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Design Report of Mammoth Dike

Detailed Engineering of Water Management and Geotechnical Infrastructures

Agnico Eagle Mines Limited - Meadowbank Division

Mining & Metallurgy

22 | 10 | 2018

Report > Client ref. AEM # 6118-E-132-002-TCR-015 > Original > Rev. 01
Internal ref. 651298-5000-40ER-0001

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Subject: **Design Report of Mammoth Dike**
Detailed Engineering of Water Management and Geotechnical Infrastructures
AEM File AEM # 6118-E-132-002-TCR-015
SNC File: 651298-5000-40ER-0001_01

Dear Sirs,

We are pleased to submit the final version of the report on the detailed design of Mammoth Dike, which is one of the key components of the water management infrastructures required during open pit mining of the Whale Tail deposit.

Do not hesitate to communicate with the undersigned should you have further questions regarding the content of this report.

Truly yours,

SNC LAVALIN INC.

Yohan Jalbert, Eng.
Project Manager
Mining and Metallurgy

YJ/ml

List of Revisions

Revision				Revised pages	Remarks
#	Prep.	App.	Date		
PA	M. D.-J.		2018-08-07		Issued for internal review
PB	M. D.-J. / G. H.	YJ	2018-09-17	All	Issued for AEM review
00	M.D.J/G.H	YJ	2018-10-16	All	Issued for use
01	G.H	YJ	2018-10-22	All	Appendices excluded

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1.0 INTRODUCTION

1.1 Context

Agnico Eagle Mines Limited, Meadowbank Division ("Agnico Eagle") is developing the Whale Tail Pit, a satellite deposit on the Whale Tail property, as a continuation of current mine operations and milling at the Meadowbank Mine. The Whale Tail property is a 408 km² site located on Inuit Owned Land, approximately 150 km north of the Hamlet of Baker Lake and approximately 50 km northwest of the Meadowbank Mine in the Kivalliq region of Nunavut (Figure 1-1). The property was acquired by Agnico Eagle in April 2013.

Figure 1-1: Whale Tail Pit locations

The Meadowbank Mine is an approved mining operation and Agnico Eagle will extend the life of the mine by constructing and operating the Whale Tail Pit. Mammoth Dike is designed to prevent flooding of the Whale Tail Pit in the event that the Mammoth lake level rises. The dike, discussed in the sections to follow, is a structure which will be dismantled or breached at the end of ore extraction from the Whale Tail Pit and once the closure conditions satisfied and monitoring completed.

This report presents the detailed design of Mammoth Dike in accordance with Type A Water Licence 2AM-WTP1826.

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7 258 000 7 257 000 7 256 000 7 255 000 7 254 000

N

Nemo Lake
A39 A11 A40 C38 C46 C43 C44 C42 C41 A113 A-P38 A48 A-P37 C39 C40 A-P49 A47 C-P1 A49 A-P57 A46 A50 A51 A-P5 A53 A53 C20 C21 A-P59 A-P47 A-P21 A54 A57 A56 A58 A61 A59 A60 A16 A-P39 A17

206.2 ha
148.3 ha
108.9 ha
162.7 ha
95.9 ha
2,301.8 ha

Whale Tail Lake (North basin)
North East dike
Whale Tail waste rock storage facility
Waste rock exploration pad
Ore stockpile
Industrial area
Open pit
WRSF dike
Water treatment plant
Whale Tail attenuation pond
Whale Tail camp
Mammoth dike
Ore stockpile
Overburden storage
Whale Tail dike
Mammoth Lake
Whale Tail Lake (South basin)
South Whale Tail channel

PROJECT COMPONENTS (PHASE I)

- Dike or cofferdam
- Modified waterbody
- Collection ditch
- Diversion ditch
- Open pit
- Storage facility
- Industrial area
- Road

HYDROGRAPHY

- Watercourse
- Lake
- Modified watershed

AGNICO EAGLE

SNC·LAVALIN

AMARUQ GOLD MINING PROJECT
Detailed Engineering of Water Management and Geotechnical Infrastructure

Mine Layout Watersheds – Phase 1

Sources:
Topography, PhotoSat, 2015
Project components : March 2018

Project: 651298
File: snc651298_004_fX_Mammoth_181016.mxd

0 200 400 m
1:20 000
UTM projection, Zone 14, NAD83 (CSRS)

October 16, 2018

Figure 1-2

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1.2 Structure of the Report

This report presents all of the available site specific geotechnical and topographic information, together with our interpretation of the factual data and the results of the thermal and stability analyses carried out for Mammoth Dike. For the design of Mammoth Dike, SNC-Lavalin has drawn on its experience and lessons learned during the detailed engineering of the Whale Tail Dike (WTD) which included a more detailed geotechnical investigation and stability, seepage, thaw settlement, thermal and stress analyses.

For completeness in presentation, the report includes the technical specifications for Mammoth Dike (SNC-Lavalin, 2018f) in Appendix A, together with the construction drawings. Therefore, when a drawing is mentioned in the report, the reader shall consult the technical specifications.

2.0 GUIDELINES AND STANDARDS

The design of Mammoth Dike has used the latest Dam Safety Guidelines produced by the Canadian Dam Association (CDA) with respect to dam classification and the American Society for Testing and Materials (ASTM) for the geotechnical components of the work. The Technical Specifications included in Appendix A (SNC-Lavalin, 2018f), provide a list of the ASTM and other construction material standards relevant to the Mammoth Dike, and hence are not repeated herein.

3.0 AVAILABLE GEOTECHNICAL INFORMATION

The subsurface condition of the Mammoth Dike foundation described next is based on three geotechnical boreholes close to the axis of either the dike or the key trench on the upstream side as shown on Drawing 651298-5000-4GEF-0003, carried out in spring 2018 (Series AMQMD-01). However, the bedrock profile shown in the longitudinal section of the dike is based on a large number of mine boreholes drilled within the footprint of the dike. The overburden consists of a surficial layer of gravel, cobles and boulders underlain by glacial till followed by bedrock. The above drawing also shows five (5) destructives boreholes with the Tamrock drill rig put down in fall 2017 on the upstream side of the dike (Series L1611) to have an order of magnitude of the overburden thickness. The thicknesses of the upper gravel cobbles and-boulder layer, the glacial till and the overall overburden vary in rounded figures from/to: 0.8/2.7 m, 1.1/1.70 m and 2.0/3.9 m respectively.

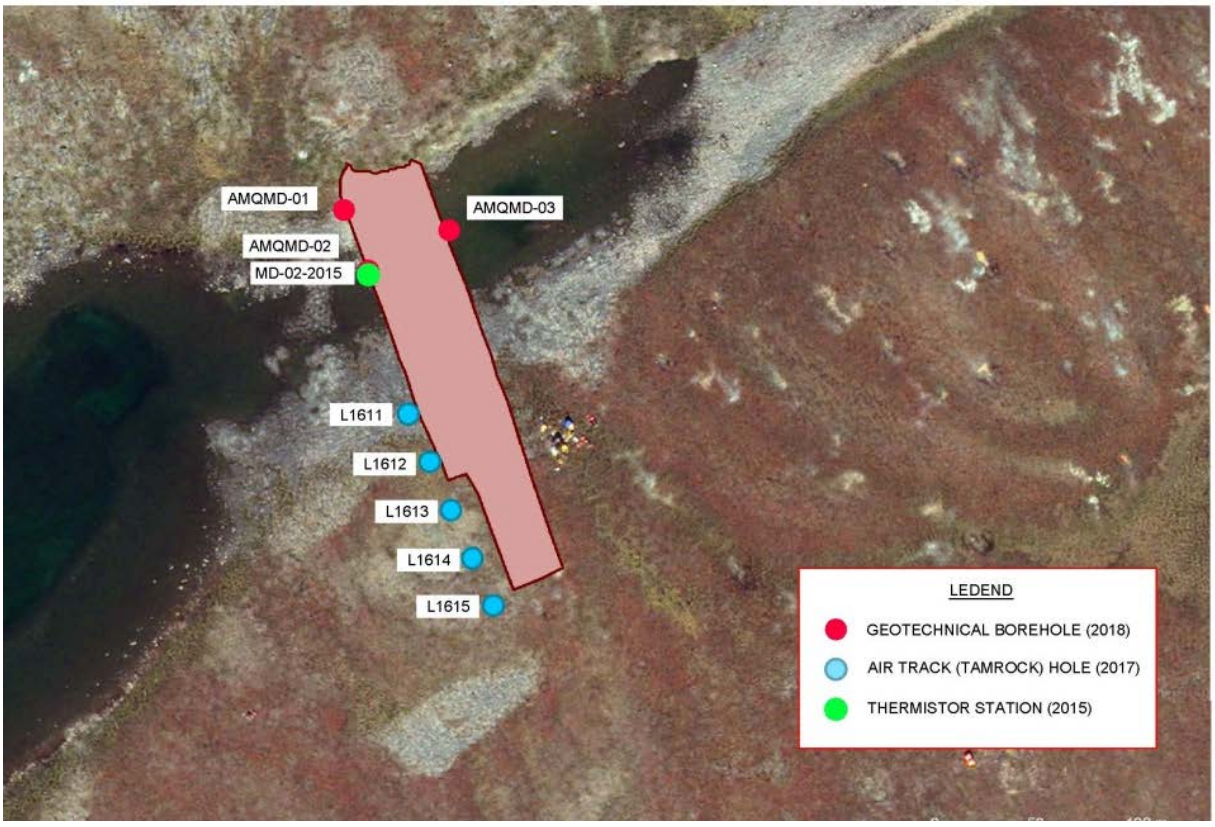


Figure 3-1: Locations of geotechnical and air track holes and thermistor station at Mammoth Dike

4.0 MAMMOTH DIKE DESIGN BASIS AND CRITERIA

4.1 Design Basis

The following elements were considered during the design of the Mammoth Dike:

- The dike will be constructed in 2018 or early 2019;
- The dike will be dismantled or breached at closure;
- The dike will be constructed with rock fill incorporating a seepage barrier on its upstream slope;
- The seepage barrier consists of a sheet of bituminous geomembrane (BGM) on the upstream slope anchored at the toe in a layer of Fine Filter Amended with Bentonite (FFAB).
- Based on the available geotechnical information, the dike will be found mainly on the surficial overburden composed of gravel, cobbles and boulders. For the installation of the FFAB component of the seepage barrier along the upstream toe of the dike, a key trench will be excavated in the overburden until the bottom reaches glacial till or bedrock.

- The hydrologic/hydraulic and seismic design criteria are provided in Section 4.2;
- Mammoth Dike has sufficient width to be used for a one way traffic by a 150-Ton[1] trucks, however if required the width can be enlarged in the downstream direction to accommodate a two-way traffic by such vehicles.

4.2 Dam Classification and Safety Criteria

Table 4-1 provides the classification of Mammoth Dike in terms of consequence of failure, based on the system proposed by the Canadian Dam Association (CDA, 2007/13) as determined in (SNC-Lavalin, 2018d). It is seen that Mammoth Dike falls into a 'High' consequence class.

For the 'High' consequence class the minimum design flood and seismic loading are as follows:

1. Table 4-2 provides the in-flow design flood criterion as well as the resulting flood level and minimum dike crest elevation;
2. For the seismic stability, the required minimum annual exceedance probability (APE) of the earthquake is 1/2475.

Table 4-1: Dam Classification Criteria for the Mammoth Dike

Risk Type	Dam Class	Commentaries	Reference
Population	**High**	Workers in the mine pit downstream of the dike are considered as permanent population of at risk of 10 or fewer loss of lives.	Dam Safety Guidelines (CDA, 2007, rev 2013)
Economy	**Low**	No infrastructure downstream of the dike	Dam Safety Guidelines (CDA, 2007, rev 2013)
Environment	**Significant**	No significant loss or deterioration of fish or wildlife habitat Loss of marginal habitat only Restoration or compensation in kind highly possible	Dam Safety Guidelines (CDA, 2007, rev 2013)
Summary: High			

[1] Nominal payload in imperial (US) units

Table 4-2: Design Criteria for the Mammoth Dike

Use	Water Type	Classification (CDA, 2007/13)	Inflow Design Flood	Water Level (m)		Crest Elevation (m)
				Normal	Design Flood	
Runoff storage	natural runoff	High	1/3 (1,000-PMF)	Low or no water	153.5	155.0

Mammoth dike will be inspected routinely for seepage on the downstream side as well as for differential movements especially during the thawing season. In addition, the thermistor strings that will be installed in the dike embankment.

5.0 HYDROLOGY

5.1 Available Data

Available hydrometeorological and hydrometric data are:

- Hydrometeorological data from Environment and Climate Change Canada, Baker Lake A station, located approximately 124 km southeast of the Whale Tail pit, and covering the period from 1946 to 2017. These data include total precipitation, rainfall, snowfall and snow on ground;
- Water level and streamflow measurements carried out at different locations on watersheds near the project site during June to September of years 2015 and 2016 (Golder Associates Ltd, 2017);
- Flow measurements were made in streams. However, the steam beds were covered with boulders, making the data less reliable.

5.1.1 Hydrometeorological Data

Data from Baker Lake A meteorological station is available for the period 1946-October 2017. However, Years 1946-1949, 1973, 1993, and 2015 have several missing records and consequently were excluded from the data set used for the analyses. The missing data from other years (1950-1972, 1974-1992, and 1994-2014) were filled using the average values from available years for the same day and month. The resulting rainfall, snowfall, daily and total precipitation data series cover 66 full years over the period 1950-2017 (1973 and 1993 data not used). The average annual precipitation, over the period 1950-2017, is 250 mm including, 145 mm of rainfall and 105 mm (water equivalent) of snow. This data is assumed to be representative of the conditions at the Whale Tail Pit.

5.1.2 Hydrometric Data

The Whale Tail Pit is located on a watershed with an extensive network of lakes and interconnecting streams, with a lake to land ratio of approximately 20%. During two summers, in 2015 and 2016, several discharge and water level measurements were made by (Golder Associates Ltd, 2017) both manually and with automated hydrometric stations. One of the automated stations was located at Whale Tail Lake outlet.

6.0 MAMMOTH DIKE DESIGN OUTLINE

6.1 Design Flood Level

Mammoth Dike is designed to last the life of the Whale Tail Pit and the transition to the closure, after which it will be dismantled or breached. The dike is required to prevent flooding of the mine pit up to the design flood elevation 153.5 m as indicated in Table 4-2.

6.2 Seepage Performance

Seepage analyses have not been carried out for the following reasons:

- The thermal analyses (see Appendix B) have shown that the FFAB component of the seepage barrier is expected to stay in the frozen state;
- Most of the year, the upstream side of the dike will stay almost dry;
- The seepage barrier will be instrumented with thermistor strings to monitor the thermal regime of the FFAB layer and along the bituminous geomembrane. The frozen state of the FFAB will be monitored closely by frequent thermistor string readings;
- If seepage is observed along the downstream toe of the dike, the water from Mammoth Lake will be collected by a ditch/sump system along the downstream side of the dike and pumped back to the lake or depending on the rate and quality, may be pumped to the attenuation pond prior to be treated.

6.3 Stability Performance

The stability of Mammoth Dike has been verified under static and earthquake loadings, the latter simulated by pseudo-static analyses. The results of the stability analyses which were submitted in a technical memorandum (SNC-Lavalin, 2018h) are included in Appendix C. The following Table 6-1 provides the calculated factors of safety together with the minimum required by CDA.

Table 6-1: Results of Stability Analyses

Analysis	FS obtained	FS required	Figure
Static Loading – Downstream Slope	1.58	1.50	1
Pseudo-Static Loading – Downstream Slope – 1/2500 AEP	1.52	1.20 -1.30	2
Static loading – Upstream Slope	Local: 2.6 Global: 4.73	1.50	3
Pseudo-Static Loading – 1/:2500 AEPs	Local: 2.39 Global: 3.91	1.0	4

The results of the analyses show that:

1. It is the downstream slope that is critical but still has factors safety in excess of the required minimum under both static and seismic loadings;
2. The difference between the static and pseudo-static FS's is negligible on account of the low seismicity of the site.

6.4 Dike Composition

Mammoth Dike will be composed of hard and non-acid generating rock, with the upstream slope to be lined with BGM embedded in the fine filter zone on the slope, and in a layer of FFAB at its toe. The fine filter is in turn separated from the rock fill by a transition zone referred to on the design drawings as coarse filter. The BGM and the FFAB layer are designed to retain water without spillage in the event that the Mammoth lake level rises up to a maximum design flood noted in Section 6.1. The gradation limits of the fine and coarse filters satisfy filter rules as noted in the Whale Tail Dike design report (SNC-Lavalin, 2018g), provided that care is taken to minimize segregation during their handling and placement.

The Technical Specifications of Mammoth Dike (SNC-Lavalin, 2018f) included in Appendix A provides the fill gradations as well as the requirements for the BGM and the sodium bentonite, which will be used to construct the FFAB.

Foundation preparation at the Mammoth Dike, will involve mainly the removal of snow, ice and boulders in the key trench area. Where bedrock is exposed at the bottom of the key trench along the FFAB alignment, it must be carefully inspected for cracks, joints and soil infills. Following the inspection, the soil infills must be cleaned and the cracks and joints treated with the appropriate sealing product to be selected during construction but before placing the FFAB.

7.0 ENVIRONMENTAL CONCERNS

During the construction of Mammoth Dike construction, excavated materials will be managed in conformity with the environmental policy of Agnico Eagle. Runoff from the construction area will be collected during construction and transferred to the Attenuation Pond for treatment.

8.0 CONSTRUCTION

The construction of Mammoth Dike is planned to start in the in fall 2018 and will be completed before the end of the winter 2019.

Careful scheduling of key trench excavation and FFAB construction is crucial to respect the above time frame as well as for the optimal performance of the dike. The rock fill zone shall be constructed ahead of key trench excavation to the extent necessary be used as a working platform and access.

The Mammoth Dike plan, profile and selected sections are shown on Drawings 651298-5000-4GDD-0004 and 651298-5000-4GDD-0005 in Appendix A.

9.0 INSTRUMENTATION AND MONITORING PLAN

Mammoth Dike will be instrumented with thermistor strings in order to monitor the thermal regime of the dike and in particular the FFAB. A minimum of three (3) thermistor strings needs to be installed within the dike foundation and in the FFAB. The specific location of thermistor strings will be selected to suit conditions encountered during foundation approval.

If required, other thermistor strings could be installed vertically to monitor the thermal regime within the dike and its foundation after the commissioning of Mammoth Dike.

10.0 ESTIMATED QUANTITIES

The quantities of materials required for the construction of Mammoth Dike are presented in Table 10-1. These quantities were generated from the 3D model developed for the design based on the topographic map of the area provided by Agnico-Eagle and SNC-Lavalin's assumptions that post construction settlement of the foundation to be negligible.

Table 10-1: Quantity estimation for the construction of Mammoth Dike

ITEM	UNIT	QUANTITY (see note)
Site clearing - dike footprint	ha	1.0
Trench excavation	m^3	11,300
Rockfill (including safety berm)	m^3	23,500
Coarse filter	m^3	1,900
Fine filter	m^3	1,550
BGM	m^2	2,500
FFAB	m^3	650
Note: the material quantities tabulated above are rounded figures and include a contingency of 20% for all earthworks and 40% for the BGM.		

11.0 CLOSURE

Mammoth Dike will be dismantled or breached after the end of mining in the Whale Tail Pit.

A closure plan, not discussed in this report, has been developed to maximize the re-use of the materials removed.

12.0 CONCLUSIONS

1. The design of Mammoth Dike was completed to the detailed engineering level in accordance with codes and standards used by the profession.
2. According to the CDA (2007/13), Mammoth Dike classifies as a high consequence structure. As the result it has been designed to safely store the design flood and resist the earthquake loading indicated in Section 6.1.
3. Careful scheduling is required for the construction of the FFAB due to the presence of a surficial layer of gravel, cobbles and boulders and water level at or above the natural ground surface.

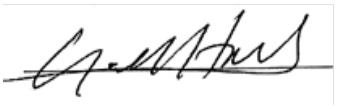
13.0 PERSONNEL

This report has been prepared by Mr. Getahun Haile, M.A.Sc, P.Eng, with contributions by Mr. Mathieu Durand –Jezequel, M.A.Sc., P.Eng and revised by Mr. Yohan Jalbert, P.Eng.

We trust that this report is to your satisfaction. Should you have any question, please do not hesitate on contacting me.

SNC LAVALIN INC.

Prepared by:



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SNC-Lavalin (2018h). Technical Memorandum No. 65

Appendix A

Technical Specifications

Appendix B

Thermal Analyses of Mammoth Dike

Appendix C

Stability Analyses of Mammoth Dike

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