APPENDIX C
EROSIONAL STABILITY EVALUATION

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1.0 INTRODUCTION

This appendix presents the hydrologic analysis and evaluation of erosion protection for the cover surface of the Primary and Secondary Impoundments. These analyses have been conducted in a manner consistent with Nuclear Regulatory Commission (NRC) guidelines documented in NRC (1990) and Johnson (2002), and are compared with analyses documented in WWL (1990) and ESCI (1995). These analyses included the tasks listed below.

1. Selection of the design event for analyses, being the Probable Maximum Precipitation (PMP) event for the site.
2. Calculation of the peak discharge (due to the PMP) from the surfaces of the Primary Impoundment (PI) and Secondary Impoundment (SI).
3. Evaluation of reclaimed tailings impoundment surfaces for erosional stability (the top surfaces and the reclaimed embankment slopes).

These tasks are presented in the following sections of this appendix.

2.0 PROBABLE MAXIMUM PRECIPITATION EVENT

As outlined in NRC (1990) and Johnson (2002), the design event for evaluation of long-term erosional stability of the reclaimed tailings impoundments is the PMP. The selected PMP events used to calculate the peak discharges for evaluation of erosional stability were the six-hour duration PMP (with a precipitation total of 22.5 inches) and the one-hour duration PMP (with a precipitation total of 11.25 inches). These events were determined for the site area from HMR 55A (NOAA, 1988). The PMP calculation method for this area has not changed since 1988 and these selected storm events are the same design events used in the analyses in WWL (1990) and ESCI (1995). Rainfall depth versus duration for short-term events (less than 1 hour) was developed using procedures in HMR 55A (NOAA, 1988).

3.0 CALCULATION OF PEAK DISCHARGE

The peak discharge calculations were made using the Rational Method as described in Johnson (2002) and Nelson et al. (1986). A runoff coefficient of 1.0 was used for the PI to represent PMP conditions (DOE, 1989). Because slopes in the SI are relatively flat (0.5%), the runoff coefficient was reduced to 0.9 to represent a small amount of infiltration. Rainfall intensity was calculated using procedures in HMR 55A (NOAA, 1988). These characteristics represent high runoff quantities and peak flow velocities.

The PMP discharge results across the PI and SI are presented in Table C.1. These discharges represent flow across a unit-width across the slope.

Table C.1. Peak Reclaimed Surface Discharges

Location	Slope Length (feet)	Time of Concentration (min)	Rainfall Intensity (in/hr)	Runoff Coefficient	Peak Unit Discharge (cfs/ft)
SI, along flow path	2400	24.0	22.1	0.9	1.11
SI, converging flow at southeast boundary	2400	24.0	22.1	0.9	4.01
PI, segment A at 20% slope	190	0.8	30.6	1.0	0.13
PI, segment B at 1% slope	710	8.0	30.6	1.0	0.64
PI, segment C at 5% slope	320	10.1	30.6	1.0	0.86
PI, segment D at 1% slope	950	19.1	25.7	1.0	1.29
PI, 5% slope located at upper edge of impoundment	440	2.7	30.6	1.0	0.31
Side slopes of PI and SI	220	0.9	30.6	1.0	0.16

The unit discharge values in Table C.1 above were used to evaluate the erosional stability of the reclaimed surfaces and size erosion protection materials where necessary. These evaluations are presented in Sections 4.0 and 5.0.

4.0 EROSIONAL STABILITY OF VEGETATED SLOPES

The surface of the reclaimed tailings impoundments was evaluated for erosional stability using the methods recommended in NRC (1990) and Johnson (2002).

Temple Method. Temple and others (1987) outlines procedures for grass-lined channel design. These procedures are recommended in Johnson (2002) for areas of vegetated cover and include methods for estimating stresses on channel vegetation as well as the channel surface soils. The evaluation for the impoundments used the peak discharge values from the PMP (summarized in Table C-1) to conservatively represent the effective stresses from runoff on the cover surface. The stresses on both the vegetated surfaces and bare soils were evaluated.

The erosional stability of the cover surface for the impoundments was evaluated by calculating a factor of safety against erosion due to the peak runoff from the PMP. Factor-of-safety values were calculated as the ratio of the allowable stresses (the resisting strength of the cover vegetation or soils) to the effective stresses (the stresses impacted by the runoff flowing over the cover). The top surfaces of both impoundments were evaluated for two conditions: (1) resistance of the vegetation, and (2) resistance of the clayey cover system layer. The peak unit discharge flow for each impoundment (from Table C.1) was conservatively multiplied by a concentration factor of 3.

Allowable stresses. Allowable stresses for the cover soils were calculated using the equations in Temple and others (1987). Materials planned for the upper layer of the cover system are

Northwest Borrow area soils (beneath the topsoil). Since the Northwest Borrow area soils are cohesive soils, the resistance is based on the plastic limit and void ratio of the material. From testing of Northwest Borrow area soils, the plastic limit (PL) was 17 and the void ratio was 0.568 (from 1990 test results). A borrow investigation is planned to take place in 2011. The properties of the borrow soils will be updated as necessary to reflect the latest investigation and laboratory test results.

The equation for allowable shear strength for cohesive soils is:

$$\tau_a = \tau_{ab} C_e^2$$

Where τ_a = allowable shear strength (in psf)
τ_{ab} = basis allowable shear strength (for a CL) = $(1.07\,[PL]^2+14.3[PL]+47.7)\times10^{-4}$
C_e = soil parameter = 1.48 - 0.57e
PL = plastic limit = 17
e = void ratio = 0.568

For the plastic limit and void ratio values given above, τ_{ab} = 0.060, C_e^2 = 1.34 and τ_a = 0.080 psf.

For a vegetated surface primarily of mixed grasses, the allowable vegetation shear strength is:

$$\tau_{va} = 0.75 C_l$$

Where τ_{va} = allowable vegetation shear strength (in psf)
C_l =cover index = $2.5\,[h(M)^{1/2}]^{1/3}$
h = stem length (in ft)
M = stem density factor

Conservatively using poor vegetation conditions, h=0.75, M=67, and C_l=4.57, and the resulting vegetation shear strength value is 3.43 psf.

Effective stresses. The effective shear stress on soil due to peak runoff from the PMP was calculated as:

$$\tau_e = \gamma d S (1 - C_f)(n_s/n)^2$$

Where τ_e = effective shear stress (in psf)
γ = unit weight of water = 62.4 pcf
d = depth of flow (ft), from Table C-2
S = slope of cover surface (ft/ft), from Table C-1
C_f = cover factor (0.375 for poor vegetation)
n_s = soil grain roughness factor (0.0156 for cohesive soil)
n = Manning's roughness coefficient for vegetated surface

$$n = e^{C_l(0.0133[\ln q]^2 - 0.0954 \ln q + 0.297) - 4.16}$$

The effective shear stress on vegetation is calculated as:

$$\tau_v = \gamma d S - \tau_e$$

Where τ_v = effective vegetal stress (in psf)

Conservatively using poor vegetation conditions and a soil grain roughness factor for fine-grained soils, the effective shear stresses on soil and vegetation on the impoundment cover surfaces are summarized in Table C.2.

Table C.2. Effective Shear Stresses on Soil and Vegetation

Location	Depth of Flow[1] (ft)	Soil: Effective Shear Stress (psf)	Soil: Allowable Shear Stress (psf)	Soil: Factor of Safety	Vegetation: Effective Shear Stress (psf)	Vegetation: Allowable Shear Stress (psf)	Vegetation: Factor of Safety
SI, along flow path	1.14	0.035	0.08	2.3	0.32	3.43	10.7
PI, segment B at 1% slope	0.74	0.032	0.08	2.5	0.43	3.43	8.0
PI, segment D at 1% slope	0.99	0.066	0.08	1.2	0.55	3.43	6.2
PI, 5% slope located at upper edge of impoundment	0.35	0.043	0.08	1.9	1.06	3.43	3.2

[1] Calculated using a concentration factor of 3 for peak unit discharge

The calculated factors of safety above show that for poor vegetation conditions, the allowable shear strengths are higher than the effective shear stresses on both the vegetation and the soil curing peak discharge from the PMP. Further details of calculations can be found in Attachment C.1.

These analyses indicate that the cover on the top surface of the SI and PI can be constructed as vegetated slopes without rock for erosion protection. However, three areas, notably the bottom portion of the SI, a portion of the 5% slope on the PI, and all side slopes of the PI and SI will require rock protection, as discussed in Section 5.0.

5.0 EROSIONAL STABILITY OF ROCK-PROTECTED SLOPES

As shown in Figure 1, three areas of the impoundments will require rock protection to provide adequate erosional stability. These three areas are the bottom portion of the SI (where flow converges to a narrower width of flow; a portion of the PI cover that will be constructed at a 5% slope, and all 5H:1V side slopes of the impoundments. The unit discharge values from Table C.1 were used to size riprap for the embankment slopes. As discussed in Johnson (2002), the Safety Factor method was used for slopes less than 10% (bottom portion of the SI and 5% slopes in the PI) and Johnson and Abt method for the side slopes.

Flow Characteristics. The peak unit discharge values from Table C.1 were used to represent flow conditions on the cover surface. Concentration factors of 3 were used.

Rock Characteristics. A specific gravity of 2.65, with a friction angle or angle of repose of 37 degrees (representing angular rock or a rock mulch) were assumed for the riprap characteristics. Further investigation of the rock source is planned in 2011. These parameters will be modified as necessary to reflect the latest finding from the investigation and laboratory test results.

The riprap sizing results on the embankment slopes are summarized in Table C.3 below.

Table C.3. Results of Riprap Sizing

Location	Design Unit Discharge (cfs/ft)	Slope (ft/ft)	Concentration Factor	Median Rock Size (inches)
SI, converging flow at southeast boundary	12.0	0.005	3	1.4
PI, segment C at 5% slope	2.6	0.05	3	4.0
Side slopes of PI and SI	0.6	0.20	3	2.0

For the embankment side slopes and the lower portion of the SI, a design median rock size of 2.0 inches was chosen from the results presented in Table C.3. This was conservatively based on a concentration factor for flow over the slope of 3. If rounded rock instead of angular rock is used, the median rock size will be approximately 40% larger (2.8 inches). For the portion of the 5% slope within the PI that requires rock protection (i.e. the area shown in Figure 1), the design median rock size is 4 inches.

6.0 REFERENCES

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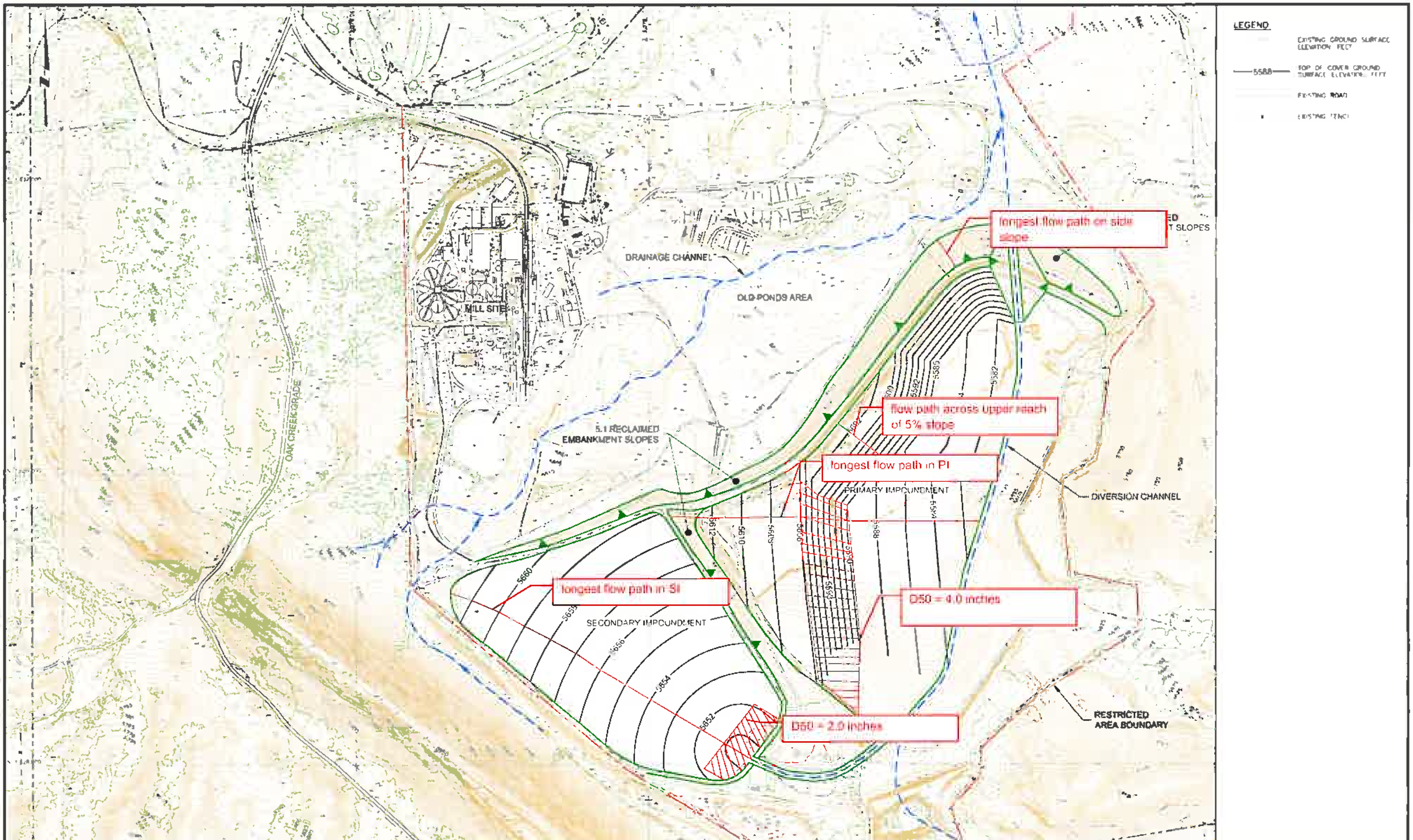


COTTER CORPORATION (N.S.L.)

CANON CITY MILLING FACILITY

RECLAMATION PLAN LAYOUT, TOP OF FINAL COVER

MWH

MAY 2011

FIGURE 1

10076330010

ATTACHMENT C.1

Supporting Calculations

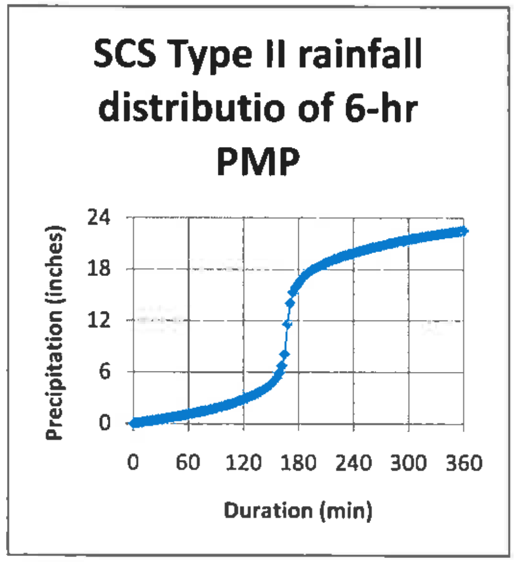
Client:	**Cotter Corporation**	**Job No.:**	**1007533**
Project:	**Canon City Milling Facility Reclamation**	**Date:**	**5/27/2011**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

PMP Event

SCS Type II Precipitation Distribution

Cotter PMP 6 Hours 22.5 inches (6-hr 10-mi2 PMP, from HMR 55A Plate 1b)

Increment	Time (minutes)	Percent of Precipitation	Cumulative inches	Incremental inches
0	0	0.0%	0	0
1	3	0.2%	0.054	0.054
2	6	0.4%	0.0945	0.0405
3	9	0.6%	0.1395	0.045
4	12	0.9%	0.1935	0.054
5	15	1.1%	0.2475	0.054
6	18	1.3%	0.2835	0.036
7	21	1.5%	0.333	0.0495
8	24	1.7%	0.387	0.054
9	27	2.0%	0.4455	0.0585
10	30	2.3%	0.5175	0.072
11	33	2.5%	0.5715	0.054
12	36	2.8%	0.6255	0.054
13	39	3.0%	0.6795	0.054
14	42	3.3%	0.7335	0.054
15	45	3.5%	0.7875	0.054
16	48	3.7%	0.8415	0.054
17	51	4.0%	0.909	0.0675
18	54	4.3%	0.972	0.063
19	57	4.6%	1.0305	0.0585
20	60	4.9%	1.1025	0.072
21	63	5.1%	1.1565	0.054
22	66	5.4%	1.224	0.0675
23	69	5.7%	1.287	0.063
24	72	6.0%	1.3455	0.0585
25	75	6.3%	1.4175	0.072
26	78	6.6%	1.4895	0.072
27	81	6.9%	1.5615	0.072
28	84	7.3%	1.6335	0.072
29	87	7.6%	1.71	0.0765
30	90	8.0%	1.8	0.09
31	93	8.4%	1.89	0.09
32	96	8.8%	1.98	0.09
33	99	9.2%	2.07	0.09
34	102	9.6%	2.16	0.09
35	105	10.0%	2.25	0.09
36	108	10.5%	2.358	0.108
37	111	11.0%	2.4795	0.1215
38	114	11.6%	2.6055	0.126
39	117	12.1%	2.7315	0.126
40	120	12.7%	2.8575	0.126
41	123	13.3%	2.9835	0.126
42	126	13.9%	3.123	0.1395
43	129	14.5%	3.267	0.144
44	132	15.2%	3.411	0.144
45	135	15.8%	3.555	0.144



Client:	**Cotter Corporation**		**Job No.:**	**1007533**		
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PMP Event

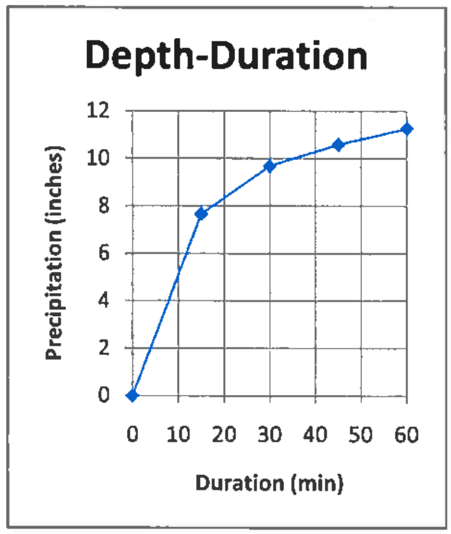
46	138	16.5%	3.717	0.162
47	141	17.3%	3.8925	0.1755
48	144	18.2%	4.0995	0.207
49	147	19.3%	4.338	0.2385
50	150	20.4%	4.59	0.252
51	153	21.9%	4.932	0.342
52	156	23.7%	5.3415	0.4095
53	159	26.2%	5.8995	0.558
54	162	30.0%	6.7455	0.846
55	165	35.9%	8.0775	1.332
56	168	51.7%	11.6415	3.564
57	171	62.3%	14.0175	2.376
58	174	68.0%	15.3045	1.287
59	177	70.5%	15.8625	0.558
60	180	72.5%	16.3125	0.45
61	183	74.5%	16.7625	0.45
62	186	76.1%	17.118	0.3555
63	189	77.4%	17.406	0.288
64	192	78.5%	17.658	0.252
65	195	79.6%	17.91	0.252
66	198	80.3%	18.072	0.162
67	201	81.0%	18.234	0.162
68	204	81.8%	18.396	0.162
69	207	82.5%	18.5535	0.1575
70	210	83.1%	18.6975	0.144
71	213	83.7%	18.8415	0.144
72	216	84.4%	18.9855	0.144
73	219	85.0%	19.1205	0.135
74	222	85.5%	19.2465	0.126
75	225	86.1%	19.3725	0.126
76	228	86.6%	19.4805	0.108
77	231	87.1%	19.5885	0.108
78	234	87.5%	19.6875	0.099
79	237	87.9%	19.7775	0.09
80	240	88.3%	19.8675	0.09
81	243	88.7%	19.9575	0.09
82	246	89.1%	20.0475	0.09
83	249	89.5%	20.1375	0.09
84	252	89.9%	20.2275	0.09
85	255	90.3%	20.3175	0.09
86	258	90.7%	20.4075	0.09
87	261	91.0%	20.484	0.0765
88	264	91.4%	20.565	0.081
89	267	91.8%	20.6505	0.0855
90	270	92.1%	20.7225	0.072
91	273	92.5%	20.8125	0.09
92	276	92.8%	20.889	0.0765
93	279	93.2%	20.961	0.072
94	282	93.5%	21.033	0.072
95	285	93.8%	21.105	0.072
96	288	94.1%	21.177	0.072

1-hr, 1-mi2 PMP from local storm

11.25 inches

(From HMR 55A, **Plate VI b and** pg 200)

Duration (min)	**Percent of 1 hr PMP**	Depth (in)
0	0%	0
15	68%	7.65
30	86%	9.675
45	94%	10.575
60	100%	11.25



Client:	**Cotter Corporation**	**Job No.:**	**1007533**
Project:	**Canon City Milling Facility Reclamation**	**Date:**	**5/27/2011**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

PMP Event

97	291	94.4%	21.2355	0.0585
98	294	94.7%	21.2985	0.063
99	297	95.0%	21.366	0.0675
100	300	95.2%	21.42	0.054
101	303	95.5%	21.492	0.072
102	306	95.8%	21.5505	0.0585
103	309	96.1%	21.6135	0.063
104	312	96.4%	21.681	0.0675
105	315	96.6%	21.735	0.054
106	318	96.8%	21.789	0.054
107	321	97.1%	21.843	0.054
108	324	97.3%	21.897	0.054
109	327	97.6%	21.951	0.054
110	330	97.8%	22.005	0.054
111	333	98.0%	22.059	0.054
112	336	98.3%	22.113	0.054
113	339	98.5%	22.167	0.054
114	342	98.7%	22.2165	0.0495
115	345	98.9%	22.2525	0.036
116	348	99.1%	22.3065	0.054
117	351	99.4%	22.3605	0.054
118	354	99.6%	22.4055	0.045
119	357	99.8%	22.446	0.0405
120	360	100.0%	22.5	0.054

Client:	**Cotter Corporation**	**Job No.:**	**1007533**
Project:	**Canon City Milling Facility Reclamation**	**Date:**	**5/27/2011**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Time of Concentration

1-hour PMP (in) 11.25

Description	Incremental Drainage Area	Slope (feet/feet)	Slope Length	Time of Concentration[1] (min)	% of 1-hour PMP	PD_{PMP} (in)	Intensity (in/hr)
SI, top surface	59.5	0.005	2400	24.0	79%	8.9	22.1
PI, top surface 1a (20% slope)	86.2	0.2	190	0.8	4%	0.4	30.6
PI, top surface 1b (1% slope)	86.2	0.01	710	8.0	36%	4.1	30.6
PI, top surface 1c (5% slope)	86.2	0.05	320	10.1	46%	5.2	30.6
PI, top surface 1d (1% slope)	86.2	0.01	950	19.1	73%	8.2	25.7
PI and SI side slopes	na	0.2	220	0.9	4%	0.5	30.6
PI "other" 5% slopes (located at upper edge of imp)	na	0.05	440	2.7	12%	1.4	30.6

Note: Flow over surfaces 1a through 1d is accumulative

[1]Source:Kirpich (1940) as presented in NUREG 4620 pg 65

Client:	**Cotter Corporation**	**Job No.:**	**1007533**
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Unit discharge of PMP

Description		Total Drainage Area (acres)	C	Tc (min)	Intensity (in/hr)	Q (cfs)	longest slope length (ft)	unit discharge (cfs/ft)
Converging Flow								
	SI, top surface	59.52	0.9	24.0	22.1	1186.3		4.01
Non-Converging Flow								
	SI, top surface	59.52	0.9	24.0	22.1		2400	1.11
	PI, top surface 1a (20% slope)	86.20	1	0.8	30.6		190	0.13
	PI, top surface 1b (1% slope)	86.20	1	8.0	30.6		900	0.64
	PI, top surface 1c (5% slope)	86.20	1	10.1	30.6		1220	0.86
	PI, top surface 1d (1% slope)	86.20	1	19.1	25.7		2170	1.29
	PI and SI side slopes	na	1	0.9	30.6		220	0.16
	PI "other" 5% slopes (located at upper edge of imp)	na	1	2.7	30.6		440	0.31

Note: Flow over surfaces 1a through 1d is accumulative

SI, Flow converging at base of impoundment
Cross-section of flow is"V" channel with 0.5% side slopes, 0.5% channel bed slope
Peak flow: 1186 cfs

Triangular channel

Bed slope (ft/ft)	0.005	ft/ft
Side Slope 1 (ft/ft)	0.005	ft/ft
Side Slope 2 (ft/ft)	0.005	ft/ft
bottom width	0	ft

n vegetated	0.0299	from Temple et al. method	
Area of flow (A)	438.36	ft^2	
Wetted Perimeter Slope 1 (	296.10	ft	
Wetted Perimeter Slope 2 (	296.10	ft	
Hydraulic Radius (R)	0.74	ft	
Top Width (T)	592.2	ft	
Maximum depth of flow (d)	1.48	ft	**iterate with d until Q calc equals Q design**
Q calc	1264.9	cfs	
average velocity (v)	2.706	fps	
average flow width	296.095		
unit discharge	4.007	cfs/ft	Q divided by average flow width

Client:	**Cotter Corporation**	**Job No.:**	**1007533**
Project:	**Canon City Milling Facility Reclamation**	**Date:**	**5/27/2011**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Temple Method for Vegetated Slopes

Reference: Temple, D.M., Robinson, K.M., Ahring, R.M., and Davis, A.G., 1987. Stability Design of Grass-Lined Open Channels, USDA Handbook 667.
And as presented in UMTRA TAD Section 4.3.3 and NUREG 1623, Appendix A

Area	SI, upper slopes, 0.5% slope	PI, upper 1% slope	PI, lower 1% slope	PI "other" 5% slopes (located at	
PMP Design flow (cfs/ft)	1.11	0.64	1.29	0.31	
Concentration Factor, F	3	3	3	3	
PMP Design flow (cfs/ft), q	**3.32**	**1.91**	**3.88**	**0.94**	
Slope, S (ft/ft)	0.005	0.01	0.01	0.05	
average dry density (pcf)	106.65	106.65	106.65	106.65	
average specific gravity	2.68	2.68	2.68	2.68	(assumed value)
void ratio, e	0.568	0.568	0.568	0.568	(assumed from 2005 RP)
unit weight water (pcf)	62.4	62.4	62.4	62.4	

Topsoil Description	Lean Clay	Lean Clay	Lean Clay	Lean Clay	
Plasticity Index, PI	17	17	17	17	(from 2005 RP)
base allowable tractive shear stress (psf) τab=	0.0600	0.0600	0.0600	0.0600	
void ratio correction factor, Ce=	1.1562	1.1562	1.1562	1.1562	
allowable tractive shear stress (psf), τa=	0.080	0.080	0.080	0.080	
Long-term, PMP precip					
Repr. stem length (in) h(ave)					
good veg	1	1	1	1	pg 36 and 39 of Temple et al. (1987)
poor veg	0.75	0.75	0.75	0.75	
Repr. stem density (stems/sq in), M(ave)					
good veg	200	200	200	200	Temple Table 3.1, grass mixture
poor veg	67	67	67	67	
Retardance curve index, Ci					
good veg	6.05	6.05	6.05	6.05	
poor veg	4.57	4.57	4.57	4.57	
Cover factor, Cf					
good veg	0.75	0.75	0.75	0.75	Temple Table 3.1, grass mixture
poor veg	0.375	0.375	0.375	0.375	
allowable vegetated shear strength (psf), τva					
good veg	4.53	4.53	4.53	4.53	
poor veg	3.43	3.43	3.43	3.43	
Mannings n for soil roughness, ns=	0.0156	0.0156	0.0156	0.0156	
Mannings n for vegetal conditions, nr					
good veg	0.0528	0.0669	0.0499	0.0978	
poor veg	0.0393	0.0470	0.0376	0.0626	
Mannings n for vegetated slopes, nv					
good veg	0.0528	0.0669	0.0499	0.0978	
poor veg	0.0393	0.0470	0.0376	0.0626	

Client:	**Cotter Corporation**	**Job No.:**	**1007533**
Project:	**Canon City Milling Facility Reclamation**	**Date:**	**5/27/2011**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Temple Method for Vegetated Slopes

Reference: Temple, D.M., Robinson, K.M., Ahring, R.M., and Davis, A.G., 1987. Stability Design of Grass-Lined Open Channels, USDA Handbook 667. And as presented in UMTRA TAD Section 4.3.3 and NUREG 1623, Appendix A

Area	SI. upper slopes, 0.5% slope	PI, upper 1% slope	PI, lower 1% slope	PI "other" 5% slopes (located at
assumed depth of flow, d (ft)				
good veg	1.360	0.914	1.171	0.461
poor veg	1.138	0.739	0.969	0.353
calculated q (cfs/ft), with veg				
good veg	3.32	1.91	3.88	0.93
poor veg	3.32	1.91	3.88	0.93
qcalc - qdesign				
good veg	**0.00**	**0.00**	**0.00**	**0.00**
poor veg	**0.00**	**0.00**	**0.00**	**0.00**
Iterate with d until q calc equals q design				
velocity (ft/s), v				
good veg	2.44	2.09	3.31	2.03
poor veg	2.92	2.59	3.92	2.65
effective shear stress (psf), τe				
good veg	0.0093	0.0077	0.0179	0.0091
poor veg	0.0350	0.0318	0.0664	0.0428
effective veg shear stress (psf) τve				
good veg	0.4152	0.5628	0.7130	1.4296
poor veg	0.3201	0.4294	0.5504	1.0576
shear stress ratio, vegetated slope				
good veg	**10.92**	**8.06**	**6.36**	**3.17**
poor veg	**10.72**	**7.99**	**6.23**	**3.24**
shear stress ratio, soil on vegetated slope				
good veg	**8.67**	**10.35**	**4.49**	**8.77**
poor veg	**2.29**	**2.52**	**1.21**	**1.88**

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Safety Factor Method

Appropriate for evaluating rock stability from flow parallel to cover and adjacent to the cover.
Design for SF of 1.5 for non-PMF applications, and slightly greater than 1.0 for PMF
Use for slopes less than 10 percent

	SI, lower converging flow, 0.5% slope	PI, 5% slope	
Slope (ft/ft)	0.005	0.05	
angle α (rad)	0.005	0.050	
Angle of repose of rock (degees)	37	37	See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded
Angle of repose of rock (rad))	0.646	0.646	
Specific gravity of rock	2.65	2.65	
PMP unit flow (cfs/ft)	4.01	0.86	(max from "PMP flow" worksheet)
Concentration Factor	3	3	Typically between 1.1 to 3.2
design flow (cfs/ft)	12.02	2.59	
design flow over rock (cfs/ft)	**12.02**	**2.59**	assumes negligible flow through rock
Assumed D50 (in)	1.4	4.0	
Manning's n for rock	0.0207	0.0353	Abt et al. 1987 as presented in UMTRA TAD
Assumed depth of flow for rock (ft)	1.678	0.461	
Calculated flow for rock (cfs/ft)	12.02	2.59	
modify depth of flow until calculated q = design q			
calculated velocity for rock, (ft/s)	7.16	5.62	
ave shear stress, τ for rock	0.52	1.44	
Stability number for rock	0.915	0.880	
Factor of Safety for rock	1.08	1.06	
Adjust assumed D50 until design criteria for Factor of Safety is met			

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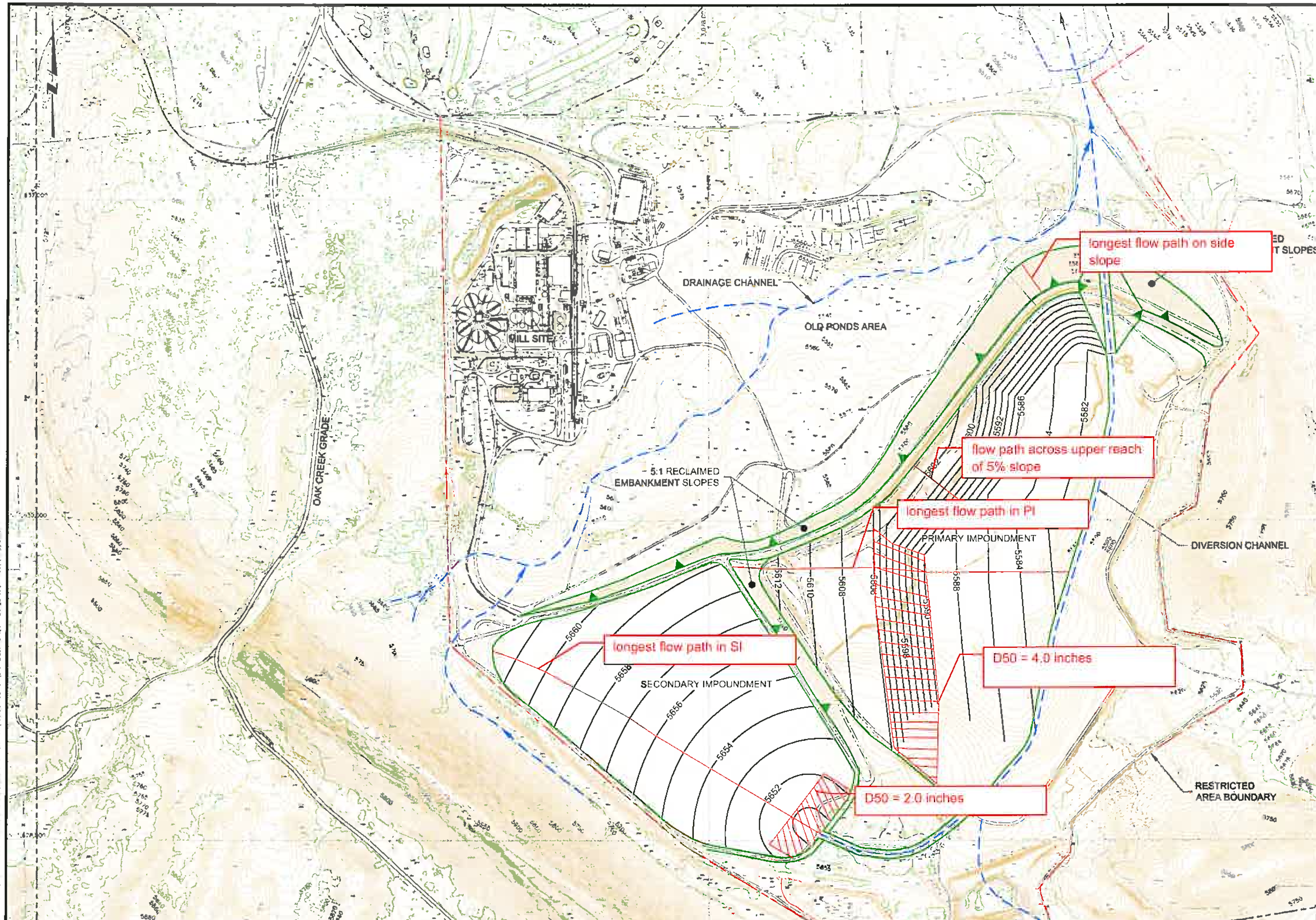
Abt and Johnson method (Abt and Johnson, 1991)

Applicable for slopes of 50% or less.
Equations assume specific gravity of rock is 2.65 or greater and angular rock.
For rounded rock, increase size by 40%.

ROCK SIZING EQUATION d50 = 5.23*S^0.43q*^0.56

Area	PI and SI side slopes	
Description	5H:1V	
Side Slope (ft/ft)	0.2	
angle α (rad)	0.197	
PMP unit flow (cfs/ft)	0.16	(max from "flow-PMP" worksheet)
Concentration Factor	3	Typically between 1.1 to 3.2
Coef. Of Movement	1.35	1.35 to prevent movement
design flow (cfs/ft)	0.63	
design flow over rock (cfs/ft)	0.63	assumes negligible flow through rock
D50 (inches) angular	2.0	
D50 (inches) rounded	2.8	



LEGEND:

EXISTING GROUND SURFACE ELEVATION, FEET

5588 TOP OF COVER GROUND SURFACE ELEVATION, FEET

EXISTING ROAD

EXISTING FENCE

REFERENCE

- TOP SURFACE OF SECONDARY IMPOUNDMENT CONTOURS GENERATED FROM DECEMBER 13, 2010 GPS SURVEY DATA FROM COTTER
- TOP SURFACE OF PRIMARY IMPOUNDMENT CONTOURS ARE A COMPOSITE OF GPS SURVEY DATA (2011) FROM COTTER, AND FUTURE REGRADE OF EVAPORATION PONDS, 3' ABOVE LINER
- REMAINDER OF EXISTING TOPOGRAPHY FROM MARCH 9, 2007 AERIAL SURVEY

COTTER CORPORATION (N.S.L.)

CANON CITY MILLING FACILITY

RECLAMATION PLAN LAYOUT, TOP OF FINAL COVER

MWH

DATE: MAY 2011

FIGURE 1

FILE NAME: 1007533D010