Golder Associates

TECHNICAL MEMORANDUM

Date:	January 5, 2013	**Project No.:**	113-2209
To:	Tom Radue and Christie Kearney	**Company:**	Barr Engineering Company
From:	Gordan Gjerapic	**Email:**	ggjerapic@golder.com
cc:	Brent Bronson		
RE:	**UNDERDRAIN PIPING CALCULATIONS**		

1.0 INTRODUCTION

This memorandum summarizes the approach and assumptions used to develop the underdrain piping design for the lined PolyMet NorthMet stockpiles located near Babbitt, Minnesota. Underdrain pipes were sized to accommodate seepage flows due to consolidation of subgrade materials when subjected to waste rock loading. Consolidation flows were calculated for two case scenarios:

- Case 1: A double drained layer assuming relatively pervious fractured bedrock; and
- Case 2: A single drained layer assuming impervious bedrock surface.

Additional piping is expected to be installed in order to convey localized under-liner seepage based on the in-situ conditions encountered during construction.

2.0 DESIGN PARAMETERS

- Determine maximum depth to bedrock for Category 2/3, Category 4 and Ore Surge Pile stockpiles based on Figure 1.
- Consolidation coefficient for foundation soils, C_v=0.81 ft^2/day (0.075 m^2/day) based on the laboratory data (see Attachment 1);
- Waste rock loading is applied in lifts with the minimum height of 40 feet. Estimated waste rock loading is summarized in Attachment 2.
- Waste rock total unit weight of approximately 2.03 tons/yd^3 (23.7 kN/m^3) based on the dry unit weight of 1.9 tons/yd^3 and assuming the average moisture content of 7 percent (see Attachment 2);
- Tertiary underdrain pipes are PCPE (ADS N-12) pipes with Manning's n = 0.012;
- Primary and secondary underdrains are PCPE (ADS N-12) with Manning's n = 0.012;
- Other, as stated.

3.0 METHOD

3.1 Flow Rate Calculation

The seepage from the compressible soil layer can be calculated using the Darcy's equation:

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$$v = -K_s \frac{\partial h}{\partial z} \qquad (1)$$

where: v = water flux;
K_s = coefficient of permeability; and
$\partial h / \partial z$ = hydraulic gradient in the z direction.

The pressure head can be calculated from the developed pore water pressure:

$$h = \frac{u}{\gamma_w} \qquad (2)$$

where: h = total head;
u = average pressure; and
γ_w = water unit weight

One can utilize Terzaghi's consolidation theory to determine the pore pressure distribution within a compressible soil layer as:

$$u = \sum_{n=1}^{n=\infty} \left(\frac{1}{H} \int_0^{2H} u_i \sin \frac{n\,\pi\,z}{2H}\, dz \right) \sin\left(\frac{n\,\pi\,z}{2H}\right) \exp\left(\frac{-n^2\pi^2 T_v}{4}\right) \qquad (3)$$

where: u = pore pressure;
H = length of the longest drainage path;
n = 2m + 1
z = location of point of evaluation in the z direction; and
T_v = dimensionless time factor can be expressed as $T_v = C_v\, t/H^2$, where C_v is the coefficient of consolidation and t is time.

For the case of a constant water pressure with depth, Equation (3) can be simplified to (Das 1997):

$$u_{(z,t)} = \sum_{m=0}^{m=\infty} \frac{2u_0}{M} \sin\left(\frac{M\,z}{H}\right) \exp(-M^2\, T_v) \qquad (4)$$

where: u_0 = initial water pore pressure
M = (2m + 1) π/2

Combining Equations (1), (2), and (4), one obtains the expression for Darcy's velocity as:

$$v_{(z,t)} = -\frac{K_s}{\gamma_w} \sum_{m=1}^{m=\infty} \frac{2\,u_0}{H} \cos\left(\frac{M\,z}{H}\right) \exp(-M^2\, T_v) \qquad (5)$$

For Case 1, where a double drained layer is assumed, the length of the longest drainage path (H) is equal to half of the total layer thickness. For Case 2, where a single drainage path is considered, the length of the longest drainage path (H) is equal to the total thickness of the compressible layer.

A flow rate reporting to a single underdrain pipe can be approximated as:

$$q = v_{(0,t)} A \tag{6}$$

where: q = flow rate;
$v_{(0,t)}$ = water flux at z=0; and
A = loading area reporting to a single underdrain pipe.

Equation (6) was used to determine required underdrain pipe capacities.

3.2 Selection of Equivalent Loading Time

Equations (5) and (6) are based on the instantaneous loading scenarios. In reality, the waste rock stockpiles are loaded gradually. Therefore, underdrain flows were determined for an equivalent loading time, i.e. the time expected to provide an estimate of a maximum seepage flow reporting to an underdrain pipe over the loading area under consideration. The following procedure was used to calculate the equivalent loading time:

- Determine maximum extents of the waste rock stockpile footprint for a given year.
- Calculate the area per day required to cover the waste rock stockpile footprint for the years 1, 2, 11, and 20. The following equation was used:

$$area\ per\ day = \frac{waste\ rock\ stockpile\ total\ area\ for\ the\ evaluated\ year}{number\ of\ days\ required\ to\ cover\ the\ area\ for\ the\ evaluate\ year}$$

- Estimate the tertiary underdrain pipe tributary area (i.e., loading area reporting to a single tertiary pipe).

$$tributary\ area = maximum\ pipe\ length\ x\ maximum\ pipe\ spacing$$

- The number of days (equivalent loading time) required to cover the tributary area of an underdrain pipe is calculated by:

$$number\ of\ days = \frac{tributary\ area}{area\ per\ day}$$

- Both cumulative tertiary pipe flows and the corresponding tributary areas for years 1, 2 and 11 were considered for the primary and secondary pipe sizing.

3.3 Discharge Rate Calculation

Discharge rates were calculated from the Manning's equation:

$$Q = \frac{1.486\, A\, R^{2/3}\, S^{1/2}}{n} \tag{7}$$

where: Q = pipe capacity (cfs);
n = Manning's "n";
A = cross-sectional flow area of the pipe (ft^2);
R = hydraulic radius (ft), where *R* = *A*/*P*, *P* is the wetted perimeter in feet;
S = pipe slope (feet/foot)

For a specific full-flowing pipe the parameters *n*, *A*, and *R* could be defined as constants. The conveyance factor for a specific pipe size can then be defined as:

$$k = \frac{1.486\, A\, R^{2/3}}{n} \tag{8}$$

Equation (7) can now be reduced to:

$$Q = k\, S^{1/2} \tag{9}$$

Equation (9) can be written as:

$$k = \frac{Q}{S^{1/2}} \tag{10}$$

Conveyance factors for different pipe sizes are displayed in Attachment 3.

3.4 Tertiary Underdrain Pipes

The tertiary underdrain pipes were designed based on:

- The tributary area (e.g. 350 ft x 100 ft); and
- The flux rate at the calculated equivalent loading time (equal to the number of days required to cover the tributary area for a single underdrain pipe).

3.5 Secondary Underdrain Pipes

The secondary underdrain pipes were designed to accommodate the time-variant flux from the tertiary underdrain pipes. The flow was calculated using the production rate required to load the corresponding stockpile footprint and the time required to load the corresponding tributary area:

$$Q_{secondary} = A_1 v_{(0,T1)} + A_2 v_{(0,T2)} \cdots + A_{n-1} v_{(0,Tn-1)} + A_n v_{(0,T\boldsymbol{n})} \tag{11}$$

where: $Q_{secondary}$ = water flow in the secondary pipe (volume per day);
A_i = tributary area required to cover the waste rock stockpile footprint under consideration during the time increment T_i;
$v_{(0,Ti)}$ = calculated seepage rate at time *Ti* and *z*=0, see Equation (5).

The number of days "n" can be calculated from the following expression (see Section 3.2):

$$number\ of\ days = \frac{tributary\ area}{area\ per\ day}$$

4.0 ASSUMPTIONS

- Minimum drain pipe slope 0.5%;
- Compressible subgrade soil layer is homogenous;
- The compressible subgrade soil layer is saturated;
- Darcy's law is valid;
- The coefficient of consolidation C_v is constant during the consolidation;
- The factor of safety (Fs) of 1.2 is applied to increase the nominal pipe capacity accounting for the pipe deformation when subjected to the waste rock loading;
- The maximum pipe length for the waste rock stockpile tertiary underdrain pipe is 256 feet;
- The maximum spacing between tertiary underdrain pipes is 100 feet;
- Determine seepage quantities assuming the following subgrade soil parameters: C_v=0.075 m^2/day and K_s= 1x10^{-7} cm/sec.

5.0 CALCULATIONS

5.1 Flow Rate Calculation

Flow rate calculations are summarized in the following attachments:

- Attachment 4-1: Case 1 and Case 2, Ore Surge Pile, Year 1
- Attachment 4-2: Case 1 and Case 2, Category 4 Stockpile, Year 1
- Attachment 4-3: Case 1 and Case 2, Category 4 Stockpile, Year 11
- Attachment 4-4: Case 1 and Case 2, Category 2/3 Stockpile, Year 1
- Attachment 4-5: Case 1 and Case 2, Category 2/3 Stockpile, Year 11

5.2 Time Selection

The equivalent loading time calculations are summarized in Attachment 5.

5.3 Tertiary Underdrain Pipes

Detailed calculations used for the tertiary underdrain pipe sizing are summarized in Attachment 6.

5.4 Primary and Secondary Underdrain Pipes

The primary and secondary underdrain pipes will be laid approximately perpendicular to the stockpile liner contours. These pipes were sized to collect the inflows from the corresponding tributary areas. For conservatism, 6 inch ADS pipe was selected to convey consolidation flows in all primary and secondary underdrain pipes. The actual layout and size of the underdrain pipes may need to be modified based on the encountered field conditions.

6.0 RESULTS

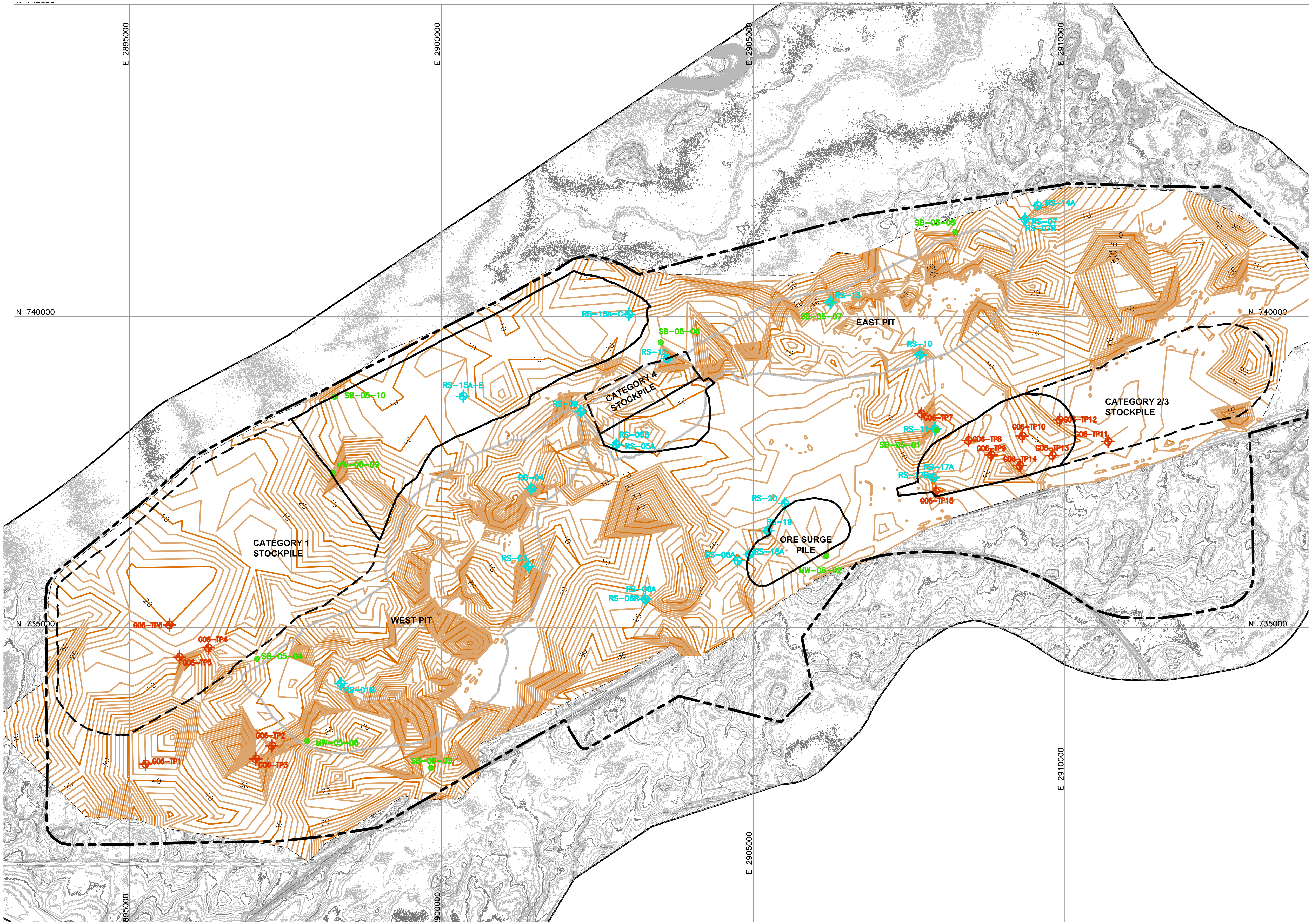
Calculations indicate that 4 inch perforated ADS pipes are likely to be adequate as tertiary underdrain pipes in order to convey consolidation flows. The 6 inch perforated ADS pipe was selected for secondary and primary pipes with solid ADS pipe conveying underdrain solution outside the stockpile perimeter. The actual layout and size of the underdrain pipes is expected to be modified based on the encountered field conditions.

7.0 REFERENCES

Das, B. M. (1997). *Advanced soil mechanics*, Taylor & Francis, Washington, DC.

Advanced Drainage Systems, Inc. ADS (2007). *Section 3 - Drainage handbook,* Ohio*.* August, 2007.

FIGURES



LEGEND

- EXISTING GROUND TOPOGRAPHY
- PROJECT BOUNDARY
- ESTIMATED DEPTH TO BEDROCK CONTOURS
- YEAR 11 PIT BOUNDARIES (SEE NOTE 1)
- YEAR 1 STOCKPILE OUTLINES (SEE NOTE 2)
- YEAR 11 STOCKPILE OUTLINES (SEE NOTE 2)
- G06-TP11 GOLDER ASSOC. TEST PIT (2006)
- SB-05-01 BARR ENGINEERING BOREHOLES (2005)
- RS-11 BARR ENGINEERING BOREHOLES (2008)

NOTES

1. OPEN PIT BOUNDARIES PROVIDED BY BARR ENGINEERING IN OCTOBER 2011.
2. STOCKPILE LAYOUTS PROVIDED BY BARR ENGINEERING IN APRIL 2011 AND MODIFIED BY GOLDER FROM JULY TO OCTOBER 2011.

REFERENCES

1. EXISTING GROUND TOPOGRAPHY PROVIDED BY BARR ENGINEERING, AUGUST 2011.
2. COORDINATE SYSTEM REFERENCE IS NAD83 MINNESOTA STATE PLANE NORTH
3. VERTICAL DATUM REFERENCE IS FEET ABOVE MEAN SEA LEVEL (AMSL).

0 800 1600
SCALE IN FEET

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POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

DEPTH TO BEDROCK ISOPACH MAP AND SITE LAYOUT

FIGURE 1

PROJECT No. 113-2209 CADD JP DATE 06/22/12 FILE No. Underdrain Calc – Figure 1.dwg

ATTACHMENT 1

CONSOLIDATION PARAMETERS

ONE-DIMENSIONAL CONSOLIDATION

ASTM D 2435

Polymet/Mine Waste Impound Dsgn/MN **053-2209**	**SAMPLE:** **G06-TP5 @ 0.5'-4'**	DATE	5/16/2006
		TECH	RT
		REVIEW	JEO

SAMPLE DATA, GENERAL

height (in)	1.075
diameter (in)	1.928
area (in^2)	2.919
volume (in^3)	3.138
specimen weight,wet (g)	104.82
specimen weight,dry (g)	87.67
water weight (g)	17.15

SAMPLE DATA, INITIAL

total height (in)	1.075
height of solids (in)	0.678
height of voids (in)	0.397
void ratio	0.585
dry density (pcf)	106.2
moist density (pcf)	127.2

SAMPLE DATA, FINAL

total height (in)	0.982
height of solids (in)	0.678
height of voids (in)	0.304
void ratio	0.448
dry density (pcf)	116.5
moist density (pcf)	139.8

DESCRIPTION

Olive brown clayey sand

LL:	-	
PL:	-	
PI:	-	
Gs:	2.70	*Assumed*

MOISTURE CONTENT, INITIAL

tare #	G5
wt soil&tare,moist	48.94
wt soil&tare,dry	43.22
wt tare	13.98
wt moisture	5.72
wt dry soil	29.24
% moisture	19.6%

MOISTURE CONTENT, FINAL

tare #	M9
wt soil&tare,moist	127.60
wt soil&tare,dry	110.60
wt tare	25.54
wt moisture	17.00
wt dry soil	85.06
% moisture	20.0%

PRESSURE (ksf)	h100 Sample Height	D50 Sample Height	t50 TIME (min)	Sample Density (pcf)	VOID RATIO e	DRAINAGE PATH (DOUBLE DRAINAGE) H (in)	H (cm)	DRAINAGE PATH (DOUBLE DRAINAGE) H^2 (in^2)	H^2 (cm^2)	COEFFICIENT OF CONSOLIDATION Cv (cm^2/sec)	(ft^2/day)	Cc
0.250	1.0662	-	-	107.1	0.574	-	-	-	-	-	-	-
0.500	1.0591	-	-	107.8	0.563	-	-	-	-	-	-	-
0.500	1.0579	-	-	107.9	0.562	-	-	-	-	-	-	-
1.0	1.0487	1.0542	0.6288	108.8	0.548	0.5271	1.3389	0.2778	1.7925	9.36E-03	8.73E-01	0.045
2.0	1.0337	1.0412	0.5571	110.4	0.526	0.5206	1.3224	0.2710	1.7487	1.03E-02	9.62E-01	0.074
4.0	1.0159	1.0236	0.9694	112.4	0.500	0.5118	1.3000	0.2619	1.6900	5.72E-03	5.34E-01	0.087
8.0	0.9950	1.0046	0.6170	114.7	0.469	0.5023	1.2759	0.2523	1.6279	8.66E-03	8.08E-01	0.102
16.0	0.9696	0.9822	0.5803	117.7	0.431	0.4911	1.2474	0.2412	1.5561	8.80E-03	8.21E-01	0.125
4.0	0.9713	-	-	117.5	0.434	-	-	-	-	-	-	-
1.0	0.9766	-	-	116.9	0.442	-	-	-	-	-	-	-
0.250	0.9819	-	-	116.2	0.449	-	-	-	-	-	-	-

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ATTACHMENT 2

WASTE ROCK PROPERTIES, BEDROCK DEPTHS AND STOCKPILE HEIGHTS FOR VARIOUS YEARS

Attachment 2: Waste Rock Properties, Bedrock Depths and Stockpile Heights for Various Years

	Stockpile Name	max depth to bedrock Yr1,2/Yr11 (ft)	max depth to bedrock Yr-1,2 (m)	max depth to bedrock Yr 11 (m)	max height of stockpile fill 1-yr (ft)	max height of stockpile fill 1-yr (m)	max height of stockpile fill 2-yr (ft)	max height of stockpile fill 2-yr (m)	max height of stockpile fill @ design capacity (ft)	max height of stockpile fill 20-yr (m)
1	Ore Surge Pile	14	4.27	4.27	40	12.19	40	12.19	40	12.19
2	Category 4 stockpile	14/26	4.27	7.92	40	12.19	80	24.38	80	24.38
3	Category 2/3 stockpile	16/22	4.88	6.71	60	18.29	65	19.81	145	44.20

Waste Rock

Specific Gravity	2.93	
Porosity	0.23	
Void Ratio (Swell)	0.30	
Dry Density	140.78	pcf
	1.90	t/cy
Assumed Moisture Content	7%	
Waste Rock Bulk Density	150.64	pcf
	23.68	kN/m^3

ATTACHMENT 3

CONVEYANCE FACTORS (ADS, 2007)

Table 3-1
Conveyance Factors (Standard Units)

Design Manning's Values for HDPE Pipe *		
Product	**Diameter**	**Design Manning's "n"**
N-12®, N-12® ST, and N-12® WT	4" - 60"	"n" = 0.012
AASHTO and Single Wall	18" - 24" 12" - 15" 10" 8" 3" - 6"	"n" = 0.024 "n" = 0.022 "n" = 0.019 "n" = 0.019 "n" = 0.017
Smoothwall	3" - 6"	"n" = 0.009 **
Conveyance Equations: k = Q/(s^0.5) Q = k s^0.5		

Conveyance Factors for Circular Pipe Flowing Full																		
		Manning's "n" Values																
Dia. (in.)	**Area (sq. ft.)**	**0.009**	**0.010**	**0.011**	**0.012**	**0.013**	**0.014**	**0.015**	**0.016**	**0.017**	**0.018**	**0.019**	**0.020**	**0.021**	**0.022**	**0.023**	**0.024**	**0.025**
3	0.05	1.3	1.1	1.0	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.5
4	0.09	2.7	2.5	2.2	2.1	1.9	1.8	1.6	1.5	1.5	1.4	1.3	1.2	1.2	1.1	1.1	1.0	1.0
6	0.20	8.1	7.3	6.6	6.1	5.6	5.2	4.9	4.6	4.3	4.1	3.8	3.6	3.5	3.3	3.2	3.0	2.9
8	0.35	17.5	15.7	14.3	13.1	12.1	11.2	10.5	9.8	9.2	8.7	8.3	7.9	7.5	7.1	6.8	6.5	6.3
10	0.55	31.6	28.5	25.9	23.7	21.9	20.3	19.0	17.8	16.8	15.8	15.0	14.2	13.6	12.9	12.4	11.9	11.4
12	0.79	51.5	46.3	42.1	38.6	35.6	33.1	30.9	28.9	27.2	25.7	24.4	23.2	22.1	21.1	20.1	19.3	18.5
15	1.23	93.3	84.0	76.3	70.0	64.6	60.0	56.0	52.5	49.4	46.7	44.2	42.0	40.0	38.2	36.5	35.0	33.6
18	1.77	151.7	136.6	124.1	113.8	105.0	97.5	91.0	85.3	80.3	75.9	71.9	68.3	65.0	62.1	59.4	56.9	54.6
21	2.41	228.9	206.0	187.3	171.6	158.4	147.1	137.3	128.7	121.2	114.4	108.4	103.0	98.1	93.6	89.6	85.8	82.4
24	3.14	326.8	294.1	267.3	245.1	226.2	210.1	196.1	183.8	173.0	163.4	154.8	147.0	140.0	133.7	127.9	122.5	117.6
27	3.98	447.3	402.6	366.0	335.5	309.7	287.6	268.4	251.6	236.8	223.7	211.9	201.3	191.7	183.0	175.0	167.8	161.0
30	4.91	592.5	533.2	484.7	444.3	410.2	380.9	355.5	333.3	313.7	296.2	280.6	266.6	253.9	242.4	231.8	222.2	213.3
33	5.94	763.9	687.5	625.0	572.9	528.9	491.1	458.3	429.7	404.4	382.0	361.9	343.8	327.4	312.5	298.9	286.5	275.0
36	7.07	963.4	867.1	788.2	722.6	667.0	619.3	578.0	541.9	510.0	481.7	456.4	433.5	412.9	394.1	377.0	361.3	346.8
42	9.62	1453.2	1307.9	1189.0	1089.9	1006.1	934.2	871.9	817.5	769.4	726.6	688.4	654.0	622.8	594.5	568.7	545.0	523.2
45	11.04	1746.8	1572.1	1429.2	1310.1	1209.3	1122.9	1048.1	982.6	924.8	873.4	827.4	786.1	748.6	714.6	683.5	655.0	628.8
48	12.57	2074.8	1867.4	1697.6	1556.1	1436.4	1333.8	1244.9	1167.1	1098.4	1037.4	982.8	933.7	889.2	848.8	811.9	778.1	746.9
54	15.90	2840.5	2556.4	2324.0	2130.4	1966.5	1826.0	1704.3	1597.8	1503.8	1420.2	1345.5	1278.2	1217.4	1162.0	1111.5	1065.2	1022.6
60	19.63	3762.0	3385.8	3078.0	2821.5	2604.4	2418.4	2257.2	2116.1	1991.6	1881.0	1782.0	1692.9	1612.3	1539.0	1472.1	1410.7	1354.3
72	28.27	6117.3	5505.6	5005.1	4588.0	4235.1	3932.6	3670.4	3441.0	3238.6	3058.7	2897.7	2752.8	2621.7	2502.5	2393.7	2294.0	2202.2

* Utah Water Research Laboratory, "Manning Friction Coefficient Testing of 4-, 10-, 12- and 15-inch Corrugated Plastic Pipe"[3]
** "Lingedburg, Michael, "Civil Engineer Reference Manual"[4]

ATTACHMENT 4

FLOW RATE CALCULATIONS

Attachment 4-1: Case 1 and Case 2, Ore Surge Pile, Year 1

Compression index	Cc	0.102	
Column height	H_T	4.27	m
Hydrulic cond.	k	8.64E-05	m/day
Water density	γ_w	9.81	kN/m^3
Load on surface	p	288.7	kN/m^2
Consolidation coef.	cv	0.075	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 1	Case 2
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	4.3	2.1
0	-1.192E-01	-2.384E-01
1	-5.244E-03	-5.244E-03
2	-3.708E-03	-3.708E-03
4	-2.622E-03	-2.622E-03
7	**-1.982E-03**	**-1.981E-03**
15	-1.354E-03	-1.307E-03
30	-9.569E-04	-7.059E-04
45	-7.747E-04	-3.841E-04
100	-4.324E-04	-4.125E-05
200	-1.568E-04	-7.138E-07
400	-2.062E-05	-2.137E-10
1000	-4.695E-08	-5.739E-21
2000	-1.849E-12	-1.382E-38
3000	-7.285E-17	-3.327E-56
4000	-2.870E-21	-8.010E-74
5000	-1.130E-25	-1.928E-91

Attachment 4-2: Case 1 and Case 2, Category 4 Stockpile, Year 1

Compression index	Cc	0.102	
Column height	H_T	4.27	m
Hydrulic cond.	k	8.64E-05	m/day
Water density	γ_w	9.81	kN/m^3
Load on surface	p	288.7	kN/m^2
Consolidation coef.	cv	0.075	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 1	Case 2
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	4.3	2.1
0	-1.192E-01	-2.384E-01
1	-5.244E-03	-5.244E-03
2	-3.708E-03	-3.708E-03
4	-2.622E-03	-2.622E-03
7	**-1.982E-03**	**-1.981E-03**
15	-1.354E-03	-1.307E-03
30	-9.569E-04	-7.059E-04
45	-7.747E-04	-3.841E-04
100	-4.324E-04	-4.125E-05
200	-1.568E-04	-7.138E-07
400	-2.062E-05	-2.137E-10
1000	-4.695E-08	-5.739E-21
2000	-1.849E-12	-1.382E-38
3000	-7.285E-17	-3.327E-56
4000	-2.870E-21	-8.010E-74
5000	-1.130E-25	-1.928E-91

Attachment 4-3: Case 1 and Case 2, Category 4 Stockpile, Year 11

Compression index	Cc	0.102	
Column height	H_T	7.92	m
Hydrulic cond.	k	8.64E-05	m/day
Water density	γ_w	9.81	kN/m^3
Load on surface	p	577.5	kN/m^2
Consolidation coef.	cv	0.075	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 1	Case 2
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	7.9	4.0
0	-1.284E-01	-2.567E-01
1	-1.049E-02	-1.049E-02
2	-7.416E-03	-7.416E-03
4	-5.244E-03	-5.244E-03
7	-3.964E-03	-3.964E-03
15	-2.708E-03	-2.708E-03
30	-1.915E-03	-1.911E-03
45	**-1.563E-03**	**-1.534E-03**
159	-8.233E-04	-3.956E-04
365	-4.389E-04	-3.507E-05
400	-3.959E-04	-2.323E-05
1000	-6.782E-05	-2.000E-08
2000	-3.583E-06	-1.559E-13
3000	-1.893E-07	-1.215E-18
4000	-1.000E-08	-9.468E-24
5000	-5.285E-10	-7.378E-29

Attachment 4-4: Case 1 and Case 2, Category 2/3 Stockpile, Year 1

Compression index	Cc	0.102	
Column height	H_T	4.88	m
Hydrulic cond.	k	8.64E-05	m/day
Water density	γ_w	9.81	kN/m^3
Load on surface	p	433.1	kN/m^2
Consolidation coef.	cv	0.075	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 1	Case 2
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	4.9	2.4
0	-1.564E-01	-3.129E-01
1	-7.866E-03	-7.866E-03
2	-5.562E-03	-5.562E-03
3	**-4.542E-03**	**-4.542E-03**
7	-2.973E-03	-2.973E-03
14	-2.102E-03	-2.088E-03
30	-1.436E-03	-1.233E-03
50	-1.109E-03	-6.621E-04
100	-7.210E-04	-1.401E-04
200	-3.310E-04	-6.274E-06
365	-9.193E-05	-3.731E-08
400	-7.005E-05	-1.258E-08
1000	-6.638E-07	-1.015E-16
2000	-2.817E-10	-3.290E-30
3000	-1.195E-13	-1.067E-43
4000	-5.073E-17	-3.459E-57
5000	-2.153E-20	-1.122E-70

Attachment 4-5: Case 1 and Case 2, Category 2/3 Stockpile, Year 11

Compression index	Cc	0.102	
Column height	H_T	6.71	m
Hydrulic cond.	k	8.64E-05	m/day
Water density	γ_w	9.81	kN/m^3
Load on surface	p	1046.6	kN/m^2
Consolidation coef.	cv	0.075	m^2/day

	Flux Rate m/day	
	For z= 0.0	
	Case 1	Case 2
	Single drain	Double drain
	$H=H_T$	$H=0.5*H_T$
t (days)	6.7	3.4
0	-2.749E-01	-5.499E-01
1	-1.901E-02	-1.901E-02
2	-1.344E-02	-1.344E-02
3	-1.098E-02	-1.098E-02
7	-7.185E-03	-7.185E-03
14	**-5.081E-03**	**-5.080E-03**
30	-3.471E-03	-3.424E-03
100	-1.892E-03	-1.064E-03
228	-1.078E-03	-1.299E-04
365	-6.140E-04	-1.368E-05
400	-5.318E-04	-7.698E-06
1000	-4.524E-05	-4.032E-10
2000	-7.445E-07	-2.957E-17
3000	-1.225E-08	-2.168E-24
4000	-2.016E-10	-1.590E-31
5000	-3.318E-12	-1.166E-38

ATTACHMENT 5

EQUIVALENT LOADING TIMES

Attachment 5: Equivalent Loading Times

Waste Stock Pile Footprint (ft^2)

		Year 1	Year 2	Year 11	Max - Yr 11	Year 20
1	Ore Surge Pile	1,367,607	1,367,607	1,367,607	1,367,607	n/a
2	Category 4 Stockpile	1,258,019	1,258,019	2,309,188	2,309,188	n/a
3	Category 2/3 Stockpile	2,703,439	2,703,439	7,454,810	7,454,810	n/a

Area per day required to cover the footprint at the corresponding year

		ft^2/day	ft^2/day	ft^2/day	ft^2/day	ft^2/day
1	Ore Surge Pile	3746.9	1873.4	340.6	340.6	n/a
2	Category 4 Stockpile	3446.6	1723.3	575.1	575.1	n/a
3	Category 2/3 Stockpile	7406.7	3703.3	1856.7	1856.7	n/a

Cover Area per Underdrain Pipe (350 ft x 100 ft and 256 ft x 100 ft)

		ft^2	ft^2	ft^2	ft^2	ft^2
1	Ore Surge Pile	25600.0	25600.0	25600.0	25600.0	n/a
2	Category 4 Stockpile	25600.0	25600.0	25600.0	25600.0	n/a
3	Category 2/3 Stockpile	25600.0	25600.0	25600.0	25600.0	n/a

Number of Days Required to Cover the Influence Area of a Under Drain Pipe

		Year 1 Days	Year 2 Days	Year 11 Days	Max -Yr 11 Days	Year 20 Days
1	Ore Surge Pile	7	14	75	75	n/a
2	Category 4 Stockpile	7	15	45	45	n/a
3	Category 2/3 Stockpile	3	7	14	14	n/a

ATTACHMENT 6

TERTIARY UNDERDRAIN PIPE SELECTION

Attachment 6: Tertiary Underdrain Pipe Selection

FLUX (m/day)

		Year 1 (30 days)		time	Year 11 (1 year)		time
		Double layer	Single layer	days	Double layer	Single layer	days
1	Ore Surge Pile	2.0E-03	2.0E-03	7			
2	Category 4 Stockpile	2.0E-03	2.0E-03	7	1.5E-03	1.6E-03	45
3	Category 2/3 Stockpile	4.5E-03	4.5E-03	3	5.1E-03	5.1E-03	14

Factored FLUX (m/day) FS=1.2

		For Year 1		For Year 11	
		Double layer	Single layer	Double layer	Single layer
1	Ore Surge Pile	2.4E-03	2.4E-03		
2	Category 4 Stockpile	2.4E-03	2.4E-03	1.8E-03	1.9E-03
3	Category 2/3 Stockpile	5.4E-03	5.4E-03	6.1E-03	6.1E-03

FLOW (ft3/sec)

		For Year 1		For Year 11	
		Double layer	Single layer	Double layer	Single layer
1	Ore Surge Pile	2.9E-04	2.9E-04		
2	Category 4 Stockpile	2.9E-04	2.9E-04	2.3E-04	2.3E-04
3	Category 2/3 Stockpile	6.7E-04	6.7E-04	7.5E-04	7.5E-04

Commodity Factor k S=0.5%

		For Year 1		For Year 11	
		Double layer	Single layer	Double layer	Single layer
1	Ore Surge Pile	0.0042	0.0042		
2	Category 4 Stockpile	0.0042	0.0042	0.0032	0.0033
3	Category 2/3 Stockpile	0.0095	0.0095	0.0106	0.0106

Note: Category 2/3 Stockpile liner grades steeper than 0.5%

Selected Pipe Dia (in)

		Year 1		For Year 11	
		Double layer	Single layer	Double layer	Single layer
1	Ore Surge Pile	4	4		
2	Category 4 Stockpile	4	4	4	4
3	Category 2/3 Stockpile	4	4	4	4

Selected Pipe commodity value k (ASD 2007)

		Year 1		For Year 11	
		Double layer	Single layer	Double layer	Single layer
1	Ore Surge Pile	2.1	2.1		
2	Category 4 Stockpile	2.1	2.1	2.1	2.1
3	Category 2/3 Stockpile	2.1	2.1	2.1	2.1