COLORADO PLATEAU UNIT HYDROGRAPH

18-May-06

Basin 3-PMP Proposed Conditions

Drainage Area = 3.47 sq. miles
Basin Slope = 57.1 ft./mile
L = 4.73 mi., Length of Watercourse
Lca = 1.83 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

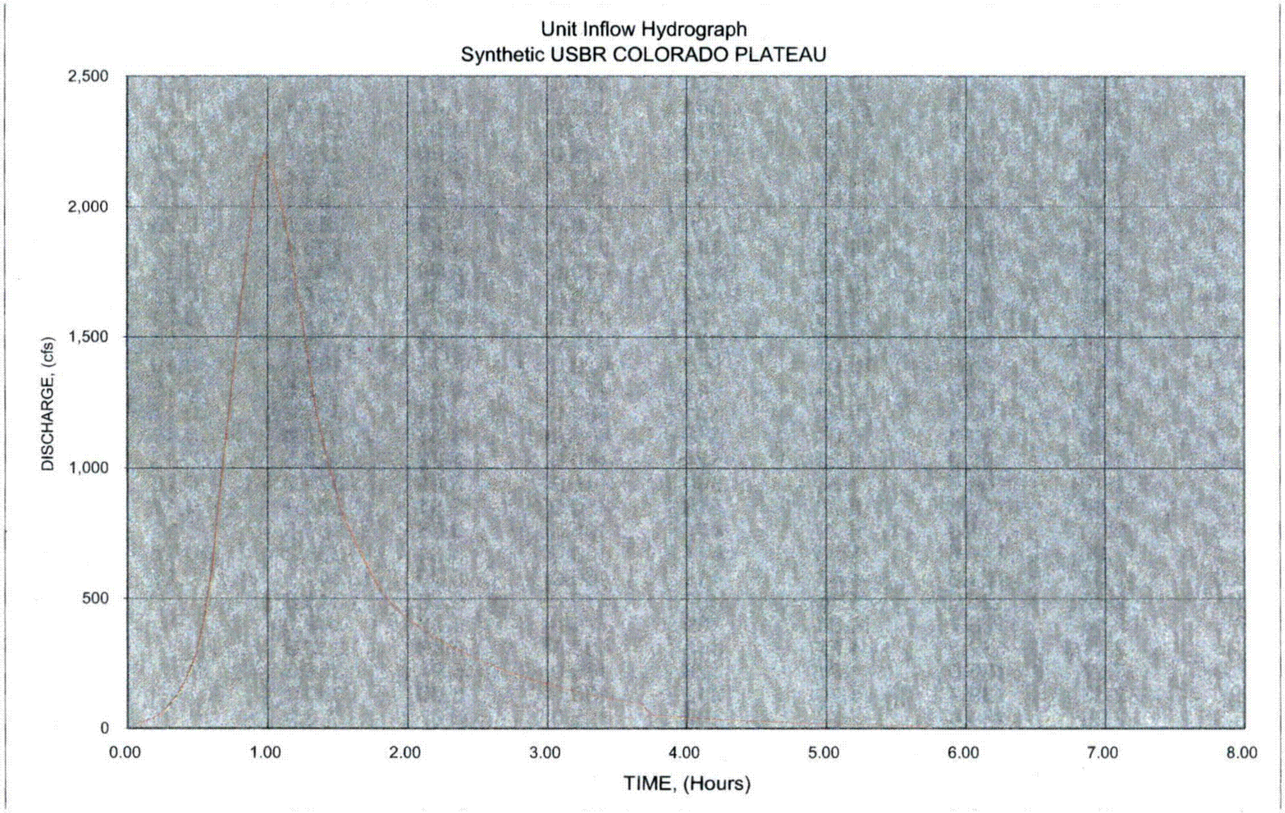
Lg+D/2 = 1.23 Hours
Basin Factor = 1.15
V' = 93.31 cfs/Day
Qs = 76.1 * q, cfs

PARAMETERS:

Calculated: Lag Time, Lg = 1.14 Hours

Unit Duration, D = 12.46 minutes
Calculated Timestep = 3.68 minutes

Data to be used in Analysis Unit Duration, D = 10 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
Selected Timestep = 5 minutes, integer value evenly divisible into 60



UI Record - Unit Graph 5 **minute interval**

UI	18	33	59	112	188	302	533	922	1330	1720
UI	2102	2181	2050	1833	1561	1276	1066	903	773	675
UI	588	520	464	426	392	361	334	311	288	267
UI	248	229	211	197	182	169	157	146	135	125
UI	116	108	101	93	86	80	74	68	64	59
UI	55	51	48	44	41	38	35	32	30	28
UI	26	24	22	21	19	18	17	16	15	14
UI	13	11	11	9	9	5				
UI										
UI										
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USBR calculated unitgraph peak = 2201 Interpolated Peak = 2181

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.06	3.7	0.19	14	305.0	3.74	224.2	0.66	50
10.0	0.12	7.4	0.32	24	310.0	3.80	227.9	0.63	48
15.0	0.18	11.0	0.48	37	315.0	3.86	231.6	0.59	45
20.0	0.25	14.7	0.74	56	320.0	3.92	235.3	0.56	43
25.0	0.31	18.4	1.21	92	325.0	3.98	239.0	0.53	40
30.0	0.37	22.1	1.81	138	330.0	4.04	242.6	0.50	38
35.0	0.43	25.7	2.63	200	335.0	4.11	246.3	0.47	36
40.0	0.49	29.4	3.68	280	340.0	4.17	250.0	0.45	34
45.0	0.55	33.1	5.47	417	345.0	4.23	253.7	0.42	32
50.0	0.61	36.8	8.41	640	350.0	4.29	257.3	0.40	30
55.0	0.67	40.4	12.61	960	355.0	4.35	261.0	0.38	29
60.0	0.74	44.1	16.50	1,256	360.0	4.41	264.7	0.36	27
65.0	0.80	47.8	20.50	1,561	365.0	4.47	268.4	0.34	26
70.0	0.86	51.5	23.97	1,825	370.0	4.53	272.0	0.33	25
75.0	0.92	55.1	27.75	2,113	375.0	4.60	275.7	0.30	23
80.0	0.98	58.8	28.91	2,201	380.0	4.66	279.4	0.28	21
85.0	1.04	62.5	28.07	2,137	385.0	4.72	283.1	0.27	21
90.0	1.10	66.2	26.38	2,009	390.0	4.78	286.7	0.26	20
95.0	1.16	69.8	24.18	1,841	395.0	4.84	290.4	0.24	18
100.0	1.23	73.5	21.55	1,641	400.0	4.90	294.1	0.23	18
105.0	1.29	77.2	18.92	1,441	405.0	4.96	297.8	0.22	17
110.0	1.35	80.9	16.08	1,224	410.0	5.02	301.4	0.21	16
115.0	1.41	84.6	14.19	1,081	415.0	5.09	305.1	0.20	15
120.0	1.47	88.2	12.61	960	420.0	5.15	308.8	0.19	14
125.0	1.53	91.9	11.04	841	425.0	5.21	312.5	0.18	14
130.0	1.59	95.6	9.99	761	430.0	5.27	316.2	0.17	13
135.0	1.65	99.3	9.04	688	435.0	5.33	319.8	0.16	12
140.0	1.72	102.9	8.20	624	440.0	5.39	323.5	0.15	11
145.0	1.78	106.6	7.36	560	445.0	5.45	327.2	0.15	11
150.0	1.84	110.3	6.78	516	450.0	5.51	330.9	0.13	10
155.0	1.90	114.0	6.20	472	455.0	5.58	334.5	0.12	9
160.0	1.96	117.6	5.83	444	460.0	5.64	338.2	0.12	9
165.0	2.02	121.3	5.47	417	465.0	5.70	341.9	0.11	8
170.0	2.08	125.0	5.15	392	470.0	5.76	345.6		
175.0	2.14	128.7	4.84	369	475.0	5.82	349.2		
180.0	2.21	132.3	4.57	348	480.0	5.88	352.9		
185.0	2.27	136.0	4.31	328	485.0	5.94	356.6		
190.0	2.33	139.7	4.10	312	490.0	6.00	360.3		
195.0	2.39	143.4	3.87	295	495.0	6.07	363.9		
200.0	2.45	147.0	3.68	280	500.0	6.13	367.6		
205.0	2.51	150.7	3.47	264	505.0	6.19	371.3		
210.0	2.57	154.4	3.28	250	510.0	6.25	375.0		
215.0	2.63	158.1	3.10	236	515.0	6.31	378.6		
220.0	2.70	161.8	2.93	223	520.0	6.37	382.3		
225.0	2.76	165.4	2.75	209	525.0	6.43	386.0		
230.0	2.82	169.1	2.63	200	530.0	6.49	389.7		
235.0	2.88	172.8	2.47	188	535.0	6.56	393.4		
240.0	2.94	176.5	2.33	177	540.0	6.62	397.0		
245.0	3.00	180.1	2.22	169	545.0	6.68	400.7		
250.0	3.06	183.8	2.10	160	550.0	6.74	404.4		
255.0	3.12	187.5	1.99	152	555.0	6.80	408.1		
260.0	3.19	191.2	1.88	143	560.0	6.86	411.7		
265.0	3.25	194.8	1.78	136	565.0	6.92	415.4		
270.0	3.31	198.5	1.68	128	570.0	6.98	419.1		
275.0	3.37	202.2	1.59	121	575.0	7.05	422.8		
280.0	3.43	205.9	1.50	114	580.0	7.11	426.4		
285.0	3.49	209.5	1.43	109	585.0	7.17	430.1		
290.0	3.55	213.2	1.36	104	590.0	7.23	433.8		
295.0	3.61	216.9	1.28	97	595.0	7.29	437.5		
300.0	3.68	220.6	1.21	92	600.0	7.35	441.1		

NOTES : Use for models including Basin 3 for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH

18-May-06

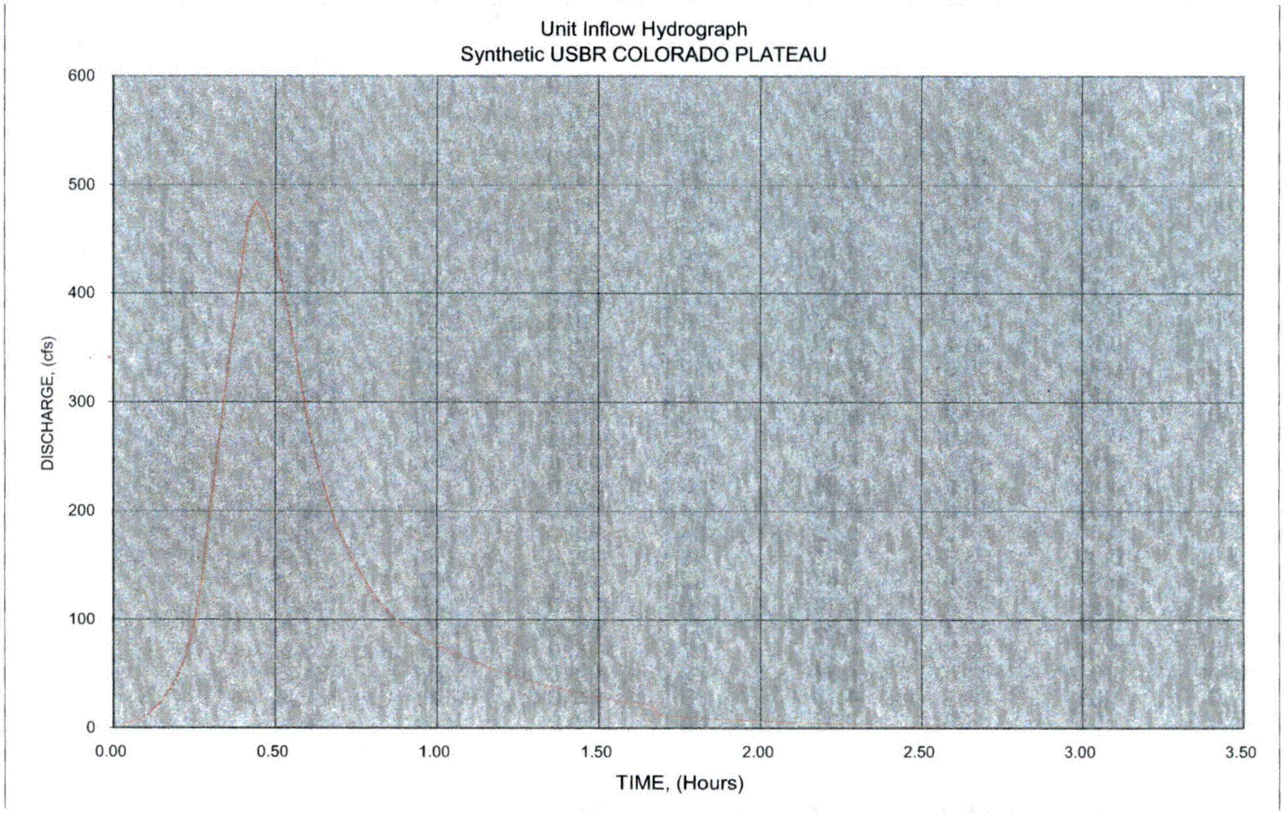
Basin A-10, 25, 100, 200 Proposed Conditions

Drainage Area = 0.3456 sq. miles
Basin Slope = 501 ft./mile
L = 1.55 mi., Length of Watercourse
Lca = 0.68 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 0.55 Hours
Basin Factor = 0.05
V' = 9.29 cfs/Day
Qs = 16.8 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.51 Hours
Unit Duration, D = 5.59 minutes
Calculated Timestep = 1.66 minutes

Data to be used in Analysis
Unit Duration, D = 5 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
Selected Timestep = 5 minutes, integer value evenly divisible into 60



UI Record - Unit Graph 5 **minute interval**

UI	8	31	93	279	467	441	314	210	151	113
UI	91	76	65	55	46	39	33	28	24	20
UI	17	14	12	10	9	7	6	5	4	4
UI	3	3	2	2						
UI										
UI										
UI										
UI										
UI										
UI										

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USBR calculated unitgraph peak = 485 Interpolated Peak = 467

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	1.7	0.19	3
10.0	0.06	3.3	0.32	5
15.0	0.08	5.0	0.48	8
20.0	0.11	6.6	0.74	12
25.0	0.14	8.3	1.21	20
30.0	0.17	10.0	1.81	30
35.0	0.19	11.6	2.63	44
40.0	0.22	13.3	3.68	62
45.0	0.25	15.0	5.47	92
50.0	0.28	16.6	8.41	141
55.0	0.30	18.3	12.61	212
60.0	0.33	19.9	16.50	277
65.0	0.36	21.6	20.50	344
70.0	0.39	23.3	23.97	402
75.0	0.42	24.9	27.75	466
80.0	0.44	26.6	28.91	485
85.0	0.47	28.2	28.07	471
90.0	0.50	29.9	26.38	443
95.0	0.53	31.6	24.18	406
100.0	0.55	33.2	21.55	362
105.0	0.58	34.9	18.92	317
110.0	0.61	36.6	16.08	270
115.0	0.64	38.2	14.19	238
120.0	0.66	39.9	12.61	212
125.0	0.69	41.5	11.04	185
130.0	0.72	43.2	9.99	168
135.0	0.75	44.9	9.04	152
140.0	0.78	46.5	8.20	138
145.0	0.80	48.2	7.36	123
150.0	0.83	49.8	6.78	114
155.0	0.86	51.5	6.20	104
160.0	0.89	53.2	5.83	98
165.0	0.91	54.8	5.47	92
170.0	0.94	56.5	5.15	86
175.0	0.97	58.2	4.84	81
180.0	1.00	59.8	4.57	77
185.0	1.02	61.5	4.31	72
190.0	1.05	63.1	4.10	69
195.0	1.08	64.8	3.87	65
200.0	1.11	66.5	3.68	62
205.0	1.14	68.1	3.47	58
210.0	1.16	69.8	3.28	55
215.0	1.19	71.4	3.10	52
220.0	1.22	73.1	2.93	49
225.0	1.25	74.8	2.75	46
230.0	1.27	76.4	2.63	44
235.0	1.30	78.1	2.47	41
240.0	1.33	79.8	2.33	39
245.0	1.36	81.4	2.22	37
250.0	1.38	83.1	2.10	35
255.0	1.41	84.7	1.99	33
260.0	1.44	86.4	1.88	32
265.0	1.47	88.1	1.78	30
270.0	1.50	89.7	1.68	28
275.0	1.52	91.4	1.59	27
280.0	1.55	93.0	1.50	25
285.0	1.58	94.7	1.43	24
290.0	1.61	96.4	1.36	23
295.0	1.63	98.0	1.28	21
300.0	1.66	99.7	1.21	20
305.0	1.69	101.4	0.66	11
310.0	1.72	103.0	0.63	11
315.0	1.74	104.7	0.59	10
320.0	1.77	106.3	0.56	9
325.0	1.80	108.0	0.53	9
330.0	1.83	109.7	0.50	8
335.0	1.86	111.3	0.47	8
340.0	1.88	113.0	0.45	8
345.0	1.91	114.6	0.42	7
350.0	1.94	116.3	0.40	7
355.0	1.97	118.0	0.38	6
360.0	1.99	119.6	0.36	6
365.0	2.02	121.3	0.34	6
370.0	2.05	123.0	0.33	6
375.0	2.08	124.6	0.30	5
380.0	2.10	126.3	0.28	5
385.0	2.13	127.9	0.27	5
390.0	2.16	129.6	0.26	4
395.0	2.19	131.3	0.24	4
400.0	2.22	132.9	0.23	4
405.0	2.24	134.6	0.22	4
410.0	2.27	136.2	0.21	4
415.0	2.30	137.9	0.20	3
420.0	2.33	139.6	0.19	3
425.0	2.35	141.2	0.18	3
430.0	2.38	142.9	0.17	3
435.0	2.41	144.6	0.16	3
440.0	2.44	146.2	0.15	3
445.0	2.46	147.9	0.15	3
450.0	2.49	149.5	0.13	2
455.0	2.52	151.2	0.12	2
460.0	2.55	152.9	0.12	2
465.0	2.58	154.5	0.11	2
470.0	2.60	156.2		
475.0	2.63	157.8		
480.0	2.66	159.5		
485.0	2.69	161.2		
490.0	2.71	162.8		
495.0	2.74	164.5		
500.0	2.77	166.2		
505.0	2.80	167.8		
510.0	2.82	169.5		
515.0	2.85	171.1		
520.0	2.88	172.8		
525.0	2.91	174.5		
530.0	2.94	176.1		
535.0	2.96	177.8		
540.0	2.99	179.4		
545.0	3.02	181.1		
550.0	3.05	182.8		
555.0	3.07	184.4		
560.0	3.10	186.1		
565.0	3.13	187.8		
570.0	3.16	189.4		
575.0	3.18	191.1		
580.0	3.21	192.7		
585.0	3.24	194.4		
590.0	3.27	196.1		
595.0	3.30	197.7		
600.0	3.32	199.4		

NOTES : Use for models including Basin A for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

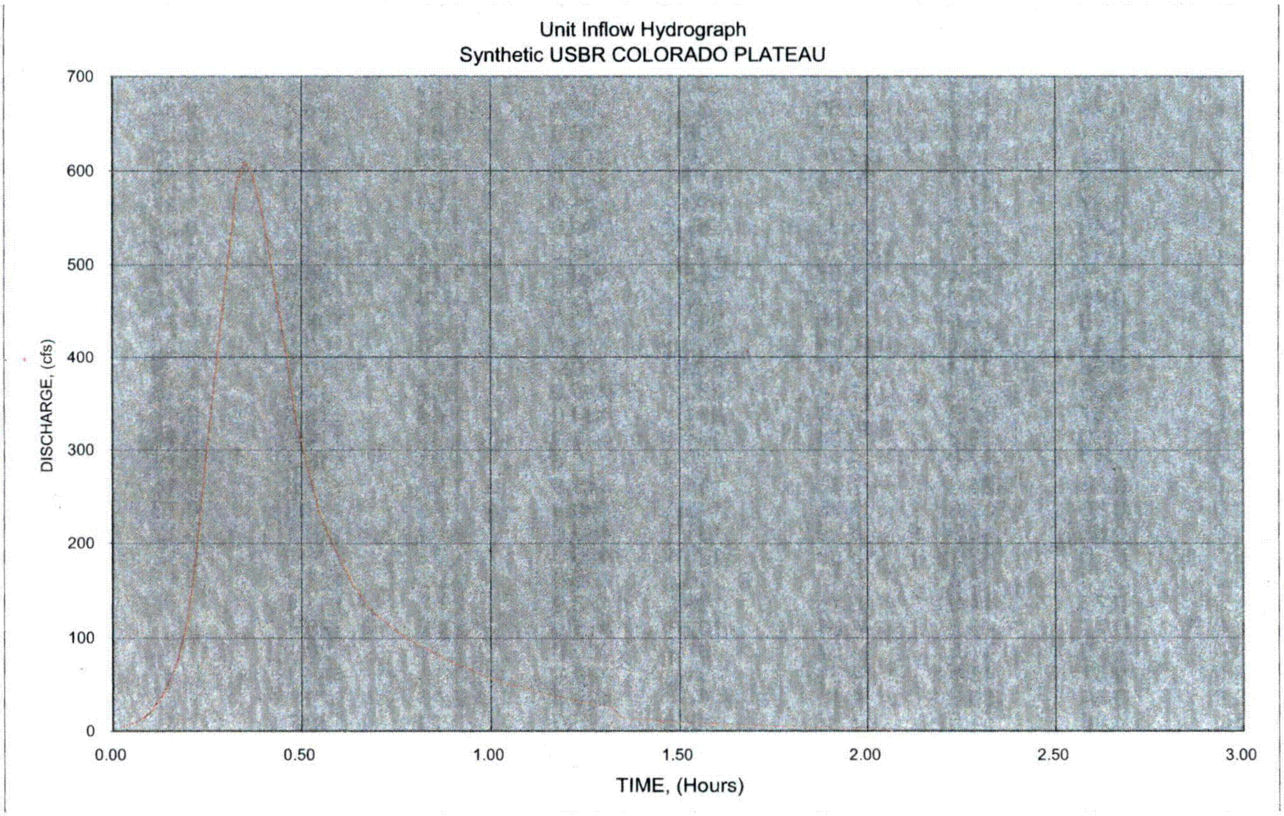
Basin A-PMP Proposed Conditions

Drainage Area = 0.3456 sq. miles
Basin Slope = 501 ft./mile
L = 1.55 mi., Length of Watercourse
Lca = 0.68 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

Lg+D/2 = 0.44 Hours
Basin Factor = 0.05
V' = 9.29 cfs/Day
Qs = 21.1 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.40 Hours
Unit Duration, D = 4.35 minutes
Calculated Timestep = 1.32 minutes

Data to be used in Analysis
Unit Duration, D = 5 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
Selected Timestep = 5 minutes, integer value evenly divisible into 60



UI Record - Unit Graph 5 **minute interval**

UI	14	68	296	590	514	311	201	140	108	87
UI	71	57	46	38	30	25	20	16	13	11
UI	9	7	6	5	4	3	2			
UI										
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USBR calculated unitgraph peak = 611 Interpolated Peak = 590

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.02	1.3	0.19	4
10.0	0.04	2.6	0.32	7
15.0	0.07	4.0	0.48	10
20.0	0.09	5.3	0.74	16
25.0	0.11	6.6	1.21	26
30.0	0.13	7.9	1.81	38
35.0	0.15	9.2	2.63	56
40.0	0.18	10.6	3.68	78
45.0	0.20	11.9	5.47	116
50.0	0.22	13.2	8.41	178
55.0	0.24	14.5	12.61	266
60.0	0.26	15.8	16.50	348
65.0	0.29	17.2	20.50	433
70.0	0.31	18.5	23.97	506
75.0	0.33	19.8	27.75	586
80.0	0.35	21.1	28.91	611
85.0	0.37	22.4	28.07	593
90.0	0.40	23.8	26.38	557
95.0	0.42	25.1	24.18	511
100.0	0.44	26.4	21.55	455
105.0	0.46	27.7	18.92	400
110.0	0.48	29.0	16.08	340
115.0	0.51	30.4	14.19	300
120.0	0.53	31.7	12.61	266
125.0	0.55	33.0	11.04	233
130.0	0.57	34.3	9.99	211
135.0	0.59	35.6	9.04	191
140.0	0.62	37.0	8.20	173
145.0	0.64	38.3	7.36	155
150.0	0.66	39.6	6.78	143
155.0	0.68	40.9	6.20	131
160.0	0.70	42.2	5.83	123
165.0	0.73	43.6	5.47	116
170.0	0.75	44.9	5.15	109
175.0	0.77	46.2	4.84	102
180.0	0.79	47.5	4.57	97
185.0	0.81	48.8	4.31	91
190.0	0.84	50.2	4.10	87
195.0	0.86	51.5	3.87	82
200.0	0.88	52.8	3.68	78
205.0	0.90	54.1	3.47	73
210.0	0.92	55.4	3.28	69
215.0	0.95	56.8	3.10	65
220.0	0.97	58.1	2.93	62
225.0	0.99	59.4	2.75	58
230.0	1.01	60.7	2.63	56
235.0	1.03	62.0	2.47	52
240.0	1.06	63.4	2.33	49
245.0	1.08	64.7	2.22	47
250.0	1.10	66.0	2.10	44
255.0	1.12	67.3	1.99	42
260.0	1.14	68.6	1.88	40
265.0	1.17	70.0	1.78	38
270.0	1.19	71.3	1.68	35
275.0	1.21	72.6	1.59	34
280.0	1.23	73.9	1.50	32
285.0	1.25	75.2	1.43	30
290.0	1.28	76.6	1.36	29
295.0	1.30	77.9	1.28	27
300.0	1.32	79.2	1.21	26
305.0	1.34	80.5	0.66	14
310.0	1.36	81.8	0.63	13
315.0	1.39	83.2	0.59	12
320.0	1.41	84.5	0.56	12
325.0	1.43	85.8	0.53	11
330.0	1.45	87.1	0.50	11
335.0	1.47	88.4	0.47	10
340.0	1.50	89.8	0.45	10
345.0	1.52	91.1	0.42	9
350.0	1.54	92.4	0.40	8
355.0	1.56	93.7	0.38	8
360.0	1.58	95.0	0.36	8
365.0	1.61	96.4	0.34	7
370.0	1.63	97.7	0.33	7
375.0	1.65	99.0	0.30	6
380.0	1.67	100.3	0.28	6
385.0	1.69	101.6	0.27	6
390.0	1.72	103.0	0.26	5
395.0	1.74	104.3	0.24	5
400.0	1.76	105.6	0.23	5
405.0	1.78	106.9	0.22	5
410.0	1.80	108.2	0.21	4
415.0	1.83	109.6	0.20	4
420.0	1.85	110.9	0.19	4
425.0	1.87	112.2	0.18	4
430.0	1.89	113.5	0.17	4
435.0	1.91	114.8	0.16	3
440.0	1.94	116.2	0.15	3
445.0	1.96	117.5	0.15	3
450.0	1.98	118.8	0.13	3
455.0	2.00	120.1	0.12	3
460.0	2.02	121.5	0.12	3
465.0	2.05	122.8	0.11	2
470.0	2.07	124.1		
475.0	2.09	125.4		
480.0	2.11	126.7		
485.0	2.13	128.1		
490.0	2.16	129.4		
495.0	2.18	130.7		
500.0	2.20	132.0		
505.0	2.22	133.3		
510.0	2.24	134.7		
515.0	2.27	136.0		
520.0	2.29	137.3		
525.0	2.31	138.6		
530.0	2.33	139.9		
535.0	2.35	141.3		
540.0	2.38	142.6		
545.0	2.40	143.9		
550.0	2.42	145.2		
555.0	2.44	146.5		
560.0	2.46	147.9		
565.0	2.49	149.2		
570.0	2.51	150.5		
575.0	2.53	151.8		
580.0	2.55	153.1		
585.0	2.57	154.5		
590.0	2.60	155.8		
595.0	2.62	157.1		
600.0	2.64	158.4		

NOTES : Use for models including Basin A for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH

18-May-06

Basin B-10, 25, 100, 200 Proposed Conditions

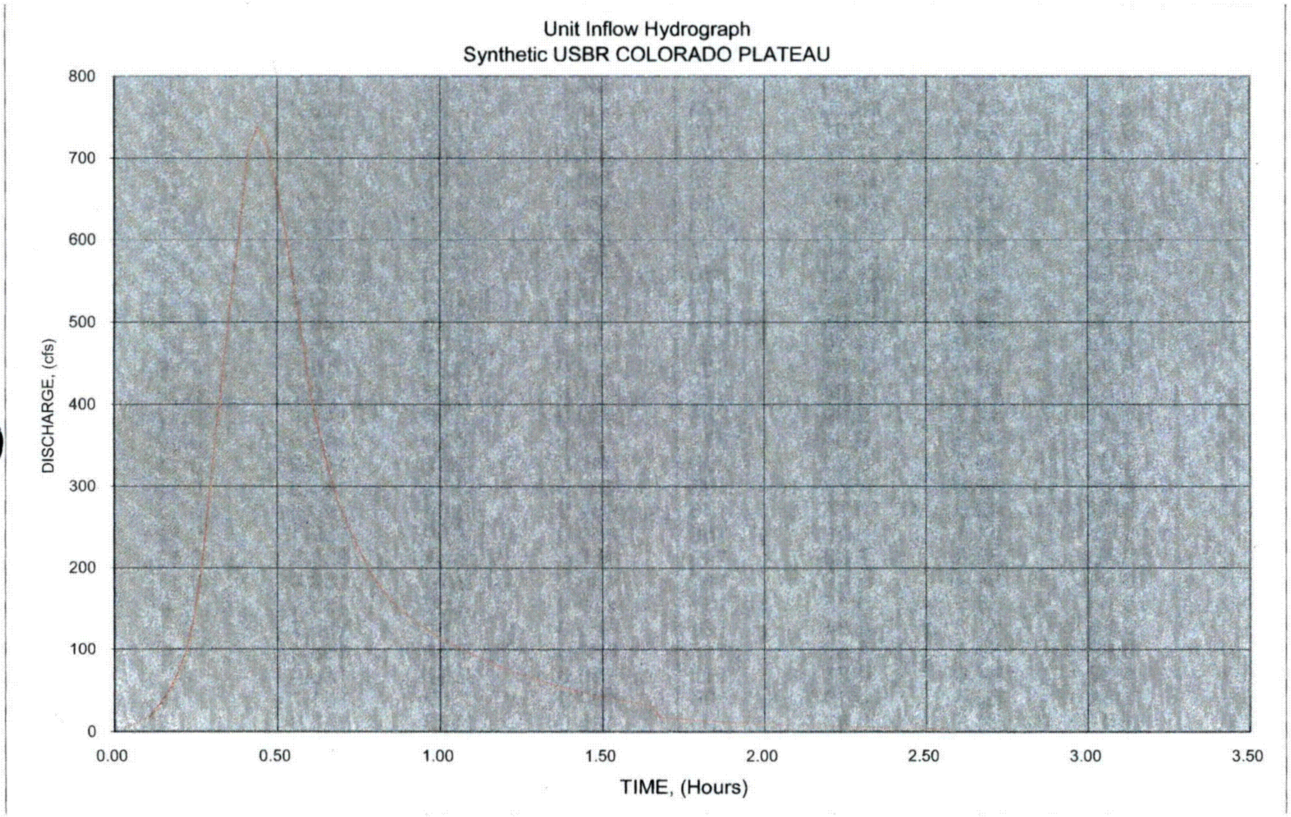
Drainage Area = 0.5218 sq. miles
Basin Slope = 666 ft./mile
L = 1.38 mi., Length of Watercourse
Lca = 0.86 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 0.55 Hours
Basin Factor = 0.05
V' = 14.03 cfs/Day
Qs = 25.5 * q, cfs

PARAMETERS:

Calculated: Lag Time, Lg = 0.51 Hours
Unit Duration, D = 5.54 minutes
Calculated Timestep = 1.65 minutes

Data to be used in Analysis
Unit Duration, D = 5 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
Selected Timestep = 5 minutes, integer value evenly divisible into 60



UI Record - Unit Graph 5 **minute interval**

UI	12	47	147	434	713	663	467	312	225	168
UI	137	114	97	82	69	58	49	42	35	30
UI	25	21	18	15	13	11	9	8	7	6
UI	5	4	3	3						
UI										
UI										
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USBR calculated unitgraph peak = 738 Interpolated Peak = 713

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	1.6	0.19	5	305.0	1.68	100.6	0.66	17
10.0	0.05	3.3	0.32	8	310.0	1.70	102.3	0.63	16
15.0	0.08	4.9	0.48	12	315.0	1.73	103.9	0.59	15
20.0	0.11	6.6	0.74	19	320.0	1.76	105.6	0.56	14
25.0	0.14	8.2	1.21	31	325.0	1.79	107.2	0.53	14
30.0	0.16	9.9	1.81	46	330.0	1.81	108.9	0.50	13
35.0	0.19	11.5	2.63	67	335.0	1.84	110.5	0.47	12
40.0	0.22	13.2	3.68	94	340.0	1.87	112.2	0.45	11
45.0	0.25	14.8	5.47	140	345.0	1.90	113.8	0.42	11
50.0	0.27	16.5	8.41	215	350.0	1.92	115.5	0.40	10
55.0	0.30	18.1	12.61	322	355.0	1.95	117.1	0.38	10
60.0	0.33	19.8	16.50	421	360.0	1.98	118.8	0.36	9
65.0	0.36	21.4	20.50	523	365.0	2.01	120.4	0.34	9
70.0	0.38	23.1	23.97	612	370.0	2.03	122.1	0.33	8
75.0	0.41	24.7	27.75	708	375.0	2.06	123.7	0.30	8
80.0	0.44	26.4	28.91	738	380.0	2.09	125.4	0.28	7
85.0	0.47	28.0	28.07	716	385.0	2.12	127.0	0.27	7
90.0	0.49	29.7	26.38	673	390.0	2.14	128.7	0.26	7
95.0	0.52	31.3	24.18	617	395.0	2.17	130.3	0.24	6
100.0	0.55	33.0	21.55	550	400.0	2.20	132.0	0.23	6
105.0	0.58	34.6	18.92	483	405.0	2.23	133.6	0.22	6
110.0	0.60	36.3	16.08	410	410.0	2.25	135.3	0.21	5
115.0	0.63	37.9	14.19	362	415.0	2.28	136.9	0.20	5
120.0	0.66	39.6	12.61	322	420.0	2.31	138.6	0.19	5
125.0	0.69	41.2	11.04	282	425.0	2.34	140.2	0.18	5
130.0	0.71	42.9	9.99	255	430.0	2.36	141.9	0.17	4
135.0	0.74	44.5	9.04	231	435.0	2.39	143.5	0.16	4
140.0	0.77	46.2	8.20	209	440.0	2.42	145.2	0.15	4
145.0	0.80	47.8	7.36	188	445.0	2.45	146.8	0.15	4
150.0	0.82	49.5	6.78	173	450.0	2.47	148.5	0.13	3
155.0	0.85	51.1	6.20	158	455.0	2.50	150.1	0.12	3
160.0	0.88	52.8	5.83	149	460.0	2.53	151.8	0.12	3
165.0	0.91	54.4	5.47	140	465.0	2.56	153.4	0.11	3
170.0	0.93	56.1	5.15	131	470.0	2.58	155.1		
175.0	0.96	57.7	4.84	124	475.0	2.61	156.7		
180.0	0.99	59.4	4.57	117	480.0	2.64	158.4		
185.0	1.02	61.0	4.31	110	485.0	2.67	160.0		
190.0	1.04	62.7	4.10	105	490.0	2.69	161.7		
195.0	1.07	64.3	3.87	99	495.0	2.72	163.3		
200.0	1.10	66.0	3.68	94	500.0	2.75	165.0		
205.0	1.13	67.6	3.47	89	505.0	2.78	166.6		
210.0	1.15	69.3	3.28	84	510.0	2.80	168.3		
215.0	1.18	70.9	3.10	79	515.0	2.83	169.9		
220.0	1.21	72.6	2.93	75	520.0	2.86	171.6		
225.0	1.24	74.2	2.75	70	525.0	2.89	173.2		
230.0	1.26	75.9	2.63	67	530.0	2.91	174.9		
235.0	1.29	77.5	2.47	63	535.0	2.94	176.5		
240.0	1.32	79.2	2.33	59	540.0	2.97	178.2		
245.0	1.35	80.8	2.22	57	545.0	3.00	179.8		
250.0	1.37	82.5	2.10	54	550.0	3.02	181.5		
255.0	1.40	84.1	1.99	51	555.0	3.05	183.1		
260.0	1.43	85.8	1.88	48	560.0	3.08	184.8		
265.0	1.46	87.4	1.78	45	565.0	3.11	186.4		
270.0	1.48	89.1	1.68	43	570.0	3.13	188.1		
275.0	1.51	90.7	1.59	41	575.0	3.16	189.7		
280.0	1.54	92.4	1.50	38	580.0	3.19	191.4		
285.0	1.57	94.0	1.43	36	585.0	3.22	193.0		
290.0	1.59	95.7	1.36	35	590.0	3.24	194.7		
295.0	1.62	97.3	1.28	33	595.0	3.27	196.3		
300.0	1.65	99.0	1.21	31	600.0	3.30	198.0		

NOTES : Use for models including Basin B for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH

18-May-06

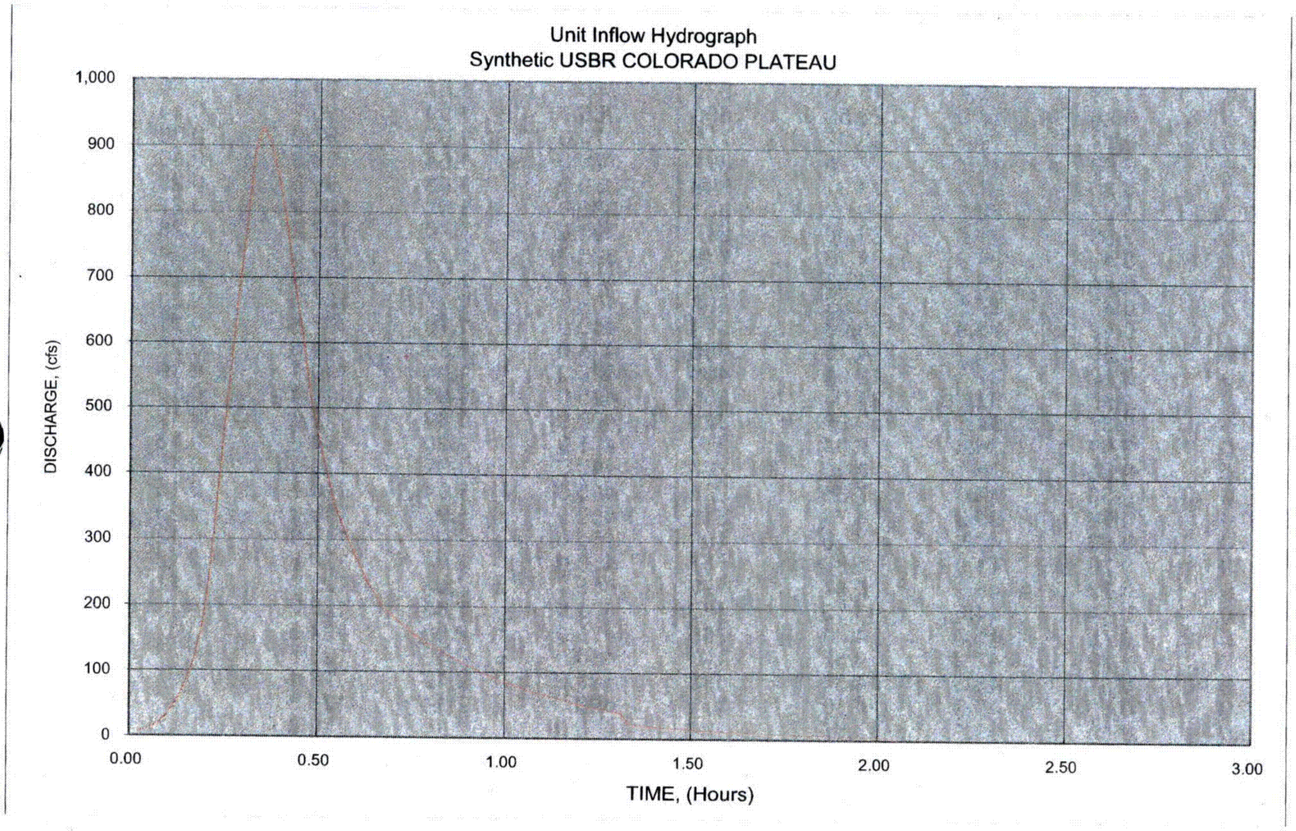
Basin B-PMP Proposed Conditions

Drainage Area = 0.5218 sq. miles
Basin Slope = 666 ft./mile
L = 1.38 mi., Length of Watercourse
Lca = 0.86 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

Lg+D/2 = 0.44 Hours
Basin Factor = 0.05
V' = 14.03 cfs/Day
Qs = 32.1 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.40 Hours
Unit Duration, D = 4.31 minutes
Calculated Timestep = 1.31 minutes

Data to be used in Analysis
Unit Duration, D = 5 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
Selected Timestep = 5 minutes, integer value evenly divisible into 60



UI Record - Unit Graph 5 **minute interval**

UI	22	106	460	901	770	463	299	208	162	131
UI	106	85	69	56	45	37	30	24	20	16
UI	13	11	8	7	6	5	4			
UI										
UI										
UI										
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USBR calculated unitgraph peak = 928 Interpolated Peak = 901

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.02	1.3	0.19	6	305.0	1.33	80.0	0.66	21
10.0	0.04	2.6	0.32	10	310.0	1.35	81.3	0.63	20
15.0	0.07	3.9	0.48	15	315.0	1.38	82.6	0.59	19
20.0	0.09	5.2	0.74	24	320.0	1.40	83.9	0.56	18
25.0	0.11	6.6	1.21	39	325.0	1.42	85.2	0.53	17
30.0	0.13	7.9	1.81	58	330.0	1.44	86.5	0.50	16
35.0	0.15	9.2	2.63	84	335.0	1.46	87.8	0.47	15
40.0	0.17	10.5	3.68	118	340.0	1.49	89.1	0.45	14
45.0	0.20	11.8	5.47	176	345.0	1.51	90.4	0.42	13
50.0	0.22	13.1	8.41	270	350.0	1.53	91.8	0.40	13
55.0	0.24	14.4	12.61	405	355.0	1.55	93.1	0.38	12
60.0	0.26	15.7	16.50	530	360.0	1.57	94.4	0.36	12
65.0	0.28	17.0	20.50	658	365.0	1.59	95.7	0.34	11
70.0	0.31	18.4	23.97	770	370.0	1.62	97.0	0.33	11
75.0	0.33	19.7	27.75	891	375.0	1.64	98.3	0.30	10
80.0	0.35	21.0	28.91	928	380.0	1.66	99.6	0.28	9
85.0	0.37	22.3	28.07	901	385.0	1.68	100.9	0.27	9
90.0	0.39	23.6	26.38	847	390.0	1.70	102.2	0.26	8
95.0	0.42	24.9	24.18	776	395.0	1.73	103.6	0.24	8
100.0	0.44	26.2	21.55	692	400.0	1.75	104.9	0.23	7
105.0	0.46	27.5	18.92	608	405.0	1.77	106.2	0.22	7
110.0	0.48	28.8	16.08	516	410.0	1.79	107.5	0.21	7
115.0	0.50	30.1	14.19	456	415.0	1.81	108.8	0.20	6
120.0	0.52	31.5	12.61	405	420.0	1.84	110.1	0.19	6
125.0	0.55	32.8	11.04	355	425.0	1.86	111.4	0.18	6
130.0	0.57	34.1	9.99	321	430.0	1.88	112.7	0.17	5
135.0	0.59	35.4	9.04	290	435.0	1.90	114.0	0.16	5
140.0	0.61	36.7	8.20	263	440.0	1.92	115.4	0.15	5
145.0	0.63	38.0	7.36	236	445.0	1.94	116.7	0.15	5
150.0	0.66	39.3	6.78	218	450.0	1.97	118.0	0.13	4
155.0	0.68	40.6	6.20	199	455.0	1.99	119.3	0.12	4
160.0	0.70	41.9	5.83	187	460.0	2.01	120.6	0.12	4
165.0	0.72	43.3	5.47	176	465.0	2.03	121.9	0.11	4
170.0	0.74	44.6	5.15	165	470.0	2.05	123.2		
175.0	0.76	45.9	4.84	155	475.0	2.08	124.5		
180.0	0.79	47.2	4.57	147	480.0	2.10	125.8		
185.0	0.81	48.5	4.31	138	485.0	2.12	127.1		
190.0	0.83	49.8	4.10	132	490.0	2.14	128.5		
195.0	0.85	51.1	3.87	124	495.0	2.16	129.8		
200.0	0.87	52.4	3.68	118	500.0	2.18	131.1		
205.0	0.90	53.7	3.47	111	505.0	2.21	132.4		
210.0	0.92	55.1	3.28	105	510.0	2.23	133.7		
215.0	0.94	56.4	3.10	100	515.0	2.25	135.0		
220.0	0.96	57.7	2.93	94	520.0	2.27	136.3		
225.0	0.98	59.0	2.75	88	525.0	2.29	137.6		
230.0	1.00	60.3	2.63	84	530.0	2.32	138.9		
235.0	1.03	61.6	2.47	79	535.0	2.34	140.3		
240.0	1.05	62.9	2.33	75	540.0	2.36	141.6		
245.0	1.07	64.2	2.22	71	545.0	2.38	142.9		
250.0	1.09	65.5	2.10	67	550.0	2.40	144.2		
255.0	1.11	66.9	1.99	64	555.0	2.42	145.5		
260.0	1.14	68.2	1.88	60	560.0	2.45	146.8		
265.0	1.16	69.5	1.78	57	565.0	2.47	148.1		
270.0	1.18	70.8	1.68	54	570.0	2.49	149.4		
275.0	1.20	72.1	1.59	51	575.0	2.51	150.7		
280.0	1.22	73.4	1.50	48	580.0	2.53	152.1		
285.0	1.25	74.7	1.43	46	585.0	2.56	153.4		
290.0	1.27	76.0	1.36	44	590.0	2.58	154.7		
295.0	1.29	77.3	1.28	41	595.0	2.60	156.0		
300.0	1.31	78.6	1.21	39	600.0	2.62	157.3		

NOTES : Use for models including Basin B for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

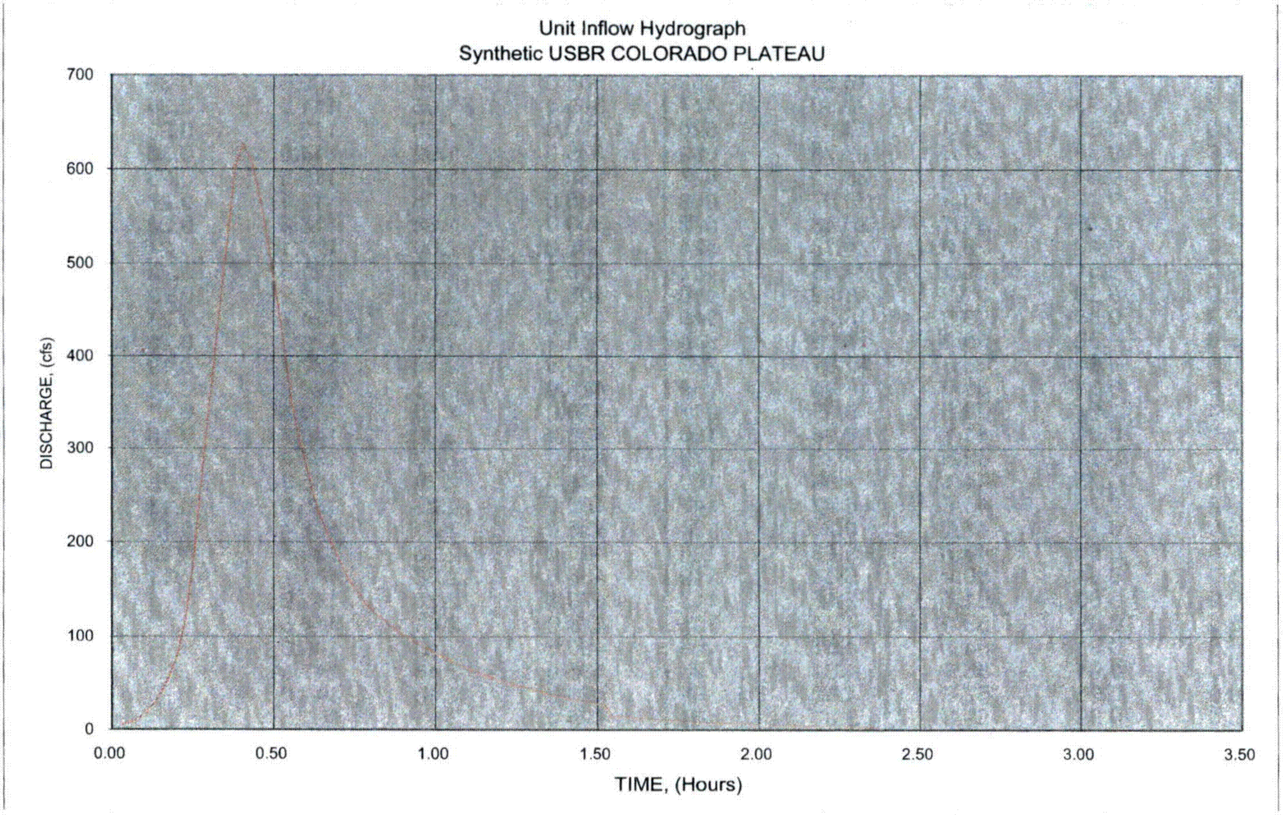
Basin for Culvert C7-10, 25, 100, 200 Proposed Conditions

Drainage Area = 0.4087 sq. miles
Basin Slope = 501 ft./mile
L = 1.27 mi., Length of Watercourse
Lca = 0.62 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 0.51 Hours
Basin Factor = 0.04
V' = 10.99 cfs/Day
Qs = 21.7 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.47 Hours
Unit Duration, D = 5.07 minutes
Calculated Timestep = 1.52 minutes

Data to be used in Analysis
Unit Duration, D = 5 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
Selected Timestep = 5 minutes, integer value evenly divisible into 60



UI Record - Unit Graph 5 **minute interval**

UI	12	49	174	456	619	483	307	210	152	120
UI	98	82	68	57	47	39	33	27	23	19
UI	16	13	11	9	8	6	5	5	4	3
UI	3									
UI										
UI										
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USBR calculated unitgraph peak = 627 Interpolated Peak = 619

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	1.5	0.19	4	305.0	1.55	92.8	0.66	14
10.0	0.05	3.0	0.32	7	310.0	1.57	94.3	0.63	14
15.0	0.08	4.6	0.48	10	315.0	1.60	95.8	0.59	13
20.0	0.10	6.1	0.74	16	320.0	1.62	97.3	0.56	12
25.0	0.13	7.6	1.21	26	325.0	1.65	98.8	0.53	11
30.0	0.15	9.1	1.81	39	330.0	1.67	100.4	0.50	11
35.0	0.18	10.6	2.63	57	335.0	1.70	101.9	0.47	10
40.0	0.20	12.2	3.68	80	340.0	1.72	103.4	0.45	10
45.0	0.23	13.7	5.47	119	345.0	1.75	104.9	0.42	9
50.0	0.25	15.2	8.41	182	350.0	1.77	106.4	0.40	9
55.0	0.28	16.7	12.61	273	355.0	1.80	108.0	0.38	8
60.0	0.30	18.2	16.50	358	360.0	1.82	109.5	0.36	8
65.0	0.33	19.8	20.50	444	365.0	1.85	111.0	0.34	7
70.0	0.35	21.3	23.97	520	370.0	1.88	112.5	0.33	7
75.0	0.38	22.8	27.75	602	375.0	1.90	114.0	0.30	7
80.0	0.41	24.3	28.91	627	380.0	1.93	115.6	0.28	6
85.0	0.43	25.9	28.07	609	385.0	1.95	117.1	0.27	6
90.0	0.46	27.4	26.38	572	390.0	1.98	118.6	0.26	6
95.0	0.48	28.9	24.18	524	395.0	2.00	120.1	0.24	5
100.0	0.51	30.4	21.55	467	400.0	2.03	121.6	0.23	5
105.0	0.53	31.9	18.92	410	405.0	2.05	123.2	0.22	5
110.0	0.56	33.5	16.08	349	410.0	2.08	124.7	0.21	5
115.0	0.58	35.0	14.19	308	415.0	2.10	126.2	0.20	4
120.0	0.61	36.5	12.61	273	420.0	2.13	127.7	0.19	4
125.0	0.63	38.0	11.04	239	425.0	2.15	129.3	0.18	4
130.0	0.66	39.5	9.99	217	430.0	2.18	130.8	0.17	4
135.0	0.68	41.1	9.04	196	435.0	2.20	132.3	0.16	3
140.0	0.71	42.6	8.20	178	440.0	2.23	133.8	0.15	3
145.0	0.73	44.1	7.36	160	445.0	2.26	135.3	0.15	3
150.0	0.76	45.6	6.78	147	450.0	2.28	136.9	0.13	3
155.0	0.79	47.1	6.20	134	455.0	2.31	138.4	0.12	3
160.0	0.81	48.7	5.83	126	460.0	2.33	139.9	0.12	3
165.0	0.84	50.2	5.47	119	465.0	2.36	141.4	0.11	2
170.0	0.86	51.7	5.15	112	470.0	2.38	142.9		
175.0	0.89	53.2	4.84	105	475.0	2.41	144.5		
180.0	0.91	54.7	4.57	99	480.0	2.43	146.0		
185.0	0.94	56.3	4.31	93	485.0	2.46	147.5		
190.0	0.96	57.8	4.10	89	490.0	2.48	149.0		
195.0	0.99	59.3	3.87	84	495.0	2.51	150.5		
200.0	1.01	60.8	3.68	80	500.0	2.53	152.1		
205.0	1.04	62.3	3.47	75	505.0	2.56	153.6		
210.0	1.06	63.9	3.28	71	510.0	2.59	155.1		
215.0	1.09	65.4	3.10	67	515.0	2.61	156.6		
220.0	1.12	66.9	2.93	64	520.0	2.64	158.1		
225.0	1.14	68.4	2.75	60	525.0	2.66	159.7		
230.0	1.17	69.9	2.63	57	530.0	2.69	161.2		
235.0	1.19	71.5	2.47	54	535.0	2.71	162.7		
240.0	1.22	73.0	2.33	51	540.0	2.74	164.2		
245.0	1.24	74.5	2.22	48	545.0	2.76	165.7		
250.0	1.27	76.0	2.10	46	550.0	2.79	167.3		
255.0	1.29	77.6	1.99	43	555.0	2.81	168.8		
260.0	1.32	79.1	1.88	41	560.0	2.84	170.3		
265.0	1.34	80.6	1.78	39	565.0	2.86	171.8		
270.0	1.37	82.1	1.68	36	570.0	2.89	173.3		
275.0	1.39	83.6	1.59	34	575.0	2.91	174.9		
280.0	1.42	85.2	1.50	33	580.0	2.94	176.4		
285.0	1.44	86.7	1.43	31	585.0	2.97	177.9		
290.0	1.47	88.2	1.36	29	590.0	2.99	179.4		
295.0	1.50	89.7	1.28	28	595.0	3.02	181.0		
300.0	1.52	91.2	1.21	26	600.0	3.04	182.5		

NOTES : Use for models including the Culvert C7 Basin for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

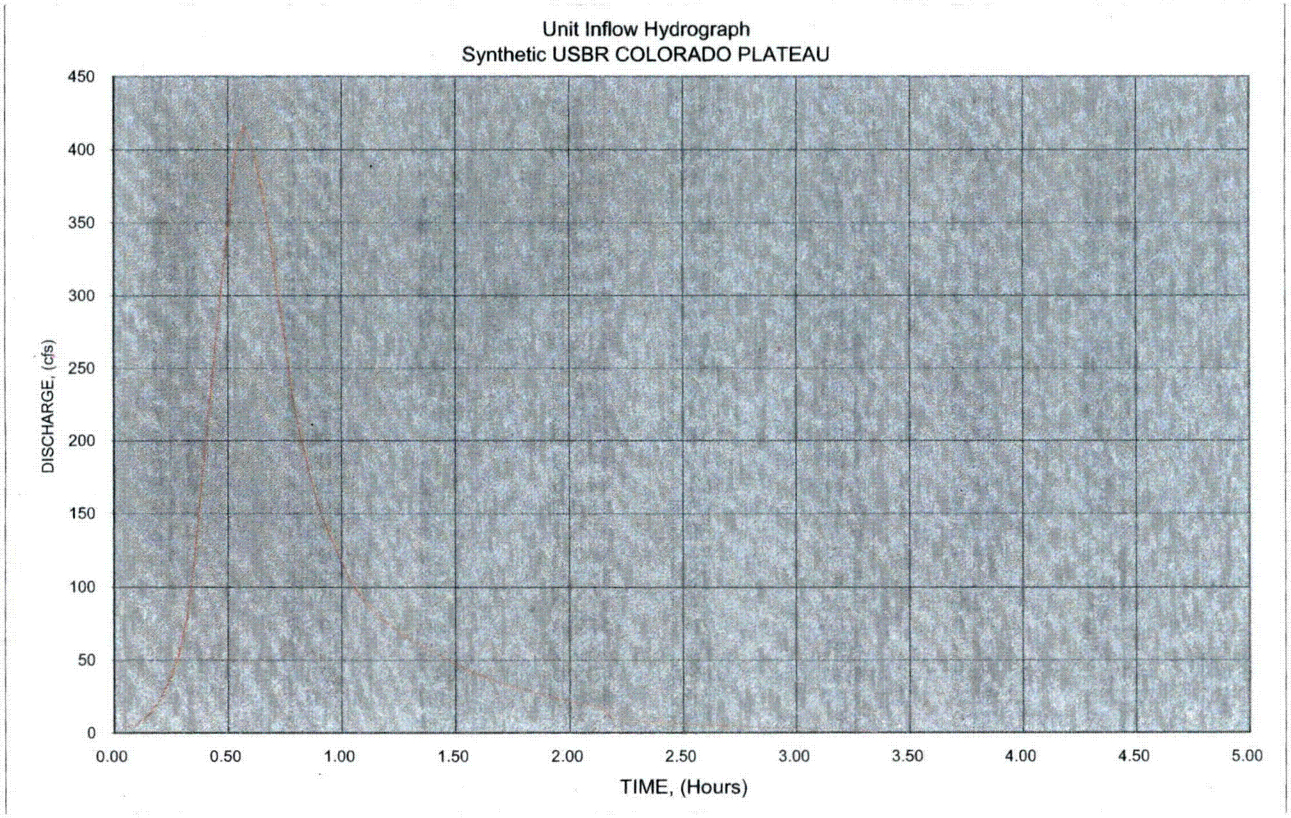
Basin D-10, 25, 100, 200 Proposed Conditions

Drainage Area = 0.3827 sq. miles
Basin Slope = 62.23 ft./mile
L = 1.25 mi., Length of Watercourse
Lca = 0.68 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 0.71 Hours
Basin Factor = 0.11
V' = 10.29 cfs/Day
Qs = 14.4 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.67 Hours
Unit Duration, D = 7.34 minutes
Calculated Timestep = 2.14 minutes

Data to be used in Analysis
Unit Duration, D = 5 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
Selected Timestep = 5 minutes, integer value evenly divisible into 60



UI Record - Unit Graph 5 **minute interval**

UI	5	15	38	93	218	345	412	359	273	197
UI	149	118	95	81	70	61	54	47	41	36
UI	32	28	25	22	19	17	15	13	11	10
UI	9	8	7	6	5	5	4	4	3	3
UI	3	2	2	2						
UI										
UI										
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USBR calculated unitgraph peak = 416 Interpolated Peak = 412

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.04	2.1	0.19	3	305.0	2.18	130.8	0.66	10
10.0	0.07	4.3	0.32	5	310.0	2.22	132.9	0.63	9
15.0	0.11	6.4	0.48	7	315.0	2.25	135.1	0.59	8
20.0	0.14	8.6	0.74	11	320.0	2.29	137.2	0.56	8
25.0	0.18	10.7	1.21	17	325.0	2.32	139.4	0.53	8
30.0	0.21	12.9	1.81	26	330.0	2.36	141.5	0.50	7
35.0	0.25	15.0	2.63	38	335.0	2.39	143.7	0.47	7
40.0	0.29	17.2	3.68	53	340.0	2.43	145.8	0.45	6
45.0	0.32	19.3	5.47	79	345.0	2.47	148.0	0.42	6
50.0	0.36	21.4	8.41	121	350.0	2.50	150.1	0.40	6
55.0	0.39	23.6	12.61	182	355.0	2.54	152.2	0.38	5
60.0	0.43	25.7	16.50	238	360.0	2.57	154.4	0.36	5
65.0	0.46	27.9	20.50	295	365.0	2.61	156.5	0.34	5
70.0	0.50	30.0	23.97	345	370.0	2.64	158.7	0.33	5
75.0	0.54	32.2	27.75	400	375.0	2.68	160.8	0.30	4
80.0	0.57	34.3	28.91	416	380.0	2.72	163.0	0.28	4
85.0	0.61	36.5	28.07	404	385.0	2.75	165.1	0.27	4
90.0	0.64	38.6	26.38	380	390.0	2.79	167.3	0.26	4
95.0	0.68	40.7	24.18	348	395.0	2.82	169.4	0.24	3
100.0	0.71	42.9	21.55	310	400.0	2.86	171.5	0.23	3
105.0	0.75	45.0	18.92	272	405.0	2.89	173.7	0.22	3
110.0	0.79	47.2	16.08	232	410.0	2.93	175.8	0.21	3
115.0	0.82	49.3	14.19	204	415.0	2.97	178.0	0.20	3
120.0	0.86	51.5	12.61	182	420.0	3.00	180.1	0.19	3
125.0	0.89	53.6	11.04	159	425.0	3.04	182.3	0.18	3
130.0	0.93	55.8	9.99	144	430.0	3.07	184.4	0.17	2
135.0	0.96	57.9	9.04	130	435.0	3.11	186.5	0.16	2
140.0	1.00	60.0	8.20	118	440.0	3.14	188.7	0.15	2
145.0	1.04	62.2	7.36	106	445.0	3.18	190.8	0.15	2
150.0	1.07	64.3	6.78	98	450.0	3.22	193.0	0.13	2
155.0	1.11	66.5	6.20	89	455.0	3.25	195.1	0.12	2
160.0	1.14	68.6	5.83	84	460.0	3.29	197.3	0.12	2
165.0	1.18	70.8	5.47	79	465.0	3.32	199.4	0.11	2
170.0	1.22	72.9	5.15	74	470.0	3.36	201.6		
175.0	1.25	75.0	4.84	70	475.0	3.40	203.7		
180.0	1.29	77.2	4.57	66	480.0	3.43	205.8		
185.0	1.32	79.3	4.31	62	485.0	3.47	208.0		
190.0	1.36	81.5	4.10	59	490.0	3.50	210.1		
195.0	1.39	83.6	3.87	56	495.0	3.54	212.3		
200.0	1.43	85.8	3.68	53	500.0	3.57	214.4		
205.0	1.47	87.9	3.47	50	505.0	3.61	216.6		
210.0	1.50	90.1	3.28	47	510.0	3.65	218.7		
215.0	1.54	92.2	3.10	45	515.0	3.68	220.9		
220.0	1.57	94.3	2.93	42	520.0	3.72	223.0		
225.0	1.61	96.5	2.75	40	525.0	3.75	225.1		
230.0	1.64	98.6	2.63	38	530.0	3.79	227.3		
235.0	1.68	100.8	2.47	36	535.0	3.82	229.4		
240.0	1.72	102.9	2.33	34	540.0	3.86	231.6		
245.0	1.75	105.1	2.22	32	545.0	3.90	233.7		
250.0	1.79	107.2	2.10	30	550.0	3.93	235.9		
255.0	1.82	109.4	1.99	29	555.0	3.97	238.0		
260.0	1.86	111.5	1.88	27	560.0	4.00	240.2		
265.0	1.89	113.6	1.78	26	565.0	4.04	242.3		
270.0	1.93	115.8	1.68	24	570.0	4.07	244.4		
275.0	1.97	117.9	1.59	23	575.0	4.11	246.6		
280.0	2.00	120.1	1.50	22	580.0	4.15	248.7		
285.0	2.04	122.2	1.43	21	585.0	4.18	250.9		
290.0	2.07	124.4	1.36	20	590.0	4.22	253.0		
295.0	2.11	126.5	1.28	18	595.0	4.25	255.2		
300.0	2.14	128.7	1.21	17	600.0	4.29	257.3		

NOTES : Use for models including Basin D for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

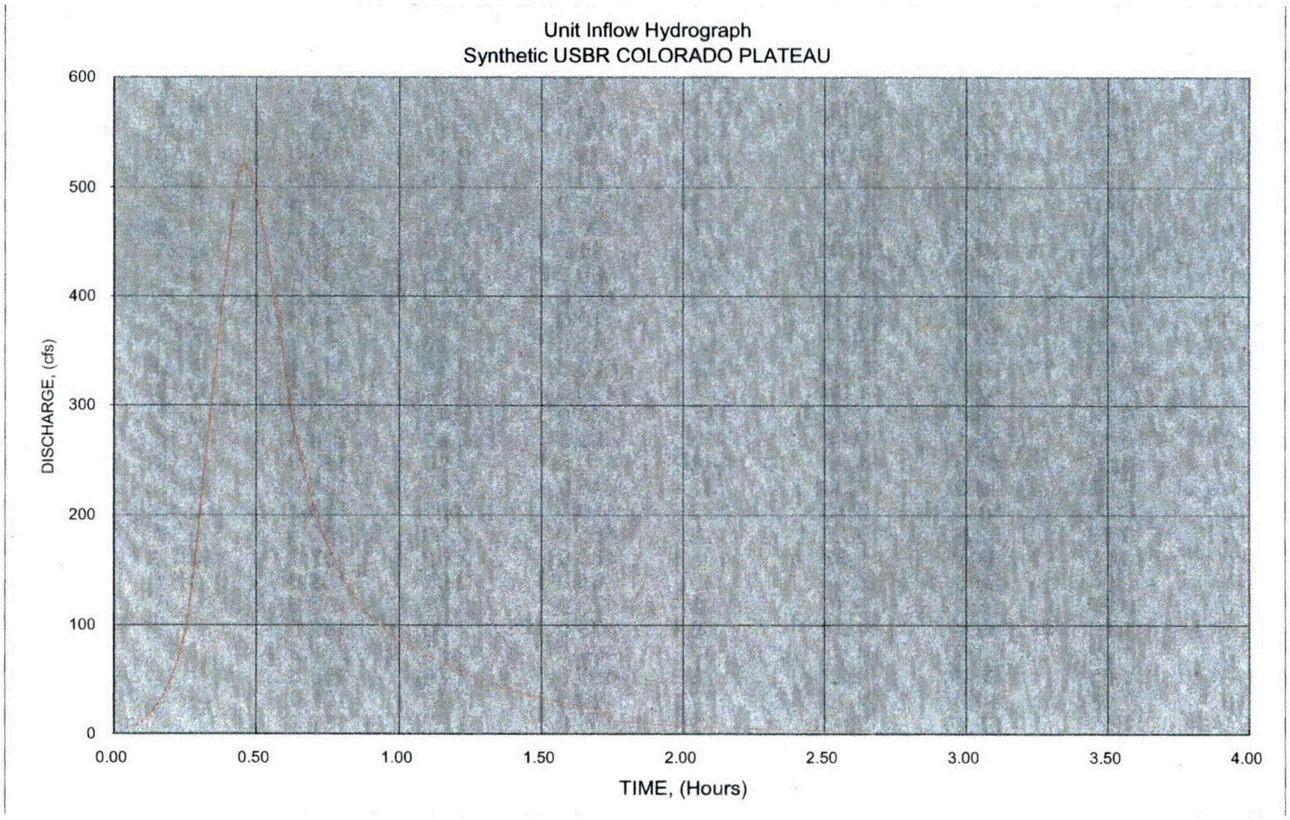
Basin D-PMP Proposed Conditions

Drainage Area = 0.3827 sq. miles
Basin Slope = 62.37 ft./mile
L = 1.28 mi., Length of Watercourse
Lca = 0.68 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

Lg+D/2 = 0.57 Hours
Basin Factor = 0.11
V' = 10.29 cfs/Day
Qs = 18.1 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.53 Hours
Unit Duration, D = 5.75 minutes
Calculated Timestep = 1.71 minutes

Data to be used in Analysis
Unit Duration, D = 5 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
Selected Timestep = 5 minutes, integer value evenly divisible into 60



UI Record - Unit Graph 5 **minute interval**

UI	8	31	92	278	477	490	366	244	175	130
UI	104	87	74	63	53	45	38	33	28	24
UI	20	17	15	12	11	9	8	7	5	5
UI	4	3	3	3	2					
UI										
UI										
UI										
UI										
UI										
II										
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UI										

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USBR calculated unitgraph peak = 523 Interpolated Peak = 490

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	1.7	0.19	3	305.0	1.74	104.1	0.66	12
10.0	0.06	3.4	0.32	6	310.0	1.76	105.9	0.63	11
15.0	0.09	5.1	0.48	9	315.0	1.79	107.6	0.59	11
20.0	0.11	6.8	0.74	13	320.0	1.82	109.3	0.56	10
25.0	0.14	8.5	1.21	22	325.0	1.85	111.0	0.53	10
30.0	0.17	10.2	1.81	33	330.0	1.88	112.7	0.50	9
35.0	0.20	12.0	2.63	48	335.0	1.91	114.4	0.47	8
40.0	0.23	13.7	3.68	67	340.0	1.93	116.1	0.45	8
45.0	0.26	15.4	5.47	99	345.0	1.96	117.8	0.42	8
50.0	0.28	17.1	8.41	152	350.0	1.99	119.5	0.40	7
55.0	0.31	18.8	12.61	228	355.0	2.02	121.2	0.38	7
60.0	0.34	20.5	16.50	298	360.0	2.05	122.9	0.36	7
65.0	0.37	22.2	20.50	371	365.0	2.08	124.6	0.34	6
70.0	0.40	23.9	23.97	433	370.0	2.11	126.3	0.33	6
75.0	0.43	25.6	27.75	502	375.0	2.13	128.0	0.30	5
80.0	0.46	27.3	28.91	523	380.0	2.16	129.8	0.28	5
85.0	0.48	29.0	28.07	508	385.0	2.19	131.5	0.27	5
90.0	0.51	30.7	26.38	477	390.0	2.22	133.2	0.26	5
95.0	0.54	32.4	24.18	437	395.0	2.25	134.9	0.24	4
100.0	0.57	34.1	21.55	390	400.0	2.28	136.6	0.23	4
105.0	0.60	35.9	18.92	342	405.0	2.30	138.3	0.22	4
110.0	0.63	37.6	16.08	291	410.0	2.33	140.0	0.21	4
115.0	0.65	39.3	14.19	257	415.0	2.36	141.7	0.20	4
120.0	0.68	41.0	12.61	228	420.0	2.39	143.4	0.19	3
125.0	0.71	42.7	11.04	200	425.0	2.42	145.1	0.18	3
130.0	0.74	44.4	9.99	181	430.0	2.45	146.8	0.17	3
135.0	0.77	46.1	9.04	163	435.0	2.48	148.5	0.16	3
140.0	0.80	47.8	8.20	148	440.0	2.50	150.2	0.15	3
145.0	0.83	49.5	7.36	133	445.0	2.53	151.9	0.15	3
150.0	0.85	51.2	6.78	123	450.0	2.56	153.7	0.13	2
155.0	0.88	52.9	6.20	112	455.0	2.59	155.4	0.12	2
160.0	0.91	54.6	5.83	105	460.0	2.62	157.1	0.12	2
165.0	0.94	56.3	5.47	99	465.0	2.65	158.8	0.11	2
170.0	0.97	58.0	5.15	93	470.0	2.67	160.5		
175.0	1.00	59.8	4.84	88	475.0	2.70	162.2		
180.0	1.02	61.5	4.57	83	480.0	2.73	163.9		
185.0	1.05	63.2	4.31	78	485.0	2.76	165.6		
190.0	1.08	64.9	4.10	74	490.0	2.79	167.3		
195.0	1.11	66.6	3.87	70	495.0	2.82	169.0		
200.0	1.14	68.3	3.68	67	500.0	2.85	170.7		
205.0	1.17	70.0	3.47	63	505.0	2.87	172.4		
210.0	1.20	71.7	3.28	59	510.0	2.90	174.1		
215.0	1.22	73.4	3.10	56	515.0	2.93	175.8		
220.0	1.25	75.1	2.93	53	520.0	2.96	177.6		
225.0	1.28	76.8	2.75	50	525.0	2.99	179.3		
230.0	1.31	78.5	2.63	48	530.0	3.02	181.0		
235.0	1.34	80.2	2.47	45	535.0	3.04	182.7		
240.0	1.37	81.9	2.33	42	540.0	3.07	184.4		
245.0	1.39	83.7	2.22	40	545.0	3.10	186.1		
250.0	1.42	85.4	2.10	38	550.0	3.13	187.8		
255.0	1.45	87.1	1.99	36	555.0	3.16	189.5		
260.0	1.48	88.8	1.88	34	560.0	3.19	191.2		
265.0	1.51	90.5	1.78	32	565.0	3.22	192.9		
270.0	1.54	92.2	1.68	30	570.0	3.24	194.6		
275.0	1.56	93.9	1.59	29	575.0	3.27	196.3		
280.0	1.59	95.6	1.50	27	580.0	3.30	198.0		
285.0	1.62	97.3	1.43	26	585.0	3.33	199.8		
290.0	1.65	99.0	1.36	25	590.0	3.36	201.5		
295.0	1.68	100.7	1.28	23	595.0	3.39	203.2		
300.0	1.71	102.4	1.21	22	600.0	3.41	204.9		

NOTES : Use for models including Basin D for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

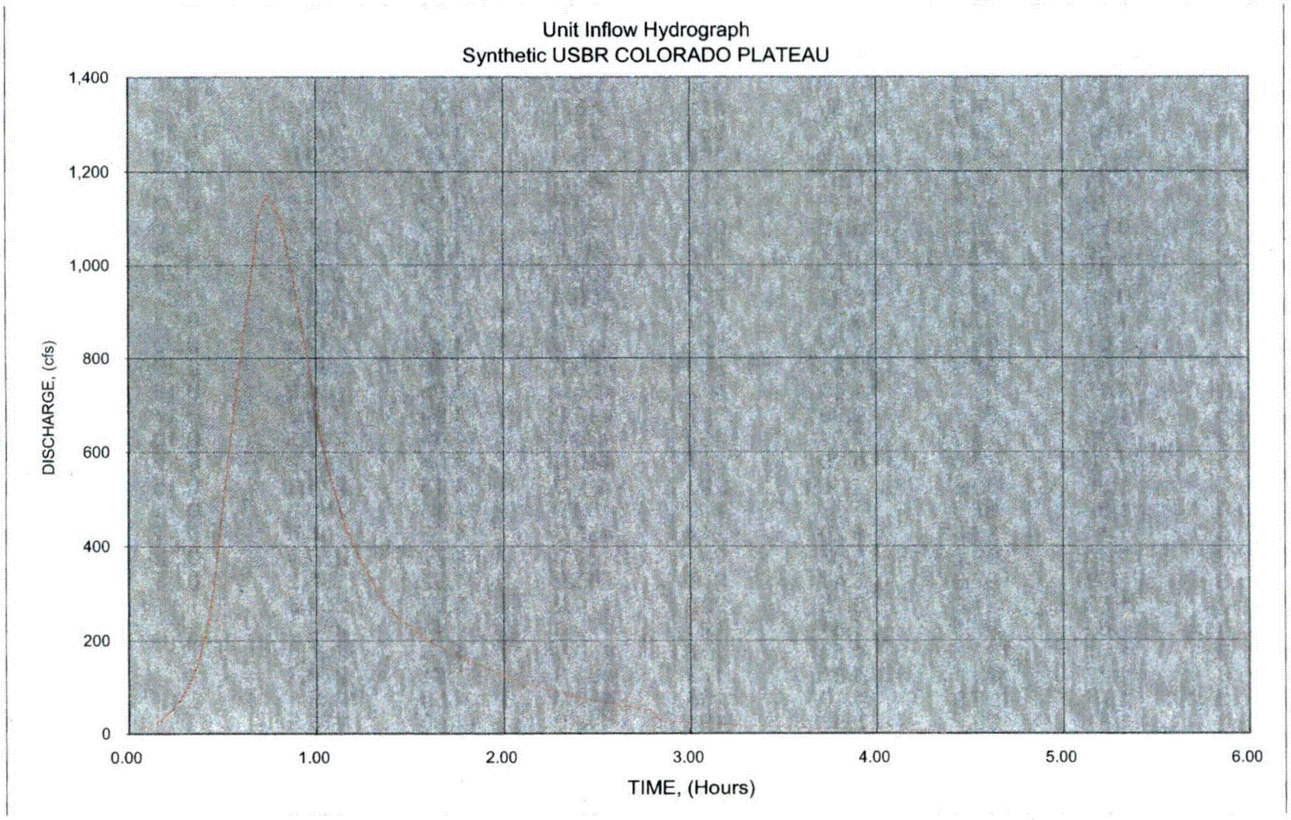
Basin G-10, 25, 100, 200 Proposed Conditions

Drainage Area = 1.3775 sq. miles
Basin Slope = 353 ft./mile
L = 2.96 mi., Length of Watercourse
Lca = 1.58 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 0.93 Hours
Basin Factor = 0.25
V' = 37.04 cfs/Day
Qs = 39.9 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.89 Hours Unit Duration, D = 9.68 minutes
Calculated Timestep = 2.79 minutes

Data to be used in Analysis Unit Duration, D = 5 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
Selected Timestep = 5 minutes, integer value evenly divisible into 60



UI Record - Unit Graph 5 **minute interval**

UI	12	25	57	112	216	463	747	1009	1148	1056
UI	887	694	545	435	364	303	259	228	204	183
UI	166	151	136	123	111	101	91	83	75	68
UI	61	56	50	46	41	37	34	31	28	25
UI	23	21	19	17	15	14	13	11	10	9
UI	9	8	7	6	6	5	5			
UI										
UI										
UI										
JI										
JI										
UI										

UI
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UI

USBR calculated unitgraph peak = 1153 Interpolated Peak = 1148

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.05	2.8	0.19	8	305.0	2.83	170.0	0.66	26
10.0	0.09	5.6	0.32	13	310.0	2.88	172.8	0.63	25
15.0	0.14	8.4	0.48	19	315.0	2.93	175.6	0.59	24
20.0	0.19	11.1	0.74	30	320.0	2.97	178.4	0.56	22
25.0	0.23	13.9	1.21	48	325.0	3.02	181.1	0.53	21
30.0	0.28	16.7	1.81	72	330.0	3.07	183.9	0.50	20
35.0	0.33	19.5	2.63	105	335.0	3.11	186.7	0.47	19
40.0	0.37	22.3	3.68	147	340.0	3.16	189.5	0.45	18
45.0	0.42	25.1	5.47	218	345.0	3.20	192.3	0.42	17
50.0	0.46	27.9	8.41	335	350.0	3.25	195.1	0.40	16
55.0	0.51	30.7	12.61	503	355.0	3.30	197.9	0.38	15
60.0	0.56	33.4	16.50	658	360.0	3.34	200.7	0.36	14
65.0	0.60	36.2	20.50	817	365.0	3.39	203.4	0.34	14
70.0	0.65	39.0	23.97	956	370.0	3.44	206.2	0.33	13
75.0	0.70	41.8	27.75	1,106	375.0	3.48	209.0	0.30	12
80.0	0.74	44.6	28.91	1,153	380.0	3.53	211.8	0.28	11
85.0	0.79	47.4	28.07	1,119	385.0	3.58	214.6	0.27	11
90.0	0.84	50.2	26.38	1,052	390.0	3.62	217.4	0.26	10
95.0	0.88	53.0	24.18	964	395.0	3.67	220.2	0.24	10
100.0	0.93	55.7	21.55	859	400.0	3.72	223.0	0.23	9
105.0	0.98	58.5	18.92	754	405.0	3.76	225.7	0.22	9
110.0	1.02	61.3	16.08	641	410.0	3.81	228.5	0.21	8
115.0	1.07	64.1	14.19	566	415.0	3.86	231.3	0.20	8
120.0	1.11	66.9	12.61	503	420.0	3.90	234.1	0.19	8
125.0	1.16	69.7	11.04	440	425.0	3.95	236.9	0.18	7
130.0	1.21	72.5	9.99	398	430.0	3.99	239.7	0.17	7
135.0	1.25	75.2	9.04	360	435.0	4.04	242.5	0.16	6
140.0	1.30	78.0	8.20	327	440.0	4.09	245.2	0.15	6
145.0	1.35	80.8	7.36	293	445.0	4.13	248.0	0.15	6
150.0	1.39	83.6	6.78	270	450.0	4.18	250.8	0.13	5
155.0	1.44	86.4	6.20	247	455.0	4.23	253.6	0.12	5
160.0	1.49	89.2	5.83	232	460.0	4.27	256.4	0.12	5
165.0	1.53	92.0	5.47	218	465.0	4.32	259.2	0.11	4
170.0	1.58	94.8	5.15	205	470.0	4.37	262.0		
175.0	1.63	97.5	4.84	193	475.0	4.41	264.8		
180.0	1.67	100.3	4.57	182	480.0	4.46	267.5		
185.0	1.72	103.1	4.31	172	485.0	4.51	270.3		
190.0	1.77	105.9	4.10	163	490.0	4.55	273.1		
195.0	1.81	108.7	3.87	154	495.0	4.60	275.9		
200.0	1.86	111.5	3.68	147	500.0	4.64	278.7		
205.0	1.90	114.3	3.47	138	505.0	4.69	281.5		
210.0	1.95	117.0	3.28	131	510.0	4.74	284.3		
215.0	2.00	119.8	3.10	124	515.0	4.78	287.0		
220.0	2.04	122.6	2.93	117	520.0	4.83	289.8		
225.0	2.09	125.4	2.75	110	525.0	4.88	292.6		
230.0	2.14	128.2	2.63	105	530.0	4.92	295.4		
235.0	2.18	131.0	2.47	98	535.0	4.97	298.2		
240.0	2.23	133.8	2.33	93	540.0	5.02	301.0		
245.0	2.28	136.6	2.22	89	545.0	5.06	303.8		
250.0	2.32	139.3	2.10	84	550.0	5.11	306.6		
255.0	2.37	142.1	1.99	79	555.0	5.16	309.3		
260.0	2.42	144.9	1.88	75	560.0	5.20	312.1		
265.0	2.46	147.7	1.78	71	565.0	5.25	314.9		
270.0	2.51	150.5	1.68	67	570.0	5.30	317.7		
275.0	2.55	153.3	1.59	63	575.0	5.34	320.5		
280.0	2.60	156.1	1.50	60	580.0	5.39	323.3		
285.0	2.65	158.9	1.43	57	585.0	5.43	326.1		
290.0	2.69	161.6	1.36	54	590.0	5.48	328.9		
295.0	2.74	164.4	1.28	51	595.0	5.53	331.6		
300.0	2.79	167.2	1.21	48	600.0	5.57	334.4		

NOTES : Use for models including Basin G for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

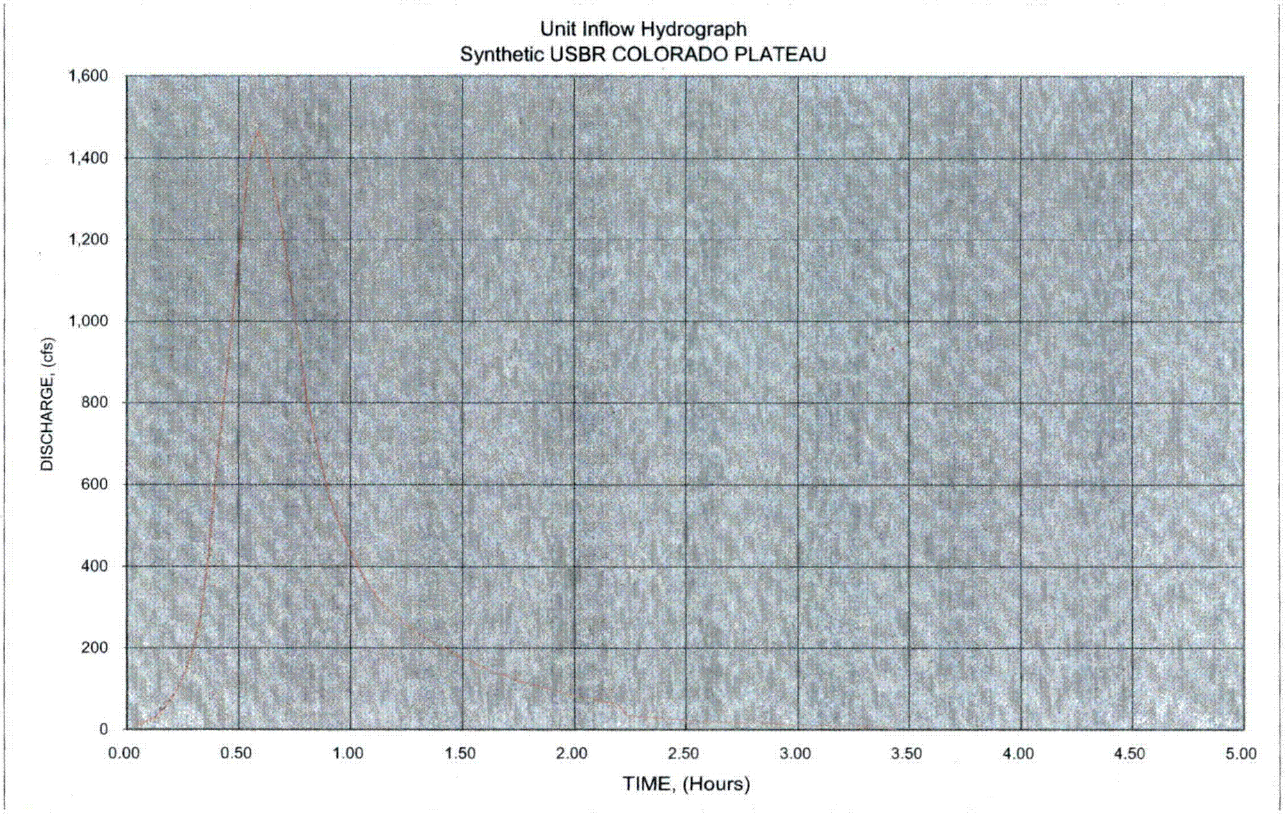
Basin G-PMP Proposed Conditions

Drainage Area = 1.3775 sq. miles
Basin Slope = 353 ft./mile
L = 2.96 mi., Length of Watercourse
Lca = 1.58 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

Lg+D/2 = 0.73 Hours
Basin Factor = 0.25
V' = 37.04 cfs/Day
Qs = 50.6 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.69 Hours
Unit Duration, D = 7.53 minutes
Calculated Timestep = 2.20 minutes

Data to be used in Analysis
Unit Duration, D = 5 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
Selected Timestep = 5 minutes, integer value evenly divisible into 60



UI Record - Unit Graph 5 **minute interval**

UI	18	51	126	293	715	1154	1460	1311	1025	740
UI	556	444	355	297	258	226	199	176	155	136
UI	119	106	93	82	73	64	56	50	43	39
UI	34	30	27	23	21	18	16	14	12	11
UI	10	9	8	6	6					
UI										
UI										
UI										
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USBR calculated unitgraph peak = 1463 Interpolated Peak = 1460

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.04	2.2	0.19	10
10.0	0.07	4.4	0.32	16
15.0	0.11	6.6	0.48	24
20.0	0.15	8.8	0.74	37
25.0	0.18	11.0	1.21	61
30.0	0.22	13.2	1.81	92
35.0	0.26	15.4	2.63	133
40.0	0.29	17.6	3.68	186
45.0	0.33	19.8	5.47	277
50.0	0.37	22.0	8.41	426
55.0	0.40	24.1	12.61	638
60.0	0.44	26.3	16.50	835
65.0	0.48	28.5	20.50	1,038
70.0	0.51	30.7	23.97	1,213
75.0	0.55	32.9	27.75	1,405
80.0	0.59	35.1	28.91	1,463
85.0	0.62	37.3	28.07	1,421
90.0	0.66	39.5	26.38	1,335
95.0	0.70	41.7	24.18	1,224
100.0	0.73	43.9	21.55	1,091
105.0	0.77	46.1	18.92	958
110.0	0.80	48.3	16.08	814
115.0	0.84	50.5	14.19	718
120.0	0.88	52.7	12.61	638
125.0	0.91	54.9	11.04	559
130.0	0.95	57.1	9.99	506
135.0	0.99	59.3	9.04	458
140.0	1.02	61.5	8.20	415
145.0	1.06	63.7	7.36	373
150.0	1.10	65.9	6.78	343
155.0	1.13	68.1	6.20	314
160.0	1.17	70.3	5.83	295
165.0	1.21	72.4	5.47	277
170.0	1.24	74.6	5.15	261
175.0	1.28	76.8	4.84	245
180.0	1.32	79.0	4.57	231
185.0	1.35	81.2	4.31	218
190.0	1.39	83.4	4.10	208
195.0	1.43	85.6	3.87	196
200.0	1.46	87.8	3.68	186
205.0	1.50	90.0	3.47	176
210.0	1.54	92.2	3.28	166
215.0	1.57	94.4	3.10	157
220.0	1.61	96.6	2.93	148
225.0	1.65	98.8	2.75	139
230.0	1.68	101.0	2.63	133
235.0	1.72	103.2	2.47	125
240.0	1.76	105.4	2.33	118
245.0	1.79	107.6	2.22	112
250.0	1.83	109.8	2.10	106
255.0	1.87	112.0	1.99	101
260.0	1.90	114.2	1.88	95
265.0	1.94	116.4	1.78	90
270.0	1.98	118.5	1.68	85
275.0	2.01	120.7	1.59	80
280.0	2.05	122.9	1.50	76
285.0	2.09	125.1	1.43	72
290.0	2.12	127.3	1.36	69
295.0	2.16	129.5	1.28	65
300.0	2.20	131.7	1.21	61
305.0	2.23	133.9	0.66	33
310.0	2.27	136.1	0.63	32
315.0	2.31	138.3	0.59	30
320.0	2.34	140.5	0.56	28
325.0	2.38	142.7	0.53	27
330.0	2.41	144.9	0.50	25
335.0	2.45	147.1	0.47	24
340.0	2.49	149.3	0.45	23
345.0	2.52	151.5	0.42	21
350.0	2.56	153.7	0.40	20
355.0	2.60	155.9	0.38	19
360.0	2.63	158.1	0.36	18
365.0	2.67	160.3	0.34	17
370.0	2.71	162.5	0.33	17
375.0	2.74	164.7	0.30	15
380.0	2.78	166.8	0.28	14
385.0	2.82	169.0	0.27	14
390.0	2.85	171.2	0.26	13
395.0	2.89	173.4	0.24	12
400.0	2.93	175.6	0.23	12
405.0	2.96	177.8	0.22	11
410.0	3.00	180.0	0.21	11
415.0	3.04	182.2	0.20	10
420.0	3.07	184.4	0.19	10
425.0	3.11	186.6	0.18	9
430.0	3.15	188.8	0.17	9
435.0	3.18	191.0	0.16	8
440.0	3.22	193.2	0.15	8
445.0	3.26	195.4	0.15	8
450.0	3.29	197.6	0.13	7
455.0	3.33	199.8	0.12	6
460.0	3.37	202.0	0.12	6
465.0	3.40	204.2	0.11	6
470.0	3.44	206.4		
475.0	3.48	208.6		
480.0	3.51	210.8		
485.0	3.55	212.9		
490.0	3.59	215.1		
495.0	3.62	217.3		
500.0	3.66	219.5		
505.0	3.70	221.7		
510.0	3.73	223.9		
515.0	3.77	226.1		
520.0	3.81	228.3		
525.0	3.84	230.5		
530.0	3.88	232.7		
535.0	3.92	234.9		
540.0	3.95	237.1		
545.0	3.99	239.3		
550.0	4.02	241.5		
555.0	4.06	243.7		
560.0	4.10	245.9		
565.0	4.13	248.1		
570.0	4.17	250.3		
575.0	4.21	252.5		
580.0	4.24	254.7		
585.0	4.28	256.9		
590.0	4.32	259.1		
595.0	4.35	261.2		
600.0	4.39	263.4		

NOTES : Use for models including Basin G for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH

18-May-06

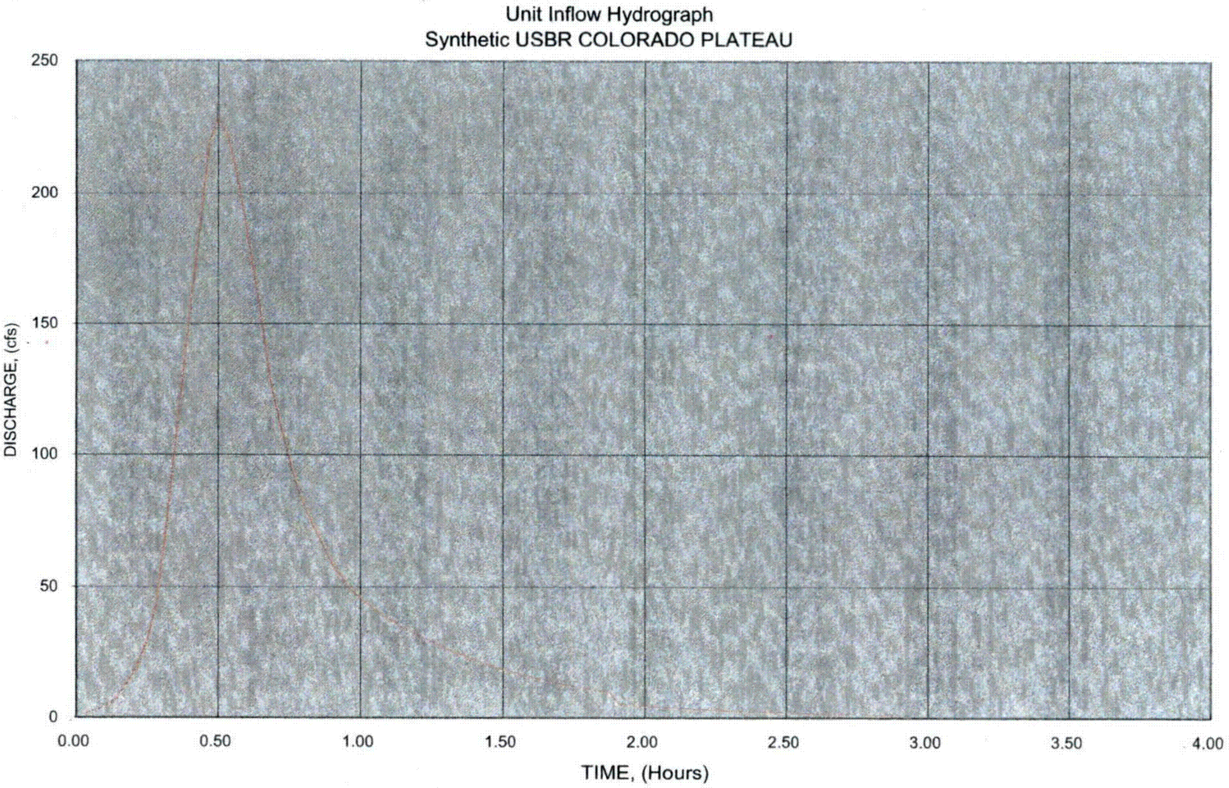
Design Point 1-10, 25, 100, 200 Proposed Conditions

Drainage Area = 0.1839 sq. miles
Basin Slope = 70.74 ft./mile
L = 1.13 mi., Length of Watercourse
Lca = 0.52 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 0.63 Hours
Basin Factor = 0.07
V' = 4.95 cfs/Day
Qs = 7.9 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.58 Hours
Unit Duration, D = 6.36 minutes
Calculated Timestep = 1.88 minutes

Data to be used in Analysis
Unit Duration, D = 5 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
Selected Timestep = 5 minutes, integer value evenly divisible into 60



UI Record - Unit Graph 5 **minute interval**

UI	6	24	88	220	282	210	133	91	66	53
UI	43	36	30	25	20	17	14	12	10	8
UI	7	6	5	4	3	3	2	2	2	1
UI										
UI										
UI										
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USBR calculated unitgraph peak = 229 Interpolated Peak = 282

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	1.9	0.19	2	305.0	1.91	114.4	0.66	5
10.0	0.06	3.8	0.32	3	310.0	1.94	116.3	0.63	5
15.0	0.09	5.6	0.48	4	315.0	1.97	118.1	0.59	5
20.0	0.13	7.5	0.74	6	320.0	2.00	120.0	0.56	4
25.0	0.16	9.4	1.21	10	325.0	2.03	121.9	0.53	4
30.0	0.19	11.3	1.81	14	330.0	2.06	123.8	0.50	4
35.0	0.22	13.1	2.63	21	335.0	2.09	125.6	0.47	4
40.0	0.25	15.0	3.68	29	340.0	2.13	127.5	0.45	4
45.0	0.28	16.9	5.47	43	345.0	2.16	129.4	0.42	3
50.0	0.31	18.8	8.41	67	350.0	2.19	131.3	0.40	3
55.0	0.34	20.6	12.61	100	355.0	2.22	133.1	0.38	3
60.0	0.38	22.5	16.50	131	360.0	2.25	135.0	0.36	3
65.0	0.41	24.4	20.50	162	365.0	2.28	136.9	0.34	3
70.0	0.44	26.3	23.97	190	370.0	2.31	138.8	0.33	3
75.0	0.47	28.1	27.75	220	375.0	2.34	140.6	0.30	2
80.0	0.50	30.0	28.91	229	380.0	2.38	142.5	0.28	2
85.0	0.53	31.9	28.07	222	385.0	2.41	144.4	0.27	2
90.0	0.56	33.8	26.38	209	390.0	2.44	146.3	0.26	2
95.0	0.59	35.6	24.18	191	395.0	2.47	148.1	0.24	2
100.0	0.63	37.5	21.55	170	400.0	2.50	150.0	0.23	2
105.0	0.66	39.4	18.92	150	405.0	2.53	151.9	0.22	2
110.0	0.69	41.3	16.08	127	410.0	2.56	153.8	0.21	2
115.0	0.72	43.1	14.19	112	415.0	2.59	155.6	0.20	2
120.0	0.75	45.0	12.61	100	420.0	2.63	157.5	0.19	2
125.0	0.78	46.9	11.04	87	425.0	2.66	159.4	0.18	1
130.0	0.81	48.8	9.99	79	430.0	2.69	161.3	0.17	1
135.0	0.84	50.6	9.04	72	435.0	2.72	163.1	0.16	1
140.0	0.88	52.5	8.20	65	440.0	2.75	165.0	0.15	1
145.0	0.91	54.4	7.36	58	445.0	2.78	166.9	0.15	1
150.0	0.94	56.3	6.78	54	450.0	2.81	168.8	0.13	1
155.0	0.97	58.1	6.20	49	455.0	2.84	170.6	0.12	1
160.0	1.00	60.0	5.83	46	460.0	2.88	172.5	0.12	1
165.0	1.03	61.9	5.47	43	465.0	2.91	174.4	0.11	1
170.0	1.06	63.8	5.15	41	470.0	2.94	176.3		
175.0	1.09	65.6	4.84	38	475.0	2.97	178.1		
180.0	1.13	67.5	4.57	36	480.0	3.00	180.0		
185.0	1.16	69.4	4.31	34	485.0	3.03	181.9		
190.0	1.19	71.3	4.10	32	490.0	3.06	183.8		
195.0	1.22	73.1	3.87	31	495.0	3.09	185.6		
200.0	1.25	75.0	3.68	29	500.0	3.13	187.5		
205.0	1.28	76.9	3.47	27	505.0	3.16	189.4		
210.0	1.31	78.8	3.28	26	510.0	3.19	191.3		
215.0	1.34	80.6	3.10	25	515.0	3.22	193.1		
220.0	1.38	82.5	2.93	23	520.0	3.25	195.0		
225.0	1.41	84.4	2.75	22	525.0	3.28	196.9		
230.0	1.44	86.3	2.63	21	530.0	3.31	198.8		
235.0	1.47	88.1	2.47	20	535.0	3.34	200.6		
240.0	1.50	90.0	2.33	18	540.0	3.38	202.5		
245.0	1.53	91.9	2.22	18	545.0	3.41	204.4		
250.0	1.56	93.8	2.10	17	550.0	3.44	206.3		
255.0	1.59	95.6	1.99	16	555.0	3.47	208.1		
260.0	1.63	97.5	1.88	15	560.0	3.50	210.0		
265.0	1.66	99.4	1.78	14	565.0	3.53	211.9		
270.0	1.69	101.3	1.68	13	570.0	3.56	213.8		
275.0	1.72	103.1	1.59	13	575.0	3.59	215.6		
280.0	1.75	105.0	1.50	12	580.0	3.63	217.5		
285.0	1.78	106.9	1.43	11	585.0	3.66	219.4		
290.0	1.81	108.8	1.36	11	590.0	3.69	221.3		
295.0	1.84	110.6	1.28	10	595.0	3.72	223.2		
300.0	1.88	112.5	1.21	10	600.0	3.75	225.0		

NOTES : Use for models including Design Point 1 (Basin E) for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

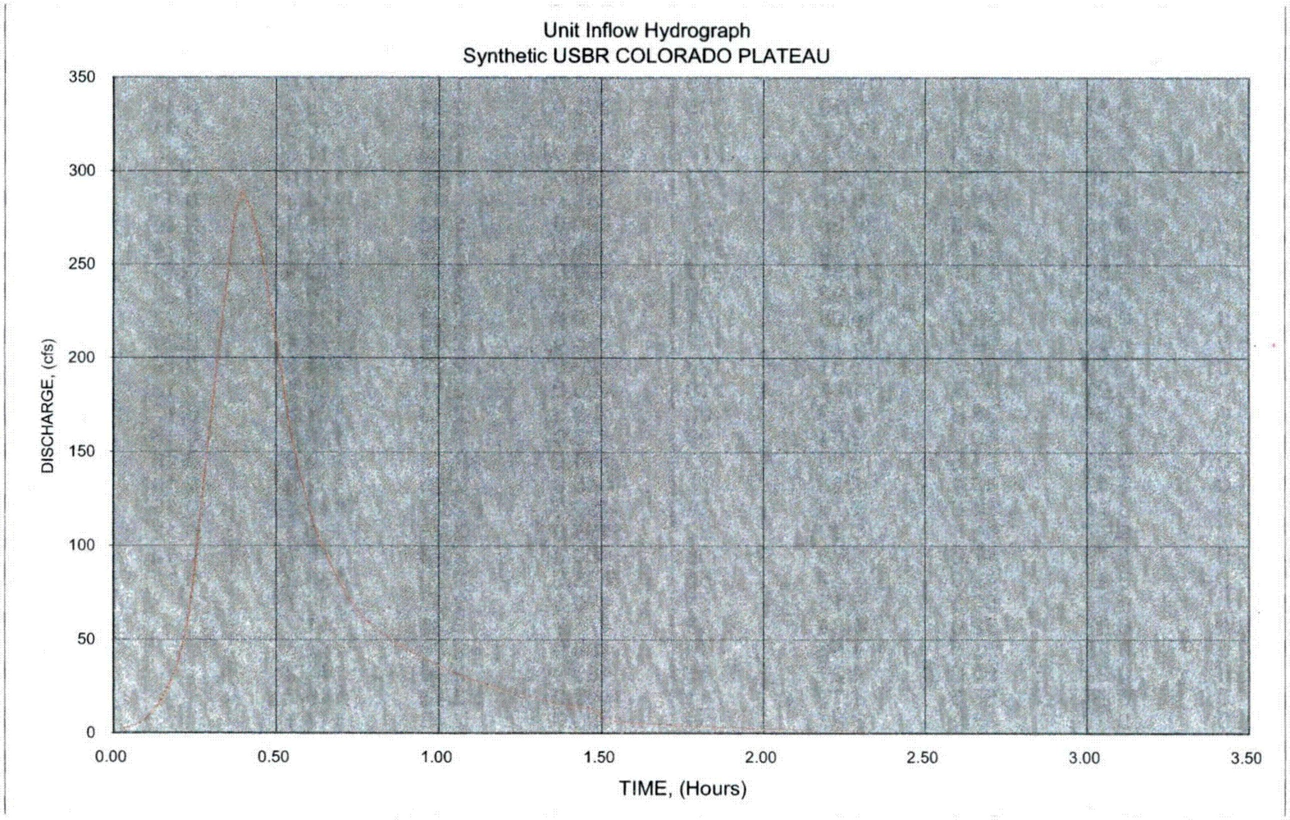
Design Point 1-PMP Proposed Conditions

Drainage Area =	0.1839	sq. miles	Lg+D/2 =	0.50	Hours
Basin Slope =	70.74	ft./mile	Basin Factor =	0.07	
L =	1.13	mi., Length of Watercourse	V' =	4.95	cfs/Day
Lca =	0.52	mi., Distance to Centroid	Qs =	10.0	* q, cfs
Kn =	0.042	-, Ave. Weighted Manning's n			

PARAMETERS:

Calculated:	Lag Time, Lg =	0.45 Hours	Unit Duration, D =	4.95	minutes
			Calculated Timestep =	1.49	minutes

Data to be used	Unit Duration, D =	5	minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
in Analysis	Selected Timestep =	5	minutes, integer value evenly divisible into 60



UI Record - Unit Graph 5 **minute interval**

UI	6	24	88	220	282	210	133	91	66	53
UI	43	36	30	25	20	17	14	12	10	8
UI	7	6	5	4	3	3	2	2	2	1
UI										
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UI										
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USBR calculated unitgraph peak = 289 Interpolated Peak = 282

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.02	1.5	0.19	2	305.0	1.51	90.7	0.66	7
10.0	0.05	3.0	0.32	3	310.0	1.54	92.1	0.63	6
15.0	0.07	4.5	0.48	5	315.0	1.56	93.6	0.59	6
20.0	0.10	5.9	0.74	7	320.0	1.59	95.1	0.56	6
25.0	0.12	7.4	1.21	12	325.0	1.61	96.6	0.53	5
30.0	0.15	8.9	1.81	18	330.0	1.63	98.1	0.50	5
35.0	0.17	10.4	2.63	26	335.0	1.66	99.6	0.47	5
40.0	0.20	11.9	3.68	37	340.0	1.68	101.1	0.45	4
45.0	0.22	13.4	5.47	55	345.0	1.71	102.6	0.42	4
50.0	0.25	14.9	8.41	84	350.0	1.73	104.0	0.40	4
55.0	0.27	16.3	12.61	126	355.0	1.76	105.5	0.38	4
60.0	0.30	17.8	16.50	165	360.0	1.78	107.0	0.36	4
65.0	0.32	19.3	20.50	205	365.0	1.81	108.5	0.34	3
70.0	0.35	20.8	23.97	239	370.0	1.83	110.0	0.33	3
75.0	0.37	22.3	27.75	277	375.0	1.86	111.5	0.30	3
80.0	0.40	23.8	28.91	289	380.0	1.88	113.0	0.28	3
85.0	0.42	25.3	28.07	280	385.0	1.91	114.4	0.27	3
90.0	0.45	26.8	26.38	263	390.0	1.93	115.9	0.26	3
95.0	0.47	28.2	24.18	241	395.0	1.96	117.4	0.24	2
100.0	0.50	29.7	21.55	215	400.0	1.98	118.9	0.23	2
105.0	0.52	31.2	18.92	189	405.0	2.01	120.4	0.22	2
110.0	0.54	32.7	16.08	161	410.0	2.03	121.9	0.21	2
115.0	0.57	34.2	14.19	142	415.0	2.06	123.4	0.20	2
120.0	0.59	35.7	12.61	126	420.0	2.08	124.8	0.19	2
125.0	0.62	37.2	11.04	110	425.0	2.11	126.3	0.18	2
130.0	0.64	38.6	9.99	100	430.0	2.13	127.8	0.17	2
135.0	0.67	40.1	9.04	90	435.0	2.16	129.3	0.16	2
140.0	0.69	41.6	8.20	82	440.0	2.18	130.8	0.15	1
145.0	0.72	43.1	7.36	73	445.0	2.20	132.3	0.15	1
150.0	0.74	44.6	6.78	68	450.0	2.23	133.8	0.13	1
155.0	0.77	46.1	6.20	62	455.0	2.25	135.3	0.12	1
160.0	0.79	47.6	5.83	58	460.0	2.28	136.7	0.12	1
165.0	0.82	49.0	5.47	55	465.0	2.30	138.2	0.11	1
170.0	0.84	50.5	5.15	51	470.0	2.33	139.7		
175.0	0.87	52.0	4.84	48	475.0	2.35	141.2		
180.0	0.89	53.5	4.57	46	480.0	2.38	142.7		
185.0	0.92	55.0	4.31	43	485.0	2.40	144.2		
190.0	0.94	56.5	4.10	41	490.0	2.43	145.7		
195.0	0.97	58.0	3.87	39	495.0	2.45	147.1		
200.0	0.99	59.5	3.68	37	500.0	2.48	148.6		
205.0	1.02	60.9	3.47	35	505.0	2.50	150.1		
210.0	1.04	62.4	3.28	33	510.0	2.53	151.6		
215.0	1.07	63.9	3.10	31	515.0	2.55	153.1		
220.0	1.09	65.4	2.93	29	520.0	2.58	154.6		
225.0	1.11	66.9	2.75	27	525.0	2.60	156.1		
230.0	1.14	68.4	2.63	26	530.0	2.63	157.5		
235.0	1.16	69.9	2.47	25	535.0	2.65	159.0		
240.0	1.19	71.3	2.33	23	540.0	2.68	160.5		
245.0	1.21	72.8	2.22	22	545.0	2.70	162.0		
250.0	1.24	74.3	2.10	21	550.0	2.72	163.5		
255.0	1.26	75.8	1.99	20	555.0	2.75	165.0		
260.0	1.29	77.3	1.88	19	560.0	2.77	166.5		
265.0	1.31	78.8	1.78	18	565.0	2.80	167.9		
270.0	1.34	80.3	1.68	17	570.0	2.82	169.4		
275.0	1.36	81.7	1.59	16	575.0	2.85	170.9		
280.0	1.39	83.2	1.50	15	580.0	2.87	172.4		
285.0	1.41	84.7	1.43	14	585.0	2.90	173.9		
290.0	1.44	86.2	1.36	14	590.0	2.92	175.4		
295.0	1.46	87.7	1.28	13	595.0	2.95	176.9		
300.0	1.49	89.2	1.21	12	600.0	2.97	178.4		

NOTES : Use for models including Design Point 1 (Basin E) for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH

18-May-06

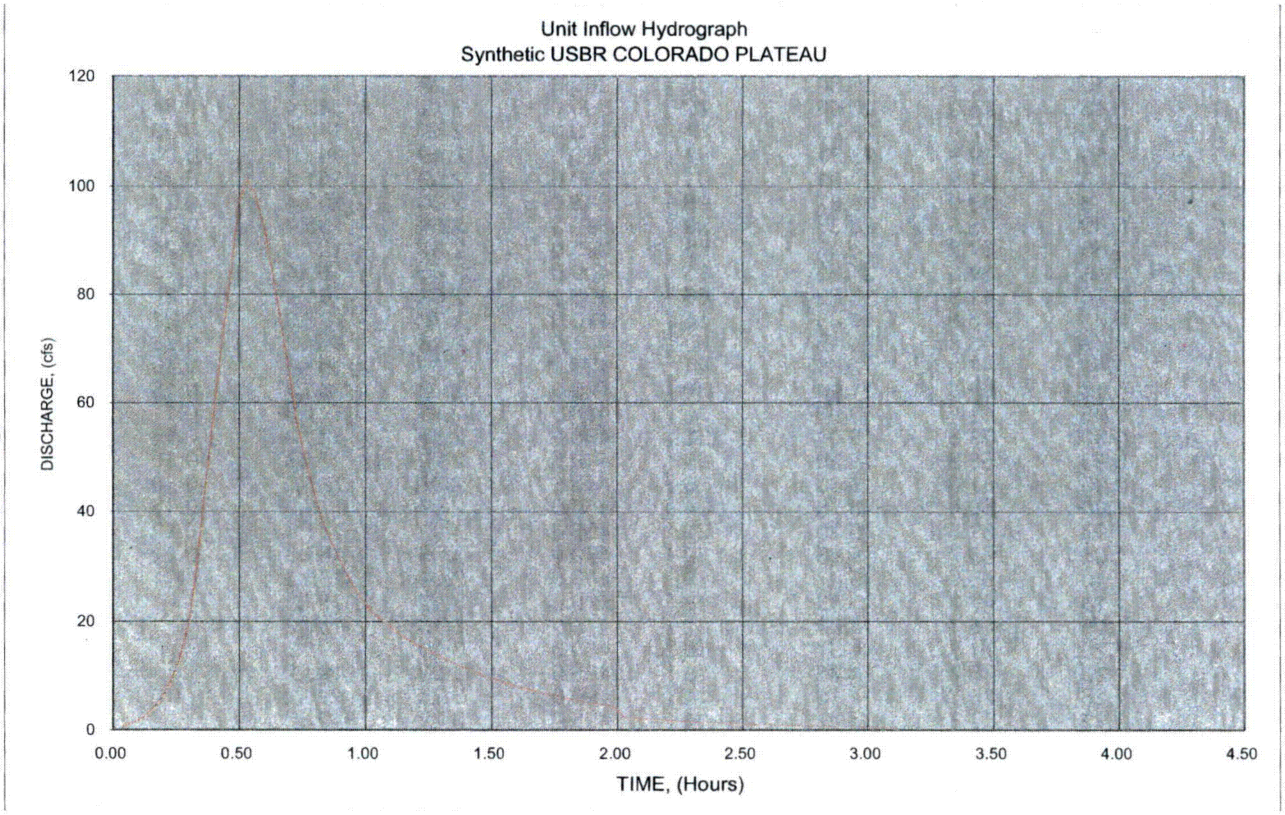
Design Point 2-10, 25, 100, 200 Proposed Conditions

Drainage Area = 0.0863 sq. miles
Basin Slope = 52.14 ft./mile
L = 1.04 mi., Length of Watercourse
Lca = 0.59 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 0.66 Hours
Basin Factor = 0.08
V' = 2.32 cfs/Day
Qs = 3.5 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.62 Hours
Unit Duration, D = 6.79 minutes
Calculated Timestep = 1.99 minutes

Data to be used in Analysis
Unit Duration, D = 5 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
Selected Timestep = 5 minutes, integer value evenly divisible into 60



UI Record - Unit Graph 5 **minute interval**

UI	1	4	11	30	65	97	95	75	52	38
UI	30	23	20	17	15	13	11	10	8	7
UI	6	5	5	4	4	3	3	2	2	2
UI	2	1	1	1	1	1	1	1	1	0
UI	0									
UI										
UI										
UI										
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UI										
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UI
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USBR calculated unitgraph peak = 101 Interpolated Peak = 97

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	2.0	0.19	1
10.0	0.07	4.0	0.32	1
15.0	0.10	6.0	0.48	2
20.0	0.13	8.0	0.74	3
25.0	0.17	10.0	1.21	4
30.0	0.20	12.0	1.81	6
35.0	0.23	13.9	2.63	9
40.0	0.27	15.9	3.68	13
45.0	0.30	17.9	5.47	19
50.0	0.33	19.9	8.41	29
55.0	0.37	21.9	12.61	44
60.0	0.40	23.9	16.50	58
65.0	0.43	25.9	20.50	72
70.0	0.46	27.9	23.97	84
75.0	0.50	29.9	27.75	97
80.0	0.53	31.9	28.91	101
85.0	0.56	33.9	28.07	98
90.0	0.60	35.9	26.38	92
95.0	0.63	37.8	24.18	85
100.0	0.66	39.8	21.55	75
105.0	0.70	41.8	18.92	66
110.0	0.73	43.8	16.08	56
115.0	0.76	45.8	14.19	50
120.0	0.80	47.8	12.61	44
125.0	0.83	49.8	11.04	39
130.0	0.86	51.8	9.99	35
135.0	0.90	53.8	9.04	32
140.0	0.93	55.8	8.20	29
145.0	0.96	57.8	7.36	26
150.0	1.00	59.8	6.78	24
155.0	1.03	61.8	6.20	22
160.0	1.06	63.7	5.83	20
165.0	1.10	65.7	5.47	19
170.0	1.13	67.7	5.15	18
175.0	1.16	69.7	4.84	17
180.0	1.20	71.7	4.57	16
185.0	1.23	73.7	4.31	15
190.0	1.26	75.7	4.10	14
195.0	1.29	77.7	3.87	14
200.0	1.33	79.7	3.68	13
205.0	1.36	81.7	3.47	12
210.0	1.39	83.7	3.28	11
215.0	1.43	85.7	3.10	11
220.0	1.46	87.7	2.93	10
225.0	1.49	89.6	2.75	10
230.0	1.53	91.6	2.63	9
235.0	1.56	93.6	2.47	9
240.0	1.59	95.6	2.33	8
245.0	1.63	97.6	2.22	8
250.0	1.66	99.6	2.10	7
255.0	1.69	101.6	1.99	7
260.0	1.73	103.6	1.88	7
265.0	1.76	105.6	1.78	6
270.0	1.79	107.6	1.68	6
275.0	1.83	109.6	1.59	6
280.0	1.86	111.6	1.50	5
285.0	1.89	113.5	1.43	5
290.0	1.93	115.5	1.36	5
295.0	1.96	117.5	1.28	4
300.0	1.99	119.5	1.21	4
305.0	2.03	121.5	0.66	2
310.0	2.06	123.5	0.63	2
315.0	2.09	125.5	0.59	2
320.0	2.12	127.5	0.56	2
325.0	2.16	129.5	0.53	2
330.0	2.19	131.5	0.50	2
335.0	2.22	133.5	0.47	2
340.0	2.26	135.5	0.45	2
345.0	2.29	137.5	0.42	1
350.0	2.32	139.4	0.40	1
355.0	2.36	141.4	0.38	1
360.0	2.39	143.4	0.36	1
365.0	2.42	145.4	0.34	1
370.0	2.46	147.4	0.33	1
375.0	2.49	149.4	0.30	1
380.0	2.52	151.4	0.28	1
385.0	2.56	153.4	0.27	1
390.0	2.59	155.4	0.26	1
395.0	2.62	157.4	0.24	1
400.0	2.66	159.4	0.23	1
405.0	2.69	161.4	0.22	1
410.0	2.72	163.3	0.21	1
415.0	2.76	165.3	0.20	1
420.0	2.79	167.3	0.19	1
425.0	2.82	169.3	0.18	1
430.0	2.86	171.3	0.17	1
435.0	2.89	173.3	0.16	1
440.0	2.92	175.3	0.15	1
445.0	2.95	177.3	0.15	1
450.0	2.99	179.3	0.13	0
455.0	3.02	181.3	0.12	0
460.0	3.05	183.3	0.12	0
465.0	3.09	185.3	0.11	0
470.0	3.12	187.3		
475.0	3.15	189.2		
480.0	3.19	191.2		
485.0	3.22	193.2		
490.0	3.25	195.2		
495.0	3.29	197.2		
500.0	3.32	199.2		
505.0	3.35	201.2		
510.0	3.39	203.2		
515.0	3.42	205.2		
520.0	3.45	207.2		
525.0	3.49	209.2		
530.0	3.52	211.2		
535.0	3.55	213.1		
540.0	3.59	215.1		
545.0	3.62	217.1		
550.0	3.65	219.1		
555.0	3.69	221.1		
560.0	3.72	223.1		
565.0	3.75	225.1		
570.0	3.78	227.1		
575.0	3.82	229.1		
580.0	3.85	231.1		
585.0	3.88	233.1		
590.0	3.92	235.1		
595.0	3.95	237.1		
600.0	3.98	239.0		

NOTES : Use for models including Design Point 2 (Basin F) for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH

18-May-06

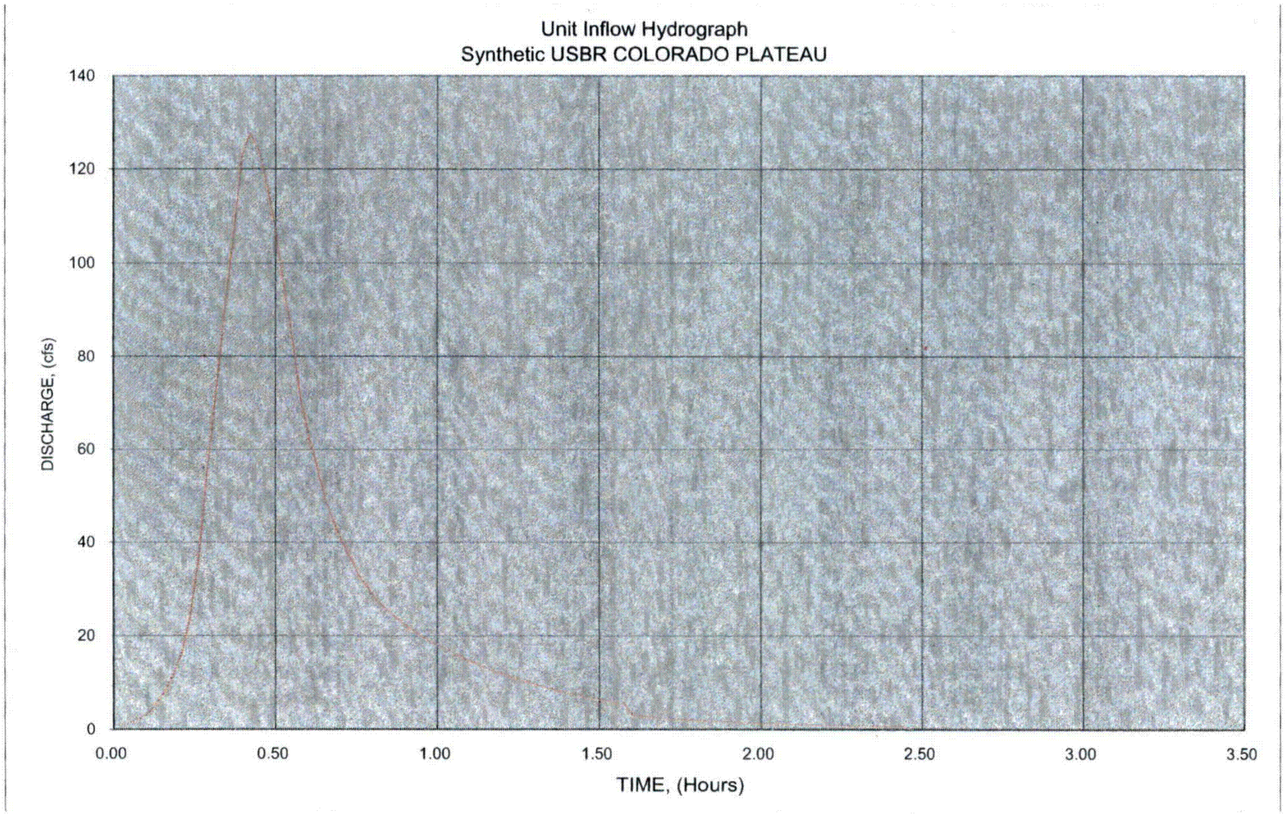
Design Point 2-PMP Proposed Conditions

Drainage Area = 0.0863 sq. miles
Basin Slope = 52.14 ft./mile
L = 1.04 mi., Length of Watercourse
Lca = 0.59 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

Lg+D/2 = 0.53 Hours
Basin Factor = 0.08
V' = 2.32 cfs/Day
Qs = 4.4 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.48 Hours
Unit Duration, D = 5.28 minutes
Calculated Timestep = 1.58 minutes

Data to be used in Analysis
Unit Duration, D = 5 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
Selected Timestep = 5 minutes, integer value evenly divisible into 60



UI Record - Unit Graph 5 **minute interval**

UI	2	9	31	85	127	106	69	47	34	26
UI	22	18	15	13	11	9	7	6	5	4
UI	4	3	3	2	2	2	1	1	1	1
UI	1	1								
UI										
UI										
UI										
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UI										
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USBR calculated unitgraph peak = 128 Interpolated Peak = 127

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	1.6	0.19	1	305.0	1.60	96.2	0.66	3
10.0	0.05	3.2	0.32	1	310.0	1.63	97.8	0.63	3
15.0	0.08	4.7	0.48	2	315.0	1.66	99.4	0.59	3
20.0	0.11	6.3	0.74	3	320.0	1.68	100.9	0.56	2
25.0	0.13	7.9	1.21	5	325.0	1.71	102.5	0.53	2
30.0	0.16	9.5	1.81	8	330.0	1.73	104.1	0.50	2
35.0	0.18	11.0	2.63	12	335.0	1.76	105.7	0.47	2
40.0	0.21	12.6	3.68	16	340.0	1.79	107.2	0.45	2
45.0	0.24	14.2	5.47	24	345.0	1.81	108.8	0.42	2
50.0	0.26	15.8	8.41	37	350.0	1.84	110.4	0.40	2
55.0	0.29	17.3	12.61	56	355.0	1.87	112.0	0.38	2
60.0	0.32	18.9	16.50	73	360.0	1.89	113.6	0.36	2
65.0	0.34	20.5	20.50	90	365.0	1.92	115.1	0.34	2
70.0	0.37	22.1	23.97	106	370.0	1.95	116.7	0.33	1
75.0	0.39	23.7	27.75	122	375.0	1.97	118.3	0.30	1
80.0	0.42	25.2	28.91	128	380.0	2.00	119.9	0.28	1
85.0	0.45	26.8	28.07	124	385.0	2.02	121.4	0.27	1
90.0	0.47	28.4	26.38	116	390.0	2.05	123.0	0.26	1
95.0	0.50	30.0	24.18	107	395.0	2.08	124.6	0.24	1
100.0	0.53	31.5	21.55	95	400.0	2.10	126.2	0.23	1
105.0	0.55	33.1	18.92	84	405.0	2.13	127.7	0.22	1
110.0	0.58	34.7	16.08	71	410.0	2.16	129.3	0.21	1
115.0	0.60	36.3	14.19	63	415.0	2.18	130.9	0.20	1
120.0	0.63	37.9	12.61	56	420.0	2.21	132.5	0.19	1
125.0	0.66	39.4	11.04	49	425.0	2.23	134.1	0.18	1
130.0	0.68	41.0	9.99	44	430.0	2.26	135.6	0.17	1
135.0	0.71	42.6	9.04	40	435.0	2.29	137.2	0.16	1
140.0	0.74	44.2	8.20	36	440.0	2.31	138.8	0.15	1
145.0	0.76	45.7	7.36	32	445.0	2.34	140.4	0.15	1
150.0	0.79	47.3	6.78	30	450.0	2.37	141.9	0.13	1
155.0	0.81	48.9	6.20	27	455.0	2.39	143.5	0.12	1
160.0	0.84	50.5	5.83	26	460.0	2.42	145.1	0.12	1
165.0	0.87	52.0	5.47	24	465.0	2.44	146.7	0.11	0
170.0	0.89	53.6	5.15	23	470.0	2.47	148.3		
175.0	0.92	55.2	4.84	21	475.0	2.50	149.8		
180.0	0.95	56.8	4.57	20	480.0	2.52	151.4		
185.0	0.97	58.4	4.31	19	485.0	2.55	153.0		
190.0	1.00	59.9	4.10	18	490.0	2.58	154.6		
195.0	1.03	61.5	3.87	17	495.0	2.60	156.1		
200.0	1.05	63.1	3.68	16	500.0	2.63	157.7		
205.0	1.08	64.7	3.47	15	505.0	2.65	159.3		
210.0	1.10	66.2	3.28	14	510.0	2.68	160.9		
215.0	1.13	67.8	3.10	14	515.0	2.71	162.4		
220.0	1.16	69.4	2.93	13	520.0	2.73	164.0		
225.0	1.18	71.0	2.75	12	525.0	2.76	165.6		
230.0	1.21	72.5	2.63	12	530.0	2.79	167.2		
235.0	1.24	74.1	2.47	11	535.0	2.81	168.8		
240.0	1.26	75.7	2.33	10	540.0	2.84	170.3		
245.0	1.29	77.3	2.22	10	545.0	2.87	171.9		
250.0	1.31	78.9	2.10	9	550.0	2.89	173.5		
255.0	1.34	80.4	1.99	9	555.0	2.92	175.1		
260.0	1.37	82.0	1.88	8	560.0	2.94	176.6		
265.0	1.39	83.6	1.78	8	565.0	2.97	178.2		
270.0	1.42	85.2	1.68	7	570.0	3.00	179.8		
275.0	1.45	86.7	1.59	7	575.0	3.02	181.4		
280.0	1.47	88.3	1.50	7	580.0	3.05	182.9		
285.0	1.50	89.9	1.43	6	585.0	3.08	184.5		
290.0	1.52	91.5	1.36	6	590.0	3.10	186.1		
295.0	1.55	93.1	1.28	6	595.0	3.13	187.7		
300.0	1.58	94.6	1.21	5	600.0	3.15	189.3		

NOTES : Use for models including Design Point 2 (Basin F) for the PMP Local event

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

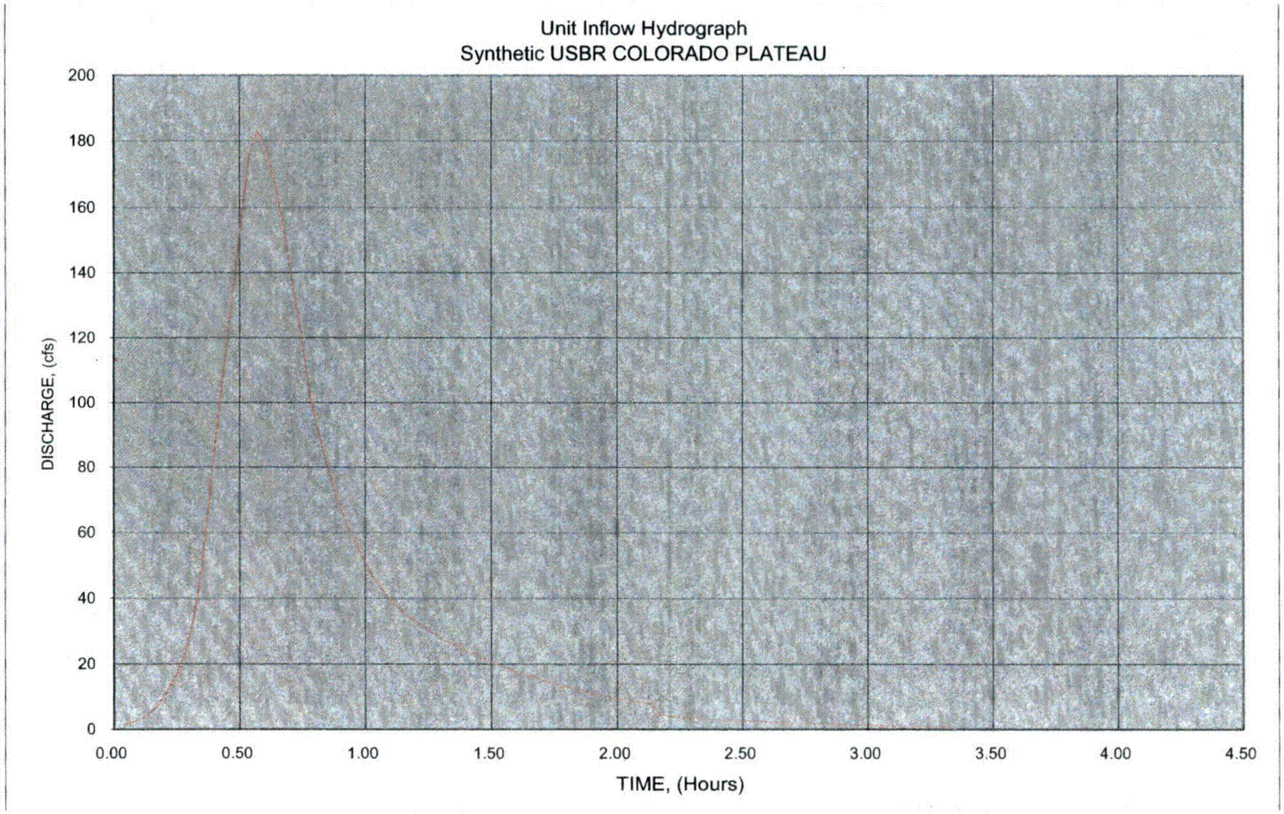
Design Point 3-10, 25, 100, 200 Proposed Conditions

Drainage Area = 0.1675 sq. miles
Basin Slope = 77.56 ft./mile
L = 1.34 mi., Length of Watercourse
Lca = 0.7 mi., Distance to Centroid
Kn = 0.054 -, Ave. Weighted Manning's n

Lg+D/2 = 0.71 Hours
Basin Factor = 0.11
V' = 4.50 cfs/Day
Qs = 6.3 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.67 Hours
Unit Duration, D = 7.31 minutes
Calculated Timestep = 2.14 minutes

Data to be used in Analysis
Unit Duration, D = 5 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
Selected Timestep = 5 minutes, integer value evenly divisible into 60



UI Record - Unit Graph 5 **minute interval**

UI	2	7	17	41	97	153	181	157	119	86
UI	65	51	41	35	30	27	24	21	18	16
UI	14	12	11	9	8	7	6	6	5	4
UI	4	3	3	3	2	2	2	2	1	1
UI	1	1	1	1						
UI										
UI										
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USBR calculated unitgraph peak = 183 Interpolated Peak = 181

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.04	2.1	0.19	1
10.0	0.07	4.3	0.32	2
15.0	0.11	6.4	0.48	3
20.0	0.14	8.5	0.74	5
25.0	0.18	10.7	1.21	8
30.0	0.21	12.8	1.81	11
35.0	0.25	15.0	2.63	17
40.0	0.28	17.1	3.68	23
45.0	0.32	19.2	5.47	35
50.0	0.36	21.4	8.41	53
55.0	0.39	23.5	12.61	80
60.0	0.43	25.6	16.50	104
65.0	0.46	27.8	20.50	130
70.0	0.50	29.9	23.97	152
75.0	0.53	32.0	27.75	176
80.0	0.57	34.2	28.91	183
85.0	0.61	36.3	28.07	178
90.0	0.64	38.5	26.38	167
95.0	0.68	40.6	24.18	153
100.0	0.71	42.7	21.55	136
105.0	0.75	44.9	18.92	120
110.0	0.78	47.0	16.08	102
115.0	0.82	49.1	14.19	90
120.0	0.85	51.3	12.61	80
125.0	0.89	53.4	11.04	70
130.0	0.93	55.5	9.99	63
135.0	0.96	57.7	9.04	57
140.0	1.00	59.8	8.20	52
145.0	1.03	62.0	7.36	47
150.0	1.07	64.1	6.78	43
155.0	1.10	66.2	6.20	39
160.0	1.14	68.4	5.83	37
165.0	1.18	70.5	5.47	35
170.0	1.21	72.6	5.15	33
175.0	1.25	74.8	4.84	31
180.0	1.28	76.9	4.57	29
185.0	1.32	79.1	4.31	27
190.0	1.35	81.2	4.10	26
195.0	1.39	83.3	3.87	24
200.0	1.42	85.5	3.68	23
205.0	1.46	87.6	3.47	22
210.0	1.50	89.7	3.28	21
215.0	1.53	91.9	3.10	20
220.0	1.57	94.0	2.93	19
225.0	1.60	96.1	2.75	17
230.0	1.64	98.3	2.63	17
235.0	1.67	100.4	2.47	16
240.0	1.71	102.6	2.33	15
245.0	1.74	104.7	2.22	14
250.0	1.78	106.8	2.10	13
255.0	1.82	109.0	1.99	13
260.0	1.85	111.1	1.88	12
265.0	1.89	113.2	1.78	11
270.0	1.92	115.4	1.68	11
275.0	1.96	117.5	1.59	10
280.0	1.99	119.6	1.50	9
285.0	2.03	121.8	1.43	9
290.0	2.07	123.9	1.36	9
295.0	2.10	126.1	1.28	8
300.0	2.14	128.2	1.21	8
305.0	2.17	130.3	0.66	4
310.0	2.21	132.5	0.63	4
315.0	2.24	134.6	0.59	4
320.0	2.28	136.7	0.56	4
325.0	2.31	138.9	0.53	3
330.0	2.35	141.0	0.50	3
335.0	2.39	143.1	0.47	3
340.0	2.42	145.3	0.45	3
345.0	2.46	147.4	0.42	3
350.0	2.49	149.6	0.40	3
355.0	2.53	151.7	0.38	2
360.0	2.56	153.8	0.36	2
365.0	2.60	156.0	0.34	2
370.0	2.64	158.1	0.33	2
375.0	2.67	160.2	0.30	2
380.0	2.71	162.4	0.28	2
385.0	2.74	164.5	0.27	2
390.0	2.78	166.6	0.26	2
395.0	2.81	168.8	0.24	2
400.0	2.85	170.9	0.23	1
405.0	2.88	173.1	0.22	1
410.0	2.92	175.2	0.21	1
415.0	2.96	177.3	0.20	1
420.0	2.99	179.5	0.19	1
425.0	3.03	181.6	0.18	1
430.0	3.06	183.7	0.17	1
435.0	3.10	185.9	0.16	1
440.0	3.13	188.0	0.15	1
445.0	3.17	190.2	0.15	1
450.0	3.20	192.3	0.13	1
455.0	3.24	194.4	0.12	1
460.0	3.28	196.6	0.12	1
465.0	3.31	198.7	0.11	1
470.0	3.35	200.8		
475.0	3.38	203.0		
480.0	3.42	205.1		
485.0	3.45	207.2		
490.0	3.49	209.4		
495.0	3.53	211.5		
500.0	3.56	213.7		
505.0	3.60	215.8		
510.0	3.63	217.9		
515.0	3.67	220.1		
520.0	3.70	222.2		
525.0	3.74	224.3		
530.0	3.77	226.5		
535.0	3.81	228.6		
540.0	3.85	230.7		
545.0	3.88	232.9		
550.0	3.92	235.0		
555.0	3.95	237.2		
560.0	3.99	239.3		
565.0	4.02	241.4		
570.0	4.06	243.6		
575.0	4.10	245.7		
580.0	4.13	247.8		
585.0	4.17	250.0		
590.0	4.20	252.1		
595.0	4.24	254.2		
600.0	4.27	256.4		

NOTES : Use for models including Design Point 3 (Basin C) for the 10, 25, 100 and 200 year events

COLORADO PLATEAU UNIT HYDROGRAPH 18-May-06

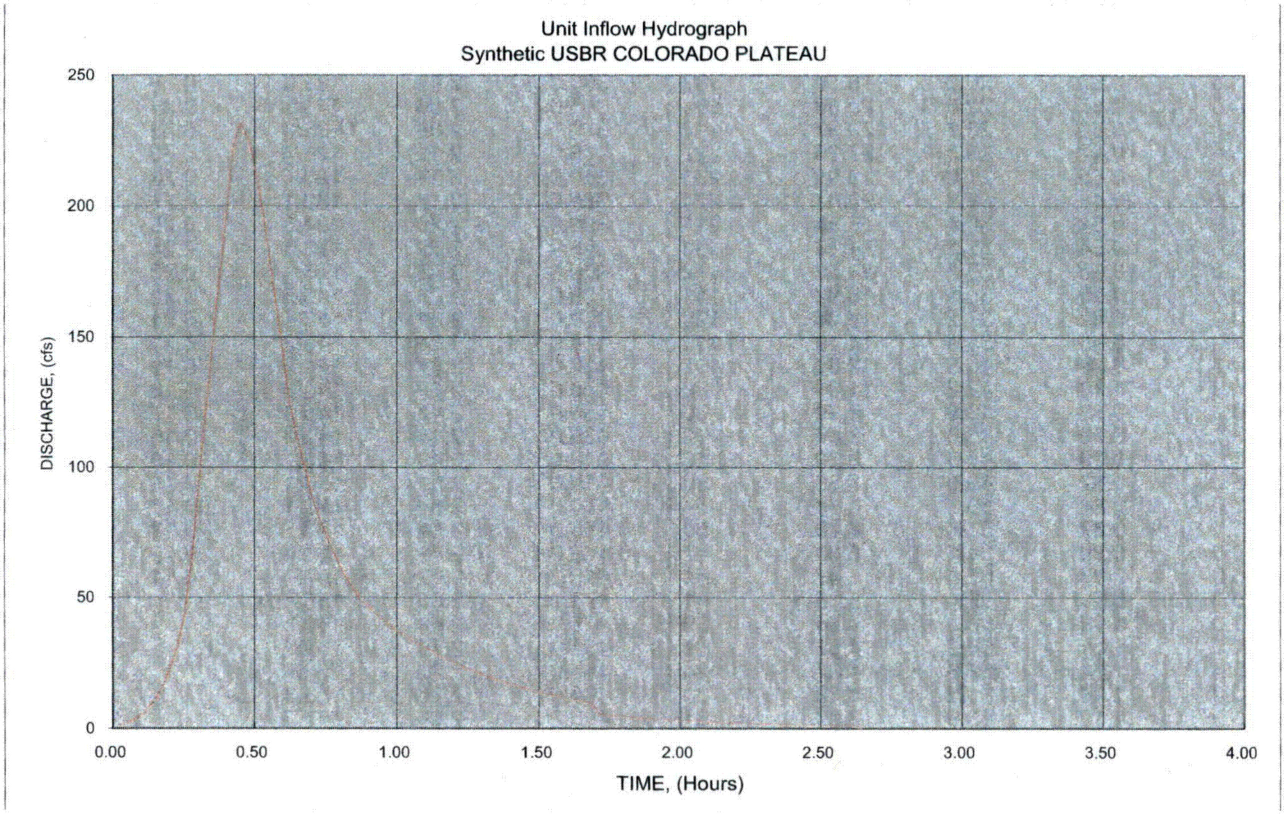
Design Point 3-PMP Proposed Conditions

Drainage Area = 0.1675 sq. miles
Basin Slope = 77.56 ft./mile
L = 1.34 mi., Length of Watercourse
Lca = 0.7 mi., Distance to Centroid
Kn = 0.042 -, Ave. Weighted Manning's n

Lg+D/2 = 0.56 Hours
Basin Factor = 0.11
V' = 4.50 cfs/Day
Qs = 8.0 * q, cfs

PARAMETERS:
Calculated: Lag Time, Lg = 0.52 Hours
Unit Duration, D = 5.69 minutes
Calculated Timestep = 1.69 minutes

Data to be used in Analysis
Unit Duration, D = 5 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360
Selected Timestep = 5 minutes, integer value evenly divisible into 60



UI Record - Unit Graph 5 **minute interval**

UI	4	14	42	127	216	214	157	105	75	56
UI	45	38	32	27	23	19	17	14	12	10
UI	9	7	6	5	4	4	3	3	2	2
UI	2	1	1	1	0					
UI										
UI										
UI										
UI										
UI										
UI										
[illegible]										
[illegible]										
[illegible]										
UI										

UI
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UI

USBR calculated unitgraph peak = 231 Interpolated Peak = 216

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.03	1.7	0.19	2	305.0	1.72	103.1	0.66	5
10.0	0.06	3.4	0.32	3	310.0	1.75	104.8	0.63	5
15.0	0.08	5.1	0.48	4	315.0	1.77	106.4	0.59	5
20.0	0.11	6.8	0.74	6	320.0	1.80	108.1	0.56	4
25.0	0.14	8.4	1.21	10	325.0	1.83	109.8	0.53	4
30.0	0.17	10.1	1.81	14	330.0	1.86	111.5	0.50	4
35.0	0.20	11.8	2.63	21	335.0	1.89	113.2	0.47	4
40.0	0.23	13.5	3.68	29	340.0	1.91	114.9	0.45	4
45.0	0.25	15.2	5.47	44	345.0	1.94	116.6	0.42	3
50.0	0.28	16.9	8.41	67	350.0	1.97	118.3	0.40	3
55.0	0.31	18.6	12.61	101	355.0	2.00	120.0	0.38	3
60.0	0.34	20.3	16.50	132	360.0	2.03	121.6	0.36	3
65.0	0.37	22.0	20.50	164	365.0	2.06	123.3	0.34	3
70.0	0.39	23.7	23.97	192	370.0	2.08	125.0	0.33	3
75.0	0.42	25.3	27.75	222	375.0	2.11	126.7	0.30	2
80.0	0.45	27.0	28.91	231	380.0	2.14	128.4	0.28	2
85.0	0.48	28.7	28.07	224	385.0	2.17	130.1	0.27	2
90.0	0.51	30.4	26.38	211	390.0	2.20	131.8	0.26	2
95.0	0.54	32.1	24.18	193	395.0	2.22	133.5	0.24	2
100.0	0.56	33.8	21.55	172	400.0	2.25	135.2	0.23	2
105.0	0.59	35.5	18.92	151	405.0	2.28	136.9	0.22	2
110.0	0.62	37.2	16.08	129	410.0	2.31	138.5	0.21	2
115.0	0.65	38.9	14.19	113	415.0	2.34	140.2	0.20	2
120.0	0.68	40.5	12.61	101	420.0	2.37	141.9	0.19	2
125.0	0.70	42.2	11.04	88	425.0	2.39	143.6	0.18	1
130.0	0.73	43.9	9.99	80	430.0	2.42	145.3	0.17	1
135.0	0.76	45.6	9.04	72	435.0	2.45	147.0	0.16	1
140.0	0.79	47.3	8.20	66	440.0	2.48	148.7	0.15	1
145.0	0.82	49.0	7.36	59	445.0	2.51	150.4	0.15	1
150.0	0.84	50.7	6.78	54	450.0	2.53	152.1	0.13	1
155.0	0.87	52.4	6.20	50	455.0	2.56	153.7	0.12	1
160.0	0.90	54.1	5.83	47	460.0	2.59	155.4	0.12	1
165.0	0.93	55.8	5.47	44	465.0	2.62	157.1	0.11	1
170.0	0.96	57.4	5.15	41	470.0	2.65	158.8		
175.0	0.99	59.1	4.84	39	475.0	2.68	160.5		
180.0	1.01	60.8	4.57	37	480.0	2.70	162.2		
185.0	1.04	62.5	4.31	34	485.0	2.73	163.9		
190.0	1.07	64.2	4.10	33	490.0	2.76	165.6		
195.0	1.10	65.9	3.87	31	495.0	2.79	167.3		
200.0	1.13	67.6	3.68	29	500.0	2.82	169.0		
205.0	1.15	69.3	3.47	28	505.0	2.84	170.6		
210.0	1.18	71.0	3.28	26	510.0	2.87	172.3		
215.0	1.21	72.6	3.10	25	515.0	2.90	174.0		
220.0	1.24	74.3	2.93	23	520.0	2.93	175.7		
225.0	1.27	76.0	2.75	22	525.0	2.96	177.4		
230.0	1.30	77.7	2.63	21	530.0	2.98	179.1		
235.0	1.32	79.4	2.47	20	535.0	3.01	180.8		
240.0	1.35	81.1	2.33	19	540.0	3.04	182.5		
245.0	1.38	82.8	2.22	18	545.0	3.07	184.2		
250.0	1.41	84.5	2.10	17	550.0	3.10	185.8		
255.0	1.44	86.2	1.99	16	555.0	3.13	187.5		
260.0	1.46	87.9	1.88	15	560.0	3.15	189.2		
265.0	1.49	89.5	1.78	14	565.0	3.18	190.9		
270.0	1.52	91.2	1.68	13	570.0	3.21	192.6		
275.0	1.55	92.9	1.59	13	575.0	3.24	194.3		
280.0	1.58	94.6	1.50	12	580.0	3.27	196.0		
285.0	1.61	96.3	1.43	11	585.0	3.29	197.7		
290.0	1.63	98.0	1.36	11	590.0	3.32	199.4		
295.0	1.66	99.7	1.28	10	595.0	3.35	201.1		
300.0	1.69	101.4	1.21	10	600.0	3.38	202.7		

NOTES : Use for models including Design Point 3 (Basin C) for the PMP Local event

Appendix B

Local Storm PMP Depth-Duration

Table 6.3A.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required.

HMR No. 49

Drainage Crescent Junction Disposal Site Area less than 1 mi^2 ~~(km^2)~~
Latitude 38°57'50" (38.96°) Longitude 109°48'00"W (109.80°) Minimum Elevation 4940 ft ~~(m)~~

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi^2 (2.6-km^2) PMP for drainage [fig. 4.5]. 8.2 in. ~~(mm)~~

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. (None req'd) 100 %

   b. Multiply step 1 by step 2a. 8.2 in. ~~(mm)~~

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.1

Duration (hr)

	5 min	1/4	1/2	3/4	1	2	3	4	5	6	
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	55	86	93	97	100	107	109	110	110	110	%
5. 1-mi^2 (2.6-km^2) PMP for indicated durations [step 2b X step 4].	4.5	7.1	7.6	8.0	8.2	8.8	8.9	9.0	9.0	9.0	in. ~~(mm)~~
6. Areal reduction [fig. 4.9].	61	61	67	71	73	76	78	80	81	82	%
7. Areal reduced PMP [steps 5 X 6].	2.7	4.3	5.1	5.7	6.0	6.7	6.9	7.2	7.3	7.4	in. ~~(mm)~~
8. Incremental PMP [successive subtraction in step 7].					6.0	0.7	0.2	0.3	0.1	0.1	in. ~~(mm)~~
		4.3	0.8	0.6	0.3	} 15-min. increments					

<1 mi^2

22 mi^2

9. Time sequence of incremental PMP according to:

   HMR No. 5

   Hourly increments [table 4.7]. 0.1 0.3 6.0 0.7 0.2 0.1 in. ~~(mm)~~

   Four largest 15-min. increments [table 4.8]. 4.3 0.8 0.6 0.3 in. ~~(mm)~~

Table 6.3A.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required.

HMR No. 49

Drainage Crescent Junction Disposal Site Area ~~less than 1~~ 1.4 mi² (~~km²~~)
Latitude 38°57'50" (38.96°) Longitude 109°48'00" W (109.80°) Minimum Elevation 4940 ft (~~m~~)

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi² (2.6-km²) PMP for drainage [fig. 4.5]. 8.2 in. (~~mm~~)

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. (None req'd) 100 %

   b. Multiply step 1 by step 2a. 8.2 in. (~~mm~~)

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.1

	Duration (hr)										
	5min	1/4	1/2	3/4	1	2	3	4	5	6	
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	55	86	93	97	100	107	109	110	110	110	%
5. 1-mi² (2.6-km²) PMP for indicated durations [step 2b X step 4].	4.5	7.1	7.6	8.0	8.2	8.8	8.9	9.0	9.0	9.0	in. (~~mm~~)
6. Areal reduction [fig. 4.9].	96 ~~61~~	96 ~~61~~	97 ~~68~~	97 ~~71~~	98 ~~73~~	98 ~~76~~	98 ~~78~~	99 ~~80~~	99 ~~81~~	99 ~~82~~	%
7. Areal reduced PMP [steps 5 X 6].	4.3 ~~3.7~~	6.8 ~~4.3~~	7.4 ~~5.1~~	7.8 ~~5.7~~	8.0 ~~6.0~~	8.6 ~~6.7~~	8.7 ~~6.9~~	8.9 ~~7.2~~	8.9 ~~7.3~~	8.9 ~~7.4~~	in. (~~mm~~)

< 1 mi²

1.4 ~~22~~ mi²

8. Incremental PMP [successive subtraction in step 7].
8.0 0.6 0.1 0.2 0.0 0.0
~~6.0~~ ~~0.7~~ ~~0.2~~ ~~0.3~~ ~~0.1~~ ~~0.1~~ in. (~~mm~~)

~~4.3~~ ~~0.8~~ ~~0.6~~ ~~0.3~~ } 15-min. increments
6.8 0.6 0.4 0.2

9. Time sequence of incremental PMP according to:

HMR No. 5

Hourly increments [table 4.7].
0.0 0.2 8.0 0.6 .2 0.0
~~0.1~~ ~~0.3~~ ~~6.0~~ ~~0.7~~ ~~0.2~~ ~~0.1~~ in. (~~mm~~)

Four largest 15-min. increments [table 4.8].
~~4.3~~ 0.8 0.6 0.3 in. (~~mm~~)
6.8 0.6 0.4 0.2

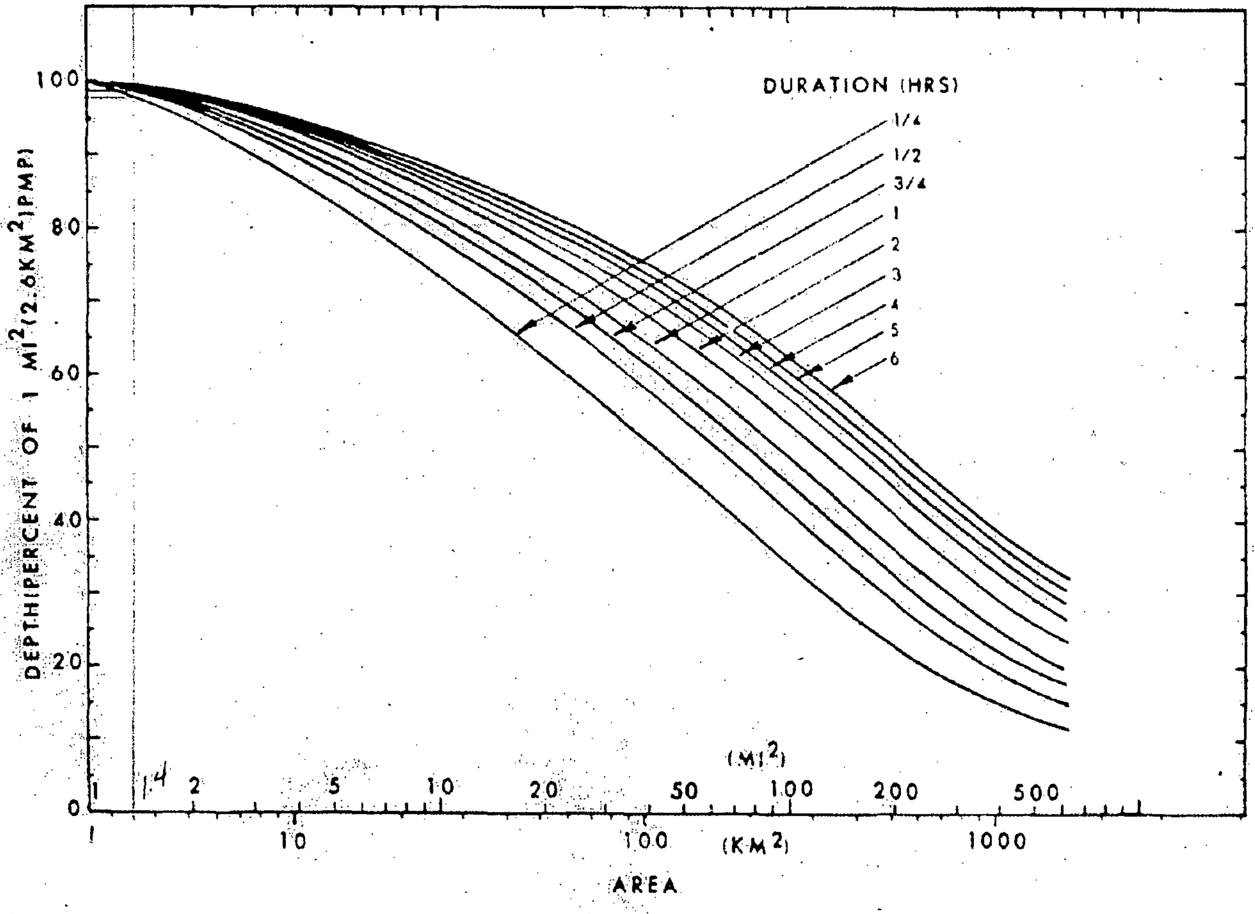


Figure 4.9.--Adopted depth-area relations for local-storm PMP.

Table 6.3A.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required.

HMR No. 49

Drainage Crescent Junction Disposal Site Area ~~less than 1~~ 2.6 mi^2 ~~(km^2)~~
Latitude 38°57'50" (38.96°) Longitude 109°48'00" W (109.80°) Minimum Elevation 4940 ft ~~(m)~~

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi^2 (2.6-km^2) PMP for drainage [fig. 4.5]. 8.2 in. ~~(mm)~~

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. (None req'd) 100 %

   b. Multiply step 1 by step 2a. 8.2 in. ~~(mm)~~

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.1

	5min	1/4	1/2	3/4	1	2	3	4	5	6	
		Duration (hr)									
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	55	86	93	97	100	107	109	110	110	110	%
5. 1-mi^2 (2.6-km^2) PMP for indicated durations [step 2b X step 4].	4.5	7.1	7.6	8.0	8.2	8.8	8.9	9.0	9.0	9.0	in. ~~(mm)~~
6. Areal reduction [fig. 4.9].	92 ~~61~~	92 ~~61~~	94 ~~67~~	95 ~~71~~	96 ~~73~~	96 ~~76~~	97 ~~78~~	97 ~~80~~	97 ~~81~~	98 ~~82~~	%
7. Areal reduced PMP [steps 5 X 6].	4.1 ~~2.7~~	6.5 ~~4.3~~	7.1 ~~5.1~~	7.6 ~~5.7~~	7.9 ~~6.0~~	8.4 ~~6.7~~	8.6 ~~6.9~~	8.7 ~~7.2~~	8.7 ~~7.3~~	8.8 ~~7.4~~	in. ~~(mm)~~

< 1 mi^2

22 mi^2

8. Incremental PMP [successive subtraction in step 7].
   7.9 0.5 0.2 0.1 0.0 0.1
   ~~6.0~~ ~~0.7~~ ~~0.2~~ ~~0.3~~ 0.1 0.1 in. ~~(mm)~~
   6.5 0.6 0.5
   ~~4.3~~ 0.8 0.6 0.3 } 15-min. increments

9. Time sequence of incremental PMP according to:

   HMR No. 5

   Hourly increments [table 4.7].
   0.1 0.2 7.9 0.5 0.1 0.0
   ~~0.1~~ ~~0.3~~ 6.0 0.7 ~~0.2~~ 0.1 in. ~~(mm)~~

   Four largest 15-min. increments [table 4.8].
   6.5 0.6 0.5
   ~~4.8~~ 0.8 0.6 0.3 in. ~~(mm)~~

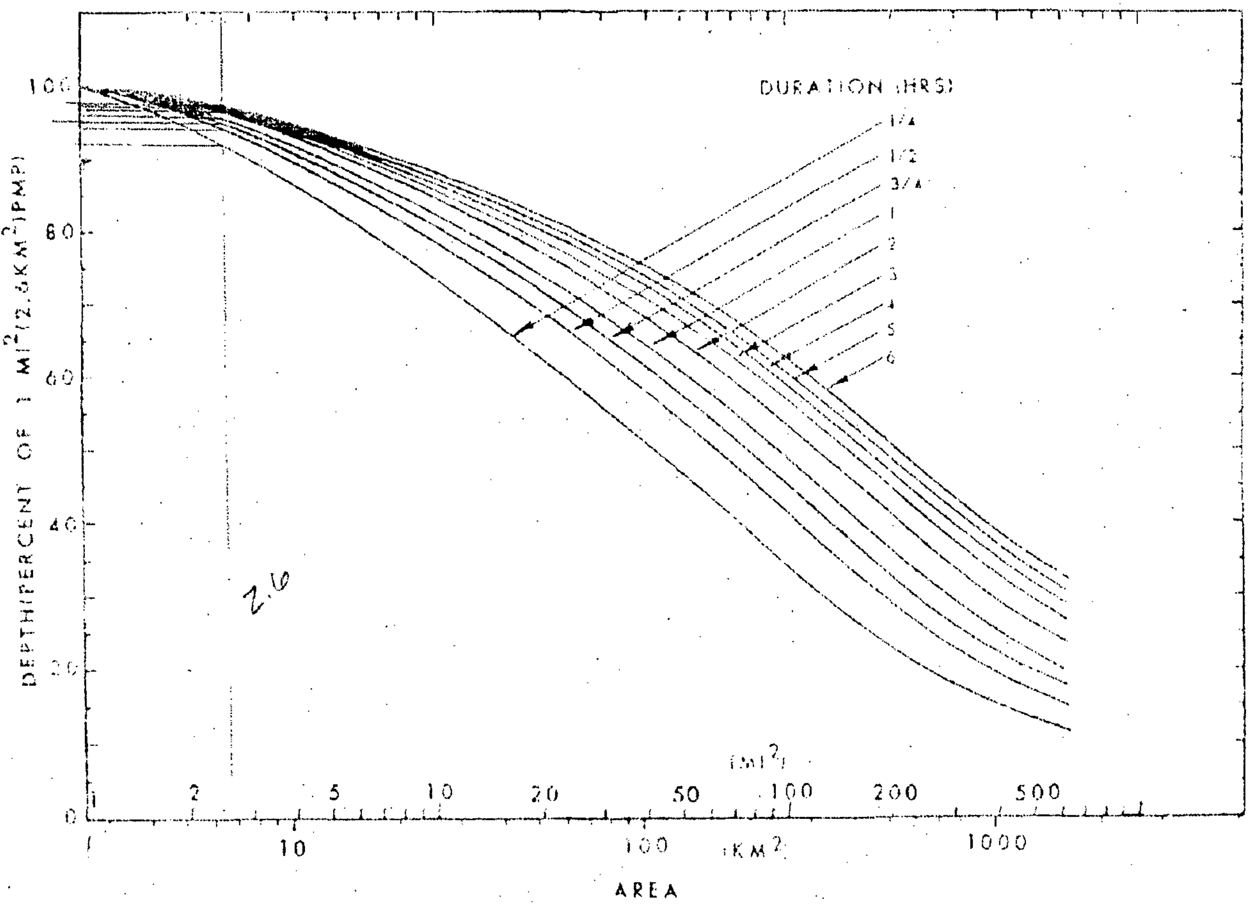


Figure 4.9.--Adopted depth-area relations for local-storm PMP.

Table 6.3A.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required.

HMR No. 49

Drainage Crescent Junction Disposal Site Area 2.7 ~~less than 1~~ mi^2 ~~(km^2)~~
Latitude 38°57'50" (38.96°) Longitude 109°48'00"W (109.80°) Minimum Elevation 4940 ft ~~(m)~~

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi^2 (2.6-km^2) PMP for drainage [fig. 4.5]. 8.2 in. ~~(mm)~~

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. (None req'd) 100 %

   b. Multiply step 1 by step 2a. 8.2 in. ~~(mm)~~

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.1

Duration (hr)

	5min.	1/4	1/2	3/4	1	2	3	4	5	6	
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	55	86	93	97	100	107	109	110	110	110	%
5. 1-mi^2 (2.6-km^2) PMP for indicated durations [step 2b X step 4].	4.5	7.1	7.6	8.0	8.2	8.8	8.9	9.0	9.0	9.0	in. ~~(mm)~~
6. Areal reduction [fig. 4.9].	92	92 ~~61~~	94 ~~67~~	95 ~~71~~	96 ~~73~~	96 ~~76~~	96 ~~78~~	97 ~~80~~	97 ~~81~~	97 ~~82~~	%
7. Areal reduced PMP [steps 5 X 6].	4.1	6.5 ~~4.3~~	7.1 ~~5.1~~	7.6 ~~5.7~~	7.9 ~~6.0~~	8.4 ~~6.7~~	8.5 ~~6.9~~	8.7 ~~7.2~~	8.7 ~~7.3~~	8.7 ~~7.4~~	in. ~~(mm)~~
8. Incremental PMP [successive subtraction in step 7].					7.9 ~~6.0~~	0.5 ~~0.7~~	0.1 ~~0.2~~	0.2 ~~0.3~~	0.0 ~~0.1~~	0.0 ~~0.1~~	in. ~~(mm)~~
		6.5 ~~4.3~~	0.6 ~~0.8~~	0.5 ~~0.6~~	0.3	} 15-min. increments					

9. Time sequence of incremental PMP according to: HMR No. 5

   Hourly increments [table 4.7]. 0.0 ~~0.1~~ 0.2 ~~0.5~~ 7.9 ~~6.0~~ 0.5 ~~0.7~~ 0.1 ~~0.2~~ 0.0 ~~0.1~~ in. ~~(mm)~~

   Four largest 15-min. increments [table 4.8]. 6.5 ~~4.3~~ 0.6 ~~0.8~~ 0.5 ~~0.6~~ 0.3 in. ~~(mm)~~

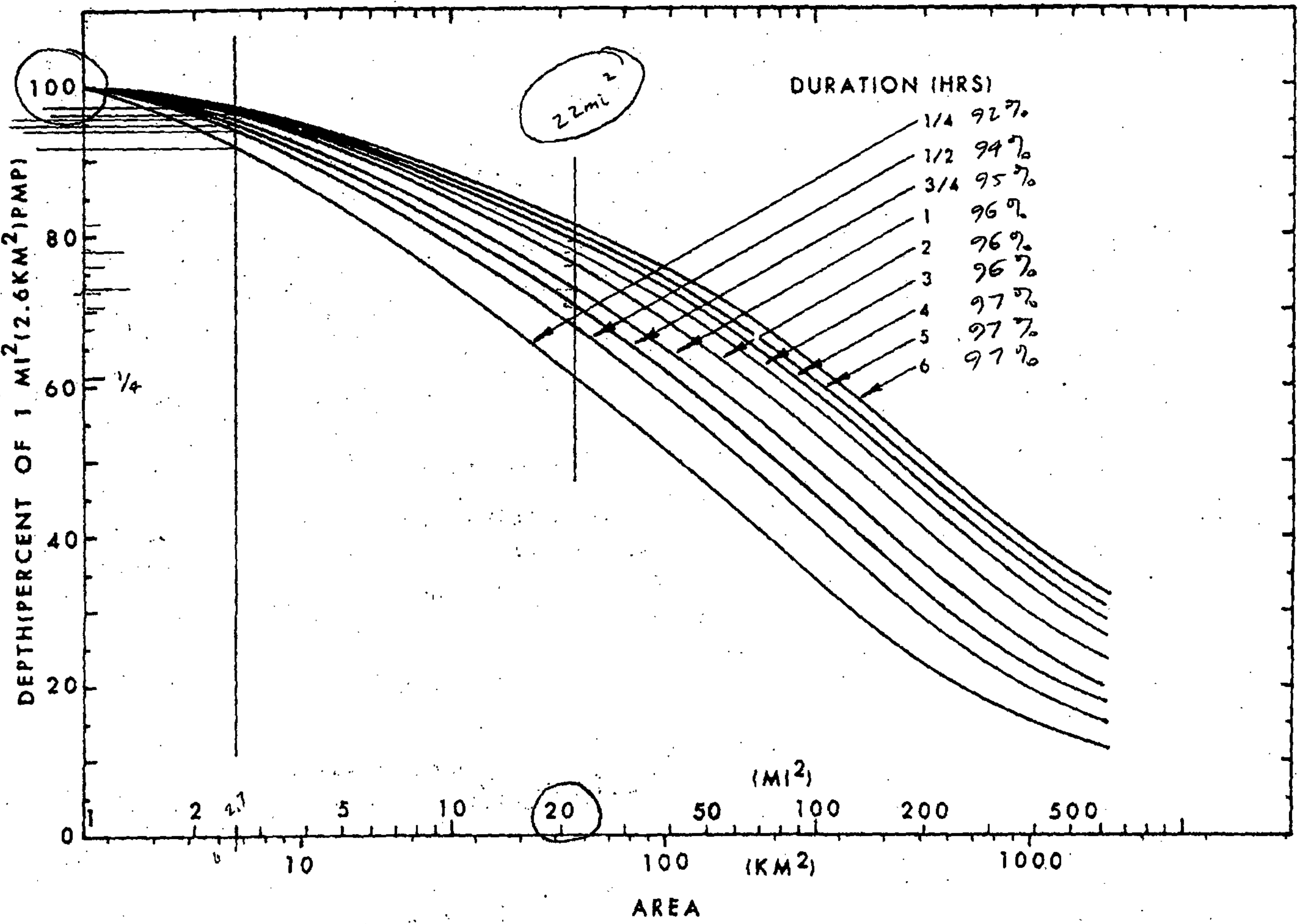


Figure 4.9.--*Adopted depth-area relations for local-storm PMP.*

Table 6.3A.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required.

HMR No. 49

Drainage Crescent Junction Disposal Site Area ~~less than 1~~ 3.5 mi^2 (~~km^2~~)
Latitude 38°57'50" (38.96°) Longitude 109°48'00"W (109.80°) Minimum Elevation 4940 ft (~~m~~)

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi^2 (2.6-km^2) PMP for drainage [fig. 4.5]. 8.2 in. (~~mm~~)

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m); 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. (None req'd) 100 %

   b. Multiply step 1 by step 2a. 8.2 in. (~~mm~~)

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.1

	Duration (hr)										
	5 min	1/4	1/2	3/4	1	2	3	4	5	6	
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	55	86	93	97	100	107	109	110	110	110	%
5. 1-mi^2 (2.6-km^2) PMP for indicated durations [step 2b X step 4].	4.5	7.1	7.6	8.0	8.2	8.8	8.9	9.0	9.0	9.0	in. (~~mm~~)
6. Areal reduction [fig. 4.9].	88 ~~60~~	88 ~~61~~	91 ~~67~~	92 ~~71~~	93 ~~73~~	94 ~~76~~	95 ~~78~~	95 ~~80~~	96 ~~81~~	96 ~~82~~	%
7. Areal reduced PMP [steps 5 X 6].	4.0 ~~2.7~~	6.2 ~~4.3~~	6.9 ~~5.1~~	7.4 ~~5.7~~	7.6 ~~6.0~~	8.3 ~~6.7~~	8.5 ~~6.9~~	8.6 ~~7.2~~	8.6 ~~7.3~~	8.6 ~~7.4~~	in. (~~mm~~)
8. Incremental PMP [successive subtraction in step 7].					6.0	0.7	0.2	0.3	0.1	0.1	in. (~~mm~~)
		4.3	0.8	0.6	0.3	} 15-min. increments					

<1 mi^2

22 mi^2

9. Time sequence of incremental PMP according to:

   HMR No. 5

   Hourly increments [table 4.7]. 0.1 0.3 6.0 0.7 0.2 0.1 in. (~~mm~~)

   Four largest 15-min. increments [table 4.8]. 4.3 0.8 0.6 0.3 in. (~~mm~~)

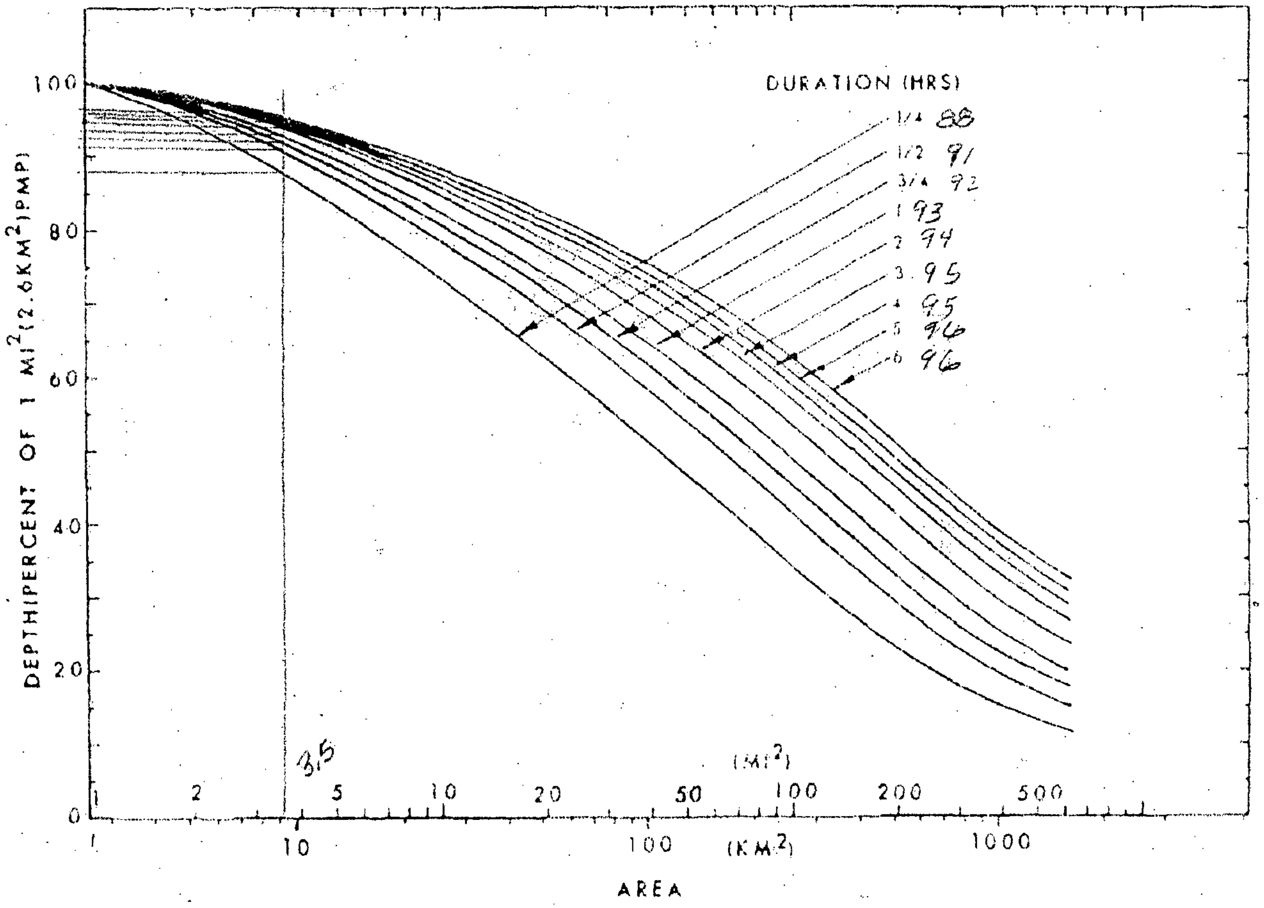


Figure 4.9.--Adopted depth-area relations for local-storm PMP.

HMR No. 49

Table 6.3A.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required. 9

Drainage Crescent Junction Disposal Site Area ~~less than~~ 1 mi^2 ~~(km^2)~~
Latitude 38°57'50" (38.96°) Longitude 109°48'00"W (109.80°) Minimum Elevation 4940 ft ~~(m)~~

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi^2 (2.6-km^2) PMP for drainage [fig. 4.5]. 8.2 in. (~~mm~~)

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. (None req'd) 100 %

   b. Multiply step 1 by step 2a. 8.2 in. (~~mm~~)

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.1

	Duration (hr)										
	5min	1/4	1/2	3/4	1	2	3	4	5	6	
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	55	86	93	97	100	107	109	110	110	110	%
5. 1-mi^2 (2.6-km^2) PMP for indicated durations [step 2b X step 4].	4.5	7.1	7.6	8.0	8.2	8.8	8.9	9.0	9.0	9.0	in. (~~mm~~)
6. Areal reduction [fig. 4.9].	76	76 ~~61~~	80 ~~67~~	82 ~~71~~	84 ~~73~~	86 ~~76~~	87 ~~78~~	88 ~~80~~	88 ~~81~~	89 ~~82~~	%
7. Areal reduced PMP [steps 5 X 6].	3.4	5.4 ~~4.3~~	6.1 ~~5.1~~	6.6 ~~5.7~~	6.9 ~~6.0~~	7.6 ~~6.7~~	7.7 ~~6.9~~	7.9 ~~7.2~~	7.9 ~~7.3~~	8.0 ~~7.4~~	in. (~~mm~~)
8. Incremental PMP [successive subtraction in step 7].					6.9 ~~6.0~~	0.3	0.1 ~~0.2~~	0.2 ~~0.3~~	0.0 ~~0.1~~	0.1	in. (~~mm~~)
		5.4 ~~4.3~~	0.7 ~~0.8~~	0.5 ~~0.6~~	0.3	} 15-min. increments					

9. Time sequence of incremental PMP according to: HMR No. 5

   Hourly increments [table 4.7]. 0.1 0.2 ~~0.3~~ 6.9 ~~6.0~~ 0.7 0.1 ~~0.2~~ 0.0 ~~0.1~~ in. (~~mm~~)

   Four largest 15-min. increments [table 4.8]. 5.4 ~~4.3~~ 0.7 ~~0.8~~ 0.5 ~~0.6~~ 0.3 in. (~~mm~~)

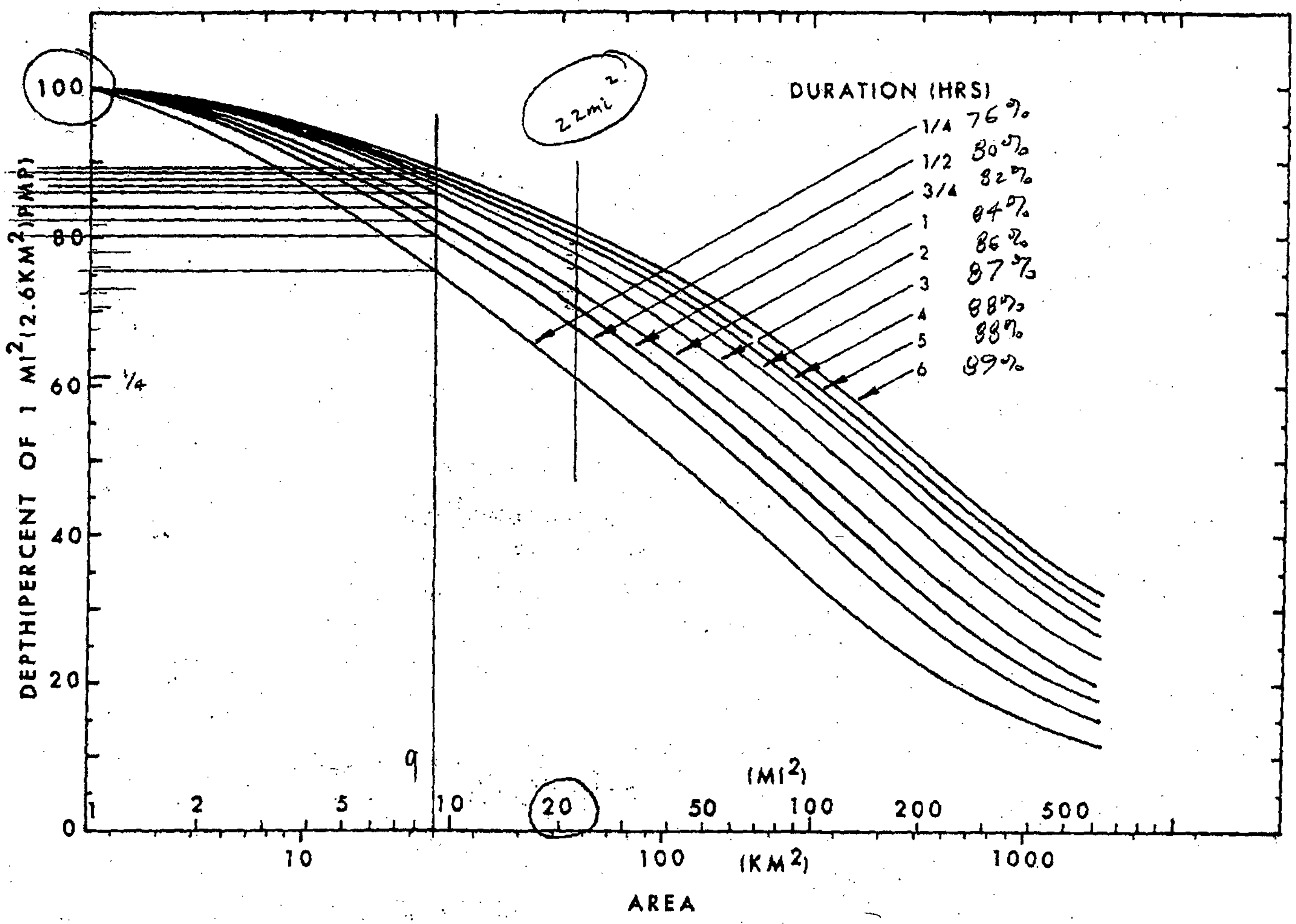


Figure 4.9.--Adopted depth-area relations for local-storm PMP.

Table 6.3A.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required.

HMR No. 49

Drainage Crescent Junction Disposal Site Area ~~less than 1~~ 15 mi^2 ~~(km^2)~~
Latitude 38°57'50" (38.96°) Longitude 109°48'00"W (109.80°) Minimum Elevation 4940 ft ~~(m)~~

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi^2 (2.6-km^2) PMP for drainage [fig. 4.5]. 8.2 in. (~~mm~~)

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. (None reg'd) 100 %

   b. Multiply step 1 by step 2a. 8.2 in. (~~mm~~)

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.1

		Duration (hr)									
	5 min	1/4	1/2	3/4	1	2	3	4	5	6	
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	55	86	93	97	100	107	109	110	110	110	%
5. 1-mi^2 (2.6-km^2) PMP for indicated durations [step 2b X step 4].	4.5	7.1	7.6	8.0	8.2	8.8	8.9	9.0	9.0	9.0	in. (~~mm~~)
6. Areal reduction [fig. 4.9].	67	67 ~~61~~	73 ~~67~~	76 ~~71~~	78 ~~75~~	81 ~~76~~	81 ~~78~~	83 ~~80~~	84 ~~81~~	85 ~~82~~	%
7. Areal reduced PMP [steps 5 X 6].	3.0	4.8 ~~4.3~~	5.5 ~~5.1~~	6.1 ~~5.7~~	6.4 ~~6.0~~	7.0 ~~6.7~~	7.2 ~~6.9~~	7.5 ~~7.2~~	7.6 ~~7.3~~	7.7 ~~7.4~~	in. (~~mm~~)
8. Incremental PMP [successive subtraction in step 7].					6.4 ~~6.0~~	0.6 ~~0.7~~	0.2	0.3	0.1	0.1	in. (~~mm~~)

4.8 ~~4.3~~ 0.7 ~~0.8~~ 0.6 0.3 } 15-min. increments

9. Time sequence of incremental PMP according to:

   HMR No. 5

   Hourly increments [table 4.7]. 0.1 0.3 ~~6.0~~ 6.4 ~~0.7~~ 0.6 0.2 0.1 in. (~~mm~~)

   Four largest 15-min. increments [table 4.8]. ~~4.3~~ 4.8 ~~0.8~~ 0.7 0.6 0.3 in. (~~mm~~)

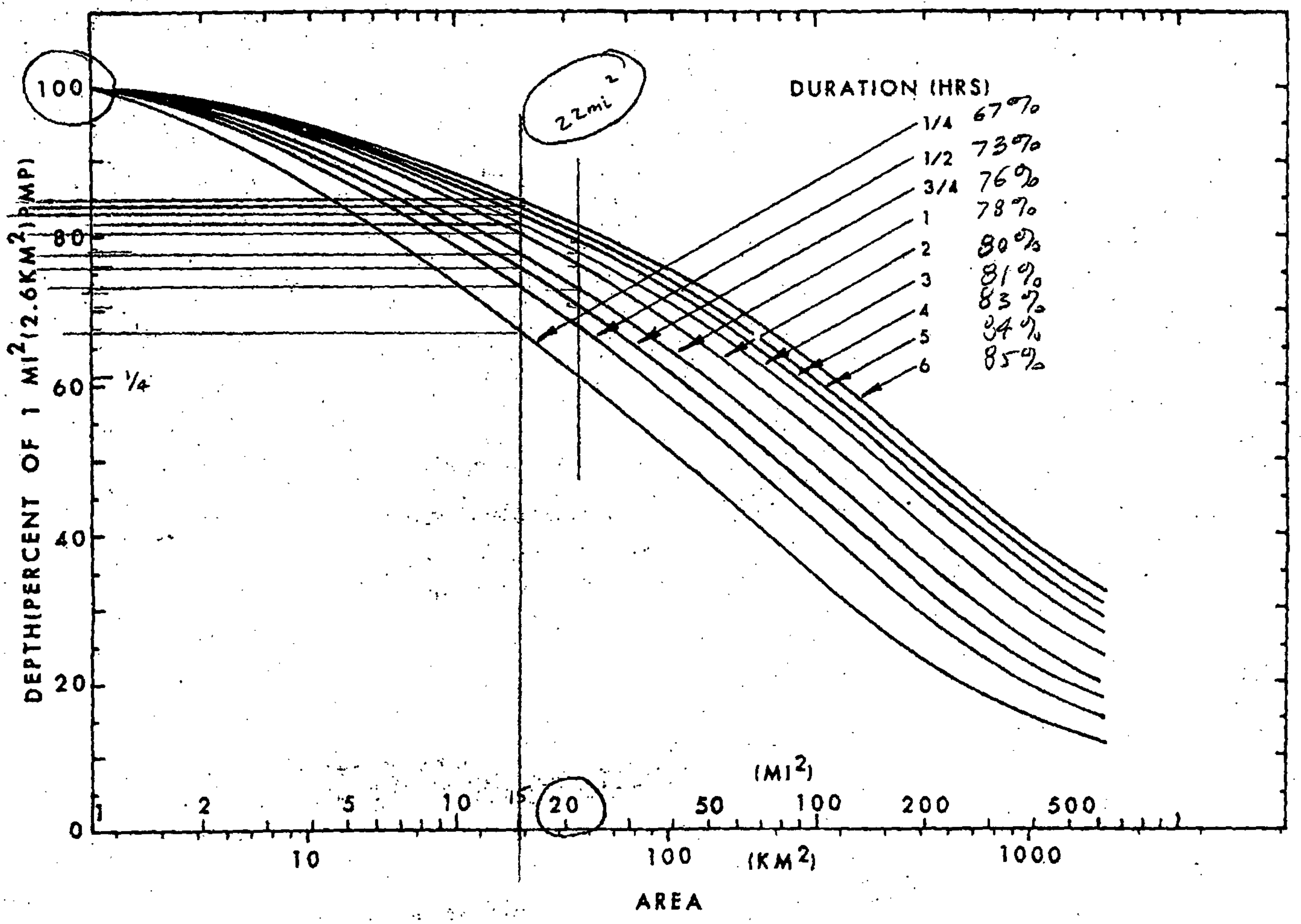


Figure 4.9.--Adopted depth-area relations for local-storm PMP.

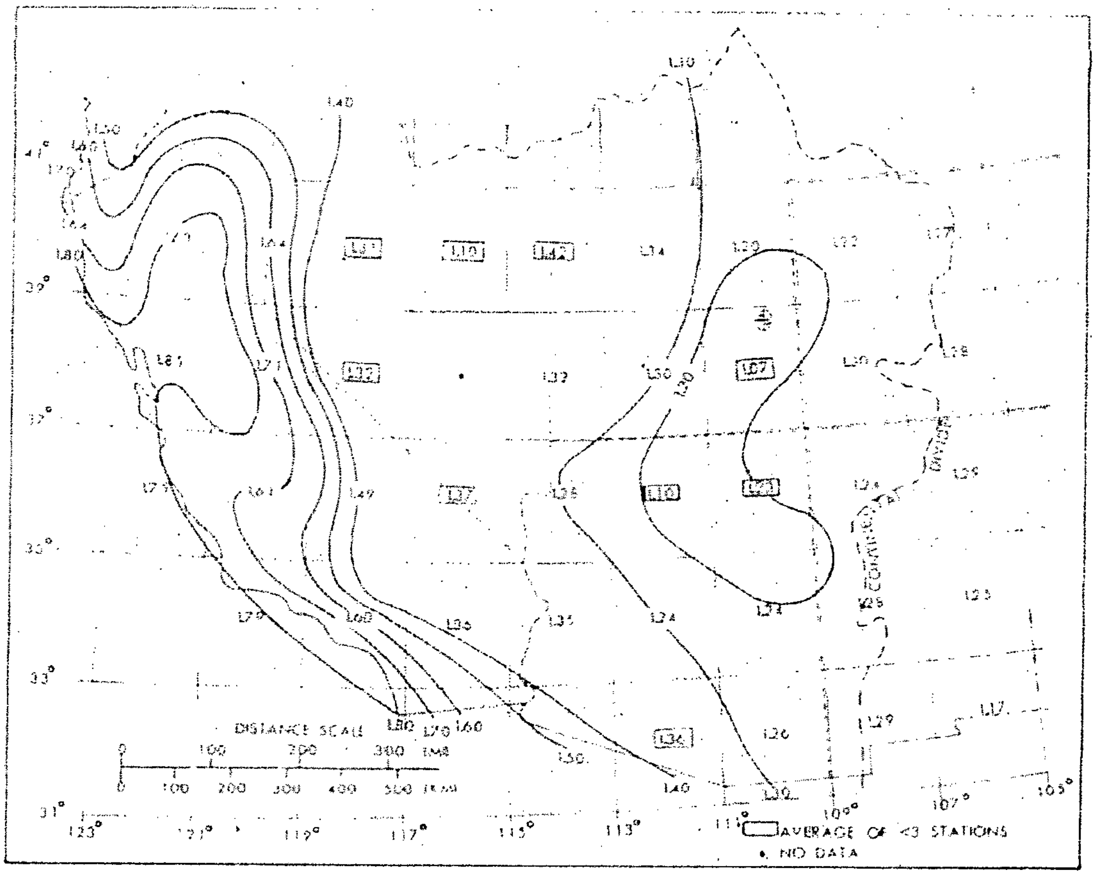


Figure 4.7.--Analysis of 6/1-hr ratios of averaged maximum station data (plotted at midpoints of a 2° latitude-longitude grid).

establish the basic depth-duration curve, then structure a variable set of depth-duration curves to cover the range of 6/1-hr ratios that are needed.

Three sets of data were considered for obtaining a base relation (see table 4.3 for depth-duration data).

a. An average of depth-duration relations from each of 17 greatest 3-hr rains from summer storms (1940-49) in Utah (U. S. Weather Bureau 1951b) and in unpublished tabulations for Nevada and Arizona (1940-63). The 3-hr amounts ranged from 1 to 3 inches (25 to 76 mm) in these events.

b. An average depth-duration relation from 14 of the most extreme short-duration storms listed in Storm Rainfall (U. S. Army, Corps of Engineers 1945-). These storms come from Eastern and Central States and have 3-hr amounts of 5 to 22 inches (127 to 559 mm).

ratios than storms with high 3/1-hr ratios. The geographical distribution of 15-min to 1-hr ratios also were inversely correlated with magnitudes of the 6/1-hr ratios of figure 4.7. For example, Los Angeles and San Diego (high 6/1-hr ratios) have low 15-min to 1-hr ratios (approximately 0.60) whereas the 15-min to 1-hr ratios in Arizona and Utah (low 6/1-hr ratios) were generally higher (approximately 0.75).

Depth-duration relations for durations less than 1 hour were then smoothed to provide a family of curves consistent with the relations determined for 1 to 6 hours, as shown in figure 4.3. Adjustment was necessary to some of the curves to provide smoother relations through the common point at 1 hour.

We believe we were justified in reducing the number of the curves shown in figure 4.3 for durations less than 1 hour, letting one curve apply to a range of 6/1-hr ratios. The corresponding curves have been indicated by letter designators, A-D, on figure 4.3. As an example, for any 6-hr amount between 115% and 135% of 1-hr, 1-mi^2 (2.6-km^2) PMP, the associated values for durations less than 1 hour are obtained from the curve designated as "B".

Table 4.4 lists durational variations in percent of 1-hr PMP for selected 6/1-hr rain ratios. These values were interpolated from figure 4.3.

To determine 6-hr PMP for a basin, use figure 4.3 (or table 4.4) and the geographical distribution of 6/1-hr ratios given in figure 4.7.

Table 4.4.--Durational variation of 1-mi^2 (2.6-km^2) local-storm PMP in percent of 1-hr PMP (see figure 4.3)

6/1-hr	Duration (hr)								
ratio	1/4	1/2	3/4	1	2	3	4	5	6
1.1	86	93	97	100	107	109	110	110	110
1.2	74	89	95	100	110	115	118	119	120
1.3	74	89	95	100	114	121	125	128	130
1.4	63	83	93	100	118	126	132	137	140
1.5	63	83	93	100	121	132	140	145	150
1.6	43	70	87	100	124	138	147	154	160
1.8	43	70	87	100	130	149	161	171	180
2.0	43	70	87	100	137	161	175	188	200

4.5 Depth-Area Relation

We have thus far developed local-storm PMP for an area of 1 mi^2 (2.6 km^2). To apply PMP to a basin, we need to determine how 1-mi^2 (2.6-km^2) PMP should decrease with increasing area. We have adopted depth-area relations based on rainfalls in the Southwest and from consideration of a model thunderstorm.

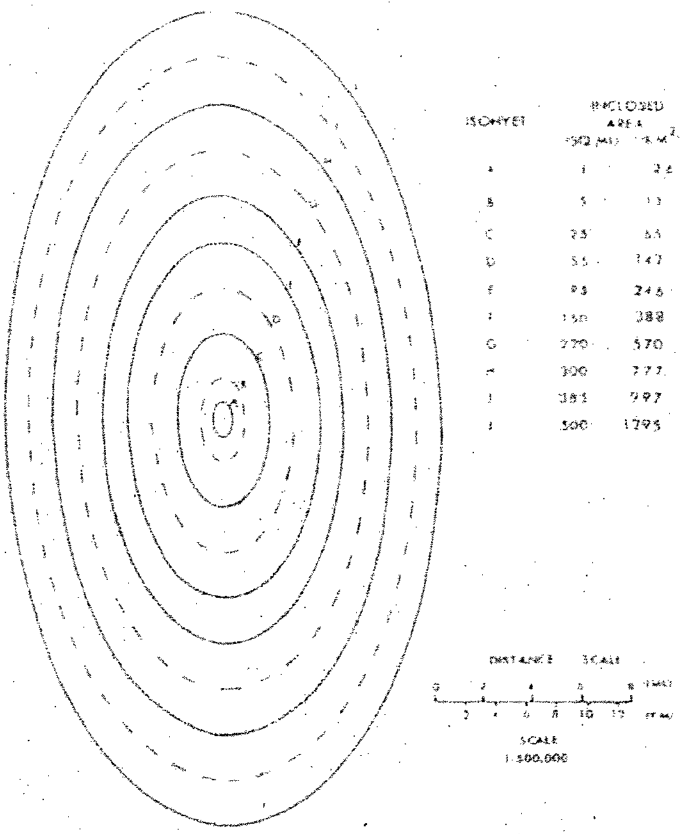


Figure 4.10.--Idealized local-storm isohyetal pattern.

storm period. The sequence of hourly incremental PMP for the Southwest 6-hr thunderstorm in accord with this study is presented in column 2 of table 4.7. A small variation from this sequence is given in Engineering Manual 1110-2-1411 (U. S. Army, Corps of Engineers 1965). The latter, listed in column 3 of table 4.7, places greater incremental amounts somewhat more toward the end of the 6-hr storm period. In application, the choice of either of these distributions is left to the user since one may prove to be more critical in a specific case than the other.

Table 4.7.--Time sequence for hourly incremental PMP in 6-hr storm

	HMR No. 5[1]	EM1110-2-1411[2]
Increment	Sequence Position	
Largest hourly amount	Third	Fourth
2nd largest	Fourth	Third
3rd largest	Second	Fifth
4th largest	Fifth	Second
5th largest	First	Last
least	Last	First

---

[1] U. S. Weather Bureau 1947.

[2] U. S. Corps of Engineers 1952.

Also of importance is the sequence of the four 15-min incremental PMP values. We recommend a time distribution, table 4.8, giving the greatest intensity in the first 15-min interval (U.S. Weather Bureau 1947). This is based on data from a broad geographical region. Additional support for this time distribution is found in the reports of specific storms by Keppell (1963) and Osborn and Renard (1969).

Table 4.8.--Time sequence for 15-min incremental PMP within 1 hr.

Increment	Sequence Position
Largest 15-min amount	First
2nd largest	Second
3rd largest	Third
least	Last

4.8 Seasonal Distribution

The time of the year when local-storm PMP is most likely is of interest. Guidance was obtained from analysis of the distribution of maximum 1-hr thunderstorm events through the warm season at the recording stations in Utah, Arizona, and in southern California (south of 37°N and east of the Sierra Nevada ridgeline). The period of record used was for 1940-72 with an average record length for the stations considered of 27 years. The month with the one greatest thunderstorm rainfall for the period of record at each station was noted. The totals of these events for each month, by States, are shown in table 4.9.

Table 4.9.--Seasonal distribution of thunderstorm rainfalls.

(The maximum event at each of 108 stations, period of record 1940-72.)

	Month						
	M	J	J	A	S	O	No. of Cases
Utah	1	5	9	14	5		34
Arizona		4	16	19	4		43
S. Calif.*		14	10	7			31
No. of cases/mo.	1	23	35	40	9	0	

*South of 37°N and east of Sierra Nevada ridgeline.

Appendix C

HEC-HMS Output

Project: Crescent Junction Ex Simulation Run: CW 25

Start of Run: 01Jan2006, 00:00 Basin Model: Crescent Wash-event
End of Run: 02Jan2006, 00:00 Meteorologic Model: 25-yr 24-hr
Compute Time: 18May2006, 13:20:23 Control Specifications: 1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Crescent Wash	22.5600	2975.47	01Jan2006, 14:15	0.49
I-70	22.5600	2975.47	01Jan2006, 14:15	0.49

Project: Crescent Junction Ex Simulation Run: CW 100

Start of Run: 01Jan2006, 00:00 Basin Model: Crescent Wash-event
End of Run: 02Jan2006, 00:00 Meteorologic Model: 100-yr 24-hr
Compute Time: 18May2006, 13:20:55 Control Specifications: 1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Crescent Wash	22.5600	5982.86	01Jan2006, 14:10	0.98
I-70	22.5600	5982.86	01Jan2006, 14:10	0.98

Project: Crescent Junction Ex Simulation Run: CW PMP Local

Start of Run:	01Jan2006, 00:00	Basin Model:	Crescent Wash-PMP
End of Run:	02Jan2006, 00:00	Meteorologic Model:	PMP Local 22 sq mi
Compute Time:	18May2006, 13:06:09	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Crescent Wash	22.5600	45196.66	01Jan2006, 04:40	6.11
Sink-1	22.5600	45196.66	01Jan2006, 04:40	6.11

Project: Crescent Junction Ex Simulation Run: BASIN 1-100

Start of Run:	01Jan2006, 00:00	Basin Model:	Basin 1-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	100-yr 24-hr
Compute Time:	18May2006, 13:22:10	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 1	2.6300	2135.13	01Jan2006, 12:35	0.99
DP 6	2.6300	2135.13	01Jan2006, 12:35	0.99

Project: Crescent Junction Ex Simulation Run: BASIN 1-PMP LOCAL

Start of Run: 01Jan2006, 00:00 Basin Model: Basin 1-PMP
End of Run: 02Jan2006, 00:00 Meteorologic Model: PMP Local 2.7 sq mi
Compute Time: 18May2006, 13:22:40 Control Specifications: 1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 1	2.6300	21287.52	01Jan2006, 03:25	7.77
DP 6	2.6300	21287.52	01Jan2006, 03:25	7.77

Project: Crescent_Junction_Pr	Simulation Run: Basin 1-100

Start of Run:	01Jan2006, 00:00	Basin Model:	Basin 1-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	100-yr 24-hr
Compute Time:	18May2006, 13:41:52	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 1 Routed	2.6300	2210.10	01Jan2006, 12:35	1.00
DP 6	2.6300	2210.10	01Jan2006, 12:35	1.00

Project: Crescent_Junction_Pr Simulation Run: Basin 1-PMP			
Start of Run:	01Jan2006, 00:00	Basin Model:	Basin 1-PMP
End of Run:	02Jan2006, 00:00	Meteorologic Model:	PMP Local 2.7 sq mi
Compute Time:	18May2006, 13:42:53	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 1 Routed	2.6300	21321.77	01Jan2006, 03:25	10.80
DP 6	2.6300	21321.77	01Jan2006, 03:25	10.80

Project: Crescent Junction Ex Simulation Run: BASIN 2-25

Start of Run:	01Jan2006, 00:00	Basin Model:	Basin 2-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	25-yr 24-hr
Compute Time:	18May2006, 13:24:57	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 2	8.9600	1726.31	01Jan2006, 13:30	0.49
RR Bridge	8.9600	1726.31	01Jan2006, 13:30	0.49

Project: Crescent Junction Ex Simulation Run: BASIN 2-100

Start of Run: 01Jan2006, 00:00 Basin Model: Basin 2-event
End of Run: 02Jan2006, 00:00 Meteorologic Model: 100-yr 24-hr
Compute Time: 18May2006, 13:26:09 Control Specifications: 1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 2	8.9600	3453.04	01Jan2006, 13:30	0.99
RR Bridge	8.9600	3453.04	01Jan2006, 13:30	0.99

Project: Crescent Junction Ex Simulation Run: BASIN 2-PMP

Start of Run: 01Jan2006, 00:00 Basin Model: Basin 2-PMP
End of Run: 02Jan2006, 00:00 Meteorologic Model: PMP Local 9 sq mi
Compute Time: 18May2006, 13:26:56 Control Specifications: 1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 2	8.9600	29868.86	01Jan2006, 04:05	7.01
RR Bridge	8.9600	29868.86	01Jan2006, 04:05	7.01

Project: Crescent Junction Ex Simulation Run: 123 100

Start of Run:	01Jan2006, 00:00	Basin Model:	Basins 123-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	100-yr 24-hr
Compute Time:	18May2006, 13:32:06	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 1	2.6300	2135.13	01Jan2006, 12:35	0.99
Basin 2	8.9600	3453.04	01Jan2006, 13:30	0.99
Basin 3	3.4700	1553.39	01Jan2006, 13:15	0.99
I-70	15.0600	5108.83	01Jan2006, 13:30	0.99
I-70 Culvert	15.0600	5108.83	01Jan2006, 13:30	0.99
Kendall Wash E	8.9600	3441.54	01Jan2006, 13:35	0.99
Kendall Wash W	2.6300	2066.77	01Jan2006, 12:40	0.99

Project: Crescent Junction Ex Simulation Run: 123 PMP Local

Start of Run: 01Jan2006, 00:00
End of Run: 02Jan2006, 00:00
Compute Time: 18May2006, 13:33:12

Basin Model: Basins 123-PMP
Meteorologic Model: PMP Local 15 sq mi
Control Specifications: 1 day at 5 min step

Volume Units: IN

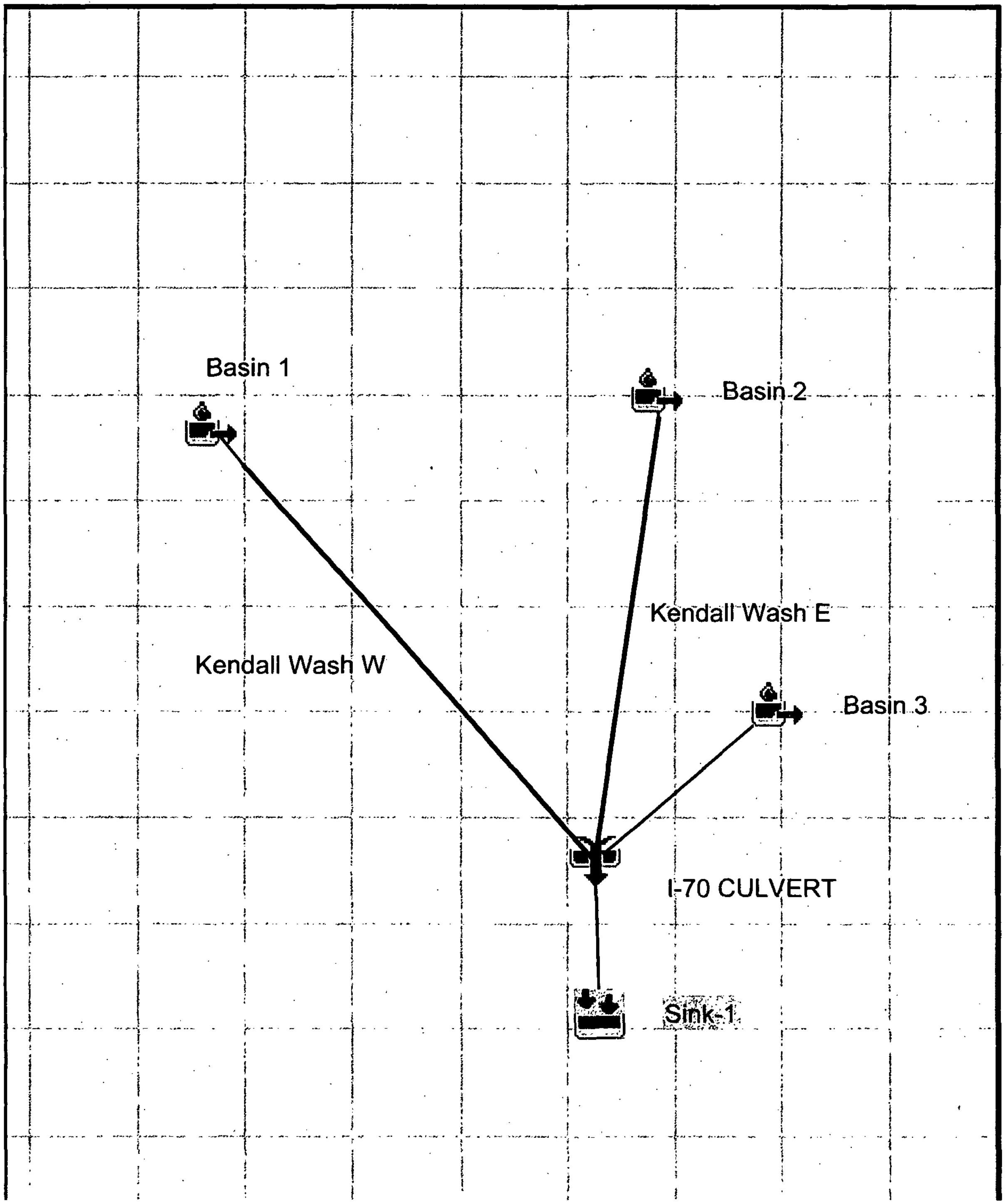
Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 1	2.6300	16218.18	01Jan2006, 03:25	6.38
Basin 2	8.9600	27260.23	01Jan2006, 04:05	6.41
Basin 3	3.4700	12147.64	01Jan2006, 03:55	6.41
I-70	15.0600	40835.44	01Jan2006, 04:05	6.41
I-70 Culvert	15.0600	40835.44	01Jan2006, 04:05	6.41
Kendall Wash E	8.9600	26892.86	01Jan2006, 04:10	6.41
Kendall Wash W	2.6300	15865.63	01Jan2006, 03:25	6.39

HEC-HMS

Project : Crescent Junction Ex

Basin Model : Basins 123-PMP

May 16 16:45:14 MDT 2006



Project: Crescent_Junction_Pr Simulation Run: Basins 123-100

Start of Run: 01Jan2006, 00:00 Basin Model: Basins 123-event
End of Run: 02Jan2006, 00:00 Meteorologic Model: 100-yr 24-hr
Compute Time: 18May2006, 13:46:23 Control Specifications: 1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 1 Routed	2.6300	2210.10	01Jan2006, 12:35	1.00
Basin 2	8.9600	3453.04	01Jan2006, 13:30	0.99
Basin 3	3.4700	1553.39	01Jan2006, 13:15	0.99
I-70	15.0600	5098.41	01Jan2006, 13:30	0.99
I-70 Culvert	15.0600	5098.41	01Jan2006, 13:30	0.99
Kendall Wash E	8.9600	3441.54	01Jan2006, 13:35	0.99
Kendall Wash W	2.6300	2166.34	01Jan2006, 12:35	1.00

Project: Crescent_Junction_Pr Simulation Run: BASINS 123 PMP

Start of Run: 01Jan2006, 00:00 Basin Model: Basins 123-PMP
End of Run: 02Jan2006, 00:00 Meteorologic Model: PMP Local 15 sq mi
Compute Time: 18May2006, 13:48:35 Control Specifications: 1 day at 5 min step

Volume Units: IN

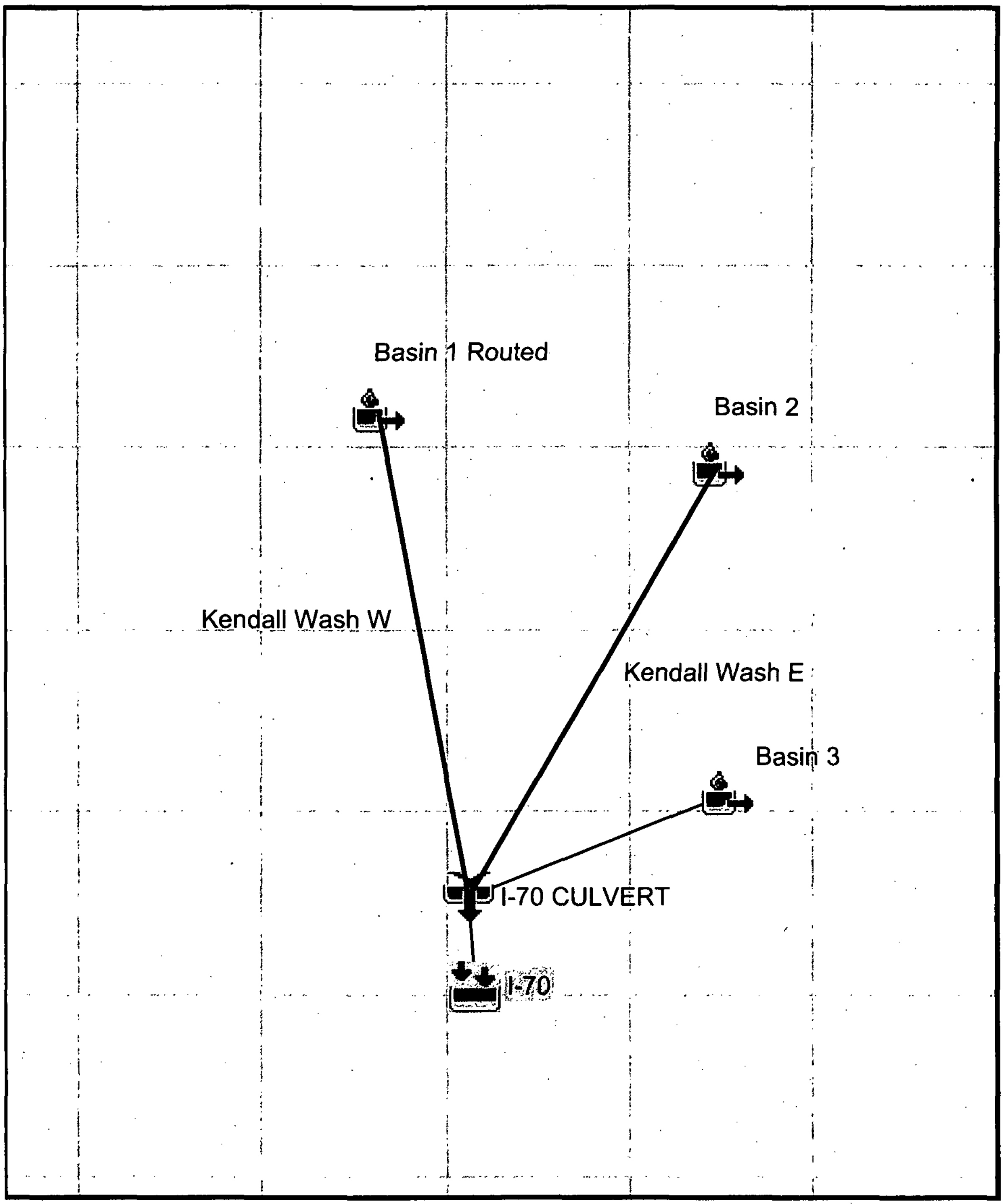
Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin 1 Routed	2.6300	16252.58	01Jan2006, 03:25	8.88
Basin 2	8.9600	27260.23	01Jan2006, 04:05	6.41
Basin 3	3.4700	12147.64	01Jan2006, 03:55	6.41
I-70	15.0600	40871.36	01Jan2006, 04:05	6.84
I-70 Culvert	15.0600	40871.36	01Jan2006, 04:05	6.84
Kendall Wash E	8.9600	26892.86	01Jan2006, 04:10	6.41
Kendall Wash W	2.6300	15899.38	01Jan2006, 03:25	8.89

HEC-HMS

Project : Crescent_Junction_Pr

Basin Model : Basins 123-PMP

May 18 13:48:18 MDT 2006



Project: Crescent_Junction_Pr Simulation Run: DP 4&5-25

Start of Run: 01Jan2006, 00:00 Basin Model: P-DP 4&5-event
End of Run: 02Jan2006, 00:00 Meteorologic Model: 25-yr 24-hr
Compute Time: 18May2006, 13:49:54 Control Specifications: 1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin B	0.5218	291.31	01Jan2006, 12:25	0.49
Basin D	0.3827	187.06	01Jan2006, 12:35	0.57
DP 4	0.5218	291.31	01Jan2006, 12:25	0.49
DP 5	0.9045	447.59	01Jan2006, 12:30	0.52
West Ditch	0.5218	281.01	01Jan2006, 12:25	0.49

Project: Crescent_Junction_Pr Simulation Run: DP 4&5-PMP

Start of Run: 01Jan2006, 00:00 Basin Model: P-DP 4&5-PMP
End of Run: 02Jan2006, 00:00 Meteorologic Model: PMP Local <1 sq mi
Compute Time: 18May2006, 13:51:38 Control Specifications: 1 day at 5 min step

Volume Units: IN

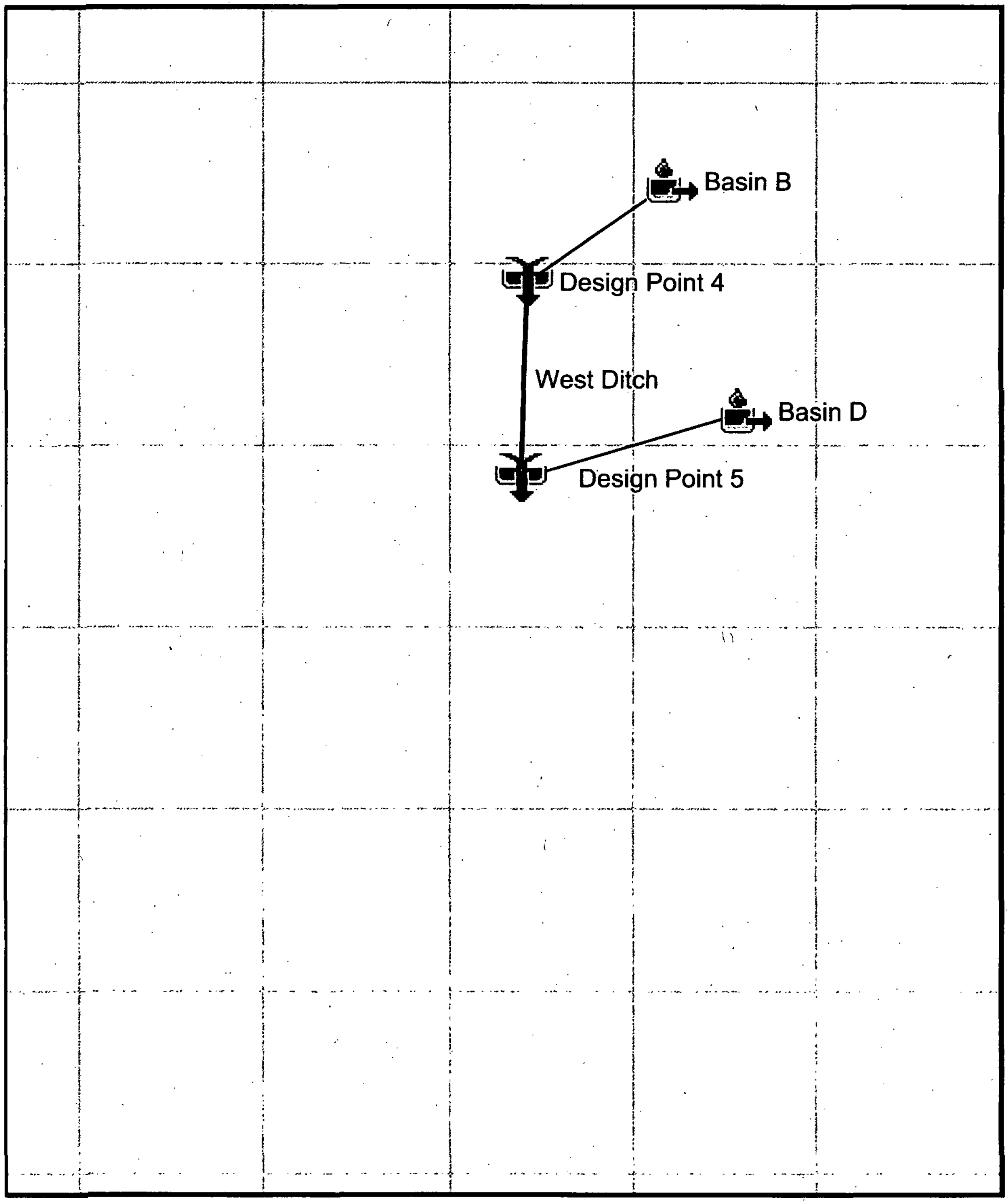
Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin B	0.5218	5858.79	01Jan2006, 03:15	8.21
Basin D	0.3827	3426.58	01Jan2006, 03:25	8.48
DP 4	0.5218	5858.79	01Jan2006, 03:15	8.21
DP 5	0.9045	8722.28	01Jan2006, 03:20	8.34
West Ditch	0.5218	5539.08	01Jan2006, 03:15	8.24

HEC-HMS

Project : Crescent Junction Pr

Basin Model : P-DP 4&5-event

May 16 16:48:01 MDT 2006



Project: Crescent_Junction_Pr Simulation Run: BASIN C-25

Start of Run:	01Jan2006, 00:00	Basin Model:	P-BASIN C-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	25-yr 24-hr
Compute Time:	18May2006, 13:56:17	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin C	0.1675	74.72	01Jan2006, 12:30	0.49
DP 3-ExCulv @ RR	0.1675	74.72	01Jan2006, 12:30	0.49

Project: Crescent_Junction_Pr Simulation Run: BASIN C-100

Start of Run:	01Jan2006, 00:00	Basin Model:	P-BASIN C-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	100-yr 24-hr
Compute Time:	18May2006, 13:57:43	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin C	0.1675	146.99	01Jan2006, 12:30	0.99
DP 3-ExCulv@RR	0.1675	146.99	01Jan2006, 12:30	0.99

Project: Crescent_Junction_Pr Simulation Run: BASIN C-PMP

Start of Run: 01Jan2006, 00:00 Basin Model: P-BASIN C-PMP
End of Run: 02Jan2006, 00:00 Meteorologic Model: PMP Local <1 sq mi
Compute Time: 18May2006, 13:58:25 Control Specifications: 1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin C	0.1675	1488.43	01Jan2006, 03:20	8.18
DP3-Ex Culv@RR	0.1675	1488.43	01Jan2006, 03:20	8.18

Project: Crescent_Junction_Pr Simulation Run: P-DRAINAGE 25

Start of Run:	01Jan2006, 00:00	Basin Model:	P-DRAINAGE-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	25-yr 24-hr
Compute Time:	18May2006, 14:02:40	Control Specifications:	1 day at 5 min step

Volume Units: IN

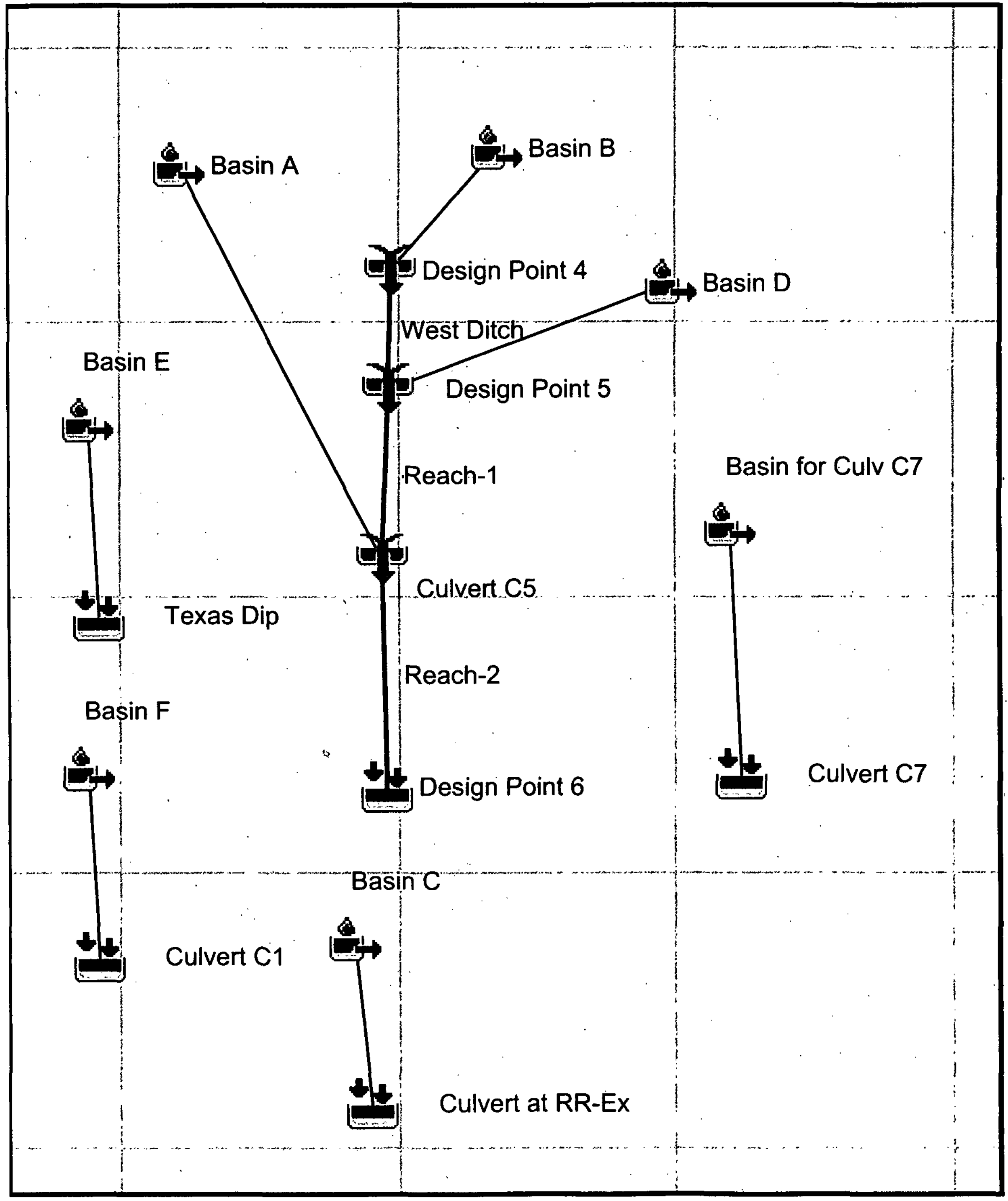
Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Basin A	0.3456	192.54	01Jan2006, 12:25	0.49
Basin B	0.5218	291.31	01Jan2006, 12:25	0.49
Basin C	0.1675	74.72	01Jan2006, 12:30	0.49
Basin D	0.3827	187.06	01Jan2006, 12:35	0.57
Basin E	0.1839	91.30	01Jan2006, 12:30	0.49
Basin F	0.0863	41.65	01Jan2006, 12:30	0.49
Basin for Culv C7	0.4087	238.92	01Jan2006, 12:20	0.49
Culv C1-DP 2	0.0863	41.65	01Jan2006, 12:30	0.49
Culv C5	1.2501	610.57	01Jan2006, 12:30	0.52
Culv C7	0.4087	238.92	01Jan2006, 12:20	0.49
DP 4	0.5218	291.31	01Jan2006, 12:25	0.49
DP 5	0.9045	447.59	01Jan2006, 12:30	0.52
DP 6	1.2501	608.41	01Jan2006, 12:30	0.52
Ex-Culv @ RR	0.1675	74.72	01Jan2006, 12:30	0.49
Reach-1	0.9045	445.60	01Jan2006, 12:30	0.53
Reach-2	1.2501	608.41	01Jan2006, 12:30	0.52
Texas Dip	0.1839	91.30	01Jan2006, 12:30	0.49
West Ditch	0.5218	281.01	01Jan2006, 12:25	0.49

HEC-HMS

Project : Crescent Junction Pr

Basin Model : P-DRAINAGE-event

May 16 16:49:09 MDT 2006



Appendix D

Rational Method Output

TIME OF CONCENTRATION

$t_c = t_i + t_t$

Initial or Overland Flow = ti
ti = $[0.395(1.1-C_5)\mathrm{SQRT}(L)]/S^{0.33}$

Overland Travel Time = t_t
$V = C_v S_w^{0.5}$
Where: C_v = conveyance coefficient from UD Table RO-2
S_w = watercourse slope (ft/ft)
$t_t = L/60V$

CHECK:
$t_c = (L/180) + 10$ forUrbanized areas only
Minimum t_c = 10 minutes

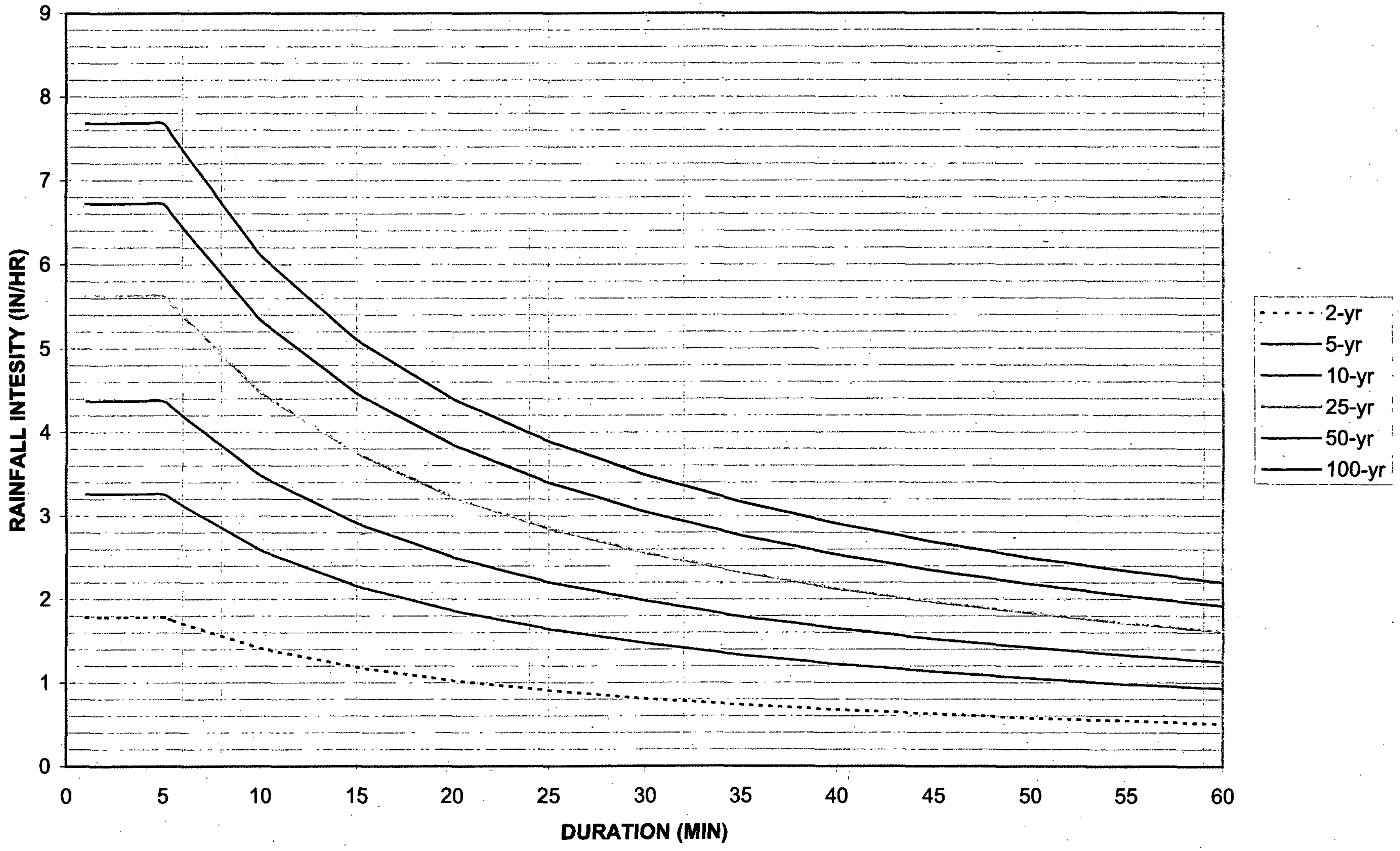
ONSITE CULVERTS

Initial/Overland Flow (t_i)					Gutter or Channelized Flow (t_t)					Total Travel Time	check max	check min	Use
Basin	L (ft)	Slope (ft/ft)	C_5	Ti (min)	L (ft)	Slope (%)	C_v^1	V (ft/sec)	Tt (min)	Tc=Ti+Tt Tc (min)	Tc (min)	Tc (min)	Tc (min)
Culvert C2	500	0.014	0.09	36.56	1700	1.400	10.00	1.18	23.95	60.51	na	10.0	60.5
Culvert C3	500	0.014	0.09	36.56	900	1.400	10.00	1.18	12.68	49.24	na	10.0	49.2
Culvert C4	500	0.014	0.09	36.56	3500	1.400	10.00	1.18	49.30	85.86	na	10.0	85.9
Culvert C6	800	0.014	0.09	46.16	400	1.400	10.00	1.18	5.63	51.79	na	10.0	51.8

TABLE RO-2
Conveyance Coefficiant, C_v

Type of Land Surface	Conveyance Coefficient, C_v
Heavy Meadow	2.5
Tillage/Field	5
Short pasture & lawns	7
Nearly bare ground	10
Grassed waterway	15
Paved areas	20

I-D-F CURVE FOR CRESCENT JUNCTION, UTAH



25 YEAR PEAK FLOWS

USE RATIONAL METHOD TO CALCULATE PEAK FLOWS"
Q = CIA

Basin	Area (ac)	Runoff Coeff. (C_{25})	T_C (min)	C*A (ac)	I (in/hr)	Q25 (cfs)
Culvert C2	32.0	0.17	60.51	5.44	1.62	8.81
Culvert C3	11.0	0.17	49.24	1.87	1.87	3.50
Culvert C4	64.0	0.17	85.86	10.88	1.62	17.63
Culvert C6	30.0	0.17	51.70	5.10	1.80	9.18

Appendix E

Calibration and Check of Flows in Crescent Wash

The purpose of this appendix is to document the calibration and provide a check of calculated flows in Crescent Wash. The USGS had a gaging station in Crescent Wash at a point slightly downstream of the analysis point for this project. The drainage area at the old gage is 23.3 square miles, as opposed to 22.5 sq miles at the I-70 crossing. There are 10 years of record taken between 1959 and 1969. It should be noted that the basin is relatively undeveloped so flows taken 37 to 47 years ago should be relatively typical of the basin today. However, there are only 10 years of record. Thus information derived from the gaging station is considered only as a relative check for order of magnitude compared to the computations.

Using the 10 years of data the USGS developed a flood frequency curve using Log-Pearson Type III probability distribution (Vaill, 2000). The results of this analysis are shown in Table E1, below. These flows are compared to the 25-year and 100-year floods calculated in HEC-HMS using the specified unit hydrograph, a CN value of 70 for determining initial losses and a constant infiltration rate of 0.3 in/hour. Precipitation values are derived from NOAA Atlas 14. The results of the analysis are within 3% of the USGS results, when adjusted for drainage area. Thus the calculated values are utilized for this project and the parameters (CN, infiltration, and precipitation) are applied to the ungaged basins within the study area for determining the 25-year and 100-year floods.

Table E1. Flow comparison for Crescent Wash, 25-year storm

Storm Event	***USGS (23.3 mi^2)***		***HEC-HMS (22.5mi^2)***	
	cfs	*cfs/mi^2*	*cfs*	*cfs/mi^2*
25-year storm	3,260	140	3,021	134
100-year storm	6,460	277	6,073	270

Several additional gaged sites were also checked for peak flows per square mile. Sites selected for comparison are similar in elevation and size and are in similar environmental conditions as the project site. Peak flows were calculated by the USGS using Log-Pearson Type III probability distribution (Vaill, 2000). Table E2 indicates that the flows per square mile are conservative as compared to the other basins. However, given the gaged information available on Crescent Wash, the calculated values will be utilized.

Table E2. Comparison of Peak Flows per Square Miles

Station no.	Station Name	DA, mi^2	elev	Q_{25}, cfs	Q_{25}/DA, cfs/mi^2	Q_{100}, cfs	Q_{100}/DA, cfs/mi^2
9181000	Onion Creek nr Moab, Ut	18.8	5,702	2,470	131.4	3,380	179.8
9185200	Kane Springs Canyon nr La Sal, Ut	17.8	6,620	1,340	75.3	1,770	99.4
9306235	Corral Gulch below Water Gulch nr Rangely, Co	8.6	7,740	382	44.4	1,120	130.2
9606242	Corral Gulch nr Rangely, Co	31.6	7,490	883	27.9	2,450	77.5
9328900	Crescent Wash nr Crescent Junction, Ut	23.3	6,180	3,260	139.9	6,460	277.3

Analysis of the Magnitude and Frequency of Floods in Colorado

By J.E. Vaill

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 99–4190

Prepared in cooperation with the
COLORADO DEPARTMENT OF TRANSPORTATION
and the BUREAU OF LAND MANAGEMENT

Denver, Colorado
2000

Table 3. Drainage-basin characteristics and flood-frequency data at streamflow-gaging stations—Continued

[LATDEG, latitude in decimal degrees; LNGDEG, longitude in decimal degree; DAREA, drainage area in square miles; YRSPK, years
P2, P5, P10, P25, P100, P200, and P500 are the indicated recurrence intervals for the 2-year, 5-year, 10-year, 25-year, 50-year, 100-year,

Map number (fig. 1)	Station number	Station name	LATDEG	LNGDEG	DAREA	YRSPK	ELEV	PRECIP
271	09302500	Marvine Creek near Buford, Colo.	40.0383	107.4875	59.7	12	9,780	32.2
272	09303000	North Fork White River at Buford, Colo.	39.9875	107.6139	259.0	24	9,529	30.9
273	09303300	South Fork White River at Budges Resort, Colo.	39.8433	107.3342	52.3	19	10.569	40.0
274	09303320	Wagonwheel Creek at Budges Resort, Colo.	39.8428	107.3361	7.4	14	10.640	40.0
275	09303400	South Fork White River near Budges Resort, Colo.	39.8642	107.5333	128.0	19	10.250	40.0
276	09304000	South Fork White River at Buford, Colo.	39.9744	107.6247	177.0	25	9,800	36.3
277	09304300	Coal Creek near Meeker, Colo.	40.0914	107.7694	25.1	11	7,956	28.5
278	09304500	White River near Meeker, Colo.	40.0336	107.8617	755.0	66	8.940	29.6
279	09306007	Piceance Creek below Rio Blanco, Colo.	39.8261	108.1825	177.0	21	7.628	24.5
280	09306058	Willow Creek near Rio Blanco, Colo.	39.8372	108.2436	48.4	12	7.500	21.8
281	09306061	Piceance Creek above Hunter Creek, near Rio Blanco, Colo.	39.8506	108.2583	309.0	14	7.552	21.2
282	09306200	Piceance Creek below Ryan Gulch, near Rio Blanco, Colo.	39.9211	108.2969	506.0	11	7.415	20.8
283	09306235	Corral Gulch below Water Gulch, near Rangely, Colo.	39.9061	108.5322	8.6	14	7,740	20.0
284	09306242	Corral Gulch near Rangely, Colo.	39.9203	108.4722	31.6	21	7.490	20.0
285	09306255	Yellow Creek near White River, Colo.	40.1686	108.4006	262.0	17	6.877	17.3
286	09306800	Bitter Creek near Bonanza, Utah	39.7533	109.3542	324.0	10	7.146	16.1
287	09307500	Willow Creek above diversions near Ouray, Utah	39.5664	109.5867	297.0	24	7.650	16.8
288	09308000	Willow Creek near Ouray, Utah	39.9389	109.6478	897.0	23	7.080	13.7
289	09328900	Crescent Wash near Crescent Junction, Utah	38.9422	109.8206	23.3	10	6.180	12.7
290	09340000	East Fork San Juan River near Pagosa Springs, Colo.	37.3694	106.8917	86.9	41	10.200	39.0
291	09341500	West Fork San Juan River near Pagosa Springs, Colo.	37.3786	106.8989	87.9	26	10,000	42.0
292	09342500	San Juan River at Pagosa Springs, Colo.	37.2661	107.0103	298.0	46	9,700	36.0
293	09343000	Rio Blanco near Pagosa Springs, Colo.	37.2128	106.7939	58.0	37	10.000	39.0
294	09343500	Rito Blanco near Pagosa Springs, Colo.	37.1936	106.9047	23.3	18	9.400	34.0
295	09344000	Navajo River at Banded Peak Ranch, near Chromo, Colo.	37.0853	106.6889	69.8	41	10.500	37.0
296	09345500	Little Navajo River at Chromo, Colo.	37.0456	106.8425	21.9	17	8,900	26.0
297	09346000	Navajo River at Edith, Colo.	37.0028	106.9069	172.0	36	9,200	33.0
298	09346200	Rio Amargo at Dulce, N. Mex.	36.9333	107.0000	168.0	26	7.930	17.7
299	09349500	Piedra River near Piedra, Colo.	37.2222	107.3422	371.0	34	9.400	33.0
300	09349800	Piedra River near Arboles, Colo.	37.0883	107.3972	629.0	20	8.300	27.0
301	09350800	Vaqueros Canyon near Gobernador, N. Mex.	36.7333	107.2833	60.5	31	7.500	15.0
302	09352500	Los Pinos River below Snowslide Canyon, near Weminuche Pass, Colo.	37.6389	107.3333	25.3	13	11.200	45.0

of record; ELEV, mean basin elevation in feet; PRECIP, mean annual precipitation in inches; BSLOPE, mean basin slope in foot per foot;
00-year, and 500-year peak discharge; --, not available]

Station number	BSLOPE	P2	P5	P10	P25	P50	P100	P200	P500
09302500	0.245	318	400	447	498	532	563	591	626
09303000	0.237	1,380	1,890	2,230	2,640	2,940	3,240	3,540	3,930
09303300	0.198	924	1,380	1,700	2,120	2,440	2,760	3,090	3,540
09303320	0.159	188	260	307	365	406	447	488	540
09303400	0.256	1,700	2,480	3,030	3,770	4,350	4,940	5,570	6,440
09304000	0.259	1,800	2,310	2,600	2,920	3,140	3,340	3,530	3,760
09304300	0.285	50	80	100	126	144	162	180	203
09304500	0.222	3,170	4,210	4,840	5,600	6,140	6,650	7,150	7,780
09306007	0.283	148	294	411	576	710	851	1,000	1,210
09306058	0.272	14	36	58	99	140	191	254	360
09306061	0.263	193	381	534	758	943	1,140	1,360	1,660
09306200	0.243	145	255	345	479	594	723	867	1,080
09306235	0.253	14	69	158	382	673	1,120	1,780	3,110
09306242	0.236	39	175	383	883	1,510	2,450	3,810	6,490
[illegible]9306255	0.197	154	508	982	2,040	3,310	5,170	7,850	13,200
[illegible]9306800	0.287	115	451	894	1,820	2,840	4,210	6,000	9,150
09307500	--	241	476	692	1,050	1,380	1,780	2,260	3,030
09308000	--	636	1,860	3,170	5,510	7,810	10,600	14,000	19,300
09328900	--	439	1,140	1,890	3,260	4,670	6,460	8,720	12,600
09340000	0.387	924	1,350	1,640	2,020	2,300	2,600	2,900	3,310
09341500	0.400	1,320	1,830	2,170	2,590	2,910	3,230	3,550	3,970
09342500	0.342	2,610	4,160	5,480	7,570	9,460	11,700	14,300	18,400
09343000	0.428	853	1,200	1,450	1,780	2,030	2,290	2,570	2,950
09343500	0.239	190	313	401	519	610	704	800	932
09344000	0.368	650	897	1,070	1,280	1,450	1,620	1,790	2,020
09345500	0.225	146	253	334	447	538	633	733	874
09346000	0.277	852	1,310	1,660	2,160	2,570	3,020	3,510	4,230
09346200	--	1,030	1,490	1,830	2,280	2,650	3,040	3,440	4,030
09349500	0.344	2,090	3,480	4,640	6,400	7,950	9,710	11,700	14,800
09349800	0.290	2,420	3,960	5,130	6,790	8,150	9,610	11,200	13,500
09350800	--	196	490	822	1,470	2,180	3,130	4,410	6,760
09352500	--	324	518	656	839	981	1,130	1,280	1,480

Project: Crescent Junction Ex Simulation Run: CW 25

Start of Run:	01Jan2006, 00:00	Basin Model:	Crescent Wash-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	25-yr 24-hr
Compute Time:	16May2006, 17:21:41	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Crescent Wash	22.5600	3020.71	01Jan2006, 14:10	0.49
Sink-1	22.5600	3020.71	01Jan2006, 14:10	0.49

Project: Crescent Junction Ex Simulation Run: CW 100

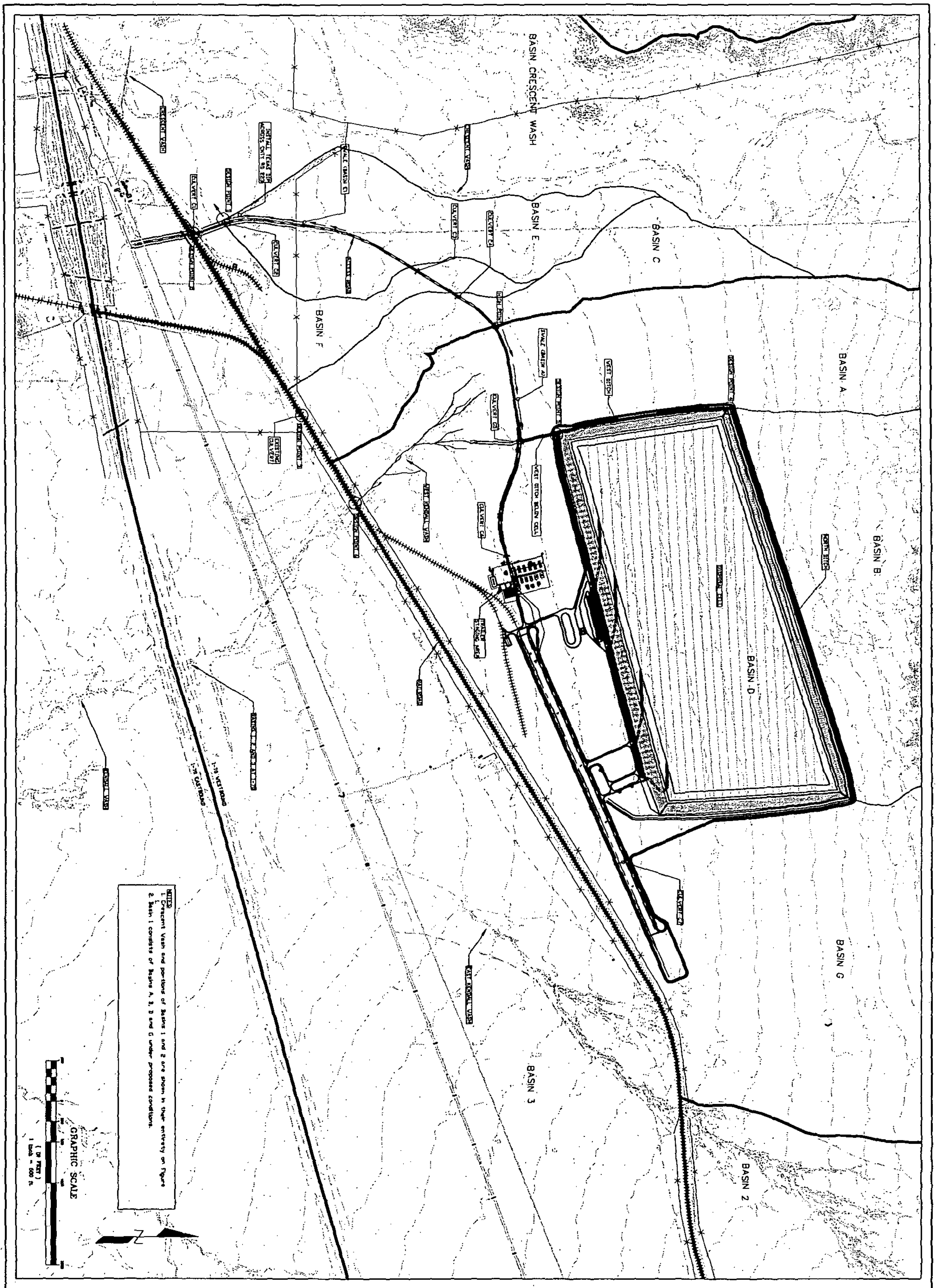
Start of Run:	01Jan2006, 00:00	Basin Model:	Crescent Wash-event
End of Run:	02Jan2006, 00:00	Meteorologic Model:	100-yr 24-hr
Compute Time:	15May2006, 15:48:31	Control Specifications:	1 day at 5 min step

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Crescent Was	22.5400	6072.68	01Jan2006, 14:10	0.98
Sink-1	22.5400	6072.68	01Jan2006, 14:10	0.98

Appendix F

Master Drainage Plan



NOTES:
1. Crescent Wash and portions of Basins 1 and 2 are shown in their entirety on Figure 1.
2. Basin 1 consists of Basins A, B, D and G under proposed conditions.

CRESCENT JUNCTION

MASTER DRAINAGE PLAN

DESIGNED BY ETA	CHECKED BY PMB	DRAWN BY ETA
DATE: 5-17-06	SCALE 1:500	PROJECT # 4704-005-01
		CADD FILE DRAINAGE PROPOSED.dwg

TETRA TECH, INC.
410 S French Street, P.O. Box 1658
Breckenridge Co 80424
(970) 453-6394 Fax (970) 453-4578

DRAWING NUMBER
C-1

REVISIONS

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-04-2007-5-25-02 **Discipline:** Engineering **No. of Sheets:** 10
Doc. No.: X0176400

Location: Attachment 1, Appendix G

Project: Moab UMTRA Project

Site: Crescent Junction Disposal Site

Feature: Diversion Channel Design, North Side Disposal Cell

Sources of Data:

Bonnin, G.M., D. Todd, T. Lin, T. Parzbok, T. A. Yekta, and D. Riley, 2003. "Precipitation-Frequency Atlas of the United States," *U. S. National Oceanic and Atmospheric Administration* (NOAA) *Atlas 14*, Volume I, Version 3, NOAA, National Weather Service, Silver Spring, Maryland, for Thompson, Utah.

"Crescent Junction Site Hydrology Report" calculation set, RAP Attachment 1, Appendix F.

Purpose of Revision:

Revision was issued to address Nuclear Regulatory Commission comments SW1–SW4.

Sources of Formulae and References:
See "References" section.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No. MOA-02-05-2006-5-25-01**

Author: Roslyn Stern 5/25/07
Name Date

Checked by: G. Greg Field 5/30/07
Name Date

Greg Smith 5/31/07
Name Date

Approved by: John E Elmer 5/31/07
Name Date

Name Date

may 31, 07
Name Date

No text for this page

Problem Statement:

- Design erosion protection for the north slope of the disposal cell to prevent detrimental erosion from surface water flows from upland area, consistent with the requirements of 40 CFR Part 192 and NRC guidance in NUREG 1623 (Johnson 2002).
- Provide grading such that upland flow will drain to the west around the north side of the disposal cell.
- Provide protection at northwest corner of disposal cell to prevent headward erosion as flow is released to native ground.

Method of Solution:

The disposal cell needs protection against erosion from precipitation events occurring in the upland area. A traditional diversion channel will likely become inundated with silt over time, reducing its capacity to carry water. Therefore, water will be allowed to flow along the north slope of the disposal cell. The north slope of the disposal cell will be armored to allow water to flow at the toe without negatively impacting the disposal cell. Excavation along the toe of the north slope will create a uniform slope that drains to the west.

The magnitude of the probable maximum flood (PMF) is obtained from the "Crescent Junction Site Hydrology" calculation (RAP Attachment 1, Appendix F). The depth and velocity of flow associated with the PMF is calculated using Manning's equation. The size of rock required to prevent erosion is calculated using the Safety Factor method as outlined in Chapter 3 of Appendix D of NUREG 1623 (Johnson 2002).

In addition to rock protection on the slopes of the disposal cell, sufficient riprap will be placed within the diversion channel bed to act as self-launching protection to prevent undercutting beneath the north slope of the disposal cell.

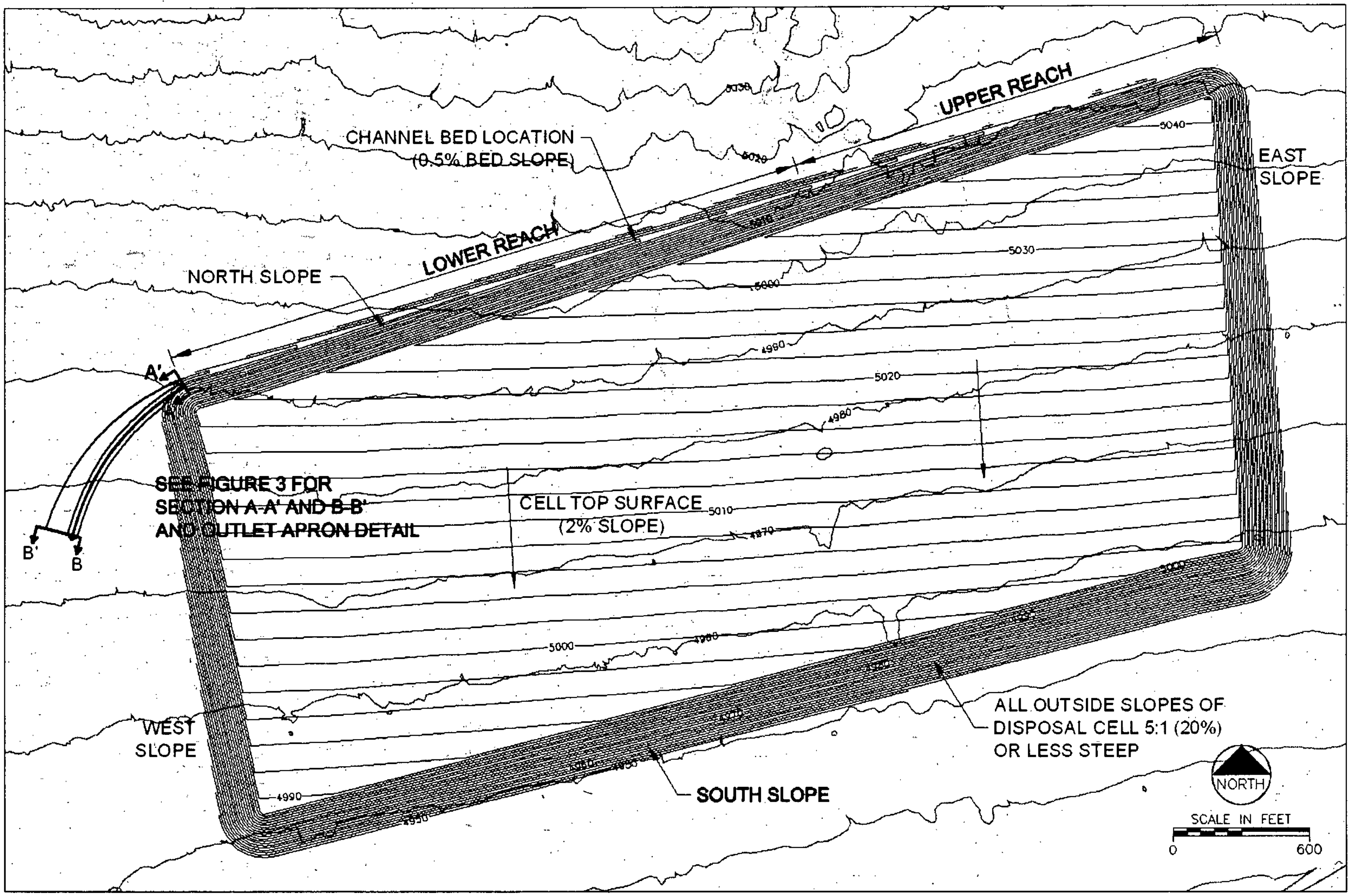
Assumptions:

- Topographic maps provided in the "Crescent Junction Site Hydrology" calculation (RAP Attachment 1, Appendix F) are accurate.
- Riprap stone is angular, possesses a specific gravity of 2.65, and has a minimum durability criteria score of 80 (Johnson 2002); thus it will not require oversizing for use in frequently saturated areas.
- Upland area contributes flow to the disposal cell uniformly, such that flows along any reach of the north toe can be calculated as a ratio of length of reach to total length of north toe multiplied by total flow at northwest corner.

Calculation:

- The upland drainage basin for the proposed disposal cell was determined in the "Crescent Junction Site Hydrology" calculation (RAP Attachment 1, Appendix F), and is shown in Figure 1. A PMF flow rate of 5,859 cubic feet (ft) per second (cfs) is the reported flow rate at the northwest corner of the cell.
- The north slope of the disposal cell is divided into five reaches, each of approximately 1,000 ft long.
- In areas not requiring excavation to meet the 0.5 percent channel bed grade, a V-shaped channel will convey flow, with the south slope consisting of the 5:1 (20 percent) side slope of the disposal cell, and the north slope consisting of natural ground at an approximate slope of 2.8 percent. In areas requiring excavation, the channel will consist of 5:1 side slopes with a 10-ft bottom width. Overbank flow will have a north slope of 2.8 percent.
- Invert slope of the channel is computed from the difference in elevation between the northeastern end to the southwest end, divided by the length between them:

$$(4{,}990 \text{ ft} - 5{,}014 \text{ ft})/4{,}955 \text{ ft} = 0.005, [-0.5\%]$$



MFG, Inc.
consulting scientists and engineers

FIGURE 1
DISPOSAL CELL LAYOUT
WITH EROSION PROTECTION FEATURES

Date: APRIL 2007
Project: 181268
File: CHANNEL-03.DWG

Figure 1. Diversion Channel Location Along the North Slope of the Disposal Cell

- Manning's n is computed using procedures discussed by Abt et al. (1987) and Abt and Johnson (1991) as follows:

$$n = 0.0456 * (D_{50} * S)^{0.159} \qquad (1)$$

where: n is Manning's n,
D_{50} is the mean riprap diameter in inches, and
S is the channel slope (ft/ft).

A weighted value for n is used based on the length of erosion riprap and native ground submerged as:

$$n_{ave} = \frac{\sqrt{p_1 * n_1^2 + p_2 * n_2^2 + ...p_n * n_n^2}}{\sqrt{p_1 + p_2 + ...p_n}} \qquad (2)$$

where: p is the wetted perimeter. Manning's n for the native ground is taken as 0.02.

The depth of flow along the toe is conservatively calculated for the point within the reach where the flow is most restricted (i.e. greatest cut required to meet 0.5 percent channel slope). The depth of flow during PMF flow is computed with Manning's equation for open-channel flow:

$$Q = \frac{1.486 * A * R_h^{\frac{2}{3}} * S^{\frac{1}{2}}}{n} \qquad (3)$$

where: Q is the PMF flow rate,
A is the cross-sectional flow area,
R_h is the hydraulic radius equal to the cross-sectional flow area divided by the wetted perimeter, and all other variables are previously defined.

Assuming a trapezoidal cross-section, flow area and hydraulic radius are expressed as a function of the flow depth (y), base width of the channel (B) and two side slopes, s_1 and s_2 (ft/ft), by:

$$A = \frac{0.5 * y^2}{s_1} + \frac{0.5 * y^2}{s_2} + y * B \qquad (4)$$

Hydraulic radius is evaluated by:

$$R_h = \frac{A}{\sqrt{y^2 + \left(\frac{y}{s_1}\right)^2} + \sqrt{y^2 + \left(\frac{y}{s_2}\right)^2} + B} \qquad (5)$$

For each reach of the north toe, equations (3), (4) and (5) are solved simultaneously to obtain depth of flow y.

Riprap to Protect Against Flows Within Channel:

Riprap size is determined using the Safety Factor Method (Johnson 2002) by computing the tractive shear stress (τ, psf) at the base of the channel as:

$$\tau = \gamma_w * S * y \qquad (6)$$

where: γ_w is the unit weight of water (62.4 pcf),
y is the depth of flow (ft),
S is the channel slope (ft/ft) as previously defined.

Tractive shear stress is related to the mean rock size through equation (6) of the Army Corps of Engineers (ACE) (ACE 1994) as:

$$\tau = \alpha^* (\gamma_S - \gamma_w) * D_{50} \qquad (7)$$

where: γ_s is the unit weight of riprap (62.4 pcf times specific gravity of 2.65), and
α is a coefficient of 0.04.

Equation (6) and (7) are solved simultaneously. The resulting D_{50} is used as input into Equation (2), and all equations are solved iteratively until a depth of flow, computed rock size, and Manning's *n* converge.

For construction purposes, the diversion channel and north erosion protection are divided into two reaches. Results for computed parameters for each reach are shown in Table 1. Further calculations are shown in Appendix A.

Table 1. Computed Depth of Flow and Required Rock Size for North Diversion Channel.

Reach	Distance of Reach from Northeast Corner of Disposal Cell (ft)	Maximum Flow (cfs)	Maximum Depth of Flow (ft)	Minimum D_{50} Required (inches)
Upper Reach, Left Channel Slope	0 to 2,000	2,344	6.0	5.0
Lower Reach, Left Channel Slope	2,000 to 5,000	5,859	8.0	7.0
Channel Bottom	All Reaches	469	3.9	30

Riprap should extend from the base of channel to the maximum depth of flow, as shown on Figure 2.

Riprap to Protect Against Flow from Gullies Discharging Into Channel:

Existing and future gullies upstream of the diversion channel will discharge into the diversion channel. Due to the steeper slopes of the natural gullies, the riprap along the channel base is increased to protect against the higher flow velocities from the gullies. In order to estimate the potential scour depth and flow velocities from natural gullies, it is assumed that the 5,859 cfs of flow reporting to northwest corner of disposal cell ("Crescent Junction Site Hydrology," RAP Attachment 1, Appendix F) is accumulated uniformly along the 5,000 ft of the north toe of the disposal cell (i.e. unit flow is approximately 1.17 cfs/ft). It is conservatively assumed that some of the larger gullies have a swath of up to 400 ft that contribute to flow in the gully. Therefore, the PMF associated with a gully is calculated to be up to 470 cfs. Using this flow, an assumed v-channel configuration of the gully with 2:1 (50 percent) side slopes, and a gully slope of approximately 3 percent, the maximum scour depth was calculated using procedures outlined in NUREG 1623 (Johnson 2002) and U.S. Department of Transportation (DOT 1983).

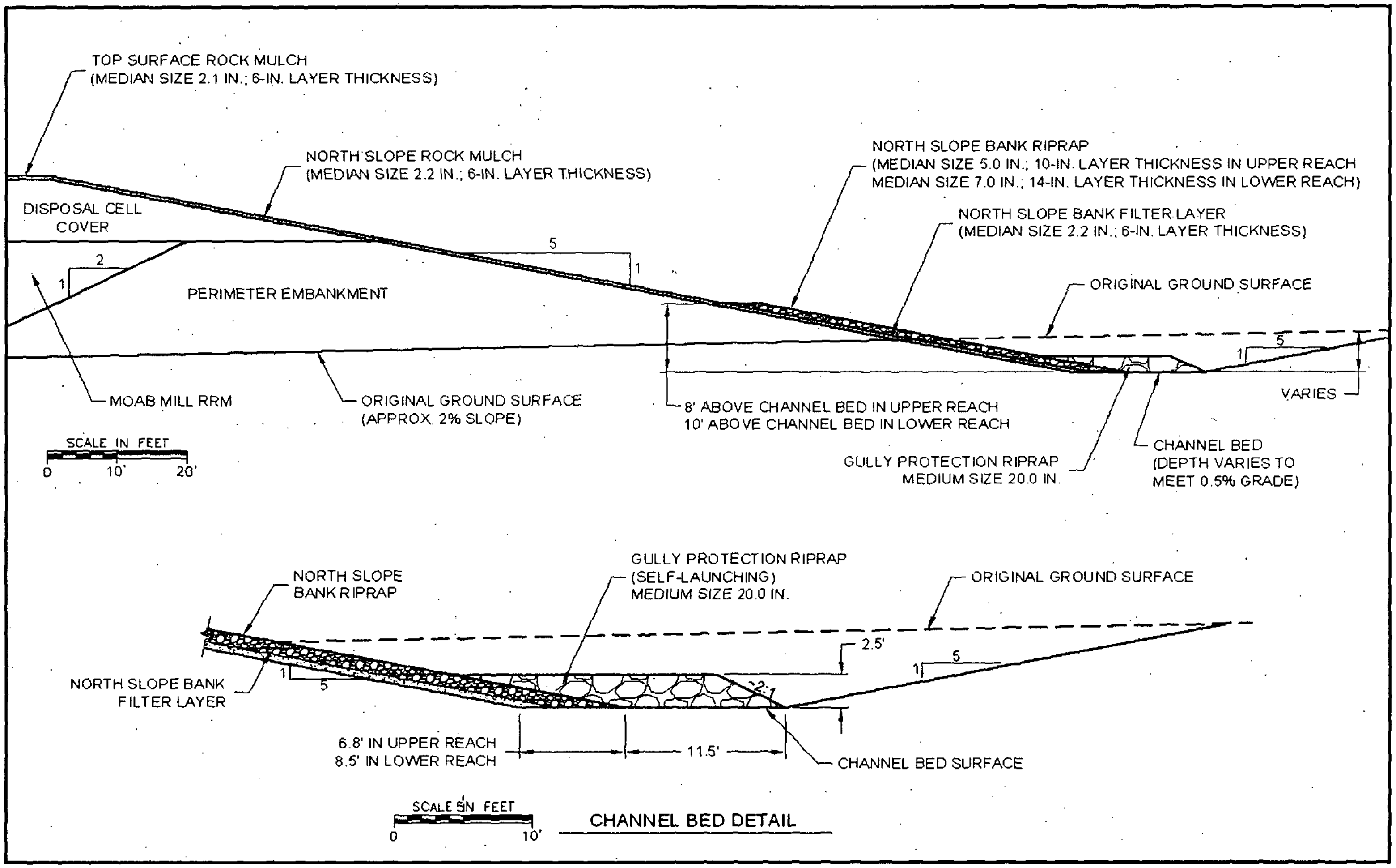


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FIGURE 2
TYPICAL CROSS SECTION THROUGH NORTH SLOPE OF DISPOSAL CELL SHOWING EROSION PROTECTION MATERIAL

Date:	APRIL 2007
Project:	181268
File:	XS-TYP-02.DWG

Figure 2. Typical Cross Section Through North Slope of Disposal Cell.

The maximum scour depth associated with a gully is estimated to be 5.4 ft. Using the Safety Factor Method, the required rock size to protect against the gully flows is 20 inches. Following guidance given in NUREG 1623, the rock placed in the channel bottom is designed to collapse into the scoured area that occurs immediately upslope of the diversion channel. The thickness of launched rock should be a minimum of 1.5 times the average rock size. A rock volume of 38 cubic feet per linear foot of channel is required. This rock volume assumes the scour hole develops at a slope of 1V to 2H to a depth of 5.4 ft, the collapsed rock thickness in the scour hole is 1.5 times the average rock size, and assumes approximately 25 percent of the launched rock is lost downstream.

Riprap for Diversion Channel Outlet:

As the diversion channel reaches the west edge of the disposal cell, it continues approximately 500 ft west of the cell, turns south and discharges the flow onto natural ground. The channel extends an adequate distance west of the cell to minimize the possibility of gully headcutting to impact the disposal cell. A 4-ft-high riprap-protected berm is used to divert the water away from the cell. The channel width at the outlet will transition from 11.5 ft to 100 ft in order to slow flow velocities. The rock size within the outlet will increase as the flow velocities increase due to the steepening slope. Assuming a unit flow of 64 cfs/ft across the outlet apron, a maximum scour depth at the outlet is estimated to be approximately 5 ft. A pre-formed rock slope will be constructed extending vertically to the estimated depth of scour along a 10H:1V buried slope. Using the Abt and Johnson (1991) method, the required median rock size for this slope is 20 inches. The rock should be placed at a minimum rock depth of 1.5 times median rock size, or 30 inches.

Expected Operational Performance:

Run-on from frequent storm events will flow along the north edge of the disposal cell. Erosion and deposition of sediments from this run-on are expected to occur in the channel over the lifetime of the facility. Scour will occur locally where upstream gullies develop and discharge into the diversion channel. The 20-in rock placed in the bottom of the diversion channel is designed to launch into any formed scour hole and prevent undermining of the disposal cell. Erosion and deposition will occur along the channel as the channel system conforms to the local climate and ecology under frequent storm events.

During large-magnitude storm events, such as the design PMF, the higher flows may erode the sediments deposited during smaller events.

At the northwest corner of the disposal cell, at the termination of the channel, flow is spread out and transition to natural ground. It is expected that erosion will occur at this transition. The amount and distance of upstream migration of this scour will be limited by the buried rock slope. This rock slope is extended below the calculated depth of scour. Figure 3 shows the recommended channel cross-section and outlet.

Conclusion and Recommendations:

Riprap protection should follow minimum sizes specified in text and figures. Design should be re-evaluated once a specific rock source and actual durability test data are available.

Computer Source:

Not applicable.

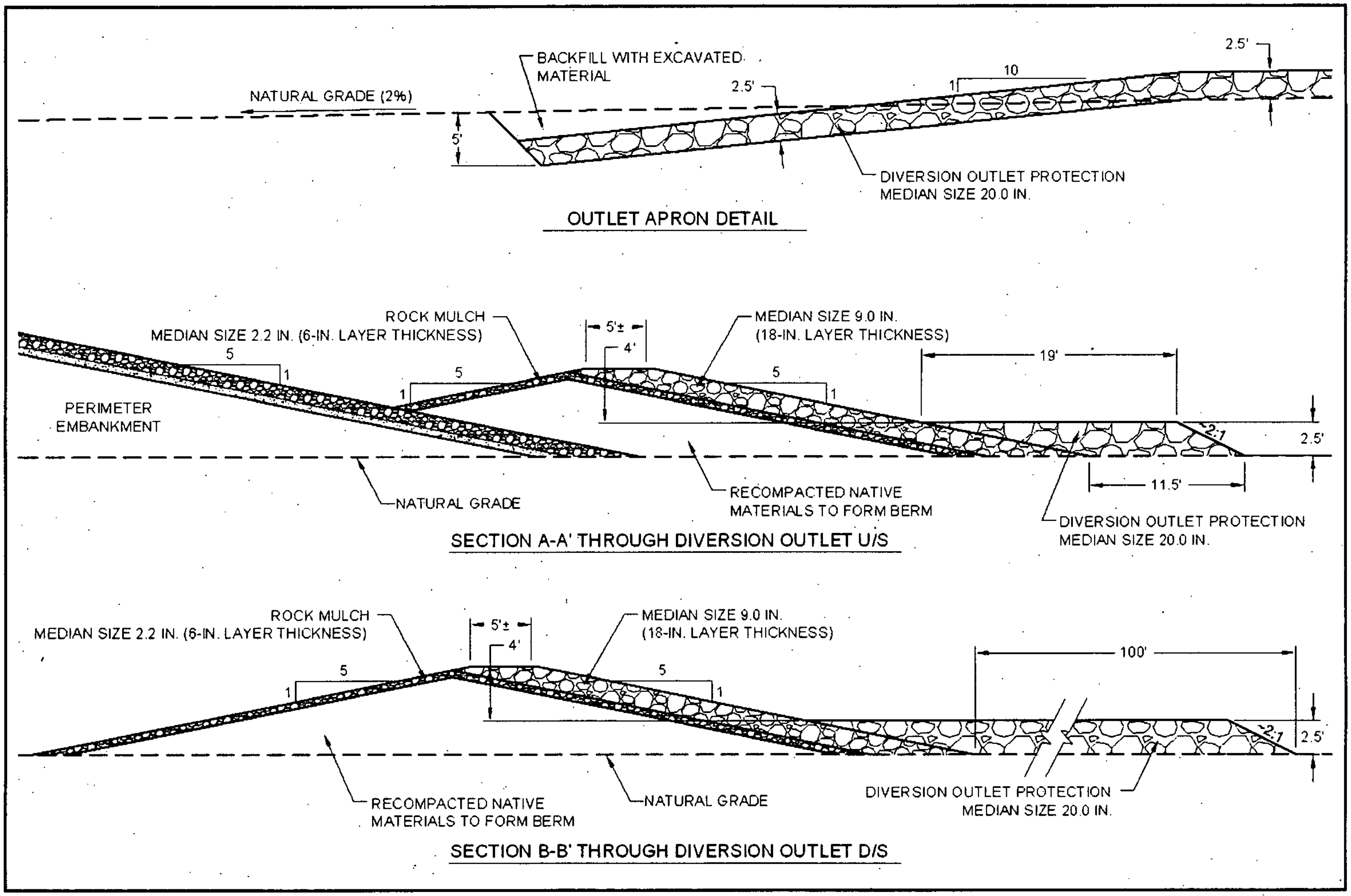

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FIGURE 3
DIVERSION CHANNEL OUTLET PLAN

Date:	APRIL 2007
Project:	181268
File:	XS-TYP-02.DWG

Figure 3. Diversion Channel Outlet Plan and Cross Section

References:

40 CFR 192. EPA (Environmental Protection Agency), "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings," *Code of Federal Regulations,* March 2007.

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Chow, V.T., 1959. *Open-Channel Hydraulics,* McGraw-Hill Book Company, New York, New York.

DOT (U.S. Department of Transportation). 1983. *Hydraulic Design of Energy Dissipaters for Culverts and Channels*, Hydraulic Engineering Circular No. 14, September.

Graf, W., 2002. *Fluvial Processes in Dryland Rivers,* The Blackburn Press.

Johnson, T.L., 2002. *Design of Erosion Protection for Long-Term Stabilization Final Report,* NUREG 1623, U.S. Nuclear Regulatory Commission, September.

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Appendix A

Supporting Calculations

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**3/16/2007**
etail:	**Erosion Protection**	**Computed By:**	**RTS**

pron Protection

This is for areas where channel has cut 5:1 slopes and then overbank flow on native upland area

Area: North side of disposal cell		
flow from upland area north of cell:	5859 cfs	Source: DP 45 PMP file from Peggy Bailey email on May 11, 2006
flow from disposal cell area A4:	0 cfs	Flow was included in DP 45 PMP calc.
total flow:	5859 cfs	conservatively assumes peak flows are cummulative from cell and upland

Reach 1	0 to 1000 feet from northeast corner of disposal cell
max flow in reach:	1171.8 cfs

Trapezoid or triangular channels	
slope (ft/ft)	0.005 ft/ft
Channel Side Slope 1 (ft/ft)	0.2 ft/ft
Channel Side Slope 2 (ft/ft)	0.2 ft/ft
maximum cut height in reach	2.5 ft
Channel Side Slope 3 (ft/ft)	0.028
bottom width	19 ft

Assume flow is in trapezoidal channel with two 20% side slopes, and overbank flow

Q	1171.8 cfs	
Assumed D50 on side slope (ft)	0.33 ft	
Assumed D50 on side slope (in)	4 in	
D50 on channel bottom (ft)	1.67 ft	
D50 on channel bottom (in)	20 in	
n riprap side	0.0245	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles
n riprap bottom	0.0316	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles
n native soils	0.020	
weighted average n	0.023	EM 1110-2-1601, U.S. Army Corps of Engineers
Area of flow (A)	178.65 ft^2	
Wetted Perimeter Rock Slope	19.81 ft	
Wetted Perimeter Rock Bottom	19.00 ft	
etted Perimeter Soil Slope	62.20 ft	
draulic Radius (R)	1.77 ft	
p Width (T)	100.4 ft	
aximum depth of flow (d)	3.88 ft	**iterate with d until Q calc equals Q design**
Q calc	1171.8 cfs	note: d>max cut, so overbank flow, but rock size is conservative
average velocity (v)	6.559094 fps	
unit discharge	30.49921 cfs/ft	take as total Q divided by average flow width

Safety Factor Method	(for rock on side slope of disposal cell)

Angle of repose of rock (degees)	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	
Side Slope	5.0	XH:1V
Angle of side slope (degrees)	11.310	
Angle of side slope (radians)	0.197	
Specific gravity of rock	2.65	
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel
design flow (cfs)	1171.8	
max shear stress, τ	1.21 psf	
Stability number for rock, η	0.742	
β	0.959	
Stability number for rock, η'	0.674	
Factor of Safety for side slope rock	1.19	**Iterate with D50 until FS equal or greater than 1.0**

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**3/16/2007**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Apron Protection

This is for areas where channel has cut 5:1 slopes and then overbank flow on native upland area

Area: North side of disposal cell		
flow from upland area north of cell:	5859 cfs	Source: DP 45 PMP file from Peggy Bailey email on May 11, 2006
flow from disposal cell area A4:	0 cfs	Flow was included in DP 45 PMP calc.
total flow:	5859 cfs	conservatively assumes peak flows are cummulative from cell and upland

Reach 2	1000 to 2000 feet from northeast corner of disposal cell
max flow in reach:	2343.6 cfs

Trapezoid or triangular channels	
slope (ft/ft)	0.005 ft/ft
Channel Side Slope 1 (ft/ft)	0.2 ft/ft
Channel Side Slope 2 (ft/ft)	0.2 ft/ft
maximum cut height in reach	5.5 ft
Channel Side Slope 3 (ft/ft)	0.028
bottom width	19 ft

Assume flow is in trapezoidal channel with two 20% side slopes		
Q	2343.6 cfs	
Assumed D50 on side slope (ft)	0.42 ft	
Assumed D50 on side slope (in)	5 in	
D50 on channel bottom (ft)	1.67 ft	
D50 on channel bottom (in)	20 in	
n riprap side	0.0254	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles
n riprap bottom	0.0316	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles
n native soils	0.020	
weighted average n	0.025	EM 1110-2-1601, U.S. Army Corps of Engineers
Area of flow (A)	250.98 ft^2	
Wetted Perimeter Rock Slope	27.71 ft	
Wetted Perimeter Rock Bottom	19.00 ft	
Wetted Perimeter Soil Slope	27.71 ft	
Hydraulic Radius (R)	3.37 ft	
Top Width (T)	73.4 ft	
Maximum depth of flow (d)	5.44 ft	**iterate with d until Q calc equals Q design**
Q calc	2343.6 cfs	
average velocity (v)	9.33777 fps	
unit discharge	50.75327 cfs/ft	take as total Q divided by average flow width

Safety Factor Method (for rock on side slope of disposal cell)

Angle of repose of rock (degees)	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	
Side Slope	5.0	XH:1V
Angle of side slope (degrees)	11.310	
Angle of side slope (radians)	0.197	
Specific gravity of rock	2.65	
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel
design flow (cfs)	2343.6	
max shear stress, τ	1.70 psf	
Stability number for rock, η	0.830	
β	1.011	
Stability number for rock, η'	0.767	
Factor of Safety for side slope rock	1.08	**Iterate with D50 until FS equal or greater than 1.0**

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**3/16/2007**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Apron Protection

This is for areas where channel has cut 5:1 slopes and then overbank flow on native upland area

Area: North side of disposal cell		
flow from upland area north of cell:	5859 cfs	Source: DP 45 PMP file from Peggy Bailey email on May 11, 2006
flow from disposal cell area A4:	0 cfs	Flow was included in DP 45 PMP calc.
total flow:	5859 cfs	conservatively assumes peak flows are cummulative from cell and upland

Reach 3	2000 to 3000 feet from northeast corner of disposal cell
max flow in reach:	3515.4 cfs

Trapezoid or triangular channels	
slope (ft/ft)	0.005 ft/ft
Channel Side Slope 1 (ft/ft)	0.2 ft/ft
Channel Side Slope 2 (ft/ft)	0.2 ft/ft
maximum cut height in reach	7.5 ft
Channel Side Slope 3 (ft/ft)	0.028
bottom width	19 ft

Assume flow is in trapezoidal channel with two 20% side slopes

Q	3515.4 cfs	
Assumed D50 on side slope (ft)	0.50 ft	
Assumed D50 on side slope (in)	6 in	
D50 on channel bottom (ft)	1.67 ft	
D50 on channel bottom (in)	20 in	
n riprap side	0.0261	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles
n riprap bottom	0.0316	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles
n native soils	0.020	
weighted average n	0.025	EM 1110-2-1601, U.S. Army Corps of Engineers
Area of flow (A)	338.58 ft^2	
Wetted Perimeter Rock Slope	33.38 ft	
Wetted Perimeter Rock Bottom	19.00 ft	
Wetted Perimeter Soil Slope	33.38 ft	
ydraulic Radius (R)	3.95 ft	
op Width (T)	84.5 ft	
Maximum depth of flow (d)	6.55 ft	**Iterate with d until Q calc equals Q design**
Q calc	3515.4 cfs	
average velocity (v)	10.3829 fps	
unit discharge	67.96047 cfs/ft	take as total Q divided by average flow width

Safety Factor Method (for rock on side slope of disposal cell)

Angle of repose of rock (degees)	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	
Side Slope	5.0	XH:1V
Angle of side slope (degrees)	11.310	
Angle of side slope (radians)	0.197	
Specific gravity of rock	2.65	
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel
design flow (cfs)	3515.4	
max shear stress, τ	2.04 psf	
Stability number for rock, η	0.833	
β	1.012	
Stability number for rock, η'	0.770	
Factor of Safety for side slope rock	1.08	**Iterate with D50 until FS equal or greater than 1.0**

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**3/16/2007**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Apron Protection

This is for areas where channel has cut 5:1 slopes and then overbank flow on native upland area

Area: North side of disposal cell		
flow from upland area north of cell:	5859 cfs	Source: DP 45 PMP file from Peggy Bailey email on May 11, 2006
flow from disposal cell area A4:	0 cfs	Flow was included in DP 45 PMP calc.
total flow:	5859 cfs	conservatively assumes peak flows are cummulative from cell and upland

Reach 4	3000 to 4000 feet from northeast corner of disposal cell
max flow in reach:	4687.2 cfs

Trapezoid or triangular channels	
slope (ft/ft)	0.005 ft/ft
Channel Side Slope 1 (ft/ft)	0.2 ft/ft
Channel Side Slope 2 (ft/ft)	0.2 ft/ft
maximum cut height in reach	5.5 ft
Channel Side Slope 3 (ft/ft)	0.028
bottom width	19 ft

Assume flow is in trapezoidal channel with two 20% side slopes, and overbank flow

Q	4687.2 cfs	
Assumed D50 on side slope (ft)	0.58 ft	
Assumed D50 on side slope (in)	7 in	
D50 on channel bottom (ft)	1.67 ft	
D50 on channel bottom (in)	20 in	
n riprap side	0.0268	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles
n riprap bottom	0.0316	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles
n native soils	0.020	
weighted average n	0.023	EM 1110-2-1601, U.S. Army Corps of Engineers
Area of flow (A)	490.12 ft^2	
Wetted Perimeter Rock Slope	38.40 ft	
Wetted Perimeter Rock Bottom	19.00 ft	
Wetted Perimeter Soil Slope	100.63 ft	
Hydraulic Radius (R)	3.10 ft	
Top Width (T)	156.7 ft	
Maximum depth of flow (d)	7.53 ft	**iterate with d until Q calc equals Q design**
Q calc	4687.2 cfs	note: d>max cut, so overbank flow, but rock size is conservative
average velocity (v)	9.563429 fps	
unit discharge	82.72764 cfs/ft	take as total Q divided by average flow width

Safety Factor Method	(for rock on side slope of disposal cell)	
Angle of repose of rock (degees)	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	
Side Slope	5.0	XH:1V
Angle of side slope (degrees)	11.310	
Angle of side slope (radians)	0.197	
Specific gravity of rock	2.65	
Concentration Factor	1	*Typically between 1.1 to 3.2 for slopes. Set to 1 for channel*
design flow (cfs)	4687.2	
max shear stress, τ	2.35 psf	
Stability number for rock, η	0.822	
β	1.006	
Stability number for rock, η'	0.758	
Factor of Safety for side slope rock	1.09	**Iterate with D50 until FS equal or greater than 1.0**

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**3/16/2007**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

pron Protection

This is for areas where channel has cut 5:1 slopes and then overbank flow on native upland area

Area: North side of disposal cell		
flow from upland area north of cell:	5859 cfs	Source: DP 45 PMP file from Peggy Bailey email on May 11, 2006
flow from disposal cell area A4:	0 cfs	Flow was included in DP 45 PMP calc.
total flow:	5859 cfs	conservatively assumes peak flows are cummulative from cell and upland

Reach 5	4000 to 5000 feet from northeast corner of disposal cell
max flow in reach:	5859 cfs

Trapezoid or triangular channels	
slope (ft/ft)	0.005 ft/ft
Channel Side Slope 1 (ft/ft)	0.2 ft/ft
Channel Side Slope 2 (ft/ft)	0.2 ft/ft
maximum cut height in reach	1.5 ft
Channel Side Slope 3 (ft/ft)	0.028
bottom width	10 ft

Assume flow is in trapezoidal channel with two 20% side slopes, and overbank flow		
Q	5859.0 cfs	
Assumed D50 on side slope (ft)	0.50 ft	
Assumed D50 on side slope (in)	6 in	
D50 on channel bottom (ft)	1.67 ft	
D50 on channel bottom (in)	20 in	
n riprap side	0.0261	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles
n riprap bottom	0.0316	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles
n native soils	0.020	
weighted average n	0.022	EM 1110-2-1601, U.S. Army Corps of Engineers
Area of flow (A)	610.14 ft^2	
Wetted Perimeter Rock Slope	32.00 ft	
Wetted Perimeter Rock Bottom	10.00 ft	
etted Perimeter Soil Slope	178.31 ft	
draulic Radius (R)	2.77 ft	
p Width (T)	219.5 ft	
Maximum depth of flow (d)	6.28 ft	**iterate with d until Q calc equals Q design**
Q calc	5859.0 cfs	note: d>max cut, so overbank flow, but rock size is conservative
average velocity (v)	9.602772 fps	
unit discharge	141.5795 cfs/ft	take as total Q divided by average flow width

Safety Factor Method	(for rock on side slope of disposal cell)	
Angle of repose of rock (degees)	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	
Side Slope	5.0	XH:1V
Angle of side slope (degrees)	11.310	
Angle of side slope (radians)	0.197	
Specific gravity of rock	2.65	
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel
design flow (cfs)	5859	
max shear stress, τ	1.96 psf	
Stability number for rock, η	0.799	
β	0.993	
Stability number for rock, η'	0.734	
Factor of Safety for side slope rock	1.12	**Iterate with D50 until FS equal or greater than 1.0**

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**3/16/2007**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Channel Outlet

Area: North side of disposal cell		
flow from upland area north of cell:	5859 cfs	Source: DP 45 PMP file from Peggy Bailey email on May 11, 2006
additional flow from upland area west of cell area	0 cfs	
total flow:	5859 cfs	conservatively assumes peak flows are cummulative from cell and upland

Outlet1	immediately west of disposal cell	
max flow in reach:	5859	cfs

Trapezoid or triangular channels			
slope (ft/ft)		0.005	ft/ft
Channel Side Slope 1 (ft/ft)		0.333	ft/ft
Channel Side Slope 2 (ft/ft)		0.01	ft/ft
maximum cut height in reach	---		ft
Channel Side Slope 3 (ft/ft)	---		
bottom width		19	ft

Assume flow is in trapezoidal channel			
Q	5859.0	cfs	
Assumed D50 on side slope (ft)	0.75	ft	
Assumed D50 on side slope (in)	9	in	
D50 on channel bottom (ft)	1.67	ft	
D50 on channel bottom (in)	20	in	
n riprap side	0.0279	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n riprap bottom	0.0316	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.021	EM 1110-2-1601, U.S. Army Corps of Engineers	
Area of flow (A)	757.04	ft^2	
Wetted Perimeter Rock Slope	11.55	ft	
Wetted Perimeter Rock Bottom	19.00	ft	
Wetted Perimeter Soil Slope	365.42	ft	
Hydraulic Radius (R)	1.91	ft	
Top Width (T)	395.4	ft	**Iterate with d until Q calc equals Q design**
Maximum depth of flow (d)	3.65	ft	
Q calc	5859.0	cfs	
average velocity (v)	7.739383	fps	take as total Q divided by average flow width
unit discharge	28.279661	cfs/ft	1.0 for angular, 1.4 for rounded rock

Safety Factor Method (for rock on side slopes of diversion channel)

Angle of repose of rock (degees)	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		
Side Slope	3.0	XH:1V	
Angle of side slope (degrees)	18.435		
Angle of side slope (radians)	0.322		
Specific gravity of rock	2.65		
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel	
design flow (cfs)	5859		
max shear stress, τ	1.14	psf	
Stability number for rock, η	0.310		
β	0.354		
Stability number for rock, η'	0.209		**Iterate with D50 until FS equal or greater than 1.0**
Factor of Safety for side slope rock	1.57		

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**3/16/2007**
etail:	**Erosion Protection**	**Computed By:**	**RTS**

hannel Outlet

Area: North side of disposal cell

flow from upland area north of cell:	5859 cfs	Source: DP 45 PMP file from Peggy Bailey email on May 11, 2006
additional flow from upland area west of cell area	586 cfs	
total flow:	6445 cfs	conservatively assumes peak flows are cummulative from cell and upland

Outlet	approximately 5500 feet from northeast corner of disposal cell
max flow in reach:	6445 cfs

Trapezoid or triangular channels

slope (ft/ft)		0.02 ft/ft
Channel Side Slope 1 (ft/ft)		0.333 ft/ft
Channel Side Slope 2 (ft/ft)		0.008 ft/ft
maximum cut height in reach	---	ft
Channel Side Slope 3 (ft/ft)	---	
bottom width		100 ft

Assume flow is in trapezoidal channel

Q	6444.9 cfs	
Assumed D50 on side slope (ft)	0.75 ft	
Assumed D50 on side slope (in)	9 in	
D50 on channel bottom (ft)	1.67 ft	
D50 on channel bottom (in)	20 in	
n riprap side	0.0347 Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n riprap bottom	0.0394 Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020	
weighted average n	0.026 EM 1110-2-1601, U.S. Army Corps of Engineers	
Area of flow (A)	615.48 ft^2	
Wetted Perimeter Rock Slope	7.64 ft	
Wetted Perimeter Rock Bottom	100.00 ft	
Wetted Perimeter Soil Slope	302.10 ft	
ydraulic Radius (R)	1.50 ft	
p Width (T)	409.3 ft	**iterate with d until Q calc equals Q design**
ximum depth of flow (d)	2.42 ft	
calc	6445.0 cfs	
average velocity (v)	10.471333 fps	take as total Q divided by average flow width
unit discharge	25.306641 cfs/ft	1.0 for angular, 1.4 for rounded rock

Safety Factor Method (for rock on side slopes of diversion channel)

Angle of repose of rock (degees)	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	
Side Slope	5.0	XH:1V
Angle of side slope (degrees)	11.310	
Angle of side slope (radians)	0.197	
Specific gravity of rock	2.65	
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel
design flow (cfs)	6444.9	
max shear stress, τ	3.02 psf	
Stability number for rock, η	0.820	
β	1.005	
Stability number for rock, η'	0.756	**Iterate with D50 until FS equal or greater than 1.0**
Factor of Safety for side slope rock	1.09	

Rock size of Channel Outlet Toe (Abt and Johnson, 1991 method)

q (cfs/ft)=	64 cfs/ft			
S (V/H)=	0.5	0.25	0.2	0.1
D50 (in)=	40	30	27	20

Client:	**Stoller**	**Job No.:**	**181268**
Project:	***Crescent Junction Disposal Cell***	***Date:***	***7/24/2006***
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Depth of Scour

Scour depth is based on equations presented by FHA based on erosion a culvert outlets
Source: US Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular No. 14, September, 1983

Flow over riprap	**upland of cell, sheet wash**		**upland of cell, gully**		
Flow, q	1.17	cfs/ft	468.72	cfs for gully picking up swath of 400 ft area	
Concentration factor	3		1		
Design Flow,q	3.52	cfs/ft	468.72	cfs	
gravity, g	32.2	ft/s^2	32.2	ft/s^2	
time, t	15	minutes	15	minutes	
base time, to	316	minutes	316	minutes	
D50	native soil		native soil		
D50					
Slope of gully	0.02	(ft/ft)	0.03	(ft/ft)	
Manning's *n*	0.025		0.025		
Side slopes of gully (XH:1V)			2.0		
angle of side slopes of gully			26.565	degrees	
Hydraulic radius of gully			1.764		
Flow area of gully			31.105	ft^2	
depth of flow (iterate until Qcalc=Qdesign)	0.59	ft	3.94	ft	
Q			468.72	CFS	
velocity	5.94	ft/s	15.07	ft/s	
Native soils					
plasticity index of alluvial soil	5	%	5	%	*from GEG, 2005 lab data*
unconfined compressive strength	1.4	psi	1.4	psi	assumed value for silty clays (200 psf)
critical tractive shear (lb/ft^2)	0.25414336		0.254143		
modified shear number	269.411592		1733.365		
d84 bedding	0.12	mm	0.12	mm	Average for Eolian/shweet wash materials from GEG, 2005 lab data
d16 bedding	0.002	mm	0.002	mm	Average for Eolian/shweet wash materials from GEG, 2005 lab data
gradation standard deviation, σ	7.74596669		7.745967		
gradation classification	graded		graded		
	Depth				
α	0.86				coefficients for clay with PI 5-16
β	0.18				
θ	0.1				
αe	1.37				
equivalent depth, ye	0.59	ft	1.40	ft	
depth of scour (ft)	1.6	ft	5.4	ft	

Client: **Stoller**
Project: **Crescent Junction Disposal Cell**
Detail: **Rock size to protect against high velocity gully flows upstream of disposal cell**

Job No.: **181268**
Date: **3/20/2007**
Computed By: **RTS**

Safety Factor Method

Use for sizing rock to resist velocities from incoming gullies
Assume gully locations can migrate, but spacing will be similar to existing conditions of 400-ft spacing
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

	Top Slope	
Slope (ft/ft)	0.03	
angle α (rad)	0.030	
Angle of repose of rock (degees)	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	
Specific gravity of rock	2.65	
PMP flow in gully, Q (cfs)	468.72	cfs for gully picking up swath of 400 ft area
average width of flow in gully (ft)	7.89	area/depth assuming 2H:1V triagular shaped gully
PMP unit flow (cfs/ft)	59.43	Q/width
Depth of flow (ft)	3.94	from "Depth of Scour" calculation sheet
Flow velocity (ft/s)	15.07	from "Depth of Scour" calculation sheet
ave shear stress	7.38	
Assumed D50 (in) #1	20	
Stability number for rock #1	0.903	
Factor of Safety for rock #1	1.06	

Adjust assumed D50 until design criteria for Factor of Safety is greater than 1.0

Client:	**Stoller**	**Job No.:**	**181268**
Project:	***Crescent Junction Disposal Cell***	***Date:***	***3/20/2007***
Detail:	**Depth of potential scour at diversion channel outlet**	**Computed By:**	**RTS**

Depth of Scour

Scour depth is based on equations presented by FHA based on erosion a culvert outlets
Source: US Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular No. 14, September, 1983

Flow at Outlet

Flow, Q	6444.90	cfs	from "Outlet"
gravity, g	32.2	ft/s^2	
time, t	15	minutes	
base time, to	316	minutes	
D50	native soil		
D50			
natural slope downgradient of outlet	0.02	(ft/ft)	
Manning's n	0.025		
velocity	10.47	ft/s	from "Outlet"
depth of flow	2.42	ft	from "Outlet"
Native soils			
plasticity index of alluvial soil	5	%	from GEG, 2005 lab data
unconfined compressive strength	1.4	psi	assumed value for silty clays (200 psf)
critical tractive shear (lb/ft^2)	0.254143		
modified shear number	837.0029		
d84 bedding	0.12	mm	Average for Eolian/shweet wash materials from GEG, 2005 lab data
d16 bedding	0.002	mm	Average for Eolian/shweet wash materials from GEG, 2005 lab data
gradation standard deviation, σ	7.745967		
gradation classification	graded		
α	0.86		coefficients for clay with PI 5-16
β	0.18		
θ	0.1		
αe	1.37		
equivalent depth, ye	1.10	ft	
depth of scour (ft)	3.73	ft	

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-08-2006-6-01-00 **Discipline:** Geotechnical **No. of Sheets:** 22
Doc. No.: X0175500

Location: Attachment 1, Appendix H

Project: Moab UMTRA Project

Site: Crescent Junction Disposal Site

Feature: Erosional Protection of Disposal Cell Cover

Sources of Data:

Remedial Action Plan (RAP) calculation sets as referenced in the text.

Sources of Formulae and References:

See "References" section.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No.**

Author: Roslyn Sten 5/25/07
Name Date

Approved by: John E Elmer 5/31/07
Name Date

Checked by: 5/30/07
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5/31/07
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Name Date
May 31, 07
Name Date

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Problem Statement:

Determine the rock protection required to protect the cover of the disposal cell from erosion due to action of surface water and wind to meet the specifications of the *Code of Federal Regulations* (CFR) (40 CFR part 192).

Method of Solution:

- Determine the peak unit discharge from both the Probable Maximum Precipitation (PMP) and the 100-year precipitation event on the drainage basins of the disposal cell using the Rational method (Chow 1964):
- Evaluate erosional stability of soil cover on top slope of disposal cell using Temple method (Temple et al. 1987).
- Evaluate erosional stability of rock mulch on top slope of disposal cell using Safety Factor method (Nelson et al. 1986).
- Evaluate erosional stability of rock mulch or riprap on side slopes of disposal cell using Abt and Johnson method (Abt and Johnson 1991).
- Evaluate surface sheet erosion of top slope of disposal cell due to action of surface water and wind using Modified Universal Soil Loss Equation (MUSLE) method (Nelson et al. 1986).
- Evaluate required rock size for toe apron to accommodate flow transitioning from cell slope to native ground using method proposed by Abt et al. (1998).
- Evaluate scour potential of toe apron from headward erosion using methods in NUREG 1623 (Johnson 2002) and U.S. Department of Transportation (1983).
- Evaluate the need for bedding layer between cover soils and erosion protection material by estimating interstitial pore velocities using method proposed by Abt and Johnson (1991).

Assumptions:

- The 100-year precipitation event is applicable for evaluating drought, fire, and post-construction conditions when little or no vegetation is on the cover.
- The PMP precipitation event is applicable for long-term erosional stability analyses.
- The 1-hour PMP event is estimated to be 8.2 inches, and the 1-hour, 100-year event is estimated to be 1.65 inches ("Site Drainage—Hydrology Parameters" calculation, RAP Attachment 1, Appendix E).
- The layout of the disposal cell is shown in Figure 1. This layout shows a 2 percent top slope, 5:1 (horizontal:vertical) side slopes, and a total footprint area of 251 acres.
- Rock available for erosion protection will be angular, have a specific gravity of 2.65, and will meet Nuclear Regulatory Commission (NRC) durability requirements.

Calculation:

See Discussion section.

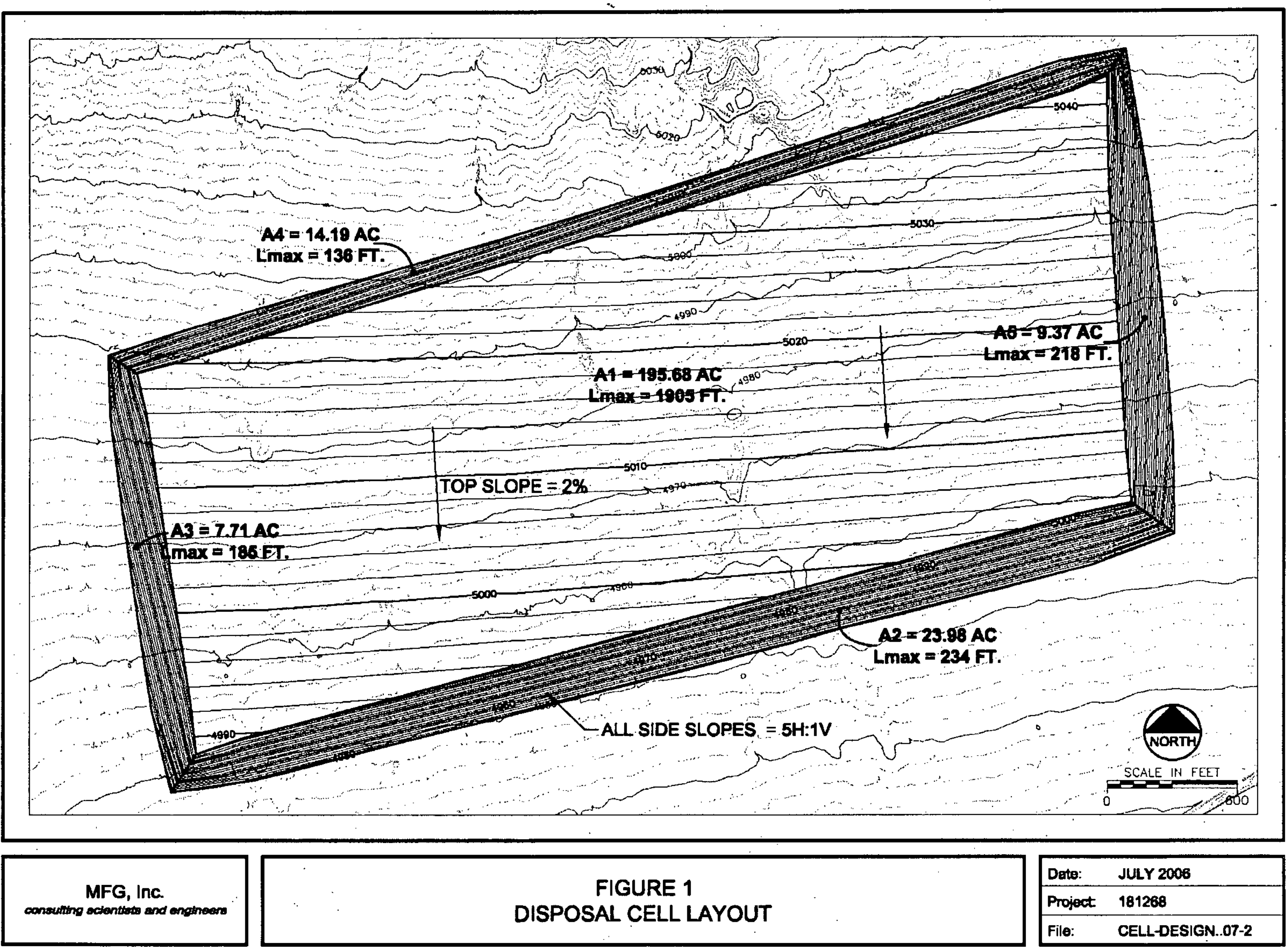

Figure 1. Disposal Cell Layout

Discussion:

Drainage Area Characteristics

Five drainage areas were delineated on the cover of the disposal cell, as shown in Figure 1. The area and flow length of these drainage areas were calculated using computer-aided design (CAD) tools.

Peak flows occurring within each drainage area are calculated using a rainfall duration equivalent to the time of concentration for each drainage basin. The time of concentration is a characteristic of the geometry and slopes of the drainage areas, and is computed by three different methods, with the average of the three methods used to calculate peak discharges. The three methods used to calculate the time of concentration are described below.

1) The Kirpich equation as presented in NUREG/CR-4620 (Nelson et al. 1986):

$$T_c = 0.0078\frac{L^{0.77}}{S^{0.385}}$$

where:

T_c = time of concentration (minutes),

L = slope length (feet [ft]), and
S = slope (ft/ft).

2) The Soil Conservation Service (SCS) Triangular Hydrograph Theory, as presented in NUREG/CR-4620 (Nelson et al. 1986):

$$T_c = \left(\frac{11.9L^3}{H}\right)^{0.385}$$

where:

T_c = time of concentration (hours),
L = slope length (miles), and
H = slope height (ft).

3) The Brant and Oberman equation as presented in the Uranium Mill Tailings Remedial Action Project (UMTRA) Technical Approach Document (TAD) (DOE 1989):

$$T_c = C\left(\frac{L}{Si^2}\right)^{\frac{1}{3}}$$

where:

T_c = time of concentration (minutes),
C = coefficient = 1.0 for bare earth,
S = slope (ft/ ft), and
i = one-hour rainfall intensity (inches/hour).

As specified in UMTRA TAD (DOE 1989), T_c is limited to a minimum of 2.5 minutes. Because precipitation falling on the top of the cover flows to the south slope, the time of concentration for the south side slope is equivalent to the time of concentration of precipitation on the top slope plus the time of concentration of precipitation occurring on the south side slope. The characteristics of the drainage areas on the disposal cell are summarized in Table 1.

Table 1. Drainage Area Characteristics

Drainage Area Description	Incremental Drainage Area (acres)	Slope (ft/ft)	Slope Length (ft)	Time of Concentration (min)			
				Kirpich	SCS	Brant and Oberman	Average
A1, top	195.7	0.02	1,950	12.0	12.0	11.3	11.8
A2, south slope	24.0	0.2	230	13.0	13.0	13.9	13.3
A3, west slope	7.7	0.2	190	0.8	0.8	2.4	2.5*
A4, north slope	14.2	0.2	140	0.7	0.7	2.2	2.5*
A5, east slope	9.4	0.2	220	0.9	0.9	2.5	2.5*

*Time of concentration is limited to a minimum of 2.5 minutes.

Peak Discharge

One of the technical criteria for the stability of the disposal cell is acceptable erosional stability from extreme storm events (10 CFR 40, Appendix A). NRC has interpreted this criterion to be able to safely pass the peak runoff from storms up to the PMP event (Johnson 2002). The PMP event has a 1-hour depth of 8.2 inches, and a 15-minute depth of 7.1 inches ("Site Drainage—Hydrology Parameters" calculation, RAP Attachment 1, Appendix E). For events with durations less than 15 minutes, precipitation depths as a percent of the 1-hour PMP are estimated using the following formula, as given in Table 4.1 of the UMTRA TAD (DOE 1989):

$$\%PMP_{1-hour} = \frac{RD}{0.0089RD + 0.0686}$$

where: RD = rainfall duration (minutes).

The precipitation depth of any given storm duration is then calculated as:

$$PD_{PMP} = \%PMP_{1-hour} \times PMP_{1-hour}$$

where: PD_{PMP} = precipitation depth of the PMP storm with duration equivalent to the time of concentration (inches).

The precipitation events for 100-year recurrence interval for several storm durations were taken from Appendix A of the "Site Drainage—Hydrology Parameters" calculation, (RAP Attachment 1, Appendix E) and are summarized in Table 2. Precipitation depths for durations other than those listed in Table 2 are interpolated.

Table 2. 100-Year Storm Event Precipitation Depths

Rainfall Duration (min)	Precipitation Depth (inches)	Intensity (inches/hr)
5	0.53	6.36
10	0.8	4.80
15	0.99	3.96
30	1.33	2.66
60	1.65	1.65
120	1.82	0.91

The rainfall intensity is calculated for a rainfall duration equivalent to the time of concentration for the drainage basin. Rainfall intensity (inches per hour) is calculated as follows:

$$I = \frac{PD \times 60}{RD}$$

The Rational method (Chow 1964) was used to determine the peak discharge from the PMP and the 100-year event for evaluation of cover erosion protection. For each drainage area, the peak flow was calculated with the Rational Formula, as follows:

$$Q = CIA$$

where:

Q = peak flow (cfs),
C = runoff coefficient,
I = rainfall intensity (inches per hour) corresponding to the time of concentration, and
A = area (acres).

The runoff coefficient is approximately 1.0 for PMP conditions, as discussed in UMTRA TAD (section 4.1.3). A runoff coefficient of 0.9 is used for 100-year storm events based on a conservative estimate for a riprap/rock surface.

Peak flow may also be expressed as a unit discharge as follows:

$$q = \frac{Q}{w} = \frac{CIL}{43200}$$

where:

q = unit discharge (cubic feet per second per foot [cfs/ft]),
w = unit width (ft),
C = runoff coefficient = 1.0,
I = rainfall intensity (inches per hour), and
L = slope length (ft).

Table 3 shows the results of the PMP peak flow in cubic feet per second (cfs) and the unit discharge calculations in cubic feet per second per foot (cfs/ft) for the areas shown in Figure 1. Table 4 shows results for the 100-year storm. These peak unit flows will be applied to the entire drainage area when evaluating erosional stability. Additional supporting calculations can be found in Appendix A.

Table 3. Results of PMP Peak Flow and Unit Discharge

Drainage Area Description	**Runoff Coef. C**	**Average T_c (min)**	**Percent $PMP_{1\text{-}hr}$**	**PD_{PMP} (inches)**	**Intensity (inches/hr)**	**Peak Flow, Q (cfs)**	**Unit Discharge, q (cfs/ft)**
A1, top	1.0	11.8	67.9	5.6	28.4	5,550	1.28
A2, south slope	1.0	13.3	71.1	5.8	26.3	5,787	1.33
A3, west slope	1.0	2.5	27.5	2.3	54.2	417	0.24
A4, north slope	1.0	2.5	27.5	2.3	54.2	769	0.18
A5, east slope	1.0	2.5	27.5	2.3	54.2	509	0.28

Table 4. Results of 100-Year Peak Flow and Unit Discharge

Drainage Area Description	Runoff Coef. C	Average T_c (min)	$PD_{100\text{-yr}}$ (inches)	Intensity (inches/hr)	Peak Flow, Q (cfs)	Unit Flow q (cfs/ft)
A1, top	0.9	11.8	0.9	4.6	817	0.19
A2, south slope	0.9	13.3	0.9	4.3	849	0.19
A3, west slope	0.9	2.5	0.5	6.4	44	0.03
A4, north slope	0.9	2.5	0.5	6.4	81	0.02
A5, east slope	0.9	2.5	0.5	6.4	54	0.03

Top Surface: Erosional Stability of Soil Cover

The top surface of the disposal cell was evaluated for erosional stability without a rock layer using the method developed by Temple et al. (1987). This procedure, developed to analyze grassy channels, estimates stresses from runoff on channel vegetation as well as the channel surface soils. The erosional stability of the cover surface was evaluated by calculating a factor of safety against erosion due to the peak runoff. 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). As outlined in UMTRA TAD (1989), the 100-year peak unit flows (Table 4) were used to analyze the stability of a non-vegetated slope, such as would be representative of post-construction, drought, or burn conditions. PMP peak unit flows (Table 3) were used to analyze the stability of a vegetated slope, assuming a poor to fair cover of grass eventually will be established on the cover. In addition, peak flows are multiplied by a concentration factor of 3.0 to account for channelization of flow.

The stress calculations are summarized below. Potential materials evaluated for use as cover soils were (1) low-plasticity silt and clayey material from excavated on-site alluvial and eolian deposits, (2) excavated on-site weathered Mancos Formation shale, and (3) imported coarse-grained sands and gravels.

Allowable Stresses

Allowable stresses for the non-vegetated cover soils were calculated using the equations in Temple et al. (1987). For cohesive soils, the resistance is based on the plastic limit and void ratio of the material. The equation for allowable shear strength for cohesive soils is:

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

where:

τ_a = allowable shear strength (pounds per square feet [psf]),
τ_{ab} = basis allowable shear strength (for a CL) = $(1.07\,[PI]^2+14.3[PI]+47.7) \times 10^{-4}$,
C_e = soil parameter = $1.48 - 0.57e$,
PI = plasticity index, and
e = void ratio.

For non-cohesive soils, the resistance is based on particle size, specifically the size where 75 percent of the material is finer, or D_{75}. The equation for allowable shear strength for non-cohesive soils is:

$$\tau_a = 0.4 D_{75}$$

where D_{75} is in inches.

Plasticity index and void ratio are estimated from preliminary geotechnical laboratory testing results for on-site material (GEG 2005), assuming compaction to approximately 85 percent of maximum dry density as determined from the Modified Proctor test.

For vegetated slopes, the allowable stresses are a function of the quality of vegetation established on the cover, as given by the following equation:

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

where:

τ_{va} = allowable vegetation shear strength (psf),

C_I = cover index = $2.5 \times \left(h \times \sqrt{M}\right)^{\frac{1}{3}}$,
h = stem length (ft), and
M = stem density factor (stems per square foot).

Because of the arid climate at the site, vegetative properties are modeled as poor, with average stem height of 0.3 ft, and a stem density factor of 17 as given in Temple et al. (1987), conservatively using poor conditions represented by a poor stand of Sudan grass (a bunch grass providing incomplete surface cover).

Effective Stresses

The effective shear stress on soil due to peak runoff from the 100-year event on the non-vegetated slope is calculated as:

$$\tau_e = \gamma dS$$

where:

τ_e = effective shear stress (psf),
γ = unit weight of water = 62.4 pcf,
d = depth of flow (ft), and
S = slope of cover surface (ft/ft).

For vegetated slopes, the effective shear stress on soil due to peak runoff from the PMP event is calculated as:

$$\tau_e = \gamma dS\left(1 - C_f\right)\left(\frac{n_s}{n_v}\right)^2$$

where:

C_F = cover factor = 0.25 for poor vegetation, and
n_s = soil grain roughness factor, calculated by the following equation:

$$n_s = 0.0156 \text{, for cohesive soil}$$

$$n_s = 0.0256\left(d_{75}\right)^{\frac{1}{6}} \text{, for granular soil, where d is in inches.}$$

n_v = combination of resistance due to soil roughness, n_s and vegetation, n_r, calculated by:

$$n_v = \sqrt{n_r^{\ 2} - 0.0156^2 + n_s^{\ 2}}$$

where: n_r = resistance due to vegetation, calculated by:

$$n_r = \exp\left(0.01329C_i(\ln q)^2 - 0.09543C_i \ln q + 0.2971C_i - 4.16\right)$$

where: q = unit flow (cfs/ft).

The cover factor, C_f, is assumed to be 0.5 for good vegetation conditions, and 0.25 for poor vegetation, as given in Temple et al. (1987) for Sudan grass. The effective shear stress on vegetation is calculated as:

$$\tau_{ve} = \gamma dS - \tau_e$$

where τ_v = effective vegetal stress (psf).

The depth of flow is calculated by iteration of Manning's equation:

$$q = \frac{1.486dR^{\frac{2}{3}}\sqrt{S}}{n}$$

where:

q = unit flow (cfs/ft),
d = depth of flow (ft),
R = hydraulic radius = d for wide channels,
S = slope (ft/ft), and
n = Manning's coefficient.

For bare-soil conditions, n is equivalent to n_s, soil grain roughness. For vegetated conditions, n is equivalent to n_v, a combination of resistance due to soil roughness (n_s) and vegetation (n_r).

Table 5 summarizes the stability of the 100-year precipitation on bare-soil conditions, and Table 6 summarizes long-term stability of the PMP event on poorly vegetated cover. More detailed calculation tables can be found in Appendix A.

As shown by the resulting shear stress ratios in Table 5 and Table 6, both the eolian/sheet wash on-site soils and the weathered Mancos materials are too erosive to resist erosion (1) during the 100-year precipitation without vegetation or (2) during the PMP event with vegetation. Imported coarse sandy gravel with D_{75} of 1.1 inches would be adequate as a soil cover. The sandy gravel will adequately resist erosion to the 100-year precipitation without vegetation, and can also resist erosion from the PMP event, assuming at least a poor stand of grass or equivalent is established on the cover.

Table 5. Erosional Stability of 100-Year Precipitation on Bare Soil

Top Slope (ft/ft) 2.0 percent			
100-Year Flow (cfs/ft) 0.19			
Concentration Factor 3			
Cover Soil Eolian/Sheet Wash		**Weathered Mancos**	**Sandy Gravel**
Soil Characteristic	PI=5	PI=10	D_{75}=1.1 in
n_s	0.0156	0.0156	0.0260
Depth of flow, d (ft)	0.15	0.15	0.20
Allowable shear stress, τ_{∂} (psf)	0.018	0.038	0.440
Effective shear stress, τ_e (psf)	0.187	0.187	0.254
Shear stress ratio[a]	0.10	0.20	1.73

[a]Design criteria is shear stress ratio of 1.0 or greater

Table 6. Erosional Stability of PMP on Poorly Vegetated Cover

Top Slope (ft/ft) 2.0 percent			
PMP Flow (cfs/ft) 1.28			
Concentration Factor 3			
Cover Soil Eolian/Sheet Wash		**Weathered Mancos**	**Coarse Sand**
Soil Characteristic	PI=5	PI=10	D_{75}=1.1 in
n_s	0.0156	0.0156	0.0260
n_r	0.0261	0.0261	0.0261
n_v	0.0261	0.0261	0.0334
Depth of flow, d (ft)	0.64	0.64	0.74
Allowable soil shear stress, τ (psf)	0.018	0.038	0.440
Allowable vegetated shear stress, τ_{va} (psf)	2.01	2.01	2.01
Effective soil shear stress, τ_e (psf)	0.214	0.214	0.422
Effective vegetated shear stress, τ_{ve} (psf)	0.587	0.587	0.506
Shear stress ratio (soil)[a]	0.09	0.18	1.04
Shear stress ratio (vegetation)[a]	3.42	3.42	3.96

[a]Design criteria is shear stress ratio of 1.0 or greater

Rock Mulch Sizing for the Top Slopes

In addition to analyzing the top slope as a soil cover, the erosional stability of rock mulch is also analyzed, using the Safety Factor method, as recommended in NUREG/CR-4620 (Nelson et al. 1986) and NUREG-1623 (Johnson 2002) for slopes less than 10 percent. The safety factor against erosion for any given rock is calculated as:

$$SF = \frac{\cos\alpha \times \tan\phi}{\eta \times \tan\phi + \sin\alpha}$$

where:

α = angle of slope measured from horizontal,
ϕ = angle or repose of rock, and
η = stability number.

The stability number is calculated as:

$$\eta = \frac{21\tau_o}{(S_s - 1)\gamma D}$$

where:

τ_o = bed shear stress (psf),
S_s = specific weight of the rock,
γ = specific weight of water,
D = representative rock size (ft),

and:

$$\tau_o = \gamma ds$$

where:

d = depth of flow (ft), and
s = slope (ft/ft).

The key parameters used in the rock mulch sizing calculations are outlined in Table 7. For a PMP event, a factor of safety slightly greater than 1.0 is recommended (Nelson et al. 1986). The method assumes uniform sheet flow across the entire drainage basin. The peak unit discharges due to the PMP (Table 3) were used to represent flow conditions on the top slope. A concentration factor of 3 was used to account for potential flow channelization. The angle of repose and specific gravity of rock were assumed and will need to be verified for final design. More details of the calculation can be found in Appendix A.

Table 7. Rock Mulch Sizing for Top Slope Using Safety Factor Method

Top Slope (ft/ft)	2.0 percent
Angle of repose of rock (degrees)	37
Specific Gravity of rock	2.65
PMP unit flow (cfs/ft)	1.28
Concentration factor	3
Design flow (cfs/ft)	3.84
D_{50} rock mulch (in)	2.1
Factor of Safety	1.01

Riprap Sizing for the Side Slopes

The erosional stability of the side slopes is analyzed using the Abt and Johnson (1991) method, as discussed in NUREG-1623 (Johnson 2002). This method is recommended for slopes greater than 10 percent. The D_{50} rock sizes using the Abt and Johnson method is calculated as:

$$D_{50} = 5.23 S^{0.43} q^{0.56}$$

where:

q = unit discharge (cfs/ft), and
S = Slope (ft/ft).

The key parameters used in the rock mulch sizing calculations are outlined in Table 8. More details of the calculation can be found in Appendix A.

Table 8. Rock Mulch Sizing for Side Slopes

Method	**Abt and Johnson**			
Side Slope (ft/ft)	**20 Percent**			
Area	**A2 South**	**A3 West**	**A4 North**	**A5 East**
PMP unit flow (cfs/ft)	1.33	0.24	0.18	0.28
Concentration factor	3	3	3	3
Coefficient of Movement	1.35	1.35	1.35	1.35
Design flow (cfs/ft)	5.38	0.96	0.71	1.12
D_{50} for angular rock (inches)	6.7	2.6	2.2	2.8

The method assumes uniform sheet flow across the entire drainage basin. The peak unit discharges due to the PMP (Table 3) were used to represent flow conditions on the top slope. A concentration factor of 3 was used to account for flow channelization. The angle of repose and specific gravity of rock were assumed and will need to be adjusted (if necessary) with actual source characteristics.

Using Abt and Johnson's methods, the side slopes will have a median rock size ranging from 2.2 inches to 2.8 inches for the north, east, and west slopes, and a median rock size of 6.7 inches for the south slope. If rounded rock is used for erosion protection, the median rock size should be increased by approximately 40 percent (Abt and Johnson 1991). In addition, median rock size may be oversized for durability considerations once the rock source has been identified.

The rock protection layer thickness should be at least 1.5 to 2 times the median rock size.

Sensitivity of Required Rock Size of Rock Mulch and Riprap Protection to Cell Configuration

The rock mulch on the top of the disposal cell and the riprap on the side slopes has been designed for minimum D_{50} rock size based on the cell configuration given in Figure 1. Figure 2 and Figure 3 show how changes in the disposal cell configuration may affect the rock sizes required for erosion protection, or conversely, what changes in the disposal cell configuration would be required in order to be able to use an available rock size.

Wind Erosion

The potential for wind erosion of the top surface of disposal cell during drought conditions was evaluated using the MUSLE method, as presented in NUREG/CR-4620 (Nelson et al. 1986). Three potential cover materials were evaluated: (1) on-site sheet wash/eolian soils, (2) on-site excavated weathered Mancos Shale, and (3) imported coarse gravel.

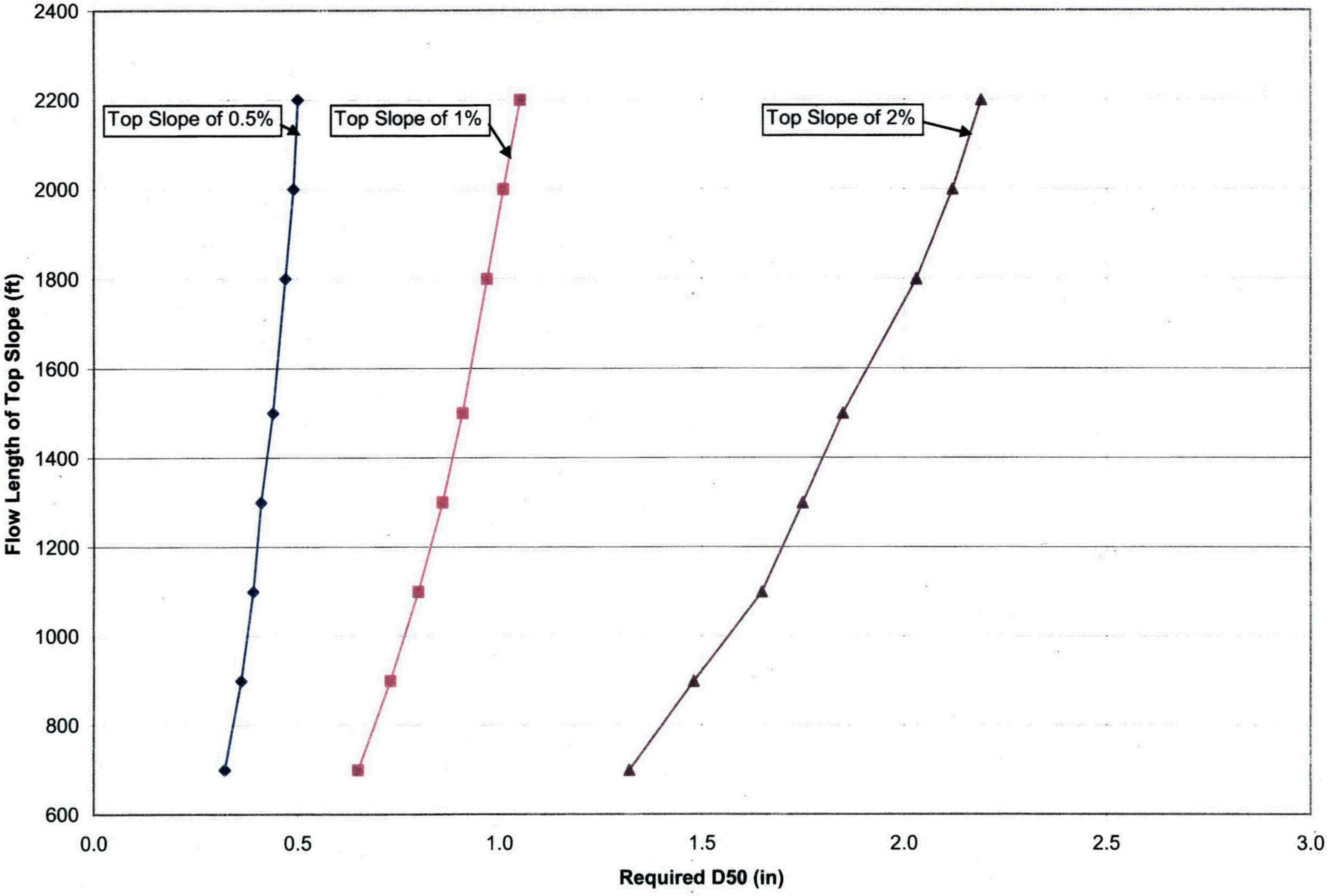

Figure 2. Required D_{50} for Top of Disposal Cell

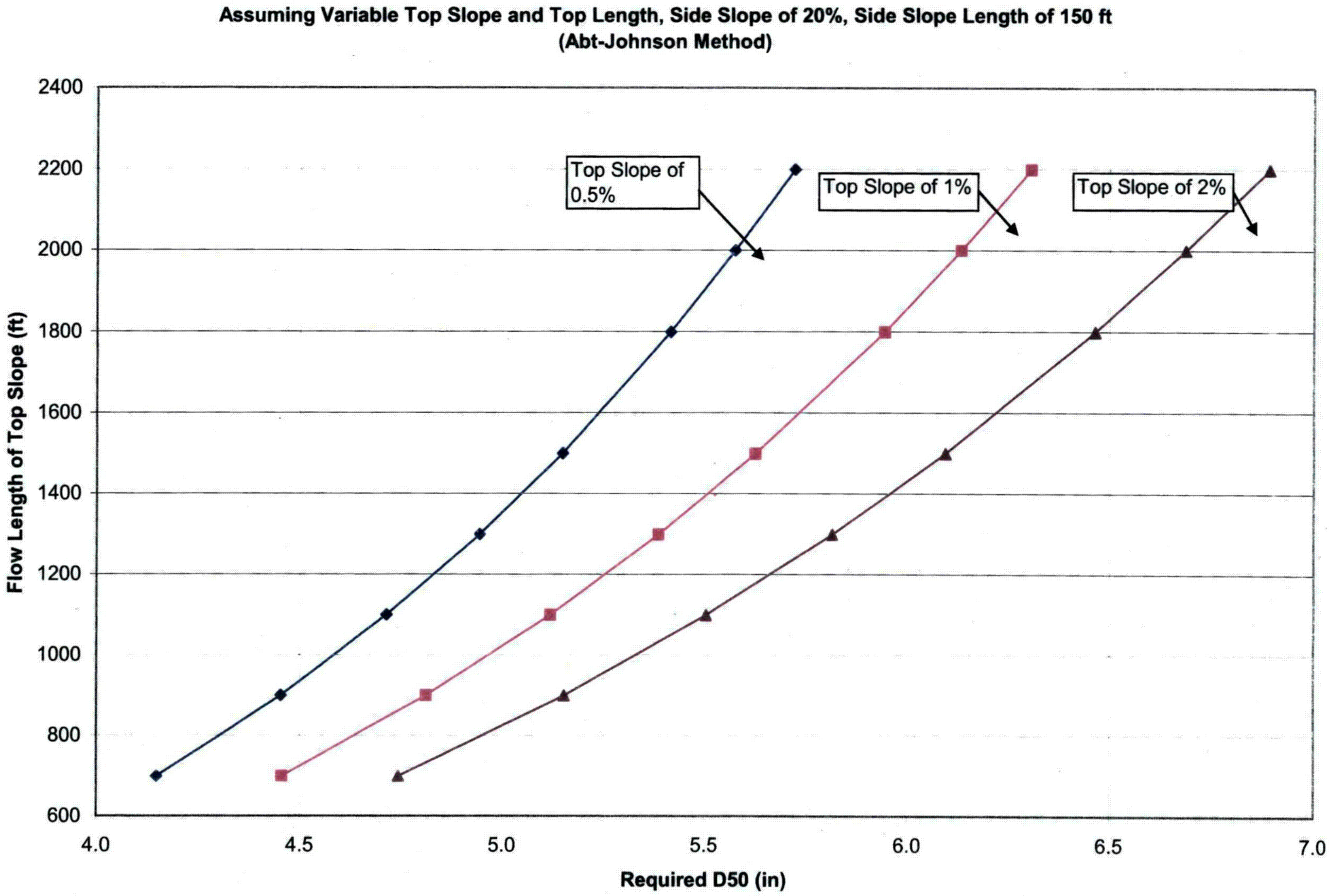

Figure 3. Required D_{50} for Side Slope With Contributed Flow From Top Slope

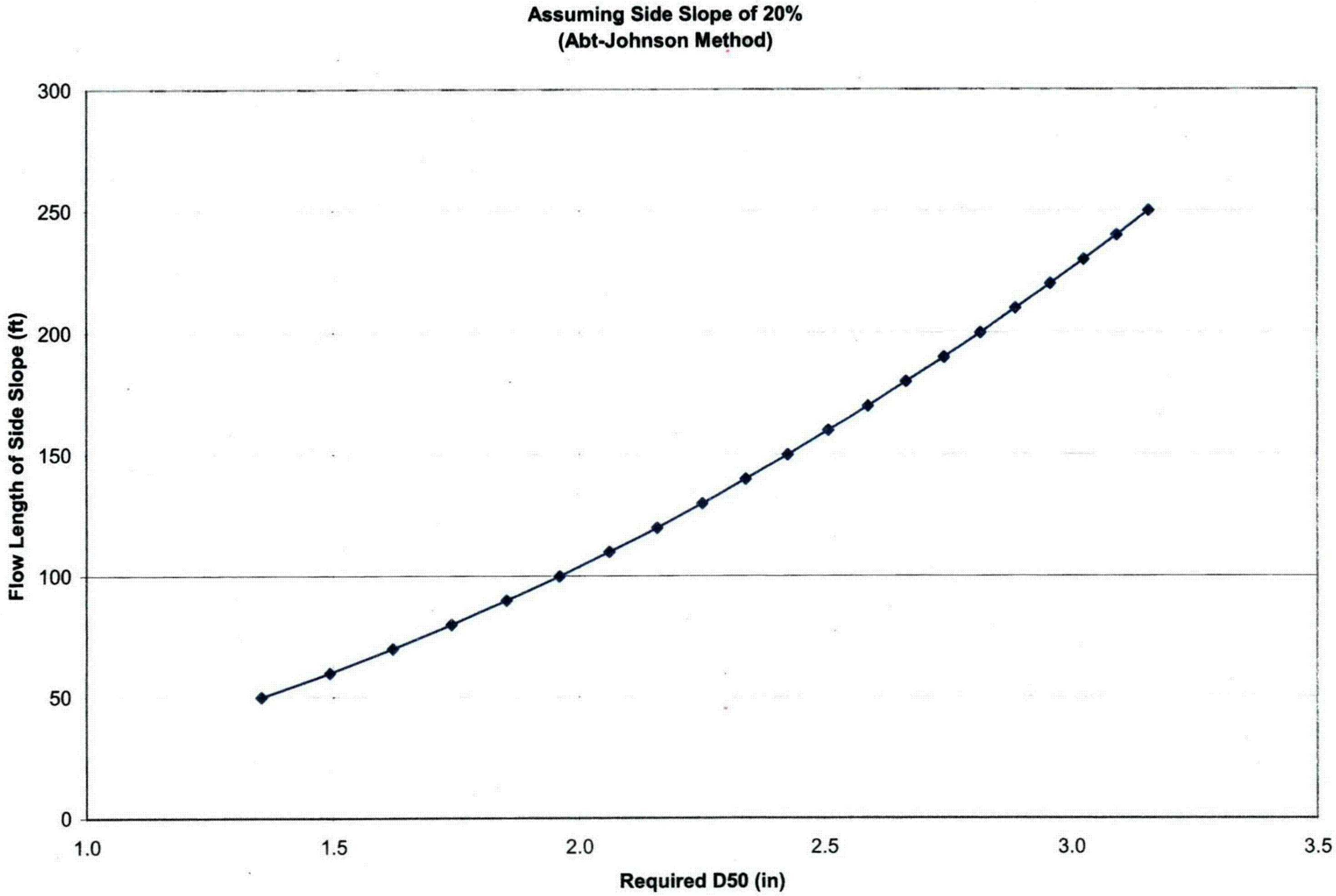

Figure 4. Required D50 for Side Slope with No Contributed Flow from Top Slope

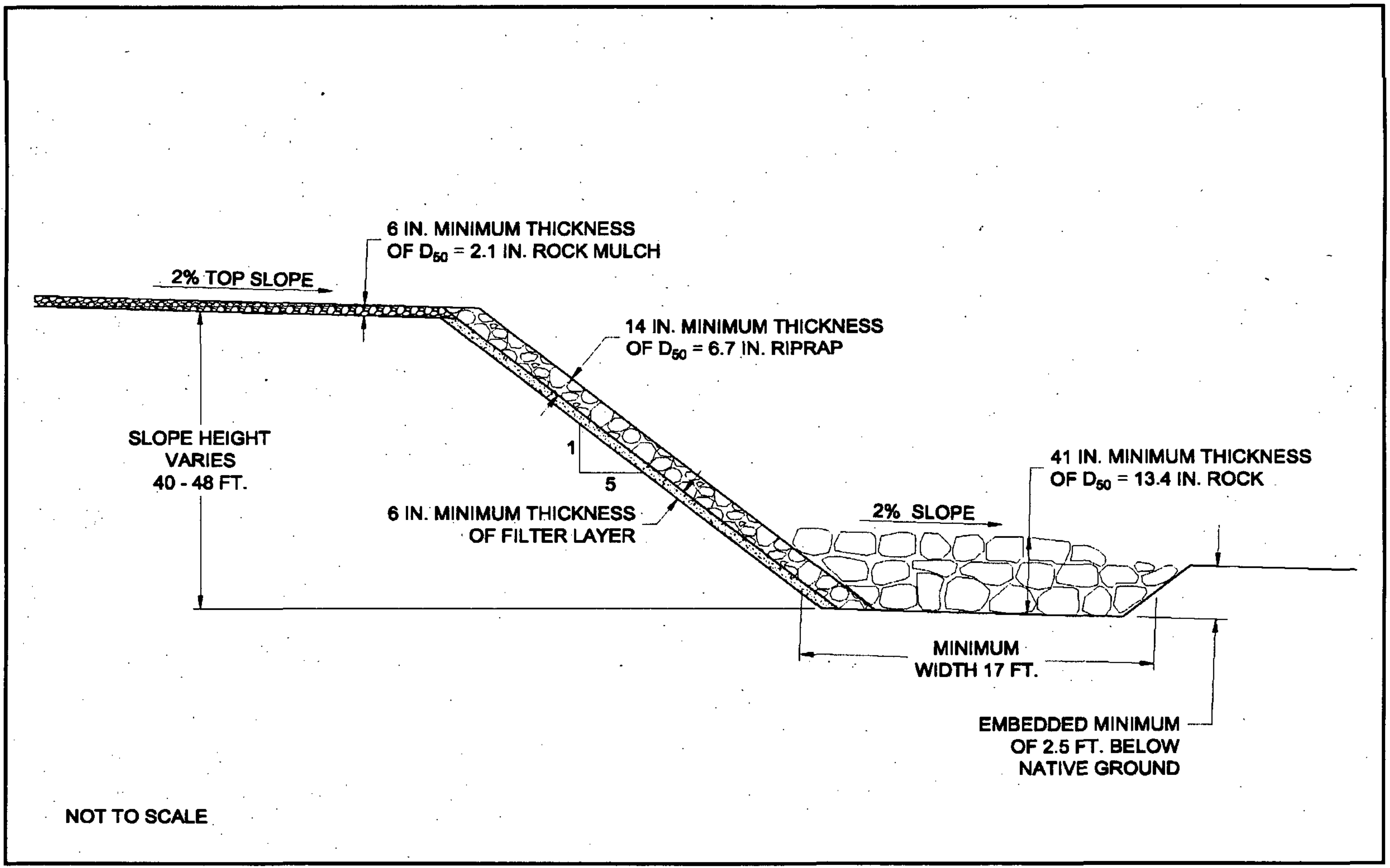

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FIGURE 5
TYPICAL SECTION SHOWING SOUTH SLOPE
REQUIRED EROSION PROTECTION

Date:	JUNE 2006
Project:	181268
File:	XS-TYP-01.DWG

Figure 5. Typical Section Showing South Slope Required Erosion Protection

The soil loss equation was calculated as follows:

$$A = R \times K \times LS \times VM$$

where:

A = soil loss in tons per acre per year,
R = rainfall factor,
K = soil erodibility factor,
LS = topographic factor, and
VM = dimensionless erosion control factor relating to vegetative and mechanical factors.

The rainfall factor is 30, as given in NUREG/CR-4620 (Nelson et al. 1986) for the eastern third of Utah. The soil erodibility factor was estimated using the nomograph given in NUREG/CR-4620 (Nelson et al. 1986).

The topographic factor is calculated by the following equation:

$$LS = \frac{650 + 450 \times s + 65 \times s^2}{10{,}000 + s^2} \times \left(\frac{L}{72.6}\right)^m$$

where:

s = slope steepness in percent,
L = slope length in ft, and
m = exponent dependent upon slope steepness.

The dimensionless erosion control factor used was 0.4, from Table 5.3 of NUREG/CR-4620 (Nelson et al. 1986), representing seedings of 0 to 60 days to mimic light vegetation on the cover. Table 9 summarizes the results of the soil loss equation.

Table 9. Results of Soil Loss Equation

Soil Cover	Sheet Wash/Eolian	Weathered Shale	Coarse Gravel
Rainfall factor, R	30	30	30
Silt and very fine sand (%)	60	55	10
Sand (%)	25	5	20
Organic matter (%)	2	2	0
Soil structure	Very fine granular	Blocky, platy or massive	Med. or coarse granular
Relative permeability	Moderate	Moderate	Moderate to rapid
Erodibility factor	0.35	0.26	0.05
Topographic factor, LS	0.49	0.49	0.49
VM (low density seedings)	0.4	0.4	0.4
Soil loss (tons/acre/year)	2.04	1.51	0.29
Soil loss (inches/1,000 years)	11.2	8.3	1.6

The soil loss equation shows that the potential for sheet erosion is unacceptably high if either the native sheet wash/eolian soils or weathered shale is used as a soil cover. The soil loss of less than 2 inches over the life of the disposal cell for coarse gravel is acceptable; especially considering vegetation is not required for stability of this material (but is required for stability of native soil cover to protect against PMP event).

Riprap Sizing for Rock Aprons

Additional erosion protection will be provided for runoff from the east, west, and south side slopes of the disposal cell with a rock apron. The north side of the disposal cell will receive runoff from the upland area north of the cell, and will require a diversion channel. The design of this diversion feature will be covered in the "Diversion Channel Design, North Side Disposal Cell" calculation (RAP Attachment 1, Appendix G).

The perimeter apron will: (1) serve as an impact basin and provide for energy dissipation of runoff, (2) provide erosion protection, and (3) transition flow from side slopes to natural ground. The median rock size required in the perimeter apron was calculated using the equations derived by Abt et al. (1998) as outlined in NUREG 1623 (Johnson 2002) as follows:

$$D_{50energydissipation} = 10.46S^{0.43}(C_f q_d)^{0.56}$$

where S is the slope, C_f is the concentration factor, and q_d is the design unit discharge.

Based on Table 10, the rock apron should have a median rock size of 13.4 inches along the south toe and between 5.1 and 5.6 inches along the east and west toes. Oversizing will be required for rounded rock or for durability considerations. The width of the apron should be a minimum of 15 times the median rock size or construction width. Rock apron thickness should be a minimum of 3 times the median rock size.

Table 10. Riprap for Toe Apron

Method Abt et al. (1998)			
Side Slope (ft/ft) 20 Percent			
Area	**A2 South**	**A3 West**	**A5 East**
PMP unit flow (cfs/ft)	1.33	0.24	0.28
Concentration factor	3	3	3
Coefficient of Movement	1.35	1.35	1.35
Design flow (cfs/ft)	5.38	0.96	1.12
D_{50} for angular rock (in)	13.4	5.1	5.6
Minimum apron width (ft)	17	6	7
Minimum apron thickness (in)	41	15	17

The maximum unit flow off the south toe is 1.33 cfs/ft. A concentration factor of 3 was used to account for flow channelization. Using this maximum flow, and an assumed slope of the rock apron of 2 percent, the maximum scour depth was calculated using procedures outlined in NUREG 1623 (Johnson 2002) and U.S. Department of Transportation (1983). The maximum scour depth from flow coming off the rock apron along the south side of the disposal cell is estimated to be 2.2 ft. Therefore, the bottom elevation of the rock apron should be placed approximately 2.5 ft below natural grade. The aprons along the east and sides of the disposal cell should be placed approximately 1.0 ft below natural grade. Details of calculations can be found in Appendix A.

Bedding Requirements

NUREG-1623, Appendix D (Johnson 2002), recommends a filter or bedding layer be placed under erosion protection if interstitial velocities are greater than 1 ft/sec, in order to prevent erosion of the underlying soils. Bedding is not required if interstitial velocities are less than 0.5 ft/sec, and recommended depending on the characteristics of the underlying soil if velocities are between 0.5 and 1 ft/sec.

Interstitial velocities are calculated by procedures presented by Abt and Johnson (1991) as given in the following equation:

$$V_i = 0.23 * (g * D_{10} * S)^{\frac{1}{2}}$$

where:

V_i = interstitial velocities (ft/s),
g = acceleration of gravity (ft/s^2),
D_{10} = stone diameter at which 10 percent is finer (inches), and
S = gradient in decimal form.

The maximum D_{10} of the erosion protection is estimated based on D_{50} required for erosion protection, assuming the erosion protection will have a coefficient of uniformity (CU) of 6 and a band width of 5. Band width refers to the ratio of the minimum and maximum allowed particle sizes acceptable for any given percent finer designation. USDA (1994) recommends CU to be a maximum of 6 in order to prevent gap-grading of filters. Table 11 summarizes the results.

Table 11. Results of Bedding Requirements

Location	A1 Top	A2 South Side Slope	A3 West Side Slope	A4 North Side Slope	A5 East Side Slope	A2 South Apron	A3 West Apron	A5 East Apron
Minimum D_{50} (inches)	2.1	6.7	2.3	2.2	2.8	13.4	5.1	5.6
Maximum D_{10} (inches)	0.9	2.1	0.9	0.9	0.9	4.2	1.6	1.7
Slope (%)	0.02	0.2	0.2	0.2	0.2	0.02	0.02	0.02
Interstitial Velocity (ft/s)	0.18	0.84	0.56	0.56	0.56	0.38	0.23	0.24

With the exception of the south side slope, the calculated interstitial velocities on the slopes and toe aprons are low enough that a bedding layer is not necessary. However, the interstitial velocities within the erosion protection on the south side slopes warrant a bedding layer beneath the rock protection.

Conclusion and Recommendations:

- Rock mulch with median rock size of 2.1 inches is recommended for the top slope of the disposal cell.
- Angular riprap protection with a median rock size of 6.7 inches is recommended for the south side slope, and a median rock size of 2.2 to 2.8 inches is recommended for the east, north, and west side slopes.
- Rock sizes should be adjusted if rock is not angular or does not meet NRC durability requirements (without oversizing). If rock is rounded, the median rock size should be increased by 40 percent. If rock has marginal durability, rock should be oversized using guidance given in NUREG-1623 (Johnson 2002).
- The riprap on the south side slope should be underlain with a bedding layer that meets filter criteria with the riprap and the underlying soils.
- A toe apron should be provided at the base of the east, south, and west side slopes. Median rock sizes of 5.6, 13.4, and 5.1 inches, respectively, should be provided. To protect against scour, the apron should be constructed such that the bottom elevation of the rock apron is a minimum of 2.5 ft below natural grade along the south side of cell and 1.0 ft below grade along the east and west sides.
- Figure 5 summarizes the different components of the erosion protection for a typical section drawn through the south side slope.

References:

10 CFR 40. U.S. Nuclear Regulatory Commission (NRC), "Domestic Licensing of Source Material," Appendix A, *Code of Federal Regulations*, February 2007.

40 CFR 192. U.S. Environmental Protection Agency (EPA) "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings," *Code of Federal Regulations*, February 2007.

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Abt, S.R., T.L. Johnson, C.I. Thornton, and S.C. Trabant, 1998. "Riprap Sizing at Toe of Embankment Slopes", *Journal of Hydraulic Engineering*, 124(7), July.

Abt, S.R., J.F. Ruff, and R.J. Wittler, 1991. "Estimating Flow Through Riprap", *Journal of Hydraulic Engineering*, 117(5), pp. 670–675.

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Geotechnical Engineering Group, Inc. (GEG), 2005. Technical Testing, Crescent Junction, GEG Job No. 2165, December 22.

Johnson, T.L., 2002 *Design of Erosion Protection for Long-Term Stabilization*, Final Report, NUREG-1623, U.S. Nuclear Regulatory Commission, September.

Nelson, J.D., S.R. Abt, R.L. Volpe, D. van Zyl, N.E. Hinkle, W.P. Staub, 1986. *Methodologies for Evaluating Long-Term Stabilization Design of Uranium Mill Tailings Impoundments*, NUREG/CR-4620, U.S. Nuclear Regulatory Commission, June.

Temple, D.M., K.M. Robinson, R.M. Ahring, and A.G. Davis, 1987. *Stability Design of Grass-Lined Open Channels*, U.S. Department of Agriculture Handbook No. 667, September.

USDA (U.S. Department of Agriculture), 1994. "Gradation Design of Sand and Gravel Filters", *National Engineering Handbook*, Part 633, Chapter 26, October.

End of current text

Appendix A

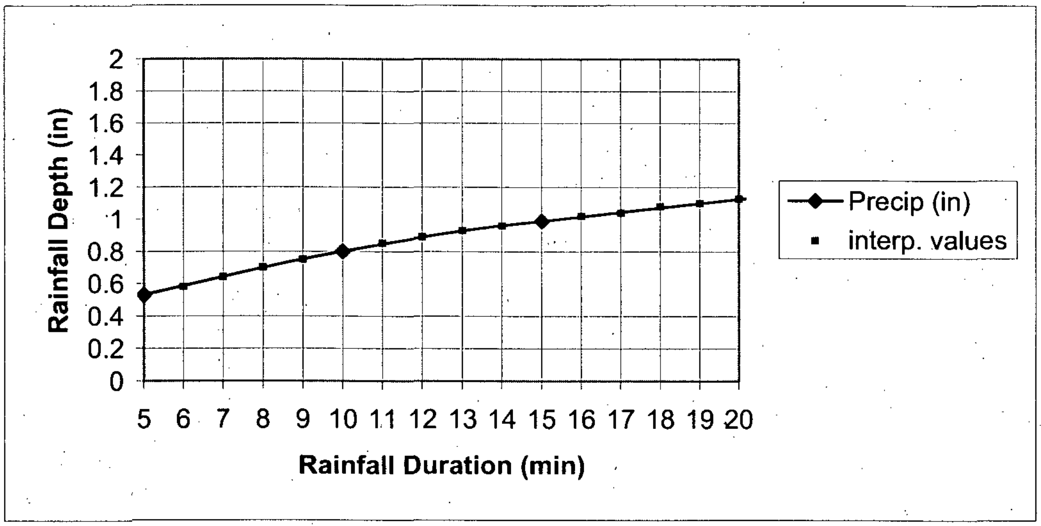
Supporting Calculations

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**5/2/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

100-year precipitation event

Values from NOAA Table (DOE 2005)		
Storm Duration (min)	Precip (in)	Intensity (in/hr)
5	0.53	6.36
10	0.8	4.8
15	0.99	3.96
30	1.33	2.66
60	1.65	1.65
120	1.82	0.91

Interpolated Values		
Storm Duration (min)	Interpolated Precip (in)	Interpolated Intensity (in/hr)
0	0.53	6.36
5	0.53	6.36
6	0.58	5.80
7	0.64	5.49
8	0.7	5.25
9	0.75	5.00
10	0.8	4.80
11	0.85	4.64
12	0.89	4.45
13	0.93	4.29
14	0.96	4.11
15	0.99	3.96
16	1.02	3.83
17	1.04	3.67
18	1.08	3.60
19	1.1	3.47
20	1.13	3.39



Client: Stoller **Job No.:** 181268
Project: Crescent Junction Disposal Cell **Date:** 4/28/2006
Detail: Erosion Protection **Computed By:** RTS

PMP Event

PMP calculation from Calc. No.: MOA-02-08-2005-2-08-00, Site Drainage--Hydrology Parameters
Use values for drainage area <1 square mile

Table 2. Estimated Precipitation Depths For Local-Storm PMP, Crescent Junction, Utah Site

Hourly Increments	First Hour	Second Hour	Third Hour				Fourth Hour	Fifth Hour	Sixth Hour
PMP Depths (inches)	0	0.1	8.2				0.6	0.1	0
Third-Hour Component Depths (inches)			7.1	0.5	0.4	0.2			

Client:	**Stoller**	**Job No.:**	**181268**
roject:	**Crescent Junction Disposal Cell**	**Date:**	**5/2/2006**
etail:	**Erosion Protection**	**Computed By:**	**RTS**

ime of Concentration

1-hour PMP (in) 8.2

For top slopes of 2.0%, side slopes at 1V:5H

Description	Incremental Drainage Area (acres)	Slope (feet/feet)	Slope Length (feet)	Time of Concentration (minutes)				% of 1-hour PMP	PD_{PMP} (in)	Intensity (in/hr)
				Kirpich	SCS	Brant and Oberman	Average			
A1, top	213.91	0.02	2130	12.9	12.9	11.7	12.5	69.4	5.7	27.4
A2, slope	16.10	0.2	170	13.6	13.6	14.0	13.7	72.0	5.9	25.8
A3, slope	4.82	0.2	115	0.6	0.6	2.0	2.5	27.5	2.3	54.2
A4, slope	7.19	0.2	80	0.4	0.4	1.8	2.5	27.5	2.3	54.2
A5, slope	6.43	0.2	150	0.7	0.7	2.2	2.5	27.5	2.3	54.2

Note: Flow over A2 includes flow from A1

Source: Brant and Oberman(1975) as presented in UMTRA TAD (1989)
Formula: tc=C(L/Si^2)^(1/3).
Source:Kirpich (1940) as presented in NUREG 4620
Formula: tc=0.00013*L^0.77/S^0.385 with L in feet, tc in hours
Source: SCS as presented in NUREG 4620
Formula: tc=(11.9L^3/H)^0.385 with L in miles, H in feet, t in hours
% of one-hour PMP=RD/(0.0089*RD+0.0686) for tc<15 min based on Table 4.1 of TAD

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**5/2/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Unit discharge of PMP

Top slope =2.0%

Description	Total Drainage Area (acres)	C	Tc (min)	Intensity (in/hr)	Q (cfs)	longest slope length (ft)	unit discharge (cfs/ft)
A1, top	213.91	1	12.5	27.4	5863.3	2130	1.35
A2, slope	230.01	1	13.7	25.8	5928.1	2300	1.37
A3, slope	4.82	1	2.5	54.2	261.0	115	0.14
A4, slope	7.19	1	2.5	54.2	389.4	80	0.10
A5, slope	6.43	1	2.5	54.2	348.2	150	0.19

Note: Flow over A2 includes flow from A1

Client: Stoller
Project: Crescent Junction Disposal Cell
Detail: Erosion Protection
Job No.: 181268
Date: 5/2/2006
Computed By: RTS

Unit discharge of 100-year precipitation

Top slope =2.0%

Description	Total Drainage Area (acres)	C	Tc (min)	Precip. Depth (in)	Intensity (in/hr)	Q (cfs)	longest slope length (ft)	unit discharge (cfs/ft)
A1, top	213.91	0.9	12.5	0.9	4.5	856.7	2130	0.20
A2, slope	230.01	0.9	13.7	0.9	4.3	888.5	2300	0.21
A3, slope	4.82	0.9	2.5	0.5	6.4	27.6	115	0.02
A4, slope	7.19	0.9	2.5	0.5	6.4	41.2	80	0.01
A5, slope	6.43	0.9	2.5	0.5	6.4	36.8	150	0.02

Note: Flow over A2 includes flow from A1

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**5/2/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Temple Method for 2% Top Slope

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

native soil is classified as CL/ML with average values of LL=22, PI=4, %fines=70
This doesn't truly fit any of Temple's soil types, as PI is less than 10, but also not a sand

100-yr Design flow (cfs/ft)	0.20	
PMP Design flow (cfs/ft)	1.35	
Concentration Factor, F	3	
100-yr Design flow (cfs/ft), q	**0.6**	
PMP Design flow (cfs/ft), q	**4.05**	
Slope, S (ft/ft)	0.02	
average dry density (pcf)	103	(at 85% modified proctor)
average specific gravity	2.68	
void ratio, e	0.624	
unit weight water (pcf)	62.4	

	If SW or SP eolian/sheetwash	If CL eolian/sheetwash	if CL weathered mancos	If ML eolian/sheetwash	If imported coarse sand
d75 (inches)	<.05				1.1
Plasticity Index, PI		5	10	5	
End-of-construction, 100-yr precip					
Manning's n for non-veg slope	0.0156	0.0156	0.0156	0.0156	0.0260
assumed depth of flow, no veg (ft), d	0.15	0.15	0.15	0.15	0.21
calculated q (cfs/ft), no veg	**0.60**	**0.60**	**0.60**	**0.60**	**0.60**
Iterate with d until calc. q equals design q					
velocity, v, no veg (ft/s)	3.88	3.88	3.88	3.88	2.86
base allowable tractive shear stress (psf) τab=		0.014595	0.02977	0.00744	
void ratio correction factor, Ce=		1.124541359	1.124541359	1.124541359	
allowable tractive shear stress (psf), τa=	0.020	0.018	0.038	0.009	0.440
effective shear stress (psf), τe (no veg)	0.193	0.193	0.193	0.193	0.262
shear stress ratio, end of construction	0.10	0.10	0.20	0.05	1.68
Limit slope such that shear stress ratio is 1.0					
Stable slope	0.08%	0.07%	0.19%	0.03%	4.17%
Long-term, PMP precip					
Repr. stem length (in) h(ave)					
good veg	1	1	1	1	1
poor veg	0.3	0.3	0.3	0.3	0.3
Repr. stem density (stems/sq in), M(ave)					
good veg	50	50	50	50	50
poor veg	17	17	17	17	17
Retardance curve index, CI					
good veg	4.80	4.80	4.80	4.80	4.80
poor veg	2.67	2.67	2.67	2.67	2.67
Cover factor, Cf					
good veg	0.5	0.5	0.5	0.5	0.5
poor veg	0.25	0.25	0.25	0.25	0.25
allowable vegetated shear strength (psf), τva					
good veg	3.60	3.60	3.60	3.60	3.60
poor veg	2.01	2.01	2.01	2.01	2.01
Mannings n for soil roughness, ns=	0.0156	0.0156	0.0156	0.0156	0.0260
Mannings n for vegetal conditions, nr					
good veg	0.0388	0.0388	0.0388	0.0388	0.0388
poor veg	0.0259	0.0259	0.0259	0.0259	0.0259
Mannings n for vegetated slopes, nv					
good veg	0.0388	0.0388	0.0388	0.0388	0.0440
poor veg	0.0259	0.0259	0.0259	0.0259	0.0332
assumed depth of flow, d (ft)					
good veg	0.840	0.840	0.840	0.840	0.906
poor veg	0.659	0.659	0.659	0.659	0.766
calculated q (cfs/ft), with veg					
good veg	***4.05***	***4.05***	***4.05***	***4.05***	***4.05***
poor veg	**4.05**	**4.05**	**4.05**	**4.05**	**4.05**
Iterate with d until q calc equals q design					
velocity (ft/s), v					
good veg	4.82	4.82	4.82	4.82	4.47
poor veg	6.14	6.14	6.14	6.14	5.29
effective shear stress (psf), τe					
good veg	0.0848	0.0848	0.0848	0.0848	0.1975
poor veg	0.2236	0.2236	0.2236	0.2236	0.4387
effective veg shear stress (psf) τve					
good veg	0.9629	0.9629	0.9629	0.9629	0.9330
poor veg	0.5993	0.5993	0.5993	0.5993	0.5166
shear stress ratio, vegetated slope					
good veg	**3.74**	**3.74**	**3.74**	**3.74**	**3.86**
poor veg	**3.35**	**3.35**	**3.35**	**3.35**	**3.88**
shear stress ratio, soil on vegetated slope					
good veg	**0.24**	**0.22**	**0.44**	**0.11**	**2.23**
poor veg	**0.09**	**0.08**	**0.17**	**0.04**	**1.00**

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**5/2/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

afety Factor Method

ppropriate 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

	Top Slope	
Slope (ft/ft)	0.02	
angle α (rad)	0.020	
Angle of repose of rock (degees)	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	
Specific gravity of rock	2.65	
PMP unit flow (cfs/ft)	1.35	(max from "flow-PMP" worksheet)
Concentration Factor	3	Typically between 1.1 to 3.2
design flow (cfs/ft)	4.05	
design flow over rock (cfs/ft)	**4.05**	assumes negligible flow through rock
Assumed D50 (in) #1	2	
Assumed D50 (in) #2	2.1	
Assumed D50 (in) #3	**2.2**	
Assumed D50 (in) #4	2.3	
Assumed D50 (in) #5	2.4	
Manning's n for rock #1	0.0273	Abt et al. 1987 as presented in UMTRA TAD
Manning's n for rock #2	0.0275	
Manning's n for rock #3	0.0278	
Manning's n for rock #4	0.0279	
Manning's n for rock #5	0.0281	
Assumed depth of flow for rock #1 (ft)	0.681	
Assumed depth of flow for rock #2 (ft)	0.684	
Assumed depth of flow for rock #3 (ft)	0.687	
ssumed depth of flow for rock #4 (ft)	0.690	
sumed depth of flow for rock #5 (ft)	0.693	
Calculated flow for rock #1 (cfs/ft)	4.05	
Calculated flow for rock #2	4.05	
Calculated flow for rock #3	4.05	
Calculated flow for rock #4	4.05	
Calculated flow for rock #5	4.05	

modify depth of flow until calculated q = design q

calculated velocity for rock #1, (ft/s)	5.95
calculated velocity for rock #2, (ft/s)	5.92
calculated velocity for rock #3, (ft/s)	5.90
calculated velocity for rock #4, (ft/s)	5.87
calculated velocity for rock #5, (ft/s)	5.85
ave shear stress, τ for rock #1	0.85
ave shear stress, τ for rock #2	0.85
ave shear stress, τ for rock #3	0.86
ave shear stress, τ for rock #4	0.86
ave shear stress, τ for rock #5	0.86
Stability number for rock #1	1.040
Stability number for rock #2	0.995
Stability number for rock #3	0.954
Stability number for rock #4	0.916
Stability number for rock #5	0.882
Factor of Safety for rock #1	0.94
Factor of Safety for rock #2	0.98
Factor of Safety for rock #3	**1.02**
Factor of Safety for rock #4	1.06
Factor of Safety for rock #5	1.10

Adjust assumed D50 until design criteria for Factor of Safety is bracketed

Client: Stoller
Project: Crescent Junction Disposal Cell
Detail: Erosion Protection

Job No.: 181268
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Computed By: RTS

Abt 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	A2	A3	A4	A5	
Side Slope (ft/ft)	0.2	0.2	0.2	0.2	
angle α (rad)	0.197	0.197	0.197	0.197	
PMP unit flow (cfs/ft)	1.37	0.14	0.10	0.19	(max from "flow-PMP" worksheet)
Concentration Factor	3	3	3	3	Typically between 1.1 to 3.2
Coef. Of Movement	1.35	1.35	1.35	1.35	1.35 to prevent movement
design flow (cfs/ft)	5.56	0.58	0.41	0.76	
design flow over rock (cfs/ft)	5.56	0.58	0.41	0.76	assumes negligible flow through rock
D50 (inches) angular	6.8	1.9	1.6	2.2	
D50 (inches) rounded	9.6	2.7	2.2	3.1	

Client: Stoller
Project: Crescent Junction Disposal Cell
Detail: Erosion Protection

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Date: 5/9/2006
Computed By: RTS

STEPHENSON'S METHOD FOR SIZING RIPRAP

Applicable for shallow flow on slopes greater than 10%

Area	A2	A3	A4	A5
slope (ft/ft)	0.2	0.2	0.2	0.2
slope angle α (rad)	0.197	0.197	0.197	0.197
Angle of repose of rock (degees)	41	41	41	41
Angle of repose of rock (rad))	0.716	0.716	0.716	0.716
Specific gravity of rock	2.65	2.65	2.65	2.65
Dry unit weight of rock (pcf)	125	125	125	125
Porosity of rock	0.32288	0.32288	0.32288	0.32288
C	0.22	0.22	0.22	0.22
PMP unit flow (cfs/ft)	1.37	0.14	0.10	0.19
flow concentration	3	3	3	3
design flow (cfs/ft)	4.12	0.43	0.30	0.56
design flow over rock (cfs/ft)	4.12	0.43	0.30	0.56
D50 (inches) for angular rock	9.47	2.11	1.65	2.52
D50 (inches) for rounded rock	13.25	2.95	2.32	3.52

Angle of repose: 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

C: varies from 0.22 for gravel and pebbles to 0.27 for crushed granite

PMP unit flow: (max from from "flow" worksheet)

design flow over rock: assumes negligible flow through rock

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**2/6/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Preliminary Gradations

This spreadsheet calculates preliminary gradations of riprap based on D50

Source: NUREG 4620

Source: USDA, National Engineering Handbook, Part 633, *Chapter 26, Gradation Design of Sand and Gravel Filters*, October 1994.

Area	A1	A2	A3	A4	A5	A2 Apron	A3 Apron	A5 Apron	Comment
Minimum D50 (in)	2.20	8.15	2.02	1.62	2.38	13.68	3.87	4.49	Assuming angular rock, average between Abt and Stephenson methods
Rock thickness (in)	6.00	16.31	6.00	6.00	6.00	27.36	7.75	8.99	Based on constructability: 2*D50. May consider 12" as *minimum thickness for rock*
Maximum D50 (in)	4.00	10.87	4.00	4.00	4.00	18.24	5.16	5.99	Based on constructability: Thickness/1.5
Maximum D50 (in)	11.00	40.77	10.11	8.09	11.91	68.40	19.37	22.47	Prevent gap-grading: minimum D50*5
Maximum D50 (in)	4.00	10.87	4.00	4.00	4.00	18.24	5.16	5.99	Smaller of two above criteria
Maximum D100 (in)	6.00	16.31	6.00	6.00	6.00	27.36	7.75	8.99	Based on constructability: 1*Thickness
Maximum D100 (in)	20.00	54.35	20.00	20.00	20.00	91.20	25.82	29.97	Based on internal stability?: 5*maximum D50
Maximum D100 (in)	6.00	16.31	6.00	6.00	6.00	27.36	7.75	8.99	Smaller of two above criteria
Minimum D100 (in)	4.40	16.31	4.04	3.24	4.76	27.36	7.75	8.99	Based on internal stability: 2*minimum D50
Minimum D15 (in)	0.38	1.02	0.38	0.38	0.38	1.71	0.48	0.56	Based on internal stability: Maximum D100/16
Maximum D15 (in)	1.88	5.10	1.88	1.88	1.88	8.55	2.42	2.81	Prevent gap-grading: Minimum D15*5
Minimum D60 (in)	3.08	11.41	2.83	2.26	3.33	19.15	5.42	6.29	Prevent gap-grading: D60/D10<=6
Maximum D60 (in)	5.60	15.22	5.60	5.60	5.60	25.54	7.23	8.39	Prevent gap-grading: D60/D10<=6
Minimum D10 (in)	0.51	1.90	0.47	0.38	0.56	3.19	0.90	1.05	Prevent gap-grading: D60/D10<=6
Maximum D10 (in)	0.93	2.54	0.93	0.93	0.93	4.26	1.21	1.40	Prevent gap-grading: D60/D10<=6

Summary

Percent Passing	Diameter (mm)							
50	56	207	51	41	60	347	98	114
50	102	276	102	102	102	463	131	152
100	152	414	152	152	152	695	197	228
100	112	414	103	82	121	695	197	228
15	10	26	10	10	10	43	12	14
15	48	129	48	48	48	217	61	71
60	78	290	72	58	85	486	138	160
60	142	387	142	142	142	649	184	213
10	13	48	12	10	14	81	23	27
10	24	64	24	24	24	108	31	36

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**2/6/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Interstitial Velocities

Source: NUREG 1623, Section D
Abt, SR, JF Ruff, RJ Wittler (1991). Estimating Flow Through Riprap, Journal of Hydraulic Engineering, Vol. 117, No. 5, May.

Area	A1	A2	A3	A4	A5	A2 apron	A3 apron	A5 apron	
Minimum D50 (inches)	2.20	8.15	2.02	1.62	2.38	13.68	3.87	4.49	from Safety Factor Method, or ave of Abt, Stephenson etc. assuming angular rock
Maximum D10 (inches)	0.93	2.54	0.93	0.93	0.93	4.26	1.21	1.40	from preliminary gradation specs
Slope (ft/ft)	0.02	0.2	0.2	0.2	0.2	0.02	0.02	0.02	from preliminary disposal cell layout
Velocity (ft/s)	0.18	0.93	0.56	0.56	0.56	0.38	0.20	0.22	calculated from Abt et al. (1991)
Underlying filter required?	no	maybe	maybe	maybe	maybe	no	no	no	Per NUREG 1623, Appendix D, section 2.1.1

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**5/9/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Modified Universal Soil Loss Equation (MUSLE)

Source : Clyde et al. (1978) as presented in NUREG 4620, section 5.1.2
A=R*K*LS*VM

	Sheet wash/eolian	weathered shale	coarse gravel/sand	
Inputs for K factor				
Percent silt and very fine sand	60	55	10	
Percent sand (0.10-2.0 mm)	25	5	20	
Percent oganic matter	2	2	0	
Soil structure	No. 1	No. 3	No. 3	
Permeability	No. 3	No. 3	No. 2	
Inputs for LS factor				
Slope length (ft)	2130	2130	2130	
slope steepness (%)	2	2	2	
m exponent	0.3	0.3	0.3	from table 5.2 of NUREG 4620

		Sheet Wash/Eolian	Weathered Shale	Coarse Sand	
R	Rainfall Factor	30	30	30	From Table 5.1 of NUREG 4620 for eastern third of Utah
K	Soil Erodibility factor	0.35	0.26	0.05	From nomograph Fig. 5.1 of NUREG 4620
LS	Topographic factor	0.50	0.50	0.50	
VM	Dimensionless erosion control factor	0.4	0.4	0.4	From Table 5.3 of NUREG 4620 for seedings, 0-60 days
A	Soil Loss (tons/acre/year)	2.09	1.56	0.30	
A	Soil density (pcf)	100	100	100	
A	Soil Loss (inches/1000 years	11.5	8.6	1.6	

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**5/12/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Apron Protection

Source: Abt, SR, Johnson, TL, Thornton, CI, and Trabant, SC, Riprap Sizing at Toe of Embankment Slopes, Journal of Hydraulic Engineering, Vol. 124, No. 7, July 1998.

Equation: D50=10.46*S^0.43*qd^0.56

	North	South	East	West
unit discharge (cfs/ft)	0.10	1.37	0.19	0.14
Cr	1	1	1	1
Cf	3	3	3	3
Cm	1.35	1.35	1.35	1.35
design discharge (cfs/ft)	0.406164	5.557379	0.761558	0.583861
Slope (ft/ft)	0.2	0.2	0.2	0.2
D50 (in)	3.2	13.7	4.5	3.9

Client:	**Stoller**	**Job No.:**	**181268**
Project:	**Crescent Junction Disposal Cell**	**Date:**	**5/12/2006**
Detail:	**Erosion Protection**	**Computed By:**	**RTS**

Scour depth is based on equations presented by FHA based on erosion a culvert outlets
Source: US Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular No. 14, September, 1983

Flow over riprap	**A2, south**	**A3, west**	**A5, east**		
Flow, q	1.37	0.14	0.19	cfs/ft	
gravity, g	32.2	32.2	32.2	ft/s^2	
time, t	15	15	15	minutes	
base time, to	316	316	316	minutes	
D50	13.7	3.9	4.5	in	
D50	1.14	0.32	0.37	ft	
Slope of Apron	0.02	0.02	0.02	(ft/ft)	
Manning's n	0.040	0.033	0.034	COE (1970) for submerged riprap	
depth of flow	0.45	0.10	0.12	ft	
velocity	3.06	1.41	1.54	ft/s	
Native soils					
plasticity index of alluvial soil	5	5	5	%	from GEG, 2005 lab data
unconfined compressive strength	1.4	1.4	1.4	psi	assumed value for silty clays (200 psf)
critical tractive shear (lb/ft^2)	0.254143	0.254143	0.254143		
modified shear number	71.41606	15.15466	18.19436		
d84 bedding	0.12	0.12	0.12	mm	Average for Eolian/shweet wash materials from GEG, 2005 lab data
d16 bedding	0.002	0.002	0.002	mm	Average for Eolian/shweet wash materials from GEG, 2005 lab data
gradation standard deviation, σ	7.745967	7.745967	7.745967		
gradation classification	graded	graded	graded		
	Depth				
α	0.86				coefficients for clay with PI 5-16
β	0.18				
θ	0.1				
αe	1.37				
equivalent depth, ye	0.45	0.10	0.12	ft	
depth of scour (ft)	0.98	0.22	0.27		

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-01-06-2006-5-02-01 **Discipline:** Geotechnical **No. of Sheets:** 14
Doc. No.: X0176600

Location: Attachment 1, Appendix I

Project: Moab UMTRA Project

Site: Moab Disposal Site

Feature: Volume Calculation for the Moab Tailings Pile

Sources of Data:

Various site topography files, including pre-2000 data, and 2003 and 2005 topography files.

Boring logs and CPTs from Steffen, Robertson, and Kirsten (2000) site investigation.

Boring logs from Dames & Moore (1981) site investigation.

Boring logs, test pit logs, CPT soundings, and laboratory test data from Golder (2005) field investigation.

Sources of Formulae and References:

ConeTec, Inc. (ConeTec), 2000. *Cone Penetration Test Report, Atlas Minerals Mill Tailings Impoundment, Moab, Utah*, Vols. I and II, Salt Lake City, Utah, May 12.

Dames & Moore (D&M), 1981. *Additions to Tailings Pond-Embankment System, Moab, Utah,* Report of Engineering Design Study for Atlas Minerals, Salt Lake City, Utah, May 26.

Steffen, Robertson, and Kirsten (SRK), 2000. *Dewatering Options for Placement of Cover, Moab Tailings Impoundment*, prepared for Moab Mill Reclamation Trust, Lakewood, Colorado, June.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No. MOA-01-05-2006-5-02-00**

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Problem Statement:

Estimate the total volume of tailings and associated fill materials requiring removal and re-location from the Moab Tailings Impoundment, including an estimate of the various material types (i.e., cover fill, sands, transitional tailings and slimes).

Method of Solution:

Review site geotechnical data including boring logs, test pit logs, laboratory test results and cone penetration test soundings conducted at the Site. Using AutoCAD and Land Development Desktop, develop cross-sections both laterally (northwest to southeast) and transversely (southwest to northeast) across the site in order to estimate the volumes. Where laboratory test data are available, use the data to divide the material into the following general classifications:

- Sand: <30 percent fines (minus 74 micron).
- Transitional tailings: >30 percent and < 70 percent fines.
- Slimes: >70 percent fines.

Assumptions:

- Relative percent fines can be estimated from the cone penetration soundings based on relative resistance, whereby higher resistances infer presence of sandy soils and lower resistance infer presence of fine-grained soils.
- The average end area method, wherein averaged cross-sectional areas from two adjacent sections multiplied by the distance between those two sections provides a reasonable estimate of the volume of material between the same sections.

Calculation:

Volumes were calculated using the average-end area method, whereby cross-sections were developed across the site and the material constituents of each cross-section were averaged with the same from the adjacent cross-section and multiplied by the distance between the sections.

Discussion:

- Based on the method discussed herein, results of the volume evaluation using lateral cross-sections (0 through 10) and transverse cross-sections (11 through 25) are summarized as follows, with volumes presented in cubic yards (yd^3):

Material Type	Lateral Cross-Sections (yd^3)	Transverse Cross-Sections (yd3)
Cover Fill	452,800	440,800
Sand Tailings	2,860,100	2,736,700
Transitional Tailings	3,930,500	3,903,100
Slimes	3,116,100	3,236,600

- The total volume of tailings and cover soils was calculated to be 10.36 million yd^3 and 10.32 million yd^3 using the lateral and transverse cross-sections, respectively.
- See Tables 1 and 2 for summary of cross-sectional areas and volumes based on the lateral and transverse cross-sections, respectively.
- See Figures 1 through 8 for map and cross-sections.

Table 1. Area and Volume Summary

GOLDER ASSOCIATES INC

TABLE 1
AREA AND VOLUME SUMMARY
BASED ON LATERAL SECTIONS

Data from AutoCAD Sections 22-May-06 *0532269 DR 18May06.dwg*

Section	Cover Fill Area (ft^2)	Sand Tailings Area (ft^2)	Transitional Tailings Area (ft^2)	Slimes Tailings Area (ft^2)
0	0	33,613	0	0
1	2,427	60,649	44,207	3,213
2	4,657	35,088	72,000	30,949
3	6,963	20,934	73,724	51,085
4	8,843	29,590	43,767	71,139
5	9,724	28,294	70,101	52,258
6	12,217	39,020	34,538	68,572
7	8,570	21,813	64,582	58,960
8	7,366	25,373	63,253	60,320
9	361	58,795	64,448	24,171
10	0	61,556	0	0

Volumes Calculations

Section Increment	Cover Fill Volume (ft^3)	Sand Tailings Volume (ft^3)	Transitional Tailings Volume (ft^3)	Slimes Tailings Volume (ft^3)	
Outside 0	0	2,100,813	0	0	
0 to 1	242,700	9,426,200	4,420,700	321,300	
1 to 2	708,400	9,573,700	11,620,700	3,416,200	
2 to 3	1,162,000	5,602,200	14,572,400	8,203,400	
3 to 4	1,580,600	5,052,400	11,749,100	12,222,400	
4 to 5	1,856,700	5,788,400	11,386,800	12,339,700	
5 to 6	2,194,100	6,731,400	10,463,900	12,083,000	
6 to 7	2,078,700	6,083,300	9,912,000	12,753,200	
7 to 8	1,593,600	4,718,600	12,783,500	11,928,000	
8 to 9	772,700	8,416,800	12,770,100	8,449,100	
9 to 10	36,100	12,035,100	6,444,800	2,417,100	
Outside 10	0	1,692,790	0	0	
Total (ft^3)	12,225,600	77,221,703	106,124,000	84,133,400	**279,704,703**
Total (yd^3)	452,800	2,860,063	3,930,519	3,116,052	**10,359,433**

Table 2. Area and Volume Summary Based on Transverse Sections

GOLDER ASSOCIATES INC

TABLE 2
AREA AND VOLUME SUMMARY
BASED ON TRANSVERSE SECTIONS

Data from AutoCAD Sections 1-Jun-06 *0532269A027*

Section	**Cover Fill Area (ft^2)**	**Sand Tailings Area (ft^2)**	**Transitional Tailings Area (ft^2)**	**Slimes Tailings Area (ft^2)**
11	0	27,774	5,649	0
12	3,430	16,667	31,875	567
13	2,897	16,159	48,193	9,117
14	5,356	21,704	38,804	29,743
15	6,681	17,276	25,998	51,026
16	8,435	17,476	20,190	58,429
17	7,138	23,344	24,057	56,265
18	4,848	18,228	23,136	70,274
19	4,790	17,565	46,072	56,152
20	5,212	25,587	50,827	52,443
21	6,864	24,841	71,631	42,733
22	2,238	31,676	100,069	10,192
23	1,624	60,991	41,118	0
24	0	44,823	0	0
25	0	12,373	0	0

Volumes Calculations

Section Increment	**Cover Fill Volume (ft^3)**	**Sand Tailings Volume (ft^3)**	**Transitional Tailings Volume (ft^3)**	**Slimes Tailings Volume (ft^3)**
Outside 11	0	2,083,050	423,675	0
11 to 12	343,000	4,444,100	3,752,400	56,700
12 to 13	632,700	3,282,600	8,006,800	968,400
13 to 14	825,300	3,786,300	8,699,700	3,886,000
14 to 15	1,203,700	3,898,000	6,480,200	8,076,900
15 to 16	1,511,600	3,475,200	4,618,800	10,945,500
16 to 17	1,557,300	4,082,000	4,424,700	11,469,400
17 to 18	1,198,600	4,157,200	4,719,300	12,653,900
18 to 19	963,800	3,579,300	6,920,800	12,642,600
19 to 20	1,000,200	4,315,200	9,689,900	10,859,500
20 to 21	1,207,600	5,042,800	12,245,800	9,517,600
21 to 22	910,200	5,651,700	17,170,000	5,292,500
22 to 23	386,200	9,266,700	14,118,700	1,019,200
23 to 24	162,400	10,581,400	4,111,800	0
24 to 25	0	5,719,600	0	0
Outside 25	0	525,853	0	0

Total (ft^3)	11,902,600	73,891,003	105,382,575	87,388,200	**278,564,378**
Total (yd^3)	440,837	2,736,704	3,903,058	3,236,600	**10,317,199**

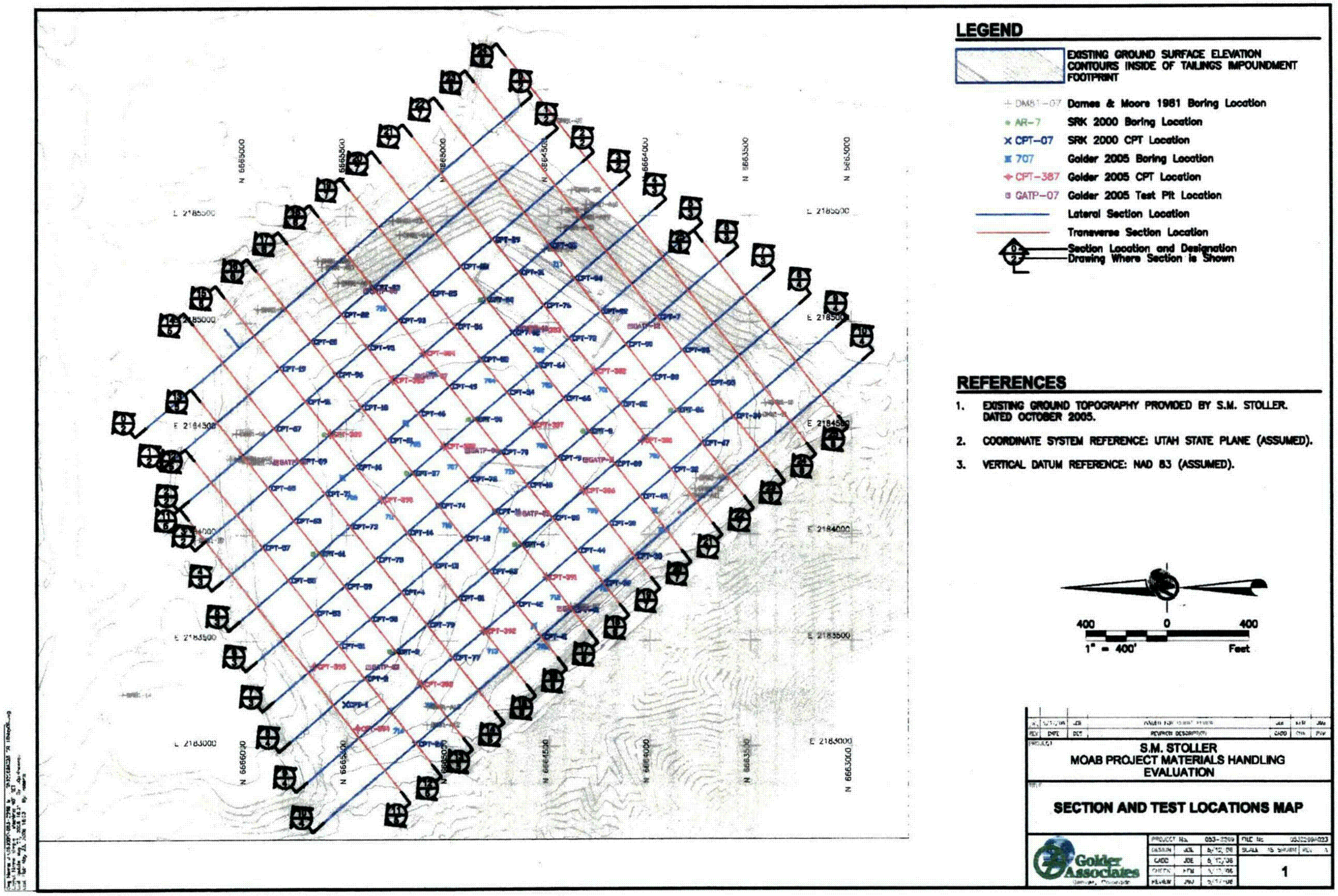


Figure 1. Section and Test Locations Map

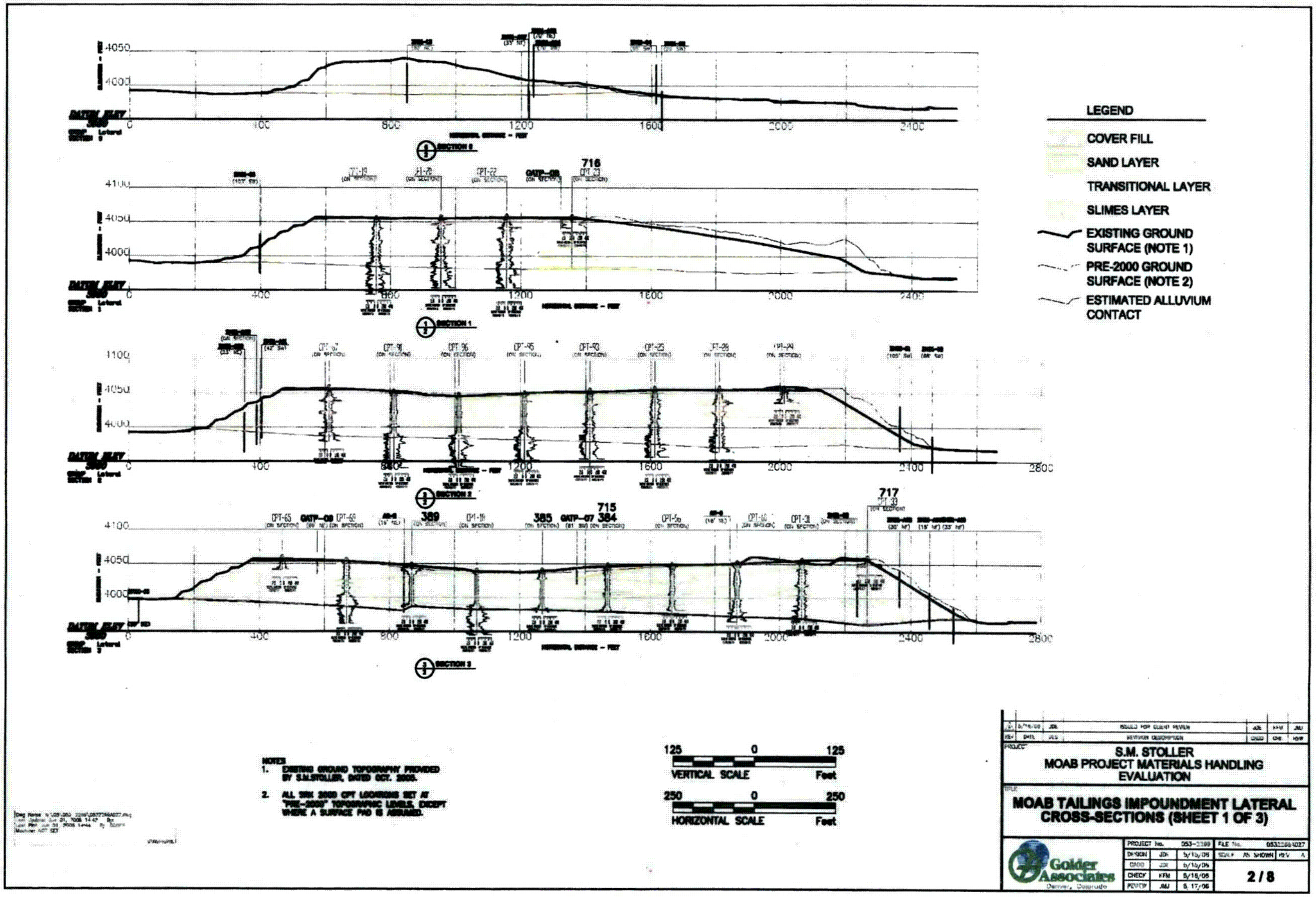


Figure 2. Moab Tailings Impoundment Lateral Cross-Section (Sheet 1 of 3)

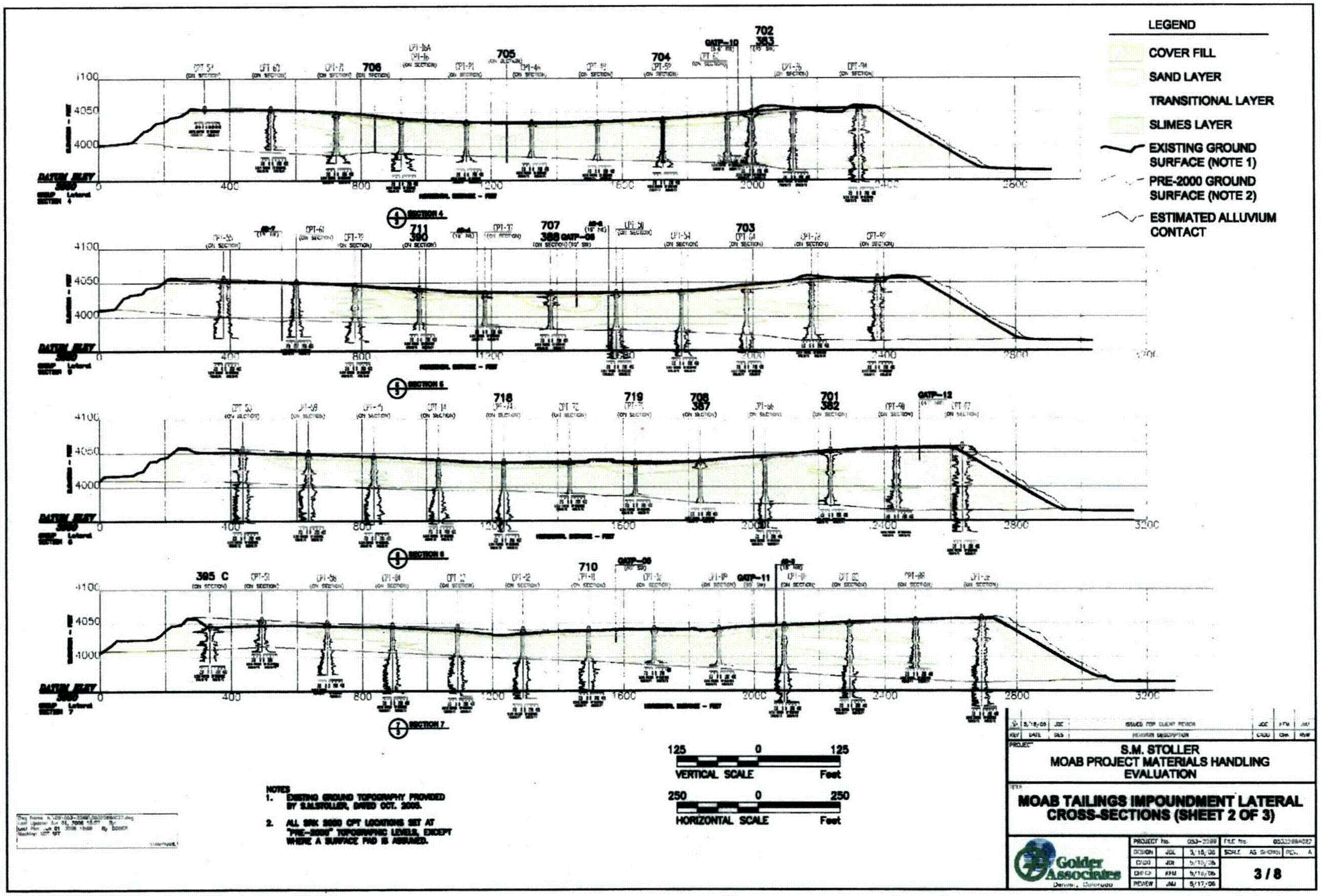


Figure 3. Moab Tailings Impoundment Lateral Cross-Section (Sheet 2 of 3)

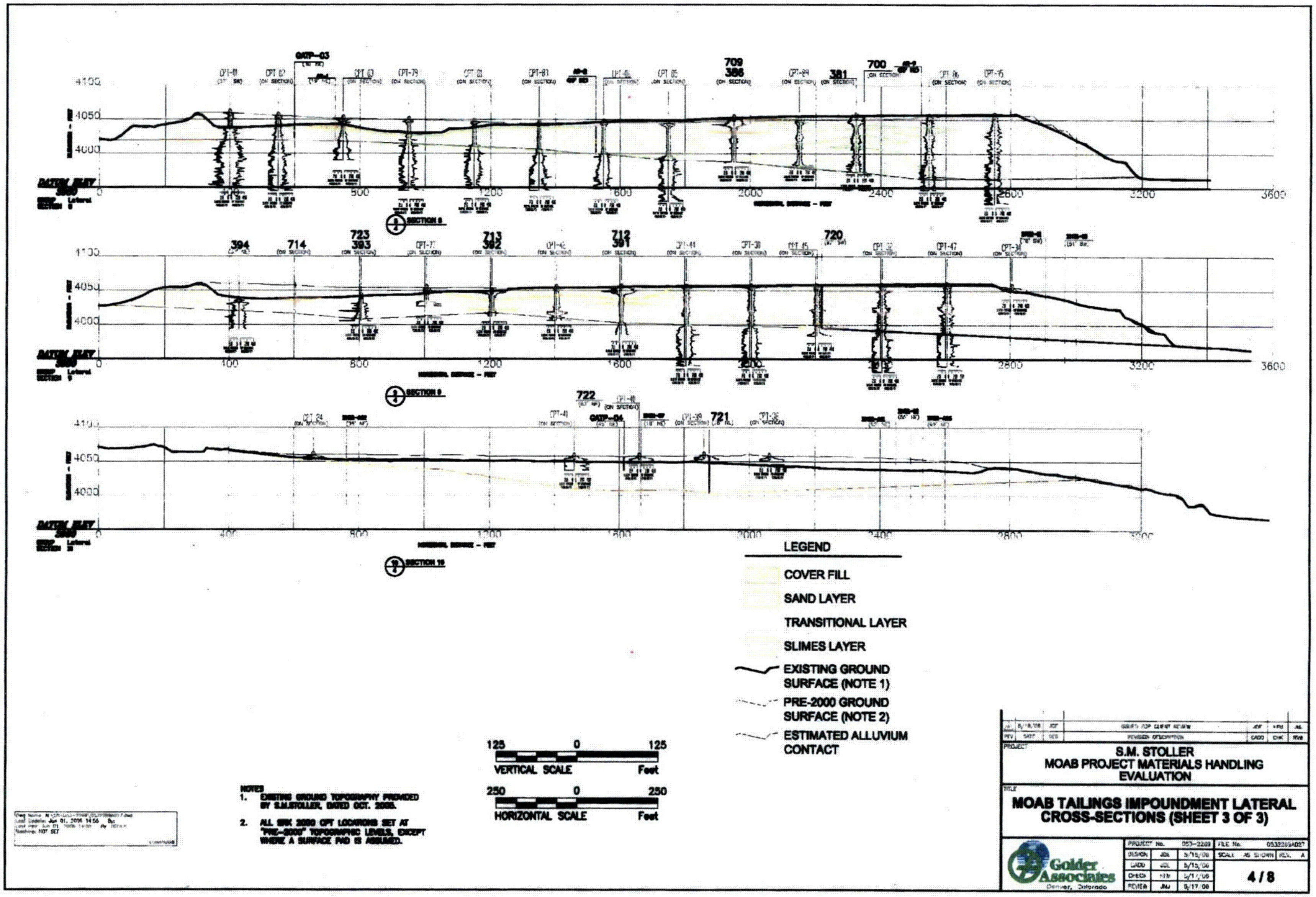


Figure 4. Moab Tailings Impoundment Lateral Cross-Sections (Sheet 3 of 3)

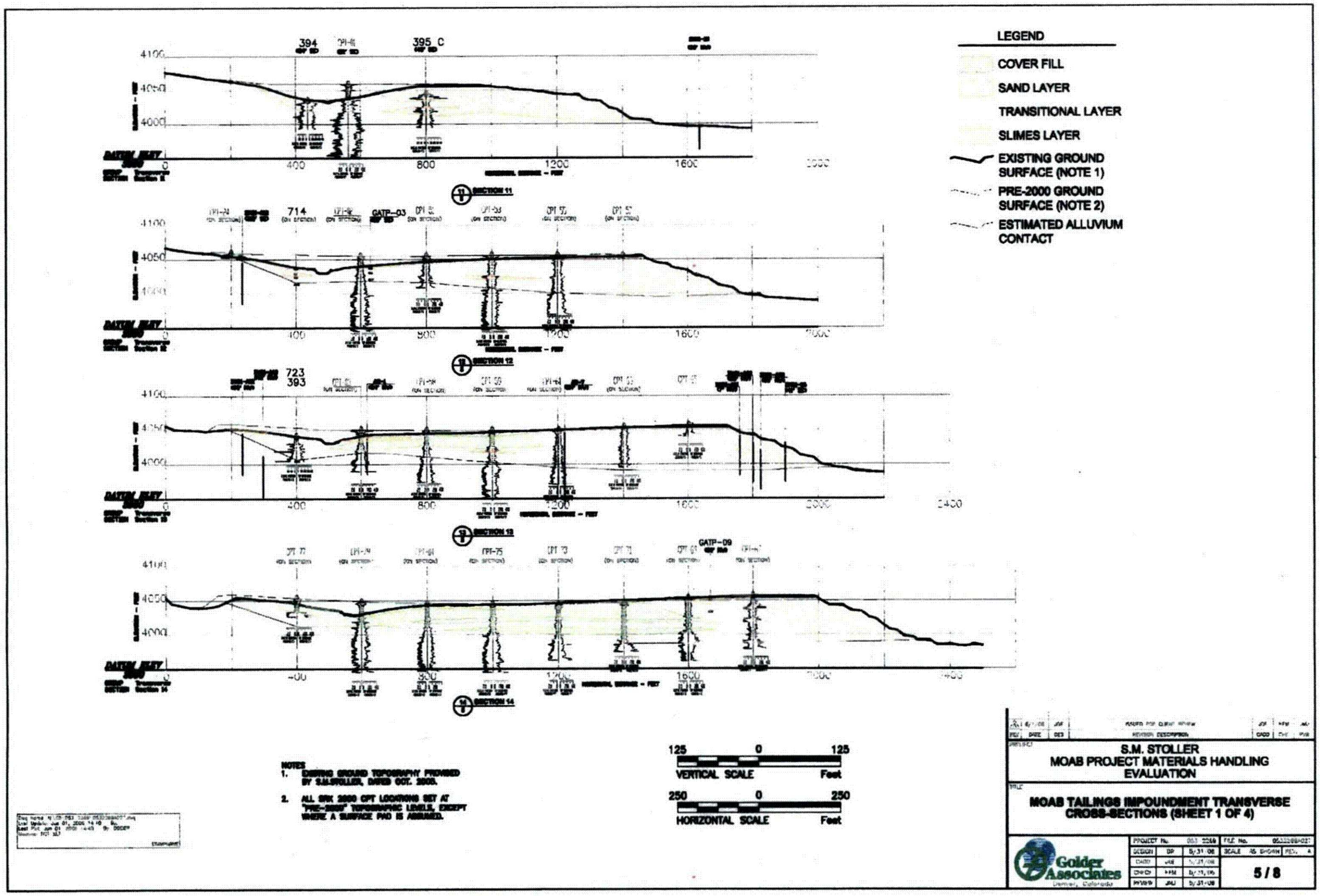
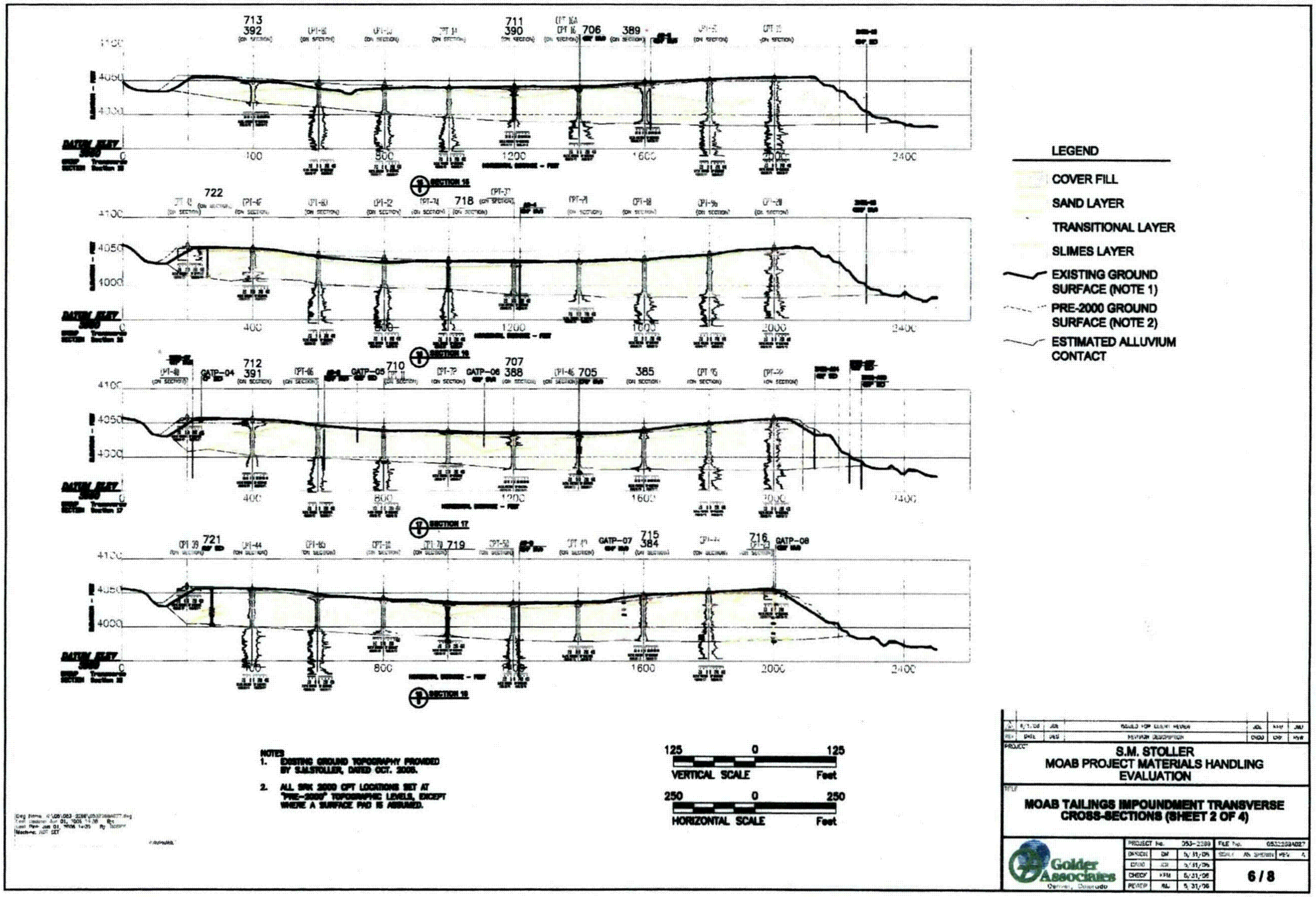


Figure 5. Moab Tailings Impoundment Transverse Cross Sections (Sheet 1 of 4)



NOTES
1. EXISTING GROUND TOPOGRAPHY PROVIDED BY S.M.STOLLER, DATED OCT. 2005.
2. ALL SRK 2000 CPT LOCATIONS SET AT "PRE-2000" TOPOGRAPHIC LEVELS, EXCEPT WHERE A SURFACE PAD IS ASSUMED.

PROJECT
S.M. STOLLER
MOAB PROJECT MATERIALS HANDLING
EVALUATION

TITLE
MOAB TAILINGS IMPOUNDMENT TRANSVERSE
CROSS-SECTIONS (SHEET 2 OF 4)

PROJECT No. 053-2389
FILE No. 0532389A027
SCALE AS SHOWN
REV A
6 / 8

Figure 6. Moab Tailings Impoundment Transverse Cross Sections (Sheet 2 of 4)

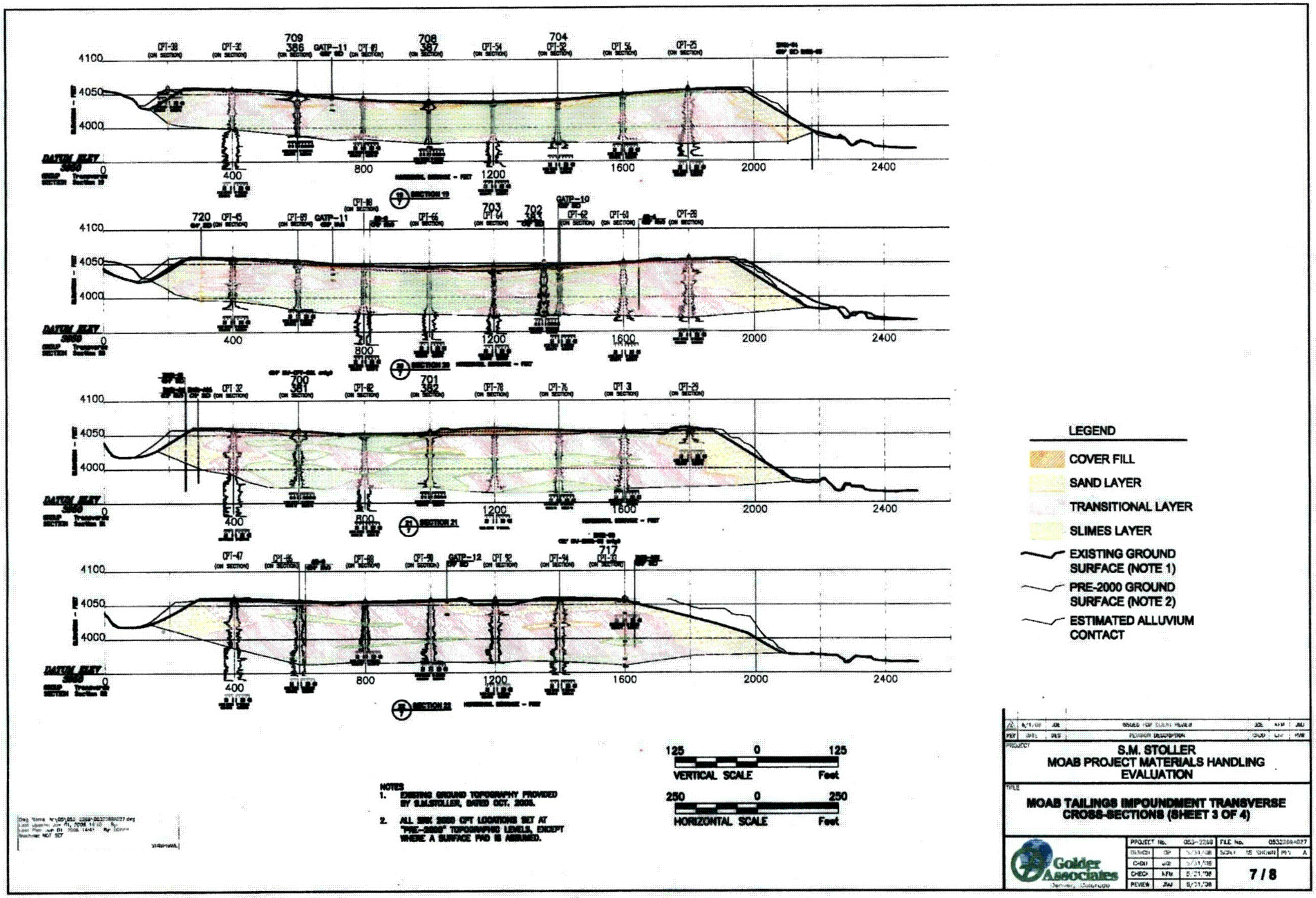


Figure 7. Moab Tailings Impoundment Transverse Cross Sections (Sheet 3 of 4)

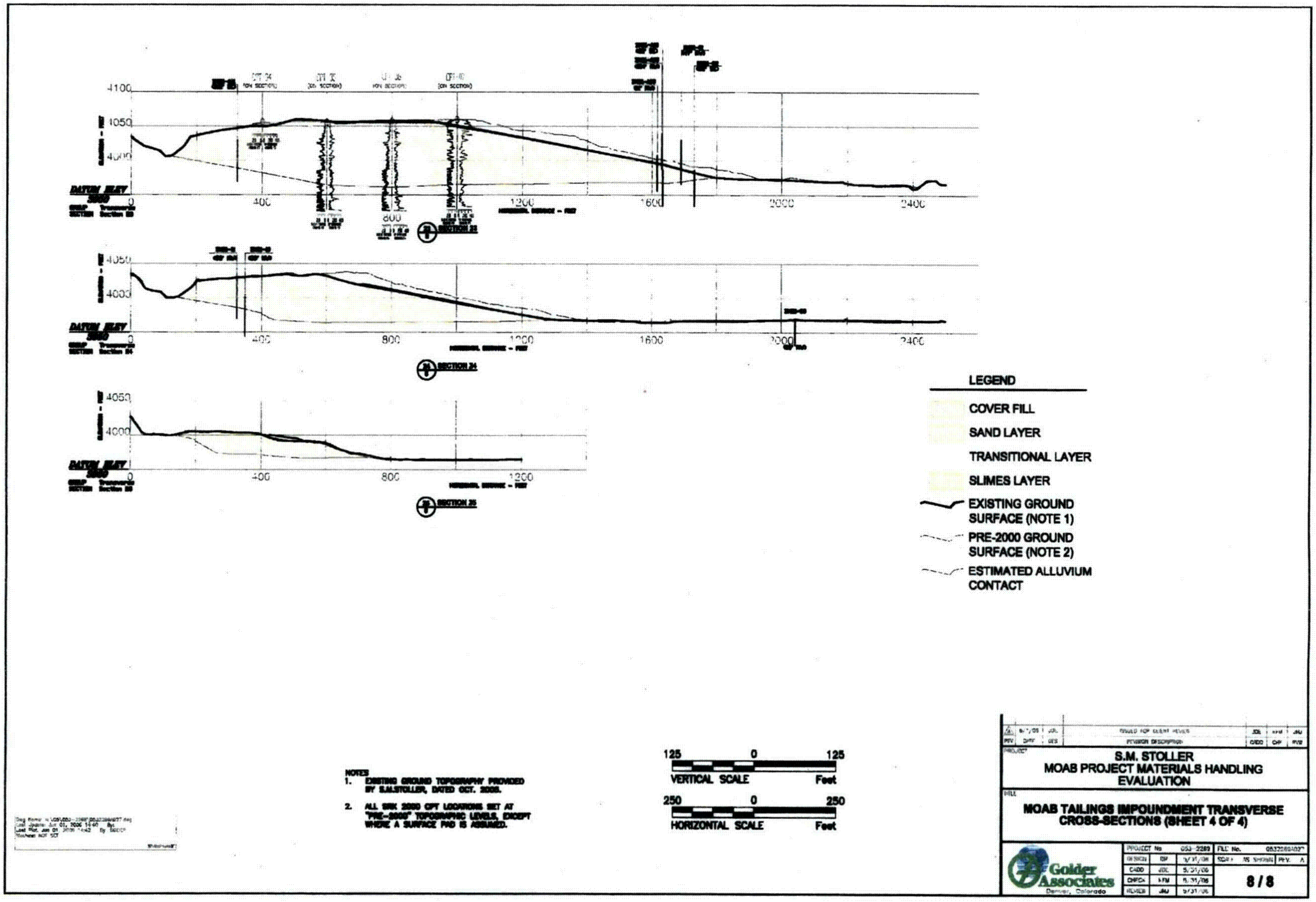


Figure 8. Moab Tailings Impoundment Transverse Cross Sections (Sheet 4 of 4)

Conclusion and Recommendations:

- The total volume of tailings and cover soils requiring removal is approximately 10.3 to 10.4 million yd^3. This volume includes no allowance for excavation of contaminated alluvial soils at the base of the tailings pile.
- Volume estimates of the individual constituents were made by developing lateral and transverse cross-sections through the impoundment. The total volumes compare well for the two sets of calculations.

Computer Source:

Not applicable.

U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-02-08-2006-5-03-00 **Discipline:** Geotechnical **No. of Sheets:** 6
Doc. No.: X0181000

Location: Attachment 1, Appendix J

Project: Moab UMTRA Project

Site: Crescent Junction Disposal Site

Feature: Weight / Volume Calculation for the Moab Tailings Pile

Sources of Data:

Laboratory test data summaries listed below.

Test data from March 2006 bench scale testing on cover soils and uranium mill tailings.

Remedial Action Plan (RAP) calculations as referenced in the text.

Sources of Formulae and References:

D&M (Dames & Moore), 1981. *Additions to Tailings Pond-Embankment System, Moab, Utah*, Report of Engineering Design Study for Atlas Minerals, Salt Lake City, Utah, May 26.

D&M (Dames & Moore), 1984. Proposed 10-foot Tailings Embankment Raise, Moab, Utah, Report of Additional Geotechnical Work as Requested by the NRC, for Atlas Minerals, Salt Lake City, Utah, September 25.

Golder (Golder Associates, Inc.), 2005a. *Materials Handling Evaluation Study for the Moab Tailings Impoundment, Moab, Utah*, Report to S.M. Stoller, Lakewood, Colorado, September 21.

Golder (Golder Associates, Inc.), 2005b. "Results of Bench Scale Testing Program on Cover Soils and Uranium Mill Tailings from the Moab Tailings Impoundment, Grand County, Utah," Draft Technical Memorandum, Lakewood, Colorado, April 3.

SRK (Steffen, Robertson, and Kirsten), 2000. *Dewatering Options for Placement of Cover, Moab Tailings Impoundment*, Prepared for Moab Mill Reclamation Trust, Lakewood, Colorado, June.

Preliminary Calc ☐ **Final Calc.** ☒ **Supersedes Calc No.**

Author: 8/2/06
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Checked by: 6/5/06
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5/31/07
Name Date

May 31, 07
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Approved by: John E Elmer 5/31/07
Name Date

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Problem Statement:

Estimate the total weight and relocated volume of tailings and associated fill materials requiring removal and re-location from the Moab Tailings Impoundment, including an estimate of the various material types (i.e., cover fill, sands, transitional tailings, and slimes).

Method of Solution:

1. Determine the average in-place wet density and in-place moisture content for each material type based on data from earlier studies plus recent lab test data (D&M 1981, D&M 1984, SRK 2000, and Golder 2005b).

2. Determine the average Standard Proctor maximum dry density and optimum moisture content for each material type based on the bench-scale Standard Proctor test results.

3. Revise and update a working draft spreadsheet sent by Greg Lord of S.M. Stoller Corp. to calculate the following:
   - In-place total weight.
   - In-place water weight.
   - Solids weight.
   - Final water weight.
   - Final total weight.
   - Final wet density.
   - Final volume.

Assumptions:

Material to be placed and compacted in the Crescent Junction Disposal Cell at 90 percent of the Standard Proctor maximum dry density at the optimum water content for each material type, based on prior UMTRA experience.

Calculation:

Table 1 shows the resulting spreadsheet. Input data are located in columns 1, 2, 3, 7, and 10. Calculations are performed in columns 4, 5, 6, 8, 9, 11, and 12. The input data and calculations are discussed on a column-by-column basis below. Note that initial input values are wet densities.

- Column 1. The in-place volumes are calculated as the average of the volumes determined using the lateral and transverse cross-sections in the "Volume Calculation for the Moab Tailings Pile" calculation (RAP Attachment 1, Appendix I).

- Column 2. The in-place wet densities were calculated as the average of all wet density lab test data from recent lab tests performed by Shaw, E & I, Inc. These lab results were separated by material type before being averaged. This same method was used to average older lab test data, the results of which were compared to the more recent averages. The numbers used in Table 1 are slightly conservative estimates based on the most recent lab test data.

- Column 3. The in-place moisture contents were calculated in the same manner as the in-place densities in Column 2.

- Column 4. The in-place total weight was calculated by multiplying the in-place volume (1) with the in-place wet density (2).

- Column 5. The in-place water weight was calculated using the following two equations: $w = W_w/W_s$, and $W_t = W_s + W_w$. Where w is the moisture content, W_w is the weight of water, W_s is the weight of solids, and W_t is the total weight. Combining these equations, W_w can be solved for knowing w (3) and W_t (4).

- Column 6. The solids weight is calculated as the total weight less the water weight.
- Column 7. The final moisture content was assumed to be equal to the average optimum moisture content determined through the Standard Proctor tests, based on a limited number of Proctor density tests.
- Column 8. The final water weight is calculated as the solids weight multiplied by the final moisture content, as per the definition of moisture content.
- Column 9. The final total weight is calculated as the solids weight added to the final water weight.
- Column 10. The final wet density was calculated by first averaging the maximum dry density (MDD) results for each material type from the Standard Proctor tests. The assumption was then made that the material would be placed at 90 percent of the MDD, based on prior UMTRA projects. Lastly, 90 percent of the MDD was converted to a wet density using the final moisture content (γwet=0.9*MDD*(1+w)).
- Column 11. The final volume is calculated by dividing the final total weight (9) by the final wet density (10).
- Column 12. The volume change is calculated by subtracting the in-place volume (1) from the final volume (11). A positive number in Column 12 indicates volume expansion, and a negative number indicates volume compression.
- Conversions Used:
    a. 1 cubic yard (yd^3) = 27 cubic feet (ft^3)
    b. 1 ton = 2,000 lbs

Discussion:

The input properties for the off-pile material, vicinity property, and subpile material were not calculated by Golder. With the exception of the in-place wet densities for these materials, the numbers in Table 1 were left unchanged from the original spreadsheet received from Stoller on June 6, 2006. The in-place wet densities were changed, as they previously appeared to represent the dry densities of these materials. All other input values for these materials appear to be reasonable based on available information.

The total in-place wet weight of the cover, sand tailings, transitional tailings, and slimes tailings is 15.8 million tons, and the equivalent dry weight of solids is 12.5 million tons. These values are slightly lower than predicted previously (Golder 2005a) (see also the "Volume Calculation for the Moab Tailings Pile" calculation, RAP Attachment 1, Appendix I) when the wet weight was estimated as 16.6 million tons and the equivalent dry weight as 13.2 million tons.

The final volume is nearly 600,000 yd^3 less than the in-place volume, indicating a net reduction in volume of material. This reduction can be attributed to a denser state following compaction, assuming sufficient water loss to achieve compactable moisture contents.

Conclusion and Recommendations:

- The total wet weight of tailings material plus interim cover soils is estimated to be 15.8 million tons. In place, this material occupies 10.3 million yd^3. When dried or wetted to the optimum moisture content and compacted, this material will occupy 9.7 million yd^3 of storage space.
- The total wet weight of tailings material and other residual radioactive material (RRM) is estimated to be 18.1 million tons. In-place, this material occupies an estimated 11.9 million yd^3. When dried or wetted to the optimum moisture content and compacted, this material will occupy 11.2 million yd^3 of storage space.

Computer Source:

Not applicable.

Table 1. Volume and Weight Calculations Per Material Type

Material	1	2	3	4	5	6	7	8	9	10	11	12
	In-Place Volume (yd^3)	**In-Place Wet Density (pcf)**	**In-Place Moisture Content**	**In-Place Total Weight (tons)**	**In-Place Water Weight (tons)**	**Solids Weight (tons)**	**Final Moisture Content**	**Final Water Weight (tons)**	**Final Total Weight (tons)**	**Final Wet Density (pcf)**	**Final Volume (yd^3)**	**Volume Change (yd^3)**
Tailings Material												
Sand Tailings	2,798,384	109	10%	4,117,821	374,347	3,743,474	14.3%	535,317	4,278,791	109	2,903,606	105,222
Transitional Tailings	3,916,789	115	25%	6,080,814	1,216,163	4,864,651	17.5%	851,314	5,715,965	115	3,676,985	–239,803
Slimes Tailings	3,176,326	114	50%	4,888,366	1,629,455	3,258,910	25.0%	814,728	4,073,638	111	2,712,368	–463,958
Subtotal	**9,891,498**			**15,087,001**	**3,219,965**	**11,867,036**		**2,201,358**	**14,068,394**		**9,292,959**	**–598,539**
Other RRM Material												
Interim Cover	452,800	109	9%	666,295	55,015	611,280	12.9%	78,855	690,135	115	443,053	–9,747
Off-Pile Material	700,000	105	9%	992,250	81,929	910,321	11.0%	100,135	1,010,456	113	659,796	–40,204
Vicinity Property	120,000	105	9%	170,100	14,045	156,055	11.0%	17,166	173,221	113	113,108	–6,892
Subpile Material	774,000	115	20%	1,201,635	200,273	1,001,363	12.0%	120,164	1,121,526	114	725,783	–48,217
Subtotal	**2,046,800**			**3,030,280**	**351,262**	**2,679,019**		**316,320**	**2,995,339**		**1,941,740**	**–105,060**
Total				18,117,281	3,571,227	14,546,054		2,517,678	17,063,733		11,234,699	–703,599

Notes:

Column 1 - In-Place Volume calculated as average of lateral and transverse method results
Column 2 - In-Place Wet Density calculated as average of lab test results per material type, conservative rounding
Column 3 - In-Place Moisture Content calculated as average of lab test results per material type
Column 4 - In-Place Total Weight calculated as In-Place Wet Density (2) times In-Place Volume (1) with appropriate unit conversion factors
Column 5 - In-Place Water Weight calculated as [(4) x (3)] / [1-(3)] (Das 1998, page 40)
Column 6 - Solids Weight calculated as Total Weight (4) less Water Weight (5)
Column 7 - Final Moisture Content calculated as average optimum moisture contents determined via Proctor tests conducted on bench-scale tests
Column 8 - Final Water Weight calculated as Solids Weight (6) times Final Moisture Content (7)
Column 9 - Final Total Weight calculated as Solids Weight (6) plus Final Water Weight (8)
Column 10 - Final Wet Density calculated as 90 percent of maximum dry density determined via Proctor tests, converted to wet density by multiplying by (1+w)
Column 11 - Final Volume calculated as Final Total Weight (9) divided by Final Wet Density (10) with appropriate unit conversion factors
Column 12 - Volume Change calculated as Final Volume (11) less In-Place Volume (1) (Positive numbers in this column indicate volume expansion)

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U.S. Department of Energy—Grand Junction, Colorado

Calculation Cover Sheet

Calc. No.: MOA-01-08-2006-5-14-00 **Discipline:** Engineering **No. of Sheets:** 6
Doc. No.: X0187200

Location: Attachment 1, Appendix K

Project: Moab UMTRA Project

Site: Moab Tailings Pile

Feature: Average Radium-226 Concentrations for the Moab Tailings Pile

Sources of Data:

Oak Ridge National Lab, 1997. Limited Ground Water Investigation, December.

Remedial Action Plan (RAP) calculations as referenced in the text.

Stoller (SM Stoller Corporation), 2003. *Determination of Subpile Soil Concentrations*, GJO-MOA 19.1.2, January.

Stoller (SM Stoller Corporation), 2005. *Soil Sample Catalogue, Information for Shipping Soil Samples*, November.

SRK (Steffen, Robertson, and Kirsten), 2000. *Dewatering Options for Placement of Cover*, June.

Sources of Formulae and References:

None.

Information was statistically evaluated using Microsoft Excel.

Data on samples below the removal criteria from the *Determination of Subpile Soil Concentrations* were not used, since this material is below the pile and below the removal concentrations.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No.**

Author: 5/30/07 **Checked by:**
Name Date Name Date

Approved by: 5/31/07 Name Date
Name Date

Name Date
May 31, 07
Name Date

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Problem Statement:

Evaluate the available radium-226 data to determine an average radium-226 concentration for the material that will be disposed of in the Crescent Junction Disposal Cell.

Method of Solution:

Review published literature and maps of radium-226 concentration at the Moab tailings pile.

Assumptions:

Literature sources are reliable and there is sufficient data, as well as geospatial variability, that the data is statistically suitable.

Calculation:

The data was averaged both on a volumetric-weighted basis and as a straight average. The straight average was determined to be the most conservative and is used in the "Radon Barrier Design Remedial Action Plan" calculation (RAP Attachment 1, Appendix B).

Discussion:

Although the data was acquired at different times by different groups and, in some cases, for different purposes, there is sufficient geospatial variability, both vertically and horizontally, to create a valid representative sampling.

Samples were obtained by Oak Ridge National Lab as part of a ground water modeling task; by Stoller as part of a task to determine the quantity of subpile soils requiring removal; by Steffen, Robertson, and Kirsten as part of a pile characterization task; and by Stoller to characterize samples for shipment.

Conclusion and Recommendations:

Based on the results of the averages, 707 pCi/g is the average radium-226 value to be used in the "Radon Barrier Design Remedial Action Plan" calculation (RAP Attachment 1, Appendix B)

Computer Source:

Not applicable.

Table 1. Moab Project, Crescent Junction Disposal Cell Tailings, and Other Contaminated Materials

Sample	Depth	Ra-226 Activity (pCi/g)	Material	Sample	Depth	Ra-226 Activity (pCi/g)	Material
BH-701	0-20	400.9	trans	PB-2	34-36	782	slime
BH-701	20-40	480.8	trans	PB-2	54-56	2070	slime
BH-703	0-20	457.6	trans	437	40.75-41	2194.9	slime
BH-703	20-40	610.1	trans	438	72.75-73	1891.7	slime
BH-705	20-40	616.9	trans	439	82-82.25	2157.5	slime
BH-709	20-40	546.6	trans	AR-10	75-86	588.8	slime
BH-713	20-36.5	631.1	trans	BH-700	30-60	466.5	slime
BH-715	20-40	278.9	trans	BH-701	40-60	758.9	slime
BH-718	0-20	717.8	trans	BH-701	60-80	1215.8	slime
BH-718	20-40	917.3	trans	BH-703	40-60	1396.3	slime
BH-719	0-20	357.4	trans	BH-703	65-73	1333	slime
PB-1	39-41	335	trans	BH-705	40-60	1232.8	slime
PB-1	44-46	464	trans	BH-709	40-60	1195.3	slime
PB-1	49-51	566	trans	BH-709	60-65	1205.8	slime
PB-1	64-66	418	trans	BH-715	0-20	1000.5	slime
PB-1	74-76	605	trans	BH-715	40-60	1225.9	slime
PB-1	76-81	220	trans	BH-715	60+	1518.6	slime
PB-1	81-83	201	trans	BH-718	40-43	1601.7	slime
PB-2	9-11	803	trans	BH-719	20-40	1117.7	slime
PB-2	29-31	192	trans	BH-719	40-51.5	1669.7	slime
PB-2	39-41	325	trans	PB-1	59-61	236	slime
PB-2	49-51	816	trans	PB-1	69-71	748	slime
PB-2	59-61	781	trans	PB-1	83-85	1600	slime
PB-2	61-66	711	trans	PB-1	85-87	2040	slime
PB-2	69-71	614	trans	PB-1	87-89	1640	slime
AR-4S	20-21	530.6	unconsol	PB-1	89-91	1690	slime
AR-8	21-22	594.8	unconsol	PB-2	44-46	1740	slime
AR-8	25-35	639.9	unconsol	PB-2	71-73	1390	slime
Impound 2	imp	12.7	imp	PB-2	73-75	1280	slime
Impound 3	imp	87.4	imp	PB-2	75-77	1130	slime
AR-10	3-4	311.8	sand	PB-2	77-79	1240	slime
AR-10	20-25	98	sand	PB-2	79-81	1550	slime
AR-6	35-40	100.4	sand	PB-2	84-86	1620	slime
AR-9	10-11	320.2	sand	437	44-44.25	135.5	alluvium
AR-9	30-32	87.2	sand	438	74-74.25	134.3	alluvium
BH-705	0-20	186.2	sand	438	75-75.25	92.8	alluvium
BH-709	0-20	289.9	sand	438	76-76.25	31.3	alluvium
PB-1	9-11	215	sand	438	78-78.25	118.4	alluvium
PB-1	14-16	99.7	sand	439	87-87.25	23.9	alluvium
PB-1	19-21	202	sand	AR-5	0-1	84.3	alluvium
PB-1	24-26	148	sand	AR-6	0-1	17.3	alluvium
PB-1	29-31	153	sand	PB-1	94-96	208	alluvium
PB-1	34-36	447	sand	PB-2	89-91	1.83	alluvium
PB-1	54-56	849	sand				

Sample	Depth	Ra-226 Activity (pCi/g)	Material	Sample	Depth	Ra-226 Activity (pCi/g)	Material
PB-2	14-16	269	sand				
PB-2	19-21	150	sand				
PB-2	24-26	100	sand				
AR-2	5.5-10	786.5	silt				
AR-7	20-25	562.2	silt				
AR-9	50-55	543.6	silt				
AR-9	60-62	239.1	silt				

Measurements	All Data	Sands	Transitional Tailings	Slimes	Subpile & Interim Cover Materials (Alluvium)	Average of All Samples Without Weighting
Max:	2,195	849	917	2,195	208	
Min:	2	13	192	236	2	
Average:	697	**272**	**530**	**1,349**	**85**	
Median:	564	202	556	1,333	89	
Std Dev.:	589	224	195	479	66	
Count:	94	23	28	33	10	
Material Dry Weight (tons)	14,546,054	3,743,474	4,864,651	3,258,910	2,679,019	
Dry Weight %:	100%	26%	33%	22%	18%	
Weighted Activity (pCi/g)	565	70	177	302	16	707

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