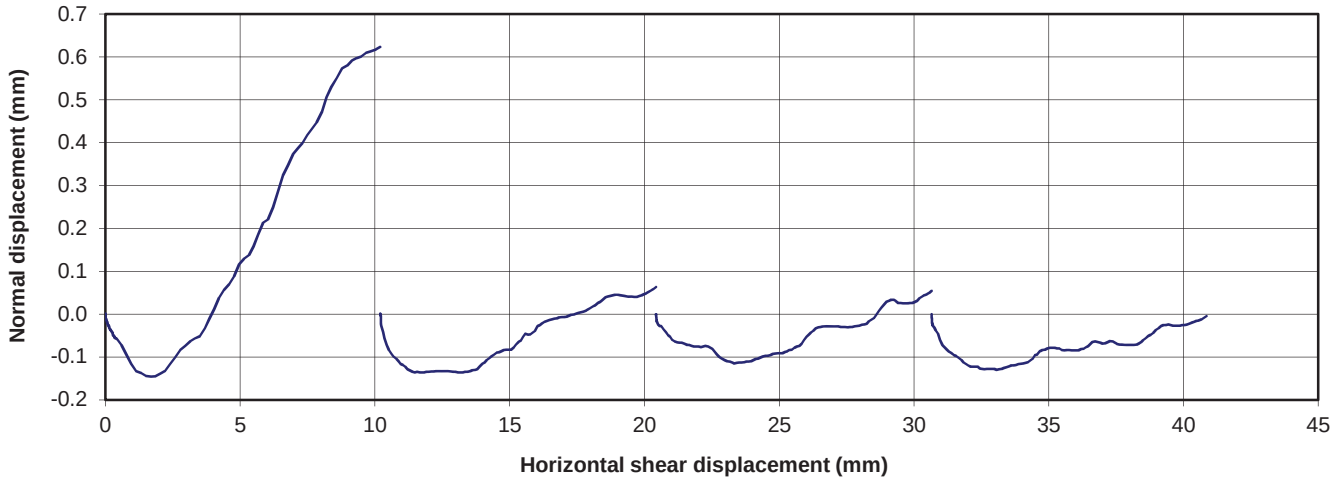
Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	October 25, 2013
Sample:	2013-MLO-146		
	In place liner. N: 11359 E: 5298 Elev. 439.02 m		

Effective Stress:	50	kPa
Sample Data:		
Sample Length:	60.0	mm
Initial Height:	20.0	mm
Initial Water Content:	8.1	%
Initial Dry Density:	1939	kg/m^3
Final Water Content:	16.2	%

Peak Shear Stress:	61	kPa
Residual Shear Stress	40	kPa

Comments:





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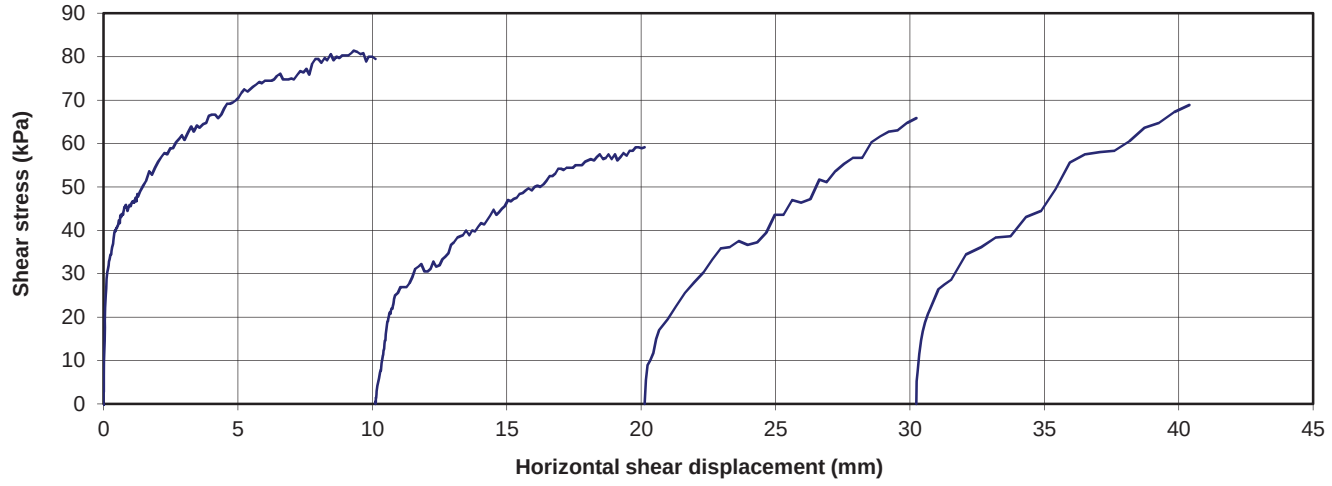
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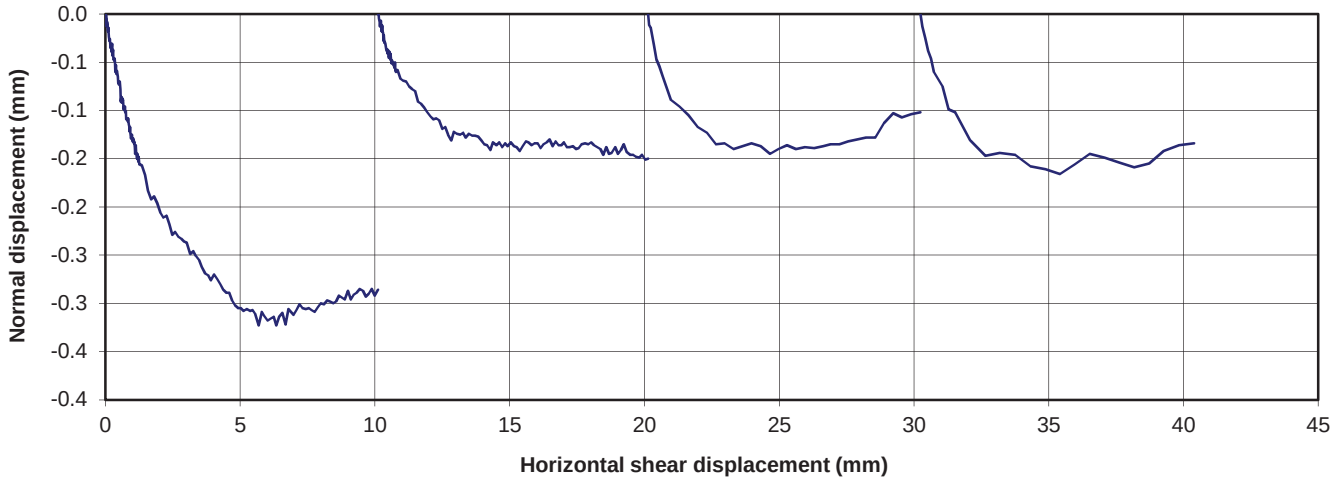
Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	October 25, 2013
Sample:	2013-MLO-146		
	In place liner. N: 11359 E: 5298 Elev. 439.02 m		

Effective Stress:	100	kPa
Sample Data:		
Sample Length:	60.0	mm
Initial Height:	20.0	mm
Initial Water Content:	8.5	%
Initial Dry Density:	1938	kg/m^3
Final Water Content:	14.6	%

Peak Shear Stress:	81	kPa
Residual Shear Stress	65	kPa

Comments:





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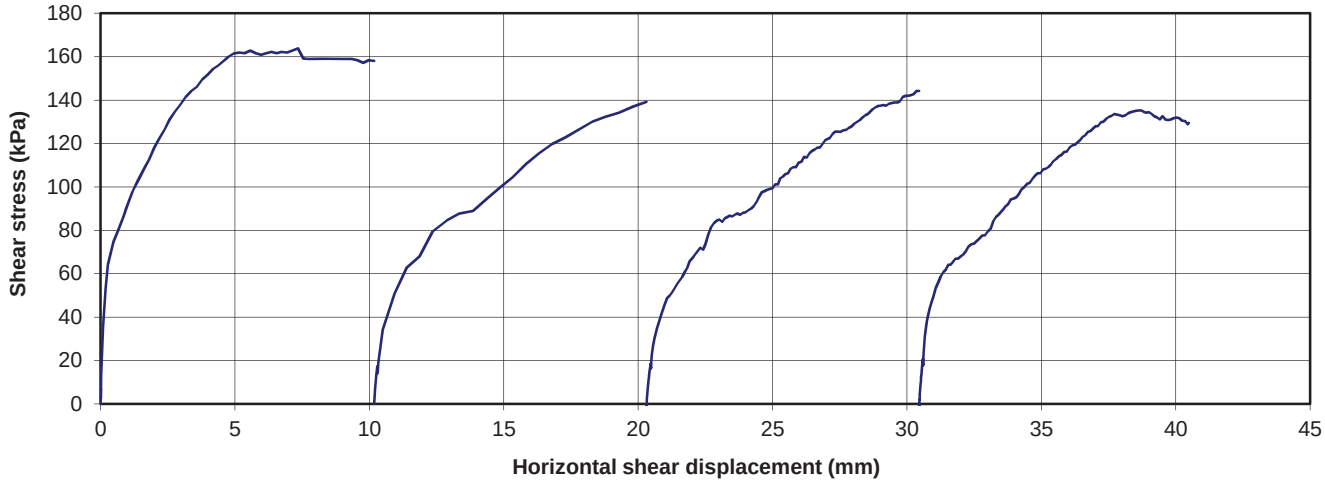
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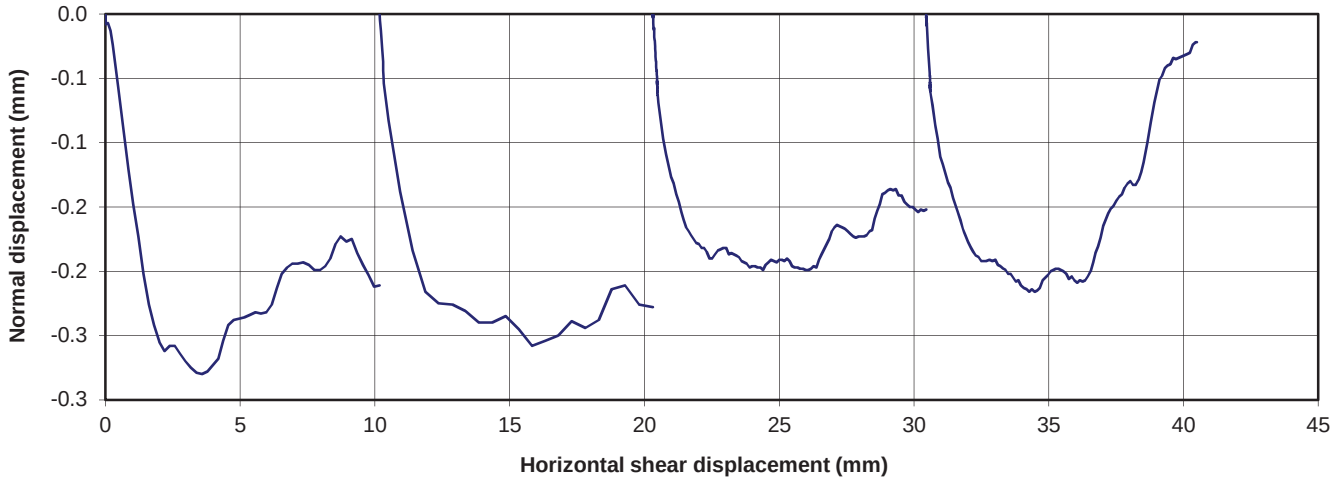
Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	October 25, 2013
Sample:	2013-MLO-146		
	In place liner. N: 11359 E: 5298 Elev. 439.02 m		

Effective Stress:	200	kPa
Sample Data:		
Sample Length:	60.0	mm
Initial Height:	20.0	mm
Initial Water Content:	8.5	%
Initial Dry Density:	1939	kg/m^3
Final Water Content:	14.2	%

Peak Shear Stress:	164	kPa
Residual Shear Stress	130	kPa

Comments:





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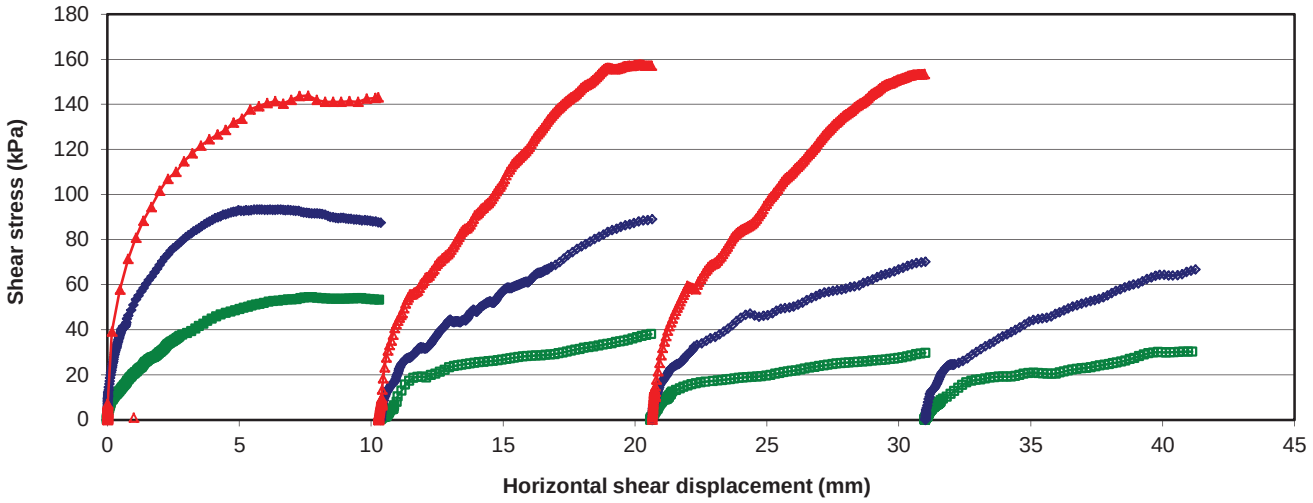
Reviewed by:

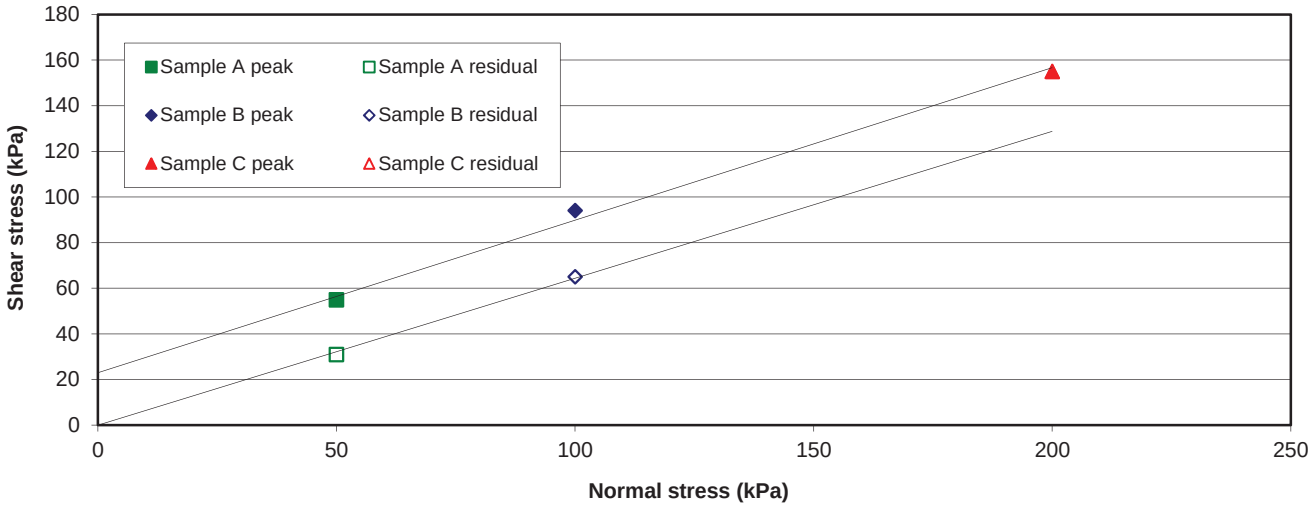
CONSOLIDATED DRAINED DIRECT SHEAR TEST-SUMMARY

Project #: 12-1362-0022 Phase: 4000 / 4200
Short Title: AREVA / JEB Stage 1 Optimization / McClean Lake
Tested By: B.Y. / D.B. Date: November 8, 2013

Sample	Normal Stress (kPa)	Shear Stress Peak (kPa)	Shear Stress Residual (kPa)
2013-MLO-167	50	55	31
In place liner. N: 11075 E: 5223	100	94	65
Elev. 435.89 m	200	155	155

	Peak	Residual
Friction angle (degrees):	33.4	32.8
cohesion (kPa):	25	0





Comments: 200 kPa residual strength not used in calculating residual friction angle

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Saskatoon, Saskatchewan, S7H 0T4

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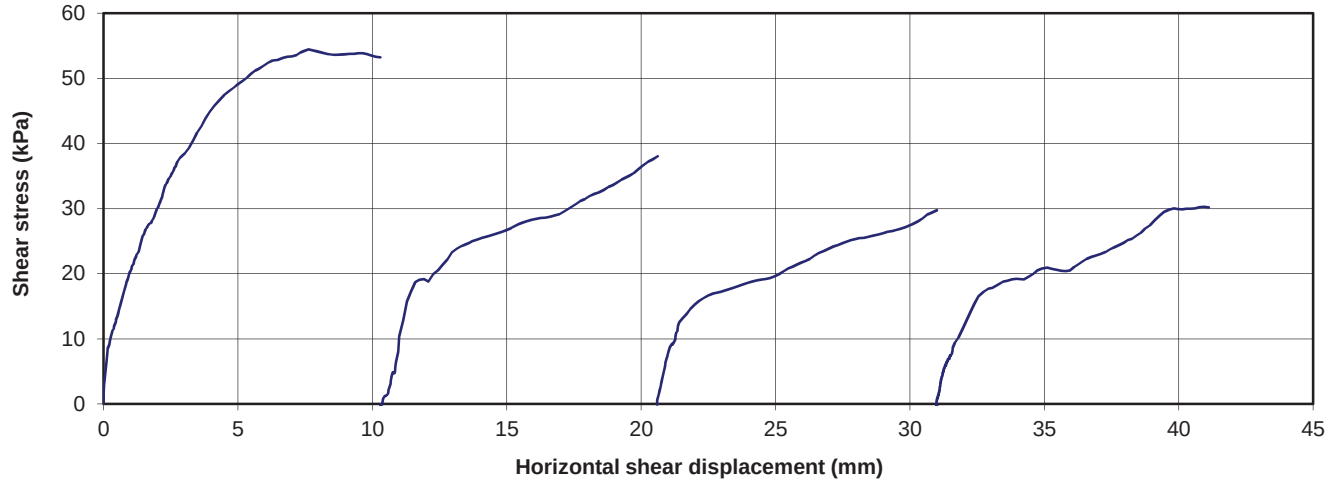
CONSOLIDATED DRAINED DIRECT SHEAR TEST

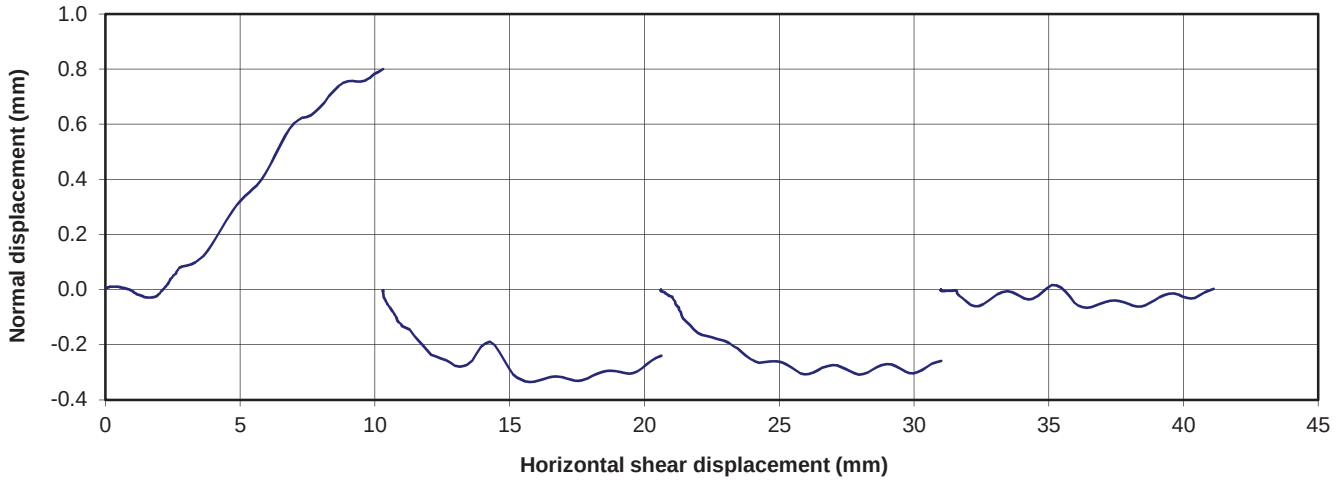
Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	November 8, 2013
Sample:	2013-MLO-167		
	In place liner. N: 11075 E: 5223 Elev. 435.89 m		

Effective Stress:	50	kPa
Sample Data:		
Sample Length:	60.0	mm
Initial Height:	20.0	mm
Initial Water Content:	8.3	%
Initial Dry Density:	1935	kg/m^3
Final Water Content:	17.2	%

Peak Shear Stress:	55	kPa
Residual Shear Stress	31	kPa

Comments:





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Reviewed by:

CONSOLIDATED DRAINED DIRECT SHEAR TEST

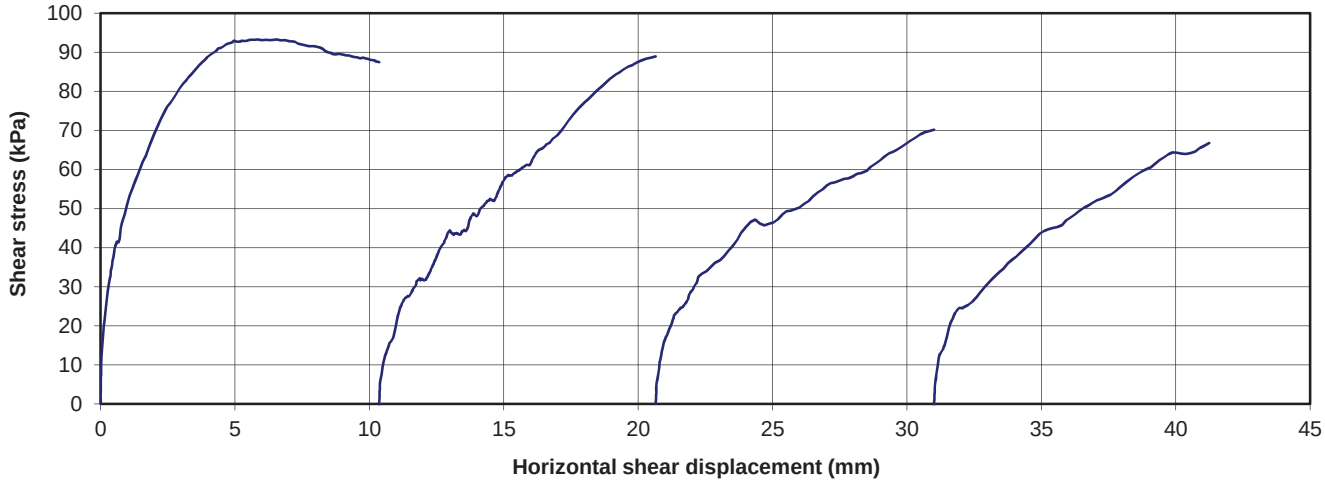
Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	November 8, 2013

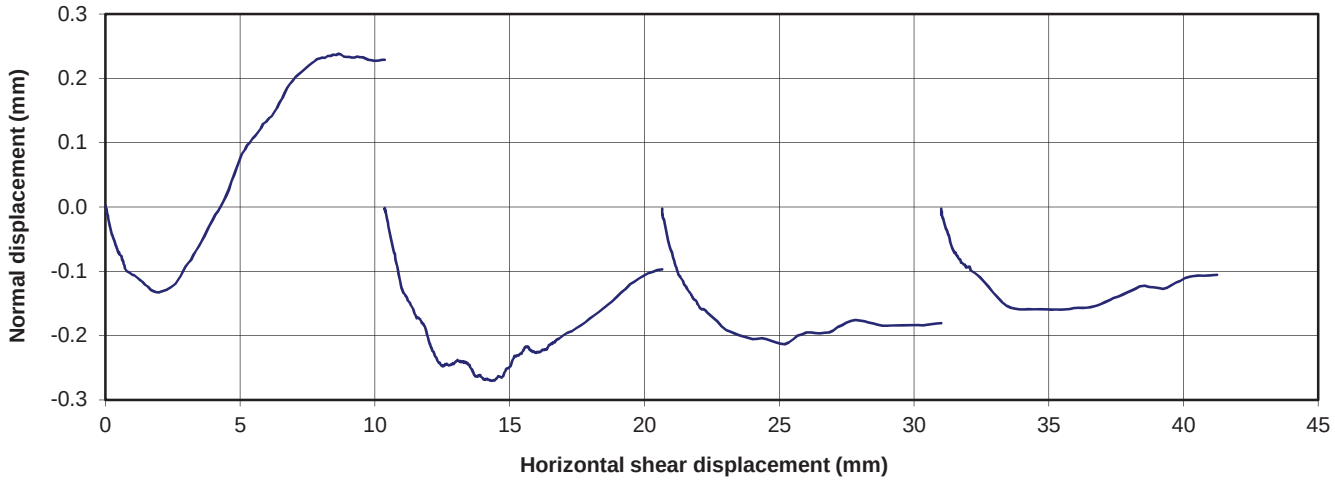
Sample: 2013-MLO-167
In place liner. N: 11075 E: 5223 Elev. 435.89 m

Effective Stress:	100	kPa
Sample Data:		
Sample Length:	60.0	mm
Initial Height:	20.0	mm
Initial Water Content:	8.3	%
Initial Dry Density:	1941	kg/m^3
Final Water Content:	14.7	%

Peak Shear Stress:	94	kPa
Residual Shear Stress	65	kPa

Comments:





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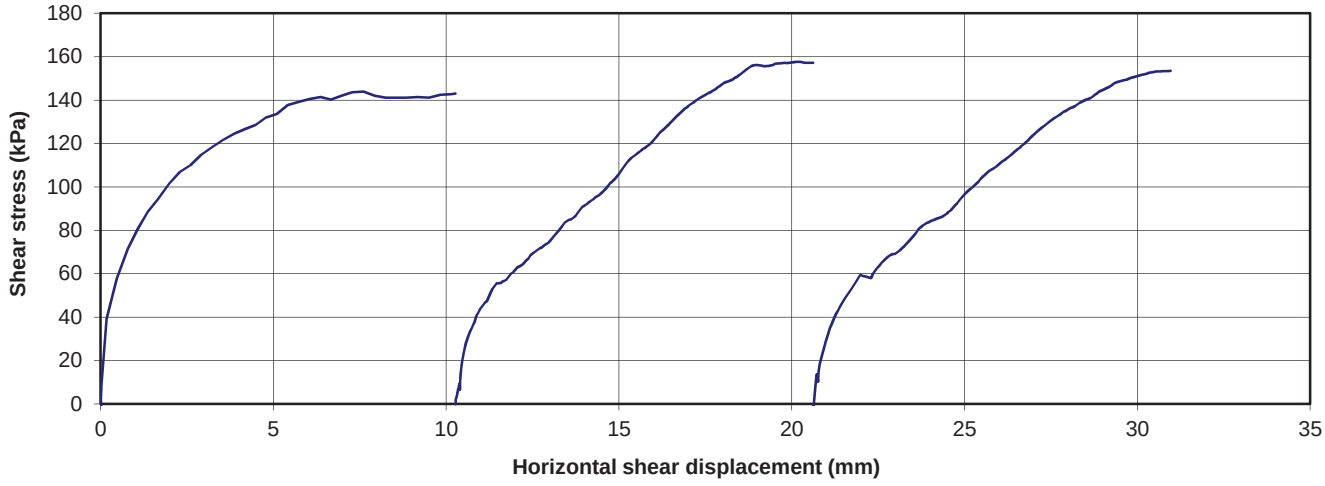
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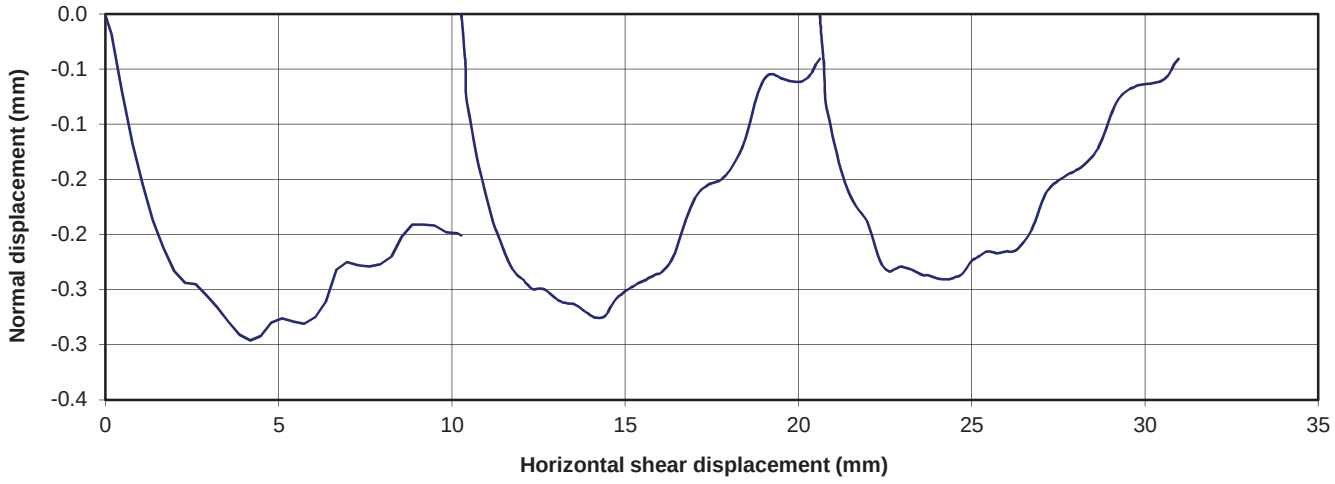
Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	November 8, 2013
Sample:	2013-MLO-167		
	In place liner. N: 11075 E: 5223 Elev. 435.89 m		

Effective Stress:	200	kPa
Sample Data:		
Sample Length:	60.0	mm
Initial Height:	20.0	mm
Initial Water Content:	8.3	%
Initial Dry Density:	1937	kg/m^3
Final Water Content:	13.7	%

Peak Shear Stress:	155	kPa
Residual Shear Stress	155	kPa

Comments:





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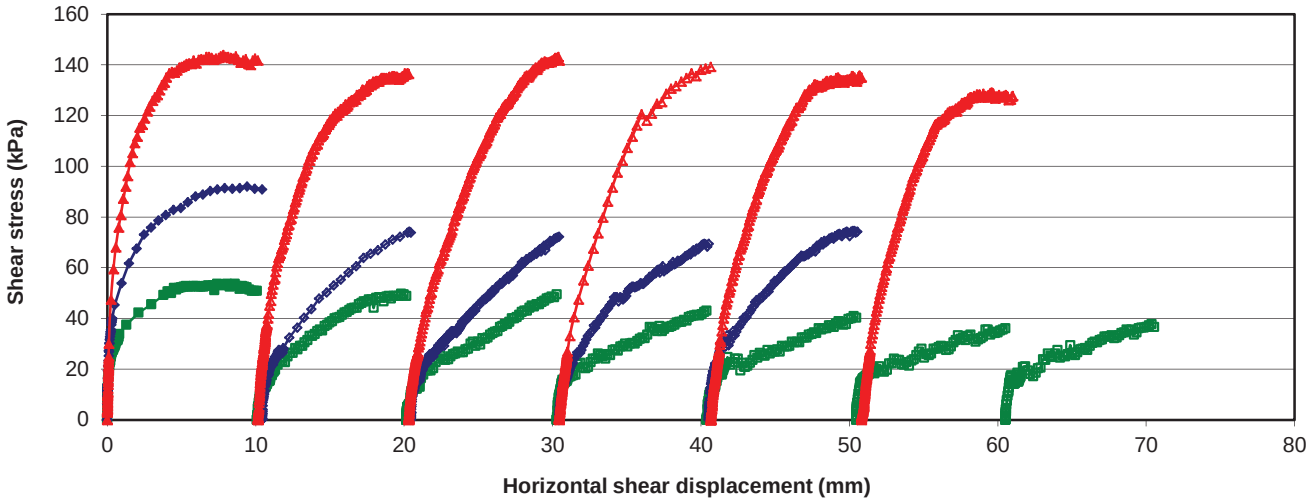
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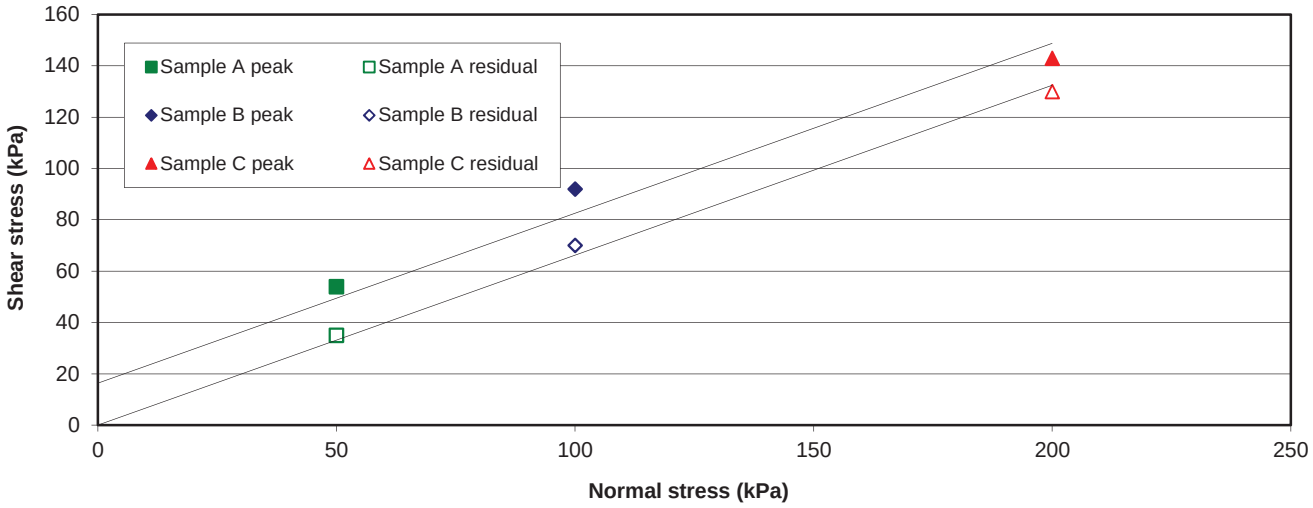
CONSOLIDATED DRAINED DIRECT SHEAR TEST-SUMMARY

Project #: 12-1362-0022 Phase: 4000 / 4200
Short Title: AREVA / JEB Stage 1 Optimization / McClean Lake
Tested By: B.Y. / D.B. Date: October 24, 2013

Sample	Normal Stress (kPa)	Shear Stress Peak (kPa)	Shear Stress Residual (kPa)
2013-MLO-198	50	54	35
In place liner. N: 11127 E: 5130	100	92	70
Elev. 436.45 m	200	143	130

	Peak	Residual
Friction angle (degrees):	33.5	33.5
cohesion (kPa):	16	0





Comments:

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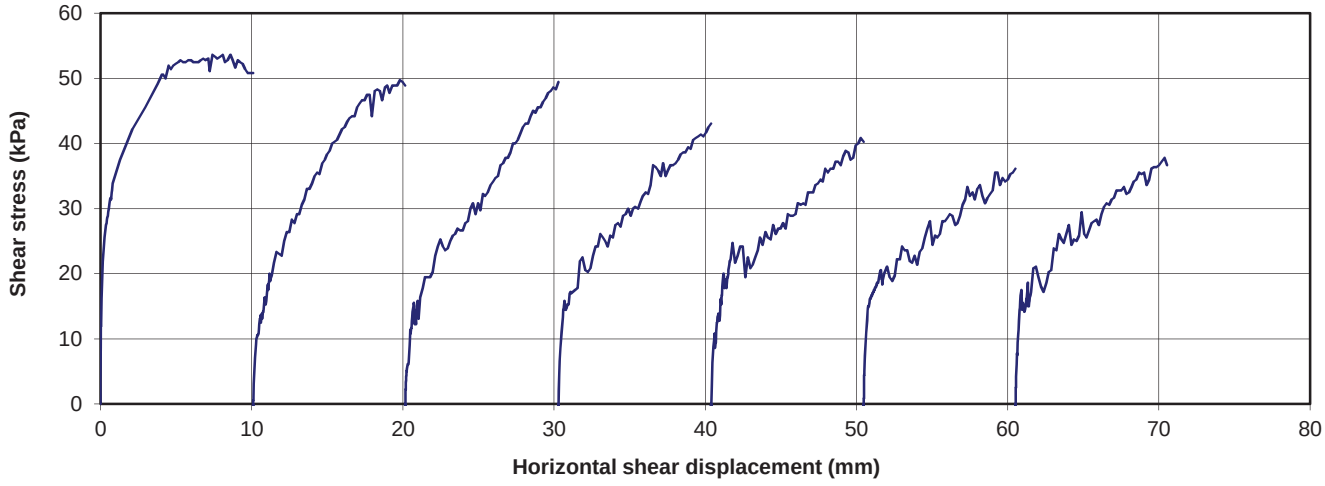
CONSOLIDATED DRAINED DIRECT SHEAR TEST

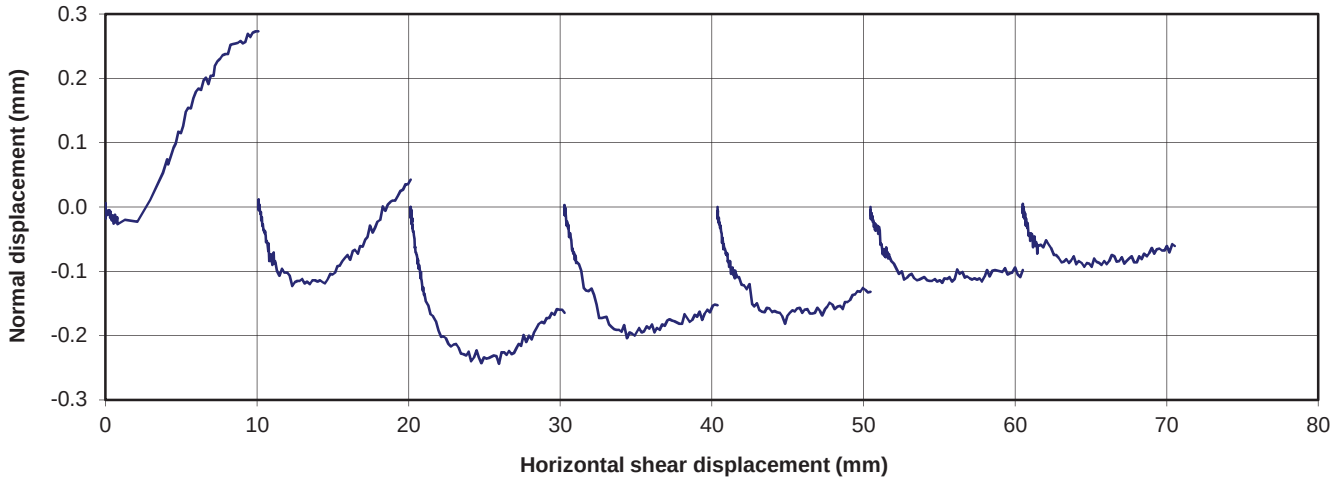
Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	October 24, 2013
Sample:	2013-MLO-198		
	In place liner. N: 11127 E: 5130 Elev. 436.45 m		

Effective Stress:	50	kPa
Sample Data:		
Sample Length:	60.0	mm
Initial Height:	20.0	mm
Initial Water Content:	9.5	%
Initial Dry Density:	1949	kg/m^3
Final Water Content:	15.7	%

Peak Shear Stress:	54	kPa
Residual Shear Stress	35	kPa

Comments:





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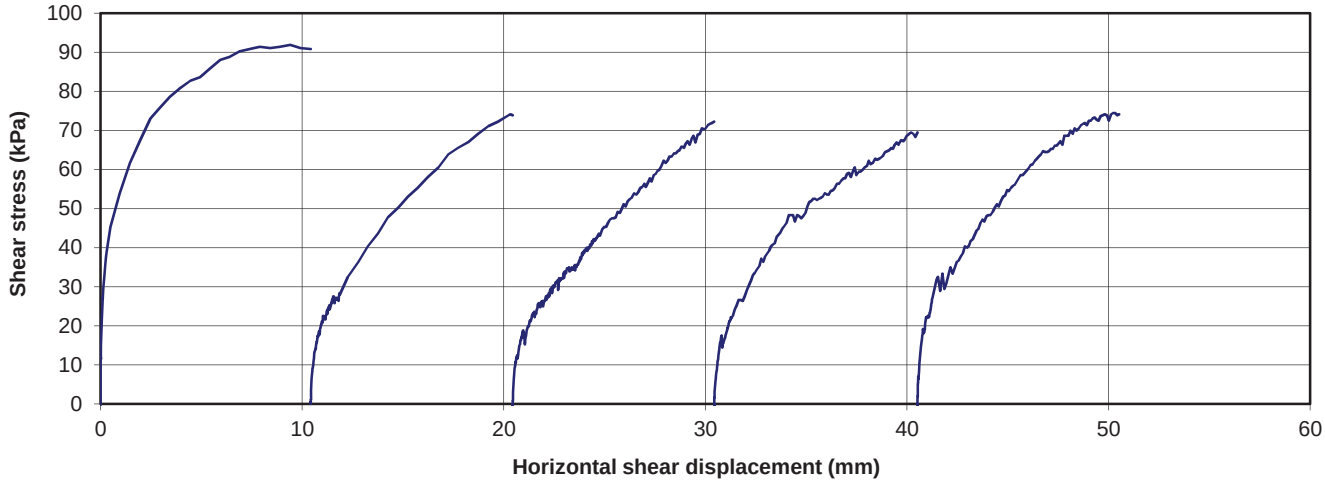
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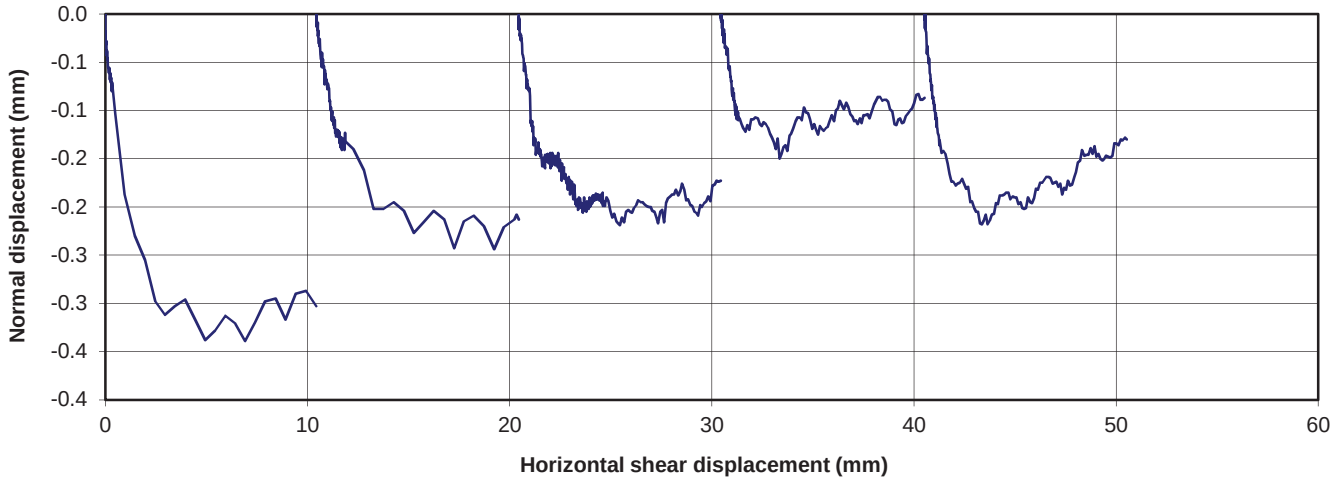
Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	October 24, 2013
Sample:	2013-MLO-198		
	In place liner. N: 11127 E: 5130 Elev. 436.45 m		

Effective Stress:	100	kPa
Sample Data:		
Sample Length:	60.0	mm
Initial Height:	20.0	mm
Initial Water Content:	9.2	%
Initial Dry Density:	1938	kg/m^3
Final Water Content:	14.3	%

Peak Shear Stress:	92	kPa
Residual Shear Stress	70	kPa

Comments:





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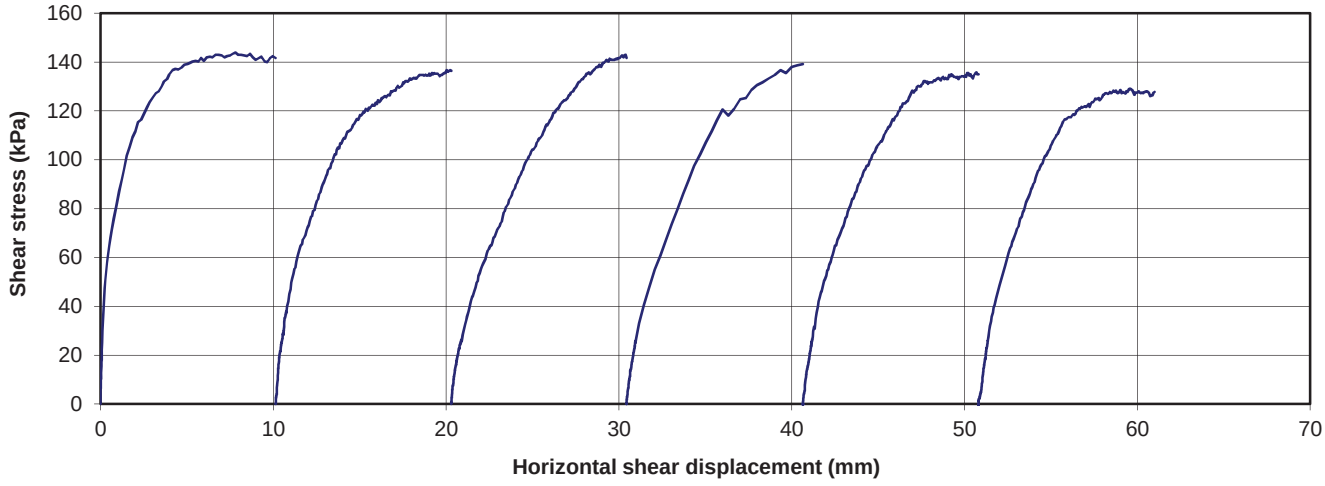
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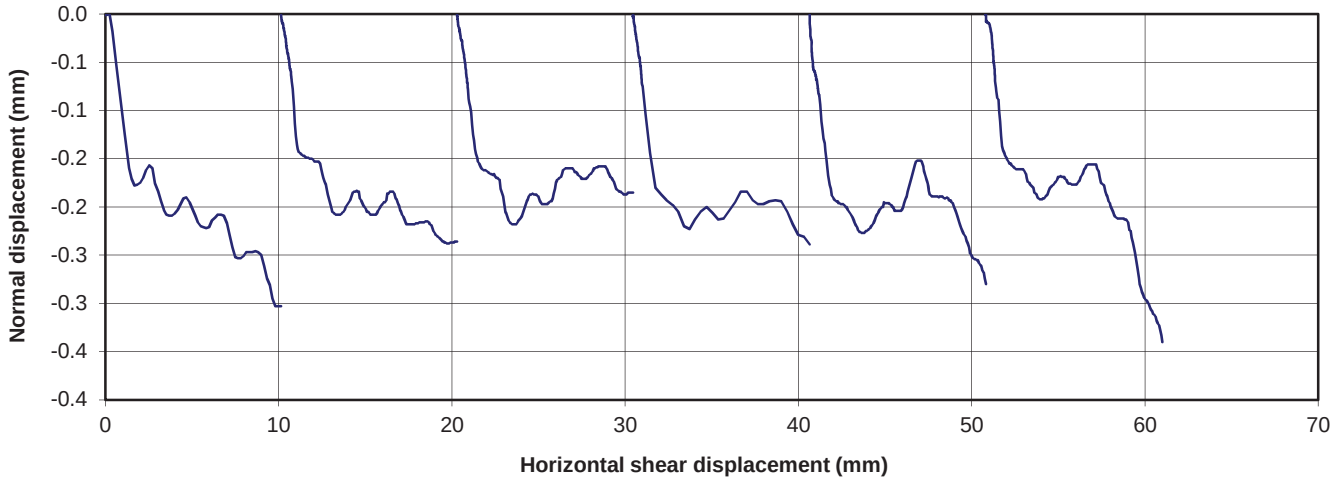
Project #:	12-1362-0022	Phase:	4000 / 4200
Short Title:	AREVA / JEB Stage 1 Optimization / McClean Lake		
Tested By:	B.Y. / D.B.	Date:	October 24, 2013
Sample:	2013-MLO-198		
	In place liner. N: 11127 E: 5130 Elev. 436.45 m		

Effective Stress:	200	kPa
Sample Data:		
Sample Length:	60.0	mm
Initial Height:	20.0	mm
Initial Water Content:	9.5	%
Initial Dry Density:	1965	kg/m^3
Final Water Content:	14.4	%

Peak Shear Stress:	143	kPa
Residual Shear Stress	130	kPa

Comments:





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1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

APPENDIX D

Permits

Saskatchewan

Ministry of Environment

Industrial Branch
Uranium and Northern Operations

112 Research Drive
Saskatoon, SK
S7N 3R3
Phone: (306)933-7274
Fax: (306)933-5773

November 18, 2010

File: S25020-50/ML/03
McClean Lake

S1-005

Ms. Tammy Van Lambalgen
VP Regulatory Affairs & General Counsel
AREVA Resources Canada Inc.
P.O. Box 9204
817 – 45th Street West
Saskatoon, SK S7K 3X5

Re: Request for Review and Approval: JEB TMF Optimization Application

Dear Ms. Van Lambalgen,

Ministry of Environment (Ministry) staff have received and reviewed AREVA Resources Canada Inc.'s (AREVA) October 29, 2010 submission "TMF Optimization – AREVA response to MOE comments on application."

AREVA has proposed to develop the existing JEB tailings management facility (TMF) to the approved capacity. The Ministry has the following understanding based on the submission, previous submissions, and discussions with AREVA.

- The proposed work will be conducted in two stages. AREVA has applied for approval to implement Stage 1 in 2011. Stage 2 work will be subject to separate application.
- Stage 1 involves re-sloping the till to 440 masl at 3H:1V from 438.1 masl as noted in Cross Section A, 435.7 masl as noted in Cross Section B, and 439.0 masl as noted in Cross Section C, liner construction to 440 masl, tailings placement to 436 masl, and pond water cap to 439 masl.
- Stage 2 will involve re-sloping the till to 1.5H:1V from 440 masl to 443 masl, liner construction to 443 masl, tailings placement to 439 masl, and pond water cap to 442 masl.
- A liner consisting of till, crushed sandstone, and 5% bentonite (by mass) will be constructed over the sandstone/till contact and is expected to have a hydraulic conductivity of approximately $5x10^{-11}$ m/s.
- The liner will have a crest width of 6.0 m.
- A rip rap layer 0.5 m thick will be used to protect the liner from erosion.
- A 1.0 m freeboard will be maintained above the pond water elevation throughout operations.
- The proposed work will require relocation of the tailings and reclaim lines, construction of a laydown area, stockpile areas, and access ramps.

- During Stage 1, material will be placed over the contaminated landfill to construct an access ramp. During Stage 2, the portion of the ramp covering the contaminated landfill will be removed so the contaminated waste can be removed and relocated to another storage location. This other storage location will be subject to a separate application and approval.
- AREVA McClean Lake's Approval to Operate Pollutant Control Facilities PO10-110 will need to be amended to reflect changes associated with monitoring wells MW#2, 6, 7, and 4 that will be required as work progresses.
- No changes to the preliminary decommissioning plan or financial assurance cost estimates are expected as a result of the proposed work.

Please find the enclosed Approval PC10-165 authorizing AREVA to proceed with alterations to the existing JEB TMF at the McClean Lake Operation. Please review the conditions of this Approval and ensure that all conditions are met.

Should any changes to the proposed work be contemplated, including changes to scheduling, AREVA shall provide information on the changes to the Ministry for approval before the changes are undertaken.

AREVA shall submit an application to amend the McClean Lake Approval to Operate Pollutant Control Facilities PO10- 110 prior to monitoring wells MW#2, 6, 7, and 4 being modified, as described in the submission.

If you have any questions or comments, you may contact the undersigned at 306-933-7274.

Sincerely,

Jana Lung, P.Eng.
Environmental Project Officer
Ministry of Environment

Enclosure:
PC10-165

cc:
T. Searcy (email) / J. Richards (email) / McClean Regulatory Mailbox (email) – AREVA
T. Gates (email) – Canadian Nuclear Safety Commission
A. Merkowsky (email) / T. Moulding (email) / File – Ministry of Environment

Saskatchewan Ministry of Environment

APPROVAL TO CONSTRUCT, ALTER, OR EXTEND A POLLUTANT CONTROL FACILITY

Issued pursuant to *The Mineral Industry Environmental Protection Regulations, 1996*

APPROVAL NO. PC10-165

AREVA Resources Canada Inc. of Saskatoon, Saskatchewan is hereinafter called "the Company." Saskatchewan Ministry of Environment is hereinafter called "Ministry."

AUTHORIZED ACTIVITY:

The Company is hereby authorized to conduct the following work and activities associated with the alterations to the McClean Lake Operation JEB Tailings Management Facility (TMF) as described in the following Company submissions to the Ministry:

- April 30, 2010 submission "Request for Review and Approval: JEB TMF Optimization Application."
- October 29, 2010 submission "TMF Optimization – AREVA response to MOE comments on Application."
- November 10, 2010 email correspondence (T. Searcy to J. Lung)

With the following conditions:

1. Prior to Stage 2 commencing, the Company shall submit an application with design drawings signed and stamped by a Qualified Person and information regarding potential changes to the preliminary decommissioning plan and financial assurance cost estimates associated with Stage 2.
2. For each stage, the Company shall notify the Ministry when work commences and when work is completed.
3. For each stage, the Company shall submit "as constructed" plans, signed and stamped by a Qualified Person, to the Ministry within 90 days of the completion of construction as per Section 9.3 of the McClean Lake Operation – Approval to Operate PO10-110.
4. The Company shall ensure that a copy of this Approval is on site during all construction activities and is available for presentation upon demand by the local authorities or an authority having jurisdiction.

Any changes to the work proposed by the Company will require the prior written approval of the Ministry. The Company shall ensure that the requirements of all previous approvals and operating limits not described in this authorization are met. The appropriate changes to the Company operating manuals and other documentation shall be made where required.

Dated at Saskatoon, Saskatchewan this 18th day of November, 2010

Recommended

Tim Moulding – Manager, Uranium and Northern Operations, For and on Behalf of the Minister of Environment

…1

Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

101 – 22nd Street East, Suite 520
Saskatoon, SK S7K 0E1
Tel: 306-975-6372
Fax: 306-975-6387

Your file Votre référence

Our file Notre référence
2.04 ML-A

Directorate of Nuclear Cycle
and Facilities Regulation

Telephone: 306-975-6384

September 30, 2010 OCT 0 4 2010

Ms. Tammy Van Lambalgen, Vice President
Regulatory Affairs and General Counsel
AREVA Resources Canada Inc.
817 - 45th Street West
Saskatoon, SK S7K 3X5

Subject: McClean Lake Operation
Request for Review and Approval
JEB TMF Optimization Application

Dear Ms. Van Lambalgen:

Canadian Nuclear Safety Commission (CNSC) staff has reviewed AREVA's McClean Lake Operation's *Request for Review and Approval: JEB TMF Optimization Application* dated April 30, 2010 (T. Van Lambalgen, AREVA to T. Gates, CNSC) and *TMF Optimization Application - Reference Documents* (T. Searcy. AREVA to T. Gates dated June 2, 2010).

The application with supporting documents (modeling and risk assessment) requests review and approval of optimization of 'approved' tailings storage capacity in the JEB Tailings Management Faciltiy (TMF). CNSC staff finds the proposed work acceptable and within the scope of approved activities. No changes to the Mine Facility Licensing Manual are required. Accordingly the TMF optimization is approved per Licence UMOL-MINEMILL-McCLEAN.00/2017 condition 3.1. AREVA's McClean Lake Operation should ensure that on commencement of construction activities that detailed construction schedules are provided to the CNSC Project Officer for inspection planning purposes.

If you have any questions, please do not hesitate to contact myself or the McClean Lake Project Officer, Mr. T. Gates, at 306-975-6362.

Sincerely,

Kevin H. Scissons, Director
Uranium Mines and Mills Division

E-Docs #3614899

c.c.: J. Lung, Sask. Ministry of Environment
C. Morrish, Sask. Ministry of Labour Relations & Workplace Safety

Canada

P004
FPP#2821h
AHPP#12PA040

Saskatchewan

Saskatchewan
Ministry of
Environment

P.O. Box 3003,
6th Floor, 800 Central Avenue
Prince Albert, SK S6V 6G1
Phone: 1-306-953-2423
Cell: 1-306-980-8603
Fax: 1-306-953-2502

May 14, 2012

PERMIT CONDITIONS FOR AREVA RESOURCES CANADA INC'S MCCLEAN LAKE OPERATION PROJECT. PERMIT# 12PA040, AQUATIC HABITAT PROTECTION PERMIT AND FOREST PRODUCT PERMIT 2821H.

Under authority of the Environmental Management and Protection Act (EMPA) 2002, Section 36 (1), The Water Regulations, 2002, Sections 8 and 9, The Forest Resources Management Act and The Provincial Lands Act and Regulations, permission is hereby granted to **Areva Resources Canada Inc** to complete the following:

- Clear approximately 2 hectares of forest/organic materials from the north stockpile area.
- Clear approximately 1 hectare of forest/organic materials from the south stockpile area.

Proponent to contact either Warner Carlson or Scott Andrew at Southend Saskatchewan Ministry of Environment office 306-758-6255 or fax a notice to 306-758-6250 or email Warner.Carlson@gov.sk.ca or Scott.Andrew@gov.sk.ca prior to work commencing and immediately upon completion.

1) The contractor completing the work must be given a copy of this permit to ensure all conditions are met.

2) This permit does not replace or super cede any approvals, licenses or authorizations, which may be required from municipal, provincial or federal legislation. The permit holder will maintain in force all such approvals, licenses or authorizations that may be required.

3) Saskatchewan Environment must be notified of any changes to this project and must approve these changes prior to their implementation.

4) A closure report is required to be submitted to Andy Cook of Saskatchewan Environment within one month following expiry of this permit.

5) This permit may be suspended by Saskatchewan Environment where spring breakup or other conditions warrant.

6) Weather permitting; all reclamation work is to be completed within 30 days of completion of this project.

7) Condition to meet OH&S concerns in respect to transportation of injured workers.
   a. Under the *Occupational Health and Safety Act, 1993 & Occupational Health and Safety Regulations, 1996* it is the responsibility of the employer to ensure that

there are adequate means to transport injured workers to a medical facility or hospital. Please ensure that contractors are familiar with this legislation. Please call Neal Crocker of Saskatchewan Labour (306) 933-5106 for clarification of this requirement.

b. It is further suggested that employers contact the local Regional Health Authority to research the emergency procedures for the area where work is being carried out. What is available in the area may directly affect employers planning for *Occupational Health and Safety Act* requirements.

8) Prior to entry of equipment on forested Crown land, all equipment must be washed and clear of any non-indigenous plants or seeds.

9) The proponent must ensure that upon abandonment of any site, all man made items are removed and disposed of properly. This includes, but is not limited to, flagging tape, nails, petroleum products and dimensional lumber. Haul out what you hauled in.

10) Forest operations are to be conducted as per the Forest Resources Management Act and Regulations unless otherwise stated.

11) Low impact and avoidance cutting techniques shall be used when clearing. This should include such techniques as cutting the path of least resistance, removing branches from trees rather than cutting the tree, avoiding the cutting of standing merchantable trees where possible.

12) No material is to be pushed into standing timber. All leaning trees are to be removed from standing timber. All trees not salvaged are to be utilized in the reclamation of access trails and any other disturbances.

13) **Clearing of vegetation within 100 meters of any watercourse/body must be hand cleared.**

14) Unless otherwise approved, any clearing of vegetation shall be minimized and follow the construction plan outlined in the program proposal. Stripping of the site shall be limited to vegetation removal and, **if required**, topsoil removal (vegetation and topsoil are to be stripped and stored separately for final reclamation).

15) All spoiled materials resulting from the clearing operations must be placed in a location where it will not be subject to erosion into any water body or watercourse.

16) Once operations are completed, sites must be re-contoured, topsoil is to be re-spread, and woody species are to be rolled back and spread on the sites. Sites will be allowed to naturally regenerate. If supplemental planting is required, approval for seeding and/or tree planting is required prior to completing any reclamation work. Contact the local Ecological Protection Specialist.

17) All activities are to occur during dry ground conditions. During overly wet conditions, work must be stopped for any activity that could potentially cause undue rutting of the ground surface (other than permanent roadways). Rutting is defined as an area 5 meters in length and greater than 15 cm in depth.

18) Any (new) Stream crossings will be identified on a 1:50,000 scale map and a description of the method to be used to cross the stream will be provided to S.E. for approval before construction of these crossings takes place.

19) Within bogs, muskegs or possible wet areas, the ground must be frozen enough to support equipment. If frozen ground conditions do not exist, alternate **approved** methods must be used to prohibit rutting of the ground surface (i.e. timber matting, planks, etc.).

20) No debris is to be deposited in any water body or watercourse or on the ice of any frozen water body or watercourse. Any debris accidentally deposited is to be removed immediately.

21) Until re-vegetation is sufficient to control sediment erosion, the proponent shall ensure that effective sediment and erosion control measures are in place and that they are functioning properly and are maintained and/or upgraded as required to prevent sediment from entering the water body or water course.

22) Felling and yarding of trees shall be away from any water body. Trees are not to be yarded across any watercourse. No cut brush or trees may be left in or on any water body during this project.

23) The bank or boundary of any water body or watercourse disturbed by construction activities will be recontoured to the natural slope and will be stabilized immediately to prevent erosion by revegetation or other means (eg. using clean riprap and/or erosion control blankets).

24) **All** spills of hazardous substances or waste dangerous goods are to be reported as per thresholds amounts identified in the *Environmental Spill Control Regulations* and handled according to the regulations.

25) All stationary fuel tanks, pumps, motors and hydraulic lines must have secondary containment. (E.g. If a pump is used to pump water, the pump and it's fuel supply must be placed in a container that is capable of holding 110% of the pump fuels and oils).

26) A spill kit must be on site during operations and all members of the crew must be properly trained in the operation of the spill kits.

27) Work operations, from April 1 to October 31, within the Provincial Forest or within 4.5 km of the Provincial Forest, work crews must have fire-fighting equipment on hand, as per Best Management Practice 006 of the Mineral Exploration Guidelines of Saskatchewan.

This permit expires on December 31, 2012.

Signature

Andy Cook
Senior Ecological Protection Specialist

Saskatchewan

Ministry of
Environment

6th Floor, 800 Central Avenue
P.O. Box 3003, Prince Albert
Saskatchewan, S6V 6G1
Phone: 1-306-953-2423
Cell: 1-306-980-8603
Fax: 1-306-953-2502
andy.cook@gov.sk.ca

May 14, 2012

AQUATIC HABITAT PROTECTION PERMIT #12PA040

Under authority of the Environmental Management and Protection Act (EMPA) 2002, Section 36 (1), The Water Regulations, 2002, Sections 8 and 9, permission is hereby granted to **AREVA Resources Canada Inc.** to;

1. Work in or in the proximity of Aquatic Habitat to complete their forest clearing proposal at McClean Lake Mine Site as submitted to the Ministry of Environment March 21, 2012.
2. As per attached conditions.

This permit expires December 31, 2012.

Andy Cook
Senior Ecological Protection Specialist

Saskatchewan Ministry of Environment

Forest Product Permit

02/2009

2821 H

Pursuant to the Forest Resource Management Act and Regulation permission is granted to the Permittee for: (check one)

☒ Timber ☐ Haying ☐ Grazing ☐ Special Products ☐ Oil & Gas Exploration ☐ Mineral Exploration ☐ Right of Way ☐ Science Projects

Effective Date: 14 / 05 / 12 (dd mm yy) Expiry Date: 31 / 12 / 12 (dd mm yy)

Method of Payment
☐ monthly returns by permittee
☐ monthly returns by other (list)

☐ equal installments ($/due date)
1st _____ / application date
2nd _____
3rd _____ / 90 days after first remittance

Company/Individual Name: Areva Resources Canada Inc (Last / First)

Date of Birth _____ (dd mm yy) Drivers License _____ or SHSC# _____

Address: P.O. Box 9204 - 817 - 45th Street West

City: Saskatoon Prov.: SK Postal Code: S7K-3X5 Telephone #: 343-4551

Operator Name: Blondeel (Last) Christopher (First)

Inspecting Officer Name: Cook (Last) Andy (First)

Application date: 21 / 03 / 12 (dd mm yy)

Received by (please print): Andy Cook

Operating Office Name: Prince Albert

Fire Year _____

Fire Name _____

*U - forest products must be used for own non-commercial use *S - authorizes permittee to offer for sale, sell, exchange, barter, deal, solicit or trade the forest products legally obtained with this permit

*U/*S	Zone	Easting	Northing	Quantity	Units	Species	Product Class	Salvage Type	Land Type	Crown Dues rate	Dues Total	Fund Code	Management Fee Rate	Fee Total	Bonus Bid Crown rate	Bid Crown Total	Bonus Bid Fee rate	Bid Fee Total
S	13	568	646									CF						
McClean Lake Operation Project																		
Permit # 12PA040																		

Allocation Holders only: Maximum annual allowable harvest from operating plans

Green	Salvage
_____ m³ SW	_____ m³ SW
_____ m³ HW	_____ m³ HW (gA, wB, wE & mM)
_____ m³ HW	_____ m³ HW (tA, bP)

Dues Subtotal + Fees Subtotal + Bid Dues Sub + Bid Fee Sub = Subtotals

Or 1st installment (2 or 3 installments): Dues + Fees + Bid Dues + Bid Fees = Installment total

(Commercial permit fee $50.00 Own Use permit fee $10.00) + 50.00 Permit Fee

GST Registrant # _____ or + 2.50 GST

Less: Credit from Permit # _____ - Credit Total

Total Paid = 52.50

Pd Chq #12641o

Permittee Signature (Individual/Company representative) _____

If representative please print name _____

Approved by _____

This license is subject to the Forest Resources Management Act and Regulations, officer's instructions and terms and conditions as stated in the following attachments:

☐ Operating Plan ☐ Scaling Plan ☐ Payment Schedule ☐ Range Management Plan ☐ Agreement Letter ☐ Access Letter (Ag & Food) ☐ Special Products Ledger ☒ Conditions

Permittee

APPENDIX E

Survey Control Report

SURVEY REPORT FOR CONTROL NETWORK

Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

1.0 EQUIPMENT

GPS BASE STATION

- Sokkia GRX1 base station receiver with integrated with GPS and GLONASS tracking in conjunction with Satel differential correction external radio.

RTK GPS ROVER

- Sokkia GRX1 RTK rover receiver with integrated with GPS and GLONASS tracking in conjunction with Satel differential correction internal radio mounted to a fixed height carbon fibre range pole.

2.0 SURVEY PROCEDURE

ESTABLISHED CONTROL

- Localization to local mine grid control was performed using coordinates provided by Areva.
- Golder Associates' site control network was established in reference to Golder MLO CP1 using the localization created.
- Coordinates established by averaging 100 fixed readings at each occupied station.

CONTROL POINT DEFINITIONS

- Golder MLO CP1, Golder MLO CP3, Golder MLO CP4, Golder MLO CP5, Golder MLO CP6, Golder MLO CP7, Golder MLO CP8, Golder MLO CP9, Golder MLO CP10 and Golder MLO CP11, are iron bars set in concrete. Specifics of the iron bar and concrete are unknown.
- Golder MLO CP2 is an iron bar driven in the ground to an unknown depth.
- All control points identified with three lathe and blue and pink flagging.

ACCURACY

- The horizontal error when establishing control did not exceed 8mm.
- The vertical error to when establishing control did not exceed 12mm.

Client: Areva – McClean Lake Operation
Crew Chief: Kyle Nontell
Date: June 05, 2012
Project/Phase No: 12-1362-0022
Survey Assistant: N/A

3.0 CONTROL DATA

Coordinates Established By Golder Associates				Coordinates Provided By Areva MLO			
STATION	NORTHING	EASTING	ELEVATION	STATION	NORTHING	EASTING	ELEVATION
Golder MLO CP1	11109.626	5040.221	453.183	1995004	11109.641	5040.221	453.183
Golder MLO CP2	10949.172	5485.630	461.420	1995002	10949.179	5485.625	461.424
Golder MLO CP3	11168.406	5080.049	454.074	1995010	11168.416	5080.053	454.076
Golder MLO CP4	11202.765	5032.194	451.656	1995005	11202.785	5032.195	451.656
Golder MLO CP5	11221.790	5079.850	452.796	1995011	11221.808	5079.992	452.699
Golder MLO CP6	11270.627	5098.761	451.451	1995012	11270.672	5098.774	451.468
Golder MLO CP7	11309.745	5120.554	450.939	1995013	11309.720	5120.568	450.955
Golder MLO CP8	11385.195	5108.893	448.702	1995006	11385.199	5108.891	448.700
Golder MLO CP9	11385.978	5337.661	453.484	1996001	11385.996	5337.650	453.503
Golder MLO CP10	11253.050	5650.665	459.211	1995008	11253.039	5650.665	459.217
Golder MLO CP11	11038.026	5436.444	457.345	1995014	11037.971	5436.440	457.359

Variance Between Given And Established Coordinates

STATION	NORTHING	EASTING	ELEVATION
Golder MLO CP1	-0.015	0.000	0.000
Golder MLO CP2	-0.007	0.005	-0.004
Golder MLO CP3	-0.010	-0.004	-0.002
Golder MLO CP4	-0.020	-0.001	0.000
Golder MLO CP5	-0.018	-0.142	0.097
Golder MLO CP6	-0.045	-0.013	-0.017
Golder MLO CP7	0.025	-0.014	-0.016
Golder MLO CP8	-0.004	0.002	0.002
Golder MLO CP9	-0.018	0.011	-0.019
Golder MLO CP10	0.011	0.000	-0.006
Golder MLO CP11	0.055	0.004	-0.014

NOTE: COORDINATES SHOWN ARE CONSIDERED ACCURATE IN REFERENCE TO *GOLDER MLO CP1* USING LOCALIZATION TO THE MINE GRID CONTROL NETWORK WITH COORDINATES PROVIDED BY AREVA. CONTROL POINTS ARE SUBJECT MOVEMENT AND DAMAGE AND ARE TO BE CONFIRMED PRIOR TO USE.

Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

4.0 PICTURES

Golder MLO CP1



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Base Station set up at Golder MLO CP1



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP2



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP3



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP4



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP5



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP6



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP7



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP8



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP9



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP10



Client:	**Areva – McClean Lake Operation**	**Project/Phase No:**	**12-1362-0022**
Crew Chief:	**Kyle Nontell**	**Survey Assistant:**	**N/A**
Date:	**June 05, 2012**		

Golder MLO CP11



At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.

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Canada
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Golder Associates

Appendix B

Section D

Subsection B: TMF Expansion Approved Submission

VIA EMAIL

June10, 2016

Mr. Salman Akhter
Senior Project Officer
Uranium Mines & Mills Division
Canadian Nuclear Safety Commission
#520, 101-22nd Street East
Saskatoon, SK S7K 0E1

Dear Mr. Akhter:

Re: McClean Lake Operation – Notification of Modification to the JEB Tailings Management Facility Expansion Project

Based on changes to the current mining and milling forecast, AREVA Resources Canada Inc. (AREVA) has modified the JEB TMF Expansion Project (Project), initially submitted in the August 2011 licence amendment request (Van Lambalgen to LeBlanc). The reduced scope of the project proposes to increase tailings storage capacity by constructing an embankment around a portion of the JEB Tailings Management Facility perimeter, and place a natural liner, to contain tailings and pond water during the operating period. The embankment will not be required post-closure. Please accept this submission as notification in accordance with the McClean Lake Operations Licence Conditions Handbook (LCH) to modify the authorized top of consolidated tailings elevation listed in the from 434 Meters Above Sea Level (mASL) to correspond with the natural ground surface on the low side of the facility at 448 mASL and to expand the outer perimeter of the JEB TMF to accommodate disposal of tailings to the modified elevation of 448 mASL.

In accordance with Appendix A of the McClean Lake Operation LCH, the documents accompanying this correspondence provide information for Canadian Nuclear Safety Commission staff to determine the Project remains within the licensing basis for the McClean Lake Operation and meets the requirements of the CNSC.

Should you have any questions, please contact Tina Searcy, Regulatory Relations Manager at (306) 343-4525 or tina.searcy@areva.com myself at (306) 343-4058 or by email at dale.huffman@areva.com.

Sincerely,

Dale Huffman
Vice President,
Health, Safety, Environment & Regulatory Relations

cc: ARC Distribution

AREVA Resources Canada Inc.
P.O. Box 9204 – 817 - 45th Street West – Saskatoon, SK S7K 3X5 – CANADA
Tel: 1 (306) 343-4500 – Fax: 1 (306) 653-3883 – Web Site: www.areva.ca

AREVA Resources Canada Inc.

McClean Lake Operation

Notification to Expand the JEB Tailings Management Facility

PIGA Status: Unrestricted

June 2016

Approval for Use

Editor:		
Regulatory Relations Manager	Tina Searcy	
Title	Name	Signature

Approver:		
VP, HSE&RR	Dale Huffman	
Title	Name	Signature

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1 Notification

AREVA Resources Canada Inc. (AREVA) is proposing to maximize tailings placement within the JEB Tailings Management Facility (TMF) through the construction of an embankment around a portion of the perimeter of the TMF and placement of a natural liner. The *JEB TMF Expansion Project* (the Project) will provide the ability to increase storage capacity within the facility by increasing the elevation of consolidated tailings from 434 Meters Above Sea Level (mASL) to 448 mASL, which corresponds to the existing ground surface on the low side of the facility. In accordance with Appendix A of the McClean Lake Operations (McClean Lake) Licence Conditions Handbook (LCH), this correspondence and its attachment provides information for the Canadian Nuclear Safety Commission (CNSC) to demonstrate that the proposed Project meets the CNSC requirements and meets the intent of the licensing basis for the McClean Lake Operation.

1.1 History

On August 26, 2011 AREVA submitted a Project Description [1] for the vertical expansion of the JEB TMF and a request to amend the McClean Lake Operation operating licence for the Project to the CNSC. Although the capacity of the JEB TMF would be increased, the process for the management of tailings was the same as had been previously assessed and approved and the Project remained within the boundary of an existing licensed uranium mine and mill. As such, it was AREVA's understanding that the Project would not trigger the requirement of a Comprehensive Study level Environmental Assessment (EA), but a Screening level EA would be required pursuant to the *Canadian Environmental Assessment Act* (S.C. 1992, c.37). In November 2011, AREVA received the CNSC determination that a federal screening level EA under CEAA was required for the proposed Project, with the EA process overseen by the CNSC. In July 2012, the *Canadian Environmental Assessment Act*, 2012 (S.C. 2012, c.19, s. 52) came into force, removing screening level EAs. AREVA was notified that an EA would no longer be required and that the Project would continue to the licensing process under the *Nuclear Safety and Control Act* (NSCA).

Following the submission of the initial Project Description for the Project in August 2011, the provincial Environmental Assessment Branch (EAB), Saskatchewan Ministry of Environment (MOE) completed an environmental screening of the proposed change to the currently approved development. Based on the description of the Project and the environmental protection commitments, the EAB determined that the Project is not a development as defined in *Section 2(d) of the Saskatchewan Environmental Assessment Act* (Chapter E-10.1). Accordingly, the province has not required an environmental

assessment (EA) for the proposed Project and AREVA was directed to proceed in obtaining other permits and approvals required to commence construction and operation of the Project from the SMOE.

The Project presented in this notification has a reduced scope relative to the proposal provided in 2011. The current Project is presented by AREVA to be within the licensing basis for the McClean Lake Operation; it is anticipated that the Project can be approved by the CNSC through an update to the LCH.

1.2 Evolution of Submission Document

In August 2011, AREVA submitted an application package [1], which included a project description, requesting a licence amendment for the McClean Lake Operation to expand the JEB TMF. Following an EA determination by the CNSC, the project description was reviewed by the CNSC staff and determined sufficient to be accepted and reviewed as a Draft Environmental Impact Statement (EIS). However, because of changes to the *Canadian Environmental Assessment Act*, in July 2012 AREVA was notified that an EA would no longer be required and the proposed project would undergo licensing approval only. As a result, in November 2012, AREVA provided the CNSC with a package titled the JEB TMF Expansion Licensing Application [2], which contained a comprehensive review of the environmental aspects of the proposed project, including responses to previous received information requests from the CNSC. Following the review of the November 2012 Licensing Application document [2], the CNSC provided additional technical comments to AREVA in May 2013. AREVA provided responses to these comments, and an updated version of the Licensing Application document in February 2014 [3]. AREVA had not yet received CNSC's comments on the February 2014 Licensing Application document [3], when AREVA requested to put the review on hold to re-evaluate alternatives addressing an update to the mine and milling plan.

With the adoption of the McClean Lake Operation's LCH framework, AREVA has the opportunity to request to approve the JEB TMF Expansion Project as Licensed Activity in the LCH, rather than a licence amendment, if AREVA can demonstrate that the project remains within the licensing basis for the McClean Lake Operation. As such, AREVA has prepared this correspondence (Notification) in accordance with Appendix A of the McClean Lake LCH and has updated the February 2014 Licensing Application document [3], providing it as an attached Project Description to this Notification. For the convenience of conducting a review of the modified Project, the key changes are as follows:

- As a result of changes in the mining and milling plan, the project tailings production was reduced from 5.5 million m^3 to 2.3 million m^3;
- JEB TMF expansion design has changed to reduce top of embankment from 468 mASL to 457.5 mASL and top of consolidated tailings reduced from 463 mASL to ground-level elevation of 448 mASL (Section 4; throughout);

- Regulatory process understanding has changed considering the Project is within the licensing basis for the McClean Lake Operation (Section 2);
- Alternatives Assessment updated to include the results of 2014 Options Study, which considered changes to mine plan and re-evaluated the conversion of existing pits to a TMF (Section 3);
- A discussion on the independent review panels conclusions from their investigation of the breach that occurred at the Mount Polley Mine in 2014 has been included (Section 5), and
- An environmental risk analysis of an embankment failure has been included (Section 5).

1.3 Licensing Basis for Tailings Management

AREVA considers the vertical expansion of the JEB TMF to remain within the intent of the licensing basis for the McClean Lake Operation, as it will continue to achieve the operational and post-closure objectives developed for tailings management. The expanded JEB TMF will continue to:

- passively limit the long-term pore water concentrations of COPCs through geochemical controls established during the operating period;
- passively limit groundwater migration through the tailings mass during the post-closure period by establishing a hydraulic conductivity contrast between the consolidated tailings and the surrounding host materials;
- passively limit infiltration through the tailings during the post-closure period;
- passively control contaminant flux to maintain surface water quality in neighboring lake below water quality guidelines;
- maintain hydrodynamic containment of the tailings through the operating period;
- employ the current tailings preparation and depositions methods;
- limit infiltration of pond water into the overburden during the operating period through the placement of a low permeability liner;
- place tailings in the TMF sub-aqueously;
- contain tailings pond water during the operating period;
- place consolidated tailings below the ground surface;
- manage storm water effectively;
- validate the geochemical and geophysical aspects of the facility design; and

- achieve low levels of radiation exposure to workers and the public in the operating period and post-decommissioning.

The use an earthen embankment around a portion of the JEB TMF perimeter to contain tailings and pond water during the operating period is the new aspect to tailings management proposed by the Project. Construction, operation, and decommissioning of the expanded JEB TMF has been evaluated in the attached Project Description. Use of an embankment for containment during the operating period is considered to meet the intent of the licensing basis because:

- robust design ensure a sufficient factor of safety in the construction and operation of the facility;
- reliance on the embankment for containment is confined to the operating period, i.e. the embankment is not used for decommissioned state;
- a system will be established to monitor embankment integrity;
- an understanding of dam and embankment failures, including the event at Mount Polley, has informed the design and the review of the structure;
- freeboard will be maintained to manage storm water for a worst-case probable maximum precipitation event; and,
- though the failure of the embankment is unlikely, the worst-case consequences have been evaluated and are expected to be limited in both duration and extent.

1.4 Regulatory Approvals

Current approvals for the McClean Lake Operation include the Uranium Mine Operating Licence UMOL-MINEMILL-McCLEAN.01/2017 issued by the CNSC and the Approval to Operate Pollutant Control Facilities PO12-071 issued by the Saskatchewan Ministry of Environment (SMOE).

1.4.1 Canadian Nuclear Safety Commission

UMOL-MINEMILL-McCLEAN.01/2017 authorizes AREVA to operate and modify a nuclear facility for the mining of uranium ore and production of uranium concentrate. Authorized activities under the Licence Conditions Handbook include, amongst other activities:

- Disposal of tailings in the JEB Tailings Management Facility (JEB TMF) up to a consolidated tailings elevation of 434 Meters Above Sea Level (MASL), which is the approximate low point of the sandstone-till contact

As per Part I, Section 2.4 of the LCH, AREVA requests an update to the LCH Part I, Section 2.4 Section IV: Licenced Activities to change the top of consolidated tailings elevation from 434 mASL to 448 mASL. AREVA expects that this correspondence demonstrates that the increase of consolidated tailings elevation meets the CNSC's requirements and is within the licensing basis of the McClean Lake Operating Licence; therefore the Project is anticipated to be approved through an update to the LCH.

More specifically, AREVA is proposing to change the authorized activity under LCH Part 2.4 Section IV: Licenced Activities from:

> "*Disposal of tailings in the JEB Tailings Management Facility (JEB TMF) up to a consolidated tailings elevation of 434 Meters Above Sea Level (MASL), which is the approximate low point of the sandstone-till contact"*
>
> To:
>
> "*Disposal of tailings in the JEB Tailings Management Facility (JEB TMF) up to a consolidated tailings elevation of 448 Meters Above Sea Level (mASL), which is the approximate low point of natural ground elevation"*
>
> And add the following activity:
>
> "*Modify/expand the outer perimeter of the JEB TMF to accommodate disposal of tailings to a consolidated tailings elevation of 448 mASL*"

An acceptance of these changes to the LCH, the Mining Facility Licensing Manual (MFLM) and Facility Description Manual (FDM) will require revision.

1.4.2 Saskatchewan Ministry of Environment

The Approval to Operate issued by the SMOE authorizes AREVA to operate pollutant control facilities associated with the McClean Lake Operation, including the mill and the JEB TMF. The Project will require an approval to construct and an amendment to operate a Pollutant Control Facility, in accordance with Section 6 of the *Mineral Industry Environmental Protection Regulations* (MIEPR) issued by the Saskatchewan Ministry of Environment (SMOE). This request will be submitted by AREVA to the SMOE prior to commencing construction of the Project.

1.4.3 Environmental Assessment (EA) Determination

As discussed in Section 1.1 of this correspondence, no further environmental assessment is expected.

On January 10, 2012, AREVA received a letter from the Saskatchewan Ministry of Environment, indicating the MOE had completed an environmental screening of AREVA's proposed change (the JEB

TMF Expansion Project) to the approved development (EAPTS #1978-041) and that it was SMOE's finding that the project is not a 'development' and would not require any further environmental assessment. The letter stated that the office must be advised if work is not commenced within two years of receipt of the letter and that the proposal's environmental acceptability would be re-examined in light of the circumstances of the day. In subsequent correspondence, the Environmental Assessment Branch (EAB) amended the screening approval to allow the project to commence by 2017. A request for further extension of the reduced-scope Project is being submitted the EAB for review and approval.

1.4.4 Public Information Program

AREVA places a high priority on providing timely, relevant information to its employees, the leadership of Aboriginal peoples, civic representatives and the general public as part of its commitments to Corporate Social Responsibility. AREVA has developed and implemented a Public Information Program (PIP) for the McClean Lake Operation that has been developed in accordance with the CNSC's RD/GD 99.*3 Public Information and Disclosure*. The PIP outlines how AREVA will ensure that information related to the health, safety and security of persons and the environment, and other activities associated with the facility are effectively communicated to the public. This includes ongoing operations, and proposed projects under environment assessment, and licensing.

Sharing of information pertinent to this Project commenced in 2011 at early development stages and has been on-going since. Project specific engagement activities have been provided in Attachment A - JEB TMF Expansion Project Description (Project Description) of this correspondence. Most recently, AREVA presented the reduced-scope Project to stakeholders in 2015.

1.5 Alternatives Evaluated

Alternatives to the Project are discussed within Section 3 of Attachment A - Project Description.

Various alternatives to obtain additional tailings storage capacity were considered both at the onset of the project and again in later stages following an update to the mining plan which resulted in a reduction in tailings storage capacity requirements. Tailings management alternatives considered by AREVA included the conversion of existing pits at the McClean Lake Operation, expansion of the existing JEB TMF, and the construction of a Purpose Built Tailings Management Facility (PBTMF). The conversion of existing mined out pits was initially deemed the least favourable alternative because the pits have already been committed and approved for other uses, have potential operating challenges or were too far away from the McClean Lake Mill to be practical. Following the update to the mining plan and reduction in required tailings storage capacity, the conversion of existing pits was re-evaluated as a potential option. The cost associated with the conversion of the Sue pit into a TMF for the volume of

tailings required was considered economically unfavourable. Construction of a dedicated PBTMF is a technically feasible alternative, however the resulting additional physical and environmental footprint made this alternative less favourable.

Accordingly, it was concluded that the preferred option is to optimize tailings storage capacity in the existing JEB TMF through the construction of an embankment around a portion of the JEB TMF perimeter and placement of a processed waste rock/till bentonite amended liner to contain the pond during the operating period. The required additional tailings storage capacity can be realized through the proposed Project while continuing to meet long-term environmental performance objectives within a physical footprint comparable to the existing facility and remain consistent with guidance provided in CNSC Regulatory Document *RD/GD-370*, *Management of Uranium Mine Waste Rock and Mill Tailings*.

2 Description of Change

2.1 Overview

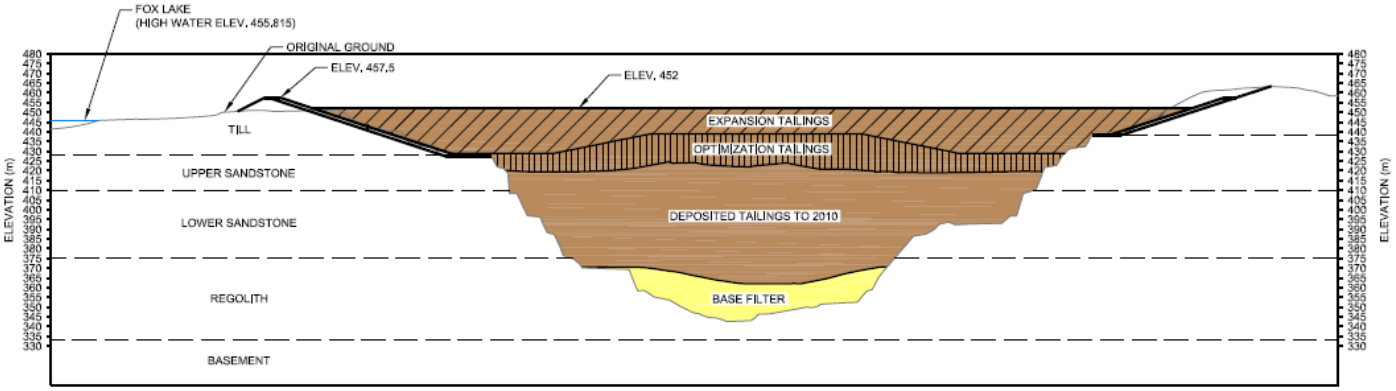
At its foundation, the Project builds on the design of the existing JEB TMF, as well as the optimization activities associated with the approved JEB TMF Optimization Project [4]. Expansion of the JEB TMF involves increasing the elevation of stored tailings above the currently approved elevation for consolidated tailings of 434 mASL to 448 mASL. The predictions of environmental performance incorporate the knowledge acquired during the operation of the McClean Lake mill and JEB TMF. AREVA's objective in the development of the Project is to optimize the storage of tailings within the environmental footprint of the existing JEB TMF, including meeting surface water quality objectives in Fox Lake and Pat Lake in the long-term. This section provides a summary of the project description; a detailed project description is provided in Section 4 of Attachment A - Project Description. The scope of the Project includes the following:

- construction of an embankment around a portion of the JEB TMF perimeter to bring the low-side elevation up from 448 mASL to 457.5 mASL;
- placement of a processed waste rock/till bentonite-amended liner to contain the operating pond throughout operations;
- continued placement of tailings into the expanded JEB TMF above the till/sandstone contact;
- construction of two new waste rock runoff ponds;
- relocating infrastructure affected by the Project footprint (e.g., power lines, tailings barge and anchor points, tailings lines, reclaim water lines, tailings delivery pipe line, and under flow pump);
- relocating the temporary contaminated landfill (under separate approval);
- decommissioning of dewatering wells and monitoring wells affected by the Project footprint, and installation of new monitoring wells (under separate approval); and
- decommissioning of the JEB TMF and placement of a soil cover incorporating a proposed waste rock/till bentonite amended layer to limit infiltration.

To achieve an expanded storage volume within the JEB TMF an embankment will be constructed around a portion of the pit perimeter. A processed waste rock/till bentonite-amended liner will also be placed along the flattened embankment slopes and inside the pit walls in the till formation to contain pond waters throughout operation of the JEB TMF. This liner will be a continuous extension of the liner used for the JEB TMF Optimization Project [4]. A conceptual cross-section through the proposed expanded JEB TMF is

presented in Figure 2.1. Section 4.2 JEB TMF Expansion Design and Construction of Attachment A – Project Description provides a detailed description of the embankment and liner design.

Figure 2-1: Conceptual Cross-Section



The height of the embankment required for the Project varies from 0 m on the east side to 9.5 m on the west side of the JEB TMF. Based on this configuration, approximately 1.7 million m^3 of additional tailings can be stored within the expanded JEB TMF, while maintaining up to 4 m water cover over the tailings mass, a 1 m freeboard to the embankment crest, and a 0.5 m allowance for storage of a Probable Maximum Precipitation (PMP) storm event during the operation period. It is estimated that this embankment configuration can expand the useable life span of the existing JEB TMF for approximately 18 years, based on current mining predictions.

A soil cover system consisting of processed waste rock/till bentonite amended layer will be installed as part of decommissioning of the JEB TMF. The soil cover system will also provide a sustainable landform configuration and drainage system for the decommissioned JEB TMF. During placement of the soil cover system, it is predicted that the tailings will consolidate to an elevation equal to the ground surface on the low side of the existing JEB TMF (448 mASL). In addition, the downstream side of the embankment slopes will be flattened during construction of the soil cover system to maintain stable slope conditions after the decommissioning period.

2.2 Schedule

The overall schedule for the Project is presented in Table 2.1. Construction milestones indicate when each of the expansion stages are anticipated to be completed and is based on the currently forecasted milling schedules. The regulatory process will continue onto licensing both Federal and Provincial as formal environmental assessments are understood to not be required. This construction schedule is preliminary in nature, and will be reviewed and updated as required.

Table 2-1: Project Schedule

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Relocate Contaminated Landfill (separate approval)																	
Decommission Dewatering wells (separate approval)																	
Relocate Infrastructure																	
Construction of Waste Rock Runoff Ponds																	
Re-sloping 443 to pit crest and placement of embankment																	
TMF Optimization Stage 2 (out of scope)																	
Liner prep and placement 443 mASL- 447 mASL																	
Liner prep and placement 447 mASL - 451 mASL																	
Liner prep and placement 451 mASL - 455 mASL																	
Liner prep and placement 455 mASL - 457.5 mASL															when needed		

2.3 Risk Analysis

The JEB TMF has been subject to numerous environmental assessments for the McClean Lake Operation and is continuously studied under the Tailings Optimization and Validation Program (TOVP), which validate the predicted performance. The results of the TOVP have provided assurances and reduced uncertainty in understanding the long-term environmental performance of the JEB TMF. The Tailings Management Technical Information Document (TID) [5] published in 2015 presented the most recent results of the TOVP, updated contaminant transport model predictions, and consolidated information on the operation of the TMF. A screening level evaluation of the potential environmental consequences to Fox Lake, Pat Lake and downstream waterbodies in the Collins Creek watershed resulting from the unlikely failure of the embankment of the expanded JEB TMF during operations subsequent to the proposed expansion was conducted under two scenarios; 1) release of pond water to the environment when the pond is at a maximum capacity; and 2) release of pond water and tailings solids to the environment when the JEB TMF is at the maximum capacity. A description of this evaluation has been provided in Section 5.4.2 of Attachment A – Project Description; it concludes that the consequences of an embankment failure at the JEB TMF would not have catastrophic effects on the Collins Creek watershed downstream of the facility. While water and sediment quality and the health of aquatic biota in Fox Lake would be affected and recovery of the lake could take many months or years, it is not anticipated that water bodies downstream of Fox Lake would be negatively impacted over the short or long term.

Section 5 of Attachment A presents the evaluation of project/environmental interactions and evaluates associated risks. Of primary concern in the evaluation of tailings management facilities is the long-term transport of contaminants from the facility, and the geotechnical stability of the facility in the operating period and post-closure. The risk assessment concludes:

- Predictions of long-term water quality in neighbouring waterbodies is anticipated to meet water quality guidelines and objectives for all constituents of potential concern;
- The embankment design has incorporated a sufficient factor of safety to be stable throughout the operating period;
- The post-closure landform will be physically stable, safe, and environmentally sustaining.

2.4 Health and Safety Considerations

The McClean Lake Operation maintains certification under the Occupational Health and Safety Assessment Series (OHSAS) 180001:2007 which provides the requirements for a comprehensive Occupational Health and Safety Management System. It includes hazard identification and risk assessment, incorporating proactive minimization of risks to workers and the public through continual

improvement in health and safety performance. Work plans consider the identification of workplace hazards, assessments of the hazards, risks, and mitigation which are reviewed and updated as required by the McClean Lake Operation.

Other than the construction of an embankment, the operation of the expanded JEB TMF does not introduce any new health and safety considerations to address. The primary considerations in the design of the JEB TMF embankment are slope stability and pond containment throughout operations. Field investigation and material characterization completed for the JEB TMF Optimization Project [4] were used for the preliminary design of the embankment and pond containment system for the Project. A summary of the field investigation and material characterization, as well as the design parameters developed for the embankment are discussed Section 4.2.1 of Attachment A – Project Description.

2.5 Radiation Protection Considerations

Appendix H of Attachment A evaluated the radiological risks of the project through operation, decommissioning and post closure. It concluded that there are no changes to operating practices anticipated to impact radiation protection of workers resulting from the expansion of the JEB TMF, and post-closure, radiological levels are anticipated to be indistinguishable from background.

No substantive changes are anticipated to the radiation protection program resulting from the expansion of the JEB TMF. The programs established at the McClean Lake Operation have anticipated the processing of high grade uranium ores and the placement of the subsequent tailings. The elevation of the placed tailings is immaterial to the radiation protection program components. Specifically:

- relevant routine radiological monitoring locations are established in and around the JEB TMF to monitor worker exposure to gamma radiation, radon progeny and long-lived radioactive dusts;
- dosimetry of workers working in the JEB TMF is conducted according to an established dosimetry monitoring strategy;
- contamination control at the McClean Lake Operation will continue to follow established zoning categorization; and
- training programs for Nuclear Energy Workers are established and adequately consider radiological hazards within the JEB TMF.

Routine radiological monitoring data will be used to validate the predicted radiological dose rates within the JEB TMF during the placement of tailings from high grade ores.

2.6 Environmental Protection

AREVA's objective in the development of the Project is to optimize the storage of tailings within the environmental footprint of the existing JEB TMF, including meeting Canadian Water Quality Guidelines (CWQG) [7] and Saskatchewan Surface Water Quality Objectives (SSWQO) [8] in Fox Lake and Pat Lake in the long-term.

Long-term performance predictions of the decommissioned JEB TMF incorporate the results of knowledge acquired during the past 16 years of operating the McClean Lake mill and JEB TMF. The knowledge acquired through the Tailing Optimization and Validation Program (TOVP) provides understanding on which the Project has been developed. Environmental monitoring provides the information necessary to determine the extent of environmental effects over the lifespan of a development and facilitates continual improvement initiatives and the implementation of adaptive management. The environmental monitoring requirements are integrated into the McClean Lake Operation Environment Monitoring Program (EMP) and results are regularly documented in the Environmental Performance Technical Information Document (EP TID) [6], McClean Lake Annual Reports, and EEM reports. The Environmental Performance TID [6] consolidates knowledge on the existing environment, past operational performance, and predicts future environmental performance through ecological and human health risk assessment. The Tailings Management TID [5] consolidates operational and performance information on the TMF, including validation of key design parameters resulting from the TOVP and predictions of long-term contaminant transport.

Section 5 of Attachment A summarizes status of the environment reporting and environmental risk assessment methodology and identifies key project-environment interactions and if these interactions have the potential to result in unacceptable effects or risks to the biophysical or socio-economic environments.

AREVA also conducted a review of the Mount Polley Independent Review Panel conclusions which investigated the breach that occurred at Mount Polley in 2014. AREVA prepared a comparison of the review panel's conclusions and features of the JEB TMF Expansion Project. This table is available is section 5.4.1 of Attachment A – Project Description.

The predicted environmental risks for the Project are within those already predicted and assessed through environmental assessments of the McClean Lake Operation listed in the LCH, and there are no major changes to the way the JEB TMF will be operated, however some changes to existing monitoring programs will be implemented as part of the Project, these changes are further discussed in Section 3.3 of this correspondence and in Section 6 of Attachment A – Project Description.

Ongoing updates to the EMP are recognized as an appropriate measure by which to optimize monitoring activities and to implement changes to the program to reflect changes in operational activities. The implementation of the Project will not require any changes to the major components of this program. The addition of monitoring stations specific to the JEB TMF area, such as an additional air quality sampling station and a sediment and benthic invertebrate sampling station, will be added within the framework of the existing program in consultation with provincial and federal regulatory agencies.

The ongoing groundwater monitoring programs, which include groundwater level and chemistry monitoring, appears to be adequate for the Project. Current JEB TMF monitoring wells will continue to be monitored. The monitoring wells that will be affected by the construction of the Project will be decommissioned and replaced with new monitoring wells as required.

A performance monitoring program will be implemented to confirm physical and environmental stability of the JEB TMF during and after the decommissioning period and is described in Section 6.1.1.3 of Attachment A – Project Description.

2.7 Nuclear Substance Inventory

The expansion to the JEB TMF at the McClean Lake Operation will not result in further changes to the Inventory of Nuclear Substances.

2.8 Expected Impacts to Decommissioning and Closure Plans

Version 8 of the McClean Lake Operation Preliminary Decommissioning Plan (PDP) and Financial Assurance [9] for decommissioning and closure of the JEB TMF presents the expected scenario at the end of the 5 year planning period (2020) for this versioning of the PDP. The PDP will be updated in the next version to reflect the JEB TMF Expansion Project.

2.9 Security and Canada's International Obligations

Currently, AREVA complies with the *CNSC G-336: Guidance for Accounting and Reporting of Nuclear Material, the Nuclear Non-Proliferation Import and Export Control Regulations*, and the Nuclear Security Regulations. In addition, AREVA follows the Global Affairs Canada Guide to Canada's Export Controls – December 2013 and General Export Permits for Certain Nuclear and Nuclear-Related Dual-use Goods and Technology to Certain Destinations (Serial No. 181 – May 2012). All contracts AREVA negotiates with end users include safeguard clauses, and all end users are required to provide AREVA with an end-use statement as to the purpose of the U_3O_8. The end-use statement is a current requirement for the Global Affairs Canada - Export Permit and CNSC Export Licence Applications.

These efforts also ensure compliance with condition 14 of the current operating licence pertaining to safeguards and non-proliferation.

The notification to increase the top of consolidated tailings from 434 mASL to 448 mASL through an expansion to the JEB TMF with the construction of an embankment will not impact nuclear material security, or Canada's international obligations. AREVA continues to maintain nuclear material security in accordance with national and international obligations.

3 Planned Administrative Controls

There are no further changes to the McClean Lake Operation, its operation, or safety and control measures specific to the proposed change to the LCH. AREVA will maintain the objective of the licensing basis with respect to the protection of the environment as well as the health, safety and security of the public and workers through the existing controls at the McClean Lake Operation.

3.1 Roles and Responsibilities

The proposed change is not anticipated to result in any changes to the organization.

3.2 Programs and Procedures

AREVA recognizes the safety and health of its workers and the public, protection of the environment, and quality of our processes as the highest priorities during all stages of activities. Programs and procedures have been developed and implemented that include change and design control processes, training and the management of risk through hazard identification, assessment, mitigation and monitoring. AREVA considers existing programs to be sufficient and will not require changes to implement the proposed expansion to the JEB TMF, while continuing to operate within the licensing basis.

3.3 Monitoring

In accordance with AREVA's IQMS, comprehensive monitoring programs exist to assess performance and compliance. No substantive changes are anticipated to the radiation protection program.

Ongoing updates to the EMP are recognized as an appropriate measure by which to optimize monitoring activities and to implement changes to the program to reflect changes in operational activities. The implementation of the Project will not require changes to the major components of this program. The addition of monitoring stations specific to the JEB TMF area, such as an additional air quality sampling station and a sediment and benthic invertebrate sampling station, will be added within the framework of the existing program in consultation with provincial and federal regulatory agencies.

The ongoing groundwater monitoring programs, which include groundwater level and chemistry monitoring, are adequate for the Project. Current JEB TMF monitoring wells will continue to be

monitored. The monitoring wells that will be affected by the construction of the Project will be decommissioned and replaced with new monitoring wells as required.

A performance monitoring program will be implemented to confirm physical and environmental stability of the JEB TMF during and after the decommissioning period and is described in Section 6.1.1.3 of Attachment A – Project Description.

New monitoring programs are discussed in section 6.1.3 of Attachment A – Project Description to this correspondence and include the evaluation of soil cover performance through the establishment of test plots to evaluate the risk of key parameters on cover performance and the monitoring of the JEB TMF embankment. Routine monitoring and preventive maintenance are important to provide good performance of the expanded JEB TMF. Monitoring of the JEB TMF embankment structure will consist of visual observation of the tailings embankment and measurement from field instrumentation. Field instrumentation will include piezometers (including monitoring wells to monitor water quality), pressure gauges, slope inclinometers and ground monitoring points. The observations of these instruments, together with tailings management operation logs and meteorological conditions can be used to evaluate the future performance of the JEB TMF embankment. Preventive maintenance, based on the early observation of potential "problem spots" (i.e., seepage or severe erosion), is anticipated to help maintain the stability and integrity of the embankment and liner system.

3.4 Change Management

3.5 Internal Reviews

This proposal was reviewed and approved by AREVA's operations management, environment, health and safety professionals and other subject matter experts.

4 Conclusion

On the basis of the detailed information and assessment of effects provided in this correspondence AREVA expects that the Project can be constructed, operated and decommissioned in a manner that, taking into account environmental design features and mitigation, does not present an unreasonable level of risk to the local biophysical or socio-economic environments and through the application of control measures remains within the licensing basis for the McClean Lake Operation.

5 References

[1] AREVA Resources Canada Inc., "JEB TMF Expansion Project Description," August 2011.

[2] AREVA Resources Canada Inc., "JEB TMF Expansion Licensing Application," November 2012.

[3] AREVA Resources Canada Inc., "JEB TMF Expansion Licensing Application Resubmission in Response to Comments," February 2014.

[4] AREVA Resources Canada Inc., "JEB Tailings Management Facility Capacity Optimization Application," April 2010.

[5] AREVA Resources Canada Inc., "Tailings Management Technical Information Document Volume 1 of 1/Version 2/Rev 00," May 2015.

[6] AREVA Resources Canada Inc., "McClean Lake Operation, Environmental Performance Technical Information Document," AREVA, 2012.

[7] CCME (Canadian Council of Ministers of Environment), "1978-2014. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Summary Table. Updated 2014.," Accessed: February 2014.

[8] Saskatchewan Water Security Agency, "Surface Water Quality Objectives," June 2015.

[9] AREVA Resources Canada Inc., "McClean Lake Operation Preliminary Decommissioning Plan and Financial Assurance 2016 - Version 8, Revision 2," March 2016.

Attachment A – JEB Tailings Management Facility Expansion – Project Description

AREVA Resources Canada Inc.

McClean Lake Operation

JEB TMF Expansion - Project Description

Version 3

PIGA: Unrestricted

June 2016

History of Revisions

Version	Date	Details of Revision
1	November 2012	Licensing submission to Saskatchewan Ministry of Environment and Canadian Nuclear Safety Commission
2	February 2014	Revision to support AREVA responses to CNSC's May 2013 technical comments
3	June 2016	Updated to reflect change in mine plan resulting in changes in TMF design. Top of berm reduced from 468 mASL to 457.5 mASL; consolidated tailings level changed to ground surface at 448 mASL. Updated Alternative Assessment (Section 3) to include an options study; inclusion of an environmental risk analysis of embankment failure (Section 5.4) Removal of information or operational activities that was initially contemplated with the expansion to the JEB TMF scope, but have been implemented at the McClean Lake Operation independent of the JEB TMF Expansion: • the loss of the need for the dewatering walls was initially included as part of the JEB TMF Expansion scope, however over time, the existing TMF pond water has risen beyond the need for the dewatering walls, independently of the expansion; • the requirement to decommission and relocate the temporary contaminated landfill is required pursuant to the construction of phase 2 of JEB TMF Optimization Project, so has been removed from the JEB TMF Expansion scope • the water recycle process initially contemplated as part of the JEB TMF Expansion Project was implemented by the McClean Lake Operation in 2014 and hence has been removed from this revision of the document (Section 4.3.2)

Executive Summary

Introduction

The JEB Tailings Management Facility (TMF) is the current repository for tailings generated from processing uranium ore at the McClean Lake Operation, a uranium mine and mill complex operated by AREVA Resources Canada Inc. (AREVA) in northern Saskatchewan. The JEB TMF has operated since 1999 and received tailings from ore processed from the JEB, Sue C, Sue E, Sue A, and Sue B uranium deposits, as well as ore from the mining equipment development project referred to as the Surface Access Borehole Recovery Extraction Program (SABRE). The remaining licensed tailings storage available in the JEB TMF, is approximately 0.8 million cubic metres (m^3). Based on current mining projections, approximately 2.4 million m^3 of tailings is expected to be generated over the next 18 years and, as a result, an additional 1.6 million m^3 of tailings storage capacity is required.

The JEB TMF Expansion Project (Project) is an expansion of the existing JEB TMF to provide the ability to store tailings above the currently approved elevation for consolidated tailings of 434 metres above sea level (mASL) through the construction of an embankment around a portion of the JEB TMF perimeter and placement of a natural liner to contain the pond above the placed tailings during the operating period. The Project will provide an estimated 1.7 million m^3 of additional tailings storage capacity. The final level of consolidated tailings would match the ground surface at 448 mASL.

Project Alternatives

Various alternatives to obtain additional tailings storage capacity were considered both at the early onset of the project and again in later stages following an update to the mining plan which resulted in a reduction in tailings storage capacity requirements. Tailings management alternatives considered by AREVA included the conversion of existing pits at the McClean Lake Operation, expansion of the existing JEB TMF, and the construction of a purpose-built tailings management facility (PBTMF). The conversion of existing mined out pits was initially deemed least favorable because the pits have already been committed and approved for other uses, have potential operating challenges or were too far away from the McClean Lake Mill to be practical. Following the update to the mining plan and reduction in required tailings storage capacity, the conversion of existing pits was re-evaluated as a potential option. The cost associated with the conversion of an existing Sue pit into a TMF for the volume of tailings required was considered economically unfavourable. Construction of a dedicated PBTMF is a technically feasible alternative however the resulting additional physical and environmental footprint made this alternative less favorable. Accordingly, it was concluded that the preferred option is to optimize tailings storage capacity in the existing JEB TMF through the construction of an embankment around a portion of the JEB TMF perimeter and placement of a processed waste rock/till bentonite amended liner to contain the pond during the operating period. The required additional tailings storage capacity can be realized through the Project while continuing to meet long-term environmental performance objectives within

a physical footprint comparable to the existing facility and remain consistent with the requirements of CNSC Regulatory Document *RD/GD-370*, *Management of Uranium Mine Waste Rock and Mill Tailings*.

Project Description

AREVA's objective in the development of the Project is to continue to meet the long-term performance objectives of the existing and approved JEB TMF through management of tailings within a comparable physical TMF footprint. Expansion of the JEB TMF involves increasing the elevation of stored tailings above the currently approved elevation for consolidated tailings through the construction of an embankment around a portion of the JEB TMF perimeter and placement of a processed waste rock/till bentonite amended liner to contain the pond during the operating period.

The Project consists of a number of modifications to, or relocations of, existing facilities and processes (e.g., culverts, power lines, tailings barges and anchor points, tailings lines, reclaim water lines, tailings delivery pipe line, and under flow pump), which will be managed through the change management process at the site. Construction of two new waste rock runoff ponds is required to compensate for the loss of overflow water storage capacity currently provided by natural drainage to the existing JEB TMF. The relocation of the temporary contaminated landfill (conducted under a separate application) will also be required. Operation of the existing waste water management system (i.e., the JEB Water Treatment Plant [JEB WTP] and the Sink/Vulture Treated Effluent Management System [S/V TEMS]) will continue to manage treated effluent discharge, with no proposed changes.

Hydraulic containment during operations is used to prevent the outward migration of constituents of potential concern (COPCs) from the JEB TMF. Hydraulic containment is achieved by maintaining a hydraulic head differential between the groundwater and the tailings pond elevation. Historically, water levels in and around the JEB TMF were controlled through a combination of pumping from perimeter dewatering wells, water reclaim pumping from the JEB TMF pond and pumping from the base drain. The purpose of the dewatering wells was to intercept and divert clean groundwater entering the JEB TMF which reduced the amount of water that required treatment, and helped control water levels within the JEB TMF. Over time the operating pond elevation increased and pumping from the existing dewatering wells was no longer required to intercept clean water. Hydraulic containment for the TMF is currently provided by pumping from the JEB TMF base drain using the existing raise wells. Dewatering wells will be decommissioning under a separate notification.

The approach, regulations, criteria, and guidelines for the decommissioning activities for the Project are largely based on those presented in the existing Preliminary Decommissioning Plan (PDP) and Financial Assurance. AREVA's key decommissioning objective, as stated in the PDP, is to remove, reduce, and control COPCs sources, and thereby limit, to a reasonable level the environmental risks associated with the decommissioned facilities. The decommissioning plan is designed to achieve an end-state for the expanded JEB TMF, which will return lands disturbed by project activities to a condition that is physically stable, safe, and environmentally sustaining, in keeping with the land use and landscape of the day. In addition, it is AREVA's intent that the site will ultimately be returned

back to the Crown through the provincial Institutional Control Program for post-closure management.

Review of Environmental Interactions

A screening approach was used to identify and assess the linkages (interactions) between the Project components or activities, and the corresponding potential risks to the environment (e.g., surface water quality, vegetation, wildlife, and socio-economics). The Project activities that may lead to interactions with the environment are considered construction, operation, and decommissioning, as well as accidents and malfunctions. Pathways determined to have no linkage to the environment or those that are considered secondary are not predicted to result in environmentally significant risks to the environment. Primary pathways require further risk analysis and classification to determine the environmental significance of the Project on the environment.

Once key Project-environment interactions and mitigation are understood, resource efforts can be focused on addressing these key issues. This understanding will also aid in the optimization of the Project design, and will focus the mitigation and monitoring plans. Project-environment interactions where mitigation eliminates or reduces potential effects such that there is no anticipated environmental risks are screened out and do not require further assessment. Key Project-environment interactions required a more comprehensive assessment to determine the potential environmental risk from the Project on the biophysical and socio-economic environments. None of the Project interactions are expected to result in an unreasonable level of risk to the biophysical or socio-economic environments.

Environmental Risk Assessment – Embankment Failure

A screening level evaluation of the potential environmental consequences to Fox Lake, Pat Lake and downstream waterbodies in the Collins Creek watershed resulting from the unlikely failure of the embankment of the expanded JEB TMF during operations subsequent to the proposed expansion was conducted under two scenarios; 1) release of pond water to the environment when the pond is at a maximum capacity and 2) release of pond water and tailings solids to the environment when the JEB TMF is at the maximum capacity.

The results of the screening level assessment indicate that the consequences of an embankment failure at the JEB TMF would not have catastrophic effects on the Collins Creek watershed downstream of the facility. While water and sediment quality and the health of aquatic biota in Fox Lake would be affected and recovery of the lake could take many months or years, it is not anticipated that water bodies downstream of Fox Lake would be negatively impacted over the short or long term.

Monitoring Programs

Continuation of the existing Tailings Optimization and Validation Program (TOVP), additions to existing monitoring programs of the expanded JEB TMF, and a cover performance component are planned through the operating period for the Project.

Public and Aboriginal Engagement

Prior to the development of the Aboriginal and Public Information Program (APIP) for the McClean Lake Operation, a specific engagement strategy was development and implemented for the Project, to provide a strategy on engaging all of the parties interested or potentially affected by the activities associated with the Project. Implemented in early stages of the Project, the strategy was initially developed considering the requirements of the CEAA and any other regulatory obligations; with the primary focus to identify if the Project infringed on Aboriginal rights. AREVA's initial analysis concluded that the Project was not expected to adversely affect Aboriginal rights. The Project activities are within the existing surface lease previously taken up for mining, are associated with an existing facility, there is no significant new disturbance to the lands, and all environmental effects are anticipated to fall within the envelope of effects previously approved. The engagement strategy progressed and was developed as the Project evolved over time.

As part of the strategy for this Project, AREVA has shared information about the Project with the leadership of Aboriginal peoples in an effort to provide adequate understanding regarding the Project such that leadership can assess whether or not the Project will result in any adverse effects on Section 35 Rights and if required, to ensure any mitigation or accommodation requirements related to the Project are implemented. AREVA communicates to the Crown any comments or questions made by the leadership of Aboriginal peoples which may be relevant to the Duty to Consult. The engagement process for this Project was divided into stages, reported to the CNSC and included into this and previous versions of this document.

Phase 1 of AREVA's engagement strategy for this Project was completed prior to the submission of the initial Project Description in 2011, which allowed AREVA to begin sharing proposed technical information with identified interested parties and soliciting comments. The results of discussions on the proposed Project had identified a limited number of concerns related to the approval and development of the Project. Many of the comments raised were related to clarifying Project details, employment and existing socio-economic concerns.

Following the submission of the Project Description, AREVA commenced Phase 2 of the engagement strategy, which further described the Project, Project-environment interactions and potential effects. AREVA conducted open house sessions in various communities in northern Saskatchewan. With all stages of engagement, it is AREVA's intention to gauge areas and level of concern and ascertain any potential infringements as a result of the Project. Feedback received by AREVA during early information sharing provides AREVA the opportunity to incorporate any mitigation features into the Project design.

Engagement activities that occurred as part of Phase 3 were designed to meet the objectives of the strategy initially developed for this Project and to meet the requirements of the APIP developed for the McClean Lake Operation, as it evolved over time and the course of the Project. Phase 3 was scheduled to coincide with the regulatory approval process, allowing for an opportunity to provide more specific project details. Engagement during this phase provided AREVA with the opportunity to demonstrate how previous issues have been considered and to provide information related to the ongoing regulatory process.

A report of activities conducted from 2010 through 2016 can be found in Appendix I.

Regulatory Approvals and Authorizations Required for the Project

Following the submission of the initial Project Description, the provincial Environmental Assessment Branch (EAB), Saskatchewan Ministry of Environment (SMOE) completed an environmental screening of the proposed change to the currently approved development. Based on the description of the Project and the environmental protection commitments, the EAB determined that the Project is not a development as defined in Section 2(d) of the *Saskatchewan Environmental Assessment Act (Chapter E-10.1).* Accordingly, the province is not requiring an environmental assessment (EA) for the proposed Project and AREVA is to proceed in obtaining other permits and approvals required to commence construction and operation of the Project from the MOE

On August 26, 2011 AREVA submitted the Project Description and the request to amend the McClean Lake Operation operating licence for the Project to the Canadian Nuclear Safety Commission (CNSC). Although the capacity of the JEB TMF will be increased, the process for the management of tailings is the same as what has been previously assessed and approved, and the Project remains within the boundary of an existing licensed uranium mine and mill. As such, it was AREVA's understanding that the Project would not trigger the requirement of a Comprehensive Study level EA, but a Screening level EA would be required pursuant to the *Canadian Environmental Assessment Act* (S.C. 1992, c.37). In November 2011, AREVA received the CNSC determination that a federal screening level EA under *CEAA* must be carried out for the proposed Project and that the CNSC would oversee the EA process. However, in July 2012, the new *Canadian Environmental Assessment Act, 2012 (S.C. 2012, c.19, s. 52)* came into force, removing the screening level EA's. AREVA was notified that an EA would no longer be required and that the Project would now continue to the licensing process under the *Nuclear Safety and Control Act* (NSCA). The revised Project meets the objective of the licensing basis for the McClean Lake Operation. AREVA understands the proposed changes described by the Project can be permitted according to section 1.2 of the Licensing Condition Handbook.

Conclusions

On the basis of the detailed information and assessment of effects provided in this document, AREVA believes that the Project can be constructed, operated and decommissioned in a manner that, taking into account environmental design features and mitigation, does not present an unreasonable level of risk to the local biophysical or socio-economic environments and through the application of control measures remains within the licensing basis for the McClean Lake Operation.

List of Acronyms

Term	Definition
AAQC	Ambient Air Quality Criteria
AAQO	Ambient Air Quality Objectives
AAQS	Ambient Air Quality Standards
AECB	Atomic Energy Control Board
ALARA	as low as reasonably achievable
APIP	Aboriginal and Public Information Program
AREVA	AREVA Resources Canada Inc.
AWG	Athabasca Working Group
BACI	Before-After-Control-Impact
CCCSN	Canadian Climate Change Scenario Network
CCME	Canadian Council of Ministers of the Environment
CEAA	*Canadian Environmental Assessment Act*
CNSC	Canadian Nuclear Safety Commission
COPCs	constituents of potential concern
CRCM	Canadian Regional Climate Models
CSR	Corporate Social Responsibility
CWQGs	Canadian Water Quality Guidelines
EA	Environmental Assessment
EAB	Environmental Assessment Branch
EEM	environmental effects monitoring program
EHS	Environment Health and Safety
EMP	Environmental Monitoring Program
EMS	Environmental Management System
EPM	equivalent porous media
EQC	Environmental Quality Committees
GCM	global climate models
Golder	Golder Associates Ltd.
HRDA	Human Resources Development Agreement
HRIA	Heritage Resources Impact Assessment
IMA	Impact Management Agreement
IOC	Investigation of Cause
IQMS	Integrated Quality Management System
JEB WTP	JEB Water Treatment Plan
LAB	local assessment boundary
LCH	License Condition Handbook
LSA	local study area
LTA	lost-time accidents
MHI	Saskatchewan Ministry of Highways and Infrastructure

List of Acronyms (continued)

Term	Definition
MMER	*Metal Mining Effluent Regulations*
NO_x	oxides of nitrogen
NSCA	*Nuclear Safety and Control Act*
OH&S	Occupational Health and Safety
OHSAS	Occupational Health and Safety Assessment Series
PBTMF	Purpose Built Tailings Management Facility
PDP	Preliminary Decommissioning Plan
PM	particulate matter
PMP	Probable Maximum Precipitation
PSPs	permanent sampling plots
RSA	regional study area
RSN	residents of Saskatchewan's north
SABRE	Surface Access Borehole Recovery Extraction Program
SEAA	*Saskatchewan Environmental Assessment Act*
SHRB	Saskatchewan Heritage Resources Branch
SI	Screening Index
SKCDC	Saskatchewan Conservation Data Centre
SMOE	Saskatchewan Ministry of Environment
SO_2	sulphur dioxide
SOE	Status of Environment
SPI	Standard Precipitation Index
SSWQO	Saskatchewan Surface Water Quality Objective
S/V TEMS	Sink/Vulture Treated Effluent Management System
SWA	Saskatchewan Watershed Authority
TDS	total dissolved solids
TID	Technical Information Document
TMF	Tailings Management Facility
TOVP	Tailings Optimization and Validation Program
TSP	total suspended particulates
VCs	valued components
VEC	valued ecosystem component
VSEC	valued socio-economic component
WHMIS	Workplace Hazardous Materials Information System
WTP	Water Treatment Plant

List of Units

Term	Definition
°C	degrees Celsius
Bq/m^3	Becquerel's per cubic metre
cm	centimetres
ha	Hectare
kg	Kilogram
km/h	kilometres per hour
km^2	square kilometres
lbs	Pounds
m	metres
mASL	metres above sea level
m/s	metres per second
m^3	cubic metres
m^3/day	cubic metres per day
m^3/h	cubic metres per hour
m^3/s	cubic metres per second
$m^3/s/km^2$	cubic metres per second per square kilometre
mm	millimetres
ppb	parts per billion
t/hr	tones per hour
U_3O_8	uranium concentrate
µS/cm	microSiemens per centimeter
Fe^{3+}	Ferric
As_{total}	Arsenic

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1 Introduction

1.1 JEB TMF Expansion Project

Based on current mining projections, approximately 2.4 million cubic metres (m^3) of tailings will be generated over the next 18 years at the McClean Lake Operation. The tailings capacity currently available in the JEB Tailings Management Facility (TMF) is approximately 0.8 million m^3 therefore, an estimated 1.6 million m^3 of additional tailings storage volume is needed to support the current milling forecast. The JEB TMF Expansion Project (Project) is designed to expand the existing JEB TMF capacity, providing an additional 1.7 million m^3 and will accommodate all of the tailings forecast with the current mine and mill plan for the McClean Lake Operation. The final level of consolidated tailings will match the ground surface at 448 mASL.

1.1.1 JEB TMF Expansion Project History

On August 26, 2011, AREVA submitted a Project Description for an expansion to the JEB TMF to accommodate a tailings production forecast of 5.0 million m^3 of tailings and the request to amend the McClean Lake Operation operating licence, anticipating that an environmental assessment (EA) would be triggered under the *Canadian Environmental Assessment Act* (S.C. 1992, c. 37) (CEAA). In November 2011, AREVA received the CNSC determination that a federal screening level EA under CEAA would be carried out, with the CNSC overseeing the environmental assessment process. However, in July 2012, when the *Canadian Environmental Assessment Act, 2012* (S.C. 2012, c.19, s. 52) (CEAA, 2012) came into force, AREVA was notified that an EA would no longer be required and that the project would continue to the licensing process under the *Nuclear Safety and Control Act* (NSCA). The document being reviewed at the time was originally prepared as an Environmental Impact Statement (EIS) to meet the requirements of CEAA. Since an EA was no longer required, the document was modified to address the licensing requirements of the CNSC. The CNSC and AREVA continued with the review and comment process of the document.

In 2014, AREVA revised its mine plan, which resulted in a reduction in the forecasted tailings production; the reduction was significant enough that AREVA determined it was necessary to revisit the alternatives assessment. The subsequent alternatives assessment confirmed that expanding the JEB TMF remained the preferred option, although with a reduced scope in design (Section 3).

1.2 Project Location and Background

The following sections provide a brief description of the existing and approved components/activities and programs at the McClean Lake Operation that are relevant to the Project.

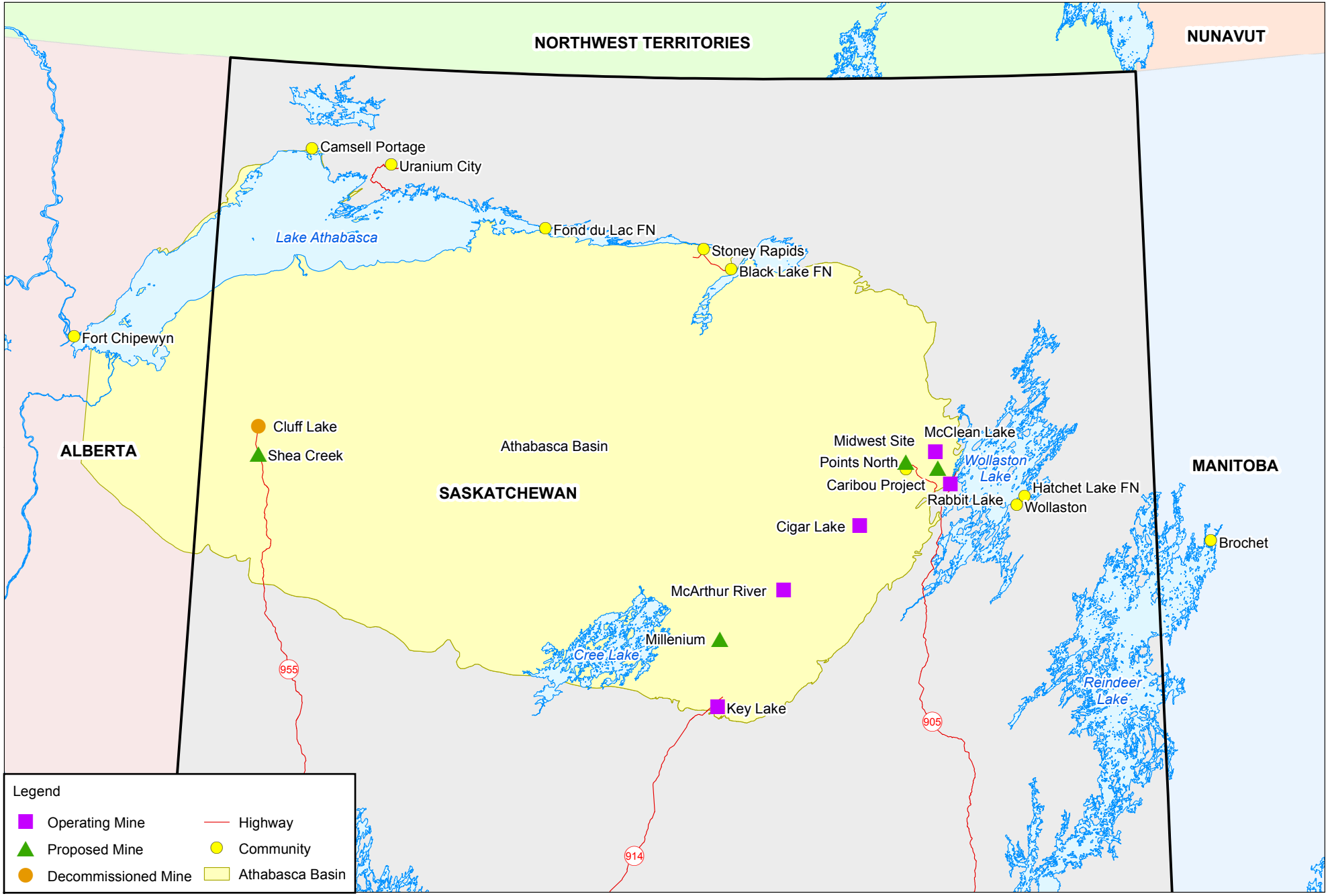
1.2.1 Project Proponent and Location

AREVA Resources Canada Inc. is a 100% subsidiary of the AREVA group. AREVA Resources Canada Inc. (AREVA) is a Canadian company, headquartered in Saskatoon, Saskatchewan, and is the operator of the McClean Lake Operation which is a joint venture among AREVA, Denison Mines Corp. and OURD Canada Co. Ltd. The McClean Lake Operation is located in northern Saskatchewan.

The Project will occur entirely on the existing McClean Lake Operation surface lease (Government of Saskatchewan, 2002). The McClean Lake Operation is a uranium mine and mill complex located in northern Saskatchewan (Figure 1.2-1). The McClean Lake Operation includes the Sue site, which is the location of a number of open pit mines, a water treatment plant and various support infrastructures and the Midwest site. The McClean Lake Operation also includes the JEB site which is the location of the existing JEB TMF, the McClean Lake Mill, a water treatment plant, office complex, camp and other support infrastructure (Figure 1.2-2).

Figure 1.2-1: Overview of Project Location

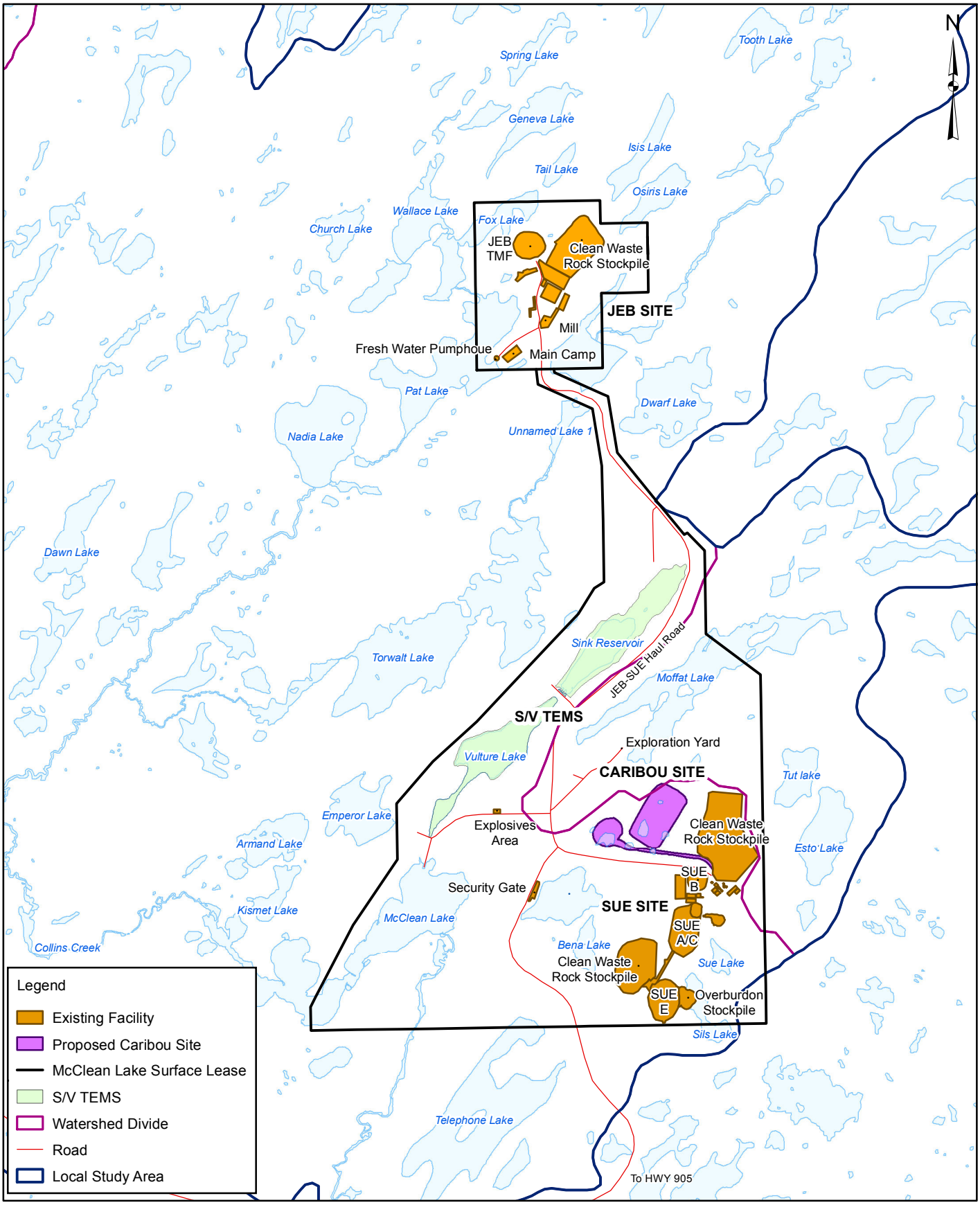
Path: \\gal1-s-archive1\Office_Archives\Prairies Region\Saskatoon_Archive\GGIS\2008\1362\08-1362-0590 AREVA McClean TMF #2\GIS\Maps\Phase 32000\Section 1\08-1362-0590-32000-Overview Map V2.mxd



AREVA

08-1362-0590			FIGURE 1.2-1
SCALE:		DATE:	Overview of Project Location
DESIGNED:			
DRAWN:	JRC	05/25/12	
REVISED:			
APPROVED:	MF	05/25/12	
REF. DWGS:			
REVISIONS:			

Figure 1.2-2: McClean Lake Operation General Site Layout



AREVA	08-1362-0590	FIGURE 1.2-2
SCALE:	1:125,000	DATE:
DESIGNED:		
DRAWN:	JRC	07/16/11
REVISED:		
APPROVED:	MF	08/23/11
REF. DWGS:		
REVISIONS:		

McClean Lake Operation
General Site Layout

1.2.1.1 Existing JEB Tailings Management Facility

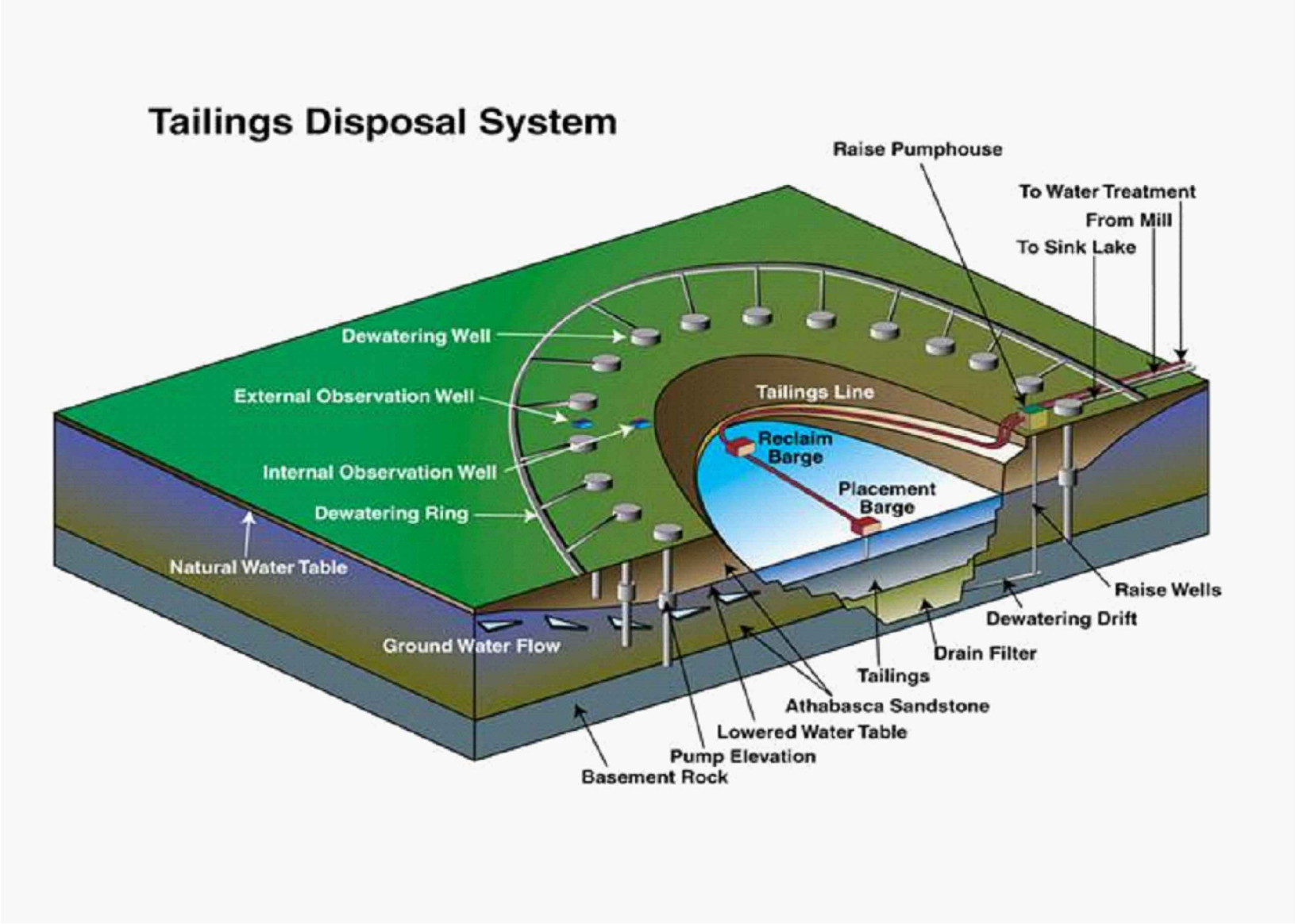
The existing JEB TMF is the repository for tailings resulting from uranium processing at the McClean Lake Mill. The overall tailings management system is comprised of the Tailings Preparation Circuit within the McClean Lake Mill, the tailings delivery system, and the JEB TMF. The facility is designed and operated to provide stable physical containment and to reduce the migration of soluble constituents from the JEB TMF to the receiving environment throughout operations and post-decommissioning periods.

Hydraulic containment during operations is used to prevent the outward migration of constituents of potential concern (COPCs) from the JEB TMF. Hydraulic containment is achieved by maintaining a hydraulic head differential between the groundwater and the tailings pond elevation. Historically, water levels in and around the JEB TMF were controlled through a combination of pumping from perimeter dewatering wells, water reclaim pumping from the JEB TMF pond and pumping from the base drain (Figure 1.2-3). The purpose of the dewatering wells was to intercept and divert clean groundwater entering the JEB TMF which reduced the amount of water that required treatment, and helped control water levels within the JEB TMF. Over time the operating pond elevation increased and pumping from the existing dewatering wells were no longer required to intercept clean water. Hydraulic containment for the TMF is currently provided by pumping from the JEB TMF base drain using the existing raise wells. Dewatering wells will be decommissioning under a separate notification.

The natural surround design, combined with control of the tailings geotechnical and geochemical properties during tailings preparation, is employed as a passive method to limit the long-term release of COPCs from the decommissioned facility. The process wastes from the McClean Lake Mill are mixed and transferred to the Tailings Preparation Circuit. The Tailings Preparation Circuit is used to treat and neutralize tailings for the control of COPCs in the tailings pore water and to thicken the resulting tailings slurry prior to storage. Prior to neutralization, the soluble arsenic and iron concentrations in the total waste stream are measured, and the Fe^{3+}/As_{total} molar ratio is then adjusted by the controlled addition of ferric sulphate. This critical step provides the means to specifically and consistently precipitate arsenic with iron in the form of a stable mineral compound that is suitable for long-term management.

Following the preparation process, tailings are thickened and the resulting tailings slurry is pumped from the McClean Lake Mill for containment in the JEB TMF. When consolidated, the hydraulic conductivity of the tailings material will be at least two orders of magnitude less than that of the surrounding fractured natural sandstone. Under these long-term conditions, the consolidated tailings represent a low-permeability material, and therefore, groundwater will preferentially flow around the tailings mass through the surrounding more permeable host rock.

Figure 1.2-3: JEB Tailings Management Facility



AREVA

08-1362-0590			FIGURE 1.2-3
SCALE:		DATE:	JEB Tailings Management Facility
DESIGNED:			
DRAWN:	TAH	05/09/11	
REVISED:			
APPROVED:			
REF. DWGS:			
REVISIONS:			

Compliance in tailings preparation and deposition does not, by itself, provide assurance that long-term performance of the tailings will be consistent with the performance estimated at the time that the operating licence was initially approved. To reflect the uncertainties in estimated performance, the initial McClean Lake Operation's operating licence was based on conservative, or precautionary, assumptions about future *in situ* tailings characteristics. To monitor and confirm predicted tailings performance and to reduce these uncertainties, the Tailings Optimization and Validation Program (TOVP) was developed and implemented, and remains a component of the approved monitoring programs for the McClean Lake Operation.

Storage of tailings in the JEB TMF is currently approved for a top of consolidated tailings elevation of 434 mASL, which is the approximate low point of the sandstone-till contact. This elevation of consolidated tailings in the JEB TMF, to 434 mASL, is following cover placement and is based on the sandstone/till contact around the JEB TMF perimeter. In order to make optimum use of the JEB TMF capacity, the unconsolidated tailings will be temporarily placed above elevation 434 mASL by an amount equal to the consolidated estimated tailings consolidation settlement of 5 meters (m) following the placement of the cover. In addition, for barge placement of tailings, a 3 m pond water cover above the tailings surface is needed for optimal operational flexibility. As a result, prior to cover placement and tailings consolidation the pond water elevation will ultimately reach 442 mASL, which is approximately 8 m above the sandstone/till contact at the JEB TMF perimeter. To achieve this operational pond water elevation it was necessary to improve the slope stability conditions and incorporate pond containment in the till layer at the JEB TMF. This project was entitled the JEB TMF Optimization (Optimization). Approval was received to re-slope the existing till above the sandstone/till contact, to achieve a slope of 1V:3H through the till zone which will become saturated and construct a low permeability liner to contain the pond water through operations (AREVA 2010b). One (1) m freeboard for wave run-up and 0.5 m for storage of a Probable Maximum Precipitation (PMP) event, above the pond water elevation will be maintained throughout operations, bringing the design elevation for the resloping and liner to 443 mASL. The first stage of the Optimization was conducted in 2012 – 2013, making sloping improvements and placing a liner to 439 mASL, the second stage of Optimization will involve sloping improvements and the placement of a liner to 443 mASL.

1.2.1.2 Tailings Optimization and Validation Program

The TOVP is an ongoing sampling, monitoring, and research program focused on the performance of the existing JEB TMF. The program's purpose is to optimize tailings performance in a fully decommissioned JEB TMF and to confirm that predictions of effects to the receiving environment in the long-term are consistent with approvals granted at the time of initial licensing. The most recent assessment of compliance and monitoring results, and the interpretation in terms of implications to long-term solute transport, are provided for regulatory review in the TOVP report section of the McClean Lake Tailings Technical Information Document (Tailings TID) (AREVA 2015a).

The Tailings TID (AREVA 2015a) describes the geochemical and geotechnical monitoring and evaluation activities completed to determine the long-term solute concentrations of COPCs in

the JEB TMF, and the long-term mass loading of these COPCs to the surrounding environment from the decommissioned facility. To date, the TOVP program has confirmed the ability of the McClean Lake Mill tailings preparation process to produce tailings with predictable long-term geochemically controlled source term characteristics for a wide variety of ore sources and ore geochemical characteristics. For example, the arsenic content in the ore feeding the McClean Lake Mill has varied over two orders of magnitude during the first decade of operation. However, despite the large range of arsenic concentrations in the ore, the arsenic concentration in the discharged tailings pore water has not exceeded established action levels. In addition, geotechnical studies have confirmed that tailings stored adjacent to the JEB TMF walls consolidate and provide sufficiently low hydraulic conductivity values, in relation to those associated with the surrounding sandstone host rock, to restrict the flow of groundwater through the JEB TMF and thereby limit movement of COPC out of the JEB TMF after decommissioning. As such, the consolidated tailings are predicted to be suitable for the long term control of groundwater flow in the decommissioned facility.

In addition to the TOVP, the JEB groundwater model was developed as part of the initial assessment of the JEB TMF. This model has been refined and calibrated to monitoring data collected periodically throughout the ~16 years of operating the JEB TMF. The most recent calibrated numerical groundwater flow model is documented in the McClean Lake Operation Hydrogeology and Groundwater Modelling of the Collins Creek Basin TID (AREVA 2011b). The knowledge acquired through the TOVP is the foundation of understanding for which the Project has been developed. The TOVP and periodic groundwater flow model updates remain as ongoing programs for evaluating the JEB TMF performance, and will continue for this Project.

1.2.1.3 JEB Site Water Management Plan

The existing JEB site water management plan consists of ditching and ponds to manage normal site runoff from the McClean Lake Mill terrace and the waste rock pile, as well as limit the amount of water that can potentially become contaminated. Runoff from the mill terrace includes the area surrounding the McClean Lake Mill and maintenance shops. This runoff currently reports to the JEB Site Runoff Pond and is pumped to the JEB TMF for eventual treatment in the JEB Water Treatment Plant (WTP) prior to release. The JEB site water management plan for PMP runoff from the mill terrace is facilitated by gravity drainage from the JEB Site Runoff Pond to the JEB TMF. Precipitation and melt water from the surrounding area is routed away from the site to reduce volumes of potentially contaminated runoff requiring treatment.

The waste rock runoff pond collects runoff from the waste rock pile. Ditching around the pile conveys runoff to the waste rock runoff pond and/or the JEB TMF. The waste rock runoff pond is pumped to the JEB TMF. All water from the JEB TMF is treated prior to release.

Reclaim water in the JEB TMF pond and water from the raise well pumphouse are pumped to the McClean Lake Mill or JEB WTP. A total of 39 dewatering wells were initially installed around the perimeter of the JEB TMF to intercept groundwater. Each dewatering well has a parallel

discharge line, which allowed each to be released to the environment, or if necessary, directed to the JEB WTP. Due to rising pond water level in the JEB TMF the dewatering wells are no longer required to intercept groundwater and will be decommissioned.

1.2.1.4 JEB Waste Water Management Plan

The JEB WTP currently has an approved capacity of 6,000 cubic metres per day (m^3/day) and receives water from various sources at the JEB site. Reclaim water from the JEB TMF and raise wells water comprises the primary source of waste water reporting to the JEB WTP. However, the quantity of effluent requiring treatment is affected by groundwater in-flows to the JEB TMF and the volume of raise well water recycled back to the McClean Lake Mill for re-use. The JEB WTP removes dissolved metals and suspended solids, and discharges treated effluent to the Sink/Vulture Treated Effluent Management System (S/V TEMS).

The S/V TEMS is the single common facility for the controlled release of effluent generated at the McClean Lake Operation (Figure 1.2-2). The S/V TEMS consists of discharge pipelines to the Sink Reservoir, and natural flow through control and measurement structures into Vulture Lake and the east basin of McClean Lake. From the JEB site, a single pipeline transports the combined effluent from the JEB WTP and JEB dewatering well system (when the dewatering wells were in use), to a discharge point at the north end of Sink Reservoir. Similarly, a pipeline transports treated effluent from the Sue site to a discharge point at the east side of Sink Reservoir. A compacted earth dam defines the reservoir's containment area. The S/V TEMS provides approximately 1.3 million m^3 of active storage capacity.

The S/V TEMS provides a means of storing effluent, as necessary, to reduce effects to the receiving environment, while allowing water treatment to proceed on demand. The operational objectives are to limit water quality and flow regime fluctuations, in order to reduce the augmentation of streambed erosion, and to minimize variations in water quality in Collins Creek, downstream of McClean Lake east basin.

1.2.1.5 Environmental Monitoring

Environmental monitoring provides the information necessary to determine the extent of environmental effects over the lifespan of a development. The environmental monitoring requirements are integrated into the McClean Lake Operation Environmental Monitoring Program (EMP). The existing EMP framework was developed in consultation with regulatory agencies during the initial environmental assessment (Minatco 1991), and during the subsequent licensing process. The EMP is subject to periodic review during operations and addresses components of the *Metal Mining Effluent Regulations* (*MMER*) monitoring requirements (Environment Canada 2002) and SMOE Status of Environment (SOE) requirements. Ongoing updates to the EMP optimize monitoring activities to reflect changes in operational activities. The *MMER* environmental effects monitoring program (EEM) is developed and modified in conjunction with the EEM Technical Advisory Panel and Environment

and Climate Change Canada. The EMP remains as an ongoing program for evaluating operational performance and will continue for this Project.

1.3 Project Scope

1.3.1 Revised Project

Based on current mining projections, approximately 2.4 million m^3 of tailings will be produced at the McClean Lake Operation over the next 18 years. The tailings capacity currently available in the JEB TMF is approximately 0.8 million m^3. The Project is to optimize tailings storage capacity in the existing JEB TMF through the construction of an embankment around a portion of the JEB TMF perimeter and placement of a processed waste rock/till bentonite amended liner to contain the pond during the operating period. The required additional tailings storage capacity can be realized through the Project while continuing to meet long-term environmental performance objectives within a physical footprint comparable to the existing facility and remain consistent with the requirements of CNSC Regulatory Document *RD/GD-370, Management of Uranium Mine Waste Rock and Mill Tailings*. Figure 1.3-1 provides a summary of the potential volume available in JEB TMF for tailings storage above the current approved elevation.

Expansion of the JEB TMF involves providing the ability to place tailings above the current approved elevation for top of consolidated tailings (i.e. 434 mASL). Modelling predictions of the long-term performance of the decommissioned JEB TMF are based on the knowledge acquired over the 16 year operating period of the McClean Lake Mill and JEB TMF. AREVA's objective in the development of the Project is to optimize the capacity for tailings within the existing and approved JEB TMF environmental footprint, including meeting CWQG and SSWQO in Fox Lake and Pat Lake throughout operations (short-term) and post-decommissioning (long-term).

The design intent of the McClean Lake Mill was to provide operational flexibility in order to process a variety of potential ore bodies and blends. The design necessitated a robust, flexible tailings preparation process that produced environmentally acceptable tailings from a wide variety of milling waste streams and chemistries. Prior to processing ore from a particular ore body, AREVA completes an amenability study to confirm that tailings pore water and liquid effluent quality will remain consistent with those originally assessed and approved. It is AREVA's intent to continue to apply this approach to operate such that it can manage tailings from any ore source.

To facilitate storage of tailings above the sandstone-till contact (434 mASL) construction of an embankment around a portion of the pit perimeter to an elevation of 457.5 mASL will be necessary. This elevation is 9.5 m higher than ground surface at the current low side of the pit (448 mASL). The inside slope of the embankment will be lined with the same processed waste rock/till bentonite amended liner being placed in the existing JEB TMF to contain the operating pond during operations. As the dewatering wells are no longer required to intercept clean water, hydraulic containment of the JEB TMF is provided by pumping from the base drain with the raise wells and pumping reclaim water from the JEB TMF. Dewatering wells and monitoring

wells affected by the Project construction will be decommissioned (under a separate notification), with new monitoring wells installed as required around the expanded JEB TMF. The Project could commence as early as 2018 , with the relocation of affected infrastructure and will be undertaken in a staged manner based on the tailings generation forecast. The Project being presented in this document is designed with an embankment to 457.5 mASL with final consolidation of placed tailings to approximately to ground surface on the low side of the JEB pit at approximately 448 mASL.

The Project consists of a number of modifications/relocations of existing facilities (e.g., culverts, power lines, tailings barge and anchor points, tailings lines, reclaim water lines, tailings delivery pipe line, and under flow pump). The construction of two new waste rock runoff ponds is required to compensate for the loss of overflow water storage capacity currently provided by the JEB TMF and, also required is the a relocation of the temporary contaminated landfill (conducted under a separate notification). Operation of the existing McClean Lake Operation waste water management system (i.e., JEB WTP and S/V TEMS) will continue to manage treated effluent discharge.

Following decommissioning and cover placement, the top of the consolidated tailings will be at approximately 448 mASL (i.e., at the same elevation as the current natural low side of the pit crest). The decommissioning approach for the Project is largely based on the approach presented in the existing Preliminary Decommissioning Plan (PDP) and Financial Assurance (AREVA 2016a). With the addition of a low permeability barrier (i.e., processed waste rock/till bentonite amended liner) within the till cover, recent engineering analyses and assessments conclude that the Project can be decommissioned with passive physical containment, with a waste rock/till bentonite amended layer within the cover to limit infiltration, and geochemical controls providing the principal means of controlling the long-term release of COPCs to the environment. An update to the PDP and FA would occur once TMF expansion work commences, which is currently beyond the period of the next regular 5-year update to these documents.

In summary, the scope of the Project includes the following:

- construction of an embankment around a portion of the JEB TMF perimeter to bring the low side elevation up from 448 mASL to 457.5 mASL and placement of a processed waste rock/till bentonite amended liner to contain the operating pond throughout operations;
- continued placement of tailings into the expanded JEB TMF above the till/sandstone contact;
- construction of two new waste rock runoff ponds;
- relocating infrastructure affected by the Project footprint (e.g., power lines, tailings barge and anchor points, tailings lines, reclaim water lines, tailings delivery pipe line, and under flow pump);

- relocating the temporary contaminated landfill (under separate approval);
- decommissioning of dewatering wells and monitoring wells affected by the Project footprint, and installation of new monitoring wells (under a separate approval); and
- decommissioning of the JEB TMF and placement of a soil cover incorporating a processed waste rock bentonite amended layer to limit infiltration.

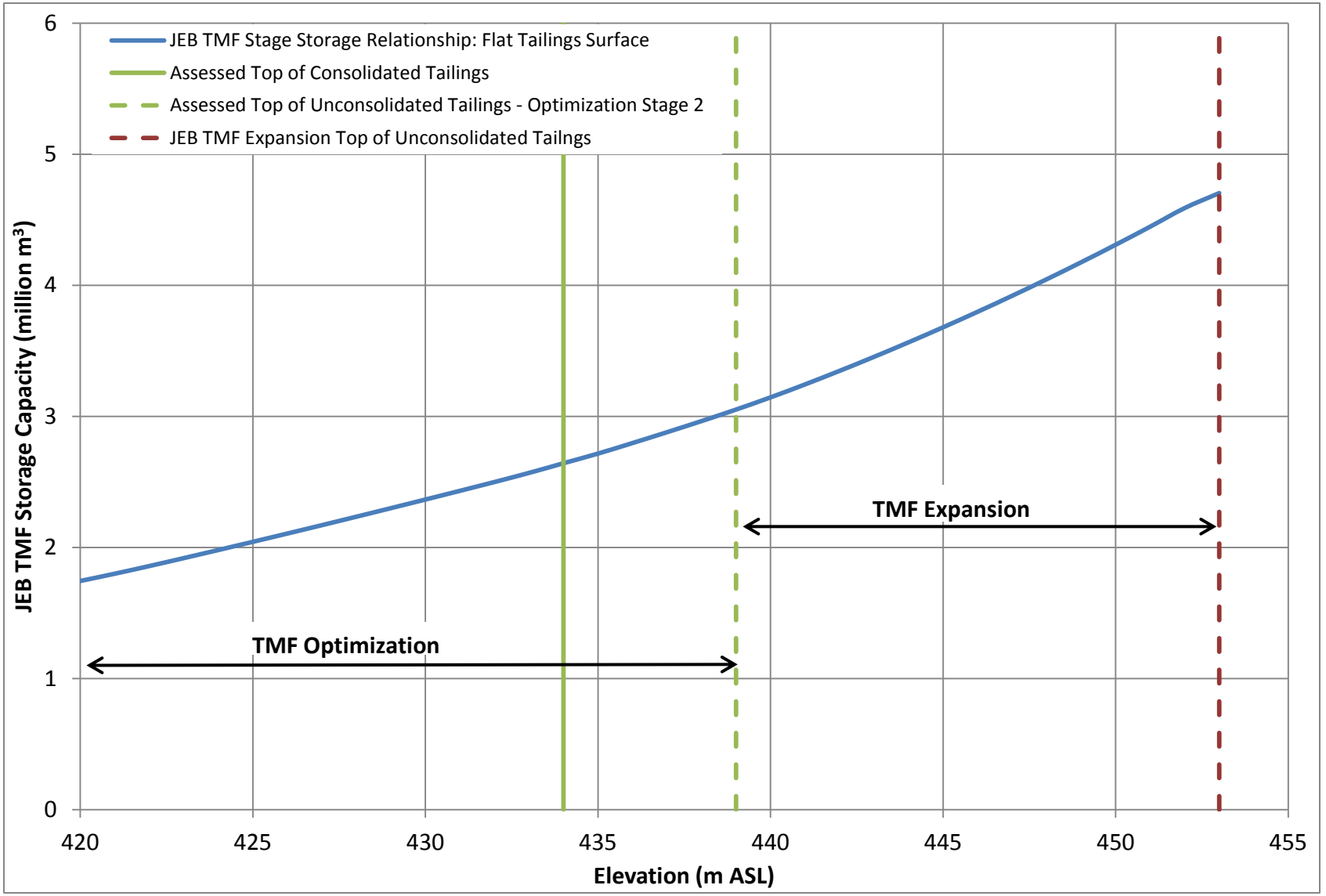
1.3.2 Future Consideration

It is noted that initial design plans submitted for the expanded JEB TMF in 2011 contemplated an embankment to 468 mASL with placed tailings consolidating at an elevation above the ground surface. Although there currently is not a need for the amount of additional tailings storage volume that would be provided by the larger expansion, AREVA considers the initially proposed expansion to be a competitive and feasible alternative for tailings management. The Project being presented in this document is designed with an embankment to 457.5 mASL. If additional volume is required in future, further vertical expansion will remain an alternative for consideration. Expansion beyond the embankment to 457.5 mASL would be subject to a future notification, requiring acceptance by regulators. In technical support documents for this Project, the construction of an embankment to 457.5 mASL is occasionally referred to as Stage 1; it does not imply that further expansion is currently being considered or approval requested.

1.4 Project Schedule

The overall schedule for the Project is presented in Figure 1.4-1. Construction milestones indicate when the expansion is expected to be completed and is based on the current forecast milling schedules. This construction schedule is preliminary in nature, and will be reviewed and updated as required.

Figure 1.3-1: Expanded JEB TMF Staging Curve



Compiled: TL
Date: 4/05/2016
Data Source: NA

FIGURE 1.3-1
EXPANDED JEB TMF STAGING CURVE

McCLEAN LAKE OPERATION
AREVA

AREVA Resources Canada Inc - P.O. Box 9204 - 817 - 45th Street West - Saskatoon, SK - S7K 3X5

1.5 Table 1.4-1: Project Schedule

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Relocate Contaminated Landfill (separate approval)																	
Decommission Dewatering wells (separate approval)																	
Relocate Infrastructure																	
Construction of Waste Rock Runoff Ponds																	
Re-sloping 443 to pit crest and placement of embankment																	
TMF Optimization Stage 2 (out of scope)																	
Liner prep and placement 443 mASL-447 mASL																	
Liner prep and placement 447 mASL - 451 mASL																	
Liner prep and placement 451 mASL - 455 mASL																	
Liner prep and placement 455 mASL - 457.5 mASL															If needed		

1.6 Approach and Organization

1.6.1 Integrated Environmental and Engineering Approach

From the outset of Project planning, AREVA implemented an integrated environmental and engineering planning team. This planning team is made of up senior practitioners and specialists responsible for incorporating the key sustainability aspects, namely the balanced integration of environmental, operational, social, and economic considerations into the Project.

The objectives of the Project included completing studies to define the increase in tailings capacity that could reasonably be undertaken in the JEB TMF, while continuing to meet CWQG and SSWQO in Fox Lake and Pat Lake in the long-term and without physical effects to Fox Lake from construction of the expansion. To meet this objective, knowledge gained by AREVA during the past 16 years of operating the McClean Lake Mill and JEB TMF was applied to the development of the Project. Specifically, key information used in this assessment includes:

- the TOVP results for the definition of tailings pore water concentrations, descriptions of the geotechnical characteristics of deposited tailings, and the description of methods for calculating mass flux from the tailings mass;
- the local JEB groundwater flow model, which has been periodically calibrated to operating conditions as the mining of JEB pit and operation of the JEB TMF progressed; and
- the Environmental Performance Technical Information Document (TID) (AREVA 2012).

1.6.2 Document Organization

This document has been organized to demonstrate that:

- the Project is an expansion of an existing facility, and therefore, the site is well characterized and have been subject to previous environmental assessments;
- the components of the Project are well known and require few additional technical studies to be completed;
- the Project does not result in new Project-environment interactions to those previously considered and assessed, and does not result in changes to effects predicted and accepted as part of previous environmental assessments;
- the Project represents an incremental change to an existing facility, and therefore, does not result in new activities that may affect First Nation, Métis, or Treaty rights;
- the Project remains within the current licence basis for the McClean Lake Operation; and

- the Project is consistent with CNSC Regulatory Document *RD/GD-370 Management of Uranium Mine Waste Rock and Mill Tailings*

The document is organized into the following main sections:

Section 1: A brief introduction is provided, which introduces AREVA, and provides an overview of the proposed Project including the location, Project scope, need, benefits, and schedule.

Section 2: Relevant licensing actions required for the Project as well as Aboriginal, public and regulatory engagement activities are described in this section.

Section 3: Alternative means of carrying out the Project are outlined.

Section 4: This section describes the development of the Project including changes to the JEB TMF, waste water management system, supporting infrastructure, decommissioning and reclamation, and human resources. This information is needed to identify Project interactions that have the potential to influence the biophysical and socio-economic environments.

Section 5: This section references the available baseline data and evaluates the potential interactions between the Project components or activities, and the correspondent potential environmental risk to the biophysical and socio-economic environments.

Section 6: This section describes the existing and proposed changes to monitoring programs relevant to the Project.

Section 7: This section provides a summary of conclusions relating to how the Project interacts with the biophysical and social environments.

Section 8: A list of references is provided.

2 Regulatory Approvals and Aboriginal and Public Engagement

Licensing and approval actions will be required by the Canadian Nuclear Safety Commission and the Saskatchewan Ministry of Environment.

2.1 Nuclear Safety Control Act

The initial Project Description for the Project was submitted by AREVA in 2011 expecting to seek a licence amendment in accordance with the NSCA. Subsequently, with the introduction of the McClean Lake Operation Licence Condition Handbook (LCH) in 2013, it is understood that the Project meets the objective of the licensing basis for the McClean Lake Operation. The Project is expected to be approved through an update to the McClean Lake Operation's LCH. The information provided within this document identifies the design criteria which ensure modifications continue to maintain a high level of protection for the health, safety, and security of the public and workers, and the protection of the environment as defined by previous safety analyses, demonstrating that the project is within the McClean Lake licensing basis.

2.2 Approval to Operate a Pollutant Control Facility

The SMOE is responsible for protecting and managing Saskatchewan's environmental and natural resources to maintain a high level of environmental quality, and to provide economic and social benefits for present and future generations (i.e., sustainable development). Currently, AREVA has an Approval to Operate Pollutant Control Facilities at the McClean Lake Operation. This includes the JEB and Sue area pollutant control facilities and associated works, air pollution monitoring and/or abatement equipment, sewage treatment associated with the McClean Lake Operation, landfills and incinerators used for the disposal of domestic waste and hazardous substances and waste dangerous goods storage facilities associated with the McClean Lake Operation.

For the Province, an approval and/or an amendment to construct and operate a Pollutant Control Facility, in accordance with Section 6 of the *Mineral Industry Environmental Protection Regulations* (MIEPR) will be required from the SMOE.

2.3 Aboriginal and Public Involvement Program

To meet AREVA's Corporate Social Responsibility principles and the requirements of the permitting and licensing processes, AREVA has developed an Aboriginal and Public Involvement Program (APIP) for the McClean Lake Operation in accordance with the CNSC's RD/GD 99.3 Public Information and Disclosure. It is the intent of the APIP to ensure information

related to the health, safety and security of persons and the environment, and other activities associated with the facility are effectively communicated to the public.

2.4 Project Specific Engagement Activities

Prior to the development of the APIP for the McClean Lake Operation, a specific engagement strategy was development and implemented for the Project, to provide a strategy on engaging all of the parties interested or potentially affected by the activities associated with the Project. Implemented in early stages of the Project, the strategy was initially developed considering the requirements of the CEAA and any other regulatory obligations, with the primary focus to identify if the Project infringed on Aboriginal rights. AREVA's initial analysis concluded that the proposed Project was not expected to adversely affect Aboriginal rights. The Project activities are within the existing surface lease previously taken up for mining, are associated with an existing facility, there is no significant new disturbance to the lands, and all environmental effects are anticipated to fall within the envelope of effects previously approved. The engagement strategy progressed and developed as the Project evolved over time. The principles of the initial project specific engagement strategy where as follows:

- engage with the leadership of Aboriginal peoples, municipal leadership and the general public in a manner that recognizes their interest in AREVA's business and understand potential effects or concerns arising out of the proposed Project;
- provide feedback from AREVA's engagement activities to the regulators to assist in the initial assessment of level of public interest or concern;
- assist the Crown in consulting and engaging with Aboriginal peoples and facilitate the Crown meeting its obligations in regards to the duty to consult Aboriginal peoples potentially affected by Project activities; and
- participate in public engagement as required by the environmental assessment and licensing processes.

Opportunities and methods for AREVA to share Project information with interested parties, including government, communities, leadership and other groups was outlined in the initial project specific engagement strategy and is now outlined in the McClean Lake Operation's APIP. Opportunities for sharing Project specific information was scheduled at the following key phases of the Project:

- Phase 1 - Engagement prior to submission of the Project Description, allowing AREVA to begin sharing proposed technical information with regulators and other identified interested parties, and provided an early indication of levels of concern. Feedback received by AREVA during early information sharing provides the opportunity to incorporate any mitigation features into the Project design. AREVA provides all feedback received to the regulators, this information was considered useful in beginning to assess the level of public concern. This phase of the engagement was completed prior to the

submission of the Project Description andallowed AREVA to introduce the Project and share initial technical information with those who have shown interest in our projects in the past.

- Phase 2 - Engagement post-submission of Project Description. This phase allowed AREVA to further explain the Project. This phase of the engagement began immediately following the submission of the Project Description mostly during the Open House tours. Further details of the project were discussed such as project-environment interactions and potential effects.

- Phase 3 - Follow-up to previous engagement. This phase will provide more details on the Project and the regulatory approval process. This phase will be ongoing as AREVA proceeds to the final stages of regulatory approval for the Project. AREVA will continue to provide interested parties and stakeholders with information and opportunities to discuss concerns as the Project develops. The focus of engagement will be following up on specific comments. Inclusion of information on the Project will be available during Open Houses, Community Visits, Environmental Quality Committee meetings, and in public information products such as the company newsletter, website, Opportunity North and Annual Reviews.

The tools used by AREVA to communicate with our stakeholders are intended to be used throughout all phases of engagement and allow for continued dialogue. The summary report regarding engagement is provided in Appendix I.

3 Project Alternatives

3.1 Overview

Upon identifying the need for additional tailings capacity at the McClean Lake Operation, multiple alternatives analyses were conducted considering several options to provide the McClean Lake Operation with the needed capacity. The objective of the options analyses was to identify a preferred tailings management option that would provide reliable and sufficient storage capacity. The preferred option would be selected based on suitability from an environmental, technological, economical and socio-economical perspective.

At the onset of the Project a list of potential options was generated, followed by a risk-based screening study undertaken to evaluate potential options. Options were considered in context of AREVA's needs and regulatory requirements including the CNSC Regulatory Document *RD/GD-370*, *Management of Uranium Mine Waste Rock and Tailings* (RD/GD 370).

Three key categories of tailings management options considered included:

- management within existing and proposed works at the McClean Lake Operation (existing pits, proposed open pit and underground mining developments, waste rock piles);
- development of a purpose built TMF (PBTMF); and
- expansion of the existing JEB TMF.

Options to construct a surface impoundment or use a neighbouring lake for tailings placement, as are common in mining, were eliminated from further consideration at an early stage of discussion.

An initial screening study of options was conducted during the planning stage of the project to identify viable options for tailings capacity increase. Following the results of the initial screening study, the most favorable options were identified as a PBTMF or an expansion to the existing JEB TMF. A Trade-off Study identified the vertical expansion of the existing JEB TMF as the preferred option as it maximized the utility of the existing infrastructure, retained a similar footprint, had staged implementation which managed expenditures, and was protective of the environment over the long term. The project description for a project to expand the JEB TMF vertically with a maximum embankment height of 468 mASL was submitted for consideration by regulators in August 2011.

In 2014, while conducting the final steps of the technical review with the CNSC, the McClean Lake Operation's mine plan was updated. The nuclear incident at Fukushima Daiichi had a

significant impact on the uranium market, resulting in a significant change in the schedule and potentially the planned methodology for mining and processing at McClean Lake. Consequently, a reduction in the rate and amount of tailings production was forecasted relative to what was initially considered when evaluating the options presented in the initial Screening Study. AREVA determined it was necessary to revisit the options analysis (2014 Options Study).

Table 3.1-1 compares the steps conducted in the two options analyses conducted by AREVA and the steps suggested by RD/GD-370.

Table 3.1-1: Alternatives Assessment Process

Major Steps suggested by RD/GD-370 (section 3.2)	AREVA Process	
1. Development of list of options	Conducted early in the project development, utilized in the initial Screening Study and then re-evaluated during the subsequent Options Study conducted in 2014.	Section 3.2
2. Screening of options to reduce the number and to provide assurance that any of the remaining options could prove to be the preferred option	Conducted an evaluation of 27 potential options in the initial Screening Study.	Initial Screening Study Results Table 3.4-1 2014 Options Study Results Table 3.6-1
3. Characterization of remaining alternatives	Trade-off study was conducted once options reduced to PBTMF and TMF Expansion; an expanded list of options was re-evaluated in 2014.	Section 3.3, 3.4 Table 3.3-1
4. Identification of evaluation criteria	The criteria considered different components of the options, and were divided into three general categories: 1) environment; 2) technical and operational; and 3) cost.	Section 3.2.2 Table 3.2-1 and 3.2-2
5. Inclusion of quantitative value judgement in decision process by scoring and weighting criteria under the environmental, technical, economic, and socio-economic characteristics		Tables 3.4-1 and 3.6-1
6. Assessment of the sensitivity of the decision-making process		Section 3.8

The following sections provide details of the process engaged in by AREVA to identify the preferred option for the long-term management of tailings at the McClean Lake Operation, including:

1. the initial Screening Study;

2. the resulting Trade-off Study; and

3. the subsequent 2014 Options Study.

3.2 Potential Options

A list of options was developed to bring forward to the initial Screening Study and again for the subsequent Options Study conducted in 2014. These options were developed based on criteria identified by AREVA and recommendations made in RD/GD-370.

3.2.1 Initial Screening Study

The 27 potential options for the long-term management of tailings considered in the initial Screening Study included:

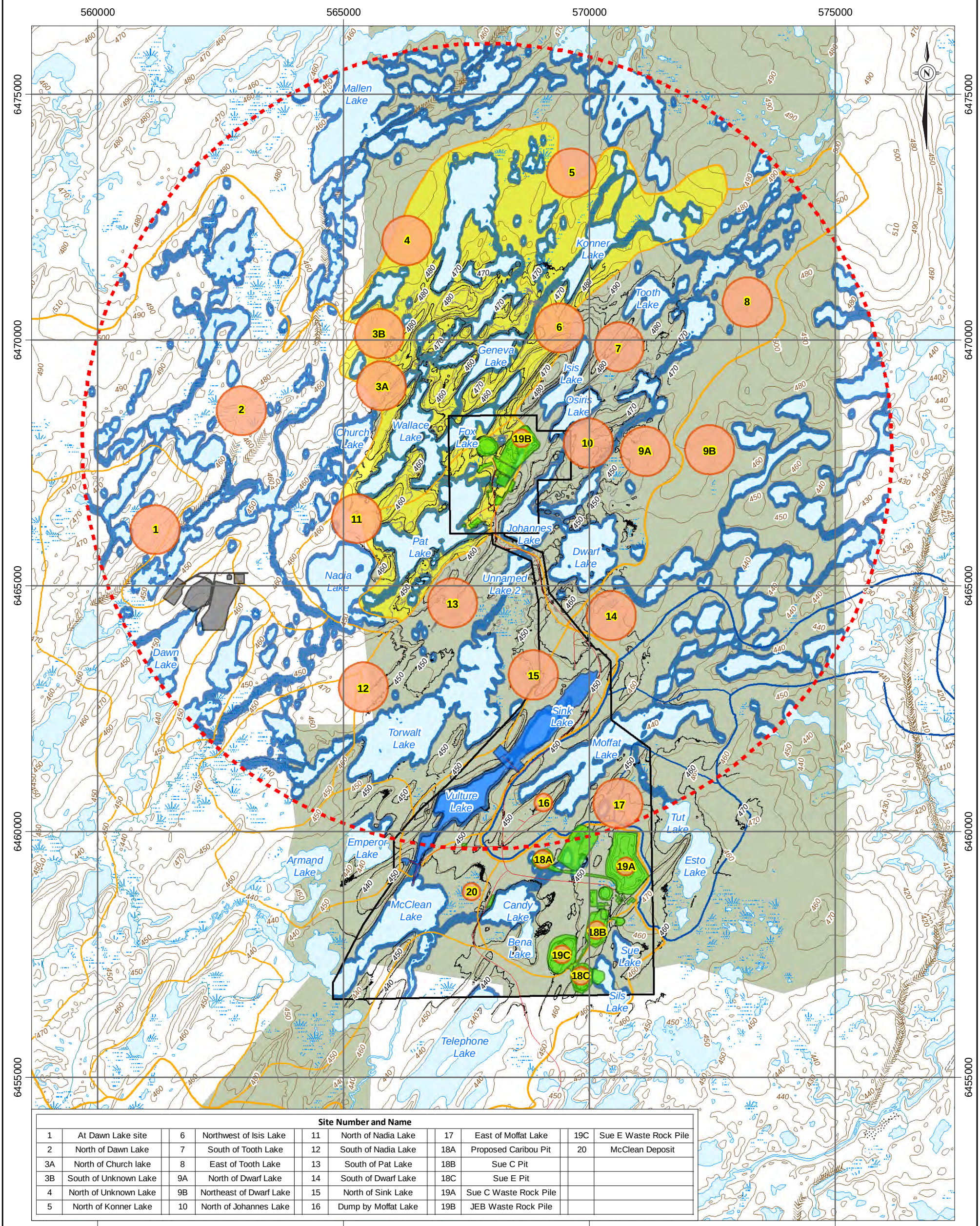
- Existing mine workings;
    - Converting existing open pits at Sue site
    - Excavating waste rock piles
    - Future open pits or underground workings
- Purpose built TMF (19 locations identified through a siting study); and
- Expansion of the existing JEB TMF

Deposition of tailings into an existing waterbody was eliminated from consideration prior to the initial Screening Study as the environmental challenges were considered unnecessary given the collection of viable options being considered. Similarly, use of a surface impoundment was eliminated from consideration prior to the screening study.

Locations of the potential PBTMF options considered are provided in Figure 3.2-1.

Figure 3.2-1: Potential Purpose Built TMF Locations

Path: G:\2008\1362\08-1362-0590 AREVA McClean TMF #2\GIS\Maps\Phase 32000\Section 3\08-1362-0590-GEO-TMF Conceptual Study Potential Options.mxd



Site Number and Name									
1	At Dawn Lake site	6	Northwest of Isis Lake	11	North of Nadia Lake	17	East of Moffat Lake	19C	Sue E Waste Rock Pile
2	North of Dawn Lake	7	South of Tooth Lake	12	South of Nadia Lake	18A	Proposed Caribou Pit	20	McClean Deposit
3A	North of Church lake	8	East of Tooth Lake	13	South of Pat Lake	18B	Sue C Pit		
3B	South of Unknown Lake	9A	North of Dwarf Lake	14	South of Dwarf Lake	18C	Sue E Pit		
4	North of Unknown Lake	9B	Northeast of Dwarf Lake	15	North of Sink Lake	19A	Sue C Waste Rock Pile		
5	North of Konner Lake	10	North of Johannes Lake	16	Dump by Moffat Lake	19B	JEB Waste Rock Pile		

Legend

- Drainage Boundary - Collins Creek
- Drainage Boundary - Collins Creek Sub Watershed
- Drainage Boundary - Moffatt Creek
- Drainage Boundary - Moffatt Creek Sub Watershed
- LiDAR 5 m Contour
- LiDAR 10 m Contour
- NTS 10 m Contour
- Site Roads and Trails
- Surface Lease Boundary
- Study Area
- Existing Mine Area
- S/V TEMS
- Watersheds Contributing to Pat Lake and Fox Lake
- Proposed Cameco Dawn Lake Site
- AREVA Mineral Lease Area
- 100 m Water Buffer
- Tailings Location Option

Reference:
Water and Drainage Area courtesy of AREVA
DMTI Highways and Roads
NTS Mapsheets 64L/04,05
NAD 83 UTM Zone 13

AREVA

08-1362-0590		
SCALE:		DATE:
DESIGNED:		
DRAWN:	JRC	05/15/12
REVISED:		
APPROVED:	GAM	05/15/12
REF. DWGS:		
REVISIONS:		

FIGURE 3.2-1

TMF POTENTIAL OPTIONS
INITIAL SCREENING

3.2.2 Potential Options – 2014 Options Study

In advance of the 2014 Options Study a review of the outcomes of the initial Screening Study was conducted to determine which options to re-evaluate. The following options were included in the 2014 Options Study:

- Existing mine workings;
    - Converting existing open pits at Sue site
- Purpose built TMF (included the locations which received the highest rankings in the initial Screening Study); and
- Expansion of the existing JEB TMF
    - Varying embankment designs

3.3 Criteria Development

Criteria were developed to evaluate each of the options. The criteria considered different components of the options, and were divided into three general categories: 1) environment; 2) technical and operational; and 3) cost. Criteria identified in each category were given an equal weighting when scored within the screening matrix. Scoring was developed so that each criterion was rated between one and five. If the option had a very high chance of successfully addressing a particular criterion, it was scored as a one. Similarly, if the option had a medium likelihood of addressing a criterion, it was scored as a three; while a low likelihood was scored as a five. Scorings of two and four were given if the option was between the three defined scores. If the option was assessed as having a very high likelihood of failing or having unacceptable risk within a particular criterion, a “red flag” score of 100 was used.

The following criteria to evaluate the identified options are further described below and are presented in Tables 3.2-1 and 3.2-2.

Table 3.2-1: Environment Evaluation Criteria

Scoring	Environment Evaluation Criteria						
	Local Status of Environment	**Physical Environment & Setting**	**Watershed Considerations**	**Size of TMF Footprint**	**Ease of Decommissioning**	**Proximity to Sensitive Environment**	**Perception & Acceptance**
1	existing mining areas (i.e., open pits, TMF's, waste rock piles) or within impacted watershed	good competent rock, recharge zone, dry ground	area with good assimilative capacity	less than JEB TMF	simple decommissioning plan and standard post decommissioning monitoring	no proximity	accepted
2							
3	within developed area (i.e., borrow areas, cleared land, cut lines, roadways)	one challenge to the above	area with moderate assimilative capacity	similar to JEB TMF	moderately complex decommissioning plan and more than standard post decommissioning monitoring	adjacent to but no direct interaction	concerns conclusively addressed
4							
5	green field development	several challenges to the above	uncertainty around area's assimilative capacity	more than JEB TMF	complex decommissioning plan and extensive decommissioning monitoring	direct interaction with sensitive environment	special study required to address concerns
100		site cannot be designed to contain or handle contaminants in the short or long-term	area does not have assimilative capacity		perpetual active remediation required	unacceptable effect	unacceptable, contravening policy

Scoring was developed so that each criterion was rated between one and five:
1 = the option had a very high chance of successfully addressing a particular criterion;
3 = the option had a medium likelihood of addressing a criterion;
2 and 4 = were given if the option was between the three defined scores;
5 = the option had a low likelihood of addressing a criterion; and
100 = the option was assessed as having a very high likelihood of failing or having unacceptable risk within a particular criterion (i.e., “red flag”)

Table 3.2-2: Technical and Operation, and Cost Evaluation Criteria

Scoring	Technical & Operation									Costs	
	Technology	Storage Capacity & Expandability	Schedule	Worker Safety	Constructability	Operational Considerations	Water Treatment Requirements	Land Access	Complexity of Monitoring	Capital Costs	Operational Costs
1	proven technology, widely used, easy to implement, environmentally acceptable	initial design for 25 year capacity at production of 14 tonnes per hour(t/hr), easily expandable	very likely to meet target of 2019	low risk of injury, negligible health and workplace impacts due to stable ground, typical construction and operational procedures, radiation exposures unlikely to exceed administration levels	conventional construction methods	no change to existing	less than JEB TMF average per year	AREVA controlled	standard monitoring, testing and reporting for designed system	<$75M	less than JEB TMF per year
2											
3	proven technology at pilot scale, needs more field scale testing to validate, some challenges to implement, environmentally acceptable	initial design for 25 year capacity at production of 14 t/hr, difficult to expand	Probable	moderate risk of injury due to inexperience with new components to process, potential unstable or soft ground conditions, radiation exposures unlikely to exceed administration levels, exposure potentially increased over conventional operations	specialized construction methods	moderate change to existing	same as JEB TMF average per year	joint venture	moderate increase in instrumentation requirements, measurements or sampling frequency over typical	$100M	same as JEB TMF per year
4											
5	conceptual idea requiring development and validation	maximum capacity for 25 year storage at production of 14 t/hr, little to no expansion available	Unlikely	high risk of injury, potential for radiation level to exceed regulatory action somewhat likely	unproven construction methods	major change to existing	more than JEB TMF average per year	other controlled	major increase in instrumentation requirements, measurements or sampling frequency over typical, extra environmental or lengthy studies required	>$150 M	more than JEB TMF per year
100	disproven technology or outdated by more modern advances, shown to be environmentally unacceptable	does not contain 25 year capacity at production of 14 t/hr, no expansion available	will not be licensed and ready to accept tailings by 2019	catastrophic risk of injury, potential for radiation level to exceed regulatory action quite likely							

t/hr = tonnes per hour; < = less than; > = greater than; $ = dollars

3.3.1 Environmental Criteria

The following criteria were developed for the environmental category:

- Local status of the environment – This criterion primarily considered brown field versus greenfield development, namely, whether construction of the TMF would occur within existing mining areas on site, within an impacted or non-impacted watershed, and within an existing disturbed (i.e., borrow areas, cleared land) or undeveloped area. Development within an existing mining area was considered most favorable, while construction within an undeveloped area was considered least favorable.

- Physical environment and setting – The most favorable condition for this criterion was competent rock conditions located within a groundwater recharge zone, and dry ground. It was then evaluated based on the number of challenges to achieving this favorable condition. The least favorable condition was several challenges within the physical environment that would have to be overcome. A red flag was identified for an area that could not be designed to contain or handle contaminants in the short or long-term.

- Watershed considerations – This criterion considered the potential effects the Project may have on the local watershed. Continued treated effluent release through the S/V TEMS and placement of the tailings facility within the Collins Creek drainage watershed were considered as favorable, whereas potential effects on a currently unaffected watershed were considered to be least favorable. A red flag was identified for this criterion if the area did not have adequate watershed assimilative capacity.

- Size of the TMF footprint – This criterion evaluated the relative size of the proposed option's footprint, using the JEB TMF footprint as a baseline. An option was considered favorable if the footprint was less than that of the JEB TMF, and unfavorable if the footprint was larger.

- Ease of decommissioning – This criterion assessed the complexity of the potential decommissioning of a particular TMF option, its performance post decommissioning, and the ability to return the site to institutional control. The potential for a simple decommissioning plan and standard post decommissioning monitoring was most favorable, while the potential for a complex decommissioning plan and extensive post decommissioning monitoring was least favorable. A red flag was identified with this criterion if a site could not be successfully decommissioned for the long-term and would require perpetual active remediation.

- Proximity to sensitive environment – This criterion evaluated whether the proposed option would interact with or increase risk to a sensitive environment. Areas considered as a sensitive environment included waterbodies, impacted watersheds, the S/V TEMS, and neighboring developments of sites. Identified heritage areas were also considered as a sensitive environment; however, no such areas were identified within the study region. Options with no proximity to a sensitive environment were most favorable, while options directly interacting with a sensitive environment were least favorable. A red flag

was identified when the option was considered to have an unacceptable risk to or effect on a sensitive environment.

- Perception and acceptance – This criterion evaluated the perception and acceptance of the option by local communities, the public, First Nations, Métis Groups, regulatory agencies, and corporate considerations. Acceptance of the option was most favorable, while needing special studies to address concerns was least favorable. A red flag for this criterion was triggered if the option was deemed unacceptable, or in contravention of corporate policy.

    - During the initial Screening Study the participants where making assumptions on potential level of perception and acceptance from stakeholders, while during the 2014 Options Study actual feedback collected during engagement activities conducted since 2011 was available for review and consideration when assigning a ranking.

3.3.2 Technical and Operational Criteria

The following criteria were developed for the technical and operational category:

- Technology – This criterion evaluated the technology to be implemented within the option being considered. Proven technology was most favorable, while unproven conceptual ideas were least favorable. A red flag was triggered if the technology was disproven or outdated.

- Storage capacity and expandability – For the initial Screening Study, options for the TMF considered 25 years of storage. The ease of expanding the option to create storage for more than 25 years was also considered. Expansion potential was assessed on the topography of the area, as well as the proximity to waterbodies, existing infrastructure, or any other feature that may impede expansion capability. The most favourable option had an initial 25 years of storage and was easily expandable, while the least favourable condition resulted when the option had a maximum of 25 years of storage with little to no expansion potential. Options that did not contain enough capacity for 25 years of tailings storage were identified as a red flag.

    - For the 2014 Options Study, the options evaluated were based on capacity requirements defined in most current mine plan and resulting tailings production forecast and providing adequate capacity for the known forecast

- Schedule – This criterion evaluated the likelihood of the option being able to meet the tailings deposition schedule from an operational perspective. An option was considered favorable if it was very likely the schedule could be met, and least favorable if it was unlikely the schedule could be met. The condition where the facility would not be approved and constructed to accept tailings in time to accommodate the deposition schedule was evaluated as a red flag.

    - This criterion evaluated options based on availability by 2019 for the initial Screening Study and 2024 for the 2014 Options Study

- Worker safety – Consideration of the risk to workers with respect to health and safety and radiation exposure. Low risk was considered favorable, while high risk was considered unfavorable. A red flag was triggered if the risk was assessed to be catastrophic.

- Constructability – This criterion evaluated the complexity of the construction methods that would be required for each option. Conventional construction methods were most favorable, while unproven construction methods were unfavorable.

- Operational considerations – This criterion considered any potential changes to the current operating procedures (i.e., length of utilidor) that may be required. No change to existing procedures was considered most favorable, while major changes were considered least favorable.

- Water treatment requirements – This criterion compared the estimated water treatment requirements for each option to current water treatment requirements at the JEB TMF. Water treatment plant quality and quantity criteria could equally be classified within the environmental category. Options that required less water treatment than the existing JEB TMF were considered both environmentally and operationally favorable, while those requiring more water treatment than the JEB TMF were considered unfavorable.

- Land access – This considered the location of the option with respect to AREVA's surface lease. Options located within AREVA's surface lease area were considered most favorable, while options located off the surface lease, on land controlled by other parties were considered least favorable.

- Complexity of monitoring – This option considered the monitoring requirements that may be needed in support of each option. Standard monitoring requirements were considered favorable, while a major increase to monitoring was considered least favorable.

3.3.3 Economic Criteria

The following criteria were developed for costs:

- Capital cost – A high level estimate of capital cost was made for each option. This estimate included costs for excavation and construction of an in-pit tailings management facility, overburden management, utilidor construction, road access construction, dewatering, monitoring, and decommissioning.

- Operational cost – Estimated operational costs for each option were assessed based on a comparison to relative current operating costs for the JEB TMF, instead of by dollar value. These costs considered the use of a particular tailings technology and distance

from the mill facility. Options that were understood to have operating costs less than the JEB TMF were considered most favorable, while options that were understood to have operating costs that were greater than the JEB TMF were considered least favorable.

3.4 Alternatives Considered

The following section provides a description on each of the options considered, Table 3.3-1 provides a summary how each option considered the requirements of RD/GC-370 and AREVA's internal requirements.

Table 3.3-1: Options Considered versus Regulatory Requirements

	Existing Waste Rock Piles	Underground Workings	Existing Open Pit - Sue E		Open Pit- Caribou	PBTMF	JEB TMF Expansion	
			Initial Screening Study	Options Study			Initial Screening Study	Options Study
RD/GD -370 Requirements								
Maximize use of mine workings, natural or engineered barriers between waste materials & the environment and controls designed to minimize releases	√	√	√	√	√	X	√	√
Due consideration of mineralized waste rock and BMP's	NA		Challenges related to co-storage	√	√	√	√	√
Ensure long-term protection of Canada's terrestrial and aquatic environment and protection of future generations	NA		√	√	√	√	√	√
Use of overburden and clean waste rock as construction material	√		√	√	√	√	√	√
Design of management systems shall minimize reliance on active institutional control	Complex decommissioning plan		√	√	√	√	√	√
AREVA Requirements								
Sufficient storage capacity	x	x	√	X (excessive)	√	X (excessive)	x	√
Adequate Timelines (regulatory and construction)	Not addressed	X U/G mine only a proposal	√	√	X Open Pit is only proposed project	x	√	√
Environmental Acceptability	Received low rating	Received low to medium rating	√	√	√	√	√	√

3.4.1 Existing Workings

For the purposes of the initial Screening Study three main areas of existing mine workings were examined for the use of long- term tailings management:

(1) convert existing open pit locations at the McClean Lake Operation's Sue site into a TMF, similar to the evolution of the JEB TMF;

(2) use of existing waste rock piles by excavating a pit into the existing waste rock piles and using this void as a tailings repository; and

(3) use of future underground mine workings as a tailings repository.

For the purposes of the 2014 Options Study the only existing mine workings examined was converting existing open pits at the Sue site into a TMF.

3.4.1.1 Existing Waste Rock Piles

Deposition of tailings within the Sue C, JEB and Sue E waste rock piles would involve excavating a pit through the waste rock material, using the waste rock pile structure as the host "landform". Constructability of a TMF within the waste rock piles could be challenging, and studies would be required to understand the interaction between the tailings material and waste rock, as well as to optimize the tailings deposition method within the waste rock. These sites would also require a complex decommissioning plan and extensive post decommissioning monitoring to confirm that the tailings material was secure within the waste rock pile over time.

These options had red flag concerns over the technical aspects of tailings management within the waste rock piles such as tailings placement and water treatment, as well as the limited storage capacity and expandability of these areas. Therefore, these options were not further considered in the initial Screening Study, nor were they re-introduced in the 2014 Options Study.

3.4.1.2 Underground Mine Workings

Underground mining is proposed for several deposits at the McClean Lake Operationhowever, this project is in the planning and design phase. For this option, tailings would be disposed of as backfill within the underground workings. Additional studies would be required to establish the optimal tailings composition to accomplish safe tailings disposal.

Concerns related to the limited storage capacity available, radiological safety considerations associated with depositing tailings in dry conditions and effects of elevated radon in the mine workings, and the lack of expandability with this option. The inability to meet the schedule for additional tailings storage requirements with uncertainty in the development schedule for

underground mining was the primary concern. This option was not further considered in the initial Screening Study, nor was this option re-introduced in the 2014 Options Study.

3.4.1.3 Existing Open Pits

Modification of an existing open pit was considered a potential tailings management option. Positive aspects included development cost and use of an already disturbed area within the McClean Lake Operation surface lease. Two existing open pits (Sue C and E) and one proposed open pit (Caribou) at the McClean Lake Operation were considered as potential TMF locations. When the Caribou Project was initially submitted for approval the intent was to mine this ore body as an open pit. However, with underground mining proposed at the McClean Lake Operation, the Caribou deposit is no longer likely to be mined via the open pit mining method, and therefore, was not considered further in the alternatives assessment. For the two remaining open pits considered, it was assumed that the existing mined open pit structure could be converted to a TMF, similar to the JEB TMF.

The mining of the Sue C pit was completed in 2002, with an approximate pit volume of 11.5 million m^3 (COGEMA 2004a). Since that time, the Sue C pit has been used to store clean and special waste rock. Special waste rock is rock that has the potential to release COPCs, or be acid generating over time. Special waste rock generated while mining the JEB, Sue C, Sue E and Sue A deposits has been placed within the Sue C pit, which has since been allowed to partially re-flood. Special waste rock generated from known future mining operations at Cigar Lake and at the McClean Lake Operation has also been allocated for deposition in the Sue C pit.

Mining of the Sue E pit was completed in 2008 (AREVA 2010a), with a mined out volume of approximately 7.9 million m^3 (AREVA 2009a). After mining of the Sue E pit was complete, mining of the Sue B pit commenced, and all waste rock from the Sue B pit was deposited into the Sue E pit (AREVA 2009a).

It is anticipated that within both the Sue C and Sue E open pits, the chemical environment for long-term stability of both waste rock differs from that of tailings. Tailings require an oxidizing environment to keep COPCs in their most stable form. Special waste rock storage, conversely, requires a reducing environment to prevent leaching of COPCs and provide a stable environment so that they remain in their initial metal/reduced form.

Development of a TMF in the Sue area would require that tailings be transported approximately 15 km from the McClean Lake Mill to the selected open pit. The maintenance of this length of tailings line would represent an operational challenge with increased risk of pipeline rupture and spillage of tailings. An expanded or new WTP would also be required at the Sue site to treat the additional water from a TMF at any of the potential Sue sites.

The outcome of the initial Screening Study, indicated that the use of the existing open pits at the Sue site were not a viable option for tailings management at the volumes required by the milling forecast. The interaction between the tailings and waste rock materials would require extensive

technical studies and detailed monitoring to understand the chemical interaction between the two material streams over the long-term.

For the reasons mentioned above (i.e., Sue pits already approved and used for long-term special waste rock storage with potentially incompatible chemical environments, technical and management challenges of developing tailings storage within a waste rock pile, and operational challenges of a lengthy tailings line utilidor), the initial Screening Study concluded that the development of a TMF within existing or proposed works at the McClean Lake Operation was not the preferred alternative for additional tailings capacity.

The conversion of existing open pits in to a TMF was re-introduced in the 2014 Options Study. Although the co-storage and lengthy transport of tailings remain an operational challenge, these challenges were set aside to reconsider remaining aspects of use of the pits. Ultimately the reduction to the amount of additional tailings storage capacity required removed the Sue pits as a preferred option during the 2014 Options Study. The substantial cost associated with the conversation of the Sue pit into a TMF for the small volume of tailings required was not considered economically feasible.

3.4.1.4 Conclusion

On the basis of the initial Screening Study it was concluded that none of the existing or planned workings at the McClean Lake Operation represented viable options with regard to long-term tailings management. The 2014 Options Study re-affirmed the selection made in the Initial Screening Study.

3.4.2 Purpose Built Tailings Management Facility

A siting study was conducted to identify favorable areas in and around the McClean Lake Operation suitable for the development of a PBTMF. This siting study identified 19 locations (Figure 3.2-1) that were included to the initial Screening Study.

3.4.2.1 PBTMF – Initial Screening Study

The results of the initial Screening Study identified the area east of the JEB TMF (Figure 3.2-2) as a potential favourable location for a PBTMF. The initial Screening Study results considered a number of locations within this area based on existing information. Although the selection of a specific location will need to be supported by a comprehensive site characterization study, it was considered a reasonable assumption that a PBTMF could be located within this general area, and perform in a similar manner to the existing JEB TMF during operations and post decommissioning.

On this basis, it was concluded that consideration of the PBTMF should be advanced to a more refined alternative assessment in the Trade-off Study, discussed in Section 3.5.

Figure 3.2-2: Results of Initial Screening for Purpose Built TMF Locations

Path: G:\2008\1362\08-1362-0590 AREVA McClean TMF #2\GIS\Maps\Phase 32000\Section 3\08-1362-0590-GEO-TMF Conceptual Study Findings.mxd

560000 565000 570000 575000

6475000 6470000 6465000 6460000 6455000

Mallen Lake
Konner Lake
Tooth Lake
Geneva Lake
Isis Lake
Osiris Lake
Wallace Lake
Church Lake
Fox Lake
Johannes Lake
Dwarf Lake
Pat Lake
Nadia Lake
Unnamed Lake 2
Dawn Lake
Torwalt Lake
Sink Lake
Moffat Lake
Vulture Lake
Tut Lake
Emperor Lake
Armand Lake
Esto Lake
McClean Lake
Candy Lake
Bena Lake
Sue Lake
Sils Lake
Telephone Lake

1 2 3A 3B 4 5 6 7 8 9A 9B 10 11 12 13 14 15 16 17 18A 18B 18C 19A 19B 19C 20

Site Number and Name									
1	At Dawn Lake site	6	Northwest of Isis Lake	11	North of Nadia Lake	17	East of Moffat Lake	19C	Sue E Waste Rock Pile
2	North of Dawn Lake	7	South of Tooth Lake	12	South of Nadia Lake	18A	Proposed Caribou Pit	20	McClean Deposit
3A	North of Church lake	8	East of Tooth Lake	13	South of Pat Lake	18B	Sue C Pit		
3B	South of Unknown Lake	9A	North of Dwarf Lake	14	South of Dwarf Lake	18C	Sue E Pit		
4	North of Unknown Lake	9B	Northeast of Dwarf Lake	15	North of Sink Lake	19A	Sue C Waste Rock Pile		
5	North of Konner Lake	10	North of Johannes Lake	16	Dump by Moffat Lake	19B	JEB Waste Rock Pile		

Legend

- Drainage Boundary Collins Creek
- Drainage Boundary Collins Creek Sub Watershed
- Drainage Boundary Moffatt Creek
- Drainage Boundary Moffatt Creek Sub Watershed
- LiDAR 5 m Contour
- LiDAR 10 m Contour
- NTS 10 m Contour
- Site Roads and Trails
- Surface Lease Boundary
- Study Area
- Existing Mine Area
- S/V TEMS
- Proposed Cameco Dawn Lake Site
- 100 m Water Buffer
- Preferred Study Area
- Watersheds Contributing to Pat Lake and Fox Lake
- AREVA Mineral Lease Area
- Tailings Location Option
- Red Flagged Option

Reference:
Water and Drainage Area courtesy of AREVA
DMTI Highways and Roads
NTS Mapsheets 64L/04,05
NAD 83 UTM Zone 13

AREVA

08-1362-0590		
SCALE:		DATE:
DESIGNED:		
DRAWN:	JRC	16/05/12
REVISED:		
APPROVED:	GAM	16/05/12
REF. DWGS:		
REVISIONS:		

FIGURE 3.2-2

TMF POTENTIAL FINDINGS
INITIAL SCREENING

3.4.2.2 PBTMF – 2014 Options Study

The 2014 Options Study evaluated the top two PBTMF locations identified from the initial Screening Study.

3.4.3 Expanding the JEB TMF

Expanding the storage capacity within the existing JEB TMF was considered as an option. During the initial development of this option, studies were undertaken to assess key operational and decommissioning aspects. A proof of concept analysis was completed in early 2010 to assess operational flows for an expanded JEB TMF and to assess long-term environmental loadings from the decommissioned expanded JEB TMF. The initial modelling concluded that expanding the JEB TMF was technically feasible and would achieve the environmental performance criteria established for the existing TMF. As such, expansion of the JEB TMF was advanced to a more refined alternative assessment in the Trade-off Study.

3.4.3.1 Expanding the JEB TMF – Initial Screening Study

Increasing the tailings storage capacity above the currently approved capacity of the JEB TMF has the potential to provide additional tailings capacity at the McClean Lake Operation. Approximately 25 years of additional tailings storage (an approximate volume of 4.5 million m3) could be available through vertical expansion of the existing JEB TMF. The stage/storage relationship in Figure 3.3-1 and discussed in Section 3.6.1 demonstrated the same design outcome as the one used to optimize the design of a PBTMF. Expansion of the JEB TMF optimizes the tailings storage volume available within a given footprint, reducing the disturbance to the surrounding environment, while controlling the surface area that tailings-water interaction can occur over. It has the benefit of not requiring additional water treatment or supporting infrastructure.

3.4.3.2 Expanding the JEB TMF - 2014 Options Study

With an updated mine plan and tailings production forecast, an option to utilize the existing footprint of the JEB TMF remained as an option, however at a significantly reduced design scope. The updated tailings production forecast was estimated to be approximately 2.3 million m^3 versus the 5.5 million m^3 used in the initial Screening Study. The option in the 2014 Option Study considered designing the expansion to what was required to accommodate the tailings production forecast.

3.5 Results of Initial Screening Study

Findings of the initial screening assessment are provided in Table 3.4-1. The use of the screening matrix as a decision guidance tool helped to identify the options that warranted further investigation, and options that had a potential fatal flaw. Each tailings management option was

evaluated against the siting criteria within the matrix. An individual assessment of each tailings management option against the criteria was conducted, without comparison to the other proposed options. After each option was evaluated against each criterion, a total score was obtained. Total scores were then compared between options. Tailings management options with the lowest total scores were evaluated to be the most likely to be successful or favourable for further investigation. The options screening matrix identified 9 options out of 27 that had at least one red flag concern (Table 3.4-1).

Table 3.4-1: Initial Screening Results

Alternatives	1	2	3A	3B	4	5	6	7	8	9A	9B	10	11	12
Site Option Considered	**At Dawn Lake site**	**North of Dawn Lake**	**North of Church Lake**	**South of Unknown Lake**	**North of Unknown Lake**	**North of Konner Lake**	**Northwest of Isis Lake**	**South of Tooth Lake**	**East of Tooth Lake**	**North of Dwarf Lake**	**Northeast of Dwarf Lake**	**North of Johannes Lake**	**North of Nadia Lake**	**South of Nadia Lake**
Option Components	pit + topo	pit + topo	pit	pit + topo	pit	pit	pit + topo	pit	pit	pit	Pit	pit	pit	pit
Proposed Volume (million m^3)	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Proposed Footprint (Pit only, Waste Rock not included) (m^2)	102,000	102,000	102,000	102,000	102,000	102,000	102,000	102,000	102,000	102,000	102,000	102,000	102,000	102,000
Length of Utilidor (km)	8	7	4.5	5	6.5	6.5	3.5	4.5	8	3	4.5	2	3.5	6
New Road Length (km)	8	7	4.5	5	6.5	5.5	2.5	3.5	7	2.5	4	1.5	3.5	4
Environment														
Local Status of Environment	5	5	1	1	1	3	1	3	5	5	5	3	1	5
Physical Environment & Setting	3	5	3	3	1	3	3	3	1	2	3	3	3	3
Watershed Considerations	3	5	5	5	5	5	5	1	1	1	3	1	5	1
Size of Footprint	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Ease of Decommissioning	3	1	1	1	1	1	1	1	1	1	1	1	1	1
Proximity to Sensitive Environment	3	5	5	5	5	5	5	1	1	1	1	1	5	1
Perception & Acceptance	5	3	5	5	5	5	5	3	3	3	3	3	5	3
Subtotal	**25**	**27**	**23**	**23**	**21**	**25**	**23**	**15**	**15**	**16**	**19**	**15**	**23**	**17**
Technical and Operation														
Technology	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Storage Capacity and Expandability	3	1	3	1	1	1	1	1	1	1	1	3	3	1
Schedule	100	100	5	5	5	5	5	5	5	5	5	5	100	100
Worker Safety	1	3	1	1	1	1	1	1	1	1	1	1	1	1
Constructability	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Operational Considerations	3	3	3	3	3	3	1	1	3	1	1	1	1	2
Water Treatment Requirements	5	5	3	3	1	1	1	2	1	2	1	3	1	1
Land Access	5	5	1	1	1	1	1	1	1	1	1	1	5	5
Complexity of Monitoring	3	1	3	3	3	3	3	1	1	1	1	1	3	1
Subtotal	**122**	**120**	**21**	**19**	**17**	**17**	**15**	**14**	**15**	**14**	**13**	**17**	**116**	**113**
Financial														
Capital Costs	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Operational Costs	5	5	5	5	5	5	3	3	5	3	3	3	3	4
Subtotal	**8**	**8**	**8**	**8**	**8**	**8**	**6**	**6**	**8**	**6**	**6**	**6**	**6**	**7**
TOTAL	**155**	**155**	**52**	**50**	**46**	**50**	**44**	**35**	**38**	**36**	**38**	**38**	**145**	**137**
Options Ranking	**16**	**16**	**10**	**9**	**7**	**9**	**5**	**1**	**3**	**2**	**3**	**3**	**15**	**14**

Table 3.4-1: Initial Screening Results (continued)

Alternatives	**13**	**14**	**15**	16	17	18A	18B	18C	19A	19B	19C	20	0
Site Option Considered	**South of Pat Lake**	**South of Dwarf Lake**	**North of Sink Lake**	**Dump by Moffat Lake**	**East of Moffat Lake**	**Proposed Caribou Pit**	**Sue C Pit[a]**	**Sue E Pit[b]**	**Sue C Waste Rock Pile**	**JEB Waste Rock Pile**	**Sue E Waste Rock Pile**	**McClean Deposit[c]**	**JEB TMF Expansion**
Option Components	pit	pit	pit	pit	pit + topo	existing pit	existing pit	existing pit	pit in WR pile	pit in WR pile	pit in WR pile	underground	existing
Proposed Volume (million m^3)	5	5	5	5	5	7.3	4.9	6.2	8.5	2.8	3.5	1	4.5
Proposed Footprint (Pit only, Waste Rock not included) (m^2)	102,000	102,000	102,000	102,000	102,000	145,000	256,470	194,250	643,800	320,840	339,000	0	72,000
Length of Utilidor (km)	3	5	6	10.5	14	11.5	13	14.5	13	0.5	15	11.5	0
New Road Length (km)	1	1	1	1	2	0	0	0	0	0	0	0	0
Environment													
Local Status of Environment	5	3	3	3	5	1	1	1	1	1	1	1	1
Physical Environment & Setting	3	3	1	1	5	3	5	5	5	5	5	5	3
Watershed Considerations	3	3	3	3	3	3	5	5	5	5	5	5	3
Size of Footprint	3	3	3	3	3	3	5	3	5	3	5	1	3
Ease of Decommissioning	1	1	1	1	1	1	5	5	5	5	5	3	1
Proximity to Sensitive Environment	3	1	5	1	3	3	5	5	5	5	5	1	3
Perception & Acceptance	3	3	5	3	3	3	5	5	5	5	5	5	3
Subtotal	**21**	**17**	**21**	**15**	**23**	**17**	**31**	**29**	**31**	**29**	**31**	**21**	**17**
Technical and Operation													
Technology	1	1	1	1	1	1	5	5	5	5	5	5	3
Storage Capacity and Expandability	1	3	2	5	3	5	5	5	5	100	100	100	5
Schedule	5	5	5	5	5	5	5	5	5	5	5	100	1
Worker Safety	1	1	1	1	1	1	1	1	3	3	3	3	1
Constructability	1	1	1	2	1	1	5	5	5	5	5	3	1
Operational Considerations	1	1	3	3	3	3	5	5	5	5	5	5	1
Water Treatment Requirements	3	1	3	3	3	3	3	3	5	5	5	3	1
Land Access	1	1	1	1	1	1	1	1	1	1	1	1	1
Complexity of Monitoring	1	1	3	1	1	1	5	5	5	5	5	5	1
Subtotal	**15**	**15**	**20**	**22**	**19**	**21**	**35**	**35**	**39**	**144**	**134**	**225**	**15**
Financial													
Capital Costs	3	3	3	3	3	2	1	1	4	1	2	1	1
Operational Costs	3	3	5	5	5	5	5	5	5	3	5	5	3
Subtotal	**6**	**6**	**8**	**8**	**8**	**7**	**6**	**6**	**9**	**4**	**7**	**6**	**4**
TOTAL	**42**	**38**	**49**	**45**	**50**	**45**	**72**	**67**	**79**	**177**	**172**	**252**	**36**
Options Ranking	**4**	**3**	**8**	**6**	**9**	**6**	**12**	**11**	**13**	**18**	**17**	**19**	**2**

(a) volume calculated based on reported mined out volume of Sue C pit (11.5 million m^3 from AREVA 2004) minus the total waste rock to be deposited in the Sue C pit (6.6 million m^3 from AREVA 2009a)

(b) volume calculated based on reported mined out volume of Sue E pit (7.9 million m^3 from AREVA 2009a) minus the total waste rock to be deposited in the Sue E pit (1.7 million m^3 from AREVA 2009a)

(c) volume based on reported proposed waste rock volumes from the McClean Lake underground development (AREVA 2009a). Does not include allowance for volume of ore recovered, however, the volume is not expected to change within 1 million m^3 of shown value

3.6 Trade-off Study (Resulting from Initial Screening Study)

The results of the trade-off study for the two alternatives identified in the initial Screening Study (PBTMF and the initial JEB TMF Expansion) are presented in Table 3.5-1, and discussed in the following section. The criteria used within the Trade-off Study included cost and cash flow, schedule flexibility, environmental effect, ease of technical operability, technical ease of decommissioning, perceived acceptance of the alternative by the Aboriginals, the public, and regulatory agencies, and flexibility to the unknown. A ranking of each criterion was applied with acceptable (1) to most acceptable (3).

Table 3.5-1: Trade-off Study Results (including schedule flexibility criterion)

Criteria	JEB TMF Expansion Ranking	PBTMF Ranking
Schedule flexibility	3	1
Environmental effect	3	2
Ease of technical operability	3	2
Technical ease of decommissioning	3	2
Acceptance of Project (regulators)	2	2
Acceptance of Project (public)	2	3
Cost/cash flow	3	1
Flexibility to the unknown	1	3
Total	**20**	**16**

The level of institutional control associated with expansion of the JEB TMF or the development of a PBTMF will not significantly differ from each other, or what is currently in place for the existing JEB TMF. The evaluation of these aspects in the screening matrix did not identify any high level risks that would preclude the development of either option, and comparison of this criterion within the trade-off study does not identify any particular advantage of one option over the other. Based on the decommissioning studies conducted during the prefeasibility studies for the JEB TMF Expansion, and the assumption that a PBTMF could be decommissioned in a similar manner to the existing JEB TMF decommissioning plan, each option should be physically and chemically stable over the long-term.

3.6.1 Purpose Built Tailings Management Facility

Additional assessment of a PBTMF included evaluation of:

- construction and operational considerations;
- decommissioning activities;
- schedule; and
- costs

The design of the PBTMF was based on optimizing the pit geometry to reduce mass loading from the JEB TMF. Mechanisms for solute to exit a decommissioned PBTMF will be similar to those for the existing JEB TMF. In the JEB TMF, the primary mechanisms are related to surface water infiltration through the cover into the surface of the tailings and diffusion from the sidewalls to groundwater adjacent to the JEB TMF. The geometry of a PBTMF was optimized by considering the volume of tailings stored per unit surface area and per unit side wall area.

The purpose of optimizing the design of the PBTMF is to evaluate the potential to achieve the largest tailings storage volume from the least amount of surface area, so as to optimize the storage capacity of the pit while reducing the area for contaminant migration and surface water infiltration. To evaluate this, a deterministic approach was used by assuming a set pit storage volume of approximately 5 million m3 and by varying the pit depth and slope angle to achieve this volume. For this approach, design assumptions were applied to a pit constructed within the bedrock materials only, and does not include any overburden portions that may be associated with pit development. The pit depth and slope angle were chosen as variables because these parameters varied the surface area and footprint of the pit. For example, for a set slope angle, a deeper pit would have a smaller surface footprint, but a larger side surface area than a shallower pit. Conversely, for a set depth, a shallower slope angle would contain more volume than a steeper slope angle, but would have a larger footprint and surface area. These comparisons were used to identify the variable that had the most effect on the pit optimization.

Two sets of volume to surface area curves are shown on Figure 3.3-1. One set compares volume to the pit footprint (or horizontal surface area). This was considered as the pit footprint acts as the primary surface area for water infiltration into the tailings material. The second set compares volume to the total surface area of the pit, which includes the footprint and the surface area of the sides and bottom of the pit. The total surface area was considered, as this area represents the areas for infiltration into the tailings material, as well as the main area for migration of contaminants out of the tailings area.

Both curve sets have the same shape and trend (Figure 3.3-1). For shallower pit slope angles, the volume to surface area ratio decreases, although the same general trend with depth occurs for each pit slope angle. Based on depth, the slope of the curves is steep at shallow depths, and begins to flatten after 60 m depth (Figure 3.3-1). This indicates that a minimum pit depth of 60 m is required to benefit from optimizing the volume per surface area ratio. The flattest portion of the curve for the total surface area occurs between 120 to 150 m depth, while the flattest portion of the curve for the footprint surface area occurs between 80 to 150 m depth (Figure 3.3-1). This indicates the depths where maximum optimization of the volume per surface area ratio occurs. Based on this approach, the pit configuration that would optimize the volume to surface area ratio would be a truncated cone that is 95 m deep, with a slope angle of 45 degrees, a bedrock crest diameter of approximately 360 m, and a floor diameter of approximately 200 m. For an open pit of this nature, there is little opportunity to stage the construction.

A preliminary assessment of assimilative capacity in the study area was completed using the flushing rate of the North Basin of Fox Lake as a benchmark for sufficient assimilative capacity.

It was concluded for the study area shown in Figure 3.2-2; a PBTMF could be located in an area with sufficient assimilative capacity. Based on the existing knowledge of the hydrogeology in this area (AREVA 2011b) and the optimal PBTMF geometry discussed above, dewatering rates for a PBTMF in this area were estimated to be in the 3,000 to 5,000 m3/day range.

Construction and operation of a PBTMF was evaluated based on common methods currently in use at the JEB TMF. This was assessed at a high level, without detailed design. Generally, construction and operation of a PBTMF will include:

- site preparation;
- excavation of overburden and rock;
- drain and filter material placement;
- development of site infrastructure, such as road access and utilities;
- development of dewatering infrastructure; and
- provision for expanded water treatment requirements.

The construction of a PBTMF will result in an additional disturbed footprint within the McClean Lake Operation surface lease. It has been assumed that this PBTMF footprint would be similar in size to the existing JEB TMF and associated waste rock pile. Construction of a PBTMF would require land disturbance for the development of pit excavation, material stockpiles, ancillary facilities not located on the JEB mill terrace, access roads, and utilities. An estimated 2.6 million m^3 of overburden and 5 million m^3 would need to be excavated and stockpiled to construct an open pit with sufficient storage volume for 25 years.

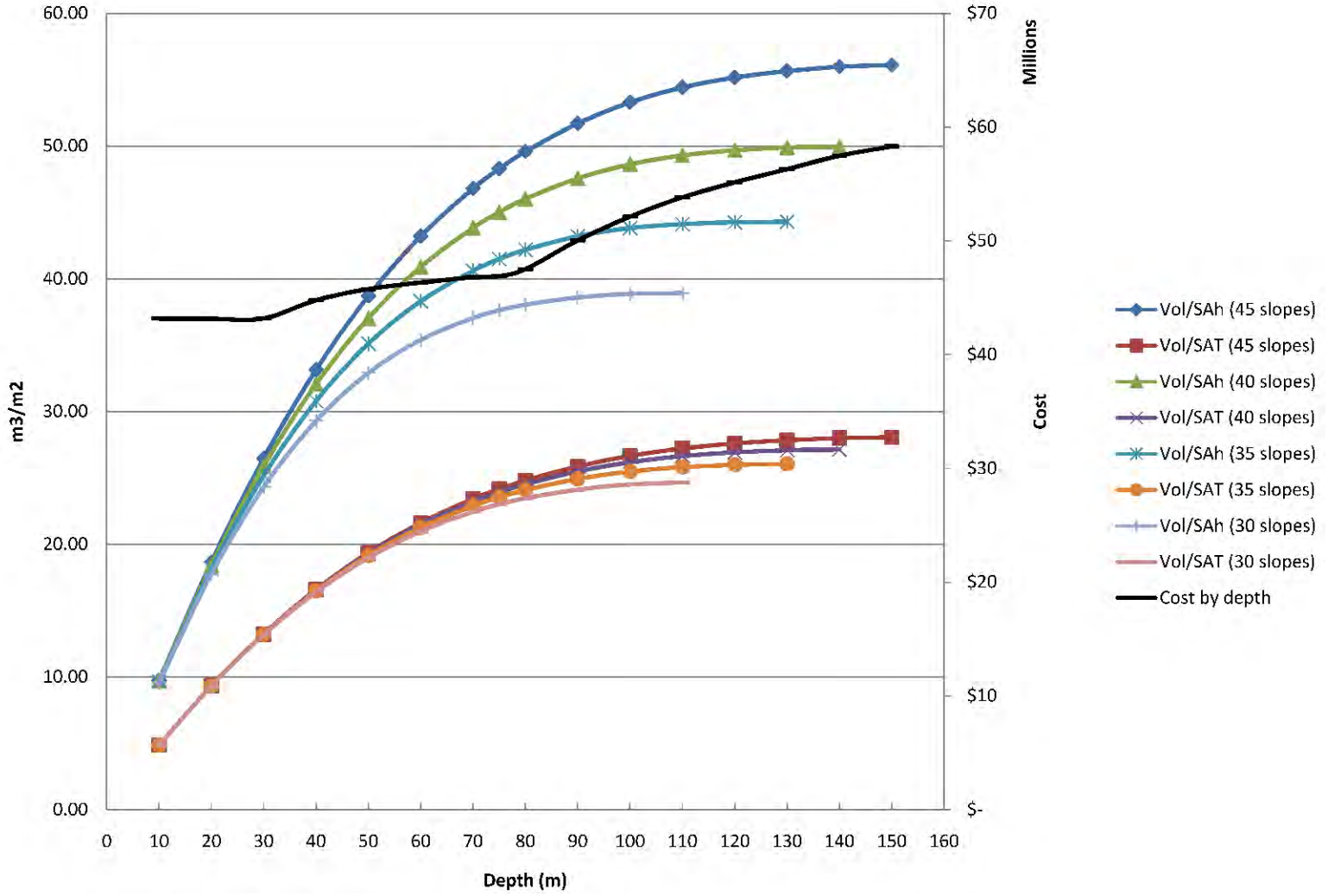
It was assumed that a dewatering well system, TMF filter system, and tailings deposition system would be implemented at a PBTMF, as is currently being used at the JEB TMF. A new WTP would also be required to manage the groundwater inflows to the pit, and tailings pore water. During the initial years of operation of the PBTMF, the reclaim water from the existing JEB TMF will also require treatment (approximately 2,400 m^3/day). The existing JEB WTP has a maximum capacity of 6,000 m^3/day and does not have sufficient capacity to treat the volume from the PBTMF in addition to the reclaim water.

Initially the site characterization, environmental assessment and licensing processes were anticipated to take up to 8 years to complete. However, recent improvements to the regulatory framework have greatly reduced this timeline. An additional 3 years is estimated to be needed for the construction and commissioning period to bring a PBTMF into operation. The approximate costs to design, permit, and construct a PBTMF with sufficient storage for 25 years operation are anticipated to be in the order of $200M with an annual operating cost in the order of $5M per year, and an incremental conceptual decommissioning cost of $30M for the PBTMF.

Decommissioning efforts for a PBTMF should be conventional and follow the existing decommissioning plan for the JEB TMF. It is also expected that the same long term performance and monitoring requirements currently anticipated for the JEB TMF will be required for a PBTMF. However, implementation of a PBTMF would also include decommissioning of the existing JEB TMF. This was factored into the capital cost estimate for a PBTMF, and would also include the management of two decommissioned facilities into institutional control.

Figure 3.3-1: Volume/Surface Area by Depth Comparison with Cost

Path: G:\2008\1362\08-1362-0590 AREVA McClean TMF #2\GIS\Maps\Phase 32000\Section 3\08-1362-0590-32000-Volume_Surface Area by Depth Comparison With Cost.mxd



AREVA

08-1362-0590		
SCALE:		DATE:
DESIGNED:		
DRAWN:	JRC	16/05/12
REVISED:		
APPROVED:	GAM	16/05/12
REF. DWGS:		
REVISIONS:		

FIGURE 3.3-1

VOLUME/SURFACE AREA BY DEPTH COMPARISON WITH COST

3.6.2 JEB TMF Expansion (Initial Design)

As described in Section 3.2.3, increasing the tailings storage capacity above the approved consolidated storage elevation of 434 mASL of the JEB TMF has the potential to provide additional tailings capacity at the McClean Lake Operation. The design considered for the expansion to the JEB TMF for the initial Screening Study and resulting Trade-off Study involved the construction of an embankment to 468 mASL and would provide approximately 25 years of additional tailings storage (an approximate volume of 4.5 million m^3).

Materials needed for the construction of embankment and liner will be sourced from the JEB waste rock pile. Construction of the expansion would occur in stages using the same construction methods as used for the JEB TMF Optimization Project (AREVA 2010b). Operation of the expanded JEB TMF will use existing infrastructure for hydraulic containment, water treatment, and tailings placement. Operation and placement methods remain, for the most part, unchanged from existing operations.

During the initial development of this alternative, further studies were undertaken to assess key operational and decommissioning aspects. Preliminary analysis was completed to assess operational flows for an expanded JEB TMF and long-term environmental loadings from the decommissioned expanded JEB TMF. Studies were also undertaken to assess the long-term stability of the JEB TMF structure after decommissioning. The initial modelling concluded that expanding the JEB TMF was technically possible, and that the decommissioned structure would be stable over the long-term. Decommissioning of the expanded JEB TMF would use the same methods proposed for the existing JEB TMF. Capital costs for the design, permitting, and construction of the JEB TMF Expansion are forecasted to be in the order of $100M, with no incremental operating costs from the existing JEB TMF, and no incremental decommissioning cost.

3.6.3 Trade-off Study Results

Based on the above discussion, a trade-off study was completed for the PBTMF and the expansion of JEB TMF. The criteria used within the trade-off study included environmental effect, cost and cash flow, schedule flexibility, ease of technical operability, technical ease of decommissioning, perceived acceptance of the alternative by the public, First Nations, Métis Groups, and regulatory agencies, and flexibility to the unknown. In considering costs, the decommissioning of the JEB TMF was considered to be common to both options, as this activity will be required for each.

Based on the results of the trade-off study, expanding tailings capacity in the JEB TMF was considered to be the preferred alternative at this time because of its environmental, operational and economic advantages. Specifically, the JEB TMF:

- uses existing disturbed areas for the additional tailings capacity, and does not substantively increase the footprint of tailings management activities on-site whereas the PBTMF would essentially replicate the spatial footprint of the existing TMF;

- uses existing site infrastructure, whereas a PBTMF requires additional infrastructure (e.g., new roads, a new WTP, and expanded waste rock pile);

- there is 16 years of proven operational experience and performance monitoring data available for the JEB site groundwater system and the JEB TMF, which provide an increased level of confidence that the JEB TMF can be expanded with the long-term performance of the facility continuing to satisfy regulatory requirements;

- will use the same construction and containment techniques that were approved for the JEB TMF Optimization Project (AREVA 2010b) (sloped pit walls and placement of a processed waste rock/till bentonite amended liner); and

- is within close proximity to the McClean Lake Mill.

Based on the milling forecast for the McClean Lake Mill, expanding the JEB TMF was also preferred because this option had the ability to provide the required increased tailings storage capacity in a timely and cost efficient manner and continues to make adequate provision for the environment and meets all other requirements of the NSCA and regulations. However, it is AREVA's view that even with the removal of any time restraints the expansion of the JEB TMF is the preferred option from an environmental, health and safety and operational perspective.

Given the above reasons, expansion of the JEB TMF was selected as the preferred option for increasing tailings management capacity at the McClean Lake Operation. However, a PBTMF remained as a viable option for future tailings management at the McClean Lake Operation, should the processing of prospective ore bodies be required beyond those presently included within the tailings storage capacity available from the proposed expansion of the JEB TMF.

3.7 2014 Options Study Summary

As previously mentioned, a subsequent alternatives assessment was determined to be necessary, following a change in mine plan which resulted in a reduction in forecasted tailings production. Table 3.6-1 provides the results of the 2014 Options Study, where the JEB TMF Expansion (with a reduced scope) was identified as the preferred option, the initial JEB TMF Expansion second, followed by the conversion of an existing open pit at the Sue site into a TMF and finally the PBTMF. AREVA considered commencing a scoping study of the conversion of Sue pits, however it was determined that the costs associated with this conversion for the volume of capacity required removed this option for further consideration, at this time. In this case, lower score values indicate the more favourable option.

Table 3.6-1: 2014 Options Study Results

Site Option Considered	PBTMF –Off surface lease	PBTMF – On surface lease	TMF Expansion (reduced scope)	Sue C Pit	Sue E Pit	JEB TMF Expansion
Option Components	pit	pit		existing pit	existing pit	existing
Proposed Volume (million m^3)	5	5	1.7	6.2	4.9	4.5
Proposed Footprint (Pit only, Waste Rock not included) (m^2)	102,000	102,000		256,470	194,250	72,000
Length of Utilidor (km)	~2-4 km	10.5km		13	14.5	0
New Road Length (km)				0	0	0
Environment						
Local Status of Environment	5	5	1	1	1	1
Physical Environment & Setting	1	2	2	2	2	2
Watershed Considerations	1	1	1	2	2	1
Size of Footprint	5	4	1	1	1	1
Ease of Decommissioning	4	4	1	3	3	2
Proximity to Sensitive Environment	2	2	3	3	3	4
Perception & acceptance - public	3	3	1	2	2	3
Perception & acceptance - regulatory	3	3	2	4	2	4
Post closure failures	1	1	2	1	1	3
Subtotal	**25**	**25**	**14**	**19**	**17**	**21**
Technical and Operation						
Technology	2	2	1	2	2	2
Storage Capacity and Expandability	3	3	5	1	3	4
Schedule	5	5	1	3	3	1
Worker Safety	4	4	2	2	2	3
Constructability	2	2	3	2	2	3
Operational Considerations	2	3	1	3	3	1
Water Treatment Requirements	3	3	1	2	2	1
Land Access	5	1	1	1	1	1
Complexity of Monitoring	2	2	2	2	2	2
Accidents and malfunctions	2	3	1	3	3	2
Subtotal	**30**	**28**	**18**	**21**	**23**	**20**
Financial						
Capital Costs	5	4	1	3	3	2
Operational Costs	4	5	1	3	3	2
Subtotal	**9**	**9**	**2**	**6**	**6**	**4**
TOTAL	**64**	**62**	**34**	**46**	**46**	**45**
Options Ranking	**5**	**5**	**1**	**3**	**3**	**2**

3.8 Selection of Preferred Option

Based on the results of the 2014 Options Study, the preferred option for the long-term management of tailings at the McClean Lake Operation remains the expansion of the existing JEB TMF due its environmental, operational and economic advantages. Specifically, an expansion to the JEB TMF:

- will provide sufficient capacity for the storage of all of the current predicted tailings production forecast;
- uses existing disturbed areas and does not substantively increase the footprint of tailings management activities on-site whereas the PBTMF would essentially replicate the spatial footprint of the existing TMF;
- uses existing site infrastructure, whereas the PBTMF requires additional infrastructure (e.g., new roads, additional WTP, and expanded waste rock pile);
- there is 16 years of proven operational experience and performance monitoring data available for the JEB site groundwater system and the JEB TMF, which provide an increased level of confidence that the JEB TMF can be expanded with the long-term performance of the facility continuing to satisfy regulatory requirements;
- will use the same construction and containment techniques that were approved for the JEB TMF Optimization Project (AREVA 2010b), including sloped walls and placement of a processed waste rock/till bentonite amended liner; and
- is within close proximity to the McClean Lake Mill.

The JEB TMF is currently approved for a consolidated top of tailings elevation of 434 mASL, allowing placement of tailings to 439 mASL. Expanding the JEB TMF to allow for the deposition of tailings to an elevation of 452 mASL, which will consolidate to an elevation of 448 mASL, will provide sufficient storage for all of the currently forcasted tailings production for the McClean Lake Mill.

The PBTMF and the conversion of Sue pits remain viable options for further consideration should the need for additional tailings storage capacity be identified in the future.

3.9 Assessment of Sensitivity

Both options studies considered environmental, technical and operational, and cost aspects of alternatives increase tailings storage capacity. Multiple variables within each aspect were considered independently and then summed to provide a final score for each aspect. Neither variables or aspects were weighted.

The preferred option of JEB TMF Expansion with a reduced scope scored most favourably in all aspects of the 2014 Options Study. The widest margin between the next closest option is apparent in the environmental aspect where almost all variables were scored more favourably. From an environmental standpoint, the preference of the JEB TMF Expansion (reduced scope) option is considered insensitive to minor scoring changes within the variables or the imposition of variable weighting within the aspect. Additionally, the preference is insensitive to cost, i.e. it remains the preferred option with financial aspects taken out of competition.

Given the JEB TMF Expansion (reduced scope) option, in the professional judgement of a multifunctional review team, was considered to be preferred from environmental, technical and operational, and financial standpoints, further trade-off analysis was not considered necessary for decision making.

4 Project Description

4.1 JEB TMF Expansion Overview

The Project builds on the design criteria and analyses completed as part of the JEB TMF as it was originally designed, as well as the optimization activities associated with the approved JEB TMF Optimization Project (AREVA 2010b). Expansion of the JEB TMF involves increasing the elevation of stored tailings above the current approved elevation for consolidated tailings of 434 mASL. The predictions of the environmental performance incorporate the knowledge acquired during the operation of the McClean Lake Mill and JEB TMF. AREVA's objective in the development of the Project is to optimize the storage of tailings within the existing JEB TMF environmental footprint, including meeting CWQG and SSWQO in Fox Lake and Pat Lake in the long-term.

As stated in Section 1.3, the scope of the Project includes the following:

- construction of an embankment around a portion of the JEB TMF perimeter to bring the low side elevation up from 448 mASL to 457.5 mASL and placement of a processed waste rock/till bentonite amended liner to contain the operating pond throughout operations;
- continued placement of tailings into the expanded JEB TMF above the till/sandstone contact;
- construction of two new waste rock runoff ponds;
- relocating infrastructure affected by the Project footprint (e.g., power lines, tailings barge and anchor points, tailings lines, reclaim water lines, tailings delivery pipe line, and under flow pump);
- relocating the temporary contaminated landfill (under separate notification)
- decommissioning of dewatering wells and monitoring wells affected by the Project footprint, and installation of new monitoring wells (under separate notification); and
- decommissioning of the JEB TMF and placement of a soil cover incorporating a proposed waste rock/till bentonite amended layer to limit infiltration.

To achieve an expanded storage volume within the JEB TMF, an embankment will need to be constructed around a portion of the pit perimeter. A processed waste rock/till bentonite amended liner will also be placed along the flattened embankment slopes and inside the pit walls in the till formation to contain pond waters throughout operation of the JEB TMF. This liner will be a continuous extension of the liner used for the JEB TMF Optimization Project

(AREVA 2010b). A conceptual cross-section through the proposed expanded JEB TMF is presented in Figure 4.1-1.

The TOVP, including periodic local groundwater flow model updates, will remain as an ongoing program for evaluating the JEB TMF performance, and will include monitoring the results of this Project. In addition, periodic updates to the Hydrogeology and Groundwater Modelling TID (AREVA 2011b) and the Environmental Performance TID (AREVA 2012), in addition, the implementation of the McClean Lake Operation EMP will continue for this Project. A monitoring program component will feature the use of test cover plots to support predictions of post-decommissioning cover performance.

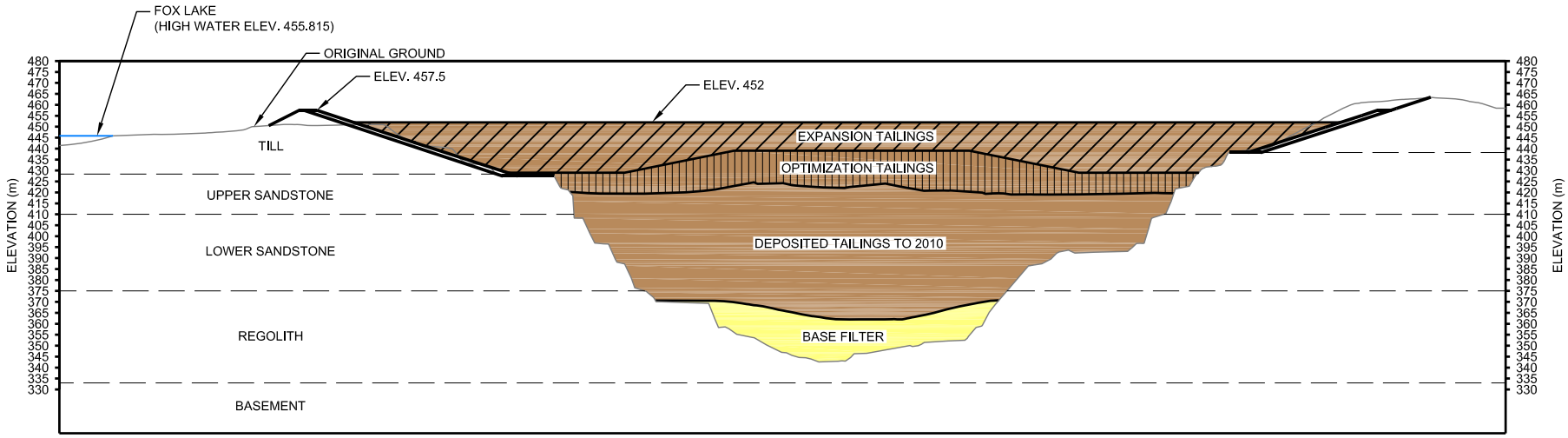
The height of the embankment required for the proposed Project varies from 0 m on the east side to 7.5 m on the west side of the JEB TMF. Based on this configuration, approximately 1.7 million m^3 of additional tailings can be stored within the expanded JEB TMF, while maintaining up to a 4 m water cover over the tailings mass, a 1 m freeboard to the embankment crest, and a 0.5 m allowance for storage of a PMP storm event during the operation period. It is estimated that this embankment configuration can expand the useable life span of the existing JEB TMF for approximately 18 years, based on current mining predictions.

Storage for site runoff that exceeds the capacity of the existing site runoff pond is provided by the existing JEB TMF through gravity drainage. Clean runoff from the JEB Waste Rock Pile will be stored separately in a waste rock pile runoff pond and diverted into the JEB TMF, to the mill or the JEB WTP. ..

A soil cover system consisting of processed waste rock/till bentonite amended layer will be installed as part of decommissioning of the JEB TMF. The soil cover system will also provide a sustainable landform configuration and drainage system for the decommissioned JEB TMF. During placement of the soil cover system, it is predicted that the tailings will consolidate to an elevation equal to the ground surface on the high side of the existing JEB TMF (448 mASL). In addition, the downstream side of the embankment slopes will be flattened during construction of the soil cover system to maintain stable slope conditions after the decommissioning period.



Figure 4.1-1: Conceptual Cross-Section through the Proposed Expanded JEB TMF



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4.2 JEB TMF Expansion Design and Construction

The development of the Project will consist of design and construction of an embankment, processed waste rock/till bentonite amended liner system, and reconfiguration of site infrastructure to support an expanded JEB TMF. These primary components are discussed in more detail below.

4.2.1 Embankment Design

The primary considerations in the design of the JEB TMF embankment are slope stability and pond containment throughout operations. Field investigation and material characterization completed for the JEB TMF Optimization Project (AREVA 2010b) were used for the preliminary design of the embankment and pond containment system for the Project. A summary of the field investigation and material characterization, as well as the design parameters developed for the embankment are discussed in the following sections.

4.2.1.1 Field Investigation and Material Characterization

A field investigation and material characterization program was completed in 2009 as part of the JEB TMF Optimization Project (AREVA 2010ba). Additional field and laboratory tests have been completed during the construction of the stage 1 of JEB TMF Optimization (Golder 2012a). The general stratigraphy encountered in the JEB TMF area, in descending order, includes the till; upper sandstone; lower sandstone; basement regolith; and intact basement (Figure 4.1-1). The thickness of the till around the perimeter of the JEB TMF ranges between 10 m and 28 m.

A laboratory testing program was completed to characterize material properties for consideration as potential construction materials. This program was completed to confirm that these materials meet the geotechnical requirements as determined by pit and embankment slope analyses and the requirements of the pond containment system. Laboratory tests were completed on samples at four stages of processing:

1. the original samples collected during the drilling and test pitting programs;
2. composite till materials;
3. crushed sandstone waste rock (processed in the laboratory); and
4. bentonite amended till and bentonite-amended crushed sandstone.

Laboratory tests completed to characterize the soil and crushed rock material included natural water content, specific gravity, Atterberg limits, grain-size analysis, standard proctor compaction, triaxial hydraulic conductivity, freeze-thaw triaxial hydraulic conductivity, soil-water characteristic curve, direct shear, triaxial compression, and collapse potential testing.

The characterization of potential liner materials was initially completed for the till and sandstone available on-site. The results of these tests indicate that without any amendment, neither screened till or crushed sandstone would provide a hydraulic conductivity that would effectively contain pond water within the JEB TMF. Therefore, the laboratory test program was expanded to characterize bentonite-amended till and bentonite-amended crushed sandstone. The test results indicate that either blended bentonite amended crushed sandstone, or bentonite amended screened till can be used as a liner material for the JEB TMF.

A soil-bentonite liner test pad program was completed as part of the Optimization Stage 1 construction. Field and laboratory test results for the soil bentonite liner associated with test pad construction are presented in Golder (2013a). Based on the results of the materials characterization program it is concluded that both the geotechnical properties of the crushed sandstone and till perform similar with addition of bentonite. The results of the freeze thaw testing indicate that the hydraulic conductivity of both the amended till and amended crushed sandstone samples would decrease after the first freeze-thaw cycle and only change slightly after subsequent freeze-thaw cycles.

A soil bentonite liner for Optimization Stage 1 was successfully constructed in 2013. Field and laboratory tests conducted as part of the construction Quality Assurance/Quality Control (QA/QC) program are documented in Golder (2013b). The construction of the test pad demonstrated the effective methodology to be used for full scale liner construction, as well as highlighting methodologies that would not be effective. Nuclear density tests allowed for the estimation of the required compaction effort to achieve the required percent compaction, and in-situ and laboratory hydraulic conductivity tests demonstrated that the required hydraulic conductivity of less than $1x10^{-9}$ m/s could be achieved.

4.2.1.2 Slope Stability

Based on the material characteristics determined by the investigations outlined above, slope stability analyses were performed on the preliminary embankment design and proposed processed waste rock/till bentonite-amended liner. The analyses were completed using GeoStudio 2007 computer software (Geo-Slope International Ltd. 2007). Pore-water pressure conditions in the slope, which were required for the stability analyses, were analyzed using a two-dimensional finite element, steady state seepage model. The slope stability analyses were performed using the Morgenstern Price limit equilibrium method with a half-sine interslice force function. The stability conditions of the embankment slopes were analyzed using both a deterministic approach and a probabilistic approach. Details of the slope stability analyses and the results of the analyses are presented in Appendix A.

Ground surface topography of the existing JEB TMF area was obtained from a contour plan based on a high resolution Light Detection and Ranging (LiDAR) survey of the site, which was completed in July 2009. The hydraulic parameters and shear strength parameters were based on previous investigations and the results of the 2009 laboratory testing program to date (Golder 2009a, 2013a, 2013b).

In deterministic slope stability analysis, soil parameters such as unit weight, effective friction angle and effective cohesion are assumed to have a single, unique value. The analysis result is a single factor of safety for each trial slip surface. A deterministic slope stability analysis was used to assess the stability conditions of various embankment slope geometries around the JEB TMF at the end of construction and for operating conditions.

The US Army Corps of Engineers (2003) recommended the minimum acceptable deterministic factors of safety for embankment slopes based on design practices developed and successfully employed by the Corps of Engineers over several decades. The recommended minimum factor of safeties for new earth and rock-fill dams are summarized in Table 4.2-1 for various types of slopes and analysis conditions. Typical minimum acceptable values of factor of safety are 1.3 for end of construction and multistage loading (i.e., short term condition); and 1.5 for normal long term conditions. These values are the same as those recommended by the Canadian Dam Association (2007). The Canadian Dam Association (2007) recommended a minimum factor of safety of 1.3 for end of construction conditions, for both an upstream slope and a downstream slope. A minimum factor of safety of 1.5 was recommended for long term conditions, downstream slope.

A minimum factor of safety of 1.5 was used to assess the stability condition of the slopes for the JEB TMF Expansion Stage 1 Project. The stability of the slopes were further analysed and evaluated using a probabilistic slope stability approach (i.e., reliability analysis) to account for potential variability of materials. The results of the reliability analysis provide additional insight into appropriate factors of safety and are necessary for remediation.

Table 4.2-1: Minimum required factors of safety: new earth and rock-fill dams (US Army Corps of Engineers 2003)

Analysis condition	Required minimum factor of safety	Slope
End-of-construction (including staged construction)	1.3	Upstream and downstream
Long-term (steady seepage, maximum storage)	1.5	Downstream
Rapid drawdown	1.1 – 1.3	Upstream

Deterministic analyses were conducted to assess the stability of the slopes for two representative cross sections. The analyses were completed for end of expansion construction conditions and end of operations at Cross Section A-A' located on the west side of the JEB TMF), and end of expansion construction conditions at Cross Section B-B' (located on the east side of the JEB TMF adjacent to the Raise Pump house).

The deterministic factor of safety for the 3H:1V upstream slope at end of construction conditions is 1.98 for Cross Sections A-A'. The factor of safety for upstream slopes at Cross Section B-B' of 2.0H:1V, 2.3H:1V and 2.5H:1V was 1.64, 1.83, and 1.95, respectively.

The deterministic factor of safety for the downstream slopes ranged from 1.26 to 2.86 for slopes ranging from 1.5H:1V to 4.0H:1V at Cross Section A-A'.

It is expected that the factor of safety for the upstream slope where the liner will be placed will increase with time as tailings are deposited against the slope. Results of the deterministic analysis are presented in Table 4.2-2.

Downstream slope of 2.0H:1.0V or flatter would provide a deterministic factor of safety of more than the target value of factor of safety of 1.5. Upstream slope of 2.0H:1.0V or flatter would provide a factor of safety of more than 1.6.

Table 4.2-2: Deterministic Slope Stability Factor of Safety

Cross Section	Description	Slope	Factor of Safety
A-A'	End of Construction Conditions	3.0H:1.0V – Upstream	1.98 (1.30)
	End of Operating Conditions	1.5H:1.0V– Downstream	1.26 (0.97)
	End of Operating Conditions	2.0H:1.0V– Downstream	1.58 (1.15)
	End of Operating Conditions	2.5H:1.0V– Downstream	1.88 (1.31)
	End of Operating Conditions	3.0H:1.0V – Downstream	2.20 (1.48)
	End of Operating Conditions	4H:1.0V – Downstream	2.86 (1.76)
	No Liner	2.0H:1.0V - Downstream	1.58 (1.15)
B-B'	End of Construction Conditions	2.0H:1.0V - Upstream	1.64 (1.20)
	End of Construction Conditions	2.3H:1.0V - Upstream	1.83 (1.31)
	End of Construction Conditions	2.5H:1.0V - Upstream	1.95 (1.37)

The JEB TMF is located within the tectonically stable interior of the "Stable Canada". The seismicity in this area during the period of historical record has been very low; no natural earthquake event with magnitude M3 and larger has been recorded in the JEB Area (Adams and Halchuk 2004). The closest earthquake location with magnitude M3 to the JEB TMF site was recorded in the northeast area of Alberta, approximately 500 kilometres from the JEB TMF site.

The assessment of embankment stability for seismic loadings was conducted in accordance with the guidelines and procedures provided in the Canadian Dam Association Guidelines (2007a). The seismic coefficient corresponding to the JEB TMF location was input into the deterministic analyses to consider the effect a seismic event might have on the embankment. Conservatively estimated mean peak ground acceleration for an annual exceedance probability of 1/10,000 of 0.143 g (where "g" equals gravitational accelerations) was used.

The calculated minimum factors of safety for seismic loading conditions for an annual probability of 1/10,000 are shown in Table 4.2-1 (values shown in parentheses). A minminimum factor of safety of 1.0, recommended by the Canadian Dam Association (CDA 2007) was used for seismic assessment of the proposed embankment for the JEB TMF expansion, pseudo-static loading condition. All embankment slopes with 2.0H:1.0V slope or flatter meet the objective of achieving a minimum factor of safety of more than 1.0 for seismic loading conditions.

The probabilistic approach extends the deterministic factor of safety concept to explicitly incorporate uncertainty in the parameters (US Corp of Engineers 1999). This uncertainty can be quantified through statistical analysis of existing data or it can be assigned using engineering judgement. In the probabilistic slope stability analysis, uncertain parameters were treated as random variables, with a range of values defined by a probability density function. These random variables can be used in the probabilistic analysis to estimate the mean factor of safety and its standard deviation, probability of unsatisfactory performance and reliability index. The probability of unsatisfactory performance is the statistical likelihood that an adverse condition (including non-catastrophic events and maintenance items) will occur. The reliability index indicates how many standard deviations that the mean factor of safety is distanced from unity. There is no direct relationship between the deterministic factor of safety and the probability of unsatisfactory performance or the reliability index.

The probabilistic analysis of a slope is useful for assessing the likelihood of slope failure in addition to the factor of safety. The mean factor of safety and the reliability index are two useful indices that can be used to quantify the stability condition or the likelihood of failure of a slope. Embankments with relatively high reliability indices are expected to perform well. Embankments with low reliability indices are expected to perform poorly and present major maintenance problems. If the reliability indices are very low, the embankment may be classified as a hazard.

Detailed parametric slope stability analyses were completed as part of the TMF Optimization Project (Golder 2009a). The parametric analyses identified that the stability condition of the TMF till slopes are sensitive to both the effective friction angle and suction angle of the till. Probabilistic analyses for expansion of the TMF were therefore conducted considering the variability of the effective friction angle, φ' and the suction angle, φ^b of the till. The effective friction angle of the liner material will be well defined due to the nature in which it is processed and the quality assurance program in place during construction. As such variability in shear strength properties of the liner material was not considered for the probabilistic analysis.

A mean factor of safety of 2.23, and a reliability index 5.16 were calculated for the 3H:1V upstream slope at Cross Section A-A'. A mean factor of safety ranging from 2.02 to 2.36 and a reliability index ranging from 5.13 to 6.01 was calculated for the upstream slope at Cross Section B-B' for slopes ranging from 2.0H:1V to 2.5H:1V.

A mean factor of safety between 1.54 and 3.43, and a reliability index between 3.48 and 6.87 were calculated for downstream slopes ranging between 1.5H:1V and 4.0H:1V at Cross Section A-A'.

Table 4.2-3 presents a summary of the results of probabilistic analyses for Cross Section's A-A' and B-B'.

A downstream slope of 2H:1V would have a mean factor of safety of 1.92 and a reliability index of 4.65. The minimum and maximum calculated factors of safety are 1.49 and 2.5, respectively. The 2:0H:1V slope meet the objective of achieving a reliability index of more than 2.5.

A downstream slope of 4H:1V would have a mean factor of safety of 3.43 and a reliability index of 6.87. The minimum and maximum calculated factors of safety are 2.57 and 4.35, respectively.

Monitoring and maintenance activities will be required during operation to control potential surficial erosion of the embankment slope, which may affect the slope stability (Section 6).

4.2.1.3 Pond Containment

Pond containment for the expanded JEB TMF will be provided by the same liner system (soil-bentonite liner) as was used for stage 1 of the JEB TMF Optimization Project. A summary of the results of the numerical evaluation of the liner for the expanded JEB TMF is presented in this section. Detailed results of the liner analysis are presented in Appendix B.

The primary purpose of the liner system is to provide containment of the JEB TMF pond water above the sandstone contact throughout operations.

It is concluded that, based on the results of the materials characterization program, both the sandstone waste rock and till materials perform similarly as an aggregate base with bentonite addition. The results of the freeze thaw testing indicate that the hydraulic conductivity of both the amended till and amended crushed sandstone samples would decrease after the first freeze-thaw cycle and changed only slightly after the subsequent freeze-thaw cycles. Due to inherent variability in the materials and the potential construction methods considered for the liner placement, to achieve a hydraulic conductivity of 1.0×10^{-9} m/s or less, a bentonite addition of 5% is recommended for the amended liner materials.

Numerical finite element analyses were carried out to evaluate the hydraulic performance of the potential liners with varying thicknesses. As tailings are deposited in the JEB TMF; the tailings

elevation is continuously raised and the pond water is raised in discrete steps. The deposition process was modelled using a transient seepage analysis. Two performance factors were considered:

- location of a wetting front in the liner during operations; and
- flux of tailings water through the liner during operations.

The desired performance is to prevent the wetting front from passing through the base of the liner during operations. The analyses were focused on the liner location and soil area adjacent to the liner.

Table 4.2-3: Results of Probabilistic Analyses

Cross Section	Description	Slope	Mean FS	Reliability Index	Standard Deviation	Minimum FS	Maximum FS
A-A'	End of Construction Conditions	3.0H:1.0V – Upstream	2.23	5.16	0.239	1.68	3.06
	End of Operating Conditions	1.5H:1.0V– Downstream	1.54	3.48	0.156	1.21	2.02
	End of Operating Conditions	2.0H:1.0V– Downstream	1.92	4.65	0.196	1.49	2.5
	End of Operating Conditions	2.5H:1.0V– Downstream	2.25	5.39	0.232	1.76	2.95
	End of Operating Conditions	3.0H:1.0V – Downstream	2.62	5.93	0.273	2.04	3.43
	End of Operating Conditions	4.0H:1.0V – Downstream	3.43	6.87	0.354	2.68	4.5
	No Liner	2.0H:1.0V - Downstream	1.91	4.61	0.198	1.49	2.51
B-B'	End of Construction Conditions	2.0H:1.0V – Upstream	2.02	5.13	0.199	1.56	2.69
	End of Construction Conditions	2.3H:1.0V – Upstream	2.26	5.52	0.228	1.73	3.02
	End of Construction Conditions	2.5H:1.0V – Upstream	2.36	6.01	0.226	1.85	3.09

Note: a reliability index of at least 2.5 is required for the JEB TMF embankment slope
FS = factor of safety

The analyses were completed to evaluate the estimated location of the wetting front and the effect of various input parameters to the calculated flux through the liner. The analysis result would help in the evaluation of a suitable liner thickness. Parametric analyses were performed for the following parameters:

- liner crest width;
- hydraulic conductivity of liner material;
- hydraulic conductivity of till;
- hydraulic conductivity of upper sandstone;
- the hydraulic head function at the base drain;
- groundwater recharge at ground surface; and
- hydraulic conductivity of lower sandstone.

The analysis results are consistent to those conducted for the JEB TMF Optimization Stage 1 project. Based on the analysis, the following conclusions can be made regarding the soil liner thickness and calculated flux through the liner:

- A liner is required to contain pond water during operations of the proposed JEB TMF expansion.
- For a hydraulic conductivity of 1x10-9 m/s, a liner crest width of 4 m (or 1.3 m thick) would limit the wetting front in the liner and result in sufficiently low flux (less than 15% compared to the unlined conditions) through the liner during the JEB TMF Expansion Stage 1 operations. A crest width of 6 m (or 1.9 m thick measured perpendicular to a 3H:1V side slope) is recommended for constructability on a general 3H:1V slope and a 2.3H:1V slope on a localized area at the raise well pump house location.
- With the same liner thickness, the saturated hydraulic conductivity of the liner has the most significant effect in the calculated flux through the liner. The effect in the calculated flux for the liner with a hydraulic conductivity of 1x10-10 m/s or less appears to be insignificant, but there is a proportional increase in the calculated flux when the hydraulic conductivity is larger than 1x10-9 m/s.
- With the same liner thickness, the saturated hydraulic conductivity of surrounding till and hydraulic head set at the base filter drain, the groundwater recharge on ground surface, the hydraulic conductivity of sandstone, and the hydraulic head in till and sandstone at a distance from the JEB TMF have an insignificant effect to the calculated flux through the liner.

A pond wave analysis was also conducted to calculate the freeboard requirement and determine the size and thickness of a rip rap layer required to protect the liner slope from wave action.

The following conclusions were made regarding freeboard requirement and liner protection:

- a freeboard of 1 m would be sufficient; and
- a rip rap layer of 0.5 m thick, a mean diameter of approximately 0.26 m would be sufficient to provide erosion protection for the liner material.

An instrumentation program to monitor the performance of the embankment and liner system during operation is proposed for the JEB TMF Expansion and is presented in Appendix B.

4.2.2 Affected Infrastructure

4.2.2.1 Site Water Management

The current surface water management plan for PMP storage at the JEB site consists of overland flow of PMP runoff from the mill terrace and the waste rock pile into the JEB TMF. Runoff from the mill terrace can continue to be stored in the JEB TMF and Runoff from the JEB Waste Rock Pile will be stored separately in an expanded waste rock pile runoff pond.

Major precipitation events have the potential to affect the Project; therefore, the facilities that comprise the McClean Lake Operation are typically designed to withstand major precipitation events. For example, at the McClean Lake Operation, the design of contaminated water holding structures to accommodate extreme precipitation events (1 in 50 year storm event) is required to prevent the inadvertent release of deleterious substances to receiving waters. The water management plan for the JEB site, inclusive of the proposed Project was developed based on a LiDAR survey completed in 2009 and considered the discharge criteria provided by SMOE (2000) for runoff management. The estimated PMP for the McClean Lake Operation is 466 millimetres (mm) over a 24 hour period (Hopkinson 1994)[1]. Figure 4.2-1 shows the delineated drainage areas for the reconfigured JEB site. Area 1 is the contributing drainage area for the mill terrace reporting to the JEB TMF. Site runoff from Area 2 reports to a section of ditch that flows counter clockwise to the JEB Waste Rock Pile Runoff Pond on the west side of the waste rock pile. Site drainage from Area 3 reports to a section of ditch that flows clockwise to the JEB Waste Rock Pile Runoff Pond on the west site of the waste rock pile. Table 4.2-4 provides delineated drainage areas and the volume of PMP runoff for the reconfigured JEB site.

[1] Methodologies for the calculation of probable maximum precipitation are the matter of some debate. The PMP of 466 mm for McClean Lake reported by Hopkinson (1994) is higher than the 245 mm reported by Hogg and Carr (1985). The value reported by Hopkinson has conservatively been used in the design of the TMF and delineated drainage areas.

Table 4.2-4: Estimated PMP Runoff Volumes for Contributing Drainage Areas

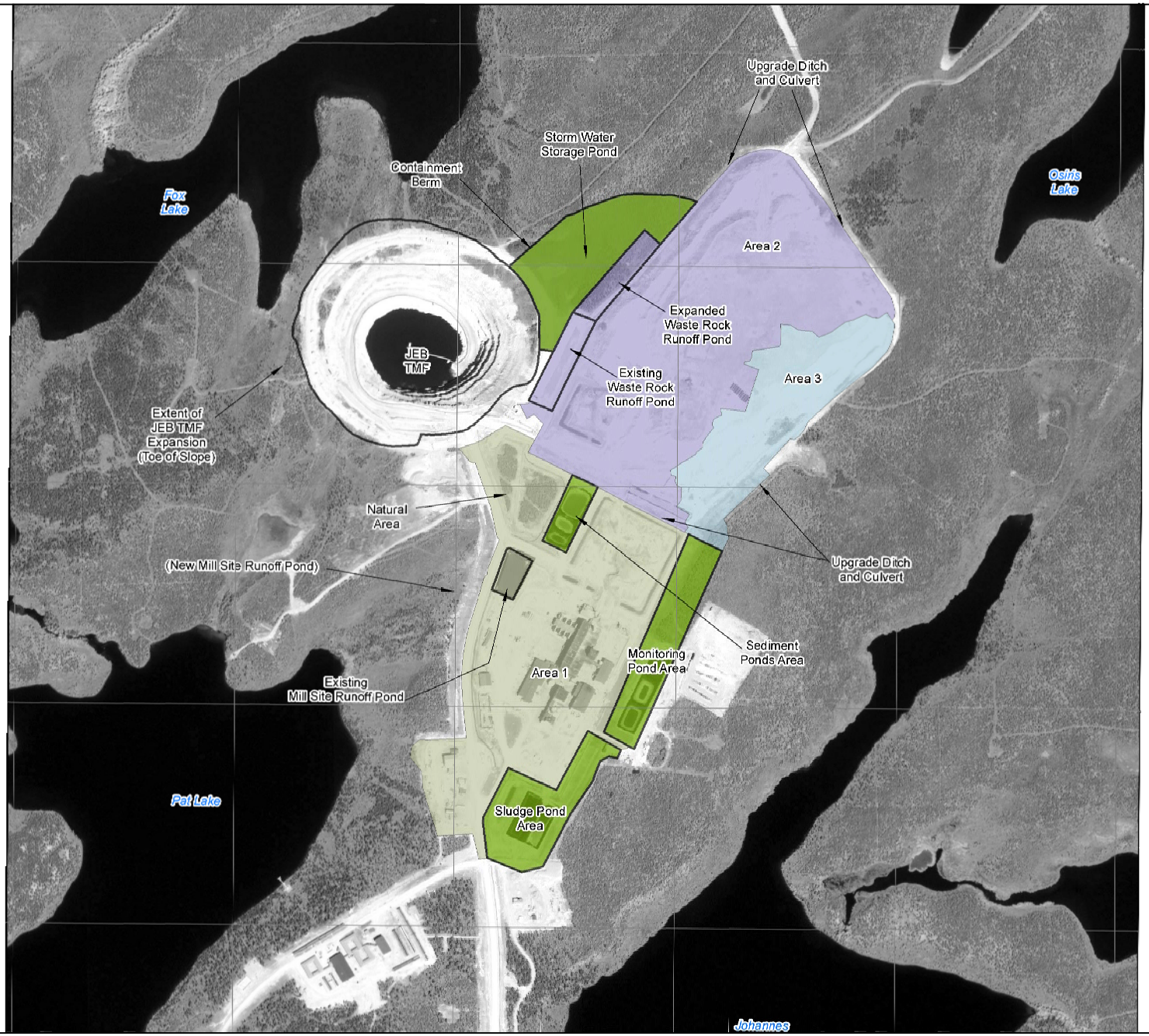
Description	Drainage Area	Area (m^2)	Volume (m^3)
Temporary Storage Areas	Sediment Pond Area	9,760	4,600
	Monitoring Pond Area	39,880	18,600
	Sludge Pond Area	41,980	19,600
JEB TMF	JEB TMF	193,000	89,900
Waste Rock Pile (west side) plus Runoff Pond and Storm Water Storage Pond	Area 2	377,774	176,000
Waste Rock Pile (east side)	Area 3	102,767	47,900

In this new configuration all runoff from the JEB Waste Rock Pile is redirected to dedicated runoff containment ponds, avoiding any mixing with runoff from the mill terrace.

Runoff from Area 2 and Area 3 (i.e., from the waste rock pile) will be stored in the expanded JEB Waste Rock Pile Runoff Pond and in the Storm Water Storage Pond (Figure 4.2-2). The capacity of the existing JEB Waste Rock Runoff Pond will be expanded to 32,000 m^3 to contain runoff from the waste rock pile resulting from a 1:100 year precipitation event. Runoff from precipitation events with a return interval greater than 1:100 years, up to and including the PMP event, will fill the expanded JEB Waste Rock Pile Runoff Pond and then report to the Storm Water Storage Pond. The Storm Water Storage Pond will be configured by constructing of an earth fill berm to obstruct surface water runoff from the waste rock pile from draining to Fox Lake. An armored spillway from the Waste Rock Pile Runoff Pond to the Storm Water Storage Pond will be provided. Upgrading of the existing ditches and culvert crossings around the waste rock pile to convey PMP runoff will also be necessary.

The storage capacity of the ponds will be restored after runoff events by pumping to either the JEB TMF or the Sink/Vulture Treated Effluent Management System (S/V TEMS).

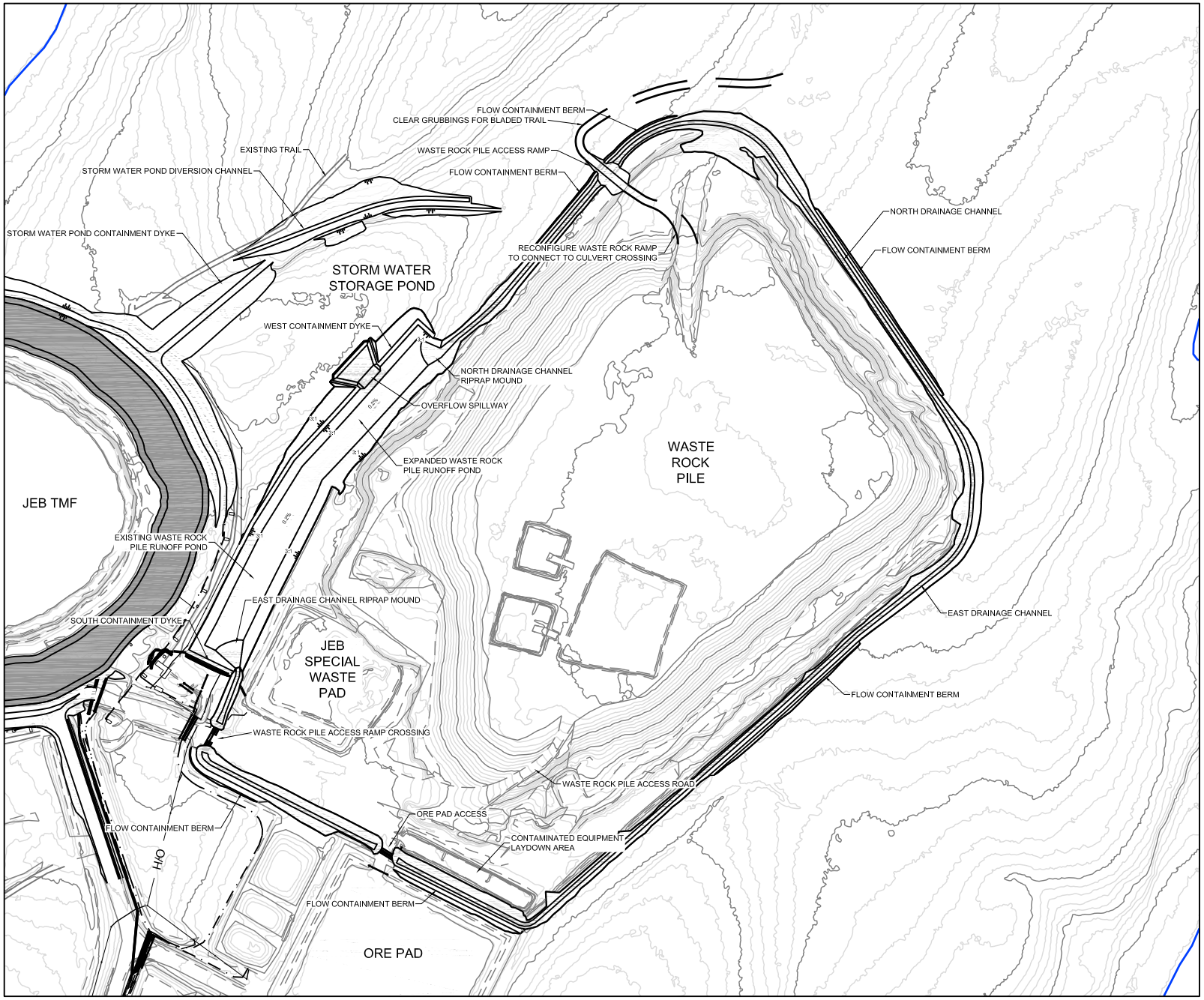
Figure 4.2-1: Drainage Areas for Surface Water Management Infrastructure



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Figure 4.2-2: Arrangement of Surface Water Management Facilities for Waste Rock Pile



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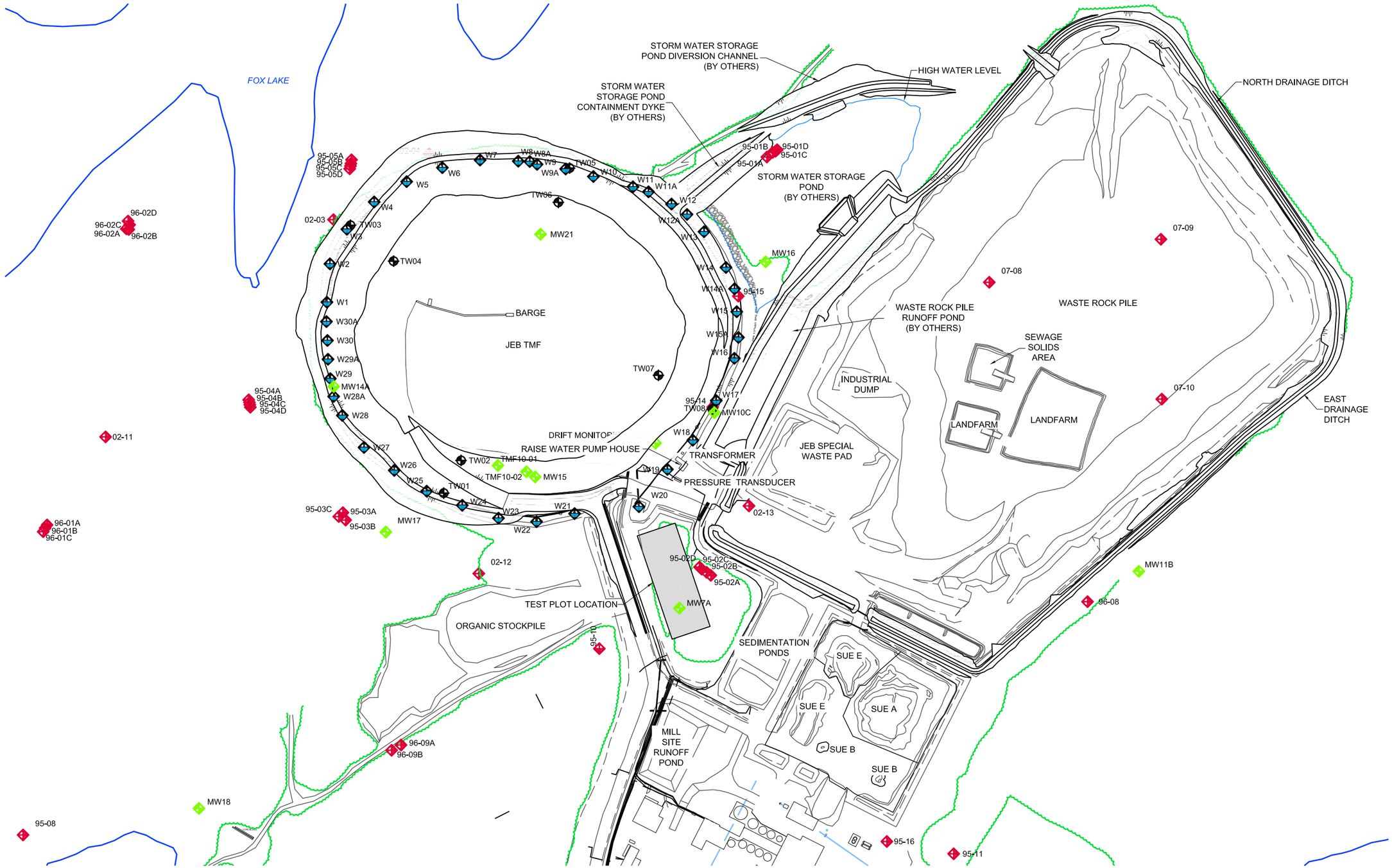
1417371			FIGURE 4.2-2
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4.2.2.2 JEB Dewatering Wells and Monitoring Wells

Figure 4.2-5 shows the location of perimeter dewatering wells and monitoring wells currently installed in the vicinity of the JEB TMF. Perimeter dewatering wells were initially installed to maintain hydraulic containment, which prevents the outward migration of COPCs, as well as to intercept and divert clean groundwater entering the JEB TMF which reduced the amount of water requiring treatment and controlled water levels within the JEB TMF. As water levels were increased in the TMF, the dewatering well pumps were raised and are now above the level of the groundwater and therefore are no longer required to control the JEB TMF pond water level or maintain hydraulic containment, hydraulic containment is now achieved through pumping of the base drain.

There are estimated 33 monitoring wells (including piezometers and trend monitoring wells) present in the vicinity of the JEB TMF These wells and their associated pipes and electrical will require decommissioning prior to the construction of the embankment. Decommissioning of the wells will be conducted under a separate application and the monitoring wells will be replaced at locations outside of the embankment footprint.

Figure 4.2-5: Locations of Existing Dewatering Wells and Monitoring Wells



LEGEND

- DEWATERING WELL LOCATION
- TREND MONITORING WELL LOCATION
- PIEZOMETER LOCATION
- MONITORING WELL LOCATION

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1417371			FIGURE 4.2-5
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4.2.3 Other Infrastructure

Infrastructure affected by the construction of the JEB TMF Expansion Project will also include the following:

- the tailings lines entering the JEB TMF will require temporary relocation during the construction of the embankment and access ramp;
- the half round culvert on the southeast side of the JEB TMF will require decommissioning prior to construction of the TMF Expansion Project; and
- the existing drainage culverts at the southeast side of the JEB TMF will require removal prior to construction of the overflow spillway.

The existing temporary contaminated material landfill will require relocation prior to the construction of the embankment; this activity is associated with a separate project and approval process.

4.3 Expanded JEB TMF Operation

4.3.1 Hydraulic Containment

Hydraulic containment during operations is used to prevent the migration of COPCs from the JEB TMF. This containment was historically achieved by maintaining a hydraulic head difference between the groundwater and the tailings pond elevation. The pond water level of the JEB TMF had been maintained lower than the water table and as a result, groundwater flows towards the JEB TMF. Groundwater flows to the JEB TMF operating pond and/or base drain, where it is pumped to the JEB WTP for treatment. To date, the pond level is maintained by pumping from the reclaim barge and the base drain using the raise wells.

Hydraulic containment will continue to be maintained by pumping from the base drain to create a downward flow field, such that any egress of tailings pore water or JEB TMF pond water will flow through to the drain and be captured. The condition of hydraulic containment is maintained by establishing the base drain as a zone of low hydraulic potential in relation to the JEB TMF pond and Fox Lake. The calibrated model was used to provide predictions of groundwater inflow to the JEB TMF to maintain hydraulic containment for two expansion scenarios, representing conditions at the beginning and end of operation of the expanded JEB TMF. The head boundary conditions applied to the drain were arbitrarily selected to represent conservative values that would ensure containment of seepage from the JEB TMF by maintaining the hydraulic head in the drain below those of the JEB TMF pond and Fox Lake. In first the scenario, at the start of operations (pond at 437 m ASL), the head in the drain was set at 7 m below that of the pond. For the end of operations scenario, the head in the drain was set at 7 m below the mean water level in Fox Lake. Pumping from the reclaim barge will be at a rate sufficient to balance the inflow to the pond from tailings deposition and precipitation. Pumping

from the base drain will be increased from current rates to maintain hydraulic containment within the sandstone layer (Section 4.3.1.1).

4.3.1.1 Base Drain Pumping

Prediction of groundwater inflow to the expanded JEB TMF was completed using a numerical flow model of the JEB site developed in FeFlow (WASY Institute for Water Resources Planning and System Research Ltd. [WASY] 2009) that was calibrated to various dewatering conditions observed during the JEB TMF operation. The model was used to determine the design pumping rate from the JEB TMF raise wells that will provide adequate containment of tailings pore water during operations. Details of the groundwater model are provided in Appendix C.

This assessment included the development and calibration of a local-scale numerical model for the JEB TMF. The numerical model was used to predict groundwater inflow rates to the TMF for two operation scenarios assuming the JEB TMF is expanded to a tailings surface elevation of 452 m and to predict contaminant transport pathways from the TMF following mine closure.

The two operation scenarios included:

- Scenario 1: TMF pond level at 437 m and the hydraulic head within the drain at 430 m.
- Scenario 2: TMF pond level at 455 m and the hydraulic head within the drain at 435 m.

Overall, the inflow to the pit for these scenarios was estimated to be 3,000 m^3/day for Scenario 1 and 2,150 m^3/day for Scenario 2. The inflow to the JEB TMF in future operational scenarios was predicted to be relatively insensitive to the hydraulic conductivity of the regolith, basement and tailings material, as well as the estimated amount of recharge. However, sensitivity analysis indicated that predicted inflows to the JEB TMF are primarily influenced by the hydraulic conductivity of the sandstone, especially the assumed hydraulic conductivity of the enhanced permeability features within the sandstone, and somewhat influenced by the hydraulic conductivity of the overburden. Increasing the hydraulic conductivity of the features, as well as the regional hydraulic conductivity of the sandstone, by a factor of two resulted in a 72% increase in the predicted inflow. Increasing the hydraulic conductivity of the overburden by a factor of two resulted in a 5% increase in predicted inflow.

The uncertainty in predicted inflows for future operational pond elevations is primarily controlled by the hydraulic properties assigned for the hydrostratigraphic units and tailings, as well as the estimated recharge in the area of the JEB TMF. Consequently a sensitivity analysis was conducted where the properties assigned to these units and the recharge rates were varied and the change in predicted inflow was calculated. This analysis identified which unit has the greatest influence on future inflows, and provided an approximate measure of the uncertainty in the inflow predictions.

The inflow to the JEB TMF in future operational scenarios was predicted to be relatively insensitive to the hydraulic conductivity of the regolith, basement and tailings material, as well as the estimated amount of recharge. This is considered reasonable as the hydraulic conductivity of these units is relatively low and flow is inferred to occur predominantly through the more permeable sandstone and overburden units.

Based on the sensitivity analysis, predicted inflows to the TMF are primarily influenced by the hydraulic conductivity of the sandstone, especially the assumed hydraulic conductivity of the enhanced permeability features within the sandstone. Increasing the hydraulic conductivity of the features, as well as the regional hydraulic conductivity of this unit, by a factor of two resulted in a 72% increase in the predicted inflow.

Predicted inflows are somewhat sensitive to the hydraulic conductivity of the overburden; however, the influence of this unit is less significant the hydraulic conductivity assigned to the sandstone. Increasing the hydraulic conductivity of this unit by a factor of two resulted in a 5% increase in predicted inflow.

4.3.1.2 Water Recycle

To minimize the fresh water consumption and effluent requiring treatment, recycled water is used in the mill. The main source of recycle water is water from the JEB TMF raise well, which is pumped to the process water tank and used for leach cooling and CCD wash water. As part of continuous improvement, other recycle streams may be evaluated and implemented where practical to further reduce the fresh water consumption.

To make better use of raise water, the raise water was separated from the JEB TMF pond water. The change was managed through McClean Lake Operation's change management process for early implementation. In 2014, modifications were completed to the raise/reclaim pumping system, and the raise and reclaim water are now pumped separately to the mill. Reclaim water is treated directly in the JEB WTP and a portion of the raise water is recycled to the mill process, with excess raise water pumped to the JEB WTP for treatment.

Modelling of the groundwater flow around the JEB TMF was completed to determine the minimum flow required from the raise well to maintain hydraulic containment of the expanded JEB TMF. The recommended design pumping rate to maintain hydraulic containment during operations is approximately 125 m^3/h or 3,000 m^3/day. The required pumping flows to keep the expanded JEB TMF hydraulically contained can be used to meet the make up water requirements of the McClean Lake Mill at peak production. The expected JEB WTP feed flow is summarized in Table 4.3-1.

Table 4.3-1: Expected JEB Water Treatment Feed Flow

	Year	2016 – 2 017	2018 – 2021	2022 – 2029	2030 – 2045
WTP Feed Flow Rate	m^3/h	154	162	156	127
Daily WTP Feed	m^3/day	3,684	3,886	3,748	3,056

WTP = Water Treatment Plant; m^3/h = cubic metres per hour; m^3/day = cubic metres per day

4.4 Expanded JEB TMF Decommissioning

4.4.1 Decommissioning Approach

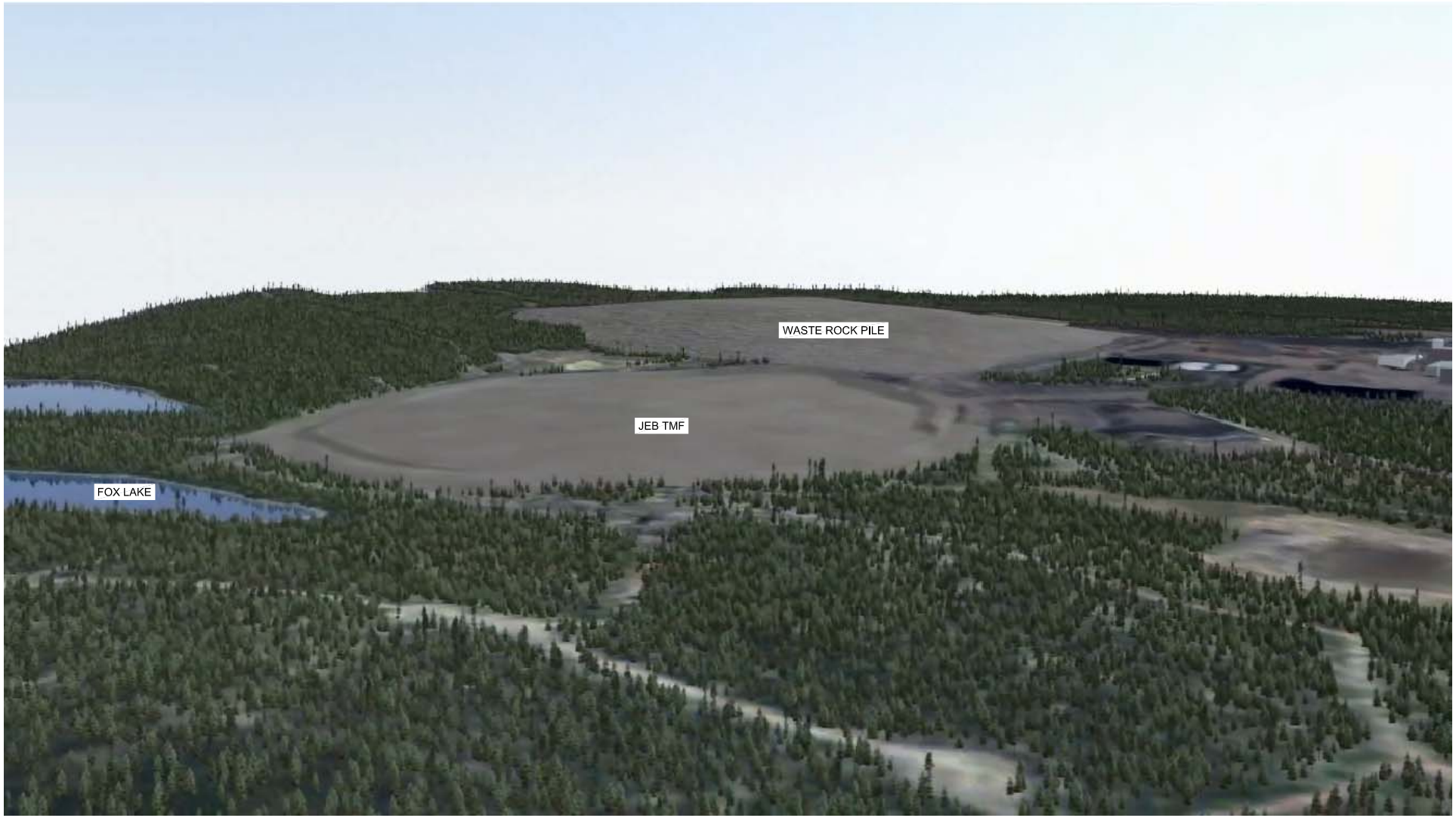
The approach, regulations, criteria, and guidelines for the decommissioning activities for the expanded JEB TMF are largely based on those presented in the existing PDP and Financial Assurance (AREVA 2016a) licence documents. AREVA's key decommissioning objective, as stated in the PDP, is to remove, reduce, and control potential COPC sources, and thereby reduce the potential for adverse environmental effects associated with the decommissioned properties (AREVA 2016a). The decommissioning plan is designed to achieve long-term conditions that will be safe for human and non-human biota, and chemically and physically stable, facilitating the ultimate return of the land to the Crown through the Provincial Institutional Control Program. The PDP was developed to reduce potential constraints on future land use planning decisions.

Security of remaining radioactive or contaminated materials will be established by removing or adequately covering these materials with local materials. For those structures that are decommissioned at the same time as the expanded JEB TMF, all salvageable materials will be decontaminated and removed from site. The deposited tailings and some other contaminated materials will be stored in the expanded JEB TMF for *in situ* confinement. The expanded JEB TMF will be capped with a low hydraulic conductivity soil cover system. The soil cover will limit the infiltration of atmospheric water to the underlying tailings and contaminated materials, thus reducing the loadings to the environment.

The end-state plan for the expanded JEB TMF will be to return lands disturbed by Project activities to a condition that is physically stable, safe, and environmentally sustaining in keeping with the land use and landscape of the day. Figure 4.4-1 provides an aerial view of the proposed decommissioned JEB TMF before vegetation. Figure 4.4-2 presents a contour plan of the proposed decommissioned JEB TMF and the waste rock pile prior to re-vegetation. At decommissioning, the tailings surface will need to be regraded in preparation for reducing the downstream slope of the embankment from operations (2H:1V) slope to the decommissioned slope (4H:1V). Figure 4.4-3 presents a typical cross section of the decommissioned expanded JEB TMF.

Due to the importance of confinement of the tailings and contaminated materials in the expanded JEB TMF, a number of engineering analyses were completed to evaluate the decommissioning approach, including the soil cover analysis (Appendix D), cover test plot design (Appendix E), groundwater flow and solute transport analyses (Appendix C), and closure landform design (Section 4.4.2.7). The results of these studies indicate that the expanded JEB TMF can be successfully decommissioned, in a manner that meets environmental regulatory criteria, by capping it with an engineered soil cover.

Figure 4.4-1: Conceptual Surface After Placement of Waste Rock



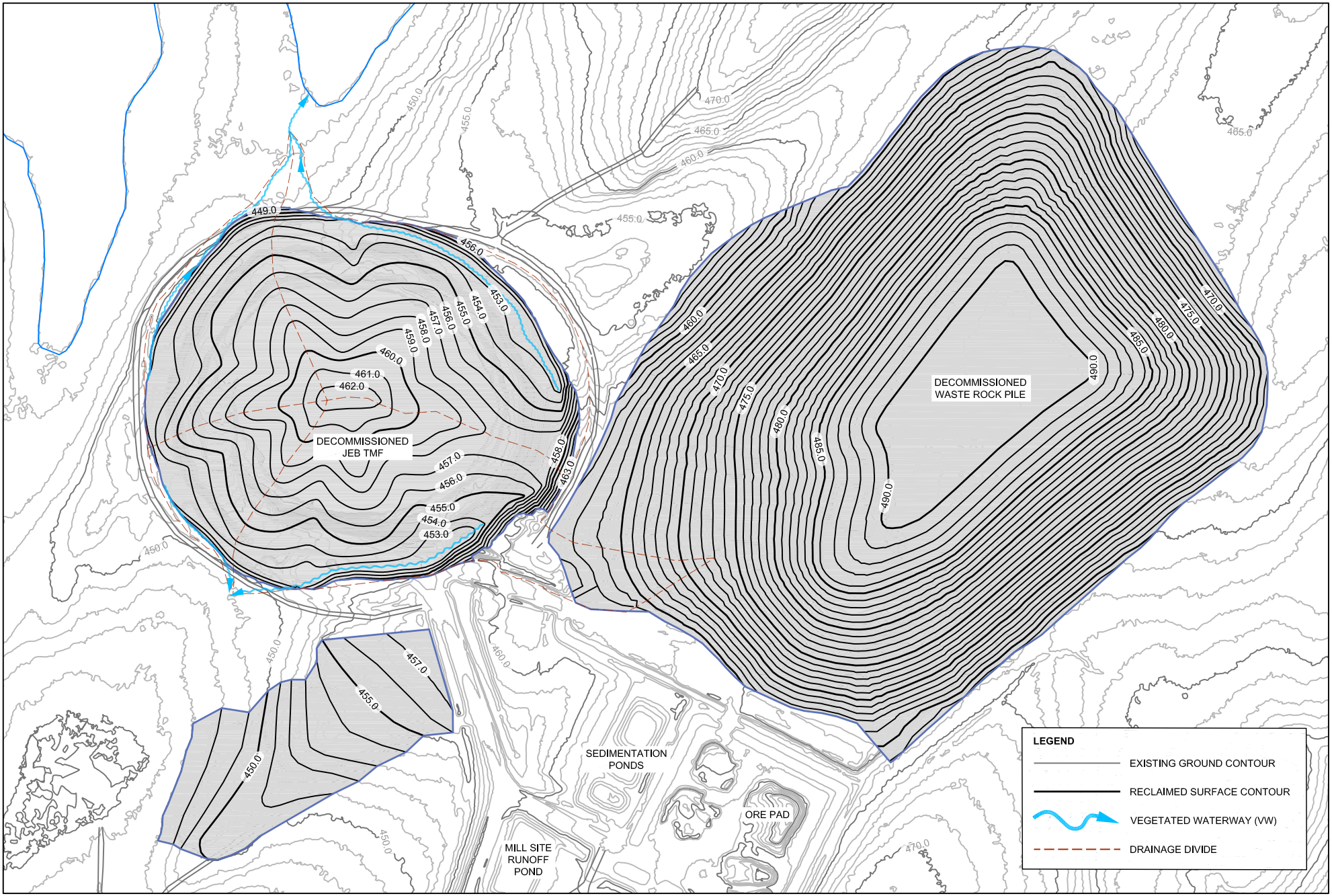
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FIGURE 4.4-1

Conceptual Surface After Placement of Waste Rock and Engineered Cover

Figure 4.4-2: Proposed Contour Plan of the Decommissioned JEB TMF ar Waste Rock Pile



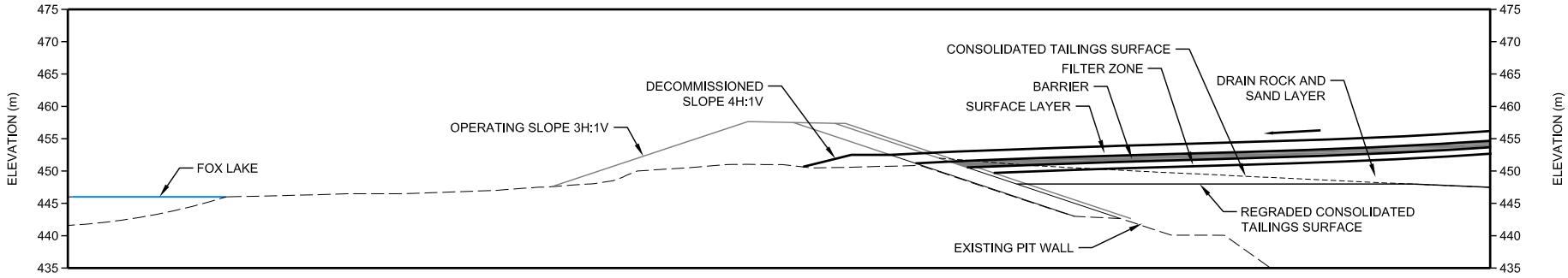
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FIGURE 4.4-2

Proposed Contour Plan of the Decommissioned JEB TMF and Waste Rock Pile

Figure 4.4-3: Typical Soil Cover Cross-Section near Fox Lake



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FIGURE 4.4-3

Typical Soil Cover Cross Section Near Fox Lake

The PDP for the expanded JEB TMF includes the following activities:

- placement of the final tailings lifts to achieve a level-to-slightly mounded tailings surface;
- progressively lowering the water cover during the last year of operations to achieve a uniform water cover sufficient for operation of the deposition barge;
- placement of a drainage sand layer to act as a working platform as well as a support filter;
- installation of instrumentation to monitor dissipation of tailings pore-pressure, temperature (of the upper tailings layer if frozen) and settlement;
- placement of a layer of drain rock over the sand layer;
- installation of a leachate collection system, consisting of corrugated metal wells, in a granular blanket within the drain rock to collect tailings water expelled during tailings consolidation;
- storage of demolition materials (if any) contaminated waste, materials from regrading of the JEB TMF downstream slope (i.e., from 2H:1V to 4H:1V), and waste rock fill;
- regrading the waste rock fill during and after the tailings consolidation, and after the tailings consolidation is complete, the excess waste rock will be relocated;
- preparation of the waste rock surface for final soil cover placement (i.e., the waste rock surface will be regraded to correspond to the shape of the final soil cover, so that each component layer of the final soil cover system can be constructed with the designed thickness);
- construction of the final soil cover system with the consideration of the closure landform of the cover; and
- installation of a post-decommissioning monitoring system to monitor cover performance.

It is expected that the decommissioning of the expanded JEB TMF could be completed within 10 years after the tailings storage capacity is reached. Time for decommissioning could be reduced by improving tailings drainage at the time of the decommissioning.

4.4.2 Environmental Performance

4.4.2.1 Tailings Characterization

Tailings source term is a key component in assessing the long-term environmental loadings from the decommissioned JEB TMF. The following sections provide an overview of the tailings

preparation process and an assessment of the long-term source term for various COPCs based on the results of TOVP program (AREVA 2015a).

4.4.2.2 Tailings Preparation

The design intent of the McClean Lake Mill was to provide operational flexibility in order to process a variety of potential ore bodies and blends. The design necessitated a robust, flexible tailings preparation process that produced environmentally acceptable tailings from a wide variety of milling waste streams and chemistries. Prior to processing ores from a particular ore body, AREVA completes an amenability study to determine the required operating parameters for the processing of the potential ore source. A key component of this study is to confirm that tailings pore water and liquid effluent quality remains consistent with that originally assessed and approved.

The current process is capable of treating an array of soluble metals, including arsenic, cadmium, chromium, lead, molybdenum, nickel, radium, selenium, uranium and zinc through reagent addition and precise control of pH and reduction-oxidation conditions. AREVA has continuously operated the JEB TMF at its McClean Lake Operation for more than a decade. In that time, the tailings preparation design has successfully demonstrated the capability to consistently treat wastes and produce tailings that are environmentally acceptable for long-term management in the tailings repository.

The key instrument for demonstrating the performance of the tailings preparation and JEB TMF performance has been the TOVP. The principle purpose of the TOVP is to monitor and confirm that the geotechnical and geochemical conditions in the JEB TMF, necessary for functional passive control of COPC release to the environment following decommissioning, are being established during the operating period. In its most recent iteration the TOVP was combined with the McClean Lake Tailings TID to provide a more comprehensive overview of the entire tailings process (AREVA, 2015a). The TOVP report may now be found as Sections 5 and 7 of the Tailings TID.

During the operational period to date, the JEB TMF has received tailings prepared from the processing of ore from five uranium deposits developed on the McClean Lake Operation surface lease, including the JEB, Sue C, Sue A, Sue E and Sue B open pit mines, as well as the Cigar Lake mine. As described in the following sections, AREVA has demonstrated the ability of the McClean Lake Mill to prepare tailings from ores with a wide range of COPC concentrations. It is anticipated that the McClean Lake Mill can reliably produce tailings of consistent quality from a variety of ore sources.

4.4.2.2.1 Tailings Source Term

Long-term solute concentrations within the tailings pore water are of importance as they represent the portion of COPCs available for transport out of the tailings mass and into the receiving environment. AREVA has undertaken numerous geochemical studies for the purpose

of predicting long-term solute concentrations within the tailings pore water. Study results of source concentrations in tailings pore water are presented in the McClean Lake Tailings TID (Section 5, AREVA 2015a). As part of these geochemical studies, detailed intrusive assessments have been completed for the tailings deposited in the JEB TMF. The most recent intrusive assessment was completed in 2013. Solid tailings and pore water samples were collected at locations and depths corresponding to strata previously sampled in 2001, 2002, 2003, 2004 and 2008 to provide insight into the aging characteristics of the tailings. The results of these studies are discussed in detail in the McClean Lake Tailings TID (AREVA 2015a).

From the data collected in the detailed intrusive assessments, volume-weighted average pore water concentrations were calculated. These calculations included a statistical analysis to remove outliers from the data set before weighting each sample by the volume of tailings it represents. The COPCs affected by geochemical aging characteristics were identified and long-term solute concentrations were selected. Geochemical aging characteristics were considered when selecting the long-term solute concentrations for arsenic, molybdenum, and uranium. For these COPCs, geochemical models were developed to estimate the long-term solute concentrations in a decommissioned JEB TMF environment. The geochemical models were developed based on detailed studies completed as part of the ongoing monitoring and research in the TOVP. Final solute concentrations used to calculate mass flux for the decommissioned JEB TMF are based on the average weighted solute concentration for each COPC.

Table 4.4-1 summarizes the final solute concentrations used to calculate mass flux for the decommissioned JEB TMF. The solute concentrations represent long-term average pore water concentrations of stored tailings based on laboratory studies, geochemical modelling, and intrusive tailings sampling. The results that have considered aging trends are highlighted. For COPCs without significant aging trends, weighted average concentrations were selected to represent respective final solute concentrations. A sensitivity case was assigned to each COPC. For COPCs that show no significant aging trends, sensitivity case concentrations are the 95^{th} percentile of the data set. For arsenic and molybdenum, the sensitivity case is the total weighted average concentration. In the case of uranium, a uranium sensitivity case concentration was chosen based on the 95^{th} percentile of bicarbonate concentration in the tailings pore water zone, where the calcite precipitation reaction appears to be in equilibrium. The geochemical properties of the tailings are not altered by the expansion of the JEB TMF capacity. Tailings will continue to be manufactured into a geochemically stable product with solute concentrations maintained at levels presented in Table 4.4-1 and as validated by the TOVP.

Table 4.4-1: JEB TMF Long-Term Solute Concentrations

Constituent	Units	Current predicted concentration based on TMF sampling	Sensitivity case concentration
chloride	mg/L	39.34	80.85
sulphate	mg/L	2009.42	2490
ammonium and ammonia	mg/L	11.72	26
arsenic	mg/L	2.37	4.38
cadmium	mg/L	0.00057	0.001
cobalt	mg/L	0.056	0.17
copper	mg/L	0.0018	0.003
lead	mg/L	0.0012	0.0026
molybdenum	mg/L	8.0	14.73
nickel	mg/L	2.03	6.09
selenium	mg/L	0.0023	0.0079
vanadium	mg/L	0.011	0.045
zinc	mg/L	0.021	0.044
polonium-210	Bq/L	0.40	1.4
lead-210	Bq/L	8.67	31.90
radium-226	Bq/L	5.31	15
thorium-230	Bq/L	0.36	0.69
uranium	mg/L	8.5	10.45

Shading indicates that results are considered to have aging trends
mg/L = milligram per litre; Bq/L = Becquerel per litre

4.4.2.3 Cover Performance

A preliminary soil cover analysis and design was completed for the Project. Detailed results of the preliminary soil cover analyses are presented in Appendix D. The soil cover design involves the development of a detailed soil-atmospheric model including geometry, material properties for individual soil layers, and a climate boundary condition based on historical weather data. The soil-atmospheric model is used to determine the preferred soil cover system and to what extent the soil cover can be expected to limit the infiltration of atmospheric water to the underlying tailings (i.e., deep percolation). The deep percolation can be converted to an average flux and applied as the surface boundary condition in long-term groundwater flow and solute transport simulations. The objective of the soil cover analyses is to design a soil cover system that will limit deep percolation of atmospheric water, and recommend a reasonable deep percolation flux to apply in long-term solute transport simulations.

The climate dataset compiled for the proposed Project includes 16 years of weather records extending over a period from 1979 to 2000. The data set includes daily values for each climatic parameter required in the soil-atmospheric simulations: precipitation, net radiation, maximum and minimum air temperature, maximum and minimum relative humidity, and wind speed. The bulk of the dataset was compiled based on weather records from AREVA's Moffat Lake weather station (located at the McClean Lake Operation) and the Environment Canada weather station located at Collin's Bay. Both of these stations are located within 20 km of the JEB TMF. The 1979-2000 record represents a reasonable length of climate record to model from and uncertaintiy is taken into account through sensitivity analyses of the key variables. More recent weather records between 2000 and 2010 contained large data gaps and were not suitable for modelling purposes.

The evaluation of potential soil cover systems was undertaken by studying a set of key variables. Some of the key variables required for this analysis include:

- thickness of each soil layer as well as the location of the groundwater table;
- saturated-unsaturated soil properties of each of the materials in the cover system;
- measured climatic conditions near to the location under consideration (i.e., precipitation, temperature, relative humidity, wind speed and net radiation);
- key dates used to partition the simulation into seasons as well as the seasons that will be simulated;
- initial conditions required for commencing the numerical modelling of thermal-moisture flow conditions;
- vegetation growth expected to develop on the cover system;
- selection of suitable runoff coefficients;
- criteria used to determine when the soil column has reached a steady state condition with the applied climatic boundary conditions; and
- selection of meaningful modelling scenarios.

The numerical modelling of the soil-atmospheric simulations was performed using the *SVFlux* software package (SoilVision Systems 2008). The soil-atmospheric simulations were used to provide the first indication regarding the anticipated soil cover performance when subject to the local climatic conditions and a range of soil properties. A multi-parameter sensitivity study was then completed to identify high priority parameters that should receive detailed consideration during the development of the design specifications for the field test plots and the final soil cover system.

A cross-section showing the different material layers within the conceptual soil cover is presented in Figure 4.4-4. Figure 4.4-5 presents the preliminary geometry and material parameters used for the baseline soil cover analyses. The geometry and soil properties for the baseline model were selected based on the results of preliminary modelling, laboratory testing results, and other practical considerations. The baseline model is made up of the first three layers of the overall conceptual soil cover including a surface layer, a barrier layer and the first layer of filter material (Figure 4.4-4). The intention was to develop a baseline model with the fewest number of layers that was still able to evaluate the primary features associated with the cover, namely:

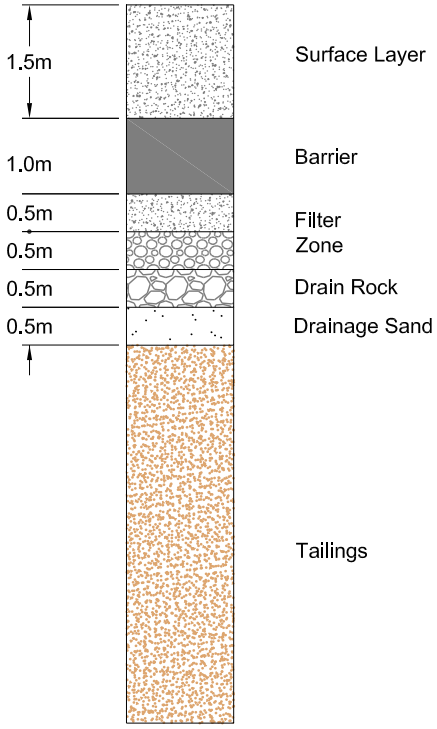
- interaction between storage, evaporation, transpiration, and runoff from the surface layer;
- the ability of the barrier layer to maintain the water near the ground surface increasing the removal of the water from the surface layer; and
- the ability to develop a capillary barrier between the barrier layer and the filter material further reducing the downward flux of atmospheric water.

The tailings, waste rock fill, and additional filter layers were incrementally added into the baseline model to develop the final design case. The minimum flux past the barrier can be evaluated as each layer is incrementally added into the numerical simulations. The following are primary considerations for the surface layer and the barrier layer based on baseline simulation results.

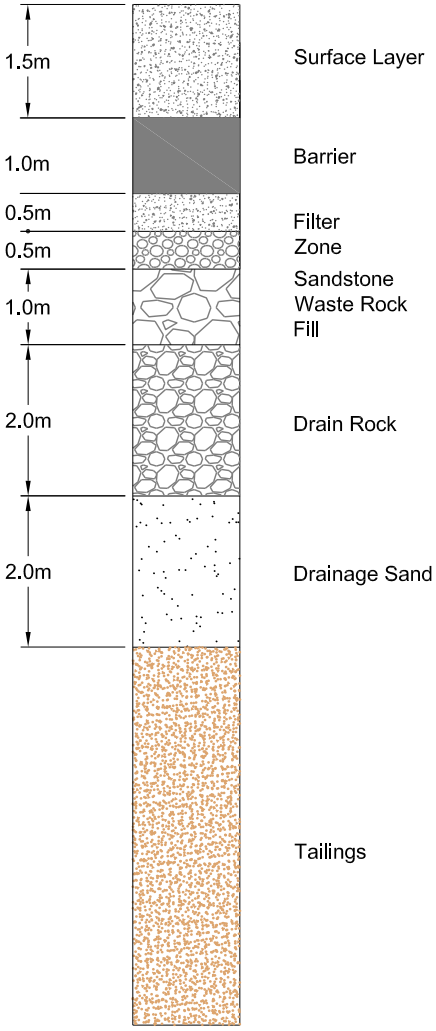
- The surface layer should consist of crushed sandstone, be elevated at a sufficient grade to promote runoff, and dressed with an appropriate growth medium to promote vegetation growth. The surface layer should be at least 1.5 m thick to protect the barrier layer against penetration from vegetation.
- The barrier layer should be designed as a mixture of crushed sandstone and bentonite and should be at least 1 m thick.

A multi-parameter sensitivity analysis was used to assess the potential uncertainty associated with the parameters specified in the baseline soil-atmospheric simulations. A series of simulations were performed where the value for one parameter was altered over a specified range using a number of increments. The relative significance of the parameter was evaluated by comparing the flux through the soil cover from each simulation to the “baseline” model. The results of the sensitivity analysis indicate that the saturated hydraulic conductivity (k_s) of the sandstone–bentonite layer (i.e., barrier layer) has an important role in the overall performance of the soil cover. Therefore, a key component of the soil cover design involves the determination of the k_s value that represents the long-term field performance of the barrier layer.

Figure 4.4-4: Cross-Section through Conceptual Soil Cover



a) Perimeter Profile

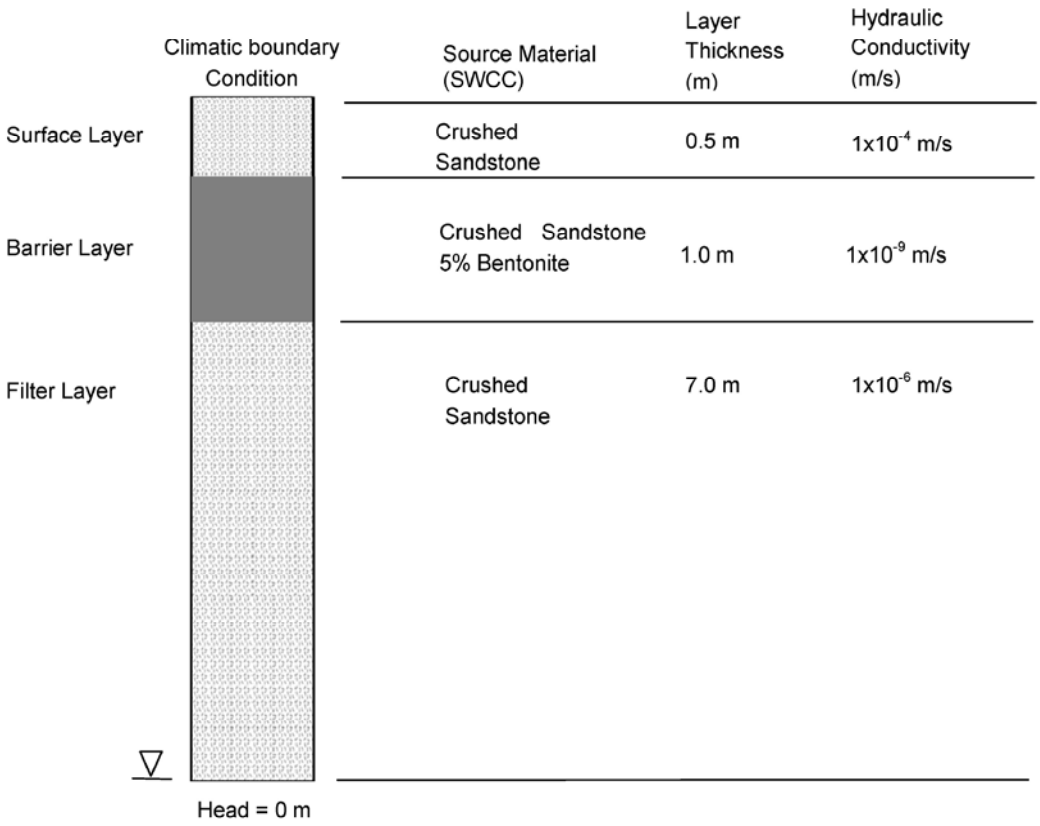


b) Maximum Profile

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Cross-Section Through Conceptual Soil Cover

Figure 4.4-5: Baseline Geometry and Modelling Parameters



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Baseline Geometry and Modelling Parameters

The long term k_s depends on the as-placed condition of the barrier layer and the susceptibility of the sandstone-bentonite mixture to environmental factors such as freeze-thaw, and wetting-drying. The 2009 laboratory test results completed on bentonite amended material for the design of the soil liner, 2010 laboratory tests conducted to optimize sand-bentonite design, and independent studies from the literature suggest that the k_s for an optimized sandstone - bentonite mixture can be as low as $1x10^{-11}$ m/s. However, a k_s value of $1x10^{-10}$ m/s was selected to represent the long-term field performance of the barrier layer for the proposed Project.

Based on the baseline modelling and the sensitivity analysis, the recommended Design Deep Percolation value through the cover into the tailings mass is 10 millimetres per year (mm/year). A "worst case" condition, in terms of the soil cover performance, is assumed to correspond to a situation where the k_s of the sandstone - bentonite barrier increase above the anticipated field k_s of $1x10^{-10}$ m/s. The "worst case" sandstone - bentonite barrier k_s value was considered to be $1x10^{-9}$ m/s, resulting in an upper bound deep percolation value of 20 mm/year.

Factors that control the initial performance of the soil bentonite cover include:

- compositional factors (e.g., including mineralogy of the material, particle size and shapes, composition, chemistry of pore water, molding water content, and organic content); and
- physical and environmental factors (e.g., including blending, method of compaction, effort of compaction, and effect of temperature and time).

The factors related to grain size distribution of parent material, molding water content, bentonite content, construction method, and effort of compaction is discussed in Appendix D. A detailed laboratory testing program was completed and a cover test plot program has been proposed to provide further understanding of these factors for the construction of the soil bentonite cover for the proposed expanded JEB TMF. The laboratory program was designed to evaluate the effects of bentonite addition higher than 5% to processed sandstone and the effects of up to 25 freeze thaw cycles on a compacted sandstone-bentonite mixture. The results of the laboratory testing program are provided in Appendix F and indicate minor improvements in measured hydraulic conductivity for bentonite addition in excess of 5% and little or no effect of freeze thaw cycles on the measured hydraulic conductivity. The findings were used to finalize considerations related to the field placement of the barrier layer, the material properties to use in subsequent analysis work, and the optimum combination of bentonite addition (5%) and parent material processing requirements. Details of the proposed cover test plot program are provided in Appendix E.

Factors and processes that can alter the long-term performance of the cover include:

- physical processes (e.g., settlement, freeze/thaw cycles, wetting/drying cycles, erosion, and changing climatic conditions);

- chemical processes (e.g., osmotic consolidation, dissolution, mineralogical transformation or cation exchange, sorption, and precipitation); and

- biological processes (bacterial clogging, root penetration, burrowing animals, and human activity).

For the decommissioned JEB TMF, chemical processes are considered to be insignificant in the long-term performance of the soil cover because it is expected that only atmospheric water will enter the barrier material. Tailings settlement is a potential concern and will be monitored through a field instrumentation monitoring program as outlined in Section 11. The freeze/thaw, wetting/drying and erosion effects is predicted to be minimal because the processed sand-bentonite barrier layer will have a low volume change potential, it will be protected by a surface layer thick enough to mitigate much of the potential drying, and the final soil cover system will be designed incorporating a closure landform configuration and a drainage system. Biological processes are mitigated through the thickness of the surface layer. In addition, the proposed soil cover test plot program will provide further confidence in the long-term behaviour of the soil cover system for the decommissioned JEB TMF (Appendix E).

A study has also been conducted to assess the long-term performance of the soil cover when exposed to climate change (Appendix G). The study included a climatic assessment to quantify general climate changes that may be observed over the period 2071 to 2099 followed by detailed soil-atmospheric analyses to assess the effect of climate change on the water balance of the soil cover. The Canadian Climate Change Scenarios Network (CCCSN 2011) provides an interface for evaluating a number of simulations based on global climate models (GCM) and Canadian Regional Climate Models (CRCM). Climate models, combined with emissions scenarios, are used to compute the change in weather parameters that are used to complete detailed soil-atmospheric simulations: precipitation, temperature, relative humidity, wind speed, and net radiation. The change in the weather parameters are applied to historical data to produce boundary conditions that are expected to be representative of future climate. The CCCSN provides the opportunity to evaluate the performance of the soil cover under 23 different climate change boundary conditions. A summary of the soil cover performance for all 23 climate change boundary conditions is provided below, with detailed results presented in Appendix G.

- The climate change scenarios indicate that in general precipitation will increase and the climate will move toward an overall wetter condition.

- At a maximum, deep percolation is shown to increase in the order of 3 mm/year for a condition where the k_s of the barrier layer was set to $1x10^{-9}$ m/s. The increase in deep percolation would be less than 3 mm/year using the design k_s of the barrier of $1x10^{-10}$ m/s providing a level of performance within the range of the original design.

- The majority of the extra precipitation will be diverted as runoff and have more influence on the landform design.

- The landform is designed based on the geomorphic approach and contains built-in self-healing features that are considered to be able to withstand the increase in runoff.

- Extreme events are expected to increase in the order of 25%. The runoff facilities have been conservatively designed and are expected to maintain performance when subjected to extreme events that are 25% larger than current values.

In general, the climate is expected to move toward a warmer and wetter condition. The future performance of the soil cover is predicted to be the same for all climate change boundary conditions: 1) there is a small essentially insignificant increase in deep percolation (1 mm/year on average); 2) the majority of the water is re-directed as runoff; 3) actual evaporation increases and is the second largest factor contributing to the change in the water balance; and 4) soil cover storage remains essentially unchanged and does not play a primary role in how the extra precipitation is managed.

The study also provides discussion surrounding the effect that extra runoff could have on the longevity of the soil cover landform. The landform was designed based on a geomorphic approach that is based on the philosophy that the landform will evolve with time and climate change. The geomorphic approach is not based on rigid design criterion and some erosion and self-healing is expected to take place over time. Sacrificial armouring has been provided to promote self-healing of potentially erodible stream sections, and for the land slope, stream slope, and stream cross-section to evolve accordingly. In addition, vegetation on the landform will take hold over the long-term, providing resistance to faster runoff if the climate predictions are correct.

4.4.2.4 Decommissioned JEB TMF Groundwater Flow

The calibrated numerical groundwater flow model, developed for the JEB area, was used to assess the transport pathway of groundwater discharging from the expanded JEB TMF following decommissioning. The model used an unconsolidated tailings surface elevation. This conservatively represents the post decommissioning scenario as it does not account for the reduction of the tailings surface area accompanying consolidation of the tailings during the decommissioning period. Details of this groundwater model are provided in Appendix C.

For the post-closure scenarios, it was assumed that the top of the expanded JEB TMF is covered by a low permeability barrier cover system. Deep percolation through the cover was assessed as part of the soil cover design report (Golder 2009c) and was estimated to be 10 mm/yr. Pumping from the dewatering wells and base drain were assumed to be inactive following mine closure.

Two post closure scenarios were simulated. In the first scenario an infiltration of 10 mm/yr was assigned to layer 1 in the area of the expanded JEB TMF to represent net percolation of precipitation through the soil cover. In the second scenario the infiltration was increased to 20

mm/yr, which is considered a reasonable upper bound of expected net percolation through the cover.

Discharge from the TMF is predicted to migrate south-west towards Fox Lake. Approximately 32% of the predicted flow discharges to Fox Lake South Basin and 68% of the flow discharges to Fox Lake North Basin. The average travel distance to Fox Lake is approximately 475 m. The average particle velocity to Fox Lake is 0.01 metres per day (m/day).

The model results indicated that, in general, most of the discharge from the JEB TMF originates from the infiltration through the soil cover (3 to 7 m^3/day). Precipitation that infiltrates through the cover is predicted to migrate through the tailings and discharge to the sandstone and to the base drain. Negligible flow is predicted to migrate through the liner that is present at the edges of the JEB TMF in the overburden. To assist in mass loading calculations, the specific discharge through the sandstone surrounding the JEB TMF and through the base drain was estimated. The specific discharge through the sandstone near the JEB TMF was estimated to be generally between 5×10^{-5} m/day and 4×10^{-3} m/day. The specific discharge in the lower sandstone is predicted to be higher than the upper sandstone, which is considered reasonable because of the higher hydraulic conductivity in lower sandstone. The specific discharge in the upper sandstone is predicted to be between 5×10^{-5} and 2×10^{-4}, whereas the discharge in the lower sandstone is predicted to be between 1×10^{-3} and 4×10^{-3} m/day. The average specific discharge through the sand and gravel filter is estimated to be approximately 0.04 m/day.

4.4.2.5 Predicted Long-Term Environmental Loading

Solute transport analyses describe the migration of solute in groundwater between a source and receptor, considering advective and diffusive transport mechanisms, and attenuation due to sorption behaviour and decay in transit. For the case of steady-state transport from a source to a receptor with no decay in transit, the mass flux from the source also defines the peak rate of solute loading to the receptor. Therefore, in this case, the mass flux from the source determines the ultimate long-term concentration at the receptor. Solute release may be due to advection, which is a function of groundwater movement, and/or molecular diffusion, which is a function of chemical gradients. As such, factors that may influence solute mass flux out of the source include the groundwater flow in and around the source, the development of chemical gradients and the chemical properties of the solute.

The long-term performance of the expanded JEB TMF was assessed using GoldSim® (Goldsim® 2002) to simulate the transport of solutes from the tailings through the groundwater flow system to down gradient surface water receptors (i.e., Fox Lake: Appendix C). The conceptual model considers low-permeability tailings in direct contact with a high-permeability host rock. As groundwater flows past the tailings mass, diffusive flux of solutes occur across the tailings/host rock interface into the active flow zone. Chemical gradients develop until equilibrium is reached between the mass flux out of the tailings and the rate of removal by groundwater flow. In addition, groundwater originating as infiltration to the tailings mass flows through the tailings, resulting in some component of advective flux out of the tailings mass.

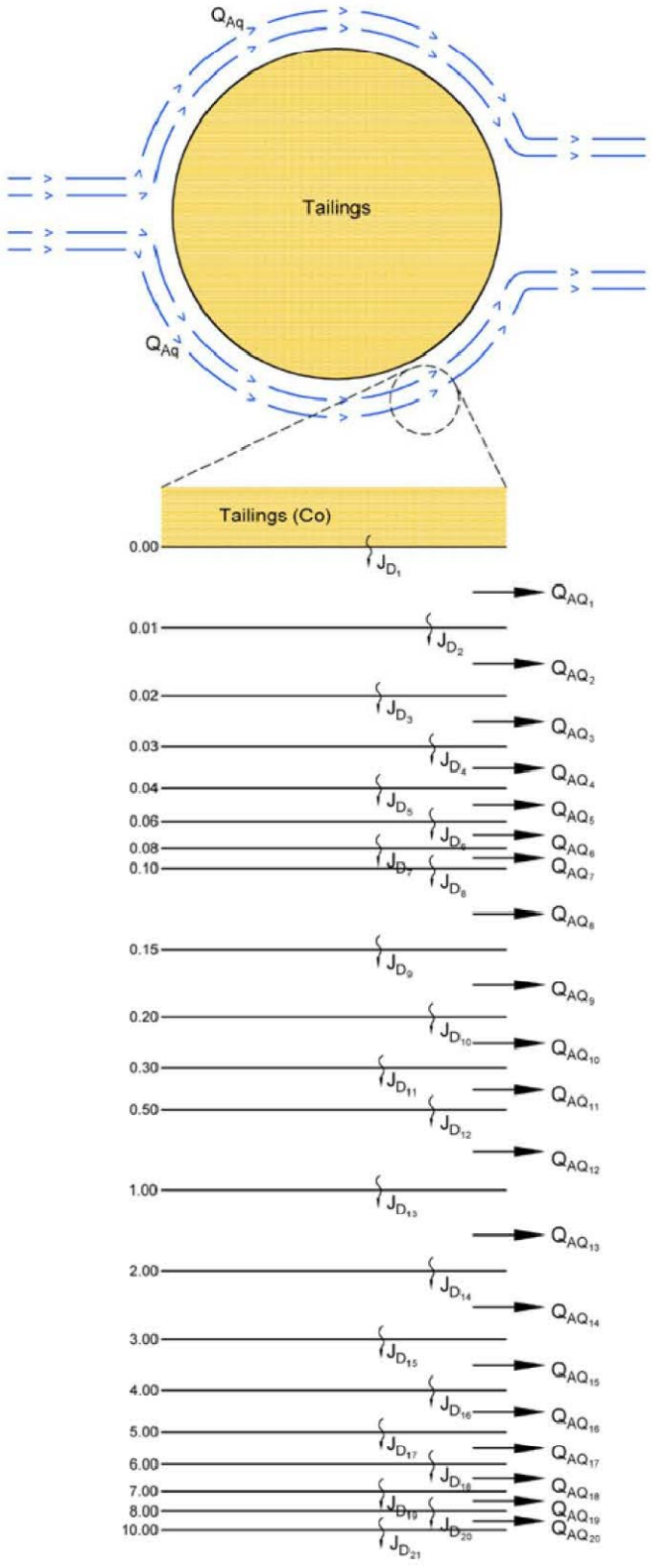
Figure 4.4-6 provides a graphical representation of the conceptual model. Input parameters applied to mass flux calculations are summarized in Table 4.4-2.

Table 4.4-2: Solute Transport Calculation Input Parameters

Parameter	TMF Expansion
Elevation Tailings Surface	448 mASL
Sandstone effective porosity (n_e)	11%
Effective Diffusion Coefficient (D^*)	$3x10^{-11}$ m^2/s
Tailings Lateral Surface Area (A_L)	145,000 m^2
Tailings Top Surface Area (A_T)	129,000 m^2
Cover Infiltration Rate (q_i)	10 mm/year to 20 mm/year
Specific Discharge Sandstone (q_{SS})	0.04 m/day

TMF = Tailings Management Facility; mASL = metres above sea level; % = percent; m2/s = square metres per second; m2 = square metres; mm/year = millimeters per year; m/day = metres per day

Figure 4.4-6: Conceptual Solute Transport Model



Goldsim

AREVA	1417371		FIGURE 4.4-6
	SCALE:	NTS	DATE:
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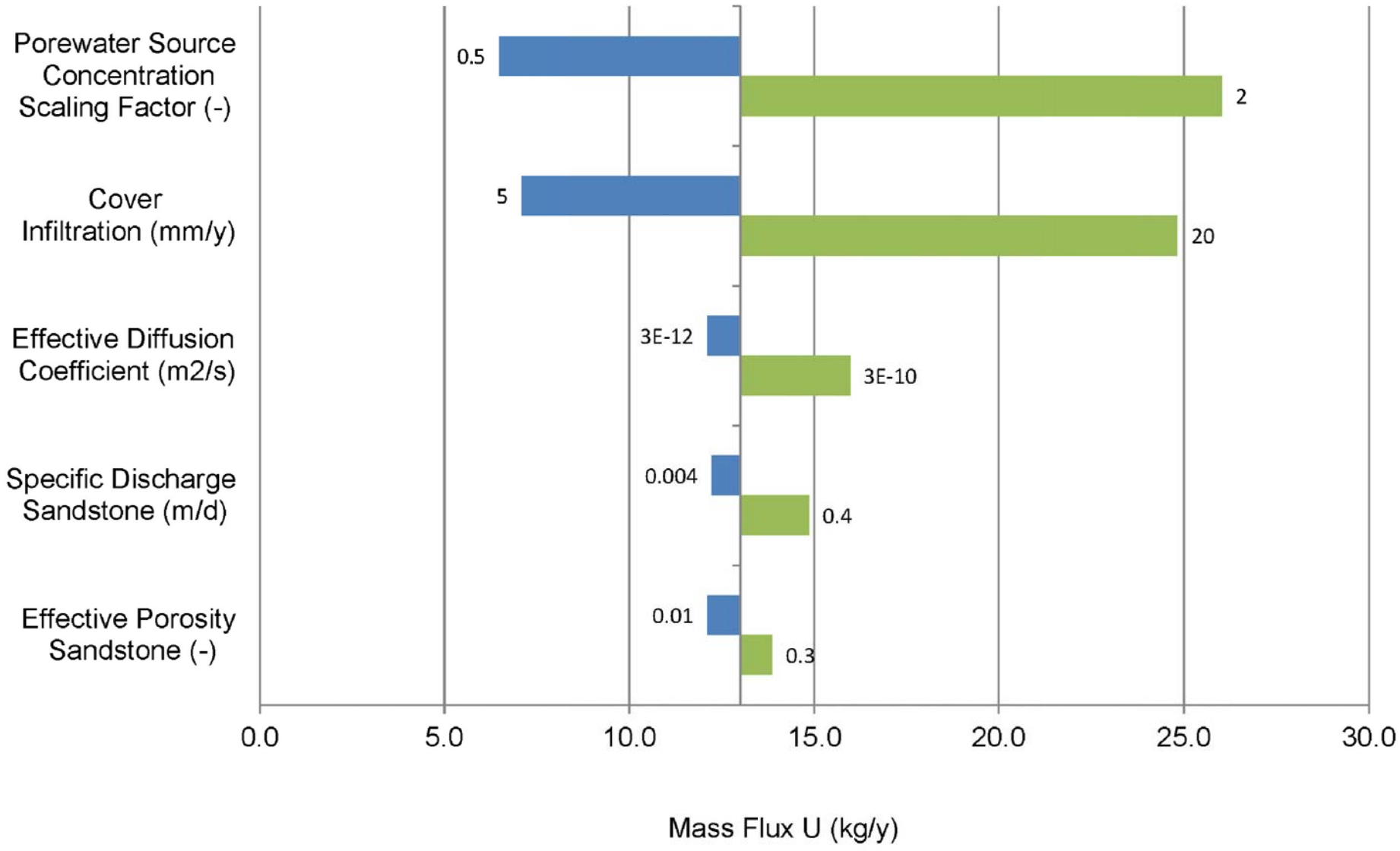
Conceptual Source Term Model

A parametric sensitivity analysis was conducted to identify those input parameters exerting the greatest influence on calculated mass loading rates from the decommissioned JEB TMF. Mass flux calculations were performed while varying each input parameter individually over the selected range. Value ranges were selected to represent reasonable variation of each parameter. Mass flux calculations were performed while varying each input parameter individually over the selected range. Figure 4.4-7 presents the results of the sensitivity analysis. It is apparent based on the results that the cover infiltration rate and tailings pore water source concentrations exert the greatest control over the predicted mass flux from the decommissioned JEB TMF. Based on the results of the sensitivity analysis, prediction and upper bound scenarios were developed for calculation of peak mass flux to receptors. The prediction case considered expected input parameter values and the upper bound case considered the compounding effects of increasing the cover infiltration from the predicted rate of 10 mm/year to the maximum rate of 20 mm/year and applying the probable maximum constituent source concentrations in tailings pore water.

Predicted and upper bound mass flux from the expanded JEB TMF were calculated with the GoldSim® model based on the results of the groundwater flow model for the expanded JEB TMF and updated tailings pore water source concentrations (Appendix C). Predicted values were calculated using best estimates of net percolation through the soil cover into the tailings and source concentrations. Predicted values were calculated using best estimate of the soil cover infiltration rate and predicted source concentrations. The upper bound values were calculated using the “worst case” soil cover infiltration rate and the sensitivity case pore water concentrations (Table 4.4-1).

Predicted and upper bound case mass fluxes of pore water constituents are presented in Table 4.4-4. The calculated mass fluxes from the expanded JEB TMF were taken as discharging via groundwater to the north basin of Fox Lake. The total mass loadings out of the JEB TMF were applied to Pat Lake since that which reports to Fox Lake would report to Pat Lake by overland flow. The incremental concentrations for each receptor were calculated based on the calculated mass loadings and the average annual flows through the north basin of Fox Lake (5,763 m^3/day), Fox Lake (14,743 m^3/day) and Pat Lake (18,465 m^3/day) (AREVA 2011b).

Figure 4.4-7: Sensitivity Analysis Results



AREVA

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FIGURE 4.4-7

Sensitivity Analysis Results

Table 4.4-3: Expanded JEB TMF Predicted Peak Mass Flux

Constituent	Concentration Tailings Pore Water		Mass Flux Out Of Tailings		Mass Flux To Fox Lake		Mass Flux To Pat Lake	
	Prediction	Upper Bound	Prediction	Upper Bound	Prediction	Upper Bound	Prediction	Upper Bound
Chloride	42 mg//L	79 mg/L	58 kg/a	225 kg/a	58 kg/a	225 kg/a	58 kg/a	225 kg/a
Sulphate	1,800 mg/L	2,600 mg/L	3,000 kg/a	6,900 kg/a	3,000 kg/a	6,900 kg/a	3,000 kg/a	6,900 kg/a
Ammonia	10 mg/L	14 mg/L	18 kg/a	72 kg/a	18 kg/a	72 kg/a	18 kg/a	72 kg/a
Arsenic	2.0 mg/L	3.7 mg/L	3.5 kg/a	12 kg/a	3.5 kg/a	12 kg/a	3.5 kg/a	12 kg/a
Cadmium	0.005 mg/L	0.0018 mg/L	0.00085 kg/a	0.0028 kg/a	0.00085 kg/a	0.0028 kg/a	0.00085 kg/a	0.0028 kg/a
Cobalt	0.011 mg/L	0.036 mg/L	0.084 kg/a	0.47 kg/a	0.084 kg/a	0.47 kg/a	0.084 kg/a	0.47 kg/a
Copper	0.010 mg/L	0.013 mg/L	0.027 kg/a	0.0084 kg/a	0.027 kg/a	0.0084 kg/a	0.027 kg/a	0.0084 kg/a
Lead	0.005 mg/L	0.003 mg/L	0.0018 kg/a	0.0072 kg/a	0.0018 kg/a	0.0072 kg/a	0.0018 kg/a	0.0072 kg/a
Molybdenum	8.0 mg/L	12.3 mg/L	12 kg/a	41 kg/a	12 kg/a	41 kg/a	12 kg/a	41 kg/a
Nickel	0.70 mg/L	2.3 mg/L	3.0 kg/a	17 kg/a	3.0 kg/a	17 kg/a	3.0 kg/a	17 kg/a
Selenium	0.006 mg/L	0.021 mg/L	0.0034 kg/a	0.022 kg/a	0.0034 kg/a	0.022 kg/a	0.0034 kg/a	0.022 kg/a
Vanadium	0.025 mg/L	0.98 mg/L	0.016 kg/a	0.13 kg/a	0.016 kg/a	0.13 kg/a	0.016 kg/a	0.13 kg/a
Zinc	0.13 mg/L	0.23 mg/L	0.031 kg/a	0.12 kg/a	0.031 kg/a	0.12 kg/a	0.031 kg/a	0.12 kg/a
Polonium-210	2 Bq/L	3.1 Bq/L	1.4E+07 Bq/a	4,3E+07 Bq/a	5.3E+04 Bq/a	1.9E+05 Bq/a	5.3E+04 Bq/a	1.9E+05 Bq/a
Lead-210	6 Bq/L	19 Bq/L	2.5E+07 Bq/a	1.2E+08 Bq/a	5.3E+04 Bq/a	1.9E+05 Bq/a	5.3E+04 Bq/a	1.9E+05 Bq/a
Radium-226	5 Bq/L	14 Bq/L	7.61E+06 Bq/a	4.71E+07 Bq/a	1.1E+03 Bq/a	3.98E+03 Bq/a	1.1E+03 Bq/a	3.98E+03 Bq/a
Thorium-230	2 Bq/L	2 Bq/L	5.4E+05 Bq/a	1.9E+06 Bq/a	5.3E+05 Bq/a	1.9E+06 Bq/a	5.3E+05 Bq/a	1.9E+06 Bq/a
Uranium	8.5 mg/L	14 mg/L	13 kg/a	24 kg/a	13 kg/a	24 kg/a	13 kg/a	24 kg/a

mg/L = milligrams per litre; Bq/L = Becquerel per litre; kg/a = kilograms per year; Bq/a = Becquerel per year

The solute transport analysis used to calculate solute loadings to receptors from the JEB TMF couples one-dimensional solute transport solutions with the particle tracking method. A local-scale finite element groundwater flow model was developed in FEFLOW and used to simulate flow in and around the decommissioned JEB TMF. A number of particles were located within the TMF and tracked down-gradient to receptors. The linear velocity and trajectory was recorded for each particle and average velocities and travel distances were applied to solute transport calculations for pathways to each receptor in GoldSim®. A source term model was developed using GoldSim® to predict the mass flux of solutes released from the facility to the groundwater flow system and subsequently determine the initial solute concentrations in groundwater for each flow path. Effects to receptors were determined based on mass flux predictions from the source term model for the most sensitive solute species and groundwater flow simulation results which provide partitioning of groundwater flows between individual surface water receptors.

The source term model described in the preceding section was applied to calculate the initial concentrations of solutes for each pathway. The one-dimensional advection-dispersion equation was solved for each aquifer pathway within GoldSim® using concentrations calculated by the source term model as a boundary condition and the corresponding travel distance and velocity distributions of for each pathway. Within GoldSim® computations are performed for each aquifer pathway by creating a temporary set of linked cell elements during the simulation, which are subsequently removed at the end of the simulation. Because the cells are linked together via advective and diffusive mechanisms, the behaviour of the cell network is mathematically described using a coupled system of differential equations. In effect, the network of cells created within an aquifer pathway is mathematically equivalent to a finite difference network. GoldSim® numerically solves the coupled system of equations to compute the contaminant mass present in the pathway (and the mass fluxes leaving the pathway) as a function of time.

The geometry of the pathways were defined by specifying the length and cross sectional area of the aquifer, based on the results of particle tracking analyses and hydrostratigraphy. The specified aquifer infill medium and fluid saturation are used to determine the quantities of media in each Cell. Advective and diffusive flux links are automatically created by GoldSim® to appropriately model advection, dispersion and diffusion through the linked cells.

Mass enters at one end of the aquifer pathway, advects along (and disperses and diffuses within) the pathway, and then exits at the other end. Aquifer pathways (and hence the cells that are internally created to represent them) contain a fluid medium and a solid medium which can impact transport (e.g., by modifying the porosity of the pathway and/or acting to sorb and hence retard species). Radioactive decay and ingrowth are also considered for transport calculations performed for each pathway. Input parameters applied to solute transport calculations for each pathway are summarized in Table 4.4-4.

Table 4.4-4: Solute Transport Calculation Input Parameters

Parameter	TMF Expansion
Travel Distance (x)	Fox Lake Pathway: 475 m
Groundwater Velocity (v)	Fox Lake Pathway: 0.01 m/day
Dispersivity (α)	0.1x
Distribution Coefficient (k_d)	^{230} Th, ^{210} Pb, ^{210} po, as: 1 l/kg Ni: 2 l/kg ^{226} Ra: 50 l/kg
First Order Decay Constant (λ)	U: 1.55 e-10 1/year ($T_{1/2}$ = 4.5 e9 year; a = 1.24 e4 Bq/g) ^{230} Th: 8.7 e-5 1/year ($T_{1/2}$ = 8000 year; a = 7.19 e9 Bq/g) ^{226} Ra: 4.3 e-4 1/year ($T_{1/2}$ = 1620 year; a = 3.62 e10 Bq/g) ^{210} Pb: 3.1 e-2 1/year ($T_{1/2}$ = 22.3 year; a = 2.83 w12 Bq/g) ^{210} Po: 1.83 1/year ($T_{1/2}$ = 0.378 year; a = 1.67 e14 Bq/g)

TMF = Tailings Management Facility; m = metre; m/day = metres per day; L/kg = litres per kilogram; Bq/g = Becquerel per gram.

Tables 4.4-5 and 4.4-6, respectively, present predicted and upper bound incremental COPC concentrations for Fox Lake and Pat Lake. Predicted COPC concentrations in all receiving waters are typically indistinguishable from to marginally above baseline concentrations and lessthan CWQG and SSWQO. Calculated cadmium and lead concentrations marginally exceed SSWQO criteria, however this is an artifact of the guideline being less than the baseline concentrations for these constituents. In each case the incremental concentration is negligible in relation to the baseline concentration.

Figure 4.4-8 graphically presents the predicted long-term water quality in receiving waters for selected constituents. Resulting concentrations of solutes are compared to baseline concentrations (AREVA 2009a) and to CWQG and SSWQO. Predicted long-term water quality is within water quality objectives for all COPCs. Arsenic and uranium appear to be the most sensitive constituents with predictions approaching 50% of objective values, and upper bound values marginally exceeding objectives. Nonetheless, predicted and bounding values are similar to those previously assessed for the Caribou Project EIS (AREVA 2009a).

Solute transport calculations were performed for the predicted rates of constituent loading from the JEB TMF to the active groundwater flow zone, as derived by the source term model. The results of the solute transport analysis are presented in terms of mass flux to surface water receptors as a function of time and are plotted for arsenic, nickel, uranium and radium-226 in Figure 4.4-9. Predicted and upper bound steady state mass fluxes to receptors for all constituents are presented in Table 4.4-5.

The peak mass flux to the receptors coincides with the condition of steady-state transport, at which time no change in solute concentrations occurs with time at any given point along the pathway. Under this condition, the mass flux to the receptor equals that leaving the source, where no decay occurs in transit. These conditions are predicted because of the application of a non-depleting source. For the case of radium, the mass flux to the receptor is lower than that leaving the source due to attenuation along the pathway owing to sorption, which allows time for radioactive decay to occur.

The average arrival time of a solute plume at a given point along the pathway may be defined as the time at which the solute concentration reaches half of the ultimate steady-state value. The arrival time will vary from one solute to another depending on the degree of attenuation. For unattenuated species, the average arrival time is approximately 100 years. Moderately attenuated species such as arsenic and nickel show break through at receptors in 3,000 to 6,000 years. Arrival time for radium is expected to occur in approximately 5,000 years.

Table 4.4-5: Expanded JEB TMF Predicted Receptor Surface Water Quality

Constituent	Units	Baseline Concentration			Incremental Concentration			Resulting Concentration			Water Quality Criteria
		Fox Lake North Basin	Fox Lake	Pat Lake	Fox Lake North Basin	Fox Lake	Pat Lake	Fox Lake North Basin	Fox Lake	Pat Lake	
Chloride	mg/L	0.133	0.133	0.120	2.8E-02	1.1E-02	8.7E-03	0.16	0.14	0.13	-
Sulphate	mg/L	0.633	0.633	0.710	1.4E+00	5.6E-01	4.5E-01	2.1	1.2	1.2	-
Ammonia	mg/L	0.021	0.021	0.014	8.3E-03	3.3E-03	2.6E-03	0.029	0.024	0.017	1.54
Arsenic	mg/L	0.00052	0.00052	0.00074	1.7E-03	6.6E-04	5.3E-04	0.0022	0.0012	0.0013	0.005
Cadmium	mg/L	0.001	0.001	0.001	4.1E-07	1.6E-07	1.3E-07	0.0010	0.0010	0.0010	0.000017
Cobalt	mg/L	0.001	0.001	0.001	4.0E-05	1.6E-05	1.2E-05	0.0010	0.0010	0.0010	-
Copper	mg/L	0.002	0.002	0.002	1.3E-05	5.0E-06	4.0E-06	0.0020	0.0020	0.0020	0.002
Lead	mg/L	0.005	0.005	0.006	8.5E-07	3.3E-07	2.7E-07	0.0050	0.0050	0.0060	0.001
Molybdenum	mg/L	0.005	0.005	0.005	5.7E-03	2.2E-03	1.8E-03	0.011	0.0072	0.0068	0.073
Nickel	mg/L	0.003	0.003	0.003	1.4E-03	5.6E-04	4.5E-04	0.0044	0.0036	0.0035	0.025
Selenium	mg/L	0.001	0.001	0.001	1.6E-06	6.4E-07	5.1E-07	0.0010	0.0010	0.0010	0.001
Vanadium	mg/L	0.01	0.01	0.01	7.8E-06	3.1E-06	2.4E-06	0.010	0.010	0.010	-
Zinc	mg/L	0.006	0.006	0.006	1.5E-05	5.8E-06	4.7E-06	0.0060	0.0060	0.0060	0.030
Polonium-210	Bq/L	0.008	0.008	0.006	2.5E-05	9.8E-06	7.8E-06	0.0080	0.0080	0.0080	-
Lead-210	Bq/L	0.022	0.022	0.020	2.5E-05	9.8E-06	7.7E-06	0.022	0.022	0.020	-
Radium-226	Bq/L	0.005	0.005	0.006	5.2E-07	2.0E-07	1.6E-07	0.0050	0.0050	0.0060	-
Thorium-230	Bq/L	0.012	0.012	0.013	2.5E-04	9.8E-05	7.8E-05	0.012	0.012	0.013	-
Uranium	mg/L	0.0006	0.0006	0.0006	6.0E-03	2.4E-03	1.9E-03	0.0066	0.0030	0.0025	0.015

[a] SSWQO (Saskatchewan Water Secutiry Agency 2015)
[b] CWQG (CCME 1987-2014)

Bold indicates an exceedance of CWQG or SSWQO
mg/L = milligrams per litre; Bq/L = Becquerel per litre; CCME = Canadian Council of Ministers of the Environment; CWQGs = Canadian Water Quality Guidelines; SSWQO = Saskatchewan Surface Water Quality Objectives

Table 4.4-6: Expanded JEB TMF Upper Bound Receptor Surface Water Quality

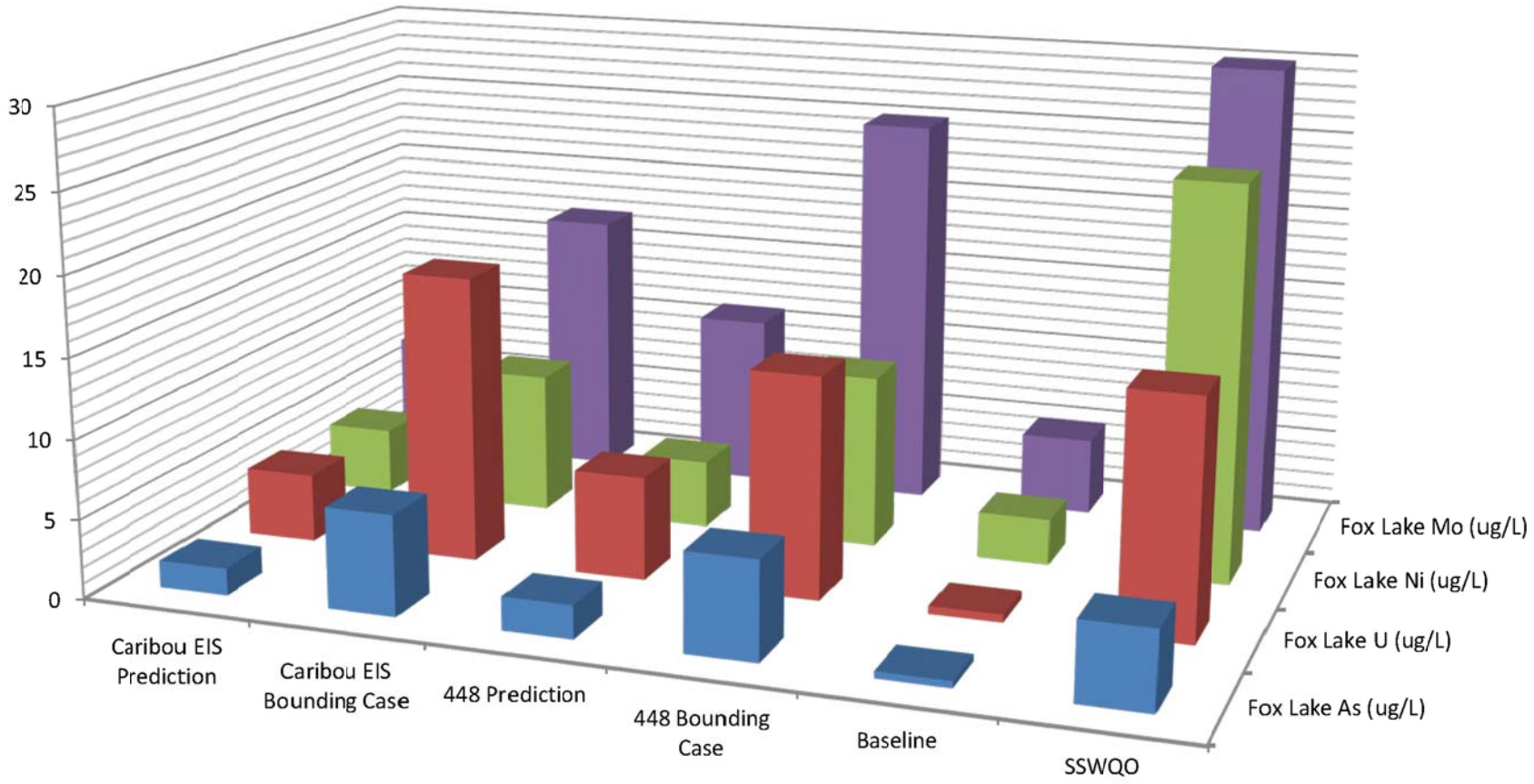
Constituent	Units	Baseline Concentration			Incremental Concentration			Resulting Concentration			Water Quality Criteria
		Fox Lake North Basin	Fox Lake	Pat Lake	Fox Lake North Basin	Fox Lake	Pat Lake	Fox Lake North Basin	Fox Lake	Pat Lake	
Chloride	mg/L	0.133	0.133	0.120	1.1E-01	4.2E-02	3.3E-02	0.24	0.17	0.15	-
Sulphate	mg/L	0.633	0.633	0.710	3.3E+00	1.3E+00	1.0E+00	3.9	1.9	1.7	-
Ammonia	mg/L	0.021	0.021	0.014	3.4E-02	1.3E-02	1.1E-02	0.055	0.034	0.025	1.54
Arsenic	mg/L	0.00052	0.00052	0.00074	5.8E-03	2.3E-03	1.8E-03	0.0063	0.0028	0.0025	0.005
Cadmium	mg/L	0.001	0.001	0.001	1.3E-06	5.2E-07	4.1E-07	0.0010	0.0010	0.0010	0.000017
Cobalt	mg/L	0.001	0.001	0.001	2.3E-04	8.8E-05	7.0E-05	0.0012	0.0011	0.0011	-
Copper	mg/L	0.002	0.002	0.002	4.0E-06	1.6E-06	1.2E-06	0.0020	0.0020	0.0020	0.002
Lead	mg/L	0.005	0.005	0.006	3.4E-06	1.3E-06	1.1E-06	0.0050	0.0050	0.0060	0.001
Molybdenum	mg/L	0.005	0.005	0.005	2.0E-02	7.6E-03	6.1E-03	0.025	0.013	0.011	0.073
Nickel	mg/L	0.003	0.003	0.003	8.1E-03	3.2E-03	2.5E-03	0.011	0.0062	0.0055	0.025
Selenium	mg/L	0.001	0.001	0.001	1.0E-05	4.1E-06	3.3E-06	0.0010	0.0010	0.0010	0.001
Vanadium	mg/L	0.01	0.01	0.01	6.0E-05	2.3E-05	1.9E-05	0.010	0.010	0.010	-
Zinc	mg/L	0.006	0.006	0.006	5.8E-05	2.3E-05	1.8E-05	0.0061	0.0060	0.0060	0.030
Polonium-210	Bq/L	0.008	0.008	0.006	8.9E-05	3.5E-05	2.8E-05	0.0081	0.0080	0.0080	-
Lead-210	Bq/L	0.022	0.022	0.020	8.9E-05	3.5E-05	2.8E-05	0.022	0.022	0.020	-
Radium-226	Bq/L	0.005	0.005	0.006	1.9E-06	7.3E-07	5.9E-07	0.0050	0.0050	0.0060	-
Thorium-230	Bq/L	0.012	0.012	0.013	8.9E-04	3.5E-04	2.8E-04	0.013	0.012	0.013	-
Uranium	mg/L	0.0006	0.0006	0.0006	1.4E-02	5.4E-03	4.3E-03	0.014	0.0060	0.0049	0.015

[a] SSWQO (Saskatchewan Water Secutiry Agency 2015)
[b] CWQG (CCME 1987-2014)

Bold indicates an exceedance of CWQG or SSWQO
mg/L = milligrams per litre; Bq/L = Becquerel per litre; CCME = Canadian Council of Ministers of the Environment; CWQGs = Canadian Water Quality Guidelines; SSWQO = Saskatchewan Surface Water Quality Objectives



Figure 4.4-8: Predicted Long-term Water Quality in North Basin of Fox Lake



	Caribou EIS Prediction	Caribou EIS Bounding Case	448 Prediction	448 Bounding Case	Baseline	SSWQO
Fox Lake As (ug/L)	1.8	6.4	2.2	6.3	0.52	5
Fox Lake U (ug/L)	4.4	18.1	6.6	14	0.6	15
Fox Lake Ni (ug/L)	4.3	9	4.4	11	3	25
Fox Lake Mo (ug/L)	7.5	17	11	25	5	73

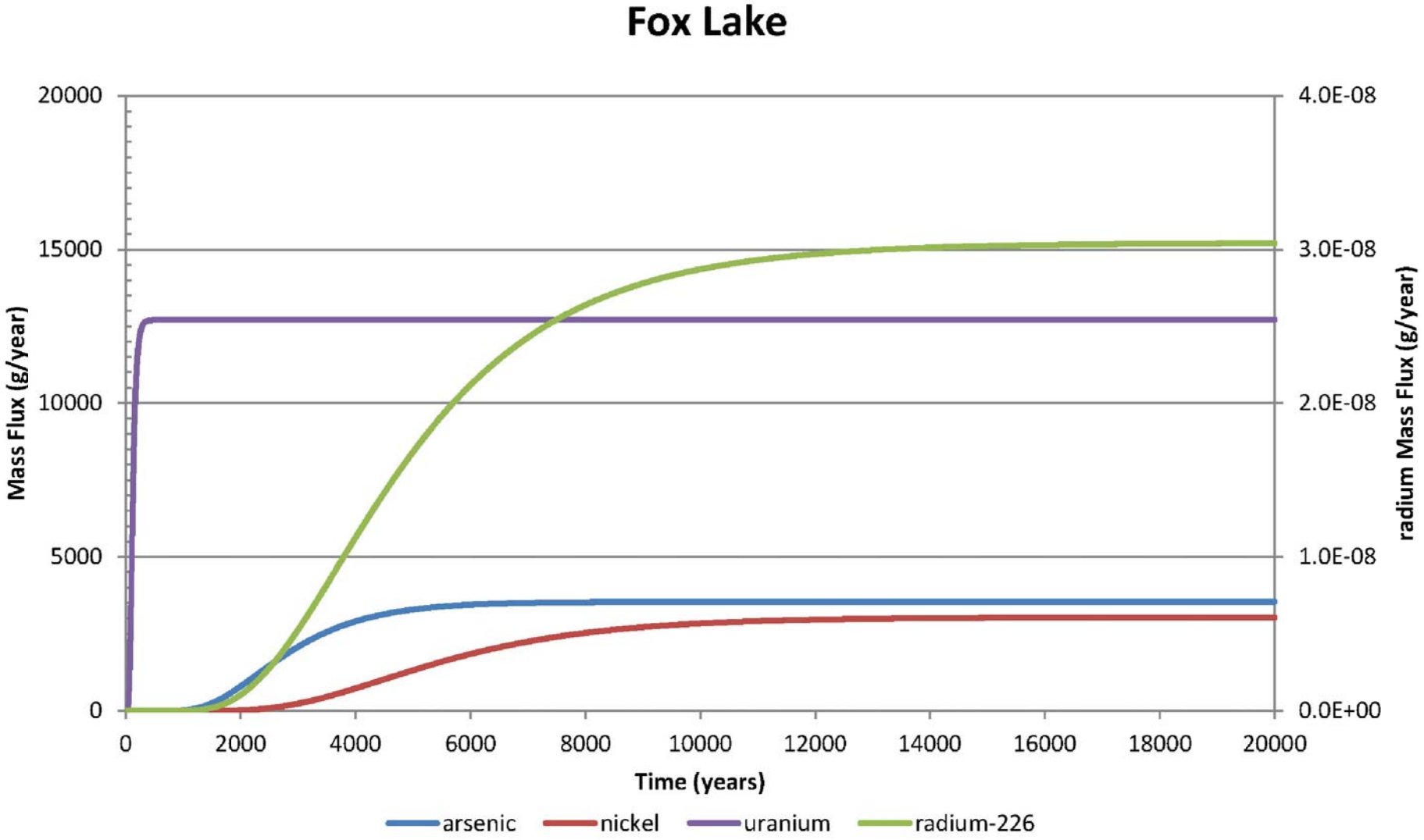
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FIGURE 4.4-8

Long-Term Water Quality Predicted and Bounding Case Long-Term Effects on Fox Lake

Figure 4.4-9: Mass Flux to Receptors vs. Time



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4.4.2.6 Radiological Assessment

An evaluation of operational and post-closure radiological conditions has been conducted and is presented in Appendix H. The proposed Project has made no changes to the operational protective measures implemented for the placement of uranium tailings from high-grade ores in the JEB TMF (i.e. tailings will be placed below sufficient water cover to attenuate gamma radiation and radon emanation). Exposure rates in working areas above the tailings will be less than the workplace exposure rate objectives developed for the McClean Lake Operation.

Successful closure and decommissioning of the JEB TMF will require that the public dose limit is not exceeded for traditional uses of the site such as hunting, trapping and gathering. The evaluation of post-closure radiation exposure conditions considered potential exposure of traditional land users to gamma radiation, radon, and long-lived radioactive dusts (Appendix H). Gamma radiation exposure on the decommissioned surface of the JEB TMF is mitigated by placement of the cover materials. Radon exposure is limited by the placement of layers of capping materials and the saturated soil cover. Radioactive dust exposure is eliminated by the containment of the tailings materials within the decommissioned JEB TMF. The anticipated radiation exposure post-decommissioning is anticipated to be indistinguishable from natural background radiation in the area.

4.4.2.7 Landform Design for the Decommissioned JEB TMF

The primary objective of the landform design was to provide a sustainable landform configuration and drainage system for the decommissioned JEB TMF. This section presents a summary of the results of the landform design for the decommissioned JEB TMF.

The physical characteristics of the decommissioned JEB TMF landform was developed using geomorphic criteria developed from local natural analoque landforms. The geomorphic approach requires the following key inputs: i) geologic and soil characteristics of nearby natural landforms whose form and physical characteristics appear to be in equilibrium with the regional hydro-climatic regime, ii) regional climatic characteristics, and iii) the physical characteristics of nearby natural landforms (e.g., slope angles, slope lengths, and drainage features) derived from LiDAR topography of the landforms.

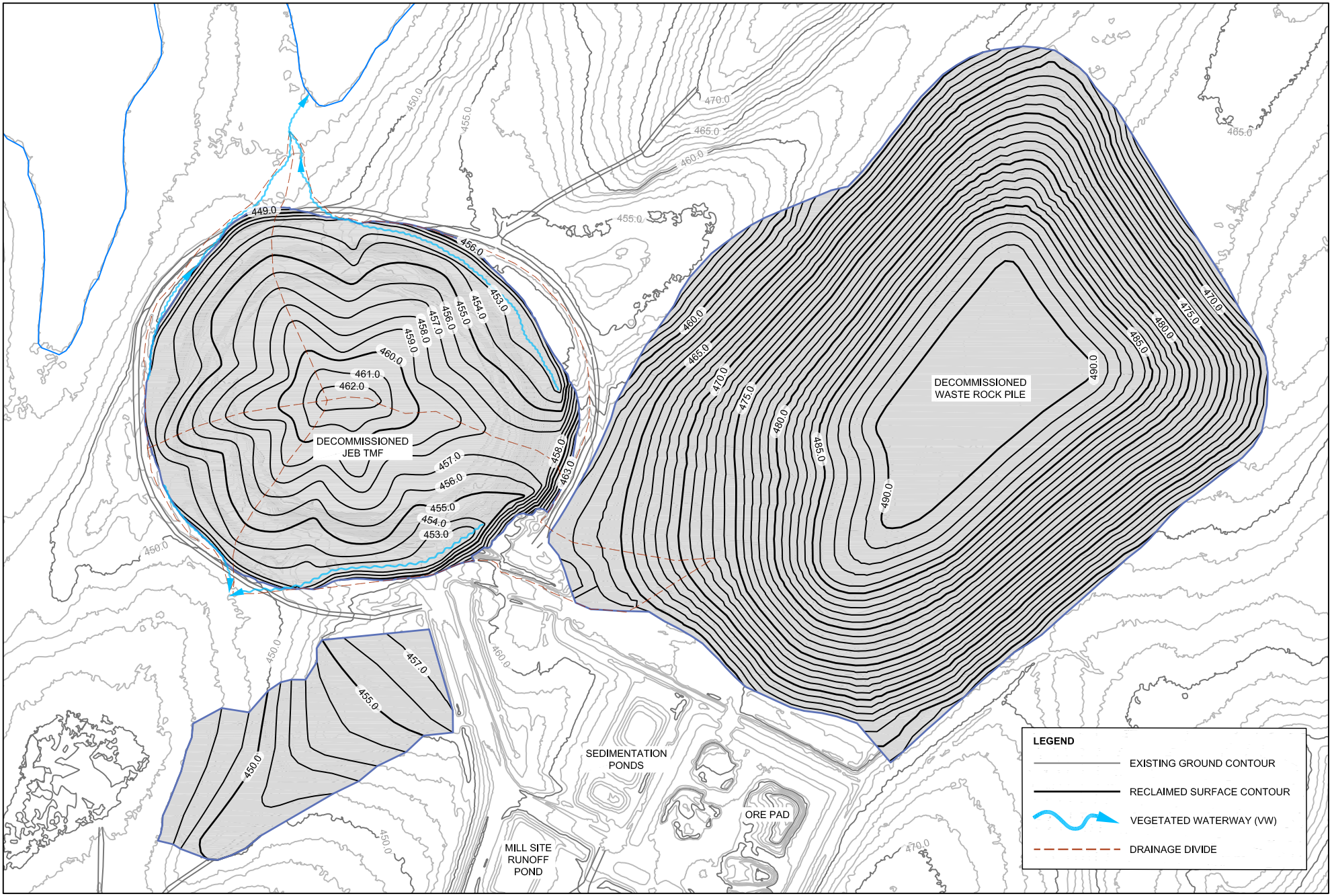
A set of geomorphic criteria for the landform design of the decommissioned JEB TMF was developed through the analyses of the regional and local climate, geology, hydrology and natural landforms near the JEB TMF. The prevailing landforms in the vicinity of the JEB TMF are drumlins. The physical characteristics of the drumlins were derived from the 2009 LiDAR topography of the area. Geomorphic analyses of these local natural analogue landforms included: i) the length, width and height of natural landforms; ii) the maximum overland flow path length and maximum valley slope; iii) the overland flow path length and upland slope; and iv) the drainage area and average channel slope.

Figure 4.4-10 presents a preliminary landform design for the decommissioned expanded JEB TMF. No drainage channels have been provided on the landform, except for an undulating topography to direct surface water to specific locations at the toe of the embankment. Drainage channels have not been provided because the maximum overland flow path length of the landform towards the embankment is within the range of values derived from the natural analogues (drumlins), and the maximum valley slope is less than the values derived from the natural analogues.

Drainage features of the TMF included four vegetated waterways that have been provided around the circumference of the landform at the toe of the embankment to capture and convey runoff from the landform towards natural waterbodies. The design allows the channel to be self-healing and gives it the ability to dynamically adapt to erosion and sediment deposition processes. Vegetated waterways are a sustainable and robust means of conveying intermittent flow over a surface without erosion. Vegetated waterways can be constructed over a variety of landforms and land types, and over a range of slopes, soil conditions and drainage characteristics. The vegetated waterways are lined with vegetation, which resists erosion of surface soil, and are designed to convey runoff or intermittent flow. In closure drainage landscapes, vegetated waterways would provide robust drainage, vegetation diversity and a natural appearance at a relatively low cost.

An undulating topography has been provided for the surface of the JEB TMF landform at closure as shown in Figure 4.4-10 to direct surface runoff to specific location at the toe of the embankment. This micro-topography of the TMF landform in the form of ridges and swales should be constructed so that positive flow towards swales and drainage of the ridges provide good conditions for upland vegetation growth. The drainage ditches in the swale are expected to form naturally after construction of the closure landscape. This natural evolution will facilitate the development of a regime of channel pattern and cross-sectional shape. The resulting drainage systems are expected to be stable over the long term.

Figure 4.4-10: Proposed Contour Plan of the Decommissioned JEB TMF and Waste Rock Pile



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FIGURE 4.4-10

Proposed Contour Plan of the Decommissioned JEB TMF and Waste Rock Pile

4.5 Validation Programs

This section provides recommended programs which should be undertaken as part of validating key design assumptions on the performance of the expanded JEB TMF. These programs are intended to provide additional confidence on the predicted environmental performance of the decommissioned JEB TMF.

4.5.1 Tailings Optimization and Validation Program

On-going evaluation of the chemical and physical characteristics of tailings stored in the JEB TMF during the operational period is required to validate the prediction of post decommissioning potential for unacceptable environmental risk. The McClean Lake Tailings TID (AREVA 2015a)) describes the geochemical and geotechnical monitoring and evaluation activities completed to determine the long-term solute concentrations of COPCs in the JEB TMF, and the long-term post decommissioning groundwater flow regime.

The geochemical and geotechnical monitoring programs are anticipated to be unchanged by the expansion of the JEB TMF and will continue throughout the operating life of the JEB TMF, until decommissioning. These activities are described briefly below.

4.5.1.1 Geochemical Validation Program: Determination of Tailings Solute Concentrations

Tailings samples are collected to determine geochemical parameters of the tailings pore water and tailings sediment. Pore water chemistry is indicative of the maximum soluble load within the tailings mass that could be transferred to the regional groundwater system.

Tailings pore water chemistry is monitored through two complimentary regimes: 1) routine process control samples; and 2) periodic *in situ* sampling campaigns. As part of operational process control, tailings pore water is routinely sampled and analyzed from the tailings preparation circuit discharge.

Detailed, intrusive, *in situ* assessments of stored tailings are conducted on a five-year frequency. The principal objective of the detailed intrusive assessment is to evaluate the geochemical behavior of the tailings pore water. Solute concentrations associated with stored tailings are compared to those predicted by laboratory aging tests and geochemical modeling. Tailings solids samples are collected to assess the relationship between solids chemistry and soluble COPCs in tailings pore water. These geochemical parameters are used to derive final solute concentrations considered representative of long-term concentrations within the tailings mass. The results of the most recent sampling campaign completed in 2013 that have been used for the prediction of final solute concentrations of COPCs in this report.

4.5.1.2 Geotechnical Monitoring Program: Determination of Tailings Geotechnical Properties

Tailings density and hydraulic conductivity are the geotechnical properties of primary interest when predicting the post-decommissioning effects of the JEB TMF. The relationship between applied load and tailings density (i.e., tailings consolidation) is used to predict the volume of the decommissioned JEB TMF. The relationship between void ratio and hydraulic conductivity is used to predict the final hydraulic conductivity of consolidated tailings within the decommissioned JEB TMF.

To facilitate the calculation of stored tailings density, annual tailings surface surveys are conducted. Average tailings density is compared with predictions based on consolidation analyses results and used to track available capacity of the JEB TMF for tailings management. Tailings surface surveys are complimented by the collection of surficial samples, at varied distances from the deposition point, for grain size analysis.

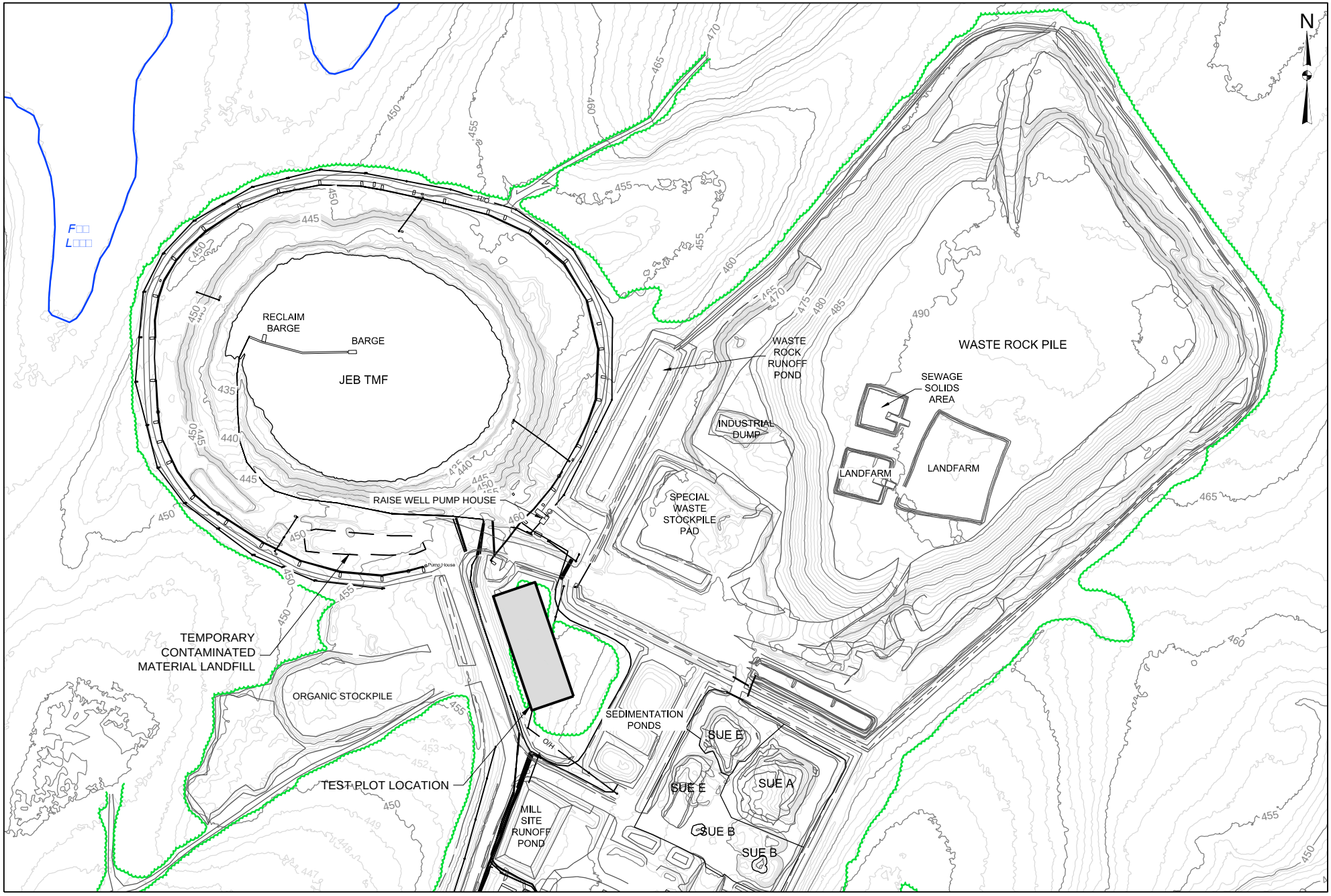
The detailed intrusive assessments currently completed on a 5-year frequency provide a profile of geotechnical tailings samples over the tailings depth. Samples are classified according to soil type, logged, and tested in terms of their geotechnical properties, including particle size gradation, density, hydraulic conductivity, and consolidation behavior. Cone penetrometer testing may also be employed to characterize tailings material using *in situ* measurements.

4.5.2 Cover Performance

The effectiveness of a cover in limiting percolation depends on the materials with which it is constructed (i.e., earthen or geosynthetic), their physical properties (e.g., hydraulic conductivity, moisture retention capability), the long-term integrity of the cover, the climate in which the facility is located, and the nature and quality of the vegetative material. Up to five test plots are anticipated to be constructed for the cover evaluation study implemented for the Project. The preliminary design of the test plots are presented in Appendix E. The test plots will make use of volumetric lysimeters to directly measure deep percolation. Each test plot will be instrumented to monitor climatologic variables, runoff, percolation, soil temperature, soil suction, and soil water content. The test plot covers are expected to provide key field data, to validate and refine the soil cover design presented in Appendix D. In addition to construction of the test cover plots, soil and meteorogical instruments will be installed within a well-developed forested area to determine the water balance. The data collected from this area will be compared to data from the test plots.

Each test plot is designed with a specific objective to optimize one of the key variables that will affect the short and long-term performance of the cover. The sand-bentonite layer in the test plots will be the primary component to prevent deep percolation. However, other layers in the soil cover can be equally important as they contribute to the long-term performance of the resistive layer. The proposed location for the test plots is a vacant area towards the southwest of the JEB TMF as shown in Figure 4.5-1. The site is large enough to accommodate up to five test plots but will require some clearing prior to construction. The site is accessible, outside the expanded JEB TMF boundary, and is away from future construction activity. The exposure of the site is also considered to be representative of the JEB TMF in terms of wind and solar radiation. The test plots will be aligned in a manner to promote drainage and avoid unnecessary cut and fill. Table 4.5-1 presents a summary of the key variables of study, the anticipated deep percolation, and the rationale behind each test plot. More detailed discussions on the proposed test plot locations, dimensions, cover materials and their relevant hydrogeological properties, monitoring instruments, and anticipated deep percolation rates for the test cover plots are provided in Appendix E.

Figure 4.5-1: Proposed Location for Soil Cover Test Plots



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FIGURE 4.5-1

Proposed Location for Soil Cover Test Plots

Table 4.5-1: Summary of the Test Plot

Test Plot	Variable of Study	Expected Deep Percolation	Key Considerations
1	No Barrier Condition	275 mm/yr	No bentonite amended crushed sandstone waste rock layer
2	Control with optimum Barrier	<10 mm/yr	Bentonite amended crushed sandstone waste rock layer constructed with optimal amount of bentonite
3	Surface Layer k_s	<<10 mm/yr	Control the gradation of the surface layer to increase the hydraulic conductivity by approximately 2 orders of magnitude when compared to test plot #2.
4	Barrier Hydraulic Conductivity	40-50 mm/yr	Bentonite amended crushed sandstone waste rock layer constructed with less than optimum bentonite amount to achieve a barrier hydraulic conductivity greater than 1×10^{-9} m/s.
5	Surface Layer Thickness	<10 mm/yr	Increase the thickness of the surface layer from 1 m to 2 m.

4.6 Human Resource Requirements

The proposed Project will enable the McClean Lake Mill to operate for approximately an additional 18 years supporting the development of regional mining projects within the Athabasca Basin, such as Cigar Lake Mine, the Midwest Project, and other McClean Deposits. The McClean Lake Operation has a major positive economic affect on the communities and residents of northern Saskatchewan, as do the mines that the proposed Project will support.

The Project will continue to provide economic benefits to northern Saskatchewan. In addition to enabling the McClean Lake Mill to remain in operation for approximately an additional 18 years, jobs will be created by the Project. These jobs would primarily involve construction contracts at each stage of construction proposed for the Project, mostly during the summer construction seasons. In total, there is a potential to create over 200 jobs with durations of approximately 1 to 4 months each between 2018 and 2030 (based on the current projection for the JEB TMF Expansion).

4.6.1 Training and Development Program

The McClean Lake Operation has a systematic approach for identifying and providing the training required by site employees:

- each department must identify and provide applicable training needs required for individual employees to perform their job, including:
- the Training Group identifies the required regulatory training;
- training materials and lesson plans are then developed on-site or purchased from outside sources;

- training is delivered by site staff or provided by contracted services;
- the Training Group retains a summary of all training records;
- job observations are periodically completed to confirm that learning has taken place and that tasks are being performed as designed; and
- the Safety, Health, Environment and Quality (SHEQ) group monitors regulatory changes that may necessitate changes in training requirements.

Facility changes are also monitored to ascertain if the changes result in a revision or creation of a training module.

4.7 Greenhouse Gas Emissions

The 2007 Intergovernmental Panel on Climate Change Fourth Assessment Report links observations of global warming to the anthropogenic emissions of greenhouse gases. In recognition of these finding, the Government of the Province of Saskatchewan created the *Management and Reduction of Greenhouse Gases Act* (*MRGGA*). The Act has not yet been proclaimed (i.e., come into force). Under the provisions of the *MRGGA*, all large emitters in the Province of Saskatchewan will be required to reduce their emissions by 2% per annum over a 10-year period, resulting in a 20% overall reduction in emissions by 2020. As defined by the *MRGGA*, "large emitters" are those facilities emitting more than 50,000 tonnes of carbon dioxide equivalents (CO_{2e}) per year.

Currently, peak annual emissions from the McClean Lake Operation are approximately 29,900 CO_{2e} per year. As such, the McClean Lake Operation is not considered a large emitter under the *MRGGA*. The proposed Project is expected to consume 2.4 million litres of diesel fuel during the construction phase. This will result in the temporary production of an additional 6,900 tonnes of CO_{2e} per year (Table 4.7-1). Therefore, the total peak annual emissions from the McClean Lake Operation during the construction phase of the Project is estimated to be 36,800 tonnes CO_{2e} per year; which is below the *MRGGA* regulatory threshold of 50,000 tonnes CO_{2e}. The temporary additions of CO_{2e} during the construction phase of the Project is a 23% increase from existing operations, however, this increase represents less than 0.01% of Saskatchewan's annual total emissions of 75,000,000 tonnes of CO_{2e} per year (Environment Canada 2010).

Table 4.7-1: Summary of Greenhouse Gas Emissions for the Construction Phase of the Project

Fuel	Quantity	Greenhouse Gas Emissions	Emissions Factor*	Emissions	Global Warming Potential	Emissions
	L/year	-	g/L	tonnes GHG/year	tonnes CO_{2e}/tonnes GHG	Tonnes CO_{2e}/year
Diesel	2,403,846	CO_2	2663	6,562.5	1	6,562.5
		CH_4	0.133	0.3	25	8.0
		N_2O	0.4	1.0	298	286.5
Total						6,857.0

*Emission Factors From http://ec.gc.ca/ges-ghg/default.asp?lang=En&n=AC2B7641-1
L/year = litres per year; CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide; g/L = gram per litre; CO_{2e}/year = carbon dioxide equavents per year

5 Existing Environment and Key Project-Environment Interactions

5.1 Introduction

This section was prepared as a carry-over from when the project required an environmental assessment and summarizes status of the environment reporting and environmental risk assessment methodology. The broad approach is to consider Project activity – environment interactions and then the potential of these interactions to result in unacceptable effects or risks to the biophysical or socio-economic environments. The underlying foundation of the Project uses a disciplined project planning process that relies on the integration of environmental and engineering considerations and the concepts of sustainable development. The approach used for determining the level of environmental risk from the Project on the biophysical and socio-economic environments is based on well-accepted ecological and socio-economic principles and environmental assessment practices.

This section provides an overview of the key Project-environment interactions that will need to be considered in determining the level of environmental risk from the Project on the biophysical and socio-economic environments. The objectives of this section are to present identified interactions - Project components and activities (e.g., footprint, mining activities, mine plan, water and waste management plans) that may affect the biophysical and socio-economic environments and then use this analysis to identify key environmental issues.

To provide a comprehensive, coherent understanding of the environment surrounding the McClean Lake Operation, and its operational performance, AREVA compiled and summarized relevant environmental studies in the Environmental Performance TID. Volume I of the Environmental Performance TID (AREVA 2016) comprehensively presents information on the status of the existing environment and of operational environmental performance. It includes baseline and operational data on the following topics in the local study area:

- Physical Environment
- Climate and Air Quality
- Aquatic Environment
- Terrestrial Environment
- Culture

Volume II provides predictive modelling of air, water, and sediment quality with results integrated into ecological and human health risk assessments based on current and anticipated

future activities at the McClean Lake Operation. Each section of VolumeII of the Environmental Performance TID describes the scenarios evaluated, the inputs to the predictive modelling, the modelling assumptions, and a discussion of the results within the context of previous predictions and current monitoring data. VolumeII includes:

- Air Dispersion Modelling
- Wastewater Management and associated water and sediment quality modelling
- Ecological Risk Assessment
- Human Health Risk Assessment
- A description of methodology including a detailed description of the pathways analysis used for the risk assessments

Volumes I and II of the Environmental Performance TID combine to provide the current status of environment within the McClean Lake Operation local study area, as well as an assessment of the anticipated future performance based on the current and future activities at the McClean Lake Operation. An update to Volume I was recently published on May 31, 2016; an updated Volume II will be published in September 2016.

5.2 Methods

A screening process is used to determine the existence and magnitude of linkages from the initial list of potential interactions for the Project. This screening step is intended to focus the evaluation of environmental risk on Project interactions that require a more comprehensive assessment of the level of environmental risk. Potential key interactions through which the Project could influence the biophysical and socio-economic environments were identified from a number of sources including:

- a review of the Project Description (Section 4.0) and scoping of potential risks by the environmental and engineering team for the Project;
- scientific knowledge, and experience with the McClean Lake Operation, as well as other uranium mines in Saskatchewan; and
- engagement with Aboriginals, the public, regulatory agencies.

Potential interactions through which the Project could affect biophysical and socio-economic environmental components are presented in Tables 5.2-1 and 5.2-2, respectively. Potential interactions are denoted by circles, considering normal operations, as well as accidents and malfunctions. Multiple interactions may be associated with each potential Project-environment interaction. For example, interactions associated with the construction of waste water management ponds and wildlife habitat may include sensory effects (e.g., noise, presence of

vehicles) and risks to vegetation from dust deposition. Project interactions determined to have the potential to result in an environmental change that could contribute affect biophysical and socio-economic environments relative to baseline or guideline values require further analysis to determine the level of risk to the environment.

Identification of potential interactions is then used to guide the design and implementation of environmental design features and mitigation (Table 5.2-3 and Table 5.2-4). Environmental design features are incorporated into the Project design to reduce or prevent environmental risk, and can include Project design considerations (i.e., berm liner) and environmental best practices, management policies and procedures, and social programs. Environmental design features are developed through an iterative process between the Project's engineering and environmental teams to avoid or limit (mitigate) risks.

Once key Project-environment interactions and mitigation are understood, efforts can be focused on addressing these key issues. This understanding aids in the optimization of the Project design, and focuses the mitigation and monitoring plans. Project-environment interactions where mitigation eliminates or reduces potential effects such that there is no anticipated environmental risks are screened out and do not require further assessment. Key Project-environment interactions that require a more comprehensive assessment to determine the potential environmental risk from the Project on the biophysical and socio-economic environments are described in Section 5.3.

The interaction table (Tables 5.2-3 and 5.2-4) highlights potential Project-environment interactions, environmental design features to mitigate risks, and anticipated monitoring requirements. Details of the monitoring programs are provided in Section 6.

Table 5.2-1: Potential Project-Environment Interactions with the Biophysical Environment

Project Phase	Key Project Activities	Biophysical Environment														
		Atmospheric and Acoustic Environmental Components		Hydro-geological and Geological Environmental Components		Aquatic Environment Components						Terrestrial Environment Components				
		Air Quality (air emissions and dust deposition)	Noise	Groundwater Quality	Groundwater Quantity	Hydrology	Surface Water Quality	Sediment Quality	Aquatic Biota Population and Communities	Aquatic Biota COPC Exposure	Aquatic Habitat	Soil Quality and Quality	Vegetation Quality and Quantity	Wildlife Populations	Wildlife COPC Exposure	Wildlife Habitat Quality and Quantity
Construction	JEB TMF Embankment	●	●			●	●	●	●		●	●	●	●		●
	Site Water Management (i.e., waste rock runoff ponds)	●	●			●	●	●	●		●	●	●	●		●
	Relocation of Site Infrastructure (e.g., contaminated material landfill, power lines, tailings barge and anchor points, tailings lines, reclaim water lines, tailings delivery pipeline, and underflow pump).	●	●				●	●	●		●	●	●	●	●	●
Operation	JEB TMF	●	●	●		●	●	●	●	●	●			●	●	●
	Site Water Management (i.e., waste rock runoff ponds, reclaim water)			●	●	●	●	●	●	●	●	●	●	●	●	●
	Waste Water Management (i.e., S/V TEMS)					●	●	●	●	●	●	●	●	●	●	●
	Site Infrastructure (e.g., contaminated material landfill, power lines, tailings barge and anchor points, tailings lines, reclaim water lines, tailings delivery pipeline, and underflow pump).	●	●	●			●	●	●		●	●	●	●	●	●
Decommissioning, Closure, and Reclamation	JEB TMF (e.g., cover placement)	●	●	●		●	●	●	●	●	●	●	●	●	●	●
	Site Water Management (i.e., waste rock runoff ponds,)	●	●			●	●	●	●		●	●	●	●		●
	Waste Water Management (i.e., S/V TEMS)					●	●	●	●	●	●	●	●	●	●	●
	Site Infrastructure (e.g., contaminated material landfill, power lines, tailings barge and anchor points, tailings lines, reclaim water lines, tailings delivery pipeline, and underflow pump).	●	●	●		●	●	●	●		●	●	●	●		●
	Radioactive or contaminated materials/wastes	●													●	
Accidents and Malfunctions	Spills and Process Upsets (petroleum products, uncontrolled effluent release)			●		●	●	●	●	●	●	●	●	●	●	●
	Failure of the JEB TMF embankment			●		●	●	●	●	●	●	●	●	●	●	●
	Cover Integrity			●	●	●	●	●	●	●	●	●	●	●	●	●
	Failure of a base drain pump or unexpected increase in pumping requirements			●			●	●	●	●	●			●	●	●

Note: ● – Project-environment interaction; Blank cell – no interaction anticipated.

Table 5.2-2: Potential Project-Environment Interactions with the Socio-economic Environment

Project Component	Potential Interaction	Key Socio-economic Components													
		Land and Resource Use						Economy		Infrastructure and Services			Culture and Community Well-being		
		Land and Resource Use for Traditional and Domestic Purposes	Land Subject to Aboriginal and Treaty Rights, Land Claims and Traditional Territory	Hunting, Trapping, and Fishing for Commercial or Recreational Purposes	Tourism, Outfitting, Lodges, and Outdoor Recreation	Forestry, Mining, and Other Resources Uses	Protected Area	Employment	Business	Population	Public Infrastructure and Services	Housing	Heritage Resources	Community Health and Well-being	Transportation and Public Safety
Construction/ Operation/ Decommissioning	Changes to the Biophysical Environment	●		●	●									●	
	Traffic														●
	Radiation Exposure													●	
	Conventional Health and Safety							●	●					●	
	Employment and Business Opportunities							●	●	●	●	●			
	Disturbance/Discovery of Heritage Resources												●		

Note: ● – Project-environment interaction; Blank cell – no interaction anticipated.

Table 5.2-3: Potential Project Interactions with the Biophysical Environment and Associated Mitigation and Monitoring Requirements

Project Component/Activity	Biophysical Environment Component	Potential Project-Environment Interactions	Mitigation	Monitoring Requirement
• Construction of the Physical Project Footprint • JEB TMF Embankment • Site Water Management • Relocation of Site Infrastructure	• Hydrology • Aquatic biota population and communities • Aquatic habitat • Vegetation quantity • Wildlife habitat quantity	• Loss or alteration hydrologic conditions, which can affect aquatic biota population and communities, aquatic habitat, vegetation (riparian), and wildlife habitat.	• the Project footprint will be located in an area that has largely been disturbed; • the contaminated landfill will use the existing special waste stockpile pad, thereby reducing land disturbance. • for those structures that are decommissioned at the same time with the expanded JEB TMF, all salvageable materials will be decontaminated and removed from the site; • waste rock will be used as the main fill material for the construction of the soil cover and the remaining waste rock within the pile will be contoured; • the diversion ditches will be backfilled, regraded, and revegetated; • waste rock runoff pond embankments will be removed or flattened, breached, and recontoured to blend in with the surrounding local topography; and • the JEB TMF will be returned to a vegetated natural setting at decommissioning.	• Standard construction monitoring and QA/QC procedures
	• Soil quantity • Vegetation quantity • Wildlife habitat quantity	• Loss or alteration of local soil, and loss and fragmentation of vegetation and wildlife habitat from the Project footprint.		• Standard construction monitoring and QA/QC procedures • Rare plant surveys have already been completed
	• Surface water quality • Aquatic biota population and communities • Aquatic habitat	• Site clearing and contouring may cause erosion to soils, that can affect surface water quality and aquatic habitat.	• Erosion control practices will limit wind and water erosion of topsoil and overburden stockpiles • the expansion will bring the toe of the JEB TMF embankment no closer than 10 m from the high water mark of Fox Lake and is considered a reasonable buffer to provide sedimentation control during construction; • erosion and sediment control may include silt fencing installed adjacent to Fox Lake, and if necessary, an erosion control blanket could be installed on the downstream slope of the embankment fill during construction; • an erosion and sediment control plan will need to be developed prior to construction to mitigate erosion of the slope and prevent transport of sediments to Fox Lake; and • the erosion and sediment control plan may include the construction of a sediment catch consisting of a berm or ditch along the downstream embankment slope adjacent to Fox Lake, and vegetating the slope.	• Standard construction monitoring and QA/QC procedures
• General Construction, Operation, and Decommissioning, Closure and Reclamation activities	• Air quality • Surface water quality • Sediment quality • Aquatic biota population and communities • Aquatic habitat • Soil quality • Vegetation quality • Wildlife populations • Wildlife habitat quality	• Air emissions (sulphur dioxide [SO_2], nitrogen oxides [NO_x], particulate matter [PM], and total suspended particulates [TSP]) can cause changes to the chemical properties of surface water, soil, vegetation, and wildlife habitat.	• low sulphur diesel for equipment; • the EMP includes air quality monitoring, which is completed to assess the potential risks from the McClean Lake Operation; and • the EMP includes soil and vegetation monitoring to assess the potential risks of air emissions from the McClean Lake Operation.	• Standard construction monitoring and QA/QC procedures • If required, additional air quality sampling stations will be added within the framework of the existing EMP

Project Component/Activity	Biophysical Environment Component	Potential Project-Environment Interactions	Mitigation	Monitoring Requirement
	• Surface water quality • Soil quality • Vegetation quality • Wildlife populations • Wildlife habitat quality	• Dust deposition cause changes to the chemical properties of surface water, soil, vegetation, and wildlife habitat.	• standard dust suppression procedures (use of water to control dust) on site roads; • adherence to speed limits will assist in reducing the potential for the generation of dust; • the EMP includes air quality monitoring, which is completed to assess the potential risks from the McClean Lake Operation; and • the EMP includes soil and vegetation monitoring to assess the potential risks of air emissions from the McClean Lake Operation.	• Standard construction monitoring and QA/QC procedures • If require, additional air quality sampling stations will be added within the framework of the existing EMP
	• Aquatic biota population and communities • Aquatic habitat • Vegetation quantity • Wildlife populations • Wildlife quantity	• Dust deposition may cover aquatic substrates and terrestrial vegetation and reduce the quantity of aquatic and wildlife habitat.		• Standard construction monitoring and QA/QC procedures • If required, additional air quality sampling stations will be added within the framework of the existing EMP
	• Noise • Wildlife populations • Wildlife habitat quality	• Sensory risks (e.g., presence of buildings, people, lights, smells, and vehicles) can change the quality of wildlife habitat and alter wildlife populations (distribution).	• use of conventional noise suppressors on equipment; • stationary equipment is housed inside buildings, reducing the amount of noise released into the environment; and • environmental awareness training for employees and contractors.	• Standard construction monitoring and QA/QC procedures
• Site Water Management (i.e., waste rock runoff ponds,).	• Surface water quality • Aquatic biota population and communities • Aquatic biota COPC exposure • Aquatic habitat • Soil quality • Vegetation quality • Wildlife populations • Wildlife COPC exposure • Wildlife habitat	• Site runoff and erosion can affect surface water quality, aquatic biota population and communities, aquatic habitat, soil, vegetation, and wildlife habitat.	• runoff from the JEB clean waste rock pile will either be diverted to the runoff collection pond or directed to a sedimentation pond to settle out solids prior to release; • runoff from the McClean Lake Mill terrace will be collected in a lined pond for treatment; • culverts would be placed to provide drainage from the existing McClean Lake Mill site pond to the new McClean Lake Mill terrace pond; • runoff from the waste rock pile will be separated from the McClean Lake Mill terrace runoff to reduce the volume of runoff requiring treatment; • the new waste rock and McClean Lake Mill site runoff ponds have the capacity to contain PMP runoff, plus the PMP directly on the ponds; and • the PMP runoff to the new waste rock runoff ponds will be conveyed through the upgraded ditch.	• Standard construction monitoring and QA/QC procedures • Surface water quality monitoring is already completed as part of the EMP. No changes to the EMP are required.

Table 5.2-3: Potential Project Interactions with the Biophysical Environment and Associated Mitigation and Monitoring Requirements

Project Component/Activity	Biophysical Environment Component	Potential Project-Environment Interactions	Mitigation	Monitoring Requirement
• Site Water Management (i.e., waste rock runoff ponds).	• Groundwater quality • Surface water quality • Aquatic biota population and communities • Aquatic biota COPC exposure • Wildlife populations • Wildlife COPC exposure	• Seepage from the McClean Lake Mill terrace pond during operations may cause changes to groundwater and surface water quality, and can affect the health of aquatic biota and wildlife (i.e., COPC exposure), and community health and well-being.	•	• Surface water quality monitoring is already completed as part of the EMP. No changes to the EMP are required. • Groundwater monitoring is already completed as part of the EMP. Monitoring wells that will be affected by the construction of the Project will be decommissioned and replaced with new wells as required.
	• Hydrology • Surface water quality • Sediment quality • Aquatic biota population and communities • Aquatic biota COPC exposure • Aquatic habitat • Soil quality • Vegetation quality • Wildlife populations • Wildlife COPC exposure • Wildlife habitat quality	• Decrease in pumping of groundwater from dewatering wells to maintain hydraulic containment may change the quantity of clean water discharged in the S/V TEMS, and can change surface water and sediment quality, which may affect the health of aquatic biota and wildlife (i.e., COPC exposure), and community health and well-being.	• the EMP includes monitoring water quality to characterize effluent streams and the residual risks in the receiving environment (both upstream and downstream of the S/V TEMS); • ongoing updates to the EMP are completed to improve and focus monitoring activities, and implement changes to the program to reflect changes in the operational activities; and • the implementation of the Environmental Code of Practice will reduce the potential for risks to the environment.	• Surface water quality monitoring is already completed as part of the EMP. No changes to the EMP are required. • Groundwater monitoring is already completed as part of the EMP. Monitoring wells that will be affected by the construction of the Project will be decommissioned and replaced with new wells as required.
• Waste Water Management (i.e., S/V TEMS)	• Hydrology • Surface water quality • Aquatic biota population and communities • Aquatic habitat • Soil quantity • Vegetation quantity • Wildlife populations • Wildlife habitat quantity	• Alterations in hydrologic conditions from changes in the treated effluent discharge rates can cause erosion, which may affect surface water quality, aquatic biota population and communities, aquatic habitat, soil, vegetation, and wildlife habitat.	• raise well water from the JEB TMF base drain will be recycled and used as mill process water, thereby reducing discharge volumes from the JEB WTP; • treated effluent releases from the JEB WTP will be continually monitored so that water quality meets specific criteria before being discharged to the S/V TEMS; • discharge volumes will not exceed approved daily discharge rates for the S/V TEMS to prevent stream bed erosion; • the JEB WTP uses a proven technology; • the JEB WTP includes infrastructure to manage inflows that exceed the JEB WTP capacity, and contained storage and collection systems within the site drainage network for additional storage; • the operation has the capacity to cease discharge from the JEB WTP by recycling monitoring pond water back to the JEB WTP in cases of effluent quality non-compliance; • extensive programs are in place to monitor and control effluent quality from the JEB WTP; • regular inspections of mechanical workings at the S/V TEMS, as well as annual geotechnical inspections of the containment dam are completed to reduce the potential of failure; • the EMP includes monitoring water quality to characterize effluent streams and the residual risks in the receiving environment (both upstream and downstream of the S/V TEMS); • ongoing updates to the EMP are completed to improve and focus monitoring activities, and implement changes to the program to reflect changes in the operational activities; and • the implementation of the Environmental Code of Practice will reduce the potential for risks to the environment.	• Surface water hydrology and surface water quality monitoring are already completed as part of the EMP. No changes to the EMP are required.
	• Surface water quality • Sediment quality • Aquatic biota population and communities • Aquatic habitat • Aquatic biota COPC exposure • Wildlife COPC exposure	• Treated effluent discharge from the JEB WTP can change surface water and sediment quality, which may affect the health of aquatic biota and wildlife (i.e., COPC exposure), and community health and well-being.		• Surface water quality monitoring is already completed as part of the EMP. No changes to the EMP are required.

Project Component/Activity	Biophysical Environment Component	Potential Project-Environment Interactions	Mitigation	Monitoring Requirement
• JEB TMF	• Groundwater quality • Surface water quality • Sediment quality • Aquatic biota population and communities • Aquatic habitat • Aquatic biota COPC exposure • Wildlife populations • Wildlife COPC exposure	• Solute transport from the JEB TMF during operations may cause changes to groundwater and surface water quality, and can affect the health of aquatic biota and wildlife (i.e., COPC exposure), and community health and well-being.	• a liner will be constructed to contain the operating pond through the till and embankment; • a pond wave analysis was completed to calculate sufficient freeboard, and to determine the size and thickness of the rip rap layer required to protect the liner slope from wave action; • hydraulic containment will be provided by pumping from the base drain using the raise wells, and from the pond, if necessary, using the reclaim barge; • Pumps currently installed in the base drain have sufficient pumping capacity to accommodate the increase rate; • pumping from the reclaim barge will be at a rate sufficient to balance the inflow to the pond from tailings deposition and precipitation; • an instrumentation program will be implemented to monitor the performance of the embankment and liner system during operations; and • new monitoring wells will be installed in each of the stratigraphic units around the JEB TMF to monitor water levels and water quality during operations.	• The EMP will be revised to re-establish the benthic invertebrate and sediment sampling station at Fox Lake (BM13E). • Groundwater monitoring is already completed as part of the EMP. Monitoring wells that will be affected by the construction of the Project will be decommissioned and replaced with new wells as required.
• Site Infrastructure (e.g., power lines, tailings barge and anchor points, tailings lines, reclaim water lines, tailings delivery pipeline, and underflow pump).	• Wildlife populations	• Hazards at the site and increased vehicle traffic during construction may cause injury or mortality to individual animals.	• at decommissioning, the entire site area will be re-contoured to reduce hazards to wildlife; and • ditches will be contoured or backfilled at decommissioning as appropriate to remove any hazards to wildlife. • speed limits are posted and enforced; and • all site roads are routinely maintained by site personnel.	• Standard construction monitoring and QA/QC procedures.

Table 5.2-3: Potential Project Interactions with the Biophysical Environment and Associated Mitigation and Monitoring Requirements

Project Component/Activity	Biophysical Environment Component	Potential Project-Environment Interactions	Mitigation	Monitoring Requirement
• Decommissioning, closure, and reclamation • JEB TMF • Site Water Management • Waste Water Management • Site Infrastructure	• Groundwater quality • Surface water quality • Sediment quality • Aquatic biota population and communities • Aquatic habitat • Aquatic biota COPC exposure • Wildlife populations • Wildlife COPC exposure	• Long-term solute transport from the JEB TMF can change groundwater and surface water quality, which may affect the health of aquatic biota and wildlife (i.e., COPC exposure), and community health and well-being.	• back-filling the JEB TMF above the tailings mass with clean waste rock and installing a compacted till cover at surface to promote consolidation of the tailings to a density and hydraulic containment conductivity that will reduce flow of groundwater through the tailings mass; • tailings settlement will be monitored to confirm tailings consolidation is complete; • a soil cover system consisting of waste rock and an amended processed waste rock-bentonite layer will provide a layer to limit infiltration; • the soil cover will limit the infiltration of atmospheric water to the underlying tailings and contaminated materials thus reducing the environmental loadings to the environment; • installation of a post decommissioning monitoring system to monitor cover performance; • the freeze/thaw, wetting/drying and erosion risks will be minimal because the amended processed waste rock-bentonite layer will have a low volume change potential, it will be protected by a surface layer thick enough to mitigate potential drying, and through a closure landform configuration and a drainage system; • implementation of the TOVP for regularly evaluating tailings performance provides the basis of continual improvement of the operational processes performed within the McClean Lake Mill and JEB TMF; • a performance monitoring program will be implemented to confirm physical and environmental stability of the JEB TMF during and after the decommissioning period; • a test plot program will be implemented to validate cover performance throughout operations; and • the post-decommissioning EMP will focus on the surrounding and downstream receiving environment and will be completed until uncertainty in the long-term predictions is reduced to an acceptable level.	• Monitoring of tailings pore water pressure and consolidation. • Instrumentation will be installed to monitor the performatnce of the final soil cover. • Groundwater monitoring is already completed as part of the EMP. Monitoring wells that will be affected by the construction of the Project will be decommissioned and replaced with new wells as required.
• Decommissioning, closure, and reclamation (continued) • JEB TMF • Site Water Management • Waste Water Management • Site Infrastructure	• Groundwater quantity • Hydrology • Aquatic biota population and communities • Aquatic habitat • Vegetation quantity • Wildlife populations • Wildlife habitat	• Changes in groundwater flows and pattern related to decommissioning of the JEB TMF can alter surface water levels in Fox Lake and Pat Lake, which can affect aquatic biota population and communities, aquatic habitat, vegetation (riparian), and wildlife habitat.	• After decommissioning, tailings in the JEB TMF will have a lower hydraulic conductivity than the surrounding sandstone. Therefore, because water will take the path of least resistance, groundwater will flow around the JEB TMF, through the sandstone, and will not pass through the tailings.	• Monitoring of tailings pore water pressure and consolidation. • Instrumentation will be installed to monitor the performatnce of the final soil cover. • Groundwater monitoring is already completed as part of the EMP. Monitoring wells that will be affected by the construction of the Project will be decommissioned and replaced with new wells as required.

Project Component/Activity	Biophysical Environment Component	Potential Project-Environment Interactions	Mitigation	Monitoring Requirement
	• Hydrology • Aquatic biota population and communities • Aquatic habitat • Vegetation quantity • Wildlife populations • Wildlife habitat	• Changes in drainage patterns and surface water flows from changes in terrain related to decommissioning of the JEB TMF may alter surface water levels, which can affect aquatic biota population and communities, aquatic habitat, vegetation (riparian), and wildlife habitat.	• the geomorphic criteria for the landform design of the decommissioned JEB TMF was developed through the analyses of the regional and local climate, geology, hydrogeology, and natural landforms nearby the JEB TMF; • the soil cover system will provide a sustainable landform configuration and drainage system for the decommissioned JEB TMF, which is representative of local terrain features; • the alluvial channel at the toe of the decommissioned embankment was designed to adjust and change over time without accelerated erosion or unacceptable environmental risks; • the design allows the channel to be self-healing and gives it the ability to dynamically adapt to erosion and sediment deposition processes; • vegetated waterways are a sustainable and robust means of conveying intermittent flow over a surface without erosion; • micro-topography in the form of ridges and swales are designed to allow positive flows towards swales; • the drainage ditches in the swales are expected to evolve naturally after construction of the decommissioned landscape; • the natural evolution will facilitate the development of a regime of channel pattern and cross-sectional shape that is expected to be stable over the long-term; and • the embankment section of the waste rock runoff pond will be breached to a width that will allow for surface drainage around the surrounding JEB TMF slope.	• Surface water hydrology and surface water quality monitoring are already completed as part of the EMP. No changes to the EMP are required.
	• Wildlife populations • Wildlife COPC exposure	• Exposure to COPCs from radon, gamma, and radioactive dust or through uptake of constituents of potential concern by wildlife through ingestion of vegetation on the decommissioned JEB TMF may affect wildlife health (COPC exposure).	• gamma radiation exposure is mitigated by placement of the cover materials; • radon exposure is limited by the placement of layers of cover materials and the saturated soil cover; • radioactive dust exposure is eliminated by the containment of the tailings materials within the decommissioned TMF; • the expanded JEB TMF will be capped with a low hydraulic conductivity soil cover system; and • cover on the JEB TMF is of suitable depth and material to prevent roots from penetrating through.	• No changes are required to the radiation protection program currently established at the McClean Lake Operation. • The soil cover performance will be evaluated prior to decommissioning through the construction of soil cover test plots. • Several soil cover test plots will be constructed to evalutate the risk of key parameters on cover performance, and the results will be incorporated into the final soil cover design.

Project Component/Activity	Biophysical Environment Component	Potential Project-Environment Interactions	Mitigation	Monitoring Requirement
	• Wildlife populations • Wildlife COPC exposure	• Exposure to radioactive or contaminated materials/wastes after decommissioning of the Project may affect wildlife health.	• remaining radioactive or contaminated materials will be established by removing or adequately covering these materials with local materials; • all salvageable materials will be decontaminated and removed from the site; • the deposited tailings and other contaminated materials will be stored in the expanded JEB TMF for in situ confinement; and • the expanded JEB TMF will be capped with a low hydraulic conductivity soil cover system.	• No changes are required to the radiation protection program currently established at the McClean Lake Operation. • The soil cover performance will be evaluated prior to decommissioning through the construction of soil cover test plots. • Several soil cover test plots will be constructed to evalutate the risk of key parameters on cover performance, and the results will be incorporated into the final soil cover design.

Table 5.2-3 Potential Project Interactions with the Biophysical Environment and Associated Mitigation and Monitoring Requirements

Project Component/Activity	Biophysical Environment Component	Potential Project-Environment Interactions	Mitigation	Monitoring Requirement
• Accidents and Malfunctions	• Surface water quality • Aquatic biota population and communities • Aquatic biota COPC exposure • Aquatic habitat • Soil quality • Vegetation quality • Wildlife populations • Wildlife COPC exposure	• Spills and process upsets (e.g., petroleum products, uncontrolled effluent release) on-site can cause changes to the chemical properties of surface water, soils, and vegetation, which can influence the quality of aquatic and wildlife habitat, and affect aquatic biota and wildlife health (i.e., COPC exposure).	• Spill Response Plan and Training; • chemical spill containment has been incorporated into the McClean Lake Mill design (e.g., berms, liners, proper storage); • spill response materials are available in designated areas where fuel and chemicals are stored; • outflow from Sink Reservoir can be stopped and effluent can be stored in Sink Reservoir until conditions for release are appropriate (high or low enough flows); • the operation has the capacity to cease discharge from the JEB WTP in cases of effluent quality non-compliance; and • regular inspections of mechanical workings at the S/V TEMS, as well as annual geotechnical inspections of the containment dam are completed to reduce the potential of failure.	• Standard construction monitoring and QA/QC procedures. • No changes required to the IQMS already implemented for the McClean Lake Operation.
•	• Groundwater quality • Surface water quality • Aquatic biota population and communities • Aquatic biota COPC exposure • Wildlife populations • Wildlife COPC exposure	• Failure of a base drain pump or an unexpected increase in the required base drain pumping from the JEB TMF can cause changes to the chemical properties of groundwater, which can alter surface water quality and influence the quality of aquatic and wildlife habitat, and affect aquatic biota and wildlife health (i.e., COPC exposure).	• the design of the base drain pumping consists of three pulmps with a total design pumping capacity of approximately 5,760 m^3/day; • the design provides both contingency if one pumps failis and extra capacity in the event that the required base drain pumping rate is greater than 3,000 m^3/day.	• The EMP will be revised to re-establish the benthic invertebrate and sediment sampling station at Fox Lake (BM13E). • Groundwater monitoring is already completed as part of the EMP. Monitoring wells that will be affected by the construction of the Project will be decommissioned and replaced with new wells as required.
•	• Surface water quality • Aquatic biota population and communities • Aquatic biota COPC exposure • Wildlife populations • Wildlife COPC exposure	• Runoff and erosion can affect stability of the JEB TMF embankment during operations, and may result in a failure that could alter surface water quality (Fox Lake), which can affect the health of aquatic biota and wildlife (i.e., COPC exposure), and community health and well-being.	• laboratory tests were completed to characterize and evaluate the soil and crushed rock material for use as potential fill and liner material; and • slope stability analyses and reliability analyses were completed and considered in the design of the embankment. • a minimum factor of safety of 1.5 was used for long-term conditions as recommended by the US Army Corps of Engineers; • during decommissioning of the expanded JEB TMF, the downstream slopes will be flattened to 4H:1V to mitigate erosion potential and to further improve long-term stability of the slope; • all embankment slopes under consideration meet the objective of achieving a minimum factor of safety of more than 1.0 under seismic loading conditions. • instrumentation will be installed in the embankment and the underlying stratigraphic units to monitor changes that may be critical to maintaining groundwater quality and slope stability, and to evaluate solute transport through the liner; • survey markers will be installed on top and downstream of the embankment to monitor slope movement and stability; and • preventative maintenance, based on early observation of seepage or severe erosion will be completed to facilitate maintenance of the stability and integrity of the embankment and liner system. • Risk assessment for a failure of the tailings embankment has been conducted to evaluate impacts on surface and sediment quality in neighbouring lakes; potential impacts are not catastrophic.	• The EMP will be revised to re-establish the benthic invertebrate and sediment sampling station at Fox Lake (BM13E). • Routine monitoring and preventative maintenance through visual observation of the embankment and measurement from field instrumentation.

Project Component/Activity	Biophysical Environment Component	Potential Project-Environment Interactions	Mitigation	Monitoring Requirement
	• Groundwater quality • Groundwater quantity • Hydrology • Surface water quality • Aquatic biota population and communities • Aquatic biota COPC exposure • Aquatic habitat • Soil quality and quantity • Vegetation quality and quantity • Wildlife populations • Wildlife COPC exposure • Wildlife habitat quality and quantity	• Erosion on-site at decommissioning and of soil covering the decommissioned JEB TMF may change surface water quality and decrease cover integrity.	• the JEB TMF will be capped with a low hydraulic conductivity soil cover system; • the soil cover will limit the infiltration of atmospheric water to the underlying tailings and contaminated materials; • cover system will be contoured to reduce flow over the decommissioned facility; • five test plots are anticipated to be constructed for the cover evaluation study for the Project to provide key field data, to validate and refine the soil cover design; • each test plot will be instrumented to monitor climatologic variables, runoff, percolation, soil temperature, soil suction, and soil water content; • soil and meteorogical instruments will be installed within a well developed forested area to determine the water balance; • the downstream slope of the embankment will be flattened to mitigate erosion potential and improve long-term stability of the slope; • the alluvial channel at the toe of the decommissioned embankment was designed to adjust and change over time without accelerated erosion or unacceptable environmental risks; • the alluvial channel facilitates self-healing and gives it the ability to dynamically adapt to erosion and sediment deposition processes; • vegetated waterways are a sustainable and robust means of conveying intermittent flow over a surface without erosion; • the natural evolution will facilitate the development of a regime of channel pattern and cross-sectional shape that is expected to be stable over the long-term; • siltation fences will be installed downstream prior to the embankment breaching and flattening; and • a test plot program will be implemented to validate cover performance throughout operations.	• The EMP will be revised to re-establish the benthic invertebrate and sediment sampling station at Fox Lake (BM13E). • The soil cover performance will be evaluated prior to decommissioning through the construction of soil cover test plots. • Several soil cover test plots will be constructed to evalutate the risk of key parameters on cover performance, and the results will be incorporated into the final soil cover design.

Table 5.2-4: Potential Project Interactions with the Socio-economic Environment and Associated Mitigation and Monitoring Requirements

Project Component/Activity	Socio-economic Environment Components	Potential Project-Environment Interactions	Mitigation	Monitoring Requirement
• General construction, operation, and decommissioning	• Land and resource use for traditional and domestic purposes. • Hunting, trapping, and fishing for commercial or recreational purposes. • Community health and well-being.	• Changes in physical, chemical, ergonomic, and biological stressors may reduce conventional health and safety in the working environment.	• The conventional health and safety controls identified for the Project are consistent with the procedures and processes that apply at the McClean Lake Operation: • communication of safety principles and the performance of activities that promote and implement the principles of the safety program to staff; • continuing the enhancement of a positive site safety culture; • ongoing implementation of program activities such as medical surveillance programs, physical conditions inspections and work place monitoring of COPCs; and • completion of accident investigations, safety statistics, risk assessments, safety meetings, hazard analysis, safety training, change management procedures, and emergency preparedness.	• No changes required to the OHS or IQMS already implemented for the McClean Lake Operation.
	• Community health and well-being.	• Radiation and radon gas emissions from the Project can affect community health and well-being.	• tailings continue to be placed under sufficient water cover to attenuate both radon and gamma emissions; • continued implementation of the current Radiation Code of Practice will reduce the potential for radiation and radon gas emissions affecting human health • gamma radiation exposure is mitigated by placement of the cover materials; • Radon exposure is limited by the placement of layers of cover materials and the saturated soil cover; and • Radioactive dust exposure is eliminated by the containment of the tailings materials within the decommissioned TMF.	• No changes are required to the radiation protection program currently established at the McClean Lake Operation. • Routine radiological monitoring data will be used to validate the predicted radiological dose rates within the JEB TMF during the placement of tailings from high ore grades. • The JEB TMF area will be subjected to the performance confirmation process desbribed by the Radiological Performance Plan.
	• Community health and well-being.	• Noise and air emissions from construction activities and traffic are nuisances that may affect local community health and well-being (i.e., quality of life).	• use of conventional noise suppressors on equipment; • low sulphur diesel for equipment; • standard dust suppression procedures (use of water to control dust); and • standard construction monitoring and QA/QC procedures.	• Standard construction monitoring and QA/QC procedures. • Additional air quality sampling stations will be added within the framework of the existing EMP
	• Heritage resources.	• Construction may cause disturbance or destruction of heritage resources.	• several archaeological surveys have been completed at the McClean Lake Operation and know sites are documented; and • management options for archaeological and/or heritage materials discovered during construction activities will be developed in consultation with the Saskatchewan Heritage Resources Branch.	• Standard construction monitoring and QA/QC procedures. • Heritage resource surveys have already been completed.

Project Component/Activity	Socio-economic Environment Components	Potential Project-Environment Interactions	Mitigation	Monitoring Requirement
	• Employment	• Hiring of additional personnel to support the Project may change employment in surrounding communities.	• Hiring preferences and training opportunities for jobs associated with the Project will be consistent with AREVA's Human Resource Development Agreement. • AREVA will prioritize the participation of northern Saskatchewan residents in the area of employment, particularly those identified as primary impact communities within the Athabasca Basin. • AREVA will continue to provide fly-in/fly-out services to remote northern and southern pick-up points, thereby reducing the requirements for workers to relocate to close-proximity communities.	• No changes required to the Human Resource Development Agreement
	• Population • Public Infrastructure and services • Housing	• Hiring of additional personnel to support the Project may change the population in surrounding communities, which may add pressure to housing, infrastructure, and services.	• AREVA address these concerns through various programs already in place, discussions with various stakeholders (e.g., AWG) and through Impact Management Agreements with northern communities; and • AREVA has a program to consider donation requests for infrastructure projects in northern Saskatchewan.	• No changes required to the Impact Management Agreements.
	• Business	• Increased business activity from the Project may change the level of business activity in surrounding communities and northern Saskatchewan.	• Hiring preferences, including contractors will be consistent with the Human Resource Development Agreement.	• No changes required to the Human Resource Development Agreement
	• Transportation and Public Safety	• Construction activities may modify local transportation infrastructure and affect local communities through increase road maintenance and traffic volume.	• AREVA and the MHI have a Transportation Partnership Agreement whereby AREVA makes monthly financial contributions to the MHI to compensate for the incremental risk on the highway system due to industrial transportation activities.	• No changes required to the Transportation Partnership Agreement.
		• Changes in traffic volume may increase the potential for collisions, and reduce public safety.	• speed limits will be followed along the haul route reducing the potential for collisions; • an ore haul procedure is enforced during active transportation of ore on site; • all site roads are routinely maintained by site personnel; • walking on the haul road is restricted during active transportation of ore on site; and • preventative maintenance is used to limit unscheduled maintenance requirements.	• No changes required to the OHS or IQMS already implemented for the McClean Lake Operation.

MHI = Saskatchewan Ministry of Highways and Infrastructure; COPCs = constituents of potential concern; AWG = Athabasca Working Group; QA/QC = quality assurance quality control

5.3 Results

Key Project-environment interactions that require a more comprehensive assessment to determine the potential environmental risk from the Project on the biophysical and socio-economic environments are described below.

- **Loss or alteration of local soil, and loss and fragmentation of vegetation and wildlife habitat from the Project footprint.**

Current infrastructure from the McClean Lake Operation has developed approximately 701.5 ha within the McClean Lake Operation surface lease (AREVA 2016b). The Project footprint will increase by 17.8 hectare (ha); however, it is located in an area that has largely been previously disturbed. Therefore, the Project is expected to result in a minor incremental loss of soils, vegetation, and wildlife habitat from current conditions within the McClean Lake Operation surface lease. As the Project will be constructed within an area that has largely been previously disturbed, within the McClean Lake Operation surface lease, effects to wildlife from loss and fragmentation of habitat are also expected to be minor. Consequently, the environmental risk from the Project on the biophysical environment is expected to be negligible.

The current McClean Lake Operation EMP (AREVA 2014) requires very little change in order to effectively monitor any potential effects from the Project, as the EMP was originally designed to monitor the existing JEB TMF and McClean Lake Operation. As indicated to Environment Canada, the SMOE will work with Environment Canada through the recovery planning process for woodland caribou. Once the Environment Canada Proposed Recovery Strategy for the Woodland Caribou, Boreal Population, in Canada is made final, provincial management plans will be developed. AREVA will continue to work through the Saskatchewan Mining Association to contribute to Environment Canada National Recovery Strategy for Woodland Caribou and will operate in accordance with the Strategy when it is finalized. Therefore, the cumulative environmental risk from the Project on the biophysical environment is expected to be negligible (i.e., it is not expected that there will be a cumulative effect on wildlife populations, including woodland caribou, from changes in habitat).

- **Solute transport from the JEB TMF during operations may cause changes to groundwater and surface water quality, and can affect the health aquatic biota and wildlife (i.e., COPC exposure), and community health and well-being.**

The JEB TMF serves as the repository for all tailings resulting from processing of ore at the McClean Lake Operation. The facility was designed to reduce environmental effects due to tailings management throughout operations and for the decommissioned facility, through application of numerous mitigation features. As the levels of the operating pond within the JEB TMF have increased to a level above the groundwater table in the vicinity of the JEB TMF, pumping from the dewatering wells is no longer required to intercept clean groundwater inflow. Hydraulic containment for the expanded JEB TMF will be provided by pumping mainly from the base drain using the raise wells, and from the pond (i.e., to maintain adequate freeboard), if

necessary, using the reclaim barge (Table 5.2-3). A liner will be constructed to contain the operating pond.

Modelling of groundwater inflow to the expanded JEB TMF was completed to determine the design pumping rate from the raise wells that will provide adequate containment of tailings pore water during operations. Pumping from the base drain will be increased from existing rates to provide hydraulic containment for expanded JEB TMF within the sandstone layer. Pumps currently installed in the base drain have sufficient pumping capacity to accommodate the increase rate (Table 5.2-3). Pumping from the reclaim barge will be at a rate sufficient to balance the inflow to the pond from tailings deposition and precipitation. As such, the environmental risk from solute transport from the JEB TMF during operations on biophysical and socio-economic environments is expected to be negligible.

- **Changes in drainage patterns and surface water flows from changes in terrain related to decommissioning the JEB TMF may alter surface water levels, which can affect aquatic biota population and communities, aquatic habitat, vegetation (riparian), and wildlife habitat.**

The end-state plan for the expanded JEB TMF will be to return lands disturbed by Project activities to a condition that is physically stable, safe, and environmentally sustaining in keeping with the land use and landscape of the day. A sustainable drainage system on a reclaimed area should have the same physical characteristics as similar natural drainage systems in the general geographic region in terms of dynamic stability, robustness, longevity, and self-healing mechanisms. In addition, the drainage systems on a decommissioned area should provide a biologically productive landscape that supports native vegetation and wildlife communities and is capable of handling extreme hydrologic events. The drainage system should also provide a balance between the ability to shed water while at the same time limiting the amount of erosion of the soil cover and other undesirable environmental risks.

A set of geomorphic criteria for the landform design of the decommissioned JEB TMF was developed through the analyses of the regional and local climate, geology, hydrogeology and natural landforms nearby the JEB TMF. The prevailing landforms in the vicinity of the JEB TMF are drumlins. Therefore, geomorphic analyses of these local natural landforms included: i) the length, width and height of natural landforms; ii) the maximum overland flow path length and maximum valley slope; iii) the overland flow path length and upland slope; and iv) the drainage area and average channel slope.

No drainage channels have been provided on the landform, except for an undulating topography to direct surface runoff to specific locations at the toe of the embankment. Drainage channels have not been provided because the maximum overland flow path length of the landform towards the embankment is within the range of values derivd from the natural analogues (drumlins), and the maximum valley slope is less than the values derived from the natural analogues.

Drainage features of the JEB TMF include four vegetated waterways that have been provided around the circumference of the landform at the toe of the embankment to capture and convey runoff from the landform towards natural waterways. The vegetated waterways are lined with vegetation, which resists erosion of surface soil, and are designed to convey ephemeral or intermittent flow. In decommissioned drainage landscapes, vegetated waterways would economically provide robust drainage, vegetation diversity and a natural appearance. Micro-topography in the form of ridges and swales were designed to allow positive flows towards swales (Table 5.2-3). The draining of the ridges provides good conditions for upland vegetation growth. The drainage ditches in the swales are expected to evolve naturally after construction of the decommissioned landscape. This natural evolution will facilitate the development of a regime of channel pattern and cross-sectional shape that is expected to be stable over the long-term (Table 5.2-3).

Mitigation incorporated in the landform design for the decommissioned JEB TMF is anticipated to reduce changes to hydrology. Although minor changes in drainage patterns and surface flows from changes in terrain related to decommissioning are expected to occur, the environmental risk to biophysical and socio-economic environments is anticipated to be negligible.

- **Exposure to COPCs from radon, gamma, radioactive dust or through uptake of constituents of potential concern by wildlife through ingestion of vegetation on the decommissioned JEB TMF may affect wildlife health**.

- **Radiation and radon gas emissions from the Project can affect community health and well-being.**

An “ALARA by design” approach has been included by AREVA in the design and construction of its facilities for the protection of its workers. The Code of Practice for Radiation Protection is a practical application of the ALARA principle, and has Administrative Levels established as indicators of radiation protection performance to facilitate internal control. The Radiation Protection Program at the McClean Lake Operation is composed of several elements, each supported by a procedure, which describes the activities completed within the element (Tables 5.2-3 and 5.2-4). For the Project, dosimetry monitoring of worker exposures to radiological components (i.e., gamma radiation, radon progeny, and long-lived radioactive dust) will be regularly completed and reported. This process demonstrates compliance with dose limits defined by federal regulations, licence conditions, and operating targets identified within the Code of Practice for Radiation Protection for the McClean Lake Operation. In addition, during operations tailings will continue to be stored under sufficient water cover to attenuate both radon and gamma emissions.

Successful closure and decommissioning of the JEB TMF will require ensuring the public dose limit is not exceeded for traditional uses of the site such as hunting, trapping and gathering, which should also provide the protection of wildlife health. An evaluation of post-closure radiation exposure conditions completed for the expanded JEB TMF considered potential exposure of traditional land users to gamma radiation, radon, and long-lived radioactive dusts

(Appendix H). Gamma radiation exposure on the decommissioned surface of the JEB TMF is mitigated by placement of the cover materials (Tables 5.2-3 and 5.2-4). Radon exposure is mitigated by the dewatering of the surficial tailings materials, the placement of layers of capping materials, and the saturated soil cover. At closure, the JEB TMF will be covered by a 1 m thick layer of crushed sandstone and bentonite (i.e., barrier layer) (Tables 5.2-3 and 5.2-4). This barrier layer will then be covered by 1.5 m thick layer of crushed sandstone (i.e., surface layer) that will be dressed with an appropriate growth medium. Vegetation is not expected to uptake COPCs from tailings in the JEB TMF as the surface layer is anticipated to protect the barrier layer against penetration from vegetation. Radioactive dust exposure is eliminated by the containment of the tailings materials within the decommissioned facility.

The anticipated radiation exposure post-decommissioning will be indistinguishable from natural background radiation in the area. No change to radiation exposure is anticipated relative to guidelines; therefore, environmental risk to the health of the general public and wildlife is predicted to be negligible.

- Runoff and erosion can affect stability of the JEB TMF embankment, and may result in a failure that could alter surface water quality (Fox Lake), which can affect the health of aquatic biota and wildlife (i.e., COPC exposure), and community health and well-being.

US Army Corps of Engineers (2003) recommended the minimum acceptable deterministic factors of safety for embankment slope based on design practice developed and successfully employed by the Corps of Engineers over several decades. As such, the JEB TMF embankment slope will be designed to achieve a required deterministic factor of safety of at least 1.5 (Table 5.2-3). The downstream toe of the embankment will have a 58 m buffer from the high water mark of Fox Lake. The downstream slope of the embankment will be 3H:1V and the upstream slope will be 3H:1V. During decommissioning of the expanded JEB TMF, the downstream slopes will be flattened to 4H:1V to mitigate erosion potential and to further improve long-term stability of the slope. All embankment slopes under consideration meet the objective of achieving a minimum factor of safety of more than 1 under seismic loading conditions.

Detailed parametric slope stability analyses were completed as part of the TMF optimization project (Golder 2009a). The parametric analyses identified that the stability condition of the TMF till slopes are sensitive to both the effective friction angle and suction angle of the till. Probabilistic analyses for expansion of the TMF were therefore conducted considering the variability of the effective friction angle, φ' and the suction angle, φ^b of the till. A mean factor of safety of 2.23, and a reliability index 5.16 were calculated for the 3H:1V upstream slope at Cross Section A-A'. A mean factor of safety ranging from 2.02 to 2.36 and a reliability index ranging from 5.13 to 6.01 was calculated for the upstream slope at Cross Section B-B' for slopes ranging from 2.0H:1V to 2.5H:1V.

Monitoring and maintenance activities will be completed during operation to control potential surficial erosion of the embankment slope. Monitoring of the JEB TMF embankment structure will consist of visual observation of the tailings embankment and measurement from field instrumentation. Field instrumentation would include piezometers (including monitoring wells to

monitor water quality), slope inclinometers, and ground monitoring points (Table 5.2-3). The observations of these instruments, together with the tailings management operation logs (e.g., date and location of deposition) and meteorological conditions can be used to evaluate the performance of the TMF embankment and help predict future performance. Preventive maintenance, based on the early observation of potential seepage or severe erosions, is anticipated to facilitate maintenance of the stability and integrity of the embankment and liner system.

Instrumentation will be installed in the embankment and the underlying stratigraphic units to monitor changes that may be critical to maintaining groundwater quality and slope stability, and to evaluate seepage through the liner (Table 5.2-3). Survey markers will be installed on top of the embankment to monitor embankment movement. A preliminary instrumentation program has been developed for the first, second, and third construction stages of the embankment. The instrumentation program will be updated for the subsequent construction stages. Monitoring wells decommissioned during construction of the embankment will be replaced to monitor water level and water quality in each of the stratigraphic units.

Frequency of the monitoring will depend on previous observation. For example, when records indicate that conditions are stable, frequency of the observations can be extended. Monitoring may only be required after the occurrence of unusual conditions such as heavy precipitations, heavy surface runoff, and fast rise of pond water. Through the monitoring programs, any areas of concern may be noted and addressed, thereby reducing the likelihood of failure. In addition to monitoring stability of the embankment and the performance of the soil-bentonite liner, the base drain filter system, and other components of the JEB TMF will be frequently evaluated.

- Erosion on-site at decommissioning and of soil covering the decommissioned TMF may change surface water quality and decrease cover integrity.

The primary objective of the landform design was to provide a sustainable landform configuration and drainage system for the decommissioned JEB TMF. After decommissioning, the sustainable drainage system on the JEB TMF will have the same physical characteristics as similar natural drainage systems in the general geographic region, in terms of dynamic stability, robustness, longevity, and self-healing mechanisms (Table 5.2-3). The physical characteristics of the decommissioned JEB TMF landform was developed using a geomorphic approach. A set of geomorphic criteria for the landform design of the decommissioned JEB TMF was developed through the analyses of the regional and local climate, geology, hydrogeology and natural landforms nearby the JEB TMF (i.e., drumlins).

The drainage system will also provide a balance between the ability to shed water while at the same time limiting the amount of erosion of the soil cover and other undesirable environmental risks. Vegetated waterways will be constructed over a variety of landforms and land types, and over a range of slopes, soil conditions and drainage characteristics. The vegetated waterways will be lined with vegetation, which resists erosion of surface soil, and are designed to convey runoff or intermittent flow. In decommissioned drainage landscapes, vegetated waterways would economically provide robust drainage, vegetation diversity and a natural

appearance. Micro-topography in the form of ridges and swales are designed to allow positive flows towards swales. The draining of the ridges provides good conditions for upland vegetation growth. The drainage ditches in the swales are expected to evolve naturally after construction of the decommissioned landscape. The natural evolution will facilitate the development of a regime of channel pattern and cross-sectional shape that is expected to be stable over the long-term. In addition, the embankment section of the waste rock runoff pond will be breached to a width that will allow for surface drainage around the surrounding JEB TMF slope. The results of a number of engineering analyses were completed to evaluate the decommissioning approach, and the results of these analyses indicate that the Project can be successfully decommissioned.

The effectiveness of a cover in limiting percolation depends on the materials with which it is constructed (i.e., earthen or geosynthetic), their physical properties (i.e., hydraulic conductivity, moisture retention capability, etc.), the long-term integrity of the cover, the climate in which the facility is located, and the nature and quality of the vegetative material. Five test plots are anticipated to be constructed for the cover evaluation study for the Project. Each test plot is designed with a specific objective to optimize one of the key variables that will affect the short and long-term performance of the cover. Each test plot will be instrumented to monitor climatologic variables, runoff, percolation, soil temperature, soil suction, and soil water content. The test plot covers are expected to provide key field data, to validate and refine the soil cover design (Table 5.2-3). In addition to construction of the test cover plots, soil and meteorogical instruments will be installed within a well-developed forested area to determine the water balance. The data collected from this area will be compared to data from the test plots.

To understand the long-term climatic effects on the TMF soil cover, soil-atmospheric modeling was completed to determine the anticipated deep percolation flux and performance of the TMF soil cover when exposed to 16 year weather dataset that represent a variety of potential climate change scenarios (Appendix G). The study also provides discussion surrounding the effect the extra runoff could have on the longevity of the soil cover landform. The landform was designed based on a geomorphic approach that is based on the philosophy that the landform will evolve with time and climate change.

In general, the climate is expected to move toward a warmer and wetter condition. The future performance of the soil cover is predicted to be the same for all climate change boundary conditions: 1) there is a small essentially insignificant increase in deep percolation (1 mm/year on average); 2) the majority of the water is re-directed as runoff, 3) actual evaporation increases and is the second largest factor contributing to the change in the water balance, and 4) soil cover storage remains essentially unchanged and does not play a primary role in how the extra precipitation is managed (Appendix G). The geomorphic approach is not based on rigid design criterion and some erosion and self-healing is expected to take place over time. Sacrificial armouring has been provided to promote self-healing of potentially erodible stream sections, and for the land slope, stream slope, and stream cross-section to evolve accordingly. In addition, vegetation on the landform will take hold over the long-term, providing resistance to faster runoff if the climate predictions are correct.

Based on the results of a number recent of engineering analyses and assessments, conclusions support the previous predictions that the JEB TMF can be successfully decommissioned. Consequently, environmental risk to the biophysical and socio-economic environments is predicted to be negligible.

- **Failure of a base drain pump or an unexpected increase in the required base drain pumping from the JEB TMF can cause changes to the chemical properties of groundwater, which can alter surface water quality and influence the quality of aquatic and wildlife habitat, and affect aquatic biota and wildlife health (i.e., COPC exposure).**

A design pumping rate of 3,000 m^3/day from the base drain was selected to maintain hydraulic containment (Section 4.3.1.1). This value corresponds to the predicted inflow rate prior to the tailings reaching the level of the liner, and therefore represents the worst case condition over the operating life of the expanded JEB TMF. As discussed in Section 4.3.1.1, pumping in excess of 3,000 m^3/day has been achieved in the past from the base drain of the JEB TMF. Currently, three pumps are installed in the base drain with a total design pumping capacity of approximately 5,760 m^3/day. This design provides both contingency if one pump fails and extra capacity in the unlikely event that the required base drain pumping rate is greater than 3,000 m^3/day. Consequently, environmental risk to the biophysical and socio-economic environments is predicted to be negligible.

- **Long-term solute transport from the JEB TMF can change groundwater and surface water quality, which may affect the health of aquatic biota, wildlife, and community health and well-being.**

As described in Section 4.4.2.5, solute transport analyses describe the migration of solute in groundwater between a source and receptor, considering advective and diffusive transport mechanisms, and attenuation due to sorption behavior and decay in transit. For the case of steady-state transport from a source to a receptor with no decay in transit, the mass flux from the source also defines the peak rate of solute loading to the receptor. Therefore, in this case, the mass flux from the source determines the ultimate long-term concentration at the receptor. AREVA has undertaken numerous geochemical studies for the purpose of predicting long-term solute concentrations within the tailings pore water. Study results of source concentrations in tailings pore water are presented in the Tailings TID (AREVA 2015a). Final solute concentrations used to calculate mass flux from the decommissioned JEB TMF are based on the average weighted solute concentration for each COPC (Table 4.4-1).

A preliminary soil cover analysis and design was completed for the Project (Appendix D). The soil atmospheric model is used to determine the preferred soil cover system and to what extent the soil cover can be expected to limit the infiltration of atmospheric water to the underlying tailings (i.e., deep percolation). The deep percolation can be converted to an average flux and applied as the surface boundary condition in long-term groundwater flow and solute transport simulations (Section 4.4.2.3).

The calibrated numerical groundwater flow model, developed for the JEB area, was used to assess the transport pathway of groundwater discharging from the expanded JEB TMF following decommissioning. The long-term performance of the expanded JEB TMF was assessed using GoldSim® (GoldSim® 2002) to simulate the transport of solutes from the tailings through the groundwater flow system to down gradient surface water receptors (i.e., Fox Lake and Pat Lake; Section 4.4.2.5 and Appendix C). A parametric sensitivity analysis was conducted to identify those input parameters exerting the greatest influence on calculated mass loading rates from the decommissioned JEB TMF. Based on the results of the sensitivity analysis, the cover infiltration rate and tailings pore water source concentrations exert the greatest control over the predicted mass flux from the decommissioned JEB TMF, while predicted values are relatively insensitive to the rate of groundwater flow within the host sandstone adjacent to the tailings. Based on the results of the sensitivity analysis, upper bound values were calculated using maximum probable values of net percolation and source concentrations.

Predicted and upper bound mass flux from the expanded JEB TMF were calculated with the GoldSim® model based on the results of the groundwater flow model for the expanded JEB TMF and updated tailings pore water source concentrations (Section 4.4.2.5 and Appendix C). Predicted values were calculated using best estimates of net percolation through the soil cover into the tailings and source concentrations. The upper bound values were calculated using the "worst case" soil cover infiltration rate and the sensitivity case pore water concentrations (Table 4.4-1).

The solute transport analysis performed for the decommissioned JEB TMF couples a one-dimensional solution to the advection-dispersion equation with particle tracking analysis conducted within the flow model. This method was used to calculate the mass of solute transported from the decommissioned JEB TMF to surface water receptors as a function of time. Particle tracking was performed in FeFlow (Appendix C). The hydraulic head distribution calculated by FeFlow was used to calculate the flow path followed by each particle assigned by the user. The output file generated by FeFlow records the linear velocity and trajectory of each particle as a function of time. The output file may be used to calculate distributions of travel distance and velocity of particles discharging to each receptor and applied to solute transport calculations.

The source term model described above was applied to calculate the initial concentrations of solutes for each pathway. The one-dimensional advection-dispersion equation was solved for each aquifer pathway within GoldSim® using concentrations calculated by the source term model as a boundary condition and the corresponding travel distance and velocity distributions of for each pathway (Appendix C). The geometry of the pathways were defined by specifying the length and cross sectional area of the aquifer, based on the results of particle tracking analyses and hydrostratigraphy. Mass enters at one end of the aquifer pathway, advects along (and disperses and diffuses within) the pathway, and then exits at the other end. Aquifer pathways (and hence the cells that are internally created to represent them) contain a fluid medium and a solid medium that can affect transport (e.g., by modifying the porosity of the pathway and/or acting to sorb and hence retard species). Radioactive decay and ingrowth are

also considered for transport calculations performed for each pathway Input parameters applied to solute transport calculations for each pathway are summarized in Table 4.4.2.

Table 4.4-3 presents predicted and upper bound incremental COPC concentrations for Fox Lake and Pat Lake. Predicted COPC concentrations in all receiving waters are typically indistinguishable from to marginally above baseline concentrations and less than CWQG and SSWQO. Calculated cadmium and lead concentrations marginally exceed SSWQO criteria, however this is an artifact of the guideline being less than the baseline concentrations for these constituents. In each case the incremental concentration is negligible in relation to the baseline concentration.

Figure 4.4-8 graphically presents predicted steady state long-term water quality in receiving waters for selected constituents. Resulting concentrations of solutes are compared to baseline concentrations (AREVA 2009a) and to CWQG and SSWQO. Predicted long-term water quality is within water quality guidelines and objectives (where applicable) for all COPCs. Arsenic and uranium appear to be the most sensitive constituents, with predictions approaching 50% of objective values and upper bound values marginally exceeding objectives. Nonetheless, predicted and bounding values are similar to those previously submitted in support of environmental assessments of the McClean Lake Operation (AREVA 2009a).

Solute transport calculations were performed for the predicted rates of constituent loading from the JEB TMF to the active groundwater flow zone. The results of the solute transport analysis are presented in terms of mass flux to surface water receptors as a function of time and are plotted for arsenic, nickel, uranium and radium-226 in Figure 4.4-11.

The peak mass flux to the receptors coincides with the condition of steady-state transport, at which time no change in solute concentrations occurs with time at any given point along the pathway. Under this condition, the mass flux to the receptor equals that leaving the source, where no decay occurs in transit. These conditions are predicted because of the application of a non-depleting source. For the case of radium, the mass flux to the receptor is lower than that leaving the source due to attenuation along the pathway owing to sorption, which allows time for radioactive decay to occur.

The average arrival time of a solute plume at a given point along the pathway may be defined as the time at which the solute concentration reaches half of the ultimate steady-state value. The arrival time will vary from one solute to another depending on the degree of attenuation. For unattenuated species, the average arrival time is approximately 100 years. Moderately attenuated species such as arsenic and nickel show break through at receptors in 3,000 to 8,000 years. Arrival time for radium is expected to occur in approximately 5,000 years. (Appendix C).

Risks predicted for the Project included Project-specific risks, as well as all current and planned future activities at the McClean Lake Operation. The assessment indicated that the transport of COPCs from the JEB TMF into the groundwater flowing to Pat Lake and Fox Lake were

anticipated to be within CWQG and SSQWO, and therefore, is anticipated to have a low magnitude of risk on surface water quality in these lakes relative to background contidions. For most COPCs, it is expected that the incremental change will be indistinguishable from background concentrations and will not noticeably affect the predicted long-term risks associated with tailings management at McClean Lake Operation.

The two key uncertainties associated with the JEB TMF are the long-term behavior of the tailings contaminants and the long-term hydraulic conductivity of the tailings, and subsequently, the long-term flow through the tailings mass. The current Tailings TID (AREVA 2015a) has already provided important findings with respect to these uncertainties. On-going evaluation of the chemical and physical characteristics of tailings stored in the JEB TMF during the operational period is required to validate the prediction of post decommissioning environmental risks. The Tailings TID describes the geochemical and geotechnical monitoring and evaluation activities completed to determine the long-term solute concentrations of COPCs in the JEB TMF, and the long-term post decommissioning groundwater flow regime. The geochemical and geotechnical monitoring programs are anticipated to continue throughout the operating life of the JEB TMF, until decommissioning, with their activities largely unchanged by the expansion of the JEB TMF.

A multi-parameter sensitivity analysis was used to assess the potential uncertainty associated with the cover performance parameters specified in the baseline soil-atmospheric simulations (Section 4.4.2.3). A series of simulations were performed where the value for one parameter was altered over a specified range using a number of increments. The relative significance of the parameter was evaluated by comparing the flux through the soil cover from each simulation to the “baseline” model. A detailed laboratory testing program was completed and a cover test plot program has been proposed to provide further understanding of these factors for the construction of the soil bentonite cover for the proposed expanded JEB TMF (Appendix F). The results from the test plots will be incorporated into the final soil cover design at the time of decommissioning.

5.4 Embankment Failure Review

5.4.1 Mount Polley Independent Review Panel Conclusions

Following the breach of the tailings storage facility at the Mount Polley Mine in 2014 an independent expert investigation and review panel was established to investigate and report on the breach (Independent Expert Engineering Investigation & Review Panel, 2015). Upon release of the report, AREVA conducted a comparison of the review panel’s conclusions and features of the JEB TMF Expansion Project. Table 5.4-1 presents that comparison.

Table 5.4-1: Mount Polley Independent Review Panel Conclusions

Review Panel Considerations	JEB TMF Expansion
Mechanism of Failure	
Site Characterization	
Presence of Weak Layer in foundations	Stratigraphy at the McClean site has been characterized by numerous boreholes. No weak layers have been identified.
Foundation Material Characterization	Foundation materials have been characterized, with engineering properties defined.
Consideration of undrained failure for silt and clay foundations	Overburden soils at the McClean Lake site consist of overconsolidated sandy matrix tills and silty and matrix tills where pore pressures as a result of embankment construction are not considered significant.
Contributing Factors	
Long Term Planning	The design storm storage for the mine site and TMF have been considered as part of the expansion design
Observational Method	
Inspections	Regular visual inspections undertaken.
Action levels	Primary Action Level is operating pond elevation. When operating pond level exceeds the maximum operating level (encroaches on Design Storm storage volume) all effort will be made to bring the operating level to below the maximum operating pond level.
Role of Water	
Water Balance	The long-term water balance for the TMF was considered as part of the expansion design to provide sufficient storage for a design flood above the maximum brine pond operating level.
Treatment/Disposal Capacity	There has been no change in the contributing areas and hence the volume of water to be managed.
Design Storm Storage/Management	Consideration of the Design Storm Management part of design of the JEB Expansion

5.4.2 Environmental Consequence Assessment of an Embankment Failure of the JEB TMF Expansion

A screening level evaluation of the potential environmental consequences to Fox Lake, Pat Lake and downstream waterbodies in the Collins Creek watershed resulting from the unlikely failure of the embankment of the expanded JEB TMF during operations subsequent to the proposed expansion was conducted under two scenarios; 1) release of pond water to the environment when the pond is at a maximum capacity and 2) release of pond water and tailings solids to the environment when the TMF is at the maximum capacity.

In the assessment of implications on surface water quality for Scenario #1, it was assumed that 579,141 m^3 of JEB TMF pond water would replace the baseline water quality in Fox Lake. For Scenario #2 it was assumed 254,904 m^3 of JEB TMF pond water would replace the baseline water quality in Fox Lake. For the second scenario, the impact of COPC mass in the tailings and porewater on water quality was not considered, since in the short-term, the water quality will be

dominated by the tailings pond water, and in the long-term, it was assumed that the tailings solid spill would be remediated and removed from Fox Lake.

The COPC considered for the modelled scenarios included uranium, thorium-230, radium-226, arsenic, cadmium, molybdenum, nickel, selenium, ammonia, sulphate, and TDS. Long-term and short-term water quality benchmarks were established for the evaluation. The recovery of water quality was considered on a monthly basis, with clean run-off flushing COPC out of Fox Lake, but influencing the water quality in downstream waterbodies. Results of the modelled scenarios indicate that the hypothetical failure of the JEB TMF embankment is expected to impact water quality in Fox Lake. Further downstream, exceedances are predicted for the long-term water quality guideline for radium-226 and molybdenum in Pat Lake, and the long-term water quality guideline for molybdenum in Nadia Lake. Exceedances are not predicted in Upper Collins Creek from the JEB TMF failure, which indicates that potential negative effects are limited to Fox Lake, Pat Lake, and Nadia Lake.

For up to two years following a failure of the JEB TMF embankment, model predictions indicate COPC concentrations in Fox Lake are at levels that could potentially effect aquatic species, however, these potential effects are limited to Fox Lake and do not extend downstream.

In addition to pond water being released, Scenario 2 also included consideration of a mass of approximately 25,490 tonnes of tailings solids displaced to Fox Lake. It is expected that the majority of solids will deposit within Fox Lake. COPC concentrations within the tailings solids are above benchmarks that are set to be protective of aquatic biota; however sediment biota would be expected to be affected by physical deposition of the solids material. It is not expected that significant tailings material would travel further downstream, so effects are limited to Fox Lake.

The results of the screening level assessment indicate that the consequences of an embankment failure at the JEB TMF would not have catastrophic effects on the Collins Creek watershed downstream of the facility. While water and sediment quality and the health of aquatic biota in Fox Lake would be affected and recovery of the lake could take many months or years, it is not anticipated that water bodies downstream of Fox Lake would be negatively impacted over the short or long term.

The full report can be found in Appendix J Assessment of Embankment Failure.

6 Monitoring Programs

This section provides an overview of the monitoring programs recommended for the Project. The predicted environmental risks for the Project are within those already predicted and assessed through the Caribou Project EIS (AREVA 2009a) and Midwest Project EIS (AREVA 2011a), and there are no major changes to the way the JEB TMF will be operated. As such, the programs described below are largely based on the existing monitoring programs.

6.1 Monitoring Programs

6.1.1 Existing Relevant Monitoring Programs

6.1.1.1 Tailings Optimization and Validation Program

The existing TOVP, as discussed in Section 4.5.1, will be continued throughout the operating period of the Project. This program will continue to study and define tailings geochemical and geotechnical properties, which will be used to update long-term closure predictions for the JEB TMF.

It is recommended that ongoing consolidation of the deposited tailings continue to be monitored to enhance the understanding of the tailings behaviour and estimation of *in situ* tailings management. The understanding of tailings behaviour and its geotechnical properties are important for the detailed design of the JEB TMF closure and construction of the soil cover system. Tailings properties and consolidation conditions will continue to be assessed through the existing TOVP.

6.1.1.2 Environmental Monitoring Program

The current McClean Lake Operation EMP (AREVA 2014) requires very little change in order to effectively monitor any potential risks from the Project as the EMP was originally designed to monitor the existing JEB TMF.

The benthic invertebrate and sediment sampling station at Fox Lake (BM13E) will be re-established once construction of the Project begins. This monitoring station will serve to detect any changes to sediment quality and benthic invertebrate communities resulting from construction activities, the associated surface water runoff and dust deposition during the construction period. During the operational period, this monitoring location will serve to monitor any potential changes due to potential erosion from the JEB TMF embankment and solute transport from the JEB TMF. The monitoring frequency and approach will follow the same procedures for similar stations as outlined in the EMP and if required; air quality sampling stations will be added within the framework of the existing EMP.

Ongoing updates to the EMP are recognized as an appropriate measure by which to optimize monitoring activities and to implement changes to the program to reflect changes in operational activities. The most recent changes are incorporated into the McClean Lake Operation Environmental Monitoring Program Locations, Frequencies and Parameters Version 8, Revision 4. February 2014 (AREVA 2014). The implementation of the Project will not require any changes to the major components of this program. The addition of monitoring stations specific to the JEB TMF area, such as an additional air quality sampling station and a sediment and benthic invertebrate sampling station, will be added within the framework of the existing program at the time of licensing in consultation with provincial and federal regulatory agencies.

6.1.1.2.1 Groundwater Monitoring Program

The ongoing groundwater monitoring programs, which include groundwater level and chemistry monitoring, appears to be adequate for the Project. Current JEB TMF monitoring wells will continue to be monitored. The monitoring wells that will be affected by the construction of the Project will be decommissioned and replaced with new monitoring wells as required.

Monitoring well nests to be installed around the pit perimeter shown in Figure 6.1-2 will be used in conjunction with the Drift Monitoring well to confirm hydraulic containment.

6.1.1.3 Expanded JEB TMF Decommissioning

A performance monitoring program will be implemented to confirm physical and environmental stability of the JEB TMF during and after the decommissioning period. Decommissioning performance monitoring is divided into two components:

- an EMP for the JEB TMF area; and
- a performance monitoring program for the JEB TMF during the construction of the soil cover structure and decommissioned landform.

The existing EMP framework is adequate for the Project throughout operations, although some revisions to the program may be necessary. The post-decommissioning EMP will focus on the surrounding and downstream receiving environments from the JEB TMF. It will be completed to verify assumptions and reduce uncertainty of the predicted long-term environmental performance. The monitoring program will continue until uncertainty in the long-term predictions is reduced to an acceptable level.

6.1.1.3.1 Prior to final cover placement

Monitoring of tailings pore water pressure and consolidation will be incorporated into the detailed design of the soil cover system to monitor settlement of the final soil cover system after placement. The following instrumentation will be used:

- vibrating wire piezometers, thermocouples (to monitor temperature of upper tailings layer), and extensometers (to monitor settlement at various depths in tailings); and

- settlement cells/plates and survey markers on top of tailings.

Instrumentation will be installed at various locations within the tailings to monitor the dissipation of induced pore water pressures, and tailings settlement during consolidation. The tailings mass will have consolidated to the desired endpoint once excess pore water pressures within the tailings have dissipated. Pore water pressures in the tailings mass, settlement of the cover at various depths, and periodic inspections of the survey markers installed on top of the final soil cover will continue to be monitored through the post-closure period to assess the tailings consolidation conditions.

6.1.1.3.2 After the placement of the final cover

Instrumentation will be installed to monitor the performance of the final soil cover. Instrumentation would include:

- settlement plates on top of final sand-bentonite layer (barrier layer);

- survey markers on top of finished soil cover (ground surface);

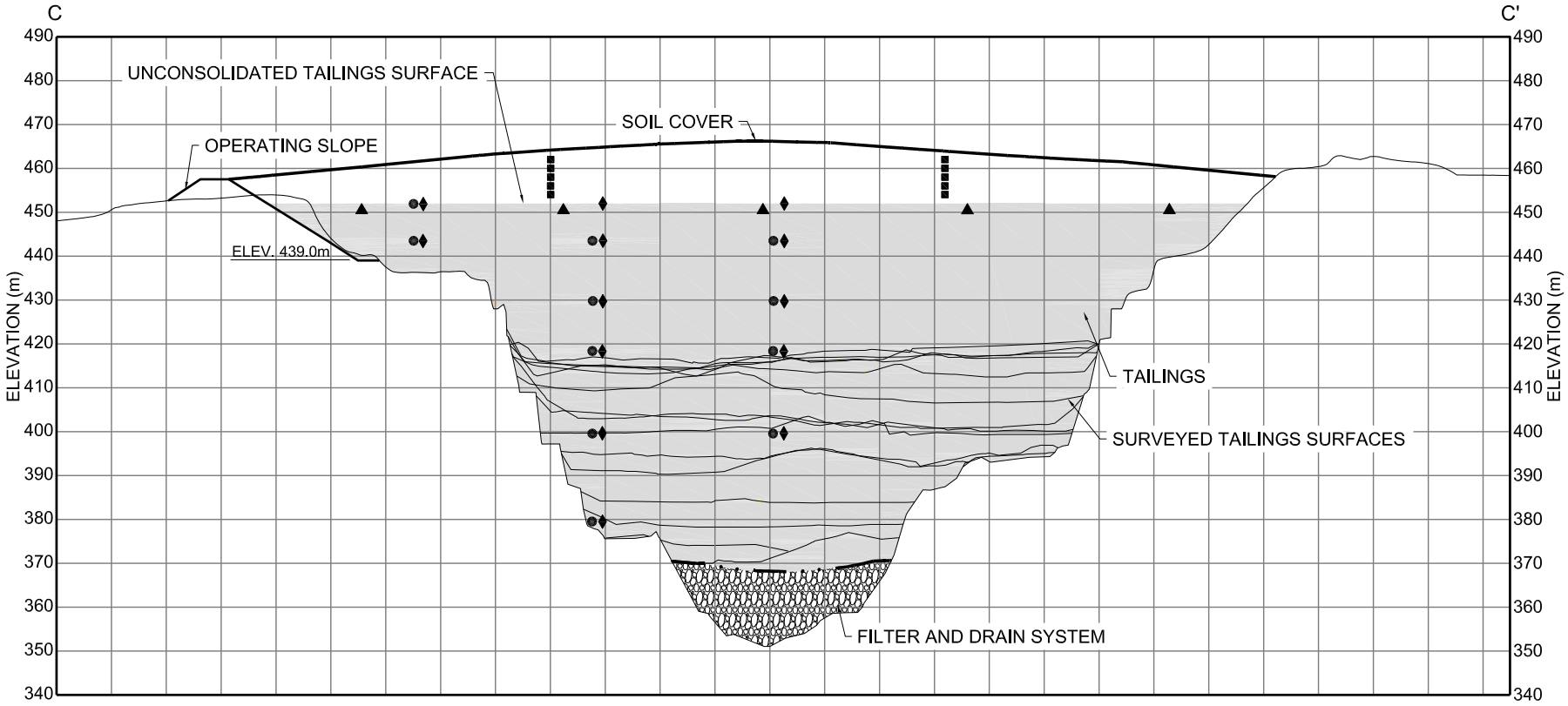
- monitoring of water content, soil suction, and soil temperatures in the soil cover system; and

- weather instrumentation.

Instrumentation for soil cover performance will be similar to that used for the evaluation of the soil cover test plots (Appendix E). Parameters monitored will include weather data, final soil cover water content and soil suction, soil temperature and soil cover settlement. Instrumentation installed to monitor tailings consolidation during decommissioning (tailings pore water pressures and settlements) will continue to be monitored.

All active instruments will be maintained in operational condition throughout decommissioning and for a period of time of post-decommissioning. These instruments will be routinely checked to confirm that they have secure caps, are protected from animals, are left in place after final sampling, and that no flowing wells exist. Figure 6.1-1 shows a proposed instrumentation profile, in both the tailings mass and soil cover system, for post decommissioning monitoring.

Figure 6.1-1: Proposed Instrumentation for JEB TMF Decommissioning and Post-Decommissioning Monitoring



IDENTIFIER	PHASE	DESCRIPTION
♦	DECOMMISSIONING	SETTLEMENT MONITORING SYSTEM
▲	DECOMMISSIONING	THERMOCOUPLES
●	DECOMMISSIONING	VIBRATING WIRE PRESSURE TRANSDUCERS
■	POST DECOMMISSIONING	WATER CONTENT & SUCTION SENSORS

AREVA

08-1362-0590		
SCALE:	1:3,000	DATE:
DESIGNED:		
DRAWN:	JMC	04/05/16
REVISED:		
APPROVED:		
REF. DWGS:		
REVISIONS:		

FIGURE 6.1-1

Proposed Instrumentation for JEB TMF Decommissioning and Post-Decommissioning Monitoring

6.1.2 Radiation Protection Program

No substantive changes are anticipated to the radiation protection program resulting from the expansion of the JEB TMF. The programs established at the McClean Lake Operation have anticipated the processing of high grade uranium ores and the placement of the subsequent tailings. The elevation of the placed tailings is immaterial to the radiation protection program components. Specifically:

- relevant routine radiological monitoring locations are established in and around the JEB TMF to monitor worker exposure to gamma radiation, radon progeny and long-lived radioactive dusts;
- dosimetry of workers working in the JEB TMF is conducted according to an established dosimetry monitoring strategy;
- contamination control at the McClean Lake Operation will continue to follow established zoning categorization; and
- training programs for Nuclear Energy Workers are established and adequately consider radiological hazards within the JEB TMF.

Routine radiological monitoring data will be used to validate the predicted radiological dose rates within the JEB TMF during the placement of tailings from high grade ores. The JEB TMF area will be subjected to the performance confirmation process described by the Radiological Performance Confirmation Plan.

6.1.3 New Monitoring Programs

6.1.3.1 Cover Performance

The soil cover performance will be evaluated prior to decommissioning through the construction of soil cover test plots, as described in Section 4.5.2 and Appendix E. Several soil cover test plots will be constructed to evaluate the risk of key parameters on cover performance. The results from the test plots will be incorporated into the final soil cover design at the time of decommissioning.

6.1.3.2 Monitoring of the JEB TMF Embankment Structure

The proposed JEB TMF embankment and liner system is subject to self weight of the structure, hydraulic pressures and external loads that may cause deformation of the structure itself and the foundation soil. Any indication of abnormal behaviour may affect the safety of the structure. Routine monitoring and preventive maintenance are important to provide good performance of the expanded JEB TMF. Monitoring of the JEB TMF embankment structure will consist of visual observation of the tailings embankment and measurement from field instrumentation. Field

instrumentation will include piezometers (including monitoring wells to monitor water quality), pressure gauges, slope inclinometers and ground monitoring points. The observations of these instruments, together with tailings management operation logs and meteorological conditions can be used to evaluate the future performance of the JEB TMF embankment. Preventive maintenance, based on the early observation of potential "problem spots" (i.e., seepage or severe erosion), is anticipated to help maintain the stability and integrity of the embankment and liner system.

Geotechnical instrumentation will be installed at six (6) cross sections around the TMF as shown in Figure 6.1-2. Three (3) cross sections (Cross Section H-H, I-I and K-K) are adjacent to Fox Lake, one (1) cross section (Cross Section M-M) on the north-east side of the TMF, one (1) cross section (Cross Section J-J) on the east side of the TMF (at the 2.3H:1V portion of the TMF slope), and one (1) cross section (Cross Section L-L) on the south-west side of the TMF. Figure 6.1-2 shows a typical instrumentation cross-section. The following instrumentation will be installed at each cross section to monitor the performance of the JEB TMF Expansion Stage 1 Embankment:

- Four (4) nested groundwater monitoring wells will be installed through both the crest and toe of the embankment at each cross section (48 wells total). The wells will consist of 100 mm diameter polyvinyl chloride (PVC) casing with a 3 m screened interval. A sand pack will be placed around the screened interval to 1 m above the screened interval. The remainder of the borehole will be backfilled with cement/bentonite grout to form an impermeable seal. The screened intervals will be placed immediately above the embankment fill/till contact, till/upper sandstone contact, and upper sandstone/lower sandstone contact, as well as within the lower sandstone for each group of nested wells.

- Vibrating wire pressure transducers (0.35 MPa) will be installed within the till below the embankment to measure pore water pressures in the foundation soil at each cross section. The vibrating wire pressure transducers will be installed below the upstream toe, centerline, and downstream toe of the embankment. High strength Kevlar reinforced signal cable will be specified to connect the VW's to the dataloggers. The signal cables will be trenched a minimum of 300 mm below the stripped ground surface beneath the embankment to protect the cables from damage during construction of the embankment. All signal cables will connect to a multi-channel datalogger installed at the downstream toe of the embankment (6 total).

- Two groups of nested vibrating wire pressure transducers (0.35 MPa) will be installed within the liner at each of the cross sections to continuously monitor pore-water pressure and the hydraulic gradient across the thickness of the liner to evaluate the liner performance (i.e., seepage through the liner). One group will be installed immediately above the contact with the Stage 2 liner, and the other will be installed immediately above the original ground surface. Kevlar reinforced cables will be specified and trenched below the stripped surface. The signal cables from these VW's will connect into the same dataloggers as for vibrating wire pressure transducers installed below the embankment footprint.

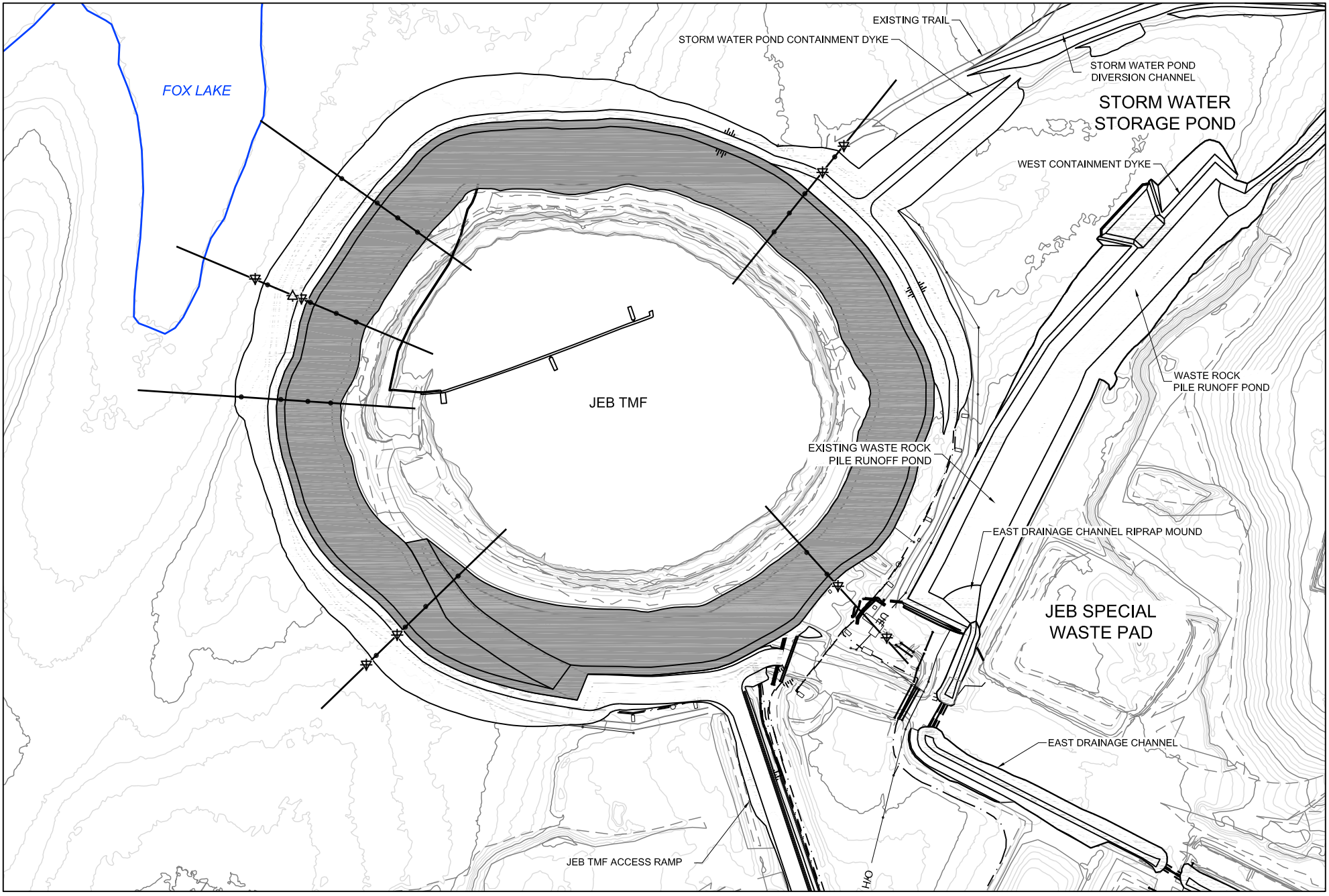
- Slope inclinometer casings will be installed below the crest and outside of the downstream toe of the embankment to monitor movement of the embankment at each of the cross sections. A projection will be built out from the crest of the embankment at each cross section to avoid impeding traffic. The slope inclinometer casings will be keyed a minimum of 3 m into the till below the embankment.

- Rebar survey markers will be installed at a spacing of 100 m around the crest and downstream toe to further monitor movement of the embankment. The rebar survey markers will consist of a 0.6 m long piece of rebar pounded into the slope. During installation the exact original location of the marker will be determined using GPS surveying equipment. Subsequent surveys will be compared against this original location.

Frequency of the monitoring will depend on previous observation. For example, when records indicate that conditions are stable, frequency of the observations can be extended. Monitoring may only be required after the occurrence of unusual conditions such as heavy precipitations, heavy surface runoff, and fast rise of pond water. Through the monitoring programs, any areas of concern may be noted and addressed, thereby reducing the likelihood of failure. In addition to monitoring stability of the embankment and the performance of the soil-bentonite liner, the base drain filter system, and other components of the JEB TMF will be frequently evaluated.

It is recommended that the dataloggers for the geotechnical instrumentation be downloaded a minimum of every three (3) months for the first year after the installation and once per year thereafter. At the same time that the dataloggers are downloaded the slope inclinometer casing profiles will be measured using a slope inclinometer probe, and the rebar locations surveyed using GPS survey equipment. The data obtained from the dataloggers (i.e., piezometric data), slope inclinometer probe, and rebar markers should be reviewed and interpreted by a qualified geotechnical engineer to assess the stability condition of the embankment and liner. A brief stability condition report should be prepared which documents, at a minimum, any trends in the data and the current water flow and stability condition of each cross section.

Figure 6.1-2: Proposed Instrumentation Location Plan for Monitoring during TMF Operations



AREVA

LEGEND

- VIBRATING WIRE PRESSURE TRANSDUCER
- NESTED MONITORING WELLS
- SLOPE INDICATOR

1417371		
SCALE:	1:4000	DATE:
DESIGNED:		
DRAWN:	JMC/JDS	04/06/2016
REVISED:		
APPROVED:		
REF. DWGS:		
REVISIONS:		

FIGURE 6.1-2

Proposed Instrumentation Location Plan for Monitoring During TMF Operations

7 Conclusion

On the basis of the detailed Project information and assessment of effects provided in this document, AREVA believes that the Project can be constructed, operated and decommissioned in a manner that, taking into account environmental design features and mitigation, does not present an unreasonable level of risk to the local biophysical or socio-economic environments, while remaining within the established licensing basis for the McClean Lake Operation.

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Appendix B

Section E: Tailings Sub-Aqueous Deposition Method Application

May 3, 2018 PIGA Unrestricted

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Saskatoon SK S7L 5X2
Tel.: +1 (306) 343-4500

Dear Ms. Lung and Mr. Akhter,

Re: McClean Lake Operation – Implementation of Sub-Aqueous Tailings Deposition Method

Orano Canada Inc. (Orano) plans to return to sub-aqueous deposition of tailings in the McClean Lake Operation's JEB Tailings Management Facility as a method of tailings placement, while preserving flexibility to use the current tremie placement method as needed. Due to changes in ore characteristics related to processing Cigar Lake ore, tremie deposition and significant set-back from the pit walls are no longer needed as mitigative measures to manage particle-size segregation. A return to sub-aqueous deposition offers several advantages in operational control and flexibility without compromise to end-state tailings objectives.

In accordance with Section 5 of *The Mineral Industry Environmental Protection Regulations, 1996* and Condition 10.1 of the *McClean Lake Operation Approval to Operate Pollutant Control Facilities, PO17-186* (Approval to Operate), Orano is seeking approval from the Saskatchewan Ministry of Environment to implement the use of the sub-aqueous tailings deposition method in addition to the current tremie method (alteration to a pollutant control facility).

Implementing sub-aqueous tailings placement does not change the licensing basis of the *McClean Lake Operation's Mine Operating Licence UMOL-MINEMILL-McCLEAN.00/2027* (McClean Lake Operating Licence) issued by the Canadian Nuclear Safety Commission. The placement method will continue to enable Orano to achieve the design objectives for placed tailings which are important for long-term protection of the environment. As per licence condition G.2 (Notification of Changes), Orano is providing notification of a change in how tailings may be deposited in the JEB TMF.

The information provided within the attached document, *Implementation of Sub-Aqueous Tailings Deposition Method Notification/Application* identifies design criterion, alternatives considered and Orano's commitment to maintain a high level of protection for the health, safety and security of the public and workers and protection of the environment during the implementation of the change.

Should you have any questions, please contact myself at dale.huffman@orano.group or 306.343.4058 or Tina Searcy, Regulatory Relations Manager at tina.searcy@orano.group or 306.343.4525

Sincerely,

Dale Huffman
VP, HSE&RR

Attach./Encl.: Implementation of Sub-Aqueous Tailings Deposition Method Notification/Application

cc: Orano Distribution
CNSC UMMD
Tim Moulding, MOE
Peter Fundarek, CNSC

DH/TS

Orano Canada Inc.

McClean Lake Operation

Implementation of Sub-Aqueous Tailings Deposition Method Notification/Application

PIGA Unrestricted

May 2018

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Executive Summary

Orano Canada Inc. (Orano) plans to return to sub-aqueous deposition of tailings in the McClean Lake Operation's Tailings Management Facility as a method of tailings placement, while preserving flexibility to use the current tremie placement method as needed. Due to changes in ore characteristics related to processing Cigar Lake ore, tremie deposition and significant set-back from the pit walls are no longer needed as mitigative measures to manage particle-size segregation. A return to sub-aqueous deposition offers several advantages in operational control and flexibility without compromise to end-state tailings objectives.

The JEB Tailings Management Facility (TMF) design limits potential environmental effects of contaminant transport from tailings throughout operations and post-decommissioning through the application of operational, geochemical and geotechnical protective measures. A key post-decommissioning geotechnical protective measure is the establishment of a sufficient hydraulic conductivity contrast between the tailings and the surrounding host rock to limit groundwater movement through the decommissioned, consolidated tailings. The low hydraulic conductivity of the tailings will result in preferential groundwater flow around the facility through the more permeable host rock, limiting the long-term migration of contaminants of potential concern (COPCs) to the environment.

Beginning in 1999, tailings generated from processing JEB and Sue ores were initially deposited from a barge with a vertical discharge pipe releasing tailings below the pond surface but above the surface of the previously placed tailings. This method of sub-aqueous deposition, combined with the physical characteristics of the JEB/Sue tailings, resulted in particle size segregation of the tailings, with coarse particles remaining in close proximity to the deposition pipe, and finer particles travelling farther away from the point of deposition. Homogeneous placement of particles with a broad particle-size distribution is preferred to promote consolidation to achieve the target hydraulic conductivity, and to conserve tailings space.

In 2001, the tremie deposition method was implemented as a means to reduce the observed segregation. Tremie deposition places tailings through a deposition pipe injected below the surface of previously placed tailings, limiting migration of tailings through the water column. With tremie deposition, segregation still occurred but was significantly reduced. It was observed that consolidation of the fine grained materials resulted in the lowest hydraulic conductivity hence the highest hydraulic conductivity contrast between tailings and the surrounding host rock. As a precautionary measure, a 50 m buffer was established between the deposition point and the edge of the JEB TMF to ensure that only fine tailings with very low hydraulic conductivity would be in the close proximity to the host rock. With sub-aqueous deposition, some segregation occurs very near the deposition point but dissipates within 15 m.

In 2014, the McClean Lake Operation began processing Cigar Lake ore and the resultant tailings. The Cigar Lake tailings are much finer than the JEB/Sue tailings, with a narrower particle-size distribution resulting in

fewer concerns with the potential effects of segregation during deposition. To illustrate, the JEB/Sue whole tailings had a median (d_{50}) particle size in the range of about 54 -80 µm while the finer Cigar Lake tailings have a d_{50} particle size range of 7 – 25 µm. The Cigar Lake tailings offer an opportunity for improving tailings management and mitigating operational challenges.

The tremie deposition method presents operational challenges, primarily:

- Mounding of tailings at deposition points, creating an uneven tailings surface, and
- Consists of only a single deposition point, which cannot be relocated during winter months, due to ice formation on pond water cover.

Mounding results in the reduced ability to access the available tailings capacity of the JEB TMF, and creates a potential operational risk of beaching the barge over the winter months.

To address these challenges, Orano initiated an investigation to determine alternate deposition methods that either maintained or improved the desired behavior of placed tailings, while providing increased operational flexibility of the deposition system. Sub-aqueous deposition was selected as one of the preferred options, and in 2017, a short duration field test was conducted to further investigate this deposition methodology. The field test indicated that, the overall degree of mounding was significantly less than when placing Cigar Lake tailings using the tremie deposition system.

The planned sub-aqueous deposition system provides the advantage of multiple, movable deposition points. Operators will be able to target multiple deposition points from one set-up; access capacity in existing voids in the tailings surface that the deposition barge cannot readily access; and change deposition locations during the winter months. The sub-aqueous deposition system also requires less water cover to operate. Overall, these improvements result in more efficient filling of the JEB TMF and increased opportunity to more efficiently access the existing tailings storage capacity.

1 Introduction

Orano Canada Inc. (Orano) plans to add sub-aqueous deposition of tailings in the McClean Lake Operation's Tailings Management Facility as a method of tailings placement, in addition to current tremie placement. Due to changes in ore characteristics, tremie deposition is no longer needed to limit particle-size segregation and is a hindrance on efficient tailings placement. Sub-aqueous deposition offers several advantages in operational control and flexibility without compromise to end-state tailings objectives. Orano intends to improve flexibility of tailings placement by making both tremie placement and sub-aqueous placement methodologies available to operators.

In 2016, as part of Orano's continual improvement process and to identify advantages created by the finer grained Cigar Lake tailings, Orano initiated a review of potential alternative tailings deposition methods to provide operational flexibility. Following an options analysis, a preferred alternative was selected: sub-aqueous deposition. Initial modelling and a short duration field test was conducted to determine the viability and investigate the performance of sub-aqueous deposition.

The short duration field test was successful in demonstrating that the sub-aqueous deposition method places tailings efficiently without impacting pond water quality, and provides significant operational advantages. The sub-aqueous deposition method was confirmed as Orano's preferred alternative. The short duration field test work was approved by the Canadian Nuclear Safety Commission (CNSC) in August 2017 and by the Saskatchewan Ministry of Environment (SMOE) in September 2017 (PC17-167).

The information provided within this document identifies the design criterion which ensures the modifications continue to maintain a high level of protection for the health, safety, and security of the public and workers, and protection of the environment.

2 Regulatory Notification

2.1 Saskatchewan Ministry of Environment

In accordance with Section 5 of *The Mineral Industry Environmental Protection Regulations, 1996* and Condition 10.1 of the *McClean Lake Operation Approval to Operate Pollutant Control Facilities, PO17-186* (Approval to Operate), Orano is seeking approval from the SMOE to implement the use of the sub-aqueous tailings deposition method in addition to the current tremie method.

2.2 Canadian Nuclear Safety Commission

Implementing sub-aqueous tailings placement does not change the licensing basis of the *McClean Lake Operation's Mine Operating Licence UMOL-MINEMILL-McCLEAN.00/2027* (McClean Lake Operating Licence) issued by the CNSC. The placement method will continue to enable Orano to achieve the design objectives for placed tailings which are important for long-term protection of the environment. As per licence condition G.2 (Notification of Changes), Orano is providing notification of a change in how tailings may be deposited in the JEB TMF.

2.3 Alternatives Evaluated

Orano retained a project team consisting of SRK Consulting (Canada) Inc. and Paterson & Cooke Canada Inc. (SRK-P&C) to complete a review and options analysis of the JEB TMF tailings deposition system with an objective of improving placement flexibility to efficiently access tailings capacity while achieving stated tailings criteria.

Through discussions with Orano staff, observations during site visits, and SRK-P&C's experience at other sites an initial list of possible modifications to the tailings deposition method was developed, and then screened to identify options preferred for further analysis/investigation.

The screening process used seven explicit criteria identified in SRK-P&C's review of project documentation and discussions with Orano staff. Table 1 provides an explanation for each criterion.

Table 1: Option Evaluation Criteria

Criterion	Description
Support efficient filling of the JEB TMF	To the maximum extent possible, create a non-mounded tailings surface, spread as evenly as possible within the pit.
Prevent development of frozen tailings layers	Prevent frozen layers from reducing the in-situ density of the tailings, and requiring thawing prior to closure.
Place finer tailings at the pit edge	Meet the requirement for a low permeability zone by ensuring that, should particle siaze segregation persist, fine grained materials are deposited adjacent to the pit wall.
Compatible with current practice	Ensures compatibility with the currently accepted sub-tailings tremie method of tailings deposition and make use of the existing equipment to the extent possible.
Support minimum water cover thickness	Maintain a minimum 1 m of water cover to maintain radiation protection practices and to prevent the development of ice lenses during winter deposition.
Minimize deposition location moves	Keep the number of deposition location (barge) moves to less than or equal to one move per year.
Facilitate raising of facility surround	Ensure that the deposition system will not interfere with future construction activities associated with raising the impermeable surround.

The initial identification of potential modifications to the existing tailings deposition method resulted in 17 potential alternatives (some alternatives were permutations of others), presented in Appendix A Table 1. The screening of these 17 potential alternatives resulted in four alternatives which proceeded through further analysis, as presented below in Table 2.

Table 2: Alternatives Evaluated Alternatives Considered

Alternatives	Description
Alternative 1:	Sub-tailings deposition (tremie) from multiple barges (one of which could be a smart barge, depending on the potential cost implications).
Alternative 2:	Sub-tailings deposition (tremie) from a single barge with “octopus arms” to multiple satellite barge locations.
Alternative 3:	Sub-aqueous deposition from pipelines placed on the tailings surface during summer (including with rupture disks or retractable piping to access additional locations).
Alternative 4:	Sub-aqueous deposition from a barge with “octopus arms”, or from suspended pipelines, with slotted pipe diffusers to minimize segregation.

Alternatives 1 to 4 were developed to conceptual design level. Alternative 1 and 2 use the current tremie deposition method. Alternative 3 and 4 use the sub-aqueous deposition method. A number of these

alternatives used several common elements such as flexible walkways and anchoring system. Advantages and challenges of each alternative were assessed and comparative level cost estimates prepared. Conceptual level design and costing was reviewed by the project team in January 2017 and it was determined to move Alternatives 2 and 4 forward for further study.

2.3.1 Alternative Selected

After the completion of test work, including the sub-aqueous test and the analysis of the resulting data, a slightly modified version of Alternative 4 was selected as the preferred option. The modified alternative is shown below as Figure 1.

Multiple deposition points offer the following advantages over the current system:

- Deposition point can be easily changed to reduce mounding at a location,
- Ability to change deposition points in the winter,
- Fewer barge and walkway movements reduce burden on operators and improve operator safety, and
- Improved maintenance flexibility without need for operational shutdown.

The advantages of a sub-aqueous placement over tremie placement include:

- Reduced mounding of tailings around deposition point,
- Reduced infrastructure needed for implementation, i.e. enclosed barges with hoisting equipment are needed for tremie deposition,
- Improved access to the targeted deposition locations from flexible walkway and piping within the JEB TMF,
- Elimination of routine pipe hoisting by operators, and
- Reduced back-pressure on pumps and piping.

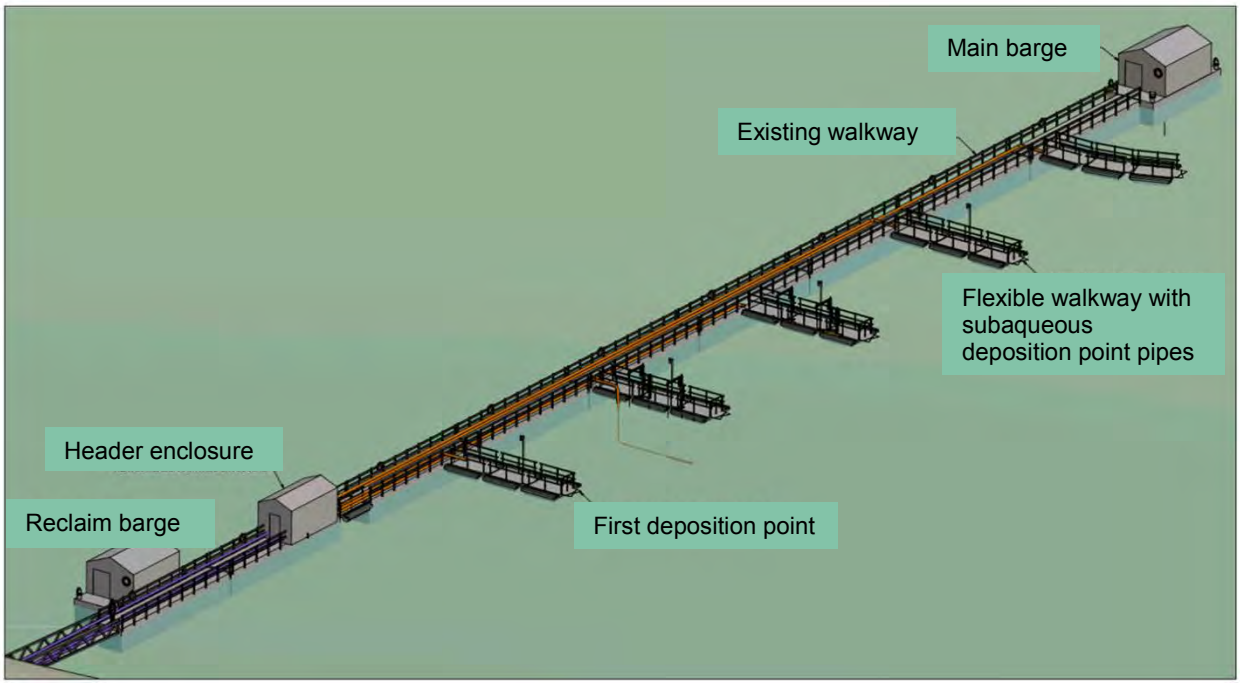


Figure 1: Initial Setup of the Sub-Aqueous Deposition System

3 Description of Change

3.1 Existing Conditions

The JEB TMF is designed to limit the post-closure potential impact of tailings constituents on the receiving environment over the long term through the establishment of two primary controls during the operating period:

1) produce engineered tailings with geochemically stable mineral phases which sequester COPCs; and

2) deposit tailings to achieve a sufficient hydraulic conductivity contrast between the tailings and the surrounding host rock to limit the migration of COPCs from the JEB TMF post-closure.

Beginning in 1999, the original configuration for tailings placement involved the use of a barge with a vertical discharge pipe that released the tailings at a distance of approximately one to two metres above the surface of the previously deposited tailings (sub-aqueous deposition). At the time, sub-aqueous deposition resulted in particle-size segregation of the placed tailings. In 2001, the tremie deposition method was implemented as a means to reduce the observed segregation. Although reduced, segregation still occurred with coarser grained fractions of the placed tailings accumulating in a mound at the deposition point while the finer grained fractions migrated away from the deposition point. Upon consolidation, the finer grained tailings are observed to result in material with a lower hydraulic conductivity than coarse grained materials. As a precautionary measure, a 50 m buffer was established between the deposition point and the edge of the JEB TMF to ensure the finest grained materials were placed adjacent to the pit walls. The finer JEB/Sue tailings near the wall of the JEB TMF are expected to consolidate and achieve the desired hydraulic conductivity contrast between the tailings and surrounding host rock. Discussion of physical segregation of the tailings has been presented in various regulatory submissions including the Tailings Management Technical Information Document (TID) (AREVA, 2015) which contains the results of the most recent Tailings Optimization and Validation Program (TOVP).

The tailings thickener overflow (TTOF) liquids are pumped to the JEB TMF through one 5-inch diameter HDPE pipeline and the tailings thickener underflow (TTUF) solids slurry are pumped in one or both of the two 3-inch HDPE pipelines to a deposition barge floating on the JEB TMF pond water cover. At the deposition barge, the two 3-inch TTUF pipelines are combined into a 6-inch pipeline, which discharges the tailings vertically, approximately 2 meters into the previously deposited tailings mass (“tremied”). The TTOF pipeline discharges over the side of the deposition barge.

The barge is connected to the edge of the JEB TMF via a fixed (i.e. no flexibility at the joints) floating walkway. The deposition barge is moved in the JEB TMF by adding or subtracting sections of the walkway, and/or by swinging the entire walkway and barge to a different location.

With the exception of the area immediately adjacent to the deposition and reclaim barges, an ice cover forms over the JEB TMF pond during winter, restricting the movement of the deposition barge to the ice-free season.

The tremie deposition method results in the mounding of tailings around the tremie deposition point. As the elevation of mounded tailings surface increases, placement in a singular location is limited by the draft of the barge and the need to maintain a suitable water cover over the tailings. Mounding is resulting in creation of hills and valleys along the tailings surface, below the water cover. To fill the valleys to achieve even tailings placement would require frequent barge movements are resource intensive, and unmanageable during the winter with an ice cover. The result is an inability to realize the full tailings storage capacity. The limits of single deposition point combined with an inability to relocate it during winter months, increases the risk of over-mounding and beaching the barge.

3.2 Tailings Characteristics and Deposition

From 1999 to 2010, the McClean Lake Operation processed ores grading from 0.4% to 6.3% uranium from JEB, Sue C, Sue A, Sue E and Sue B open pit mines and minor amounts of ore from the SABRE Project. From July 2010 to October 2014, the McClean Lake Operation was in care and maintenance and no ore was processed. In October 2014, the mill was successfully restarted with Sue ore and then ramped-up with high grade ore slurry from the Cigar Lake Phase 1 Mine (i.e. monthly average of 8.2% to 25.4% uranium. Cigar Lake Phase 1 ore is currently the only source of ore for the mill.

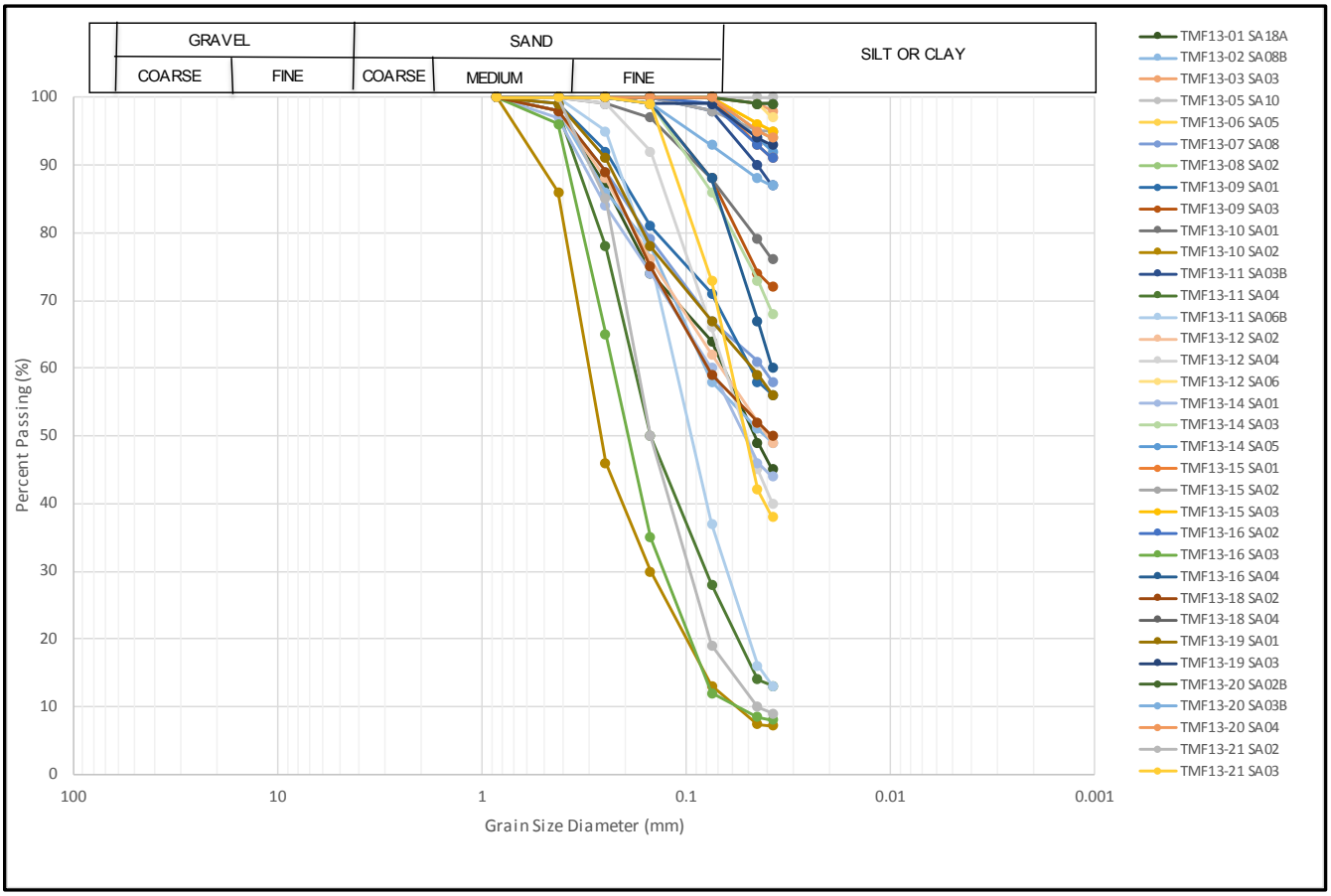
Future mine planning considers ores from Cigar Lake Phase 2, McClean Lake and Midwest, and other potentially deposits. Future tailings will be either from a sandstone ore body similar to the JEB/Sue ore bodies, a clay-rich ore body similar to the Cigar Lake Phase 1 ore body, or a blend of the two ore types. The fine-grained Cigar Lake Phase 1 tailings and the coarser JEB/Sue tailings are therefore considered to provide the bounds of potential physical characteristics of the tailings created at the McClean Lake Mill. As a result, while sub-aqueous deposition is the preferred method for Cigar Lake Phase 1, Orano is not removing the tremie method as an option for deposition, rather implementing an additional method along with the required infrastructure to be used depending on the source of ore and the resultant tailings behavior.

Orano conducts a periodic intrusive sampling campaign under the Tailings Optimization and Validation Program (TOVP) (AREVA, 2010b) and publishes results as an update to the Tailings TID. The majority of field work for the TOVP is planned for the summer of 2018 with an update to the Tailings TID anticipated in 2019.

3.2.1 JEB / Sue Tailings

Figure 2 illustrates the range of particle size distribution observed during the processing of JEB/Sue ores. A 2009 survey of the tailings surface indicated that the tailings deposited with the tremie system were observed to mound at a slope of 37%, extending to a minimum 3% (discussed in more detail in Section 3.3.1).

Figure 2: Sue Tailings Particle Size Distribution



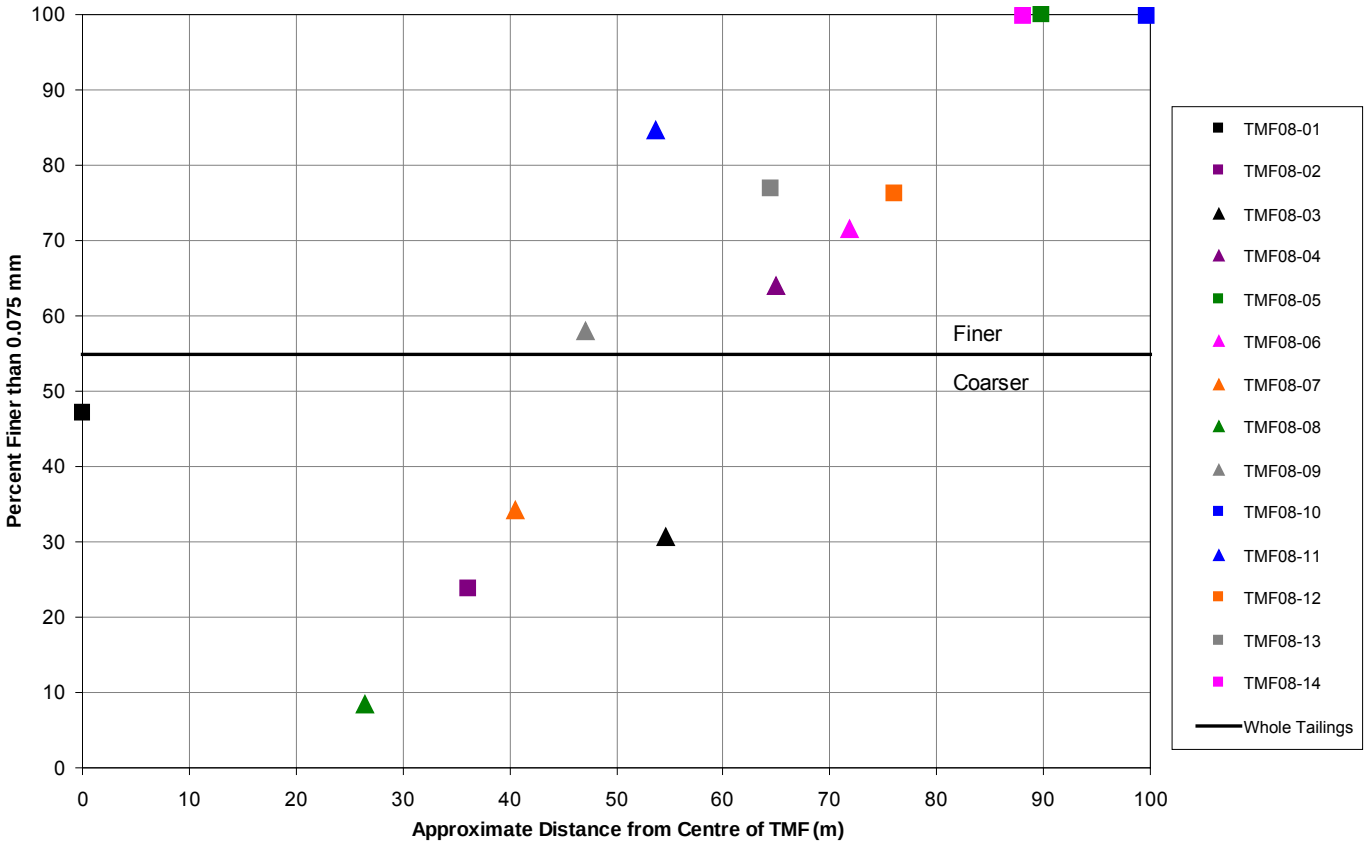
Historically the JEB/Sue tailings samples were grouped as those coarser and those finer than whole tailings (AREVA, 2015). Based on the gradation of whole tailings, a homogenous (non-segregated) tailings mass would consist of approximately 55% silt and clay sized particles (<75 µm) with approximately 46% finer than 40 µm based on an analysis of whole tailings (samples collected directly from the mill).

The characteristics of placed JEB/Sue tailings vary with position in relation to the deposition point. Dredge sampling results show that the zone of coarse tailings extended approximately 40 m from the deposition point in all directions before grading towards fine-grained material. To ensure that the material reaching the extents of the JEB TMF is limited to fine material the positioning of the barge was constrained to greater than 50 m from the pit walls.

Figure 3 plots the percent fines (less than 75 µm) versus distance from the centre of the JEB TMF as observed in the 2008 intrusive sampling campaign. This figure indicates segregation occurring, with a concentration of coarse-grained tailings remaining in the centre of the TMF and fine tailings extending to the periphery of the JEB TMF walls. The JEB TMF is currently over 250 m in diameter. The tailings at the outer

edges of the pit are generally classified as fine tailings (i.e. more than 55% that are <75 µm) (AREVA, 2015).

Figure 3: 2008 Percent Fines vs Distance from the Centre of TMF



3.2.2 Cigar Lake Phase 1 Tailings

To date, the Cigar Lake Phase 1 whole tailings have at greater than 80% of the particle sizes less than 75 µm. Tailings surface surveys with the associated surface tailings particle size sampling of the tremie placed Cigar Lake tailings was conducted in 2015, 2016 and 2017. Figure 4 illustrates the particle size distribution observed in 2017 from the surface sampling around tremie deposition location. Figure 4 indicates that the median grain size (d_{50}) for the Cigar Lake Phase 1 tailings range from approximately 7 µm to about 20 µm.

Figure 4: Cigar Lake Tailings Particle Size Distribution with Tremie Deposition

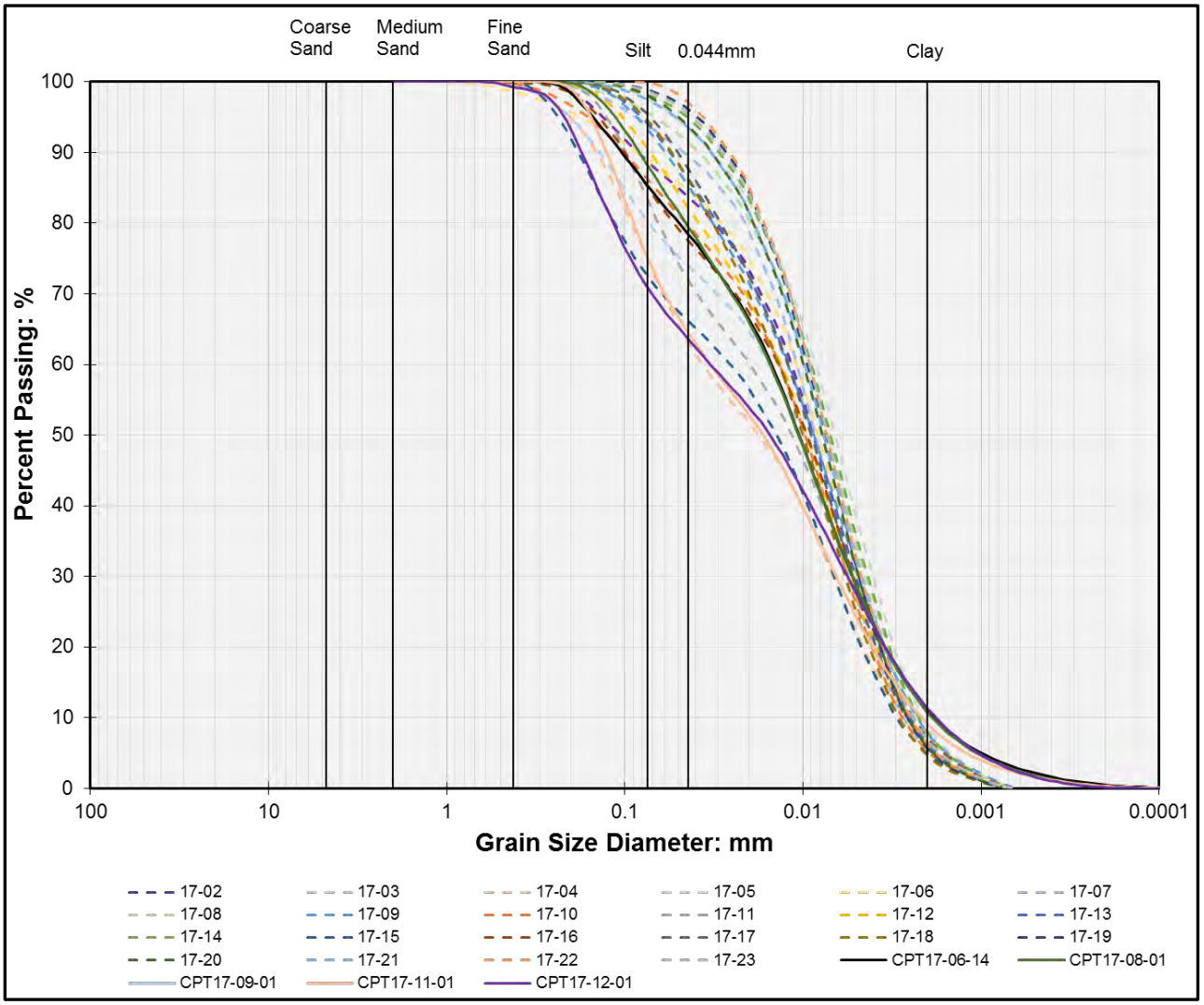
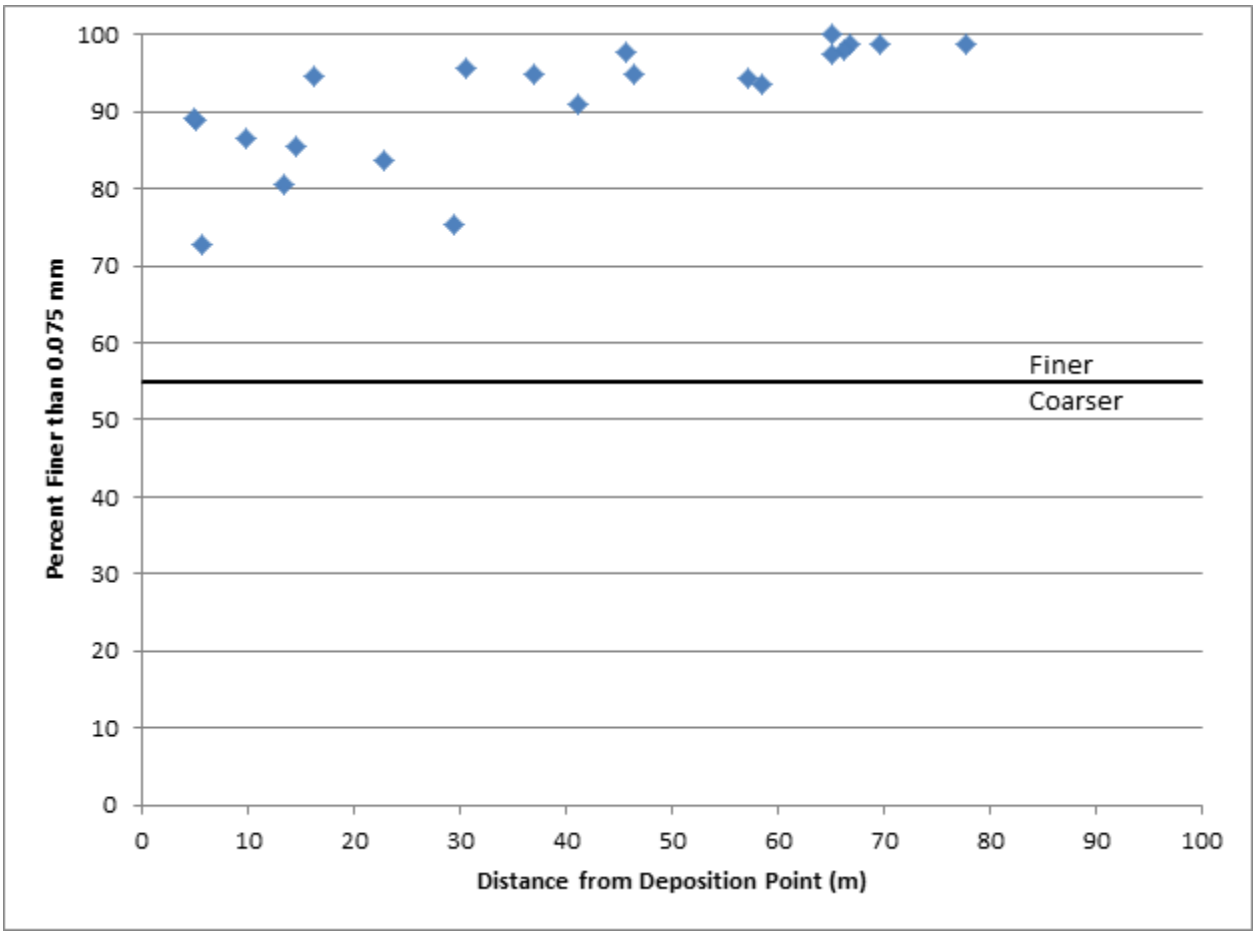


Figure 5 presents the percent fines versus the distance from the deposition point for the tremie deposition of the Cigar Lake tailings, in a manner similar to observations presented in Figure 3 for JEB/Sue tailings. It is observed that all Cigar Lake tailings are in the fine region identified as achieving the lowest hydraulic conductivity

Figure 5: Percent Fines vs versus Distance from the Deposition Point of Tremied Cigar Lake Tailings



The Cigar Lake whole tailings are classified as finer grained than the JEB/Sue whole tailings. Given the fine classification of the Cigar Lake tailings, they, as desired, result in less mounding at the deposition point, and extend further away from the deposition point. The fine grained nature of these tailings also provides an opportunity to explore alternate deposition systems and address existing operational constraints.

3.3 Operational Constraints

The use of the tremie deposition method presents a number of operational challenges and/or constraints which hinders effective access to tailings storage capacity and therefore prevents use of the available capacity of the JEB TMF. These constraints include: the system is limited to a single deposition point; 3 m water cover is required to float the placement barge; weather conditions, and inability to move the deposition point easily, or at all during the winter, results in undesirable mounding at the deposition point. These constraints are further discussed below.

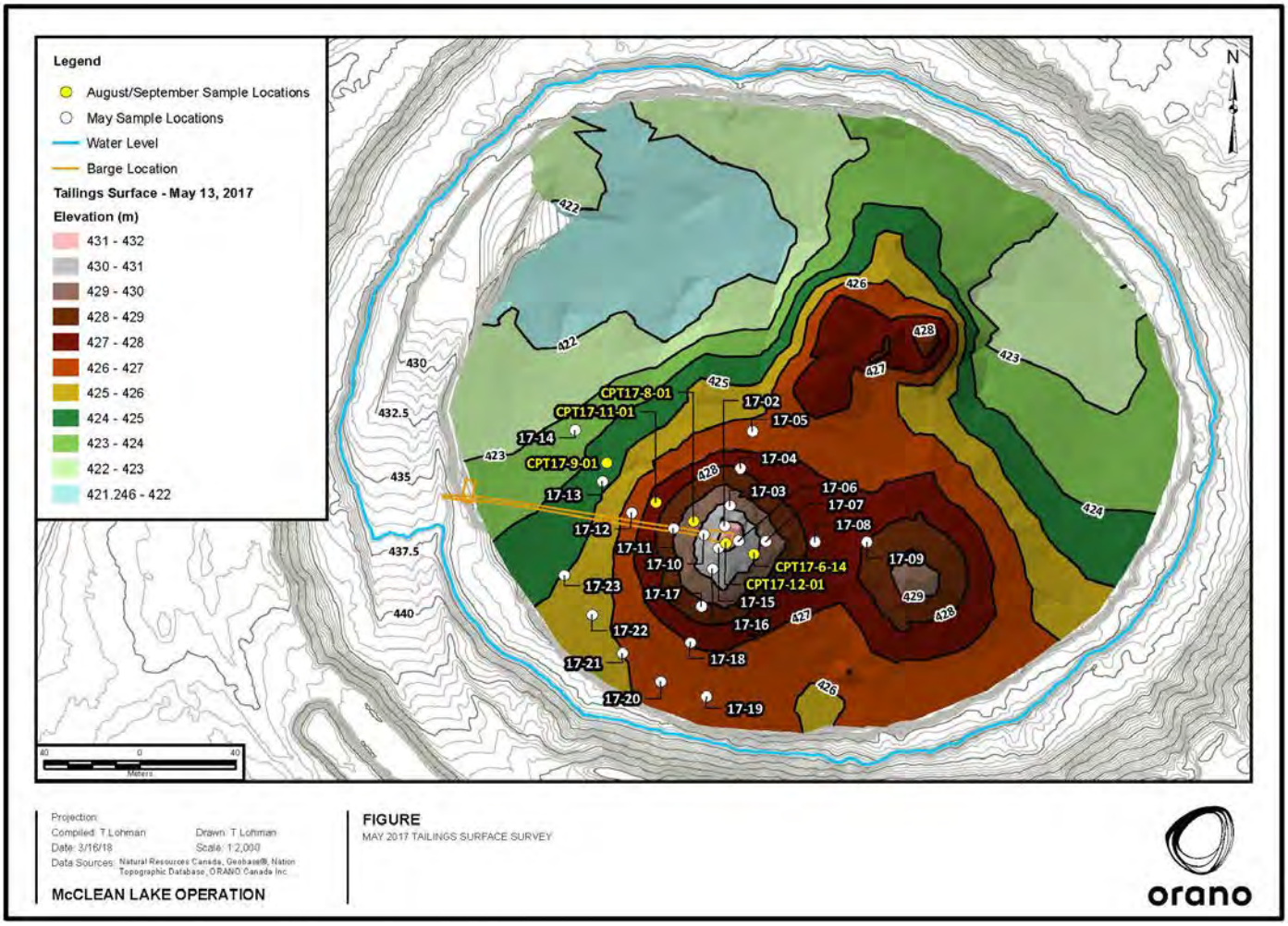
3.3.1 Mounding

As reported in previous annual reports (e.g. AREVA 2010, Orano 2018) and the Tailings TID (AREVA 2015), tailings surface surveys indicate that the deposition of the tailings via the tremie method results in mounding at the deposition points. The creation of mounding is a factor of the tailings characteristics, the piping and pumping system and the constraint of being limited to a single deposition point, often required to be used for a long duration of time. The elevation of the top of tailings and the amount of space required for current pond water cover requirements drives the requirements to create additional tailings capacity through advancing further stages of JEB TMF Optimization and/or Expansion earlier. The pond water elevation becomes an increasing constraint as the elevation of the top or peak of the tailings mounds approach the surface of the JEB TMF. Steeply sloped mounds, combined with the imposed 50 m setback, renders tailings capacity inaccessible. The inability to use multiple deposition points with the tremie system, which is also restricted by ice formation preventing movement over a long duration, creates the risk of beaching the barge during the winter months.

Tailings surface surveys conducted in 2008 of placed JEB/Sue tailings indicate there was approximately 15 m of elevation change between the lowest and highest points on the tailings surface (AREVA, 2010a).

Tailings surface surveys conducted in May 2017 of placed Cigar Lake tailings indicate there is approximately 10 m of elevation difference between the lowest and highest point on the tailings surface (refer to Figure 6).

Figure 6: Tailings Surface Survey of Cigar Lake Tailings (May 2017)



Surface tailings surveys indicate that the mounding created from the tremie deposition the finer sized Cigar Lake tailings are flatter (i.e. lower angle) than the slopes created by the coarser grained JEB/Sue tailings. Based on the 2017 tailings surface survey, the angle of deposition of Cigar Lake tailings placed with the tremie system, was approximately 13.6% between 4 m and 44 m from the deposition point and decreased to approximately 3.9% further away from the deposition point (71 to 106 m). These angles are significantly less than the 37% slope created by the placement of JEB/Sue tailings with the tremie method. The mounding from the sub-aqueous test is discussed in below in Section 3.5.1.

This development of peaks in the tailings surface versus a flat tailings surface results in several specific challenges:

- Inefficient filling and use of the JEB TMF storage capacity
- Reduced ability to re-position the deposition barge

- Reduced ability to find a location with adequate capacity to place the barge for longer durations (i.e. during winter months when the barge/deposition point cannot be relocated)

The operational requirements of the tremie deposition system limits the opportunity to use the capacity created in between these tailings mounds.

3.3.2 Water Cover

For radiation protection and to prevent the creation of ice lenses within the tailings, 1 m of water cover above the surface of the placed tailings if required. Orano currently maintains a water cover of 3 m to accommodate the submerged depth of the tremie deposition barge. The maximum elevation of the tailings pond is constrained by the placement of bentonite amended liner as part of the TMF Optimization and Expansion projects. As the top of tailings approaches the current maximum elevation of the JEB TMF the barge requirement of 3 m pond water is becoming a constraint, driving the completion of liner placement to create capacity, or the implementation of a deposition system with less restricting operational requirements.

3.3.3 Effects of Weather

The tremie deposition system involves depositing tailings within the existing tailings (sub-tailings), requiring accurate positioning of the deposition barge and tremie pipe, with minimal movement after placement to prevent shearing off the tremie pipe. Wind, waves and wet conditions complicate the ability to maintain a secure placement of the tremie pipe and can affect the safe use of the walkway. It is expected that these concerns will increase as the JEB TMF top of tailings and pond water level increases, increasing the pond surface area and the exposure to the elements (i.e. decreases wind block from JEB TMF walls).

With the exception of the area immediately adjacent to the deposition and reclaim barges, an ice cover forms over the JEB TMF pond during winter, restricting the movement of the deposition barge to the ice-free season. The inability to relocate the barge in the winter months requires the ability to place the barge in an area of the JEB TMF that provides adequate capacity to accommodate deposition in a single spot for the duration of the winter.

3.4 Sub-Aqueous Deposition

The sub-aqueous deposition method is a commonly used deposition method. Sub-aqueous deposition is used around the world for both uranium and non-uranium mining; examples of projects are included in Table 3. The method of deposition in these examples may not be identical to that proposed by Orano, however in general these examples operate a system that deposits tailings though a water column and illustrate that sub-aqueous deposition is a proven deposition method.

Table 3: Selected Examples of Subaqueous Deposition

Site	Location	Description
Key Lake	Saskatchewan	Subaqueous deposition with extended lateral deposition pipes placed on the tailings surface.
Anderson Lake Mine	Manitoba	Subaqueous deposition into Anderson Lake using a deposition point floated into the lake.
Brucejack Mine	British Columbia	Subaqueous deposition into a lake, using a pipe floated onto the water surface, with cable system to control the depth of discharge.
Myra Falls Mine	British Columbia	Until 1984 in Buttle Lake
Slate Lake	Alaska	Subaqueous deposition of tailings into the lake through the water column. Deposition pipes floated to the barge.
Jerrit Canyon	Nevada	Prior to 1987, then in the late 1990's until 2001. Details of the deposition system unavailable.
Lisheen Mine	Ireland	A system of cables attached to control units that operate on rails along each side of the impoundment. By changing the location of either the control train or the anchor train, and pulling on the cables, it is possible to move the barge to any point in the impoundment, and thereby to ensure a uniform distribution of tailings even with the relatively steep deposition cones.
Neves Corvo Mine	Portugal	Details of the deposition system unavailable.
Cerro Corona Mine	Peru	Details of the deposition system unavailable.
Hjerkinn Tailings Pond	Norway	Details of the deposition system unavailable.
Lokken (1974-1987)	Norway	Details of the deposition system unavailable.

Initial test and modelling work was conducted on the sub-aqueous deposition methodology prior to running the field test. This initial test work included computational fluid dynamics (CFD) modelling to gain a better understanding of the flow behavior at discharge and to optimize the diffuser design for completing the subaqueous deposition test.

The CFD results indicate that a laminar subaqueous discharge was most effective at limiting the suspended solids within the water column. A custom fabricated trumpet type diffuser was not required provided the discharge pipe was sufficiently long for the laminar flow conditions to stabilize before discharge into the water column. As a result, a commonly available length of at least 1.5 m of 150 mm (6-inch diameter) HDPE pipe was used for the field trial and is proposed for sub-aqueous deposition. These CFD results were similar to the observed behaviour during the test (i.e. low angle of mounding and low suspended solids).

In order to determine a preferred tailings deposition alternative, a 25-day field test was conducted on the sub-aqueous deposition method to investigate the viability of the method and the tailings behaviour. The

results from the sub-aqueous test are summarized below. Success criteria for a preferred deposition method, include:

- The mounding produced is less pronounced than using the tremie deposition system;
- The design allows for multiple deposition points;
- If segregation continues, it does not impact the performance of the JEB TMF; (e.g. that the tailings extending to the periphery of the JEB TMF are fine enough to consolidate to an acceptable hydraulic conductivity);
- That the proposed design does not introduce operational hardship;
- If an increase in the suspended solids concentration occurs in the pond, it remains within the water treatment plant's ability to remove it.

The test location and configuration were described in the August 10 and September 14, 2017 submission to the CNSC and the SMOE (Huffman to Akter, e-Doc 5317379 and Huffman to Lung CRM:0233213). Following the receipt of approvals, Orano completed this 25-day test on the subaqueous deposition method between September 24, and October 18, 2017. Figure 7 shows the arrangement of the test relative to the existing deposition barge walkway.

Figure 7: Aerial view of the subaqueous test location



The flexible walkway includes 1-hp de-icing propellers to keep the surrounding water from freezing; these were maintained over the majority of the winter months to monitor their effectiveness. Observations made

during the winter of 2017/2018 determined that these motors were effective in keeping an ice free zone adjacent to the majority of the length of flexible walkway used for the sub-aqueous test.

3.4.1 Sub-Aqueous Test Results Summary

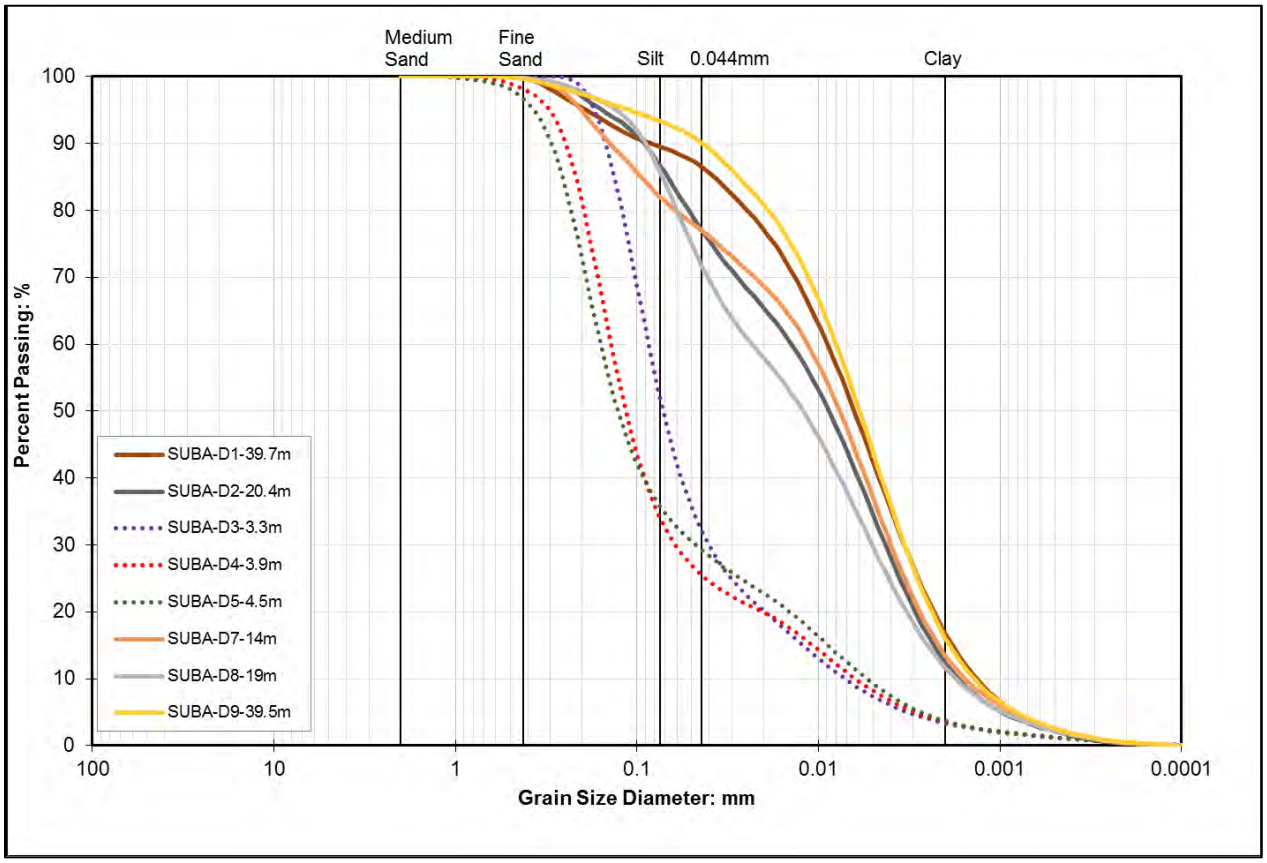
The ultimate intent of this test was to assess the effectiveness of the sub-aqueous deposition methodology with the Cigar Lake tailings, compared to the current tremie methodology. The most relevant results from the 25-day test of the sub-aqueous deposition method are summarized below. In general these results demonstrate that the selected method of sub-aqueous deposition performed as required and provides increased operational flexibility.

The TSS in the vicinity of the sub-aqueous deposition point(s) and reclaim water quality were monitored during the sub-aqueous test, the TSS at the deposition point was observed to flow out in a laminar fashion with little disturbance of the JEB TMF pond water. There was a slight TSS cloud at the point where the tailings were deposited but overall there was a reduced effect on TSS compared to tremie deposition. The reclaim water quality was therefore not affected by the sub-aqueous deposition.

Figure 8 shows the particle size distribution from the dredge samples collected from the tailings surface after the test. Figure 8 shows that there is some segregation within the deposited tailings mass between the tailings at the deposition point and the tailings farther from the deposition point. The physical segregation of the Cigar Lake tailings was more pronounced at the deposition point but more limited in area than the tremie system. The suspended solids were comparable to those observed with tremie deposition. The main improvement was the reduction in the degree of mounding at the deposition point; the discussion in section 3.5.1 will focus on the critical aspect of mounding.

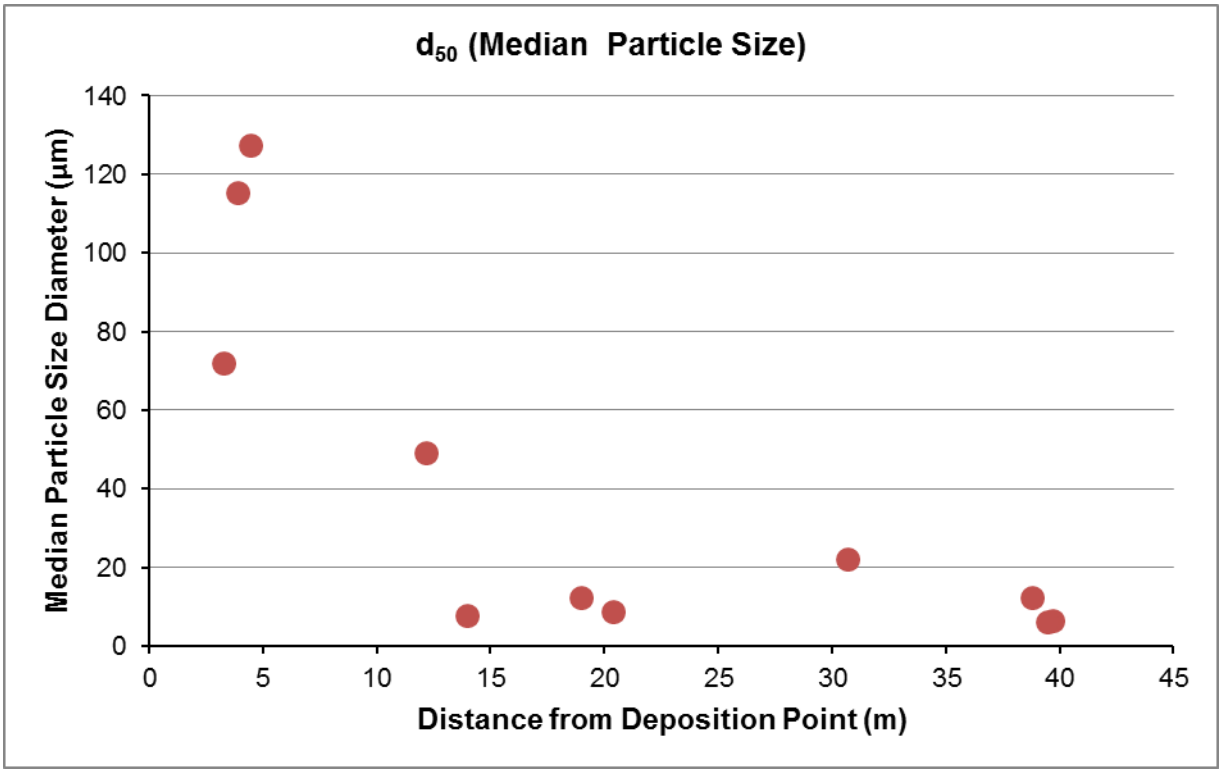
Based on the particle size distribution analysis, the coarser fraction of tailings is deposited near the deposition point, while the fines extend away from the deposition point. Using the definition applied for fine grained tailings that was used for tremie deposition of the JEB/Sue tailings of 55% less than 75 µm, the majority of the samples (8 of the 11 samples) would be classified as fine grained. At only three sample locations (D3, D4 and D5) within 5 m of the deposition point, tailings would be classified as coarse grained. Figure 8 shows that the median or d_{50} grain size of these samples ranges from 6 µm up to 127 µm. This is a wider range of median particle size than is observed in the tremie deposition of the Cigar Lake tailings but the coarser fraction is located much closer to the deposition point.

Figure 8: Tailings Samples Collected Post Sub-Aqueous Test



A plot of d_{50} in dredge samples from the sub-aqueous deposition test with distance from the tailings deposition point is shown in Figure 9. The plot indicates the median particle size of the tailings decreases with distance from tailings deposition point to distance of 15 m after which there is little to no decrease up to the distance of 40 m. The coarser fraction is generally limited to the first 5 m from the deposition point and that there is little to no physical segregation of the tailings occuring at distances greater than approximately 15 m from the deposition point.

Figure 9: Plot of d_{50} (median particle size) in dredge samples from the sub-aqueous deposition test with distance from the tailings deposition point



In summary there is slightly more pronounced particle size segregation immediately adjacent to the deposition point with the sub-aqueous deposition system, however it is much more limited in area (i.e. predominantly within 5 m to a maximum extent of 15 m from the deposition point) and more regular (i.e. there are not coarser outliers further away from the deposition point). This physical segregation is less of concern with the Cigar Lake tailings due to their fine grain size. With the sub-aqueous deposition, reducing the set-back constraint for tailings placement from the current 50 m for tremie placement to within approximately 15 m of the deposition point is achievable.

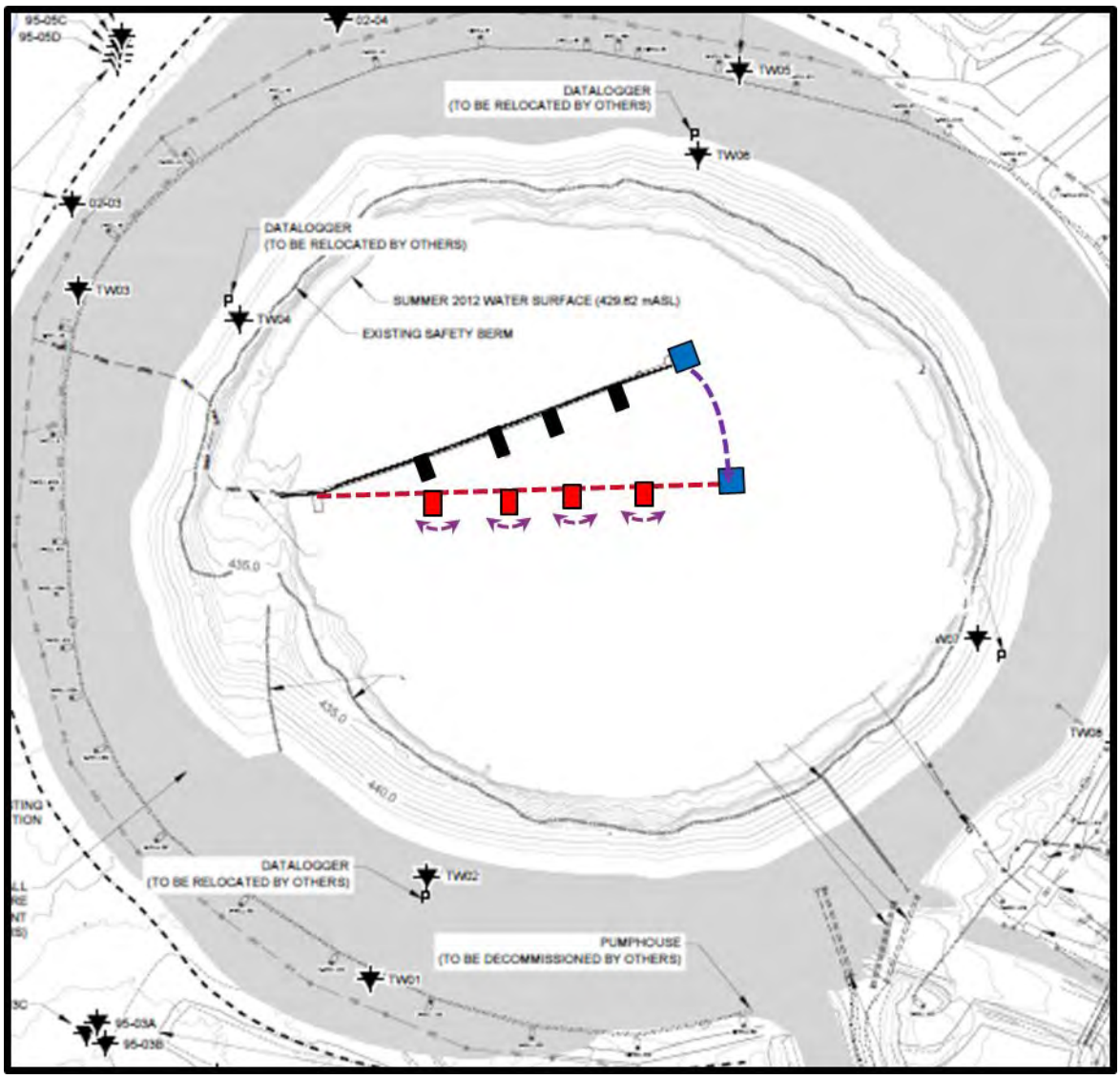
3.5 Project Description

The implementation of the sub-aqueous deposition method does not result in changes to the McClean Lake Mill or to the pipelines leading to the JEB TMF. Engineering changes are restricted to within the JEB TMF footprint.

Figure 1 in Section 2.3 illustrates the layout of the sub-aqueous deposition system. The system will run off the existing walkway. Initially there will be up to five deposition points, each deposition point associated with a length of flexible walkway. The flexible walkway is available in 3.5 m lengths and allows for approximately 10^{o} bend at the end of each section, making it less sensitive to wind and wave action. The flexible walkway

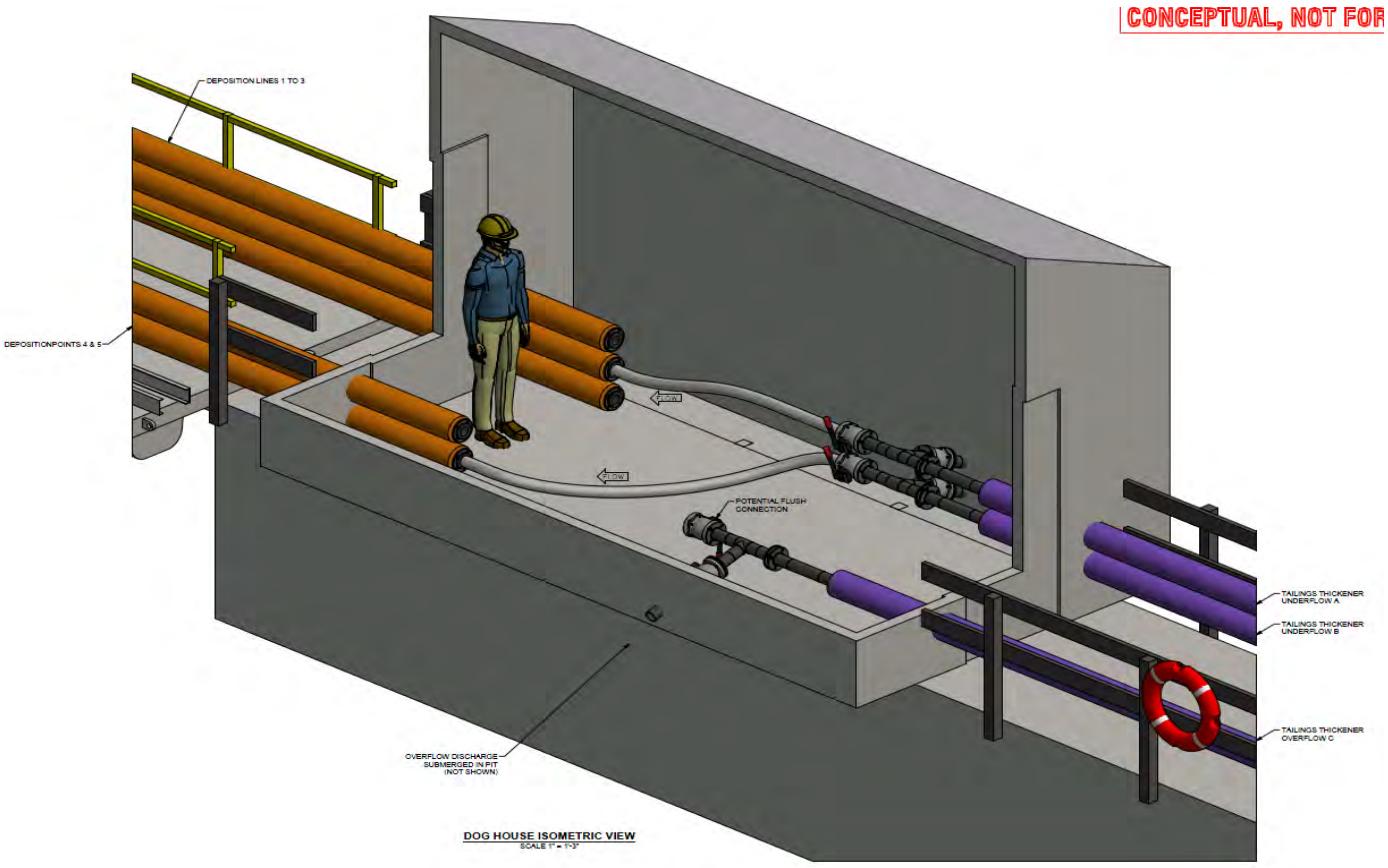
will be connected with a flexible joint to the existing walkway. Figure 10 indicates flexible walkway ability for each of the deposition points to rotate slightly, with minimal effort, increasing operational flexibility. As the surface area of the JEB TMF pond increases, additional sections of walkway can be added to the main walkway.

Figure 10: Available Movements of the Deposition System



A schematic of the piping enclosure is shown in Figure 11. The insertion of the header enclosure is the first location where changes are made to the existing deposition system.

Figure 11: Layout of the Header Enclosure



The header enclosure will be on a barge. The existing walkway will be connected to both ends of the barge and the header enclosure installed on the barge. Ventilation for radiation protection within this enclosure will be the same type of system that is used on the existing deposition and reclaim barges.

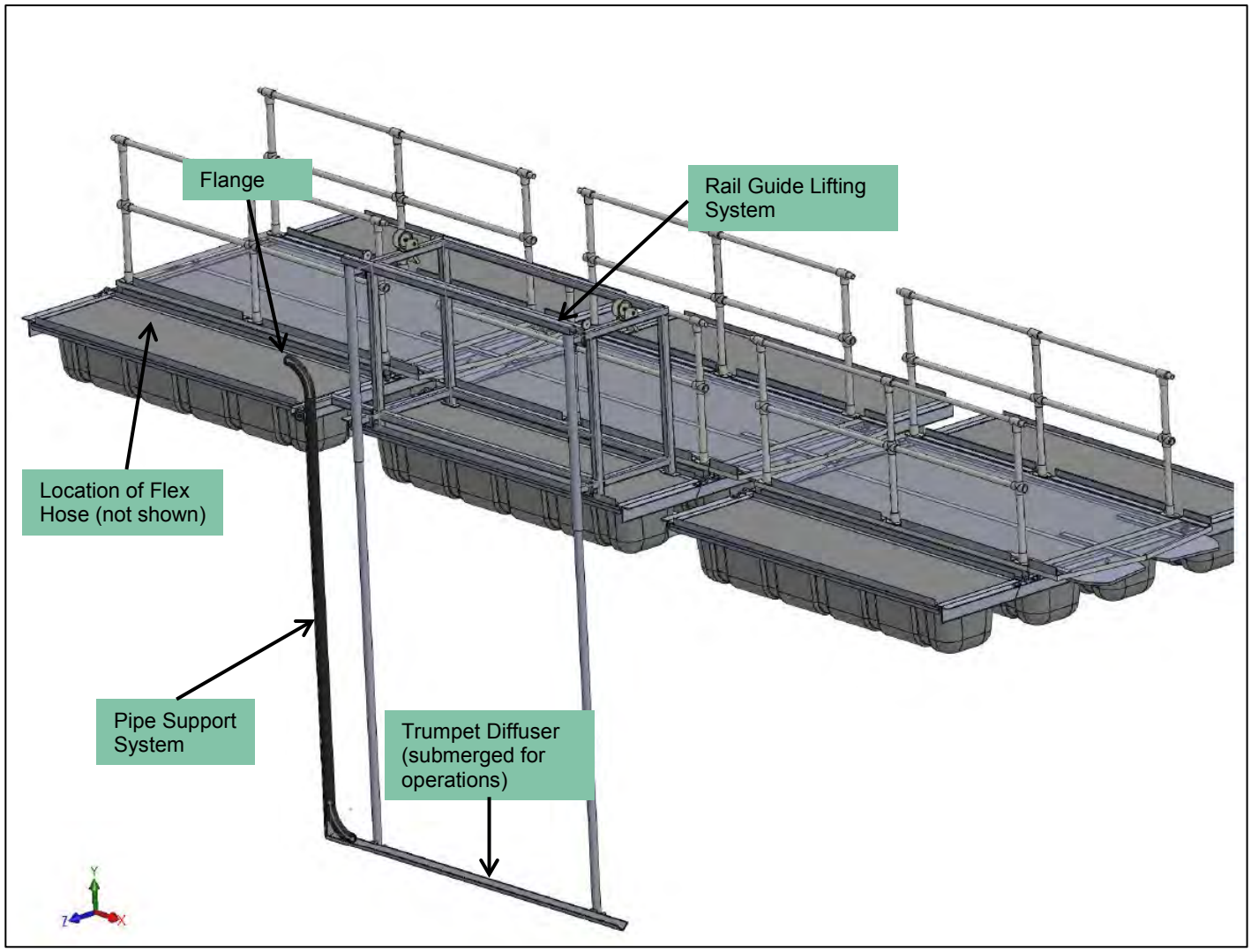
Figure 11 shows the three existing pipelines from the mill coming into the enclosure on the southwestern end, which consist of; one 5-inch HDPE line (Line “C”) used for TTOF; one 3-inch HDPE line (Line “A”) for TTUF and one 3-inch HDPE line (Line “B”) can be used for either TTOF or TTUF, however is not always in use. These three pipes are terminated within the enclosure and equipped with emergency dump piping through the walls of the enclosure. The main TTUF line will be the primary deposition point and be connected to one of the 5 pipes leaving the enclosure. Tailings Line B, when not in use has water running through it and will be connected to another one of the 5 pipes leaving the enclosure and act as a secondary deposition point.

Each of the five pipes that leave the header enclosure will consist of 3-inch HDPE pipe and will be associated in one deposition location. Each pipeline will run along the main walkway until it reaches its

deposition location and then make a long radius 90 degree elbow at the start of the flexible walkway associated with that deposition point.

Figure 12 shows a schematic of the piping arrangement at each deposition point. A lifting system and support system will allow for the piping to be removed from the water when that deposition point is not in use. When that deposition point is required the piping will be lowered to below the water surface and one flange connection will be made to put the piping into service. When not in service the diffuser and pipe will be supported above the water.

Figure 12: Cross Sectional View of Proposed Deposition System



The piping will drop at least 1.5 m below the surface of the JEB TMF pond water to a 90 degree joint, which will direct the pipe horizontally and parallel to the flexible walkway. The 3-inch pipe transitions to a 6-inch

HDPE pipe using a 3x6 reducer to increase the pipe size. The 6-inch HDPE pipe section will be about 1.5 m in length. When submerged, the piping will be held at the correct depth by the rail guide system or weighs.

The deposition barge, with its associated tremie system will be disconnected from the deposition system, however will remain in place and be reconnected if any concerns develop.

The proposed sub-aqueous deposition system is discussed in more detail in Section 4. The impact of the proposed sub-aqueous deposition system on the constraints outlined above in Section 3.3, are discussed below.

3.5.1 Mounding

Figure 13 shows the tailings surface immediately after the 25-day sub-aqueous test of Cigar Lake tailings. Figure 14 compares the degree of mounding observed with tremie deposition vs with sub-aqueous testing.

Figure 14 compares three surfaces starting at 10 m, at zero, or at the deposition point, using the 2009 survey of the JEB/Sue tailings , the 2017 survey of the Cigar Lake tailings, each placed via the tremie deposition method and the 2017 survey taken following the 25-day test of the sub-aqueous deposition method.

Figure 14 indicates that the mounding produced by tremie deposition of the JEB/Sue tailings has the steepest mound and the slopes from depositing these coarser tailings does not extend out as far as with the tremie deposition of the finer Cigar Lake tailings where the slope of the mound decreases but tailings extend further out.

Overall the sub-aqueous test produced the least amount of mounding. Although these tailings displayed a higher initial slope at the deposition point than the tremied Cigar Lake tailings, the remaining profile is shallower. It is expected that for deposition occurring over a longer duration in one location, a larger volume of tailings can be placed at a single deposition location using the sub-aqueous deposition than with the tremie deposition.

Figure 13: Tailings Surface Immediately after Sub-aqueous Test

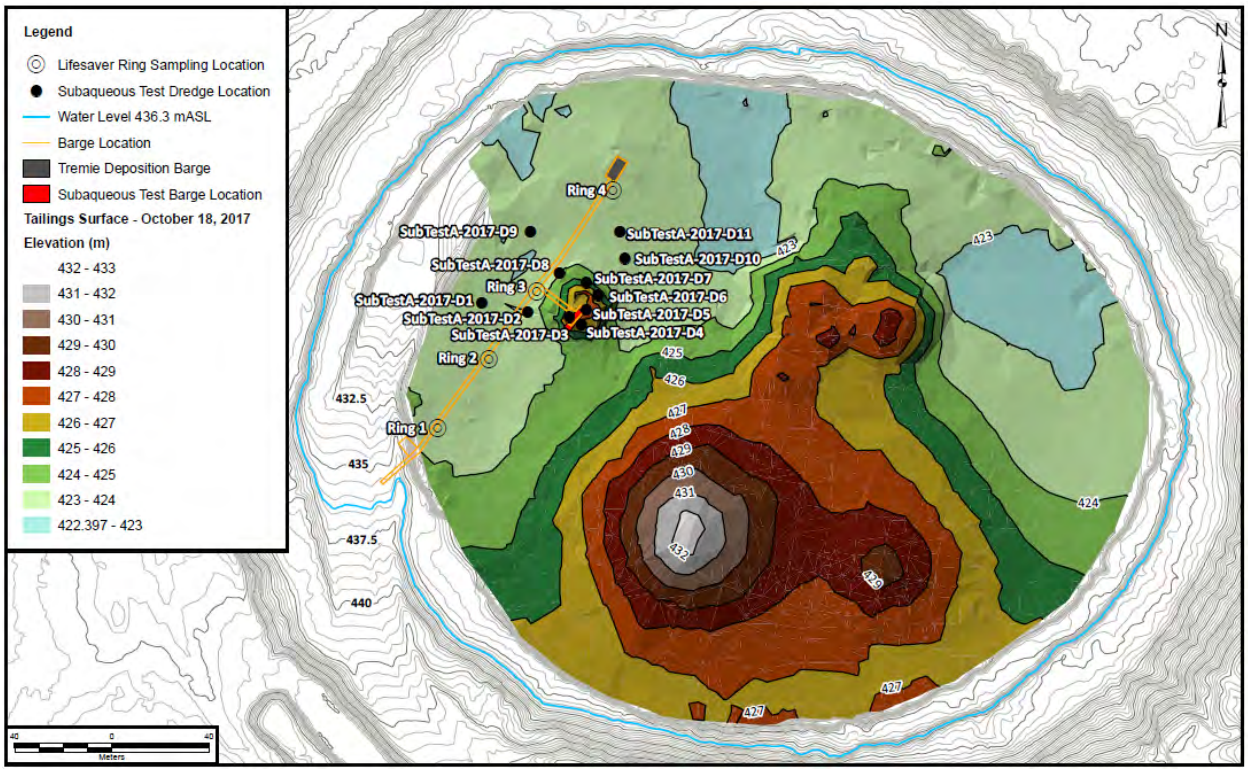
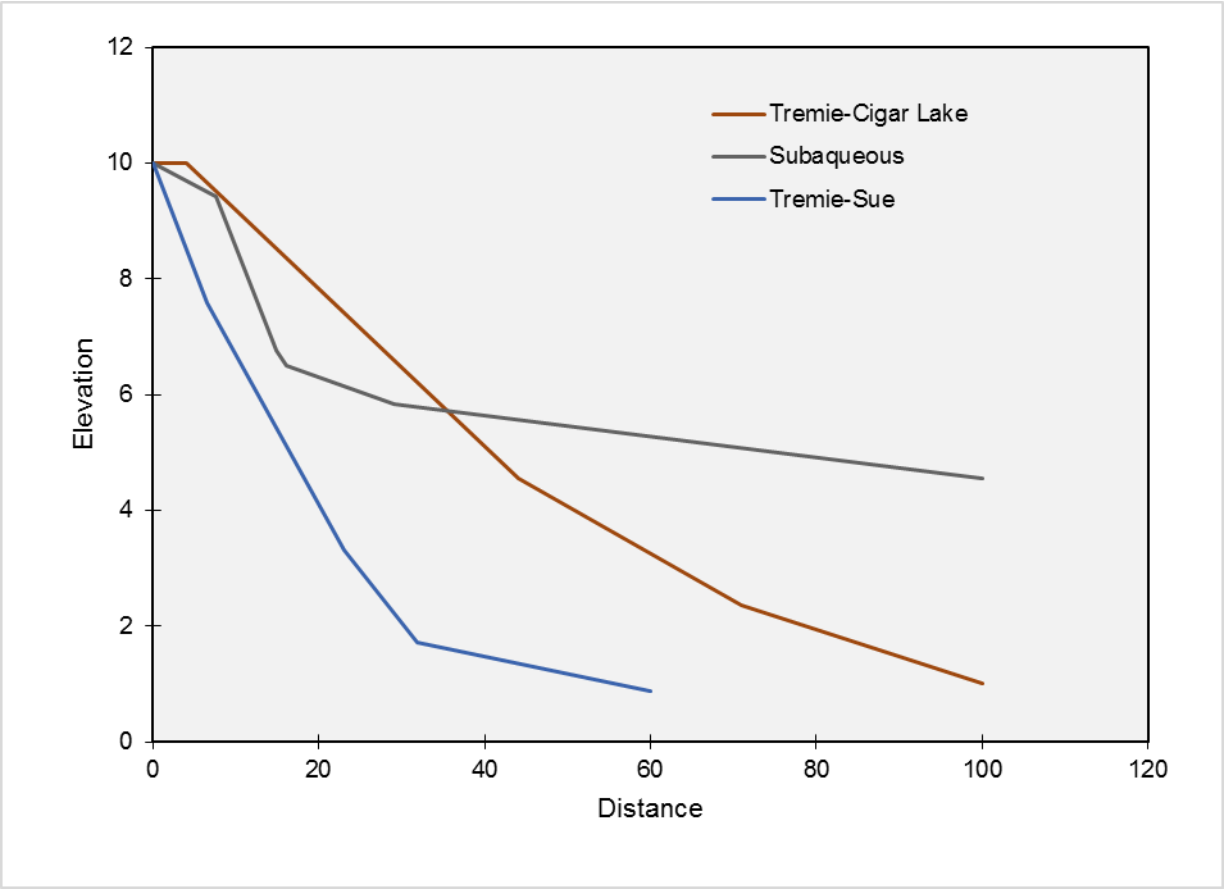


Figure 14: Comparison of Resulting Profile at a Fixed 10 m Deposit Height Considering Compound Slopes



3.5.2 Water Cover

Currently with the tremie deposition system, Orano maintains a minimum water cover of 3 m to accommodate the submerged depth or draft of the tremie deposition barge. The sub-aqueous deposition system will discharge tailings at a depth of 1.5 m below the JEB TMF pond surface, requiring a reduced amount of water cover, providing operational flexibility and additional usable capacity for the storage of tailings.

3.5.3 Effects of Weather

The sub-aqueous system will not be impacted by wind and waves to the same degree as the tremie system, as small movements at the deposition points does not cause an issue for deposition.

Currently an ice cover forms over the JEB TMF pond during winter, restricting the movement of the single deposition barge to the ice-free season. The sections of flexible walkway will have de-icing motors to keep the water around these deposition points open throughout the winter (as was successful demonstrated over the winter of 2017/2018). The deposition locations will not become iced-in to the same degree as with the existing system. This will allow for both changing the deposition location in winter and small-scale movements of each deposition location.

3.6 Schedule

Orano intends to modify the piping system in the summer and early fall of 2018, in order to commission the new deposition system prior to the winter of 2018/2019.

3.7 Risk Management Overview

The McClean Lake Operation maintains certification under the Occupational Health and Safety Assessment Series (OHSAS) 18001:2007 which provides the requirements for a comprehensive Occupational Health and Safety Management System. It includes hazard identification and risk assessment. This includes proactive minimization of risks to workers and the public through continual improvement in health and safety performance. Work plans consider the identification of workplace hazards, assessment of the hazards, and development of controls to mitigate risk. The OHSAS 18001 system includes a register of hazards, risks, and mitigation measures which are reviewed and updated as required by the McClean Lake Operation.

A risk assessment considering this sub-aqueous deposition was conducted on March 8, 2018. Table 4 identifies minor concerns and their mitigation.

Table 4: Risk Assessment Results

Risk	Mitigation	Risk Ranking
Safety Risks		
Climate – introducing outdoor winter work requirements including raising/ lowering subaqueous piping, bolted flange connection and operations tailings depth measurement at deposition point (currently conducted inside deposition barge)	•Design of raising/lowering system to require very little operator input •Limiting pipe connection/disconnecting requirement to one location (per deposition point) •Using a flanged connection to ease pipe alignment issues (vs other connection types). •All normal work will be inside of the railings of the walkways. If upset conditions are encountered stop and develop a SWP •Keep walkways clear of snow for safe access •Minimum (2) person crew during deposition point changes •Proper cold weather PPE (including water proof gloves)	1

Risk	Mitigation	Risk Ranking
Pinch Points/Cuts and Abrasions – manual cable/winch system used to articulate the flexible walkways (similar type winches in use, new location and application)	•PPE requirement – always wear proper gloves when using winch and/or handling cable •Have PM plan for all winches and cables	1
Energy Isolation – Tailings 'A Line' & 'B Line' to have flow redirected out drain and have line broken downstream of flow redirection (existing site risk – new location).	•Positive isolation method (double block and bleed or lockable knife gate valves) •Normal LOTO procedures will be followed •Drain valve downstream of isolation point to verify if pressure has been bled off the system prior to conducting a line break	1
Fall Risk – working near open water year round (i.e. raising and lowering subaqueous piping) (existing JEB TMF risk – more frequent)	•Flange requiring regular access will be located just outside handrail so it can be accessed from inside handrail •All lifting equipment controls to located inside handrail •Travel restraint tie point to be included on walkway, inside handrail, to be used if work outside handrail is required (won't be required during normal operations) •100% life vest requirement and a minimum (2) person crew during deposition point changes	1
Dropped suspended load risk – lifting equipment for raising and lowering subaqueous piping located on flexible walkways and to be used in adverse conditions (i.e. cold/snow)	•Engineered lifting points provided for all piping intended to be raised and lowered •All lifting device controls to be separated from suspended loads by handrail •Loads will not be, nor have capacity to be lifted overhead	1
Slips/Trips/Falls – congested walkway, covered in snow, piping and hoses crossing intended walking paths (existing risk exacerbated with additional piping)	•Pipe crossings will have walkway bridges •Clear work area (e.g. snow) prior initiating work, add to work instruction. •Piping will be organized and secured leaving an open, dedicated walkway that facilitates easy snow clearing (improvement over existing).	1
Environmental Risks		
Risk of increases to TSS and lack of chemical buffering in reclaim water, and whether there is a risk to performance of the JWTP.	•2017 test work indicated that TSS at the deposition point is similar to tremie deposition. • On-going monitoring of the reclaim water for TSS and general chemistry	1

Risk	Mitigation	Risk Ranking
Risk of tailings segregation issues and the effect on the long-term performance of the JEB TMF.	• The grain size of Cigar Lake tails are much finer than JEB/Sue tails (i.e. mean particle size is between 5 – 15 µm) which limits risks of segregation as the whole Cigar Lake tailings sample would be classified as fine grained under the JEB / Sue tailings classification system • Keep header enclosure outside of the 15 m buffer from the edge of the JEB TMF	1
Tailings Risks		
Risk of tailings 'mounding' (existing risk, changed due to difference in deposition method)	•Test work and modelling show overall the amount of mounding is less than experienced with the tremie •Some local mounding was observed which will be addressed by having small swings in location at the end of each flexible walkway (~6m range of motion) •On-going monitoring of mounding and tailings behavior	1
Radiation Risks		
Radon exposure inside of the Header Barge. Past experience has shown that radon will build up above administrative levels inside JEB TMF enclosures (i.e. deposition barge/reclaim barge)	•Install a ventilation fan duplicating performance of those installed in the deposition and reclaim barges •Add header barge to the regular RP monitoring schedule	1
Increased potential for exposure to radioactive tailings due to switching deposition points more frequently (i.e. in Header Shack when switching hoses)	•Procedural – thorough flush with process water before breaking lines •Positive LOTO of slurry lines prior to line break •Drainage in Header barge floor to prevent slurry build-up	1
Operational Risks		
Freeze Risk – increased risk of freezing deposition piping on walkway due to increased quantity of piping, no pipe insulation; operational philosophy that includes removing piping from service during winter months, design that incorporates stagnant piping with no provision for constant freeze protection flow (as is standard practice for 'A Line')	•All valves are located inside a heated enclosure to prevent freezing •Included in the heated enclosure are provisions for blowing and pigging deposition pipes to prevent freezing •Proper pipe layout and support will limit 'low point' areas (improvement over existing) •Hose header system prevents valve passing risk leading to downstream frozen piping (vs a valve header system) •Worst case scenario one of the five deposition pipes freezes, redundancy is available while the frozen pipe is cleared with work being conducted under a SWP	1
Directing tailings flow to the wrong deposition point during deposition point changes	•Daily tailings depth checks by Operations Department •Hose header system to be used instead of a valve header system. •Simple to follow, highly visual signage, no valve passing issues	1
Potential to dead head tailings thickener underflow pumps (existing risk that is exacerbated due to requirement of more frequent redirection of tailings flow)	•System design pressure exceeds deadhead pressure of pump (centrifugal) •Hose header system simplicity reduces complexity and risk (vs valve header)	1

Risk	Mitigation	Risk Ranking
Unplanned relocation of deposition point through flexible walkway articulation (i.e. someone articulates the deposition point without operational plan/approval to do so changing the planned deposited tailings profile)	•Well communicated operational procedure •This can be corrected when it is noticed (should be observed in daily tailings level measurements) and then the situation can be reversed or the deposition system can be adjusted accordingly •If necessary, the use of a LOTO on the winches for the articulating walkways can be reviewed	1

3.8 Health & Safety Considerations

The McClean Lake Operation's Safety department actively participated in the 2017 test work and has continued to be involved in the planning and execution of the project, promoting a positive safety culture, and assessing ongoing work procedures and potential hazards. Safe Work Plans will be developed, reviewed, and signed off by all parties prior to the start of the implementation of the sub-aqueous deposition method with routine operations described by mill operations work instructions and procedures.

The 2017 test work demonstrated that there are no new health and safety concerns as a result of the implementation of the sub-aqueous deposition method. The health and safety considerations are included above in Table 4.

3.9 Radiation Protection Considerations

No new radiation protection issues are associated with the implementation of the sub-aqueous deposition method. As with the current tremie deposition method, sub-aqueous deposition will involve the deposition of the tailings below the surface of the JEB TMF pond water cover, which will reduce worker exposure to dust, gamma radiation, and radon. The 2017 test demonstrated that there are no additional radiation concerns.

The main radiation consideration is that the depth to the deposition point must be at least 1 m below the pond surface. This depth provides sufficient radiation shielding for the protection of any workers in the area and helps mitigate considerations about the deposition pipe freezing into the ice during the winter months. Design features for radiation protection for the header enclosure will be similar to those implemented for the existing barge enclosures.

3.10 Environmental Protection

Historically the JEB/Sue tailings samples were grouped as those coarser and those finer than whole tailings, so the JEB/Sue tailings samples that had >55% of the particles that were <75 µm, were classified as fine grained. The Cigar Lake tailings are much finer that the historical JEB/Sue tailings and generally >80% of the tailings mass is <75 µm with the median particle size being between 7-25 µm. A homogeneous mass of

the Cigar Lake tailings would therefore be classified as fine grained using the criterion used for the Jeb/Sue tailings.

The finer grained Cigar Lake tailings, combined with the sub-aqueous deposition method are anticipated to result in more limited segregation compared with what was observed using the tremie deposition method of JEB and Sue ore tailings, and deposition of tailings will be in a more predictable shape. Therefore, it is anticipated that the Cigar Lake tailings will perform as required, creating a hydraulic conductivity contrast between the tailings and the surrounding host rock of the JEB TMF. The precautionary deposition point setback of 50 m from the pit walls can be reduced to 15 m given the properties of the tailings and the observed performance of sub-aqueous placement.

3.11 Nuclear Substance Inventory

The implementation of the sub-aqueous deposition will not result in any changes to the Inventory of Nuclear Substances.

3.12 Expected Impacts to Decommissioning or Closure Plans

The implementation of the sub-aqueous deposition method will not result in any changes to the McClean Lake Operation Preliminary Decommissioning Plan (PDP) and Financial Assurance (FA).

3.13 Security and Canada's International Obligations

The implementation of the sub-aqueous deposition method will not impact nuclear material security, or Canada's obligations. Orano continues to maintain nuclear material security in accordance with national and international obligations.

4 Design Control, Operating Specifications

4.1 Design Basis and Criteria

In summary, the proposed sub-aqueous system addresses the operational constraints discussed in Section 3.3, providing a system that is easier and safer to operate and provides the ability to more efficiently fill the JEB TMF, enabling a more efficient use of the available capacity. The operational improvements include:

- Multiple sub-aqueous deposition points, each deposition point located beneath a section of flexible walkway and suspended at least 1.5 m below the JEB TMF pond surface.
- Ability of small-scale movements at each sub-aqueous deposition point, requiring little effort to move, increasing operational flexibility.
- The precautionary deposition point setback of 50 m from the pit walls can be reduced to 15 m given the properties of the tailings and the observed performance of sub-aqueous placement.
- Retaining the current tremie system at the end of the existing walkway (for at least two years), providing the ability to reconnect quickly, if necessary.
- Ability to change deposition points in winter, utilizing the header barge.
- Ability to clean the lines from the header enclosure to the deposition points that are no longer in use with either a pipeline “pig” or compressed air.
- When not in use the diffuser pipe assembly will be supported above the JEB TMF pond surface. When that diffuser is put into use the diffuser assembly will be lowered with the lifting mechanism and the single flange connection made with the 3-inch HDPE pipe that runs along the walkway. To change the deposition point the only other change that is required is a re-routing of the tailings flows in the header enclosure with the flexible hose.
- The diffuser pipe is suspended beneath the flexible walkway using rail guide system or similar lifting mechanism. The lifting mechanism will require a counter balance to balance the loads on the flexible walkway.
- The 6-inch diffuser pipe will be positioned at least 1.5m below water surface.

4.2 Design Drawings

The following drawings have been issued for regulatory review and are included in Appendix A of this notification/application:

- Subaqueous Discharge Walkway Layout – General Arrangement Isometric View
- Subaqueous Discharge Walkway Layout – General Arrangement – Plan View
- Header Enclosure Isometric View

- Submerged Pipe Lifting Frame, Sections and Details
- Tailings Deposition System P&ID

4.3 Quality Management Program

The implementation of the alternate tailings deposition method will be controlled using *Procedure 115 Change Control* and *Procedure 116 Design Control*. The validation step (*Work Instruction 116-06 Design Validation)* will be developed prior to commissioning of the new system and will also help ensure that the new deposition methodology operates as designed.

4.4 Changes to Contingency Plans

For the first two years of operations, the existing deposition barge will be left in place at the end of the walkway. If any issue arises with the sub-aqueous deposition, Orano will be able to rapidly return to the tremie deposition system. The implementation of the subaqueous deposition system will not result in any changes to the existing contingency plans.

5 Planned Administrative Controls

5.1 Changes to Organization

The implementation of the alternate deposition method will not result in any changes to the organization. The work will be performed by McClean Lake Operation personnel and third party contractors. The construction of the system will also be supervised by competent personnel.

5.2 Internal Reviews

Orano confirms that all internal reviews and approvals have been completed in accordance with our documented procedures.

5.3 Changes to Applicable Programs and Procedures

The activity will result in some changes to existing programs or procedures that are related to tailings deposition and the monitoring of this deposition. These documents will be updated prior to the system being put into operations. There will also a change required to McClean Lake Operation Facility Description Manual.

5.4 Monitoring and Inspections

Monitoring and inspections will continue as previously conducted, these include:

- Daily inspections of the operations and the depth to tailings;
- Annual bathymetry surveys; and
- Annual collection of tailings surface samples for particle size analyses.

6 Conclusion

On the basis of the information provided in this correspondence, and taking into account identified mitigation and control measures, Orano expects that the implementation of an additional tailings deposition system can be conducted in a manner that does not present an unreasonable level of risk to the public, workers, or the environment. Orano will realize greater operational flexibility and have improved access to available tailings disposal capacity without compromise to the design objectives for the JEB TMF described by licence basis documents.

7 References

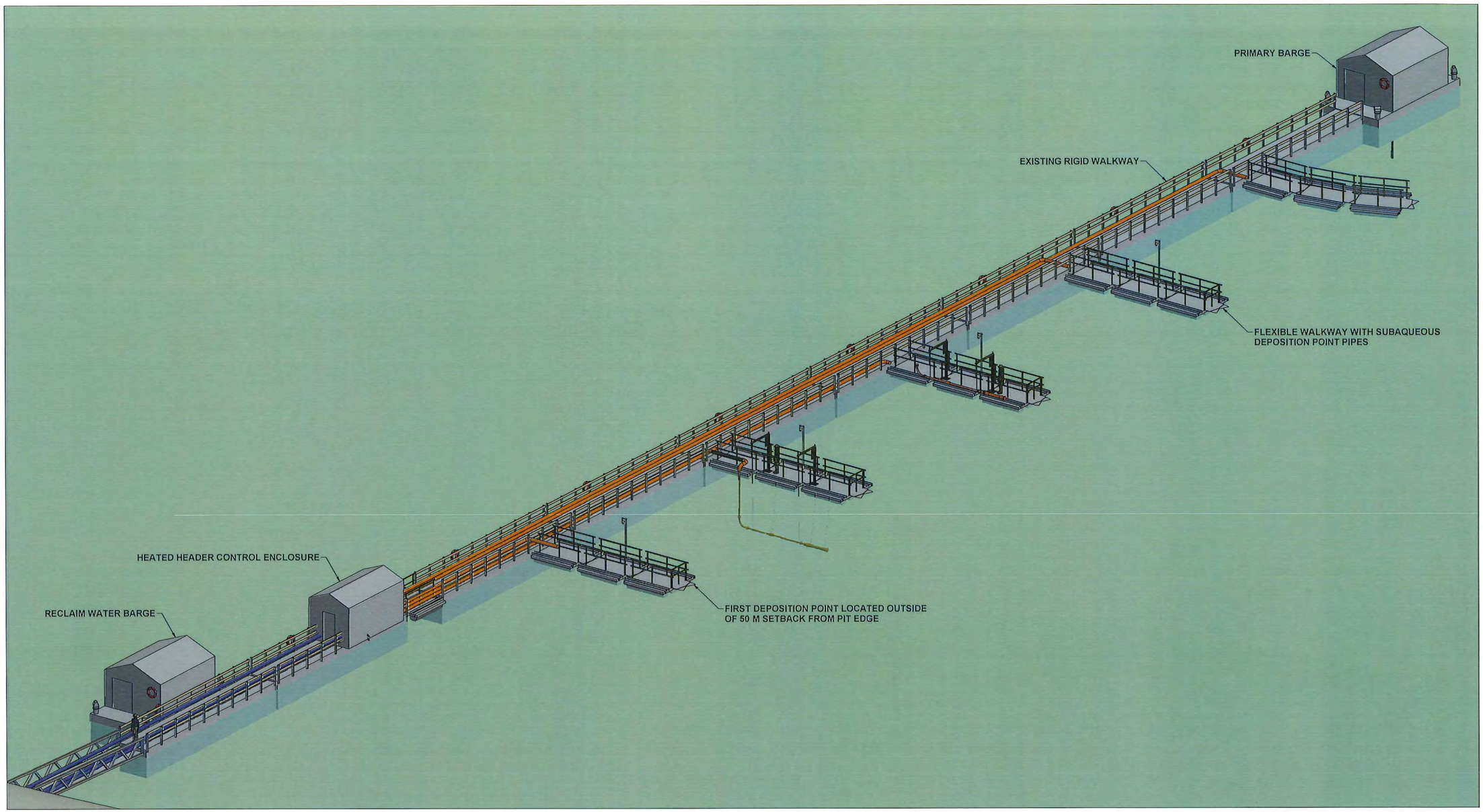
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Appendix A Drawings



ISOMETRIC VIEW
SCALE 1" = 10'-0"

ISSUED FOR REGULATORY REVIEW (26MAR2018)

Drawing No.	Description
Reference Drawings	

Rev.	Date	Description	Originator	Drawn	Checked
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A	02-FEB-18	ISSUED FOR CLIENT REVIEW	JMT	DJS	JMT
Revisions					

Engineer's Stamp
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MEMBER 17026
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VER. DATE DAY
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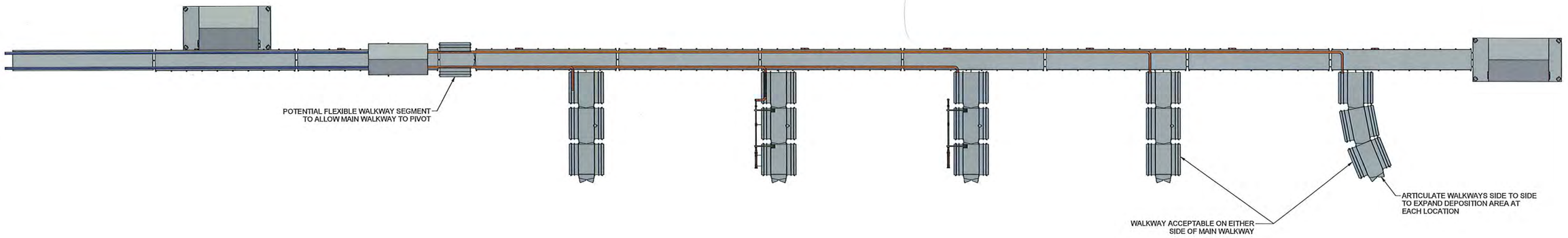
McCLEAN LAKE
TAILINGS DEPOSITION SYSTEM

SUBAQUEOUS DISCHARGE WALKWAY LAYOUT
GENERAL ARRANGEMENT

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PLAN VIEW
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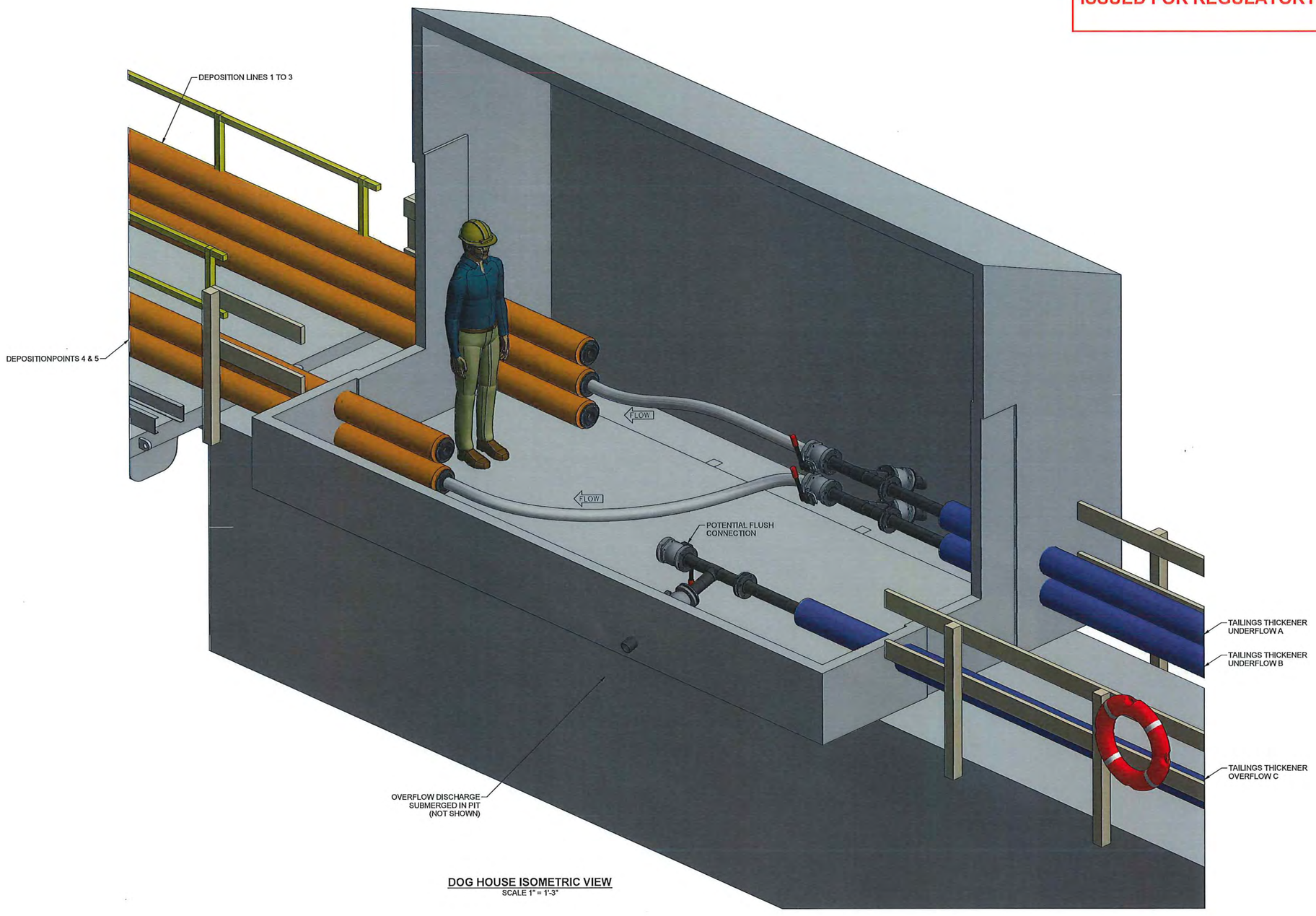
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SUBAQUEOUS DISCHARGE WALKWAY LAYOUT
GENERAL ARRANGEMENT

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DOG HOUSE ISOMETRIC VIEW
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Reference Drawings		Revisions					

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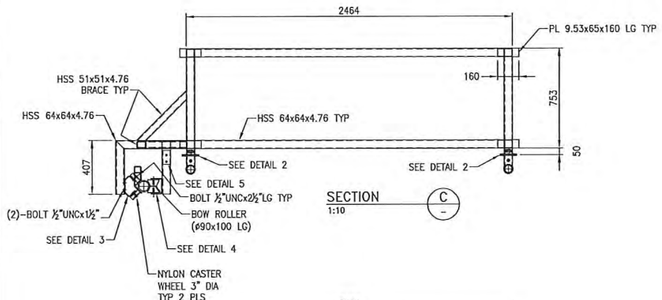
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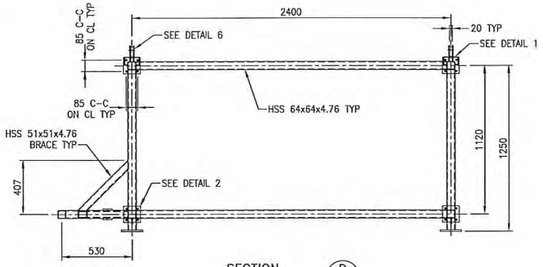
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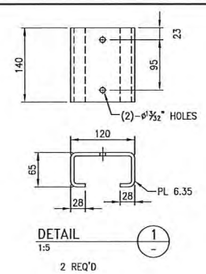


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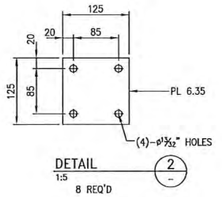


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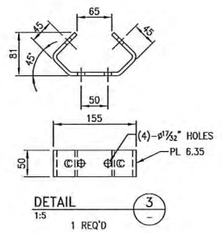
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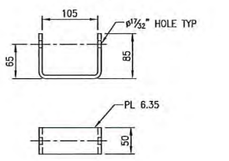
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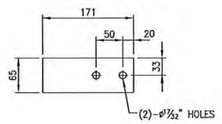
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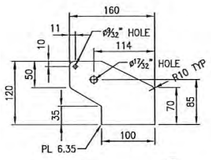
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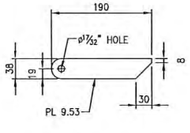
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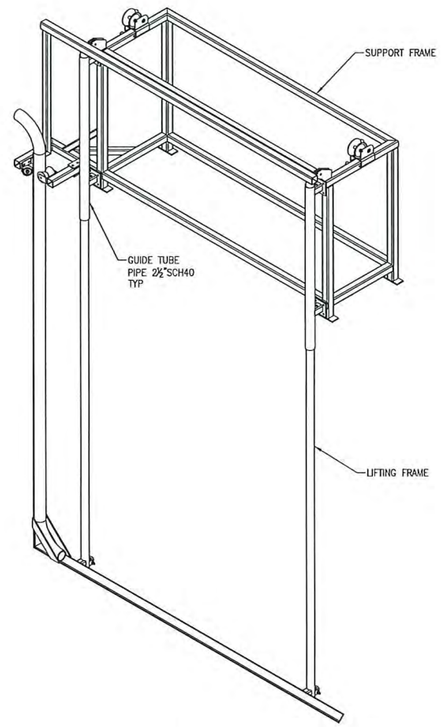
NOTES:

1. ALL DIMENSION IN MILLIMETERS U/N

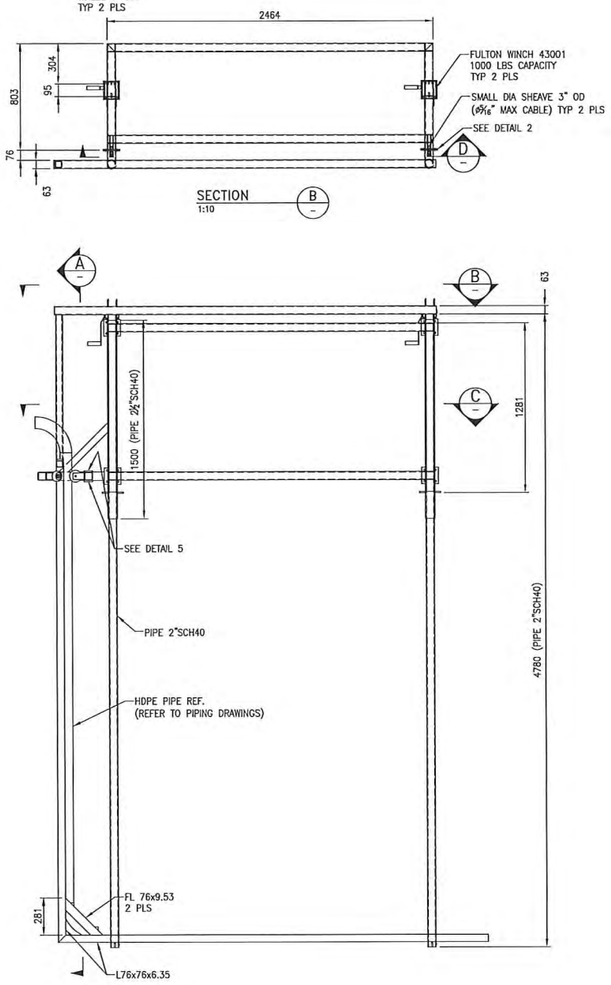
CODES AND STANDARDS:

2. ALL WORK SHALL CONFORM TO THE LATEST EDITION OF THE FOLLOWING CODES, STANDARDS AND REGULATIONS.
   - THE NATIONAL BUILDING CODE OF CANADA (NBC)
   - CAN/CSA S16 AND CSA W59 AND W59.2
   - PROJECTS SPECIFICATIONS AND DESIGN CRITERIA
   - OCCUPATIONAL HEALTH AND SAFETY REGULATIONS
   - THE MINES REGULATIONS
   - MANUFACTURER'S PROCEDURES AND RECOMMENDATIONS

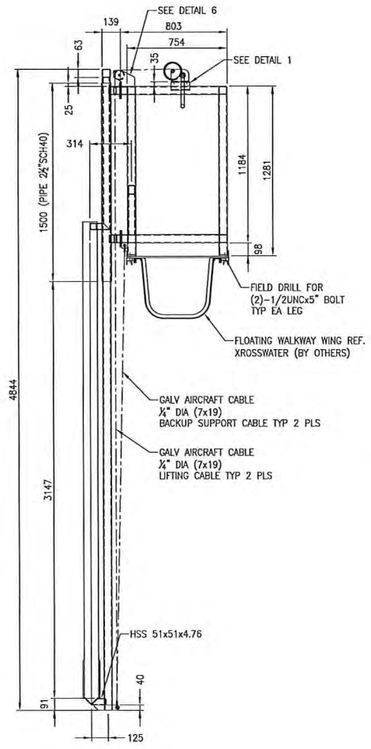
MATERIAL:
ALL ROLLED SECTIONS TO BE 6061-T6 ALUMINUM U/N
ALL PLATE TO BE 5052-H32 ALUMINUM U/N
ALL PIPE TO BE 6061-T6 ALUMINUM

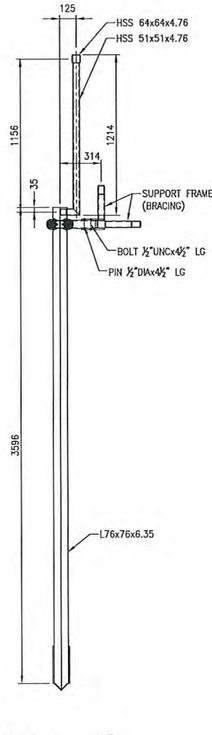


ISOMETRIC VIEW – SHOWN IN LOWERED POSITION



LIFTING FRAME GENERAL ASSEMBLY – SHOWN IN LOWERED POSITION





SECTION 1:10 (A)

LIFTING FRAME

PROFESSIONAL ENGINEER
SASKATCHEWAN
J.J. KOOF
MEMBER 17026
18 04 10
YR MO DAY

ISSUED FOR REGULATORY REVIEW (09MAR2018)

REFERENCE	DWG No.	DESCRIPTION

REFERENCE	DWG No.	DESCRIPTION

REVISIONS	No.	DATE	DESCRIPTION	BY	CHK	DSN	AP1	AP2

REVISIONS	No.	DATE	DESCRIPTION	BY	CHK	DSN	AP1	AP2
	A	08APR18	ISSUED FOR REVIEW	DLC				

SCALE:		DATE	
DESIGNED:			
DRAWN:	DLC	08APR18	
CHECKED:			
APPROVED:			
APPROVED:			

orano

PROJECT No. MC16ML19/287ML

SUBAQUEOUS TAILINGS DEPOSITION

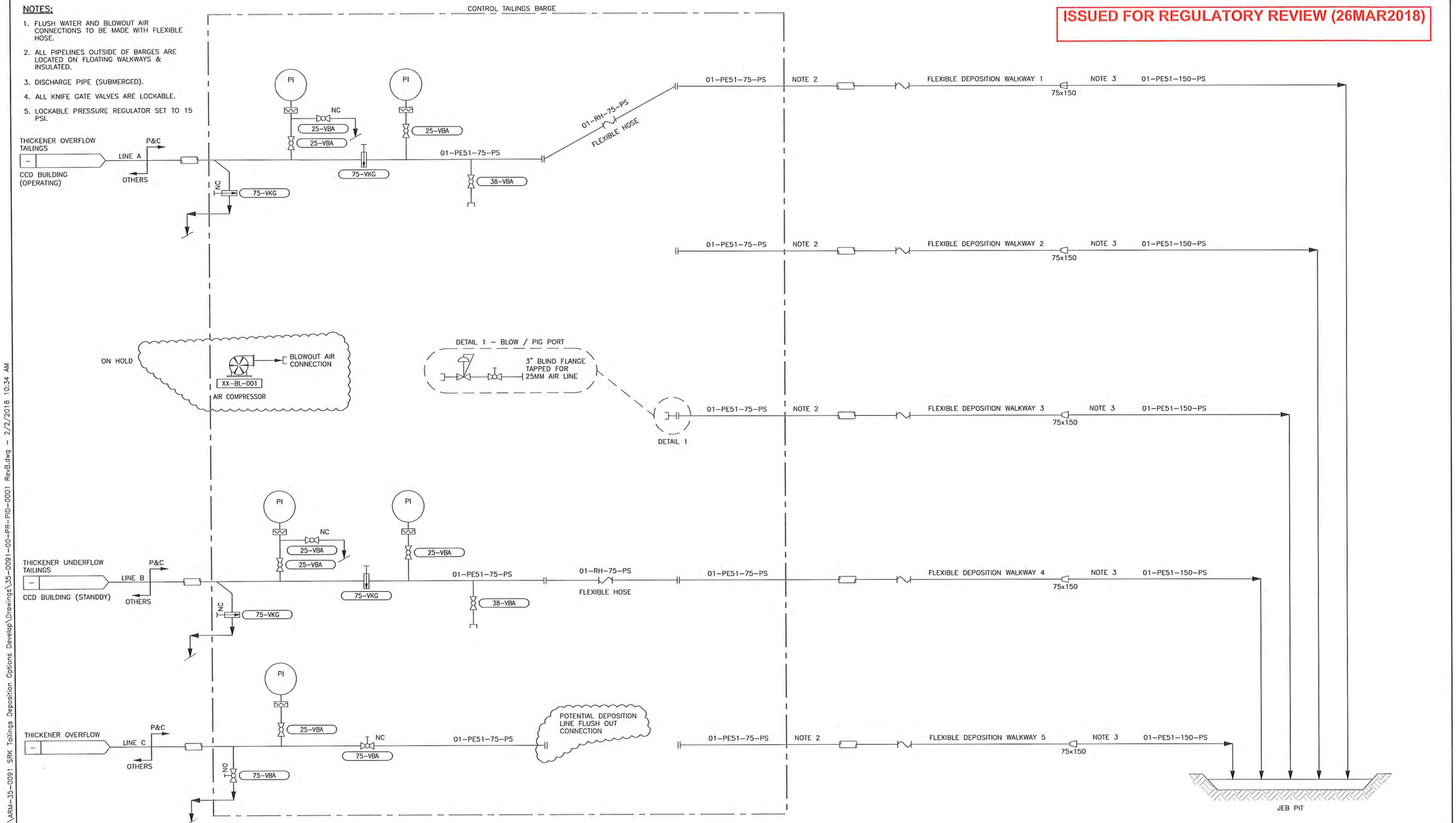
DETAILED ENGINEERING #1
SUBMERGED PIPE LIFTING FRAME
SECTIONS AND DETAILS

DRAWING No. GA-05 | REV A

ISSUED FOR REGULATORY REVIEW (26MAR2018)

NOTES:

1. FLUSH WATER AND BLOWOUT AIR CONNECTIONS TO BE MADE WITH FLEXIBLE HOSE.
2. ALL PIPELINES OUTSIDE OF BARGES ARE LOCATED ON FLOATING WALKWAYS & INSULATED.
3. DISCHARGE PIPE (SUBMERGED).
4. ALL KNIFE GATE VALVES ARE LOCKABLE.
5. LOCKABLE PRESSURE REGULATOR SET TO 15 PSI.



Rev.	Date	Description	Originator	Drawn	Checked
B	01-FEB-18	UPDATED	JMT	CLS	JMT
A	31-JAN-17	ISSUED FOR CLIENT INFOMATION	JMT	CLS	JMT

Revisions

Drawing No. | Description

Reference Drawings

Engineer's Stamp: PROFESSIONAL ENGINEER, J.M. AYDT, MEMBER 17026, 18 03 26, SASKATCHEWAN

CLIENT: AREVA

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AREVA TAILINGS DEPOSITION SYSTEM

TAILINGS DEPOSITION SYSTEM P&ID

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	Off. Code	Proj. Code	Area Code	Disc. Code	Doc. Type	Unique. No	Sheet No	Rev.
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Matt Treinen - L:\3 - Projects\ARM-35-0091 SRK Tailings Deposition Options Develop\Drawings\35-0091-00-PR-PID-0001 RevB.dwg - 2/2/2018 10:34 AM