

DATE March 1, 2016**REFERENCE No.** 1114220046-582-TM-Rev0-3100**TO** Derek Holmes
BURNCO Rock Products**CC** Alan Calder, Jeff Fillipone, Sarah Morse**FROM** Adam Bontempo**EMAIL** Adam_Bontempo@golder.com**BURNCO AGGREGATE PROJECT – GEOTECHNICAL STABILITY ANALYSIS OF PIT SLOPES**

BURNCO Rock Products Ltd. (BURNCO) is proposing to develop a sand and gravel pit, processing facility and marine barge load-out facility as primary components of the BURNCO Aggregate Project (the Project). The project is situated in McNab Valley on the northwest shore of Howe Sound, BC. Investigations have indicated that the valley's glaciofluvial fan-delta consists of a substantial sand and gravel deposit. Open pit extraction of this deposit will impact the stability of the ground in the vicinity of the pit, resulting in the need to assess the extent of this impact and how it will affect mine personnel.

This memorandum presents the results of analyses carried out to assess the stability of the proposed slopes of the sand and gravel pit.

1.0 PROPOSED DEVELOPMENT

Our understanding of the proposed geometry of the open pit is based on cross-sections produced by Golder for BURNCO Rock Products Ltd. (Golder 2014a, Golder 2014b, Golder 2014c). Based on the information provided in these drawings, we understand that the elevation of the base of the pit is expected to reach approximately -35 m above sea level (asl). The elevation of the crest of the pit slopes varies from approximately 6 m to 14 m asl; the average pit slope elevation is approximately 9.1 m asl. The overall pit slopes are designed to be 2H:1V.

We understand that earth berms will be placed adjacent to the pit slopes. Based on Figure 1-9 (Golder 2014d), the typical berm will be 32 m long and 7 m high, with a 4 m wide crest at the midpoint of the top of the berm. The typical berm maintains an overall slope of 2H:1V from the base to the crest. Based on Figure 1-5 (Golder 2014e), the currently proposed setbacks for the berms range from approximately 6 m on the east edge of the pit to 30 m on the south edge of the pit. The currently proposed setback for the berms north of the pit ranges from approximately 100 m to over 300 m.

2.0 SOIL AND GROUNDWATER CONDITIONS

The soil conditions for the stability analysis were interpreted using geologic information from three boreholes (DH10-01, DH10-02, and DH10-07) located within the expected final pit boundaries and extending to depth from the existing ground surface to the approximate elevation of the base of the pit. The soils encountered in these three boreholes generally comprised sand and gravel with variable amounts of cobbles and silt. The sand content increased with depth in each of the three boreholes with a corresponding decrease in gravel content. The percentage of cobbles encountered during drilling was also observed to decrease with depth. Detailed



descriptions of the soils encountered during drilling are presented in the report titled “Concrete Aggregate Assessment – McNab Creek, British Columbia” (Golder 2012).

The groundwater conditions in the area of the proposed pit were interpreted using data from monitoring wells installed in the vicinity of the proposed pit. The highest groundwater elevation observed in the monitoring wells located near the proposed final outline of the pit was 7.1 m at MW05-1, located immediately east of the western pit boundary. The future lake level within the pit is predicted to remain at an average annual elevation of approximately 5.0 m asl upon closure of the mine. However, during the average wet season the pit lake level is predicted to reach an elevation of approximately 6.2 m. For analysis purposes, pit lake elevations ranging from 4.0 m to 6.3 m were considered. Further details regarding the site hydrology are available in the technical memorandum titled “Hydrogeological Modelling to Assess Proposed Mine Plan – McNab Valley Aggregate Project” (Golder 2015).

3.0 STABILITY ANALYSES

3.1 Material Strength Parameters

The material strength parameters were selected based on borehole information, typical details for the north flood control berm, and previous experience with similar materials. A summary of the material strength parameters used in the slope stability analysis is provided in the table below.

Table 1: Summary of Material Properties for Waste Rock Pile Stability Analysis

Material	Unit Weight (kN/m ³)	Mohr – Coulomb	
		Effective Cohesion c' (kPa)	Effective Friction Angle Ø' (°)
Sand and Gravel (<i>in situ</i>)	20	0	36
Berm Fills	22	0	38

3.2 2-d Limit Equilibrium Analysis

Slope stability analyses were performed using the commercially available computer program SLOPE/W, a component of GeoStudio 2007. The program can accommodate piezometric surfaces and allow for a variety of strength characteristics for each of the geologic units. Circular failure surfaces using the Morgenstern-Price method were analyzed in order to assess the slope conditions.

The pit slopes were analyzed for stability based on the design slope angle of 2H:1V with and without a surcharge load, as well as for pit lake water levels of 4.0 and 6.3 m asl. The modeled surcharge load was based on the dimensions and materials used to construct the north flood control berm. The proposed berms are planned to be located at approximately 6 m to 30 m from the pit edge, on the eastern and southern sides of the pit, respectively, however, the analysis was carried out assuming the load would be placed immediately adjacent to the pit edge. This was done to assess the potential impact of surcharge loading by the berm or other potential permanent or transient loads that may be placed in the area.

3.3 Results

The results of the stability analysis are provided in Table 2 below. The minimum calculated Factor of Safety for shallow failure surfaces as well as deep seated failure surfaces was determined for the pit slope with and without surcharge loading from a structure similar to the proposed north flood control berm. Pit lake water levels of 4.0 and 6.3 m asl were analyzed for each alternative to account for the uncertainty in the hydrogeological model (Golder, 2015). The presumed berm load was placed immediately adjacent to the crest of the pit slope to assess

the minimum recommended offset of infrastructure from the pit edge. Figures 1 through 3 are cross-sections of the pit slope, illustrating the critical failure surface and indicating the minimum calculated Factor of Safety for the stability analysis cases considered.

Table 2: Summary of Stability Analysis Results

Pit Slope Model	Pit Lake Water Level (m asl)	Minimum Calculated Factor of Safety	
		Shallow Failure	Deep Seated Failure
Pit Slope only (no surcharge)	4.0	1.5	2.2
	6.3	1.5	2.3
Pit Slope with berm immediately adjacent to slope crest	4.0	1.4	1.8
	6.3	1.4	1.8
Pit Slope with berm 7 m from slope crest	4.0	1.5	1.8
	6.3	1.5	1.9

In general, a minimum calculated Factor of Safety (FoS) of 1.5 is considered suitable for long-term stability; a minimum calculated FoS of 1.3 is considered suitable for short term or temporary conditions. Based on this, the minimum calculated FoS for the overall pit slopes is considered adequate for long-term stability. With surcharge loading immediately adjacent to the slope crest, the minimum calculated factor of safety is reduced to less than the generally desired long-term factor of safety. In order to achieve a minimum calculated FoS of 1.5 with the assessed surcharge loading, an offset of 7 m is required. If larger infrastructure loads are to be placed adjacent to the pit slopes, additional analyses may be required.

4.0 CLOSURE

We trust that this information is sufficient for your immediate requirements.

GOLDER ASSOCIATES LTD.



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Reviewed by



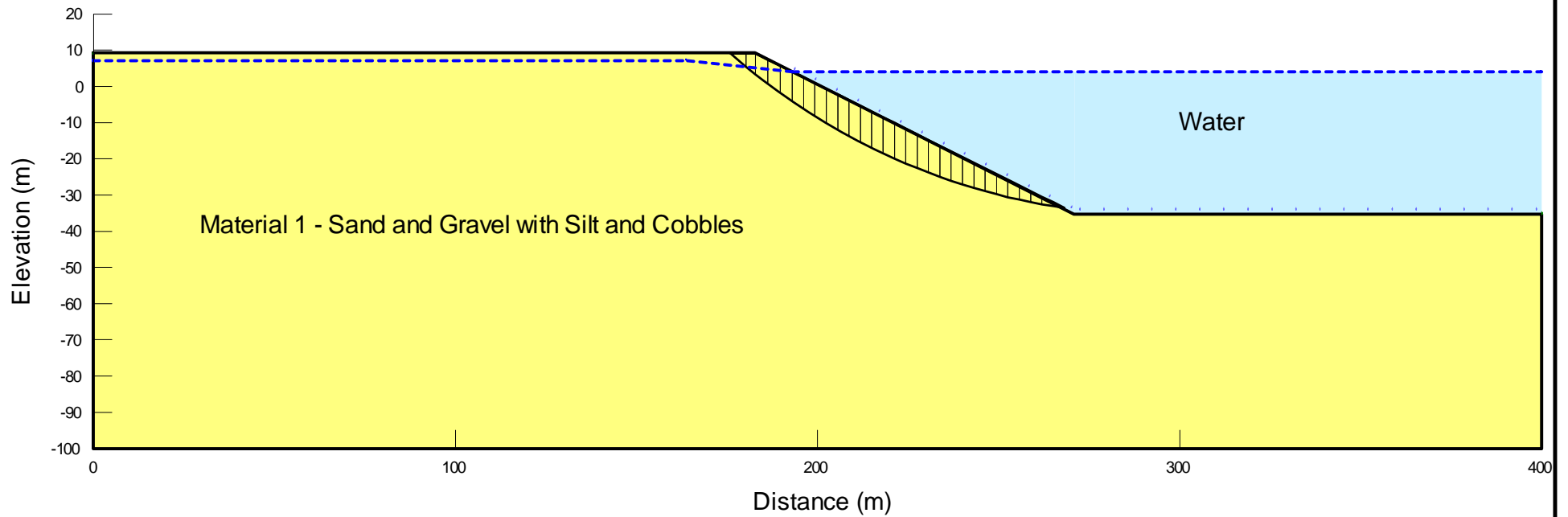
Jeff Fillipone, P.Geo, Ph.D.
Principal

Attachments: Figures 1 to 3

5.0 REFERENCES

- Golder 2012. Concrete Aggregate Assessment – McNab Creek, British Columbia. April 13, 2012. Submitted to BURNCO Rock Products Ltd. 368p.
- Golder 2014a. Figure 1-6: Subsurface Conditions and Conceptual Mining and Operational Site Layout Section A-A1. November 4, 2014. Submitted to BURNCO Rock Products Ltd. 1p.
- Golder 2014b. Figure 1-7: Subsurface Conditions and Conceptual Mining and Operational Site Layout Section B-B1. November 4, 2014. Submitted to BURNCO Rock Products Ltd. 1p.
- Golder 2014c. Figure 1-8: Subsurface Conditions and Conceptual Mining and Operational Site Layout Section C-C1. November 4, 2014. Submitted to BURNCO Rock Products Ltd. 1p.
- Golder 2014d. Figure 1-9: Typical Details. November 4, 2014. Submitted to BURNCO Rock Products Ltd. 1p.
- Golder 2014e. Figure 1-5: Proposed Conceptual Site Layout and Cross Sections. December 4, 2014. Submitted to BURNCO Rock Products Ltd. 1p.
- Golder 2015. Hydrogeological Modelling to Assess Proposed Mine Plan – McNab Valley Aggregate Project. March 19, 2015. Submitted to BURNCO Rock Products Ltd. 36p.

Minimum Calculated Factor of Safety = 1.50

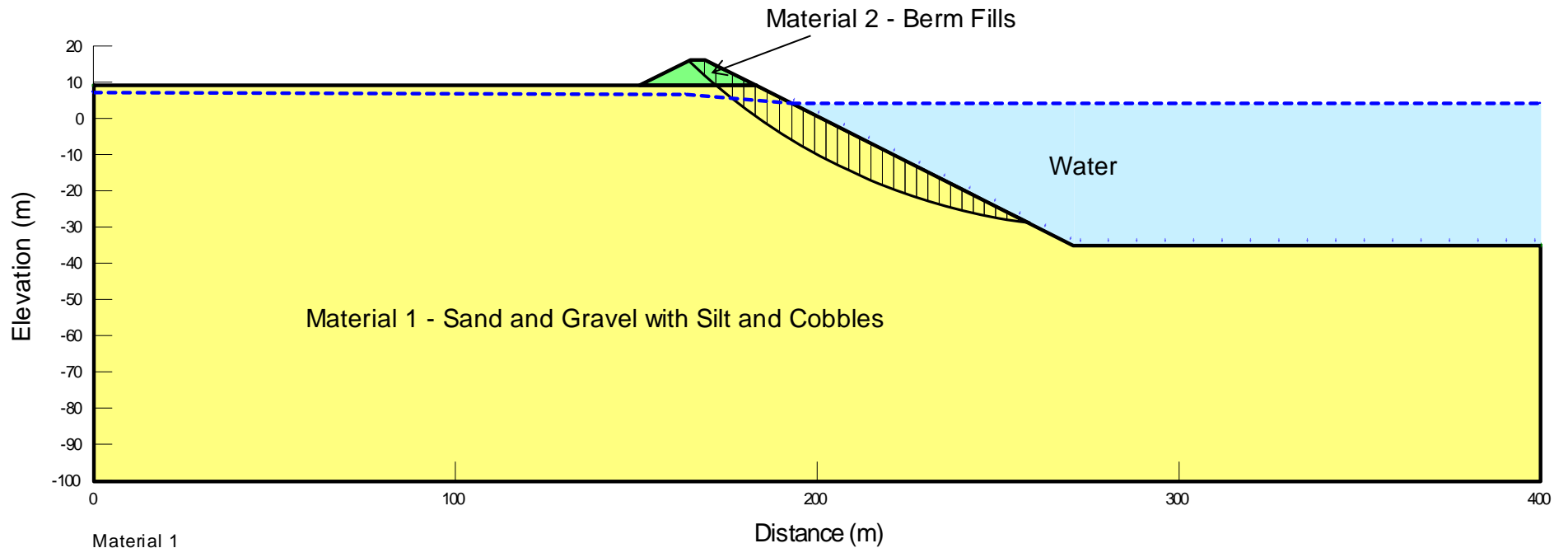


Material 1
 Name: Sand and gravel, with silt and cobbles
 Model: Mohr-Coulomb
 Unit Weight: 20 kN/m³
 Cohesion: 0 kPa
 Phi: 36 °

PROJECT		BURNCO ROCK PRODUCTS LTD. BURNCO AGGREGATE PROJECT HOWE SOUND, BC		
TITLE		SLOPE STABILITY ANALYSIS SHALLOW FAILURE, NO SURCHARGE, PIT LAKE WATER LEVEL OF 4.0 M ASL		
PROJECT No.		11-1422-0046	PHASE No. 3100	
DESIGN	AB	26 FEB 16	SCALE	NTS REV.
CADD	--	--		
CHECK	SEM	26 FEB 16	FIGURE 1	
REVIEW	JAF	01 MAR 16		



Minimum Calculated Factor of Safety = 1.42



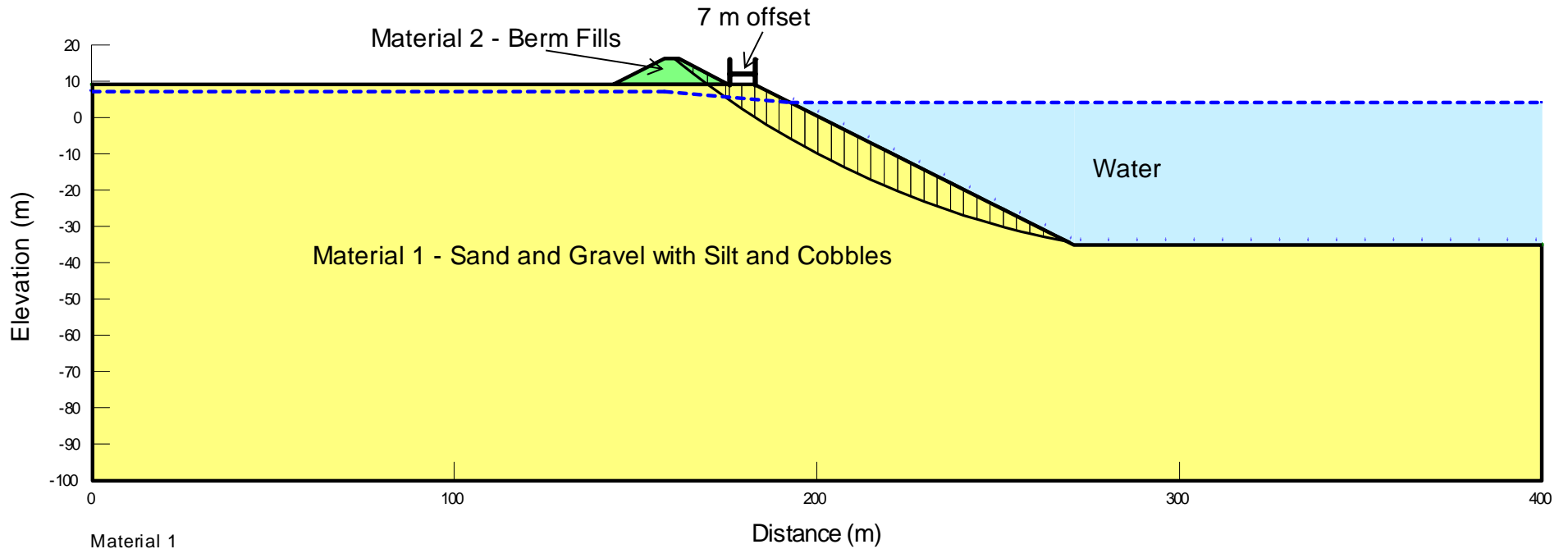
Material 1
 Name: Sand and gravel, with silt and cobbles
 Model: Mohr-Coulomb
 Unit Weight: 20 kN/m³
 Cohesion: 0 kPa
 Phi: 36 °

Material 2
 Name: Berm Fills
 Model: Mohr-Coulomb
 Unit Weight: 22 kN/m³
 Cohesion: 0 kPa
 Phi: 38 °

PROJECT		BURNCO ROCK PRODUCTS LTD. BURNCO AGGREGATE PROJECT HOWE SOUND, BC		
TITLE		SLOPE STABILITY ANALYSIS SHALLOW FAILURE, WITH BERM ADJACENT TO PIT SLOPE PIT LAKE WATER LEVEL OF 4.0 M ASL		
PROJECT No.		11-1422-0046	PHASE No. 3100	
DESIGN	AB	26 FEB 16	SCALE NTS	REV.
CADD	--	--		
CHECK	SEM	26 FEB 16	FIGURE 2	
REVIEW	JAF	01 MAR 16		



Minimum Calculated Factor of Safety = 1.50



Material 1
 Name: Sand and gravel, with silt and cobbles
 Model: Mohr-Coulomb
 Unit Weight: 20 kN/m³
 Cohesion: 0 kPa
 Phi: 36 °

Material 2
 Name: Berm Fills
 Model: Mohr-Coulomb
 Unit Weight: 22 kN/m³
 Cohesion: 0 kPa
 Phi: 38 °

PROJECT		BURNCO ROCK PRODUCTS LTD. BURNCO AGGREGATE PROJECT HOWE SOUND, BC			
TITLE		SLOPE STABILITY ANALYSIS SHALLOW FAILURE, WITH BERM OFFSET 7 M FROM SLOPE CREST, PIT LAKE WATER LEVEL OF 4.0 M ASL			
		PROJECT No.	11-1422-0046	PHASE No.	3100
DESIGN	AB	26 FEB 16	SCALE	NTS	REV.
CADD	--	--			
CHECK	SEM	26 FEB 16	FIGURE 3		
REVIEW	JAF	01 MAR 16			

