RUBY DAM REHABILITATION FEASIBILITY STUDY

Volume II

Prepared for:

Montana Department of Natural Resources and Conservation
State Water Projects Bureau
Helena, MT

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January 2008

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TAILWATER HYDRAULICS

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RUBY DAM TAILWATER HYDRAULICS

1.1 INTRODUCTION

This report summarizes the results of the hydraulic analysis that was performed for the two channels located downstream of Ruby Dam as part of the Ruby Dam Rehabilitation Feasibility Study. For this analysis, the main channel was considered as the channel that extends downstream of the spillway chute stilling basin. The second channel was referred to as the outlet channel, which extends from the outlet conduit concrete apron downstream approximately 430 feet to the confluence with the main channel of the Ruby River. The primary purpose of analyzing the hydraulics of both channels was to estimate the water surfaces at certain flowrates. The water surface estimates could then be used in the design of the spillway and outlet stilling basins. Figure 1 in Appendix A is a topographic map of the area downstream of Ruby Dam which includes the main and outlet channels.

1.2 BACKGROUND

Ruby Dam is located on the Ruby River in Madison County, Montana approximately 6 miles south of the town of Alder. Construction of Ruby Dam started in 1936 and was completed in 1938. The dam is owned by the State of Montana and is operated and maintained by the Ruby River Water Users Association. The purpose of the dam and reservoir is to provide water for irrigation and to augment stream flows. In 2005 the Montana Department of Natural Resources and Conservation (DNRC) performed a hydrologic analysis, to develop design flood hydrographs for use in design of the Ruby Dam rehabilitation. Based on the DNRC hydrologic analysis it was determined the existing spillway does not provide adequate capacity to pass the design flood without overtopping the dam. As part of the rehabilitation the spillway and outlet stilling basins will be reconstructed. Design of the new stilling basins requires the elevation of the tailwater at the stilling basins for certain flowrates to be known.

1.3 MAIN CHANNEL HYDRAULIC ANALYSIS

The spillway design flow (SDF) was selected as 20,000 cfs, which is also the maximum design flow that was considered in design of the spillway stilling basin; discussion on selection of the SDF is included in the Design Options Summary. The 20,000 cfs SDF was the largest flow of interest in the tailwater analyses; however larger flows up to the probable maximum flood (PMF) of approximately 80,000 cfs were included in the analyses for comparison purposes.

The tailwater elevation at the spillway stilling basin for the range of flowrates considered were calculated with a model created using the U.S. Army Corps of Engineers Hydrologic Engineering Center – River Analysis System (HEC-RAS v3.1.3) computer software. Approximately 800 ft of the Ruby River main channel was modeled using 19 cross sections located at intervals between 20 ft and 50 ft. The upstream HEC-RAS cross section was located in the model at station -1365, just downstream of the existing stilling basin. The downstream most HEC-RAS cross section was at station -2165, approximately 100 ft downstream of the USGS gage station. The locations of these cross sections are shown on the plan drawing in Appendix A.

In order to compute the water surface elevation at the spillway stilling basin, HEC-RAS was used to model the main channel of the Ruby River, which is located downstream of the spillway at Ruby Dam. The channel geometry used in HEC-RAS was based on topographic maps of the area which were based on aerial photography performed by Horizons, Inc. in September 2005 and surveying conducted by HKM. The HEC-RAS steady flow simulation was used with a 'mixed flow regime' because the flow through this reach was assumed to vary between subcritical and supercritical flow due to the changing channel geometry and bed slope. Initial conditions for the HEC-RAS model were set equal to normal depth based on the channel slope at the up and downstream cross sections. These boundary conditions are necessary to give HEC-RAS a starting point for calculations.

With the HEC-RAS geometry and modeling parameters determined, calibration and sensitivity of the model was performed by varying the roughness coefficient (Manning's n). The range of Manning's n-values used in the calibration procedure were selected based on possible roughness coefficients for a channel similar to this reach of the Ruby River; calibration was also used to check the model's sensitivity to the roughness coefficient. The USGS Gage located on the Ruby River below the dam (Ruby River below Reservoir near Alder, MT; USGS 06020600) located at HEC-RAS station -2065 was used to calibrate the model. The data for this gage was attained from the USGS website at: http://nwis.waterdata.usgs.gov/nwis/peak?site_no=06020600. This stream gage has over 40 years of record, with the peak flow for that time period occurring on May 16, 1984 at 3,010 cfs. The gage height measurement of 8.52 ft from this peak flow of 3,010 cfs was used to calibrate the model by adjusting the n-value of the model's main channel until the water surface at station -2065 was near the gage water surface elevation of ***5295.12 ft***. A lower flowrate of 500 cfs at the stream gage was also used to check the model accuracy at lower flows. The gage height for the 500 cfs flow which occurred on June 8, 1989 was 4.03 ft or elevation 5290.6 ft. Results of the roughness coefficient calibration are shown in Table 1.

TABLE 1 HEC-RAS CALIBRATION RESULTS

Manning's n-value	Flowrate (cfs)	W.S. Elev. @ STA -2065	Velocity @ STA -2065 (ft/s)
0.040	500	5289.99	2.32
	1,500	5292.72	3.64
	3,010	5294.64	4.80
0.045	500	5290.18	2.18
	1,500	5293.00	3.27
	3,010	5294.93	4.53
0.050	500	5290.42	2.02
	1,500	5293.26	3.10
	3,010	5295.17	4.32

Based on the calibration results, an n-value near 0.050 would give a water surface elevation that very nearly matched the measured gage elevation. However it was believed that a coefficient of that magnitude may be overestimating the roughness for a channel of this type, so a slightly lower value of ***0.040*** was chosen for the final n-value to be used in the model. This roughness value slightly underestimates water surface elevations at higher flows and overestimates elevations at lower flows.

After calibration of the HEC-RAS model was complete a sensitivity analysis was performed to demonstrate the affect the roughness coefficient has on the water surface elevations and flow velocities in the model. The results of the sensitivity analysis are shown in Table 2. Based on results of the sensitivity analysis it can be seen that varying the channel roughness coefficient changes the water surface elevation only slightly. For example, at 3,010 cfs the water surface elevation at Station -1365 increased 0.46 ft and the flow velocity decreased 0.48 ft/s when the channel roughness coefficient was increased from 0.040 to 0.050.

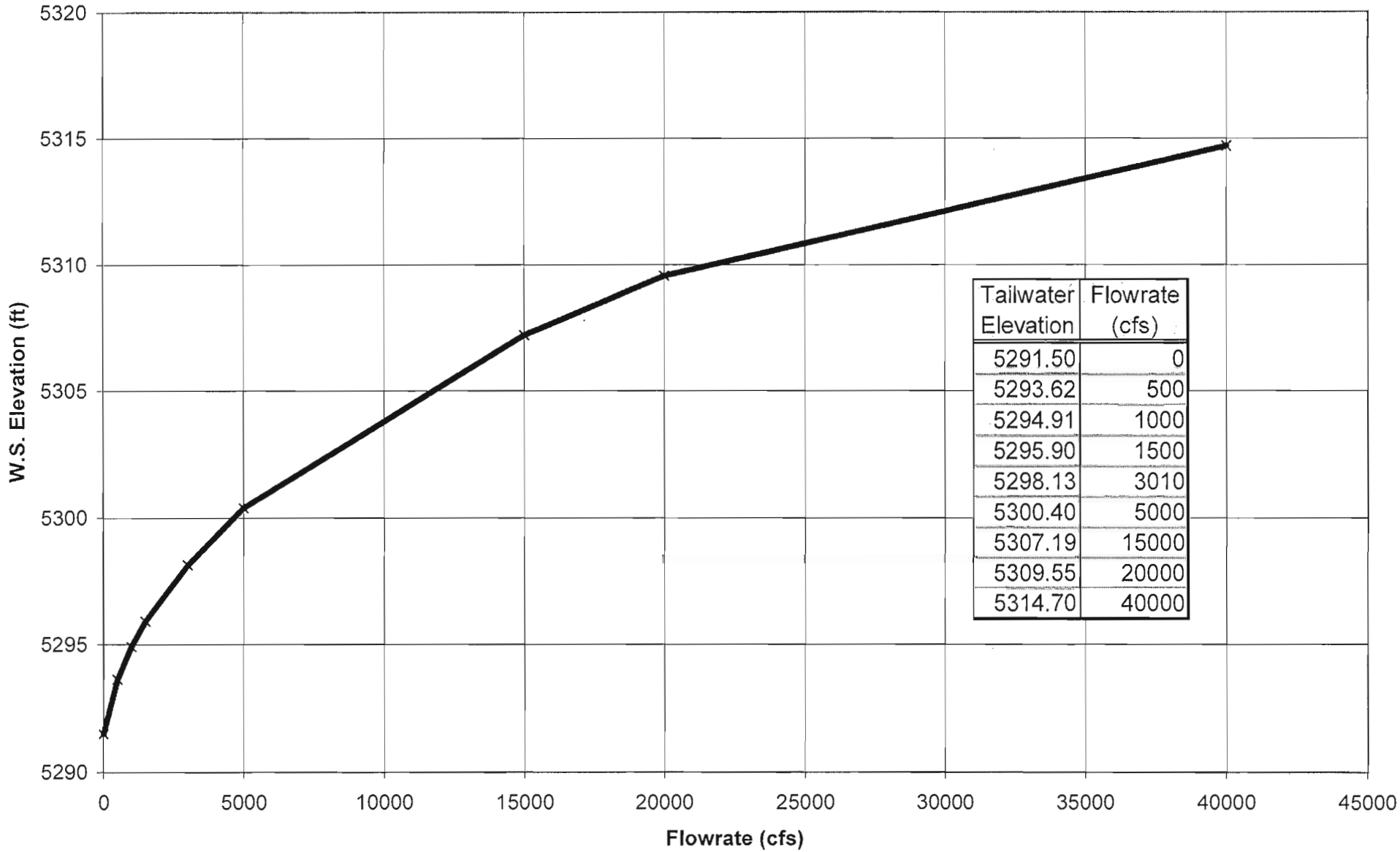
TABLE 2 HEC-RAS SENSITIVITY RESULTS

Manning's n-value	Flowrate (cfs)	Upstream W.S. Elev. @ STA -1365	Velocity @ STA -1365 (ft/s)	W.S. Elev. @ STA -2065	Velocity @ STA -2065 (ft/s)
0.040	500	5293.62	3.66	5289.99	2.32
	1,500	5295.90	4.73	5292.72	3.64
	3,010	5298.13	5.91	5294.64	4.80
	20,000	5309.55	11.93	5297.82	16.39
0.045	500	5293.73	3.44	5290.18	2.18
	1,500	5296.06	4.53	5293.00	3.27
	3,010	5298.33	5.71	5294.93	4.53
	20,000	5309.80	11.72	5299.31	12.36
0.050	500	5293.85	3.23	5290.42	2.02
	1,500	5296.26	4.32	5293.26	3.10
	3,010	5298.59	5.47	5295.17	4.32
	20,000	5310.07	11.50	5299.67	11.39

After the HEC-RAS model was calibrated the model was run with a range of flows in order to develop a rating for the upstream cross section at station -1365. The flowrates used in the HEC-RAS model to develop the rating curve were selected to represent a range of flows in the main channel, from a typical flow of 500 cfs to the approximate PMF of 80,000 cfs. Water surface elevations and flow velocities at the spillway stilling basin (Station -1365) for each flow are presented in Table 3 and the computed rating curve for this cross section is presented as Figure 1. The HEC-RAS profile number from the first column in Table 3 can be used to locate the water surface for each flow on the HEC-RAS profile plot in Appendix B. Selected output tables and cross section plots from HEC-RAS are also included in Appendix B.

Figure 1

Ruby Dam - Ruby River Main Channel
Rating Curve at Cross Section 1365



Tailwater Elevation	Flowrate (cfs)
5291.50	0
5293.62	500
5294.91	1000
5295.90	1500
5298.13	3010
5300.40	5000
5307.19	15000
5309.55	20000
5314.70	40000

TABLE 3 MAIN CHANNEL HEC-RAS FLOWS

HEC-RAS Profile Number	Flowrate (cfs)	W.S. Elevation @ STA -1365 (ft)	Flow Velocity @ STA -1365 (ft/s)	Froude Number
PF 1	500	5293.62	3.66	0.48
PF 2	1,000	5294.91	4.22	0.43
PF 3	1,500	5295.90	4.73	0.43
PF 4	3,010	5298.13	5.91	0.44
PF 5	5,000	5300.40	6.95	0.45
PF 6	15,000	5307.19	10.58	0.51
PF 7	20,000	5309.55	11.93	0.53
PF 8	40,000	5314.70	17.51	0.67
PF 9	80,000	5314.65	35.10	1.35

The calibrated rating curve that resulted from modeling the Ruby River below Ruby Dam can be used to determine the flow depth at a specific flowrate which can then be used in the design of the spillway stilling basin. It should be noted that at large flows the actual water surface elevations may differ than those presented in this report due to scour and deposition of bed material that could not be accounted for in this model. The HEC-RAS computed water surface elevation for 80,000 cfs was slightly less than the 40,000 cfs water surface. This lower water surface is because HEC-RAS calculated the flow regime for 80,000 cfs to be supercritical with the flow velocity twice the subcritical flow velocity at 40,000 cfs.

2.0 OUTLET CHANNEL HYDRAULIC ANALYSIS

2.1.1 Existing Channel

The channel located downstream of the Ruby Dam outlet conduit was modeled using HEC-RAS; this channel will be referred to as the outlet channel. The primary purpose of modeling this channel was to estimate the water surface elevation at the outlet conduit terminal structure. Three separate models were created to demonstrate the effect that changing the channel geometry has on the tailwater elevation. The first model is of the existing channel which includes the existing Cipoletti weir located approximately 190 feet downstream from the outlet terminal structure. In the second model the weir was removed, and in the third model the weir was removed and the channel was graded to a uniform slope.

The HEC-RAS model of the outlet channel was set up similar to that for the main channel with

the channel geometry taken from the same topographic maps (Horizons, Inc., September 2005). Cross sections were selected at 25 ft to 50 ft intervals from the outlet conduit concrete apron, HEC-RAS station 000, downstream approximately 400 ft to just upstream of the confluence with the main channel located at HEC-RAS station -400. The model of the existing channel also included the Cipoletti weir which was modeled as an inline structure at station -188.

The HEC-RAS steady flow simulation was used with a 'mixed flow regime' due to the probable change between subcritical and supercritical flow because of the Cipoletti weir, changing channel geometry, and bed slope. The initial water surface elevation at the upstream and downstream cross sections was set equal to normal depth based on channel slope.

Calibration was not performed on this channel because there was not a known water surface elevation on this reach to use in calibration. However, a sensitivity analysis was performed in order to check the models' sensitivity to the roughness coefficient; the same n-values that were used in the calibration of the main channel were also used for the outlet channel. A Manning's n-value of **0.040** was selected for this channel to match the main channel calibrated n-value and the outlet channel is composed of similar bed material to that found in the main channel. The roughness coefficient has little effect on the upstream water surface elevation due to the Cipoletti weir. Results of the outlet channel roughness sensitivity analysis are shown in Table 4.

TABLE 4 OUTLET CHANNEL SENSITIVITY RESULTS

Manning's n-value	Flowrate (cfs)	Upstream W.S. Elev @ STA 000	Upstream Velocity (ft/s)	Downstream W.S. Elev @ STA -400	Downstream Velocity (ft/s)
0.040	**250**	**5304.53**	**1.53**	**5291.15**	**5.55**
0.045	250	5304.53	1.53	5291.27	5.12
0.050	250	5304.54	1.53	5291.38	4.76

The flowrates used in the HEC-RAS model to develop the rating curve at the upstream cross section were chosen to represent a range of flows anticipated from the outlet conduit, from a typical low flow of 50 cfs to a maximum of 2,000 cfs.

Water surface elevations at station 000 for each flow are presented in Table 5 and the rating curve for this cross section is presented as Figure 2. The HEC-RAS profile number from the first column in can be used to locate the water surface for each flow on the HEC-RAS profile plot in Appendix C. Output tables and cross section plots from HEC-RAS are also included in Appendix C.

TABLE 5 EXISTING OUTLET CHANNEL HEC-RAS RESULTS

HEC-RAS Profile Number	Flowrate (cfs)	W.S. Elevation @ STA 000	Flow Velocity @ STA 000 (ft/s)	Froude Number @ STA 000
PF 1	50	5303.14	0.41	0.03
PF 2	100	5303.57	0.74	0.06
PF 3	250	5304.53	1.53	0.12
PF 4	450	5305.52	2.30	0.17
PF 5	750	5306.73	3.15	0.22
PF 6	1,000	5307.61	3.68	0.25
PF 7	1,250	5308.32	4.15	0.27
PF 8	1,500	5308.82	4.66	0.30
PF 9	2,000	5309.61	5.61	0.35

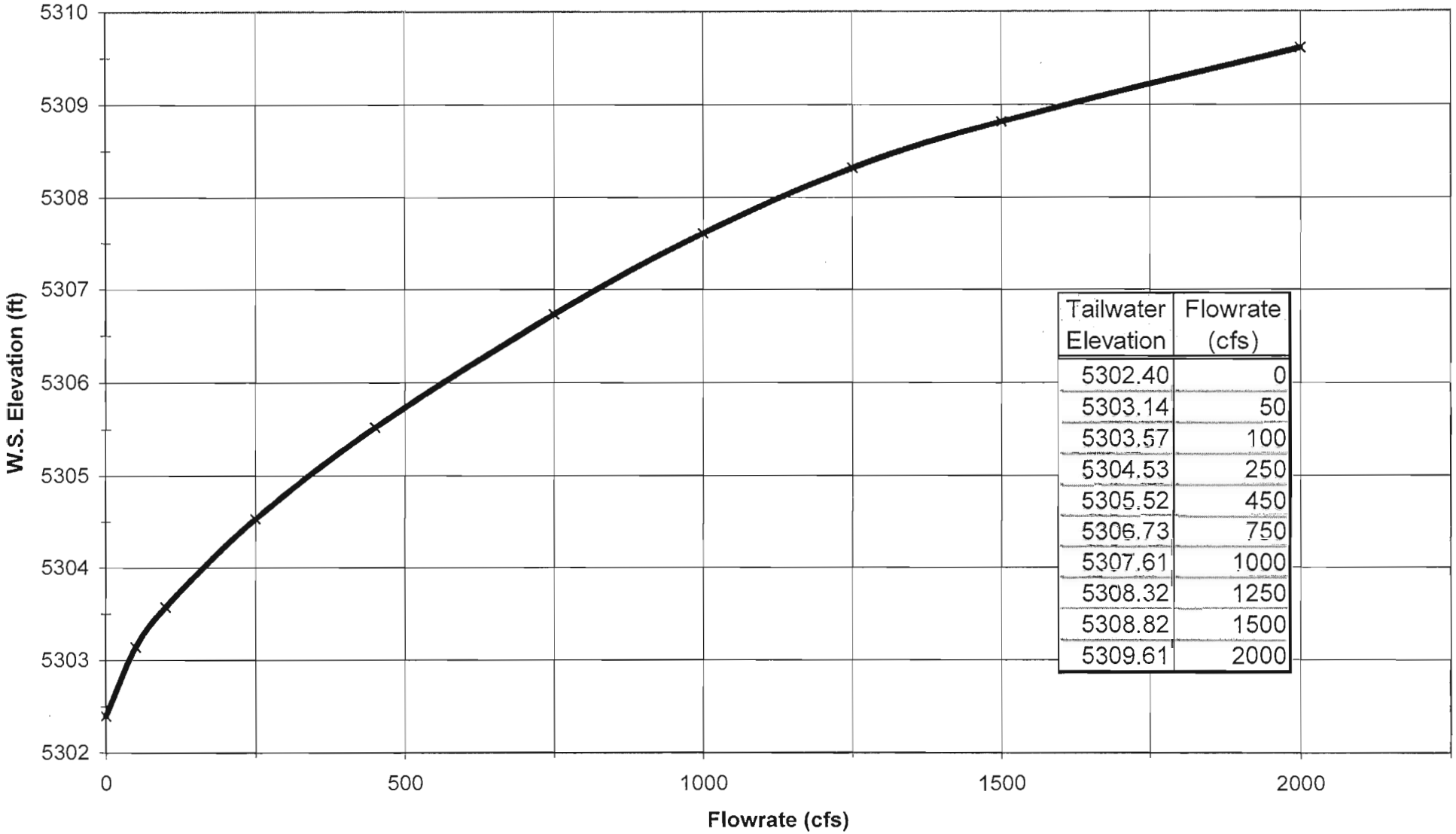
The top of the concrete apron at the conduit outlet is at elevation 5296.0; the modified horse shoe conduit has a height of 7.5 ft with the top of the conduit located at approximately 5303.5 ft. With the Cipoletti weir crest at elevation 5302.4 ft, the rating curve for the existing channel shows that for flows greater than 100 cfs the conduit outlet becomes submerged due to the backwater created by the weir. Additionally with the top of the weir wall at elevation 5308.1, the weir wall becomes overtopped at flows greater than approximately 1,200 cfs. The other two models discussed in the following sections illustrate the effects of removing the weir and changing the channel slope and geometry.

2.1.2 Removed Weir

The HEC-RAS model used to analyze the existing outlet channel was modified by removing the inline structure at station -188. This model was created in order to determine the water surface levels at the conduit outlet if the Cipoletti weir was removed from the channel. The same flows and flow analysis parameters were used as in the model of the existing channel. The results of this analysis are presented in Table 6; the rating curve for the cross section located at the conduit terminal structure for this scenario is shown in Figure 3.

Figure 2

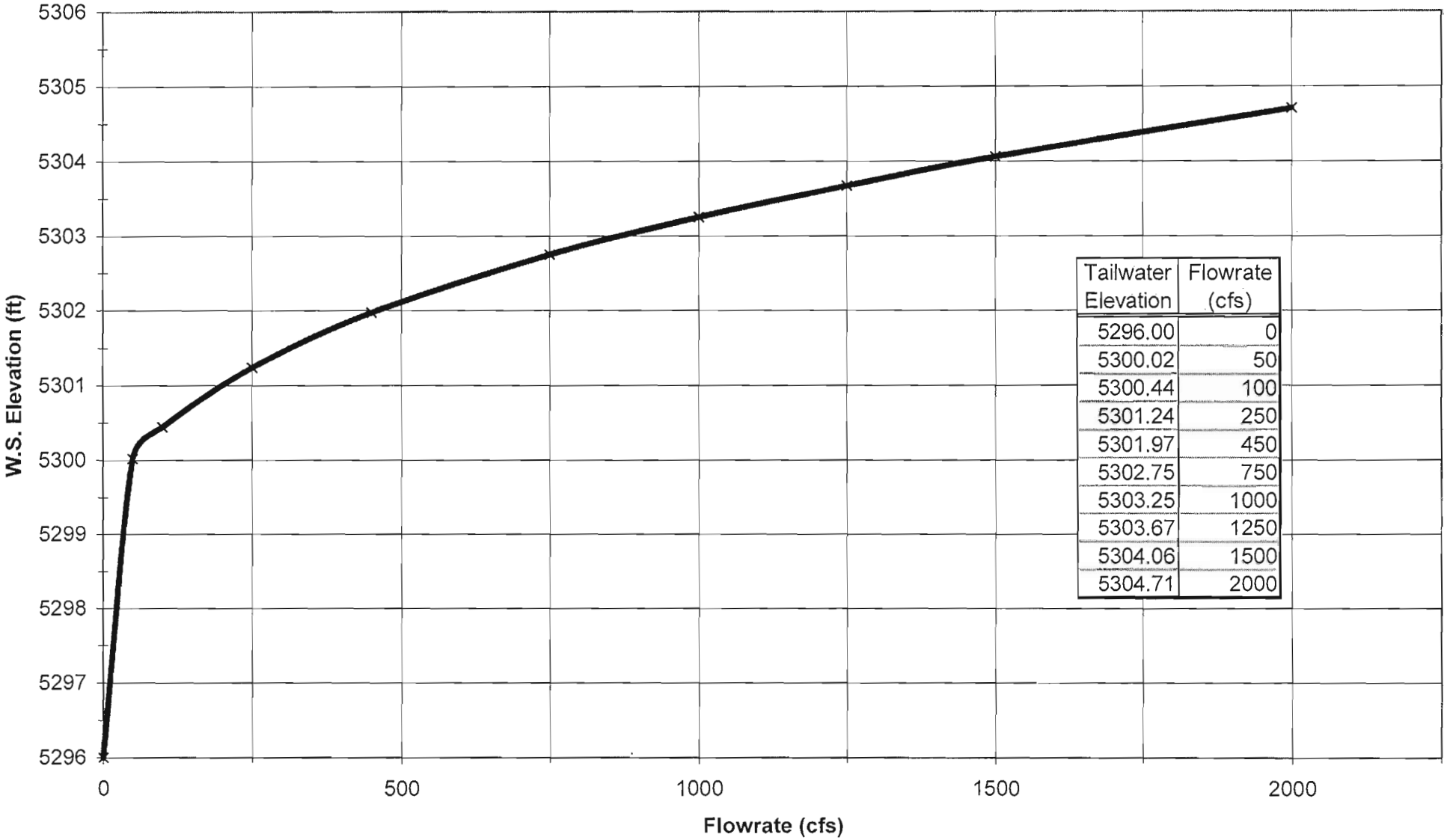
Ruby Dam - Outlet Channel
Existing Geometry
Rating Curve at Cross Section 000



Tailwater Elevation	Flowrate (cfs)
5302.40	0
5303.14	50
5303.57	100
5304.53	250
5305.52	450
5306.73	750
5307.61	1000
5308.32	1250
5308.82	1500
5309.61	2000

Figure 3

Ruby Dam - Outlet Channel
No Weir Geometry
Rating Curve at Cross Section 000



Tailwater Elevation	Flowrate (cfs)
5296.00	0
5300.02	50
5300.44	100
5301.24	250
5301.97	450
5302.75	750
5303.25	1000
5303.67	1250
5304.06	1500
5304.71	2000

TABLE 6 OUTLET CHANNEL WITHOUT WEIR HEC-RAS RESULTS

HEC-RAS Profile Number	Flowrate (cfs)	W.S. Elevation @ STA 000	Flow Velocity @ STA 000 (ft/s)	Froude Number @ STA 000
PF 1	50	5300.02	0.94	0.10
PF 2	100	5300.44	1.64	0.16
PF 3	250	5301.24	3.23	0.30
PF 4	450	5301.97	4.81	0.42
PF 5	750	5302.75	6.64	0.56
PF 6	1,000	5303.25	7.93	0.65
PF 7	1,250	5303.67	9.06	0.72
PF 8	1,500	5304.06	10.06	0.79
PF 9	2,000	5304.71	11.84	0.90

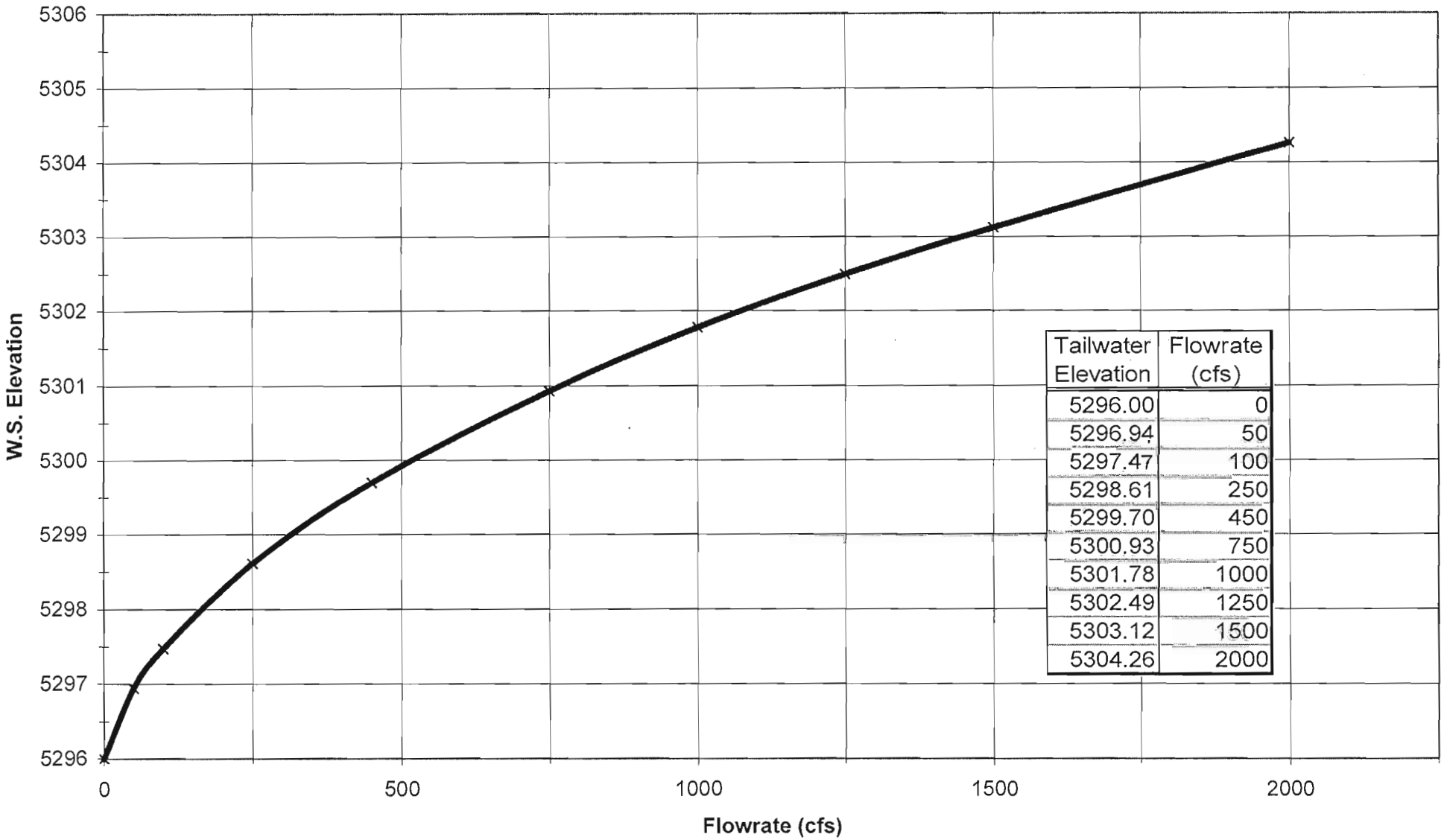
The results of this analysis illustrate that by removing the weir the water surface elevation at the outlet is lowered between 3 and 4.5 ft and the flow velocities are approximately two times greater than with the weir located in the channel. This model verified that the weir effectively dissipates energy from outlet conduit flows by creating a backwater pool. Removing the weir increases the flowrate at which the conduit outlet becomes completely submerged from 100 cfs for the existing geometry to approximately 1,150 cfs.

2.1.3 Removed Weir and Graded Channel

This HEC-RAS model was created in order to determine the water surface levels at the Ruby Dam conduit outlet for the scenario with the Cipoletti weir removed and the channel graded to a uniform slope. The same flows and flow analysis parameters were used as in the other two outlet channel models. The model geometry was changed from the existing by removing the weir and lowering the elevations between cross sections -50 and -225 to create a uniform slope of approximately 1.37% in order match the existing elevation downstream of the weir. Each cross section's geometry was also changed by narrowing the bottom width based on the existing side slopes to match the uniform slope. The results of this analysis are summarized in Table 7; the rating curve for the cross section located at the conduit terminal structure is shown in Figure 4.

Figure 4

Ruby Dam - Outlet Channel
No Weir/Channel Graded Geometry
Rating Curve at Cross Section 000



Tailwater Elevation	Flowrate (cfs)
5296.00	0
5296.94	50
5297.47	100
5298.61	250
5299.70	450
5300.93	750
5301.78	1000
5302.49	1250
5303.12	1500
5304.26	2000

TABLE 7 OUTLET CHANNEL GRADED W/O WEIR HEC-RAS RESULTS

HEC-RAS Profile Number	Flowrate (cfs)	W.S. Elevation @ STA 000	Flow Velocity @ STA 000 (ft/s)	Froude Number @ STA 000
PF 1	50	5296.94	5.34	1.01
PF 2	100	5297.47	6.50	1.01
PF 3	250	5298.61	8.24	1.00
PF 4	450	5299.70	9.46	1.00
PF 5	750	5300.93	10.59	1.01
PF 6	1,000	5301.78	11.20	1.00
PF 7	1,250	5302.49	11.77	1.01
PF 8	1,500	5303.12	12.22	1.01
PF 9	2,000	5304.26	12.90	1.00

When compared to the existing channel, the results of the analysis of this scenario illustrate that by removing the weir and making the channel slope uniform, the water surface elevation is lowered by 5 to 6 ft and the flow velocities are approximately two to ten times greater than the existing channel. Removing the Cipolleti weir and grading the channel increases the flowrate at which the conduit outlet becomes completely submerged from 100 cfs for the existing geometry to approximately 1,665 cfs.

3.0 CONCLUSIONS

Analysis of the two tailwater channels downstream of Ruby Dam can be used in the design of certain stilling basin types for the spillway and outlet conduit. Several different outlet channel geometries were analyzed in order to determine tailwater elevations for different outlet stilling basin configurations. The modeled outlet channel geometries were chosen to represent a range of possible modifications that could be made to the channel to accommodate a new outlet stilling basin.

Hydraulic modeling of the main channel of the Ruby River below the spillway was performed for the existing channel geometry. Water surface elevations for flowrates greater than the stilling basin design flow are likely to change from those presented in Table 3 in Section 1.3 due to scour and deposition along the river channel that will occur during flooding. Also if significant channel excavation is performed for a new spillway stilling basin, the water surface elevations presented in this report may be affected.

4.0 REFERENCES

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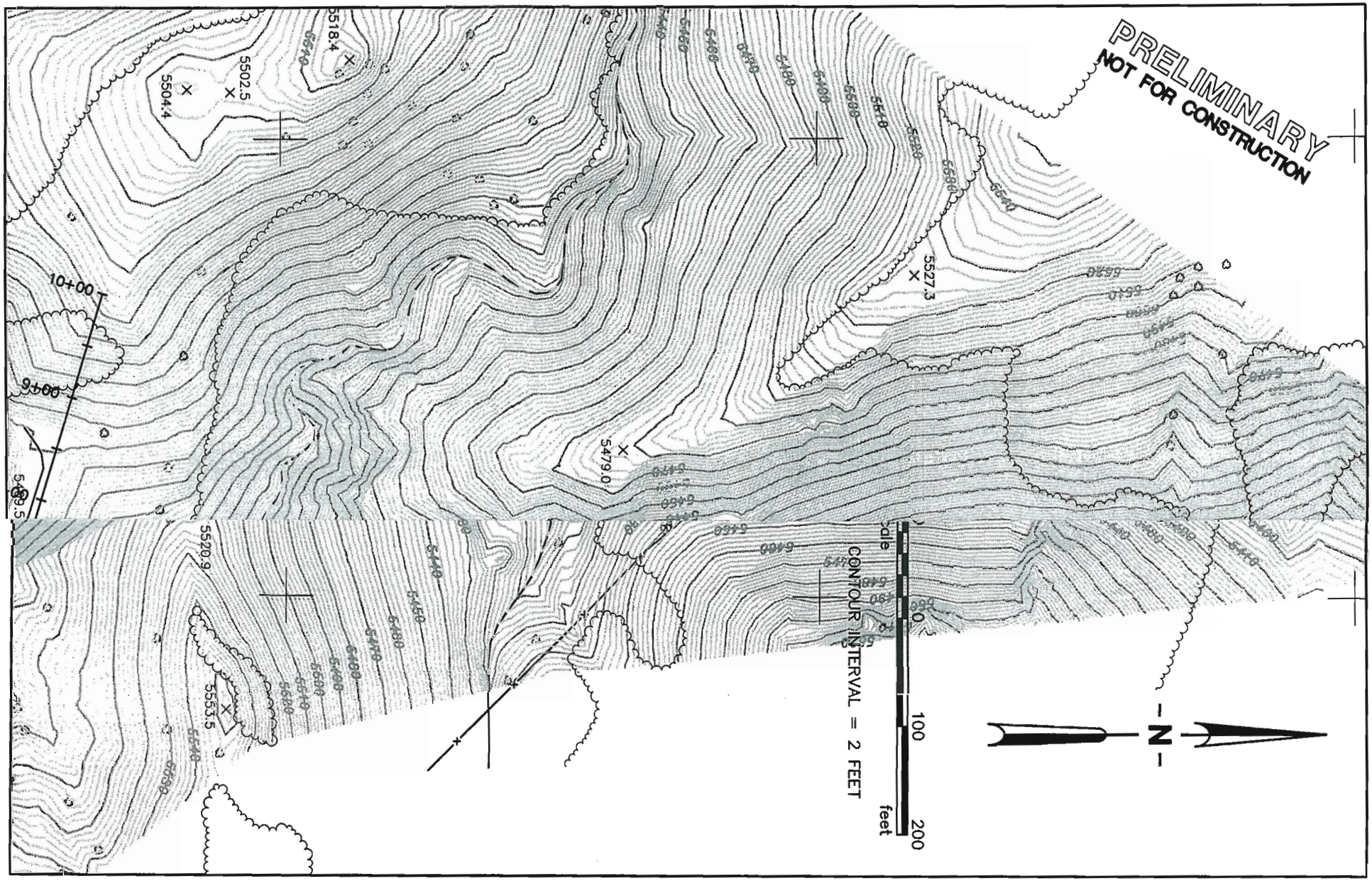
APPENDIX A

TAILWATER PLAN DRAWING



RUBY DAM FEASIBILITY STUDY
HEC-RAS MODEL PLAN VIEW AND X-SECTIONS

FIGURE #1

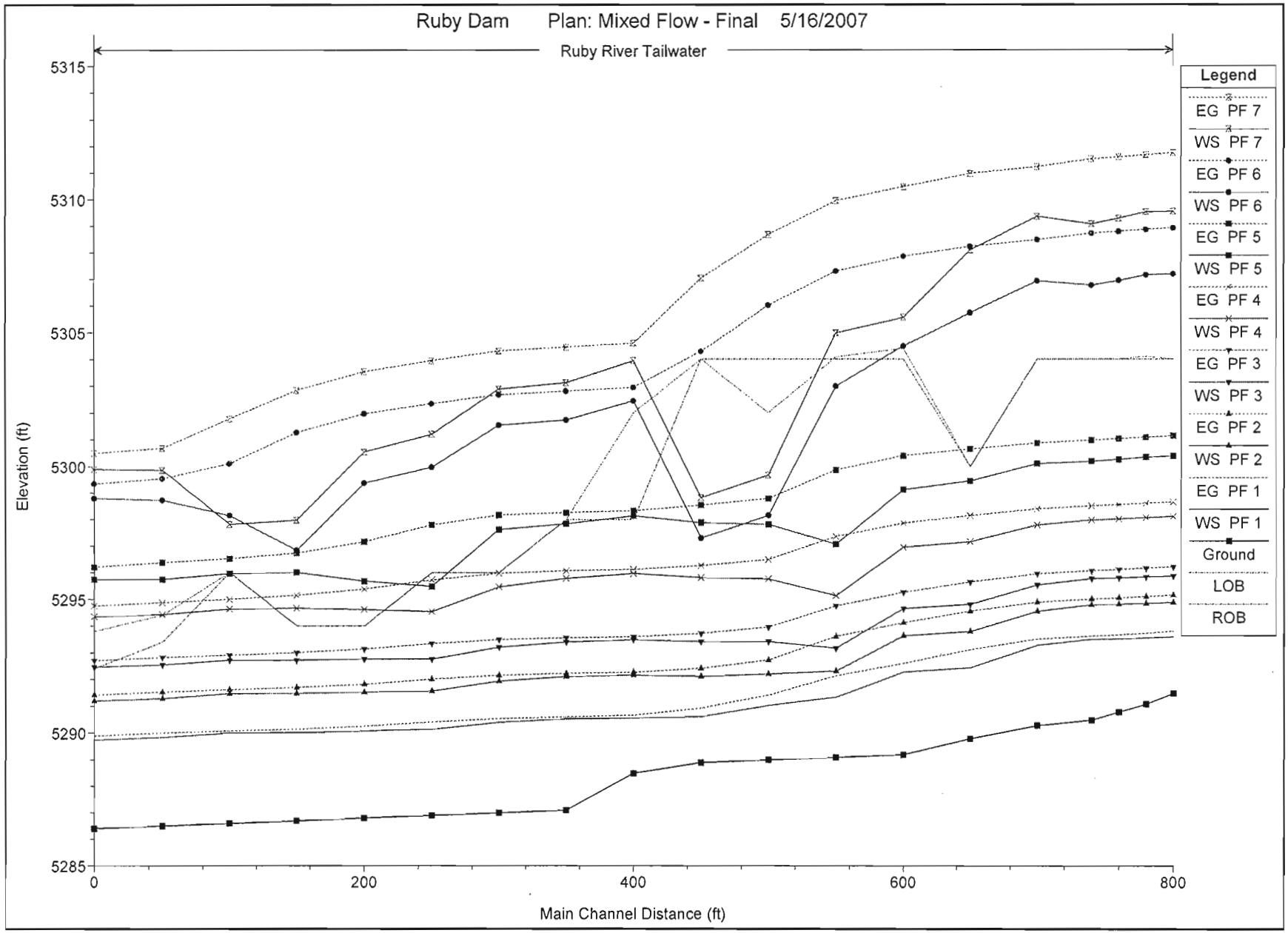
HKM ENGINEERING

8M087.175 MAY 2007

APPENDIX B

MAIN CHANNEL

HEC-RAS MODEL


Ruby Dam Plan: Mixed Flow - Final 5/16/2007
Ruby River Tailwater
Elevation (ft)
5315
5310
5305
5300
5295
5290
5285
0
200
400
600
800
Main Channel Distance (ft)
Legend
EG PF 7
WS PF 7
EG PF 6
WS PF 6
EG PF 5
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
LOB
ROB

HEC-RAS Plan: Final River: Ruby River Reach: Tailwater

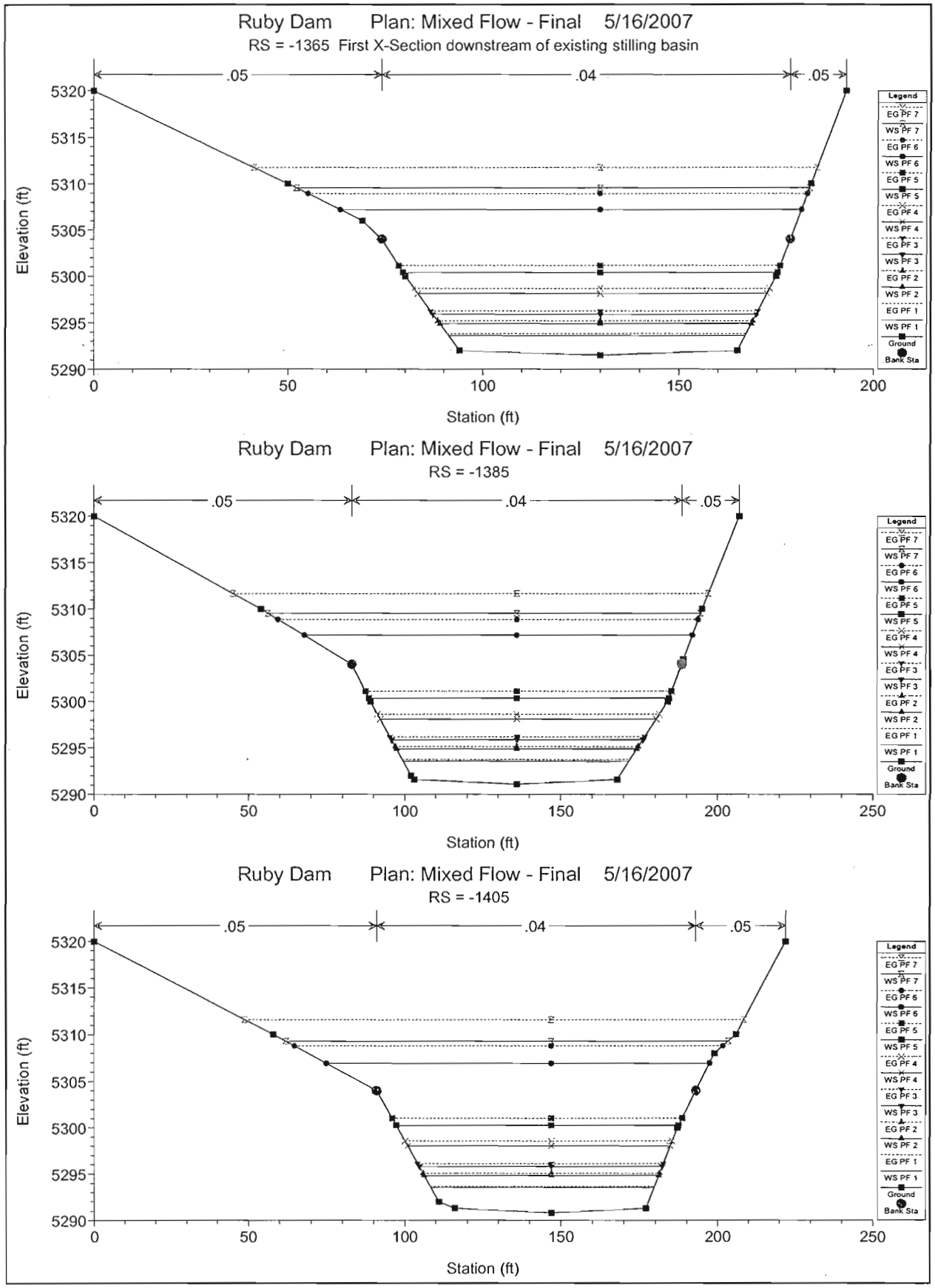
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Tailwater	-1365	PF 1	500.00	5291.50	5293.62	5292.90	5293.83	0.004517	3.66	136.53	75.85	0.48
Tailwater	-1365	PF 2	1000.00	5291.50	5294.91	5293.56	5295.18	0.003118	4.22	236.80	79.72	0.43
Tailwater	-1365	PF 3	1500.00	5291.50	5295.90	5294.12	5296.24	0.002804	4.73	317.21	82.69	0.43
Tailwater	-1365	PF 4	3010.00	5291.50	5298.13	5295.48	5298.68	0.002622	5.91	509.73	89.40	0.44
Tailwater	-1365	PF 5	5000.00	5291.50	5300.40	5296.93	5301.15	0.002558	6.95	719.65	95.95	0.45
Tailwater	-1365	PF 6	15000.00	5291.50	5307.19	5302.08	5308.92	0.002778	10.58	1432.99	118.10	0.51
Tailwater	-1365	PF 7	20000.00	5291.50	5309.55	5304.05	5311.74	0.002850	11.93	1727.36	131.43	0.53
Tailwater	-1365	PF 8	40000.00	5291.50	5314.70	5310.56	5319.29	0.004219	17.51	2481.88	161.70	0.67
Tailwater	-1365	PF 9	80000.00	5291.50	5314.65	5320.76	5333.14	0.017009	35.10	2474.46	161.43	1.35
Tailwater	-1385	PF 1	500.00	5291.10	5293.57		5293.74	0.002965	3.29	152.03	72.32	0.40
Tailwater	-1385	PF 2	1000.00	5291.10	5294.87		5295.12	0.002522	4.02	248.71	76.89	0.39
Tailwater	-1385	PF 3	1500.00	5291.10	5295.86		5296.19	0.002448	4.59	326.50	80.38	0.40
Tailwater	-1385	PF 4	3010.00	5291.10	5298.09		5298.62	0.002483	5.85	514.70	88.26	0.43
Tailwater	-1385	PF 5	5000.00	5291.10	5300.35		5301.09	0.002496	6.91	723.20	95.91	0.44
Tailwater	-1385	PF 6	15000.00	5291.10	5307.15		5308.86	0.002718	10.50	1452.06	124.10	0.50
Tailwater	-1385	PF 7	20000.00	5291.10	5309.53		5311.66	0.002759	11.79	1764.27	138.22	0.52
Tailwater	-1385	PF 8	40000.00	5291.10	5314.79		5319.13	0.003958	17.09	2581.18	172.63	0.66
Tailwater	-1385	PF 9	80000.00	5291.10	5314.24	5320.60	5332.79	0.017460	35.26	2486.19	168.96	1.37
Tailwater	-1405	PF 1	500.00	5290.80	5293.54		5293.68	0.002159	3.00	166.42	71.15	0.35
Tailwater	-1405	PF 2	1000.00	5290.80	5294.84		5295.07	0.002085	3.83	261.10	74.80	0.36
Tailwater	-1405	PF 3	1500.00	5290.80	5295.83		5296.14	0.002140	4.46	336.25	77.58	0.38
Tailwater	-1405	PF 4	3010.00	5290.80	5298.04		5298.57	0.002348	5.84	515.11	83.82	0.42
Tailwater	-1405	PF 5	5000.00	5290.80	5300.27		5301.04	0.002507	7.06	708.52	90.18	0.44
Tailwater	-1405	PF 6	15000.00	5290.80	5306.94		5308.79	0.003001	10.93	1397.22	122.57	0.53
Tailwater	-1405	PF 7	20000.00	5290.80	5309.28		5311.59	0.003052	12.27	1705.30	141.54	0.54
Tailwater	-1405	PF 8	40000.00	5290.80	5314.40		5319.02	0.004374	17.72	2531.68	180.54	0.68
Tailwater	-1405	PF 9	80000.00	5290.80	5315.24	5320.81	5331.90	0.015065	33.76	2686.10	186.77	1.28
Tailwater	-1425	PF 1	500.00	5290.50	5293.52		5293.64	0.001652	2.79	179.32	69.74	0.31
Tailwater	-1425	PF 2	1000.00	5290.50	5294.81		5295.02	0.001786	3.68	271.86	73.13	0.34
Tailwater	-1425	PF 3	1500.00	5290.50	5295.80		5296.09	0.001922	4.35	345.00	75.69	0.36
Tailwater	-1425	PF 4	3010.00	5290.50	5298.00		5298.53	0.002247	5.81	518.17	81.45	0.41
Tailwater	-1425	PF 5	5000.00	5290.50	5300.21		5300.99	0.002492	7.10	704.09	87.30	0.44
Tailwater	-1425	PF 6	15000.00	5290.50	5306.77		5308.71	0.003201	11.22	1361.75	120.91	0.54
Tailwater	-1425	PF 7	20000.00	5290.50	5309.07		5311.51	0.003282	12.62	1664.80	145.32	0.56
Tailwater	-1425	PF 8	40000.00	5290.50	5314.16		5318.91	0.004624	18.06	2532.13	191.29	0.70
Tailwater	-1425	PF 9	80000.00	5290.50	5315.63	5320.92	5331.33	0.014165	33.08	2822.70	203.07	1.23
Tailwater	-1465	PF 1	500.00	5290.30	5293.30		5293.53	0.004028	3.88	128.96	60.45	0.47
Tailwater	-1465	PF 2	1000.00	5290.30	5294.57		5294.91	0.003819	4.69	213.19	71.95	0.48
Tailwater	-1465	PF 3	1500.00	5290.30	5295.56		5295.98	0.003668	5.20	288.59	80.86	0.48
Tailwater	-1465	PF 4	3010.00	5290.30	5297.82		5298.41	0.003141	6.18	487.28	93.12	0.48
Tailwater	-1465	PF 5	5000.00	5290.30	5300.11		5300.88	0.002831	7.01	712.80	103.42	0.47
Tailwater	-1465	PF 6	15000.00	5290.30	5306.93		5308.48	0.002629	10.03	1526.94	144.34	0.50
Tailwater	-1465	PF 7	20000.00	5290.30	5309.36		5311.22	0.002529	11.06	1904.28	166.21	0.50
Tailwater	-1465	PF 8	40000.00	5290.30	5314.95		5318.36	0.003172	15.29	2987.07	221.50	0.59
Tailwater	-1465	PF 9	80000.00	5290.30	5313.11	5318.69	5330.52	0.018032	34.27	2596.56	203.11	1.39
Tailwater	-1515	PF 1	500.00	5289.80	5292.46	5292.28	5293.14	0.015216	6.62	75.58	43.01	0.88
Tailwater	-1515	PF 2	1000.00	5289.80	5293.81		5294.57	0.010461	7.00	142.79	56.16	0.77
Tailwater	-1515	PF 3	1500.00	5289.80	5294.83		5295.67	0.008632	7.32	204.96	65.22	0.73
Tailwater	-1515	PF 4	3010.00	5289.80	5297.18		5298.16	0.005975	7.95	378.57	79.96	0.64
Tailwater	-1515	PF 5	5000.00	5289.80	5299.46		5300.65	0.004908	8.75	571.21	88.89	0.61
Tailwater	-1515	PF 6	15000.00	5289.80	5305.73		5308.22	0.004326	12.81	1255.14	138.68	0.64
Tailwater	-1515	PF 7	20000.00	5289.80	5308.09		5310.97	0.004086	13.96	1624.17	174.71	0.64
Tailwater	-1515	PF 8	40000.00	5289.80	5313.55		5318.06	0.004630	18.30	2775.86	241.23	0.71
Tailwater	-1515	PF 9	80000.00	5289.80	5321.26	5319.75	5327.24	0.004515	22.40	4941.93	309.00	0.74
Tailwater	-1565	PF 1	500.00	5289.20	5292.29		5292.62	0.005090	4.61	108.54	46.33	0.53
Tailwater	-1565	PF 2	1000.00	5289.20	5293.65		5294.14	0.005121	5.59	178.82	57.19	0.56
Tailwater	-1565	PF 3	1500.00	5289.20	5294.67		5295.28	0.004843	6.23	240.64	62.33	0.56
Tailwater	-1565	PF 4	3010.00	5289.20	5296.97		5297.88	0.004565	7.66	392.81	70.28	0.57
Tailwater	-1565	PF 5	5000.00	5289.20	5299.13		5300.40	0.004684	9.04	553.04	77.77	0.60
Tailwater	-1565	PF 6	15000.00	5289.20	5304.49		5307.85	0.007375	14.72	1021.34	103.95	0.79
Tailwater	-1565	PF 7	20000.00	5289.20	5305.57	5304.98	5310.47	0.009493	17.79	1143.76	124.29	0.91
Tailwater	-1565	PF 8	40000.00	5289.20	5312.32	5312.32	5317.71	0.006418	19.78	2545.80	264.79	0.81
Tailwater	-1565	PF 9	80000.00	5289.20	5322.08		5326.60	0.003652	19.78	5487.16	312.00	0.65
Tailwater	-1615	PF 1	500.00	5289.10	5291.35	5291.26	5292.14	0.017593	7.17	69.72	38.75	0.94
Tailwater	-1615	PF 2	1000.00	5289.10	5292.32	5292.32	5293.62	0.018120	9.13	109.51	42.96	1.01
Tailwater	-1615	PF 3	1500.00	5289.10	5293.19	5293.19	5294.77	0.016939	10.10	148.52	47.45	1.01
Tailwater	-1615	PF 4	3010.00	5289.10	5295.16	5295.16	5297.37	0.015299	11.94	252.08	57.70	1.01
Tailwater	-1615	PF 5	5000.00	5289.10	5297.08	5297.08	5299.87	0.014232	13.40	373.03	67.73	1.01
Tailwater	-1615	PF 6	15000.00	5289.10	5302.99	5302.99	5307.29	0.012298	16.64	901.34	105.44	1.00
Tailwater	-1615	PF 7	20000.00	5289.10	5304.99	5304.99	5309.95	0.011257	17.88	1126.00	126.98	0.99
Tailwater	-1615	PF 8	40000.00	5289.10	5309.78	5311.79	5317.11	0.010693	22.53	2147.78	295.97	1.03
Tailwater	-1615	PF 9	80000.00	5289.10	5322.69		5326.11	0.002699	17.12	6144.28	315.00	0.57

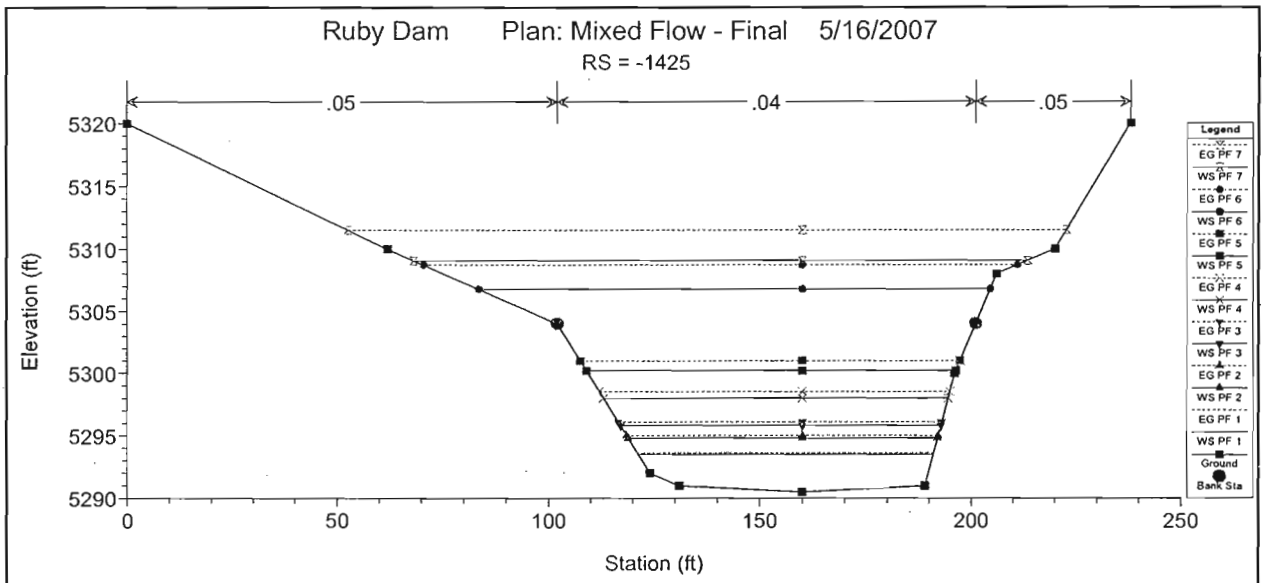
HEC-RAS Plan: Final River: Ruby River Reach: Tailwater (Continued)

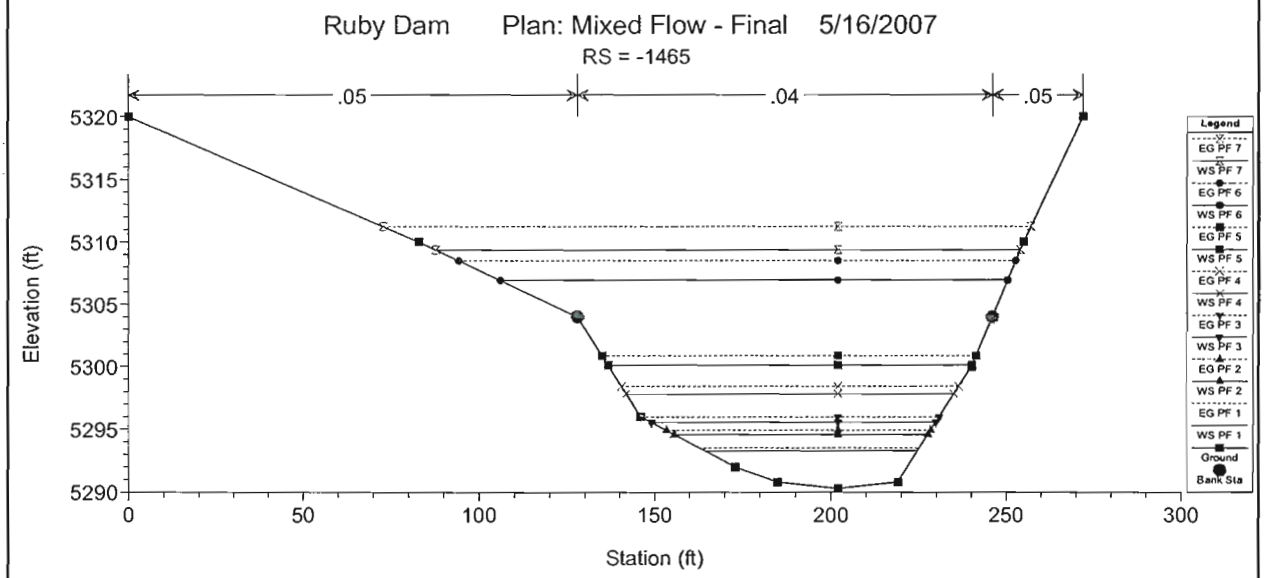
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Tailwater	-1665	PF 1	500.00	5289.00	5291.04		5291.41	0.008755	4.92	101.53	59.18	0.66
Tailwater	-1665	PF 2	1000.00	5289.00	5292.21	5291.39	5292.73	0.006591	5.79	172.72	63.19	0.62
Tailwater	-1665	PF 3	1500.00	5289.00	5293.43	5292.04	5293.97	0.004789	5.89	254.87	71.35	0.55
Tailwater	-1665	PF 4	3010.00	5289.00	5295.78	5293.68	5296.50	0.004073	6.83	440.85	87.05	0.53
Tailwater	-1665	PF 5	5000.00	5289.00	5297.82	5295.33	5298.79	0.004107	7.90	632.90	100.73	0.56
Tailwater	-1665	PF 6	15000.00	5289.00	5298.16	5300.59	5306.00	0.031896	22.47	667.57	103.01	1.56
Tailwater	-1665	PF 7	20000.00	5289.00	5299.68	5302.51	5308.67	0.031027	24.07	831.04	113.12	1.56
Tailwater	-1665	PF 8	40000.00	5289.00	5304.62	5308.57	5315.94	0.024309	27.10	1517.41	189.49	1.47
Tailwater	-1665	PF 9	80000.00	5289.00	5323.07		5325.79	0.001852	14.68	6731.63	297.00	0.48
Tailwater	-1715	PF 1	500.00	5288.90	5290.61		5290.94	0.009643	4.59	109.02	76.56	0.68
Tailwater	-1715	PF 2	1000.00	5288.90	5292.12		5292.42	0.003620	4.39	227.93	81.17	0.46
Tailwater	-1715	PF 3	1500.00	5288.90	5293.42		5293.73	0.002432	4.45	337.25	86.85	0.40
Tailwater	-1715	PF 4	3010.00	5288.90	5295.82		5296.28	0.002148	5.39	558.14	97.32	0.40
Tailwater	-1715	PF 5	5000.00	5288.90	5297.89		5298.55	0.002314	6.51	768.55	106.33	0.43
Tailwater	-1715	PF 6	15000.00	5288.90	5297.31	5299.27	5304.29	0.026538	21.21	707.35	103.79	1.43
Tailwater	-1715	PF 7	20000.00	5288.90	5298.83	5301.20	5307.03	0.025801	22.98	870.32	110.43	1.44
Tailwater	-1715	PF 8	40000.00	5288.90	5304.80	5307.11	5314.40	0.017343	24.88	1619.25	152.80	1.26
Tailwater	-1715	PF 9	80000.00	5288.90	5315.02	5315.02	5324.90	0.008203	25.75	3356.60	180.39	0.96
Tailwater	-1765	PF 1	500.00	5288.50	5290.56		5290.67	0.002264	2.58	193.83	109.42	0.34
Tailwater	-1765	PF 2	1000.00	5288.50	5292.16		5292.27	0.001148	2.62	381.97	126.39	0.27
Tailwater	-1765	PF 3	1500.00	5288.50	5293.50		5293.61	0.000859	2.66	563.13	145.82	0.24
Tailwater	-1765	PF 4	3010.00	5288.50	5295.97		5296.13	0.000727	3.14	957.80	170.17	0.23
Tailwater	-1765	PF 5	5000.00	5288.50	5298.15		5298.33	0.000953	3.46	1447.07	274.15	0.26
Tailwater	-1765	PF 6	15000.00	5288.50	5302.45	5296.99	5302.94	0.001194	5.67	2659.60	293.05	0.33
Tailwater	-1765	PF 7	20000.00	5288.50	5303.95	5298.34	5304.60	0.001291	6.51	3111.23	308.93	0.35
Tailwater	-1765	PF 8	40000.00	5288.50	5308.74	5301.60	5309.96	0.001491	8.92	4638.25	327.38	0.40
Tailwater	-1765	PF 9	80000.00	5288.50	5315.82	5306.71	5317.97	0.001642	11.99	7112.94	365.68	0.44
Tailwater	-1815	PF 1	500.00	5287.10	5290.53		5290.59	0.000779	2.11	237.34	80.31	0.22
Tailwater	-1815	PF 2	1000.00	5287.10	5292.11		5292.22	0.000793	2.71	368.79	85.81	0.23
Tailwater	-1815	PF 3	1500.00	5287.10	5293.41		5293.56	0.000776	3.11	483.06	89.61	0.24
Tailwater	-1815	PF 4	3010.00	5287.10	5295.79		5296.07	0.000993	4.26	718.70	132.13	0.28
Tailwater	-1815	PF 5	5000.00	5287.10	5297.85		5298.26	0.001182	5.26	1065.79	202.91	0.31
Tailwater	-1815	PF 6	15000.00	5287.10	5301.73		5302.81	0.002201	9.13	2122.21	290.34	0.45
Tailwater	-1815	PF 7	20000.00	5287.10	5303.12		5304.45	0.002448	10.32	2531.38	297.04	0.48
Tailwater	-1815	PF 8	40000.00	5287.10	5307.89		5309.77	0.002848	13.41	3932.76	317.07	0.55
Tailwater	-1815	PF 9	80000.00	5287.10	5314.54		5317.76	0.003046	17.09	6208.70	347.15	0.60
Tailwater	-1865	PF 1	500.00	5287.00	5290.40		5290.54	0.001571	2.92	171.11	59.51	0.30
Tailwater	-1865	PF 2	1000.00	5287.00	5291.94		5292.16	0.001633	3.75	266.98	65.27	0.33
Tailwater	-1865	PF 3	1500.00	5287.00	5293.21		5293.49	0.001602	4.25	353.20	70.05	0.33
Tailwater	-1865	PF 4	3010.00	5287.00	5295.47		5295.98	0.002263	5.70	532.16	107.34	0.41
Tailwater	-1865	PF 5	5000.00	5287.00	5297.63		5298.17	0.001886	6.20	997.18	254.59	0.39
Tailwater	-1865	PF 6	15000.00	5287.00	5301.54		5302.68	0.002723	9.75	2032.45	271.71	0.50
Tailwater	-1865	PF 7	20000.00	5287.00	5302.89		5304.30	0.003001	11.00	2403.33	276.13	0.54
Tailwater	-1865	PF 8	40000.00	5287.00	5307.22		5309.58	0.003583	14.54	3631.03	290.28	0.61
Tailwater	-1865	PF 9	80000.00	5287.00	5313.56		5317.50	0.004102	19.12	5535.64	310.97	0.69
Tailwater	-1915	PF 1	500.00	5286.90	5290.15		5290.41	0.003380	4.13	121.09	43.46	0.44
Tailwater	-1915	PF 2	1000.00	5286.90	5291.57		5292.02	0.003746	5.38	186.02	47.96	0.48
Tailwater	-1915	PF 3	1500.00	5286.90	5292.77		5293.35	0.003718	6.10	246.01	51.77	0.49
Tailwater	-1915	PF 4	3010.00	5286.90	5294.55		5295.73	0.006330	8.74	344.49	62.85	0.66
Tailwater	-1915	PF 5	5000.00	5286.90	5295.49	5294.99	5297.80	0.012371	12.22	409.31	75.22	0.92
Tailwater	-1915	PF 8	15000.00	5286.90	5299.97		5302.34	0.007714	13.97	1426.89	253.10	0.80
Tailwater	-1915	PF 7	20000.00	5286.90	5301.20		5303.94	0.007881	15.32	1739.97	258.23	0.83
Tailwater	-1915	PF 8	40000.00	5286.90	5304.48	5304.48	5309.08	0.009742	20.36	2609.96	271.97	0.96
Tailwater	-1915	PF 9	80000.00	5286.90	5309.97	5309.97	5316.90	0.009791	25.46	4167.02	294.99	1.02
Tailwater	-1965	PF 1	500.00	5286.80	5290.08		5290.25	0.002129	3.35	149.41	52.33	0.35
Tailwater	-1965	PF 2	1000.00	5286.80	5291.53		5291.82	0.002375	4.35	229.76	58.49	0.39
Tailwater	-1965	PF 3	1500.00	5286.80	5292.77		5293.14	0.002333	4.91	305.48	63.75	0.40
Tailwater	-1965	PF 4	3010.00	5286.80	5294.62		5295.38	0.003344	6.99	434.12	81.42	0.49
Tailwater	-1965	PF 5	5000.00	5286.80	5295.68	5293.82	5297.16	0.005347	9.81	537.69	143.72	0.64
Tailwater	-1965	PF 6	15000.00	5286.80	5299.37	5299.37	5301.96	0.006886	14.63	1447.89	265.96	0.78
Tailwater	-1965	PF 7	20000.00	5286.80	5300.53	5300.53	5303.54	0.007382	16.20	1759.94	271.98	0.82
Tailwater	-1965	PF 8	40000.00	5286.80	5303.75	5304.12	5308.59	0.009460	21.44	2660.58	288.66	0.96
Tailwater	-1965	PF 9	80000.00	5286.80	5308.16	5309.42	5316.25	0.011906	28.46	3984.68	311.55	1.13
Tailwater	-2015	PF 1	500.00	5286.70	5290.02		5290.15	0.001540	2.88	173.68	60.67	0.30
Tailwater	-2015	PF 2	1000.00	5286.70	5291.48		5291.70	0.001654	3.78	264.65	63.86	0.33
Tailwater	-2015	PF 3	1500.00	5286.70	5292.72		5293.01	0.001947	4.28	350.35	79.44	0.36
Tailwater	-2015	PF 4	3010.00	5286.70	5294.67		5295.15	0.002663	5.57	554.87	154.91	0.43
Tailwater	-2015	PF 5	5000.00	5286.70	5296.01		5296.74	0.003069	6.99	823.19	235.27	0.48
Tailwater	-2015	PF 6	15000.00	5286.70	5296.84	5298.15	5301.26	0.016696	17.66	1025.42	251.96	1.15
Tailwater	-2015	PF 7	20000.00	5286.70	5297.98	5299.33	5302.84	0.015961	19.01	1324.81	274.81	1.15
Tailwater	-2015	PF 8	40000.00	5286.70	5301.10	5302.94	5307.79	0.016061	23.52	2262.89	326.91	1.22

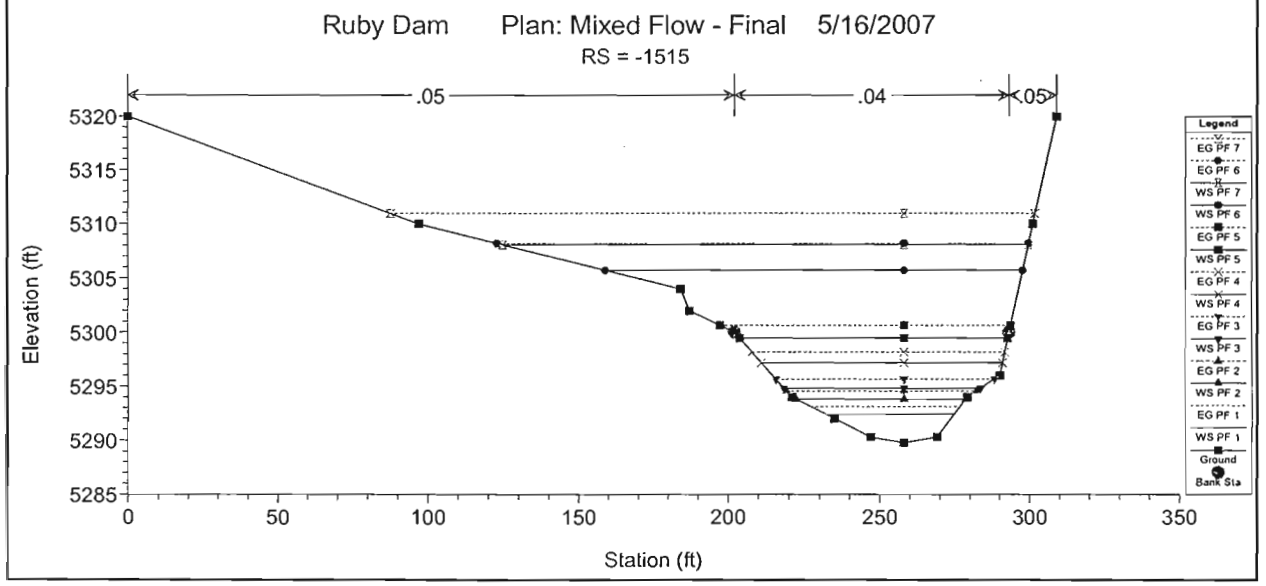
HEC-RAS Plan: Final River: Ruby River Reach: Tailwater (Continued)

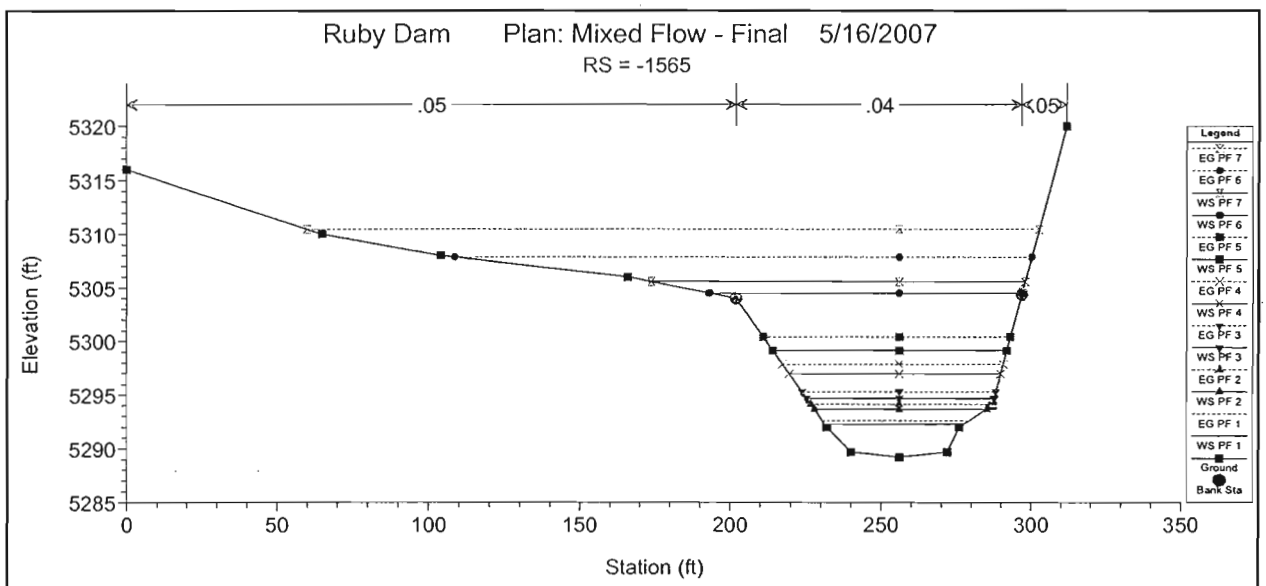
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Tailwater	-2015	PF 9	80000.00	5286.70	5304.89	5308.76	5315.29	0.018525	30.51	3620.82	390.13	1.37
Tailwater	-2065	PF 1	500.00	5286.60	5289.99		5290.07	0.000971	2.32	215.10	73.91	0.24
Tailwater	-2065	PF 2	1000.00	5286.60	5291.47		5291.61	0.001059	3.04	329.06	80.20	0.26
Tailwater	-2065	PF 3	1500.00	5286.60	5292.72		5292.91	0.001091	3.46	434.00	88.96	0.28
Tailwater	-2065	PF 4	3010.00	5286.60	5294.64		5295.00	0.001988	4.80	626.70	123.62	0.38
Tailwater	-2065	PF 5	5000.00	5286.60	5295.97		5296.53	0.003349	6.03	859.00	246.24	0.49
Tailwater	-2065	PF 6	15000.00	5286.60	5298.15	5297.56	5300.11	0.007521	11.57	1454.60	372.15	0.77
Tailwater	-2065	PF 7	20000.00	5286.60	5297.82	5298.97	5301.77	0.016110	16.39	1348.00	278.07	1.12
Tailwater	-2065	PF 8	40000.00	5286.60	5299.93	5302.22	5306.85	0.021039	22.54	2212.61	479.89	1.34
Tailwater	-2065	PF 9	80000.00	5286.60	5302.06	5305.55	5313.97	0.030296	31.27	3550.09	640.36	1.67
Tailwater	-2115	PF 1	500.00	5286.50	5289.84		5290.00	0.002235	3.21	155.58	61.84	0.36
Tailwater	-2115	PF 2	1000.00	5286.50	5291.28		5291.53	0.002277	3.98	251.28	73.13	0.38
Tailwater	-2115	PF 3	1500.00	5286.50	5292.54		5292.82	0.002149	4.24	354.16	89.89	0.38
Tailwater	-2115	PF 4	3010.00	5286.50	5294.43		5294.88	0.002417	5.43	605.06	204.87	0.42
Tailwater	-2115	PF 5	5000.00	5286.50	5295.75		5296.37	0.002694	6.66	943.65	378.60	0.46
Tailwater	-2115	PF 6	15000.00	5286.50	5298.73		5299.54	0.002959	8.95	2732.67	643.74	0.51
Tailwater	-2115	PF 7	20000.00	5286.50	5299.85	5298.45	5300.67	0.002762	9.32	3457.99	649.08	0.50
Tailwater	-2115	PF 8	40000.00	5286.50	5303.36	5300.47	5304.35	0.002452	10.61	5766.07	665.79	0.50
Tailwater	-2115	PF 9	80000.00	5286.50	5308.51	5303.44	5309.89	0.002283	12.59	9259.63	690.32	0.50
Tailwater	-2165	PF 1	500.00	5286.40	5289.74	5288.30	5289.89	0.002000	3.08	162.51	63.31	0.34
Tailwater	-2165	PF 2	1000.00	5286.40	5291.19	5289.10	5291.41	0.002001	3.76	265.88	76.09	0.35
Tailwater	-2165	PF 3	1500.00	5286.40	5292.46	5289.76	5292.71	0.002001	3.98	376.73	99.47	0.36
Tailwater	-2165	PF 4	3010.00	5286.40	5294.35	5291.37	5294.75	0.002001	5.15	661.66	257.17	0.38
Tailwater	-2165	PF 5	5000.00	5286.40	5295.74	5292.94	5296.21	0.002001	5.96	1263.35	612.40	0.40
Tailwater	-2165	PF 6	15000.00	5286.40	5298.79	5297.05	5299.34	0.002001	7.59	3187.51	642.64	0.42
Tailwater	-2165	PF 7	20000.00	5286.40	5299.89	5297.78	5300.49	0.002003	8.14	3892.94	648.43	0.43
Tailwater	-2165	PF 8	40000.00	5286.40	5303.36	5299.78	5304.19	0.002000	9.75	6177.65	666.84	0.45
Tailwater	-2165	PF 9	80000.00	5286.40	5308.50	5302.70	5309.75	0.002001	11.92	9675.97	694.08	0.47

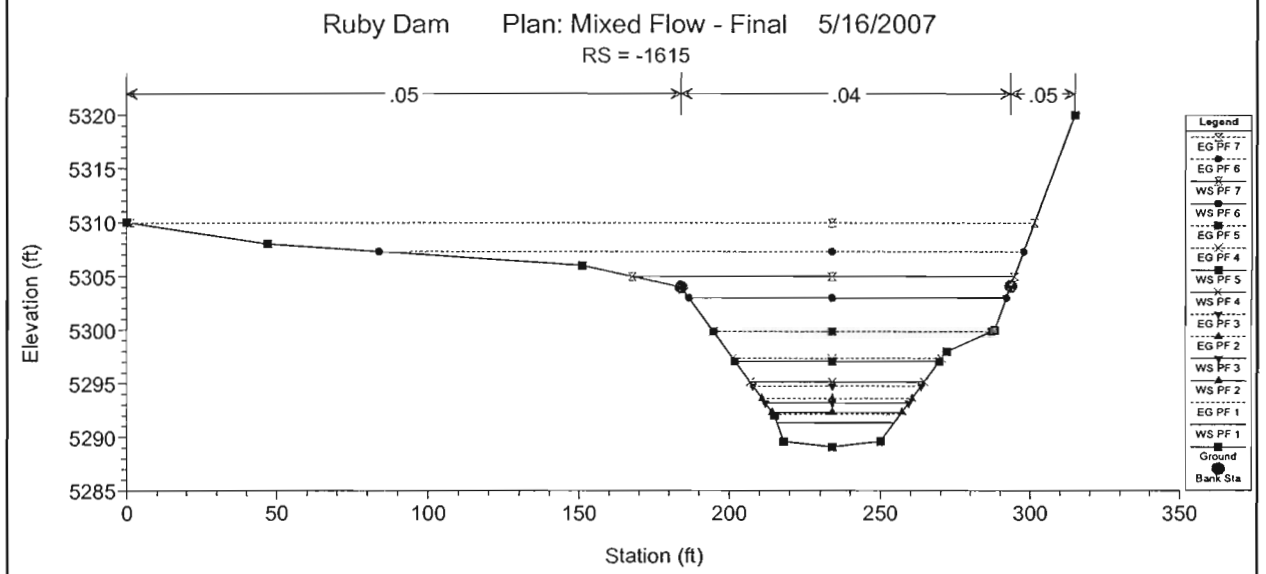

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -1365 First X-Section downstream of existing stilling basin
.05
.04
.05
Elevation (ft)
Station (ft)
Legend
EG PF 7
WS PF 7
EG PF 6
WS PF 6
EG PF 5
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta
Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -1385
.05
.04
.05
Elevation (ft)
Station (ft)
Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -1405
.05
.04
.05
Elevation (ft)
Station (ft)

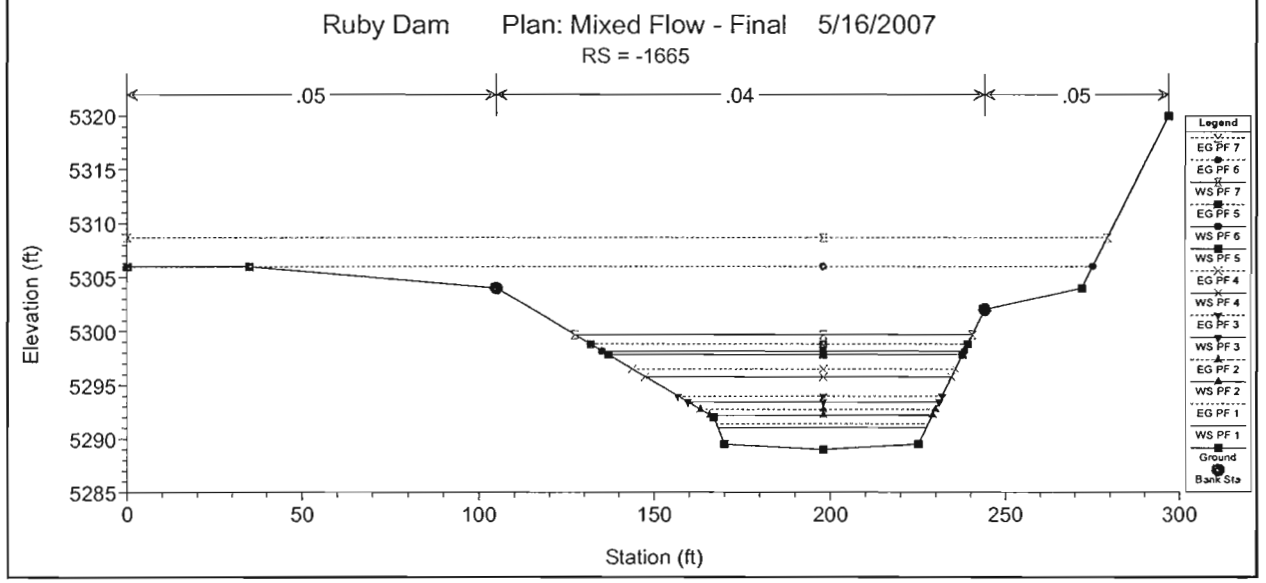

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -1425
.05
.04
.05
Elevation (ft)
Station (ft)
Legend
EG PF 7
WS PF 7
EG PF 6
WS PF 6
EG PF 5
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta

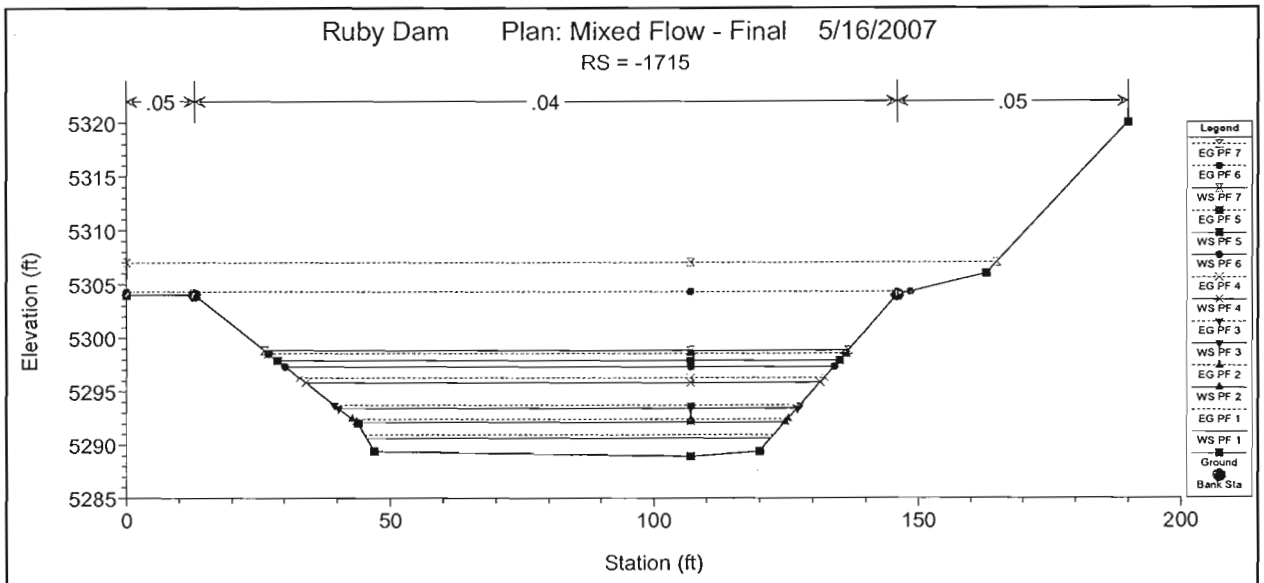

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -1465
.05
.04
.05
Elevation (ft)
Station (ft)
Legend
EG PF 7
WS PF 7
EG PF 6
WS PF 6
EG PF 5
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta

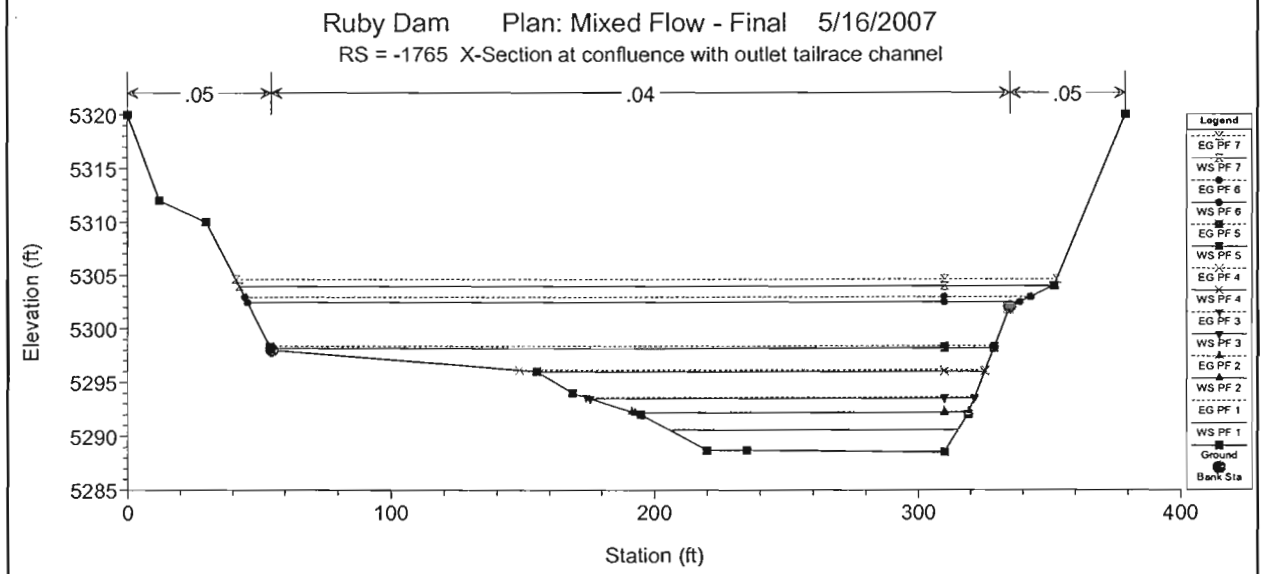

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -1515
.05
.04
.05
Elevation (ft)
Station (ft)
Legend
EG PF 7
EG PF 6
WS PF 7
WS PF 6
EG PF 5
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta

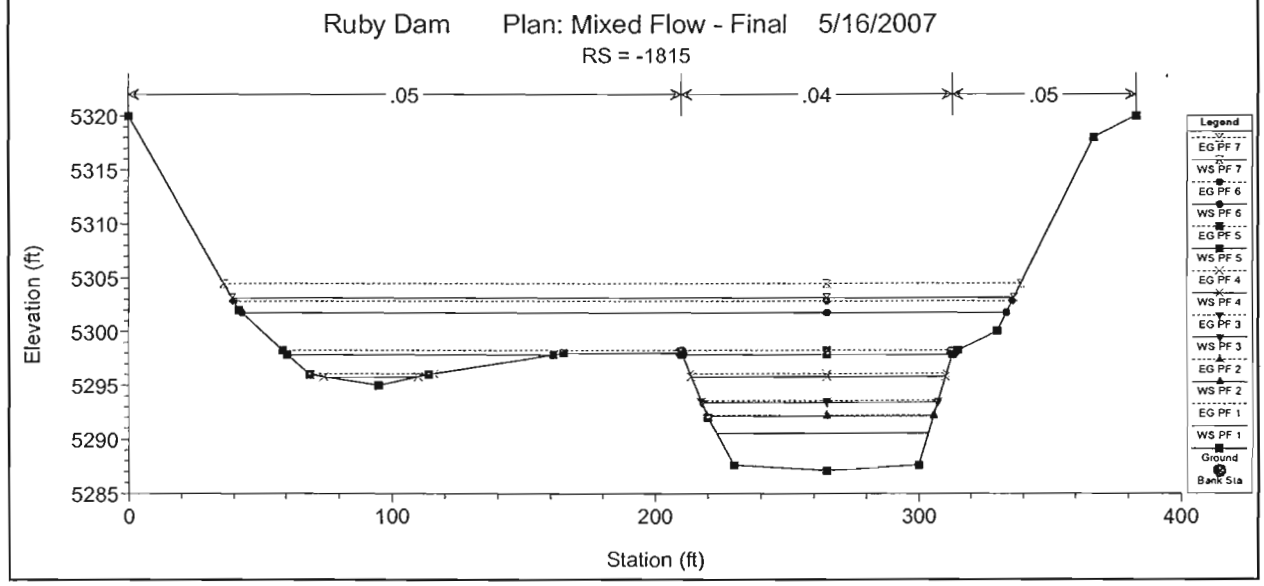

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -1565
.05
.04
.05
Elevation (ft)
Station (ft)
Legend
EG PF 7
EG PF 6
WS PF 7
WS PF 6
EG PF 5
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta

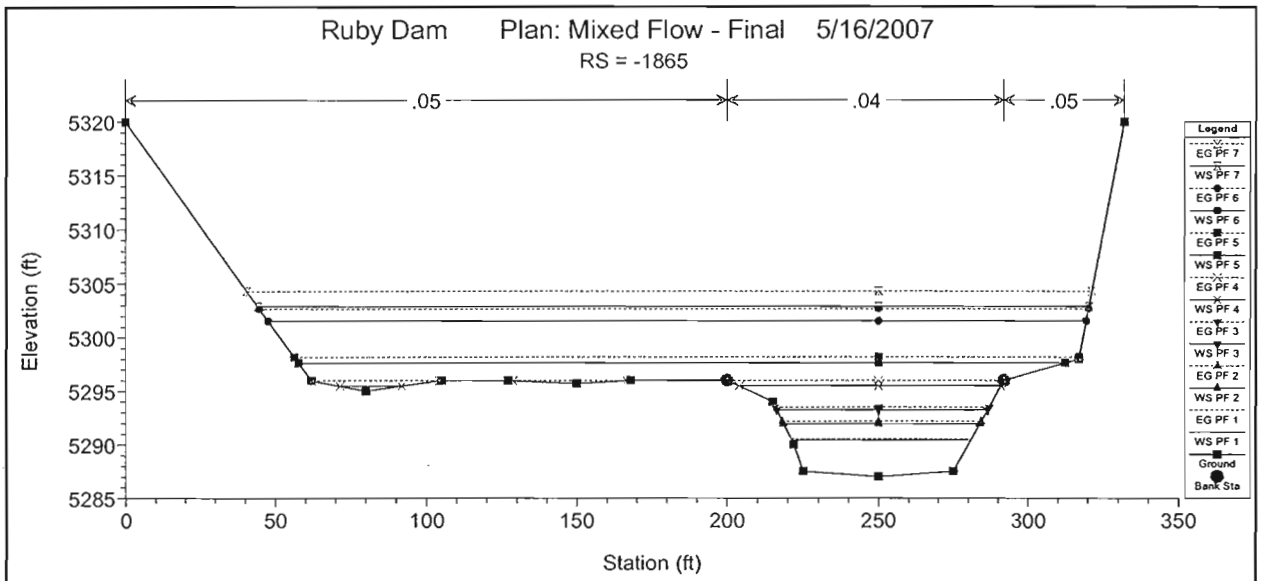

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -1615
.05
.04
.05
Elevation (ft)
Station (ft)
Legend
EG PF 7
EG PF 6
WS PF 7
WS PF 6
EG PF 5
EG PF 4
WS PF 5
WS PF 4
EG PF 3
EG PF 2
WS PF 3
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta

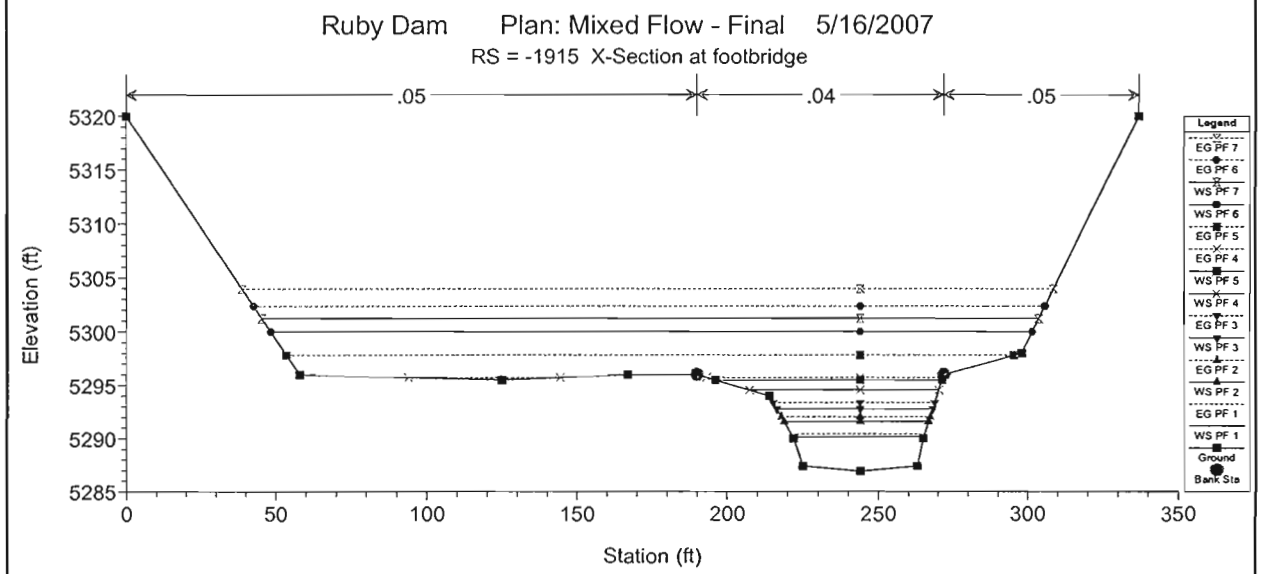

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -1665
.05
.04
.05
Elevation (ft)
Station (ft)
Legend
EG PF 7
EG PF 6
WS PF 7
EG PF 5
WS PF 6
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta

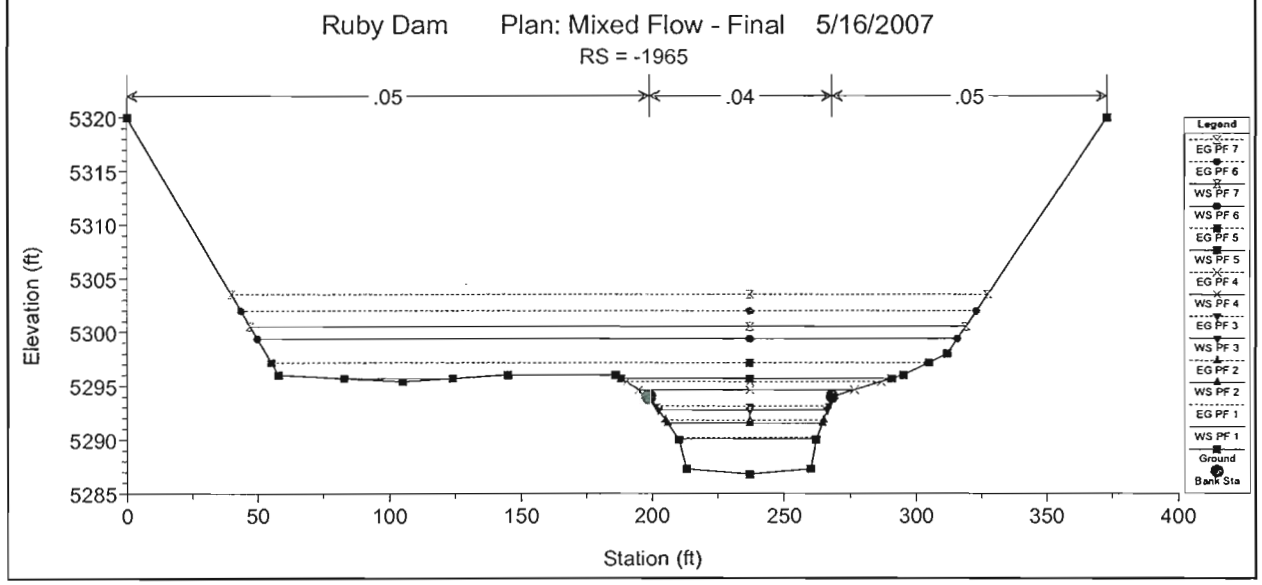

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -1715
.05
.04
.05
Elevation (ft)
Station (ft)
Legend
EG PF 7
EG PF 6
WS PF 7
EG PF 5
WS PF 5
WS PF 6
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta

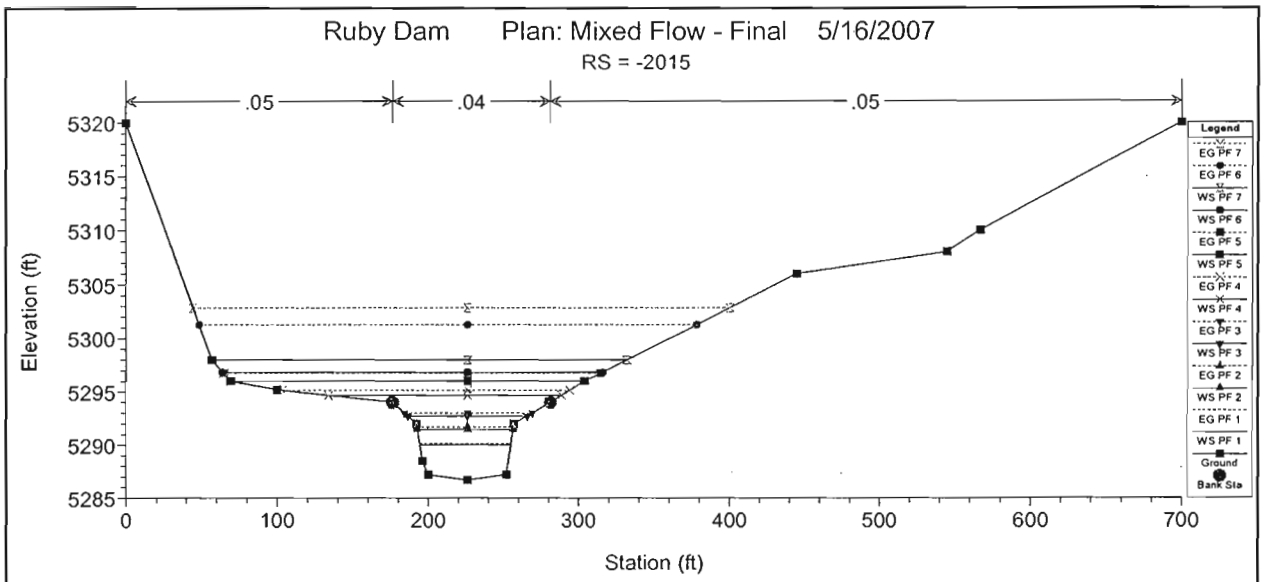

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -1765 X-Section at confluence with outlet tailrace channel
.05
.04
.05
Elevation (ft)
Station (ft)
Legend
EG PF 7
WS PF 7
EG PF 6
WS PF 6
EG PF 5
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta

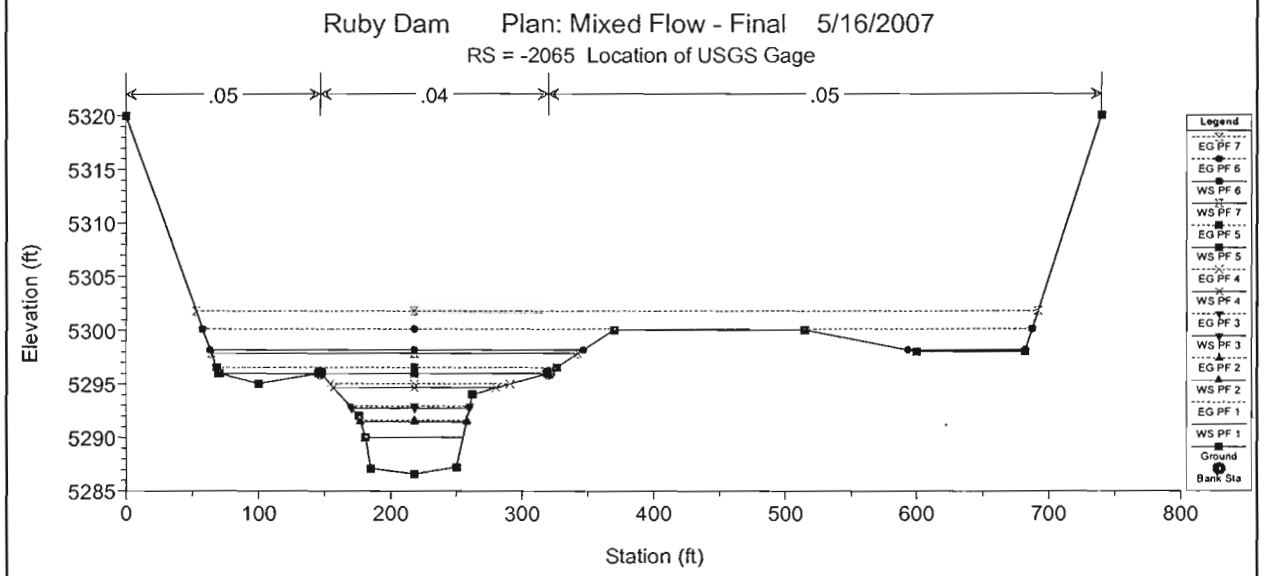

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -1815
.05
.04
.05
Elevation (ft)
Station (ft)
Legend
EG PF 7
WS PF 7
EG PF 6
WS PF 6
EG PF 5
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta

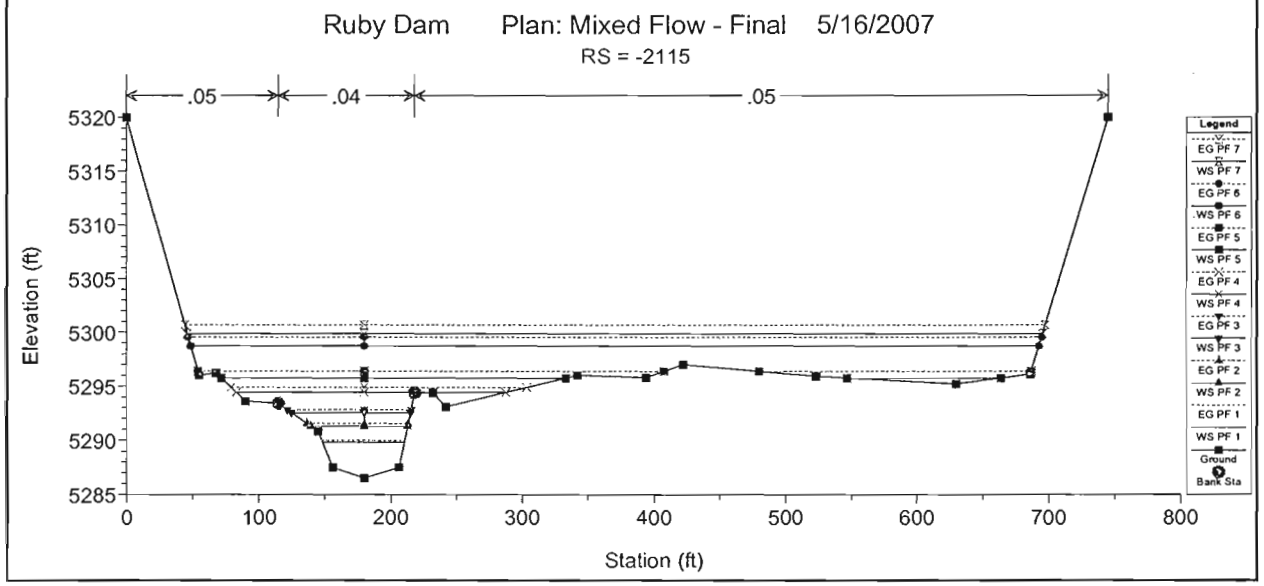

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -1865
.05
.04
.05
Elevation (ft)
Station (ft)
Legend
EG PF 7
WS PF 7
EG PF 6
WS PF 6
EG PF 5
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta

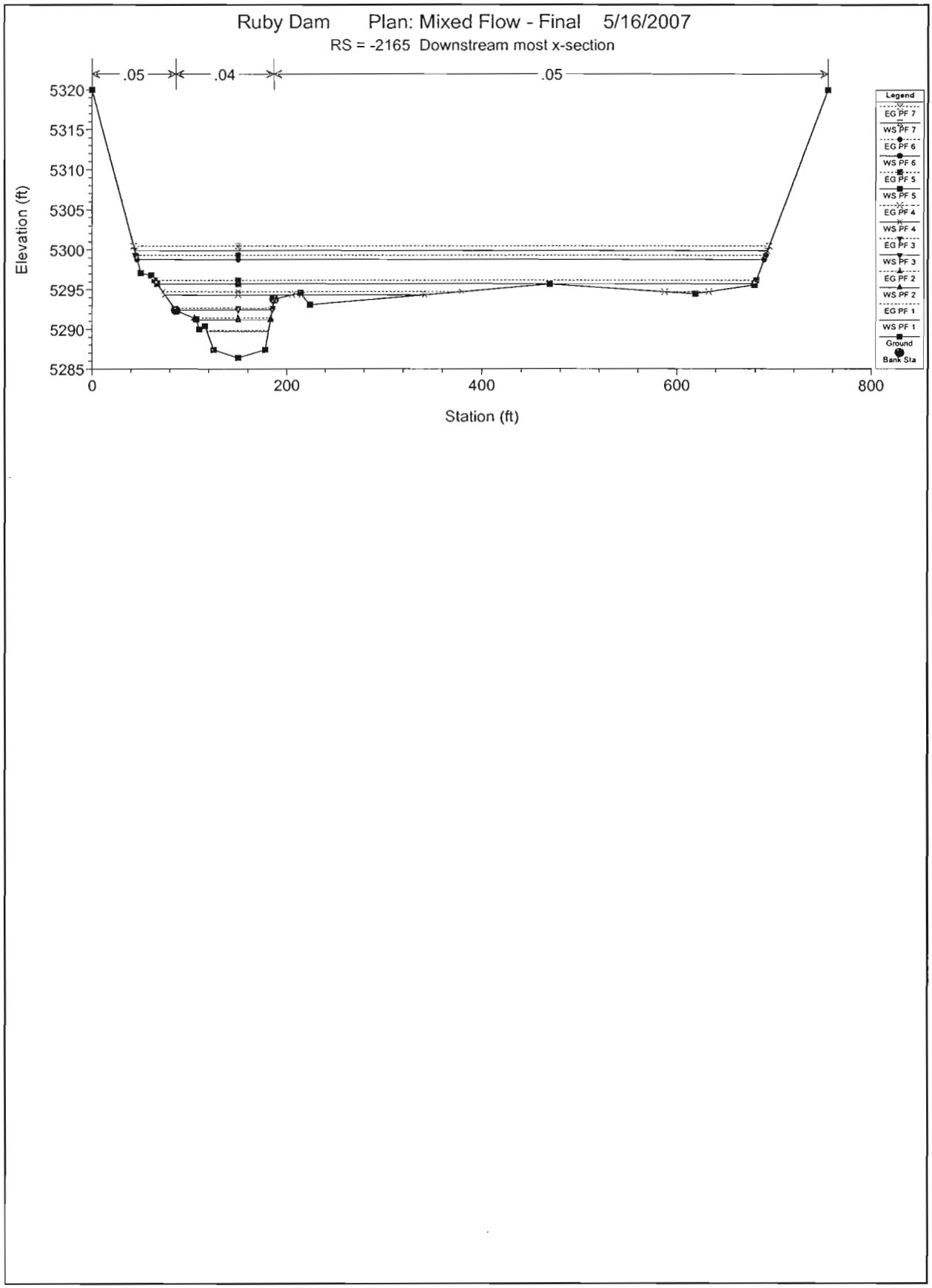

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -1915 X-Section at footbridge
.05
.04
.05
Elevation (ft)
Station (ft)
Legend
EG PF 7
EG PF 6
WS PF 7
WS PF 6
EG PF 5
EG PF 4
WS PF 5
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta


Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -1965
.05
.04
.05
Elevation (ft)
Station (ft)
Legend
EG PF 7
EG PF 6
WS PF 7
WS PF 6
EG PF 5
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta


Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -2015
.05
.04
.05
Elevation (ft)
Station (ft)
Legend
EG PF 7
EG PF 6
WS PF 7
WS PF 6
EG PF 5
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta


Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -2065 Location of USGS Gage
.05
.04
.05
Elevation (ft)
Station (ft)
Legend
EG PF 7
EG PF 6
WS PF 6
WS PF 7
EG PF 5
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta

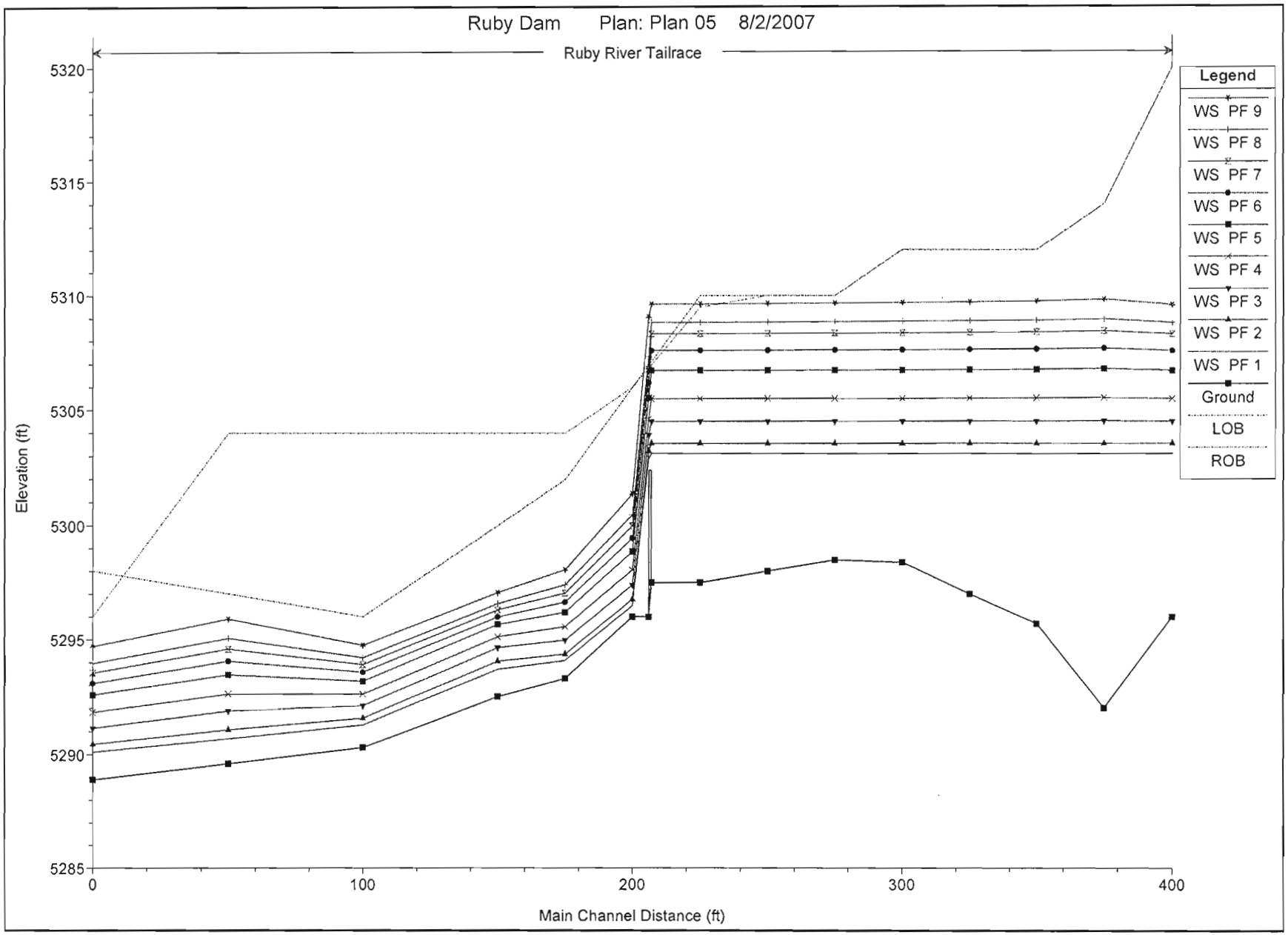

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -2115
.05
.04
.05
Elevation (ft)
Station (ft)
Legend
EG PF 7
WS PF 7
EG PF 6
WS PF 6
EG PF 5
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta


Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -2165 Downstream most x-section
.05
.04
.05
Elevation (ft)
5320
5315
5310
5305
5300
5295
5290
5285
0
200
400
600
800
Station (ft)
Legend
EG PF 7
WS PF 7
EG PF 6
WS PF 6
EG PF 5
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta

APPENDIX C

OUTLET CHANNEL HEC-RAS MODEL

Existing Outlet Channel Geometry

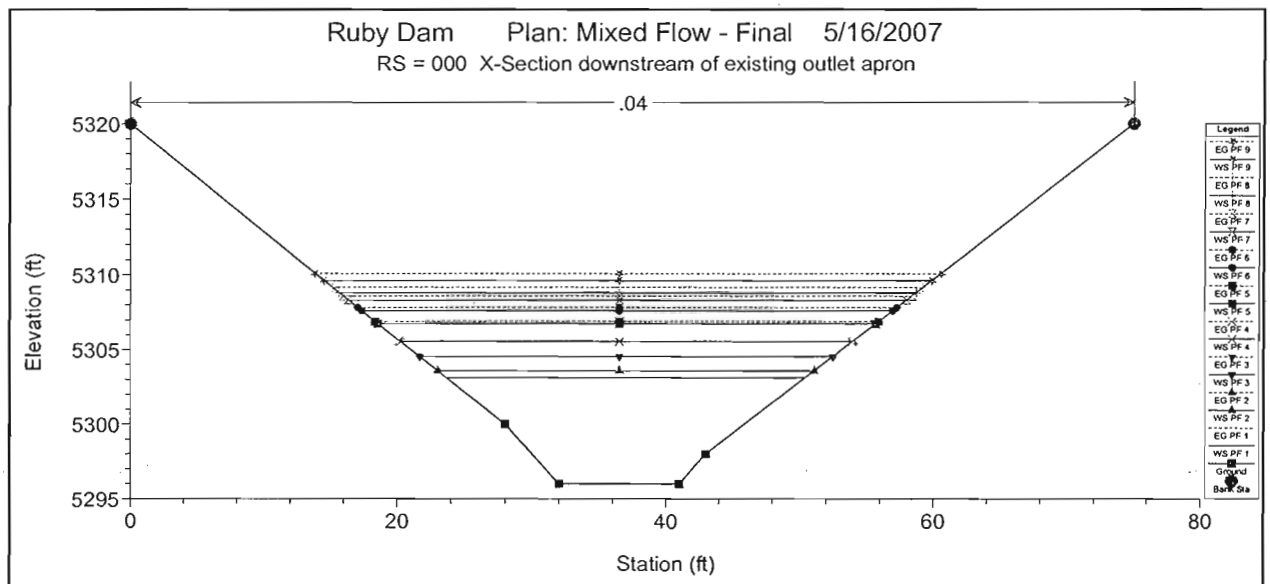

Ruby Dam Plan: Plan 05 8/2/2007
Ruby River Tailrace
Elevation (ft)
5320
5315
5310
5305
5300
5295
5290
5285
0
100
200
300
400
Main Channel Distance (ft)
Legend
WS PF 9
WS PF 8
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
LOB
ROB

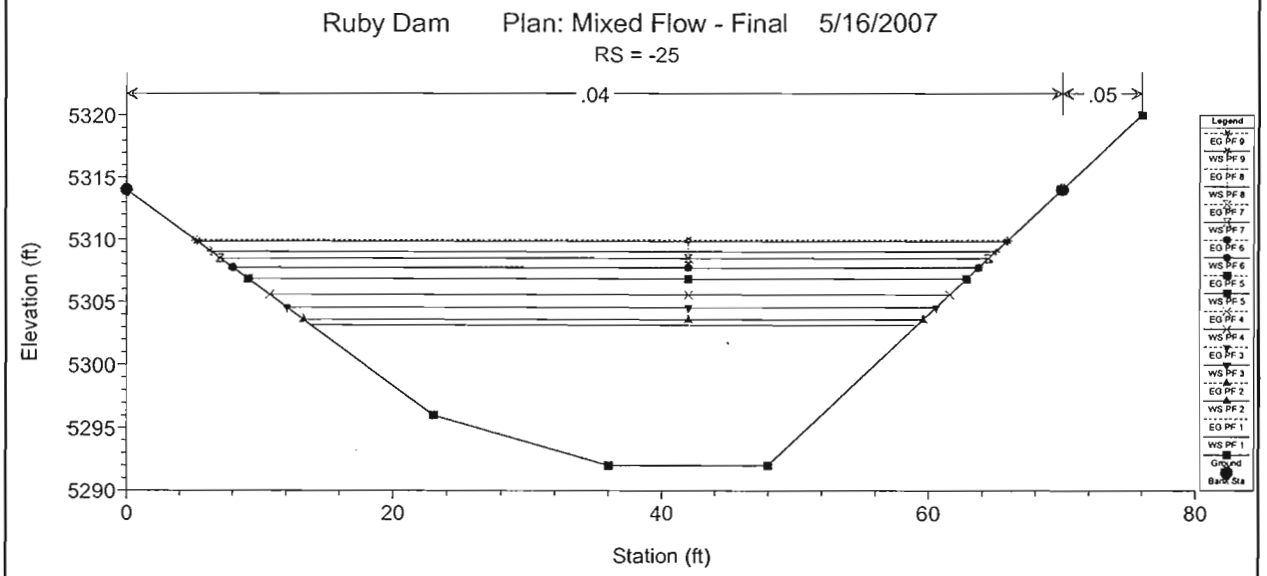
HEC-RAS Plan: Plan 05 River: Ruby River Reach: Tailrace

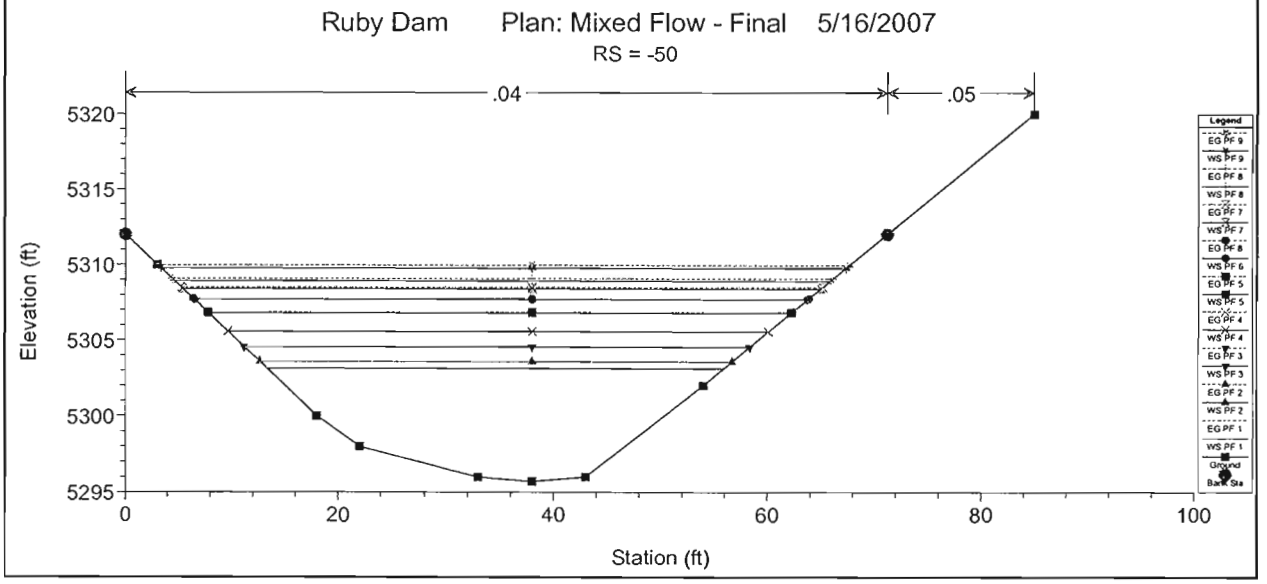
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Tailrace	000	PF 1	50.00	5296.00	5303.14	5296.94	5303.14	0.000020	0.41	123.09	26.86	0.03
Tailrace	000	PF 2	100.00	5296.00	5303.57	5297.47	5303.58	0.000062	0.74	134.99	28.10	0.06
Tailrace	000	PF 3	250.00	5296.00	5304.53	5298.61	5304.56	0.000233	1.53	163.20	30.83	0.12
Tailrace	000	PF 4	450.00	5296.00	5305.52	5299.70	5305.60	0.000469	2.30	195.29	33.67	0.17
Tailrace	000	PF 5	750.00	5296.00	5306.73	5300.93	5306.89	0.000766	3.15	238.25	37.13	0.22
Tailrace	000	PF 6	1000.00	5296.00	5307.61	5301.78	5307.82	0.000960	3.68	271.75	39.62	0.25
Tailrace	000	PF 7	1250.00	5296.00	5308.32	5302.49	5308.59	0.001144	4.15	300.89	41.67	0.27
Tailrace	000	PF 8	1500.00	5296.00	5308.82	5303.13	5309.16	0.001376	4.66	321.87	43.08	0.30
Tailrace	000	PF 9	2000.00	5296.00	5309.61	5304.26	5310.10	0.001860	5.61	356.78	45.34	0.35
Tailrace	-25	PF 1	50.00	5292.00	5303.14		5303.14	0.000001	0.14	346.97	45.26	0.01
Tailrace	-25	PF 2	100.00	5292.00	5303.57		5303.57	0.000004	0.27	366.94	46.25	0.02
Tailrace	-25	PF 3	250.00	5292.00	5304.55		5304.55	0.000019	0.61	413.03	48.47	0.04
Tailrace	-25	PF 4	450.00	5292.00	5305.57		5305.58	0.000045	0.97	463.60	50.79	0.06
Tailrace	-25	PF 5	750.00	5292.00	5306.82		5306.85	0.000087	1.42	528.87	53.64	0.08
Tailrace	-25	PF 6	1000.00	5292.00	5307.72		5307.76	0.000122	1.73	578.06	55.68	0.09
Tailrace	-25	PF 7	1250.00	5292.00	5308.46		5308.52	0.000158	2.02	620.12	57.38	0.11
Tailrace	-25	PF 8	1500.00	5292.00	5308.99		5309.07	0.000200	2.31	650.73	58.58	0.12
Tailrace	-25	PF 9	2000.00	5292.00	5309.85		5309.97	0.000289	2.85	701.94	60.54	0.15
Tailrace	-50	PF 1	50.00	5295.70	5303.14		5303.14	0.000005	0.24	210.89	42.66	0.02
Tailrace	-50	PF 2	100.00	5295.70	5303.57		5303.57	0.000017	0.44	229.76	44.06	0.03
Tailrace	-50	PF 3	250.00	5295.70	5304.54		5304.55	0.000065	0.91	273.84	47.18	0.07
Tailrace	-50	PF 4	450.00	5295.70	5305.55		5305.58	0.000133	1.39	323.07	50.43	0.10
Tailrace	-50	PF 5	750.00	5295.70	5306.78		5306.84	0.000225	1.93	387.88	54.41	0.13
Tailrace	-50	PF 6	1000.00	5295.70	5307.67		5307.75	0.000288	2.29	437.59	57.28	0.15
Tailrace	-50	PF 7	1250.00	5295.70	5308.41		5308.51	0.000348	2.60	480.55	59.65	0.16
Tailrace	-50	PF 8	1500.00	5295.70	5308.92		5309.06	0.000423	2.93	511.79	61.31	0.18
Tailrace	-50	PF 9	2000.00	5295.70	5309.76		5309.96	0.000577	3.54	564.24	64.01	0.21
Tailrace	-75	PF 1	50.00	5297.00	5303.14		5303.14	0.000009	0.28	180.99	44.72	0.02
Tailrace	-75	PF 2	100.00	5297.00	5303.57		5303.57	0.000027	0.50	200.70	46.07	0.04
Tailrace	-75	PF 3	250.00	5297.00	5304.53		5304.55	0.000094	1.01	246.47	49.05	0.08
Tailrace	-75	PF 4	450.00	5297.00	5305.54		5305.57	0.000179	1.51	297.30	52.16	0.11
Tailrace	-75	PF 5	750.00	5297.00	5306.77		5306.83	0.000281	2.06	363.88	55.98	0.14
Tailrace	-75	PF 6	1000.00	5297.00	5307.66		5307.75	0.000346	2.41	414.77	58.73	0.16
Tailrace	-75	PF 7	1250.00	5297.00	5308.39		5308.50	0.000409	2.73	458.59	61.00	0.18
Tailrace	-75	PF 8	1500.00	5297.00	5308.90		5309.05	0.000489	3.06	490.27	62.59	0.19
Tailrace	-75	PF 9	2000.00	5297.00	5309.73		5309.94	0.000655	3.68	543.23	65.16	0.22
Tailrace	-100	PF 1	50.00	5298.40	5303.14		5303.14	0.000015	0.31	159.01	48.03	0.03
Tailrace	-100	PF 2	100.00	5298.40	5303.57		5303.57	0.000042	0.56	180.03	49.18	0.05
Tailrace	-100	PF 3	250.00	5298.40	5304.53		5304.55	0.000128	1.09	228.42	51.74	0.09
Tailrace	-100	PF 4	450.00	5298.40	5305.53		5305.57	0.000224	1.60	281.52	54.41	0.12
Tailrace	-100	PF 5	750.00	5298.40	5306.76		5306.83	0.000328	2.14	350.32	57.68	0.15
Tailrace	-100	PF 6	1000.00	5298.40	5307.64		5307.74	0.000391	2.48	402.42	60.04	0.17
Tailrace	-100	PF 7	1250.00	5298.40	5308.37		5308.49	0.000453	2.80	446.96	61.99	0.18
Tailrace	-100	PF 8	1500.00	5298.40	5308.88		5309.03	0.000535	3.13	478.91	63.35	0.20
Tailrace	-100	PF 9	2000.00	5298.40	5309.70		5309.92	0.000707	3.76	531.93	65.54	0.23
Tailrace	-125	PF 1	50.00	5298.50	5303.14		5303.14	0.000015	0.32	157.93	47.75	0.03
Tailrace	-125	PF 2	100.00	5298.50	5303.57		5303.57	0.000043	0.56	178.84	49.02	0.05
Tailrace	-125	PF 3	250.00	5298.50	5304.52		5304.54	0.000131	1.10	227.08	51.84	0.09
Tailrace	-125	PF 4	450.00	5298.50	5305.52		5305.56	0.000229	1.61	280.30	54.79	0.13
Tailrace	-125	PF 5	750.00	5298.50	5306.75		5306.82	0.000335	2.15	349.60	58.40	0.15
Tailrace	-125	PF 6	1000.00	5298.50	5307.63		5307.73	0.000398	2.49	402.40	61.01	0.17
Tailrace	-125	PF 7	1250.00	5298.50	5308.36		5308.48	0.000459	2.79	447.63	63.16	0.18
Tailrace	-125	PF 8	1500.00	5298.50	5308.87		5309.02	0.000543	3.12	480.08	64.66	0.20
Tailrace	-125	PF 9	2000.00	5298.50	5309.69		5309.90	0.000714	3.74	534.05	67.07	0.23
Tailrace	-150	PF 1	50.00	5298.00	5303.13		5303.14	0.000012	0.30	165.43	44.72	0.03
Tailrace	-150	PF 2	100.00	5298.00	5303.57		5303.57	0.000036	0.54	185.02	46.05	0.05
Tailrace	-150	PF 3	250.00	5298.00	5304.52		5304.54	0.000117	1.09	230.39	49.01	0.09
Tailrace	-150	PF 4	450.00	5298.00	5305.52		5305.56	0.000215	1.60	280.73	52.10	0.12
Tailrace	-150	PF 5	750.00	5298.00	5306.74		5306.81	0.000329	2.16	346.61	55.88	0.15
Tailrace	-150	PF 6	1000.00	5298.00	5307.62		5307.72	0.000398	2.52	397.06	58.61	0.17
Tailrace	-150	PF 7	1250.00	5298.00	5308.34		5308.47	0.000466	2.84	440.38	60.86	0.19
Tailrace	-150	PF 8	1500.00	5298.00	5308.85		5309.00	0.000555	3.18	471.44	62.42	0.20
Tailrace	-150	PF 9	2000.00	5298.00	5309.66		5309.89	0.000738	3.82	523.09	64.94	0.24
Tailrace	-175	PF 1	50.00	5297.50	5303.13	5298.27	5303.14	0.000009	0.28	175.92	41.61	0.02
Tailrace	-175	PF 2	100.00	5297.50	5303.57	5298.56	5303.57	0.000028	0.51	194.18	43.05	0.04
Tailrace	-175	PF 3	250.00	5297.50	5304.52	5299.20	5304.54	0.000102	1.06	236.72	46.23	0.08
Tailrace	-175	PF 4	450.00	5297.50	5305.51	5299.87	5305.55	0.000198	1.58	284.28	49.54	0.12
Tailrace	-175	PF 5	750.00	5297.50	5306.73	5300.66	5306.80	0.000316	2.16	347.03	53.60	0.15
Tailrace	-175	PF 6	1000.00	5297.50	5307.61	5301.23	5307.71	0.000392	2.53	395.39	56.52	0.17
Tailrace	-175	PF 7	1250.00	5297.50	5308.33	5301.75	5308.46	0.000479	2.86	437.35	60.55	0.19
Tailrace	-175	PF 8	1500.00	5297.50	5308.83	5302.20	5308.99	0.000596	3.20	468.71	64.68	0.21

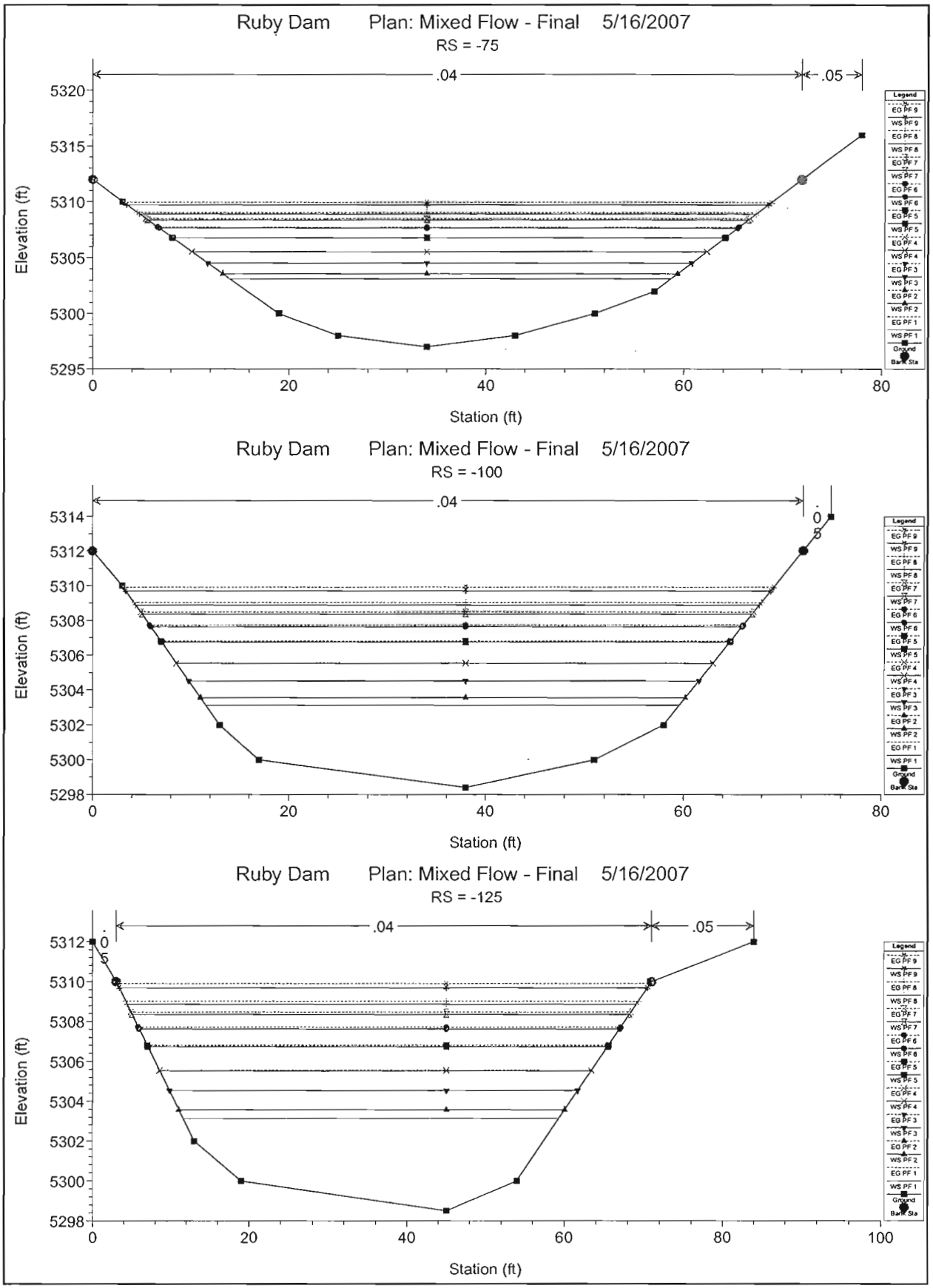
HEC-RAS Plan: Plan 05 River: Ruby River Reach: Tailrace (Continued)

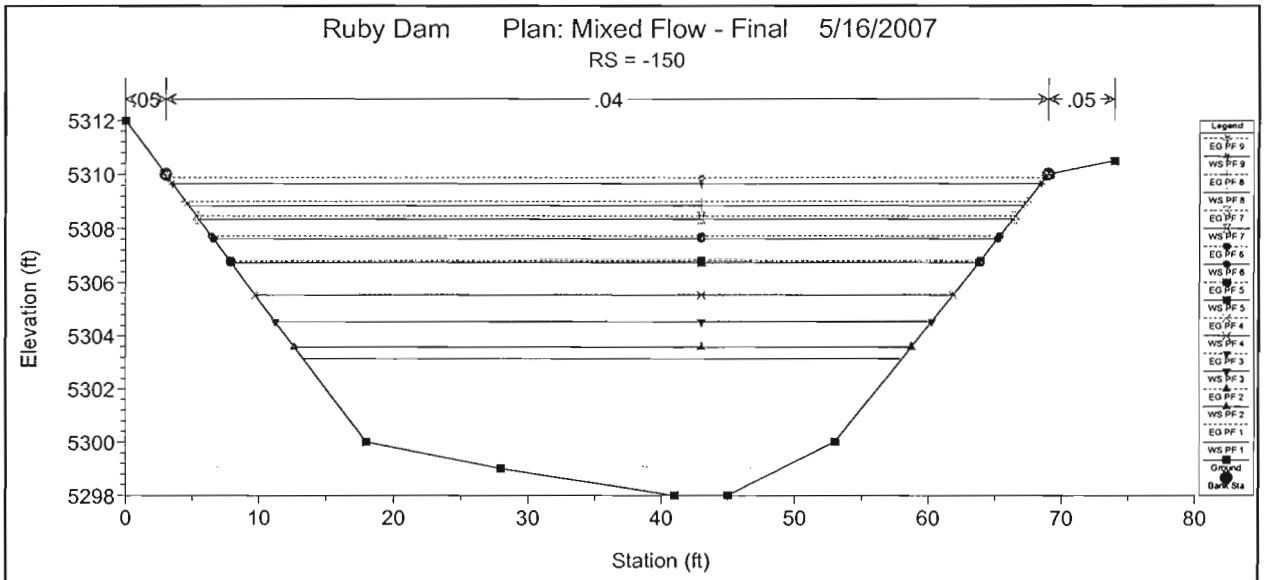
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Tailrace	-175	PF 9	2000.00	5297.50	5309.64	5303.04	5309.87	0.000818	3.82	523.65	70.43	0.25
Tailrace	-188		Inl Struct									
Tailrace	-200	PF 1	50.00	5296.00	5296.48	5296.48	5296.72	0.030488	3.92	12.77	26.73	1.00
Tailrace	-200	PF 2	100.00	5296.00	5296.76	5296.76	5297.14	0.027408	4.95	20.19	27.14	1.01
Tailrace	-200	PF 3	250.00	5296.00	5297.39	5297.39	5298.08	0.023030	6.63	37.69	28.09	1.01
Tailrace	-200	PF 4	450.00	5296.00	5298.05	5298.05	5299.04	0.020802	7.96	56.52	29.08	1.01
Tailrace	-200	PF 5	750.00	5296.00	5298.87	5298.87	5300.21	0.019188	9.29	80.71	30.30	1.00
Tailrace	-200	PF 6	1000.00	5296.00	5299.45	5299.45	5301.05	0.018560	10.14	98.57	31.17	1.01
Tailrace	-200	PF 7	1250.00	5296.00	5299.98	5299.98	5301.80	0.018033	10.83	115.42	31.97	1.00
Tailrace	-200	PF 8	1500.00	5296.00	5300.47	5300.47	5302.50	0.017675	11.42	131.31	32.71	1.00
Tailrace	-200	PF 9	2000.00	5296.00	5301.37	5301.37	5303.76	0.017143	12.40	161.25	34.06	1.00
Tailrace	-225	PF 1	50.00	5293.30	5294.08	5294.39	5295.15	0.164205	8.31	6.02	14.59	2.28
Tailrace	-225	PF 2	100.00	5293.30	5294.37	5294.79	5295.77	0.123729	9.52	10.51	16.74	2.12
Tailrace	-225	PF 3	250.00	5293.30	5294.98	5295.59	5296.95	0.088726	11.25	22.22	21.35	1.94
Tailrace	-225	PF 4	450.00	5293.30	5295.56	5296.31	5298.00	0.074665	12.53	35.92	25.72	1.87
Tailrace	-225	PF 5	750.00	5293.30	5296.20	5297.13	5299.23	0.065984	13.97	53.68	29.58	1.83
Tailrace	-225	PF 6	1000.00	5293.30	5296.64	5297.71	5300.09	0.059673	14.90	67.09	30.87	1.78
Tailrace	-225	PF 7	1250.00	5293.30	5297.04	5298.22	5300.87	0.055862	15.70	79.61	32.03	1.76
Tailrace	-225	PF 8	1500.00	5293.30	5297.41	5298.71	5301.57	0.053079	16.38	91.58	33.10	1.74
Tailrace	-225	PF 9	2000.00	5293.30	5298.07	5299.56	5302.84	0.049534	17.53	114.07	35.03	1.71
Tailrace	-250	PF 1	50.00	5292.50	5293.69	5293.69	5293.99	0.027952	4.38	11.41	19.11	1.00
Tailrace	-250	PF 2	100.00	5292.50	5294.06	5294.06	5294.47	0.026538	5.17	19.36	24.34	1.02
Tailrace	-250	PF 3	250.00	5292.50	5294.65	5294.75	5295.45	0.028306	7.18	34.82	27.89	1.13
Tailrace	-250	PF 4	450.00	5292.50	5295.12	5295.44	5296.45	0.034524	9.26	48.59	30.71	1.30
Tailrace	-250	PF 5	750.00	5292.50	5295.66	5296.23	5297.66	0.039464	11.34	66.11	33.96	1.43
Tailrace	-250	PF 6	1000.00	5292.50	5296.00	5296.75	5298.56	0.044057	12.85	77.84	35.97	1.54
Tailrace	-250	PF 7	1250.00	5292.50	5296.30	5297.24	5299.37	0.046602	14.06	88.92	37.34	1.61
Tailrace	-250	PF 8	1500.00	5292.50	5296.58	5297.66	5300.11	0.048387	15.08	99.49	38.59	1.65
Tailrace	-250	PF 9	2000.00	5292.50	5297.06	5298.44	5301.47	0.051761	16.86	118.61	40.76	1.74
Tailrace	-300	PF 1	50.00	5290.30	5291.28	5291.46	5291.86	0.070551	6.10	8.19	16.72	1.54
Tailrace	-300	PF 2	100.00	5290.30	5291.57	5291.83	5292.39	0.070228	7.25	13.80	21.70	1.60
Tailrace	-300	PF 3	250.00	5290.30	5292.11	5292.47	5293.36	0.063818	8.98	27.85	29.54	1.63
Tailrace	-300	PF 4	450.00	5290.30	5292.61	5293.10	5294.29	0.053329	10.40	43.28	32.00	1.58
Tailrace	-300	PF 5	750.00	5290.30	5293.18	5293.86	5295.43	0.049509	12.03	62.32	34.80	1.58
Tailrace	-300	PF 6	1000.00	5290.30	5293.57	5294.38	5296.24	0.048380	13.11	76.29	36.73	1.60
Tailrace	-300	PF 7	1250.00	5290.30	5293.90	5294.86	5296.98	0.048557	14.09	88.74	38.36	1.63
Tailrace	-300	PF 8	1500.00	5290.30	5294.21	5295.29	5297.66	0.048565	14.91	100.59	39.85	1.65
Tailrace	-300	PF 9	2000.00	5290.30	5294.74	5296.02	5298.87	0.048707	16.30	122.70	42.49	1.69
Tailrace	-350	PF 1	50.00	5289.60	5290.68	5290.41	5290.80	0.008504	2.77	18.08	24.77	0.57
Tailrace	-350	PF 2	100.00	5289.60	5291.07	5290.75	5291.26	0.008950	3.49	28.66	28.73	0.62
Tailrace	-350	PF 3	250.00	5289.60	5291.88	5291.42	5292.20	0.008896	4.55	54.98	36.76	0.66
Tailrace	-350	PF 4	450.00	5289.60	5292.61	5292.06	5293.06	0.008149	5.38	83.67	40.44	0.66
Tailrace	-350	PF 5	750.00	5289.60	5293.46	5292.74	5294.08	0.007779	6.28	119.41	43.82	0.67
Tailrace	-350	PF 6	1000.00	5289.60	5294.05	5293.24	5294.78	0.007626	6.85	146.06	46.18	0.68
Tailrace	-350	PF 7	1250.00	5289.60	5294.58	5293.68	5295.41	0.007543	7.32	170.78	48.27	0.69
Tailrace	-350	PF 8	1500.00	5289.60	5295.05	5294.08	5295.98	0.007486	7.73	194.16	50.16	0.69
Tailrace	-350	PF 9	2000.00	5289.60	5295.90	5294.81	5296.99	0.007422	8.41	237.90	53.52	0.70
Tailrace	-400	PF 1	50.00	5288.90	5290.10	5289.95	5290.26	0.014015	3.22	15.52	24.60	0.72
Tailrace	-400	PF 2	100.00	5288.90	5290.44	5290.26	5290.70	0.014000	4.10	24.37	26.79	0.76
Tailrace	-400	PF 3	250.00	5288.90	5291.15	5290.94	5291.63	0.014016	5.55	45.03	31.29	0.82
Tailrace	-400	PF 4	450.00	5288.90	5291.83	5291.59	5292.51	0.014010	6.66	67.56	35.56	0.85
Tailrace	-400	PF 5	750.00	5288.90	5292.58	5292.35	5293.53	0.014017	7.84	95.70	39.26	0.88
Tailrace	-400	PF 6	1000.00	5288.90	5293.09	5292.87	5294.23	0.014005	8.58	116.60	41.58	0.90
Tailrace	-400	PF 7	1250.00	5288.90	5293.55	5293.34	5294.86	0.014026	9.19	136.01	43.63	0.92
Tailrace	-400	PF 8	1500.00	5288.90	5293.96	5293.76	5295.43	0.014019	9.71	154.49	45.50	0.93
Tailrace	-400	PF 9	2000.00	5288.90	5294.70	5294.52	5296.43	0.014008	10.57	189.18	48.81	0.95

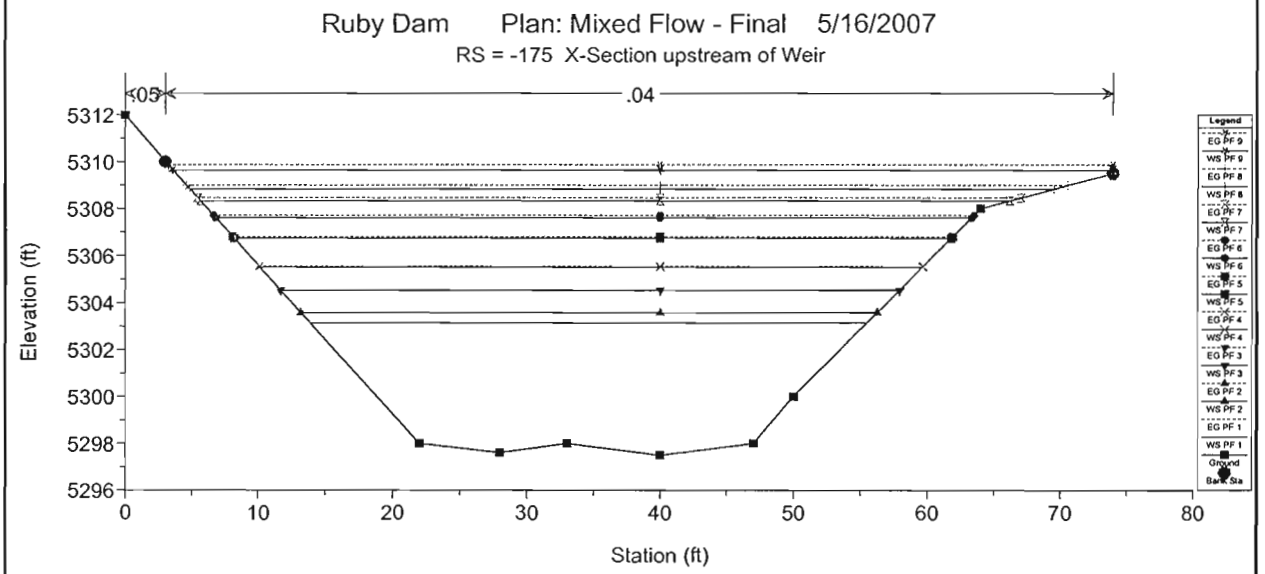

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = 000 X-Section downstream of existing outlet apron
.04
Elevation (ft)
Station (ft)
Legend

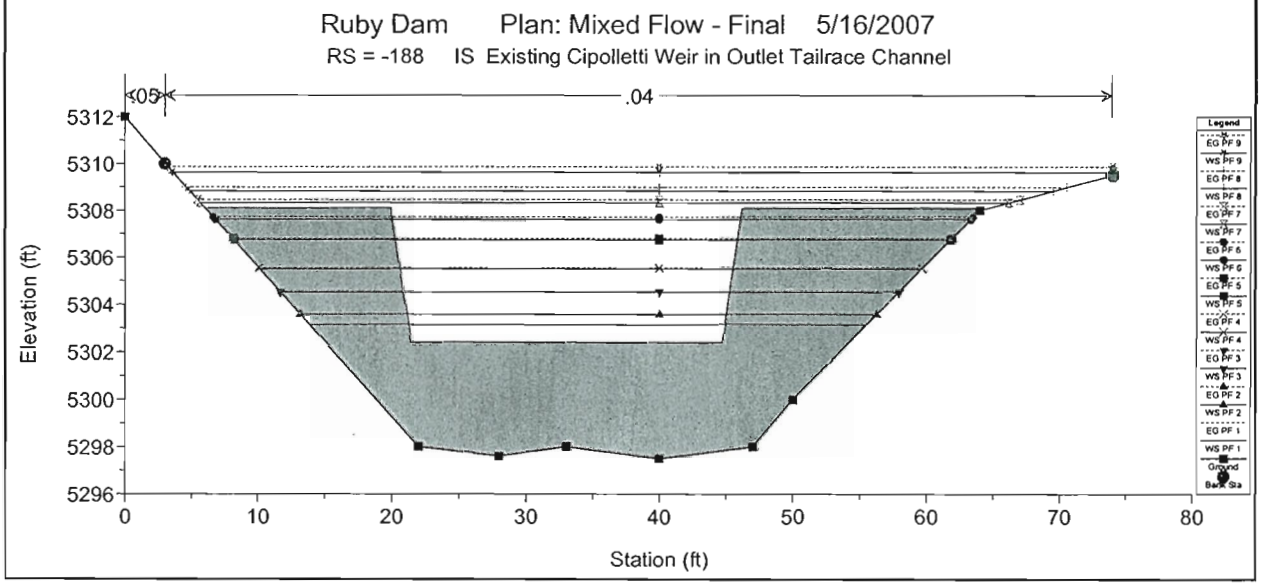

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -25
.04
.05
Elevation (ft)
Station (ft)
Legend

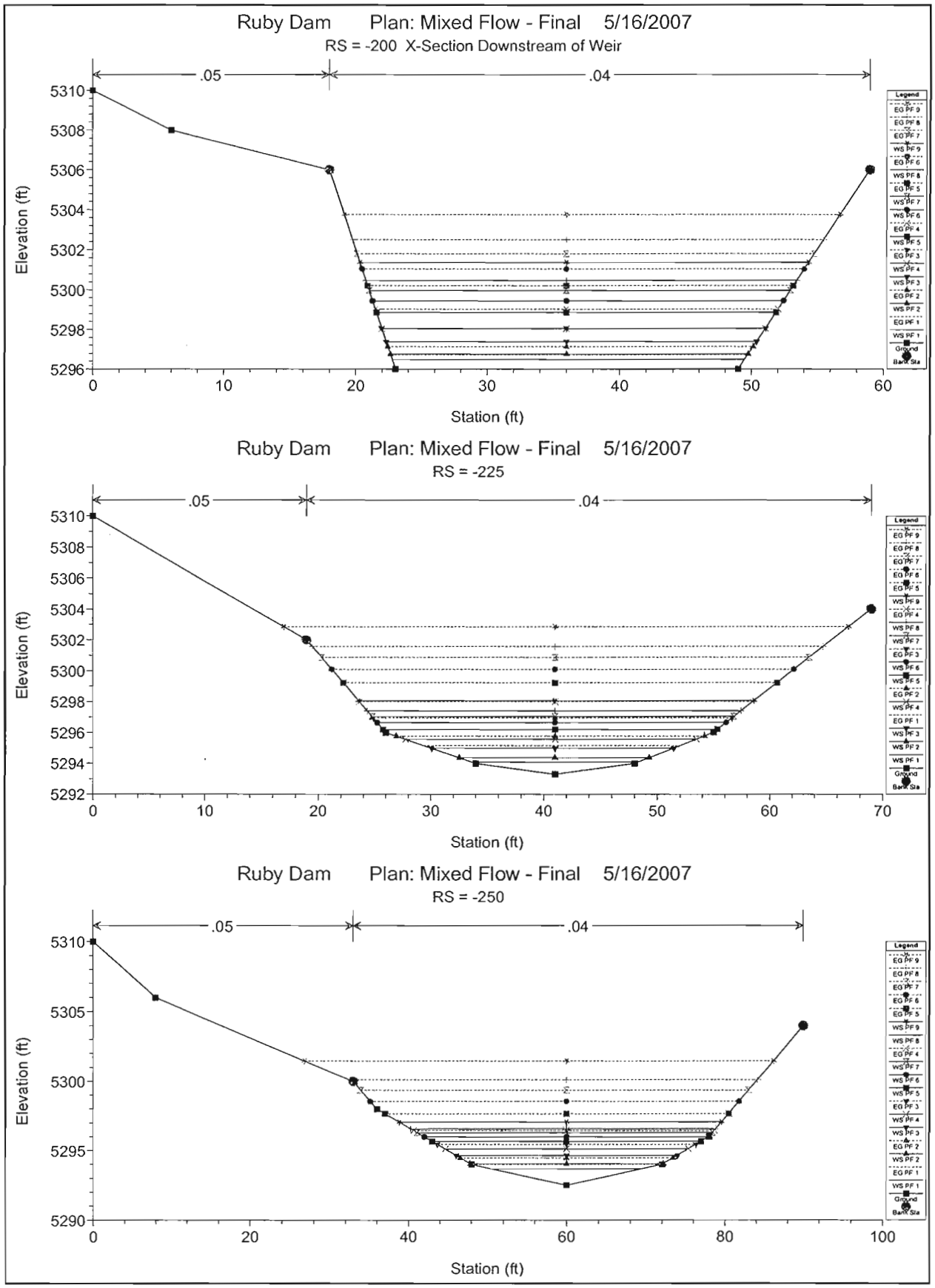

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -50
.04
.05
Elevation (ft)
Station (ft)
Legend

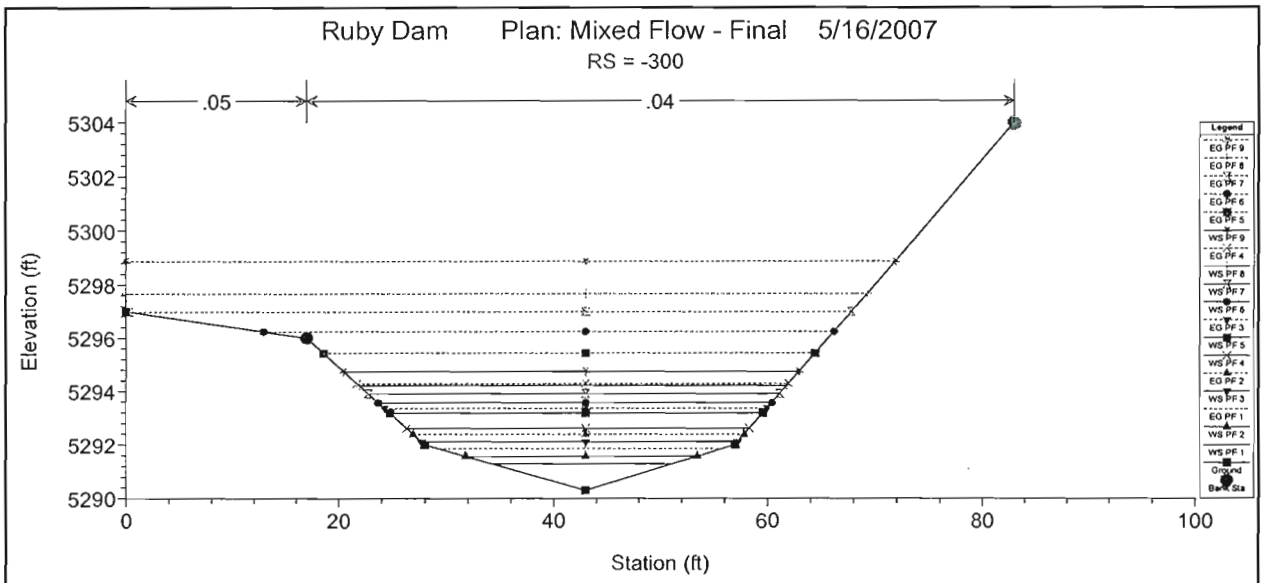

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -75
.04
.05
Elevation (ft)
Station (ft)
Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -100
.04
.05
Elevation (ft)
Station (ft)
Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -125
.04
.05
Elevation (ft)
Station (ft)
Legend
EG PF 9
WS PF 9
EG PF 8
WS PF 8
EG PF 7
WS PF 7
EG PF 6
WS PF 6
EG PF 5
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta

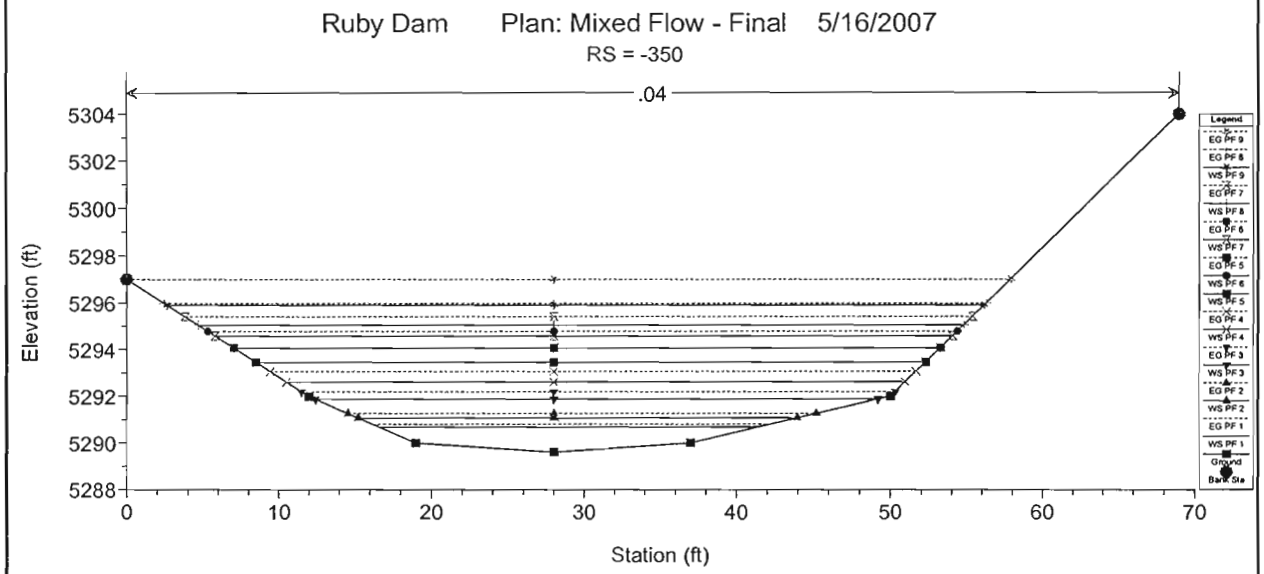

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -150
.05
.04
.05
Elevation (ft)
Station (ft)
Legend
EG PF 9
WS PF 9
EG PF 8
WS PF 8
EG PF 7
WS PF 7
EG PF 6
WS PF 6
EG PF 5
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta

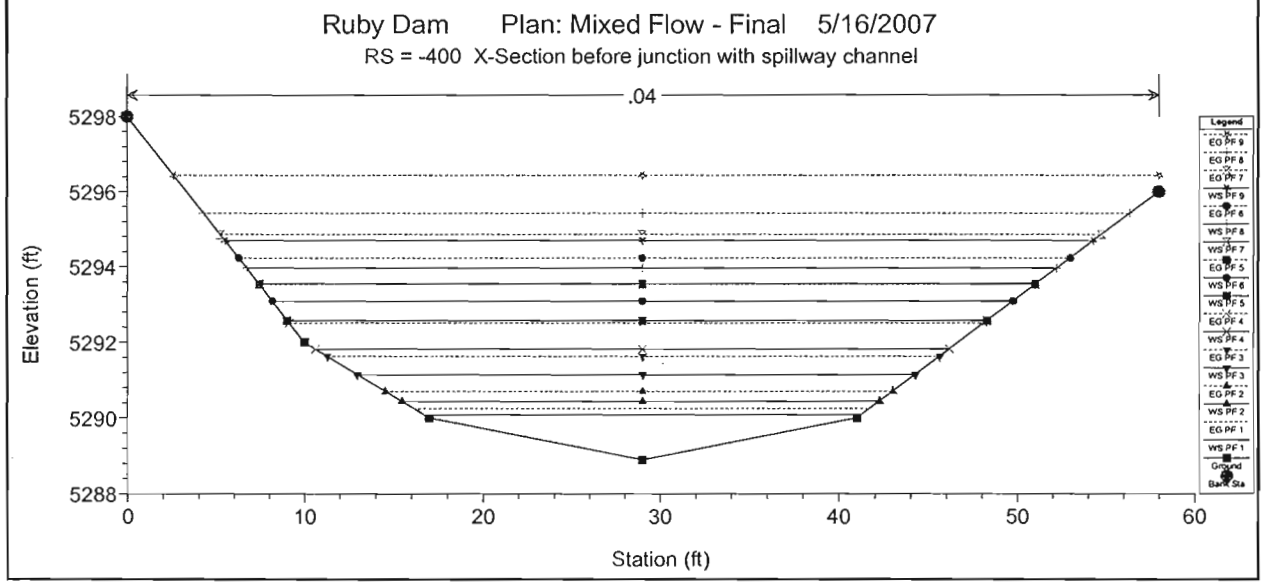

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -175 X-Section upstream of Weir
.05
.04
Elevation (ft)
Station (ft)
Legend
EG PF 9
WS PF 9
EG PF 8
WS PF 8
EG PF 7
WS PF 7
EG PF 6
WS PF 6
EG PF 5
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta


Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -188 IS Existing Cipolletti Weir in Outlet Tailrace Channel
.05
.04
Elevation (ft)
Station (ft)
Legend
EG PF 9
WS PF 9
EG PF 8
WS PF 8
EG PF 7
WS PF 7
EG PF 6
WS PF 6
EG PF 5
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta

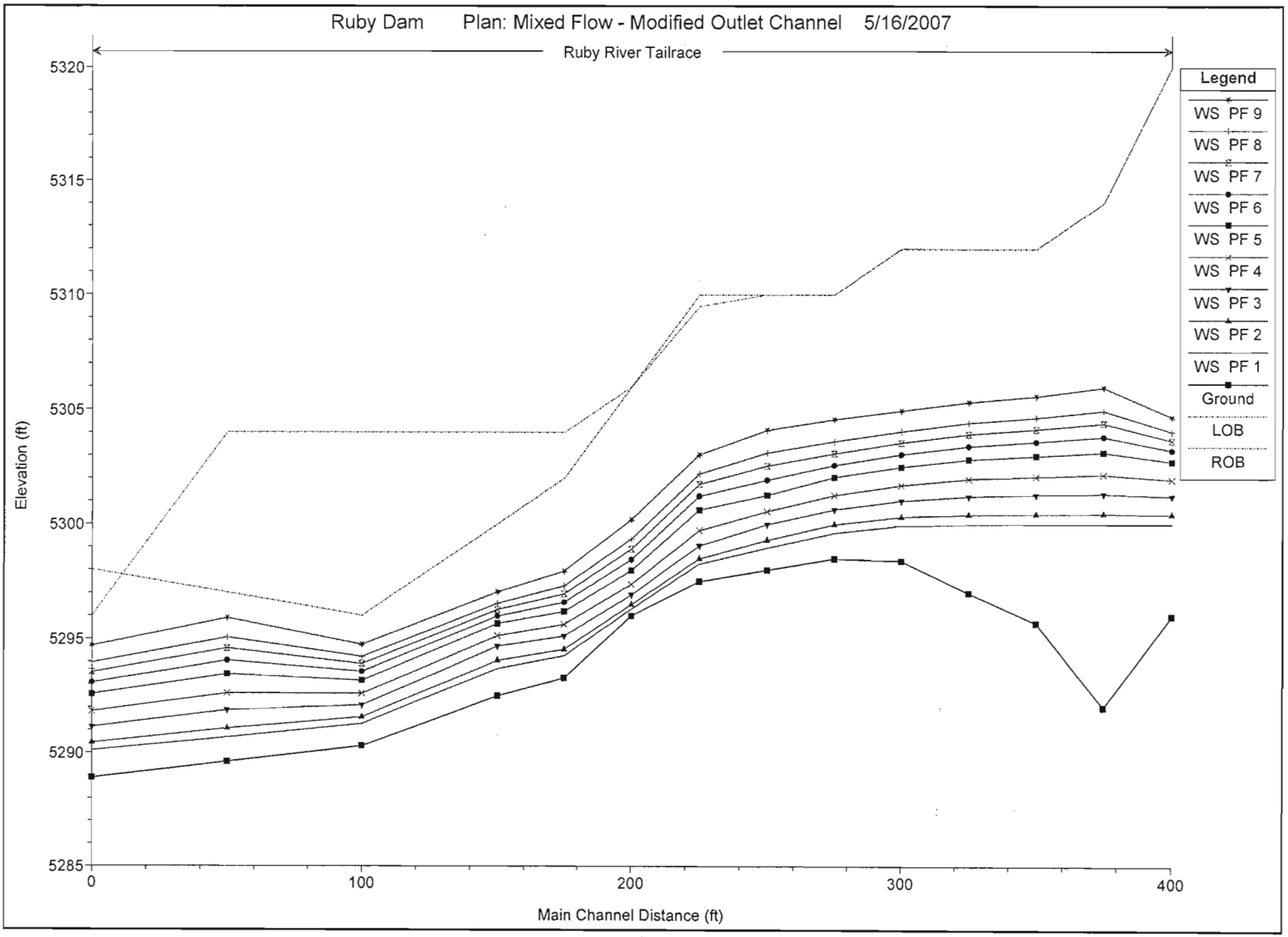

Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -200 X-Section Downstream of Weir
.05
.04
Elevation (ft)
Station (ft)
Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -225
.05
.04
Elevation (ft)
Station (ft)
Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -250
.05
.04
Elevation (ft)
Station (ft)
Legend
EG PF 9
EG PF 8
EG PF 7
WS PF 9
EG PF 6
WS PF 8
EG PF 5
WS PF 7
WS PF 6
EG PF 4
WS PF 5
EG PF 3
WS PF 4
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta


Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -300
.05
.04
Elevation (ft)
Station (ft)
Legend


Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -350
.04
Elevation (ft)
Station (ft)
Legend


Ruby Dam Plan: Mixed Flow - Final 5/16/2007
RS = -400 X-Section before junction with spillway channel
.04
Elevation (ft)
Station (ft)
Legend

Outlet Channel Without Weir

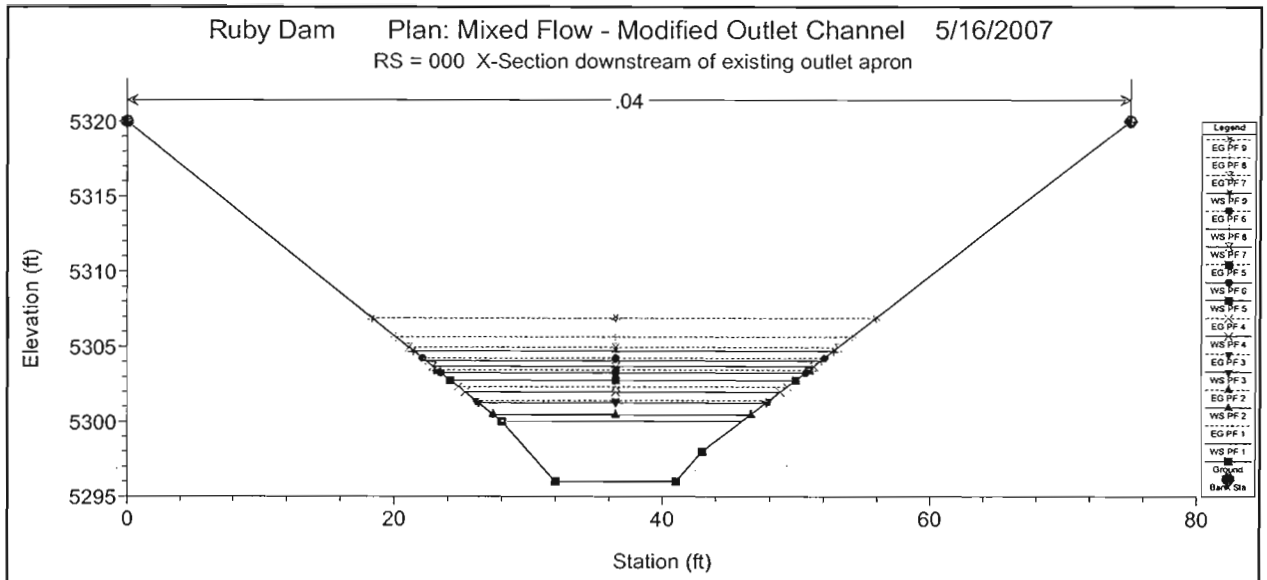

Ruby Dam Plan: Mixed Flow - Modified Outlet Channel 5/16/2007
Ruby River Tailrace
Elevation (ft)
5320
5315
5310
5305
5300
5295
5290
5285
0
100
200
300
400
Main Channel Distance (ft)
Legend
WS PF 9
WS PF 8
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
LOB
ROB

HEC-RAS Plan: Flow 6 River: Ruby River Reach: Tailrace

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Tailrace	000	PF 1	50.00	5296.00	5300.02	5296.94	5300.03	0.000186	0.94	53.20	17.96	0.10
Tailrace	000	PF 2	100.00	5296.00	5300.44	5297.47	5300.49	0.000513	1.64	61.15	19.18	0.16
Tailrace	000	PF 3	250.00	5296.00	5301.24	5298.61	5301.41	0.001709	3.23	77.37	21.46	0.30
Tailrace	000	PF 4	450.00	5296.00	5301.97	5299.70	5302.33	0.003325	4.81	93.64	23.52	0.42
Tailrace	000	PF 5	750.00	5296.00	5302.75	5300.93	5303.44	0.005601	6.64	112.95	25.76	0.56
Tailrace	000	PF 6	1000.00	5296.00	5303.25	5301.78	5304.22	0.007422	7.93	126.11	27.18	0.65
Tailrace	000	PF 7	1250.00	5296.00	5303.67	5302.49	5304.95	0.009133	9.06	137.93	28.39	0.72
Tailrace	000	PF 8	1500.00	5296.00	5304.06	5303.12	5305.63	0.010688	10.06	149.09	29.49	0.79
Tailrace	000	PF 9	2000.00	5296.00	5304.71	5304.26	5306.89	0.013615	11.84	168.95	31.36	0.90
Tailrace	-25	PF 1	50.00	5292.00	5300.03		5300.03	0.000004	0.23	217.17	38.17	0.02
Tailrace	-25	PF 2	100.00	5292.00	5300.47		5300.47	0.000015	0.43	234.39	39.18	0.03
Tailrace	-25	PF 3	250.00	5292.00	5301.34		5301.36	0.000062	0.93	269.43	41.17	0.06
Tailrace	-25	PF 4	450.00	5292.00	5302.18		5302.22	0.000142	1.48	304.87	43.08	0.10
Tailrace	-25	PF 5	750.00	5292.00	5303.16		5303.23	0.000274	2.16	347.94	45.30	0.14
Tailrace	-25	PF 6	1000.00	5292.00	5303.83		5303.94	0.000386	2.64	378.85	46.83	0.16
Tailrace	-25	PF 7	1250.00	5292.00	5304.43		5304.58	0.000494	3.07	407.39	48.20	0.19
Tailrace	-25	PF 8	1500.00	5292.00	5304.99		5305.17	0.000596	3.45	434.69	49.47	0.21
Tailrace	-25	PF 9	2000.00	5292.00	5305.99		5306.26	0.000784	4.12	485.54	51.76	0.24
Tailrace	-50	PF 1	50.00	5295.70	5300.02		5300.03	0.000053	0.53	93.83	32.40	0.06
Tailrace	-50	PF 2	100.00	5295.70	5300.46		5300.47	0.000141	0.92	108.32	33.86	0.09
Tailrace	-50	PF 3	250.00	5295.70	5301.30		5301.35	0.000443	1.81	137.92	36.66	0.16
Tailrace	-50	PF 4	450.00	5295.70	5302.09		5302.20	0.000822	2.68	168.07	39.29	0.23
Tailrace	-50	PF 5	750.00	5295.70	5303.00		5303.20	0.001308	3.66	204.95	42.21	0.29
Tailrace	-50	PF 6	1000.00	5295.70	5303.61		5303.90	0.001655	4.32	231.55	44.19	0.33
Tailrace	-50	PF 7	1250.00	5295.70	5304.16		5304.53	0.001949	4.88	256.38	45.97	0.36
Tailrace	-50	PF 8	1500.00	5295.70	5304.68		5305.12	0.002189	5.35	280.48	47.63	0.39
Tailrace	-50	PF 9	2000.00	5295.70	5305.61		5306.19	0.002568	6.13	326.20	50.63	0.43
Tailrace	-75	PF 1	50.00	5297.00	5300.01		5300.02	0.000233	0.84	59.34	32.05	0.11
Tailrace	-75	PF 2	100.00	5297.00	5300.44		5300.46	0.000500	1.36	73.34	34.00	0.16
Tailrace	-75	PF 3	250.00	5297.00	5301.23		5301.33	0.001205	2.45	101.99	37.68	0.26
Tailrace	-75	PF 4	450.00	5297.00	5301.98		5302.17	0.001891	3.42	131.56	41.13	0.34
Tailrace	-75	PF 5	750.00	5297.00	5302.84		5303.15	0.002565	4.47	167.87	43.80	0.40
Tailrace	-75	PF 6	1000.00	5297.00	5303.42		5303.83	0.002998	5.16	193.89	45.61	0.44
Tailrace	-75	PF 7	1250.00	5297.00	5303.95		5304.46	0.003330	5.73	218.21	47.23	0.47
Tailrace	-75	PF 8	1500.00	5297.00	5304.44		5305.04	0.003562	6.20	242.02	48.77	0.49
Tailrace	-75	PF 9	2000.00	5297.00	5305.35		5306.10	0.003883	6.96	287.37	51.57	0.52
Tailrace	-100	PF 1	50.00	5298.40	5299.94		5300.00	0.004061	1.98	25.21	32.73	0.40
Tailrace	-100	PF 2	100.00	5298.40	5300.32		5300.43	0.004494	2.60	38.46	35.78	0.44
Tailrace	-100	PF 3	250.00	5298.40	5301.03		5301.26	0.005633	3.84	65.05	39.65	0.53
Tailrace	-100	PF 4	450.00	5298.40	5301.71		5302.07	0.006225	4.82	93.30	43.39	0.58
Tailrace	-100	PF 5	750.00	5298.40	5302.51		5303.03	0.006390	5.79	129.58	46.36	0.61
Tailrace	-100	PF 6	1000.00	5298.40	5303.06		5303.71	0.006500	6.43	155.54	47.83	0.63
Tailrace	-100	PF 7	1250.00	5298.40	5303.57		5304.32	0.006513	6.94	180.13	49.19	0.64
Tailrace	-100	PF 8	1500.00	5298.40	5304.06		5304.90	0.006382	7.33	204.76	50.50	0.64
Tailrace	-100	PF 9	2000.00	5298.40	5304.98		5305.95	0.006129	7.94	251.88	52.93	0.64
Tailrace	-125	PF 1	50.00	5298.50	5299.62		5299.80	0.018093	3.39	14.74	26.23	0.80
Tailrace	-125	PF 2	100.00	5298.50	5300.00		5300.23	0.015532	3.81	26.25	35.00	0.78
Tailrace	-125	PF 3	250.00	5298.50	5300.65		5301.04	0.012945	5.02	49.80	38.03	0.77
Tailrace	-125	PF 4	450.00	5298.50	5301.27		5301.84	0.012196	6.04	74.49	40.97	0.79
Tailrace	-125	PF 5	750.00	5298.50	5302.06		5302.80	0.011038	6.94	108.13	44.56	0.78
Tailrace	-125	PF 6	1000.00	5298.50	5302.59		5303.48	0.010602	7.56	132.19	46.13	0.79
Tailrace	-125	PF 7	1250.00	5298.50	5303.10		5304.09	0.010010	8.01	156.09	47.63	0.78
Tailrace	-125	PF 8	1500.00	5298.50	5303.63		5304.69	0.009116	8.25	181.82	49.20	0.76
Tailrace	-125	PF 9	2000.00	5298.50	5304.59		5305.76	0.007987	8.67	230.76	52.05	0.73
Tailrace	-150	PF 1	50.00	5298.00	5298.97	5298.95	5299.25	0.027118	4.23	11.83	20.45	0.98
Tailrace	-150	PF 2	100.00	5298.00	5299.31	5299.31	5299.71	0.026260	5.06	19.75	25.38	1.01
Tailrace	-150	PF 3	250.00	5298.00	5300.00	5300.00	5300.59	0.023205	6.19	40.38	34.95	1.02
Tailrace	-150	PF 4	450.00	5298.00	5300.56	5300.56	5301.42	0.020856	7.41	60.73	36.75	1.02
Tailrace	-150	PF 5	750.00	5298.00	5301.27	5301.27	5302.41	0.018722	8.57	87.56	38.95	1.01
Tailrace	-150	PF 6	1000.00	5298.00	5301.93	5301.77	5303.13	0.014983	8.78	113.91	40.99	0.93
Tailrace	-150	PF 7	1250.00	5298.00	5302.55	5302.25	5303.79	0.012648	8.93	139.93	42.91	0.87
Tailrace	-150	PF 8	1500.00	5298.00	5303.13	5302.65	5304.41	0.011135	9.08	165.23	44.70	0.83
Tailrace	-150	PF 9	2000.00	5298.00	5304.11	5303.40	5305.51	0.009719	9.49	210.74	47.75	0.80
Tailrace	-175	PF 1	50.00	5297.50	5298.27	5298.27	5298.52	0.030968	4.00	12.49	25.82	1.01
Tailrace	-175	PF 2	100.00	5297.50	5298.49	5298.56	5298.95	0.035373	5.43	18.42	26.52	1.15
Tailrace	-175	PF 3	250.00	5297.50	5299.06	5299.20	5299.90	0.031560	7.35	34.03	28.28	1.18
Tailrace	-175	PF 4	450.00	5297.50	5299.73	5299.87	5300.83	0.025098	8.40	53.58	30.34	1.11
Tailrace	-175	PF 5	750.00	5297.50	5300.63	5300.66	5301.92	0.019336	9.14	82.05	33.25	1.03
Tailrace	-175	PF 6	1000.00	5297.50	5301.23	5301.23	5302.70	0.017683	9.73	102.81	35.27	1.00
Tailrace	-175	PF 7	1250.00	5297.50	5301.75	5301.75	5303.39	0.016979	10.29	121.51	37.00	1.00
Tailrace	-175	PF 8	1500.00	5297.50	5302.20	5302.20	5304.02	0.016705	10.82	138.64	38.51	1.00

HEC-RAS Plan: Flow 6 River: Ruby River Reach: Tailrace (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Tailrace	-175	PF 9	2000.00	5297.50	5303.04	5303.04	5305.14	0.016025	11.63	172.00	41.30	1.00
Tailrace	-200	PF 1	50.00	5296.00	5296.29	5296.48	5296.96	0.166562	6.56	7.62	26.44	2.16
Tailrace	-200	PF 2	100.00	5296.00	5296.49	5296.76	5297.42	0.117957	7.75	12.90	26.73	1.97
Tailrace	-200	PF 3	250.00	5296.00	5296.91	5297.39	5298.55	0.093857	10.28	24.31	27.37	1.92
Tailrace	-200	PF 4	450.00	5296.00	5297.37	5298.06	5299.67	0.079664	12.19	36.92	28.05	1.87
Tailrace	-200	PF 5	750.00	5296.00	5297.97	5298.86	5300.94	0.065672	13.82	54.25	28.96	1.78
Tailrace	-200	PF 6	1000.00	5296.00	5298.45	5299.45	5301.79	0.057155	14.65	68.25	29.68	1.70
Tailrace	-200	PF 7	1250.00	5296.00	5298.91	5299.98	5302.52	0.050720	15.24	82.03	30.37	1.63
Tailrace	-200	PF 8	1500.00	5296.00	5299.35	5300.48	5303.18	0.045935	15.70	95.52	31.03	1.58
Tailrace	-200	PF 9	2000.00	5296.00	5300.20	5301.37	5304.34	0.038639	16.33	122.50	32.30	1.48
Tailrace	-225	PF 1	50.00	5293.30	5294.26	5294.39	5294.76	0.052327	5.68	8.80	15.95	1.35
Tailrace	-225	PF 2	100.00	5293.30	5294.54	5294.79	5295.38	0.058457	7.37	13.57	18.06	1.50
Tailrace	-225	PF 3	250.00	5293.30	5295.12	5295.59	5296.64	0.061415	9.88	25.31	22.41	1.64
Tailrace	-225	PF 4	450.00	5293.30	5295.63	5296.30	5297.85	0.065420	11.95	37.67	26.22	1.76
Tailrace	-225	PF 5	750.00	5293.30	5296.18	5297.12	5299.26	0.067634	14.09	53.25	29.53	1.85
Tailrace	-225	PF 6	1000.00	5293.30	5296.58	5297.71	5300.23	0.065094	15.34	65.18	30.69	1.86
Tailrace	-225	PF 7	1250.00	5293.30	5296.95	5298.22	5301.07	0.062206	16.28	76.79	31.77	1.85
Tailrace	-225	PF 8	1500.00	5293.30	5297.30	5298.71	5301.81	0.059803	17.05	87.96	32.78	1.83
Tailrace	-225	PF 9	2000.00	5293.30	5297.95	5299.56	5303.09	0.055321	18.21	109.83	34.67	1.80
Tailrace	-250	PF 1	50.00	5292.50	5293.69	5293.69	5293.99	0.027952	4.38	11.41	19.11	1.00
Tailrace	-250	PF 2	100.00	5292.50	5294.06	5294.06	5294.47	0.026538	5.17	19.36	24.34	1.02
Tailrace	-250	PF 3	250.00	5292.50	5294.67	5294.75	5295.44	0.026726	7.04	35.51	28.04	1.10
Tailrace	-250	PF 4	450.00	5292.50	5295.13	5295.44	5296.44	0.033521	9.17	49.08	30.81	1.28
Tailrace	-250	PF 5	750.00	5292.50	5295.66	5296.23	5297.66	0.039691	11.37	65.98	33.94	1.44
Tailrace	-250	PF 6	1000.00	5292.50	5295.98	5296.75	5298.58	0.045029	12.95	77.25	35.87	1.55
Tailrace	-250	PF 7	1250.00	5292.50	5296.27	5297.25	5299.42	0.048462	14.25	87.74	37.20	1.63
Tailrace	-250	PF 8	1500.00	5292.50	5296.53	5297.67	5300.18	0.050746	15.33	97.87	38.40	1.69
Tailrace	-250	PF 9	2000.00	5292.50	5297.03	5298.44	5301.54	0.053339	17.04	117.38	40.63	1.77
Tailrace	-300	PF 1	50.00	5290.30	5291.28	5291.46	5291.86	0.070551	6.10	8.19	16.72	1.54
Tailrace	-300	PF 2	100.00	5290.30	5291.57	5291.83	5292.39	0.070228	7.25	13.80	21.70	1.60
Tailrace	-300	PF 3	250.00	5290.30	5292.09	5292.47	5293.39	0.067108	9.12	27.41	29.46	1.67
Tailrace	-300	PF 4	450.00	5290.30	5292.60	5293.10	5294.30	0.054156	10.45	43.07	31.97	1.59
Tailrace	-300	PF 5	750.00	5290.30	5293.18	5293.87	5295.43	0.049469	12.03	62.34	34.81	1.58
Tailrace	-300	PF 6	1000.00	5290.30	5293.57	5294.38	5296.24	0.048414	13.11	76.27	36.72	1.60
Tailrace	-300	PF 7	1250.00	5290.30	5293.91	5294.86	5296.97	0.048052	14.04	89.05	38.40	1.62
Tailrace	-300	PF 8	1500.00	5290.30	5294.21	5295.28	5297.65	0.048159	14.87	100.88	39.88	1.65
Tailrace	-300	PF 9	2000.00	5290.30	5294.74	5296.02	5298.87	0.048755	16.30	122.66	42.48	1.69
Tailrace	-350	PF 1	50.00	5289.60	5290.68	5290.41	5290.80	0.008504	2.77	18.08	24.77	0.57
Tailrace	-350	PF 2	100.00	5289.60	5291.07	5290.75	5291.26	0.008937	3.49	28.68	28.73	0.62
Tailrace	-350	PF 3	250.00	5289.60	5291.88	5291.42	5292.20	0.008904	4.55	54.96	36.76	0.66
Tailrace	-350	PF 4	450.00	5289.60	5292.61	5292.06	5293.06	0.008149	5.38	83.67	40.44	0.66
Tailrace	-350	PF 5	750.00	5289.60	5293.46	5292.74	5294.07	0.007784	6.28	119.39	43.82	0.67
Tailrace	-350	PF 6	1000.00	5289.60	5294.06	5293.24	5294.78	0.007619	6.84	146.11	46.19	0.68
Tailrace	-350	PF 7	1250.00	5289.60	5294.58	5293.68	5295.41	0.007528	7.31	170.90	48.28	0.69
Tailrace	-350	PF 8	1500.00	5289.60	5295.06	5294.08	5295.98	0.007475	7.72	194.26	50.17	0.69
Tailrace	-350	PF 9	2000.00	5289.60	5295.90	5294.81	5297.00	0.007408	8.40	238.06	53.53	0.70
Tailrace	-400	PF 1	50.00	5288.90	5290.10	5289.95	5290.26	0.014015	3.22	15.52	24.60	0.72
Tailrace	-400	PF 2	100.00	5288.90	5290.44	5290.26	5290.70	0.014000	4.10	24.37	26.79	0.76
Tailrace	-400	PF 3	250.00	5288.90	5291.15	5290.94	5291.63	0.014016	5.55	45.03	31.29	0.82
Tailrace	-400	PF 4	450.00	5288.90	5291.83	5291.59	5292.51	0.014010	6.66	67.56	35.56	0.85
Tailrace	-400	PF 5	750.00	5288.90	5292.58	5292.35	5293.53	0.014017	7.84	95.70	39.26	0.88
Tailrace	-400	PF 6	1000.00	5288.90	5293.09	5292.87	5294.23	0.014005	8.58	116.60	41.58	0.90
Tailrace	-400	PF 7	1250.00	5288.90	5293.55	5293.34	5294.86	0.014026	9.19	136.01	43.63	0.92
Tailrace	-400	PF 8	1500.00	5288.90	5293.96	5293.78	5295.43	0.014019	9.71	154.49	45.50	0.93
Tailrace	-400	PF 9	2000.00	5288.90	5294.70	5294.52	5296.43	0.014008	10.57	189.18	48.81	0.95


Ruby Dam Plan: Mixed Flow - Modified Outlet Channel 5/16/2007
RS = 000 X-Section downstream of existing outlet apron
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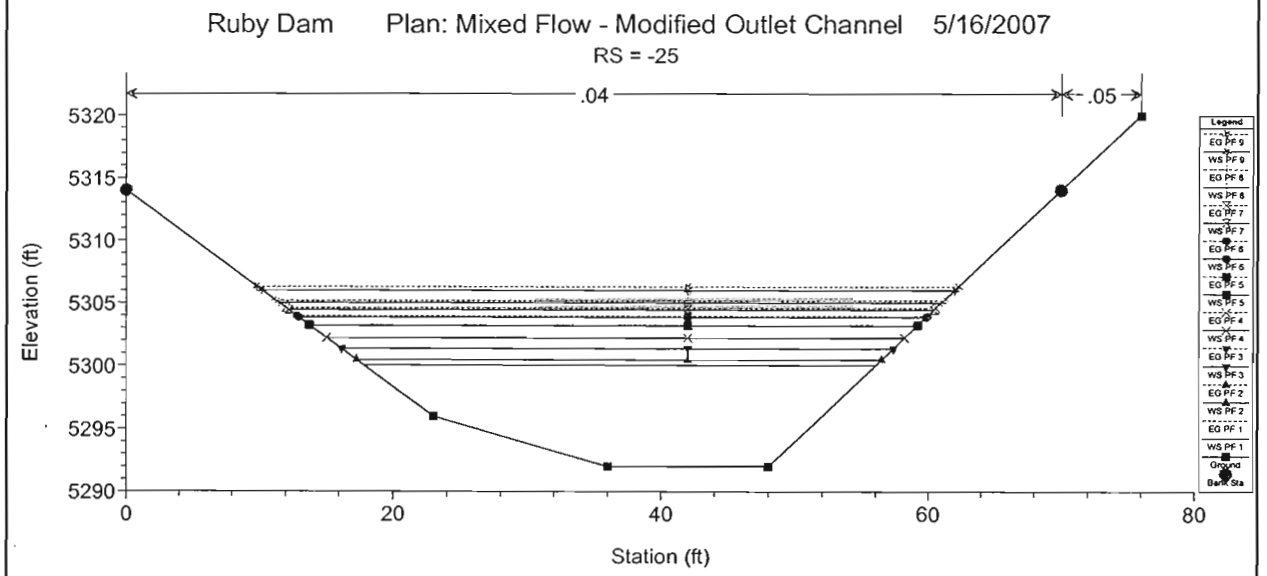
Elevation (ft)
Station (ft)
Legend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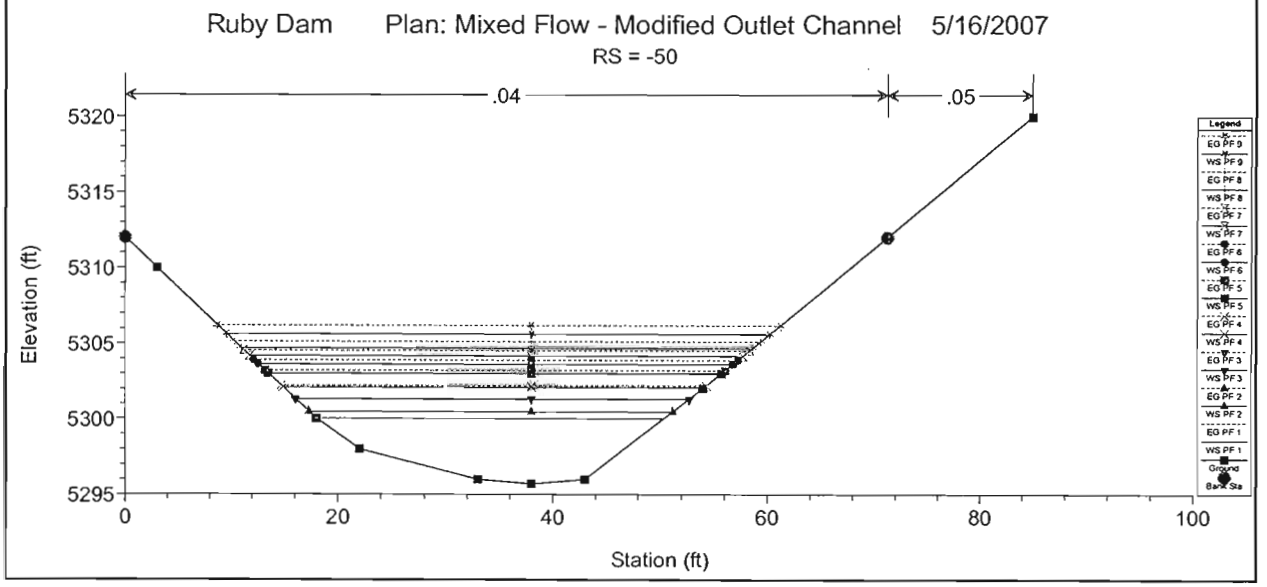
.04
.05
Elevation (ft)
Station (ft)
Legend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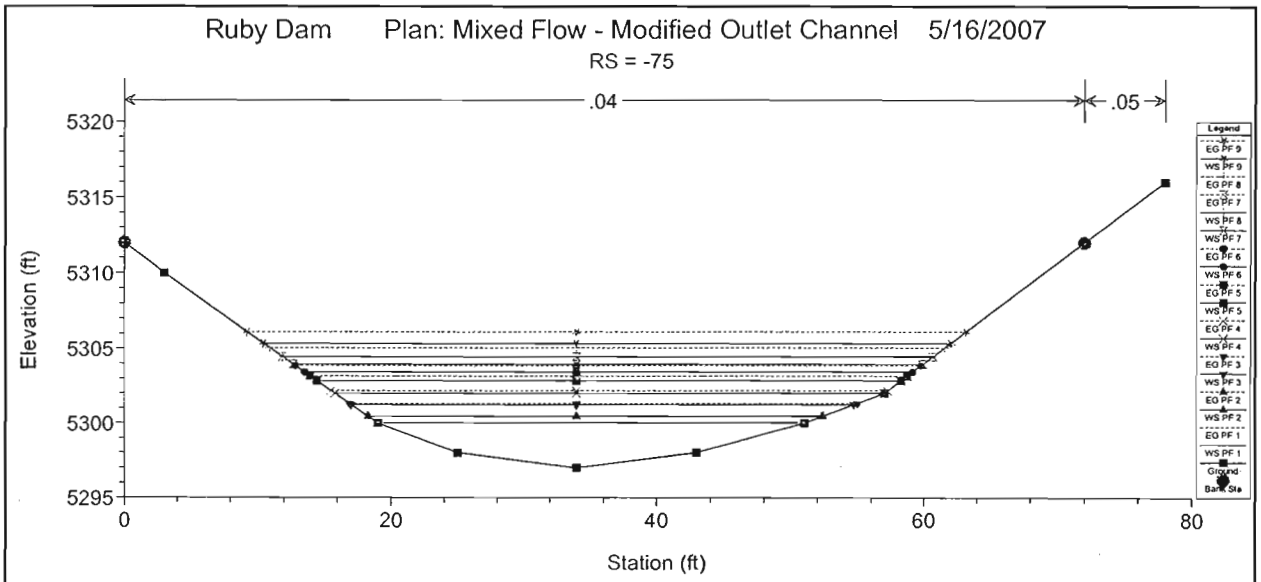
Station (ft)
Legend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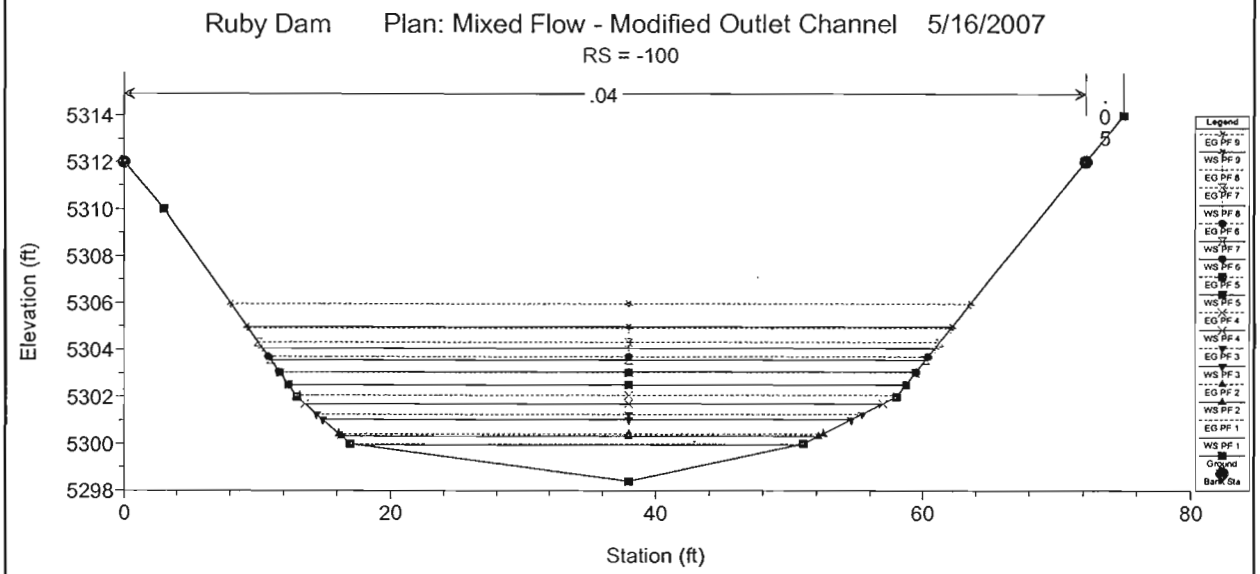
Elevation (ft)
Station (ft)
Legend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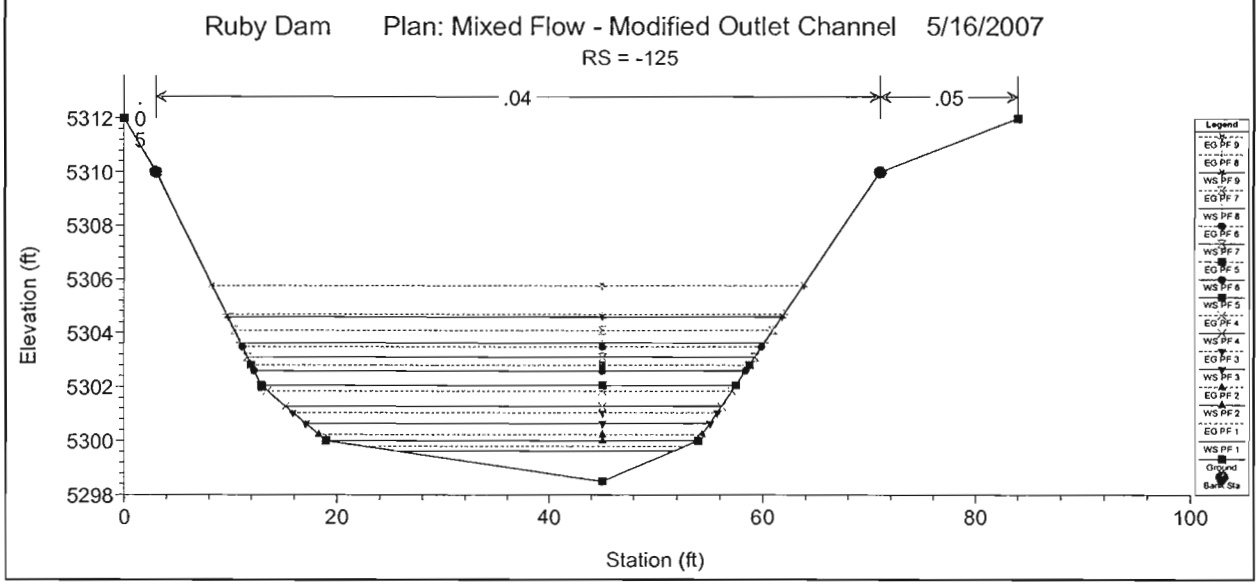
Elevation (ft)
Station (ft)
Legend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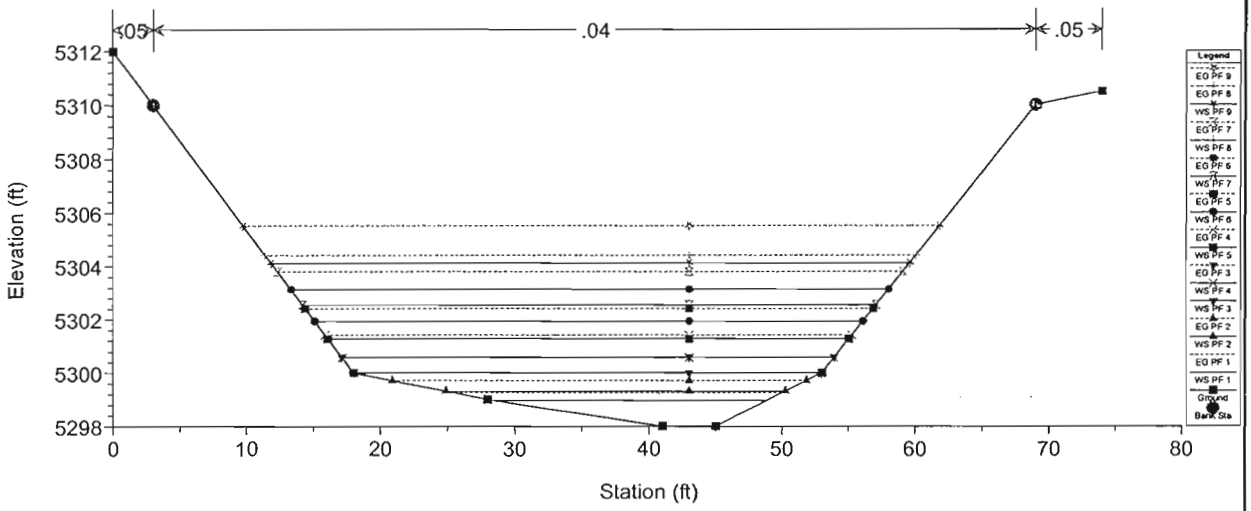
Elevation (ft)
Station (ft)
Legend

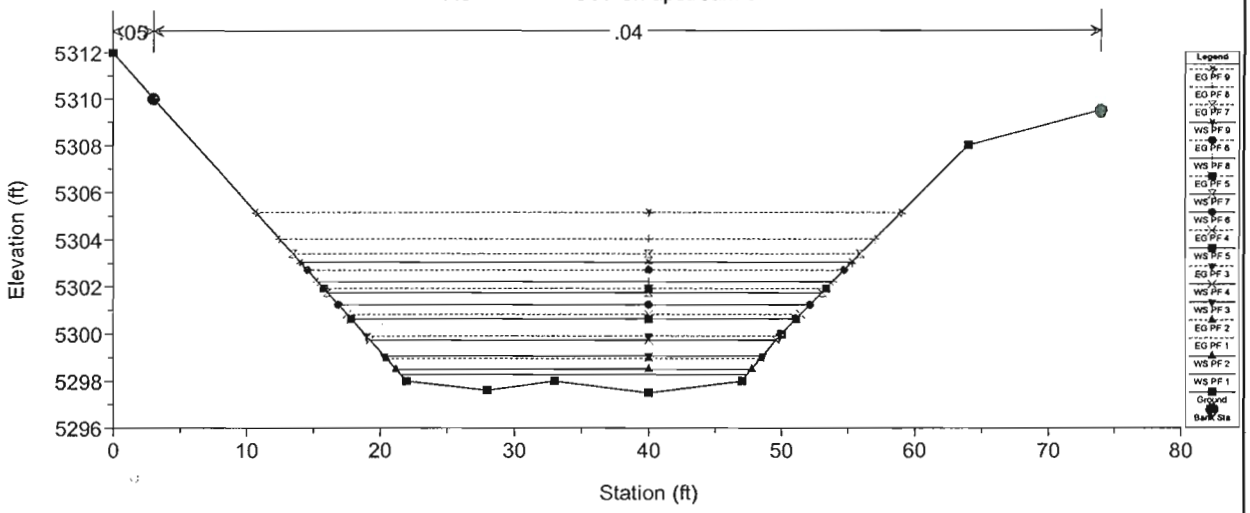
Ruby Dam Plan: Mixed Flow - Modified Outlet Channel 5/16/2007

RS = -150



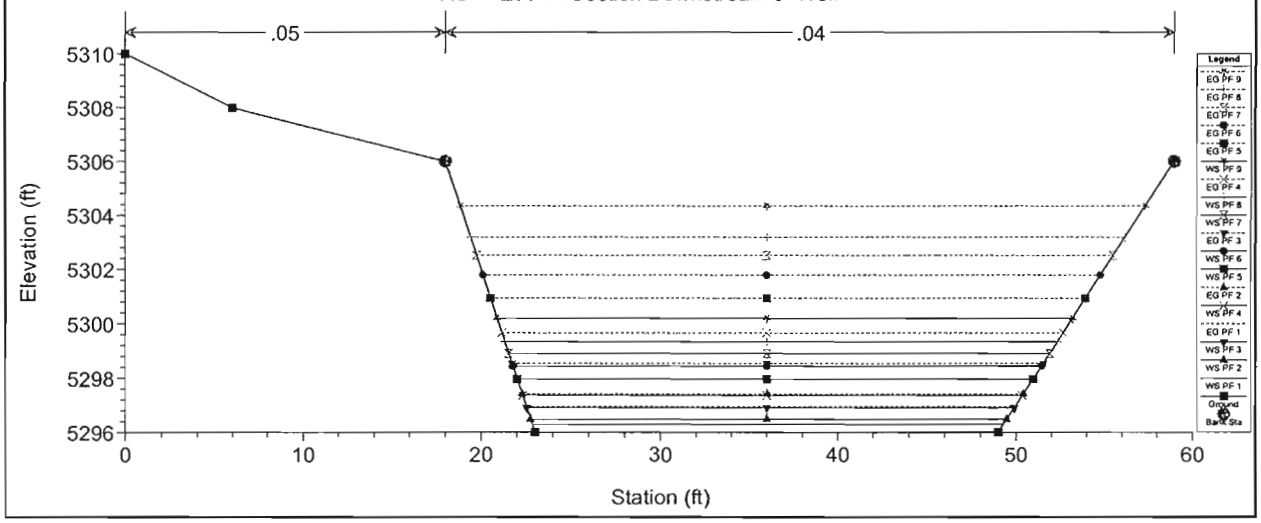
Ruby Dam Plan: Mixed Flow - Modified Outlet Channel 5/16/2007

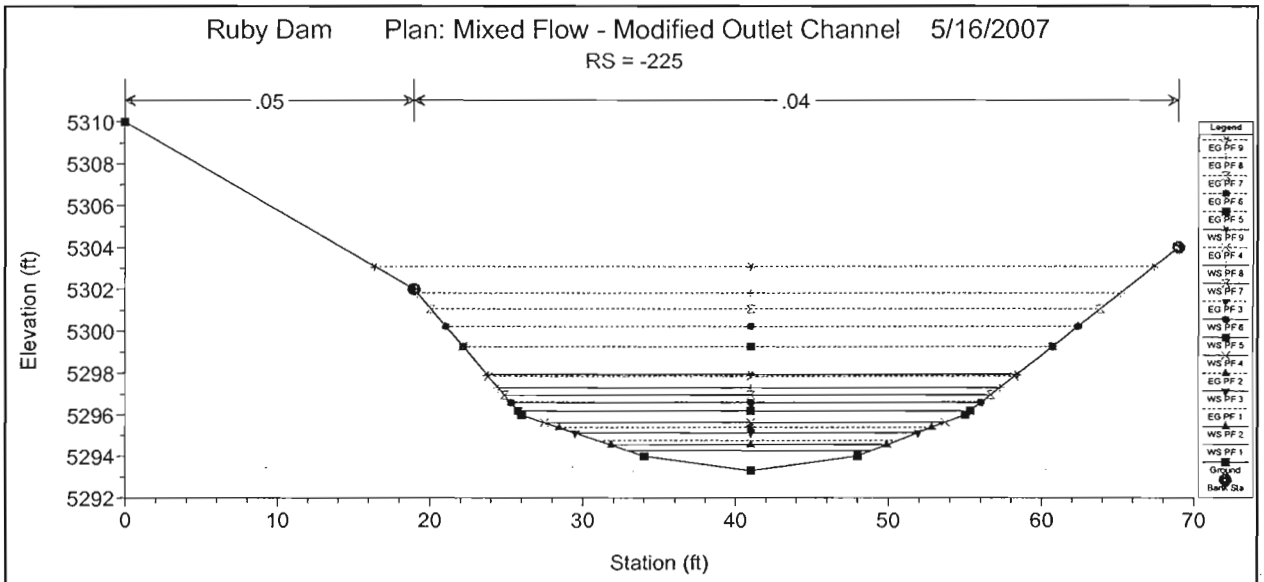
RS = -175 X-Section upstream of Weir

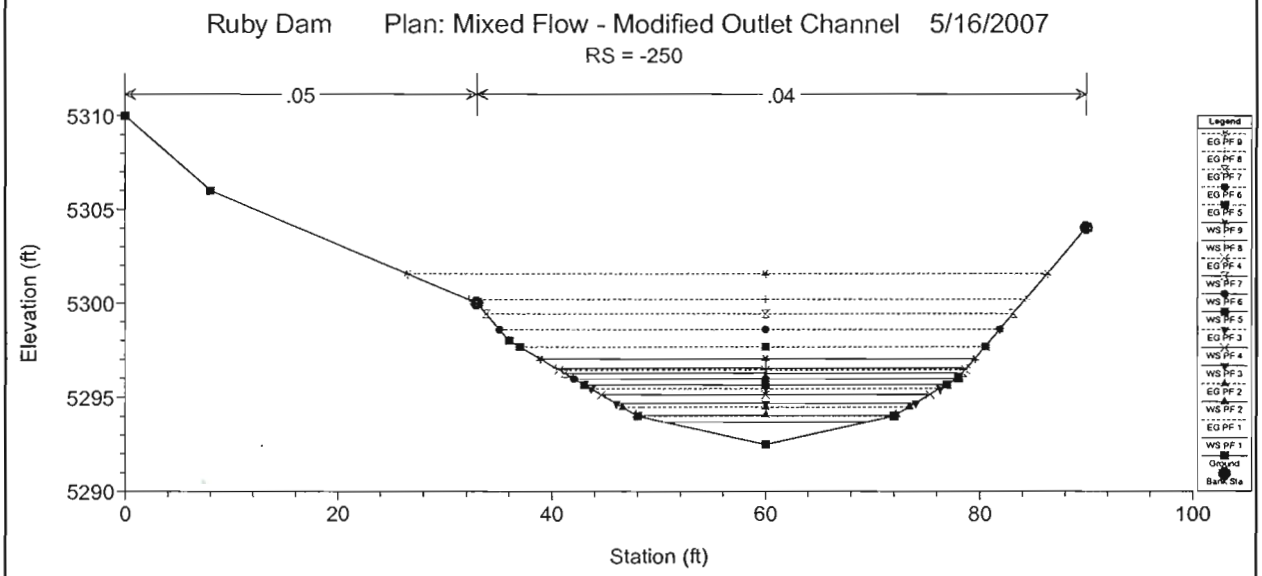


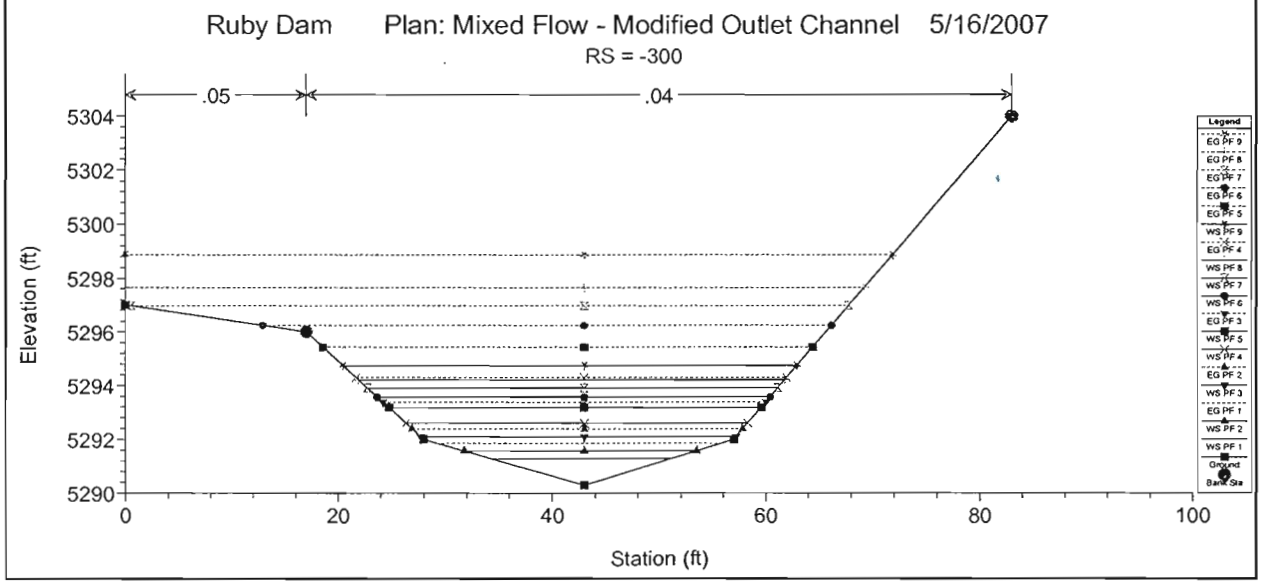
Ruby Dam Plan: Mixed Flow - Modified Outlet Channel 5/16/2007

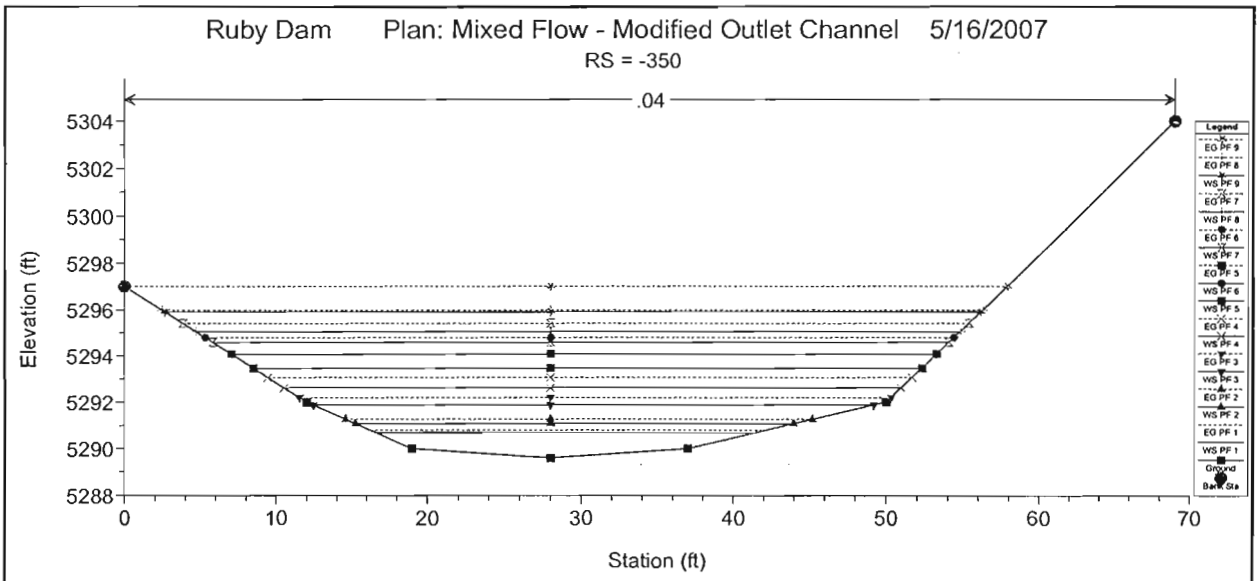
RS = -200 X-Section Downstream of Weir

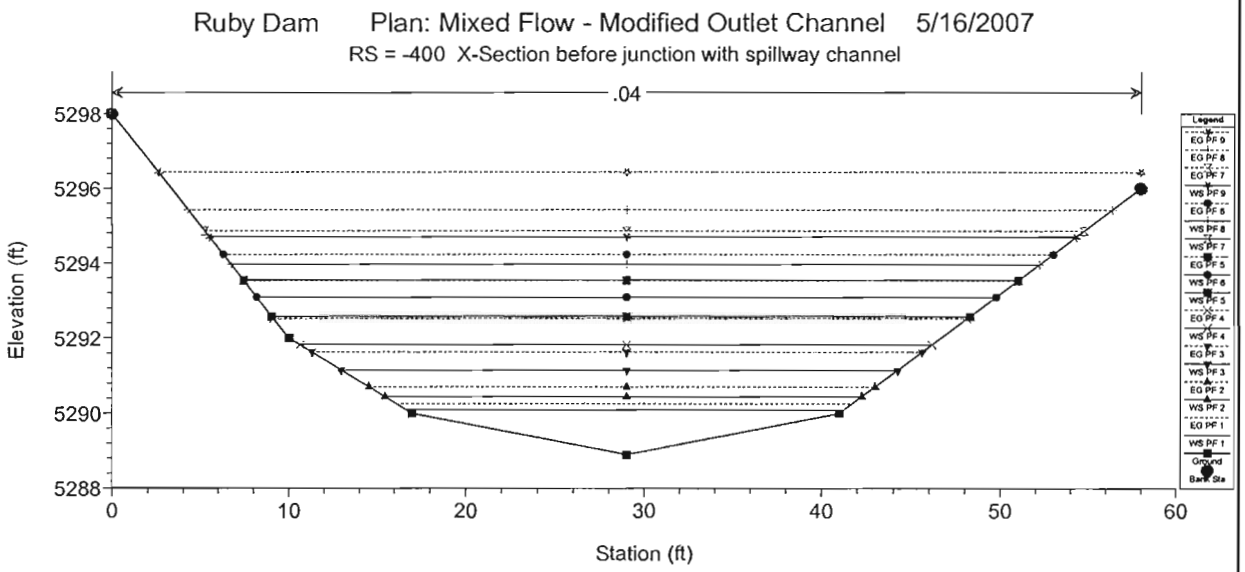



Ruby Dam Plan: Mixed Flow - Modified Outlet Channel 5/16/2007
RS = -225
.05
.04
Elevation (ft)
Station (ft)
Legend

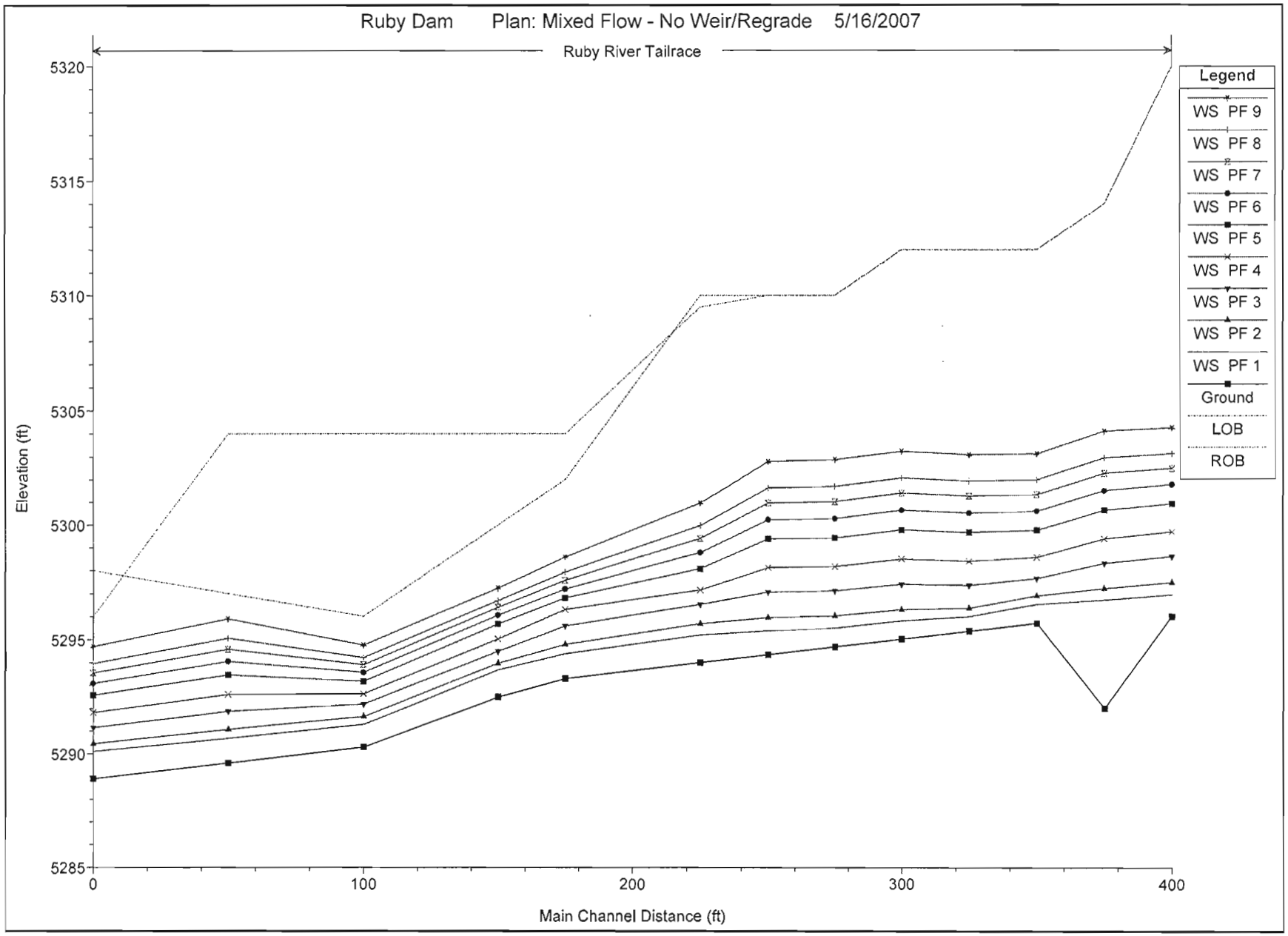

Ruby Dam Plan: Mixed Flow - Modified Outlet Channel 5/16/2007
RS = -250
.05
.04
Elevation (ft)
Station (ft)
Legend


Ruby Dam Plan: Mixed Flow - Modified Outlet Channel 5/16/2007
RS = -300
.05
.04
Elevation (ft)
Station (ft)
Legend


Ruby Dam Plan: Mixed Flow - Modified Outlet Channel 5/16/2007
RS = -350
.04
Elevation (ft)
Station (ft)
Legend
EG PF 9
EG PF 8
WS PF 9
EG PF 7
WS PF 8
EG PF 6
WS PF 7
EG PF 5
WS PF 6
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta


Ruby Dam Plan: Mixed Flow - Modified Outlet Channel 5/16/2007
RS = -400 X-Section before junction with spillway channel
.04
Elevation (ft)
Station (ft)
Legend
EG PF 9
EG PF 8
EG PF 7
WS PF 9
EG PF 6
WS PF 8
WS PF 7
EG PF 5
WS PF 6
WS PF 5
EG PF 4
WS PF 4
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta

Outlet Channel Graded Without Weir


Ruby Dam Plan: Mixed Flow - No Weir/Regrade 5/16/2007
Ruby River Tailrace
Elevation (ft)
5320
5315
5310
5305
5300
5295
5290
5285
0
100
200
300
400
Main Channel Distance (ft)
Legend
WS PF 9
WS PF 8
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
LOB
ROB

HEC-RAS Plan: Flow 7 River: Ruby River Reach: Tailrace

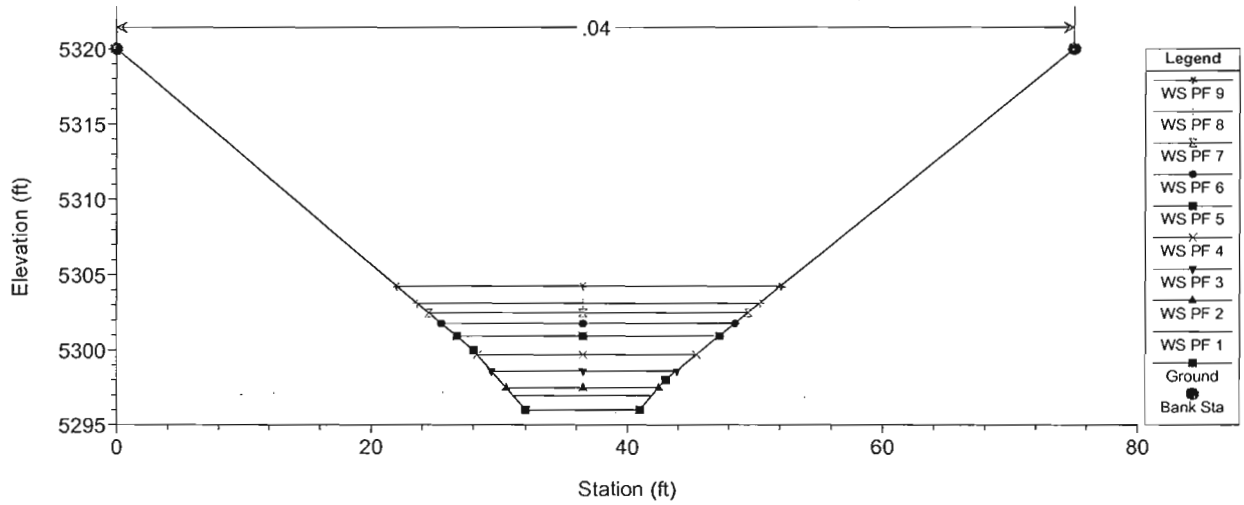
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Tailrace	000	PF 1	50.00	5296.00	5296.94	5296.94	5297.39	0.027641	5.34	9.37	10.88	1.01
Tailrace	000	PF 2	100.00	5296.00	5297.47	5297.47	5298.13	0.024809	6.50	15.39	11.94	1.01
Tailrace	000	PF 3	250.00	5296.00	5298.61	5298.61	5299.66	0.021974	8.24	30.35	14.49	1.00
Tailrace	000	PF 4	450.00	5296.00	5299.70	5299.70	5301.09	0.020503	9.46	47.56	17.16	1.00
Tailrace	000	PF 5	750.00	5296.00	5300.93	5300.93	5302.67	0.019464	10.59	70.84	20.57	1.01
Tailrace	000	PF 6	1000.00	5296.00	5301.78	5301.78	5303.73	0.018637	11.20	89.30	22.99	1.00
Tailrace	000	PF 7	1250.00	5296.00	5302.49	5302.49	5304.64	0.018328	11.77	106.22	25.00	1.01
Tailrace	000	PF 8	1500.00	5296.00	5303.12	5303.12	5305.44	0.017947	12.22	122.75	26.82	1.01
Tailrace	000	PF 9	2000.00	5296.00	5304.26	5304.26	5306.84	0.017128	12.90	155.01	30.06	1.00
Tailrace	-25	PF 1	50.00	5292.00	5296.71	5292.77	5296.71	0.000038	0.49	103.01	30.61	0.05
Tailrace	-25	PF 2	100.00	5292.00	5297.22	5293.19	5297.23	0.000100	0.84	119.00	31.77	0.08
Tailrace	-25	PF 3	250.00	5292.00	5298.30	5294.08	5298.34	0.000293	1.61	154.80	34.24	0.13
Tailrace	-25	PF 4	450.00	5292.00	5299.38	5294.93	5299.46	0.000508	2.33	192.97	36.70	0.18
Tailrace	-25	PF 5	750.00	5292.00	5300.64	5295.90	5300.79	0.000756	3.11	241.10	39.57	0.22
Tailrace	-25	PF 6	1000.00	5292.00	5301.51	5296.53	5301.71	0.000920	3.62	276.24	41.54	0.25
Tailrace	-25	PF 7	1250.00	5292.00	5302.27	5297.08	5302.52	0.001061	4.05	308.39	43.27	0.27
Tailrace	-25	PF 8	1500.00	5292.00	5302.94	5297.61	5303.25	0.001185	4.44	338.15	44.81	0.28
Tailrace	-25	PF 9	2000.00	5292.00	5304.12	5298.54	5304.52	0.001400	5.10	392.44	47.49	0.31
Tailrace	-50	PF 1	50.00	5295.70	5296.52	5296.33	5296.69	0.011882	3.32	15.06	19.85	0.67
Tailrace	-50	PF 2	100.00	5295.70	5296.89	5296.69	5297.19	0.013335	4.41	22.69	21.15	0.75
Tailrace	-50	PF 3	250.00	5295.70	5297.65	5297.47	5298.26	0.015391	6.30	39.68	23.78	0.86
Tailrace	-50	PF 4	450.00	5295.70	5298.57		5299.36	0.012856	7.13	63.11	27.14	0.82
Tailrace	-50	PF 5	750.00	5295.70	5299.77		5300.67	0.010136	7.63	98.31	31.63	0.76
Tailrace	-50	PF 6	1000.00	5295.70	5300.60		5301.58	0.008921	7.94	126.00	34.46	0.73
Tailrace	-50	PF 7	1250.00	5295.70	5301.33		5302.38	0.008198	8.22	152.11	36.84	0.71
Tailrace	-50	PF 8	1500.00	5295.70	5301.99		5303.10	0.007750	8.48	176.81	38.96	0.70
Tailrace	-50	PF 9	2000.00	5295.70	5303.12		5304.37	0.007230	8.97	223.01	42.61	0.69
Tailrace	-75	PF 1	50.00	5295.36	5295.99	5295.97	5296.26	0.025937	4.18	11.96	20.13	0.96
Tailrace	-75	PF 2	100.00	5295.36	5296.35	5296.31	5296.76	0.022023	5.11	19.58	21.38	0.94
Tailrace	-75	PF 3	250.00	5295.36	5297.35		5297.89	0.012827	5.86	42.63	24.78	0.79
Tailrace	-75	PF 4	450.00	5295.36	5298.40		5299.04	0.009482	6.38	70.49	28.35	0.71
Tailrace	-75	PF 5	750.00	5295.36	5299.66		5300.40	0.007570	6.88	108.98	32.64	0.66
Tailrace	-75	PF 6	1000.00	5295.36	5300.52		5301.33	0.006920	7.23	138.26	35.72	0.65
Tailrace	-75	PF 7	1250.00	5295.36	5301.27		5302.15	0.006527	7.53	166.00	38.49	0.64
Tailrace	-75	PF 8	1500.00	5295.36	5301.93		5302.88	0.006269	7.80	192.38	40.95	0.63
Tailrace	-75	PF 9	2000.00	5295.36	5303.09		5304.15	0.005890	8.28	241.65	44.56	0.63
Tailrace	-100	PF 1	50.00	5295.02	5295.80		5295.90	0.007113	2.55	19.64	26.35	0.52
Tailrace	-100	PF 2	100.00	5295.02	5296.29		5296.44	0.005512	3.03	32.97	27.83	0.49
Tailrace	-100	PF 3	250.00	5295.02	5297.40		5297.63	0.004129	3.81	65.67	31.16	0.46
Tailrace	-100	PF 4	450.00	5295.02	5298.49		5298.80	0.003654	4.44	101.45	34.44	0.46
Tailrace	-100	PF 5	750.00	5295.02	5299.78		5300.18	0.003365	5.06	148.22	38.31	0.45
Tailrace	-100	PF 6	1000.00	5295.02	5300.65		5301.11	0.003286	5.47	182.70	40.93	0.46
Tailrace	-100	PF 7	1250.00	5295.02	5301.40		5301.93	0.003259	5.83	214.45	43.20	0.46
Tailrace	-100	PF 8	1500.00	5295.02	5302.07		5302.66	0.003259	6.15	244.05	45.19	0.47
Tailrace	-100	PF 9	2000.00	5295.02	5303.23		5303.93	0.003283	6.71	298.25	48.28	0.48
Tailrace	-125	PF 1	50.00	5294.68	5295.49		5295.67	0.012358	3.37	14.85	19.74	0.68
Tailrace	-125	PF 2	100.00	5294.68	5296.02		5296.25	0.008895	3.87	25.85	21.54	0.62
Tailrace	-125	PF 3	250.00	5294.68	5297.11		5297.48	0.007165	4.88	51.27	25.22	0.60
Tailrace	-125	PF 4	450.00	5294.68	5298.17		5298.66	0.006453	5.64	79.77	28.79	0.60
Tailrace	-125	PF 5	750.00	5294.68	5299.43		5300.05	0.005807	6.31	118.78	33.06	0.59
Tailrace	-125	PF 6	1000.00	5294.68	5300.28		5300.98	0.005636	6.75	148.11	36.29	0.59
Tailrace	-125	PF 7	1250.00	5294.68	5301.02		5301.80	0.005553	7.08	176.54	39.80	0.59
Tailrace	-125	PF 8	1500.00	5294.68	5301.69		5302.53	0.005446	7.34	204.28	42.95	0.59
Tailrace	-125	PF 9	2000.00	5294.68	5302.87		5303.81	0.005088	7.77	257.44	46.97	0.58
Tailrace	-150	PF 1	50.00	5294.34	5295.38		5295.47	0.004302	2.34	21.33	21.95	0.42
Tailrace	-150	PF 2	100.00	5294.34	5295.95		5296.08	0.003984	2.92	34.20	23.55	0.43
Tailrace	-150	PF 3	250.00	5294.34	5297.06		5297.31	0.004150	4.03	62.05	26.68	0.47
Tailrace	-150	PF 4	450.00	5294.34	5298.12		5298.49	0.004251	4.89	92.04	29.69	0.49
Tailrace	-150	PF 5	750.00	5294.34	5299.38		5299.89	0.004233	5.69	131.78	33.26	0.50
Tailrace	-150	PF 6	1000.00	5294.34	5300.23		5300.83	0.004297	6.22	160.87	35.71	0.52
Tailrace	-150	PF 7	1250.00	5294.34	5300.96		5301.65	0.004367	6.65	187.96	37.98	0.53
Tailrace	-150	PF 8	1500.00	5294.34	5301.62		5302.39	0.004422	7.02	213.64	40.03	0.54
Tailrace	-150	PF 9	2000.00	5294.34	5302.77		5303.68	0.004511	7.64	261.71	43.59	0.55
Tailrace	-175	PF 1	50.00	5294.00	5295.19		5295.33	0.006598	3.02	16.56	15.86	0.52
Tailrace	-175	PF 2	100.00	5294.00	5295.68		5295.93	0.008050	4.05	24.67	17.45	0.60
Tailrace	-175	PF 3	250.00	5294.00	5296.52		5297.11	0.011851	6.15	40.62	20.20	0.76
Tailrace	-175	PF 4	450.00	5294.00	5297.15	5297.04	5298.23	0.017128	8.34	53.98	22.25	0.94
Tailrace	-175	PF 5	750.00	5294.00	5298.07	5298.07	5299.59	0.018355	9.89	75.85	25.23	1.00
Tailrace	-175	PF 6	1000.00	5294.00	5298.78	5298.78	5300.52	0.017739	10.59	94.41	27.40	1.01
Tailrace	-175	PF 7	1250.00	5294.00	5299.40	5299.40	5301.33	0.017237	11.15	112.10	29.33	1.01
Tailrace	-175	PF 8	1500.00	5294.00	5299.96	5299.96	5302.06	0.016858	11.62	129.04	31.06	1.00

HEC-RAS Plan: Flow 7 River: Ruby River Reach: Tailrace (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Tailrace	-175	PF 9	2000.00	5294.00	5300.96	5300.96	5303.34	0.016268	12.36	161.76	34.38	1.00
Tailrace	-225	PF 1	50.00	5293.30	5294.39	5294.39	5294.72	0.027751	4.59	10.90	16.91	1.01
Tailrace	-225	PF 2	100.00	5293.30	5294.79	5294.79	5295.25	0.025019	5.49	18.22	19.89	1.01
Tailrace	-225	PF 3	250.00	5293.30	5295.59	5295.59	5296.31	0.021789	6.82	36.65	25.93	1.01
Tailrace	-225	PF 4	450.00	5293.30	5296.30	5296.30	5297.28	0.019984	7.92	56.81	29.88	1.01
Tailrace	-225	PF 5	750.00	5293.30	5296.81	5297.12	5298.48	0.026812	10.37	72.30	31.36	1.20
Tailrace	-225	PF 6	1000.00	5293.30	5297.20	5297.71	5299.36	0.029686	11.80	84.74	32.49	1.29
Tailrace	-225	PF 7	1250.00	5293.30	5297.58	5298.22	5300.14	0.030848	12.85	97.28	33.60	1.33
Tailrace	-225	PF 8	1500.00	5293.30	5297.93	5298.71	5300.85	0.031514	13.72	109.36	34.63	1.36
Tailrace	-225	PF 9	2000.00	5293.30	5298.59	5299.56	5302.12	0.031931	15.07	132.70	36.55	1.39
Tailrace	-250	PF 1	50.00	5292.50	5293.68	5293.69	5293.99	0.030319	4.52	11.07	18.82	1.04
Tailrace	-250	PF 2	100.00	5292.50	5293.97	5294.06	5294.49	0.037501	5.82	17.19	23.45	1.20
Tailrace	-250	PF 3	250.00	5292.50	5294.49	5294.75	5295.54	0.042469	8.23	30.38	26.92	1.36
Tailrace	-250	PF 4	450.00	5292.50	5295.02	5295.44	5296.53	0.041213	9.84	45.72	30.14	1.41
Tailrace	-250	PF 5	750.00	5292.50	5295.67	5296.23	5297.65	0.038819	11.28	66.49	34.03	1.42
Tailrace	-250	PF 6	1000.00	5292.50	5296.06	5296.75	5298.48	0.040511	12.48	80.10	36.26	1.48
Tailrace	-250	PF 7	1250.00	5292.50	5296.40	5297.25	5299.22	0.041248	13.48	92.72	37.80	1.52
Tailrace	-250	PF 8	1500.00	5292.50	5296.70	5297.67	5299.92	0.042363	14.40	104.16	39.13	1.56
Tailrace	-250	PF 9	2000.00	5292.50	5297.24	5298.44	5301.15	0.043488	15.87	126.03	41.57	1.61
Tailrace	-300	PF 1	50.00	5290.30	5291.30	5291.46	5291.84	0.064337	5.90	8.48	17.01	1.47
Tailrace	-300	PF 2	100.00	5290.30	5291.65	5291.83	5292.29	0.051499	6.45	15.50	23.00	1.38
Tailrace	-300	PF 3	250.00	5290.30	5292.19	5292.47	5293.25	0.049183	8.25	30.29	29.94	1.45
Tailrace	-300	PF 4	450.00	5290.30	5292.64	5293.10	5294.25	0.050124	10.19	44.18	32.14	1.53
Tailrace	-300	PF 5	750.00	5290.30	5293.18	5293.87	5295.43	0.049590	12.04	62.28	34.80	1.59
Tailrace	-300	PF 6	1000.00	5290.30	5293.57	5294.38	5296.24	0.048481	13.12	76.24	36.72	1.60
Tailrace	-300	PF 7	1250.00	5290.30	5293.91	5294.86	5296.97	0.048111	14.04	89.02	38.39	1.63
Tailrace	-300	PF 8	1500.00	5290.30	5294.22	5295.29	5297.64	0.048051	14.86	100.96	39.89	1.65
Tailrace	-300	PF 9	2000.00	5290.30	5294.75	5296.02	5298.85	0.048238	16.24	123.12	42.54	1.68
Tailrace	-350	PF 1	50.00	5289.60	5290.68	5290.41	5290.80	0.008504	2.77	18.08	24.77	0.57
Tailrace	-350	PF 2	100.00	5289.60	5291.07	5290.75	5291.26	0.008950	3.49	28.66	28.73	0.62
Tailrace	-350	PF 3	250.00	5289.60	5291.88	5291.43	5292.20	0.008904	4.55	54.96	36.76	0.66
Tailrace	-350	PF 4	450.00	5289.60	5292.61	5292.07	5293.06	0.008149	5.38	83.67	40.44	0.66
Tailrace	-350	PF 5	750.00	5289.60	5293.46	5292.74	5294.07	0.007784	6.28	119.39	43.82	0.67
Tailrace	-350	PF 6	1000.00	5289.60	5294.06	5293.25	5294.78	0.007619	6.84	146.11	46.19	0.68
Tailrace	-350	PF 7	1250.00	5289.60	5294.58	5293.68	5295.41	0.007528	7.31	170.90	48.28	0.69
Tailrace	-350	PF 8	1500.00	5289.60	5295.06	5294.09	5295.98	0.007472	7.72	194.29	50.17	0.69
Tailrace	-350	PF 9	2000.00	5289.60	5295.90	5294.81	5297.00	0.007406	8.40	238.09	53.53	0.70
Tailrace	-400	PF 1	50.00	5288.90	5290.10	5289.95	5290.26	0.014015	3.22	15.52	24.60	0.72
Tailrace	-400	PF 2	100.00	5288.90	5290.44	5290.26	5290.70	0.014000	4.10	24.37	26.79	0.76
Tailrace	-400	PF 3	250.00	5288.90	5291.15	5290.94	5291.63	0.014016	5.55	45.03	31.29	0.82
Tailrace	-400	PF 4	450.00	5288.90	5291.83	5291.59	5292.51	0.014010	6.66	67.56	35.56	0.85
Tailrace	-400	PF 5	750.00	5288.90	5292.58	5292.35	5293.53	0.014017	7.84	95.70	39.26	0.88
Tailrace	-400	PF 6	1000.00	5288.90	5293.09	5292.87	5294.23	0.014005	8.58	116.60	41.58	0.90
Tailrace	-400	PF 7	1250.00	5288.90	5293.55	5293.34	5294.86	0.014026	9.19	136.01	43.63	0.92
Tailrace	-400	PF 8	1500.00	5288.90	5293.96	5293.78	5295.43	0.014019	9.71	154.49	45.50	0.93
Tailrace	-400	PF 9	2000.00	5288.90	5294.70	5294.52	5296.43	0.014008	10.57	189.18	48.81	0.95

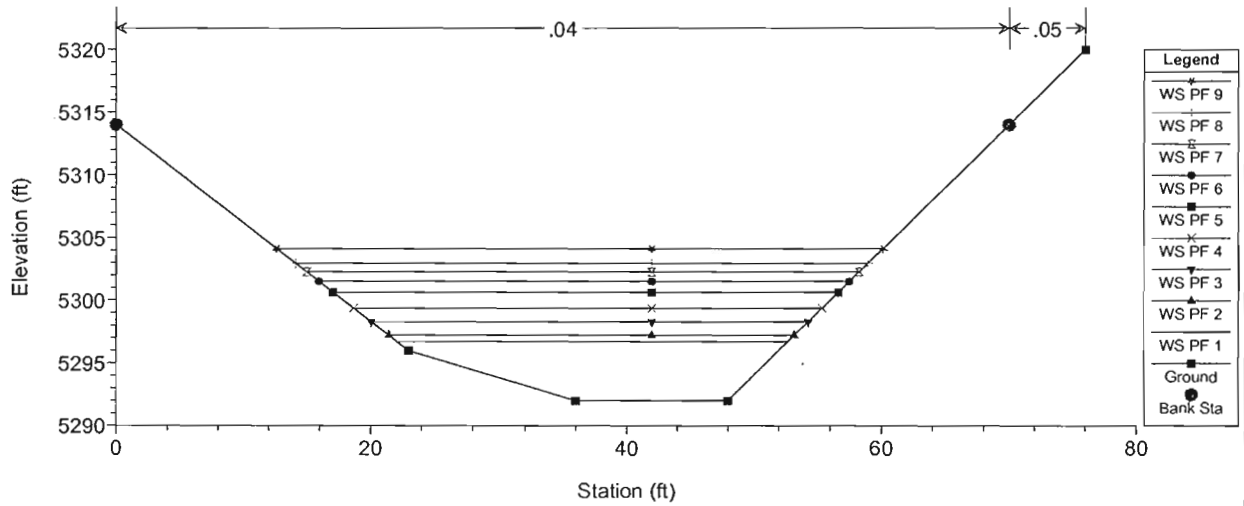
Ruby Dam Plan: Mixed Flow - No Weir/Regrade 5/16/2007

RS = 000 X-Section downstream of existing outlet apron



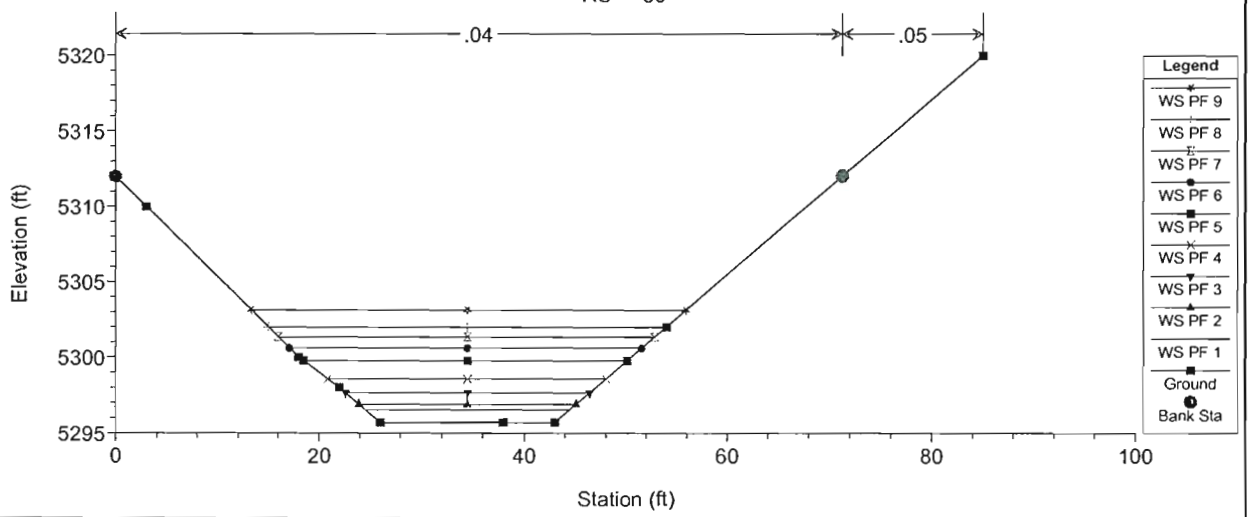
Ruby Dam Plan: Mixed Flow - No Weir/Regrade 5/16/2007

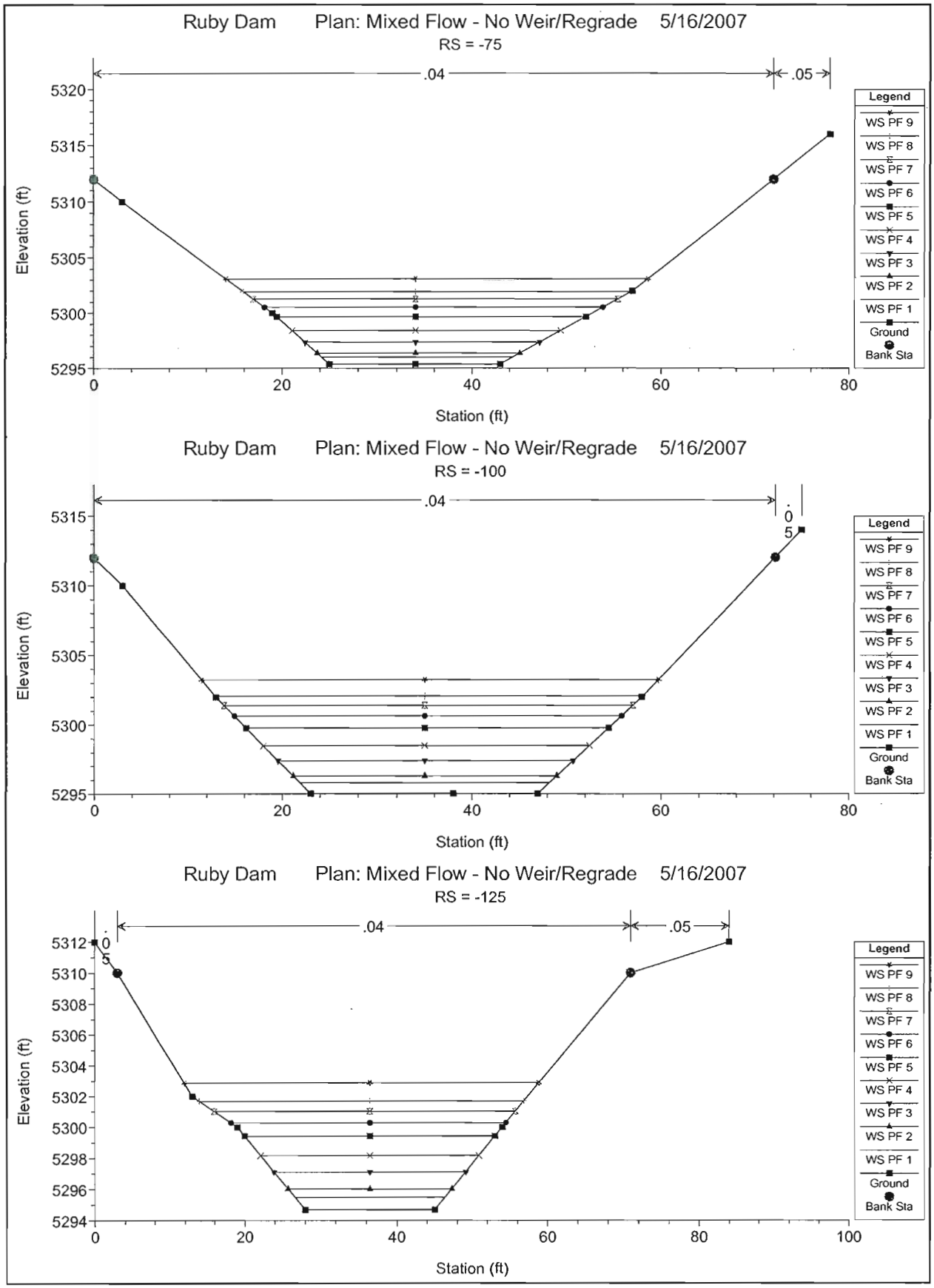
RS = -25

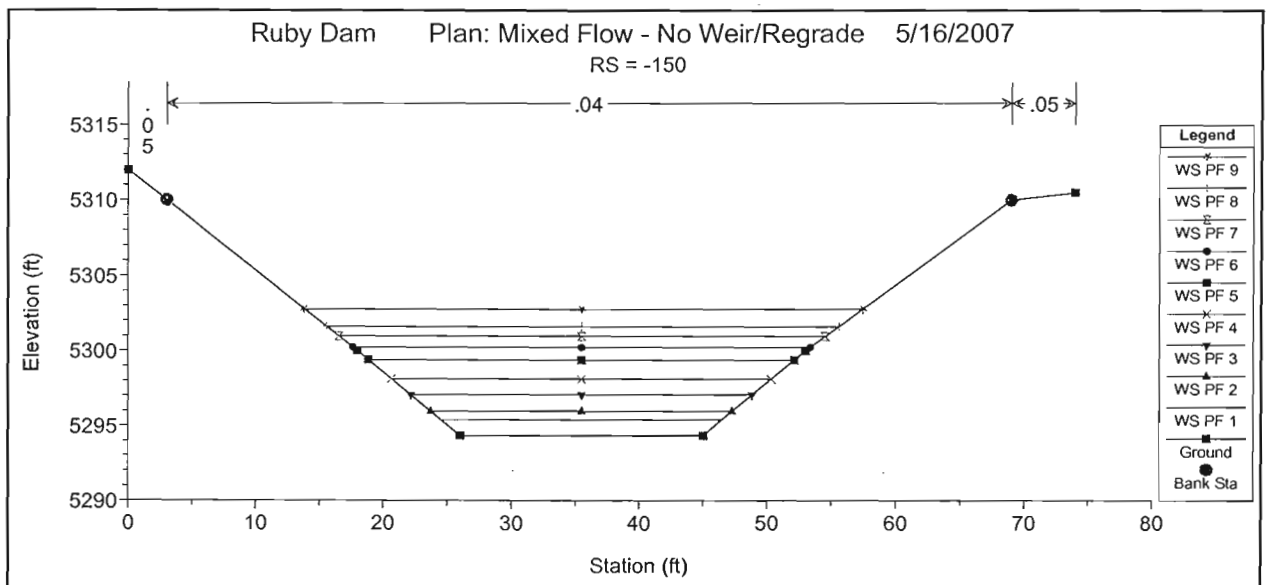


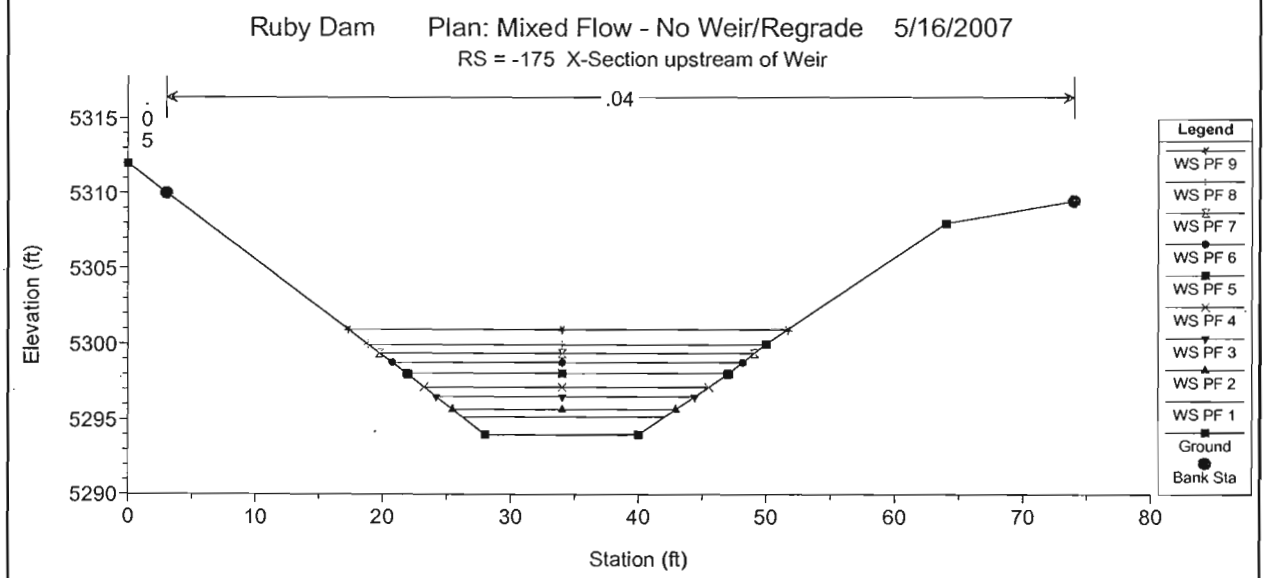
Ruby Dam Plan: Mixed Flow - No Weir/Regrade 5/16/2007

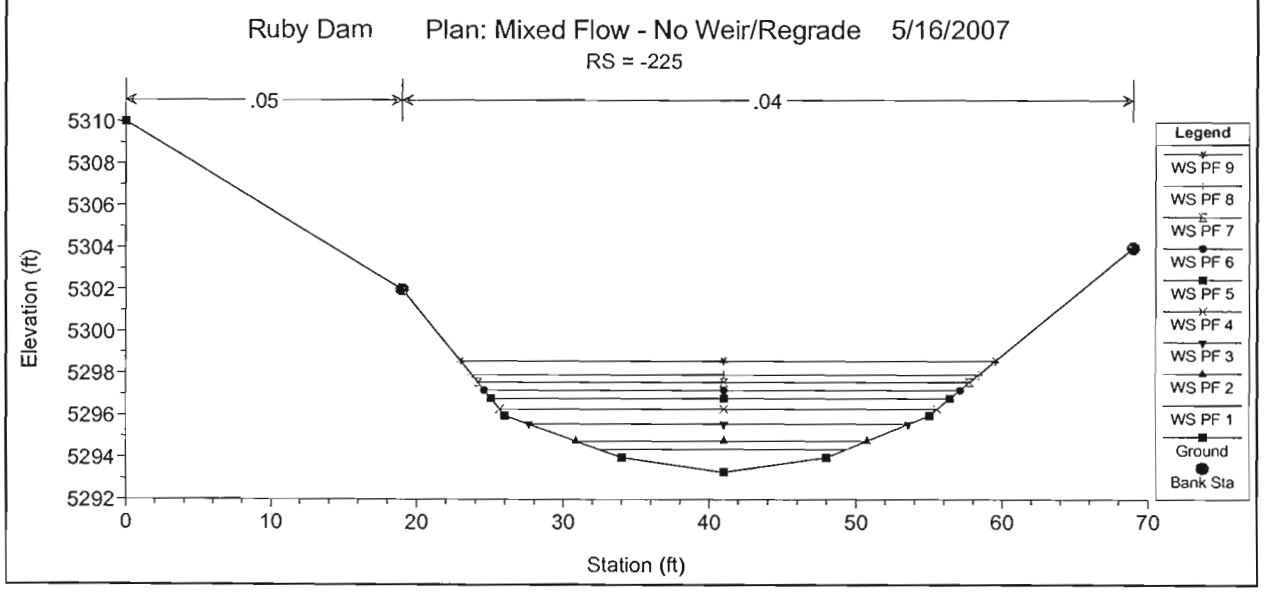
RS = -50

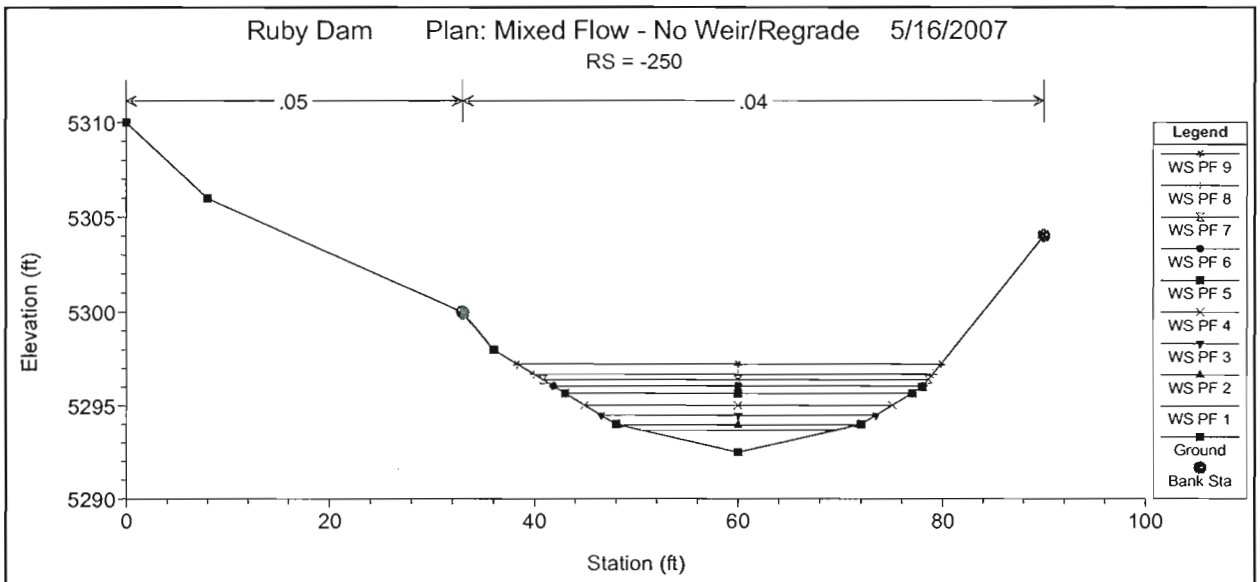


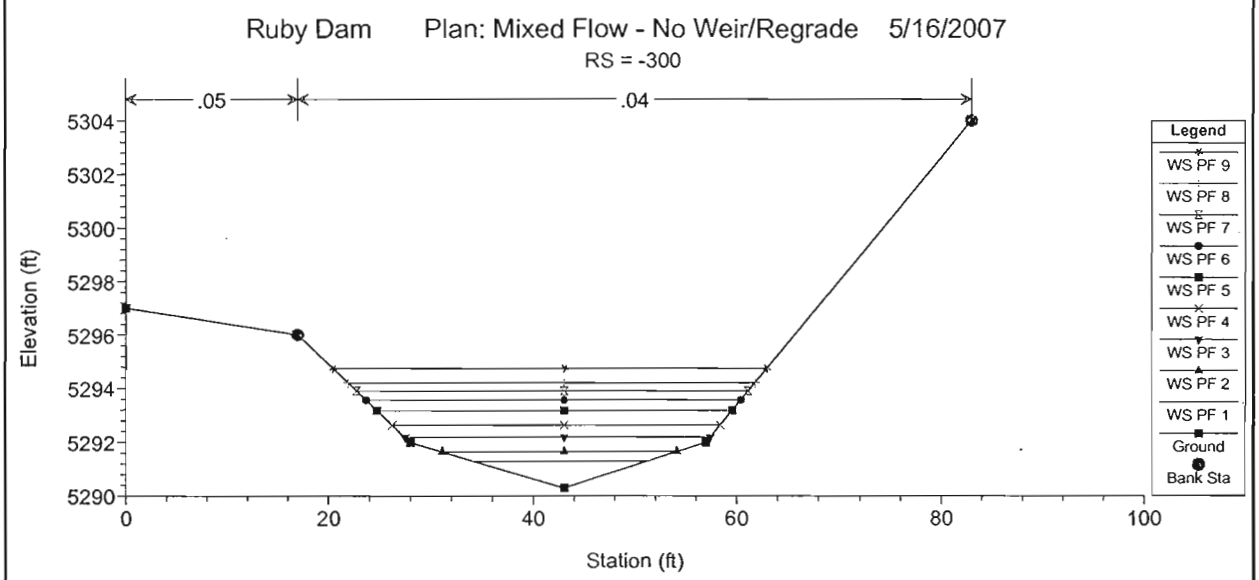

Ruby Dam Plan: Mixed Flow - No Weir/Regrade 5/16/2007
RS = -75
.04
.05
Elevation (ft)
Station (ft)
Legend
WS PF 9
WS PF 8
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Ruby Dam Plan: Mixed Flow - No Weir/Regrade 5/16/2007
RS = -100
.04
.05
Elevation (ft)
Station (ft)
Legend
WS PF 9
WS PF 8
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Ruby Dam Plan: Mixed Flow - No Weir/Regrade 5/16/2007
RS = -125
.04
.05
Elevation (ft)
Station (ft)
Legend
WS PF 9
WS PF 8
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta

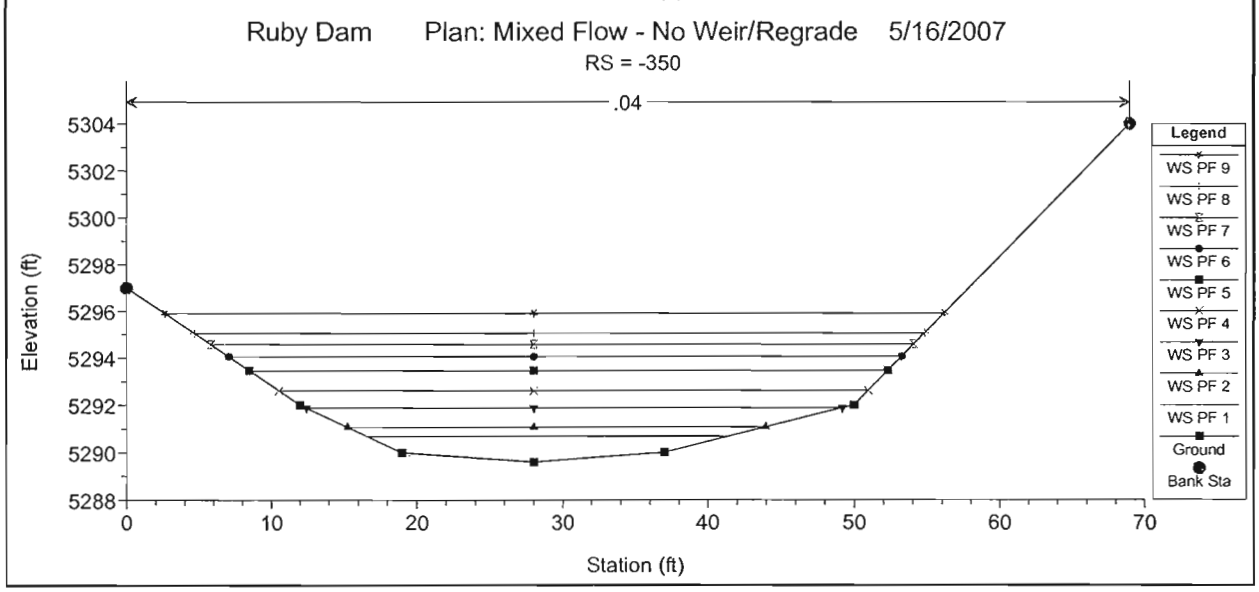

Ruby Dam Plan: Mixed Flow - No Weir/Regrade 5/16/2007
RS = -150
.04
.05
.05
Elevation (ft)
Station (ft)
Legend
WS PF 9
WS PF 8
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta

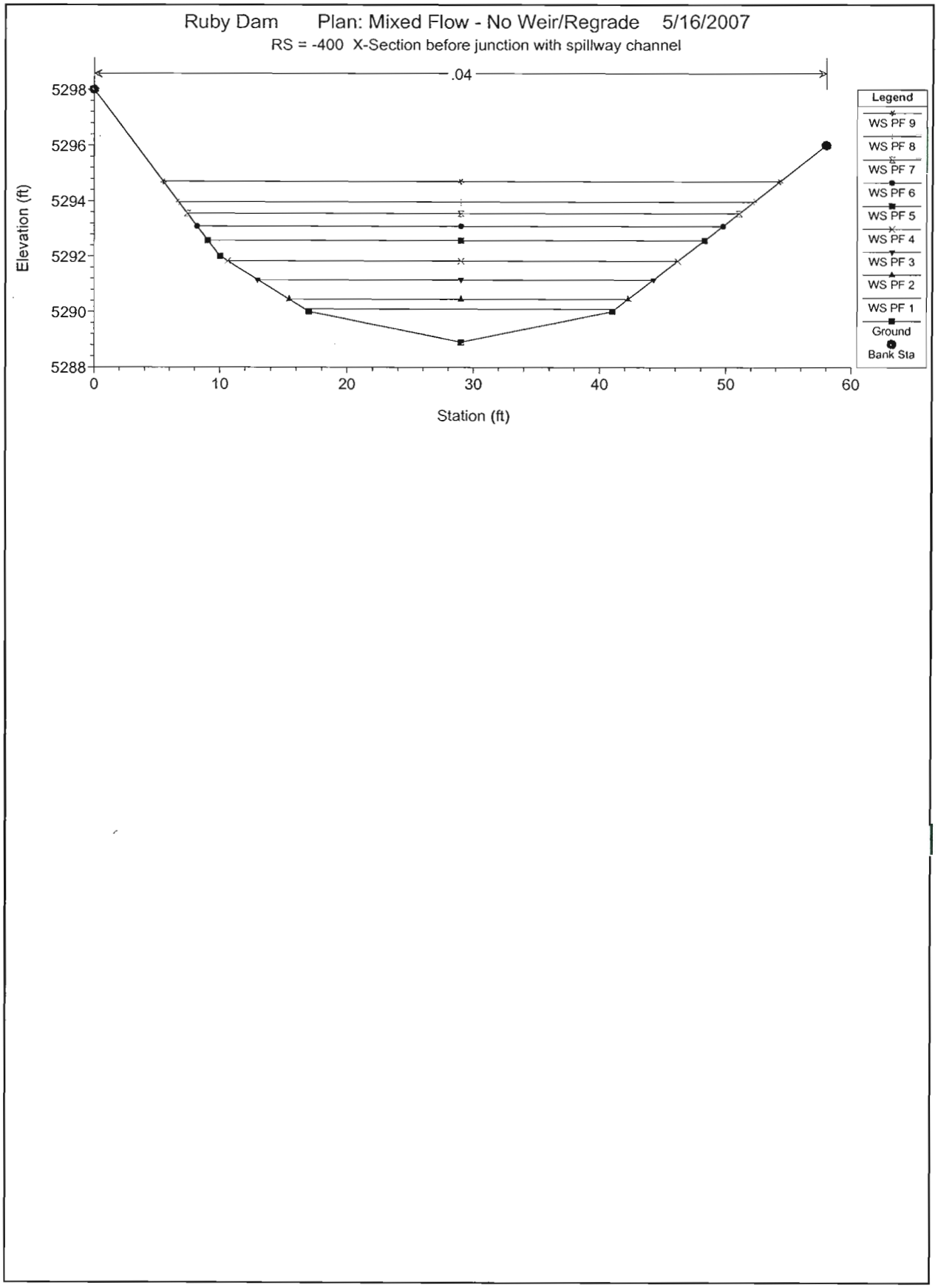

Ruby Dam Plan: Mixed Flow - No Weir/Regrade 5/16/2007
RS = -175 X-Section upstream of Weir
.04
.05
Elevation (ft)
Station (ft)
Legend
WS PF 9
WS PF 8
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta


Ruby Dam Plan: Mixed Flow - No Weir/Regrade 5/16/2007
RS = -225
.05
.04
Elevation (ft)
Station (ft)
Legend
WS PF 9
WS PF 8
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta


Ruby Dam Plan: Mixed Flow - No Weir/Regrade 5/16/2007
RS = -250
.05
.04
Elevation (ft)
Station (ft)
Legend
WS PF 9
WS PF 8
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta


Ruby Dam Plan: Mixed Flow - No Weir/Regrade 5/16/2007
RS = -300
.05
.04
Elevation (ft)
Station (ft)
Legend
WS PF 9
WS PF 8
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta


Ruby Dam Plan: Mixed Flow - No Weir/Regrade 5/16/2007
RS = -350
.04
Elevation (ft)
Station (ft)
Legend
WS PF 9
WS PF 8
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta


Ruby Dam Plan: Mixed Flow - No Weir/Regrade 5/16/2007
RS = -400 X-Section before junction with spillway channel
.04
Elevation (ft)
5298
5296
5294
5292
5290
5288
0
10
20
30
40
50
60
Station (ft)
Legend
WS PF 9
WS PF 8
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta

RUBY DAM REHABILITATION FEASIBILITY STUDY

Water Availability Analysis

Prepared for:

Montana Department of Natural Resources and Conservation

State Water Projects Bureau

Helena, MT

Prepared by:

HKM Engineering Inc.

P.O. Box 31318

Billings, MT 59107

January 2008

H:\08\M087175\Ruby Reports\Final\WaterAvailabilityMemo_0108.doc

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Appendix C – Period of Record Analysis

Appendix D – Existing Operation Model

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Executive Summary

The water availability analysis for Ruby Dam was performed using data from upstream and downstream US Geological Survey (USGS) stream gauges, end of month (EOM) reservoir storage records, and precipitation and evaporation data. The analysis included an investigation of the suitability of the period of record analyzed, creating an operation model accounting for net evaporation, estimation of spill volumes, and an evaluation of spilled water available for storage.

Two USGS stream gauges located near Ruby Reservoir were utilized in this analysis: USGS Site No. 06019500 (located 4.2 miles upstream of the reservoir) and USGS Site No. 06020600 (located 0.2 miles downstream of the reservoir). The period of record for this analysis was 40 years (1964-2003) which was the period of record for the gauge downstream of the reservoir. A period comparison was conducted using the total yearly volume of water passing through the upstream gauge and volumes recorded for the months of May and June (when water is typically spilling from the reservoir) for a 40-year and 64-year period (full period of record for the upstream gauge). Based on the records, the 40-year period may be slightly wetter than the 64-year period. For example, using the 40-year data set, on average, approximately 5,000 acre-ft more water was recorded during May and June as compared to results if the 64-year data set was used. When water volumes were evaluated in terms of 80% exceedance, the 40-year period was drier than the 64-year period.

A reservoir operation model was developed to define a relationship between EOM storage records, gauge data, and net evaporation. Because there are no diversions on the Ruby River before the downstream gauge, demand was not included in the existing operation model. After adjusting the net evaporation value to provide a "best-fit" between EOM storage and gauge data, it was found the most appropriate value for net evaporation was zero. This value could result from inaccurate reservoir storage data, a difference in actual reservoir storage capacity versus the published storage values, reservoir storage measured other than the last day of the corresponding month, etc. This operation model could be further refined if a detailed evaluation is needed, but was not utilized to draw conclusions for this water availability analysis because of uncertainty in EOM storage records, net evaporation data, and other assumptions used in developing the model.

Based on EOM storage data, the reservoir is often spilling water during the months of May and June. Available water for new storage was calculated using outflow gauge data to estimate the total volume available above the demand baseflow for storage each year. Using outflow gauge data was the most straight-forward method of analysis.

The method utilized to estimate the volume of water available for new storage computed excess water available after historic storage operations and delivery of the estimated demand baseflow. Demand was included as a variable in this process. The 80% exceedance value was highlighted as a conservative estimation of water volumes above demand baseflow for each month. Meaning, in 80% of years on record, the estimated volume may be available to add to storage. The 50% exceedance represents the median flow.

From a range of demands analyzed, a reasonable and slightly conservative demand baseflow volume of 15,000 acre-ft was assumed for May and 20,000 acre-ft for June to estimate available water. **For these demands, approximately 7,000 acre-ft of water was available for storage based on 80% exceedance, and approximately 23,000 acre-ft based on 50% exceedance.**

1.0 Introduction

The Montana Department of Natural Resources and Conservation (DNRC) State Water Projects Bureau (SWPB) contracted with HKM Engineering Inc. (HKM) to perform the Ruby Dam Feasibility Study. The water availability analysis presented in this report was performed in accordance with Task 2 of contract WE-HKM-579.

1.1 Purpose

The purpose of the water availability analysis was to evaluate the volume of excess water not currently allocated to downstream water users or being stored at Ruby Dam. Based on the availability of excess water, the possibility of increasing storage in Ruby Reservoir can be considered.

1.2 Site Description

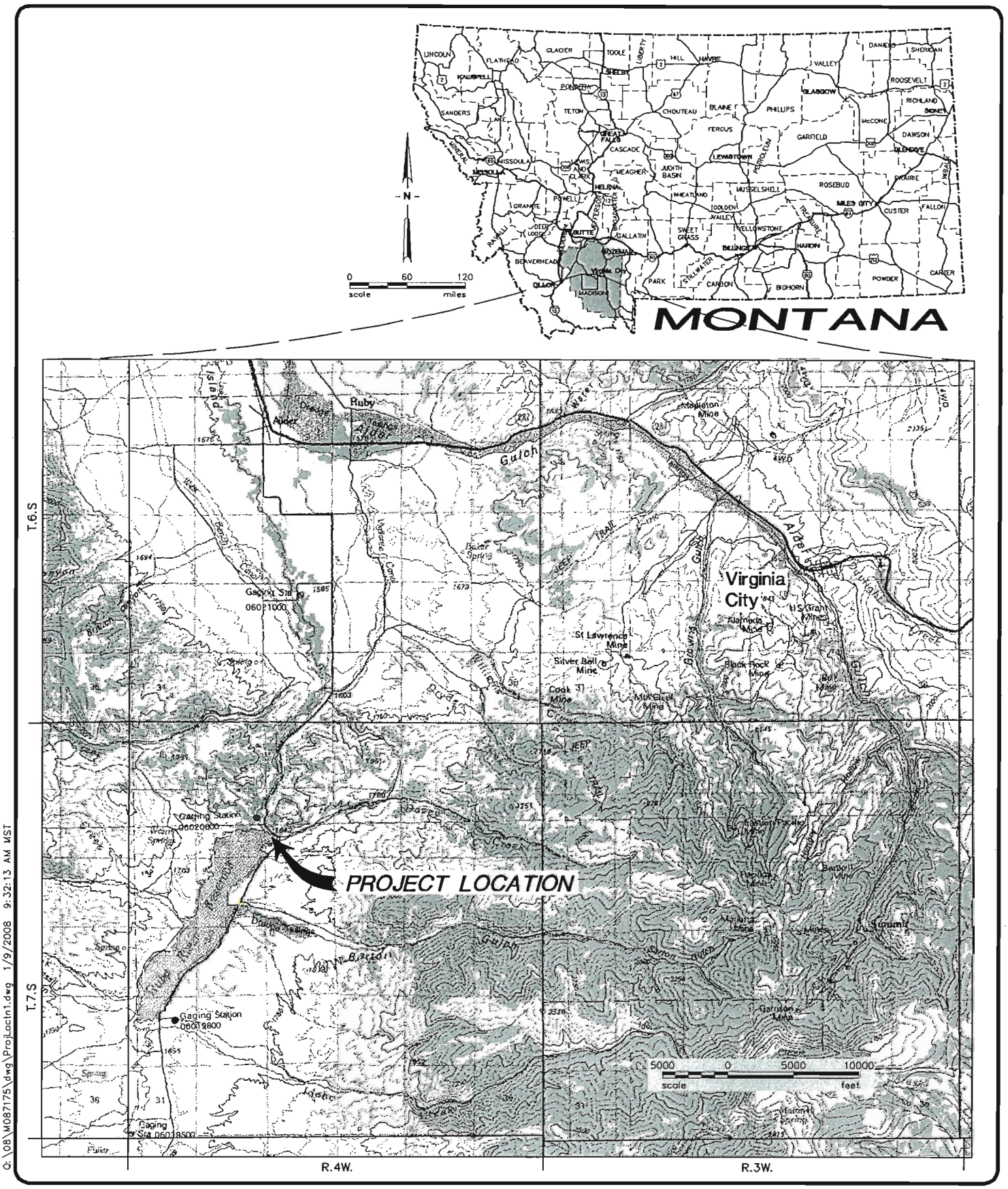
Ruby Reservoir is located about 6 miles south of Alder, MT on the Upper Ruby Road in Madison County. The reservoir is primarily fed by the Ruby River which originates in the Snowcrest and Gravelly Ranges, about 30 miles south of the dam. A location map is presented in Figure 1 and the drainage basin boundary is shown in Figure 2.

The earthfill dam was completed in 1938 and stores approximately 38,850 acre-ft at normal full pool capacity. The dam is owned by the DNRC and is managed by the SWPB of the DNRC. The Ruby River Water Users Association operates and maintains the dam.

Water from the reservoir is primarily used for agricultural irrigation. The reservoir is also used for water-based recreation and regulation of stream flows.

1.3 Project Background

On September 1, 1994, the reservoir was completely drained, resulting in a large discharge of sediment causing a fish kill in the river below the dam. As a result of the water quality violations that occurred when the reservoir was drained, a task force appointed by the Director of the DNRC identified a minimum conservation pool for the reservoir of 2,600 acre-feet. The minimum pool size was agreed upon in a Consent Decree dated May of 1995 by DNRC, the Department of Environmental Sciences, and the Ruby River Water Users Association. The consent decree was



RUBY DAM REHABILITATION FEASIBILITY STUDY

PROJECT LOCATION MAP

FIGURE 1

HKM ENGINEERING

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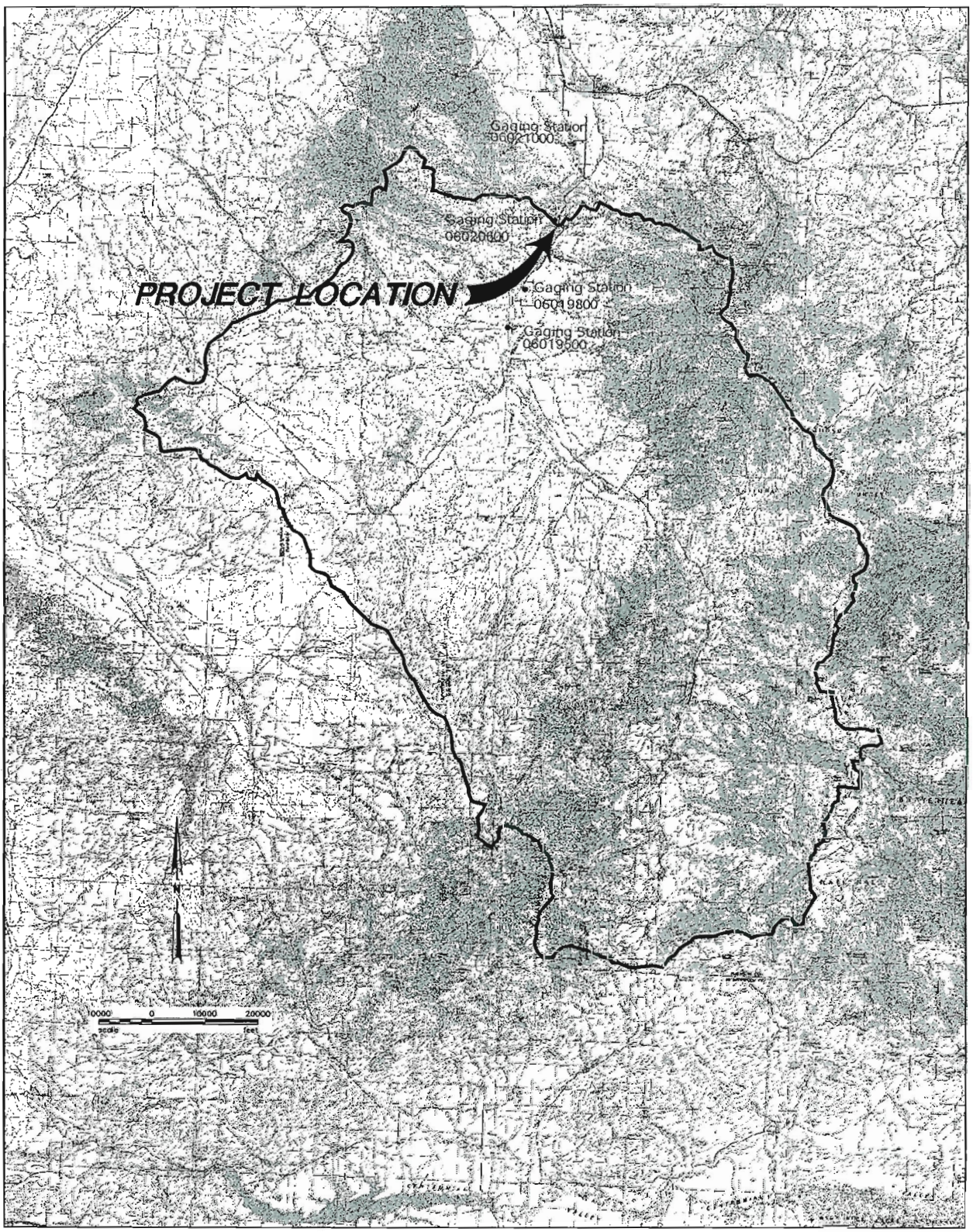
Q:\08\M087175\dwg\ProjLocfn1.dwg 1/9/2008 9:32:13 AM MST



RUBY DAM REHABILITATION FEASIBILITY STUDY

DRAINAGE BASIN BOUNDARY

FIGURE #2

HKM ENGINEERING

8M087.175 | JANUARY 2008

terminated in November of 2002 given that the Ruby River Water Users Association had operated the reservoir in a reasonable manner and that safeguards were in place to prevent future sediment discharges.

The current feasibility study included consideration of two scenarios for enlarging storage volumes in the reservoir. These scenarios could be accomplished by raising the spillway crest and may impact the required top of dam elevation. The two scenarios for increasing storage are:

1. Provide for 2,600 acre-ft of minimum (inactive) pool as per the consent decree and restore the original active pool of 38,850 acre-ft. A new water right may be necessary for initial filling and periodic refilling of the inactive pool. Total (active plus inactive) storage would increase 3,800 acre-ft; 1,200 acre-ft due to sedimentation loss below the existing crest and 2,600 acre-ft for minimum conservation pool (el. 5396.7 - an increase of 3.7 feet above the existing flashboards).

2. Increasing the active storage pool to utilize water currently spilled and not allocated to downstream senior water users. An increase in the active pool would require a new water right.

Evaluating the rights of senior water users entitled to the water spilled at Ruby Dam was outside of the scope of this study. For purposes of this study, it was assumed that the selected demand baseflow volumes of 15,000 acre-ft in May and 20,000 acre-ft in June would provide adequate flow volume for existing senior water rights and existing project contract deliveries.

2.0 Water Availability Analysis

The water availability analysis was performed considering data from upstream and downstream stream gauges, end of month reservoir storage records, and precipitation and evaporation data (Appendices A and B). The analysis included estimation of spill volumes and an evaluation of spilled water available for storage. A discussion of the suitability of the period of record analyzed is included in Appendix C.

An existing reservoir operation model accounting for net evaporation was created and calibrated for this water availability analysis and is included in Appendix D. Due to possible errors and inaccuracies (discussed in Appendix D), the existing operation model was not used to estimate the volume of water available for storage in the final analysis.

2.1 Estimation of Spill Volumes

Spill volumes were estimated to determine the volume of water leaving the reservoir for reasons other than fulfilling downstream water rights (demand baseflow).

As observed per the EOM storage data provided by DNRC SWPB, the reservoir is typically spilling water during the months of May and June. The reservoir usually spills for an estimated two to six week period during these two months. There were several years when water spills during other months, but this is atypical. There were also a few years when water has not spilled in May and June. Overall, it appears reasonable to assume spill volumes estimated using May and June data are a reasonable approximation of spill volumes for a typical year.

Evaluation of spill volumes was based on outflow gauge data due to the simplicity and conservatism of the method. Utilizing this technique eliminates the effects of potentially inaccurate reservoir EOM storage data, and eradicates the need to adjust the upstream gauge data to account for change in drainage area and make assumptions to develop a method to account for reservoir losses. Using this method, water volumes can be measured as spilled or intentionally released from the reservoir. Water intentionally released from the reservoir during the months of May and June was accounted for with a variable downstream demand baseflow in this analysis.

2.2 Evaluation of Spill Volumes Available for Storage

Spills estimated using outflow gauge data were used to estimate the total volume of water available above the downstream demand baseflow to add to storage each year. Using the

outflow stream gauge data was the simplest method of evaluation and was determined to be a sound and conservative approach.

The minimum outflow from the reservoir for the months of November through March is 20-30 cfs per the Ruby Dam Manual for Operation and Maintenance (DNRC, December1993). Prior to this publication, a minimum outflow from the reservoir was not established for winter months. Outflow gauge data was reviewed to ensure that the incorporation of a minimum winter outflow would not result in lower spring storage volumes than those that have occurred in the past. For the period of record analyzed, only one downstream gauge reading (March, 1991 at 19.3 cfs) was below the 20 cfs minimum outflow standard. Approximately 10-15% of the downstream gauge records were below 25 cfs, with equal distribution before and after the implementation of the minimum winter flow. From this information, it was concluded that a minimum outflow of 20 cfs was generally maintained prior to the 1995 consent decree and the current minimum flow criteria does not have a significant effect on storage volumes at the start of each spring.

Spill volumes were estimated by assuming all water passing through the downstream gauge minus the demand baseflow was excess water potentially available for storage. Downstream gauge data was collected for the period of record and assembled into tables by month according to the Weibull plotting position function (McCuen, 1998). Because downstream demands were not known on a monthly basis, demand baseflow was included as a variable in this process. From these tables, the 80% exceedance value was highlighted and assumed to be a good estimation of reliable spill volumes for each month. The 80% exceedance value means in 80% of years on record at least the specified volume was available to add to storage. Tables for all months, including six alternatives for demand baseflow volume, are included in Appendix E.

From the range of demands analyzed, a reasonable demand volume of 15,000 acre-ft was assumed for May and 20,000 acre-ft for June to estimate available water. This demand assumption was based on the following.

- The SCS Ruby River Reservoir Operation Guide states that the irrigation demand during the season's peak is between 350 and 450 cfs (20,000 and 27,000 acre-ft if maintained over entire month).

- The Ruby River Reservoir Operation Guidelines state that irrigation demand is estimated to be between 300 and 375 cfs (18,000 to 22,000 acre-ft if maintained over entire month) outside of the irrigation peak.

- Flows in the West Bench and Vigilante Canals were reviewed. Total flow in these canals has never exceeded 18,000 acre-ft in May or June.

- Based on crop consumptive use patterns for this region, July represents the peak month, June utilizing 75% of July, and May utilizing 30% of July.

- During the study period, there were only four years where the flow volume was less than 15,000 acre-ft in May and five years where the flow volume was less than 20,000 acre-ft in June. These values seem to represent a reasonable estimate of flows that were maintained when water was not spilled.

Using these demands, 4492 acre-ft of spilled water was estimated to be available for storage in May (80% exceedance value). In June, 2552 acre-ft was estimated to be available. **Based on all of the stated assumptions and the analysis performed, the approximate 80% exceedance volume of water available to be stored annually is 7,000 acre-ft. If the 50% exceedance volume for May and June is used, 23,000 acre-ft is estimated to be available.** A plot summarizing 50% and 80% exceedance spill volumes for different demand baseflows is included in Appendix E.

Ruby Reservoir spills water almost every year based on end of month storage records. From the analysis performed, it appears that additional active storage of 7,000 to 20,000 acre-ft could be developed.

3.0 References

Department of Natural Resources and Conservation, State Water Project Bureau, Water Resources Division. Ruby Dam Manual for Operation and Maintenance. Helena, MT. December 1993.

McCuen, Richard H. "Hydrologic Analysis and Design." Second Edition. Copyright 1998, Prentice Hall, Inc. Upper Saddle River, New Jersey 07458.

United States Geological Survey. "Methods for Estimating Flood Frequency in Montana Based on Data through Water Year 1998." Water Resouces Investigations Report 03-4308. Helena, MT. February 2004.

APPENDIX A

END OF MONTH STORAGE DATA

RUBY RIVER RESERVOIR 41C 01900

USEABLE CAPACITY = 36,633 A.F. *

CONTENTS IN ACRE-FEET

YEAR	31-Jan	28-Feb	31-Mar	30-Apr	31-May	30-Jun	31-Jul	31-Aug	30-Sep	31-Oct	30-Nov	31-Dec
1960				37037	38850	32400	20550	11700	7550		5290	13120
1961	16300	21105	27000	31548	31200	16322	10400	0		8000	11000	16400
1962	19189	23847	28552	38850	38850	38850	28750	17858	9916	9916	12433	15196
1963	19189	23182	27175	32389	38850	38850	31479	15861	8238		14530	19854
1964	21851	24513	28672	36027	38850	38850	35118	22516	14530	9077		19854
1965	23847	31479	28752	31479	38850	38850	32389	21185	16527	19854	20520	23847
1966	27175	31479	36000	38850	36100		20520	4000	8000	7000		
1967	23847	23847	28750	35118	38850	38850	38850					
1968	23182	27175	30569	36027	38850	38850	36937	25178	19854	21185	25178	27175
1969	27840	31479	30569	37894	38850	37894	36937	21185	8657	11594	20520	24513
1970	29659	32389	36937	36937	38850	38850	32389	14530	9496	9496	16527	21185
1971	27175	29659	31479	31479	36937	38850	30569	19854	13691	14111	23182	26509
1972	27175	28750	32389	34208	37894	38850	35118	21851	13691	12852	12852	17192
1973	25178	26509	29659	38850	38850	37894	28750					22369
1974	26050	29582	31046	33589	38850	38850	30314	20040			13582	
1975	22822	26050	29332	32762		38850	38850	30314	21956		20413	21791
1976	22290		30533	35582	38850	38850	31343	18317		14663		18051
1977	22822	25471	29195	38850		38793	27115	13582				
1978		29832	29896	36518				18616	13360			
1979		29195		33007	39847	30314	17425	7734	1000			
1980		14500		33689	40390	32334			15320			
1981												23000
1982				36382		41742			14796		20969	23262
1983	26050		31970	34973	38850		38850	23974		21611		26682
1984	27115	27767	33639	40074	41265	40800	39847	32762	19269	16234	13582	19894
1985	24732	27876	33271	37798	37664	26682		9327	8414	13150	19016	23169
1986	26482	29686	34008	40163	41350	35772	27627	12555	11749	14796	19894	23974
1987	26915	31534	36045	40442	32762	25697	20620	13528	7300	8141	12925	18157
1988	23720	27202	31970	39847		30751	18051		2000	6000	11892	16786
1989	21791	25285	29686	36518	37500	27767	16500	7000		5550	11338	15502
1990	21525	25100	29832	39097	36660	38180		17425	7055	8141	13070	16230
1991		25290	29960	34330	40390	23260	24620	12550		10010		
1992	25098	28000	33300		30310	40530		5670	500		12500	15200
1993	21530	24730	29690	34770	40710	27610		32230	21330	19130	23170	26080
1994	30550	32520	36380	39490	34240	39260	11450		1600	8150	11800	14200
1995	18960	23280	30070	33750	38350	39060	36830	25090	17490	20270	24060	24760
1996	25590	29130	31910	34430	38830	38050	29050	14200	8860	10290	14840	
1997		27710	29430	30250	38970	38850	34210	23760	15640	14200	19230	24210
1998	29430	29960	30740	37610	38880	37040	32870	20620	15510	17020	18600	21430
1999	25590	28170	32910	37640	39260		27020	12890	7830	9640	13400	17020
2000	20620	26740	30400	38020	37640	33380	23350	10480	4800	9530	15200	17900
2001	22630	28460	31000	37610	32350	28840	23420	9180	3500	5790	12000	15540
2002	19420	22820	27110	31330	28120	29700	20030	8660	6800	9900	14430	18660
2003	22820	25660	32140	37620	38290	30840	18660	6440	4560	7760	11350	15290
2004	22060	23290	27790	33790	28120	30650	23190	11250	6740	10750	13360	18310
2005	22820	25490	31000	36500	36620	38600	32270	21890	15290			
# records	38	41	41	44	40	41	38	39	36	32	33	36
MEAN	23975	26969	30994	35980	37392	35005	27954	16303	10634	11994	15838	20064
MIN	16300	14500	27000	30250	28120	16322	10400	0	500	5550	5290	13120
MAX	30550	32520	36937	40442	41350	41742	39847	32762	21956	21611	25178	27175

*NOTE: CAPACITY AT CONCRETE CREST ELEVATION; CAPACITY AT TOP OF FLASHBOARDS IS 37,612 A.F..
CAPACITY REVISED 3/30/95 PER 1994 SURVEY; PRIOR CAPACITY AT CREST ELEV. WAS 38,850 A.F.

APPENDIX B

UPSTREAM AND DOWNSTREAM GAGE DATA

Reservoir Inflow - Gage 06019500

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	(acre-ft)	(acre-ft)	(acre-ft)	(acre-ft)	(acre-ft)	(acre-ft)	(acre-ft)	(acre-ft)	(acre-ft)	(acre-ft)	(acre-ft)	(acre-ft)
1939	4673	4548	6456	10889	21090	10235	6020	4064	4963	6333	6069	5565
1940	5325	4814	5454	7617	23304	14102	6764	3646	5320	5128	5224	4937
1941	5436	4843	5970	6248	18016	14757	5522	5060	6129	6579	5635	5688
1942	4833	4399	5183	14876	23550	30942	12175	6210	5587	6948	6248	5878
1943	4292	5198	7624	9997	16048	21183	8362	5780	4623	6702	6545	5983
1944	5497	5286	5460	7914	16294	23028	11252	6825	5308	6333	6486	5921
1945	5663	4654	5183	5629	14819	25706	11560	8055	5944	6764	6307	6075
1946	5737	4776	5768	13626	25948	20410	7993	6087	6486	6518	6724	5786
1947	6143	5942	6579	8569	30744	39154	13035	7317	6724	8547	7319	6887
1948	9715	7708	9777	15293	40459	34334	15802	11252	8033	7932	8033	10453
1949	7440	6442	7624	12972	27608	17554	8793	6093	6426	9838	9045	8485
1950	6641	5665	6702	9699	17647	26539	12851	8116	6248	8547	8271	7133
1951	6395	5609	6333	8866	20414	13983	6764	7256	5772	7194	7498	6948
1952	6641	5925	6518	12496	34679	21779	10760	6948	5439	6518	7260	6007
1953	6641	5665	6333	6664	13589	33858	10637	7256	5254	5798	6664	6764
1954	6210	5354	5958	7200	16294	18863	8301	7071	5308	5589	6783	6887
1955	5681	4882	5632	6664	20045	32489	10576	7256	5879	6118	6248	6100
1956	6764	5700	7133	8807	27608	16959	6106	5540	5379	5891	7081	7194
1957	5700	5171	5571	6129	31789	27074	11929	6518	6724	5392	6724	6149
1958	6063	5298	5817	6426	28161	16364	9715	6001	5921	7133	6664	6579
1959	5319	4854	5522	7260	13650	31835	10330	6641	7379	6518	6843	6210
1960	7071	6327	11129	13448	23058	19636	6333	5497	6426	9900	9045	7747
1961	6210	5554	6395	6069	14696	12020	4599	4396	6129	6210	7319	6825
1962	4618	5720	6026	17137	27546	25111	11191	8608	7021	7071	6843	5897
1963	5798	6054	6641	7498	20291	23028	8731	5989	5933	6579	7140	6702
1964	5977	5626	5761	7676	26009	49210	18077	8301	7319	5700	6605	6333
1965	6887	5998	5872	9521	21890	35762	17278	9285	8985	6948	8093	7747
1966	6641	5609	6518	8866	24103	12317	6149	4655	4499	7809	7081	7010
1967	5884	5259	6075	6724	23550	35345	18200	7133	6129	6518	6783	6038
1968	6948	6270	6764	7200	19430	40998	13773	9346	8509	7932	7974	7317
1969	7071	6498	7256	14519	42672	22969	15556	8547	6724	8485	8271	7563
1970	7010	6442	7010	8390	35724	52066	17217	8977	8807	9162	8628	7563
1971	7624	7498	7440	10056	39537	47008	19676	8977	9283	9039	8331	7993
1972	7317	6442	9592	10354	31543	40939	16048	8977	8212	9223	8628	7870
1973	6825	6054	6764	10235	35171	25706	9961	6764	7319	7747	8271	7870
1974	6764	5831	7440	10711	25825	34988	12298	7809	6129	7993	7914	7379
1975	6210	5554	6579	6843	20229	62182	29637	14450	9223	7317	7557	6641
1976	7747	6442	7624	12496	44701	28979	14265	9162	8628	9900	8688	8116
1977	6272	5887	6825	12793	16663	24397	9654	7317	8212	8793	8093	7440
1978	6825	6054	8670	14043	31297	32489	13589	8854	8390	8670	7200	7133
1979	6149	6220	7317	8569	26686	15769	7133	6764	5617	8055	7617	7194
1980	6395	6040	6395	11901	32896	31121	12113	8424	9164	6130	6783	7010
1981	6456	5776	6764	11841	29883	27134	8362	6764	6188	8116	7379	7133
1982	6149	6664	6825	10711	33080	44747	23119	10453	8985	7686	7200	6887
1983	7563	6553	7870	10532	32342	51769	27792	13404	9164	9408	8390	7809
1984	8608	7363	8731	12853	62102	66466	23058	13773	10175	11375	10532	8916
1985	7686	6387	7440	13329	21521	10354	4814	6333	6962	9777	9104	7993
1986	6395	6276	7686	11187	28838	25170	8977	6887	7319	6948	6783	6395
1987	5792	5509	6456	10354	13281	8152	9223	7993	6486	7379	7498	6641
1988	5737	5234	5946	10830	25333	11603	5048	4876	4362	6333	6902	6272
1989	5423	4510	5977	8093	17770	12912	5841	5442	4939	5854	6605	5792
1990	5946	5098	6149	11960	16602	23147	8854	5712	5242	7194	6664	5989
1991	5134	4760	5325	6307	18877	29038	7194	5571	7140	6641	6367	5245
1992	5860	5752	6764	9223	15003	9521	9469	3781	6188	7071	6664	6272
1993	6007	5048	6395	7438	38676	29276	15372	11560	8390	6641	6248	6026
1994	6518	6387	6456	10592	16294	8985	5737	4495	5076	8485	6902	6641
1995	5454	5509	6702	7974	32281	61706	26009	11498	9342	6456	5718	5731
1996	7379	6787	7563	12853	33572	44033	11990	7071	7855	8977	8152	7747
1997	6948	5776	7747	9045	39168	46651	13958	9531	7438	8116	7736	7256
1998	6887	5665	8178	10532	36585	46949	28469	12912	9818	9039	7319	7133
1999	7256	6387	7747	9104	24841	34929	12789	8424	8569	10145	8866	7870
2000	6825	6270	6887	9461	21213	14995	7440	4802	6188	7932	7260	7010
2001	5811	4998	6579	8926	19000	12853	8424	5103	5671	7624	6486	6210
2002	5804	5154	5636	6129	11498	18565	7440	4771	6248	6702	6307	6075
2003	5491	5104	6764	8569	23242	17732	7133	5761	5784	5995	5635	5503
2004	5866	5533	6456	7379	13712	17732	9285	5319	6545	6579	5950	6087
Minimum	4292	4399	5183	5629	11498	8152	4599	3646	4362	5128	5224	4937
Maximum	9715	7708	11129	17137	62102	66466	29637	14450	10175	11375	10532	10453
Average	6334	5737	6784	9759	25606	27843	11856	7416	6842	7484	7261	6813
Median	6210	5683	6579	9342	23826	25438	10453	7010	6456	7163	7111	6794

Reservoir Outflow - Gage 06020600

Year	Jan (acre-ft)	Feb (acre-ft)	Mar (acre-ft)	Apr (acre-ft)	May (acre-ft)	Jun (acre-ft)	Jul (acre-ft)	Aug (acre-ft)	Sep (acre-ft)	Oct (acre-ft)	Nov (acre-ft)	Dec (acre-ft)
1964	1943	1846	2109	2071	16909	51590	23304	24472	16721	11375	2505	1875
1965	2011	1799	3609	11425	12912	36119	22566	22689	12674	15003	5528	1912
1966	2097	1955	2257	5064	25763	23028	17831	20106	12020	13220	9402	3210
1967	1439	1205	1377	2214	13589	38737	22197	24718	20945	5860	3225	1457
1968	2017	1910	2644	3094	14634	43736	20414	20967	14876	11252	6307	2970
1969	5565	4948	8424	7855	42058	27312	17831	27792	17256	9039	3921	5356
1970	2626	2277	2453	9223	34556	55874	26932	29084	15531	7501	3124	2939
1971	3517	5132	6210	9521	34433	43200	28838	20414	14519	9961	4927	3277
1972	5319	5171	6456	9521	25886	42545	20475	23919	16423	9285	4284	4944
1973	1906	1766	2004	4504	34433	28383	16356	21398	12853	10453	8866	2878
1974	3019	2866	6456	8926	20537	39154	19184	22197	17256	7932	4463	3191
1975	2890	2588	2798	3951	22259	60635	34372	21828	23742	10145	3035	2644
1976	7809	3773	3609	7617	40766	32370	24042	24902	17613	14388	6486	8547
1977	4077	2677	2650	2856	20168	25111	17954	22566	14281	8793	5576	5220
1978	3523	3871	6456	7914	26809	36952	19922	25087	16721	5103	3969	3775
1979	2582	2516	5122	6248	21521	28800	21398	21521	12674	10330	4368	3074
1980	2312	2186	2367	2475	31666	37785	20598	25394	12912	3763	2291	2275
1981	3234	2510	3800	8212	33941	33084	23857	21644	16304	5860	4873	4692
1982	2558	2344	3167	8033	29330	48972	27977	28469	21362	3505	2993	2601
1983	6395	4004	5183	6783	22504	54565	28715	27423	21302	8116	6188	6333
1984	8547	4970	4193	7676	63640	71940	26255	21582	23028	7256	7676	8731
1985	3351	3138	3708	9283	24841	22552	16356	13650	8093	14696	13210	4175
1986	3283	2993	3523	4528	27362	34215	18754	22812	10830	2337	2243	3087
1987	3160	2099	2103	5623	21090	16721	15618	14941	15293	4827	4201	3050
1988	1857	1720	2189	2374	25271	23623	20352	18631	7795	5442	2095	1802
1989	1285	1483	1697	1952	17647	23683	19061	15556	11722	3646	1999	1482
1990	1832	1238	1500	2243	19492	22493	22013	18323	15174	3302	1999	1900
1991	1629	1188	1187	1815	12851	30704	19492	17278	12912	7440	2910	2115
1992	1943	1921	2109	3279	24042	17554	12113	20106	9699	5356	2690	1734
1993	1470	1388	1525	2160	34126	31835	18200	20229	19993	2951	2172	1795
1994	3406	3155	3548	7260	23181	18625	20168	16356	3535	10637	4005	3960
1995	1562	1438	1519	3499	27792	62717	30129	23488	17970	3499	2458	1832
1996	7133	3014	5804	9818	27116	43438	23427	22381	14638	7870	5260	7686
1997	2810	2649	6518	7498	28961	41772	19860	20229	17256	6764	2517	2693
1998	2373	3032	10699	5927	35724	45937	33019	26440	17018	8239	4665	2582
1999	4366	2877	3265	4891	25517	37071	24780	22443	17137	9469	7379	5239
2000	2367	2019	1875	2987	21275	20172	18200	19061	11663	5399	3939	2810
2001	2078	1744	1568	3594	23673	17494	15679	20967	13091	2490	2386	2312
2002	1937	1788	1925	2035	15249	18268	18016	17217	9580	2976	2142	1894
2003	1396	1250	1593	2214	21705	25587	21705	19184	9461	2472	1720	1451
Minimum	1285	1188	1187	1815	12851	16721	12113	13650	3535	2337	1720	1451
Maximum	8547	5171	10699	11425	63640	71940	34372	29084	23742	15003	13210	8731
Average	3116	2561	3530	5454	26131	35359	21699	21687	14847	7449	4350	3388
Median	2570	2310	2724	4978	25056	33650	20445	21613	15025	7471	3954	2908

APPENDIX C

PERIOD OF RECORD ANALYSIS

Appendix C - Period of Record Analysis

End of month (EOM) storage records were obtained from DNRC State Water Projects Bureau for Ruby Reservoir. Storage records were maintained from 1960 to current, with several monthly values missing from the data. A copy of the EOM records received from DNRC is included in Appendix A.

United States Geological Survey (USGS) surface water gauging records were available for upstream and downstream gauges to evaluate inflow and outflow from the reservoir. Data was presented from 1939 through 2004 for USGS Site No. 06019500, located 4.2 miles upstream of the reservoir. For USGS Site No. 06020600, located 0.2 miles downstream of the reservoir, data was presented from 1964-2003. In the gauge records, a value was present for every month during the reporting period. Up- and downstream gauge data is included in Appendix B.

Because of the availability of data, the period of record chosen for this analysis coincides with the downstream gauge data (shortest length of record maintained). **The period of record for this analysis is 40 years (1964-2003).**

To ensure the period of record chosen was representative of the natural fluctuation between wet and dry periods, the 40-year period of record for the upstream gauge (inflow into the reservoir) was compared to data collected from 1939-2003. The upstream gauge was chosen for this comparison because it has the longest period of record and recorded values are not affected by changes in storage or evaporation.

The period comparison was conducted using the total yearly volume of water passing through the upstream gauge and gauge volumes recorded for the months of May and June (when water is typically spilling from the reservoir and may be available to add to storage).

To compare the entire period of record at the upstream gauge to the 40-year period between 1964 and 2003, the key parameters evaluated were average flow volumes, a moving 5-year average, 50% exceedance values, and 80% exceedance values. To determine 50% and 80% exceedance values the Weibull plotting position equation was used according to "Hydrologic Analysis and Design" (McCuen, 1998).

From this study, it was concluded that the period of record selected (beginning in 1964) may be wetter than the period beginning in 1939. Based on annual inflow volume average and 50% exceedance values, the extended period was estimated to be approximately 9,000 acre-ft and

16,000 acre-ft drier than the 40-year period. At the 80% exceedance value, the longer period is equal to the 40-year period, indicating the selected period has many wet years and a similar number of dry years in comparison to the longer period.

Similar results were found when examining the months of May and June individually. All results are summarized in the table below.

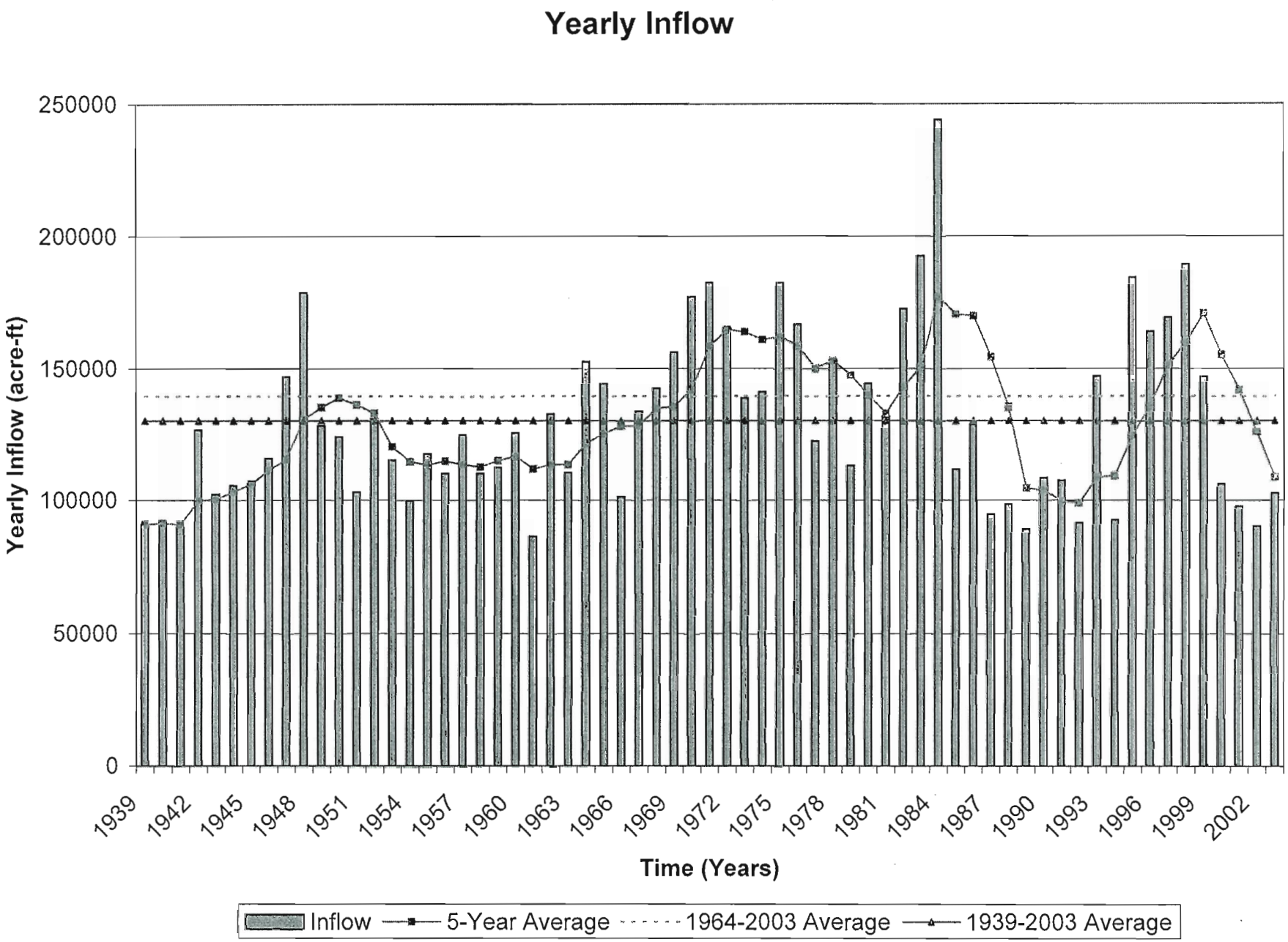
	Average Volume (acre-ft)	50% Exceedance Volume (acre-ft)	80% Exceedance Volume (acre-ft)
1939-2003 Period (Annual)	130,247	124,869	101,256
1964-2003 Period (Annual)	139,481	141,080	101,256
Difference	***9,234***	***16,211***	***0***
1939-2003 Period (May)	25,606	23,550	16,602
1964-2003 Period (May)	27,381	25,825	17,770
Difference	***1,775***	***2,275***	***1,168***
1939-2003 Period (June)	27,843	25,170	14,757
1964-2003 Period (June)	30,894	29,038	12,912
Difference	***3,051***	***3,868***	***-1,845***

Plots and data summarizing both periods of record are included in the following pages.

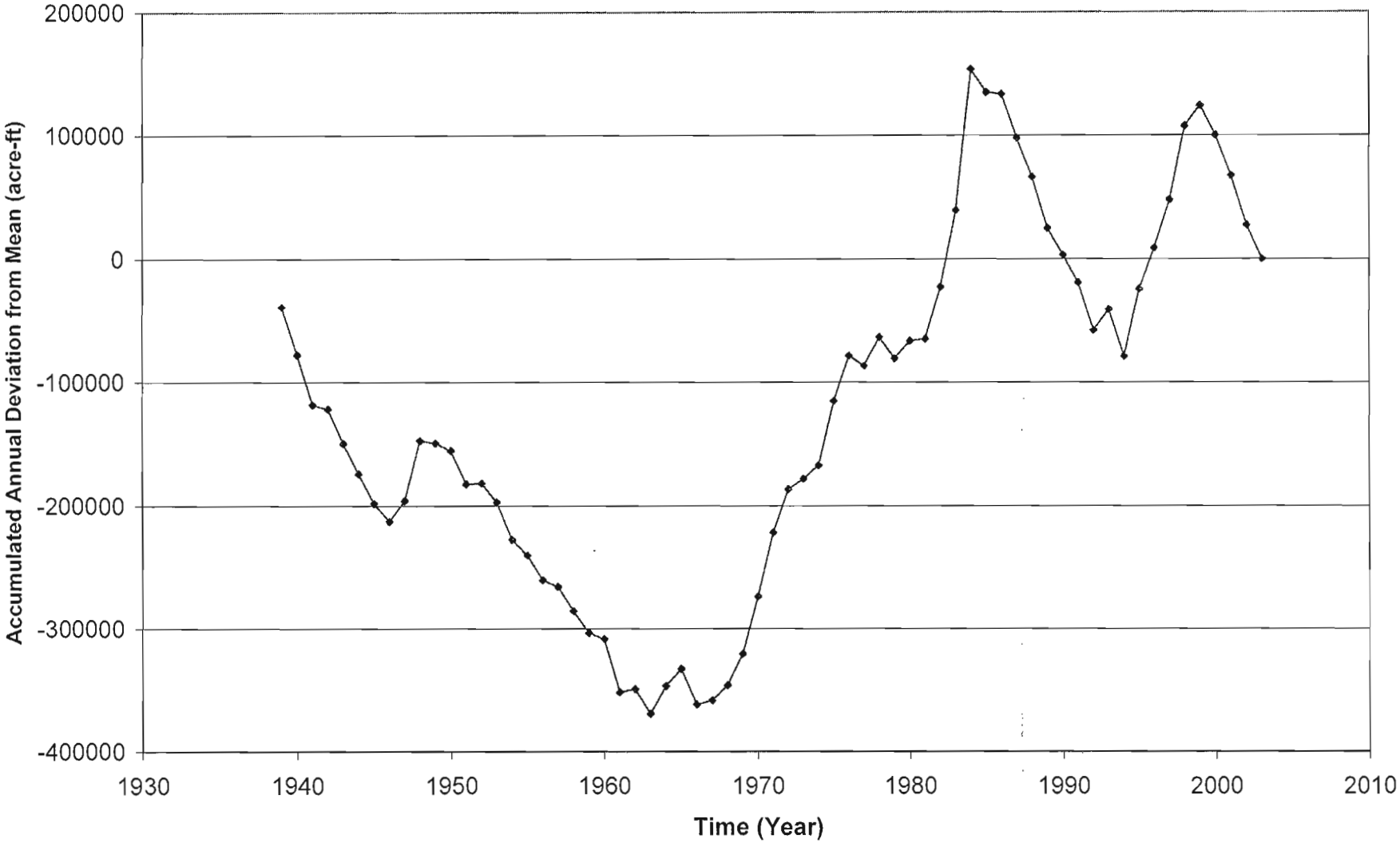
Based on these findings and data availability, the 40-year period will be used for this analysis, but it is important to recognize the spill volumes reported may be slightly larger than if a longer period had been considered. **Based on the months of May and June, approximately 5,000 acre-ft of storage may be over-estimated in an average year. Based on a year correlating to 80% exceedance, the 40-year period is actually slightly drier than the full period, therefore water determined to be available for storage should not be over-estimated.**

Annual Inflow Volume			
Year	Yearly Total Inflow (acre-ft)	Accumulated Surplus/Deficit (acre-ft)	5-Year Average (acre-ft)
1939	90906	-39341	90906
1940	91636	-77952	91271
1941	89882	-118316	90808
1942	126829	-121733	99813
1943	102339	-149641	100318
1944	105605	-174282	103258
1945	106359	-198170	106203
1946	115859	-212558	111398
1947	146959	-195845	115424
1948	178790	-147302	130714
1949	128321	-149228	135258
1950	124058	-155416	138797
1951	103031	-182631	136232
1952	130968	-181910	133034
1953	115123	-197033	120300
1954	99818	-227462	114600
1955	117570	-240138	113302
1956	110160	-260225	114728
1957	124869	-265602	113508
1958	110142	-285707	112512
1959	112359	-303595	115020
1960	125618	-308223	116630
1961	86422	-352047	111882
1962	132789	-349505	113466
1963	110384	-369368	113514
1964	152594	-347020	121561
1965	144265	-333002	125291
1966	101256	-361993	128257
1967	133639	-358601	128427
1968	142461	-346386	134843
1969	156131	-320502	135550
1970	176995	-273754	142096
1971	182461	-221539	158337
1972	165146	-186640	164639
1973	138686	-178200	163884
1974	141080	-167366	160874
1975	182422	-115191	161959
1976	166748	-78689	158817
1977	122344	-86591	150256
1978	153213	-63625	153162
1979	113088	-80784	147563
1980	144370	-66660	139953
1981	131796	-65111	132962
1982	172506	-22851	142995
1983	192597	39499	150871
1984	243953	153206	177045
1985	111700	134659	170510
1986	128860	133272	169923
1987	94764	97790	154375
1988	98476	66019	135551
1989	89157	24930	104591
1990	108558	3241	103963
1991	107599	-19407	99711
1992	91569	-58085	99072
1993	147076	-41255	108792
1994	92567	-78935	109474
1995	184380	-24801	124638
1996	163980	8932	135914
1997	169369	48054	151474
1998	189485	107292	159956
1999	146928	123973	170828
2000	106283	100009	155209
2001	97685	67448	141950
2002	90333	27534	126143
2003	102712	0	108788
Average	130247		

Upstream Gage (1939-2003)		Upstream Gage (1964-2003)	
Inflow		Inflow	
Descending (acre-ft)	Percentile	Descending (acre-ft)	Percentile
243953	1.52%		
192597	3.03%		
189485	4.55%		
184380	6.06%		
182461	7.58%		
182422	9.09%		
178790	10.61%		
176995	12.12%		
172506	13.64%		
169369	15.15%		
166748	16.67%		
165146	18.18%		
163980	19.70%		
156131	21.21%		
153213	22.73%		
152594	24.24%		
147076	25.76%		
146959	27.27%		
146928	28.79%		
144370	30.30%		
144265	31.82%		
142461	33.33%		
141080	34.85%		
138686	36.36%		
133639	37.88%		
132789	39.39%	243953	2.44%
131796	40.91%	192597	4.88%
130968	42.42%	189485	7.32%
128860	43.94%	184380	9.76%
128321	45.45%	182461	12.20%
126829	46.97%	182422	14.63%
125618	48.48%	176995	17.07%
124869	**50.00%**	172506	19.51%
124058	51.52%	169369	21.95%
122344	53.03%	166748	24.39%
117570	54.55%	165146	26.83%
115859	56.06%	163980	29.27%
115123	57.58%	156131	31.71%
113088	59.09%	153213	34.15%
112359	60.61%	152594	36.59%
111700	62.12%	147076	39.02%
110384	63.64%	146928	41.46%
110160	65.15%	144370	43.90%
110142	66.67%	144265	46.34%
108558	68.18%	142461	48.78%
107599	69.70%	**141080**	**51.22%**
106359	71.21%	138686	53.66%
106283	72.73%	133639	56.10%
105605	74.24%	131796	58.54%
103031	75.76%	128860	60.98%
102712	77.27%	122344	63.41%
102339	78.79%	113088	65.85%
101256	**80.30%**	111700	68.29%
99818	81.82%	108558	70.73%
98476	83.33%	107599	73.17%
97685	84.85%	106283	75.61%
94764	86.36%	102712	78.05%
92567	87.88%	**101256**	**80.49%**
91636	89.39%	98476	82.93%
91569	90.91%	97685	85.37%
90906	92.42%	94764	87.80%
90333	93.94%	92567	90.24%
89882	95.45%	91569	92.68%
89157	96.97%	90333	95.12%
86422	98.48%	89157	97.56%
Average **130247**		**139481**	


Yearly Inflow
250000
200000
150000
100000
50000
0
Yearly Inflow (acre-ft)
1939
1942
1945
1948
1951
1954
1957
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
Time (Years)
Inflow
5-Year Average
1964-2003 Average
1939-2003 Average

Annual Accumulated Surplus/Deficit



May Inflow Volume

Year	May Inflow (acre-ft)	Accumulated Surplus/Deficit (acre-ft)	5-Year Average (acre-ft)
1939	21090	0	21090
1940	23304	-4516	22197
1941	18016	-6818	20803
1942	23550	-14408	21490
1943	16048	-16464	20402
1944	16294	-26021	19442
1945	14819	-35333	17745
1946	25948	-46120	19332
1947	30744	-45778	20771
1948	40459	-40641	25653
1949	27608	-25788	27915
1950	17647	-23785	28481
1951	20414	-31744	27374
1952	34679	-36936	28161
1953	13589	-27863	22787
1954	16294	-39880	20525
1955	20045	-49192	21004
1956	27608	-54753	22443
1957	31789	-52751	21865
1958	28161	-46568	24780
1959	13650	-44012	24251
1960	23058	-55968	24853
1961	14696	-58516	22271
1962	27546	-69426	21422
1963	20291	-67485	19848
1964	26009	-72800	22320
1965	21890	-72397	22086
1966	24103	-76113	23968
1967	23550	-77616	23169
1968	19430	-79672	22996
1969	42672	-85848	26329
1970	35724	-68781	29096
1971	39537	-58663	32183
1972	31543	-44732	33781
1973	35171	-38795	36929
1974	25825	-29230	33560
1975	20229	-29011	30461
1976	44701	-34387	31494
1977	16663	-15292	28518
1978	31297	-24235	27743
1979	26686	-18543	27915
1980	32896	-17463	30449
1981	29883	-10173	27485
1982	33080	-5896	30768
1983	32342	1578	30977
1984	62102	8315	38061
1985	21521	44811	35786
1986	28838	40726	35577
1987	13281	43958	31617
1988	25333	31634	30215
1989	17770	31361	21348
1990	16602	23525	20365
1991	18877	14520	18372
1992	15003	7791	18717
1993	38676	-2812	21385
1994	16294	10258	21090
1995	32281	947	24226
1996	33572	7622	27165
1997	39168	15588	31998
1998	36585	29150	31580
1999	24841	40129	33289
2000	21213	39364	31076
2001	19000	34972	28161
2002	11498	28365	22627
2003	23242	14258	19959
2004	13712	11894	17733
Average	25606		

Upstream Gage May Inflow (1939-2003) Descending (acre-ft)	Percentile
62102	1.49%
44701	2.99%
42672	4.48%
40459	5.97%
39537	7.46%
39168	8.96%
38676	10.45%
36585	11.94%
35724	13.43%
35171	14.93%
34679	16.42%
33572	17.91%
33080	19.40%
32896	20.90%
32342	22.39%
32281	23.88%
31789	25.37%
31543	26.87%
31297	28.36%
30744	29.85%
29883	31.34%
28838	32.84%
28161	34.33%
27608	35.82%
27608	37.31%
27546	38.81%
26686	40.30%
26009	41.79%
25948	43.28%
25825	44.78%
25333	46.27%
24841	47.76%
24103	49.25%
23550	50.75%
23550	52.24%
23304	53.73%
23242	55.22%
23058	56.72%
21890	58.21%
21521	59.70%
21213	61.19%
21090	62.69%
20414	64.18%
20291	65.67%
20229	67.16%
20045	68.66%
19430	70.15%
19000	71.64%
18877	73.13%
18016	74.63%
17770	76.12%
17647	77.61%
16663	79.10%
16602	80.60%
16294	82.09%
16294	83.58%
16294	85.07%
16048	86.57%
15003	88.06%
14819	89.55%
14696	91.04%
13712	92.54%
13650	94.03%
13589	95.52%
13281	97.01%
11498	98.51%
25606	

Upstream Gage May Inflow (1964-2003) Descending (acre-ft)	Percentile
62102	2.38%
44701	4.76%
42672	7.14%
39537	9.52%
39168	11.90%
38676	14.29%
36585	16.67%
35724	19.05%
35171	21.43%
33572	23.81%
33080	26.19%
32896	28.57%
32342	30.95%
32281	33.33%
31543	35.71%
31297	38.10%
29883	40.48%
28838	42.86%
26686	45.24%
26009	47.62%
25825	50.00%
25333	52.38%
24841	54.76%
24103	57.14%
23550	59.52%
23242	61.90%
21890	64.29%
21521	66.67%
21213	69.05%
20229	71.43%
19430	73.81%
19000	76.19%
18877	78.57%
17770	80.95%
16663	83.33%
16602	85.71%
16294	88.10%
15003	90.48%
13712	92.86%
13281	95.24%
11498	97.62%
27381	

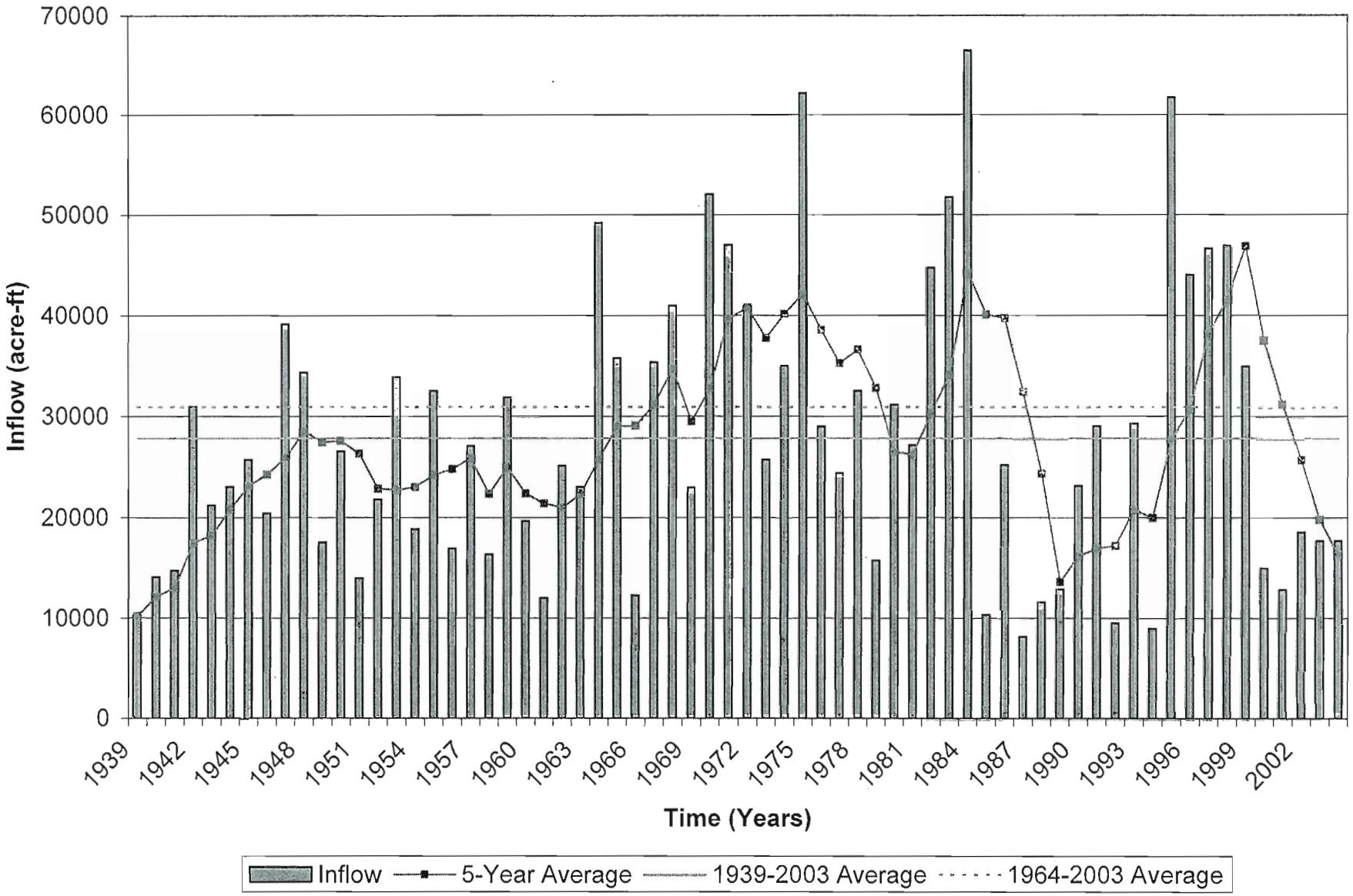
June Inflow Volume

Year	June Inflow	Accumulated Surplus/Deficit	5-Year Average
	(acre-ft)	(acre-ft)	(acre-ft)
1939	10235	0	10235
1940	14102	-17608	12169
1941	14757	-31348	13031
1942	30942	-44433	17509
1943	21183	-41334	18244
1944	23028	-47993	20803
1945	25706	-52807	23123
1946	20410	-54944	24254
1947	39154	-62377	25896
1948	34334	-51065	28526
1949	17554	-44574	27431
1950	26539	-54863	27598
1951	13983	-56166	26313
1952	21779	-70026	22838
1953	33858	-76090	22742
1954	18863	-70074	23004
1955	32489	-79054	24194
1956	16959	-74407	24789
1957	27074	-85291	25849
1958	16364	-86059	22350
1959	31835	-97538	24944
1960	19636	-93546	22374
1961	12020	-101752	21386
1962	25111	-117575	20993
1963	23028	-120307	22326
1964	49210	-125121	25801
1965	35762	-103754	29026
1966	12317	-95834	29086
1967	35345	-111359	31133
1968	40998	-103856	34727
1969	22969	-90701	29478
1970	52066	-95574	32739
1971	47008	-71351	39677
1972	40939	-52185	40796
1973	25706	-39089	37738
1974	34988	-41226	40141
1975	62182	-34080	42165
1976	28979	260	38559
1977	24397	1396	35250
1978	32489	-2050	36607
1979	15769	2597	32763
1980	31121	-9477	26551
1981	27134	-6199	26182
1982	44747	-6908	30252
1983	51769	9997	34108
1984	66466	33923	44247
1985	10354	72546	40094
1986	25170	55058	39701
1987	8152	52385	32382
1988	11603	32695	24349
1989	12912	16456	13638
1990	23147	1525	16197
1991	29038	-3170	16971
1992	9521	-1974	17244
1993	29276	-20296	20779
1994	8985	-18863	19993
1995	61706	-37720	27705
1996	44033	-3857	30704
1997	46651	12334	38130
1998	46949	31142	41665
1999	34929	50249	46854
2000	14995	57335	37511
2001	12853	44487	31275
2002	18565	29498	25658
2003	17732	20221	19815
2004	17732	10110	16376
Average	27843		

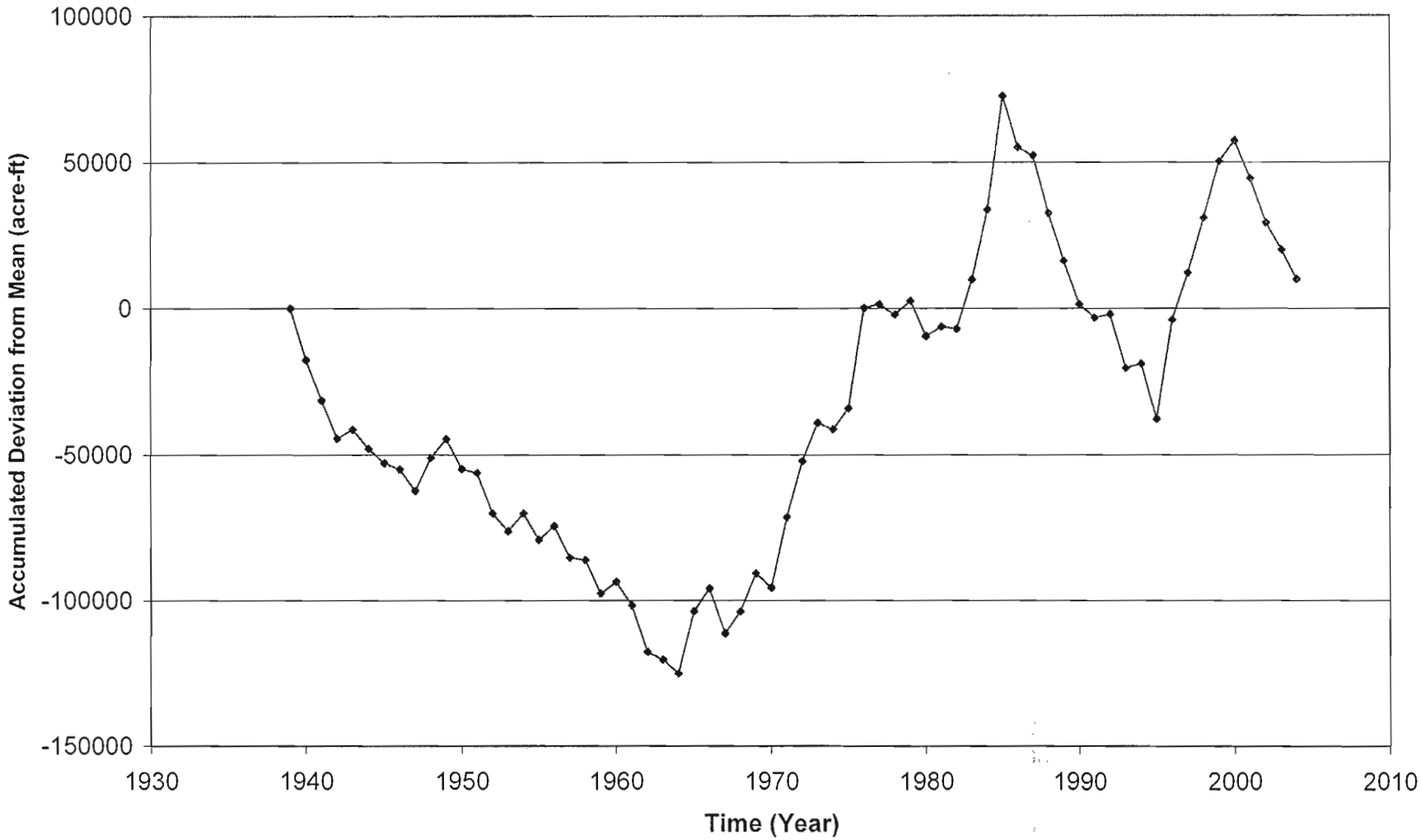
Upstream gage	
June Inflow (1939-2003)	
Descending (acre-ft)	Percentile
66466	1.49%
62182	2.99%
61706	4.48%
52066	5.97%
51769	7.46%
49210	8.96%
47008	10.45%
46949	11.94%
46651	13.43%
44747	14.93%
44033	16.42%
40998	17.91%
40939	19.40%
39154	20.90%
35762	22.39%
35345	23.88%
34988	25.37%
34929	26.87%
34334	28.36%
33858	29.85%
32489	31.34%
32489	32.84%
31835	34.33%
31121	35.82%
30942	37.31%
29276	38.81%
29038	40.30%
28979	41.79%
27134	43.28%
27074	44.78%
26539	46.27%
25706	47.76%
25706	49.25%
25170	50.75%
25111	52.24%
24397	53.73%
23147	55.22%
23028	56.72%
23028	58.21%
22969	59.70%
21779	61.19%
21183	62.69%
20410	64.18%
19636	65.67%
18863	67.16%
18565	68.66%
17732	70.15%
17732	71.64%
17554	73.13%
16959	74.63%
16364	76.12%
15769	77.61%
14995	79.10%
14757	80.60%
14102	82.09%
13983	83.58%
12912	85.07%
12853	86.57%
12317	88.06%
12020	89.55%
11603	91.04%
10354	92.54%
10235	94.03%
9521	95.52%
8985	97.01%
8152	98.51%
27843	

Upstream Gage	
June Inflow (1964-2003)	
Descending (acre-ft)	Percentile
66466	2.38%
62182	4.76%
61706	7.14%
52066	9.52%
51769	11.90%
49210	14.29%
47008	16.67%
46949	19.05%
46651	21.43%
44747	23.81%
44033	26.19%
40998	28.57%
40939	30.95%
35762	33.33%
35345	35.71%
34988	38.10%
34929	40.48%
32489	42.86%
31121	45.24%
29276	47.62%
29038	50.00%
28979	52.38%
27134	54.76%
25706	57.14%
25170	59.52%
24397	61.90%
23147	64.29%
22969	66.67%
18565	69.05%
17732	71.43%
17732	73.81%
15769	76.19%
14995	78.57%
12912	80.95%
12853	83.33%
12317	85.71%
11603	88.10%
10354	90.48%
9521	92.86%
8985	95.24%
8152	97.62%
30894	

Reservoir Inflow in June



Accumulated Surplus/Deficit in June



APPENDIX D

EXISTING OPERATION MODEL

Appendix D - Operation Model

An operation model was created using gauge data, EOM storage records, and evaporation and precipitation data. USGS Site No. 06019500 is located 4.2 miles above the reservoir with a drainage area of 534 mi^2. USGS Site No. 06020600 is located 0.2 miles downstream of the dam with a drainage area of 596 mi^2. Upstream gauge data was adjusted to compensate for the different drainage areas using Equation 19 from the USGS publication Methods for Estimating Flood Frequency in Montana Based on Data through Water Year 1998. A regression coefficient value of 0.894 was used for drainage areas in the southwest region of Montana and a 2-year flood. A 2-year flood coefficient was selected to best approximate common flows in the area.

Several records were left vacant in the EOM storage data provided by DNRC State Water Projects Bureau for Ruby Reservoir. These data gaps were filled in using a combination of linear interpolation (for one to two adjacent blank months) and the judgment of HKM personnel (for data gaps larger than two adjacent months). When judgment was used; inflow, outflow, and storage records were compared to correlate data to other similar years for which data was recorded.

The operation model was calibrated in an attempt to define a relationship between EOM storage records, gauge data, and net evaporation. Because there are no diversions of the Ruby River before the downstream gauge, demand was not used in calibrating the existing operation model. After adjusting the net evaporation value to provide a "best-fit" between EOM storage record and gauge data, it was found the most appropriate value for net evaporation is zero. This value could result from inaccurate reservoir storage data, a change in reservoir storage capacity, reservoir storage measured on any day other than the last day of the corresponding month, etc. Data and plots for the calibrated existing operation model (with a net evaporation of 0.0 in/year) can be seen in the following pages. Due to possible errors and inaccuracies, the existing operation model was not used to estimate the volume of water available for storage in the final analysis.

The operation model is intended to be utilized as a tool for modeling potential changes to the reservoir's use. If the reservoir operating criteria is altered for hydropower or the addition of more storage volume, the calibrated model can be used to predict and model potential impacts of these changes.

Source: USGS
Gage #: 06019500
6020600

Reservoir Existing Operation Model - Missouri Data

Interpolated Value
Value derived from interpolated value

Evap. = 0

Water Year	Month-Yr	Inflow (acre-ft)	Outflow (acre-ft)	Records EOM Storage (acre-ft)	Record Storage Change (acre-ft)	Prev. Month Reservoir Surf. Area (acres)	NET Reser. Evapor. Depth (in)	Reser. Evapor. Volume (acre-ft)	Storage Change Equation (acre-ft)	Cumulative Storage (acre-ft)	Cumulative Storage (w/ Reset) (acre-ft)	Yearly Drawdown (acre-ft)
1964	Oct	6288	11375	11868		417.2	0.00	0.0	-5087	11868		26982.0
	Nov	7286	2505	14530	2662	467.5	0.00	0.0	4781	16649	4781	
	Dec	6987	1875	19854	5324	556.8	0.00	0.0	5111	21761	9893	
	Jan	6593	1943	21851	1997	588.7	0.00	0.0	4650	26411	21851	
	Feb	6206	1846	24513	2662	630.9	0.00	0.0	4360	30771	26211	
	Mar	6356	2109	28672	4159	692.8	0.00	0.0	4247	35017	30457	
	Apr	8468	2071	36027	7355	792.6	0.00	0.0	6397	38850	36855	
	May	28693	16909	38850	2823	831.2	0.00	0.0	11784	38850	38850	
	Jun	54288	51590	38850	0	831.2	0.00	0.0	2698	38850	38850	
	Jul	19943	23304	35118	-3732	779.8	0.00	0.0	-3361	35489	35489	
	Aug	9157	24472	22516	-12602	600.2	0.00	0.0	-15315	20174	20174	
	Sep	8074	16721	14530	-7986	467.5	0.00	0.0	-8646	11528	11528	
1965	Oct	7665	15003	9077	-5453	360.2	0.00	0.0	-7338	4190	4190	29773.0
	Nov	8928	5528	14465.5	5388.5	467.5	0.00	0.0	3400	7589	7589	
	Dec	8547	1912	19854	5388.5	556.8	0.00	0.0	6635	14224	14224	
	Jan	7597	2011	23847	3993	618.8	0.00	0.0	5587	19811	23847	
	Feb	6617	1799	31479	7632	730.2	0.00	0.0	4818	24628	28665	
	Mar	6478	3609	28752	-2727	692.8	0.00	0.0	2869	27497	31533	
	Apr	10503	11425	31479	2727	730.2	0.00	0.0	-922	26575	30611	
	May	24148	12912	38850	7371	831.2	0.00	0.0	11236	37811	38850	
	Jun	39452	36119	38850	0	831.2	0.00	0.0	3333	38850	38850	
	Jul	19061	22566	32389	-6461	743.1	0.00	0.0	-3505	35345	35345	
	Aug	10243	22689	21185	-11204	578.4	0.00	0.0	-12446	22899	22899	
	Sep	9912	12674	16527	-4658	500.7	0.00	0.0	-2762	20137	20137	
1966	Oct	8615	13220	19854	3327	556.8	0.00	0.0	-4605	15531	15531	34850.0
	Nov	7812	9402	20520	666	567.7	0.00	0.0	-1590	13941	13941	
	Dec	7733	3210	23847	3327	618.8	0.00	0.0	4523	18465	18465	
	Jan	7326	2097	27175	3328	673.8	0.00	0.0	5229	23694	27175	
	Feb	6188	1955	31479	4304	730.2	0.00	0.0	4233	27927	31408	
	Mar	7190	2257	36000	4521	792.6	0.00	0.0	4934	32860	36342	
	Apr	9781	5064	38850	2850	831.2	0.00	0.0	4717	37578	38850	
	May	26590	25763	36100	-2750	792.6	0.00	0.0	827	38405	38850	
	Jun	13588	23028	28310	-7790	686.5	0.00	0.0	-9440	28965	29410	
	Jul	6783	17831	20520	-7790	567.7	0.00	0.0	-11048	17917	18362	
	Aug	5135	20106	4000	-16520	228.2	0.00	0.0	-14972	2945	3390	
	Sep	4963	12020	8000	4000	339.4	0.00	0.0	-7057	0	0	
1967	Oct	7190	5860	7000	-1000	312.5	0.00	0.0	1330	1330	1330	31850.0
	Nov	7483	3225	12615.67	5615.667	434.7	0.00	0.0	4258	5589	5589	
	Dec	6661	1457	18231.33	5615.667	530.5	0.00	0.0	5204	10793	10793	
	Jan	6492	1439	23847	5615.667	618.8	0.00	0.0	5053	15845	23847	
	Feb	5802	1205	23847	0	618.8	0.00	0.0	4597	20442	28444	
	Mar	6702	1377	28750	4903	692.8	0.00	0.0	5324	25767	33768	
	Apr	7418	2214	35118	6368	779.8	0.00	0.0	5204	30971	38850	
	May	25980	13589	38850	3732	831.2	0.00	0.0	12391	38850	38850	
	Jun	38993	38737	38850	0	831.2	0.00	0.0	255	38850	38850	
	Jul	20078	22197	38850	0	831.2	0.00	0.0	-2119	36731	36731	
	Aug	7869	24718	32762	-6088	749.4	0.00	0.0	-16849	19882	19882	
	Sep	6761	20945	19269	-13493	545.6	0.00	0.0	-14184	5698	5698	
1968	Oct	8750	11252	16234	-3035	495.5	0.00	0.0	-2502	3196	3196	25268.0
	Nov	8796	6307	13582	-2652	448.0	0.00	0.0	2489	5685	5685	
	Dec	8072	2970	19894	6312	556.8	0.00	0.0	5102	10787	10787	
	Jan	7665	2017	23182	3288	612.7	0.00	0.0	5648	16435	23182	
	Feb	6917	1910	27175	3993	673.8	0.00	0.0	5007	21442	28189	
	Mar	7462	2644	30569	3394	717.1	0.00	0.0	4818	26260	33007	
	Apr	7943	3094	36027	5458	792.6	0.00	0.0	4849	31108	37855	
	May	21435	14634	38850	2823	831.2	0.00	0.0	6801	37909	38850	
	Jun	45229	43736	38850	0	831.2	0.00	0.0	1493	38850	38850	
	Jul	15194	20414	36937	-1913	805.1	0.00	0.0	-5219	33631	33631	
	Aug	10310	20967	25178	-11759	642.6	0.00	0.0	-10657	22974	22974	
	Sep	9387	14876	19854	-5324	556.8	0.00	0.0	-5489	17485	17485	
1969	Oct	9361	9039	21185	1331	578.4	0.00	0.0	322	17807	17807	30193.0
	Nov	9125	3921	25178	3993	642.6	0.00	0.0	5203	23010	23010	

Source: USGS
Gage #: 06019500
6020600

Reservoir Existing Operation Model - Missouri Data

Interpolated Value
Value derived from interpolated value

Evap. = 0

Water Year	Month-Yr	Inflow (acre-ft)	Outflow (acre-ft)	Records EOM Storage (acre-ft)	Record Storage Change (acre-ft)	Prev. Month Reservoir Surf. Area (acres)	NET Reser. Evapor. Depth (in)	Reser. Evapor. Volume (acre-ft)	Storage Change Equation (acre-ft)	Cumulative Storage (acre-ft)	Cumulative Storage (w/ Reset) (acre-ft)	Yearly Drawdown (acre-ft)
	Dec	8343	5356	27175	1997	673.8	0.00	0.0	2988	25998	25998	
	Jan	7801	5565	27840	665	680.2	0.00	0.0	2236	28234	27840	
	Feb	7168	4948	31479	3639	730.2	0.00	0.0	2220	30454	30060	
	Mar	8004	8424	30569	-910	717.1	0.00	0.0	-420	30034	29640	
	Apr	16017	7855	37894	7325	818.3	0.00	0.0	8163	38197	37803	
	May	47076	42058	38850	956	831.2	0.00	0.0	5018	38850	38850	
	Jun	25339	27312	37894	-956	818.3	0.00	0.0	-1974	36876	36876	
	Jul	17162	17831	36937	-957	805.1	0.00	0.0	-670	36206	36206	
	Aug	9429	27792	21185	-15752	578.4	0.00	0.0	-18364	17843	17843	
	Sep	7418	17256	8657	-12528	351.5	0.00	0.0	-9838	8004	8004	
1970	Oct	10107	7501	11594	2937	412.6	0.00	0.0	2606	10610	10610	29354.0
	Nov	9518	3124	20520	8926	567.7	0.00	0.0	6394	17004	17004	
	Dec	8343	2939	24513	3993	630.9	0.00	0.0	5404	22408	22408	
	Jan	7733	2626	29659	5146	705.1	0.00	0.0	5107	27516	29659	
	Feb	7107	2277	32389	2730	743.1	0.00	0.0	4830	32346	34489	
	Mar	7733	2453	36937	4548	805.1	0.00	0.0	5280	37625	38850	
	Apr	9256	9223	36937	0	805.1	0.00	0.0	33	37658	38850	
	May	39411	34556	38850	1913	831.2	0.00	0.0	4854	38850	38850	
	Jun	57439	55874	38850	0	831.2	0.00	0.0	1564	38850	38850	
	Jul	18993	26932	32389	-6461	743.1	0.00	0.0	-7939	30911	30911	
	Aug	9903	29084	14530	-17859	467.5	0.00	0.0	-19180	11731	11731	
	Sep	9715	15531	9496	-5034	369.3	0.00	0.0	-5815	5916	5916	
1971	Oct	9971	9961	9496	0	369.3	0.00	0.0	10	5926	5926	29354.0
	Nov	9190	4927	16527	7031	500.7	0.00	0.0	4263	10190	10190	
	Dec	8818	3277	21185	4658	578.4	0.00	0.0	5541	15731	15731	
	Jan	8411	3517	27175	5990	673.8	0.00	0.0	4894	20625	27175	
	Feb	8271	5132	29659	2484	705.1	0.00	0.0	3140	23764	30315	
	Mar	8208	6210	31479	1820	730.2	0.00	0.0	1997	25762	32312	
	Apr	11094	9521	31479	0	730.2	0.00	0.0	1573	27335	33885	
	May	43616	34433	36937	5458	805.1	0.00	0.0	9183	36518	38850	
	Jun	51859	43200	38850	1913	831.2	0.00	0.0	8659	38850	38850	
	Jul	21706	28838	30569	-8281	717.1	0.00	0.0	-7131	31719	31719	
	Aug	9903	20414	19854	-10715	556.8	0.00	0.0	-10510	21208	21208	
	Sep	10240	14519	13691	-6163	453.0	0.00	0.0	-4279	16930	16930	
1972	Oct	10175	9285	14111	420	458.0	0.00	0.0	890	17820	17820	25159.0
	Nov	9518	4284	23182	9071	612.7	0.00	0.0	5234	23054	23054	
	Dec	8683	4944	26509	3327	660.7	0.00	0.0	3739	26793	26793	
	Jan	8072	5319	27175	666	673.8	0.00	0.0	2753	29546	27175	
	Feb	7107	5171	28750	1575	692.8	0.00	0.0	1936	31482	29111	
	Mar	10582	6456	32389	3639	743.1	0.00	0.0	4126	35608	33237	
	Apr	11422	9521	34208	1819	767.9	0.00	0.0	1901	37509	35138	
	May	34798	25886	37894	3686	818.3	0.00	0.0	8912	38850	38850	
	Jun	45163	42545	38850	956	831.2	0.00	0.0	2618	38850	38850	
	Jul	17704	20475	35118	-3732	779.8	0.00	0.0	-2771	36079	36079	
	Aug	9903	23919	21851	-13267	588.7	0.00	0.0	-14015	22064	22064	
	Sep	9059	16423	13691	-8160	453.0	0.00	0.0	-7364	14699	14699	
1973	Oct	8547	10453	12852	-839	438.8	0.00	0.0	-1906	12793	12793	29354.0
	Nov	9125	8866	12852	0	438.8	0.00	0.0	258	13052	13052	
	Dec	8683	2878	17192	4340	516.0	0.00	0.0	5805	18857	18857	
	Jan	7529	1906	25178	7986	642.6	0.00	0.0	5623	24480	25178	
	Feb	6678	1766	26509	1331	660.7	0.00	0.0	4912	29392	30090	
	Mar	7462	2004	29659	3150	705.1	0.00	0.0	5457	34849	35547	
	Apr	11291	4504	38850	9191	831.2	0.00	0.0	6786	38850	38850	
	May	38800	34433	38850	0	831.2	0.00	0.0	4367	38850	38850	
	Jun	28358	28383	37894	-956	818.3	0.00	0.0	-25	38825	38825	
	Jul	10989	16356	28750	-9144	692.8	0.00	0.0	-5367	33458	33458	
	Aug	7462	21398	14530	-14220	467.5	0.00	0.0	-13936	19522	19522	
	Sep	8074	12853	9496	-5034	369.3	0.00	0.0	-4779	14743	14743	
1974	Oct	8818	7932	9496	0	369.3	0.00	0.0	886	15629	15629	29354.0
	Nov	8731	4463	16527	7031	500.7	0.00	0.0	4268	19897	19897	
	Dec	8140	3191	22369	5842	600.2	0.00	0.0	4949	24846	24846	
	Jan	7462	3019	26050	3681	654.1	0.00	0.0	4442	29288	26050	
	Feb	6433	2866	29582	3532	705.1	0.00	0.0	3567	32856	29617	

Source: USGS
Gage #: 06019500
6020600

Reservoir Existing Operation Model - Missouri Data

Interpolated Value
Value derived from interpolated value

Evap. = 0

Water Year	Month-Yr	Inflow (acre-ft)	Outflow (acre-ft)	Records EOM Storage (acre-ft)	Record Storage Change (acre-ft)	Prev. Month Reservoir Surf. Area (acres)	NET Reser. Evapor. Depth (in)	Reser. Evapor. Volume (acre-ft)	Storage Change Equation (acre-ft)	Cumulative Storage (acre-ft)	Cumulative Storage (w/ Reset) (acre-ft)	Yearly Drawdown (acre-ft)
	Mar	8208	6456	31046	1464	730.2	0.00	0.0	1751	34607	31369	
	Apr	11816	8926	33589	2543	761.8	0.00	0.0	2890	37498	34259	
	May	28490	20537	38850	5261	831.2	0.00	0.0	7953	38850	38850	
	Jun	38599	39154	38850	0	831.2	0.00	0.0	-555	38295	38295	
	Jul	13566	19184	30314	-8536	717.1	0.00	0.0	-5618	32677	32677	
	Aug	8615	22197	20040	-10274	562.3	0.00	0.0	-13582	19095	19095	
	Sep	6761	17256	17887.33	-2152.667	525.7	0.00	0.0	-10495	8600	8600	
1975	Oct	8072	10145	15734.67	-2152.667	490.2	0.00	0.0	-2073	6527	6527	25268.0
	Nov	8337	3035	13582	-2152.667	448.0	0.00	0.0	5302	11829	11829	
	Dec	7326	2644	18202	4620	530.5	0.00	0.0	4682	16511	16511	
	Jan	6851	2890	22822	4620	606.5	0.00	0.0	3961	20472	22822	
	Feb	6127	2588	26050	3228	654.1	0.00	0.0	3539	24011	26361	
	Mar	7258	2798	29332	3282	705.1	0.00	0.0	4460	28471	30821	
	Apr	7549	3951	32762	3430	749.4	0.00	0.0	3598	32069	34419	
	May	22317	22259	35806	3044	792.6	0.00	0.0	58	32127	34477	
	Jun	68598	60635	38850	3044	831.2	0.00	0.0	7963	38850	38850	
	Jul	32695	34372	38850	0	831.2	0.00	0.0	-1676	37174	37174	
	Aug	15941	21828	30314	-8536	717.1	0.00	0.0	-5888	31286	31286	
	Sep	10175	23742	21956	-8358	588.7	0.00	0.0	-13567	17719	17719	
1976	Oct	10921	14388	21184.5	-771.5	578.4	0.00	0.0	-3467	14252	14252	22360.0
	Nov	9584	6486	20413	-771.5	567.7	0.00	0.0	3098	17350	17350	
	Dec	8954	8547	21791	1378	588.7	0.00	0.0	407	17757	17757	
	Jan	8547	7809	22290	499	593.8	0.00	0.0	738	18495	22290	
	Feb	7107	3773	26411.5	4121.5	660.7	0.00	0.0	3334	21828	25624	
	Mar	8411	3609	30533	4121.5	717.1	0.00	0.0	4802	26630	30426	
	Apr	13785	7617	35582	5049	786.3	0.00	0.0	6169	32799	36594	
	May	49314	40766	38850	3268	831.2	0.00	0.0	8548	38850	38850	
	Jun	31969	32370	38850	0	831.2	0.00	0.0	-402	38448	38448	
	Jul	15737	24042	31343	-7507	730.2	0.00	0.0	-8305	30144	30144	
	Aug	10107	24902	18317	-13026	530.5	0.00	0.0	-14795	15348	15348	
	Sep	9518	17613	16490	-1827	500.7	0.00	0.0	-8095	7254	7254	
1977	Oct	9700	8793	14663	-1827	472.2	0.00	0.0	907	8161	8161	27101.0
	Nov	8928	5576	16357	1694	500.7	0.00	0.0	3352	11513	11513	
	Dec	8208	5220	18051	1694	530.5	0.00	0.0	2987	14500	14500	
	Jan	6919	4077	22822	4771	606.5	0.00	0.0	2842	17342	22822	
	Feb	6494	2677	25471	2649	648.4	0.00	0.0	3817	21160	26639	
	Mar	7529	2650	29195	3724	699.0	0.00	0.0	4879	26039	31519	
	Apr	14113	2856	38850	9655	831.2	0.00	0.0	11257	37297	38850	
	May	18383	20168	38821.5	-28.5	831.2	0.00	0.0	-1785	35511	37065	
	Jun	26914	25111	38793	-28.5	831.2	0.00	0.0	1803	37314	38850	
	Jul	10650	17954	27115	-11678	667.3	0.00	0.0	-7305	30010	31545	
	Aug	8072	22566	13582	-13533	448.0	0.00	0.0	-14494	15516	17051	
	Sep	9059	14281	11749	-1833	417.2	0.00	0.0	-5222	10294	11829	
1978	Oct	9564	5103	14796	3047	472.2	0.00	0.0	4461	14755	16290	25490.0
	Nov	7943	3969	19894	5098	556.8	0.00	0.0	3974	18729	20264	
	Dec	7869	3775	23974	4080	624.9	0.00	0.0	4093	22822	24357	
	Jan	7529	3523	26915	2941	667.3	0.00	0.0	4006	26828	26915	
	Feb	6678	3871	29832	2917	711.1	0.00	0.0	2807	29635	29722	
	Mar	9564	6456	29896	64	711.1	0.00	0.0	3108	32743	32830	
	Apr	15492	7914	36518	6622	798.9	0.00	0.0	7578	38850	38850	
	May	34527	26809	38850	2332	831.2	0.00	0.0	7718	38850	38850	
	Jun	35842	36952	38850	0	831.2	0.00	0.0	-1110	37740	37740	
	Jul	14991	19922	32389	-6461	743.1	0.00	0.0	-4931	32809	32809	
	Aug	9768	25087	18616	-13773	535.2	0.00	0.0	-15319	17489	17489	
	Sep	9256	16721	13360	-5256	448.0	0.00	0.0	-7465	10025	10025	
1979	Oct	8886	10330	13796	436	453.0	0.00	0.0	-1444	8581	8581	38847.0
	Nov	8402	4368	18894	5098	539.9	0.00	0.0	4035	12615	12615	
	Dec	7936	3074	22974	4080	606.5	0.00	0.0	4862	17477	17477	
	Jan	6783	2582	25915	2941	654.1	0.00	0.0	4201	21678	25915	
	Feb	6862	2516	29195	3280	699.0	0.00	0.0	4346	26024	30261	
	Mar	8072	5122	31101	1906	730.2	0.00	0.0	2950	28974	33211	
	Apr	9453	6248	33007	1906	755.6	0.00	0.0	3205	32179	36416	
	May	29439	21521	39847	6840	843.9	0.00	0.0	7919	38850	38850	

Source: USGS
Gage #: 06019500
6020600

Reservoir Existing Operation Model - Missouri Data

Interpolated Value
Value derived from interpolated value

Evap. = 0

Water Year	Month-Yr	Inflow (acre-ft)	Outflow (acre-ft)	Records EOM Storage (acre-ft)	Record Storage Change (acre-ft)	Prev. Month Reservoir Surf. Area (acres)	NET Reser. Evapor. Depth (in)	Reser. Evapor. Volume (acre-ft)	Storage Change Equation (acre-ft)	Cumulative Storage (acre-ft)	Cumulative Storage (w/ Reset) (acre-ft)	Yearly Drawdown (acre-ft)
	Jun	17396	28800	30314	-9533	717.1	0.00	0.0	-11404	27446	27446	
	Jul	7869	21398	17425	-12889	516.0	0.00	0.0	-13529	13917	13917	
	Aug	7462	21521	7734	-9691	330.8	0.00	0.0	-14059	0	0	
	Sep	6197	12674	1000	-6734	92.7	0.00	0.0	-6478	0	0	
1980	Oct	6763	3763	3700	2700	218.9	0.00	0.0	3000	3000	3000	36690.0
	Nov	7483	2291	6400	2700	300.5	0.00	0.0	5193	8192	8192	
	Dec	7733	2275	9100	2700	360.2	0.00	0.0	5458	13650	13650	
	Jan	7055	2312	11800	2700	417.2	0.00	0.0	4743	18393	11800	
	Feb	6663	2186	14500	2700	467.5	0.00	0.0	4477	22870	16277	
	Mar	7055	2367	24094.5	9594.5	624.9	0.00	0.0	4687	27557	20964	
	Apr	13129	2475	33689	9594.5	761.8	0.00	0.0	10653	38211	31618	
	May	36290	31666	40390	6701	850.9	0.00	0.0	4624	38850	36242	
	Jun	34332	37785	32334	-8056	743.1	0.00	0.0	-3453	35397	32789	
	Jul	13363	20598	26662.67	-5671.333	660.7	0.00	0.0	-7235	28161	25553	
	Aug	9293	25394	20991.33	-5671.333	578.4	0.00	0.0	-16101	12060	9452	
	Sep	10109	12912	15320	-5671.333	481.4	0.00	0.0	-2803	9257	6649	
1981	Oct	8954	5860	13150	-2170	442.9	0.00	0.0	3094	12351	9743	29601.0
	Nov	8140	4873	19016	5866	545.6	0.00	0.0	3266	15617	13009	
	Dec	7869	4692	23169	4153	612.7	0.00	0.0	3177	18794	16186	
	Jan	7122	3234	26482	3313	660.7	0.00	0.0	3888	22682	26482	
	Feb	6372	2510	29686	3204	705.1	0.00	0.0	3862	26544	30344	
	Mar	7462	3800	34008	4322	767.9	0.00	0.0	3662	30206	34005	
	Apr	13063	8212	40163	6155	843.9	0.00	0.0	4852	35057	38850	
	May	32966	33941	41350	1187	864.9	0.00	0.0	-975	34083	37875	
	Jun	29934	33084	35772	-5578	792.6	0.00	0.0	-3151	30932	34725	
	Jul	9225	23857	27627	-8145	680.2	0.00	0.0	-14632	16300	20093	
	Aug	7462	21644	12555	-15072	430.4	0.00	0.0	-14182	2118	5911	
	Sep	6827	16304	11749	-806	417.2	0.00	0.0	-9477	0	0	
1982	Oct	8479	3505	14796	3047	472.2	0.00	0.0	4974	4974	4974	26946.0
	Nov	7943	2993	19894	5098	556.8	0.00	0.0	4950	9924	9924	
	Dec	7597	2601	23000	3106	606.5	0.00	0.0	4996	14920	14920	
	Jan	6783	2558	27550	4550	680.2	0.00	0.0	4225	19146	27550	
	Feb	7352	2344	29520	1970	705.1	0.00	0.0	5008	24154	32558	
	Mar	7529	3167	33380	3860	761.8	0.00	0.0	4363	28517	36921	
	Apr	11816	8033	36382	3002	798.9	0.00	0.0	3783	32300	38850	
	May	36494	29330	39062	2680	831.2	0.00	0.0	7164	38850	38850	
	Jun	49364	48972	41742	2680	864.9	0.00	0.0	392	38850	38850	
	Jul	25505	27977	32760	-8982	749.4	0.00	0.0	-2472	36378	36378	
	Aug	11531	28469	23778	-8982	618.8	0.00	0.0	-16937	19441	19441	
	Sep	9912	21362	14796	-8982	472.2	0.00	0.0	-11450	7991	7991	
1983	Oct	10378	8116	17882.5	3086.5	525.7	0.00	0.0	2262	10253	10253	20967.5
	Nov	9256	6188	20969	3086.5	578.4	0.00	0.0	3067	13320	13320	
	Dec	8615	6333	23262	2293	612.7	0.00	0.0	2281	15602	15602	
	Jan	8343	6395	26050	2788	654.1	0.00	0.0	1949	17550	26050	
	Feb	7230	4004	29010	2960	699.0	0.00	0.0	3225	20776	29275	
	Mar	8683	5183	31970	2960	743.1	0.00	0.0	3499	24275	32774	
	Apr	11619	6783	34973	3003	779.8	0.00	0.0	4836	29110	37610	
	May	35680	22504	38850	3877	831.2	0.00	0.0	13175	38850	38850	
	Jun	57110	54565	38850	0	831.2	0.00	0.0	2545	38850	38850	
	Jul	30660	28715	38850	0	831.2	0.00	0.0	1945	38850	38850	
	Aug	14787	27423	23974	-14876	624.9	0.00	0.0	-12636	26214	26214	
	Sep	10109	21302	22792.5	-1181.5	606.5	0.00	0.0	-11193	15021	15021	
1984	Oct	12549	7256	21611	-1181.5	583.6	0.00	0.0	5293	20314	20314	21996.0
	Nov	11619	7676	24146.5	2535.5	624.9	0.00	0.0	3943	24257	24257	
	Dec	9836	8731	26682	2535.5	660.7	0.00	0.0	1104	25361	25361	
	Jan	9497	8547	27115	433	667.3	0.00	0.0	950	26311	27115	
	Feb	8122	4970	27767	652	680.2	0.00	0.0	3153	29464	30268	
	Mar	9632	4193	33639	5872	761.8	0.00	0.0	5439	34902	35706	
	Apr	14179	7676	40074	6435	843.9	0.00	0.0	6503	38850	38850	
	May	68511	63640	41265	1191	857.9	0.00	0.0	4871	38850	38850	
	Jun	73324	71940	40800	-465	857.9	0.00	0.0	1384	38850	38850	
	Jul	25437	26255	39847	-953	843.9	0.00	0.0	-818	38032	38032	
	Aug	15194	21582	32762	-7085	749.4	0.00	0.0	-6388	31644	31644	

Source: USGS
Gage #: 06019500
6020600

Reservoir Existing Operation Model - Missouri Data

Interpolated Value
Value derived from interpolated value

Evap. = 0

Water Year	Month-Yr	Inflow	Outflow	Records EOM Storage	Record Storage Change	Prev. Month Reservoir Surf. Area	NET Reser. Evapor. Depth	Reser. Evapor. Volume	Storage Change Equation	Cumulative Storage	Cumulative Storage (w/ Reset)	Yearly Drawdown
		(acre-ft)	(acre-ft)	(acre-ft)	(acre-ft)	(acres)	(in)	(acre-ft)	(acre-ft)	(acre-ft)	(acre-ft)	(acre-ft)
	Sep	11225	23028	19269	-13493	545.6	0.00	0.0	-11803	19841	19841	
1985	Oct	10785	14696	16234	-3035	495.5	0.00	0.0	-3910	15931	15931	29384.0
	Nov	10044	13210	13582	-2652	448.0	0.00	0.0	-3166	12765	12765	
	Dec	8818	4175	19894	6312	556.8	0.00	0.0	4643	17408	17408	
	Jan	8479	3351	24732	4838	636.8	0.00	0.0	5128	22536	24732	
	Feb	7046	3138	27876	3144	680.2	0.00	0.0	3908	26444	28640	
	Mar	8208	3708	33271	5395	755.6	0.00	0.0	4500	30944	33140	
	Apr	14704	9283	37798	4527	818.3	0.00	0.0	5422	36365	38562	
	May	23741	24841	37664	-134	818.3	0.00	0.0	-1100	35266	37462	
	Jun	11422	22552	26682	-10982	660.7	0.00	0.0	-11130	24136	26332	
	Jul	5311	16356	18004.5	-8677.5	525.7	0.00	0.0	-11044	13091	15287	
	Aug	6987	13650	9327	-8677.5	369.3	0.00	0.0	-6664	6428	8624	
	Sep	7680	8093	8414	-913	347.6	0.00	0.0	-412	6015	8212	
1986	Oct	7665	2337	13150	4736	442.9	0.00	0.0	5329	11344	13540	29601.0
	Nov	7483	2243	19016	5866	545.6	0.00	0.0	5240	16584	18780	
	Dec	7055	3087	23169	4153	612.7	0.00	0.0	3968	20552	22748	
	Jan	7055	3283	26482	3313	660.7	0.00	0.0	3771	24323	26482	
	Feb	6923	2993	29686	3204	705.1	0.00	0.0	3930	28253	30412	
	Mar	8479	3523	34008	4322	767.9	0.00	0.0	4956	33209	35368	
	Apr	12341	4528	40163	6155	843.9	0.00	0.0	7813	38850	38850	
	May	31813	27362	41350	1187	864.9	0.00	0.0	4451	38850	38850	
	Jun	27767	34215	35772	-5578	792.6	0.00	0.0	-6447	32403	32403	
	Jul	9903	18754	27627	-8145	680.2	0.00	0.0	-8850	23552	23552	
	Aug	7597	22812	12555	-15072	430.4	0.00	0.0	-15215	8338	8338	
	Sep	8074	10830	11749	-806	417.2	0.00	0.0	-2756	5582	5582	
1987	Oct	8140	4827	14796	3047	472.2	0.00	0.0	3313	8895	8895	33142.0
	Nov	8271	4201	19894	5098	556.8	0.00	0.0	4070	12965	12965	
	Dec	7326	3050	23974	4080	624.9	0.00	0.0	4276	17241	17241	
	Jan	6390	3160	26915	2941	667.3	0.00	0.0	3229	20471	26915	
	Feb	6078	2099	31534	4619	736.7	0.00	0.0	3978	24449	30893	
	Mar	7122	2103	36045	4511	792.6	0.00	0.0	5020	29469	35913	
	Apr	11422	5623	40442	4397	850.9	0.00	0.0	5799	35268	38850	
	May	14652	21090	32762	-7680	749.4	0.00	0.0	-6438	28829	32412	
	Jun	8993	16721	25697	-7065	648.4	0.00	0.0	-7727	21102	24684	
	Jul	10175	15618	20620	-5077	567.7	0.00	0.0	-5443	15659	19241	
	Aug	8818	14941	13528	-7092	448.0	0.00	0.0	-6123	9535	13118	
	Sep	7155	15293	7300	-6228	321.9	0.00	0.0	-8137	1398	4980	
1988	Oct	6987	5442	8141	841	339.4	0.00	0.0	1545	2943	6525	37847.0
	Nov	7615	2095	12925	4784	438.8	0.00	0.0	5520	8463	12046	
	Dec	6919	1802	18157	5232	530.5	0.00	0.0	5117	13581	17163	
	Jan	6329	1857	23720	5563	618.8	0.00	0.0	4472	18052	23720	
	Feb	5774	1720	27202	3482	673.8	0.00	0.0	4055	22107	27775	
	Mar	6559	2189	31970	4768	743.1	0.00	0.0	4370	26477	32145	
	Apr	11947	2374	39847	7877	843.9	0.00	0.0	9573	36050	38850	
	May	27947	25271	35299	-4548	786.3	0.00	0.0	2675	38726	38850	
	Jun	12801	23623	30751	-4548	723.7	0.00	0.0	-10823	27903	28027	
	Jul	5569	20352	18051	-12700	530.5	0.00	0.0	-14783	13120	13244	
	Aug	5379	18631	10025.5	-8025.5	382.3	0.00	0.0	-13252	0	0	
	Sep	4812	7795	2000	-8025.5	148.2	0.00	0.0	-2983	0	0	
1989	Oct	6458	3646	6000	4000	287.6	0.00	0.0	2811	2811	2811	31500.0
	Nov	7286	1999	11892	5892	417.2	0.00	0.0	5287	8099	8099	
	Dec	6390	1482	16786	4894	505.9	0.00	0.0	4908	13007	13007	
	Jan	5983	1285	21791	5005	588.7	0.00	0.0	4698	17704	21791	
	Feb	4975	1483	25285	3494	642.6	0.00	0.0	3492	21196	25283	
	Mar	6593	1697	29686	4401	705.1	0.00	0.0	4896	26093	30179	
	Apr	8928	1952	36518	6832	798.9	0.00	0.0	6976	33068	37155	
	May	19604	17647	37500	982	811.7	0.00	0.0	1957	35025	38850	
	Jun	14245	23683	27767	-9733	680.2	0.00	0.0	-9438	25587	29412	
	Jul	6444	19061	16500	-11267	500.7	0.00	0.0	-12617	12970	16795	
	Aug	6003	15556	7000	-9500	312.5	0.00	0.0	-9553	3417	7242	
	Sep	5448	11722	6275	-725	296.3	0.00	0.0	-6274	0	968	
1990	Oct	7936	3302	5550	-725	273.6	0.00	0.0	4634	4634	5602	33547.0
	Nov	7352	1999	11338	5788	408.0	0.00	0.0	5353	9987	10955	

Source: USGS
Gage #: 06019500
6020600

Reservoir Existing Operation Model - Missouri Data

Interpolated Value
Value derived from interpolated value

Evap. = 0

Water Year	Month-Yr	Inflow (acre-ft)	Outflow (acre-ft)	Records EOM Storage (acre-ft)	Record Storage Change (acre-ft)	Prev. Month Reservoir Surf. Area (acres)	NET Reser. Evapor. Depth (in)	Reser. Evapor. Volume (acre-ft)	Storage Change Equation (acre-ft)	Cumulative Storage (acre-ft)	Cumulative Storage (w/ Reset) (acre-ft)	Yearly Drawdown (acre-ft)
	Dec	6607	1900	15502	4164	485.8	0.00	0.0	4707	14694	15662	
	Jan	6559	1832	21525	6023	583.6	0.00	0.0	4727	19421	21525	
	Feb	5624	1238	25100	3575	642.6	0.00	0.0	4386	23807	25911	
	Mar	6783	1500	29832	4732	711.1	0.00	0.0	5283	29090	31194	
	Apr	13194	2243	39097	9265	831.2	0.00	0.0	10951	38850	38850	
	May	18315	19492	36660	-2437	805.1	0.00	0.0	-1177	37673	37673	
	Jun	25536	22493	38180	1520	824.8	0.00	0.0	3043	38850	38850	
	Jul	9768	22013	27802.5	-10377.5	680.2	0.00	0.0	-12245	26605	26605	
	Aug	6302	18323	17425	-10377.5	516.0	0.00	0.0	-12022	14584	14584	
	Sep	5783	15174	7055	-10370	312.5	0.00	0.0	-9390	5193	5193	
1991	Oct	7326	7440	8141	1086	339.4	0.00	0.0	-114	5079	5079	32249.0
	Nov	7024	2910	13070	4929	442.9	0.00	0.0	4114	9193	9193	
	Dec	5786	2115	16230	3160	495.5	0.00	0.0	3671	12864	12864	
	Jan	5664	1629	20760	4530	573.1	0.00	0.0	4035	16899	20760	
	Feb	5251	1188	25290	4530	642.6	0.00	0.0	4062	20961	24822	
	Mar	5874	1187	29960	4670	711.1	0.00	0.0	4688	25648	29510	
	Apr	6958	1815	34330	4370	773.9	0.00	0.0	5143	30792	34653	
	May	20824	12851	40390	6060	850.9	0.00	0.0	7974	38765	38850	
	Jun	32034	30704	23260	-17130	612.7	0.00	0.0	1330	38850	38850	
	Jul	7936	19492	24620	1360	630.9	0.00	0.0	-11555	27295	27295	
	Aug	6146	17278	12550	-12070	430.4	0.00	0.0	-11132	16162	16162	
	Sep	7877	12912	11280	-1270	408.0	0.00	0.0	-5035	11127	11127	
1992	Oct	7801	5356	10010	-1270	382.3	0.00	0.0	2445	13572	13572	40030.0
	Nov	7352	2690	15039.33	5029.333	476.8	0.00	0.0	4663	18235	18235	
	Dec	6919	1734	20068.67	5029.333	562.3	0.00	0.0	5185	23420	23420	
	Jan	6464	1943	25098	5029.333	642.6	0.00	0.0	4521	27941	25098	
	Feb	6346	1921	28000	2902	686.5	0.00	0.0	4424	32366	29522	
	Mar	7462	2109	33300	5300	755.6	0.00	0.0	5353	37718	34875	
	Apr	10175	3279	31805	-1495	736.7	0.00	0.0	6896	38850	38850	
	May	16551	24042	30310	-1495	717.1	0.00	0.0	-7491	31359	31359	
	Jun	10503	17554	40530	10220	850.9	0.00	0.0	-7051	24309	24309	
	Jul	10446	12113	22550	-17980	600.2	0.00	0.0	-1667	22642	22642	
	Aug	4172	20106	4570	-17980	247.5	0.00	0.0	-15935	6707	6707	
	Sep	6827	9699	500	-4070	60.4	0.00	0.0	-2872	3835	3835	
1993	Oct	7326	2951	6500	6000	300.5	0.00	0.0	4374	8209	8209	34210.0
	Nov	6893	2172	12500	6000	430.4	0.00	0.0	4721	12930	12930	
	Dec	6648	1795	15200	2700	481.4	0.00	0.0	4852	17782	17782	
	Jan	6627	1470	21530	6330	583.6	0.00	0.0	5158	22940	21530	
	Feb	5569	1388	24730	3200	636.8	0.00	0.0	4181	27121	25711	
	Mar	7055	1525	29690	4960	711.1	0.00	0.0	5530	32650	31240	
	Apr	8206	2160	34770	5080	779.8	0.00	0.0	6046	38696	37286	
	May	42666	34126	40710	5940	850.9	0.00	0.0	8541	38850	38850	
	Jun	32297	31835	27610	-13100	680.2	0.00	0.0	462	38850	38850	
	Jul	16958	18200	29920	2310	711.1	0.00	0.0	-1242	37608	37608	
	Aug	12752	20229	32230	2310	743.1	0.00	0.0	-7477	30131	30131	
	Sep	9256	19993	21330	-10900	583.6	0.00	0.0	-10738	19393	19393	
1994	Oct	9361	10637	17130	-4200	511.0	0.00	0.0	-1277	18117	18117	37890.0
	Nov	7615	4005	23170	6040	612.7	0.00	0.0	3610	21727	21727	
	Dec	7326	3960	26080	2910	654.1	0.00	0.0	3366	25093	25093	
	Jan	7190	3406	30550	4470	717.1	0.00	0.0	3784	28877	30550	
	Feb	7046	3155	32520	1970	749.4	0.00	0.0	3891	32768	34441	
	Mar	7122	3548	36380	3860	798.9	0.00	0.0	3575	36342	38016	
	Apr	11685	7260	39490	3110	837.6	0.00	0.0	4425	38850	38850	
	May	17976	23181	34240	-5250	767.9	0.00	0.0	-5205	33645	33645	
	Jun	9912	18625	39260	5020	837.6	0.00	0.0	-8713	24932	24932	
	Jul	6329	20168	11450	-27810	408.0	0.00	0.0	-13839	11093	11093	
	Aug	4959	16356	6525	-4925	300.5	0.00	0.0	-11397	0	0	
	Sep	5599	3535	1600	-4925	126.8	0.00	0.0	2065	2065	2065	
1995	Oct	7122	3499	8150	6550	339.4	0.00	0.0	3624	5689	5689	30910.0
	Nov	6308	2458	11800	3650	417.2	0.00	0.0	3851	9540	9540	
	Dec	6322	1832	14200	2400	462.8	0.00	0.0	4490	14029	14029	
	Jan	6017	1562	18960	4760	545.6	0.00	0.0	4455	18484	18960	
	Feb	6078	1438	23280	4320	612.7	0.00	0.0	4639	23123	23599	

Source: USGS
Gage #: 06019500
6020600

Reservoir Existing Operation Model - Missouri Data

Interpolated Value
Value derived from interpolated value

Evap. = 0

Water Year	Month-Yr	Inflow	Outflow	Records EOM Storage	Record Storage Change	Prev. Month Reservoir Surf. Area	NET Reser. Evapor. Depth	Reser. Evapor. Volume	Storage Change Equation	Cumulative Storage	Cumulative Storage (w/ Reset)	Yearly Drawdown
		(acre-ft)	(acre-ft)	(acre-ft)	(acre-ft)	(acres)	(in)	(acre-ft)	(acre-ft)	(acre-ft)	(acre-ft)	(acre-ft)
	Mar	7394	1519	30070	6790	711.1	0.00	0.0	5875	28998	29474	
	Apr	8796	3499	33750	3680	761.8	0.00	0.0	5297	34296	34772	
	May	35612	27792	38350	4600	824.8	0.00	0.0	7820	38850	38850	
	Jun	68073	62717	39060	710	831.2	0.00	0.0	5356	38850	38850	
	Jul	28693	30129	36830	-2230	805.1	0.00	0.0	-1436	37414	37414	
	Aug	12685	23488	25090	-11740	642.6	0.00	0.0	-10804	26610	26610	
	Sep	10306	17970	17490	-7600	520.9	0.00	0.0	-7664	18946	18946	
1996	Oct	9903	7870	20270	2780	562.3	0.00	0.0	2033	20979	20979	29990.0
	Nov	8993	5260	24060	3790	624.9	0.00	0.0	3733	24712	24712	
	Dec	8547	7686	24760	700	636.8	0.00	0.0	861	25573	25573	
	Jan	8140	7133	25590	830	648.4	0.00	0.0	1007	26581	25590	
	Feb	7488	3014	29130	3540	699.0	0.00	0.0	4474	31054	30064	
	Mar	8343	5804	31910	2780	736.7	0.00	0.0	2539	33593	32603	
	Apr	14179	9818	34430	2520	773.9	0.00	0.0	4361	37954	36964	
	May	37036	27116	38830	4400	831.2	0.00	0.0	9920	38850	38850	
	Jun	48577	43438	38050	-780	818.3	0.00	0.0	5139	38850	38850	
	Jul	13227	23427	29050	-9000	699.0	0.00	0.0	-10199	28651	28651	
	Aug	7801	22381	14200	-14850	462.8	0.00	0.0	-14581	14070	14070	
	Sep	8665	14638	8840	-5360	355.5	0.00	0.0	-5973	8097	8097	
1997	Oct	8954	6764	10290	1450	386.4	0.00	0.0	2190	10287	10287	28680.0
	Nov	8534	2517	14840	4550	472.2	0.00	0.0	6017	16304	16304	
	Dec	8004	2693	19130	4290	545.6	0.00	0.0	5311	21615	21615	
	Jan	7665	2810	23420	4290	612.7	0.00	0.0	4855	26470	23420	
	Feb	6372	2649	27710	4290	680.2	0.00	0.0	3723	30192	27143	
	Mar	8547	6518	29430	1720	705.1	0.00	0.0	2029	32222	29172	
	Apr	9978	7498	30250	820	717.1	0.00	0.0	2480	34702	31652	
	May	43209	28961	38970	8720	831.2	0.00	0.0	14248	38850	38850	
	Jun	51465	41772	38850	-120	831.2	0.00	0.0	9693	38850	38850	
	Jul	15398	19860	34210	-4640	767.9	0.00	0.0	-4463	34387	34387	
	Aug	10514	20229	23760	-10450	618.8	0.00	0.0	-9715	24672	24672	
	Sep	8206	17256	15640	-8120	485.8	0.00	0.0	-9051	15621	15621	
1998	Oct	9971	8239	14200	-1440	462.8	0.00	0.0	1732	17353	17353	24680.0
	Nov	8074	4665	19230	5030	545.6	0.00	0.0	3409	20762	20762	
	Dec	7869	2582	24210	4980	624.9	0.00	0.0	5286	26048	26048	
	Jan	7597	2373	29430	5220	705.1	0.00	0.0	5224	31272	29430	
	Feb	6249	3032	29960	530	711.1	0.00	0.0	3217	34489	32647	
	Mar	9022	10699	30740	780	723.7	0.00	0.0	-1677	32812	30970	
	Apr	11619	5927	37610	6870	811.7	0.00	0.0	5692	38504	36662	
	May	40360	35724	38880	1270	831.2	0.00	0.0	4636	38850	38850	
	Jun	51793	45937	37040	-1840	805.1	0.00	0.0	5856	38850	38850	
	Jul	31406	33019	32870	-4170	755.6	0.00	0.0	-1613	37237	37237	
	Aug	14245	26440	20620	-12250	567.7	0.00	0.0	-12195	25043	25043	
	Sep	10831	17018	15510	-5110	485.8	0.00	0.0	-6187	18856	18856	
1999	Oct	11192	9469	17020	1510	511.0	0.00	0.0	1723	20579	20579	31430.0
	Nov	9781	7379	18600	1580	535.2	0.00	0.0	2402	22981	22981	
	Dec	8683	5239	21430	2830	583.6	0.00	0.0	3444	26425	26425	
	Jan	8004	4366	25590	4160	648.4	0.00	0.0	3639	30064	25590	
	Feb	7046	2877	28170	2580	686.5	0.00	0.0	4169	34233	29759	
	Mar	8547	3265	32910	4740	755.6	0.00	0.0	5282	38850	35041	
	Apr	10044	4891	37640	4730	811.7	0.00	0.0	5152	38850	38850	
	May	27404	25517	39260	1620	837.6	0.00	0.0	1887	38850	38850	
	Jun	38533	37071	33140	-6120	755.6	0.00	0.0	1462	38850	38850	
	Jul	14109	24780	27020	-6120	667.3	0.00	0.0	-10670	28180	28180	
	Aug	9293	22443	12890	-14130	438.8	0.00	0.0	-13150	15030	15030	
	Sep	9453	17137	7830	-5060	335.1	0.00	0.0	-7684	7345	7345	
2000	Oct	8750	5399	9640	1810	373.7	0.00	0.0	3352	10697	10697	33220.0
	Nov	8009	3939	13400	3760	448.0	0.00	0.0	4069	14766	14766	
	Dec	7733	2810	17020	3620	511.0	0.00	0.0	4923	19689	19689	
	Jan	7529	2367	20620	3600	567.7	0.00	0.0	5162	24851	20620	
	Feb	6917	2019	26740	6120	667.3	0.00	0.0	4898	29749	25518	
	Mar	7597	1875	30400	3660	717.1	0.00	0.0	5722	35471	31240	
	Apr	10437	2987	38020	7620	818.3	0.00	0.0	7450	38850	38690	
	May	23402	21275	37640	-380	811.7	0.00	0.0	2127	38850	38850	

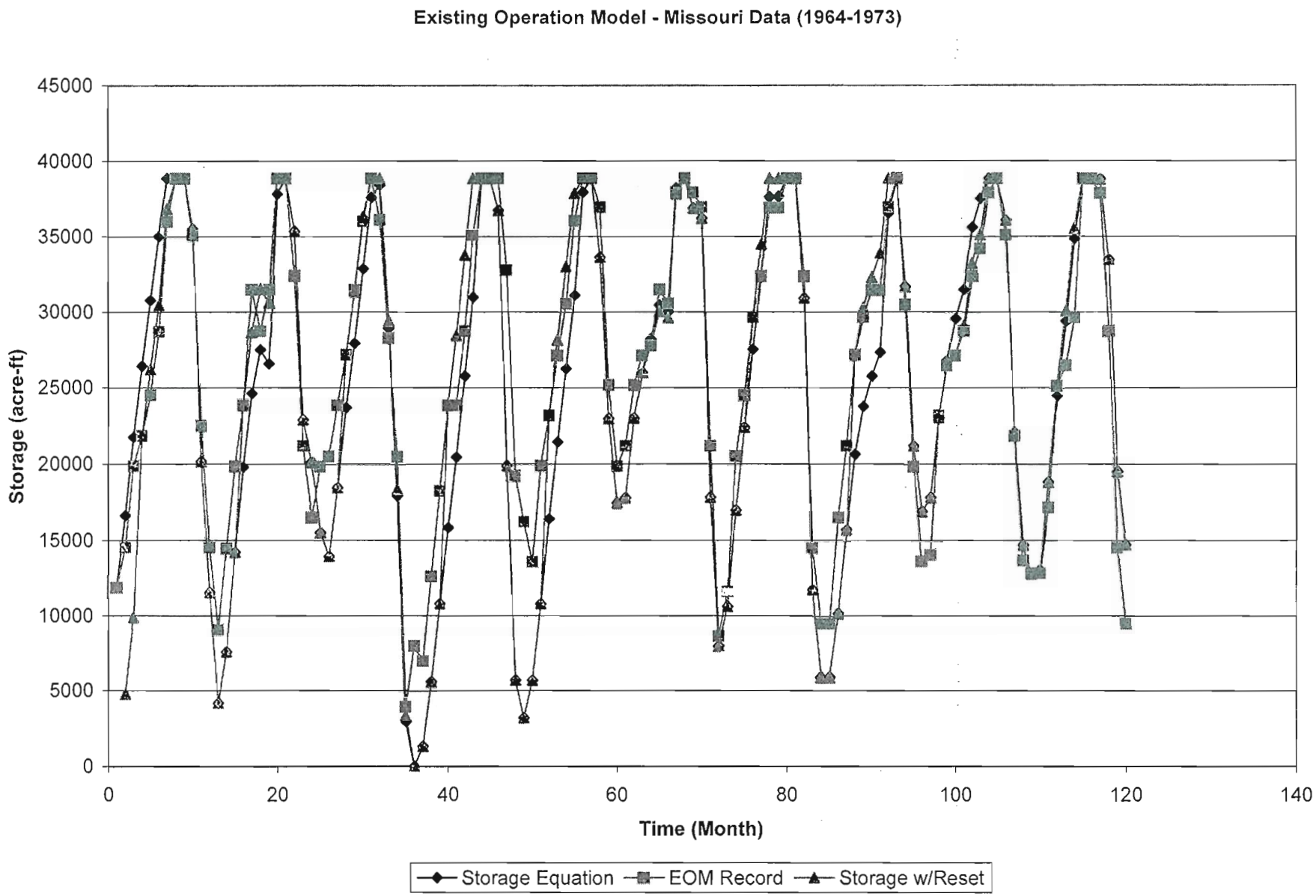
Source: USGS
Gage #: 06019500
6020600

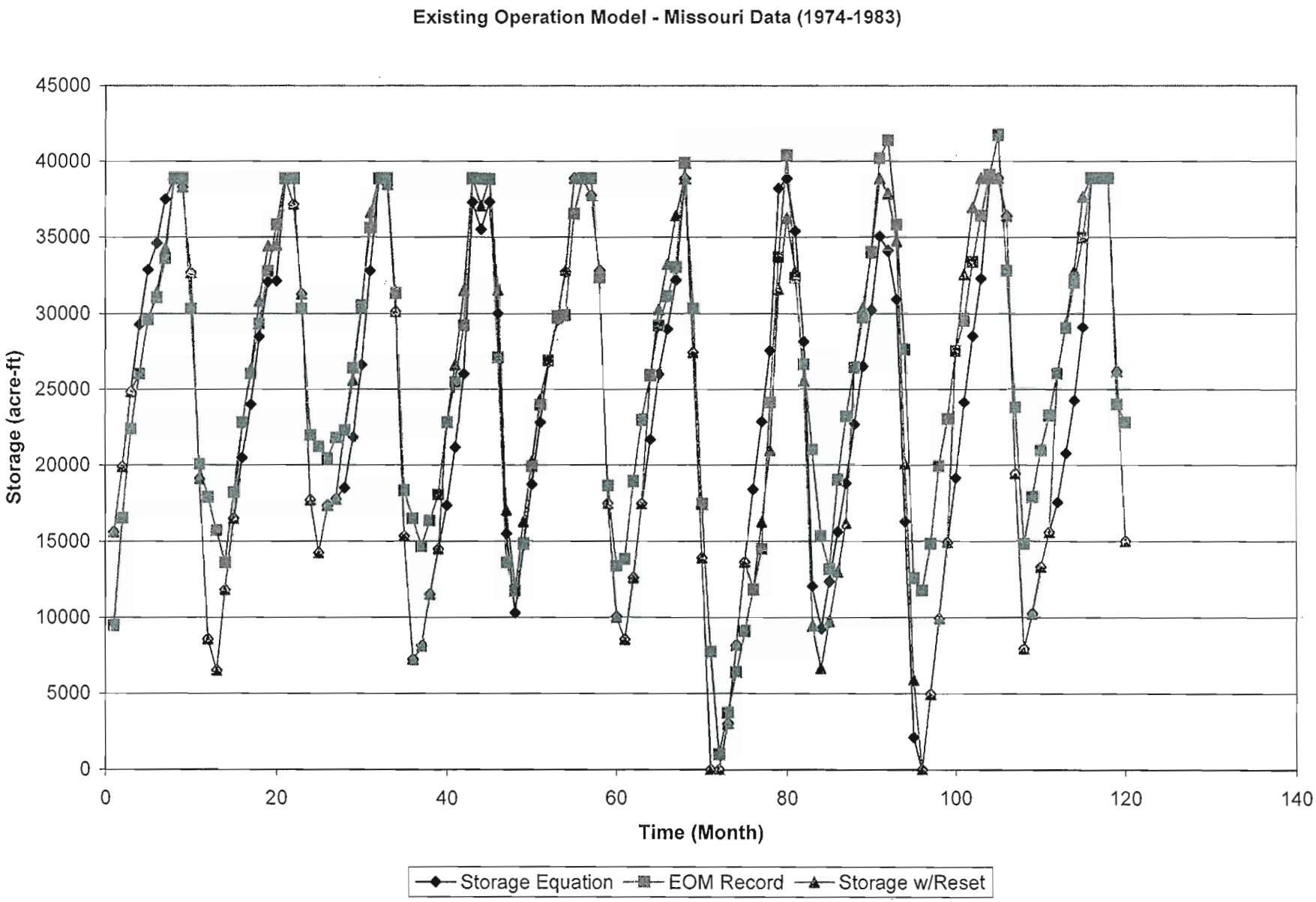
Reservoir Existing Operation Model - Missouri Data

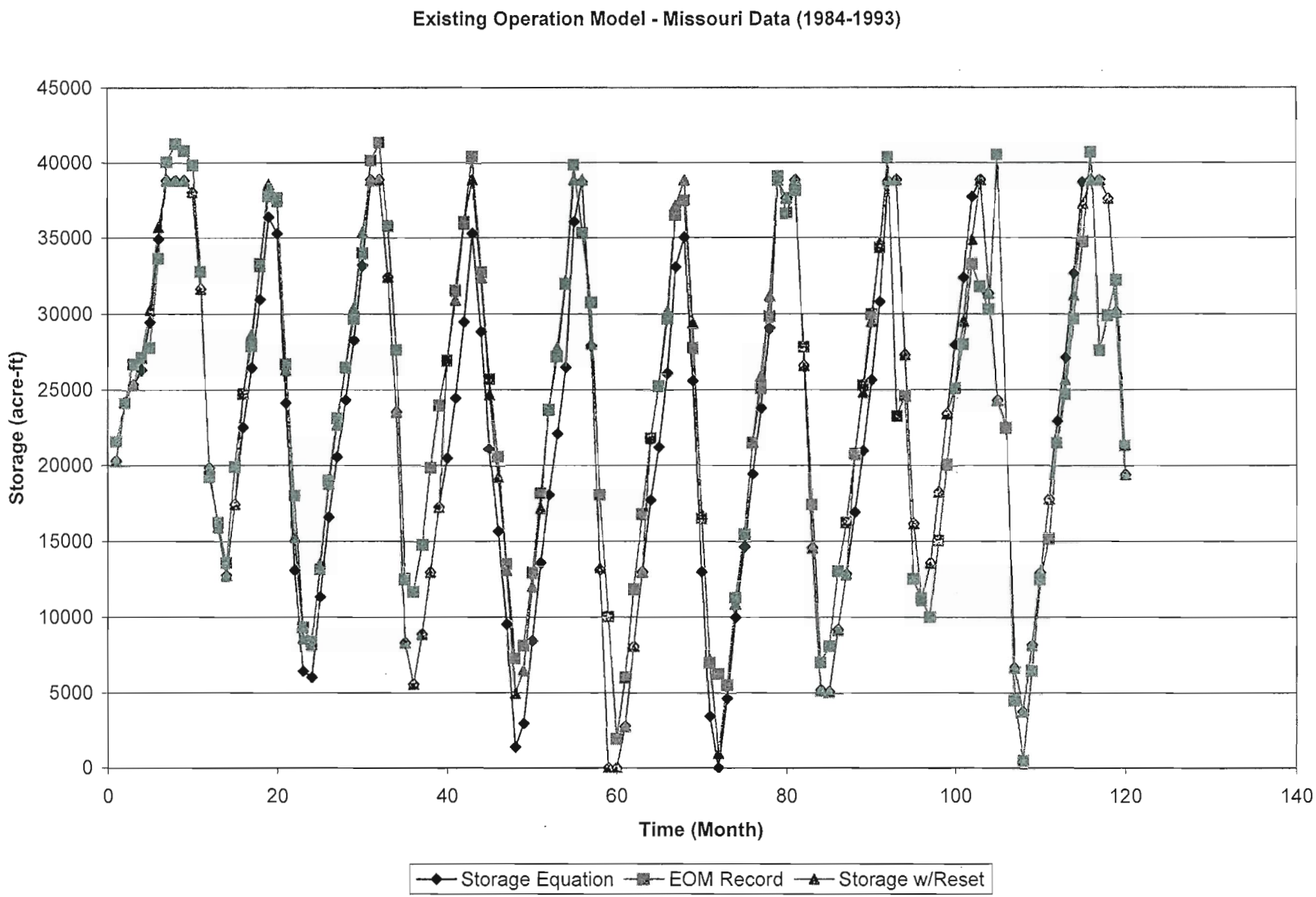
Interpolated Value
Value derived from interpolated value

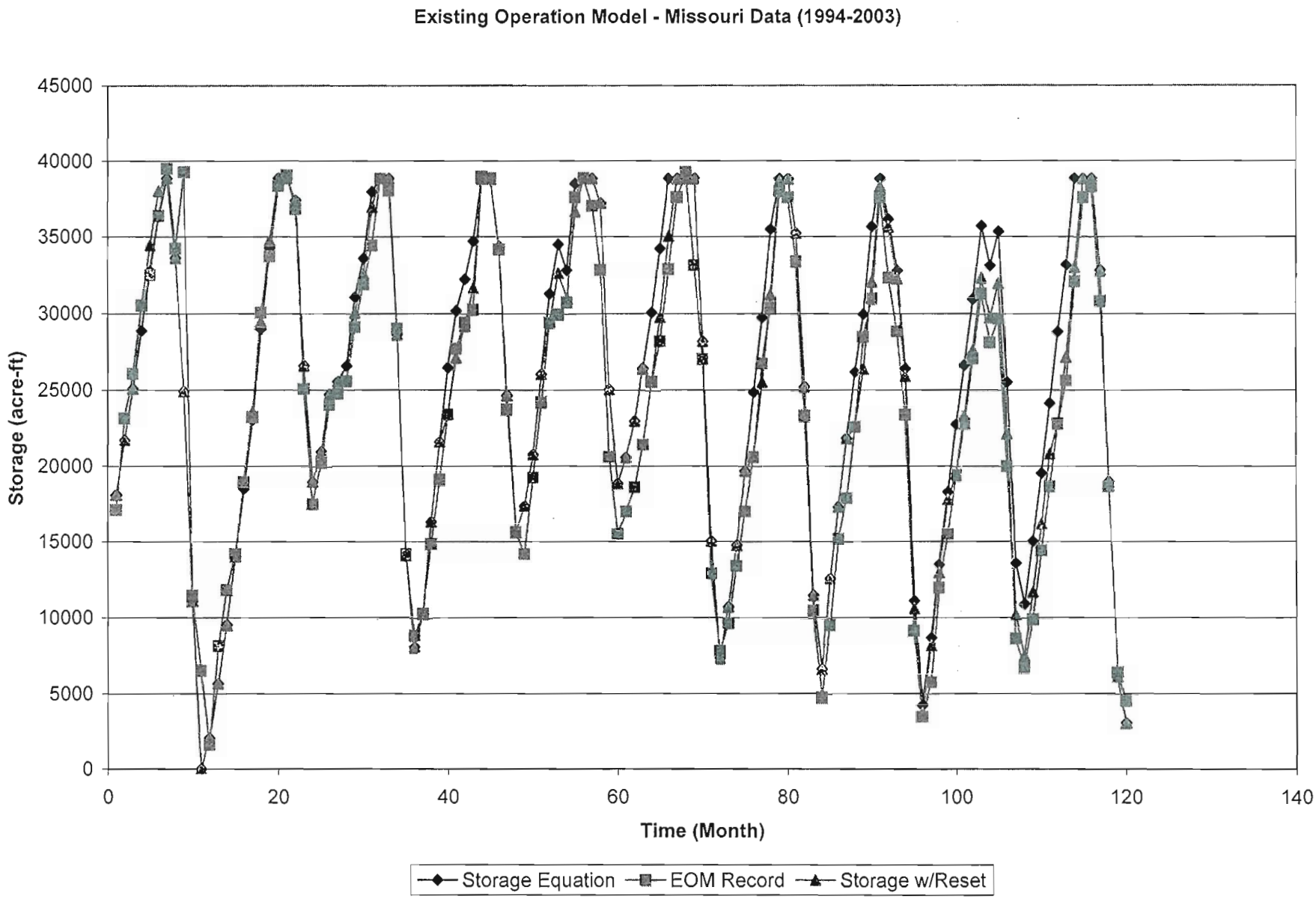
Evap. = 0

Water Year	Month-Yr	Inflow	Outflow	Records EOM Storage	Record Storage Change	Prev. Month Reservoir Surf. Area	NET Reser. Evapor. Depth	Reser. Evapor. Volume	Storage Change Equation	Cumulative Storage	Cumulative Storage (w/ Reset)	Yearly Drawdown
		(acre-ft)	(acre-ft)	(acre-ft)	(acre-ft)	(acres)	(in)	(acre-ft)	(acre-ft)	(acre-ft)	(acre-ft)	(acre-ft)
	Jun	16542	20172	33380	-4260	761.8	0.00	0.0	-3630	35220	35220	
	Jul	8208	18200	23350	-10030	612.7	0.00	0.0	-9993	25228	25228	
	Aug	5298	19061	10480	-12870	390.5	0.00	0.0	-13763	11464	11464	
	Sep	6827	11663	4800	-5680	251.9	0.00	0.0	-4836	6628	6628	
2001	Oct	8411	2490	9530	4730	373.7	0.00	0.0	5921	12549	12549	34110.0
	Nov	7155	2386	15200	5670	481.4	0.00	0.0	4769	17319	17319	
	Dec	6851	2312	17900	2700	525.7	0.00	0.0	4539	21858	21858	
	Jan	6410	2078	22630	4730	600.2	0.00	0.0	4332	26189	22630	
	Feb	5514	1744	28460	5830	692.8	0.00	0.0	3770	29960	26400	
	Mar	7258	1568	31000	2540	723.7	0.00	0.0	5690	35650	32090	
	Apr	9847	3594	37610	6610	811.7	0.00	0.0	6253	38850	38343	
	May	20960	23673	32350	-5260	743.1	0.00	0.0	-2713	36137	35630	
	Jun	14179	17494	28840	-3510	699.0	0.00	0.0	-3315	32822	32315	
	Jul	9293	15679	23420	-5420	612.7	0.00	0.0	-6386	26436	25929	
	Aug	5630	20967	9180	-14240	364.8	0.00	0.0	-15337	11099	10592	
	Sep	6256	13091	3500	-5680	210.2	0.00	0.0	-6835	4264	3757	
2002	Oct	7394	2976	5790	2290	283.0	0.00	0.0	4418	8681	8174	25540.0
	Nov	6958	2142	12000	6210	421.7	0.00	0.0	4816	13498	12990	
	Dec	6702	1894	15540	3540	485.8	0.00	0.0	4808	18306	17798	
	Jan	6403	1937	19420	3880	551.3	0.00	0.0	4466	22772	19420	
	Feb	5686	1788	22820	3400	606.5	0.00	0.0	3897	26669	23317	
	Mar	6220	1925	27110	4290	667.3	0.00	0.0	4296	30965	27613	
	Apr	6761	2035	31330	4220	730.2	0.00	0.0	4726	35691	32339	
	May	12685	15249	28120	-3210	686.5	0.00	0.0	-2564	33127	29775	
	Jun	20481	18268	29700	1580	711.1	0.00	0.0	2213	35340	31988	
	Jul	8208	18016	20030	-9670	562.3	0.00	0.0	-9808	25532	22180	
	Aug	5264	17217	8660	-11370	351.5	0.00	0.0	-11953	13579	10227	
	Sep	6893	9580	6800	-1860	308.6	0.00	0.0	-2688	10892	7540	
2003	Oct	6614	2472	9900	3100	378.0	0.00	0.0	4142	15034	11682	33730.0
	Nov	6216	1720	14430	4530	467.5	0.00	0.0	4497	19530	16178	
	Dec	6071	1451	18660	4230	539.9	0.00	0.0	4620	24150	20798	
	Jan	6057	1396	22820	4160	606.5	0.00	0.0	4662	28812	22820	
	Feb	5631	1250	25660	2840	648.4	0.00	0.0	4381	33193	27201	
	Mar	7462	1593	32140	6480	743.1	0.00	0.0	5869	38850	33070	
	Apr	9453	2214	37620	5480	811.7	0.00	0.0	7239	38850	38850	
	May	25641	21705	38290	670	824.8	0.00	0.0	3935	38850	38850	
	Jun	19562	25587	30840	-7450	723.7	0.00	0.0	-6025	32825	32825	
	Jul	7869	21705	18660	-12180	539.9	0.00	0.0	-13837	18989	18989	
	Aug	6356	19184	6440	-12220	300.5	0.00	0.0	-12828	6160	6160	
	Sep	6381	9461	4560	-1880	247.5	0.00	0.0	-3081	3080	3080	


Existing Operation Model - Missouri Data (1964-1973)
Storage (acre-ft)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0
20
40
60
80
100
120
140
Time (Month)
Storage Equation
EOM Record
Storage w/Reset


Existing Operation Model - Missouri Data (1974-1983)
Storage (acre-ft)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0
20
40
60
80
100
120
140
Time (Month)
Storage Equation
EOM Record
Storage w/Reset


Existing Operation Model - Missouri Data (1984-1993)
Storage (acre-ft)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0
20
40
60
80
100
120
140
Time (Month)
Storage Equation
EOM Record
Storage w/Reset


Existing Operation Model - Missouri Data (1994-2003)
Storage (acre-ft)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0
20
40
60
80
100
120
140
Time (Month)
Storage Equation
EOM Record
Storage w/Reset

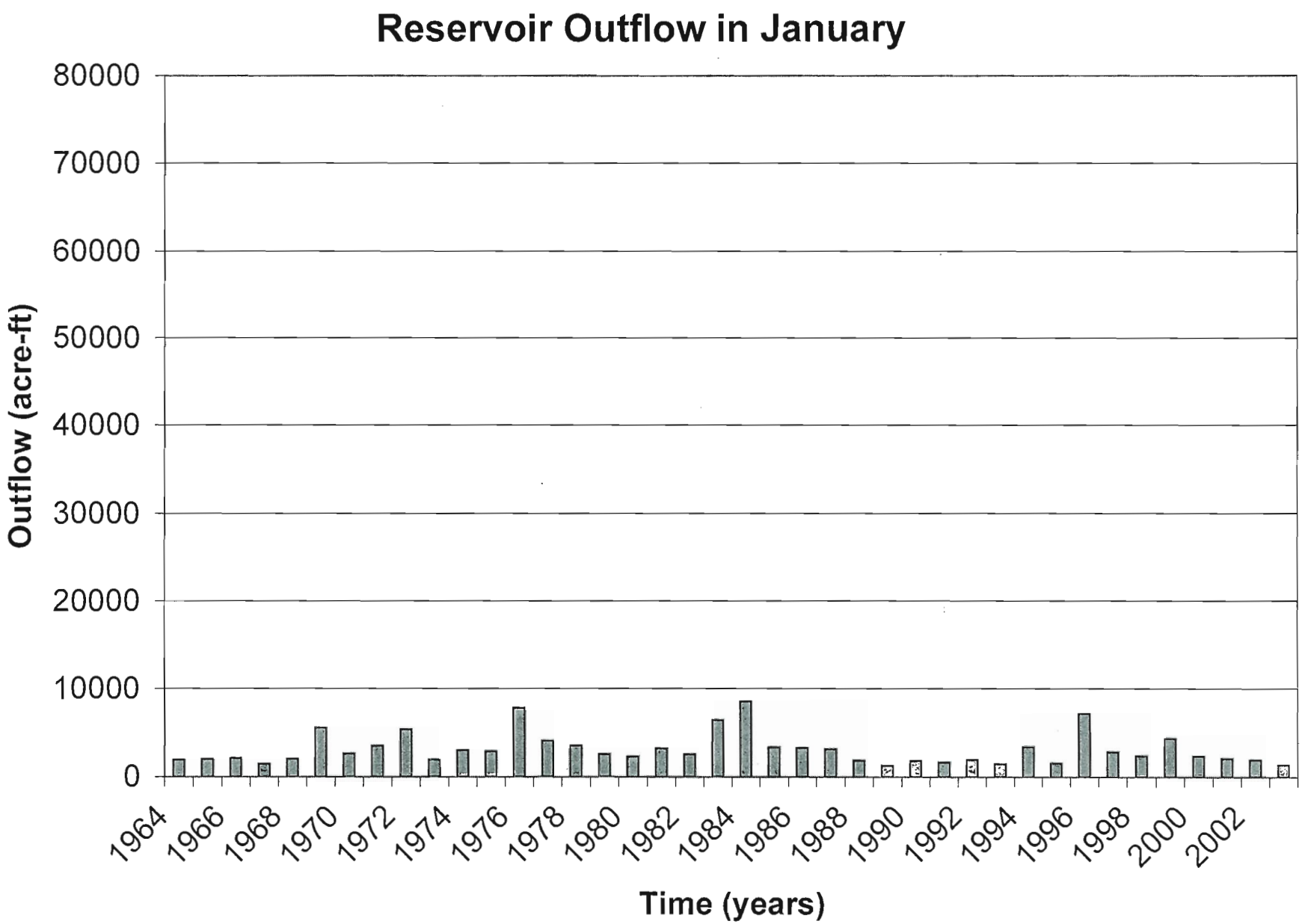
APPENDIX E

SPILL VOLUME ESTIMATION

		Outflow in Descending Order											
Percentile	Rank	January (acre-ft)	February (acre-ft)	March (acre-ft)	April (acre-ft)	May (acre-ft)	June (acre-ft)	July (acre-ft)	August (acre-ft)	September (acre-ft)	October (acre-ft)	November (acre-ft)	December (acre-ft)
2.44%	1	8547	5171	10699	11425	63640	71940	34372	29084	23742	15003	13210	8731
4.88%	2	7809	5132	8424	9818	42058	62717	33019	28469	23028	14596	9402	8547
7.32%	3	7133	4970	6518	9521	40766	60635	30129	27792	21362	14388	8866	7686
9.76%	4	6395	4948	6456	9521	35724	55874	28838	27423	21302	13220	7676	6333
12.20%	5	5565	4004	6456	9283	34556	54565	28715	26440	20945	11375	7379	5356
14.63%	6	5319	3871	6456	9223	34433	51590	27977	25394	19993	11252	6486	5239
14.63%	7	4366	3773	6210	8926	34433	48972	26932	25087	17970	10637	6307	5220
19.51%	8	4077	3155	5804	8212	34126	45937	26255	24902	17613	10453	6188	4944
21.95%	9	3523	3138	5183	8033	33941	43736	24780	24718	17256	10330	5576	4692
24.39%	10	3517	3032	5122	7914	31666	43438	24042	24472	17256	10145	5528	4175
26.83%	11	3406	3014	4193	7855	29330	43200	23857	23919	17256	9961	5260	3960
29.27%	12	3351	2993	3800	7676	28961	42545	23427	23488	17137	9469	4927	3775
31.71%	13	3283	2877	3708	7617	27792	41772	23304	22812	17018	9285	4873	3277
34.15%	14	3234	2866	3609	7498	27362	39154	22566	22689	16721	9039	4665	3210
36.59%	15	3160	2677	3609	7260	27116	38737	22197	22566	16721	8793	4463	3191
39.02%	16	3019	2649	3548	6783	26809	37785	22013	22443	16423	8239	4368	3087
41.46%	17	2890	2588	3523	6248	25886	37071	21705	22381	16304	8116	4284	3074
43.90%	18	2810	2516	3265	5927	25763	36952	21398	22197	15531	7932	4201	3050
46.34%	19	2626	2510	3167	5623	25517	36119	20598	21828	15293	7870	4005	2970
48.78%	20	2582	2344	2798	5064	25271	34215	20475	21644	15174	7501	3969	2939
51.22%	21	2558	2277	2650	4891	24841	33084	20414	21582	14876	7440	3939	2878
53.66%	22	2373	2186	2644	4528	24042	32370	20352	21521	14638	7256	3921	2810
56.10%	23	2367	2099	2453	4504	23673	31835	20168	21398	14519	6764	3225	2693
58.54%	24	2312	2019	2367	3951	23181	30704	19922	20967	14281	5860	3124	2644
60.98%	25	2097	1955	2257	3594	22504	28800	19860	20967	13091	5860	3035	2601
63.41%	26	2078	1921	2189	3499	22259	28383	19492	20414	12912	5442	2993	2582
65.85%	27	2017	1910	2109	3279	21705	27312	19184	20229	12912	5399	2910	2312
68.29%	28	2011	1846	2109	3094	21521	25587	19061	20229	12853	5356	2690	2275
70.73%	29	1943	1799	2103	2987	21275	25111	18754	20106	12674	5103	2517	2115
73.17%	30	1943	1788	2004	2856	21090	23683	18200	20106	12674	4827	2505	1912
75.61%	31	1937	1766	1925	2475	20537	23623	18200	19184	12020	3763	2458	1900
78.05%	32	1906	1744	1875	2374	20168	23028	18016	19061	11722	3646	2386	1894
80.49%	33	1857	1720	1697	2243	19492	22552	17954	18631	11663	3505	2291	1875
82.93%	34	1832	1483	1593	2214	17647	22493	17831	18323	10830	3499	2243	1832
85.37%	35	1629	1438	1568	2214	16909	20172	17831	17278	9699	3302	2172	1802
87.80%	36	1562	1388	1525	2160	15249	18625	16356	17217	9580	2976	2142	1795
90.24%	37	1470	1250	1519	2071	14634	18268	16356	16356	9461	2951	2095	1734
92.68%	38	1439	1238	1500	2035	13589	17554	15679	15556	8093	2490	1999	1482
95.12%	39	1396	1205	1377	1952	12912	17494	15618	14941	7795	2472	1999	1457
97.56%	40	1285	1188	1187	1815	12851	16721	12113	13650	3535	2337	1720	1451

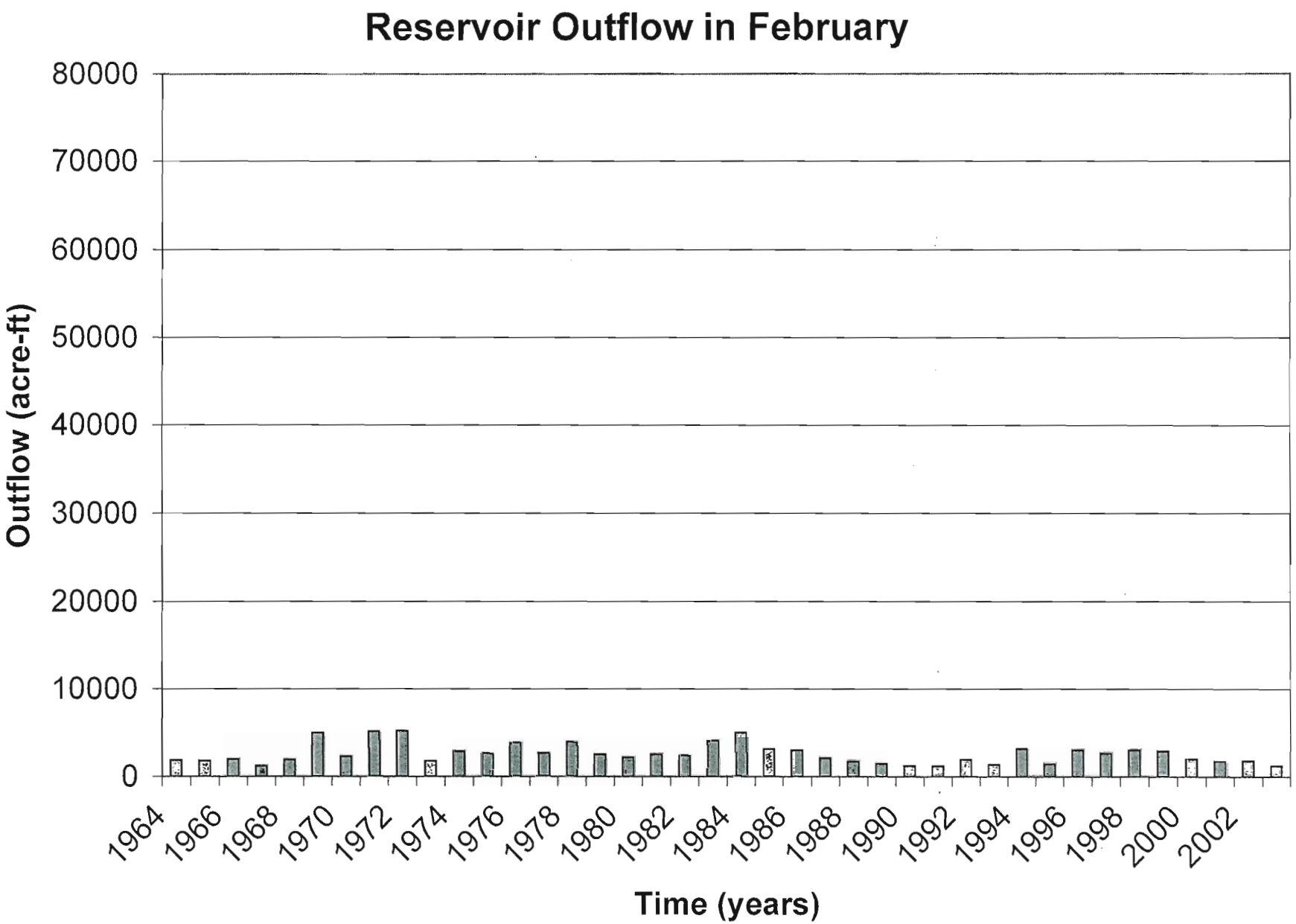
January

		Demand	30000	25000	20000	17500	15000	10000
Outflow - Descending Order (acre-ft)	Rank	Percentile	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)
8547	1	2.44%	0	0	0	0	0	0
7809	2	4.88%	0	0	0	0	0	0
7133	3	7.32%	0	0	0	0	0	0
6395	4	9.76%	0	0	0	0	0	0
5565	5	12.20%	0	0	0	0	0	0
5319	6	14.63%	0	0	0	0	0	0
4366	6	14.63%	0	0	0	0	0	0
4077	8	19.51%	0	0	0	0	0	0
3523	9	21.95%	0	0	0	0	0	0
3517	10	24.39%	0	0	0	0	0	0
3406	11	26.83%	0	0	0	0	0	0
3351	12	29.27%	0	0	0	0	0	0
3283	13	31.71%	0	0	0	0	0	0
3234	14	34.15%	0	0	0	0	0	0
3160	15	36.59%	0	0	0	0	0	0
3019	16	39.02%	0	0	0	0	0	0
2890	17	41.46%	0	0	0	0	0	0
2810	18	43.90%	0	0	0	0	0	0
2626	19	46.34%	0	0	0	0	0	0
2582	20	48.78%	0	0	0	0	0	0
2558	21	51.22%	0	0	0	0	0	0
2373	22	53.66%	0	0	0	0	0	0
2367	23	56.10%	0	0	0	0	0	0
2312	24	58.54%	0	0	0	0	0	0
2097	25	60.98%	0	0	0	0	0	0
2078	26	63.41%	0	0	0	0	0	0
2017	27	65.85%	0	0	0	0	0	0
2011	28	68.29%	0	0	0	0	0	0
1943	29	70.73%	0	0	0	0	0	0
1943	30	73.17%	0	0	0	0	0	0
1937	31	75.61%	0	0	0	0	0	0
1906	32	78.05%	0	0	0	0	0	0
1857	**33**	**80.49%**	**0**	**0**	**0**	**0**	**0**	**0**
1832	34	82.93%	0	0	0	0	0	0
1629	35	85.37%	0	0	0	0	0	0
1562	36	87.80%	0	0	0	0	0	0
1470	37	90.24%	0	0	0	0	0	0
1439	38	92.68%	0	0	0	0	0	0
1396	39	95.12%	0	0	0	0	0	0
1285	40	97.56%	0	0	0	0	0	0


Reservoir Outflow in January
Outflow (acre-ft)
80000
70000
60000
50000
40000
30000
20000
10000
0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Time (years)

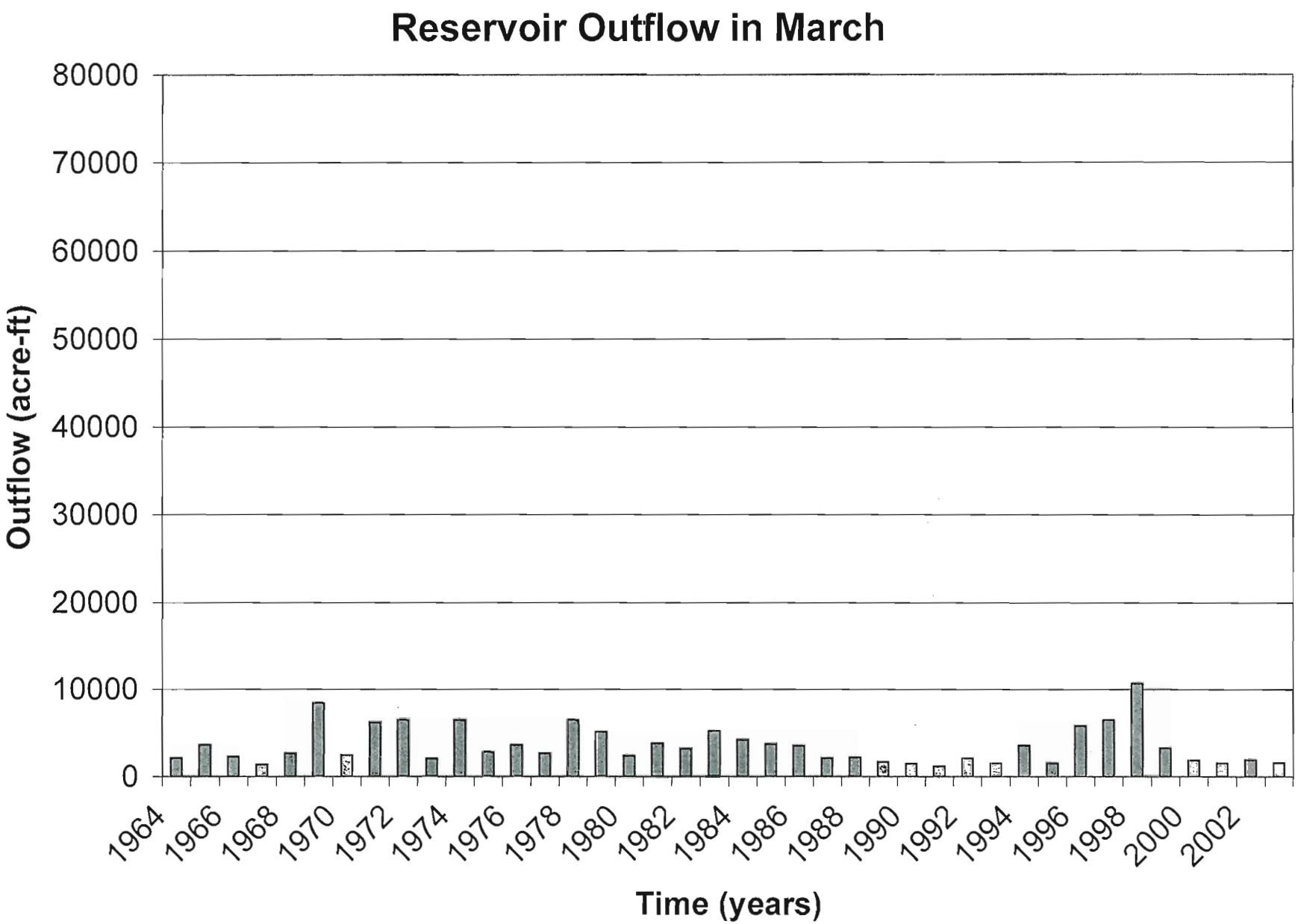
February

		Demand	30000	25000	20000	17500	15000	10000
Outflow - Descending Order (acre-ft)	Rank	Percentile	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)
5171	1	2.44%	0	0	0	0	0	0
5132	2	4.88%	0	0	0	0	0	0
4970	3	7.32%	0	0	0	0	0	0
4948	4	9.76%	0	0	0	0	0	0
4004	5	12.20%	0	0	0	0	0	0
3871	6	14.63%	0	0	0	0	0	0
3773	6	14.63%	0	0	0	0	0	0
3155	8	19.51%	0	0	0	0	0	0
3138	9	21.95%	0	0	0	0	0	0
3032	10	24.39%	0	0	0	0	0	0
3014	11	26.83%	0	0	0	0	0	0
2993	12	29.27%	0	0	0	0	0	0
2877	13	31.71%	0	0	0	0	0	0
2866	14	34.15%	0	0	0	0	0	0
2677	15	36.59%	0	0	0	0	0	0
2649	16	39.02%	0	0	0	0	0	0
2588	17	41.46%	0	0	0	0	0	0
2516	18	43.90%	0	0	0	0	0	0
2510	19	46.34%	0	0	0	0	0	0
2344	20	48.78%	0	0	0	0	0	0
2277	21	51.22%	0	0	0	0	0	0
2186	22	53.66%	0	0	0	0	0	0
2099	23	56.10%	0	0	0	0	0	0
2019	24	58.54%	0	0	0	0	0	0
1955	25	60.98%	0	0	0	0	0	0
1921	26	63.41%	0	0	0	0	0	0
1910	27	65.85%	0	0	0	0	0	0
1846	28	68.29%	0	0	0	0	0	0
1799	29	70.73%	0	0	0	0	0	0
1788	30	73.17%	0	0	0	0	0	0
1766	31	75.61%	0	0	0	0	0	0
1744	32	78.05%	0	0	0	0	0	0
1720	33	80.49%	0	0	0	0	0	0
1483	34	82.93%	0	0	0	0	0	0
1438	35	85.37%	0	0	0	0	0	0
1388	36	87.80%	0	0	0	0	0	0
1250	37	90.24%	0	0	0	0	0	0
1238	38	92.68%	0	0	0	0	0	0
1205	39	95.12%	0	0	0	0	0	0
1188	40	97.56%	0	0	0	0	0	0


Reservoir Outflow in February
Outflow (acre-ft)
80000
70000
60000
50000
40000
30000
20000
10000
0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Time (years)

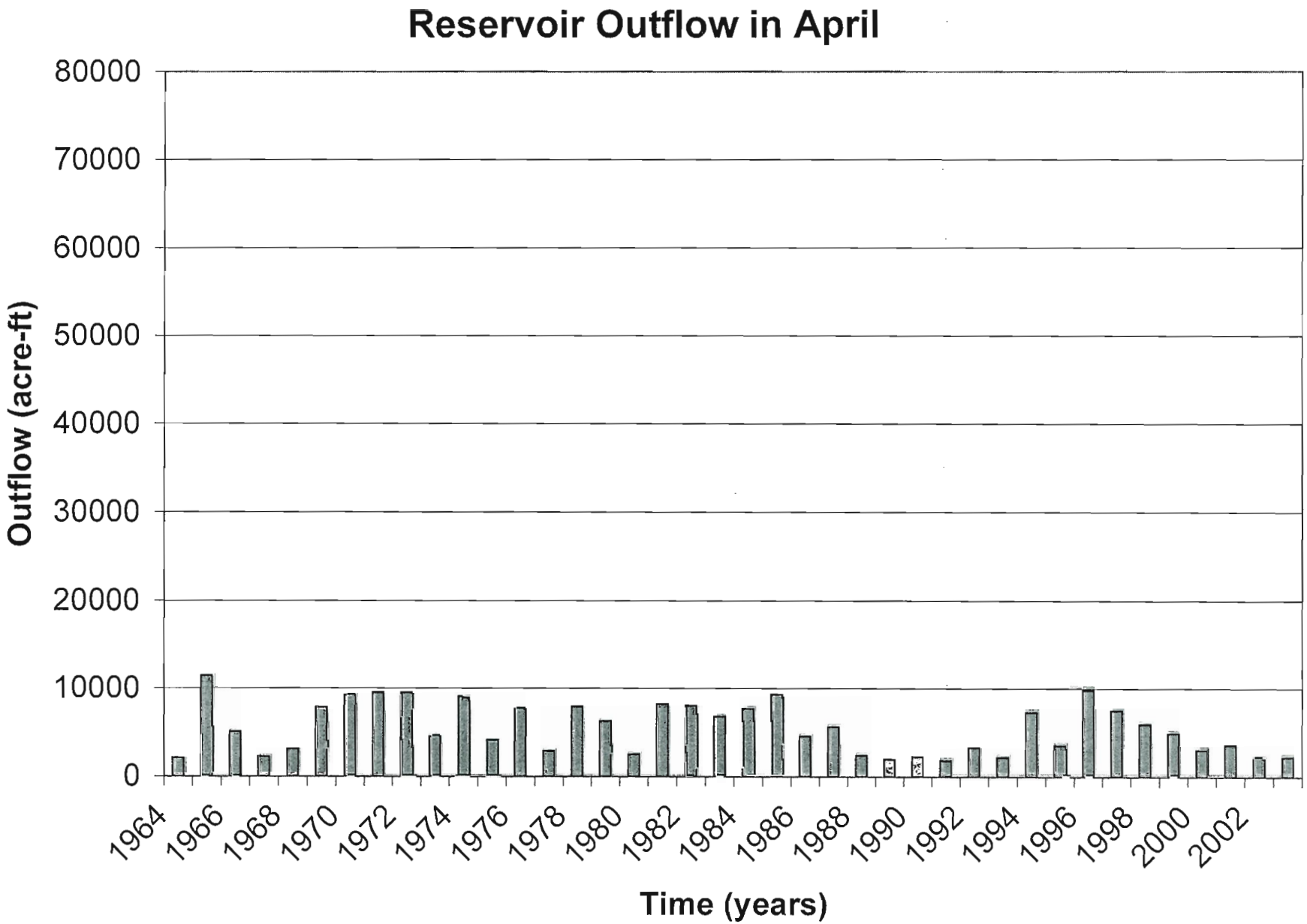
March

		Demand	30000	25000	20000	17500	15000	10000
Outflow - Descending Order (acre-ft)	Rank	Percentile	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)
10699	1	2.44%	0	0	0	0	0	699
8424	2	4.88%	0	0	0	0	0	0
6518	3	7.32%	0	0	0	0	0	0
6456	4	9.76%	0	0	0	0	0	0
6456	5	12.20%	0	0	0	0	0	0
6456	6	14.63%	0	0	0	0	0	0
6210	6	14.63%	0	0	0	0	0	0
5804	8	19.51%	0	0	0	0	0	0
5183	9	21.95%	0	0	0	0	0	0
5122	10	24.39%	0	0	0	0	0	0
4193	11	26.83%	0	0	0	0	0	0
3800	12	29.27%	0	0	0	0	0	0
3708	13	31.71%	0	0	0	0	0	0
3609	14	34.15%	0	0	0	0	0	0
3609	15	36.59%	0	0	0	0	0	0
3548	16	39.02%	0	0	0	0	0	0
3523	17	41.46%	0	0	0	0	0	0
3265	18	43.90%	0	0	0	0	0	0
3167	19	46.34%	0	0	0	0	0	0
2798	20	48.78%	0	0	0	0	0	0
2650	21	51.22%	0	0	0	0	0	0
2644	22	53.66%	0	0	0	0	0	0
2453	23	56.10%	0	0	0	0	0	0
2367	24	58.54%	0	0	0	0	0	0
2257	25	60.98%	0	0	0	0	0	0
2189	26	63.41%	0	0	0	0	0	0
2109	27	65.85%	0	0	0	0	0	0
2109	28	68.29%	0	0	0	0	0	0
2103	29	70.73%	0	0	0	0	0	0
2004	30	73.17%	0	0	0	0	0	0
1925	31	75.61%	0	0	0	0	0	0
1875	32	78.05%	0	0	0	0	0	0
1697	33	80.49%	0	0	0	0	0	0
1593	34	82.93%	0	0	0	0	0	0
1568	35	85.37%	0	0	0	0	0	0
1525	36	87.80%	0	0	0	0	0	0
1519	37	90.24%	0	0	0	0	0	0
1500	38	92.68%	0	0	0	0	0	0
1377	39	95.12%	0	0	0	0	0	0
1187	40	97.56%	0	0	0	0	0	0


Reservoir Outflow in March
Outflow (acre-ft)
80000
70000
60000
50000
40000
30000
20000
10000
0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Time (years)

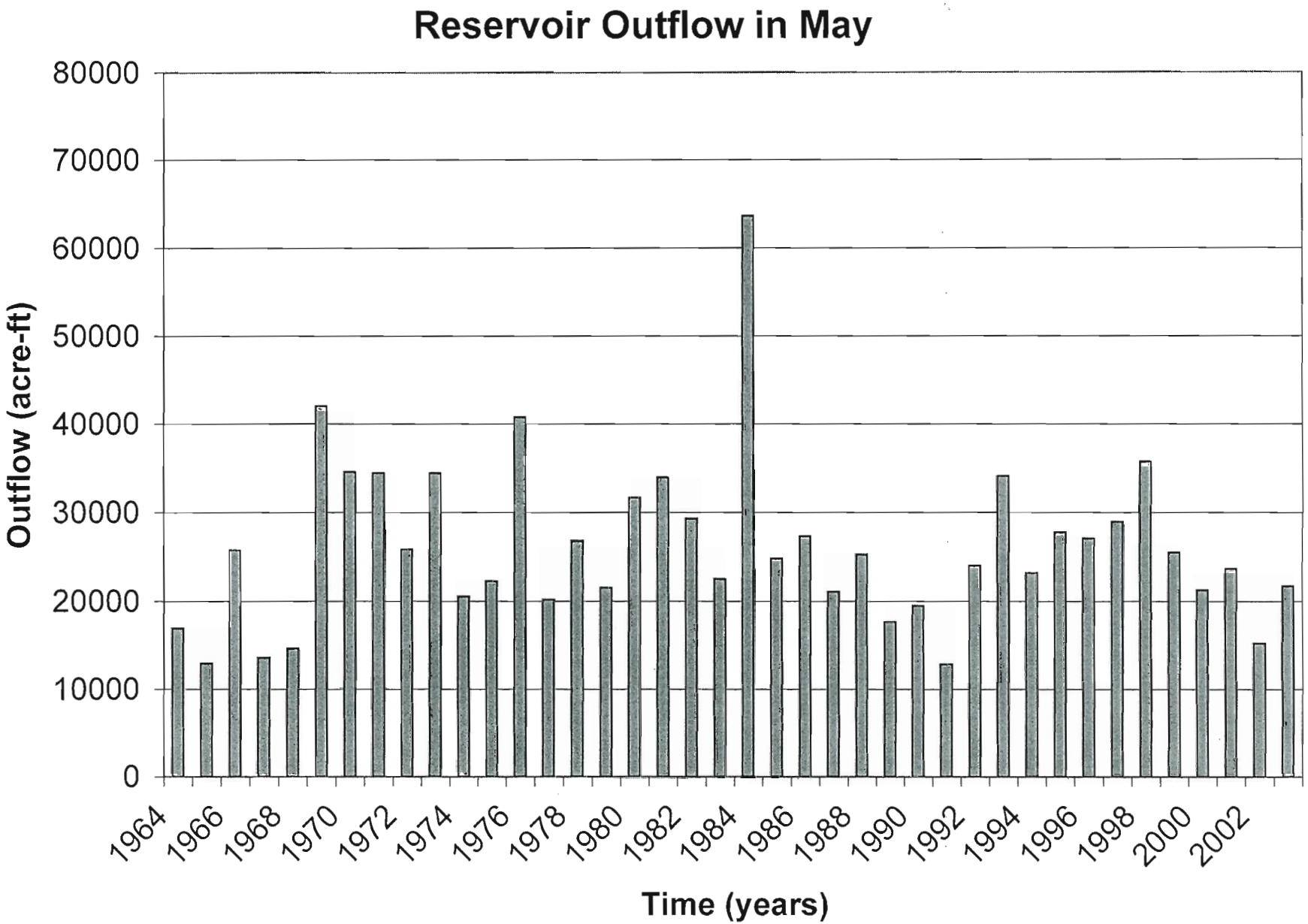
April

		Demand	30000	25000	20000	17500	15000	10000
Outflow - Descending Order (acre-ft)	***Rank***	***Percentile***	***Outflow minus Demand (acre-ft)***	***Outflow minus Demand (acre-ft)***	***Outflow minus Demand (acre-ft)***	***Outflow minus Demand (acre-ft)***	***Outflow minus Demand (acre-ft)***	***Outflow minus Demand (acre-ft)***
11425	1	2.44%	0	0	0	0	0	1425
9818	2	4.88%	0	0	0	0	0	0
9521	3	7.32%	0	0	0	0	0	0
9521	4	9.76%	0	0	0	0	0	0
9283	5	12.20%	0	0	0	0	0	0
9223	6	14.63%	0	0	0	0	0	0
8926	6	14.63%	0	0	0	0	0	0
8212	8	19.51%	0	0	0	0	0	0
8033	9	21.95%	0	0	0	0	0	0
7914	10	24.39%	0	0	0	0	0	0
7855	11	26.83%	0	0	0	0	0	0
7676	12	29.27%	0	0	0	0	0	0
7617	13	31.71%	0	0	0	0	0	0
7498	14	34.15%	0	0	0	0	0	0
7260	15	36.59%	0	0	0	0	0	0
6783	16	39.02%	0	0	0	0	0	0
6248	17	41.46%	0	0	0	0	0	0
5927	18	43.90%	0	0	0	0	0	0
5623	19	46.34%	0	0	0	0	0	0
5064	20	48.78%	0	0	0	0	0	0
4891	21	51.22%	0	0	0	0	0	0
4528	22	53.66%	0	0	0	0	0	0
4504	23	56.10%	0	0	0	0	0	0
3951	24	58.54%	0	0	0	0	0	0
3594	25	60.98%	0	0	0	0	0	0
3499	26	63.41%	0	0	0	0	0	0
3279	27	65.85%	0	0	0	0	0	0
3094	28	68.29%	0	0	0	0	0	0
2987	29	70.73%	0	0	0	0	0	0
2856	30	73.17%	0	0	0	0	0	0
2475	31	75.61%	0	0	0	0	0	0
2374	32	78.05%	0	0	0	0	0	0
2243	**33**	**80.49%**	**0**	**0**	**0**	**0**	**0**	**0**
2214	34	82.93%	0	0	0	0	0	0
2214	35	85.37%	0	0	0	0	0	0
2160	36	87.80%	0	0	0	0	0	0
2071	37	90.24%	0	0	0	0	0	0
2035	38	92.68%	0	0	0	0	0	0
1952	39	95.12%	0	0	0	0	0	0
1815	40	97.56%	0	0	0	0	0	0


Reservoir Outflow in April
Outflow (acre-ft)
80000
70000
60000
50000
40000
30000
20000
10000
0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Time (years)

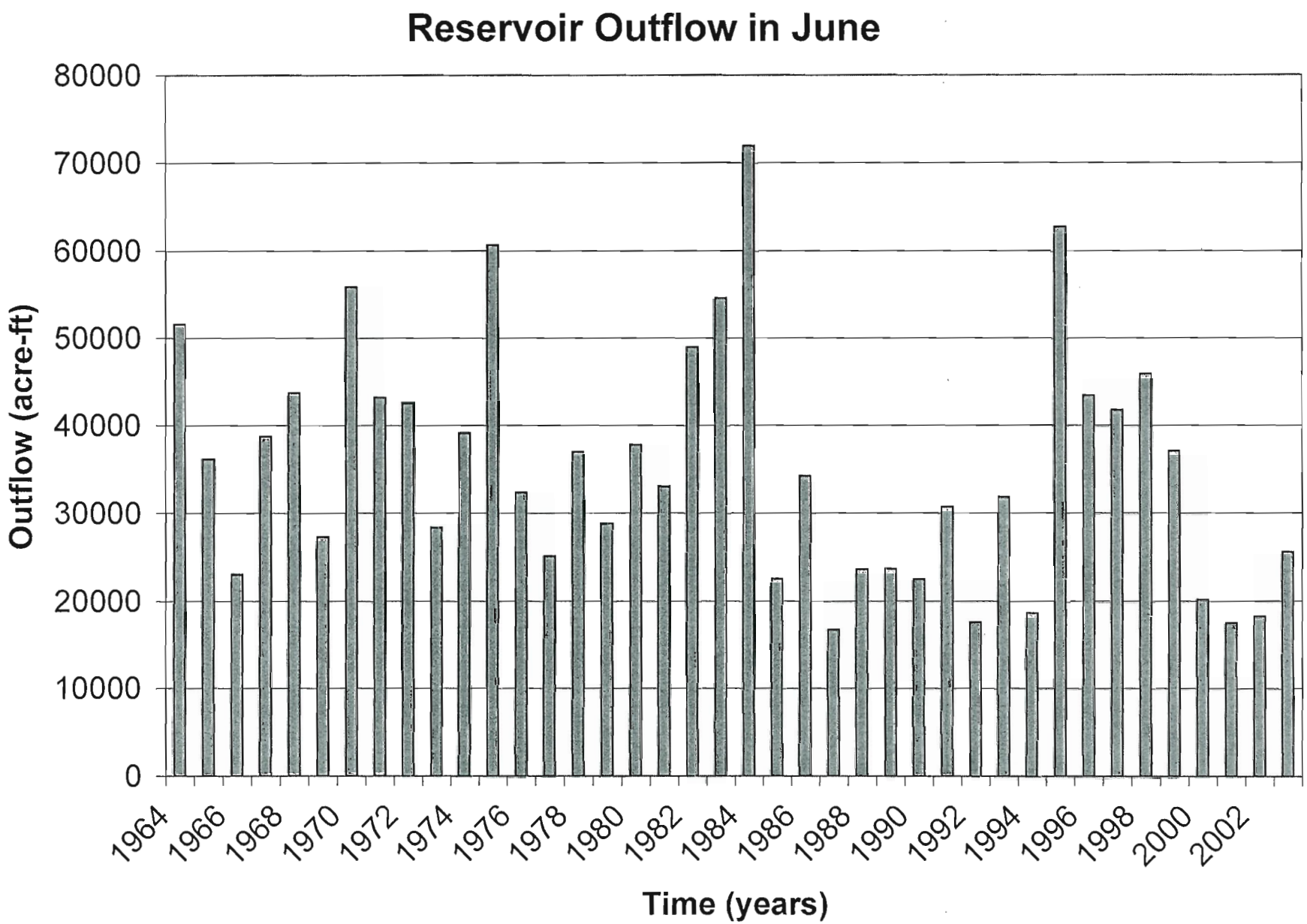
May

		Demand	30000	25000	20000	17500	15000	10000
Outflow - Descending Order (acre-ft)	Rank	Percentile	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)
63640	1	2.44%	33640	38640	43640	46140	48640	53640
42058	2	4.88%	12058	17058	22058	24558	27058	32058
40766	3	7.32%	10766	15766	20766	23266	25766	30766
35724	4	9.76%	5724	10724	15724	18224	20724	25724
34556	5	12.20%	4556	9556	14556	17056	19556	24556
34433	6	14.63%	4433	9433	14433	16933	19433	24433
34433	6	14.63%	4433	9433	14433	16933	19433	24433
34126	8	19.51%	4126	9126	14126	16626	19126	24126
33941	9	21.95%	3941	8941	13941	16441	18941	23941
31666	10	24.39%	1666	6666	11666	14166	16666	21666
29330	11	26.83%	0	4330	9330	11830	14330	19330
28961	12	29.27%	0	3961	8961	11461	13961	18961
27792	13	31.71%	0	2792	7792	10292	12792	17792
27362	14	34.15%	0	2362	7362	9862	12362	17362
27116	15	36.59%	0	2116	7116	9616	12116	17116
26809	16	39.02%	0	1809	6809	9309	11809	16809
25886	17	41.46%	0	886	5886	8386	10886	15886
25763	18	43.90%	0	763	5763	8263	10763	15763
25517	19	46.34%	0	517	5517	8017	10517	15517
25271	20	48.78%	0	271	5271	7771	10271	15271
24841	21	51.22%	0	0	4841	7341	9841	14841
24042	22	53.66%	0	0	4042	6542	9042	14042
23673	23	56.10%	0	0	3673	6173	8673	13673
23181	24	58.54%	0	0	3181	5681	8181	13181
22504	25	60.98%	0	0	2504	5004	7504	12504
22259	26	63.41%	0	0	2259	4759	7259	12259
21705	27	65.85%	0	0	1705	4205	6705	11705
21521	28	68.29%	0	0	1521	4021	6521	11521
21275	29	70.73%	0	0	1275	3775	6275	11275
21090	30	73.17%	0	0	1090	3590	6090	11090
20537	31	75.61%	0	0	537	3037	5537	10537
20168	32	78.05%	0	0	168	2668	5168	10168
19492	**33**	**80.49%**	**0**	**0**	**0**	**1992**	**4492**	**9492**
17647	34	82.93%	0	0	0	147	2647	7647
16909	35	85.37%	0	0	0	0	1909	6909
15249	36	87.80%	0	0	0	0	249	5249
14634	37	90.24%	0	0	0	0	0	4634
13589	38	92.68%	0	0	0	0	0	3589
12912	39	95.12%	0	0	0	0	0	2912
12851	40	97.56%	0	0	0	0	0	2851


Reservoir Outflow in May
Outflow (acre-ft)
80000
70000
60000
50000
40000
30000
20000
10000
0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Time (years)

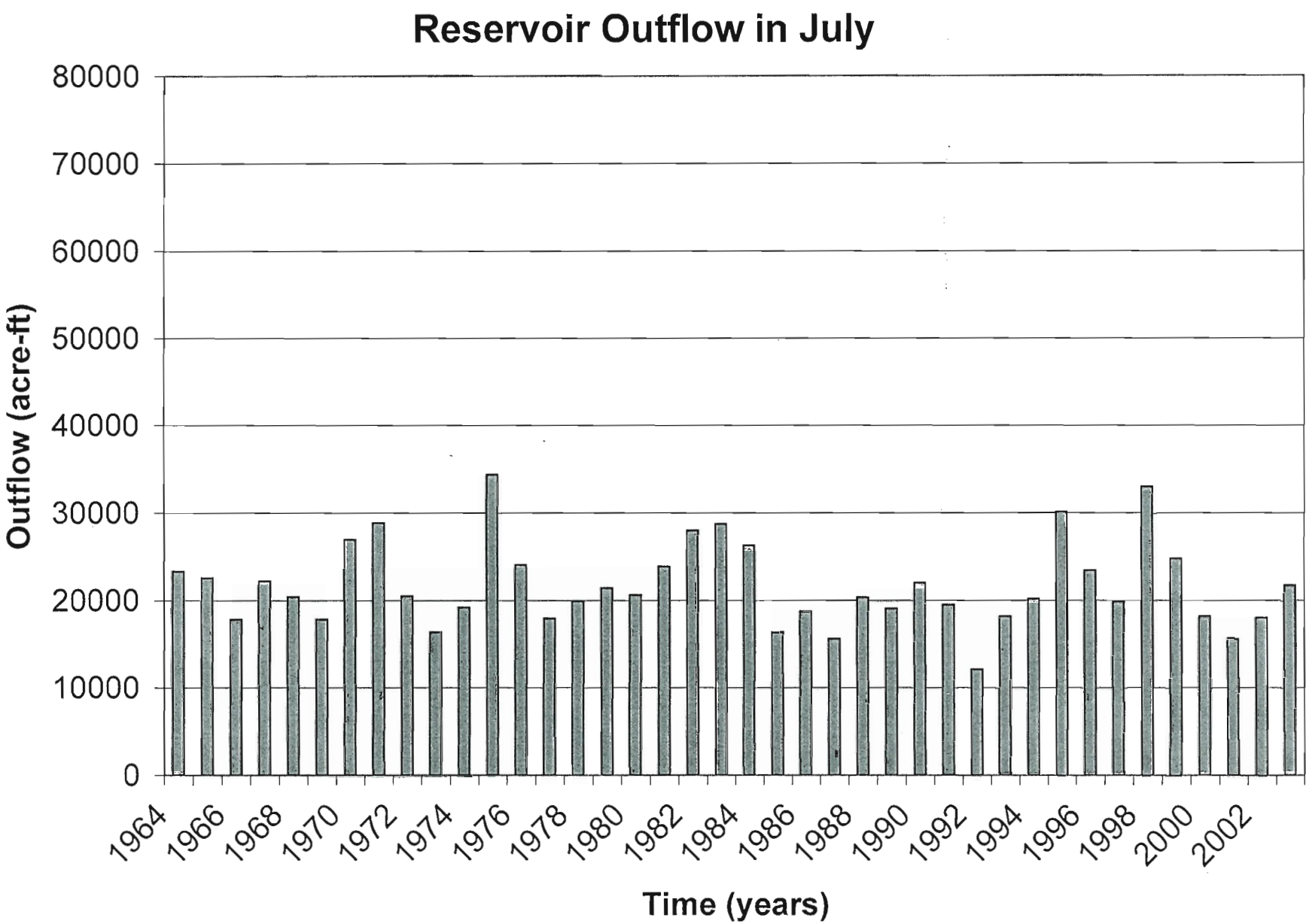
June

		Demand	30000	25000	20000	17500	15000	10000
Outflow - Descending Order (acre-ft)	Rank	Percentile	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)
71940	1	2.44%	41940	46940	51940	54440	56940	61940
62717	2	4.88%	32717	37717	42717	45217	47717	52717
60635	3	7.32%	30635	35635	40635	43135	45635	50635
55874	4	9.76%	25874	30874	35874	38374	40874	45874
54565	5	12.20%	24565	29565	34565	37065	39565	44565
51590	6	14.63%	21590	26590	31590	34090	36590	41590
48972	6	14.63%	18972	23972	28972	31472	33972	38972
45937	8	19.51%	15937	20937	25937	28437	30937	35937
43736	9	21.95%	13736	18736	23736	26236	28736	33736
43438	10	24.39%	13438	18438	23438	25938	28438	33438
43200	11	26.83%	13200	18200	23200	25700	28200	33200
42545	12	29.27%	12545	17545	22545	25045	27545	32545
41772	13	31.71%	11772	16772	21772	24272	26772	31772
39154	14	34.15%	9154	14154	19154	21654	24154	29154
38737	15	36.59%	8737	13737	18737	21237	23737	28737
37785	16	39.02%	7785	12785	17785	20285	22785	27785
37071	17	41.46%	7071	12071	17071	19571	22071	27071
36952	18	43.90%	6952	11952	16952	19452	21952	26952
36119	19	46.34%	6119	11119	16119	18619	21119	26119
34215	20	48.78%	4215	9215	14215	16715	19215	24215
33084	21	51.22%	3084	8084	13084	15584	18084	23084
32370	22	53.66%	2370	7370	12370	14870	17370	22370
31835	23	56.10%	1835	6835	11835	14335	16835	21835
30704	24	58.54%	704	5704	10704	13204	15704	20704
28800	25	60.98%	0	3800	8800	11300	13800	18800
28383	26	63.41%	0	3383	8383	10883	13383	18383
27312	27	65.85%	0	2312	7312	9812	12312	17312
25587	28	68.29%	0	587	5587	8087	10587	15587
25111	29	70.73%	0	111	5111	7611	10111	15111
23683	30	73.17%	0	0	3683	6183	8683	13683
23623	31	75.61%	0	0	3623	6123	8623	13623
23028	32	78.05%	0	0	3028	5528	8028	13028
22552	33	80.49%	0	0	2552	5052	7552	12552
22493	34	82.93%	0	0	2493	4993	7493	12493
20172	35	85.37%	0	0	172	2672	5172	10172
18625	36	87.80%	0	0	0	1125	3625	8625
18268	37	90.24%	0	0	0	768	3268	8268
17554	38	92.68%	0	0	0	54	2554	7554
17494	39	95.12%	0	0	0	0	2494	7494
16721	40	97.56%	0	0	0	0	1721	6721


Reservoir Outflow in June
Outflow (acre-ft)
80000
70000
60000
50000
40000
30000
20000
10000
0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Time (years)

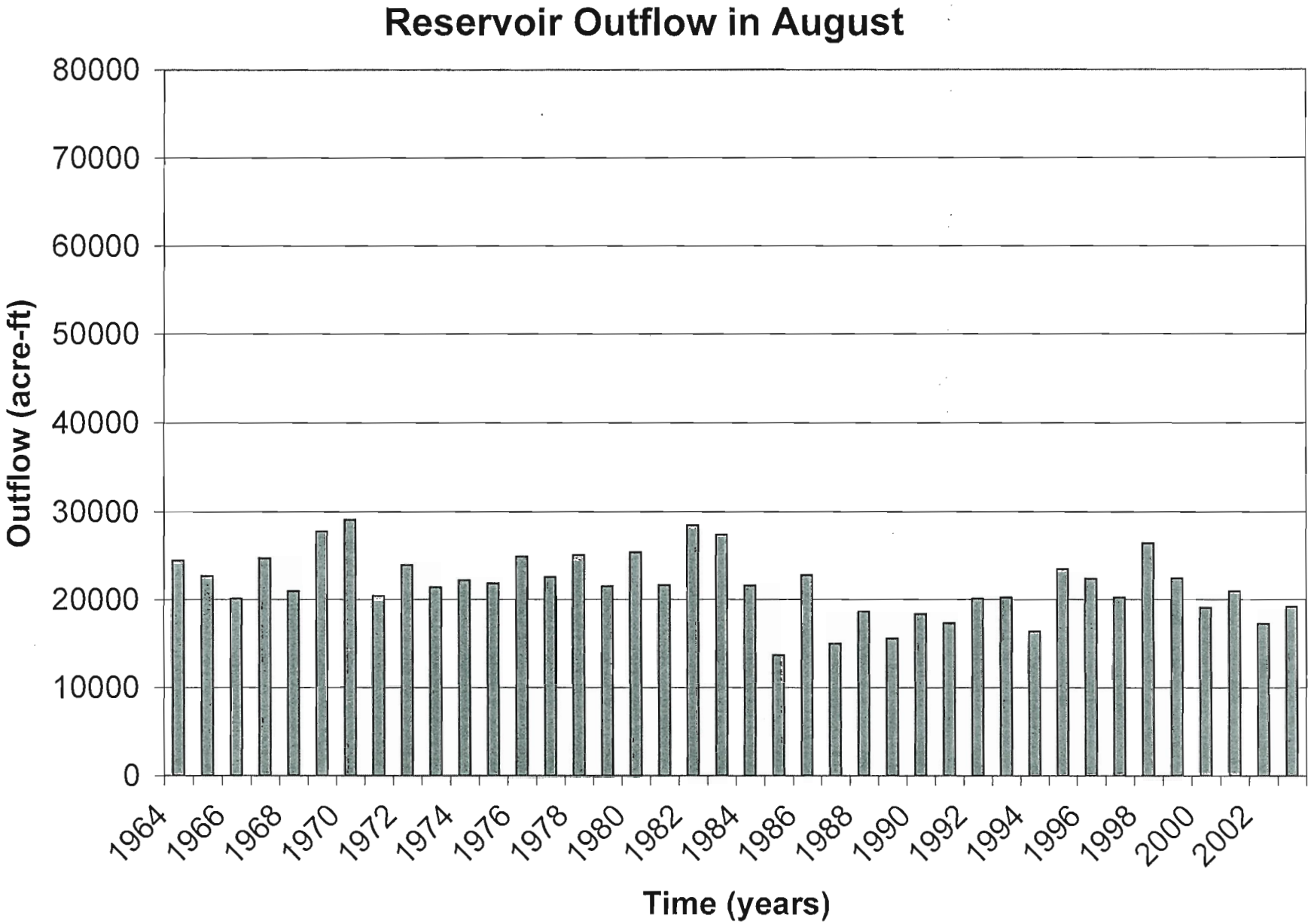
July

		Demand	30000	25000	20000	17500	15000	10000
Outflow - Descending Order (acre-ft)	Rank	Percentile	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)
34372	1	2.44%	4372	9372	14372	16872	19372	24372
33019	2	4.88%	3019	8019	13019	15519	18019	23019
30129	3	7.32%	129	5129	10129	12629	15129	20129
28838	4	9.76%	0	3838	8838	11338	13838	18838
28715	5	12.20%	0	3715	8715	11215	13715	18715
27977	6	14.63%	0	2977	7977	10477	12977	17977
26932	6	14.63%	0	1932	6932	9432	11932	16932
26255	8	19.51%	0	1255	6255	8755	11255	16255
24780	9	21.95%	0	0	4780	7280	9780	14780
24042	10	24.39%	0	0	4042	6542	9042	14042
23857	11	26.83%	0	0	3857	6357	8857	13857
23427	12	29.27%	0	0	3427	5927	8427	13427
23304	13	31.71%	0	0	3304	5804	8304	13304
22566	14	34.15%	0	0	2566	5066	7566	12566
22197	15	36.59%	0	0	2197	4697	7197	12197
22013	16	39.02%	0	0	2013	4513	7013	12013
21705	17	41.46%	0	0	1705	4205	6705	11705
21398	18	43.90%	0	0	1398	3898	6398	11398
20598	19	46.34%	0	0	598	3098	5598	10598
20475	20	48.78%	0	0	475	2975	5475	10475
20414	21	51.22%	0	0	414	2914	5414	10414
20352	22	53.66%	0	0	352	2852	5352	10352
20168	23	56.10%	0	0	168	2668	5168	10168
19922	24	58.54%	0	0	0	2422	4922	9922
19860	25	60.98%	0	0	0	2360	4860	9860
19492	26	63.41%	0	0	0	1992	4492	9492
19184	27	65.85%	0	0	0	1684	4184	9184
19061	28	68.29%	0	0	0	1561	4061	9061
18754	29	70.73%	0	0	0	1254	3754	8754
18200	30	73.17%	0	0	0	700	3200	8200
18200	31	75.61%	0	0	0	700	3200	8200
18016	32	78.05%	0	0	0	516	3016	8016
17954	**33**	**80.49%**	**0**	**0**	**0**	**454**	**2954**	**7954**
17831	34	82.93%	0	0	0	331	2831	7831
17831	35	85.37%	0	0	0	331	2831	7831
16356	36	87.80%	0	0	0	0	1356	6356
16356	37	90.24%	0	0	0	0	1356	6356
15679	38	92.68%	0	0	0	0	679	5679
15618	39	95.12%	0	0	0	0	618	5618
12113	40	97.56%	0	0	0	0	0	2113


Reservoir Outflow in July
Outflow (acre-ft)
80000
70000
60000
50000
40000
30000
20000
10000
0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Time (years)

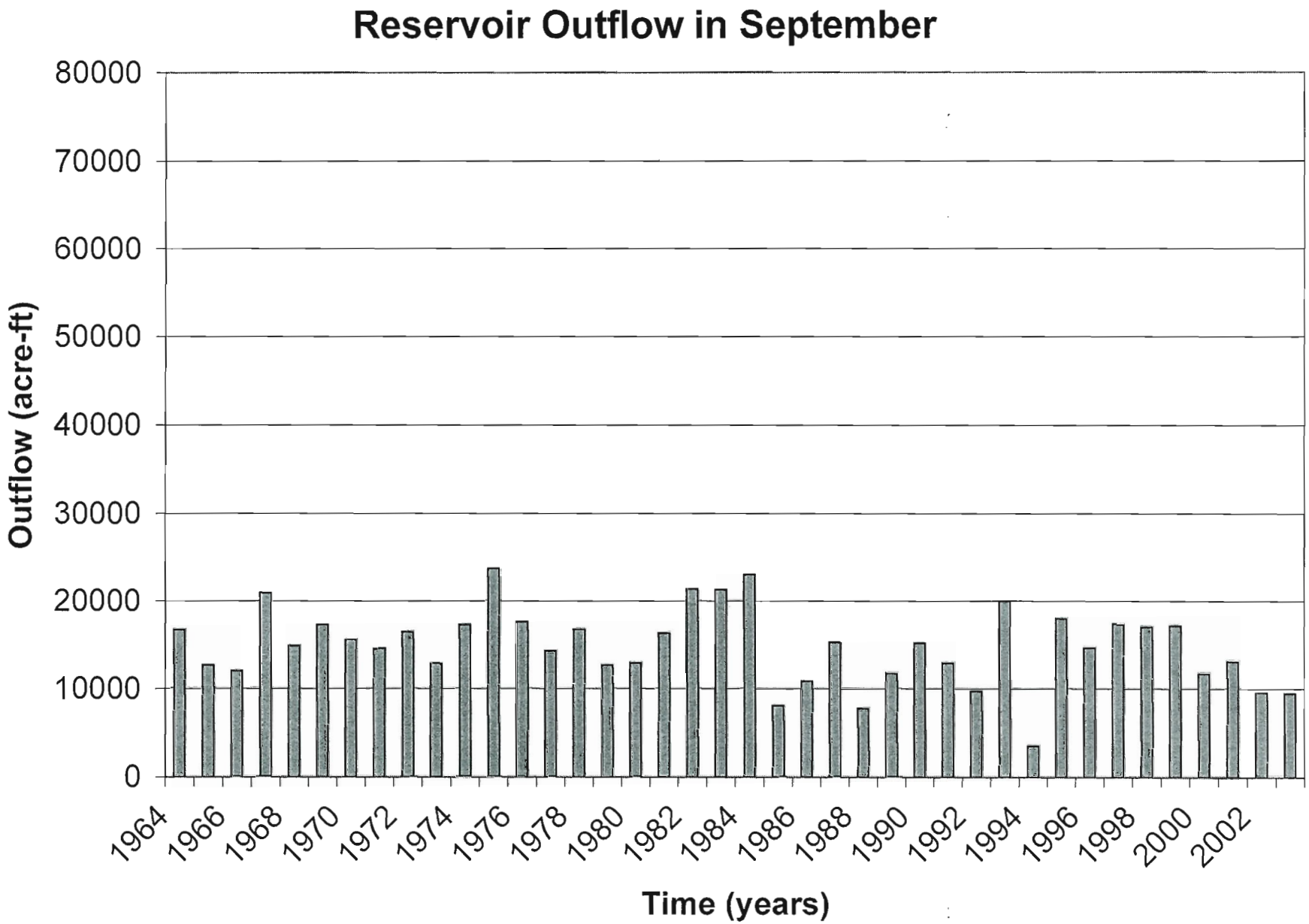
August

		Demand	30000	25000	20000	17500	15000	10000
Outflow - Descending Order (acre-ft)	Rank	Percentile	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)
29084	1	2.44%	0	4084	9084	11584	14084	19084
28469	2	4.88%	0	3469	8469	10969	13469	18469
27792	3	7.32%	0	2792	7792	10292	12792	17792
27423	4	9.76%	0	2423	7423	9923	12423	17423
26440	5	12.20%	0	1440	6440	8940	11440	16440
25394	6	14.63%	0	394	5394	7894	10394	15394
25087	6	14.63%	0	87	5087	7587	10087	15087
24902	8	19.51%	0	0	4902	7402	9902	14902
24718	9	21.95%	0	0	4718	7218	9718	14718
24472	10	24.39%	0	0	4472	6972	9472	14472
23919	11	26.83%	0	0	3919	6419	8919	13919
23488	12	29.27%	0	0	3488	5988	8488	13488
22812	13	31.71%	0	0	2812	5312	7812	12812
22689	14	34.15%	0	0	2689	5189	7689	12689
22566	15	36.59%	0	0	2566	5066	7566	12566
22443	16	39.02%	0	0	2443	4943	7443	12443
22381	17	41.46%	0	0	2381	4881	7381	12381
22197	18	43.90%	0	0	2197	4697	7197	12197
21828	19	46.34%	0	0	1828	4328	6828	11828
21644	20	48.78%	0	0	1644	4144	6644	11644
21582	21	51.22%	0	0	1582	4082	6582	11582
21521	22	53.66%	0	0	1521	4021	6521	11521
21398	23	56.10%	0	0	1398	3898	6398	11398
20967	24	58.54%	0	0	967	3467	5967	10967
20967	25	60.98%	0	0	967	3467	5967	10967
20414	26	63.41%	0	0	414	2914	5414	10414
20229	27	65.85%	0	0	229	2729	5229	10229
20229	28	68.29%	0	0	229	2729	5229	10229
20106	29	70.73%	0	0	106	2606	5106	10106
20106	30	73.17%	0	0	106	2606	5106	10106
19184	31	75.61%	0	0	0	1684	4184	9184
19061	32	78.05%	0	0	0	1561	4061	9061
18631	33	80.49%	0	0	0	1131	3631	8631
18323	34	82.93%	0	0	0	823	3323	8323
17278	35	85.37%	0	0	0	0	2278	7278
17217	36	87.80%	0	0	0	0	2217	7217
16356	37	90.24%	0	0	0	0	1356	6356
15556	38	92.68%	0	0	0	0	556	5556
14941	39	95.12%	0	0	0	0	0	4941
13650	40	97.56%	0	0	0	0	0	3650


Reservoir Outflow in August
Outflow (acre-ft)
80000
70000
60000
50000
40000
30000
20000
10000
0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Time (years)

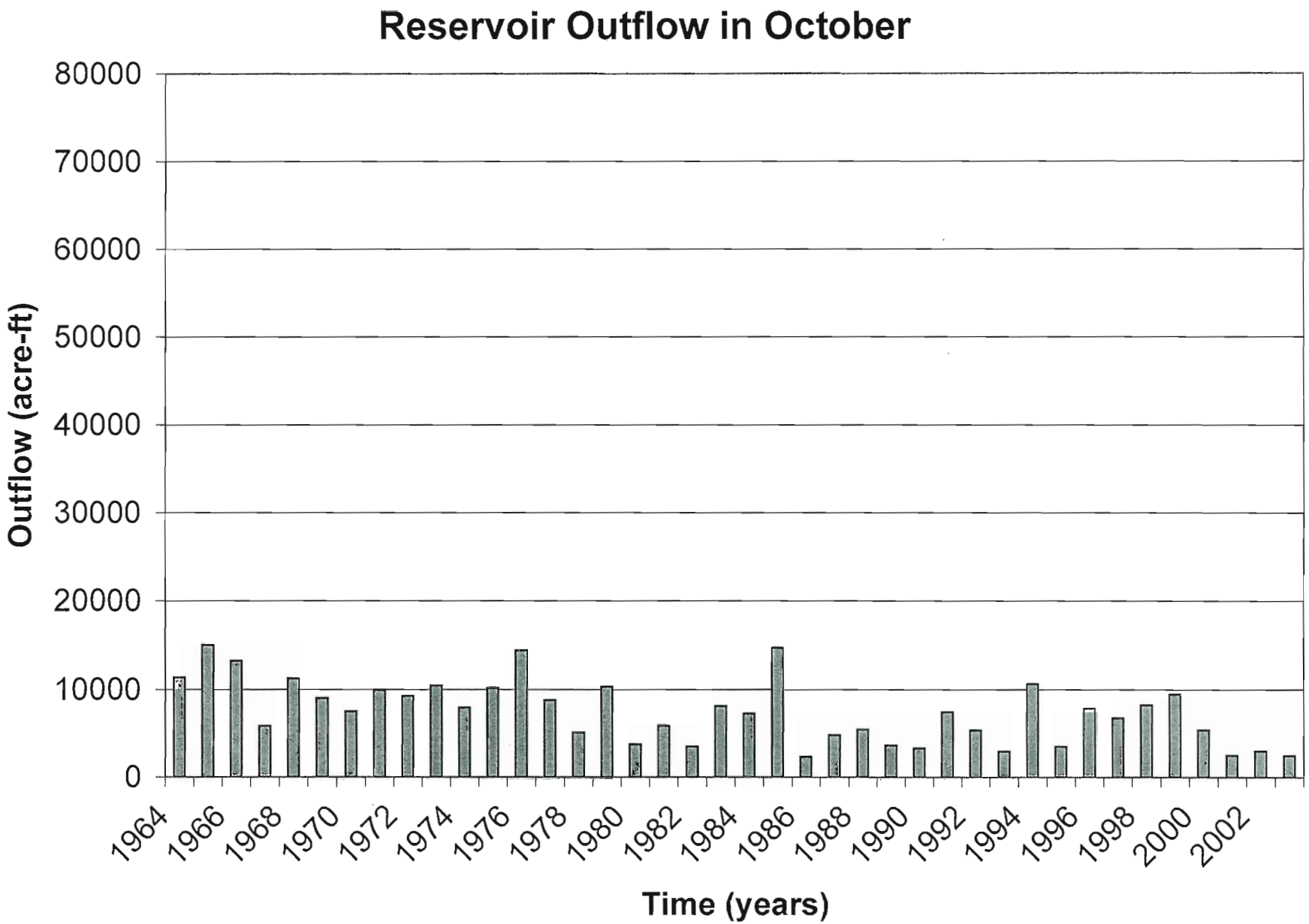
September

		Demand	30000	25000	20000	17500	15000	10000
Outflow - Descending Order (acre-ft)	***Rank***	***Percentile***	***Outflow minus Demand (acre-ft)***	***Outflow minus Demand (acre-ft)***	***Outflow minus Demand (acre-ft)***	***Outflow minus Demand (acre-ft)***	***Outflow minus Demand (acre-ft)***	***Outflow minus Demand (acre-ft)***
23742	1	2.44%	0	0	3742	6242	8742	13742
23028	2	4.88%	0	0	3028	5528	8028	13028
21362	3	7.32%	0	0	1362	3862	6362	11362
21302	4	9.76%	0	0	1302	3802	6302	11302
20945	5	12.20%	0	0	945	3445	5945	10945
19993	6	14.63%	0	0	0	2493	4993	9993
17970	6	14.63%	0	0	0	470	2970	7970
17613	8	19.51%	0	0	0	113	2613	7613
17256	9	21.95%	0	0	0	0	2256	7256
17256	10	24.39%	0	0	0	0	2256	7256
17256	11	26.83%	0	0	0	0	2256	7256
17137	12	29.27%	0	0	0	0	2137	7137
17018	13	31.71%	0	0	0	0	2018	7018
16721	14	34.15%	0	0	0	0	1721	6721
16721	15	36.59%	0	0	0	0	1721	6721
16423	16	39.02%	0	0	0	0	1423	6423
16304	17	41.46%	0	0	0	0	1304	6304
15531	18	43.90%	0	0	0	0	531	5531
15293	19	46.34%	0	0	0	0	293	5293
15174	20	48.78%	0	0	0	0	174	5174
14876	21	51.22%	0	0	0	0	0	4876
14638	22	53.66%	0	0	0	0	0	4638
14519	23	56.10%	0	0	0	0	0	4519
14281	24	58.54%	0	0	0	0	0	4281
13091	25	60.98%	0	0	0	0	0	3091
12912	26	63.41%	0	0	0	0	0	2912
12912	27	65.85%	0	0	0	0	0	2912
12853	28	68.29%	0	0	0	0	0	2853
12674	29	70.73%	0	0	0	0	0	2674
12674	30	73.17%	0	0	0	0	0	2674
12020	31	75.61%	0	0	0	0	0	2020
11722	32	78.05%	0	0	0	0	0	1722
11663	**33**	**80.49%**	**0**	**0**	**0**	**0**	**0**	**1663**
10830	34	82.93%	0	0	0	0	0	830
9699	35	85.37%	0	0	0	0	0	0
9580	36	87.80%	0	0	0	0	0	0
9461	37	90.24%	0	0	0	0	0	0
8093	38	92.68%	0	0	0	0	0	0
7795	39	95.12%	0	0	0	0	0	0
3535	40	97.56%	0	0	0	0	0	0


Reservoir Outflow in September
Outflow (acre-ft)
80000
70000
60000
50000
40000
30000
20000
10000
0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Time (years)

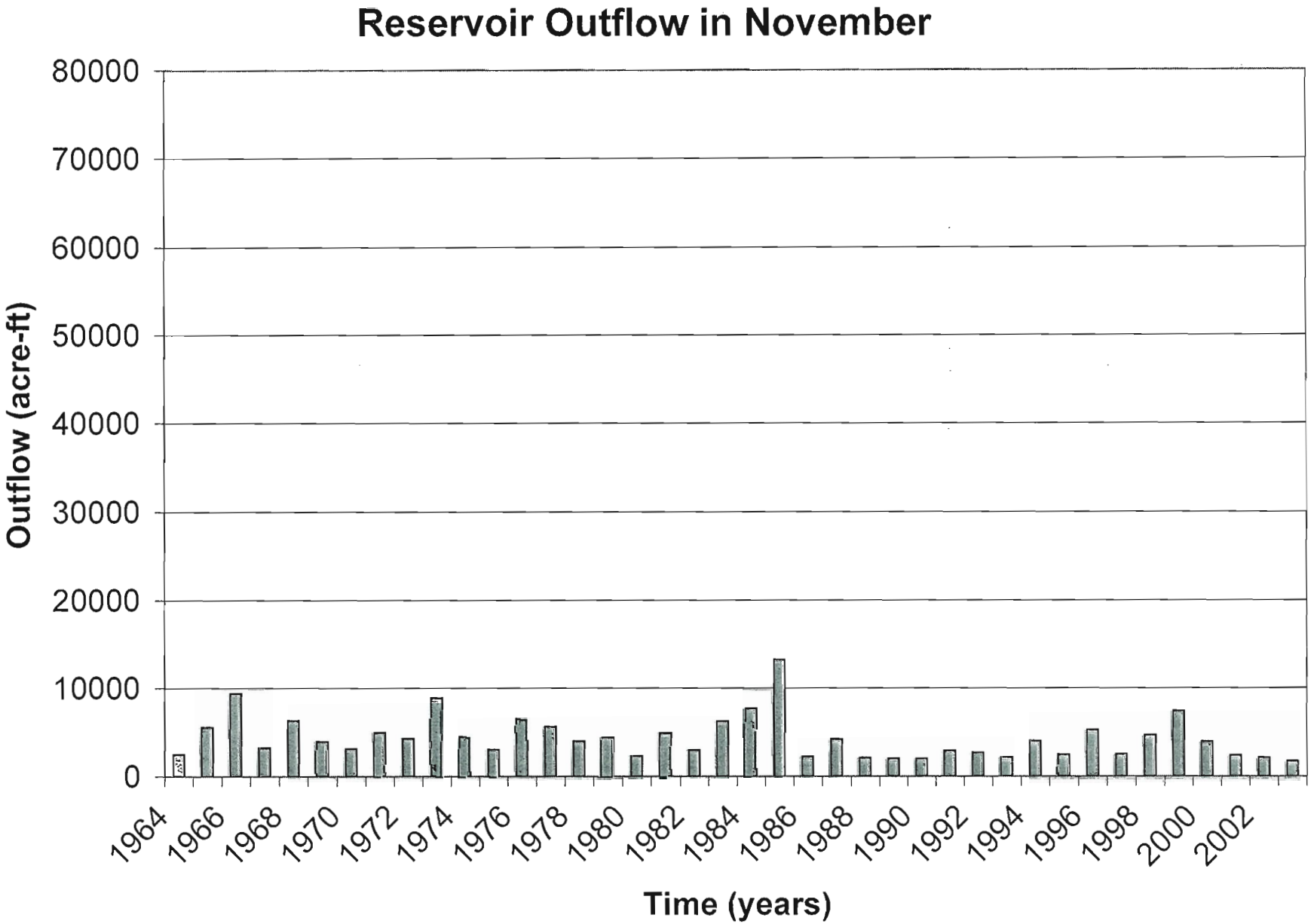
October

		Demand	30000	25000	20000	17500	15000	10000
Outflow - Descending Order (acre-ft)	***Rank***	***Percentile***	***Outflow minus Demand (acre-ft)***	***Outflow minus Demand (acre-ft)***	***Outflow minus Demand (acre-ft)***	***Outflow minus Demand (acre-ft)***	***Outflow minus Demand (acre-ft)***	***Outflow minus Demand (acre-ft)***
15003	1	2.44%	0	0	0	0	3	5003
14696	2	4.88%	0	0	0	0	0	4696
14388	3	7.32%	0	0	0	0	0	4388
13220	4	9.76%	0	0	0	0	0	3220
11375	5	12.20%	0	0	0	0	0	1375
11252	6	14.63%	0	0	0	0	0	1252
10637	6	14.63%	0	0	0	0	0	637
10453	8	19.51%	0	0	0	0	0	453
10330	9	21.95%	0	0	0	0	0	330
10145	10	24.39%	0	0	0	0	0	145
9961	11	26.83%	0	0	0	0	0	0
9469	12	29.27%	0	0	0	0	0	0
9285	13	31.71%	0	0	0	0	0	0
9039	14	34.15%	0	0	0	0	0	0
8793	15	36.59%	0	0	0	0	0	0
8239	16	39.02%	0	0	0	0	0	0
8116	17	41.46%	0	0	0	0	0	0
7932	18	43.90%	0	0	0	0	0	0
7870	19	46.34%	0	0	0	0	0	0
7501	20	48.78%	0	0	0	0	0	0
7440	21	51.22%	0	0	0	0	0	0
7256	22	53.66%	0	0	0	0	0	0
6764	23	56.10%	0	0	0	0	0	0
5860	24	58.54%	0	0	0	0	0	0
5860	25	60.98%	0	0	0	0	0	0
5442	26	63.41%	0	0	0	0	0	0
5399	27	65.85%	0	0	0	0	0	0
5356	28	68.29%	0	0	0	0	0	0
5103	29	70.73%	0	0	0	0	0	0
4827	30	73.17%	0	0	0	0	0	0
3763	31	75.61%	0	0	0	0	0	0
3646	32	78.05%	0	0	0	0	0	0
3505	**33**	**80.49%**	**0**	**0**	**0**	**0**	**0**	**0**
3499	34	82.93%	0	0	0	0	0	0
3302	35	85.37%	0	0	0	0	0	0
2976	36	87.80%	0	0	0	0	0	0
2951	37	90.24%	0	0	0	0	0	0
2490	38	92.68%	0	0	0	0	0	0
2472	39	95.12%	0	0	0	0	0	0
2337	40	97.56%	0	0	0	0	0	0


Reservoir Outflow in October
Outflow (acre-ft)
80000
70000
60000
50000
40000
30000
20000
10000
0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Time (years)

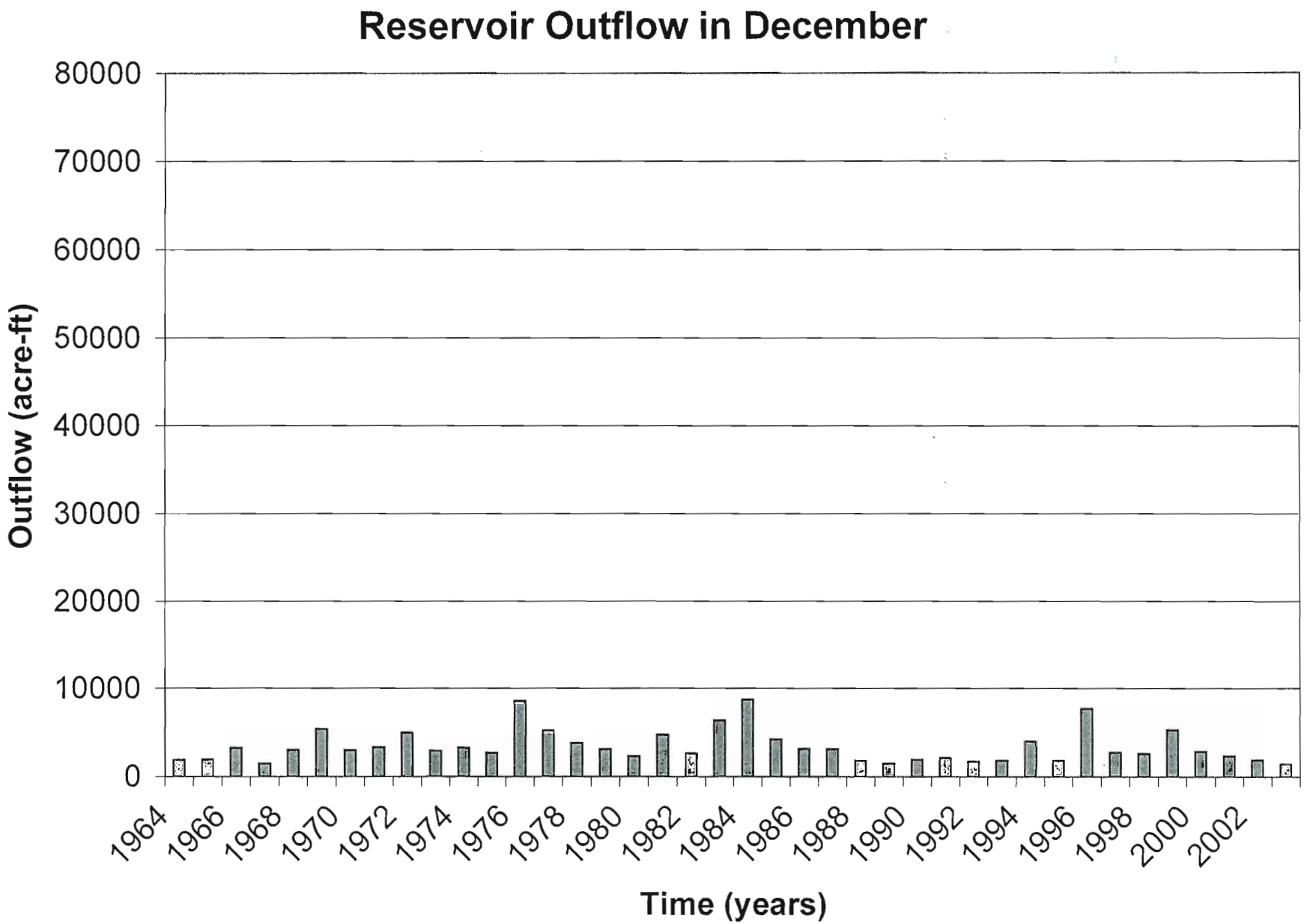
November

		Demand	30000	25000	20000	17500	15000	10000
Outflow - Descending Order (acre-ft)	Rank	Percentile	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)
13210	1	2.44%	0	0	0	0	0	3210
9402	2	4.88%	0	0	0	0	0	0
8866	3	7.32%	0	0	0	0	0	0
7676	4	9.76%	0	0	0	0	0	0
7379	5	12.20%	0	0	0	0	0	0
6486	6	14.63%	0	0	0	0	0	0
6307	6	14.63%	0	0	0	0	0	0
6188	8	19.51%	0	0	0	0	0	0
5576	9	21.95%	0	0	0	0	0	0
5528	10	24.39%	0	0	0	0	0	0
5260	11	26.83%	0	0	0	0	0	0
4927	12	29.27%	0	0	0	0	0	0
4873	13	31.71%	0	0	0	0	0	0
4665	14	34.15%	0	0	0	0	0	0
4463	15	36.59%	0	0	0	0	0	0
4368	16	39.02%	0	0	0	0	0	0
4284	17	41.46%	0	0	0	0	0	0
4201	18	43.90%	0	0	0	0	0	0
4005	19	46.34%	0	0	0	0	0	0
3969	20	48.78%	0	0	0	0	0	0
3939	21	51.22%	0	0	0	0	0	0
3921	22	53.66%	0	0	0	0	0	0
3225	23	56.10%	0	0	0	0	0	0
3124	24	58.54%	0	0	0	0	0	0
3035	25	60.98%	0	0	0	0	0	0
2993	26	63.41%	0	0	0	0	0	0
2910	27	65.85%	0	0	0	0	0	0
2690	28	68.29%	0	0	0	0	0	0
2517	29	70.73%	0	0	0	0	0	0
2505	30	73.17%	0	0	0	0	0	0
2458	31	75.61%	0	0	0	0	0	0
2386	32	78.05%	0	0	0	0	0	0
2291	33	80.49%	0	0	0	0	0	0
2243	34	82.93%	0	0	0	0	0	0
2172	35	85.37%	0	0	0	0	0	0
2142	36	87.80%	0	0	0	0	0	0
2095	37	90.24%	0	0	0	0	0	0
1999	38	92.68%	0	0	0	0	0	0
1999	39	95.12%	0	0	0	0	0	0
1720	40	97.56%	0	0	0	0	0	0

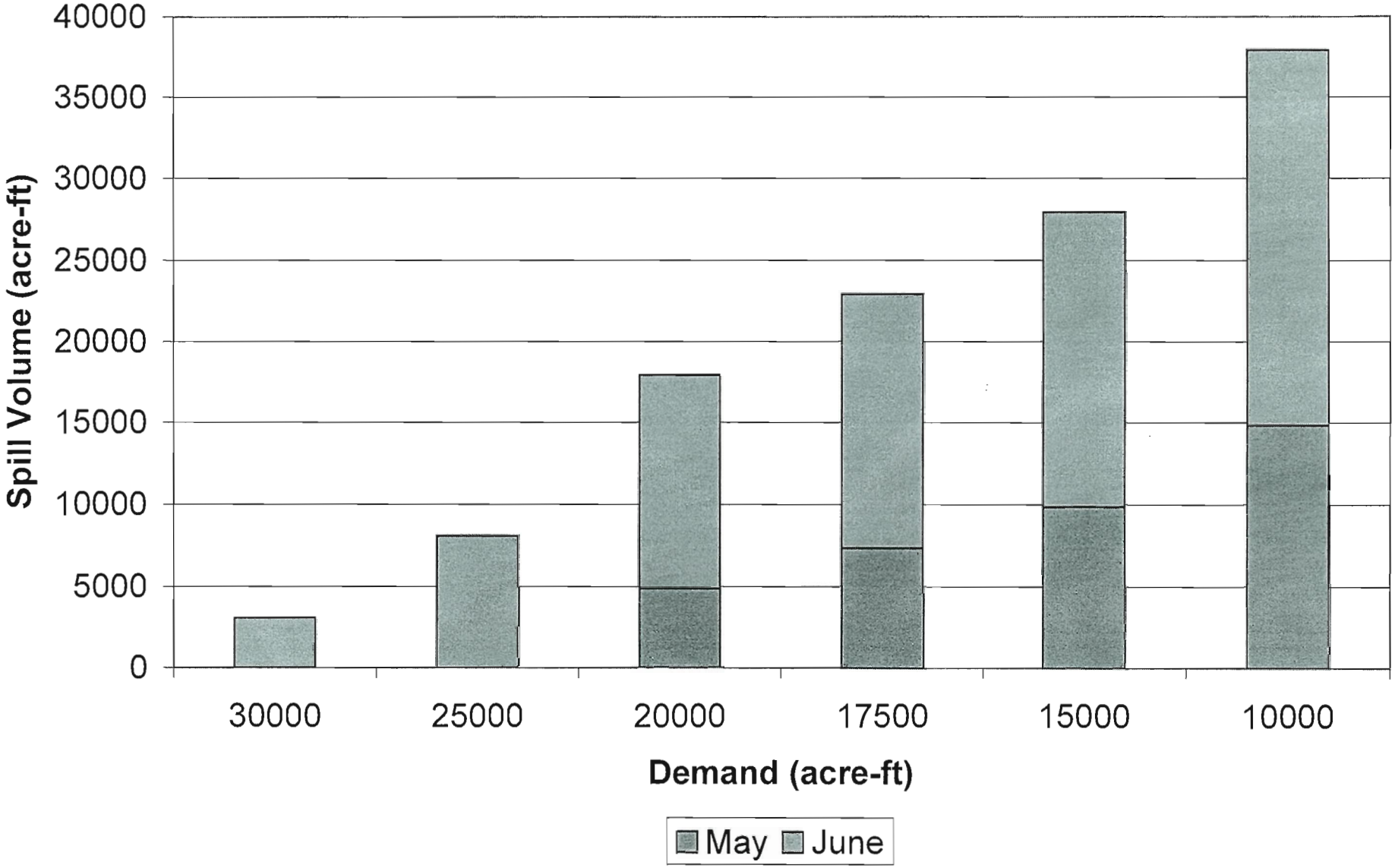

Reservoir Outflow in November
Outflow (acre-ft)
80000
70000
60000
50000
40000
30000
20000
10000
0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Time (years)

December

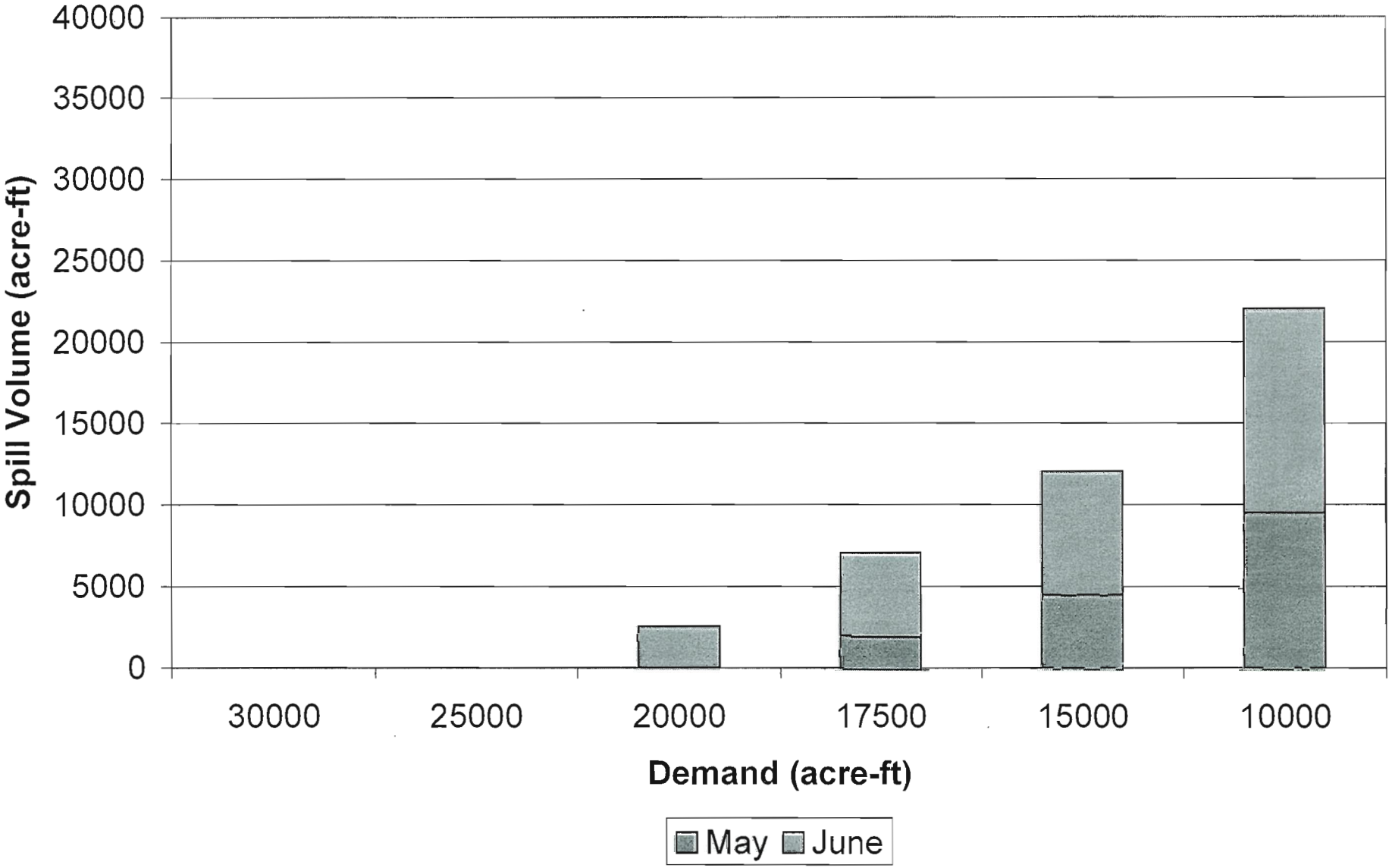
		Demand	30000	25000	20000	17500	15000	10000
Outflow - Descending Order (acre-ft)	Rank	Percentile	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)	Outflow minus Demand (acre-ft)
8731	1	2.44%	0	0	0	0	0	0
8547	2	4.88%	0	0	0	0	0	0
7686	3	7.32%	0	0	0	0	0	0
6333	4	9.76%	0	0	0	0	0	0
5356	5	12.20%	0	0	0	0	0	0
5239	6	14.63%	0	0	0	0	0	0
5220	6	14.63%	0	0	0	0	0	0
4944	8	19.51%	0	0	0	0	0	0
4692	9	21.95%	0	0	0	0	0	0
4175	10	24.39%	0	0	0	0	0	0
3960	11	26.83%	0	0	0	0	0	0
3775	12	29.27%	0	0	0	0	0	0
3277	13	31.71%	0	0	0	0	0	0
3210	14	34.15%	0	0	0	0	0	0
3191	15	36.59%	0	0	0	0	0	0
3087	16	39.02%	0	0	0	0	0	0
3074	17	41.46%	0	0	0	0	0	0
3050	18	43.90%	0	0	0	0	0	0
2970	19	46.34%	0	0	0	0	0	0
2939	20	48.78%	0	0	0	0	0	0
2878	21	51.22%	0	0	0	0	0	0
2810	22	53.66%	0	0	0	0	0	0
2693	23	56.10%	0	0	0	0	0	0
2644	24	58.54%	0	0	0	0	0	0
2601	25	60.98%	0	0	0	0	0	0
2582	26	63.41%	0	0	0	0	0	0
2312	27	65.85%	0	0	0	0	0	0
2275	28	68.29%	0	0	0	0	0	0
2115	29	70.73%	0	0	0	0	0	0
1912	30	73.17%	0	0	0	0	0	0
1900	31	75.61%	0	0	0	0	0	0
1894	32	78.05%	0	0	0	0	0	0
1875	33	80.49%	0	0	0	0	0	0
1832	34	82.93%	0	0	0	0	0	0
1802	35	85.37%	0	0	0	0	0	0
1795	36	87.80%	0	0	0	0	0	0
1734	37	90.24%	0	0	0	0	0	0
1482	38	92.68%	0	0	0	0	0	0
1457	39	95.12%	0	0	0	0	0	0
1451	40	97.56%	0	0	0	0	0	0


Reservoir Outflow in December
Outflow (acre-ft)
80000
70000
60000
50000
40000
30000
20000
10000
0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Time (years)

50% Exceedance Spills Volumes (May and June)



80% Exceedance Spills Volumes (May and June)



RUBY DAM REHABILITATION FEASIBILITY STUDY

ECONOMIC EVALUATION

Prepared for:

Montana Department of Natural Resources and Conservation
State Water Projects Bureau
Helena, MT

Prepared by:

HKM Engineering Inc.
P.O. Box 31318
Billings, MT 59107

January 2008

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ECONOMIC BENEFITS **3**
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Ruby Dam Feasibility Study
Economic Evaluation

This section of the Ruby Dam Rehabilitation Feasibility Study Report presents an evaluation of the financial and economic aspects of the rehabilitation. Ruby Dam provides an important base for the viability of the local irrigation enterprises as well as providing important benefits to the state and region.

PROJECT COSTS

The preferred rehabilitation alternative estimated total project cost is $11,930,000. This alternative includes raising the normal storage pool to Elevation 5400 which will increase total storage to 45,115 acre-feet. Dividing the project cost by the total storage results in a capital cost of $264 per acre-foot.

In selecting the preferred alternative, costs of various storage levels were evaluated to determine the incremental cost associated with enlarging the storage. Table 1 presents the comparison of incremental costs for the labyrinth spillway options with storage level as the primary variable. As such, matching storage to the existing crest elevation of 5393 is considered the baseline for comparison of incremental cost (Alternative L2-100-93). The second storage level (5396.7 feet) in the comparison is to replenish the original storage lost to sedimentation and increase the pool by 2600 acre-feet which corresponds to the desired conservation pool (Alternative L2-100-96.7). The third storage level is to the practical maximum storage elevation of 5400 (Alternative L2-100-00), which provides 3665 acre-feet of additional storage beyond the second alternative. The incremental costs for the "L2-100-96.7" option reflects the additional cost for the increase from the "L2-100-93" options. The incremental cost for the "L2-100-00" option is the increment from the "L2-100-96.7" option. Annualized incremental costs are based on a 75-year project life and a discount rate of 4.5%.

RUBY DAM REHABILITATION
Table 1 – ALTERNATIVE COST ESTIMATES
(2007 dollars)

PARAMETER	ALTERNATIVE		
	L2-100-93 (Existing Crest)	**L2-100-96.7** (Original Storage plus 2600 AF)	**L2-100-00** (Maximum Storage)
Spillway Crest Elev.	5,393	5,396.7	5,400
Dam Crest Elev.	5,410	5,410	5,413
Total Storage (AF)	37,642	41,450	45,115
Total Marketable Storage (AF)	35,042	38,850	42,515
Estimated Project Cost	$9,020,000	$9,820,000	$11,930,000
Cost per AF	$240	$237	$264
Annual Cost per AF**	**$11.20**	**$11.07**	**$12.35**
Incremental Storage (AF)		3,808	3,665
Incremental Cost		$800,000	$2,110,000
Incremental Cost per AF		$210	$576
Annual Incremental Cost per AF*		**$9.82**	**$26.90**

* Based on 75 yr project life, 4.5% discount rate,

ENTERPRISE REPAYMENT CAPACITY

A farm enterprise budget model and economic analysis was prepared for this study by Wicks & Associates, LLC. This study is presented in Appendix A. The farm enterprise budget presents an estimate of the "ability to pay" value of water for a "typical" enterprise in the project area. For purposes of this study, the enterprise budget was based on the value of utilizing the water for irrigation to grow hay. The impacts of utilizing that hay in a beef cattle operation were not included.

The "ability to pay" reflects the cash available to pay for water after all other enterprise costs are covered. Return on equity, return on labor and return on management are all accounted for in the "ability to pay." Enterprises within irrigation projects in Montana often pay a higher rate for water than the estimated "ability to pay". This higher rate may reflect a reduction in returns to management, labor and equity or it may reflect innovative management that reduces operating costs or increases operating revenue. The term "willingness to pay" is utilized to define the higher rate that includes a reduction in returns to the enterprise.

The farm enterprise budget model determined the "ability to pay" is $4.33 per acre-foot. This would indicate that a total annual assessment of $4.33 per share would be the ability to pay for water contract holders. If all return on equity and management (non-cash ownership costs in the model) were foregone, an additional $16.82 per share could be assessed. It is unrealistic to expect that all returns to equity and management for a "typical" operation can be foregone. Typical assessments for similar projects in Montana have resulted in water assessments of $10 to $15 per share reflecting a typical "willingness to pay."

ECONOMIC BENEFITS

The project provides numerous economic benefits beyond the agricultural enterprise willingness to pay. The direct economic benefits of the irrigation from this project vs. eliminating the project are presented in the enterprise analysis in Appendix A. The direct economic benefit reflected in the existing irrigation vs. dryland operations is $15.20 per acre-foot or $590,000 per year. Indirect economic benefits associated with the irrigation (such as increased economic activity within the region, increased taxes, etc.) often are considered to be 2-3 times the direct economic benefit.

The project also provides non-irrigation economic benefits. The Ruby River downstream from the dam is a very popular trout fishery. The Montana Department of Fish Wildlife and Parks estimates use at 10,009 fishing days per year on the reservoir and 11,458 fishing days per year on the Ruby River below Ruby Reservoir (http://fwp.mt.gov/fishing/guide/). The study in Appendix A presents an average economic benefit of $114 per fisherman day in Montana. The reservoir provides a stable water supply for this fishery. Assuming that 20% of the fishery value below the reservoir could be attributed to the reservoir, the economic value of the stream fishery would be over $1,400,000 per year.

The benefits to fish and wildlife were not included in this study, but these would contribute additional benefits that have not been quantified. There are also flood benefits associated with the operation of the dam (reduced downstream flooding) that is not quantified.

The total economic benefits provided by the Ruby Dam project are conservatively estimated by combining $590,000 of direct irrigation benefits, $600,000 of indirect agricultural benefits and $1,400,000 of recreation benefits. This results in an annual economic benefit of $2,590,000.

FINANCIAL EVALUATION

The project financing will consist of utilizing various sources of funding. As the water users are the primary direct beneficiaries of the project, it is anticipated that a portion of the funding will consist of a loan and grant utilizing the Montana DNRC Renewable Resources Loan and Grant Program (RRGL). Grants under this program are limited to $100,000 and the loan will be limited to the water users' willingness to pay. The loan program allows a repayment term up to 20 years and a 4.5% interest rate was assumed for the loan. Utilizing the existing 38,845 shares, annual assessment of $1.00 per share will provide repayment of approximately $500,000 of loan. Stated another way, a $5.00 assessment would repay a $2,500,000 loan.

The selected preferred alternative includes increasing the storage 7,473 acre-feet above the existing spillway flashboards. Allocating 1,200 ac-ft to offset sediment accumulation in the reservoir and 2,600 acre-feet for an inactive pool, there would be approximately 3,600 acre-feet of additional storage that could be marketed. At an assumed rate of $10.00 per acre-foot, this would generate $36,000 per year. An annual loan repayment of $36,000 would correspond to an RRGL 20-year loan of $468,000.

The economic benefits of the project extend well beyond the existing water users. The State of Montana has utilized various sources of funds, such as DNRC Broadwater Hydropower Earnings and the Water Storage Account. It is anticipated that the financing plan will be developed by DNRC for presentation to the 2009 Montana legislative session.

ECONOMIC EVALUATION

An annual economic benefit of $2,590,000 is estimated for this project. The preferred alternative includes storage of 45,115 acre-feet. This results in an annual economic benefit of $57.41 per acre-foot.

The economic benefits were compared to the annualized incremental costs of varying the storage level to establish the preferred storage level. Increasing the spillway crest to elevation 5400.0 is considered the maximum viable raise as higher raises will require extensive modifications to the dam and the impacts around the reservoir become much more significant. Water availability will also become a greater concern for larger raises. The annual incremental cost per acre-foot presented in Table 1 above is $26.90. Therefore, economic benefits of $57.41 per acre-foot are well in excess of the incremental cost of $26.90 and the maximum raise was selected as the preferred alternative.

The annualized total project cost is $12.35 per acre-foot for a total cost of $11,930,000 with a 75-yr project life, 4.5% discount rate and 45,115 acre-feet of storage. Dividing the economic benefit of $57.41 by the project cost of $12.35 results in a benefit/cost ratio of 4.65.

APPENDIX A

WICKS & ASSOCIATES ECONOMIC REPORT

Economic Analysis of the Proposed Ruby Dam Project Area

Prepared for

Jay Thom
HKM Engineering, Inc. (HKM)

by

John E. Wicks
and
Brett Crosby
of
Wicks and Associates, LLC

For the

Montana Department of Natural Resources
and Conservation (DNRC)

Ruby Dam Feasibility Study

Report Date
July 19, 2006
(Revised January 30, 2008)

2820 Lyndale Lane, Billings, MT 59102 • Phone: (406) 652-1989 • Fax: (406) 652-6871

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Appendix C – Economic Benefit Yield Sensitivity (continued)
Appendix C – Economic Benefit Yield Sensitivity (continued)

INTRODUCTION

Wicks & Associates, LLC. as authorized by HKM Engineering, Inc. (HKM), has provided professional economic evaluation services related to the Montana Department of Natural Resources and Conservation's (DNRC) Ruby Dam Feasibility Study. Specifically, we have assessed the financial and economic feasibility of the selected rehabilitation plan by developing a farm budget model to,

1. Determine the agricultural ability to pay for the proposed project, and
2. Determine the effect on farm/ranch net income if the dam is removed.

In the following sections, we describe and explain the results of our analyses.

METHODOLOGY

Three farm budget models were developed using cost studies, personal interviews with local ranchers, and other relevant economic data. The farm budget models were then used to calculate 1) the agricultural ability to pay for the project, 2) the economic impact of dam removal, and 3) the economic benefits of the proposed rehabilitation project. In the sections below, we detail our methodology.

Farm Budget Models

We first constructed a farm budget to model a representative irrigated hay enterprise in the Ruby River Valley (the as-is scenario). Next, we developed a model to reflect the same enterprise operated with no irrigation and producing dryland alfalfa hay (the non-augmented scenario). For both models, we gathered yield, price, and cost information from Montana and surrounding western states. Whenever possible, we used data specific to Madison County. We considered both cash and non-cash costs in developing each enterprise budget.

For this analysis, we considered irrigated hay to be the typical commodity produced and flood irrigation to be the typical irrigation practice using reservoir water. This assumption is supported by National Agricultural Statistics Service (NASS) data, personal interviews with local ranchers, and an inspection of the area. We considered the typical hay enterprise to be a 300-acre enterprise planted to alfalfa mixed with grass that is managed according to a typical stand replacement cycle for the area: 7 years for irrigated alfalfa and 10 years for dryland alfalfa. The enterprise was considered to be part

of a full-time farm producing hay and cattle, generally producing hay for consumption by the cattle. Further, we assume that the project provides all irrigation water used by the typical enterprise.

We conducted several personal interviews and inspected the general area to gather information for the budget model. Information was also gathered from county, state, regional, and federal sources that are detailed in Appendix A. Using this information, estimates were made for each item of income and expense in the typical operating budget. Because no recent enterprise cost budgets have been constructed by the Montana State University Extension, recent enterprise cost budgets from Idaho, North Dakota, and Wyoming were considered. Available irrigated and non-irrigated alfalfa hay yield data for Madison County were used for the as-is and non-augmented budgets.

Both cash and non-cash costs were considered in the farm budget. Cash costs included cash variable costs such as fuel and labor as well as fixed cash costs such as property taxes and mortgage interest. Non-cash costs included such costs as returns to management and returns to land investment.

Assumptions and Calculations

Enterprise budgets for the typical enterprise under irrigated and non-irrigated scenarios are included as Appendix B. Key inputs, assumptions, calculations, and outputs for the enterprise budgets are explained below.

Harvested Acres: The number of harvested acres for a typical farm is approximated by dividing total acres in Madison County under irrigation by the total number of irrigated farms in the county as reported by NASS. Based on discussions with local operators, 300 acres harvested would be representative of a full-time operation in this area.

Yield: Yield for the as-is irrigated scenario is the average of irrigated alfalfa hay yields reported by NASS for Madison County, Montana, over the last 15 years. The dryland non-augmented hay yield is the 15-year average of non-irrigated alfalfa yields in Madison County. We also prepared budgets using yields 5% higher and lower than the average to address the possibility that representative yields for a typical farm affected by the project may be different from the rest of the county. These budget calculations are included as Appendix C.

Price: Marketing year prices for alfalfa hay reported by Montana Agricultural Statistics Service (MASS) were inflation adjusted to 2006 dollars (using the All Farm Index published by ERS) and averaged over the last 15 years. Area ranchers indicated that alfalfa/grass hay is sold at alfalfa prices in the area.

Fertilizer: Regional fertilizer and fertilizer application costs are based on Patterson and Smathers (University of Idaho, 2005). The amount of nitrogen applied per acre is based on Bauder (Montana State University Extension, 1998), and the amount of phosphate applied per ton of expected yield is based on McKenzie and McKenzie (Alberta, 2001).

Irrigation Labor: Estimated at 1.3 hours per acre at a wage rate of $9.63 per hour as reported by the Bureau of Labor Statistics for Montana farm labor.

Corrugate: Equipment and labor required to harrow/corrugate once annually is estimated to be $3.00 per acre.

Swath/Bale/Stack: Harvesting costs of $35 per ton are based on custom labor rates as reported by Hewlitt (University of Wyoming Cooperative Extension, 2004). Costs considered here include harvest labor and repair and replacement costs of harvesting machinery.

Repairs: Estimated cost of repairs and replacement for a typical complement of vehicles, buildings, and irrigation equipment were developed using values adapted from several regional enterprise budgets and based on the authors' extensive farm budgeting experience. Repair and replacement allocations for harvest machinery are included in charges for custom harvesting. Estimated costs for the dryland enterprise do not include repairs for irrigation equipment.

Fuel & Lubrication: Fuel costs for management and irrigation purposes are estimated at $4.70 per acre based on Patterson and Smathers (University of Idaho, 2005). Harvest fuel charges are included in charges for swath/bale/stack.

Miscellaneous: The cost of miscellaneous irrigation supplies (including boots, dams, etc.) is estimated to be $7.00 per acre.

Interest on Operating Capital: Interest is estimated at 9% on a typical revolving line of operating credit.

General Overhead: General overhead costs include phone bills, utilities, postage, dues and subscriptions, etc. This cost category is estimated at $5 per acre based on the authors' experience with farm economics and management. This is also consistent with enterprise budgets from other states in the region.

Stand Depletion: The amortized cost of alfalfa seed for stand replacement is $2.40/lb of seed x 13 lbs of seed per acre. Stand replacement cycles are assumed to be 7 years for irrigated alfalfa and 10 years for dryland alfalfa.

Capital Replacement: Depreciation for a typical complement of vehicles, buildings, and irrigation equipment (for irrigated operations) was developed using purchase costs and salvage values adapted from several regional enterprise budgets and based on the authors' farm budgeting experience. Capital replacement for harvest equipment is included in custom rates.

Land Interest: Land interest is estimated to be 6.5%, based on a 9% debt-to-asset ratio and financial indicators that are derived from information published by USDA-ERS for Montana operations, and a cropland value of $1,800 per acre as published by MASS. Because the land was assumed to have been purchased as irrigated cropland, land interest is not reduced for the dryland non-augmented farm.

Property Taxes: Estimates were developed using taxable values of sample properties in the valley.

Equipment Interest: Interest on irrigation equipment is estimated using financial indicators (rate of interest and debt to asset ratio) that are derived from information published by USDA-ERS for Montana operations and typical equipment values.

Property Insurance: Property insurance is estimated to be $2.00 per acre.

Net Cash Return: This is the difference between market income and cash costs. It represents cash returns prior to accounting for indirect expenses, such as returns to management, labor, and capital.

Management Fee: This non-cash cost represents the return to farm management. It is estimated as 8% of the expected gross land rent. The gross land rent is approximated using the cash rental rate published by MASS, which is $53 per acre for irrigated cropland and $19.50 per acre for non-irrigated cropland.

Net Land Return: This is a non-cash cost that represents the opportunity cost of using the land rather than leasing it at market rates. It is estimated as the cash rental rate for irrigated cropland (from MASS) minus interest, taxes, and management fees. Because the land was assumed to have been purchased as irrigated cropland, net land returns were not reduced for the dryland non-augmented farm.

Equipment Return: This is a non-cash cost that represents the return to irrigation equipment assets. It is estimated to be $1.00 per acre for irrigated operations based on equity and returns information for Montana farms from USDA-ERS.

Net Income: This is the expected return to the owner after all costs are met.

Agricultural Repayment Capacity

Agricultural repayment capacity is considered to be the net income of the typical as-is irrigated hay enterprise as defined and explained above. This represents the long-term repayment capacity, accounting for appropriate returns to management, land, and capital.

Economic Benefits

The economic benefit of irrigation was estimated to be the total marginal value of hay production resulting from reservoir water. This value was calculated for the typical hay enterprise by subtracting the net income of the non-augmented dryland alfalfa model from the net income of the irrigated as-is model.

Calculations of Repayment Capacity and Economic Benefits

Repayment capacity and economic benefits of the project were calculated for the total project, per acre, and per acre-foot using irrigation water requirement information for the typical enterprise. Data for these calculations, including reservoir data, were provided by HKM.

According to the NRCS Montana Irrigation Guide, the net irrigation requirement for the typical irrigated alfalfa operation in Madison County is 11.1 inches. Assuming 40% project efficiency, the typical operation will use 27.75 inches (2.3125 acre feet) of irrigation water per acre. Repayment capacity and economic benefits per acre foot of project water is calculated by dividing per acre net income for the typical operation by the 2.3125 acre feet of water required.

Results

The typical irrigated enterprise in the area shows net income, or repayment capacity, of value of $10.01 per acre (see Appendix B). Calculations of annual repayment capacity per acre foot are displayed in Table 1.

Table 1. Calculation of Annual Repayment Capacity

Repayment Capacity (Net Income) Per Acre	$10.01	
Irrigation Water Use Per Acre	2.3125	acre feet
Repayment Capacity Per Acre Foot	**$4.33**	

Table 1 shows that the repayment capacity of the project is $4.33 per acre-foot.

Annual economic benefits of the reservoir to agriculture are calculated as the difference between the as-is irrigated and non-augmented dryland enterprise scenarios. The budgets in Appendix B show net income for the as-is irrigated and dryland scenarios of $10.01 and -$25.15 per acre, respectively. Annual direct economic benefits calculations are shown in the following Table 2.

Table 2. Calculation of Annual Direct Economic Benefits to Agriculture

Net Income – Irrigated	$10.01	
Net Income – Non-irrigated	-$25.15	
Average Annual Benefit Per Acre	**$35.16**	
Irrigation Water Use Per Acre	2.3125	acre feet
Average Annual Benefit Per Acre Foot	**$15.20**	

Table 2 shows that the average direct economic benefits of the reservoir from irrigation are $35.16 per acre. The average annual benefit per acre-foot is $15.20.

Ranges for the above estimates based on yield variation of plus or minus 5% from the county average are presented in Appendix C.

CONCLUSIONS

The irrigated enterprises using irrigation water appear to have some repayment capacity for the proposed project. Total annual direct economic benefit to agriculture for this project is estimated to be $590,000 (equal to $15.20 average annual benefit per acre foot x 38,845 acre feet project size, and rounded to the nearest $1,000). While this reflects a long-term profitability expectation for a typical enterprise, actual operations under irrigation with reservoir water may be more or less profitable than the model suggests. Profitability is dependant on myriad factors and conditions and can vary dramatically between operations in any given year. Further, with any given operation, profitability can also vary substantially between years due to variations in prices and growing conditions.

Irrigation adds substantially more value to the area and its economy than the total repayment capacity. Without the project, net income potential for land that had been capitalized as irrigated cropland would be substantially diminished. The difference in net income per acre with and without irrigation is more than $35. This will be reflected in the local economy in a number of ways as follows.

Increased Cash

Without irrigation, the amount of cash in the local economy would be reduced in one of two ways. First, producers will purchase hay elsewhere, sending cash outside of the local area. This will have a lesser impact on the state economy, because much of the hay will be purchased from other parts of Montana.

Higher Land Values

As profitability of these operations decreases, the attractiveness of these properties to buyers also decreases. Therefore, the value of these lands will decrease without irrigation potential. Statewide, differences between irrigated and dry crop land range from $400 to $3,000 per acre. Aside from the obvious decrease in the net worth of the agricultural owner, decreased land values can have the adverse financial consequences of decreasing the borrowing power of an operation.

Non-Agricultural Benefits

The reservoir may also offer substantial recreational and aesthetic benefits, including fishing, floating, and wildlife. For example, for the four years in which it measured fishing pressure between 1999 and 2005, the Montana Department of Fish Wildlife and Parks (MTFWP) estimated an average of 10,009 fishing days on the reservoir,[1] 11,458 fishing days per year below the Ruby River Reservoir and 1,430 fishing days per year above the reservoir.[2] The MTFWP also estimates that fishing generates $343 million in economic impact in the state, and that anglers spend nearly 3 million days fishing per year[3], which equates to over $100 of economic impact per fishing day ($343M/3M=$114). These figures suggest that the economic impact from fishing on Ruby River and Ruby Reservoir is over $2.6 million per year ((10,009 days on reservoir + 11,458 days below + 1,430 days above) x $114 per day = $2,610,258). While some of this recreation would occur if the project were not there, the reservoir enhances the fishery and significantly contributes to the recreation use below the reservoir. Assuming that the reservoir only enhances the downstream fishery by 20% of the recreational use (20% of 11,458 = 2,292 days) plus the reservoir use (10,009 days), the economic benefit from fishing attributed to the reservoir is over $1.4 million per year.

---

[1] http://fwp.mt.gov/fishing/guide/q_Ruby_River__Reservoir_1121257452190.aspx
[2] http://fwp.mt.gov/fishing/guide/q_Ruby_River__1123453455129_0_97.1849975585938.aspx
[3] http://fwp.mt.gov/budget/general.html

The total marginal economic value of these and other non-agricultural benefits is nearly impossible to quantify using the limited data available. Therefore, this analysis does not estimate the reservoir's entire non-agricultural benefits. Nonetheless, the total non-agricultural benefits are substantial.

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APPENDIX B –ENTERPRISE BUDGET TABLE

Typical Agricultural Enterprise Budget – County Average Yields

	Irrigated – As-Is		Non-Augmented - Dryland	
	Per Acre	**Total**	**Per Acre**	**Total**
INCOME				
Harvested Acres	1	300	1	300
Yield (County Average)	3.18	954.00	1.66	497.14
Price	$82.00	$82.00	$82.00	$82.00
Market Income	$260.76	$78,228.00	$135.89	$40,765.71
OPERATING COSTS				
Fertilizer	$28.78	$8,634.60	$25.13	$7,538.14
Corrugate	$3.00	$900.00	$0.00	$0.00
Labor (Irrigation)	$12.52	$3,755.70	$0.00	$0.00
Swath/Bale/Stack	$111.30	$33,390.00	$58.00	$17,400.00
Repairs/Replacement	$5.85	$1,754.05	$4.09	$1,228.33
Fuel & Lubrication	$4.70	$1,410.99	$3.75	$1,123.95
Miscellaneous	$6.00	$1,800.00	$6.00	$1,800.00
Interest on operating capital @ 9%	$7.75	$2,324.04	$4.36	$1,309.07
Sum of Operating Costs	$179.90	$53,969.38	$101.33	$30,399.50
FIXED COSTS				
General Overhead	$5.00	$1,500.00	$5.00	$1,500.00
Stand Depletion	$4.46	$1,337.14	$3.12	$936.00
Capital Replacement	$4.53	$1,359.29	$3.02	$905.00
Land Interest	$10.53	$3,159.00	$10.53	$3,159.00
Property Taxes (Land)	$4.50	$1,350.00	$0.75	$225.00
Equipment Interest	$0.86	$259.35	$0.00	$0.00
Property Insurance	$2.00	$600.00	$2.00	$600.00
Sum of Cash Ownership Costs	$31.88	$9,564.78	$24.42	$7,325.00
Net Cash Returns	**$48.98**	**$14,693.84**	**$10.14**	**$3,041.22**
NON-CASH RETURNS				
Management	$4.24	$1,272.00	$1.56	$468.00
Net Land Return	$33.73	$10,119.00	$33.73	$10,119.00
Equipment/ Return	$1.00	$300.20	$0.00	$0.00
Total Non-Cash Ownership Costs	$38.97	$11,691.20	$35.29	$10,587.00
Total Expense	**$250.75**	**$75,225.36**	**$161.04**	**$48,311.50**
Net Income	**$10.01**	**$3,002.64**	**-$25.15**	**-$7,545.78**

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APPENDIX C – ECONOMIC BENEFIT YIELD SENSITIVITY

***Typical Agricultural Enterprise Budget – County Average Yields* Plus 5%**

	Irrigated – As-Is		Non-Augmented - Dryland	
	Per Acre	**Total**	**Per Acre**	**Total**
INCOME				
Harvested Acres	1	300	1	300
Yield (County Average)	3.34	1,002.00	1.74	522.00
Price	$82.00	$82.00	$81.00	$81.00
Market Income	$273.88	$82,164.00	$142.68	$42,804.00
OPERATING COSTS				
Fertilizer	$29.17	$8,749.80	$25.33	$7,597.80
Corrugate	$3.00	$900.00	$0.00	$0.00
Labor (Irrigation)	$12.52	$3,755.70	$0.00	$0.00
Swath/Bale/Stack	$116.90	$35,070.00	$60.90	$18,270.00
Repairs/Replacement	$5.85	$1,754.05	$4.09	$1,228.33
Fuel & Lubrication	$4.70	$1,410.99	$3.75	$1,123.95
Miscellaneous	$6.00	$1,800.00	$6.00	$1,800.00
Interest on operating capital @ 9%	$8.02	$2,404.82	$4.50	$1,350.90
Sum of Operating Costs	$186.15	$55,845.36	$104.57	$31,370.99
FIXED COSTS				
General Overhead	$5.00	$1,500.00	$5.00	$1,500.00
Stand Depletion	$4.46	$1,337.14	$3.12	$936.00
Capital Replacement	$4.53	$1,359.29	$3.02	$905.00
Land Interest	$10.53	$3,159.00	$10.53	$3,159.00
Property Taxes (Land)	$4.50	$1,350.00	$0.75	$225.00
Equipment Interest	$0.86	$259.35	$0.00	$0.00
Property Insurance	$2.00	$600.00	$2.00	$600.00
Sum of Cash Ownership Costs	$31.88	$9,564.78	$5.00	$7,325.00
		$19,129.56		
Net Cash Returns	**$55.85**	**$1,500.00**	**$13.69**	**$4,108.01**
NON-CASH RETURNS				
Management	$4.24	$1,272.00	$1.56	$468.00
Net Land Return	$33.73	$10,119.00	$33.73	$10,119.00
Equipment/ Return	$1.00	$300.20	$0.00	$0.00
Total Non-Cash Ownership Costs	$38.97	$11,691.20	$35.29	$10,587.00
Total Expense	**$257.00**	**$77,101.34**	**$164.28**	**$49,282.99**
Net Income	**$16.88**	**$5,062.66**	**-$21.60**	**-$6,478.99**

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APPENDIX C – ECONOMIC BENEFIT YIELD SENSITIVITY (CONTINUED)

***Typical Agricultural Enterprise Budget – County Average Yields* Minus 5%**

	Irrigated – As-Is		Non-Augmented - Dryland	
	Per Acre	**Total**	**Per Acre**	**Total**
INCOME				
Harvested Acres	1	300	1	300
Yield (County Average)	3.02	906.00	1.57	471.00
Price	$82.00	$82.00	$82.00	$82.00
Market Income	$247.64	$74,292.00	$128.74	$38,622.00
OPERATING COSTS				
Fertilizer	$28.40	$8,519.40	$24.92	$7,475.40
Corrugate	$3.00	$900.00	$0.00	$0.00
Labor (Irrigation)	$12.52	$3,755.70	$0.00	$0.00
Swath/Bale/Stack	$105.70	$31,710.00	$54.95	$16,485.00
Repairs/Replacement	$5.85	$1,754.05	$4.09	$1,228.33
Fuel & Lubrication	$4.70	$1,410.99	$3.75	$1,123.95
Miscellaneous	$6.00	$1,800.00	$6.00	$1,800.00
Interest on operating capital @ 9%	$7.48	$2,243.26	$4.22	$1,265.07
Sum of Operating Costs	$173.64	$52,093.39	$97.93	$29,377.75
FIXED COSTS				
General Overhead	$5.00	$1,500.00	$5.00	$1,500.00
Stand Depletion	$4.46	$1,337.14	$3.12	$936.00
Capital Replacement	$4.53	$1,359.29	$3.02	$905.00
Land Interest	$10.53	$3,159.00	$10.53	$3,159.00
Property Taxes (Land)	$4.50	$1,350.00	$0.75	$225.00
Equipment Interest	$0.86	$259.35	$0.00	$0.00
Property Insurance	$2.00	$600.00	$2.00	$600.00
Sum of Cash Ownership Costs	$31.88	$9,564.78	$24.42	$7,325.00
Net Cash Returns	**$42.11**	**$12,633.83**	**$6.40**	**$1,919.25**
NON-CASH RETURNS				
Management	$4.24	$1,272.00	$1.56	$468.00
Net Land Return	$33.73	$10,119.00	$33.73	$10,119.00
Equipment/ Return	$1.00	$300.20	$0.00	$0.00
Total Non-Cash Ownership Costs	$38.97	$11,691.20	$35.29	$10,587.00
Total Expense	**$244.50**	**$73,349.37**	**$157.63**	**$47,289.75**
Net Income	**$3.14**	**$942.63**	**-$28.89**	**-$8,667.75**

APPENDIX C – ECONOMIC BENEFIT YIELD SENSITIVITY (CONTINUED)

Comparison of Annual Repayment Capacity

	Yield Minus 5%	County Average Yield	Yield Plus 5%	
Repayment Capacity (Net Income) Per Acre	$3.14	$10.01	$16.88	
Irrigation Water Use Per Acre	2.3125	2.3125	2.3125	acre feet
Repayment Capacity Per Acre-Foot	**$1.36**	**$4.33**	**$7.30**	

Comparison of Annual Direct Economic Benefits to Agriculture

	Yield Minus 5%	County Average	Yield Plus 5%	
Net Income – Irrigated	$3.14	$10.01	$16.88	
Net Income – Non-irrigated	-$28.89	-$25.15	-$21.60	
Average Annual Benefit Per Acre	**$32.03**	**$35.16**	**$38.47**	
Irrigation Water Use Per Acre	2.3125	2.3125	2.3125	acre feet
Average Annual Benefit Per Acre-Foot	**$13.85**	**$15.20**	**$16.64**	

The budgets and calculations shown here in Appendix C demonstrate sensitivity to yield variations of plus or minus 5% around the county average yield. The budgets show that net income per acre ranges from $3.14 to $16.88 for the as-is irrigated scenario and from -$28.89 to -$21.60 for the dryland scenario under these assumptions. Repayment capacity of the project ranges from $1.36 to $7.30 per acre-foot. Average direct economic benefits of the reservoir from irrigation range from $32.03 to $38.47 per acre. And average annual benefit per acre-foot ranges from $13.85 to $16.64.

RUBY DAM REHABILITATION FEASIBILITY STUDY

Seepage and Slope Stability Analyses

Prepared for:

Montana Department of Natural Resources and Conservation
State Water Projects Bureau
Helena, MT

Prepared by:

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January 2008

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1.0 EMBANKMENT EVALUATION SEEPAGE AND SLOPE STABILITY ANALYSES

1.1 INTRODUCTION

This seepage and slope stability analysis has been completed in accordance to the scope of work outlined in the Ruby Dam Feasibility Study Proposal submitted to DNRC by HKM on July 28, 2005. Figure 1-Appendix A presents a site location map for the dam site. The purpose of this study is to review and evaluate the existing geologic and geotechnical information about the dam and utilize this information to assess the stability of the existing embankment and proposed alternative designs. In the course of the study HKM conducted a field investigation to obtain additional information regarding the embankment conditions. The investigation consisted of excavating nine (9) test pits located within the dam crest, toe area, and downstream fill zone. The results of this investigation are detailed in a separate report entitled "Ruby Dam Feasibility Study Geotechnical Data Report-Test Pit Investigation" (HKM 2005) which is included in Appendix G. This report presents the results of the Seepage and Stability Analysis of the existing embankment and includes stability evaluation of proposed dam raise options.

1.2 BACKGROUND INFORMATION

During this study in conjunction with the additional test pit investigation and numerous visits to the dam site HKM reviewed the following reports and information:

Summary Report on the Geology of Ruby Dam Site (Stiles 2005)
Construction as-built plan drawings
Phase 1 Inspection Report Ruby Dam (CH2M HILL 1980)
Ruby Dam Periodic Engineer's Inspection Report (DNRC 2000)
1999 drill logs and test data (Stiles 2005)
"A Seismic Stability Analysis of Ruby Dam near Alder, Montana" (Flack 2000)
"Geologic Mapping in the Ruby Dam Area, Southwest Montana" (St. Jean 2002)
Monitoring well records (DNRC)
Ruby Dam Abbreviated Chronology and Construction Information (DNRC 2005a)
Ruby Dam Abbreviated Chronology and Construction Information Addendum No.1 (DNRC 2005b)

1.3 EXISTING EMBANKMENT AND FOUNDATION CONDITIONS

1.3.1 Existing Embankment and Typical Maximum Section

The existing embankment zoning and foundation characteristics have been described in several reports. HKM has reviewed these reports and utilized the information along with the most recent site survey, 1999 DNRC drilling data, historical monitoring well information, HKM test pit investigation, as-built drawing No.1-A 1938 (Figure 2-Appendix A), as built cross section data information and construction history information provided by DNRC to establish the typical maximum section used for this evaluation. Figure 3-Appendix A, presents a plan view of the embankment and the location of the maximum section. Figure 4-Appendix A, presents the maximum section determined for the analysis.

The dam has a crest elevation of 5410 and operates at an approximate normal pool elevation of 5392 although review of the monitoring records from 1999 to 2005 indicate the reservoir elevation at times was as high as 5395. In summary, the embankment is described as a 111-foot-high zoned earth, gravel and rockfill embankment that is 826 feet long with a crest width (excluding the riprap section) of 25 feet. (Recent survey indicates the crest width to be 35 feet including the riprap section which daylights at the crest.) The embankment downstream shell has a 2:1 (H:V) slope and the upstream shell has a 3:1 (H:V) slope the upper 10 feet of which consists of a 2:1 (H:V) slope. Extensive fill has been placed at the toe of the downstream slope. This fill thickness according to as-built record drawing geometry and current site topography extends to a thickness of approximately 20 feet at the immediate toe area. Based on construction records this fill was placed after the downstream rockfill shell was essentially completed and consisted of overburden from the spillway excavation. This fill acts as a significant buttress (toe berm) to the downstream toe of the embankment.

According to the as-built record drawing DWG. NO.-1A 1938, the embankment consists of four zones. Each zone is described following:

"Selected Clay & Loam" Zone A (upstream core)

"Shovel mix clay & loam, sand & gravel pit run" Zone B (middle transition).

"Sand and Gravel zone" Zone C (downstream transition)

"Rock Fill voids filled with small rock and sluiced sand & gravel" Zone D (Downstream rockfill shell)

The results of HKM Test pit investigation indicates good correlation with three of the zones (Zones A, B and D) shown on the as-built drawing. While the HKM test pit investigation identified three distinct zones it was not logistically possible to locate a test pit that would allow excavation to confirm the sand and gravel zone. It is also not possible to confirm the actual slopes of the interfaces between the zones however it is assumed the slopes shown on the as-built drawings are accurate.

1.3.2 Existing Embankment Performance

Historical inspection reports indicate the existing embankment has performed well over the last 67 years. No slump areas or instability has been noted within the downstream face or abutment areas. An upstream slope failure did occur during the fall of 1957. This failure was not catastrophic and was located in the lower portion of the upstream slope. Based on review of photographs the slump scarp appeared to extend for several hundred feet longitudinally along the dam face. Survey data which would help in defining the limits of the slope failure could not be located in the DNRC records. Photographs taken indicate this slump was repaired during December of 1957 by constructing a berm of compacted fill along the toe of the upstream slope. The upstream slope has performed satisfactorily since the repair. The cause of this slump has not been determined but may have been related to drawdown of the reservoir. Around 1957 the reservoir was drawn down to replace the guard gate in the outlet works. Assessment of the cause of this failure is difficult due to the lack of survey information which could define the failure plane and availability of in-place soil strength information for the upstream core zone.

1.3.3 Existing Embankment Compaction

Standard penetration tests results from the 1999 DNRC drilling program where reviewed to assess in place compaction. DNRC Borings DH-1, DH-2 and DH-3 were advanced through the crest within the middle transition "Zone B". The standard penetration test results "N" values recorded within the embankment ranged from 8 to 55 blows per foot and averaged 18 which indicates the average embankment consistency to be medium dense. A Shelby tube was also taken from DH-2 within the zone B material at a depth between 51.0 to 53.5 feet on which a triaxial test was performed. Results from the triaxial test are as follows: dry unit weight = 107 pcf; natural moisture content = 18.1%; effective stress parameters C'=219 psf, ϕ'= 32.6 degrees. The material from this Shelby tube classifies as sandy lean clay. The dry unit weight and effective stress parameters of this sample are within the typical average range for well compacted

saturated clay embankment soil (USBR 1987a). Based on the boring logs the middle transition zone consists of silty and clayey sand with scattered gravels and rock fragments in the upper 50 feet and lean clay with gravel from 55 feet to 120 feet. A gravel layer was encountered in DH-2 between the depths 120 to 132 feet at which point bedrock is encountered. This gravel layer is most likely native alluvium.

Discussion of embankment placement and zoning is presented in the HKM's Test pit Investigation Data Report (Appendix G). In-place density tests using a nuclear densometer were conducted in test pits excavated within the upper 7 feet of the dam crest during HKM's test pit investigation. The results of HKM's in-place density tests are summarized in Table 2 of the corresponding report. The dry densities of the clayey sand and sandy clay materials ranged from 116 pounds per cubic foot (pcf) to 100 pcf. These values are considered slightly low when compared to maximum dry densities that could be achieved according to ASTM D 698. However these readings were taken in the upper eight to nine feet of the embankment which according to construction records "Earth embankment will not require watering above elevation 5402". This would indicate that the upper 10 foot portion of the embankment most likely has not been compacted as well as possible.

Available construction records indicate that particle size gradations and proctor (moisture density) testing was conducted on the embankment fill material. In-place compaction testing was also conducted during embankment placement although the records were not complete and the available records did not cover the full height of the embankment.

Overall, the best indication of compaction of the existing embankment is the long term performance which, other than the upstream slope failure, has not shown any signs of instability over the last 67 years.

1.3.4 Foundation Conditions

The as-built embankment section foundation elevations correlated very well with the bedrock elevations determined in DNRC Drill Holes DH-2, DH-4 and DH-6 (DNRC1999). Based on this information it appears that the approximate upstream 1/3 of the embankment is founded on bedrock and the downstream rockfill zone (zone D) is keyed into bedrock. Bedrock at the site is a complex assemblage of fractured metamorphic rocks (Stiles, 2005). There appears to be a layer of alluvium between the centerline of embankment and downstream rock fill (zone D) keyway; the alluvium layer was intercepted by drill hole DH-2. Blow count (N-values) data for

the alluvial zone was obtained from borings DH-4 and DH-6, located at the toe of the dam. Standard penetration test N-values recorded for boring DH-4 ranged from 39 to 76 blows per foot which indicated gravels ranging from dense to very dense in consistency. Construction records indicated that if bedrock was not encountered at depth then the excavation was to continue to competent foundation material. The foundation gravel was described in numerous ways: "material [alluvium] good sand and gravel with occasional medium size rocks"; "progress [excavation] slow due to boulders laying in compacted sand and gravel". Based on construction information the abutments are founded on bedrock and a core cutoff was excavated 5 to 6 feet into bedrock. In summary, based on available records, it appears that the dam is founded in part on bedrock and in-part on dense alluvium.

1.3.5 Seepage Conditions / Embankment Phreatic Surface

Based on historical inspections there are no emergent seepage areas within the toe, abutments or downstream of the embankment other than in the spillway area and overall there are no observed seepage problems with the dam. Construction records indicate that during preparation of the dam's foundation drain tile was installed in order to pickup seepage which was emerging from a "spring" area just southeast of the inlet conduit alignment. This drain tile was apparently routed under the dam and "daylighted" within the spillway just downstream of the stilling basin. Citation records also indicate that 8-inch and 10-inch drain tile was installed under the rock fill zone at the embankment toe. Both drains were joined together and discharged via a CMP pipe into the river below the stilling basin. There is no visible evidence of the drain outlet, apparently because the pipe grade resulted in the outlet invert being placed several feet below the stream bed. DNRC inspections in 2007 have identified a point where water is upwelling in the streambed that corresponds to the approximate location of the as-built drain discharge. A drain may have also been constructed paralleling the outlet conduit. The approximate locations of these drains based on review of construction drawings are shown on Figure 5, Appendix A of this report.

Specific construction installation details of these drain lines were not available in the construction records. The condition of these drains or if they are functioning to effectively lower the phreatic surface in the embankment is not known. As discussed previously, the relatively extensive alluvial gravel lense under the embankment toe most likely is acting as an effective blanket drain. There is no indication from the level of the phreatic surface if the drains are working or plugged (based on the monitoring well records the phreatic surface remains very low in embankment and does not respond to fluctuations in the reservoir's water level).

Consideration should be given to the condition of the drain lines. If the drain lines are crushed, piping of embankment soils could possibly occur along the drain lines. Piping failure is not a significant concern under the rock portion of the embankment (Zones C and D) as these coarse grained materials are most likely self filtering. There is some concern where the drain lines lie in close proximity to Zone A and B materials as these materials are typically fine grained. However, there are gravel and sand size particles in these materials which would help filtering characteristics. Following the July 26, 2005 earthquake, DNRC personnel observed what appeared to be fresh sediment deposits in the stream channel where historical cloudy seepage was apparently observed (See Figure 5 of Appendix A). It is possible that the earthquake event mobilized material through the drain system. DNRC also noted that the sediment could be from a recent severe thunderstorm that washed material down a small draw on the east side of the channel. Evidence of material transport was not observed following a small earthquake that occurred on May 5, 2007 (per com. Brian Grant DNRC)

Review of monitor well data collected from 1999 through 2005 (attached in Appendix E) indicates that the monitor well water level elevations are essentially "flat lined" exhibiting minimal response to reservoir level fluctuations. This indicates very effective seepage cut off, tight impervious core zone and good drainage. The monitoring well data was used to establish the phreatic surface within the maximum embankment section. The monitor well completion data is shown on the boring logs for the 1999 DNRC drilling program (Stiles 2005) (Appendix E). Based on the boring logs the screen intervals in the monitor wells consist of slotted PVC pipe with the exception to the intervals in Monitor Well DH-3 which consist of Sparge Point piezometers. The data indicates that the phreatic surface drops rapidly within the embankment from full pool elevation 5395 at the upstream face to elevation 5320 in monitor well DH-2, located near the crest center. The phreatic surface at the toe of the dam is at elevation 5292 in monitor well DH-4. This elevation is approximately 35 feet below the toe fill elevation of the dam. The phreatic surface used for the steady state seepage analysis is shown in Figure 4-Appendix A. It is most likely that the "wedge" of alluvium left in place under the downstream portion of the embankment is acting like a blanket drain.

During construction of the dam's spillway a drainage system was installed beneath the spillway's concrete floor. There are several drain outlets through the floor that seep water at higher reservoir pool elevations. In 1955 and 1965 repair work was done on the spillway apparently to control seepage, fill voids, and prevent piping of materials from beneath the floor (DNRC, 2005b). Some sediment deposition was observed at the drain outlets following an earthquake in

2005 (DNRC, 2005a). It is unclear if the sediment was the result of the earthquake or from normal seepage.

1.4 DAM SITE GEOLOGY

The dam site geology has been evaluated and presented in several publications. The geologic conditions are summarized effectively in the "Summary Report on the Geology of Ruby Dam Site Madison County, Montana," (Stiles C.A. 2005) and are further discussed in the Seismic Stability Report (Appendix F).

1.5 SEEPAGE ANALYSIS

A cross section of the existing maximum section (Figure 4-Appendix A) was created using survey and drilling data. This maximum section was used in the computer program SEEP\W version 4.22 to model both saturated and unsaturated seepage under various reservoir conditions.

SEEP\W is a finite-element software program that evaluates two-dimensional user-defined sections by dividing the section into small, discrete elements. Individual elements are assigned hydraulic conductivity functions, which are a function of water content and pore-water pressure. Boundary conditions were assigned to elements based on known elevation or pressure head, or known flux or no-flow conditions. The program iterates through solutions to the governing equations based on updated head values and re-evaluation of the hydraulic conductivity functions.

1.5.1 Steady State

A steady-state seepage analysis was conducted to estimate the seepage flows through the embankment and approximate pore-pressure distribution through the dam cross-section. As discussed above, input parameters included known no-flow boundaries and constant elevation boundaries (e.g., the reservoir surface). Since no borehole permeability or laboratory permeability testing was conducted on the embankment materials the selection of conductivity parameters is based on empirical correlations assuming representative material compositions of each zone. As discussed previously the phreatic surface within the embankment has been well established from six (6) years of monitoring. The seepage model was therefore calibrated by assigning estimated hydraulic conductivity values to the various embankment zones and

adjusting the values until the phreatic surface created by the model approximated the actual surface measured in the monitor wells.

The drains, as discussed previously, were not included in the analysis because of the uncertainty of location and functionality. More significant to the analysis is the extensive alluvial layer under the downstream toe of the embankment that is likely functioning as a blanket drain which controls the phreatic surface.

Table 1 summarizes published sources, and parameters used in the analysis.

TABLE 1: HYDRAULIC CONDUCTIVITY PARAMETERS

Material	USCS	Field Tests		Laboratory Test Data (ft/sec) #(cm/sec)	Published Data (Fetter-1994)	Used for Analysis (ft/sec)
		Packer Test Data (ft/sec)	Gravity Test Data (ft/sec)			
Zone A	CL/SC	*N.A.	*N.A.	*N.A.	$1*10^{-6}$ to $1*10^{-11}$	$1*10^{-7}$
Zone B	SM, SC, CL,	N.A.	N.A.	N.A.	$1*10^{-6}$ to $1*10^{-9}$	$1*10^{-7}$
Zone C	SP,GP	N.A.	N.A.	N.A.	$1*10^{-2}$ to $1*10^{-4}$	$1*10^{-4}$
Zone D	SC,GP, Rockfill	N.A.	N.A.	N.A.	10 to $1*10^{-5}$	$1*10^{-4}$
Riprap	(Rock)	N.A.	N.A.	N.A.	10 to 0.1	1.0
Fill at toe of dam	GP, GC,SC,	N.A.	N.A.	N.A.	$1*10^{-4}$ to $1*10^{-7}$	$1*10^{-4}$
Alluvium	GW, GP, SP, SW	N.A.	N.A.	N.A.	$1*10^{-2}$ to $1*10^{-4}$	$1*10^{-3}$
Foundation	(Fractured Bedrock)	N.A.	N.A.	N.A.	_	$1*10^{-8}$

* Not tested

Results from the steady-state seepage analysis indicate between $5.8*10^{-5}$ and $5.8*10^{-7}$ cubic feet per second per foot may seep through the dam structure. Projected across the alignment of the dam, flows between 0.18 and 18 gallons per minute may flow through the structure. An annual loss of 94,608 to 9,460,800 gallons or 0.29 to 29 acre-feet may be expected to seep through the foundation and embankment. Summary results of the steady state seepage analysis are included in Appendix B.

The seepage model may be used to assess the potential change in the embankment phreatic surface from a raise of the normal pool elevation as a result of implementation of specific rehabilitation alternatives.

1.5.2 Rapid Drawdown

The SEEP\W rapid drawdown analysis was utilized to estimate the phreatic surface coupled with the SLOPE\W program to conduct a rapid drawdown slope stability analysis for the upstream face of the dam. It was assumed that the pool would be drawn down from a maximum elevation of 5394 feet to an evacuated pool elevation of 5306 feet at a rate of 1 foot per day. Pore pressures were modeled during a simulated 88-day drawdown period. The phreatic surface within the embankment at the 88-day interval was utilized in the SLOPE/W for the rapid drawdown analysis. HKM has used this analysis method for numerous dam projects reviewed and accepted by the Bureau of Reclamation (Bonneau Dam, Browns Dam and East Fork Dam, Rocky Boy Reservation, Montana).

1.6 STABILITY ANALYSIS

A stability analysis has been performed to assess the static stability of the existing embankment. A typical maximum section through the dam was selected at the location shown on Figure 3-Appendix A. The typical maximum cross section configuration was created using recent topographic survey, borehole log information (DNRC 1999) and transposition of as-built cross section geometry taken from the as-built record drawing DWG no.-1A 1938 (Figure 4-Appendix A). The phreatic surface used in the analysis is based on recorded monitor well (piezometer) data reported in "Summary Report on the Geology of Ruby Dam Site Madison County Montana" (Stiles C.A. 2005). The section geometry is shown in Figure 4. Engineering strength parameters were assigned as discussed in Section 1.6.1. The maximum dam section was analyzed for steady-state seepage conditions static stability, seismic stability and rapid-drawdown. Stability analysis was performed using a two-dimensional, limit equilibrium slope stability program, SLOPE\W version 4.22. The seismic stability was assessed using a methodology developed by the Montana DNRC Dam Safety Program (DNRC, 2005c).

1.6.1 Soil Strength Parameters

Engineering strength parameters were estimated and were assigned to the various embankment zone materials based on laboratory and field data collected during the 1999 DNRC investigation and typical strengths for similar materials described in engineering literature (USBR 1987, Bowles 1988). Embankment zone materials have been discussed previously and defined by material testing during DNRC and HKM investigations. Unified soil classifications are listed for each zone in Table 2. Zone A and B exhibited a range of material types but can be grossly

classified as cohesive (sandy lean clay with scattered gravel and clayey/silty sand). It is noted that the triaxial strength values (Effective Strengths C' =212 psf and ϕ'=32°) taken from a clay sample in DH-2 are probably representative for the sandy lean clay /clayey sand material in Zone 2. In the analysis HKM has elected to use more conservative strength values taken from USBR Design of Small Dams for compacted saturated lean clay. The lower strengths used for this material is intended to help account for areas that may not have been compacted as well as possible (e.g. see test data for TP-7A samples) and areas that may contain a higher clay content than has been observed to date. Strength values for the granular soils shown in the table (zones C and D, alluvium, fill and riprap) are typical for these materials (taken from Bowles 1988). Table 2 presents the strength parameters used in the analysis.

For the seismic analysis, Zones A and B, total stress internal angle of friction and cohesion strength parameters were determined by averaging the total stress values from the triaxial tests conducted on DH-2 and TP7A samples and then reducing these values by 10 percent to derive the corresponding parameters shown on Table 3.

TABLE 2: ASSUMED EMBANKMENT STRENGTH PARAMETERS
RUBY DAM STATIC STABILITY ANALYSES

Embankment Material	Estimated Engineering Properties					
	γ (pcf)	Effective Stress		Total Stress		
		ϕ	C (psf)	ϕ	C (psf)	
Zone (A) CL/SC	125	25	200	15.8	205	
Zone (B) CL/SC/SM	125	25	200	15.8	205	
Zone (C) SP/GP	125	38	0	-	-	
Zone (D) Rockfill	125	45	0	-	-	
Alluvium GP /GW	115	32	0	-	-	
Fill GP-Gm/Rockfill	115	32	0	-	-	
Riprap and gravel bedding	120	45	0	-	-	
Bedrock	135	45	2000	-	-	

* Total stress values are taken as the average value from triaxial test conducted on samples from DH-2 and TP-7A.

1.6.2 Steady State Seepage

The static slope stability analysis, using steady state seepage assumptions and effective stress parameters, was performed for the downstream slope of the maximum section. Results of the static stability analysis are presented in Table 4. The results of the analysis indicate that the lowest factor of safety failure surface projects through the upper portion of the embankment within the 2:1 slope. Factors of safety for deep seated failure zones are also shown. Printouts of the dam cross sections showing the failure surface locations for the various computer runs are presented in Appendix C. A steady state stability analysis was also conducted for the upstream slope of the dam assuming fully drained conditions to gather additional data on the embankment.

1.6.3 Seismic Stability Analysis

An analysis of the seismic stability of the embankment was performed following a methodology developed by the Montana DNRC Dam Safety Section (DNRC 2005c). Important components of the methodology used in the evaluation of Ruby Dam included determining peak ground acceleration (PGA) at the base of the dam for a seismic recurrence interval of 1 in 5000 years and determining the yield acceleration (a_y) at which point the embankment's slope would yield (i.e. displacement along a failure surface would occur). The seismic stability of the embankment is then evaluated based on the equation:

If $a_y > PGA/3$, then embankment slope passes and is considered stable

NTL, Inc. was retained by HKM to assist with the analysis and a preliminary evaluation they completed is contained in Appendix F. In the NTL evaluation the PGA for the site was defined (PGA = 0.23g) and the embankment's stability was evaluated using preliminary strength values developed by HKM for the soil types. The soil strengths were subsequently revised to more conservative values, primarily to comply with the DNRC's Dam Safety methodology (e.g. a 10% reduction in soil strengths), and the slope stability was reanalyzed. The revised soil strength values are presented in Table 3 and incorporated into the stability models contained in Appendix C.

TABLE 3: ASSUMED EMBANKMENT STRENGTH PARAMETERS
RUBY DAM SEISMIC STABILITY ANALYSES

Embankment Material	Estimated Engineering Properties				
	γ (pcf)	Effective Stress Analysis		Total Stress Analysis	
		ϕ	C (psf)	ϕ	C (psf)
Zone (A) CL/SC	125	22	180	14.4	186
Zone (B) CL/SC/SM	125	22	180	14.4	186
Zone (C) SP/GP	125	34	0	NA	NA
Zone (D) Rockfill	125	40	0	NA	NA
Alluvium GP /GW	115	29	0	NA	NA
Fill GP-GM/Rockfill	115	29	0	NA	NA
Riprap and gravel bedding	120	40	0	NA	NA
Bedrock	135	45	2000	NA	NA

NA – not applicable

In the seismic analysis of the dam effective stress and total stress strength parameters were used depending on the material characteristics and degree of saturation In the case of saturated Zone A and B materials, total stress properties were used to model undrained conditions. As presented previously total stress strength parameters were determined by averaging the total stress values from the triaxial tests conducted on DH-2 and TP7A samples and then reducing these values by 10 percent.

Since total stress values were used for zones A and B saturated materials no phreatic surface was specified. Effective stress strength parameters were use for zone A and B in upper embankment areas above the approximated saturated zones. Effective stress properties were used for all other materials and a phreatic surface was assigned to them. The analysis was then conducted by performing successive stability iterations and varying the acceleration imparted to the embankment until a factor of safety (FS) of near 1.0 was attained. The acceleration value at FS=1.0 is referred to as the yield acceleration (a_y). The yield acceleration is the acceleration where the embankment would just begin to exhibit displacement if it was imparted to the embankment for a long enough duration. In actuality, earthquake shaking may impart several brief acceleration peaks equal to or greater than a_y to an embankment without any displacement

occurring. Computer runs where the yield acceleration was determined are contained in Appendix C and the results are summarized below.

Ruby Dam Yield Accelerations (a_y), g's	
Upstream Face	Downstream Face
0.18	0.18

It is noted that the above yield accelerations closely approximate those determined by DNRC (upstream face: 0.17 and downstream face: 0.15, see NTL report). With respect to the downstream face, the difference in the DNRC's lower FS is attributed to their analysis not including the toe berm which was only recently ground surveyed.

Table 5 presents the yield accelerations and compares a_y with respect to screening test criteria. As shown in Table 5, for each analysis the embankment passes the screening test. In order to fail the screening test, the yield acceleration would need to be less than 0.08g; yield accelerations determined for the embankment sections are roughly a factor of 2 greater that the screening test criteria.

1.6.4 Rapid Draw Down

The SEEP\W rapid drawdown analysis was utilized to estimate the phreatic surface coupled with the SLOPE\W program to conduct a rapid drawdown slope stability analysis for the upstream face of the dam. HKM has used this analysis method for numerous dam projects reviewed and accepted by the Bureau of Reclamation (Bonneau Dam, Browns Dam and East Fork Dam, Rocky Boy Reservation, Montana). It was assumed that the pool would be drawn down from a maximum elevation of 5394 feet to an evacuated pool elevation of 5306 feet at a rate of 1 foot per day. Pore pressures were modeled during a simulated 88-day drawdown period. The phreatic surface within the embankment at the 88-day interval was utilized in the SLOPE/W for the rapid drawdown analysis. One (1) foot per day rate was taken as a trial value initially. However using the results from the seepage model and selected soil parameters indicates that rates greater than this could cause instability in the upstream embankment slope. The rapid drawdown output section is included in Appendix C. The results of the analysis, presented in Table 4, indicate that the FS for rapid draw down (FS=1.18) is slightly below the recommended FS of 1.2. Because of the minimal data available for the Zone A (upstream zone soils) and a lack of accurate survey data of the upstream slope configuration (in particular the toe berm

constructed in 1957) the rapid drawdown case should be re-analyzed when more information is obtained as part of final design.

1.6.5 Liquefaction Potential

Liquefaction potential has been assessed by following DNRC's methodology (DNRC, 2005c). Based on the soil testing conducted the embankment may be grossly classified as a clay embankment with no liquefiable layers. The embankment is founded on bedrock with portions of the toe area on dense gravel (see Section 1.3.4). Extensive intervals of loose sand or gravels were not encountered. Based on existing available information the dense gravel layer does not exhibit liquefaction potential. Therefore the dam embankment or foundation materials are considered non liquefiable. HKM performed an analysis following the Cyclic Stress/Cyclic Resistance ratio methodology procedure developed by Yound and Idriss as outlined in USBR Design standards No.13 (USBR, March 7, 2001) and using grain size data and corrected standard penetration test results from the DNRC drilling investigation (DNRC 1999). Samples were evaluated assuming a peak ground acceleration of 0.25g and Magnitude 7.5 earthquake. The results of the analysis indicated that of the samples evaluated one sample exhibited factors of safety of less then 1. This sample was from an isolated interval (DH-2 (41-42.5)).

1.6.6 Stability Summary

Select output sheets for the stability analyses are included in Appendix-C. Individual results are summarized below in Table 4. Table 5 presents the results of the DNRC seismic screening test.

TABLE 4: EXISTING EMBANKMENT SLOPE STABILITY SUMMARY
RUBY DAM STABILITY ANALYSIS

Notes	Minimum Factor of Safety		
	Bishop	Spencer	Recommended*
DOWNSTREAM SLOPE UPPER EMBANKMENT			
Steady State Seepage, Static	1.7	1.72	> 1.5
Yield Acceleration = 0.22g	0.98	1.00	NA
DOWNSTREAM SLOPE DEEP SEATED FAILURE			
Steady State Seepage, Static	2.00	2.04	>1.5
Yield Acceleration = 0.18g	0.97	1.03	NA
UPSTREAM SLOPE			
Low Pool Fully Drained State Reservoir pool at 5310, Static	1.76	1.77	>1.5
Pool Elevation at 5372 (typical low pool). Yield Acceleration = 0.18g	1.05	1.06	NA
Rapid Drawdown	1.18	1.18	>1.2

* USBR 1987

NA – not applicable

TABLE 5: SEISMIC STABILITY SCREENING TEST RESULTS

Yield Acceleration (a_y) values determined for Ruby Dam	Screening Test Criteria* (PGA/3)	Screening Test Result
Downstream Slope, Upper Embankment a_y = 0.22	.08	Pass
Downstream Slope, Deep Seated a_y = 0.18	.08	Pass
Upstream face a_y = 0.18	.08	Pass

* Criteria is, If a_y > PGA/3 then slope passes test. From the NTL analysis, PGA/3 = 0.23g/3 = 0.08g

2.0 CONCLUSIONS / RECOMMENDATIONS

2.1 STABILITY ANALYSIS

The results from the analysis indicate that Ruby Dam exhibits adequate static stability and has passed the Montana DNRC seismic stability screening test. It is noted that the majority of the embankment strength values are estimated but the values used are conservative and within the lower bounds for accepted strength limits for corresponding embankment materials. Additionally, in-place density and shear strengths determined from the triaxial test conducted on the Shelby tube sample taken from depths between 51 to 52.5 feet in DH -2 (Zone B material) correspond with typical values for saturated compacted clay embankment soils (USBR 1987). Based on construction records compaction monitoring was conducted during placement of the embankment soils. There appear to be some data gaps in the available compaction documentation however. Past performance of the structure over the last 67 years is a good indicator of the embankment's inherent stability.

It is noted that NTL did bring up some concern regarding validity of the penetration data because of the use of a Safety Hammer to perform the penetration tests (Appendix F). It is noted that the likely strengths of the Zone A and B materials are greater than the very conservative strengths used for the analysis. With the conservative strengths used, the yield accelerations calculated are still considerably greater than the minimum values required. Some additional drilling should be performed during the final design stage to obtain final design information for the proposed dam crest raise option (Section 3 of this report). Information obtained from the additional drilling will be used to confirm assumptions used in the stability assessment. One or two additional borings in the upstream edge of the embankment crest would provide additional information for design of the dam raise option. One of these borings should be located near embankment station 4+00 to install a monitoring well in the foundation near the tile drains.

Consideration should be given to the upstream slope failure which occurred in 1957. Since the repair, involving construction of an upstream toe berm, the slope has functioned satisfactorily with no indications of additional movement. It is difficult to assess the cause of the instability without construction survey data which would have defined the failure surface and in-place or laboratory test data which would aid in estimating the strength characteristics of the Zone A material. It is recommended that a survey be conducted to determine the configuration of the existing embankment upstream face and toe. The toe berm referred to in the documentation of the repair of the upstream face should provide improved drawdown stability from the analysis

presented in this report. This information will allow a more accurate evaluation of the rapid draw down stability of the upstream face during the final design stage of the project.

2.2 SEEPAGE ANALYSIS

Problems associated with seepage do not appear to be a major concern within this embankment. Piping potential through the internal tile drains should be further evaluated however. The results of the monitoring program over the last six years indicate a low phreatic surface within the embankment and good seepage cutoff. Also no seepage problems have been reported during the life of the embankment. The seepage model was developed predominately to assist with rapid draw down analysis and to evaluate the effect that raising the normal pool elevation would have on the existing phreatic surface within the embankment. Hydraulic conductivity values used in the seepage model were estimated as no permeability tests are available for the site.

As discussed previously, based on construction records, eight and ten-inch drainage tiles were installed under the embankment and upstream of the embankment's centerline. This system supposedly discharges through a CMP conduit downstream of the spillway. Sediment discharges may also have occurred through the drains as noted in DNRC and historical inspection reports. The CMP should be located and evaluated for condition prior to final design to allow for observation and evaluation of the drain flows. A new outlet for the CMP conduit should be constructed in advance or during final design to allow for monitoring of the drain. The outlet should include provisions to measure flow and to trap/observe sediment in the flow. An additional monitoring well should also be installed near the intersection of the tile drains at approximate embankment station 4+00.

The spillway floor/foundation has experienced historic seepage problems in developing voids under the floor slab. During final design, the drainage system for the new spillway will need to incorporate drainage and filtering features to ensure adequate drainage for the structure.

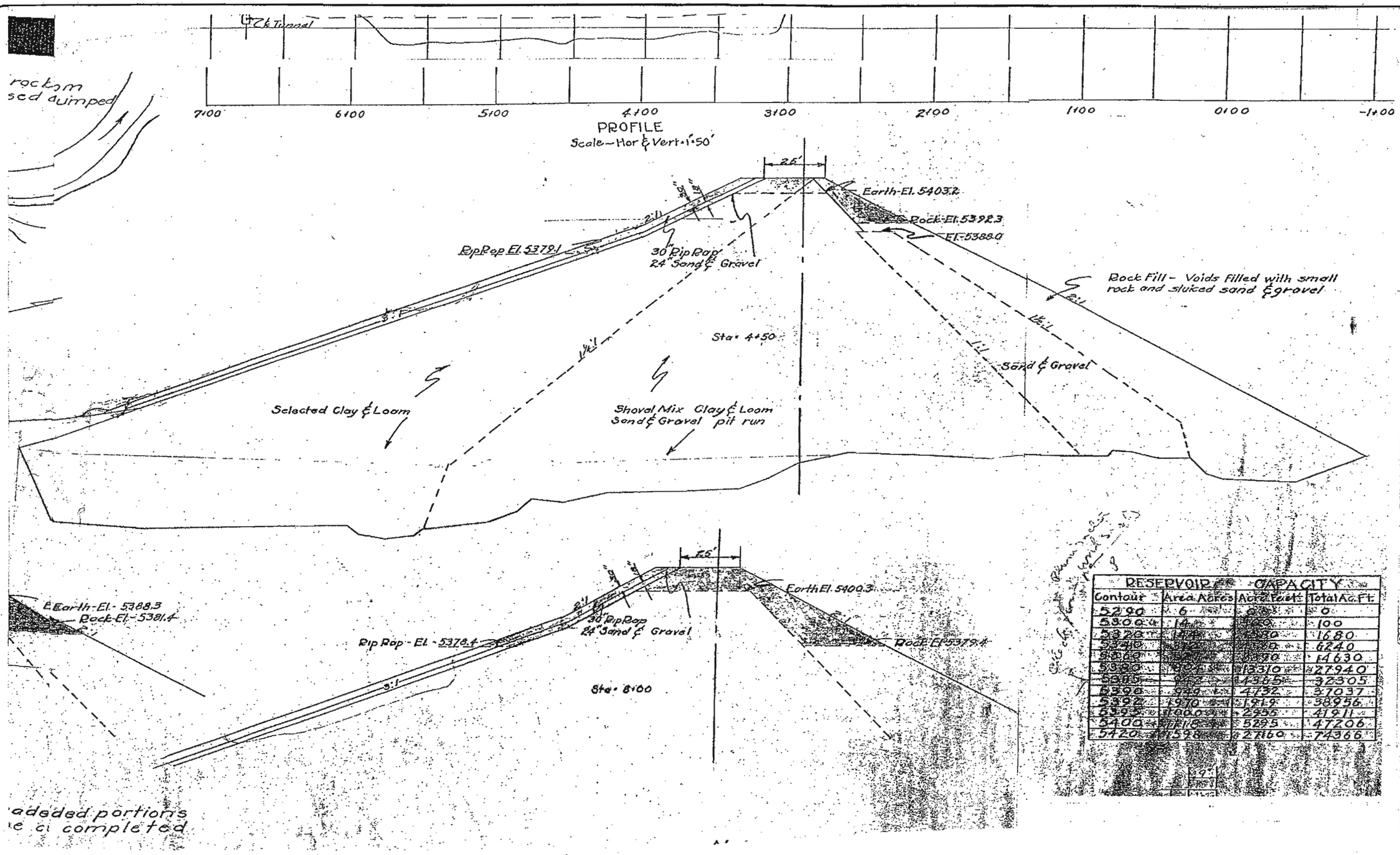
3.0 DAM RAISE OPTIONS

The preferred rehabilitation option requires raising the dam crest which would consist of raising the embankment by construction of either a gabion wall or wire-faced MSE (mechanically stabilized earth) wall on the upstream side of the crest with a 2 to 1 back slope catching on the downstream edge of the crest. A 30 foot top width would be maintained. Construction of this option would likely require removal and recompaction of the upper 8 feet of the existing embankment. As discussed previously, based on construction records and information obtained during HKM's field investigation (Appendix G) it appears that the upper 8 to 10 feet of the embankment may not have been compacted as thoroughly as possible. Further evaluation of the upper portion of the embankment should be conducted during the final design phase.

A stability analysis was completed for a five-foot dam raise option to make sure raising the dam crest does not significantly impact the stability of the existing dam embankment. Results of the stability analysis are shown in Table 6 and computations are contained in Appendix D. The results show there is minimal impact to the factors of safety results for the existing embankment. All factors of safety calculated for the 5-foot raise are within acceptable limits, except for rapid drawdown which is just slightly below the minimum recommended limit. A toe berm was not incorporated in the rapid drawdown analysis. As discussed in Section 2.1 additional survey and investigation is warranted to further define the upstream slope geometry and soil strengths.

TABLE 6: 5-FOOT RAISE OPTION SLOPE STABILITY SUMMARY
RUBY DAM STABILITY ANALYSIS

Notes	Minimum Factor of Safety		
	Bishop	Spencer	Recommended
DOWNSTREAM SLOPE UPPER EMBANKMENT			
Steady State Seepage	1.69	1.69	>1.5
Yield Acceleration = 0.22g		0.99	NA
DOWNSTREAM SLOPE DEEP SEATED FAILURE			
Steady State Seepage	2.0	1.97	>1.5
Yield Acceleration = 0.18g	0.96	1.02	NA
UPSTREAM SLOPE			
Low Pool Fully Drained State Reservoir pool at 5306	1.76	1.76	>1.5
Pool elevation @ 5372 Yield Acceleration = 0.18g	1.02	1.05	NA
Rapid Drawdown	1.16	1.17	1.2



RESERVOIR CAPACITY			
Contour	Area Acres	Acre Feet	Total Ac. Ft.
5290	6	0	0
5300	14	100	100
5320	140	330	1680
5340	300	770	6240
5360	500	1390	14630
5380	900	1331 0	27940
5395	940	14365	32305
5390	940	4732	37037
5392	1970	1919	38956
5395	1000	2955	41911
5400	1118	5295	47206
5420	1598	27160	74366

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RUBY DAM FEASIBILITY STUDY
MADISON COUNTY, MONTANA

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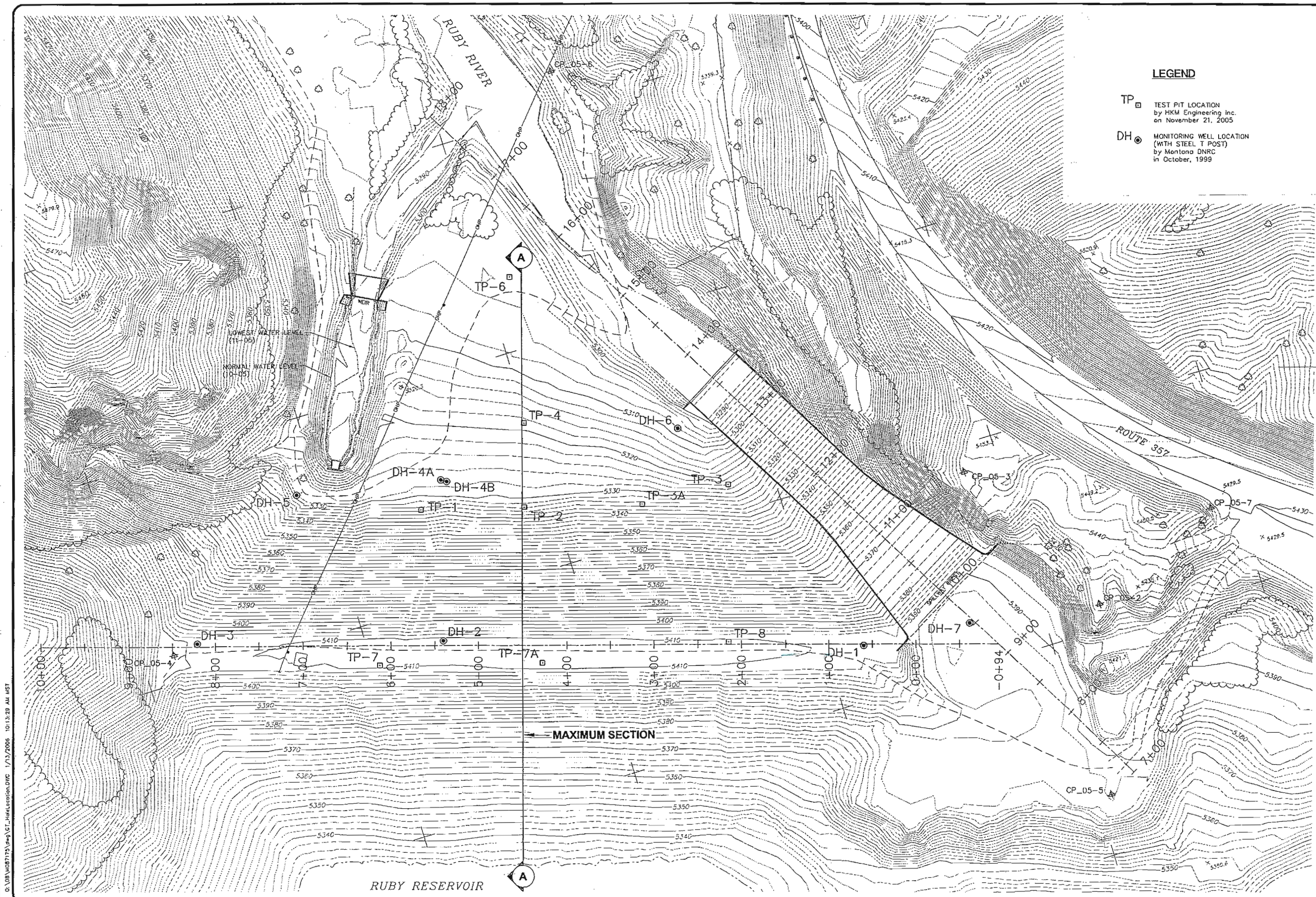

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RUBY DAM FEASIBILITY STUDY

LOCATION OF MAXIMUM SECTION

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Maximum Section and Embankment Zones: Ruby Dam
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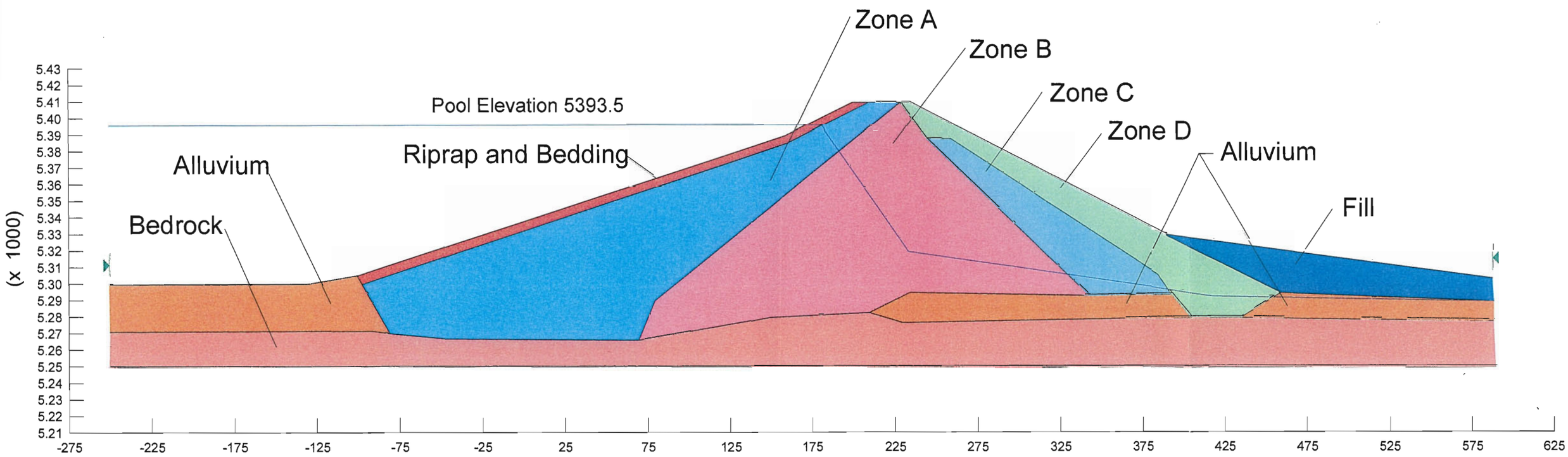

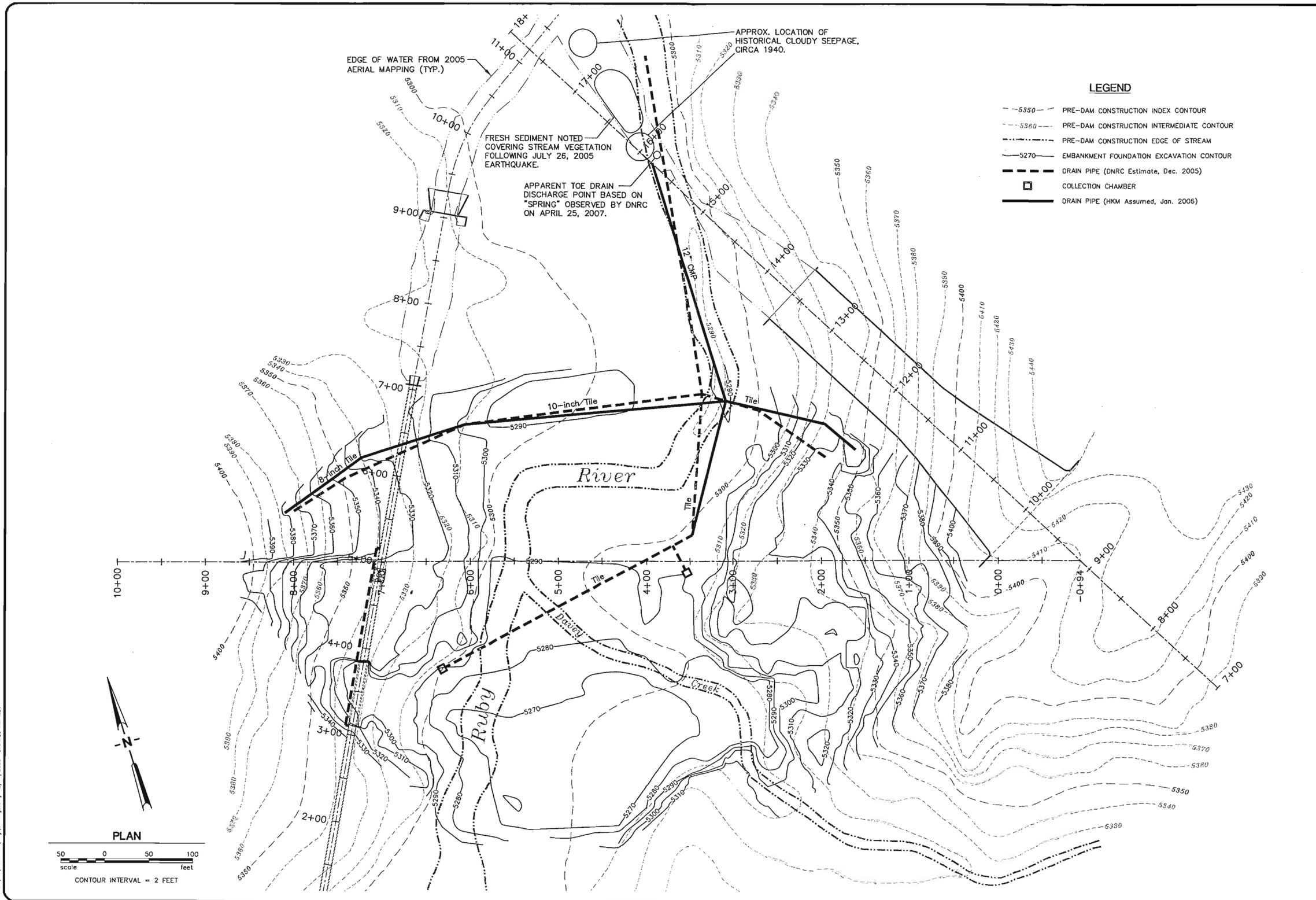

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RUBY DAM REHABILITATION FEASIBILITY STUDY
MADISON COUNTY, MONTANA

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FIGURE
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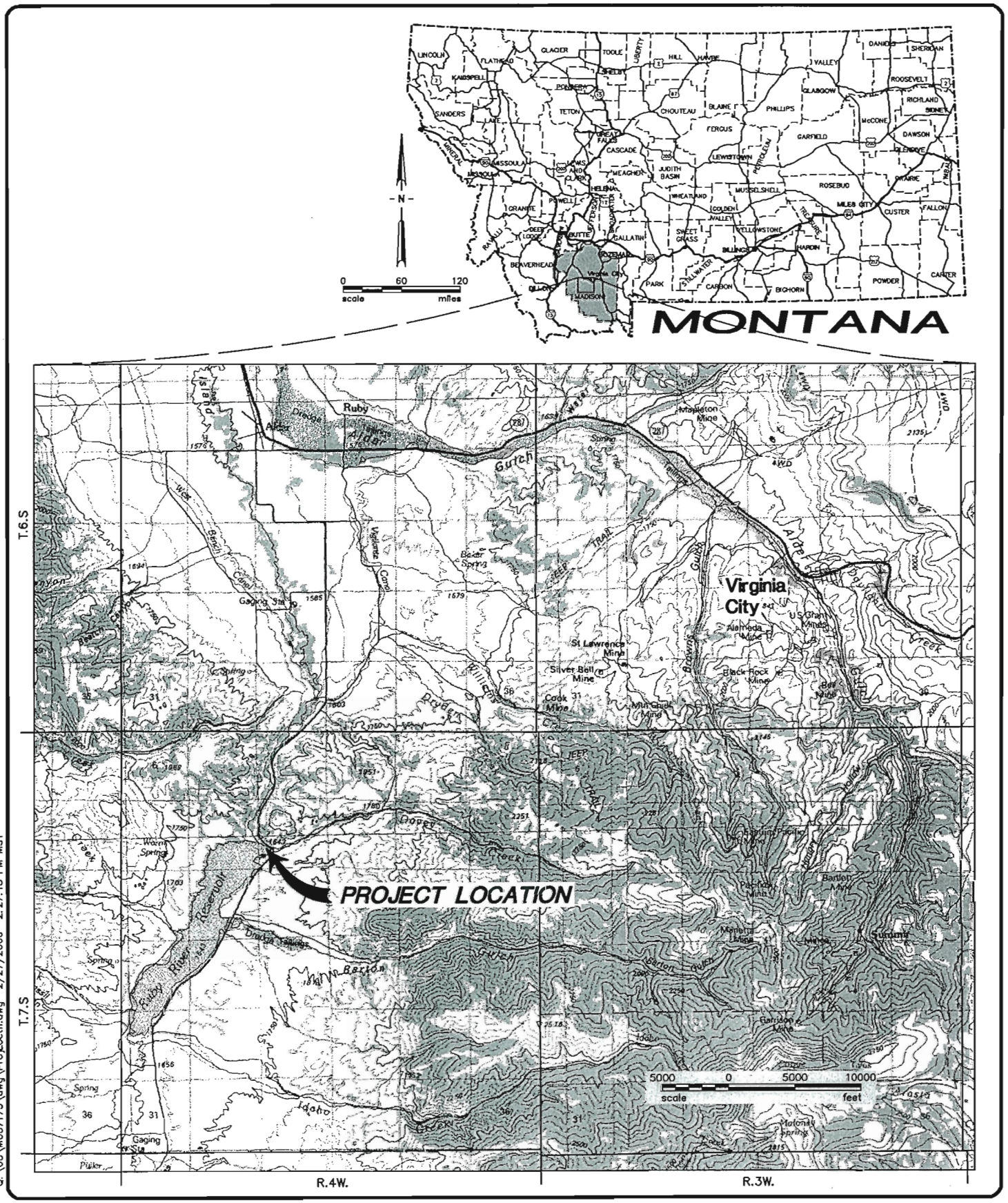
APPENDIX A

FIGURES



RUBY DAM REHABILITATION FEASIBILITY STUDY
PROJECT LOCATION MAP

FIGURE # 1

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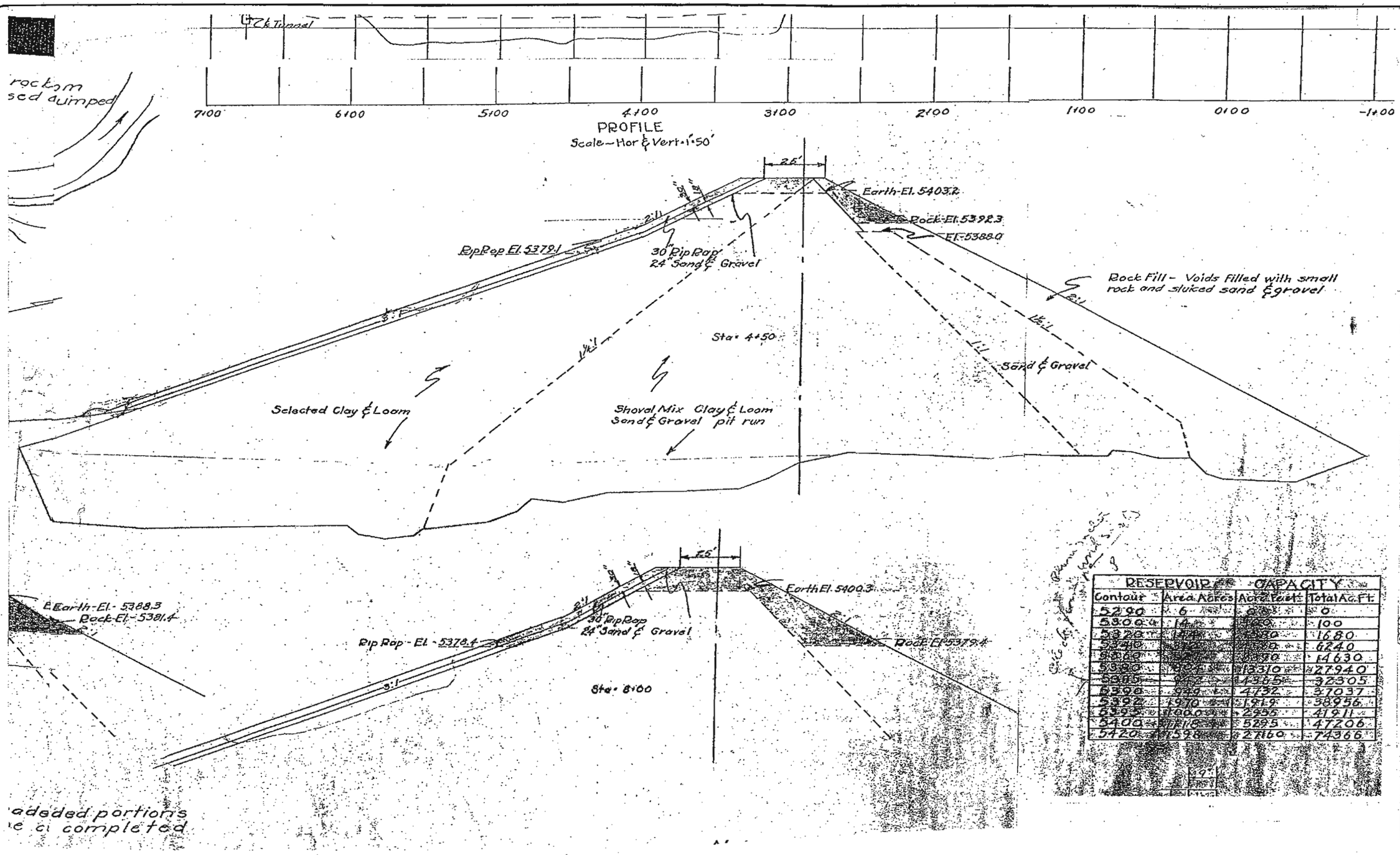

RESERVOIR CAPACITY			
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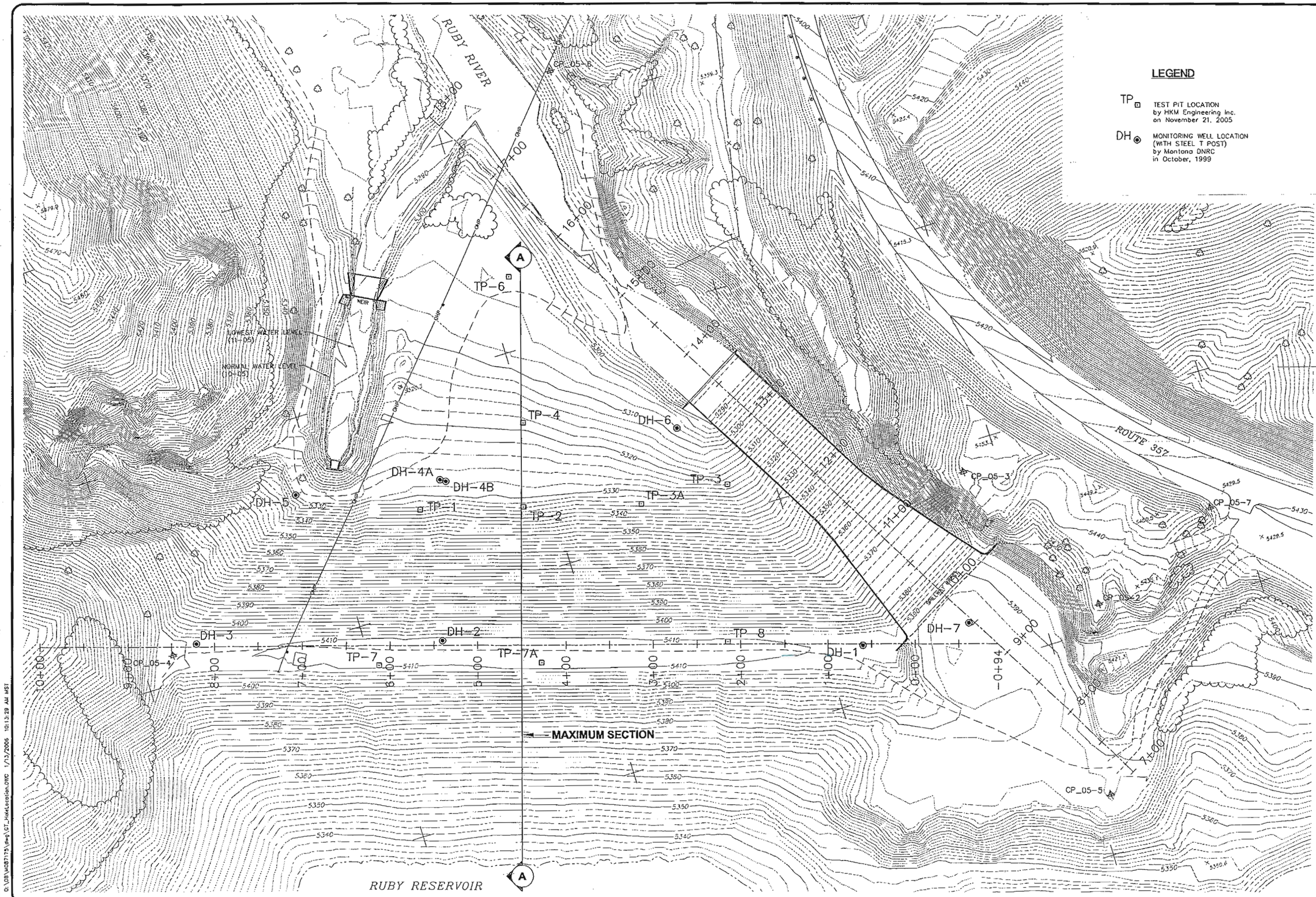

LEGEND

TP ⊡ TEST PIT LOCATION by HKM Engineering Inc. on November 21, 2005

DH ◉ MONITORING WELL LOCATION (WITH STEEL T POST) by Montana DNRC in October, 1999

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Maximum Section and Embankment Zones: Ruby Dam
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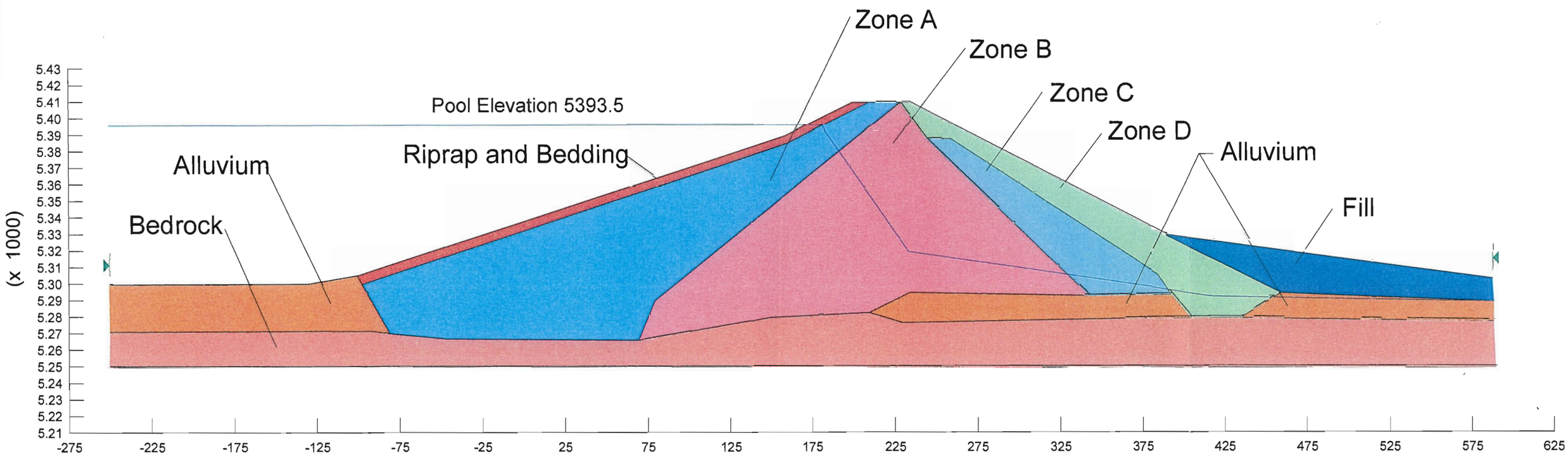

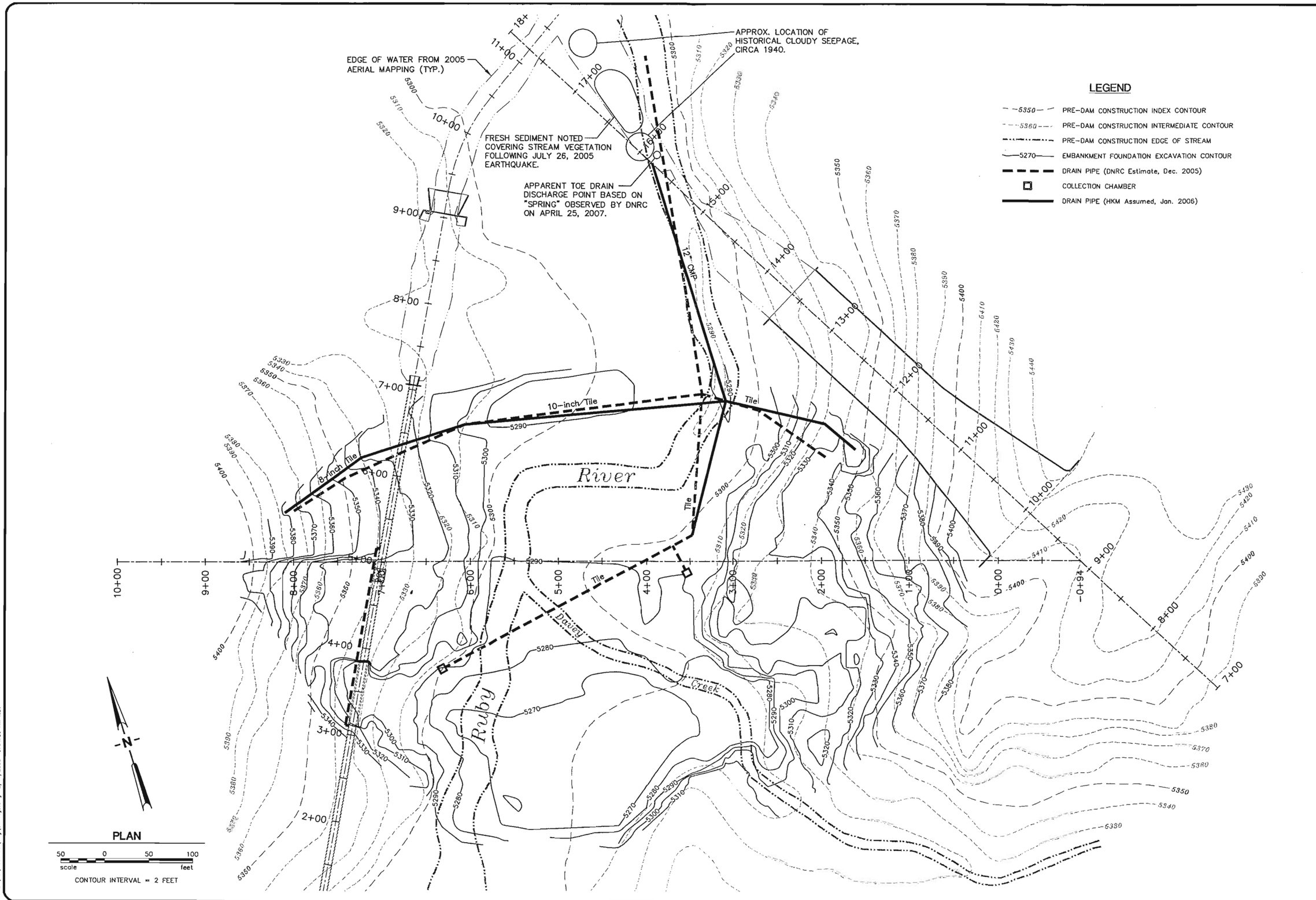

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APPENDIX B

SEEPAGE ANALYSIS RESULTS

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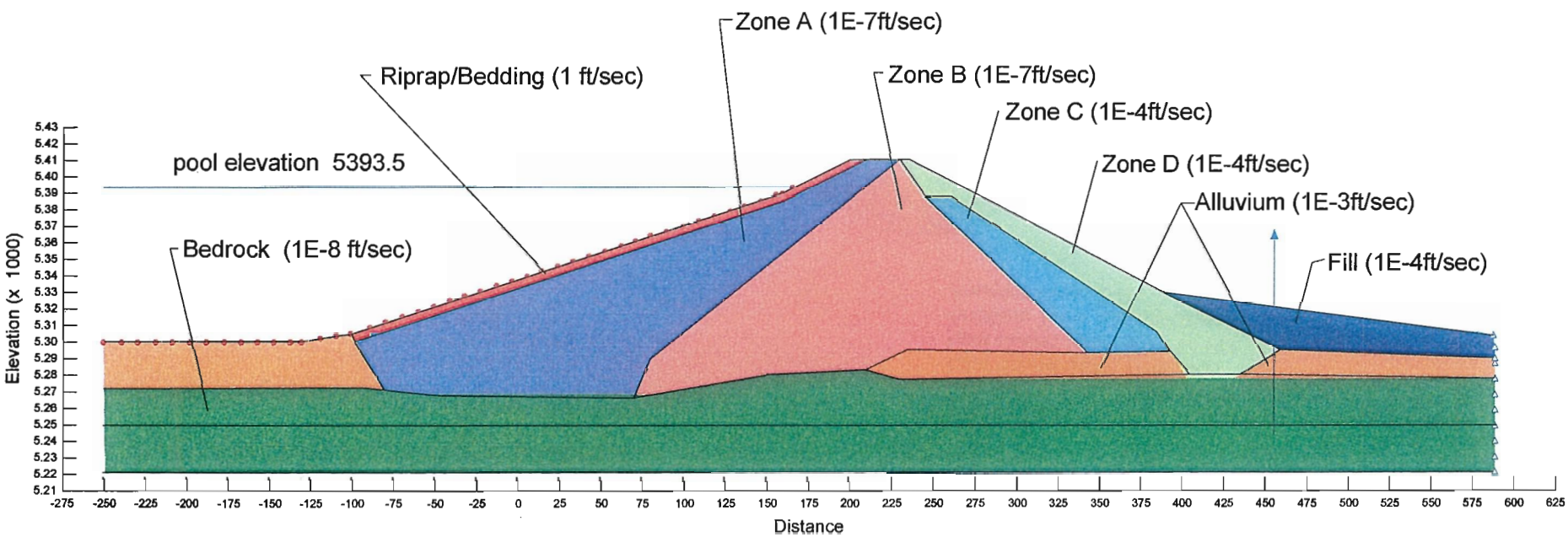

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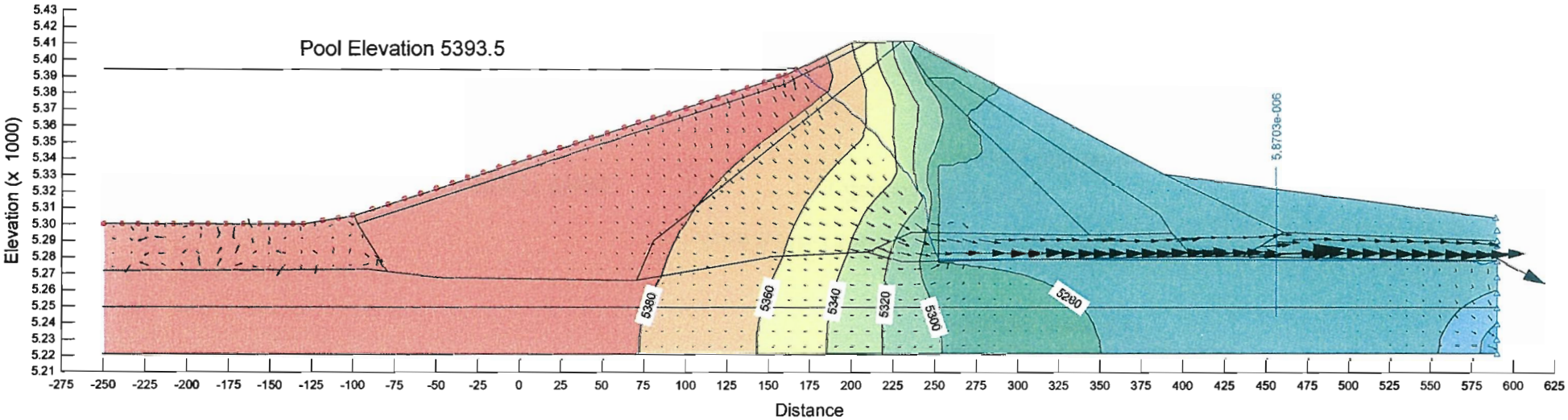
Analysis View: 2-D



APPENDIX C

STABILITY ANALYSIS RESULTS

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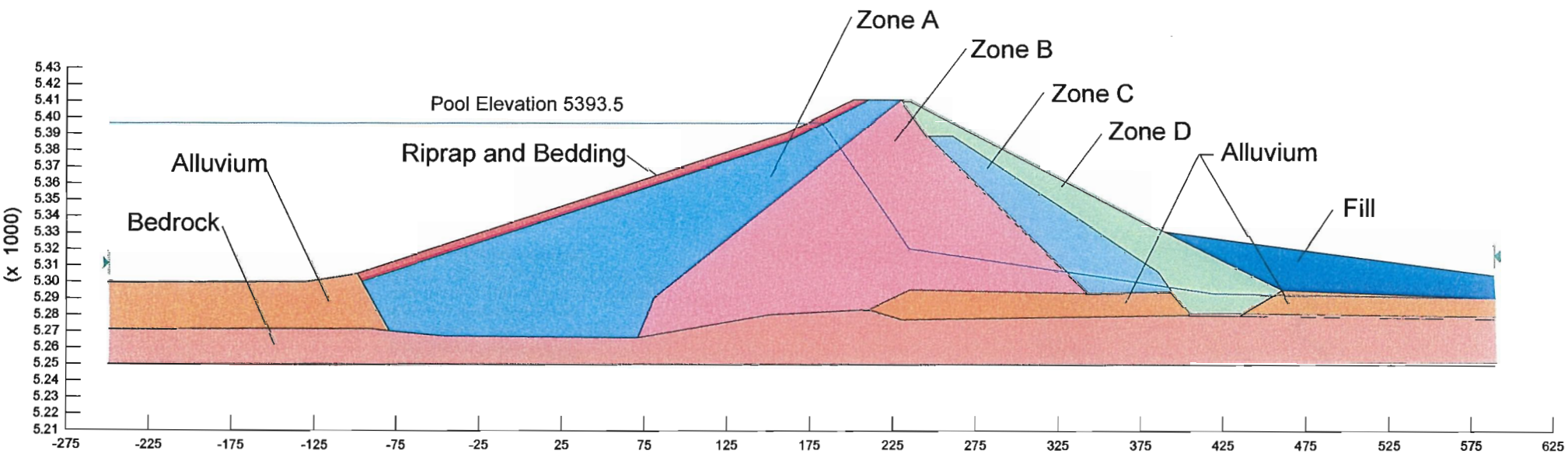

Steady State Seepage Upper Embankment Portion Ruby Dam
File NameRuby Max SectionT3SSUpper Embankment.slp
Last Saved Date9/5/2007
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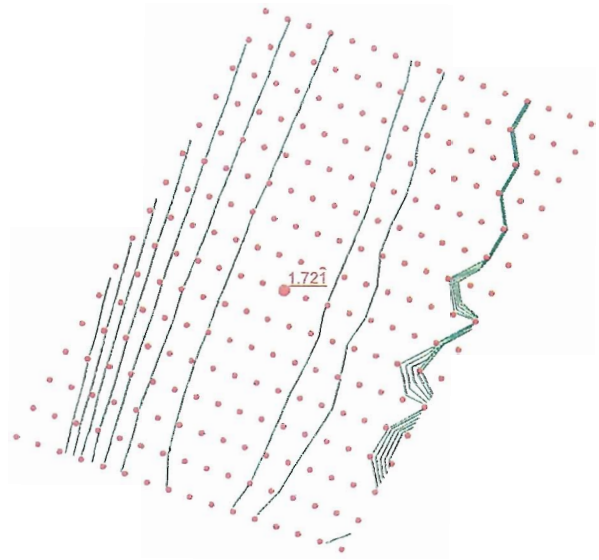
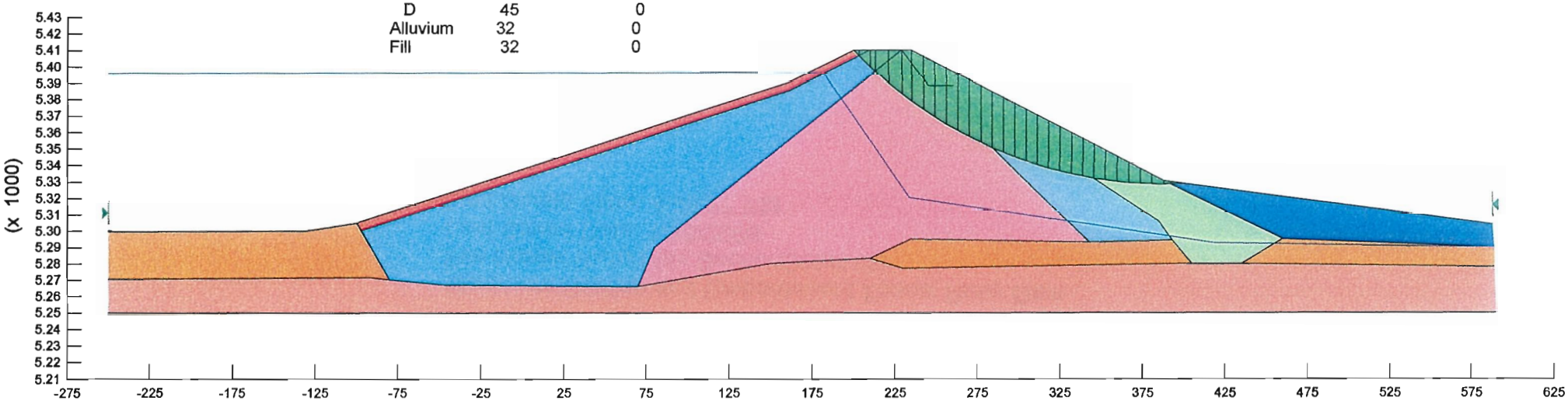
Analysis MethodSpencer
Slip Surface OptionGrid and Radius
P.W.P. OptionPiezometric Lines / Ru
Seismic Coefficient(none)



Soil Strengths Used For Analysis

Zone	Phi(degrees)	C(psf)
A	25	200
B	25	200
C	38	0
D	45	0
Alluvium	32	0
Fill	32	0



Steady State Seepage Full Embankment : Ruby Dam
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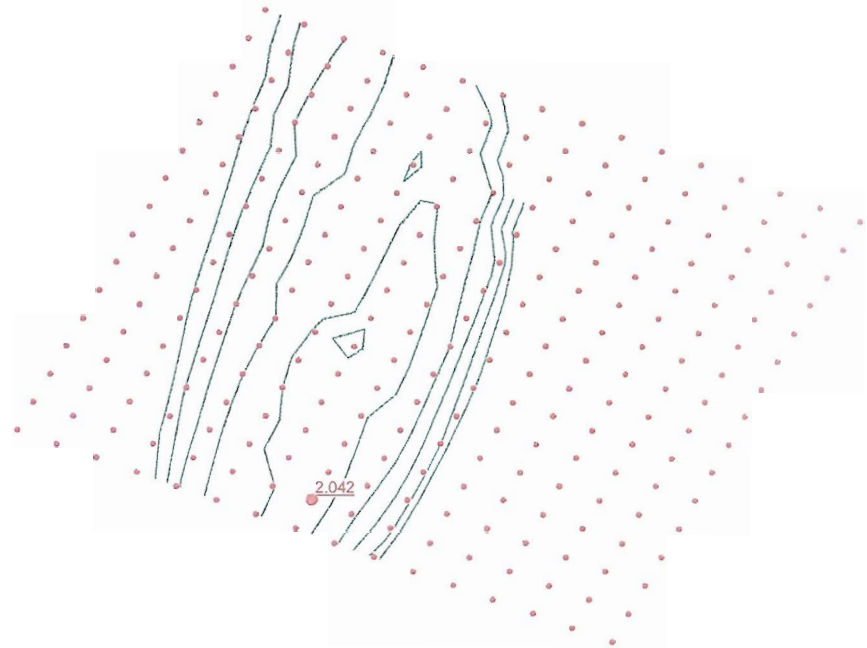
Seismic Coefficient: (none)



Soil Strengths Used For Analysis

Zone	Phi(degrees)	C(psf)
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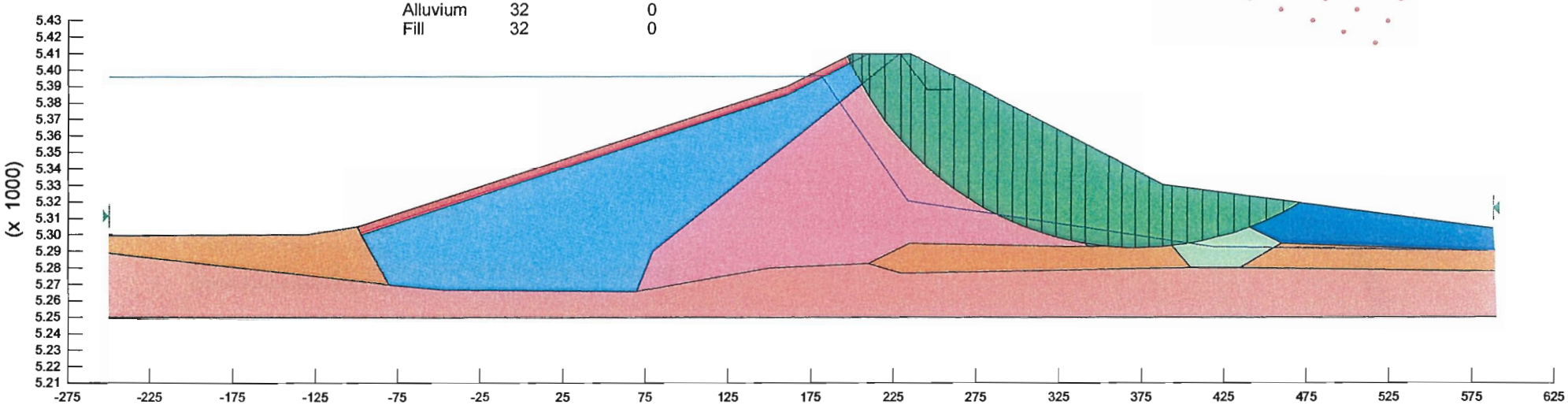

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Analysis Method: Spencer
Seismic Coefficient 0.22: Horizontal

Soil Strengths Used For Analysis

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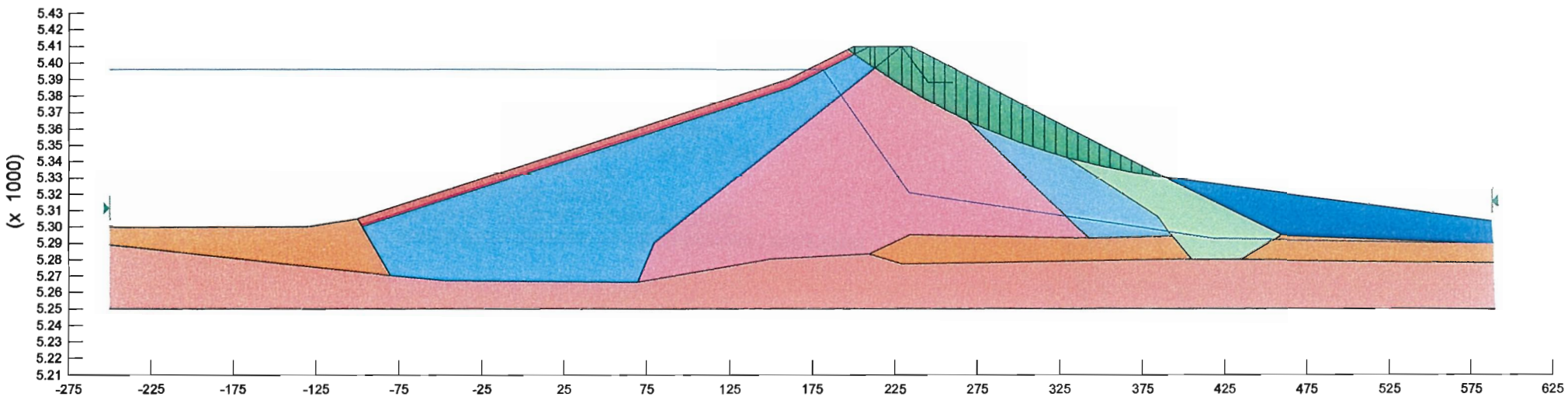
C	35	0
D	41	0
Alluvium	29	0
Fill	32	0



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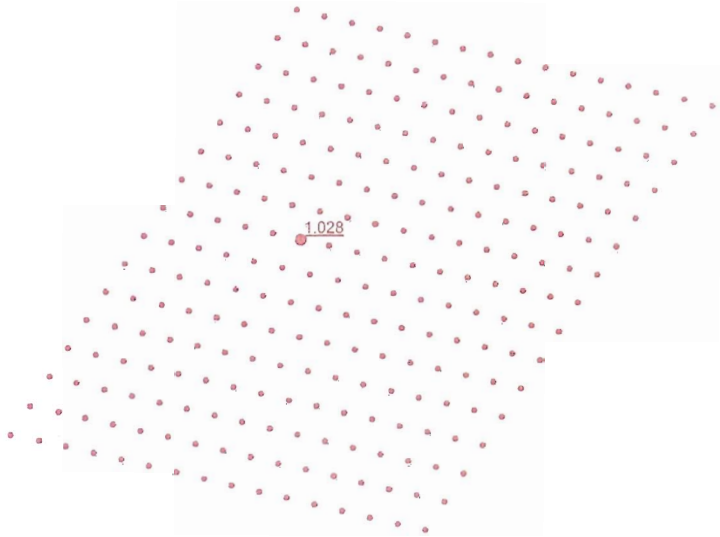
Seismic Coefficient=.18: Horizontal



Soil Strengths Used For Analysis

Zone	Phi(degrees)	C(psf)
A	22	180
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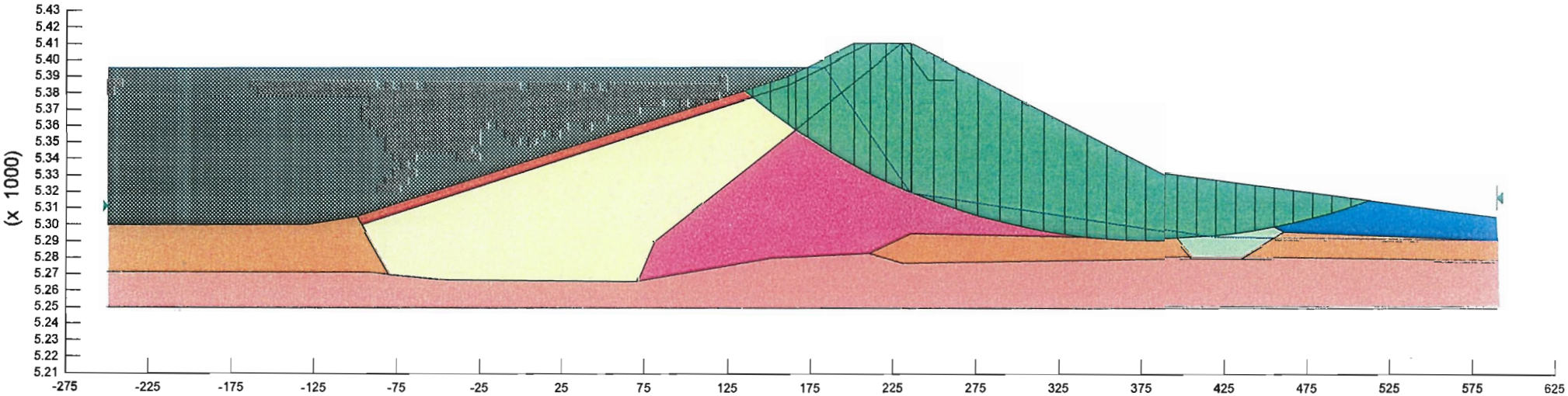
B	22	180
B2	14.4	186
C	35	0
D	35	0
Alluvium	29	0
Fill	32	0



Upstream Slope Pool Elevation 5372 Yield Acceleration : Ruby Dam
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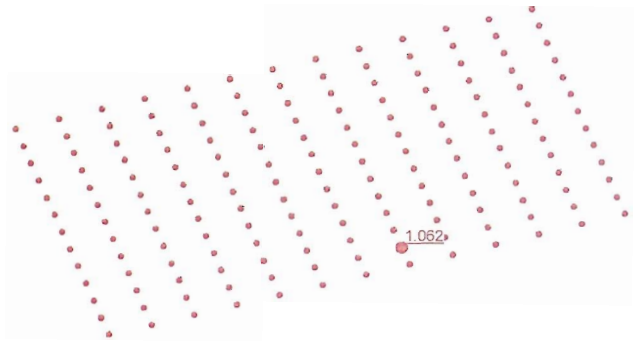
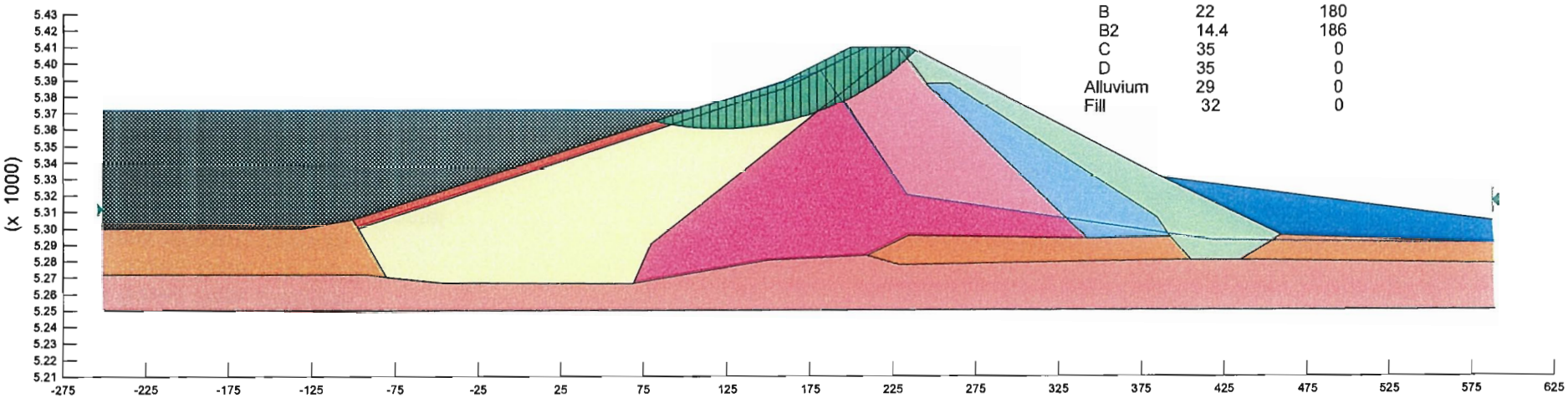
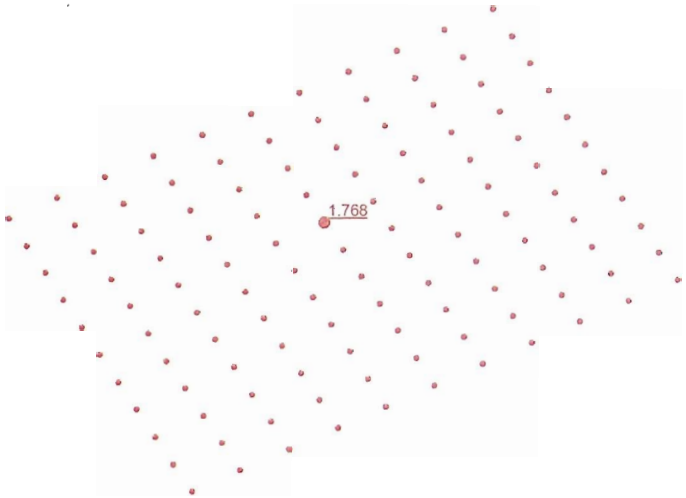


Soil Strengths Used For Analysis

Zone	Phi(degrees)	C(psf)
A	22	180
A2	14.4	186
B	22	180
B2	14.4	186
C	35	0
D	35	0
Alluvium	29	0
Fill	32	0





Ruby Dam Upstream slope fully drained : Ruby Dam
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Soil Strengths Used For Analysis

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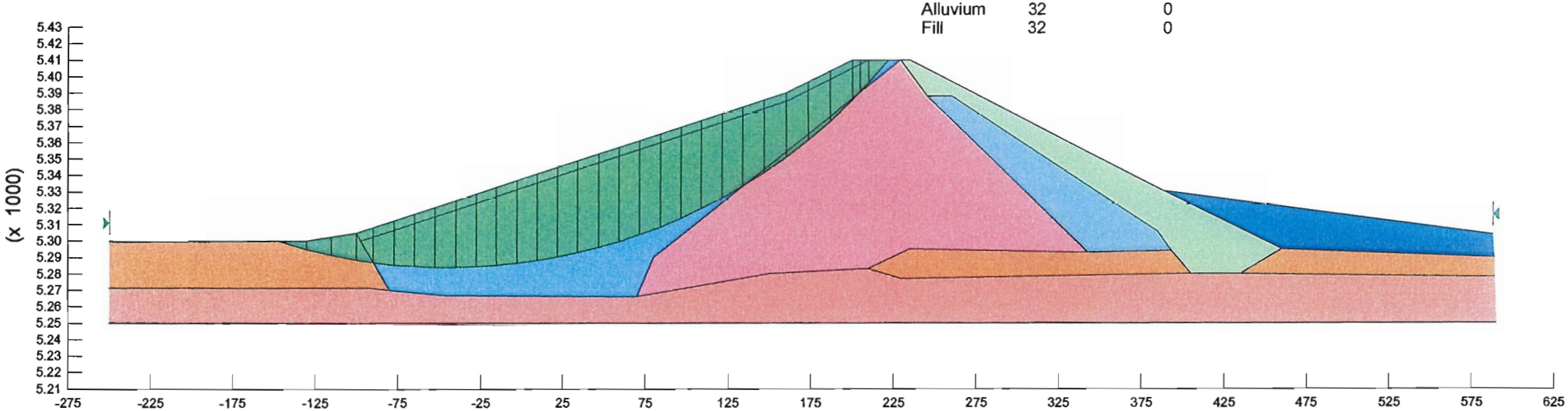
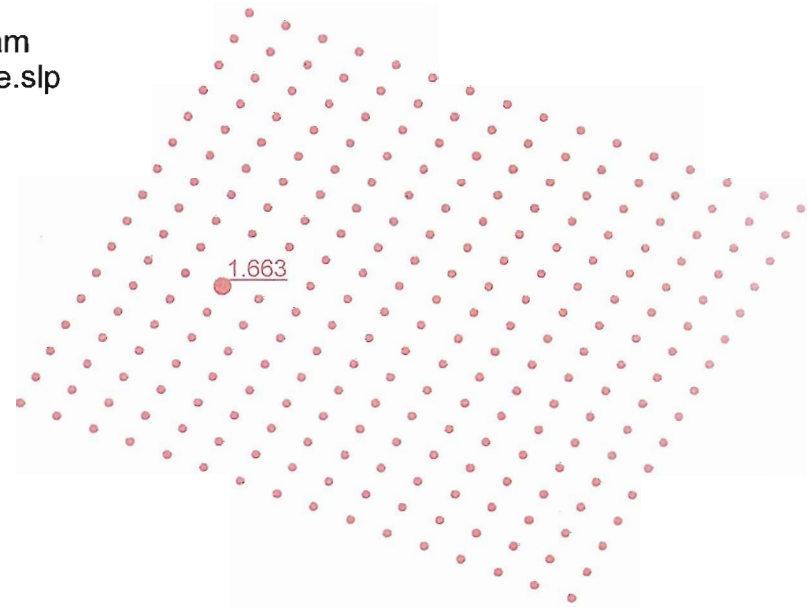


APPENDIX D

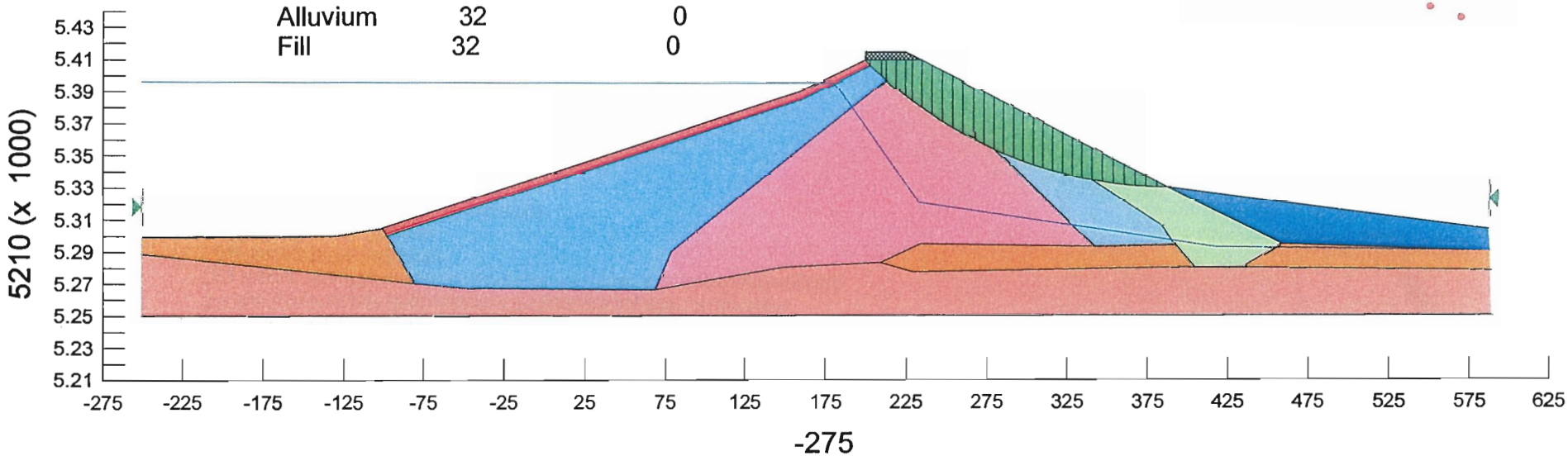
RAISE OPTIONS STABILITY ANALYSIS RESULTS

5-Foot Raise Downstream slope Upper Embankment : Ruby Dam
File Name: Ruby Max SectionT3SSUpper Embankment 5ft raise.slp
Last Saved Date: 9/5/2007
Last Saved Time: 1:50:29 PM
Analysis Method: Spencer
P.W.P. Option: Piezometric Lines / Ru
Seismic Coefficient:none: (none)



Soil Strengths Used For Analysis

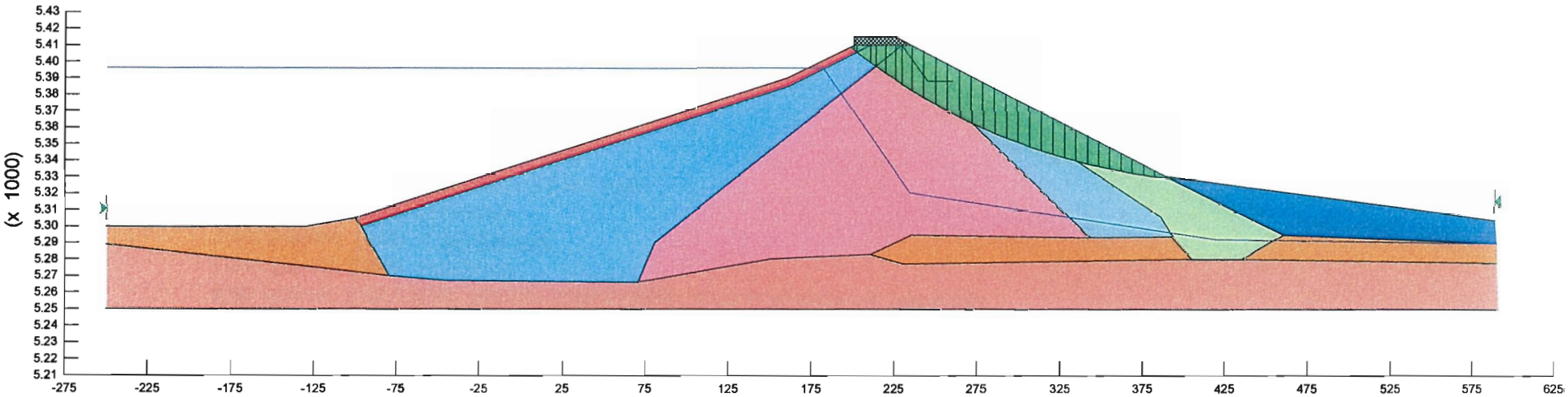
Zone	Phi(degrees)	C(psf)
A	25	200
B	25	200
C	38	0
D	45	0
Alluvium	32	0
Fill	32	0



5-Foot Raise Upper Embankment PseudostaitcYeild : Ruby Dam
File Name: Ruby Max Section5ftraise8-07Upper Embankmentseisy.slp
Last Saved Date: 9/5/2007
Analysis Method: Spencer
Seismic Coefficient: 0.22 : Horizontal

Soil Strengths Used For Analysis

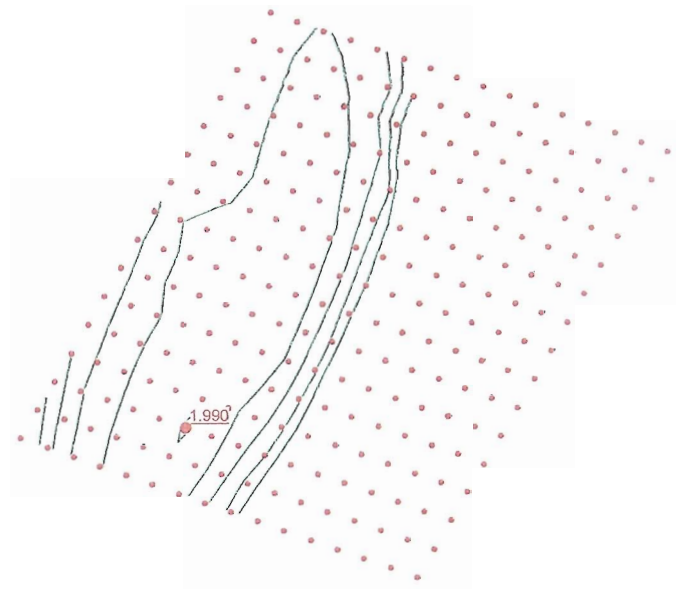
Zone	Phi(degrees)	C(psf)
A	22	200
B	22	200
C	35	0
D	41	0
Alluvium	29	0
Fill	32	0

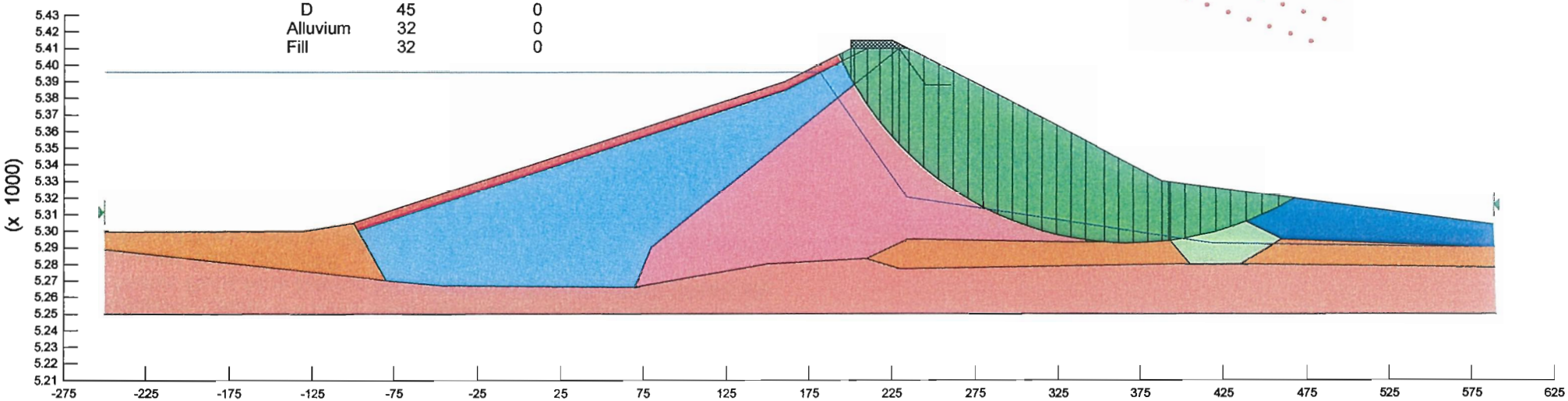


5-Foot Raise Max section : Ruby Dam
File Name: Ruby 5-foot raise max embankment T3SSFnl.slp
Last Saved Date: 9/5/2007
Last Saved Time: 2:00:32 PM
Analysis Method: Spencer
P.W.P. Option: Piezometric Lines / Ru
Seismic Coefficient: none: (none)

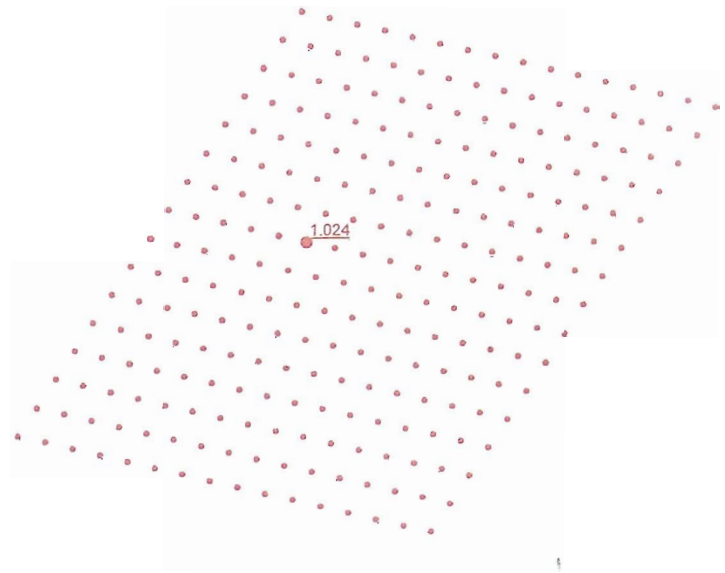
Soil Strengths Used For Analysis

Zone	Phi(degrees)	C(psf)
A	25	200
B	25	200
C	38	0
D	45	0
Alluvium	32	0
Fill	32	0



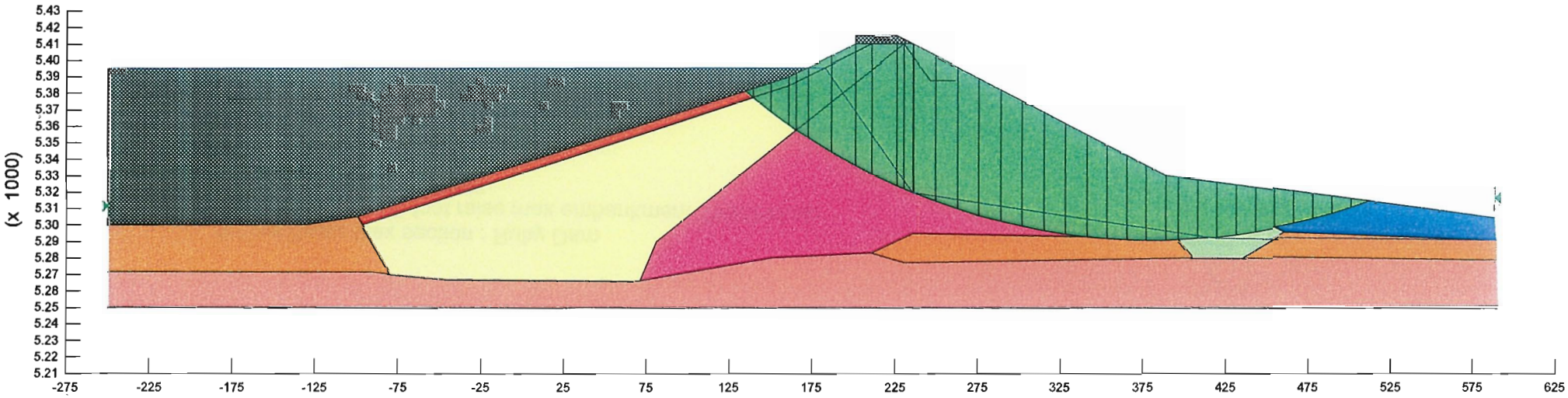


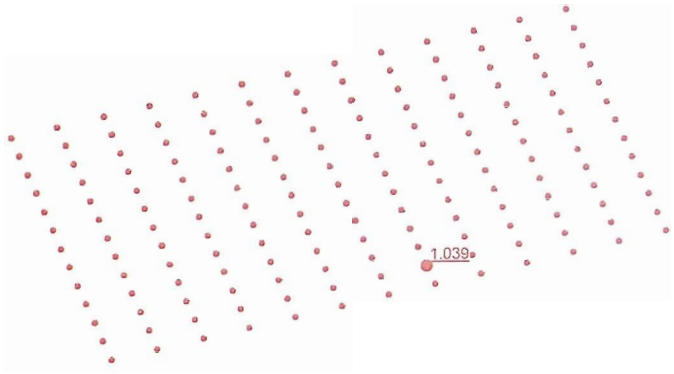
Downstream Slope 5 ft raise Yield Accleration Determination : Ruby Dam
File Name: Ruby Max SectionT4downstream 5-ft raise Fnl2-08seis.slp
Last Saved Date: 2/5/2008
Last Saved Time: 1:07:11 PM
Analysis Method: Spencer
Seismic Coefficient=.18: Horizontal



Soil Strengths Used For Analysis

Zone	Phi(degrees)	C(psf)
A	22	180
A2	14.4	186
B	22	180
B2	14.4	186
C	35	0
D	35	0
Alluvium	29	0
Fill	32	0

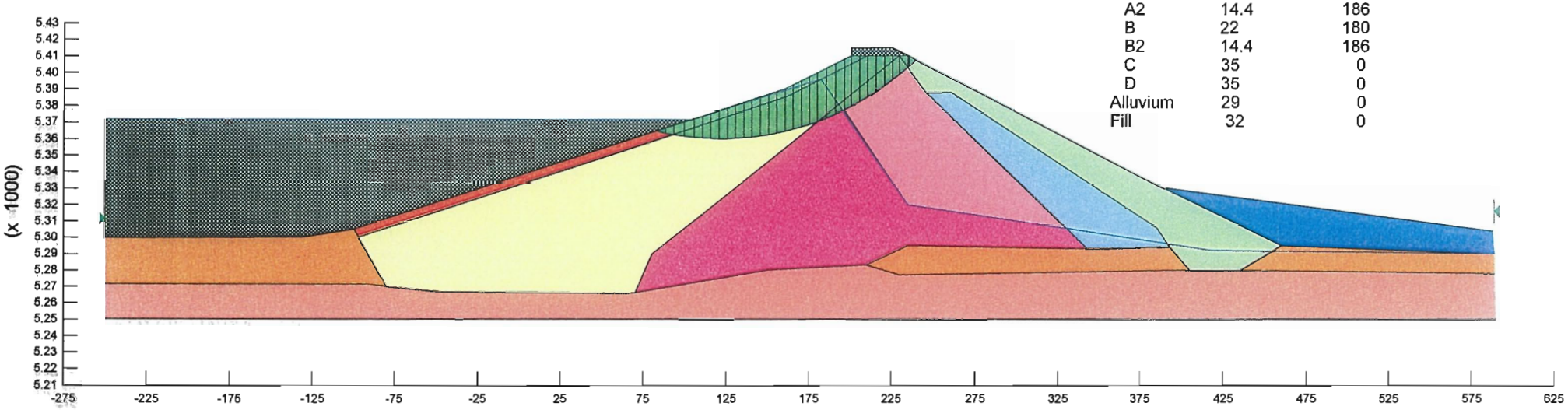




5 ft raise Yield Accleration Determination : Ruby Dam
File Name: Ruby 5-ft raise upstream yield2 2-08seis.slp
Last Saved Date: 2/5/2008
Last Saved Time: 12:27:55 PM
Analysis Method: Spencer
Seismic Coefficient=.18: Horizontal

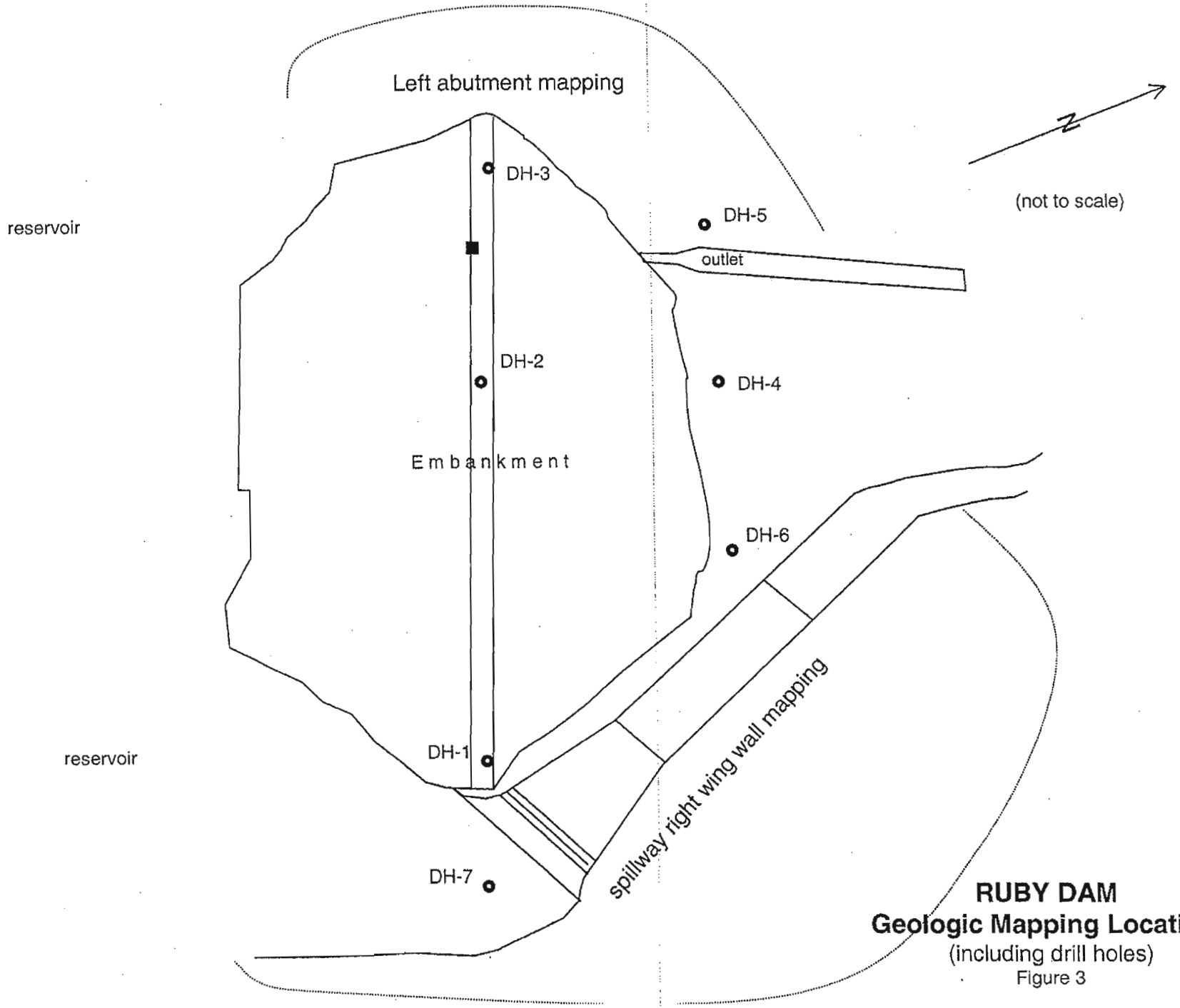
Soil Strengths Used For Analysis

Zone	Phi(degrees)	C(psf)
A	22	180
A2	14.4	186
B	22	180
B2	14.4	186
C	35	0
D	35	0
Alluvium	29	0
Fill	32	0



APPENDIX E

DNRC BORING LOGS AND MONITORING WELL DATA



RUBY DAM
Geologic Mapping Locations
(including drill holes)
Figure 3

SOIL LOG OF BOREHOLE NO: DH1

MT DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR : Ruby
DATE STARTED : 10/23/1999
DATE COMPLETED : 10/28/1999
DRILL COMPANY : Bush Drilling
DRILLER : .

DRILL RIG : Track B53
DRILLING METHOD : Auger/Coring
SAMPLING METHOD : Split Spoon
LOGGED BY : Bob Arrington
APPROVED BY : Kevin Smith

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 5410.1	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
0	5410		0 to 2' SILTY GRAVEL WITH SAND, 2 to 6 inch cobbles, light brown	GM								
			2 to 20' SILTY SAND, with gravel, brown, slightly moist, low plasticity fines									
5	5405											
10	5400	X		SM		SS	10 11 12	22	14.4/18	80%		
15	5395	X				SL	10 14 17	22	18/18	100%		% Finer #200 = 22% m = 9.2%
20	5390	X	20 to 30' CLAYEY SAND, some rocks/gravel, brown to tan, slightly moist.			SS	11 12 12	19	18/18	100%		% Finer # 200 = 49% LL=38% PL=22% PI-16% (Lean Clay, CL) m = 11.2%
25	5385	X		SC		SL	7 6 5	7	16.8/18	93%		% Finer #200 = 29% m = 10.5% dry unit weight = 105.4 pcf moist unit weight = 116.4 pcf
		X				SS	5 13 7	15	15/18	83%		
30												

Core descriptions reviewed and relogged by C. Stiles 2/2/2005.

Hollow Stem Auger 4 1/2"
Core Barrel HQ3
Hammer 140 lbs 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

Logs\Ruby Logs\Ruby DH-1 Soil.bor

SOIL LOG OF BOREHOLE NO: DH1

MT DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: Track B53
DATE STARTED	: 10/23/1999	DRILLING METHOD	: Auger/Coring
DATE COMPLETED	: 10/28/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Bob Arrington
DRILLER	:	APPROVED BY	: Kevin Smith

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 5410.1	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
30	5380	X	30 to 55' METAMORPHIC, dolomitic marble At 30 to 37' very weathered, brown, many small pieces with sand, scattered chert fragments			SS	15 12 4	11	10.8/18	60%		30' Bedrock Stopped augering, begin coring. 30 to 37' Cored 7' Recovered 2.3' 33% RQD = 0 Fractures/ft = rubbly
35	5375		At 37 to 39.4' weathered, tan, oxidized single fracures at 37.4' and 38.6' multiple fractures at 39.3 to 40'									37 to 39.4' Cored 3.4 ' Recovered 3.4' 100% RQD = 46% Fractures/ft = 1 to 3+
40	5370		At 39.4 to 45' dolomitic marble with cherty and siliceous "clots" (possibly remobilized SiO2), competent, greenish white, several single fractures Lots of fluid movement along fractures, healing and cementing fractures.	ME								40.4 to 47' Cored 6.6' Recovered 6.6 ' 100% RQD = 73% Fractures/ft = 0 to 2 44.5' Fracture at 35 degrees to core axis
45	5365		At 45 to 55' whitish with some orange and gray, very competent, 5 single fractures									46.3' Fracture at 35 degrees to core axis 47 to 55' Cored 8' Recoverd 8' 100% RQD = 96% Fracture/ft = 0 to 1
50	5360											48.8' Fractures filled with calcite and silica at 55 degrees to core axis
55	5355		55 BOTTOM OF HOLE									Refer to the digital photos in project file.
60												

Hollow Stem Auger 4 1/2"
Core Barrel HQ3
Hammer 140 lbs 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

Core descriptions reviewed and relogged by C. Stiles 2/2/2005.

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WELL COMPLETION LOG NO: DH1

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: Track B53
DATE STARTED	: 10/23/1999	DRILLING METHOD	: Auger/Coring
DATE COMPLETED	: 10/28/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Bob Arrington
DRILLER	:	APPROVED BY	: Kevin Smith

Depth In Feet | Surf. Elev. 5410.1

0 — 5410
5 — 5405
10 — 5400
15 — 5395
20 — 5390
25 — 5385
30 — 5380
35 — 5375
40 — 5370
45 — 5365
50 — 5360
55

Well Construction Information

WELL CONSTRUCTION

Date Compl.	: 10/28/1999
Hole Diameter	: 8 inch
DNRC Rep.	: Tim Kuehn

STANDPIPE

Material	: PVC pipe
Diameter	: 1 inch
Joints	: screwed
Bottom Cap	: glued

WELL SCREEN

Material	: PVC pipe
Diameter	: 1 inch
Length	: 5 feet
Opening	: .02 inch

SAND PACK

Material	: Colorado Silica 10/20

ANNULUS

Material	: 3/8 inch Bentonite

WELL COVER

Diameter	: 7 inch
Length	: 5 feet

NOTES:

Surface Elev: 5410.1 feet

DH1A TOP Elev: 5410.15 feet

DH1B TOP Elev: 5410.25 feet

Top of Cover Elev: 5410.38 feet

Northing: 10157.96

Easting: 9840.28

Surveyed By: Mike Lesnik

Date Surveyed: 4/2000

DESCRIPTION

0 to 5 SAND

0 to 2 silty gravel with sand

5 to 16 BENTONITE

2 to 20 silty sand

16 to 25 SAND

19 to 24 SCREEN FOR DH1B

25 to 42 BENTONITE

20 to 30.5 clayey sand
30.5 to 37 very weathered bedrock
37 to 52 competent bedrock

42 to 51 SAND

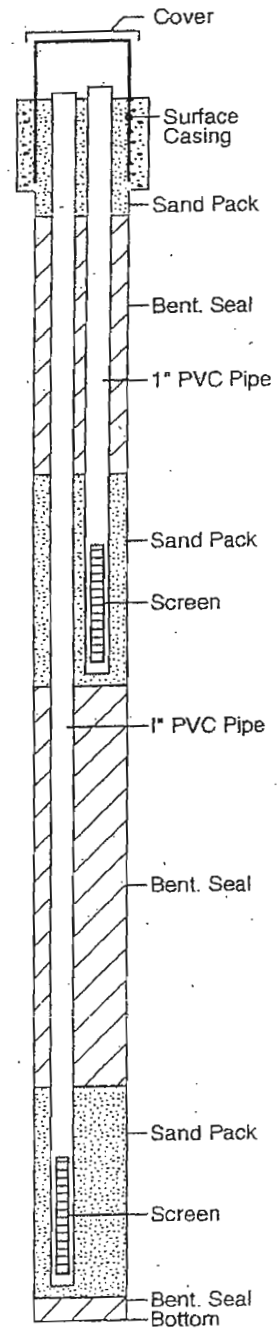
45 to 50 SCREEN FOR DH1A

51 to 52 BENTONITE

52 BOTTOM OF HOLE

Depth In Feet: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55

Standpipe1: DH-1A
Standpipe2: DH-1B



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SOIL LOG OF BOREHOLE NO: DH2

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: Drilltech DK25/Track B53
DATE STARTED	: 10/11/1999	DRILLING METHOD	: Air Rotary ODEX/Coring
DATE COMPLETED	: 10/21/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Warren/Uthman/Azevedo
DRILLER	:	APPROVED BY	: Kevin Smith

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube
SP Pushed 5' Split Spoon

Depth in Feet	Surf. Elev. 5410.6	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count (blows/foot)	Inches Recoverd Inches Driven.	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
0	5410		0 to 35' SILTY SAND with gravel, rock fragments, light brown, dense, moist									
5	5405											
10	5400	X				SS	10 24 17	40	6/18	33%		
15	5395	X	At 15' thin layers of clay 3" to 5" thick	SM		SS	13 20 25	48	12/18	66%		
20	5390	X				SL	8 12 12	17	9/18	50%		
25	5385	X				SS	9 7 15	17	6/18	33%		% Finer # 200 = 25% % Sand = 56% m = 10.42%
30	5380	X				SS	9 12 12	18	9/18	66%		
35												

Hollow Stem Auger 4 1/2" ID
Core Barrel HQ3
Hammer 140 lbs 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

Core descriptions reviewed and relogged by C. Stiles 2/2/2005.

SOIL LOG OF BOREHOLE NO: DH2

MT DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: Drilltech DK25/Track B53
DATE STARTED	: 10/11/1999	DRILLING METHOD	: Air Rotary ODEX/Coring
DATE COMPLETED	: 10/21/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Warren/Uthman/Azevedo
DRILLER	:	APPROVED BY	: Kevin Smith

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube
SP Pushed 5' Split Spoon

Depth in Feet	Surf. Elev. 5410.6	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
35	5375	X	35 to 51' CLAYEY SAND, with small angular rock fragments, brown, moist, medium dense			SL	5 12 27	21	12/18	66%		
40	5370	X		SC		SS	5 5 8	8	12/18	66%		
45	5365	X				SS	7 12 15 15	16	0/24	0%		
50	5360	X	51 to 55' SANDY LEAN CLAY, with rock fragments, greenish grey, moist,	CL		ST						At 51 to 53.5' -- Shelby Tube dry unit weight = 107 pcf wet unit weight = 127 pcf CU Test: c=302 psf, phi=16.9 Eff: c=219 psf, phi=32.6 % Finer #200 = 56% e = 0.55 m = 18.1 %
55	5355	X	55 to 63' CLAYEY SAND with gravel, brown, moist	SC		SS	7 15 12	15	12/18	66%		At 55 to 56.5' % Finer #200 = 28% % Sand = 55% LL = 31% PL = 21% PI = 10% m = 14.3% At 55' -- Cuttings begin to clog up. Begin adding water to air.
60	5350	X				SS	7 9 11	10	12/18	66%		
65	5345	X	63 to 120' SANDY LEAN CLAY with some gravel, brown to gray, moist, stiff to very stiff	CL		SL	10 13 17	13	12/18	66%		
70												

Hollow Stem Auger 4 1/2" ID
Core Barrel HQ3
Hammer 140 lbs 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

Core descriptions reviewed and relogged by C. Stiles 2/2/2005.

SOIL LOG OF BOREHOLE NO: DH2

MT DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: Drilltech DK25/Track B53
DATE STARTED	: 10/11/1999	DRILLING METHOD	: Air Rotary ODEX/Coring
DATE COMPLETED	: 10/21/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Warren/Uthman/Azevedo
DRILLER	:	APPROVED BY	: Kevin Smith

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube
SP Pushed 5' Split Spoon

Depth in Feet	Surf. Elev. 5410.6	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
70	5340	☒	SANDY LEAN CLAY			SS	8 15 18	16	12/18	66%		
75	5335	☒				SS	11 17 30	22	12/18	66%		% Finer #200 = 57% % Sand = 37% dry unit weight = 112.6 pcf m = 16.2% Pinhole Dispersion = ND1
80	5330	☒				SL	9 12 12	9	0/18	0%		
85	5325	☒	At 85 to 91' Intermittent cobble lenses.	CL		SL	9 17 25	15	14/18	78%	2.7	At 85' Sampler wet % Finer #200 = 66% dry unit weight = 94.7 pcf wet unit weight = 116.3 pcf m = 22.7% Torvane = 3.0 tons/sf
90	5320	☒				SS	7 18 17	15	12/18	66%	2.2	
95	5315	☒				SL	24 30 42	25	6/18	33%		Torvane = 1.5 tons/sf
100	5310											
105												

Hollow Stem Auger 4 1/2" ID
Core Barrel HQ3
Hammer 140 lbs 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

Core descriptions reviewed and relogged by C. Stiles 2/2/2005.

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SOIL LOG OF BOREHOLE NO: DH2

MT DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: Drilltech DK25/Track B53
DATE STARTED	: 10/11/1999	DRILLING METHOD	: Air Rotary ODEX/Coring
DATE COMPLETED	: 10/21/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Warren/Uthman/Azevedo
DRILLER	:	APPROVED BY	: Kevin Smith

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube
SP Pushed 5' Split Spoon

Depth in Feet	Surf. Elev. 5410.6	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
105	5305		SANDY LEAN CLAY	CL		ST			14/14	100%		Sample 108' % Finer # 200 = 50% % Sand = 44% LL = 39% PL = 20% PI = 19% m = 18.6 %
						SP				100%	*	
110	5300											At 106.3 to 108.9' * PP = 4.25, 3.0, 2.75, +4.5 tons/sf
						SP				100%		At 108.9 to 111.3' * PP = 2.25, 3.0, 3.75, 3.85 tons/sf
115	5295											At 115.5 to 119.5' * PP = 3.7, 4.0, 4.5+, 4.5+ tons/sf
						SP				100%	*	
120	5290		120 to 132.5' WELL GRADED GRAVEL with sand, brown, wet	GW		SP				80%		Sample 123.4 to 124.7 % Sand = 27% % Finer #200 = 5%
125	5285					SP				71%		
130	5280					SP				79%		Sample 130.4 to 131.4' % Sand = 25% % Finer #200 = 2.5%
			132.5 to 156' METAMORPHIC, dolomitic marble, coarse grained At 135 to 150.5' hard, competent, mottle colors include orange, green, white, brown, and pink. Fractures healed with silica, FeOx, and calcite	ME								132.5' Bedrock Contact
135	5275											135' Stopped ODEX, started coring 135 to 145.5' Cored 10.5' Recovered 10' 95% RQD = 64% Factures/ft = 1 to 2
140												

Hollow Stem Auger 4 1/2" ID
Core Barrel HQ3
Hammer 140 lbs 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

Core descriptions reviewed and relogged by C. Stiles 2/2/2005.

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SOIL LOG OF BOREHOLE NO: DH2

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: Drilltech DK25/Track B53
DATE STARTED	: 10/11/1999	DRILLING METHOD	: Air Rotary ODEX/Coring
DATE COMPLETED	: 10/21/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Warren/Uthman/Azevedo
DRILLER	:	APPROVED BY	: Kevin Smith

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube
SP Pushed 5' Split Spoon

Depth in Feet	Surf. Elev. 5410.6	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
140	5270		At 141 to 141.6' broken zones At 143 to 143.6' broken zones									
145	5265		At 145.5 to 156' mostly competent, several fracture zones at 153.9' and 155.5'	ME								145.5 to 156' Cored 10.5' Recovered 10.2' 97% RQD = 82% Generally < 1 fracture/ft Fractures at 20 degrees to core axis
150	5260		At 150.5 to 156' same marble but more FeOx throughout rock. Silica - FeOx fracture filling at 150.5'									
155	5255											Refer to the digital photos in project file.
			156 BOTTOM OF HOLE									
160	5250											
165	5245											
170	5240											
175												

Hollow Stem Auger 4 1/2" ID
Core Barrel HQ3
Hammer 140 lbs 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

Core descriptions reviewed and relogged by C. Stiles 2/2/2005.

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WELL COMPLETION LOG NO: DH2

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: Drillteck DK25/Track B53
DATE STARTED	: 10/11/1999	DRILLING METHOD	: Air Rotary ODEX/Coring
DATE COMPLETED	: 10/21/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Warren/Uthman/Azevedo
DRILLER	:	APPROVED BY	: Kevin Smith

Depth In Feet | Surf. Elev. 5410.6

0 5410, 5 5405, 10 5400, 15 5395, 20 5390, 25 5385, 30 5380, 35 5375, 40 5370, 45 5365, 50 5360, 55 5355, 60 5350, 65 5345, 70 5340, 75 5335, 80 5330, 85 5325, 90 5320, 95 5315, 100 5310, 105 5305, 110 5300, 115 5295, 120 5290, 125 5285, 130 5280, 135 5275, 140 5270, 145 5265, 150 5260, 155 5255, 160

Well Construction Information

WELL CONSTRUCTION

Date Compl.	: 10/15/1999
Hole Diameter	: 7 inch
DNRC Rep.	: Uthman/Arrington

STANDPIPE

Material	: PVC pipe
Diameter	: 1 inch
Joints	: screwed
Bottom Cap	: glued

WELL SCREEN

Material	: PVC Pipe
Diameter	: 1 inch
Length	: 5 feet
Opening	: .02 inch

SAND PACK

Material	: Colorado Silica 10/20

ANNULUS

Material	: 3/8 inch Bentonite

WELL COVER

Diameter	: 7 inch
Length	: 5 feet

NOTES:

Surface Elev: 5410.62 feet

DH2A TOP Elev: 5410.85 feet

DH2B TOP Elev: 5410.97 feet

DH2C TOP Elev: 5411.08 feet

Top of Cover Elev: 5411.17 feet

Northing: 10621.27

Easting: 9967.06

Surveyed By: Mike Lesnik

Date Surveyed: 4/2000

DESCRIPTION

0 to 5 SAND

5 to 90 BENTONITE

90 to 100 SAND

93 to 98 SCREEN FOR DH2C

100 to 118 BENTONITE

118 to 128 SAND

122 to 127 SCREEN FOR DH2B

128 to 137 BENTONITE

137 to 150 SAND

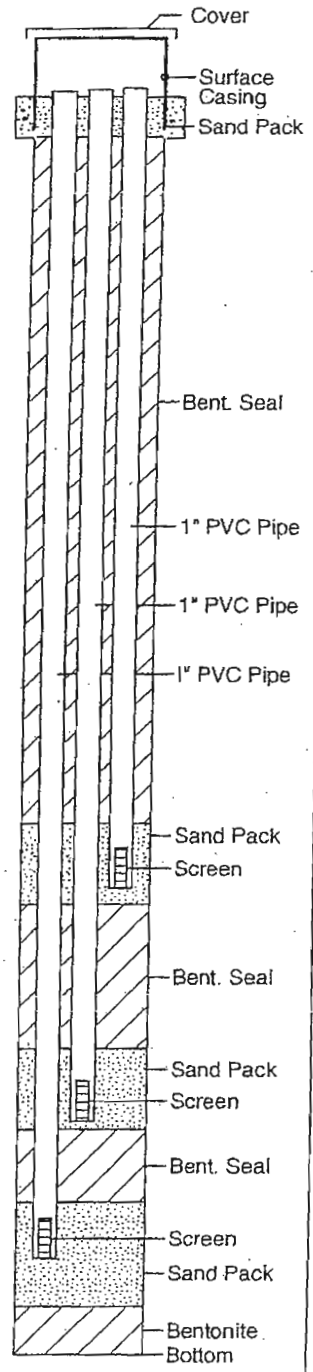
139 to 144 SCREEN FOR DH2A

150 to 156 BENTONITE

156 BOTTOM OF HOLE

Depth In Feet: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105, 110, 115, 120, 125, 130, 135, 140, 145, 150, 155, 160

Standpipe1: DH-2A
Standpipe2: DH-2B
Standpipe3: DH-2C



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SOIL LOG OF BOREHOLE NO: DH3

MT DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: Drilltech DK25/Track B53
DATE STARTED	: 10/6/1999	DRILLING METHOD	: Air Rotary ODEX/Coring
DATE COMPLETED	: 10/15/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Kirk Warren/Rob Kingery
DRILLER	:	APPROVED BY	: Kevin Smith

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 5410	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
0	5410		0 to 10 ODEX - no samples taken, light brown Estimated: 0 to 3 SILTY GRAVEL WITH SAND 3 to 10 SILTY SAND	GM								
5	5405											
10	5400	X	10 to 15 SILTY SAND some broken rock fragments 1/4" to 1 1/2", light brown, moist, low plasticity	SM		SS	25 17 14	30	7/18	40%		
15	5395	X	15 to 20 SILTY CLAY some rocks fragments, brown, very dense, moist 16.5 to 18.5' large rock(s)	SC		SS	34 44 27	55	9/18	50%		
20	5390		20 to 32.4 CLAY At 20 to 27.5' gray brown with some rust coloered areas, soft to stiff, moist, some fine sand	CL								20' stopped ODEX, begin coring. 20 to 27.5' Cored 7.5' Recovered 3' 40%
25	5385		At 27.5 to 32.4 brown, soft to medium stiff, moist, sandy with trace of gravel. At bottom of core, weathered granitic-like rock.									27.5 to 32.4' Cored 4.9' Recovered 1.2' 24%
30	5380		32.4 to 67.5 METAMORPHIC, dolomitic marble	ME								32.5' Bedrock contact 32.4 to 37.5' Cored 5' Recovered 5' 100% RQD = 42% Fractures/ft = >2 to rubble
35			At 32.4 to 36.5' oxidized, fractured									

Hollow Stem Auger 4 1/2"
Core Barrel HQ3
Hammer 140 lbs 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

Core descriptions reviewed and relogged by C. Stiles 2/2/2005.

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SOIL LOG OF BOREHOLE NO: DH3

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: Drilltech DK25/Track B53
DATE STARTED	: 10/6/1999	DRILLING METHOD	: Air Rotary ODEX/Coring
DATE COMPLETED	: 10/15/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Kirk Warren/Rob Kingery
DRILLER	:	APPROVED BY	: Kevin Smith

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 5410	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
35	5375		METAMORPHIC At 36.5 to 39' silicified zone, fine grained silica FeOx chert like									37.5 to 47.5' Cored 10' Recovered 10' 100% RQD = 89%' Fracture common at 50 degrees to core axis. Fractures/ft = 1
40	5370		At 39 to 51.5' coarse grained, fresh, competent, dolomitic marble (white/black mottled and tan to redish brown)									
45	5365											47.5 to 57.5' Cored 10' Recovered 10' 100% RQD = 94% Fractures/ft = 1 to 2
50	5360		At 51.5 to 67.5' medium grained, light brown to yellow brown, oxidized, dolomitic marble with scattered solution cavities 1" to 3" in length	ME								
55	5355		At 57.5 to 67.5' granitic texture, competent, light gray, moderaterly fractured									57.5 to 67.5' Cored 10' Recovered 9.7' 97% RQD = 77% Fractures/ft = 1
60	5350											62 to 62.1 Lost circulation
65	5345											Refer to the digital photos in project file.
70			67.5 BOTTOM OF HOLE									

Hollow Stem Auger 4 1/2"
Core Barrel HQ3
Hammer 140 lbs 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

Core descriptions reviewed and relogged by C. Stiles 2/2/2005.

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WELL COMPLETION LOG NO: DH3

MT DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: Drilltech DK25/Track B53
DATE STARTED	: 10/6/1999	DRILLING METHOD	: Air Rotary ODEX/Coring
DATE COMPLETED	: 10/15/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Kirk Warren/Rob Kingery
DRILLER	:	APPROVED BY	: Kevin Smith

Depth In Feet | Surf. Elev. 5410

Well Construction Information

WELL CONSTRUCTION

Date Compl.	: 10/15/1999
Hole Diameter	: 7 inch
DNRC Rep.	: Rob Kingery

STANDPIPE

Material	: PVC pipe
Diameter	: 1 inch
Joints	: screwed
Bottom Cap	: glued

WELL SCREEN

Material	: Piezometer - Sparge Point
Diameter	: 1 inch
Length	: 19.5 inches
Opening	: porus plastic-hydrophobic

SAND PACK

Material	: Colorado Silica 10/20

ANNULUS

Material	: 3/8 inch Bentonite

WELL COVER

Diameter	: 7 inch
Length	: 5 feet

NOTES:

Surface Elev: 5410.0 feet

DH3A TOP Elev: 5410.07 feet

DH3B TOP Elev: 5410.27 feet

Top of Cover Elev: 5410.36 feet

Northing: 10893.71

Easting: 10035.14

Surveyed By: Mike Lesnik

Date Surveyed: 4/2000

DESCRIPTION

0 to 6.1 SAND

6.1to 21.7 BENTONITE

21.7 to 28.8 SAND

25.4 to 26.8 PIEZOMETER - DH3B

28.8 to 35.9 BENTONITE

35.9 to 44.6 SAND

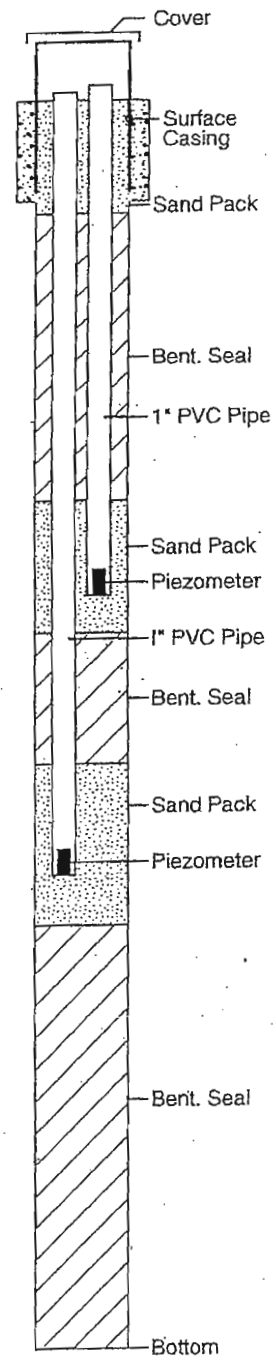
40.5 to 41.9 PIEZOMETER - DH3A

44.6 to 67.5 BENTONITE

67.5 BOTTOM OF HOLE

Depth In Feet

Standpipe1: DH-3A
Standpipe2: DH-3B



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SOIL LOG OF BOREHOLE NO: DH4

MT DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR : Ruby
DATE STARTED : 10/25/1999
DATE COMPLETED : 10/29/1999
DRILL COMPANY : Bush Drilling
DRILLER :

DRILL RIG : D366/Drilltech DK25
DRILLING METHOD : Auger/Air Rotary ODEX
SAMPLING METHOD : Split Spoon
LOGGED BY : Uthman/Kuehn
APPROVED BY : Kevin Smith

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 5327.4	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
0	5327		0 to 6.5 SILTY SAND with gravels and cobbles, broken cobble in coarse sand/rock fragment matrix, moist, light brown	SM								0 to 8' Auguer drilling – rocky, difficult drilling.
5	5322	X				SS	15 30 20	68	12/18	66%		% Sand = 44% % Finer #200 = 15%
		X	6.5 to 45 GRAVEL with sand, rockdust with broken rockchips, buff colored, dry, low plasticity			SS	21 34 36	76	12/18	66%		8 to 82' ODEX drilling Appear to be in river cobbles.
10	5317											
15	5312			GW								
20	5307	X				SS	5 21 29 20	39	9/18	50%		
25	5302											
30												

Hollow Stem Auger 4 1/2"
Core Barrel HQ3
Hammer 140 lbs 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

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SOIL LOG OF BOREHOLE NO: DH4

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: D366/Drilltech DK25
DATE STARTED	: 10/25/1999	DRILLING METHOD	: Auger/Air Rotary ODEX
DATE COMPLETED	: 10/29/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Uthman/Kuehn
DRILLER	:	APPROVED BY	: Kevin Smith

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 5327.4	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
30	5297	☒				SS	14 50		5/12	40%		
												At 33' Hole becoming wet
35	5292			GW								
40	5287	☒				SS	6 50		0/6	0%		
45	5282		45 to 82 BEDROCK (estimated) METAMORPHIC, dolomitic marble									At 45' area increasingly hard drilling.
50	5277			ME								At 50' Did not attempt sampling due to hard drilling.
55	5272											
60												

Hollow Stem Auger 4 1/2"
Core Barrel HQ3
Hammer 140 lbs 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

SOIL LOG OF BOREHOLE NO: DH4

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: D366/Drilltech DK25
DATE STARTED	: 10/25/1999	DRILLING METHOD	: Auger/Air Rotary ODEX
DATE COMPLETED	: 10/29/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Uthman/Kuehn
DRILLER	:	APPROVED BY	: Kevin Smith

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 5327.4	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
60	5267	☒				SS	50		0/0	0%		
65	5262											
70	5257			ME								At 70' Drill chips are dark colored rocks not indicative of bedrock
75	5252											
80	5247											
			82 BOTTOM OF HOLE									
85	5242											
90												

Hollow Stem Auger 4 1/2"
Core Barrel HQ3
Hammer 140 lbs 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

WELL COMPLETION LOG NO: DH4A

MT DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: Track B53/Drilliteck DK25
DATE STARTED	: 10/25/1999	DRILLING METHOD	: Auger/Air Rotary ODEX
DATE COMPLETED	: 10/29/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Uthman/Kuehn
DRILLER	:	APPROVED BY	: Kevin Smith

Depth In Feet | Surf. Elev. 5327.4

0 – 5327
5 – 5322
10 – 5317
15 – 5312
20 – 5307
25 – 5302
30 – 5297
35 – 5292
40 – 5287
45 – 5282
50 – 5277
55 – 5272
60 – 5267
65 – 5262
70 – 5257
75 – 5252
80 – 5247
85

Well Construction Information

WELL CONSTRUCTION

Date Compl.	: 10/29/1999
Hole Diameter	: 8 inch
DNRC Rep.	: Tim Kuehn

STANDPIPE

Material	: PVC pipe
Diameter	: 1 inch
Joints	: screwed
Bottom Cap	: glued

WELL SCREEN

Material	: PVC pipe
Diameter	: 1 inch
Length	: 5 feet
Opening	: .02 inch

SAND PACK

Material	: Colorado Silica 10/20

ANNULUS

Material	: 3/8 inch Bentonite

WELL COVER

Diameter	: 7 inch
Length	: 5 feet

NOTES:

Surface Elev: 5327.41 feet

DH4A TOP Elev: 5327.63 feet

Top of Cover Elev: 5328.14 feet

Northing: 10575.09

Easting: 10144.81

Surveyed By: Mike Lesnik

Date Surveyed: 4/2000

DESCRIPTION

0 to 5 SAND

5 to 36 BENTONITE

36 to 53 HOLE CAVED

Bentonite bridged in ODEX casing around 53 feet. Pulled casing, hole caved to 36 feet.

53 to 63 BENTONITE

63 to 75 SAND

69 to 74 SCREEN FOR DH4A

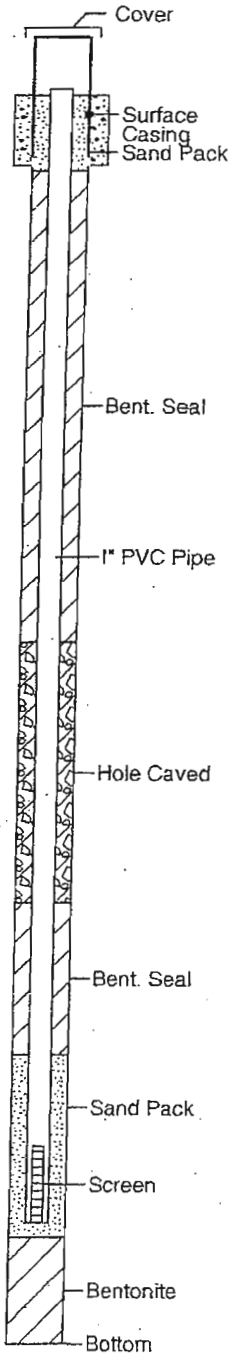
75 to 82 BENTONITE

82 BOTTOM OF HOLE

Depth In Feet

0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85

Standpipe: DH-4A



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WELL COMPLETION LOG NO: DH4B

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: Drilltech DK25
DATE STARTED	: 10/30/1999	DRILLING METHOD	: Air Rotary ODEX
DATE COMPLETED	: 10/31/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Bob Arrington
DRILLER	:	APPROVED BY	: Kevin Smith

Depth In Feet | Surf. Elev. 5327.4

0 – 5327
5 – 5322
10 – 5317
15 – 5312
20 – 5307
25 – 5302
30 – 5297
35 – 5292
40 – 5287
45 – 5282
50

Well Construction Information

WELL CONSTRUCTION

Date Compl.	: 10/31/1999
Hole Diameter	: 8 inch
DNRC Rep.	: Bob Arrington

STANDPIPE

Material	: PVC pipe
Diameter	: 1 inch
Joints	: screwed
Bottom Cap	: glued

WELL SCREEN

Material	: PVC pipe
Diameter	: 1 inch
Length	: 5 feet
Opening	: .02 inch

SAND PACK

Material	: Colorado Silica 10/20

ANNULUS

Material	: 3/8 inch Bentonite

WELL COVER

Diameter	: 7 inch
Length	: 5 feet

NOTES:

Surface Elev: 5327.41 feet

DH4B TOP Elev: 5327.93 feet

Top of Cover Elev: 5328.26 feet

Northing: 10575.09

Easting: 10144.81

Surveyed By: Mike Lesnik

Date Surveyed: 4/2000

DESCRIPTION

0 to 5 SAND

5 to 34.7 BENTONITE

34.7 to 45 SAND

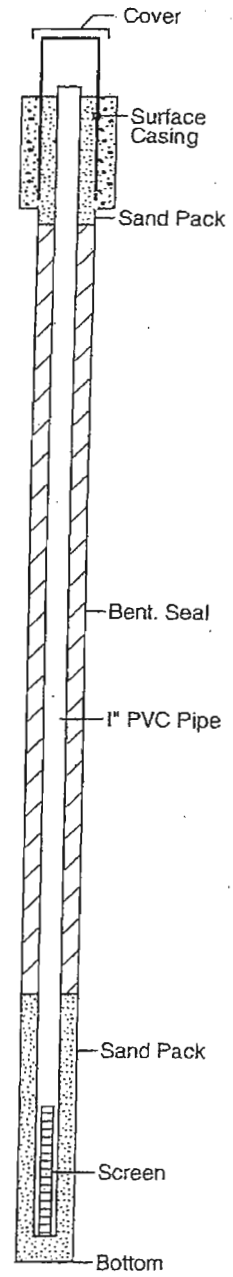
39 to 44 SCREEN FOR DH4B

45 BOTTOM OF HOLE

Depth In Feet

0
5
10
15
20
25
30
35
40
45
50

Standpipe: DH-4B



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SOIL LOG OF BOREHOLE NO: DH5

MT DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: Track B53
DATE STARTED	: 10/18/1999	DRILLING METHOD	: Auger/Coring
DATE COMPLETED	: 10/19/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Uthman/Kuehn
DRILLER	:	APPROVED BY	: Kevin Smith

SAMPLER TYPE
- SS Split spoon
- SL Split Spoon Brass Liners
- ST Shelby Tube

Depth in Feet	Surf. Elev. 5328	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
0	5328		0 to 6.5 SANDY LEAN CLAY with small pebbles and rock fragments, moist, brown	CL								
5	5323	☒				SS	29 38 50		12/12	100%		% Sand = 38% % Finer #200 = 60% 5' Stopped augering, begin coring 5 to 10' Cored 5' Recoverd 4' 80% RQD = 6%
			6.5 to 32.5 METAMORPHIC, dolomitic marble, white, gray, and tan,	ME								
10	5318		At 6.5 to 10' weathered bedrock, largely fractured and rubbly.									10 to 17' Cored 7' Recoverd 6.6' 95% RQD = 59% Fractures/ft = approx 3
			At 7' vertical fracture									
15	5313		Other fracture orientations at 30 degrees, 40 degrees, and 65 degrees to core axis throughout hole.									17 to 27' Cored 10' Revoverd 6.75' 68% RQD = 20% Fractures/ft = rubbly to 3+
20	5308											
												23.5' Lost circulation
25	5303											
												27 to 32.5' Cored 5' Recoverd 3' 60% RQD = 47% Fractures/ft = 1 to 3
30	5298											
												Refer to the digital photos in project file.
35			32.5 BOTTOM OF HOLE									

Hollow Stem Auger 4 1/2"
Core Barrel HQ3
Hammer 140 lb 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

Core descriptions reviewed and relogged by C. Stiles 2/2/2005.

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SOIL LOG OF BOREHOLE NO: DH5

MT DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR : Ruby
DATE STARTED : 10/18/1999
DATE COMPLETED : 10/19/1999
DRILL COMPANY : Bush Drilling
DRILLER :

DRILL RIG : Track B53
DRILLING METHOD : Auger/Coring
SAMPLING METHOD : Split Spoon
LOGGED BY : Uthman/Kuehn
APPROVED BY : Kevin Smith

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 5328	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
0	5328		0 to 6.5 SANDY LEAN CLAY with small pebbles and rock fragments, moist, brown	CL								
5	5323	☒				SS	29 38 50		12/12	100%		% Sand = 38% % Finer #200 = 60% 5' Stopped augering, begin coring 5 to 10' Cored 5' Recoverd 4' 80% RQD = 6%
10	5318		6.5 to 32.5 METAMORPHIC, dolomitic marble, white, gray, and tan; At 6.5 to 10' weathered bedrock, largely fractured and rubbly. At 7' vertical fracture Other fracture orientations at 30 degrees, 40 degrees, and 65 degrees to core axis throughout hole.									10 to 17' Cored 7' Recoverd 6.6' 95% RQD = 59% Fractures/ft = approx 3
15	5313											17 to 27' Cored 10' Revoverd 6.75' 68% RQD = 20% Fractures/ft = rubbly to 3+
20	5308			ME								23.5' Lost circulation
25	5303											27 to 32.5' Cored 5' Recoverd 3' 60% RQD = 47% Fractures/ft = 1 to 3
30	5298											Refer to the digital photos in project file.
35			32.5 BOTTOM OF HOLE									

Hollow Stem Auger 4 1/2"
Core Barrel HQ3
Hammer 140 lb 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

Core descriptions reviewed and relogged by C. Stiles 2/2/2005.

G:\WATER_RT\WRB-STAF\Bob A\Well Logs\Ruby Logs\Ruby DH-5 Soil.bor

SOIL LOG OF BOREHOLE NO: DH6

MT DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: D366
DATE STARTED	: 10/26/1999	DRILLING METHOD	: Coring
DATE COMPLETED	: 10/27/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Uthman/Arrington
DRILLER	:	APPROVED BY	: Kevin Smith

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 5308.2	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
0	5308		0 to 12' GRAVELS with sand, silt, cobbles and boulders, brown. This layer is likely fill material.									Started coring from ground surface. 0 to 12' Soil description based on cuttings.
5	5303	☒	At 5' broken angular rocks	GW		SS	2 8 7	21	6/18	33%		
10	5298											
			12 to 19' SILTY SAND, fine to coarse, dark brown, moist. Layer still contains cobbles and boulders.									
15	5293	☒		SM		SS	2 3 5	7	6/18	33%		% Sand = 84% % Finer #200 = 14%
												Lost circulation at 19'
20	5288		19 to 30' GRAVEL, small to medium, well rounded, sand and fines may have been washed away by drilling water									20 to 23' Cored 3' Recovered 1' 33% Rounded gravel/cobbles
												23 to 26' Cored 3' Rounded gravels up to 1.5"
25	5283			GW								26 to 31' Cored 5' Recoverd 1' 20%
30												

Core Barrel HQ3
Hammer 140 lbs 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

Core descriptions reviewed and relogged by C. Stiles 2/2/2005.

08-15-2005 G:\WATER_RT\WRB-STAF\Bob A\Well Logs\Ruby Logs\Ruby DH-6 Soil.bor

SOIL LOG OF BOREHOLE NO: DH6

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: D366
DATE STARTED	: 10/26/1999	DRILLING METHOD	: Coring
DATE COMPLETED	: 10/27/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Uthman/Arrington
DRILLER	:	APPROVED BY	: Kevin Smith

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 5308.2	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
30	5278		30 to 30.5' CLAY, tan 30.5 to 51 METAMORPHIC, dolomitic marble, silicified At 30.5 to 31' weathered bedrock At 31 to 35' numerous fractures At 35 to 40' silicified, dolomitic marble breccia. Hard, with numerous silica coated cavities. Fractures and cavities probably transmit water. At 40 to 51' mostly competent dolomitic marble, with stockwork fractures filled with calcite and silica. Strong fractures between 43 to 44'.	ME								30.5' Bedrock 31 to 35 feet Cored 4' Recoverd 4' 100% RQD = 65% Fractures/ft = 3+ 35 to 45 feet Cored 10' Recovered 9.2' 92% RQD = 67% Fractures/ft = 1 to 2 Calcite and quartz veinlets at 20 to 25 degrees to core axis. 45 to 51 Cored 6' Recovered 6' 100% RQD = 93% Fractures/ft = <1 Refer to the digital photos in project file.
35	5273											
40	5268											
45	5263											
50	5258											
			51 BOTTOM OF HOLE									
55	5253											
60												

Core Barrel HQ3
Hammer 140 lbs 30" drop free-fall hoist
Standard Spoon OD 2.0" ID 1.5"
Brass Liner Spoon OD 2.5" ID 2.0"

Core descriptions reviewed and relogged by C. Stiles 2/2/2005.

09-15-2005 G:\WATER_RT\WRB-STAF\Bob A\Well Logs\Ruby Logs\Ruby DH-6 Soil.bor

WELL COMPLETION LOG NO: DH6

MT DEPARTMENT OF NATURAL
RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: D366
DATE STARTED	: 10/26/1999	DRILLING METHOD	: Coring
DATE COMPLETED	: 10/27/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Uthman/Arrington
DRILLER	:	APPROVED BY	: Kevin Smith

Depth In Feet | Surf. Elev. 5308.2

0 – 5308
5 – 5303
10 – 5298
15 – 5293
20 – 5288
25 – 5283
30 – 5278
35 – 5273
40 – 5268
45 – 5263
50 – 5258
55

Well Construction Information

WELL CONSTRUCTION

Date Compl.	: 10/28/1999
Hole Diameter	: 8 inch
DNRC Rep.	: Tim Kuehn

STANDPIPE

Material	: PVC pipe
Diameter	: 1 inch
Joints	: screwed
Bottom Cap	: glued

WELL SCREEN

Material	: PVC pipe
Diameter	: 1 inch
Length	: 5 feet
Opening	: .02 inch

SAND PACK

Material	: Colorado Silica 10/20

ANNULUS

Material	: 3/8 inch Bentonite

WELL COVER

Diameter	: 7 inch
Length	: 5 feet

NOTES:

Surface Elev: 5308.20 feet

DH6A TOP Elev: 5308.21 feet

DH6B TOP Elev: 5308.35 feet

Top of Cover Elev: 5308.57 feet

Northing: 10302.32

Easting: 10134.29

Surveyed By: Mike Lesnik

Date Surveyed: 4/2000

DESCRIPTION

0 to 5 SAND

5 to 9 BENTONITE

9 to 20.6 SAND

14.2 to 19.2 SCREEN FOR DH6B

20.6 to 24 HOLE CAVED

24 to 36 BENTONITE

36 to 46 SAND

40 to 45 SCREEN FOR DH6A

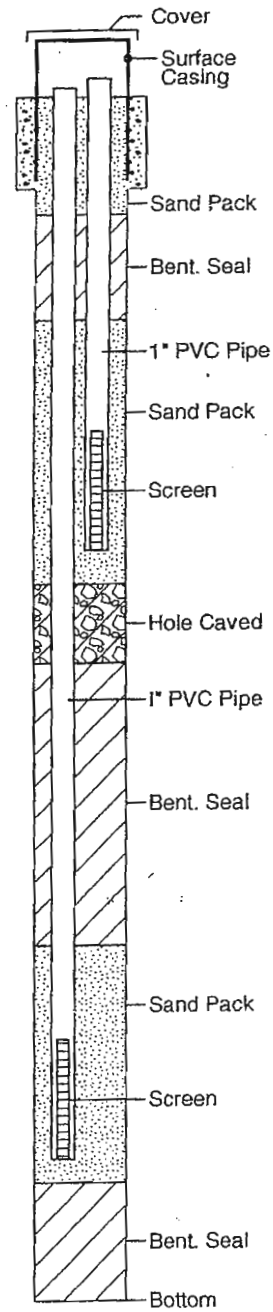
46 to 51 BENTONITE

51 BOTTOM OF HOLE

Depth In Feet

0
5
10
15
20
25
30
35
40
45
50
55

Standpipe1: DH-6A
Standpipe2: DH-6B



06-17-2005 G:\WATER_RT\WRB-STAF\Bob A\Well Logs\Ruby Logs\Ruby DH-6 WC.bor

SOIL LOG OF BOREHOLE NO: DH7

MT DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: Track B53
DATE STARTED	: 10/30/1999	DRILLING METHOD	: Coring
DATE COMPLETED	: 10/31/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Kirk Warren
DRILLER	:	APPROVED BY	: Kevin Smith

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 5386.5	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
0	5386		0 to 16.5 METAMORPHIC, dolomitic marble, tan to gray, fractures at 6' and 12' filled with cherty silica and white calcite respectively. FeOx commonly in fracture fillings. Also calcite and chert common. At 10.5 to 16.5' very broken and fractured with chert and calcite fillings	ME								0 to 5.5' No core in the barrel 5.5 to 13.75' Cored 8.25' Recoverd 4.7' 57% RQD approx 30% At 6 and 8' Fractures at 12 degrees to core axis At 11.5 to 13.75 Lost core 13.75 to 16.5' Cored 2.75' Recovered 1.2' 45% RQD = 0
5	5381											
10	5376											
15	5371											
			16.5 to 22 SAND, fine and medium, some coarse, brown to rusty dark brown (similar to sand in outcrop to east of hole)	SP								16.5 to 26.5' Cored 10' Recoverd 4.5' 45% RQD = 5% Fractures/ft = multiple to rubbly
20	5366											
			22 to 26.5 METAMORPHIC, dolomitic marble, highly fractured, weathered, dark brown (Fe oxides)	ME								
25	5361											26.5 to 36.5' Cored 10' Recovered 3.3' 33% RQD = approx 20% Fractures/ft = multiple to rubbly
			26.5 to 33 SAND, medium to coarse	SP								
30	5356											
			33 to 36.5' METAMORPHIC, dolomitic marble, highly fractured, with chert at 36'	ME								
35												

Core Barrel HQ3

Core descriptions reviewed and relogged by C. Stiles 2/2/2005.

05 G:\WATER_RT\WHB-STAF\Bob A\Well Logs\Ruby Logs\Ruby DH-7 Soil.bor

SOIL LOG OF BOREHOLE NO: DH7

MT DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: Track B53
DATE STARTED	: 10/30/1999	DRILLING METHOD	: Coring
DATE COMPLETED	: 10/31/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Kirk Warren
DRILLER	:	APPROVED BY	: Kevin Smith

SAMPLER TYPE
SS Split spoon
SL Split Spoon Brass Liners
ST Shelby Tube

Depth in Feet	Surf. Elev. 5386.5	Sample Interval	DESCRIPTION	USCS	GRAPHIC	Sampler Type	Blow Count	Adjusted Blow Count (blows/foot)	Inches Recoverd Inches Driven	% Recovery	Pocket Penetrometer (tons/square foot)	REMARKS
35	5351			ME								36.5 to 46.5' Cored 10' Recovered 3.5 35% RQD = 14 to 24% (depending on whether clay is counted)
			36.5 to 43 SAND, medium to coarse	SW								At 36.5 to 43' Lost core
40	5346											
			43 to 45 CLAY, greenish brown, fault gouge with chert, calcite, and garnet fragments	CL								
45	5341		45 to 60.5 METAMORPHIC, dolomitic marble, mostly competent									46.5 to 56.5' Cored 10' Recovered 9.5' 95% RQD = 75% Fractures/ft = >2 Fractures generally at 60 to 75 degrees to core axis.
			At 46 to 47.5' white to gray chert									
50	5336			ME								
55	5331		At 55' weathered zone									56.5 to 60.5' Cored 4' Recovered 4' 100% RQD = 79% Fractures/ft = 1 to multiple in last foot Refer to the digital photos in project file.
			At 58' quartzite or chert fragment with silver sulfide									
60	5326		60 to 60.5' weathered zone									
			60.5 BOTTOM OF HOLE									
65	5321											
70												

Core Barrel HQ3

Core descriptions reviewed and relogged by C. Stiles 2/2/2005.

06-15-2005 G:\WATER_RT\WRB-STAF\Bob A\Well Logs\Ruby Logs\Ruby DH-7 Soil.bor

WELL COMPLETION LOG NO: DH7

MT DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
P.O. Box 201601
Helena, MT 59601-1601
(406) 444-6646

RESERVOIR	: Ruby	DRILL RIG	: Track B53
DATE STARTED	: 10/30/1999	DRILLING METHOD	: Coring
DATE COMPLETED	: 10/31/1999	SAMPLING METHOD	: Split Spoon
DRILL COMPANY	: Bush Drilling	LOGGED BY	: Kirk Warren
DRILLER	:	APPROVED BY	: Kevin Smith

Depth In Feet | Surf. Elev. 5386.5

Well Construction Information

WELL CONSTRUCTION

Date Compl.	: 10/22/1999
Hole Diameter	: 8 inch
DNRC Rep.	: Kirk Warren

STANDPIPE

Material	: PVC pipe
Diameter	: 1 inch
Joints	: screwed
Bottom Cap	: glued

WELL SCREEN

Material	: PVC pipe
Diameter	: 1 inch
Length	: 5 feet
Opening	: .02 inch

SAND PACK

Material	: Colorado Silica 10/20

ANNULUS

Material	: 3/8 inch Bentonite

WELL COVER

Diameter	: 7 inch
Length	: 5 feet

NOTES:

Surface Elev: 5386.5 feet (estimate)

DH7 TOP Elev: 5386.7 feet (estimate)

Top of Cover Elev: 5386.94 feet

Northing: 10034.43

Easting: 9835.02

Surveyed By: Mike Lesnik

Date Surveyed: 4/2000

DESCRIPTION

0 to 29.5 HOLE CAVED

31.5 to 49.5 BENTONITE

This zone is estimated.

Bentonite chips bridged, but got in about two bags prior to bridging.

49.5 to 60.5 SAND

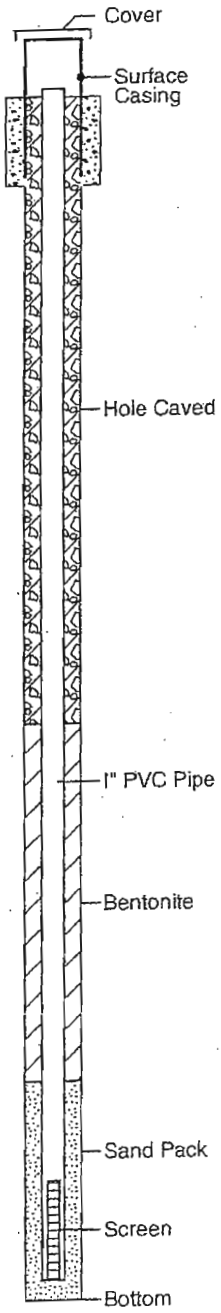
54.5 to 59.5 SCREEN FOR DH7

60.5 BOTTOM OF HOLE

Depth In Feet: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65

Surf. Elev.: 5386, 5381, 5376, 5371, 5366, 5361, 5356, 5351, 5346, 5341, 5336, 5331, 5326

Standpipe: DH-7



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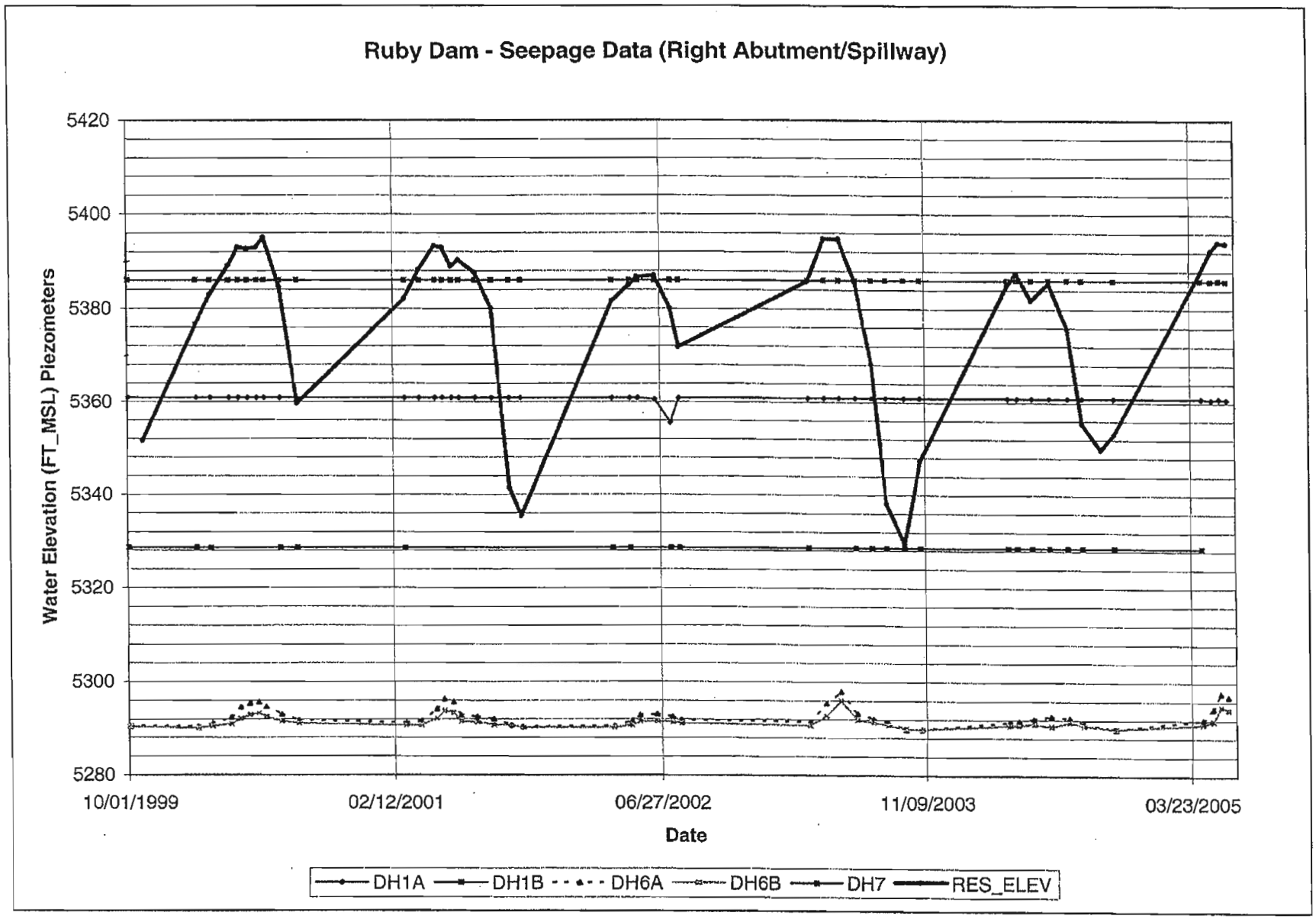
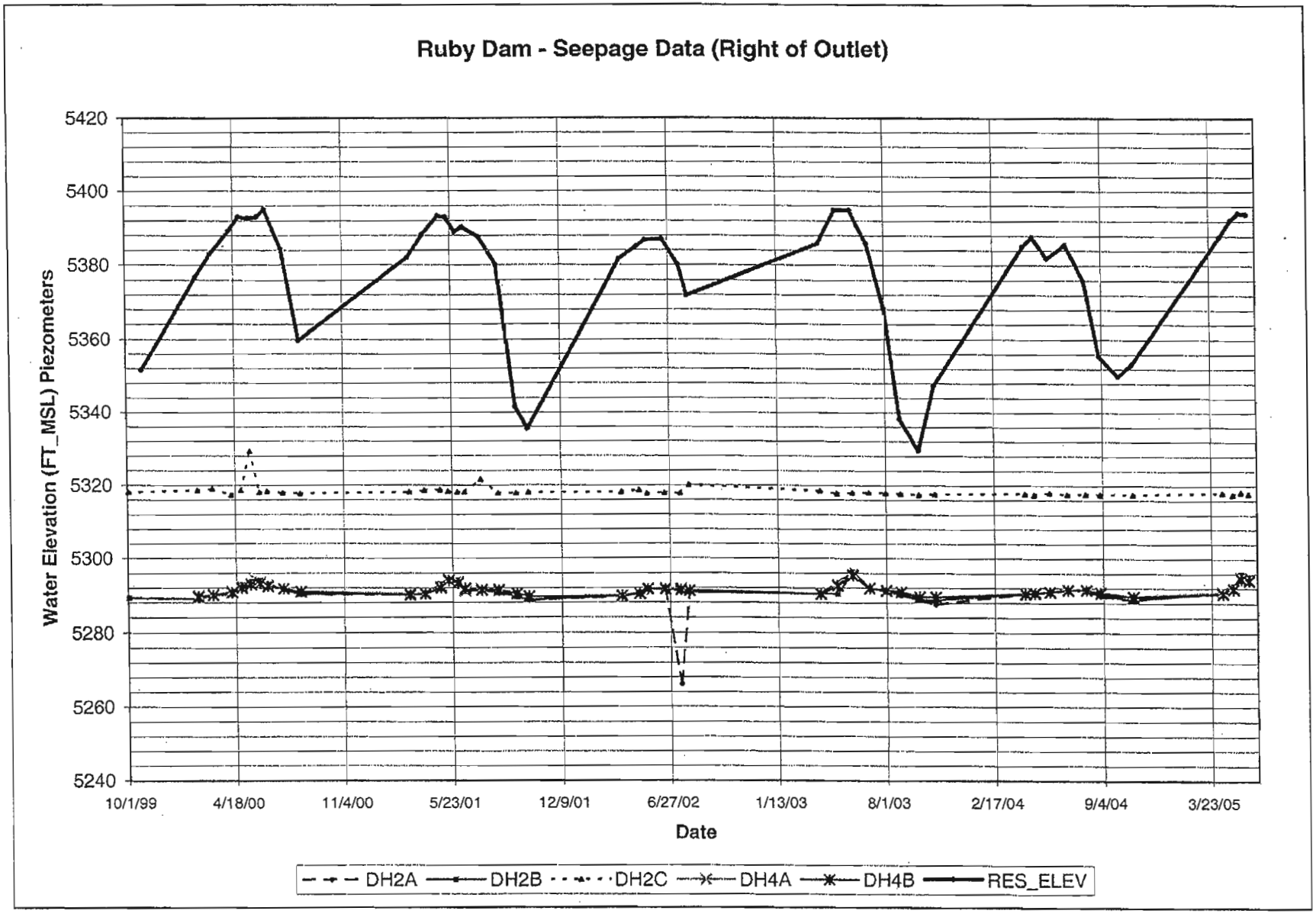
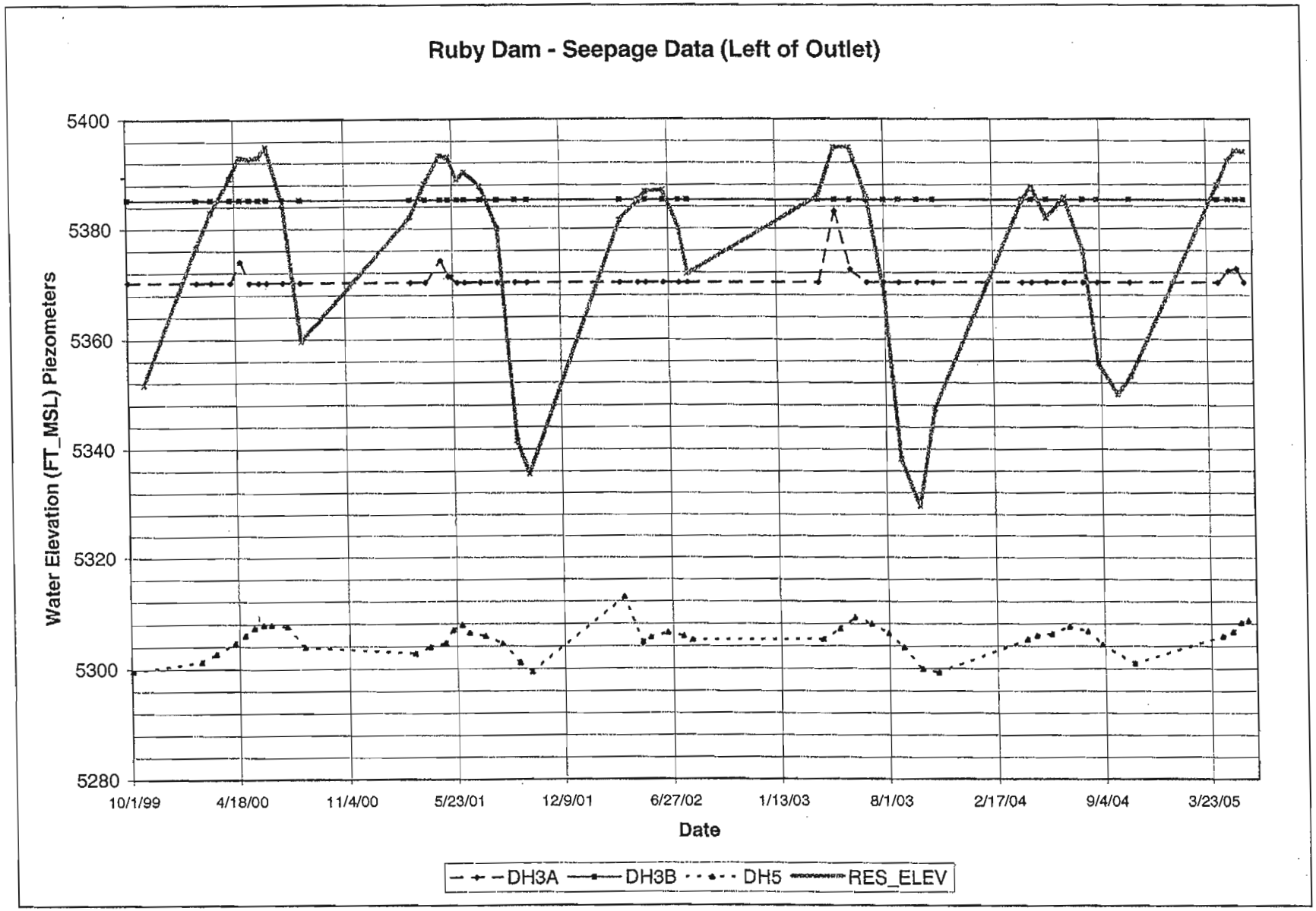

Ruby Dam - Seepage Data (Right Abutment/Spillway)
Water Elevation (FT_MSL) Piezometers
5420
5400
5380
5360
5340
5320
5300
5280
10/01/1999
02/12/2001
06/27/2002
11/09/2003
03/23/2005
Date
DH1A
DH1B
DH6A
DH6B
DH7
RES_ELEV


Ruby Dam - Seepage Data (Right of Outlet)
Water Elevation (FT_MSL) Piezometers
5420
5400
5380
5360
5340
5320
5300
5280
5260
5240
10/1/99
4/18/00
11/4/00
5/23/01
12/9/01
6/27/02
1/13/03
8/1/03
2/17/04
9/4/04
3/23/05
Date
DH2A
DH2B
DH2C
DH4A
DH4B
RES_ELEV


Ruby Dam - Seepage Data (Left of Outlet)
Water Elevation (FT_MSL) Piezometers
5400
5380
5360
5340
5320
5300
5280
10/1/99
4/18/00
11/4/00
5/23/01
12/9/01
6/27/02
1/13/03
8/1/03
2/17/04
9/4/04
3/23/05
Date
DH3A
DH3B
DH5
RES_ELEV

APPENDIX F

PRELIMINARY

SEISMIC STABILITY ANALYSIS REPORT

NTL ENGINEERING

1392 13th Avenue SW
P.O. Box 3269
Great Falls, MT 59403-3269

Tel. (406) 453-5400
Fax. (406) 761-6655
ntlengineering.com

January 26, 2006

HKM Engineering, Inc.
P.O. Box 31318
Billings, MT 59107-1318

Attention: Mr. Jason H. Thom

Subject: Seismic Stability Analysis, Ruby Dam
HKM Project Number 08M087.175, Subcontract Number 06X06

Mr. Thom:

In accordance with our subcontract agreement dated December 5, 2005, NTL Engineering & Geoscience, Inc. has completed the seismic stability evaluation of Ruby Dam. Our analysis indicates that, based on currently available information, Ruby Dam is seismically stable, in accordance with current recommended analysis procedures developed by the Montana Department of Natural Resources and Conservation (DNRC) Dam Safety Division. We do, however, recommend that additional subsurface exploration be conducted to provide a more definitive characterization of the dam.

The attached report describes our review of the project and our analysis of the seismic stability of the dam. Please contact us with any questions.

Sincerely,
NTL Engineering & Geoscience, Inc.

Brian J. Williams, P.E.,P.G.
Geotechnical Project Manager

Gary A. Quinn, P.E.
President, Senior Geotechnical Engineer

In seven copies

SEISMIC STABILITY ANALYSIS

PROJECT
RUBY DAM
HKM PROJECT NUMBER 08M087.175
SUBCONTRACT Number 06X06

NTL PROJECT NUMBER 05-392

CLIENT
HKM ENGINEERING, INC.
BILLINGS, MT 59107-1318

PREPARED BY
NTL ENGINEERING & GEOSCIENCE, INC.
GREAT FALLS, MONTANA

January 26, 2006

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INTRODUCTION	1
PROJECT HISTORY	1
SITE GEOLOGY	2
PREVIOUS GEOTECHNICAL STUDIES	2
ENGINEERING ANALYSIS	4
CONCLUSIONS AND RECOMMENDATIONS	6
CLOSURE	7
REFERENCES	8

APPENDIX

Figure 1 - Seismic Analysis of Montana Dams; Recommended Analysis Procedures
Figure 2 - Montana DNRC Site Characterization (Response) Map; Ruby Dam Site
Figure 3 - Montana DNRC Surface Shaking (PGA), 5,000 yr. PGA, Ruby Dam Site
Figure 4 - Montana DNRC Seismic Stability Screening Test

INTRODUCTION

Under subcontract to HKM Engineering, Inc. (HKM), NTL Engineering & Geoscience, Inc. (NTL) was retained to perform a seismic stability analysis of Ruby Dam, as part of a Feasibility Study commissioned by the Montana Department of Natural Resources and Conservation (DNRC). Per the subcontract agreement and other supporting documentation, the evaluation was performed using available documentation. This documentation consisted of historic reports and data collated by DNRC, and also included the results of a limited subsurface study conducted by HKM (HKM, 2006) to augment the existing data set.

PROJECT HISTORY

Ruby Dam is a zoned earthfill structure that was completed in 1938. The dam is situated across the Ruby River, approximately 6 miles south of Alder, Montana (CH2M Hill, 1980). The structure is approximately 110 feet high and 850 feet long, and has an average upstream slope of 3H:1V and an average downstream slope of 2H:1V. Based on previous characterization efforts sponsored by DNRC, the dam is classified as a High Hazard dam.

Available records indicate that the dam was constructed as a zoned earth dam with an upstream clay/loam section (Zone A of previous reports), a central clay/loam/sand/gravel section (Zone B of previous reports), a transitional gravel transition section (Zone C of previous reports), and a downstream rockfill shell (Zone D of previous reports) (CH2M Hill, 1980; McLeod 2005a; and McLeod 2005b). The above-referenced reports also indicate that, while much of the dam is either situated on or keyed into bedrock, part of the downstream dam section (an upstream-downstream wedge consisting of Zones C and D and trending along the former stream channel) is situated on a layer of dense granular alluvium that now (essentially) functions as a blanket drain beneath the central section of Zones C and D. A zone of fill is also observed partially overlying and downstream of Zone D (the rockfill section). This fill is believed to consist of materials derived from the excavation of the spillway at the right abutment (HKM, 2006). Both recent and historic observations indicate that seepage has never been observed on the downstream face or abutments of the dam, and piezometric data indicates that the phreatic surface through the dam is well below the toe of the dam (HKM, 2006).

There is also limited documentation of compaction testing that took place during construction of the dam. That data, however, exhibits several large data gaps (in both vertical elevation within the dam and by days between test intervals), and our comparison of available moisture-density curves (both those historic and those developed by HKM in 2005) indicate that there are likely at least 5 depth zones (portrayed in the historical data) and 3 depth zones in the recent (HKM 2005) data where in-place densities are less than the currently accepted minimum compaction standard of 95% minimum dry density (per ASTM D 698).

SITE GEOLOGY

Geology of the dam site (Stiles, 2005; St. Jean, 2002) includes primarily Pre-Cambrian metamorphic rocks consisting of dolomitic marble, chert, quartzite, and granitic gneiss. Faulting near the site was identified by Stickney, et al., (2000), who characterized the Ruby Range Northern Border Fault (located approximately 2.5 miles north of the dam site) as exhibiting evidence of Quaternary movement. That same study, however, characterized the fault as having a very low slip rate. In their 2004 mapping of seismic hazard potential for the DNRC, URS Corporation (URS, 2004) included this fault in their analysis, but because of the low apparent slip rate, the impact of the Ruby Northern Border fault was (probabilistically) regarded as minimal to the Ruby Dam site. Based on detailed data developed by URS and provided by DNRC (Lemieux, 2005), the dam site is (for the purpose of seismic site characterization) characterized as being a hard rock site (see attached Figure 1) with a Peak Ground Acceleration (PGA) on the order of 0.22g to 0.23g (see attached Figure 2).

PREVIOUS GEOTECHNICAL STUDIES

The paragraphs below summarize the geotechnical studies conducted at or for the Ruby Dam project and which have relevance to the current seismic evaluation. This summary does not include reference to the many historical notes of inspections that have been performed during the life of the project.

- A Phase I geotechnical study of the dam was undertaken by CH2M hill in 1980 (CH2M Hill, 1980). This study identified the major features of the dam and summarized the project history of the facility. The 1980Phase I study, like later documentation generated by DNRC and the U.S. Bureau of Reclamation, recommended that stability analysis of the Ruby Dam be undertaken.

- In 1999, in an effort to better characterize the dam, Montana DNRC undertook a limited drilling and laboratory testing program at the site. During the 1999 DNRC study, seven borings were drilled at the dam (McLeod, 2005b). The borings made for this study included penetration testing (purportedly in accordance with ASTM D 1586; see discussion below) and collection of both disturbed and relatively undisturbed samples. Field logs indicate that pocket penetrometer testing (an approximation of unconfined compressive strength) was conducted on selected soil samples in the field. Limited laboratory testing was conducted on samples obtained during the study, and included primarily index tests (including gradation and Atterberg limits), one pinhole dispersion test (with negative or non-dispersive results) and one triaxial shear test (McLeod, 2005a).

- In 2000, Phyllis Flack (a graduate student from Montana Tech) published her thesis, which included static and pseudo-static slope stability analysis of Ruby Dam (Flack, 2000). In developing her thesis, Flack briefly discussed the limited available shear strength data (specifically, the single triaxial test from DNRC 1999), and then went on to develop correlative shear strength properties for

use in her stability analyses. Her shear strength properties were based on published correlations partially scaled to the penetration testing conducted at the site, and partially scaled to index tests such as gradation and Atterberg limits. In reviewing her notes, it appears that she also used, in part, some of the pocket penetrometer data recorded on the 1999 DNRC boring logs.

Employing her soil model and the limiting equilibrium program XSTABL, and using both Bishop's and Janbu's method of slices, Ms. Flack developed yield accelerations on the order of 0.36 to 0.40 for the upstream face and 0.35 and 0.41 for the downstream face.

At one point in her thesis, Ms. Flack recounted an assertion from a 1998 USBR memo (USBR, 1998) indicating that Ruby Dam was inherently stable because it had already undergone accelerations on the order of 0.2g from the 1959 Hebgen earthquake event. Analysis performed by NTL as a part of this study (discussed in the Engineering Analysis section below) indicates that assertion (that the Hebgen event imparted 0.2g to the Ruby Dam site) to be in error.

- In 2002, another graduate student from Montana Tech (Zachary St. Jean) published his thesis, which included (in part) stability analysis of Ruby Dam. In his thesis, he used essentially the same shear strength parameters cited by Flack (Flack, 2000), but arrived at lower yield accelerations than Flack (0.19g for the upstream face, 0.23 to 0.25 g for the downstream face).

- In early 2005, Montana DNRC performed a stability analysis of Ruby Dam as the partial basis of a paper they were developing for presentation to the Association of State Dam Safety Officials (ASDSO), (Lemieux and Grant, 2005). The shear strength data they developed is unpublished, but is presumably more conservative than the Flack data, since the DNRC analysis developed significantly lower yield accelerations than (Flack, 200) or (St. Jean, 2002), on the order of 0.17g for the upstream face and 0.15g for the downstream face.

- In late 2005 and early 2006, as a part of this Feasibility Study, HKM performed additional (limited) subsurface exploration and laboratory testing on soil samples obtained during the exploration, and developed additional shear strength data to augment the existing [limited] data set (HKM, 2005; HKM, 2006). Based on the additional field test and laboratory data, HKM developed a soil model with shear strengths that were generally more conservative than values used in the previous analyses (Flack, 2000 and St. Jean, 2002). The results of the HKM analysis indicated static factors of safety exceeding 1.5 for all cases and yield accelerations of 0.21g for the upstream face and 0.23 g for the downstream face of the dam.

ENGINEERING ANALYSIS

Evaluation of Past Seismic Impacts to the Ruby Dam Site

Because several of the geotechnical reports associated with this project either assert or recount the assertion that Ruby Dam has already been subjected to accelerations on the order of 02g by the 1959 Hebgen event (USBR, 1998, Flack, 2000; St. Jean, 2002), and believing that assertion to be in error, NTL performed analysis of past seismic impacts to Ruby Dam, focusing on the 1959 Mw7.5 Hebgen event and the 2005 Mw5.6 Southwestern Montana event that occurred on July 26, 2005. This analysis was conducted using published data (URS, 2004), Spudich, et al., (1999), and Stewart, et al., (2001) as the basis for analysis.

The 1959 Mw 7.5 Hebgen event occurred at a distance of approximately 70 kilometers from the Ruby Dam site, and the 2005 Mw 5.6 Southwestern Montana event occurred at a distance of approximately 55 kilometers from the Ruby Dam site. Using attenuation relationships developed specifically for an extensional regime by Spudich (Spudich, et al, 1999), and chart solutions for the Spudich data published in Stewart, et al, (2001) and URS (2004), our analysis indicates that impacts to the Ruby Dam site were likely on the order of 0.05g from the 1959 Hebgen event, and less than 0.02g from the 2005 Southwestern Montana event.

Evaluation of Available Geotechnical Data

Historical records indicate that Ruby Dam consists of the four previously described zones, including the upstream core (Zone A, "selected clay & loam"), the middle transition (Zone B, "shovel mix clay & loam, sand, and gravel pit run"), the downstream transition (Zone C, "sand and gravel"), and the downstream rockfill shell (Zone D, "rock fill voids filled with small rock and sluiced sand and gravel"), (HKM, 2006). During the 1999 DNRC studies at Ruby Dam, three of the seven borings were drilled into the main body of the dam (primarily into Zone B), while the other four borings were made either at the toe of the dam or adjacent to the spillway approach. The laboratory testing from the 1999 DNRC studies included primarily index testing (gradations and Atterberg limits) and one shear strength test from Zone B (McLeod, 2005a; McLeod, 2005b; McLeod, 2005c). Our review of previous stability analyses (Flack, 2000; St. Jean, 2002) and conversations with DNRC personnel (Lemieux, 2005) indicate that shear strengths for the various stability analyses performed prior to the fall of 2005 were based on either the single triaxial shear test performed in 1999 or correlations to the penetration tests performed in the 1999 DNRC study. Our review of these previous analyses (in particular, Flack, 2000) also indicates that the shear strength estimates used in those analyses are, in our opinion, too high (and unconservative) for use in a stability analysis performed in accordance with current DNRC guidance.

Test pits excavated along the dam crest during the 2005 HKM subsurface exploration (HKM 2005) exposed a wedge of the upstream (Zone A) material and the central Zone B material, and test pits excavated along the toe of the dam during that same study also penetrated the rockfill shell (Zone D) and fill overlying the rockfill shell. Based on conversations with HKM engineers, the model shear strength values presented in HKM's 2006 report were based either on the single 1999 triaxial test, on the density test results obtained during their 2005 field study, or on a correlation of median penetration "N" values (primarily from the 1999 DNRC boring DH-2) to published shear strength correlations. Our review of the 1999 DNRC data and the HKM soil model, and our independent comparison of the 1999 DNRC field data to published correlations of shear strength (Gibbs and Holtz [1957], Meyerhof [1956], and Winterkorn and Fang [1975]) indicates that, based on currently available data (the unpublished 2005 DNRC model notwithstanding), the HKM model of shear strengths in Ruby Dam presents the most suitable soil model for use in the "Feasibility" level analysis discussed herein.

Evaluation of Seismic Stability of the Ruby Dam

The feasibility-level evaluation of the seismic stability of Ruby Dam generally follows the methodology developed by Michele Lemieux of the Montana DNRC Dam Safety Section (Williams, 2004), and as updated in 2005 (Lemieux and Grant, 2005). The Recommended Analysis matrix is shown on the attached Figure 1.

The first step in the analysis procedure is to determine the Peak Ground Acceleration (PGA) at the base of the dam, using the new ground-shaking maps developed by URS for DNRC. The attached Figure 2 is the site characterization used by URS in their mapping project, and the characterization shown on Figure 2 is "hard rock" which corresponds to ground conditions at the site. The attached Figure 3 is a map showing the surface-shaking PGA for hard rock sites; in particular, for the Ruby Dam site. In this case, the PGA for the Ruby Dam site is "0.22-0.23". A PGA of 0.23g was used for the purposes of this study.

Referring back to the analysis matrix shown on Figure 1, and having confirmed that the acceleration at the base of the dam exceeds 0.1g, and having confirmed that the map is representative of site conditions, the next step in the analysis is to evaluate whether or not the dam is a "clay embankment on clay/bedrock foundation, with no sensitive layers?". At this step, one must evaluate whether or not the dam is composed of clay, whether or not it is no a non-liquefiable foundation, and whether or not there are no potentially liquefiable layers within the dam that could lead to a loss-of-pool failure. Based on the laboratory test data provided by DNRC (McLeod, 2005a) and the data developed by HKM, we characterized the dam as essentially a clay dam with no layers susceptible to liquefaction (based on currently available data). Since the dam is founded either on bedrock or dense alluvium, there are, in our opinion, no liquefaction issues associated with the dam foundation, either. Therefore, the answer to this step in the analysis matrix is "YES", and the evaluation process then proceeds to the screening test. In the screening test step, ALL of the steps must be satisfied for the dam to pass the screening test.

Reviewing the screening test (as shown on the attached Figure 4), we determined that Step1 is satisfied (see the discussion of clay dam and foundation in the paragraphs above). Step 2 requires that the subject dam have documented compaction records. Based on the results of our review of recent and historical compaction records (see discussion above), Step 2 is not satisfied, and Ruby Dam therefore fails the screening test, despite the fact that it satisfies the remaining steps in the screening test process.

Since Ruby Dam fails the screening test, we next have to proceed to the determination of whether or not the PGA at the base of the dam exceeds 0.35g. Since the PGA at the base of the dam does not exceed 0.35g (being only 0.23g, see the paragraphs above), we next proceed to the determination of pseudostatic yield acceleration.

In this part of the evaluation, we evaluated both the 2005 HKM (HKM, 2006) and 2005 DNRC (Lemieux and Grant, 2005) data, as shown in the table below. Although we consider HKM's recent analyses to likely be the most accurate (given updated subsurface and laboratory data), we also considered the DNRC results in this next evaluation step.

Yield Acceleration, Ay, g's			
Montana DNRC (2005)		HKM (2006)	
Upstream	Downstream	Upstream	Downstream
0.17	0.15	0.21	0.23

The next step in the analysis procedure is to determine if the pseudostatic yield acceleration (for any of the cases discussed above) is greater than the value of PGA ÷ 3. In the case of Ruby Dam, the value of PGA ÷ 3 = 0.08g, and since the yield acceleration for all of the data sets is greater than 0.08g, and for the purposes of this Feasibility Study, Ruby Dam is considered seismically stable.

CONCLUSIONS AND RECOMMENDATIONS

For the purposes of this Feasibility Study, analysis indicates that the Ruby Dam is seismically stable. Based on our review of the currently available data, it is our opinion that HKM's 2006 soil model is reasonable and probably conservative. Ruby Dam is, however, a high hazard dam with the potential for loss of life if failure were to occur. Therefore, there is, in our opinion, insufficient definitive shear strength data upon which to reach a final conclusion in regard to the seismic stability of the dam. The 1999 DNRC studies provided characterization of only Zone B, primarily from boring DH-2 of that study (McLeod, 2005a; McLeod, 2005b), and the 2005 HKM studies were limited to relatively shallow depths in their exploration of Zones A and D. Therefore, there is no definitive data characterizing the full depth of the upstream core (Zone A) or the downstream gravel

section (Zone C). In addition, evaluation of the original penetration data by NTL indicates that the penetration data obtained during the 1999 DNRC study may not have been performed in accordance with the requirements of ASTM D 1586 (ASTM, 2000), with the potential that shear strength correlations based on that data (and used in all of the stability analyses performed to date) may not be representative of actual site conditions.

Because of the limited shear strength data currently available, and because of potential inconsistencies in the original field penetration data, we recommend that additional geotechnical studies be performed at Ruby Dam, and that those studies include exploratory borings and/or seismic cone penetrometer soundings, and that the additional subsurface studies be augmented by additional laboratory testing to determine definitive shear strength values for the zones within the dam not adequately characterized by previous studies.

CLOSURE

We appreciate the opportunity to work with you on this project. Please contact us with any questions you may have regarding this report.

Sincerely,

NTL Engineering & Geoscience, Inc.

Brian J. Williams, P.E., P.G.
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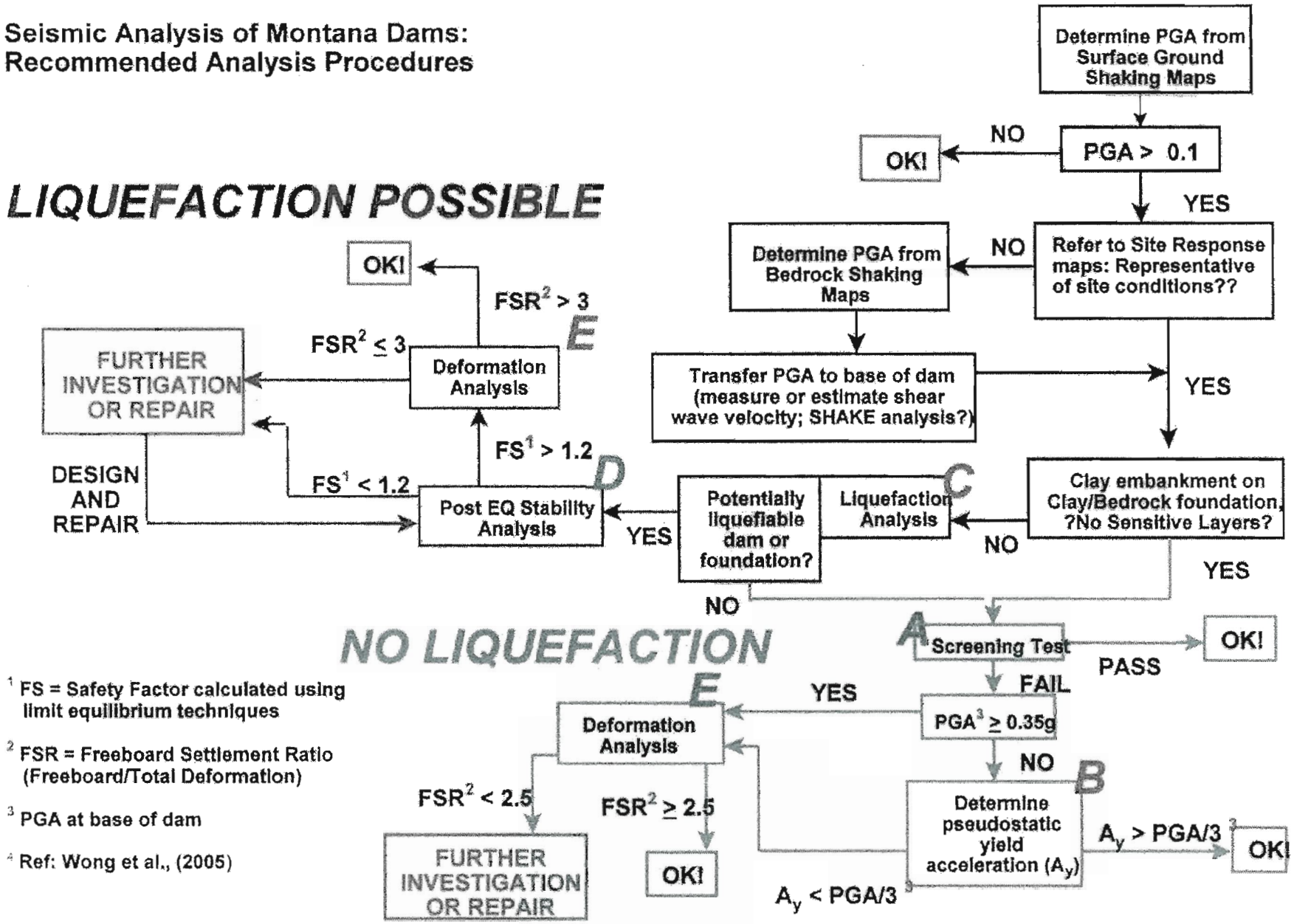
Appendix

Seismic Analysis of Montana Dams:
Recommended Analysis Procedures



[1] FS = Safety Factor calculated using limit equilibrium techniques

[2] FSR = Freeboard Settlement Ratio (Freeboard/Total Deformation)

[3] PGA at base of dam

[4] Ref: Wong et al., (2005)

Ruby Dam Feasibility Study; Seismic Stability Characterization
NTL Engineering & Geoscience, Inc. Project Number 05-392
January, 2006

Figure 1

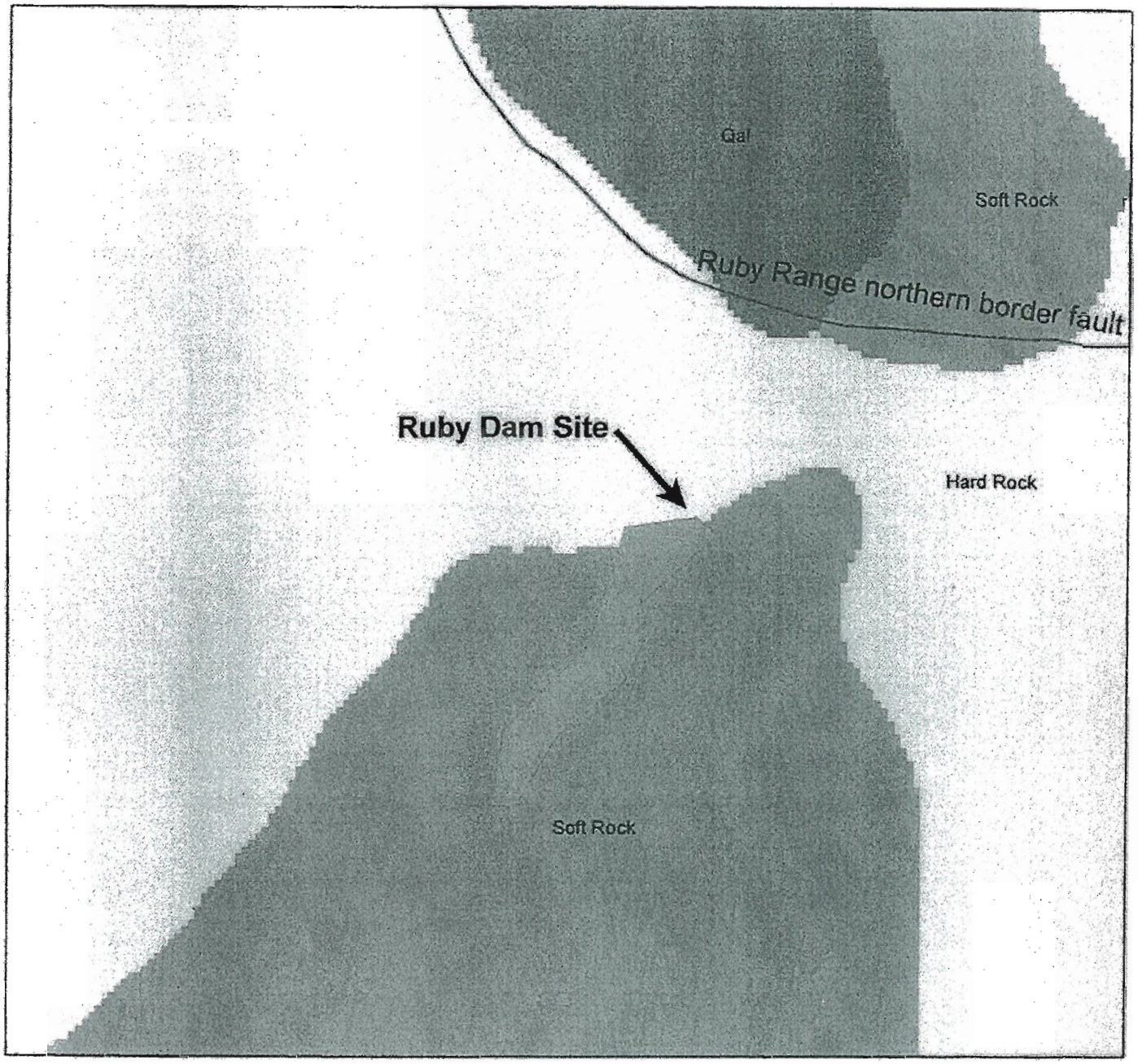


Figure 2. Montana DNRC Site Characterization (Response) Map; Ruby Dam Site

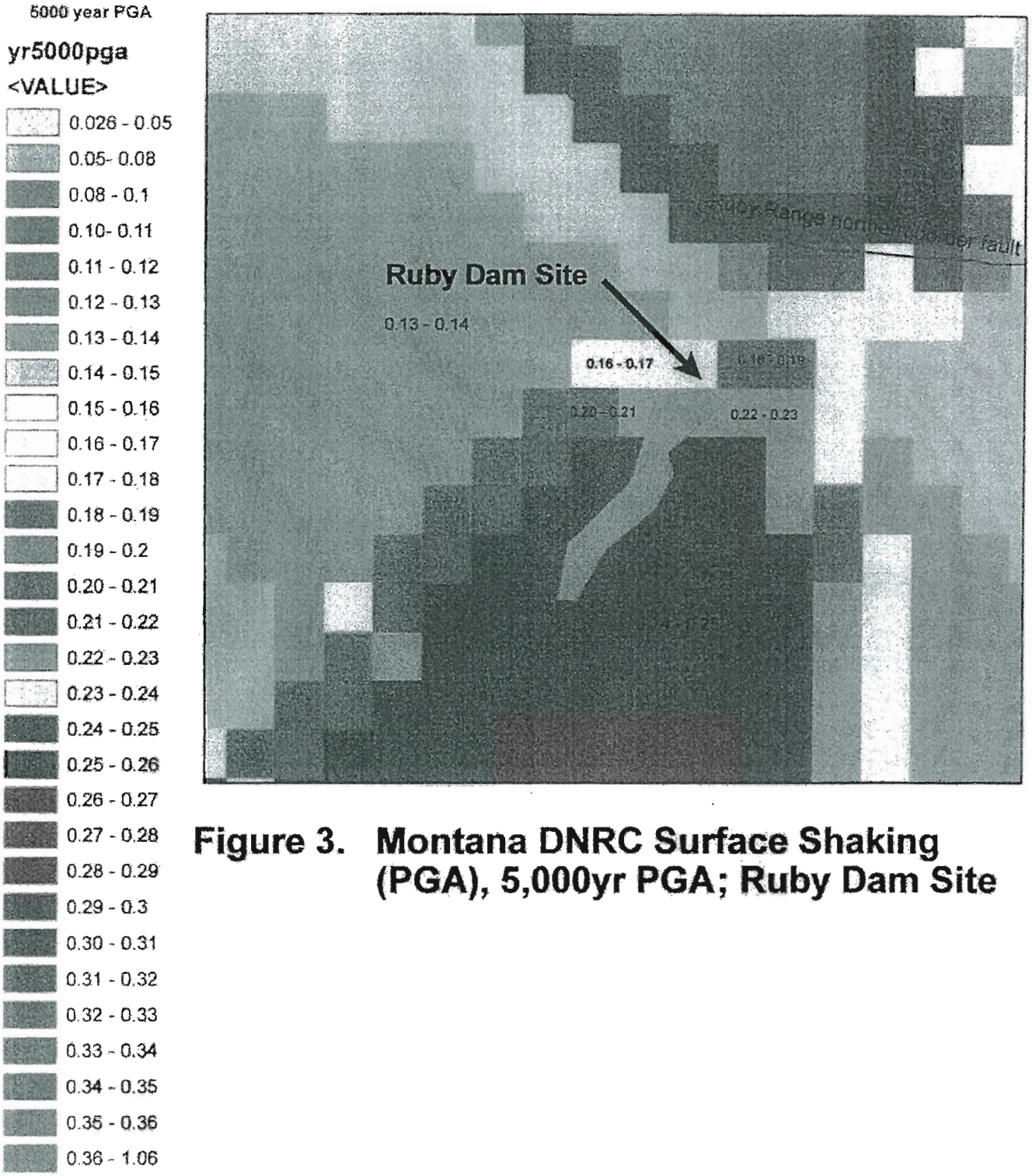


Figure 3. Montana DNRC Surface Shaking (PGA), 5,000yr PGA; Ruby Dam Site

A Screening Test (USBR, 2001)

1. Dam and foundation materials are not subject to liquefaction and do not include sensitive clays
2. The dam is relatively well built and compacted to at least 95% of laboratory maximum dry density (ASTM D 698) or relative density greater than 75%
3. The slopes of the dam are 3H:1V or flatter, and/or the phreatic line is well below the downstream face of the embankment
4. The peak horizontal acceleration (PGA) at the base of the dam is no more than 0.30g
5. The static factors of safety for all potential failure surfaces involving loss of crest elevation(i.e., slides other than shallow surficial slides) are greater than 1.5 under loading and pore pressure conditions expected immediately prior to the earthquake
6. The freeboard at the time of the earthquake is at least 3 to 5% of the embankment height and not less than 3 feet, and there are no critical appurtenant features that would be harmed by small movements of the embankment

Figure 4

APPENDIX G

GEOTECHNICAL DATA REPORT HKM

TEST PIT INVESTIGATION

RUBY DAM REHABILITATION

FEASIBILITY STUDY

Geotechnical Data Report
Test Pit Investigation

Prepared for:

Montana Department of Natural Resources and Conservation
State Water Projects Bureau
Helena, MT

Prepared by:

HKM Engineering Inc.
P.O. Box 31318
Billings, MT 59107

January 2006

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APPENDIX C PHOTOGRAPHS OF TEST PITS

INVESTIGATION

A geotechnical investigation has been conducted at the Ruby Dam site as outlined in HKM's proposed scope of work memorandum dated November 17, 2005. HKM completed the test pit investigation on November 21, 2005. The purpose of the investigation was to obtain additional information and/or confirm conditions regarding the embankment and foundation soils at the site. Table 1 presents the informational purpose for the respective test pits. Some of the test pit locations were adjusted in the field during the investigation due to excavator access limitations and to obtain additional information regarding embankment zoning at the dam crest.

TABLE 1
RUBY DAM TEST PITS AND INFORMATIONAL PURPOSE

Test Pits	Purpose
TP-1,TP-2,TP-3A	Assess characteristics of embankment shell zone material and fill at toe
TP4	Assess characteristics of fill north of embankment downstream toe and depth to bedrock
TP-6	Assess characteristics of native alluvial material and depth to bedrock
TP-7,TP-7A,	Assess upstream shell characteristics and riprap and bedding thickness
TP-8	Assess downstream shell characteristics
TP-3	Assess limits of embankment contact with native soil for spillway widening considerations

The originally proposed Test pits TP-5, TP-9 and TP-10 were not excavated. Additional test pits TP-3A and TP-7A were added.

The test pits were excavated at the locations shown on Figure 1. The test pits were extended to depths from 8.0 to 18.7 feet. Test pits TP-7, TP-7A and TP-8 were excavated within the crest of the dam. Test pits TP-1, TP-2 and TP-3A were excavated within the downstream toe of the dam, Test pits TP-4 and TP-6 were excavated downstream of the dam toe. Test pit TP-3 was excavated on the right groin area within the fill area between the spillway and dam embankment. The test pits were logged and soil samples taken for laboratory testing. Nuclear density tests were taken of the in-place embankment soils within the upper 7 feet of the embankment crest. Logs of the test pits are presented in Appendix A, laboratory test results are presented in Appendix B and photographs of the test pit excavations and excavated material are presented in Appendix C.

FINDINGS

The results of the investigation appear to confirm that the embankment exhibits zoning as shown on the as-built record drawing DWG. NO.-1A (Figure 2). This drawing indicates that the embankment has four zones as described following:

"Selected Clay & Loam" (upstream core)

"Shovel mix clay & loam, sand & gravel pit run" (middle transition).
"Sand and Gravel zone" (downstream transition)
"Rock Fill voids filled with small rock and sluiced sand & gravel" (Downstream shell)

The drawing also has a note that states: "Earth Embankment will not require watering above elevation 5402". The drawing also shows a dashed line and shaded area at the dam crest above elevations 5488.3 to the dam crest 5410. It is believed that this line indicated the stop limits at various embankment sections during construction seasons.

Three distinct zones were indicated by the test pit excavations and are discussed in the following paragraphs. It was not logistically possible to locate a test pit that would allow excavation to confirm the sand and gravel zone.

Test pits TP-7, TP-7A and TP-8 were excavated in the crest in order to identify the presence of "Selected Clay & Loam" (upstream core) and "Shovel mix clay & loam, sand & gravel pit run" (middle transition) zones. The soil profile in the upper nine feet of these test pits appeared to consist of random soil materials consisting predominately of layers of silty sand and clayey sand with scattered gravel with random clayey zones. Below the nine-foot depth a distinct clayey zone with scattered small gravels was encountered in the upstream portion of the crest in TP-7 and TP-7A. A distinct sandy zone with varying amounts of gravel and occasional cobbles was encountered in TP-8 which was excavated on the downstream edge of the crest.

Test pits TP-1, TP-2 And TP-3A were excavated within the downstream toe of the dam and confirm the existence of a rockfill zone. Rock sizes ranged from cobble size (3 to 12 inches) to boulders as large as 7 feet in diameter. The predominate mass of the rock fragments were angular with the larger boulders exhibiting angular to sub-rounded shape characteristics.

Test pits TP-4 and TP-6 were excavated downstream of the dam toe and encountered loose to medium dense fill which ranged in thickness from greater than 18.5 feet in TP-4 to 8 feet in TP-6. According to construction records it appears that the fill originated from portions of the spillway excavation. The fill contained angular "blasted" rock fragments ranging from 3-inches to 8-inches in diameter and occasional boulders from 14-inches to 36-inches in diameter. Groundwater was encountered only in TP-6 at a depth of 16.5 feet.

Laboratory Testing Results

Representative samples were taken of the various embankment zones and submitted to the laboratory for testing. The test results are attached.

The following test results appear to correspond with the various zones of the embankment:

TP-7 (depth from 4 to 8 feet) - This sample was taken from the upper 9 feet of the dam crest random material fill. This sample classified as silty clayey sand with gravel (SM-SC) that exhibits a rock corrected maximum dry density of 132 pounds per cubic foot (pcf) at an optimum moisture content of 9.5 percent.

TP-7 (depth from 9.5 to 11 feet) – This sample as taken from the distinct clayey zone encountered at a depth of 9 feet in the upstream side of the embankment which is described as "Selected Clay and Loam", (upstream core zone). From a visual classification these soils are borderline between sandy lean clay and clayey sand. The laboratory classification is skewed by the gravel content (test results classify as clayey sand (SC) with 42% fines). Visually the gross character of this material would be described as sandy lean clay/ clayey sand (CL/SC) with gravel because of fines content bordering on 50 percent passing the number 200 sieve. This material exhibits a rock corrected maximum dry density of 108.7 pcf at an optimum moisture content of 16.8 percent.

TP-7A (depth from 9 to 10.5 feet) - A Shelby tube sample was obtained at this location. The Shelby tube was pushed utilizing the bucket of the excavator. The Shelby tube sample (representative of the selected Clay and Loam upstream core zone) was sent to Advanced Terra Testing in Lakewood Colorado for triaxial tests to aid in estimating the engineering strength parameters of this embankment zone.

TP-8 (depth from 9.0 to 10.5 feet)- This material was taken from the downstream side of the dam crest within the "shovel mix clay and loam sand and gravel" middle "Transition". This material classified as silty clayey sand with gravel (SM-SC) that exhibits a rock corrected Maximum dry density of 131.2 pcf and optimum moisture of 9.7 percent. This classification is consistent with soils encountered in DNRC borings DH-1 and DH-2 which were advanced on the downstream edge of the dam crest.

It was not feasible to obtain representative samples of the rockfill zone material due to the large rock sizes and variability. Based on a visual classification this material is consistent with the description shown on the as-built drawings.

In Place Nuclear Density Tests

Table 2 presents the location and results of the in-place nuclear density testing:

TABLE 2
RUBY DAM
NOVEMBER 21, 2005 TEST PIT INVESTIGATION
RESULTS OF IN-PLACE NUCLEAR DENSITY TESTING IN THE UPPER 7 FEET OF EMBANKMENT

Location/Soil material	Dry density (pcf)	Moisture content (%)
Vicinity of BH-2 on dam crest SC/SM	130.4	5.2
TP-7A (3.5' to 4.2')/SC/SM	116.4	10.9
TP-7 (6.0' to 6.7')SC/SM	111.5	10.4
TP-8 (5.0' to 5.8')SC/CL	100.5	14.8

In-place density tests are shown on the logs these test were conducted in the sand deposits of the upper 9 feet of the crest.

CONCLUSIONS

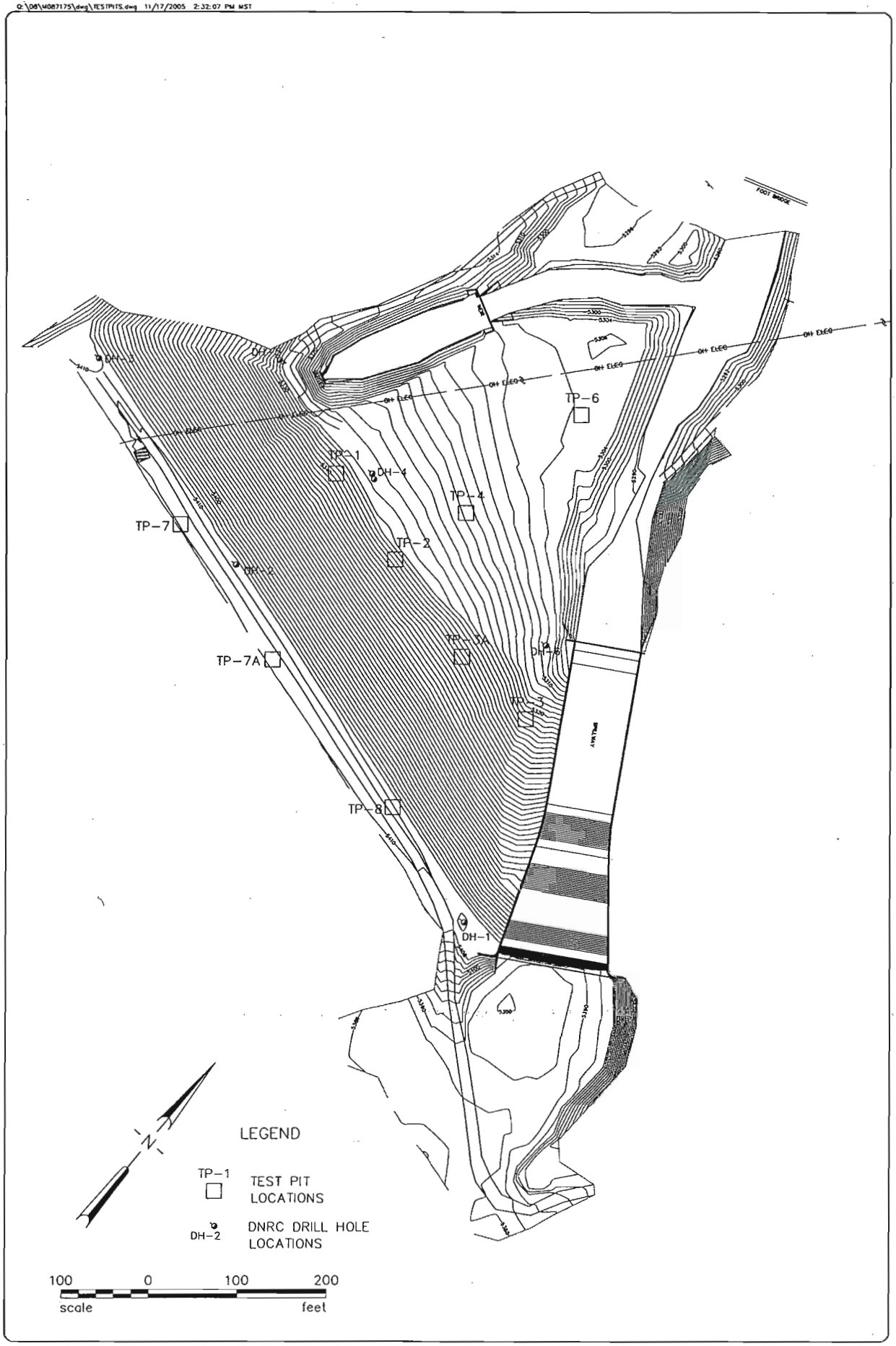
The results of the Test pit investigation confirm the existence of distinct zones within the embankment as shown on the as-built drawings. It was not logistically possible to locate a test pit that would allow excavation to confirm the sand and gravel zone.

Based on excavation difficulty and material composition, the rockfill zone is considered to exhibit high strength. The in-place densities taken at within the upper 7 feet of the embankment crest indicate in-place compaction values (using the average value of the rock corrected proctor curve) ranging from 76 to 98 percent of maximum dry density according to ASTM D 698. These values are not considered indicative of the entire embankment because, according to the note shown on the plans, watering was not required for this portion of the embankment which would considerably effect the compaction achieved.

Based on examination of the side walls of TP-7 and TP-7A which were excavated into the "Selected Clay & Loam" (upstream core), this material appears to be relatively consistent in composition and well compacted. Performance of this layer is confirmed by the monitoring well records that indicate a very low phreatic surface in the downstream transition zone of the embankment.

Test pits TP-4 and TP-6 indicate that considerable fill has been placed immediately downstream of the embankment toe. Thickness of this fill ranged from greater than 18.5 feet in TP-4 to 8 feet in TP-6. The fill does not appear to be compacted but the high percentage of angular cobble and boulder size rock fragments indicates that this fill material has relatively high shear strengths. Native alluvium was encountered between 8 to 16.5 feet in TP-6. Alluvium was not encountered in TP-4.

Test Pit TP-3 indicates that the fill placed adjacent to the spillway between the right groin of the dam is similar in nature to fill encountered in TP-4 and TP-6 with the exception that an abundance of large boulders were encountered in this area.

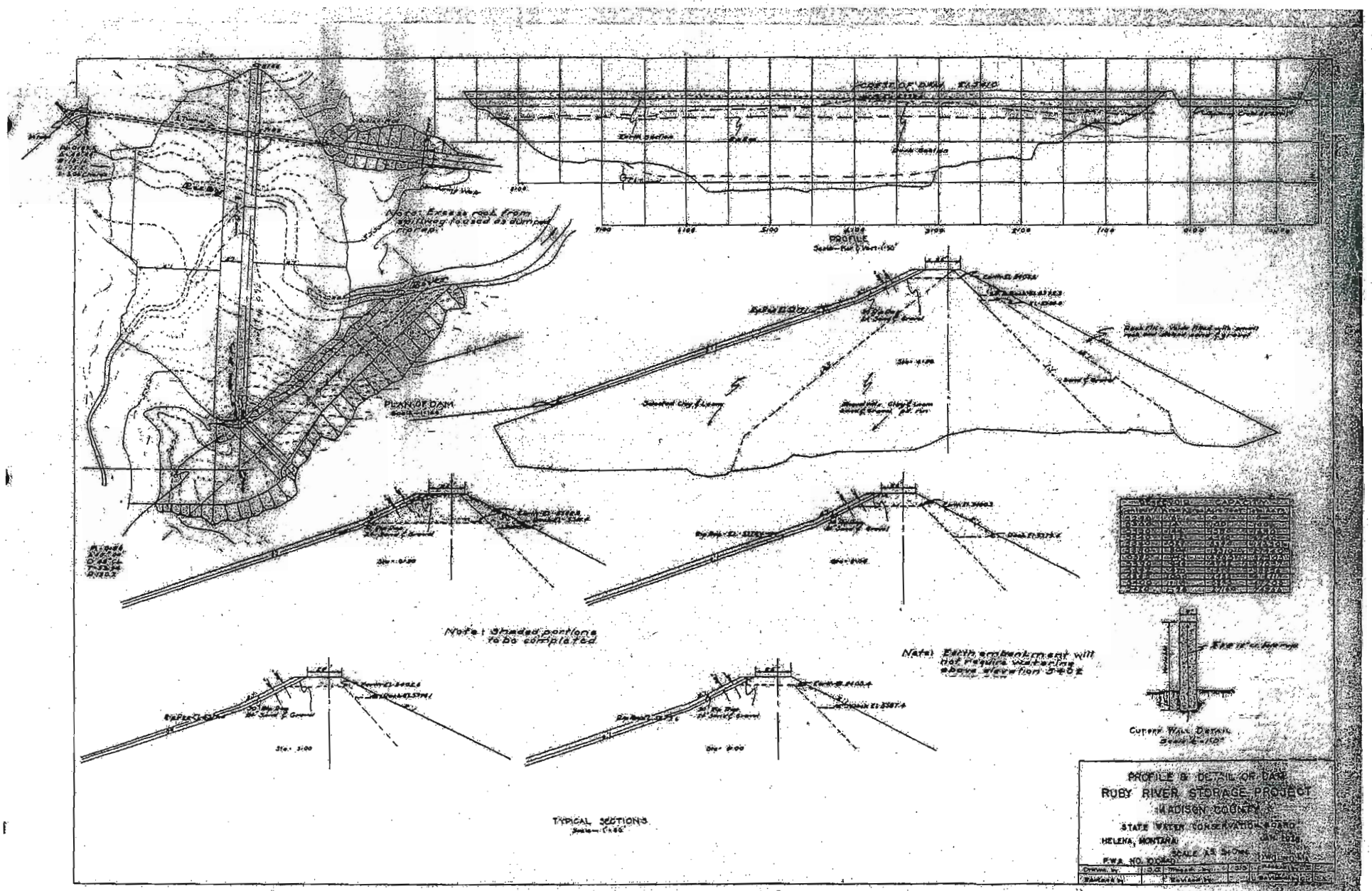


RUBY DAM FEASIBILITY STUDY
GEOTECHNICAL TEST PIT LOCATIONS

FIGURE 1

HKM ENGINEERING

8M087.175 | JANUARY 2006



PROFILE
PLAN OF DAM
Note: Excess rock from spillway to used as dumped riprap.
Note: Shaded portions to be completed
Note: Earth embankment will not require watering above elevation 5402
TYPICAL SECTIONS
CUTOFF WALL DETAIL
PROFILE & DETAIL OF DAM
RUBY RIVER STORAGE PROJECT
MADISON COUNTY
STATE WATER CONSERVATION BOARD
HELENA, MONTANA
SCALE AS SHOWN
F.W.A. NO. 10,080

APPENDIX A

RUBY DAM

LOGS OF TEST PITS

Project No.: 8M087.175	LOG OF TEST PIT TP-1	Sheet 1 of 1

CLIENT	ARCHITECT/ENGINEER
DNRC	HKM Engineering
SITE	**PROJECT**
Dam Site	Ruby Dam

DEPTH (FT.)	MATERIAL DESCRIPTION Surface Elevation: 5335.1	GRAPHIC LOG	ELEVATION (FT.)	SAMPLES: BULK	POCKET PENETROMETER, TSF	M.C. (PL 10 20 30 40 LL)	ADDITIONAL DATA/ REMARKS
0	Abundant 18-36" boulders with silty, clayey sand and angular gravel matrix, loose to 6'						
			5332				
4	72-84" boulder at 6', moved excavation towards dam toe (Rockfill)						
			5328				
8	8.0 — 5327.1 Trackhoe bucket refusal in large boulders and cobbles; excavation terminated at 8'						
	No groundwater observed						
12	Test pit located at dam toe, adjacent to DH-4						
16							
20							
24							
28							

HKM ENGINEERING

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Billings, Montana 59101
Telephone: (406) 656-6399
Fax: (406) 656-6398

STARTED	11/21/05	FINISHED	11/21/05
CONTRACTOR		EXCAVATOR	Hitachie
OPERATOR	Dan Madisk	MODEL	EX200LC
LOGGED BY	G.Underhill	APPROVED BY	G.Underhill

Project No.: 8M087.175	LOG OF TEST PIT TP-2	Sheet 1 of 1

CLIENT	ARCHITECT/ENGINEER
DNRC	HKM Engineering
SITE	**PROJECT**
Dam Site	Ruby Dam

Surface Elevation: 5333.5

DEPTH (FT.)	MATERIAL DESCRIPTION	ELEVATION (FT.)
0	4" Topsoil and organic matter	
0.3	5333.2	
	Abundant angular 2-8" rock fragments with silty sand matrix, loose to medium dense to 8' (Rockfill)	5332
4		5328
6.0	5327.5	
	Silty gravel with sand and cobbles (GM), dense to very dense, moist, brown (Rockfill)	
8		5324
	Tough excavating 6.5'	
12	12.0 5321.5	
	Trackhoe bucket near refusal in boulders and cobbles; excavation terminated at 12'	
	No groundwater observed	
16	Test pit located at downstream toe near the center of the dam	
20		
24		
28		

GRAPHIC LOG

SAMPLES: BULK | POCKET PENETROMETER, TSF | M.C. (PL 10 20 30 40 LL)

ADDITIONAL DATA/ REMARKS

HKM Engineering Inc.
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Fax: (406) 656-6398

STARTED	11/21/05	FINISHED	11/21/05
CONTRACTOR		EXCAVATOR	Hitachie
OPERATOR	Dan Madisk	MODEL	EX200LC
LOGGED BY	G.Underhill	APPROVED BY	G.Underhill

Project No.: 8M087.175	LOG OF TEST PIT TP-3	Sheet 1 of 1

CLIENT	ARCHITECT/ENGINEER
DNRC	HKM Engineering
SITE	**PROJECT**
Dam Site	Ruby Dam

DEPTH (FT.)	MATERIAL DESCRIPTION Surface Elevation: 5324.0	GRAPHIC LOG	ELEVATION (FT.)	SAMPLES: BULK	POCKET PENETROMETER, TSF	M.C. ● PL 10 20 30 40 LL	ADDITIONAL DATA/ REMARKS
0	6" Topsoil and organic matter 0.5 — 5323.5						
	Abundant angular to subrounded cobbles and up to 36" boulders with silty, clayey sand matrix, slightly moist, very difficult excavating due to large boulders, sides of test pit caving (Fill adjacent to spillway wall)						
4			5320				
8	8.0 — 5316		5316				
	Trackhoe bucket refusal in large boulders and cobbles; excavation terminated at 8'						
	No groundwater observed						
12	Test pit located at the right abutment spillway groin						
16							
20							
24							
28							

HKM ENGINEERING

HKM Engineering Inc.
222 N. 32nd Street, Suite 700
Billings, Montana 59101
Telephone: (406) 656-6399
Fax: (406) 656-6398

STARTED	11/21/05	FINISHED	11/21/05
CONTRACTOR		EXCAVATOR	Hitachie
OPERATOR	Dan Madisk	MODEL	EX200LC
LOGGED BY	G.Underhill	APPROVED BY	G.Underhill

Project No.: 8M087.175	LOG OF TEST PIT TP-3A	Sheet 1 of 1

CLIENT	ARCHITECT/ENGINEER
DNRC	HKM Engineering
SITE	**PROJECT**
Dam Site	Ruby Dam

Surface Elevation: 5334.9

DEPTH (FT.)	MATERIAL DESCRIPTION	ELEVATION (FT.)
0	1" Topsoil and organic matter	
0.1	5334.8	
	Abundant angular cobbles and occasional boulders with silty, clayey sand matrix, loose to medium dense (Rockfill)	5332
4		
6.0	5328.9	
	Sandy gravel with abundant cobbles and scattered boulders, slightly moist, very dense (Rockfill)	5328
8		
10.0	5324.9	
	Trackhoe bucket near refusal in boulders and cobbles; excavation terminated at 10'	
12	No groundwater observed	
	Test pit located at the downstream toe, right abutment	
16		
20		
24		
28		

GRAPHIC LOG

SAMPLES: BULK | POCKET PENETROMETER, TSF | M.C. (PL 10 20 30 40 LL)

ADDITIONAL DATA/ REMARKS

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Billings, Montana 59101
Telephone: (406) 656-6399
Fax: (406) 656-6398

STARTED	11/21/05	FINISHED	11/21/05
CONTRACTOR		EXCAVATOR	Hitachie
OPERATOR	Dan Madisk	MODEL	EX200LC
LOGGED BY	G.Underhill	APPROVED BY	G.Underhill

Project No.: 8M087.175	LOG OF TEST PIT TP-4	Sheet 1 of 1

CLIENT	ARCHITECT/ENGINEER
DNRC	HKM Engineering
SITE	**PROJECT**
Dam Site	Ruby Dam

Surface Elevation: 5318.9

DEPTH (FT.)	MATERIAL DESCRIPTION	ELEVATION (FT.)
0	5" Topsoil and organic matter	
0.4	5318.5	
	Silty sand/poorly graded sand with abundant subrounded to rounded 6-8" cobbles, clayey in part, loose to medium dense, brown (Fill)	5316
4		
		5312
8.0	5310.9	
	Sandy gravel with angular 4-8" rock fragments, loose (Fill, possible blasted rockfill)	5308
12		
		5304
16		
18.5	5300.4	
	Test pit terminated at 18.5'	
20	No groundwater observed	
	Test pit located between the dam toe and TP-6	
24		
28		

SAMPLES: BULK | POCKET PENE-TROMETER, TSF | M.C. (PL 10 20 30 40 LL) | ADDITIONAL DATA/ REMARKS

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Telephone: (406) 656-6399
Fax: (406) 656-6398

STARTED	11/21/05	FINISHED	11/21/05
CONTRACTOR		EXCAVATOR	Hitachie
OPERATOR	Dan Madisk	MODEL	EX200LC
LOGGED BY	G.Underhill	APPROVED BY	G.Underhill

Project No.: 8M087.175	LOG OF TEST PIT TP-6	Sheet 1 of 1

CLIENT	ARCHITECT/ENGINEER
DNRC	HKM Engineering
SITE	**PROJECT**
Dam Site	Ruby Dam

Surface Elevation: 5306.0

DEPTH (FT.)	MATERIAL DESCRIPTION	ELEVATION (FT.)	BULK	POCKET PENETROMETER, TSF	M.C. (PL 10 20 30 40 LL)	ADDITIONAL DATA/ REMARKS
0	6" Topsoil and organic matter					
0.5 / 5305.5	Silty sand/poorly graded sand with scattered gravel and occasional cobbles (SP/SM), moist, loose to medium dense, brown (Fill)	5304				
2.0 / 5304	Silty sand/poorly graded sand with 8" angular to subrounded cobble and up to 36" subrounded boulders (Fill)	5300				
8.0 / 5298	Poorly graded gravel (GP), slightly moist, loose to medium dense, gray (Alluvium)					
9.5 / 5296.5	Sandy silt (ML), moist to very moist, loose to medium dense, light gray (Alluvium)	5296	X			Lab Sample #3342: USCS=ML Gravel=0% Sand=38% Fines=62% Liquid Limit=31 Plasticity Index=6 MC=29.3%
		5292				
16.0 / 5290	Poorly graded gravel with rounded 6" cobble (GP), saturated, loose to medium dense, gray brown (Alluvium)					
17.5 / 5288.5	Test pit terminated at 17.5'					
	Groundwater observed at 16.5' on 11/21/05					
	Test pit located at north edge of toe fill near powerline					

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STARTED	11/21/05	FINISHED	11/21/05
CONTRACTOR		EXCAVATOR	Hitachie
OPERATOR	Dan Madisk	MODEL	EX200LC
LOGGED BY	G.Underhill	APPROVED BY	G.Underhill

Project No.: 8M087.175	LOG OF TEST PIT TP-7	Sheet 1 of 1

CLIENT	ARCHITECT/ENGINEER
DNRC	HKM Engineering
SITE	**PROJECT**
Dam Site	Ruby Dam

Surface Elevation: 5411.2

DEPTH (FT.)	MATERIAL DESCRIPTION	ELEVATION (FT.)	ADDITIONAL DATA/ REMARKS
0	4" Topsoil and organic matter		Nuclear Densometer Reading at Top of Crest Near DH-2: WD=137.6pcf DD=130.4pcf MC=5.2%
0.3 / 5410.9	Poorly graded gravel with sand (GP), loose to medium dense, dry, yellow brown, occasional 3-8" cobbles		
1.8 / 5409.4	Silty, clayey sand with gravel (SC-SM), loose, dry, red brown, medium to fine grained (Variable dam crest fill)	5408	Lab Sample #3343: USCS=SC-SM Gravel=17% Sand=69% Fines=14% Liquid Limit=23 Plasticity Index=4 Max Unit Wt.=132.0pcf Opt Moisture=9.5% MC=7.6%
4		5404	
8			
9.0 / 5402.2	Clayey sand (SC), medium dense, moist, yellow brown, widely scattered 1" gravel (Select clay loam core material as shown on as-built plans)	5400	Lab Sample #3344: USCS=SC Gravel=9% Sand=48% Fines=43% Liquid Limit=47 Plasticity Index=29 Max Unit Wt.=108.7pcf Opt Moisture=16.8% MC=7.6%
12			
15.5 / 5395.7	Test pit terminated at 15.5'	5396	
16	No groundwater observed		
	Test pit located top of dam crest adjacent to the left abutment		
20			
24			
28			

GRAPHIC LOG

SAMPLES: BULK; POCKET PENETROMETER, TSF; M.C. (PL 10 20 30 40 LL)

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STARTED	11/21/05	FINISHED	11/21/05
CONTRACTOR		EXCAVATOR	Hitachie
OPERATOR	Dan Madisk	MODEL	EX200LC
LOGGED BY	G.Underhill	APPROVED BY	G.Underhill

Project No.: 8M087.175	LOG OF TEST PIT TP-7A	Sheet 1 of 1

CLIENT	ARCHITECT/ENGINEER
DNRC	HKM Engineering
SITE	**PROJECT**
Dam Site	Ruby Dam

Surface Elevation: 5411.3

DEPTH (FT.)	MATERIAL DESCRIPTION	ELEVATION (FT.)	ADDITIONAL DATA/ REMARKS
0	10" Topsoil and organic matter		
0.8	5410.5		
	Poorly graded gravel with sand (GP), medium dense		
1.2	5410.1		
	Poorly graded sand/sandy lean clay with scattered angular to subrounded cobbles (SP/CL), medium dense/stiff, moist, yellow brown, cobble size ranges from 6-12" (Variable dam crest fill)	5408	Nuclear Densometer Reading at 3.5': WD=128.7pcf DD=116.1pcf MC=10.9% Nuclear Densometer Reading 6.0' to 6.7': WD=125.0pcf DD=111.5pcf MC=10.4%
4			
		5404	
8			
9.0	5402.3		
	Sandy lean clay (CL)/Clayey sand(SC), stiff/medium dense, moist, yellow brown, scattered pebbles and gravel (Select clay loam core material)		
10.5	5400.8		
12	Test pit terminated at 10.5'		
	No groundwater observed		
	Test pit located 108' west of DH-2		
16			
20			
24			
28			

GRAPHIC LOG

SAMPLES: BULK | POCKET PENETROMETER, TSF | M.C. (PL 10 20 30 40 LL)

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STARTED	11/21/05	FINISHED	11/21/05
CONTRACTOR		EXCAVATOR	Hitachie
OPERATOR	Dan Madisk	MODEL	EX200LC
LOGGED BY	G.Underhill	APPROVED BY	G.Underhill

Project No.: 8M087.175	LOG OF TEST PIT TP-8	Sheet 1 of 1

CLIENT	ARCHITECT/ENGINEER
DNRC	HKM Engineering
SITE	**PROJECT**
Dam Site	Ruby Dam

DEPTH (FT.)	MATERIAL DESCRIPTION (Surface Elevation: 5410.5)	ELEVATION (FT.)	BULK	POCKET PENETROMETER, TSF	M.C. (PL 10 20 30 40 LL)	ADDITIONAL DATA/ REMARKS
0	6" topsoil and organic matter					
0.5 (5410)	Sandy poorly graded gravel (GP), brown					
1.0 (5409.5)	Sandy lean clay with scattered pebbles and occasional cobbles (CL), stiff, moist, yellow brown	5408				Nuclear Densometer Reading at 2.0': DD=89.0pcf MC=20.0%
4						
5.0 (5405.5)	Interbedded silt/clay/sand seams (Variable dam crest fill)	5404				Nuclear Densometer Reading at 5.0': WD=115.4pcf DD=100.0pcf MC=14.8%
8						
9.0 (5401.5)	Silty, clayey sand with gravel (SC-SM), medium dense, slightly moist to moist, red brown	5400	X		■ ⊣	Lab Sample #3346: USCS=SC-SM Gravel=17% Sand=65% Fines=15% Liquid Limit=24 Plasticity Index=4 Max Unit Wt.=131.2pcf Opt Moisture=9.7% MC=6.9%
12	(Shovel mixed clay and loam, sand and gravel pit-run with cobbles 11-12.5')					
12.8 (5397.7)	Test pit terminated at 12.8'					
	No groundwater observed					
16	Test pit located on dam crest, downstream side					
20						
24						
28						

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STARTED	11/21/05	FINISHED	11/21/05
CONTRACTOR		EXCAVATOR	Hitachie
OPERATOR	Dan Madisk	MODEL	EX200LC
LOGGED BY	G.Underhill	APPROVED BY	G.Underhill

APPENDIX B

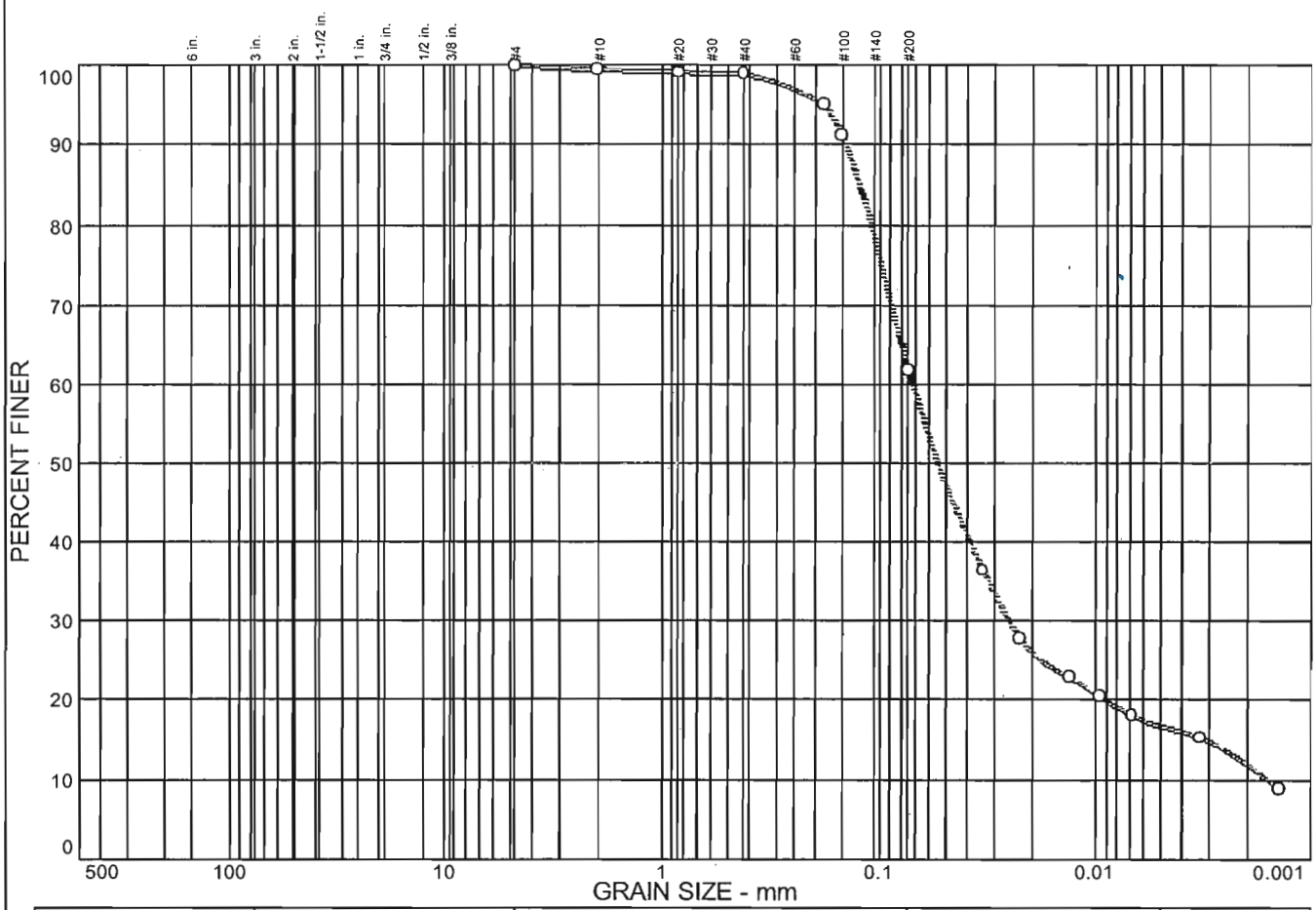
RUBY DAM

LABORATORY TEST RESULTS

SUMMARY OF PHYSICAL PROPERTIES TEST RESULTS

LAB NUMBER	LOCATION	DEPTH RANGE	CLASSIFICATION SYMBOL	SMALLER THAN 0.075 mm	SAND NO. 200(0.075 mm) TO NO. 4(4.76 mm)	GRAVEL NO. 4(4.76 mm) TO 3 IN.(76.2 mm)	COBBLES 3 IN.(76.2 mm) TO 5 IN.(127 mm)	LIQUID LIMIT - %	PLASTICITY INDEX - %	MAXIMUM DRY UNIT WEIGHT(D698)-pcf	OPTIMUM MOISTURE CONTENT - %	SPECIFIC GRAVITY(BULK)	ABSORPTION	CALIFORNIA BEARING RATIO	UNIT WT. DRY - PCF	UNCONFINED - qu (KSF)	NATURAL MOISTURE - %	Resistivity (Ohm-Cm) Natural Moisture	Resistivity (Ohm-Cm) Saturated	pH	WATER SOLUBLE SO4 - %
3342	TP-6	9.5' - 10.0'	ML	62	38	0	0	31	6								29.3				
3343	TP-7	4.0' - 8.0'	SC-SM	14	69	17	0	23	4	132.0	9.5	2.52	2.77				7.6				
3344	TP-7	9.5' - 11.0'	SC	43	48	9	0	47	29	108.7	16.8	2.27	5.13				16.5				
3346	TP-8	9.0' - 10.5	SC-SM	15	65	17	3	24	4	131.2	9.7	2.58	1.64				6.9				

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	38.2	45.1	16.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	99.4		
#20	99.1		
#40	98.9		
#80	95.0		
#100	91.1		
#200	61.8		

* (no specification provided)

Soil Description

Sandy silt

Atterberg Limits

PL= 25 LL= 31 PI= 6

Coefficients

D_{85}= 0.125 D_{60}= 0.0719 D_{50}= 0.0548
D_{30}= 0.0256 D_{15}= 0.0031 D_{10}= 0.0016
C_u= 44.36 C_c= 5.62

Classification

USCS= ML AASHTO= A-4(2)

Remarks

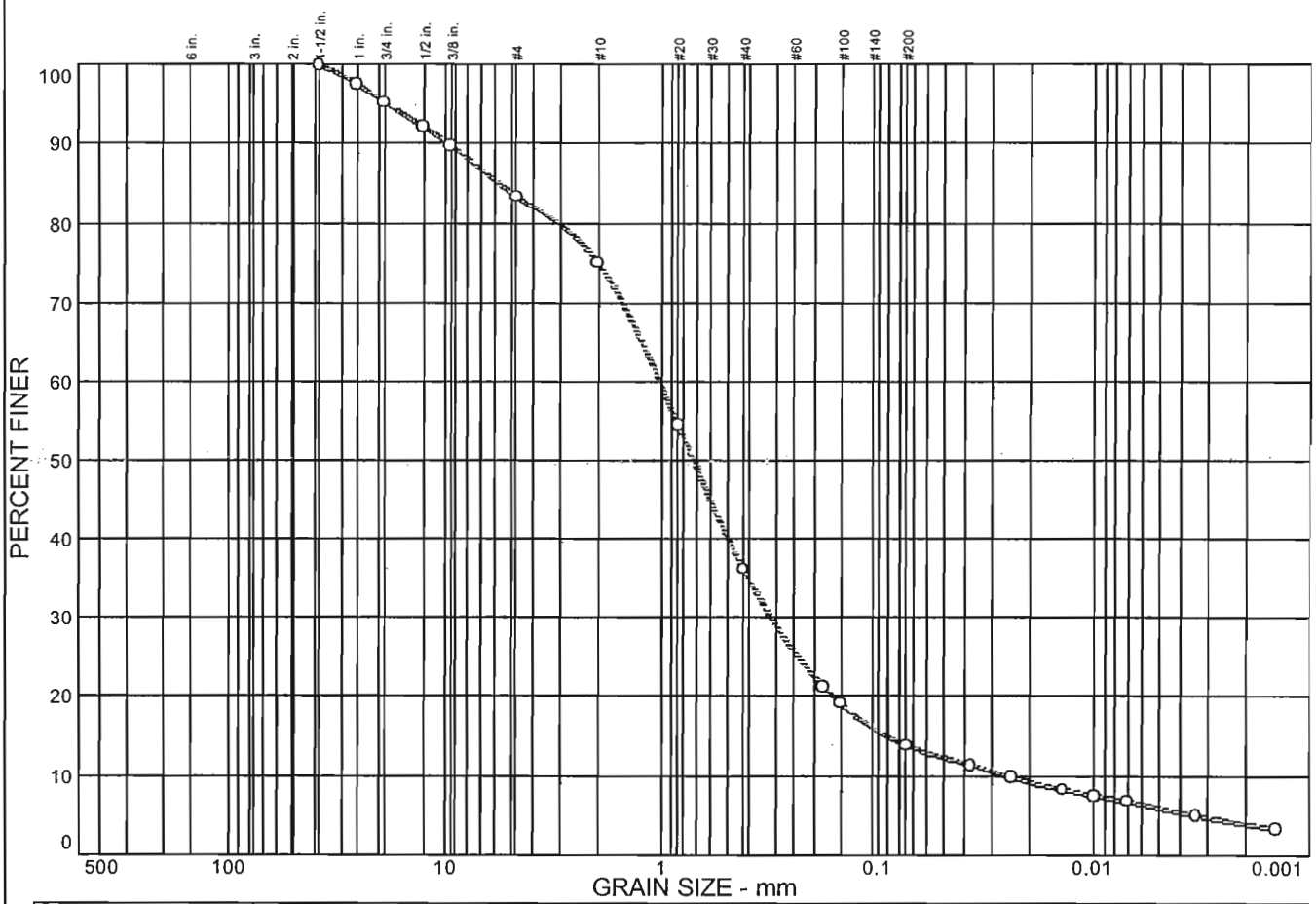
Sampled By: GU/HKM/11-21-05
Tested By: JMB/HKM/12-5-05

Sample No.: 3342 **Source of Sample:** TP-6 **Date:** 12-9-05
Location: TP-6 **Elev./Depth:** 9.5' - 10.0'

HKM ENGINEERING, INC.

Client: MT DNRC
Project: Ruby Dam Feasibility Study
Project No: 08M087.175 **Lab ID** 3342

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	16.7	69.5	7.9	5.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5 in.	100.0		
1 in.	97.5		
.75 in.	95.2		
.5 in.	92.2		
.375 in.	89.8		
#4	83.3		
#10	75.0		
#20	54.5		
#40	36.1		
#80	21.2		
#100	19.1		
#200	13.8		

* (no specification provided)

Soil Description

Silty, clayey sand with gravel

Atterberg Limits

PL= 19 LL= 23 PI= 4

Coefficients

D_{85}= 5.77 D_{60}= 1.04 D_{50}= 0.724
D_{30}= 0.318 D_{15}= 0.0926 D_{10}= 0.0263
C_u= 39.47 C_c= 3.71

Classification

USCS= SC-SM AASHTO= A-1-b

Remarks

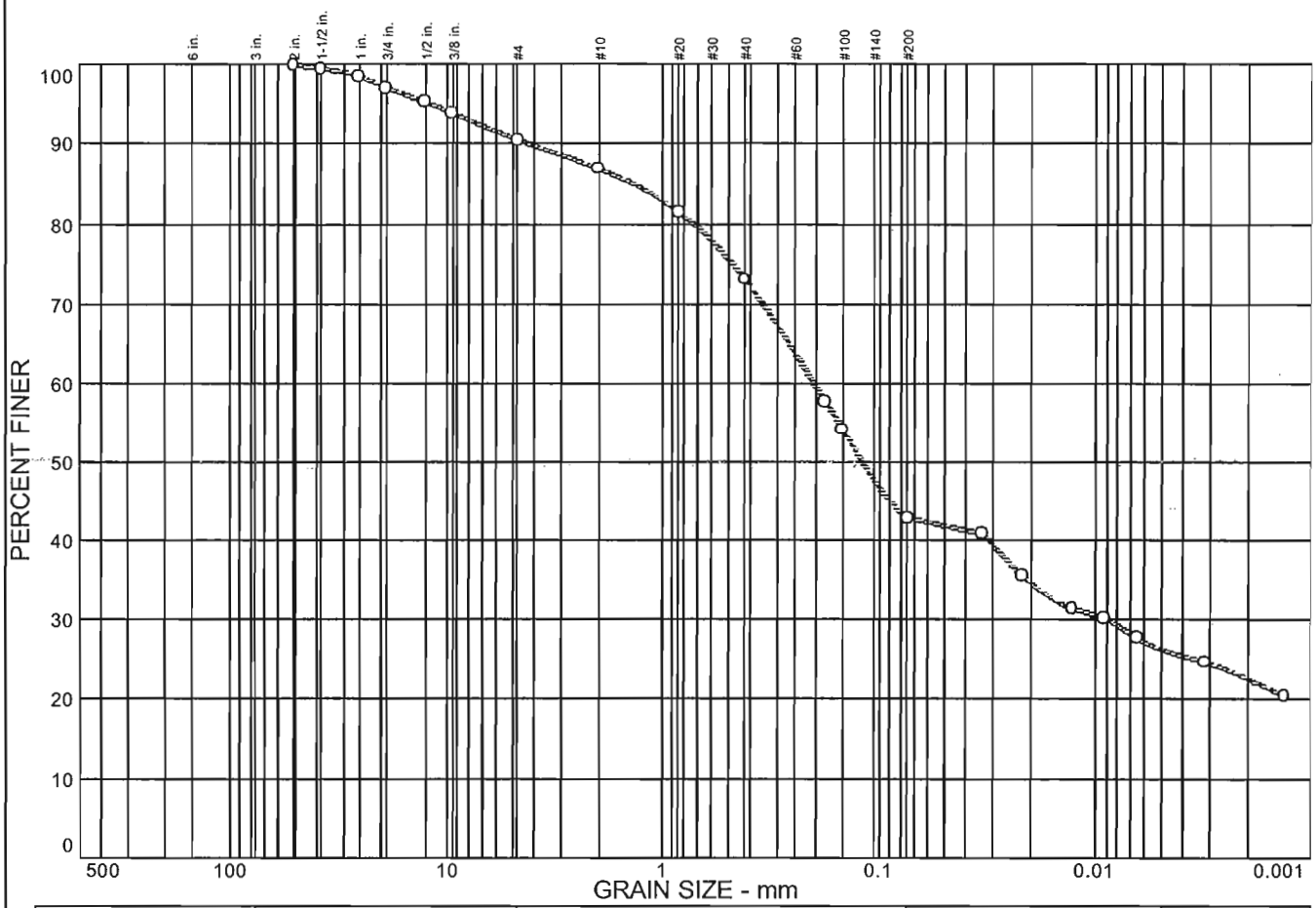
Sampled By: GU/HKM/11-21-05
Tested By: JMB/HKM/12-5-05

Sample No.: 3343 **Source of Sample:** TP-7 **Date:** 12-9-05
Location: TP-7 **Elev./Depth:** 4.0' - 8.0'

HKM ENGINEERING, INC.

Client: MT DNRC
Project: Ruby Dam Feasibility Study
Project No: 08M087.175 **Lab ID** 3343

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	9.5	47.6	16.6	26.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
2 in.	100.0		
1.5 in.	99.5		
1 in.	98.5		
.75 in.	97.1		
.5 in.	95.3		
.375 in.	93.9		
#4	90.5		
#10	86.9		
#20	81.5		
#40	73.1		
#80	57.6		
#100	54.1		
#200	42.9		

* (no specification provided)

Soil Description

Clayey sand

Atterberg Limits

PL= 18 LL= 47 PI= 29

Coefficients

D_{85}= 1.37 D_{60}= 0.204 D_{50}= 0.122
D_{30}= 0.0088 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SC AASHTO= A-7-6(7)

Remarks

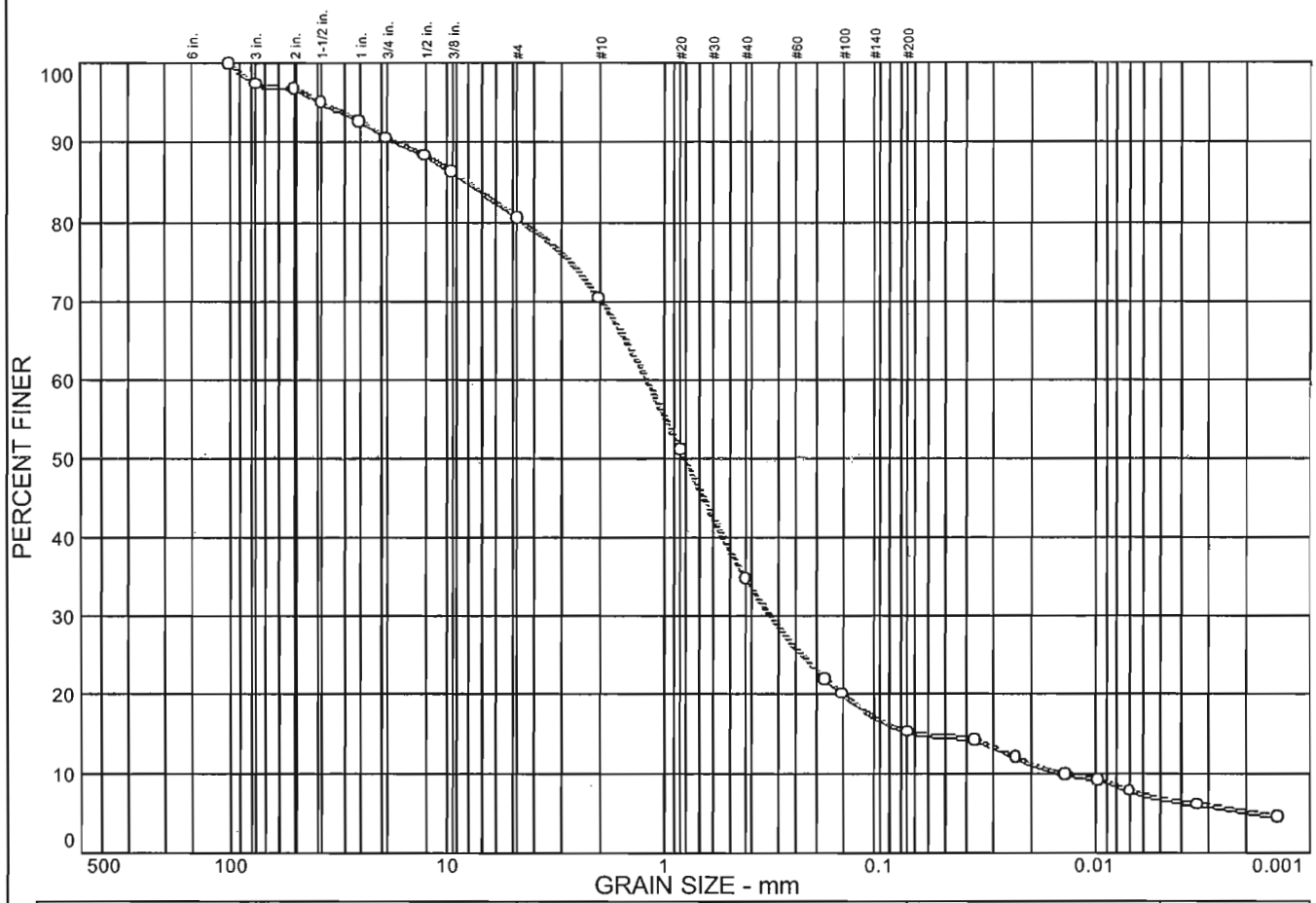
Tested By: GU/HKM/11-21-05
Sampled By: JMB/HKM/12-5-05

Sample No.: 3344 **Source of Sample:** TP-7 **Date:** 12-9-05
Location: TP-7 **Elev./Depth:** 9.5' - 10.5'

HKM ENGINEERING, INC.

Client: MT DNRC
Project: Ruby Dam Feasibility Study
Project No: 08M087.175 **Lab ID** 3344

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
2.6	16.9	65.3	8.5	6.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
4 in.	100.0		
3 in.	97.4		
2 in.	96.7		
1.5 in.	95.0		
1 in.	92.7		
.75 in.	90.6		
.5 in.	88.4		
.375 in.	86.3		
#4	80.5		
#10	70.4		
#20	51.0		
#40	34.8		
#80	22.0		
#100	20.1		
#200	15.2		

* (no specification provided)

Soil Description

Silty, clayey sand with gravel

Atterberg Limits

PL= 20 LL= 24 PI= 4

Coefficients

D_{85}= 8.11 D_{60}= 1.22 D_{50}= 0.817
D_{30}= 0.326 D_{15}= 0.0697 D_{10}= 0.0149
C_u= 81.76 C_c= 5.83

Classification

USCS= SC-SM AASHTO= A-1-b

Remarks

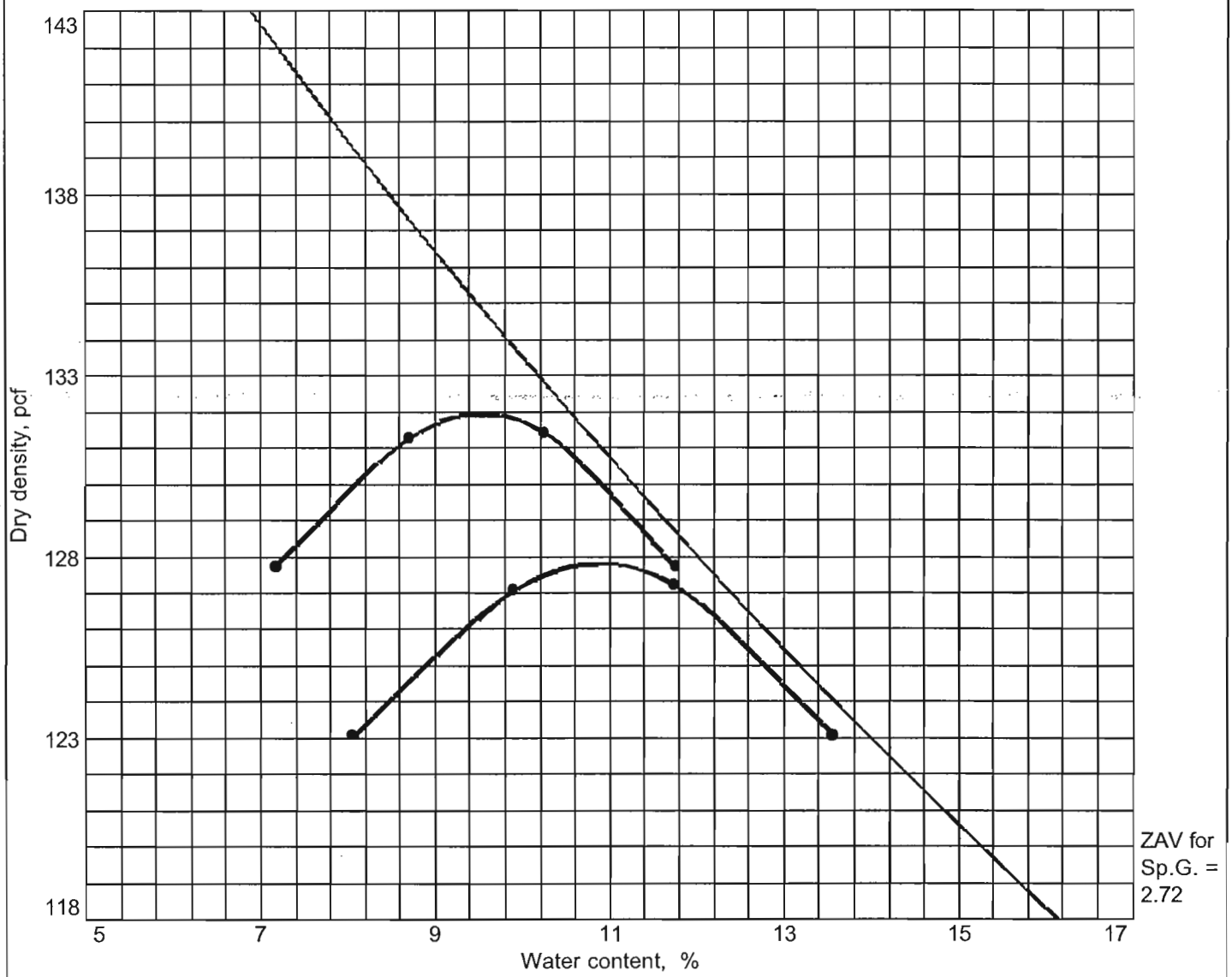
Sampled By: GU/HKM/11-21-05
Tested By: JMB/HKM/12-5-05

Sample No.: 3346 **Source of Sample:** TP-8 **Date:** 12-9-05
Location: TP-8 **Elev./Depth:** 9.0' - 10.5'

HKM ENGINEERING, INC.

Client: MT DNRC
Project: Ruby Dam Feasibility Study
Project No: 08M087.175 **Lab ID** 3346

MOISTURE-DENSITY TEST REPORT



Test specification: ASTM D 698-91 Procedure A Standard
Oversize correction applied to each point

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > No.4	% < No.200
	USCS	AASHTO						
4.0' - 8.0'	SC-SM	A-1-b	7.6		23	4	16.7	13.8

ROCK CORRECTED TEST RESULTS	UNCORRECTED	MATERIAL DESCRIPTION
Maximum dry density = 132.0 pcf	127.8 pcf	Silty, clayey sand with gravel
Optimum moisture = 9.5 %	10.9 %	

Project No. 08M087.175 **Client:** MT DNRC
Project: Ruby Dam Feasibility Study

● **Location:** TP-7

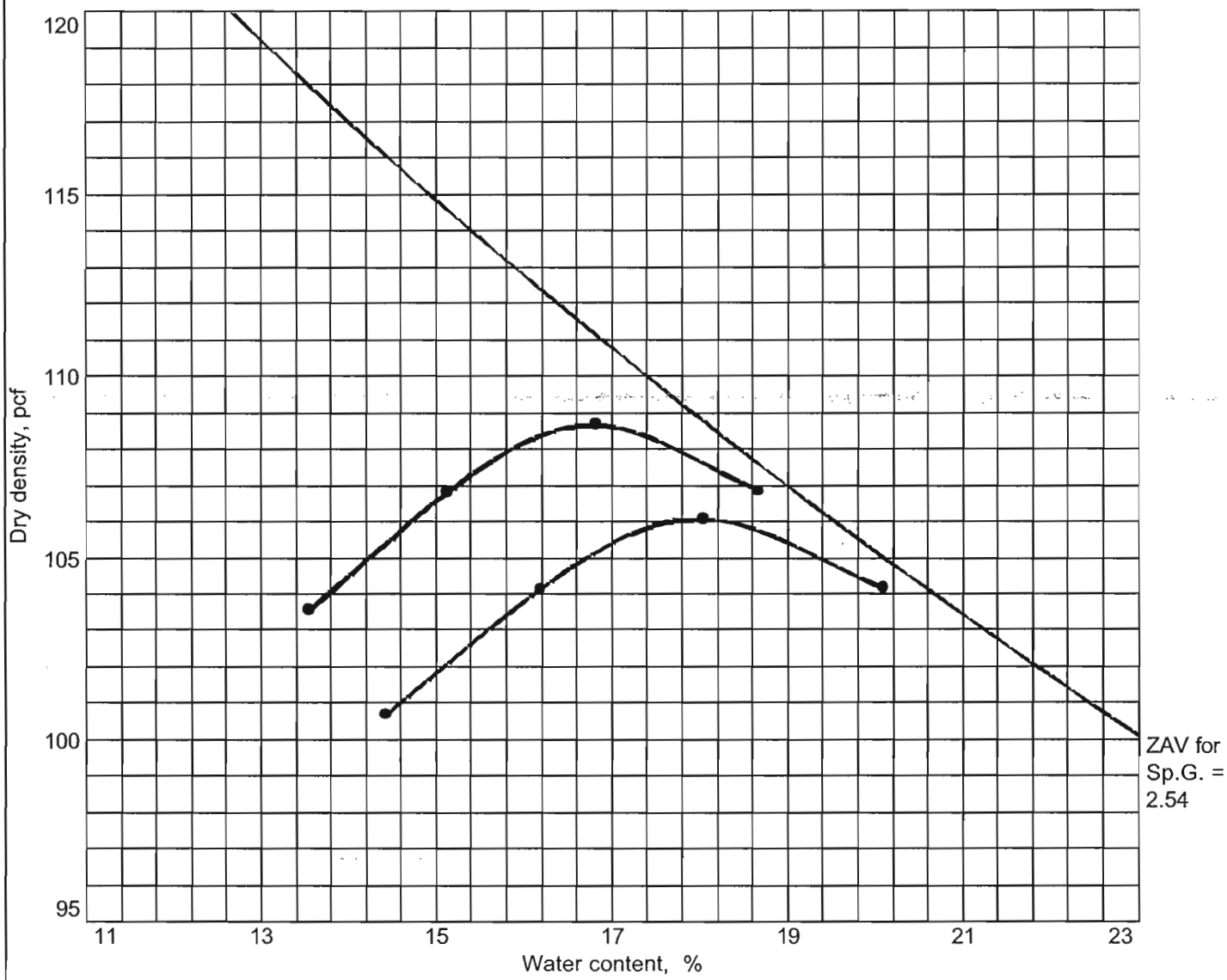
Remarks:
Sampled By: GU/HKM/11-22-05
Tested By: JMB/HKM/12-5-05

MOISTURE-DENSITY TEST REPORT

HKM ENGINEERING, INC.

Lab ID 3343

MOISTURE-DENSITY TEST REPORT



Test specification: ASTM D 698-91 Procedure A Standard
Oversize correction applied to each point

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > No.4	% < No.200
	USCS	AASHTO						
9.5' - 10.5'	SC	A-7-6(7)			47	29	9.5	42.9

ROCK CORRECTED TEST RESULTS	UNCORRECTED	MATERIAL DESCRIPTION
Maximum dry density = 108.7 pcf	106.1 pcf	Clayey sand
Optimum moisture = 16.8 %	18.0 %	

Project No. 08M087.175 **Client:** MT DNRC
Project: Ruby Dam Feasibility Study

● **Location:** TP-7

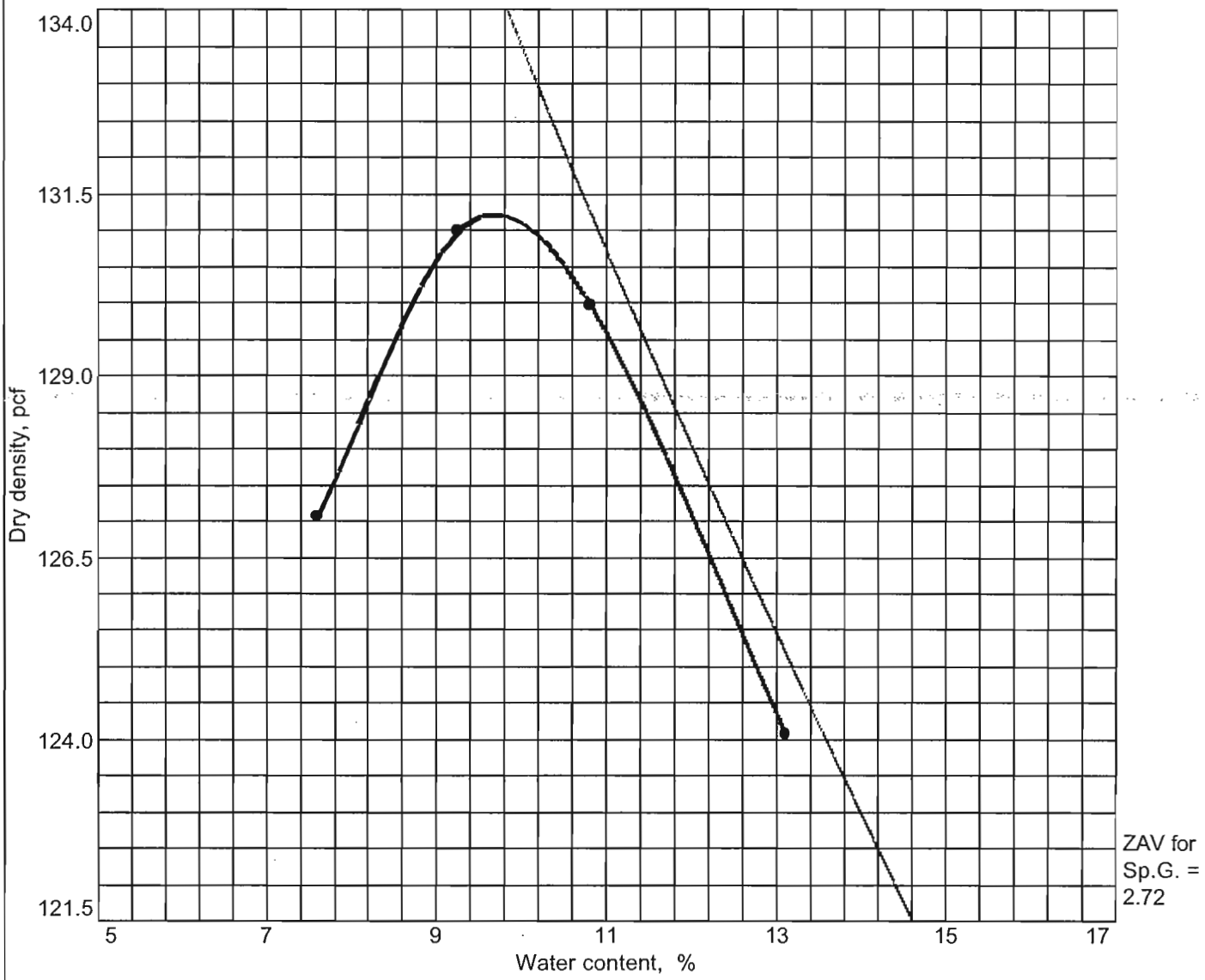
Remarks:
Sampled By: GU/HKM/11-22-05
Tested By: JMB/HKM/12-5-05

MOISTURE-DENSITY TEST REPORT

HKM ENGINEERING, INC.

Lab ID 3344

MOISTURE-DENSITY TEST REPORT



Test specification: ASTM D 698-91 Procedure C Standard
Oversize correction applied to each point

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > 3/4 in.	% < No.200
	USCS	AASHTO						
9.0' - 10.5'	SC-SM	A-1-b	6.9		24	4	9.4	15.2

ROCK CORRECTED TEST RESULTS	UNCORRECTED	MATERIAL DESCRIPTION
Maximum dry density = 131.2 pcf	128.8 pcf	Silty, clayey sand with gravel
Optimum moisture = 9.7 %	10.5 %	

Project No. 08M087.175 **Client:** MT DNRC
Project: Ruby Dam Feasibility Study

● **Location:** TP-8

Remarks:
Sampled By: GU/HKM/11-22-05
Tested By: JMB/HKM/12-05-05

MOISTURE-DENSITY TEST REPORT

HKM ENGINEERING, INC.

Lab ID 3346

APPENDIX C

RUBY DAM

PHOTOGRAPHS OF TEST PITS

Test Pit TP-1 Excavated Material

Test Pit TP-1 -Excavated Material

Test Pit TP-1 -Test Pit Wall

Test Pit TP-2 - Excavated Material

Test Pit TP-2 - Test Pit wall

Test Pit TP-3 - Excavated Material

Test Pit TP-3 - Excavated Material

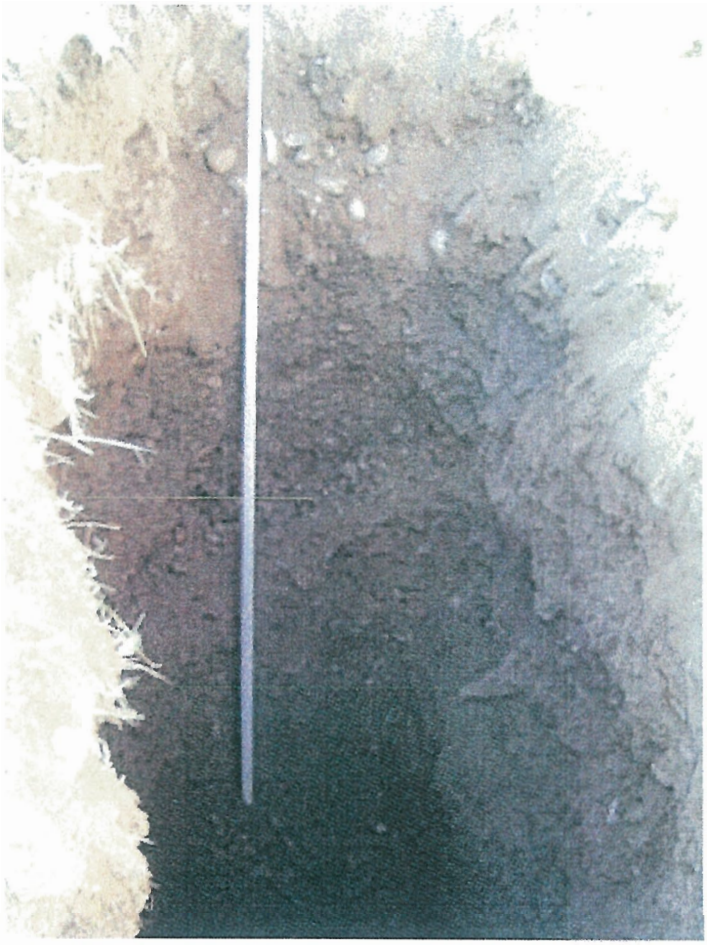
Test Pit TP-3 – Test Pit Wall

Test Pit TP-3A – Excavated Material

Test Pit TP-3A – Test Pit Wall

Test Pit TP-4 – Excavated Material

Test Pit TP-4 – Excavated Material



Test Pit TP-4 – Test Pit Wall

Test Pit TP-6 – Excavated Material

Test Pit TP-6 – Excavated Material

Test Pit TP-7 – Excavated Material

Test Pit TP-7 – Test Pit Wall

Test Pit TP-7A – Test Pit Wall

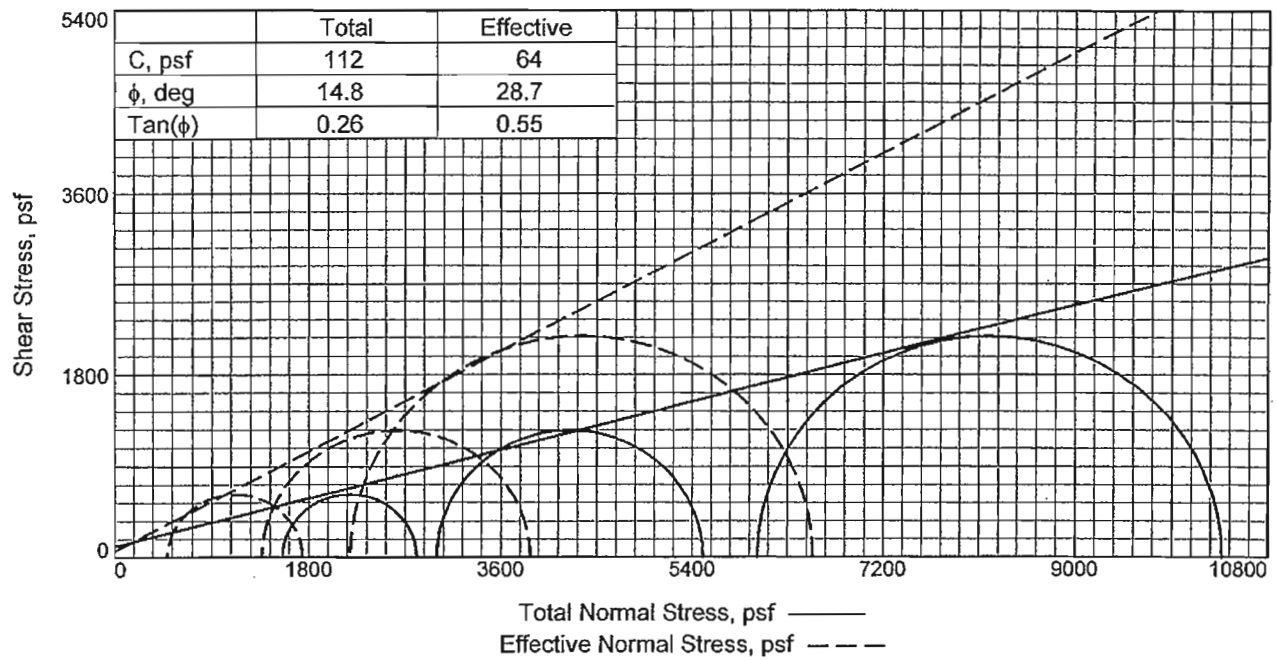
Test Pit TP-8 – Excavated Material

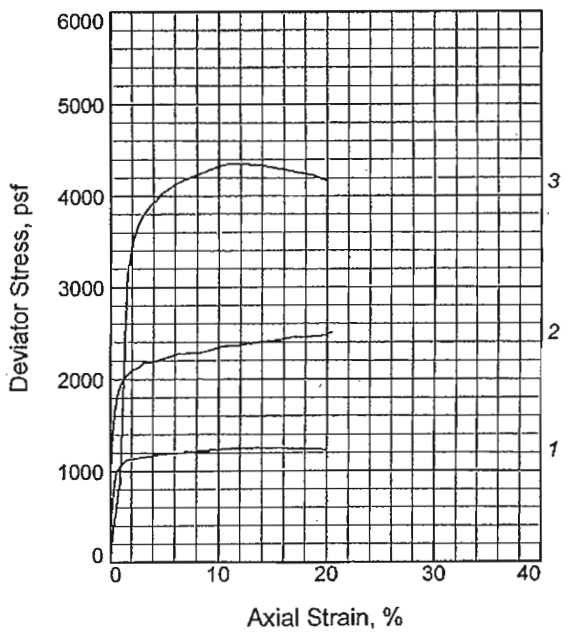
Test Pit TP-8 – Test Pit Wall

APPENDIX H

TRIAXIAL TEST RESULTS TEST PIT- TP7A

	Total	Effective
C, psf	112	64
ϕ, deg	14.8	28.7
Tan(ϕ)	0.26	0.55





Sample No.		1	2	3
Initial	Water Content, %	21.6	21.7	21.4
	Dry Density, pcf	87.7	87.6	88.0
	Saturation, %	63.2	63.6	62.9
	Void Ratio	0.9210	0.9232	0.9161
	Diameter, in.	2.398	2.398	2.398
	Height, in.	4.996	4.996	4.993
At Test	Water Content, %	29.0	26.0	24.3
	Dry Density, pcf	94.5	99.1	101.7
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.7837	0.7017	0.6573
	Diameter, in.	2.339	2.302	2.284
	Height, in.	4.875	4.799	4.761
Strain rate, in./min.		0.005	0.003	0.005
Back Pressure, psi		60.20	72.40	69.20
Cell Pressure, psi		71.02	93.20	110.97
Fail. Stress, psf		1249	2507	4354
Total Pore Pr., psf		9734	12053	13795
Ult. Stress, psf				
Total Pore Pr., psf				
$\bar{\sigma}_1$ Failure, psf		1741	3875	6538
$\bar{\sigma}_3$ Failure, psf		492	1368	2184

Type of Test:
CU with Pore Pressures

Sample Type: Remolded

Description:

Assumed Specific Gravity= 2.70

Remarks:

Client: HKM Engineering

Project: RUBY DAM

Source of Sample: TP-7A **Depth:** 9.0'-10.5'

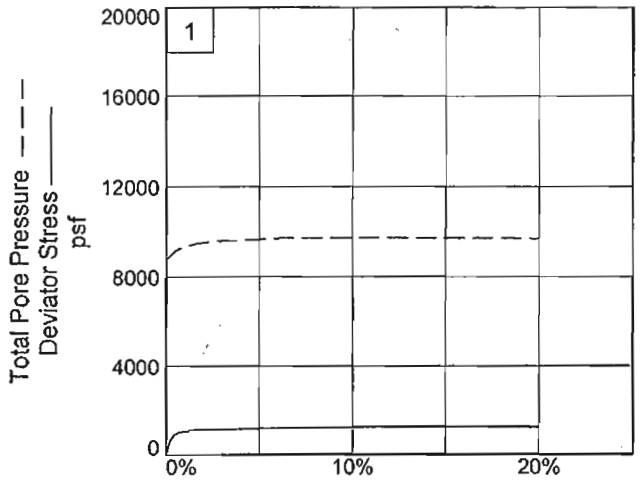
Sample Number: Pt A,B &C

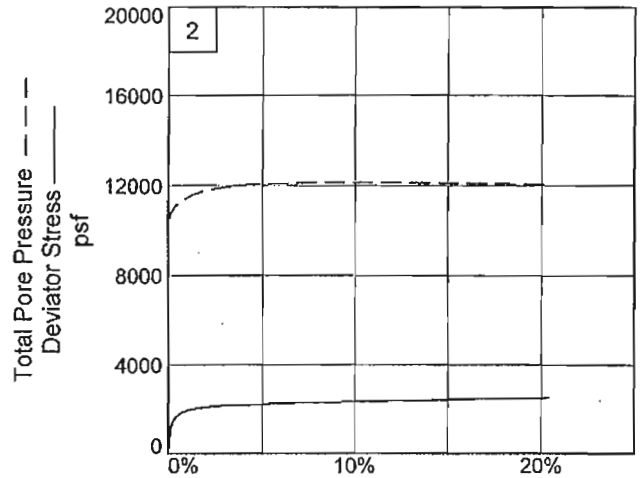
Proj. No.: 2262-01 **Date Sampled:**

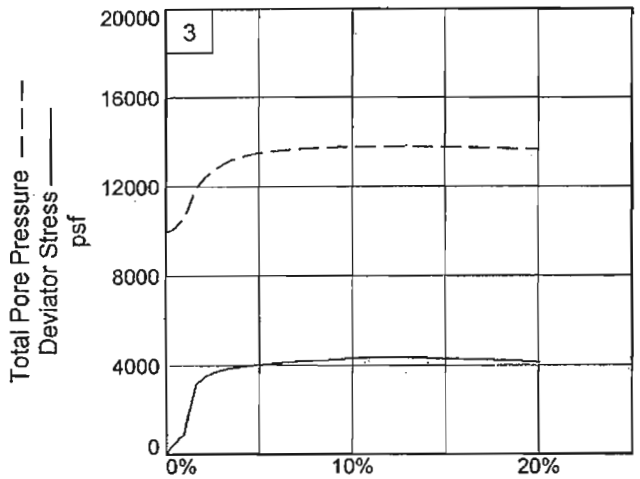
TRIAXIAL SHEAR TEST REPORT

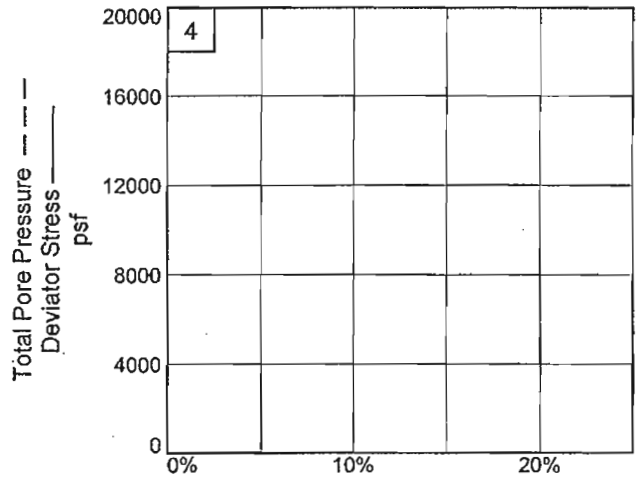
Tetra Tech, Inc.

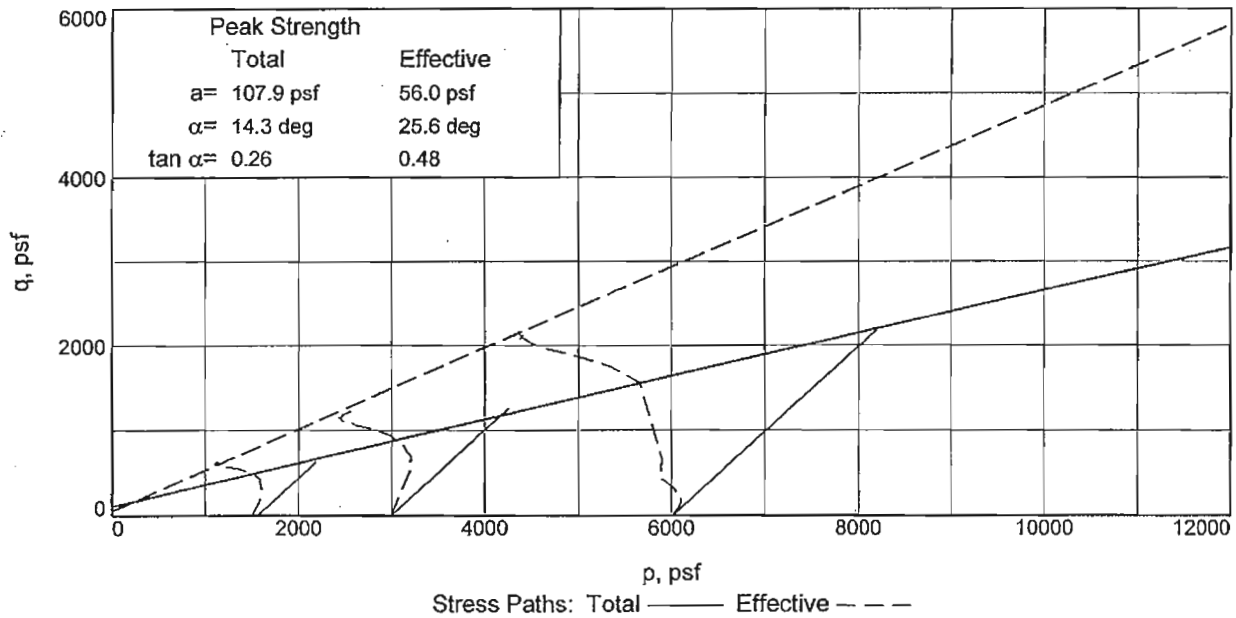
Report No. _____











Client: HKM Engineering

Project: RUBY DAM

Source of Sample: TP-7A **Depth:** 9.0'-10.5' **Sample Number:** Pt A,B &C

Project No.: 2262-01 **Report No.** _____

Tetra Tech, Inc.

TRIAXIAL COMPRESSION TEST

CU with Pore Pressures

8/24/2007
8:13 AM

Date:
Client: HKM Engineering
Project: RUBY DAM
Project No.: 2262-01
Location: TP-7A
Depth: 9.0'-10.5' **Sample Number:** Pt A,B &C
Description:
Remarks:
Type of Sample: Remolded
Assumed Specific Gravity=2.70 **LL=** **PL=** **PI=**
Test Method: COE uniform strain

Parameters for Specimen No. 1

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	631.800			668.300
Moisture content: Dry soil+tare, gms.	519.700			519.700
Moisture content: Tare, gms.	0.000			0.000
Moisture, %	21.6	34.1	29.0	28.6
Moist specimen weight, gms.	631.80			
Diameter, in.	2.398	2.398	2.339	
Area, in.^{2}	4.516	4.516	4.298	
Height, in.	4.996	4.996	4.875	
Net decrease in height, in.		0.000	0.121	
Wet Density, pcf	106.7	117.7	121.9	
Dry density, pcf	87.7	87.7	94.5	
Void ratio	0.9210	0.9210	0.7837	
Saturation, %	63.2	100.0	100.0	

Test Readings for Specimen No. 1

Consolidation cell pressure = 71.02 psi (10227 psf)
Consolidation back pressure = 60.20 psi (8669 psf)
Consolidation effective confining stress = 1558 psf
Strain rate, in./min. = 0.005
Fail. Stress = 1249 psf **at reading no.** 16

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Test Readings for Specimen No. 1

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress psf	Minor Eff. Stress psf	Major Eff. Stress psf	1:3 Ratio	Pore Press. psi	P psf	Q psf
0	0.0000	0.00	0.0	0.0	0	1500	1500	1.00	60.60	1500	0
1	0.0050	9.00	9.0	0.1	301	1428	1730	1.21	61.10	1579	151
2	0.0100	17.00	17.0	0.2	568	1328	1896	1.43	61.80	1612	284
3	0.0150	22.00	22.0	0.3	735	1227	1962	1.60	62.50	1594	367
4	0.0200	26.00	26.0	0.4	868	1155	2022	1.75	63.00	1589	434
5	0.0250	28.00	28.0	0.5	933	1083	2016	1.86	63.50	1550	467
6	0.0300	30.00	30.0	0.6	999	1025	2024	1.97	63.90	1525	500
7	0.0400	31.00	31.0	0.8	1030	939	1969	2.10	64.50	1454	515
8	0.0500	32.00	32.0	1.0	1061	881	1943	2.20	64.90	1412	531
9	0.0750	34.00	34.0	1.5	1122	766	1888	2.46	65.70	1327	561
10	0.1250	35.00	35.0	2.6	1143	651	1794	2.76	66.50	1222	571
11	0.1750	36.00	36.0	3.6	1163	608	1771	2.91	66.80	1189	581
12	0.2250	37.00	37.0	4.6	1183	579	1761	3.04	67.00	1170	591
13	0.3000	38.00	38.0	6.2	1195	507	1702	3.36	67.50	1104	597
14	0.3500	39.00	39.0	7.2	1213	492	1705	3.46	67.60	1099	606
15	0.4250	40.00	40.0	8.7	1223	492	1716	3.48	67.60	1104	612
16	0.5500	42.00	42.0	11.3	1249	492	1741	3.54	67.60	1117	624
17	0.6500	43.00	43.0	13.3	1249	507	1756	3.46	67.50	1131	624
18	0.7490	44.00	44.0	15.4	1248	521	1769	3.39	67.40	1145	624
19	0.8490	45.00	45.0	17.4	1245	521	1767	3.39	67.40	1144	623
20	0.9740	46.00	46.0	20.0	1233	536	1769	3.30	67.30	1152	617

Parameters for Specimen No. 2

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	631.900			653.800
Moisture content: Dry soil+tare, gms.	519.100			519.100
Moisture content: Tare, gms.	0.000			0.000
Moisture, %	21.7	34.2	26.0	25.9
Moist specimen weight, gms.	631.90			
Diameter, in.	2.398	2.398	2.302	
Area, in.²	4.516	4.516	4.160	
Height, in.	4.996	4.996	4.799	
Net decrease in height, in.		0.000	0.197	
Wet Density, pcf	106.7	117.6	124.8	
Dry density, pcf	87.6	87.6	99.1	
Void ratio	0.9232	0.9232	0.7017	
Saturation, %	63.6	100.0	100.0	

Test Readings for Specimen No. 2

Consolidation cell pressure = 93.20 psi (13421 psf)

Consolidation back pressure = 72.40 psi (10426 psf)

Consolidation effective confining stress = 2995 psf

Strain rate, in./min. = 0.003

Fail. Stress = 2507 psf **at reading no.** 28

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress psf	Minor Eff. Stress psf	Major Eff. Stress psf	1:3 Ratio	Pore Press. psi	P psf	Q psf
0	0.0000	0.00	0.0	0.0	0	2995	2995	1.00	72.40	2995	0
1	0.0050	30.00	30.0	0.1	1037	2678	3716	1.39	74.60	3197	519
2	0.0100	40.00	40.0	0.2	1382	2520	3902	1.55	75.70	3211	691
3	0.0150	44.00	44.0	0.3	1518	2405	3923	1.63	76.50	3164	759
4	0.0200	48.00	48.0	0.4	1655	2304	3959	1.72	77.20	3131	827
5	0.0250	50.00	50.0	0.5	1722	2218	3939	1.78	77.80	3078	861
6	0.0300	52.00	52.0	0.6	1789	2146	3934	1.83	78.30	3040	894
7	0.0350	54.00	54.0	0.7	1856	2074	3929	1.89	78.80	3001	928
8	0.0400	55.00	55.0	0.8	1888	2030	3918	1.93	79.10	2974	944
9	0.0450	56.00	56.0	0.9	1920	1987	3907	1.97	79.40	2947	960
10	0.0500	57.00	57.0	1.0	1952	1930	3882	2.01	79.80	2906	976
11	0.0750	60.00	60.0	1.6	2044	1742	3787	2.17	81.10	2765	1022
12	0.1000	62.00	62.0	2.1	2101	1613	3714	2.30	82.00	2663	1051
13	0.1250	63.00	63.0	2.6	2124	1541	3665	2.38	82.50	2603	1062
14	0.1500	65.00	65.0	3.1	2180	1483	3663	2.47	82.90	2573	1090
15	0.2000	66.00	66.0	4.2	2189	1397	3586	2.57	83.50	2491	1095
16	0.2500	68.00	68.0	5.2	2231	1354	3585	2.65	83.80	2469	1116
17	0.3000	70.00	70.0	6.3	2272	1325	3596	2.71	84.00	2461	1136
18	0.3500	71.00	71.0	7.3	2278	1310	3589	2.74	84.10	2450	1139
19	0.4000	72.00	72.0	8.3	2284	1296	3580	2.76	84.20	2438	1142
20	0.4500	74.00	74.0	9.4	2321	1296	3617	2.79	84.20	2457	1161
21	0.5000	76.00	76.0	10.4	2357	1296	3653	2.82	84.20	2474	1178
22	0.5500	77.00	77.0	11.5	2360	1296	3656	2.82	84.20	2476	1180
23	0.6500	80.00	80.0	13.5	2394	1310	3704	2.83	84.10	2507	1197
24	0.7490	83.00	83.0	15.6	2425	1325	3749	2.83	84.00	2537	1212
25	0.7990	85.00	85.0	16.6	2452	1339	3792	2.83	83.90	2565	1226
26	0.8490	86.00	86.0	17.7	2450	1339	3789	2.83	83.90	2564	1225

Test Readings for Specimen No. 2

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress psf	Minor Eff. Stress psf	Major Eff. Stress psf	1:3 Ratio	Pore Press. psi	P psf	Q psf
27	0.9490	89.00	89.0	19.8	2471	1368	3839	2.81	83.70	2604	1236
28	0.9790	91.00	91.0	20.4	2507	1368	3875	2.83	83.70	2622	1254

Parameters for Specimen No. 3

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	631.900			638.600
Moisture content: Dry soil+tare, gms.	520.700			520.400
Moisture content: Tare, gms.	0.000			0.000
Moisture, %	21.4	33.9	24.3	22.7
Moist specimen weight, gms.	631.90			
Diameter, in.	2.398	2.398	2.284	
Area, in.^{2}	4.516	4.516	4.097	
Height, in.	4.993	4.993	4.761	
Net decrease in height, in.		0.000	0.232	
Wet Density, pcf	106.8	117.8	126.5	
Dry density, pcf	88.0	88.0	101.7	
Void ratio	0.9161	0.9161	0.6573	
Saturation, %	62.9	100.0	100.0	

Test Readings for Specimen No. 3

Consolidation cell pressure = 110.97 psi (15980 psf)

Consolidation back pressure = 69.20 psi (9965 psf)

Consolidation effective confining stress = 6015 psf

Strain rate, in./min. = 0.005

Fail. Stress = 4354 psf **at reading no.** 25

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress psf	Minor Eff. Stress psf	Major Eff. Stress psf	1:3 Ratio	Pore Press. psi	P psf	Q psf
0	0.0000	0.00	0.0	0.0	0	6015	6015	1.00	69.20	6015	0
1	0.0050	2.00	2.0	0.1	70	6000	6071	1.01	69.30	6036	35
2	0.0100	7.00	7.0	0.2	246	5972	6217	1.04	69.50	6094	123
3	0.0150	10.00	10.0	0.3	350	5928	6279	1.06	69.80	6104	175
4	0.0200	13.00	13.0	0.4	455	5871	6326	1.08	70.20	6098	228
5	0.0250	15.00	15.0	0.5	524	5799	6323	1.09	70.70	6061	262
6	0.0300	18.00	18.0	0.6	629	5712	6341	1.11	71.30	6027	314
7	0.0350	21.00	21.0	0.7	733	5612	6344	1.13	72.00	5978	366
8	0.0400	23.00	23.0	0.8	802	5540	6341	1.14	72.50	5941	401
9	0.0450	25.00	25.0	0.9	870	5439	6309	1.16	73.20	5874	435
10	0.0500	38.00	38.0	1.1	1322	5237	6559	1.25	74.60	5898	661
11	0.0750	90.00	90.0	1.6	3114	4100	7213	1.76	82.50	5657	1557
12	0.1000	102.00	102.0	2.1	3510	3581	7091	1.98	86.10	5336	1755
13	0.1250	108.00	108.0	2.6	3697	3207	6903	2.15	88.70	5055	1848
14	0.1500	112.00	112.0	3.2	3813	2948	6761	2.29	90.50	4854	1906
15	0.1750	115.00	115.0	3.7	3894	2760	6654	2.41	91.80	4707	1947
16	0.2000	117.00	117.0	4.2	3940	2631	6571	2.50	92.70	4601	1970
17	0.2250	120.00	120.0	4.7	4019	2530	6549	2.59	93.40	4539	2009
18	0.2500	122.00	122.0	5.3	4063	2458	6521	2.65	93.90	4490	2032
19	0.2750	124.00	124.0	5.8	4107	2400	6507	2.71	94.30	4454	2053
20	0.3000	126.00	126.0	6.3	4150	2357	6507	2.76	94.60	4432	2075

Test Readings for Specimen No. 3

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress psf	Minor Eff. Stress psf	Major Eff. Stress psf	1:3 Ratio	Pore Press. psi	P psf	Q psf
21	0.3500	129.00	129.0	7.4	4201	2285	6486	2.84	95.10	4386	2101
22	0.3990	132.00	132.0	8.4	4251	2242	6493	2.90	95.40	4368	2126
23	0.4490	135.00	135.0	9.4	4298	2213	6511	2.94	95.60	4362	2149
24	0.4990	138.00	138.0	10.5	4342	2199	6541	2.97	95.70	4370	2171
25	0.5490	140.00	140.0	11.5	4354	2184	6538	2.99	95.80	4361	2177
26	0.6490	143.00	143.0	13.6	4341	2184	6526	2.99	95.80	4355	2171
27	0.7490	145.00	145.0	15.7	4295	2213	6508	2.94	95.60	4361	2148
28	0.8490	147.00	147.0	17.8	4246	2256	6502	2.88	95.30	4379	2123
29	0.8940	148.00	148.0	18.8	4225	2285	6511	2.85	95.10	4398	2113
30	0.9240	148.00	148.0	19.4	4193	2285	6478	2.83	95.10	4382	2096
31	0.9540	148.00	148.0	20.0	4160	2300	6460	2.81	95.00	4380	2080

ADVANCED TERRA TESTING, Inc.
ATT
833 Parfet Street • Lakewood, Colorado 80215 • (303) 232-8308 • Fax: (303) 232-1579

TRIAXIAL COMPRESSION TEST DATA
ASTM D 4767

CLIENT HKM Engineering

JOB NO. 2662-01

BORING NO.	TP-7A	SAMPLED	
DEPTH	9-10.5'	TEST STARTED	12-29-05 CAL
SAMPLE NO.	Pt. A	TEST FINISHED	1-04-06 CAL
SOIL DESCR.	Ruby Dam	CELL NUMBER	19S
TEST TYPE	TX/CUpp	SATURATED TEST	Yes
CONF. PRES. PSF	6000		

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil + Moisture (g)	631.9	638.6
Wt. Wet Soil & Pan (g)	640.2	646.8
Wt. Dry Soil & Pan (g)	528.7	528.7
Wt. Lost Moisture (g)	111.5	118.2
Wt. of Pan Only (g)	8.3	8.3
Wt. of Dry Soil (g)	520.4	520.4
Moisture Content %	21.4	22.7
Wet Density PCF	106.7	130.1
Dry Density PCF	87.9	106.0

Init. Diameter (in)	2.398
Init. Area (sq in)	4.516
Init. Height (in)	4.993
Vol. Bef. Consol. (cu ft)	0.01305
Vol. After Consol. (cu ft)	0.01082

Notes & Comments: **REMOLDED SAMPLE**

Data entry by: CAL Date: 01/18/2006
Data checked by: RB Date: 1/18/06
FileName: HKSPP7AA

ADVANCED TERRA TESTING, INC.

TRIAXIAL COMPRESSION TEST DATA
ASTM D 4767

CLIENT	HKM Engineering	JOB NO.	2662-01
BORING NO.	TP-7A	SAMPLED	
DEPTH	9-10.5'	TEST STARTED	12-29-05 CAL
SAMPLE NO.	Pt. A	TEST FINISHED	1-04-06 CAL
SOIL DESCR.	Ruby Dam	CELL NUMBER	19S
TEST TYPE	TX/CUpp	SATURATED TEST	Yes
CONF. PRES. PSF	6000		

SATURATION DATA

Cell Pres. (PSI)	Back Pres. (PSI)	Burette Reading (CC)		Pore Pressure (PSI)		Change	B
		Close	Open	Close	Open		
40.0	38.0	5.9	24.5				
50.0	48.0	22.1	24.3	35.3	44.0	8.7	0.87
60.0	58.0	23.7	25.0	47.5	56.7	9.2	0.92
70.0	68.0	24.8	26.0	57.0	66.3	9.3	0.93
80.0		25.8	25.9	66.8	76.4	9.6	0.96

CONSOLIDATION DATA

Elapsed Time (Min)	SQRT TIME (Min)	Burette Reading (CC)	Vol. Defl. (CC)
0.00	0.0	0.5	0.00
0.25	0.5	15.1	-14.60
0.5	0.7	18.2	-17.70
1	1.0	21.8	-21.30
2	1.4	26.0	-25.45
4	2.0	30.3	-29.80
9	3.0	35.9	-35.40
16	4.0	39.9	-39.35
30	5.5	44.0	-43.45
60	7.7	47.7	-47.20
120	11.0	50.6	-50.10
240	15.5	53.2	-52.65
360	19.0	54.1	-53.60

Initial Height (in)	4.993	Init. Vol. (CC)	369.60
Height Change (in)	0.232	Vol. Change (CC)	75.70
Ht. After Cons. (in)	4.761	Cell Exp. (CC)	12.65
Initial Area (sq in)	4.516	Net Change (CC)	63.05
Area After Cons. (sq in)	3.928	Cons. Vol. (CC)	306.55

Data entry by: CAL Date: 01/18/2006
Data checked by: AS Date: 1/18/06
FileName: HKSPP7AA

ADVANCED TERRA TESTING, INC.

TRIAXIAL COMPRESSION TEST DATA

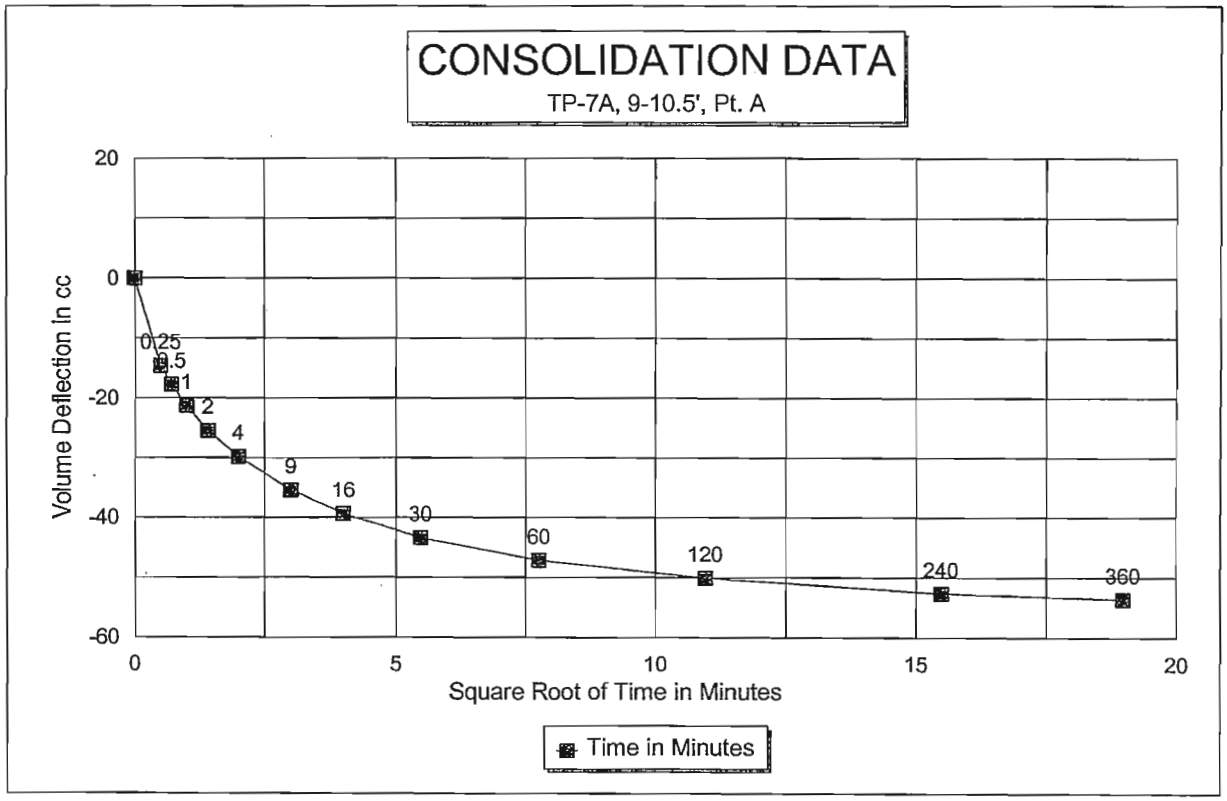
CLIENT	HKM Engineering	JOB NO.	2662-01
BORING NO.	TP-7A	SAMPLED	
DEPTH	9-10.5'	TEST STARTED	12-29-05 CAL
SAMPLE NO.	Pt. A	TEST FINISHED	1-04-06 CAL
SOIL DESCR.	Ruby Dam	CELL NUMBER	19S
TEST TYPE	TX/CUpp	SATURATED TEST	Yes
CONF. PRES. PSF	6000		

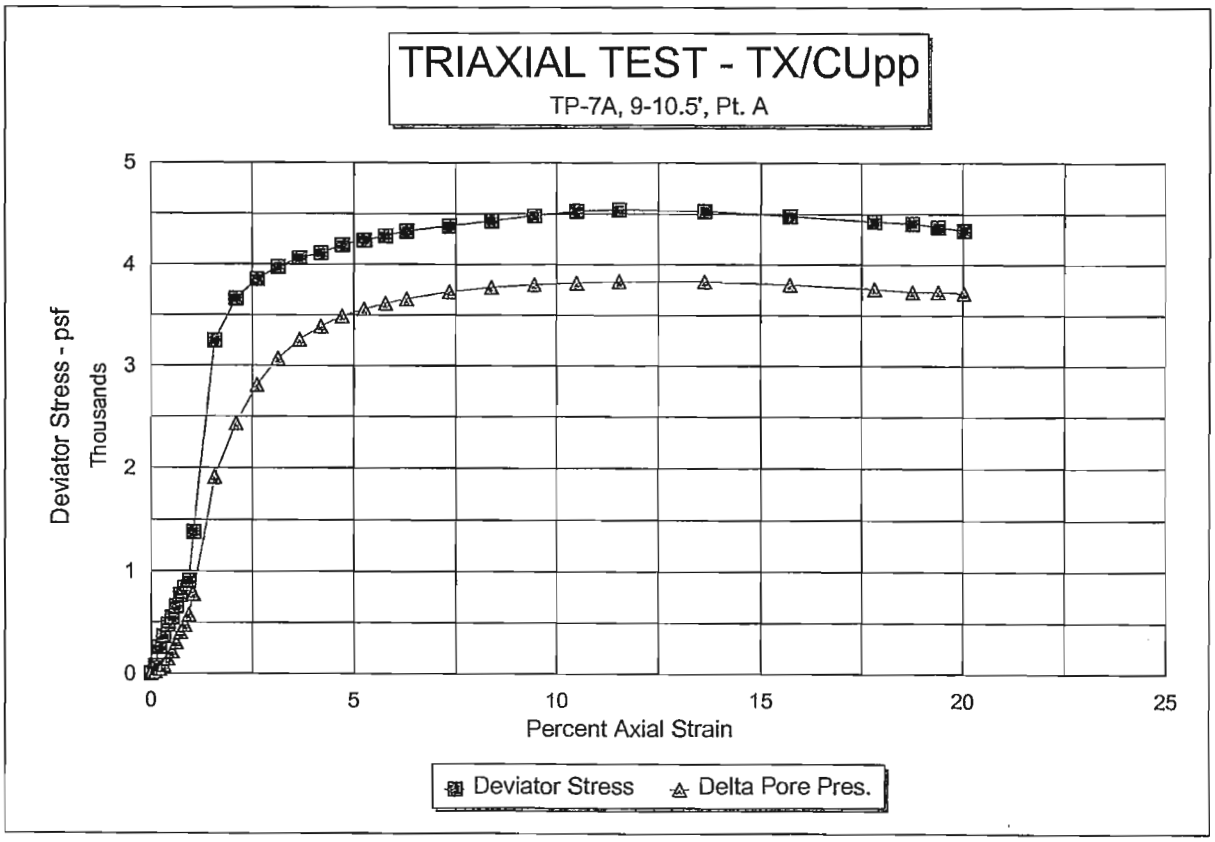
Init. Ht. (in)	4.993	Init. Area (sq in)	4.516
Consol. Ht. (in)	4.761	Consol. Area (sq in)	3.928
Back Pres. PSI	69.2	Strain Rate (in/min)	0.005

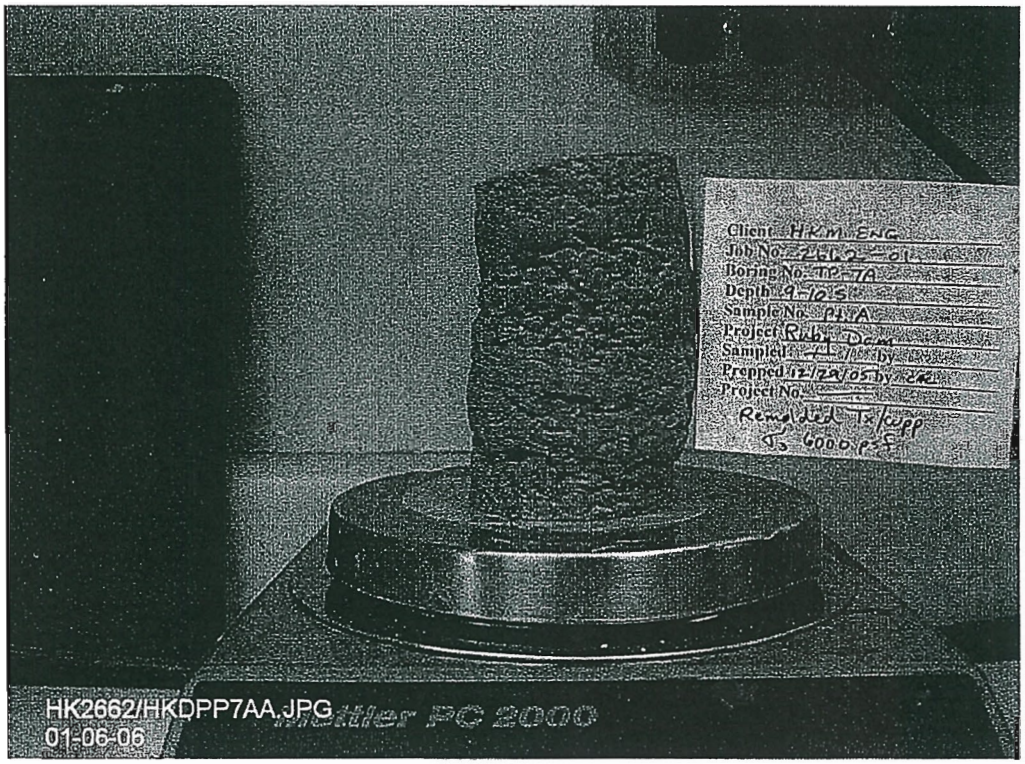
Axial Load Lbs.	Axial Load PSF	Delta Ht. In.	Axial % Strain	Area Final Sq In.	Dev. Stress PSF	Pore Pres. PSI	Delta Pres. PSF	σ 3' PSF	σ 1' PSF	Prin. Stress Ratio
0.0	0	0.00	0.00	3.928	0	69.2	0	6000	6000	1.00
2.0	73	0.005	0.11	3.933	73	69.3	14	5986	6059	1.01
7.0	257	0.010	0.21	3.937	256	69.5	43	5957	6213	1.04
10.0	367	0.015	0.32	3.941	365	69.8	86	5914	6279	1.06
13.0	477	0.020	0.42	3.945	475	70.2	144	5856	6331	1.08
15.0	550	0.025	0.53	3.949	547	70.7	216	5784	6331	1.09
18.0	660	0.030	0.63	3.953	656	71.3	302	5698	6353	1.12
21.0	770	0.035	0.74	3.958	764	72.0	403	5597	6361	1.14
23.0	843	0.040	0.84	3.962	836	72.5	475	5525	6361	1.15
25.0	916	0.045	0.95	3.966	908	73.2	576	5424	6332	1.17
38.0	1393	0.050	1.05	3.970	1378	74.6	778	5222	6601	1.26
90.0	3299	0.075	1.58	3.991	3247	82.5	1915	4085	7332	1.79
102.0	3739	0.100	2.10	4.013	3660	86.1	2434	3566	7227	2.03
108.0	3959	0.125	2.63	4.034	3855	88.7	2808	3192	7047	2.21
112.0	4105	0.150	3.15	4.056	3976	90.5	3067	2933	6909	2.36
115.0	4215	0.175	3.68	4.078	4060	91.8	3254	2746	6806	2.48
117.0	4289	0.200	4.20	4.101	4109	92.7	3384	2616	6725	2.57
120.0	4399	0.225	4.73	4.123	4191	93.4	3485	2515	6706	2.67
122.0	4472	0.250	5.25	4.146	4237	93.9	3557	2443	6680	2.73
124.0	4545	0.275	5.78	4.169	4283	94.3	3614	2386	6668	2.80
126.0	4619	0.300	6.30	4.193	4328	94.6	3658	2342	6670	2.85
129.0	4729	0.350	7.35	4.240	4381	95.1	3730	2270	6651	2.93
132.0	4839	0.399	8.38	4.288	4433	95.4	3773	2227	6660	2.99
135.0	4948	0.449	9.43	4.338	4482	95.6	3802	2198	6680	3.04
138.0	5058	0.499	10.48	4.388	4528	95.7	3816	2184	6712	3.07
140.0	5132	0.549	11.53	4.441	4540	95.8	3816	2184	6724	3.08
143.0	5242	0.649	13.63	4.549	4527	95.8	3830	2170	6697	3.09
145.0	5315	0.749	15.73	4.662	4479	95.6	3802	2198	6677	3.04
147.0	5388	0.849	17.83	4.781	4427	95.3	3758	2242	6669	2.98
148.0	5425	0.894	18.78	4.837	4406	95.1	3730	2270	6677	2.94
148.0	5425	0.924	19.41	4.875	4372	95.1	3730	2270	6643	2.93
148.0	5425	0.954	20.04	4.913	4338	95.0	3715	2285	6623	2.90

Data entry by: CAL Date: 01/18/2006
Data checked by: RB Date: 1/18/06
FileName: HKSPP7AA

ADVANCED TERRA TESTING, INC.


CONSOLIDATION DATA
TP-7A, 9-10.5', Pt. A
Volume Deflection in cc
20
0
-20
-40
-60
0.25
0.5
1
2
4
9
16
30
60
120
240
360
0
5
10
15
20
Square Root of Time in Minutes
Time in Minutes


TRIAXIAL TEST - TX/CUpp
TP-7A, 9-10.5', Pt. A
Deviator Stress - psf
Thousands
5
4
3
2
1
0
0
5
10
15
20
25
Percent Axial Strain
Deviator Stress
Delta Pore Pres.


Client HKM ENG
Job No. 2662-01
Boring No. TP-7A
Depth 9-10.5
Sample No. Pt A
Project Ruby Dam
Sampled / / by
Prepped 12/29/05 by
Project No.
Remolded Tx/wpp
σ3 6000 psf
HK2662/HKDPP7AA.JPG
01-06-06
Mettler PC 2000

TRIAXIAL COMPRESSION TEST DATA
ASTM D 4767

CLIENT HKM Engineering

JOB NO. 2662-01

BORING NO.	TP-7A	SAMPLED	
DEPTH	9-10.5'	TEST STARTED	12-29-05 CAL
SAMPLE NO.	Pt. B	TEST FINISHED	01-04-06 CAL
SOIL DESCR.	Ruby Dam	CELL NUMBER	22S
TEST TYPE	TX/CUpp	SATURATED TEST	Yes
CONF. PRES. PSF	3000		

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil + Moisture (g)	631.9	653.8
Wt. Wet Soil & Pan (g)	640.2	662.1
Wt. Dry Soil & Pan (g)	527.4	527.4
Wt. Lost Moisture (g)	112.8	134.7
Wt. of Pan Only (g)	8.3	8.3
Wt. of Dry Soil (g)	519.1	519.1
Moisture Content %	21.7	26.0
Wet Density PCF	106.7	124.5
Dry Density PCF	87.6	98.8

Init. Diameter (in)	2.398
Init. Area (sq in)	4.516
Init. Height (in)	4.996
Vol. Bef. Consol. (cu ft)	0.01306
Vol. After Consol. (cu ft)	0.01158

Notes & Comments: **REMOLDED SAMPLE**

Data entry by: CAL Date: 01/18/2006
Data checked by: RR Date: 4/18/06
FileName: HKSPP7AA

ADVANCED TERRA TESTING, INC.

TRIAXIAL COMPRESSION TEST DATA
ASTM D 4767

CLIENT HKM Engineering JOB NO. 2662-01

BORING NO.	TP-7A	SAMPLED	
DEPTH	9-10.5'	TEST STARTED	12-29-05 CAL
SAMPLE NO.	Pt. B	TEST FINISHED	01-04-06 CAL
SOIL DESCR.	Ruby Dam	CELL NUMBER	22S
TEST TYPE	TX/CUpp	SATURATED TEST	Yes
CONF. PRES. PSF	3000		

SATURATION DATA

Cell Pres. (PSI)	Back Pres. (PSI)	Burette Reading (CC)		Pore Pressure (PSI)		Change	B
		Close	Open	Close	Open		
40.0	38.0	7.6	23.0				
50.0	48.0	20.7	22.7	38.0	46.8	8.8	0.88
60.0	58.0	22.4	23.8	48.1	57.1	9.0	0.90
70.0	68.0	24.0	25.0	58.4	67.7	9.3	0.93
80.0		25.0	25.0	67.2	76.9	9.7	0.97

CONSOLIDATION DATA

Elapsed Time (Min)	SQRT TIME (Min)	Burette Reading (CC)	Vol. Defl. (CC)
0.00	0.0	0.6	0.00
0.25	0.5	16.4	-15.80
0.5	0.7	18.8	-18.20
1	1.0	21.3	-20.70
2	1.4	23.9	-23.30
4	2.0	26.8	-26.20
9	3.0	30.4	-29.80
18	4.2	33.0	-32.40
30	5.5	35.6	-35.00
60	7.7	37.6	-37.00
120	11.0	38.9	-38.30
240	15.5	39.6	-39.00
360	19.0	40.0	-39.40

Initial Height (in)	4.996	Init. Vol. (CC)	369.82
Height Change (in)	0.197	Vol. Change (CC)	57.60
Ht. After Cons. (in)	4.799	Cell Exp. (CC)	15.70
Initial Area (sq in)	4.516	Net Change (CC)	41.90
Area After Cons. (sq in)	4.169	Cons. Vol. (CC)	327.92

Data entry by: CAL Date: 01/18/2006
Data checked by: [illegible] Date: 1/18/06
FileName: HKSPP7AA

ADVANCED TERRA TESTING, INC.

TRIAXIAL COMPRESSION TEST DATA
ASTM D 4767

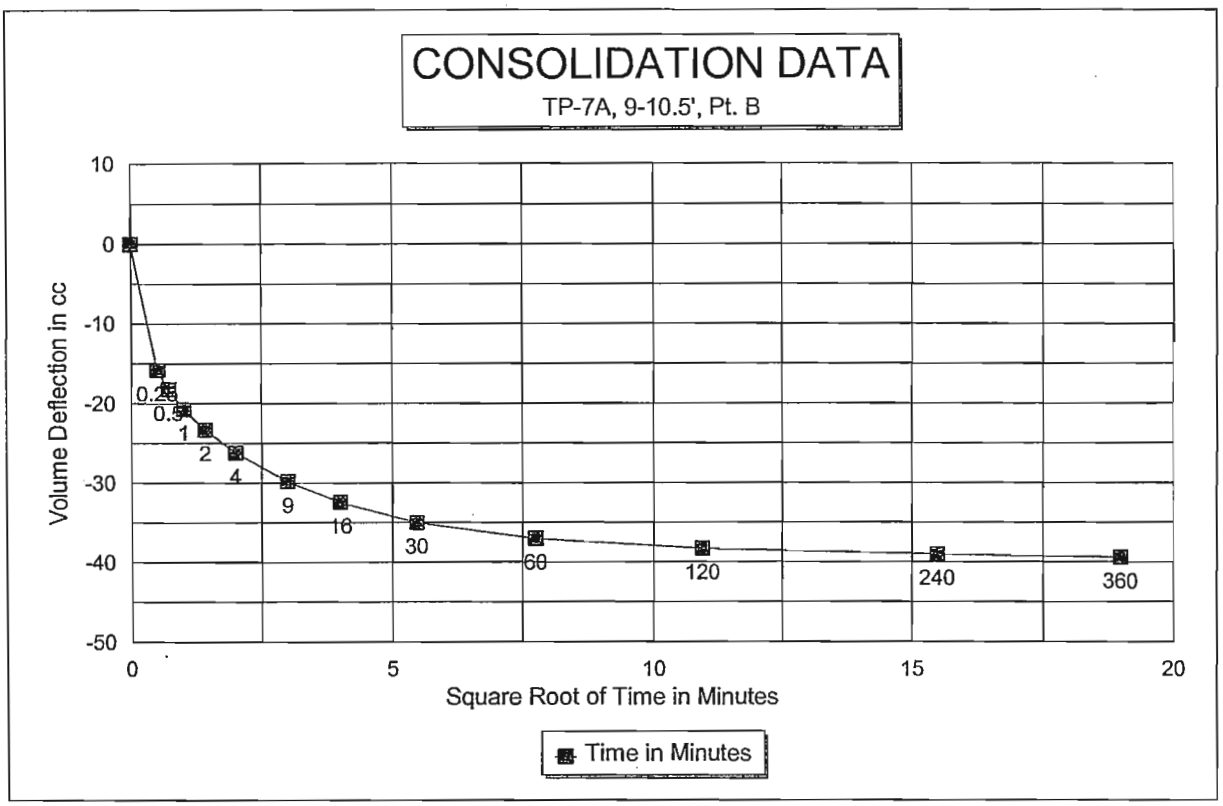
CLIENT	HKM Engineering	JOB NO.	2662-01
BORING NO.	TP-7A	SAMPLED	
DEPTH	9-10.5'	TEST STARTED	12-29-05 CAL
SAMPLE NO.	Pt. B	TEST FINISHED	01-04-06 CAL
SOIL DESCR.	Ruby Dam	CELL NUMBER	22S
TEST TYPE	TX/CUpp	SATURATED TEST	Yes
CONF. PRES. PSF	3000		

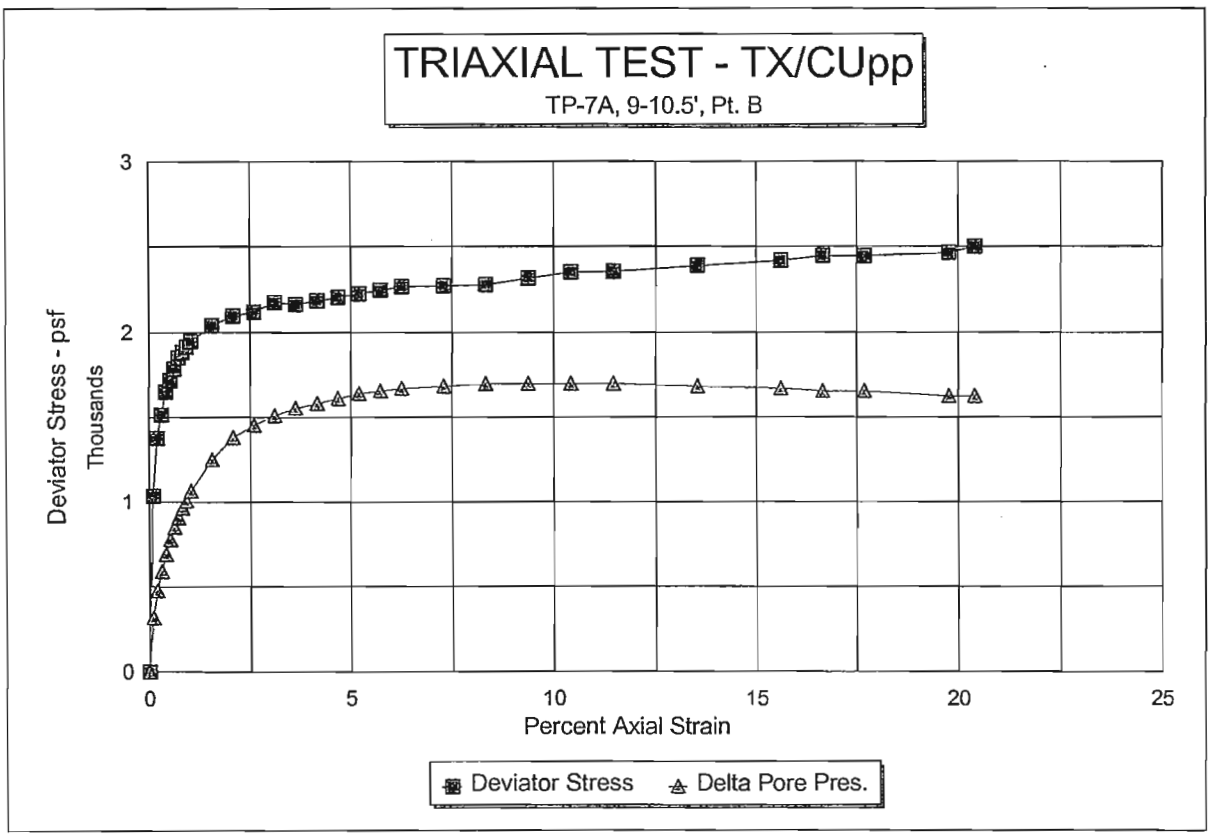
Init. Ht. (in)	4.996	Init. Area (sq in)	4.516
Consol. Ht. (in)	4.799	Consol. Area (sq in)	4.169
Back Pres. PSI	72.4	Strain Rate (in/min)	0.003

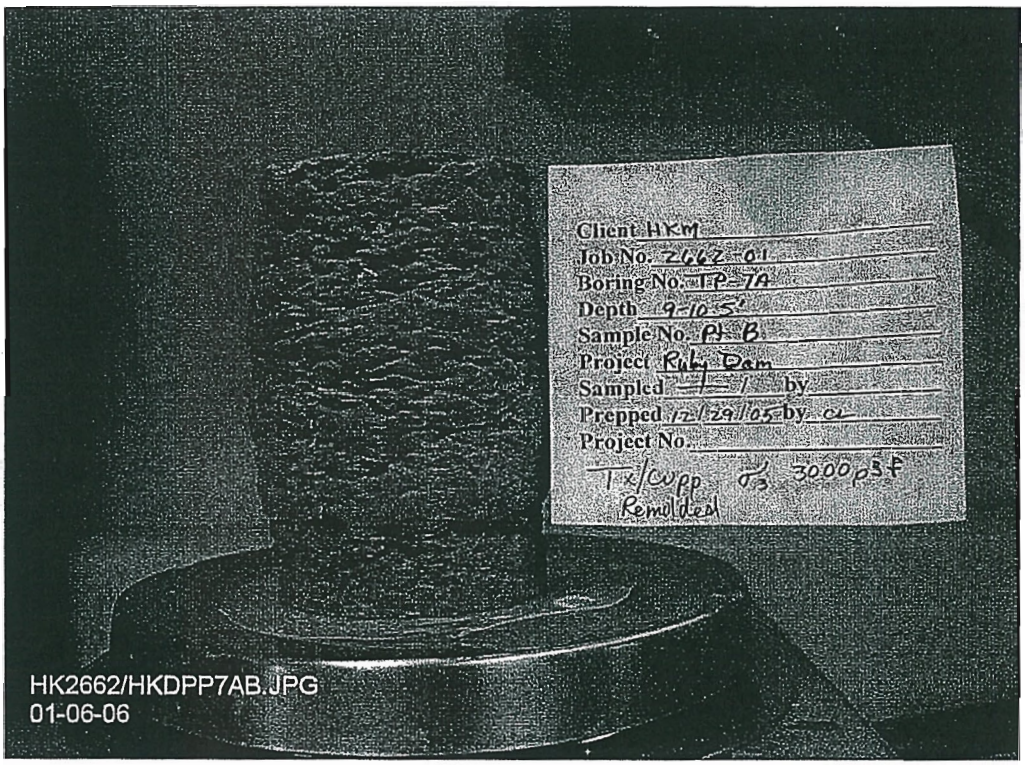
Axial Load Lbs.	Axial Load PSF	Delta Ht. In.	Axial % Strain	Area Final Sq In.	Dev. Stress PSF	Pore Pres. PSI	Delta Pres. PSF	σ 3' PSF	σ 1' PSF	Prin. Stress Ratio
0.0	0	0.00	0.00	4.169	0	72.4	0	3000	3000	1.00
30.0	1036	0.005	0.10	4.173	1035	74.6	317	2683	3718	1.39
40.0	1382	0.010	0.21	4.178	1379	75.7	475	2525	3904	1.55
44.0	1520	0.015	0.31	4.182	1515	76.5	590	2410	3925	1.63
48.0	1658	0.020	0.42	4.186	1651	77.2	691	2309	3960	1.72
50.0	1727	0.025	0.52	4.191	1718	77.8	778	2222	3940	1.77
52.0	1796	0.030	0.63	4.195	1785	78.3	850	2150	3935	1.83
54.0	1865	0.035	0.73	4.200	1852	78.7	907	2093	3944	1.88
55.0	1900	0.040	0.83	4.204	1884	79.1	965	2035	3919	1.93
56.0	1934	0.045	0.94	4.208	1916	79.4	1008	1992	3908	1.96
57.0	1969	0.050	1.04	4.213	1948	79.8	1066	1934	3883	2.01
60.0	2072	0.075	1.56	4.235	2040	81.1	1253	1747	3787	2.17
62.0	2142	0.100	2.08	4.258	2097	82.0	1382	1618	3714	2.30
63.0	2176	0.125	2.60	4.281	2119	82.5	1454	1546	3665	2.37
65.0	2245	0.150	3.13	4.304	2175	82.9	1512	1488	3663	2.46
65.0	2245	0.175	3.65	4.327	2163	83.2	1555	1445	3608	2.50
66.0	2280	0.200	4.17	4.350	2185	83.4	1584	1416	3601	2.54
67.0	2314	0.225	4.69	4.374	2206	83.6	1613	1387	3593	2.59
68.0	2349	0.250	5.21	4.398	2226	83.8	1642	1358	3585	2.64
69.0	2383	0.275	5.73	4.422	2247	83.9	1656	1344	3591	2.67
70.0	2418	0.300	6.25	4.447	2267	84.0	1670	1330	3596	2.70
71.0	2452	0.350	7.29	4.497	2274	84.1	1685	1315	3589	2.73
72.0	2487	0.400	8.34	4.548	2280	84.2	1699	1301	3580	2.75
74.0	2556	0.450	9.38	4.600	2316	84.2	1699	1301	3617	2.78
76.0	2625	0.500	10.42	4.654	2352	84.2	1699	1301	3652	2.81
77.0	2660	0.550	11.46	4.709	2355	84.2	1699	1301	3656	2.81
80.0	2763	0.650	13.54	4.822	2389	84.1	1685	1315	3704	2.82
83.0	2867	0.749	15.61	4.940	2419	84.0	1670	1330	3749	2.82
85.0	2936	0.799	16.65	5.002	2447	83.9	1656	1344	3791	2.82
86.0	2970	0.849	17.69	5.065	2445	83.9	1656	1344	3789	2.82
89.0	3074	0.949	19.77	5.197	2466	83.7	1627	1373	3839	2.80
91.0	3143	0.979	20.40	5.237	2502	83.7	1627	1373	3875	2.82

Data entry by: CAL Date: 01/18/2006
Data checked by: AB Date: 1/18/06
FileName: HKSPP7AA

ADVANCED TERRA TESTING, INC.


CONSOLIDATION DATA
TP-7A, 9-10.5', Pt. B
Volume Deflection in cc
10
0
-10
-20
-30
-40
-50
0.25
0.5
1
2
4
9
16
30
60
120
240
360
0
5
10
15
20
Square Root of Time in Minutes
Time in Minutes


TRIAXIAL TEST - TX/CUpp
TP-7A, 9-10.5', Pt. B
Deviator Stress - psf
Thousands
3
2
1
0
0
5
10
15
20
25
Percent Axial Strain
Deviator Stress
Delta Pore Pres.


Client: HKM
Job No. 2662-01
Boring No. TP-7A
Depth 9-10.5'
Sample No. A-B
Project Ruby Dam
Sampled / / by
Prepped 12/29/05 by CL
Project No.
Tx/CUpp σ3 3000 psf
Remolded
HK2662/HKDPP7AB.JPG
01-06-06

TRIAXIAL COMPRESSION TEST DATA
ASTM D 4767

CLIENT HKM Engineering

JOB NO. 2662-01

BORING NO.	TP-7A	SAMPLED	
DEPTH	9-10.5'	TEST STARTED	12-29-06 CAL
SAMPLE NO.	Pt. C	TEST FINISHED	01-04-06 CAL
SOIL DESCR.	Ruby Dam	CELL NUMBER	9S
TEST TYPE	TX/CUpp	SATURATED TEST	Yes
CONF. PRES. PSF	1500		

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil + Moisture (g)	631.8	668.3
Wt. Wet Soil & Pan (g)	639.9	676.3
Wt. Dry Soil & Pan (g)	527.8	527.8
Wt. Lost Moisture (g)	112.2	148.6
Wt. of Pan Only (g)	8.1	8.1
Wt. of Dry Soil (g)	519.7	519.7
Moisture Content %	21.6	28.6
Wet Density PCF	106.7	121.7
Dry Density PCF	87.7	94.6

Init. Diameter (in)	2.398
Init. Area (sq in)	4.516
Init. Height (in)	4.996
Vol. Bef. Consol. (cu ft)	0.01306
Vol. After Consol. (cu ft)	0.01211

Notes & Comments: **REMOLDED SAMPLE**

Data entry by: CAL Date: 01/18/2006
Data checked by: RB Date: 1/18/06
FileName: HKSPP7AA

ADVANCED TERRA TESTING, INC.

TRIAXIAL COMPRESSION TEST DATA
ASTM D 4767

CLIENT	HKM Engineering	JOB NO.	2662-01
BORING NO.	TP-7A	SAMPLED	
DEPTH	9-10.5'	TEST STARTED	12-29-06 CAL
SAMPLE NO.	Pt. C	TEST FINISHED	01-04-06 CAL
SOIL DESCR.	Ruby Dam	CELL NUMBER	9S
TEST TYPE	TX/CUpp	SATURATED TEST	Yes
CONF. PRES. PSF	1500		

SATURATION DATA

Cell Pres. (PSI)	Back Pres. (PSI)	Burette Reading (CC)		Pore Pressure (PSI)		Change	B
		Close	Open	Close	Open		
40.0	38.0	6.0	21.9				
50.0	48.0	21.1	22.7	38.3	47.2	8.9	0.89
60.0	58.0	23.3	24.2	48.3	57.6	9.3	0.93
70.0		24.1	24.3	57.2	66.7	9.5	0.95

CONSOLIDATION DATA

Elapsed Time (Min)	SQRT TIME (Min)	Burette Reading (CC)	Vol. Defl. (CC)
0.00	0.0	0.20	0.00
0.25	0.5	10.40	-10.20
0.5	0.7	12.60	-12.40
1	1.0	15.10	-14.90
2	1.4	17.00	-16.80
4	2.0	18.40	-18.20
9	3.0	19.60	-19.40
16	4.0	20.30	-20.10
30	5.5	21.05	-20.85
60	7.7	21.65	-21.45
120	11.0	22.10	-21.90
240	15.5	22.40	-22.20
360	19.0	22.70	-22.50

Initial Height (in)	4.996	Init. Vol. (CC)	369.82
Height Change (in)	0.121	Vol. Change (CC)	41.45
Ht. After Cons. (in)	4.875	Cell Exp. (CC)	14.52
Initial Area (sq in)	4.516	Net Change (CC)	26.93
Area After Cons. (sq in)	4.291	Cons. Vol. (CC)	342.89

Data entry by: CAL Date: 01/18/2006
Data checked by: RS Date: 1/18/06
FileName: HKSPP7AA

ADVANCED TERRA TESTING, INC.

TRIAXIAL COMPRESSION TEST DATA
ASTM D 4767

CLIENT	HKM Engineering	JOB NO.	2662-01
BORING NO.	TP-7A	SAMPLED	
DEPTH	9-10.5'	TEST STARTED	12-29-06 CAL
SAMPLE NO.	Pt. C	TEST FINISHED	01-04-06 CAL
SOIL DESCR.	Ruby Dam	CELL NUMBER	9S
TEST TYPE	TX/CUpp	SATURATED TEST	Yes
CONF. PRES. PSF	1500		

Init. Ht. (in)	4.996	Init. Area (sq in)	4.516
Consol. Ht. (in)	4.875	Consol. Area (sq in)	4.291
Back Pres. PSI	60.6	Strain Rate (in/min)	0.005

Axial Load Lbs.	Axial Load PSF	Delta Ht. In.	Axial % Strain	Area Final Sq In.	Dev. Stress PSF	Pore Pres. PSI	Delta Pres. PSF	σ 3' PSF	σ 1' PSF	Prin. Stress Ratio
0.0	0	0.00	0.00	4.291	0	60.6	0	1500	1500	1.00
9.0	302	0.005	0.10	4.296	302	61.1	72	1428	1730	1.21
17.0	570	0.010	0.21	4.300	569	61.8	173	1327	1896	1.43
22.0	738	0.015	0.31	4.305	736	62.5	274	1226	1962	1.60
26.0	872	0.020	0.41	4.309	869	63.0	346	1154	2023	1.75
28.0	940	0.025	0.51	4.314	935	63.5	418	1082	2017	1.86
30.0	1007	0.030	0.62	4.318	1000	63.9	475	1025	2025	1.98
31.0	1040	0.035	0.72	4.322	1033	64.2	518	982	2014	2.05
31.0	1040	0.040	0.82	4.327	1032	64.5	562	938	1970	2.10
32.0	1074	0.045	0.92	4.331	1064	64.7	590	910	1973	2.17
32.0	1074	0.050	1.03	4.336	1063	64.9	619	881	1944	2.21
34.0	1141	0.075	1.54	4.358	1123	65.7	734	766	1889	2.47
34.0	1141	0.100	2.05	4.381	1117	66.2	806	694	1811	2.61
35.0	1174	0.125	2.56	4.404	1144	66.5	850	650	1795	2.76
35.0	1174	0.150	3.08	4.428	1138	66.7	878	622	1760	2.83
36.0	1208	0.175	3.59	4.451	1165	66.8	893	607	1772	2.92
36.0	1208	0.200	4.10	4.475	1158	66.9	907	593	1751	2.95
37.0	1242	0.225	4.62	4.499	1184	67.0	922	578	1763	3.05
37.0	1242	0.250	5.13	4.523	1178	67.1	936	564	1742	3.09
37.0	1242	0.275	5.64	4.548	1172	67.3	965	535	1707	3.19
38.0	1275	0.300	6.15	4.573	1197	67.5	994	506	1703	3.36
38.0	1275	0.325	6.67	4.598	1190	67.5	994	506	1696	3.35
39.0	1309	0.350	7.18	4.623	1215	67.6	1008	492	1707	3.47
39.0	1309	0.375	7.69	4.649	1208	67.6	1008	492	1700	3.46
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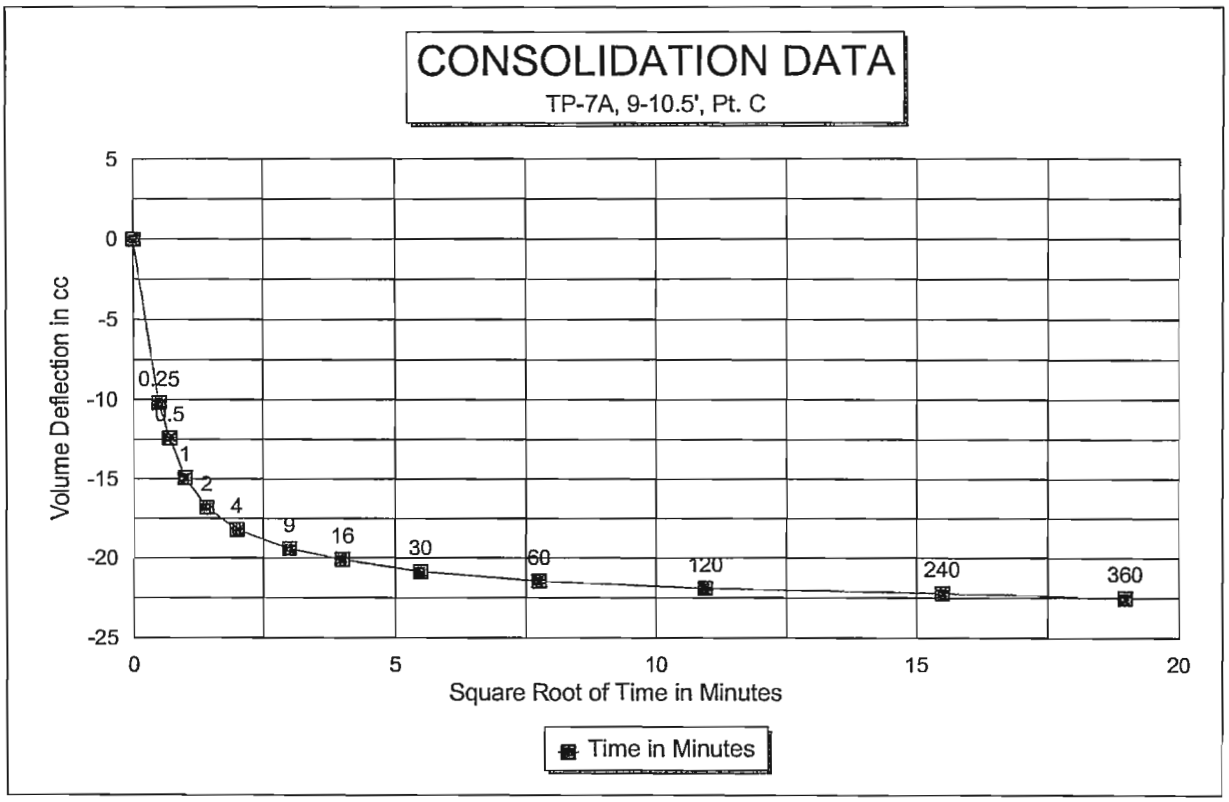
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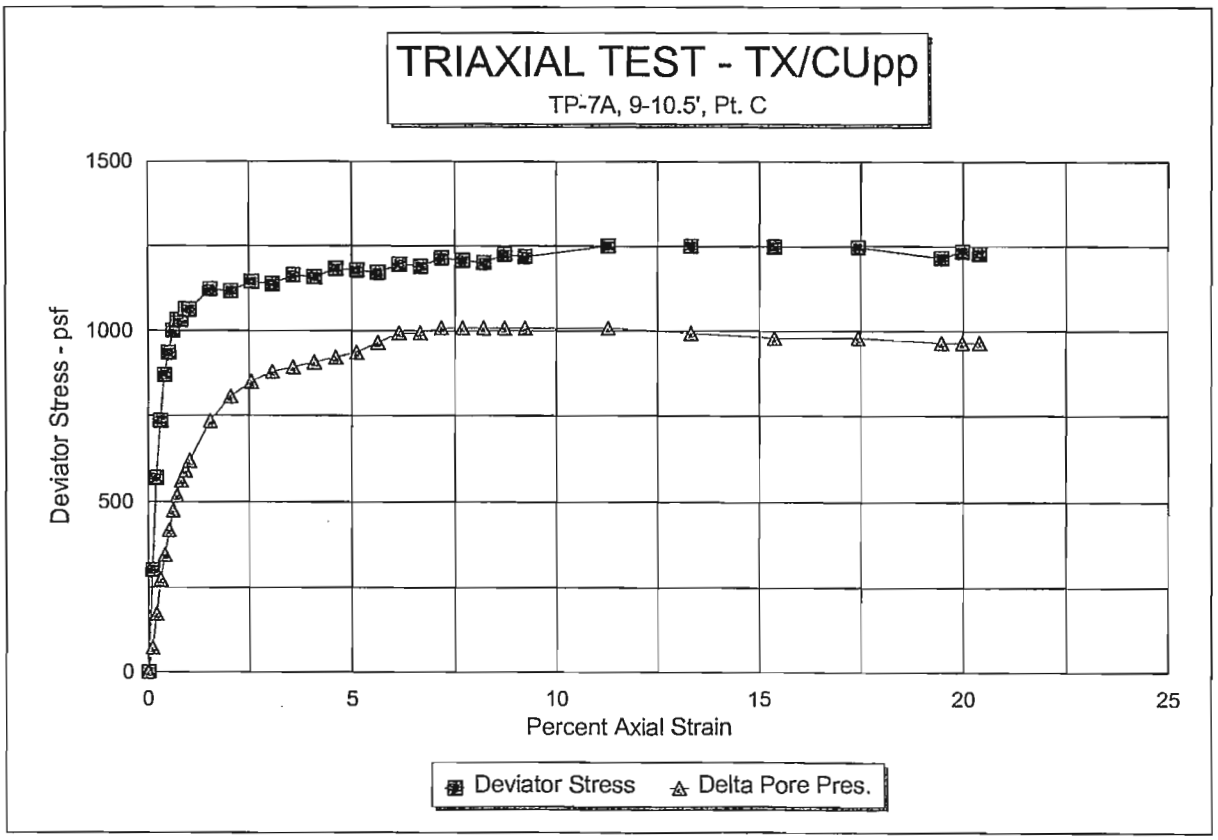
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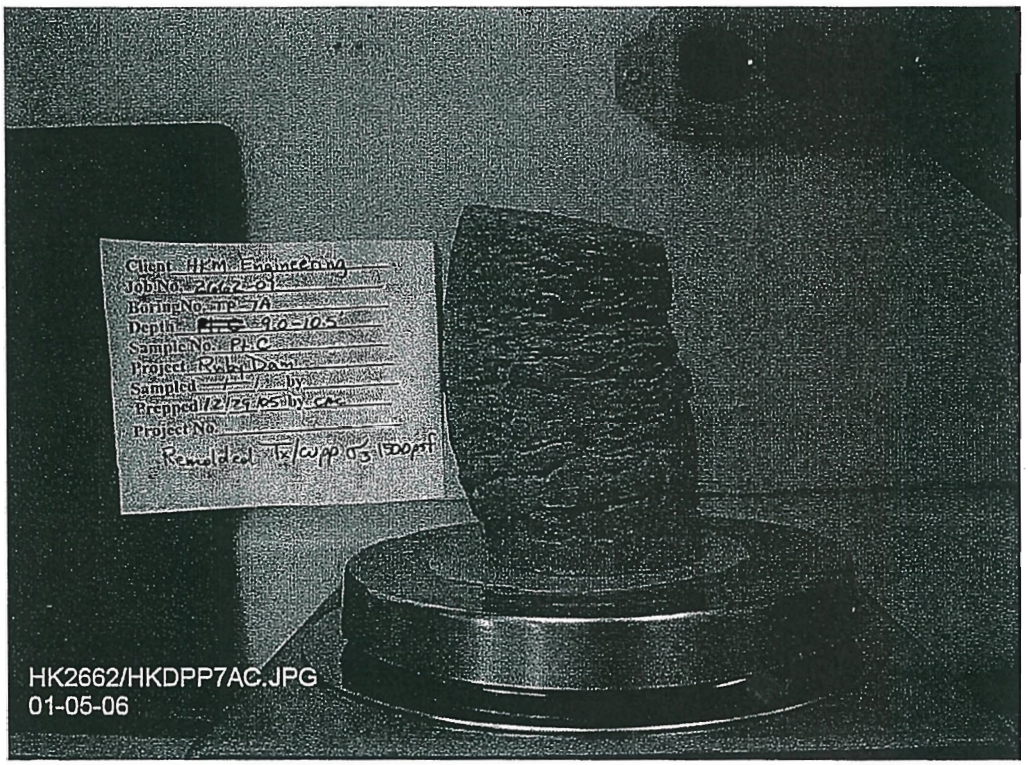
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Job No. 2662-01
Boring No. TP-7A
Depth 9.0-10.5
Sample No. Pt C
Project Ruby Dam
Sampled / / by
Prepped 12/29/05 by CAC
Project No.
Remolded Tx/cupp σ3 1500psf
HK2662/HKDPP7AC.JPG
01-05-06

STRESS PATH ANALYSIS TEST DATA

CLIENT	HKM Engineering	JOB NO.	2662-01
BORING NO.	TP-7A	SAMPLED	
DEPTH	9-10.5'	SATURATED TEST	Yes
SAMPLE NO.	A, B, & C		
SOIL DESCR.	Ruby Dam		
TEST TYPE	TX/CUpp		

CONF. PRES. PSF		
SAMPLE A	6000	
SAMPLE B	3000	
SAMPLE C	1500	

Peak Points	p' PSF	p PSF
SAMPLE A	4454	2270
SAMPLE B	2624	1251
SAMPLE C	1132	625

SAMPLE A				SAMPLE B				SAMPLE C			
σ 3' PSF	σ 1' PSF	p' PSF	q PSF	σ 3' PSF	σ 1' PSF	p' PSF	q PSF	σ 3' PSF	σ 1' PSF	p' PSF	q PSF
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2342	6670	4506	2164	1330	3596	2463	1133	506	1703	1105	598
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Data checked by: RS Date: 1/18/06
FileName: HKSPP7AA

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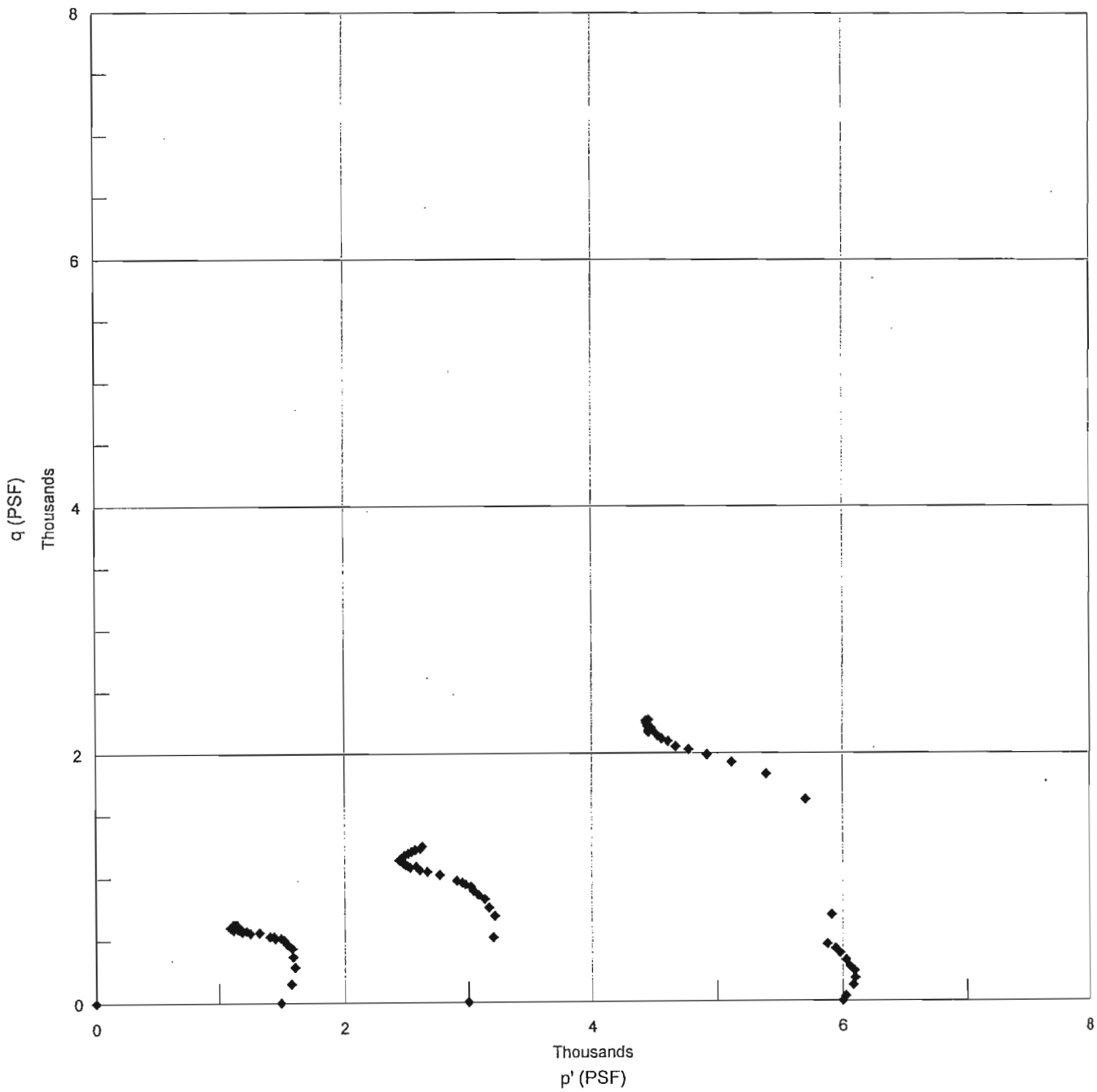
Stress Path Analysis - p' q Plots

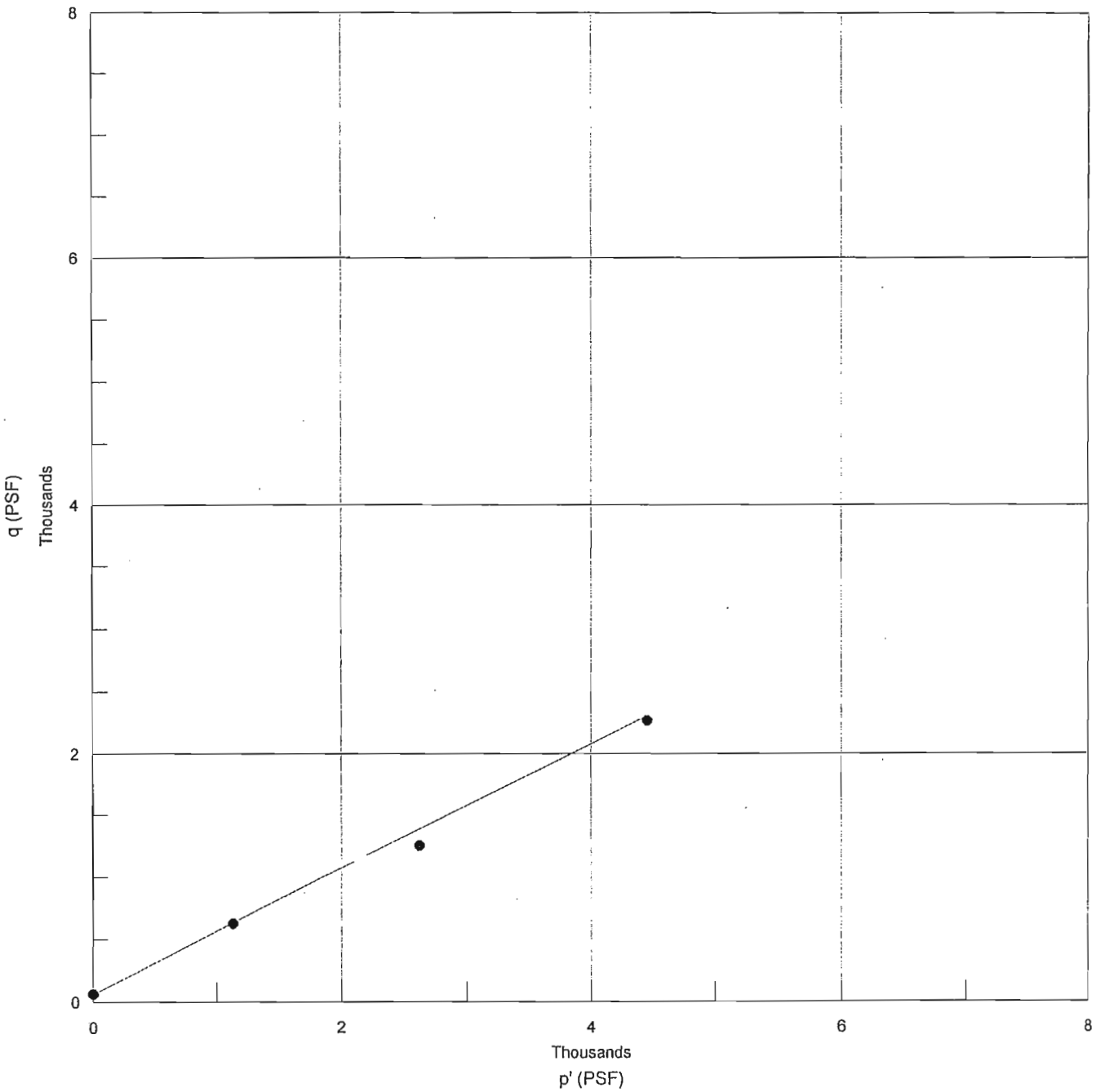
HKM Engineering,TP-7A,9-10.5',Pt. A,Pt. B,Pt. C



◆ Stress Paths of Samples A, B & C

Stress Path Analysis - Regression Plot

HKM Engineering,TP-7A,9-10.5',Pt. A,Pt. B,Pt. C



● Shear Data – Best Fit Line Phi = 26.7 degrees c = 66.1 PSF

RUBY DAM REHABILITATION
FEASIBILITY STUDY

Incremental Hazard Screening Study

Prepared for:

Montana Department of Natural Resources and Conservation
State Water Projects Bureau
Helena, MT

Prepared by:

HKM Engineering Inc.
P.O. Box 31318
Billings, MT 59107

January 2008

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1.0 INTRODUCTION

The flood routing and downstream flood hazard evaluation was performed in accordance with the Amendment to Agreement WE-HKM-579 (Amendment No. 2) entered into between the Montana Department of Natural Resources and Conservation (DNRC) and HKM Engineering Inc. (HKM). This task was incorporated into the Ruby Dam Rehabilitation Feasibility Study with the purpose of assessing whether Federal Energy Regulatory Commission (FERC) spillway requirements would allow a design flood less than the probable maximum flood (PMF) if the dam is modified for hydropower generation.

In order to evaluate the potential for hydropower development in the Ruby Dam Rehabilitation Feasibility Study, it is necessary to review the impacts that the Federal Energy Regulatory Commission (FERC) regulations have on selection of the inflow design flood (IDF). Without hydropower development, the Montana Dam Safety Regulations are the controlling design standard. With hydropower development, FERC regulations may require a larger IDF than the Montana standards. The IDF in compliance with Montana standards has a peak inflow of approximately 24,000 cfs. The PMF inflow established by DNRC has a peak inflow of approximately 84,000 cfs. FERC regulations require that the IDF is the PMF unless an incremental hazard evaluation determines that selection of a smaller flood inflow does not present an unacceptable increase in failure consequences. It should be noted that the PMF inflow established by DNRC was not developed following FERC guidelines and may not meet FERC requirements.

2.0 FLOOD ROUTING

In accordance with FERC regulations, the IDF can be selected as the flood flow above which the incremental increase in water surface elevation due to failure of the dam is no longer considered to present an unacceptable threat to downstream life or property (FERC, 1993). The initial IDF for this evaluation was selected as the PMF with the reasoning that if an incremental increase in water surface resulted downstream, design for a smaller IDF would not be acceptable. This study is intended to determine if there is potential for an IDF less than the PMF following FERC standards. Therefore, liberal values will be utilized to derive the lowest possible incremental increase in water surface downstream. If this technique determines potential for selection of an IDF less than the PMF, then a more detailed evaluation may be worthwhile. A flood routing model, created with the Hydrologic Engineering Center's Hydraulic Modeling System (HEC-HMS) computer software, was used to route the PMF hydrograph established by DNRC (84,000 cfs) through Ruby Reservoir. HEC-HMS simulates a precipitation event over a basin and routes

the runoff from that precipitation event to the outlet of the basin, when the basin is connected to a lake or reservoir the corresponding flood event can be routed through the reservoir and then downstream of the dam through a spillway, or with a dam overtopping or failure. The PMF spillway P1-100-96.7 developed in the "Design Options Summary Report" (HKM, 2007) completed as part of the Ruby Dam Rehabilitation Feasibility Study was used in the HEC-HMS model to route the runoff through the reservoir and then downstream of the dam for this downstream flood hazard evaluation.

2.1 PMF ROUTING WITH NO DAM BREACH

The HEC-HMS final basin model developed by DNRC was used for reservoir flood routing. The basin model uses a drainage area of 595 mi^2, an Initial/Constant loss rate method including: initial loss of 0.0 in, constant loss of 0.22 in/hr, and 10% imperviousness. In addition, the basin uses a user-defined dimensionless unit hydrograph and no base flow. While this model meets Montana Dam Safety Regulations criteria for the PMF, the model has not been evaluated for conformance with FERC standards.

For routing the flood through the reservoir, it was assumed that there was no flow through the outlet works and all excess storage exits the reservoir through the spillway. The HEC-HMS basin storage table option "Elevation-Storage" was used to input reservoir elevation-capacity data. Elevation-capacity data for Ruby Dam is presented in Appendix A.

It was assumed that an insignificant portion of the PMF flow would be released through the outlet works in a PMF event, so "no outlet" was selected in the model. A hydrograph was generated for the PMF event assuming the initial reservoir water surface elevation was 5396.7 ft, which is the proposed spillway crest elevation for Option P1-100-96.7 (3.7 feet above existing flashboard elevation). Level dam overtopping was assumed to occur at the proposed top of dam elevation for Option P1-100-96.7 (5415 ft). See Appendix B for the PMF event inflow hydrograph.

In addition to routing the PMF through the reservoir, six downstream cross sections were selected to be included in the model for downstream flood routing. From the Emergency Action Plan (EAP) Flood Inundation Maps (included in Appendix C), cross sections at locations 4, 7, and 8 were selected to approximate the channel geometry between Ruby Dam and the Alder Resthome (approximately 5.31 miles downstream). Cross sections at locations 10, 11, and 12 were included in the model to detail the area immediately around the towns of Alder and Laurin, which were determined to be key areas of incremental hazard that might prevent the selection of

an IDF smaller than the PMF. Cross section geometry was estimated by HKM using USGS 7.5-minute series topographic maps and is presented in Appendix C.

HEC River Analysis System (HEC-RAS) was used to develop a rating curve for each cross section mentioned above. A Manning's n of 0.05 was used to represent the main channel and 0.060 was used to represent rough earth and rocks in the channel overbanks. Normal depth was used as the initial condition up- and downstream with channel slope of 0.00440 ft/ft and 0.00544 ft/ft respectively. Channel slope was approximated using USGS 7.5-minute topographic maps. A HEC-RAS input report, rating curves, and rating table printouts for each cross section are included in Appendix D. For the cross sections in the area of Alder and Laurin (10, 11, and 12), plots of discharge versus top width and flow area are also included.

Cross section geometry at each location was entered into HEC-HMS as a downstream reach to model the stream routing below the dam. The reach length for each cross section was estimated from the EAP Ruby Reservoir cross section data and the rating data from HEC-RAS was entered for each reach. The flood wave was routed through Laurin, MT (approximately 8.86 miles below the dam) in HEC-HMS using the Muskingum-Cunge 8 Point routing method.

In accordance with FERC guidelines, the HEC-HMS model also included the possibility of a concurrent flood over the basin. FERC guidelines state that concurrent inflows may be assumed equal to the mean annual flood for the channel and tributaries downstream from the dam. The drainage area for a concurrent event was approximated by subtracting the USGS drainage areas for the gauge near cross section location 12 at Laurin, MT (USGS Site No. 06021500 with drainage area of 650 mi^2) and the gauge 0.2 miles downstream of the reservoir (USGS Site No. 06020600 with drainage area of 596 mi^2). It was determined that a 100-year flood event would be used to represent a concurrent flood over the incremental basin because during a PMF event on a neighboring basin, an event larger than a mean annual flood would likely occur. Also, using a larger flood is a liberal assumption when evaluating incremental damage. A 100-yr flood event for the incremental basin was estimated using the method outlined in "Methods for Estimating Flood Frequency in Montana Based on Data Through Water Year 1998" (Parrett, 2004). The 100-yr flow was estimated to be 2,270 cfs and was included in the HEC-HMS model as a constant-flow source entering the model at cross section 10. All input data for the HEC-HMS model is presented in Appendix E.

2.2 RESULTS

Hydrologic element information, outflow results, maximum water surface elevation, and time of peak as computed in HEC-HMS for all model elements using the PMF hydrograph are summarized in the Table 1.

Table 1. HEC-HMS PMF Routing with No Dam Breach Summary

Hydrologic Element	Element Type	Peak Discharge (cfs)	Stage Peak (ft)	Time of Peak
Ruby Basin	Basin	83,727		26 Feb 05 1000
Ruby Reservoir	Reservoir	81,941	5,422.4	26 Feb 05 1200
XS 4	Reach	81,908	5,311.1	26 Feb 05 1200
XS 7	Reach	81,835	5,264.1	26 Feb 05 1200
XS 8	Reach	81,818	5,225.0	26 Feb 05 1300
100 yr Concurrent	Source	2,270		n/a - Constant Flow
XS 10 - Ald Resthome	Reach	84,040	5,151.9	26 Feb 05 1300
XS 11 - Alder	Reach	83,933	5,110.1	26 Feb 05 1300
XS 12 - Laurin	Reach	83,886	5,045.8	26 Feb 05 1400

The maximum reservoir elevation at Ruby Dam resulting from routing of the PMF is 5422.4 ft with a corresponding peak outflow from the reservoir of 81,941 cfs. The maximum reservoir discharge resulting from the PMF routes to a flow of 84,040 cfs (flow is larger than peak reservoir outflow due to consideration of a concurrent inflow of 2,270 cfs) at the time it reaches the key area of incremental hazard near Alder, MT.

Inclusion of the concurrent flood provided a minimal change in water surface downstream. The maximum change in water surface elevation observed was 0.1 feet at cross section 10 when comparing model results with and without the concurrent flood. It was considered liberal to include the concurrent flood in the routing model because the change in water surface elevation due to the additional flow will be greater in the model without dam breach, which lessens the difference between the peak water surface elevation in the model without and with a dam breach. HEC-HMS result print-outs are included in Appendix E.

3.0 DOWNSTREAM FLOOD HAZARD EVALUATION

3.1 HAZARD EVALUATION

Hazard evaluation of dams is necessary in order to ultimately determine the IDF for design of the new embankment and spillway. In particular, this task was performed with the purpose of assessing FERC design requirements if the dam is modified for hydropower generation in the future. When a dambreak analysis shows downstream incremental water surface effects of approximately two feet or more, engineering judgment and further analysis is necessary to evaluate the need for modification of the dam. As a general guideline, the consequences of failure are considered acceptable when the incremental effect of failure on downstream structures is two feet or less (FERC, 1993). As mentioned previously, assumptions made throughout this evaluation were developed to be liberal and thus make the incremental increase in water surface as small as possible.

3.2 PMF ROUTING WITH DAM BREACH

The "Dam Break" routine in HEC-HMS was used to evaluate hydrologic failure of Ruby Dam. Hydrologic failure corresponds to failure of the dam during a flood event. The PMF was assumed to be the flood event that would cause the dam embankment to fail.

The failure mechanism modeled in HEC-HMS is an overtopping failure that develops a breach in the dam embankment. In order for HEC-HMS to model the dam failure, a description of the breach characteristics such as the breach bottom elevation, bottom width, side slopes, and top elevation need to be entered. The breach parameters were estimated using FERC guidelines. For comparison, breach parameters were also computed using the procedure outlined in the article "Breach Characteristics of Dam Failures," (MacDonald, 1984). Calculations for the breach parameters are presented in Appendix F. FERC breach parameter guidelines were used in the final model. The breach parameters associated with hydrologic dam failure using average values given in FERC guidelines will be designated as breach "A" parameters from this point forward.

The trigger elevation that corresponds to the reservoir water surface elevation at which the breach development starts and breach formation time are also required inputs. The trigger elevation was determined using an iterative process so that the dam would fail as close to the peak of the inflow flood hydrograph as possible (FERC, 1993). Triggering the dam breach at the

peak of the inflow hydrograph is not a liberal assumption, but is the process outlined by FERC. Dam failure at the inflow hydrograph peak creates the largest outflow flood wave for a given breach size.

A sensitivity analysis was performed for the failure by varying the parameters described above to determine which parameters have a large affect on the peak flow through the breach. Through the sensitivity analysis it was determined that the HEC-HMS dam break model was most sensitive to the breach bottom width and breach development time. Because the initial HEC-HMS run (with breach "A" parameters) provided a water surface elevation difference much greater than two feet near Alder, the sensitivity analysis focused on varying parameters to lessen the peak discharge from the dam, ultimately minimizing the incremental difference in water surface elevation downstream. In order to provide the smallest outflow reasonably possible from Ruby Dam in the event of a dam breach and create the most liberal dam breach acceptable by FERC guidelines, the lowest breach bottom width allowed (average breach width equal to the height of the dam) was used along with the highest breach formation time permitted (one hour). Because modifying parameters to increase the discharge from the dam would result in the same conclusion as the initial analysis with breach "A" parameters (incremental increase in water surface downstream greater than two feet), an analysis was not performed that would increase peak outflow. Breach parameters associated with hydrologic dam failure using parameters selected to provide the lowest reasonable discharge from Ruby Dam will be designated as breach "B" parameters from this point forward. Table 2 presents breach "A" and breach "B" parameters.

Table 2. HEC-HMS Breach Parameters

Parameter	Breach "A" Parameters	Breach "B" Parameters
Dam Break Mode	Overtopping	Overtopping
Breach Bottom Elevation (ft)	5299	5299
Breach Bottom Width (ft)	285	75
Breach Side Slopes	1 H:1V	½ H:1V
Breach Top Elevation (ft)	5415	5415
Breach Development Time (hr)	0.5	1.0
Breach Trigger Elevation (ft)	5422.2	5422.2
Initial Reservoir Elevation (ft)	5396.7	5396.7

Breach "A" parameters developed using FERC guidelines define a larger breach area and a

smaller breach development time than the parameters calculated in the EAP, resulting in a larger magnitude peak outflow from the reservoir in the event of a dam breach. In comparison to the EAP, breach "B" parameters resulted in a similar peak discharge. A more detailed comparison of HKM and EAP inundation study parameters is presented in Appendix I.

HEC-HMS requires several other variables be entered to model the dam break. It was assumed that an insignificant amount of flow would be released through the outlet works in a failure event, so "no outlet" was selected in the model. As in the model without a dam breach, the spillway crest elevation was set at 5396.7 ft and level dam overtopping was assuming to occur at elevation 5415 ft. The initial water surface elevation was assumed to be at the crest of proposed spillway Option P1-100-96.7. Documentation of all variables input into HEC-HMS is included in Appendix E.

For both sets of breach parameters, inclusion of a concurrent flood provided a minimal change in water surface downstream. The maximum change in water surface elevation observed was 0.1 feet at any cross section when comparing model results with and without the concurrent flood. The concurrent flood was included in the final model because its effects are minimal and liberal as discussed previously.

Tables 3 and 4 present flood wave data resulting from a hydrologic dam failure routed through Laurin (near cross section location 12) for both sets of breach parameters.

Table 3. HEC-HMS PMF Routing with Breach "A" Parameters Summary

Hydrologic Element	Element Type	Peak Discharge (cfs)	Stage Peak (ft)	Time of Peak
Ruby Basin	Basin	83,727		26 Feb 05 1000
Ruby Reservoir	Reservoir	1,016,644	5,422.3	26 Feb 05 1200
XS 4	Reach	985,433	5,354.1	26 Feb 05 1200
XS 7	Reach	934,064	5,292.2	26 Feb 05 1200
XS 8	Reach	867,471	5,236.3	26 Feb 05 1200
100 yr Concurrent	Source	2,270		n/a - Constant Flow
XS 10-Ald Resthome	Reach	682,584	5,161.5	26 Feb 05 1200
XS 11 - Alder	Reach	597,818	5,118.2	26 Feb 05 1200
XS 12 - Laurin	Reach	536,047	5,053.1	26 Feb 05 1300

Table 4. HEC-HMS PMF Routing with Breach "B" Parameters Summary

Hydrologic Element	Element Type	Peak Discharge (cfs)	Stage Peak (ft)	Time of Peak
Ruby Basin	Basin	83,727		26 Feb 05 1000
Ruby Reservoir	Reservoir	465,343	5,422.3	26 Feb 05 1200
XS 4	Reach	451,439	5,336.5	26 Feb 05 1200
XS 7	Reach	424,194	5,277.9	26 Feb 05 1200
XS 8	Reach	389,682	5,231.2	26 Feb 05 1200
100 yr Concurrent	Source	2,270		n/a - Constant Flow
XS 10 - Ald Resthome	Reach	352,012	5,157.7	26 Feb 05 1300
XS 11 - Alder	Reach	340,033	5,115.0	26 Feb 05 1300
XS 12 - Laurin	Reach	316,285	5,050.5	26 Feb 05 1300

The maximum reservoir elevation at Ruby Dam resulting from breach "A" and breach "B" parameters is 5422.3 ft. Breach "A" parameters produce a peak reservoir discharge of 1,016,644 cfs, routing down to 682,584 cfs as the flood wave reaches Alder Resthome (cross section location 10). Breach "B" parameters produce a peak reservoir discharge of 465,343 cfs and route down to 352,012 cfs near Alder Resthome. The EAP inundation study reports the flow routing down to a lower flow with higher depths near Alder and Laurin than the HKM study. A comparison of the results to the EAP analysis is presented in Appendix I.

Table 5 presents a summary of breach "A" and "B" modeling results. The difference between peak stage at each HEC-HMS element is included in the table. Positive values indicate the results in the breach "A" model were higher than the breach "B" parameter model results.

Table 5. HEC-HMS Sensitivity Analysis Summary

Hydrologic Element	Element Type	Δ Peak Discharge (cfs)	Δ Stage Peak (ft)
Ruby Basin	Basin	0	n/a
Ruby Reservoir	Reservoir	551,301	0.0
XS 4	Reach	533,994	17.6
XS 7	Reach	509,870	14.3
XS 8	Reach	477,789	5.1
XS 10 - Ald Resthome	Reach	330,572	3.8
XS 11 - Alder	Reach	257,785	3.2
XS 12 - Laurin	Reach	219,762	2.6

Large changes in breach parameters and peak discharge have an impact on peak stage in the area of interest. Even though the breach parameters have an effect on the downstream water surface elevation, it was determined that breach "A" and "B" parameters both indicate incremental damage to downstream life and property when compared to the model without dam breach. The extent of incremental damage will be discussed in the following section.

HEC-HMS results for the dam failure with breach "A" and "B" parameters are presented in Appendix G and H respectively.

4.0 RESULTS AND CONCLUSION

In the area of interest near Alder, the main focus in determining whether the dam breach causes incremental damage is flow depth and peak water surface elevation. In Table 6, flow depth and peak stage for the PMF event without and with a hydrologic dam breach are presented. The table also includes the difference between the model without dam breach and model with dam breach "A". Breach "A" parameters were used to evaluate incremental damage in this analysis because these parameters represent average FERC recommended values and it was determined that the use of more liberal values still resulted in incremental damage downstream of the reservoir.

Table 6. Downstream Flood Hazard Evaluation Results

Hydrologic Element	Element Type	No Breach PMF Peak Discharge	No Breach PMF Peak Stage	PMF Breach "A" Peak Discharge	PMF Breach "A" Peak Stage	Δ Peak Discharge	Δ Peak Stage
		(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
Ruby Basin	Basin	83,727		83,727		0	
Ruby Reservoir	Reservoir	81,941		1,016,644		934,703	
XS 4	Reach	81,908	31.1	985,433	74.1	903,525	43.0
XS 7	Reach	81,835	18.1	934,064	46.2	852,229	28.1
XS 8	Reach	81,818	11.0	867,471	22.3	785,653	11.3
100 yr Concurrent	Source	2,270		2,270		0	n/a
XS 10 - Ald Resthome	Reach	84,040	9.9	682,584	19.5	598,544	9.6
XS 11 - Alder	Reach	83,933	7.1	597,818	15.2	513,885	8.1
XS 12 - Laurin	Reach	83,886	5.8	536,047	13.1	452,161	7.3

From the above summary table, a large difference in the depth of flow near Alder and Laurin resulted in the event of a dam breach (versus flood routing without a dam breach). The smallest difference in peak stage resulted at cross section 12 at 7.3 feet, far above the general FERC guideline of 2 feet of difference equating to incremental damage. The smallest difference in peak stage with breach "B" parameters also resulted at cross section 12 at 4.7 feet. Figure 1 graphically depicts some of the information in Table 6 (breach "A") and also includes HEC-HMS results for the breach "B" parameters. Figure 2 illustrates peak stage with respect to distance from the dam spillway for both breaches.

Several buildings and homes in and around Alder and Laurin are located in areas that would be inundated by a PMF event with or without a dam breach. Most of these buildings and homes would be damaged significantly more in the event of a dam breach with a corresponding increase in the potential for loss of life. There are also a number of buildings and homes that are not impacted by the PMF event without a breach that would be significantly impacted during the same event if a dam breach occurred.

Figure 3 presents a map indicating the location of buildings, homes, and roadways in the area of interest around Alder and Laurin. The figure shows the flow areas around cross sections 10, 11, and 12 in a PMF event without dam breach and a PMF event resulting in breach "A". The peak stage difference between the FERC PMF breach "A" and no breach model is very significant at cross sections 11 and 12. Even with liberal assumptions (breach "B" parameters), the incremental level of damage is considerable.

In a PMF event, substantially more residences, highways and railroads would be impacted if the event resulted in a dam breach. Utilizing FERC regulations, an IDF of smaller magnitude than the PMF event would present an unacceptable hazard to areas downstream of Ruby Dam, and the IDF would be the PMF.

The flow depths resulting from this evaluation were quite different in comparison to the flood inundation study and maps from the EAP. As a basis for comparison, the cross section geometry used in the EAP versus HKM cross section geometry is presented in Figures 4, 5, and 6 for cross sections near the area of interest (cross sections 10, 11, and 12). The figures also show the peak stage reported in the EAP and the peak stage determined from this study.

Based on a brief review of the EAP, it is clear the HKM and EAP evaluations are not in concurrence. Major modeling and methodology differences between the HKM and EAP evaluation were not determined in association with this analysis. Thorough comparison of the models and review of the EAP flood inundation study were outside of the scope of this task and the Ruby Dam Rehabilitation Feasibility Study, and were not performed. HKM recommends DNRC review and verify the EAP flood inundation analysis and mapping as it appears the EAP inundation boundaries may be inaccurate. A more detailed summary of the HKM study compared to the EAP is included in Appendix I.

5.0 REFERENCES

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U.S. Army Corps of Engineering, Hydrologic Engineering Center, May 2005. HEC-RAS, River Analysis System Version 3.1.3. Davis, CA.

FIGURES

Figure 1 - Ruby Dam PMF Hydrographs

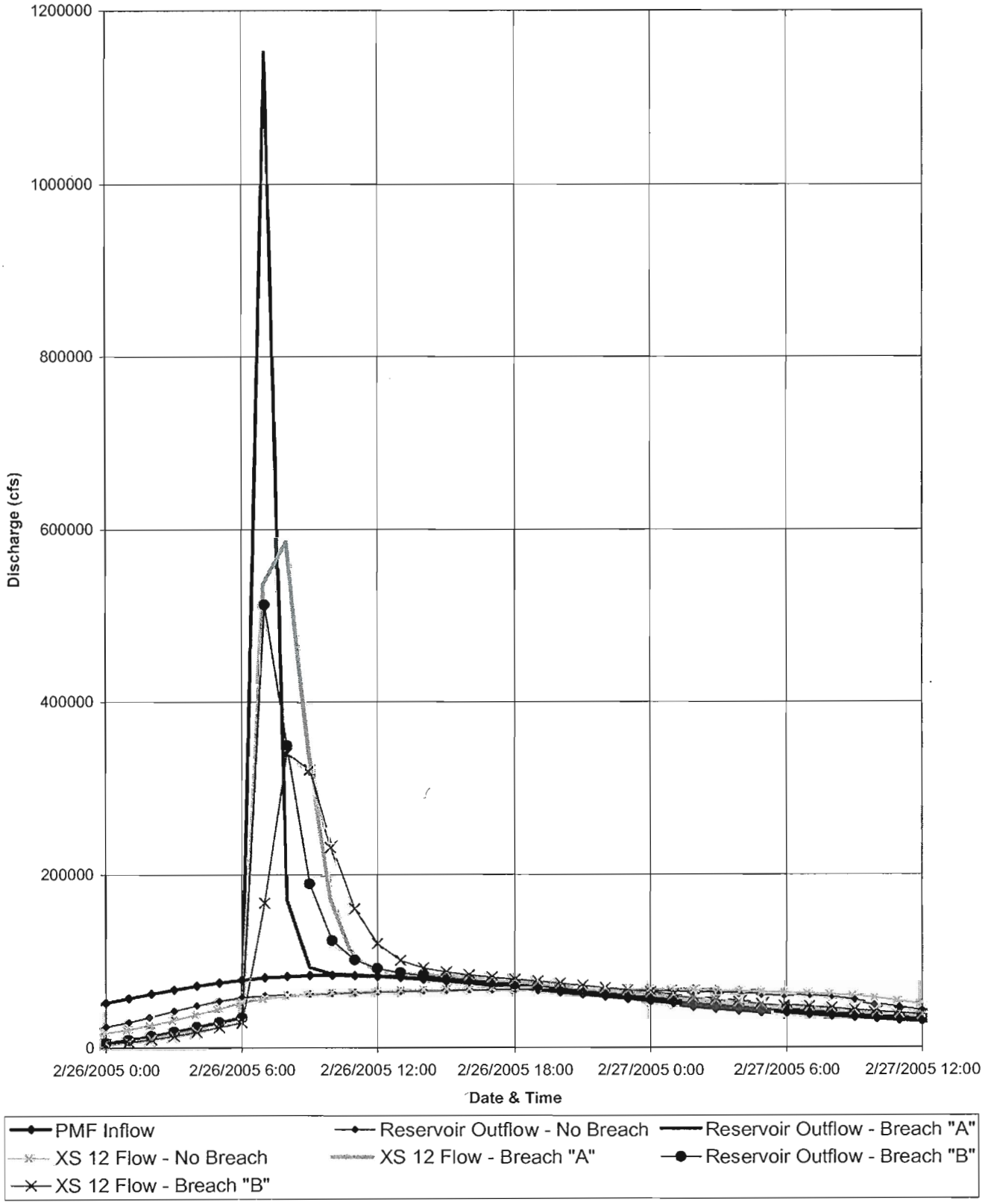
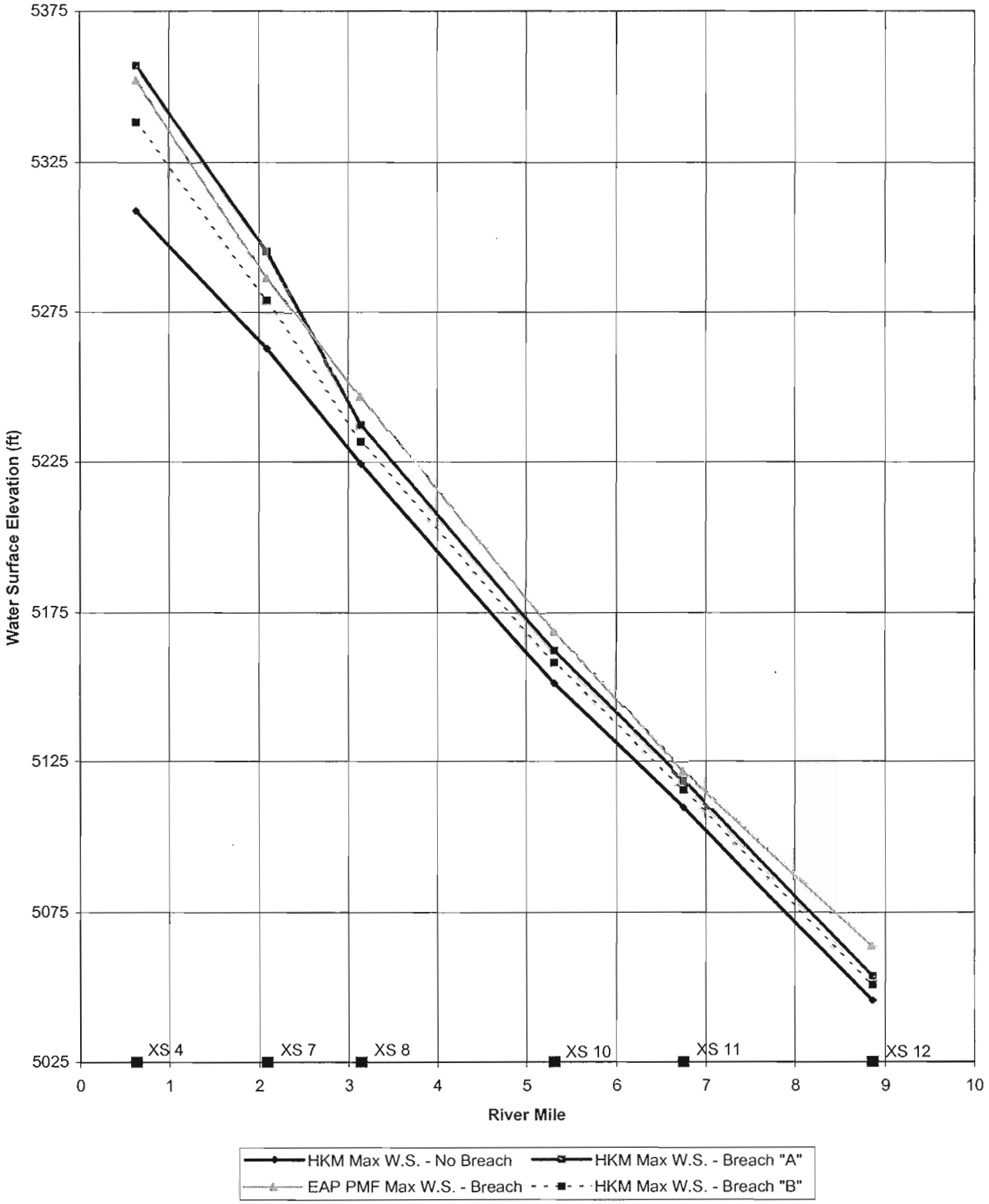
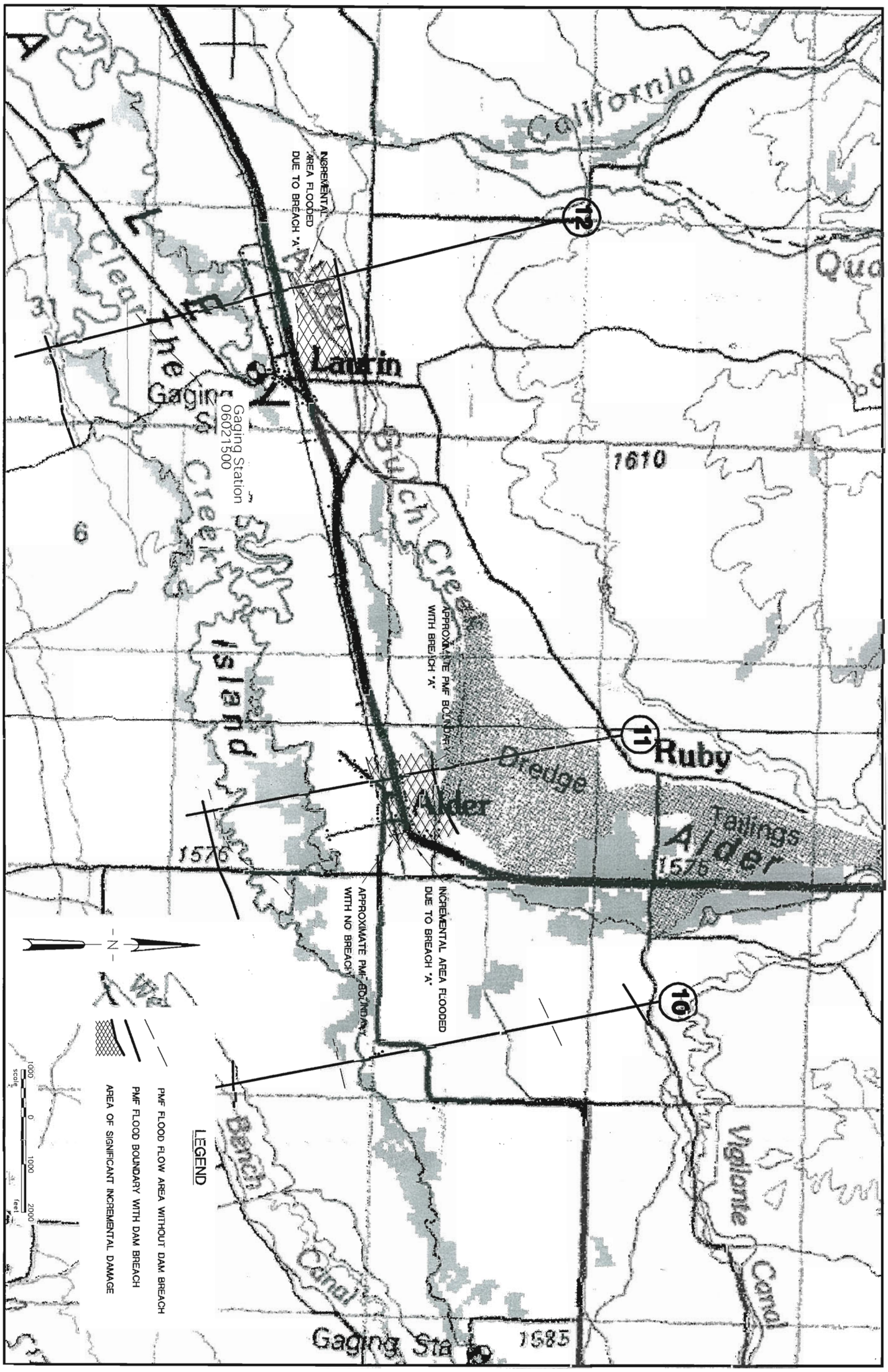


Figure 2 - Ruby Dam PMF Peak Water Surface Elevations





RUBY DAM REHABILITATION FEASIBILITY STUDY

DOWNSTREAM HAZARD ANALYSIS
ALDER, MT

FIGURE # 3

HKM ENGINEERING

08M087.175 | JANUARY 2008

Figure 4 - Water Surface Elevation near Alder Resthome (XS 10)

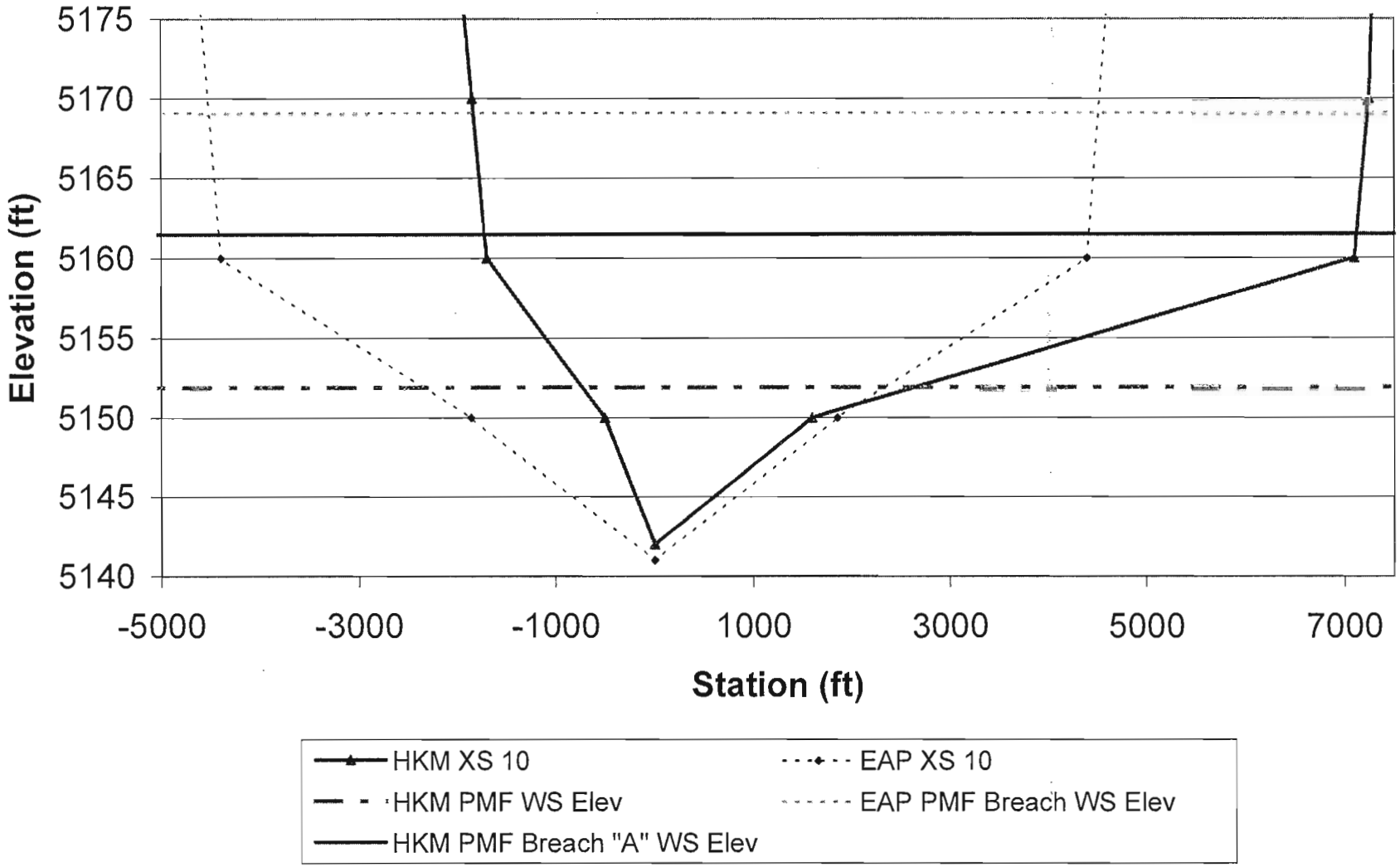


Figure 5 - Water Surface Elevation near Alder, MT (XS 11)

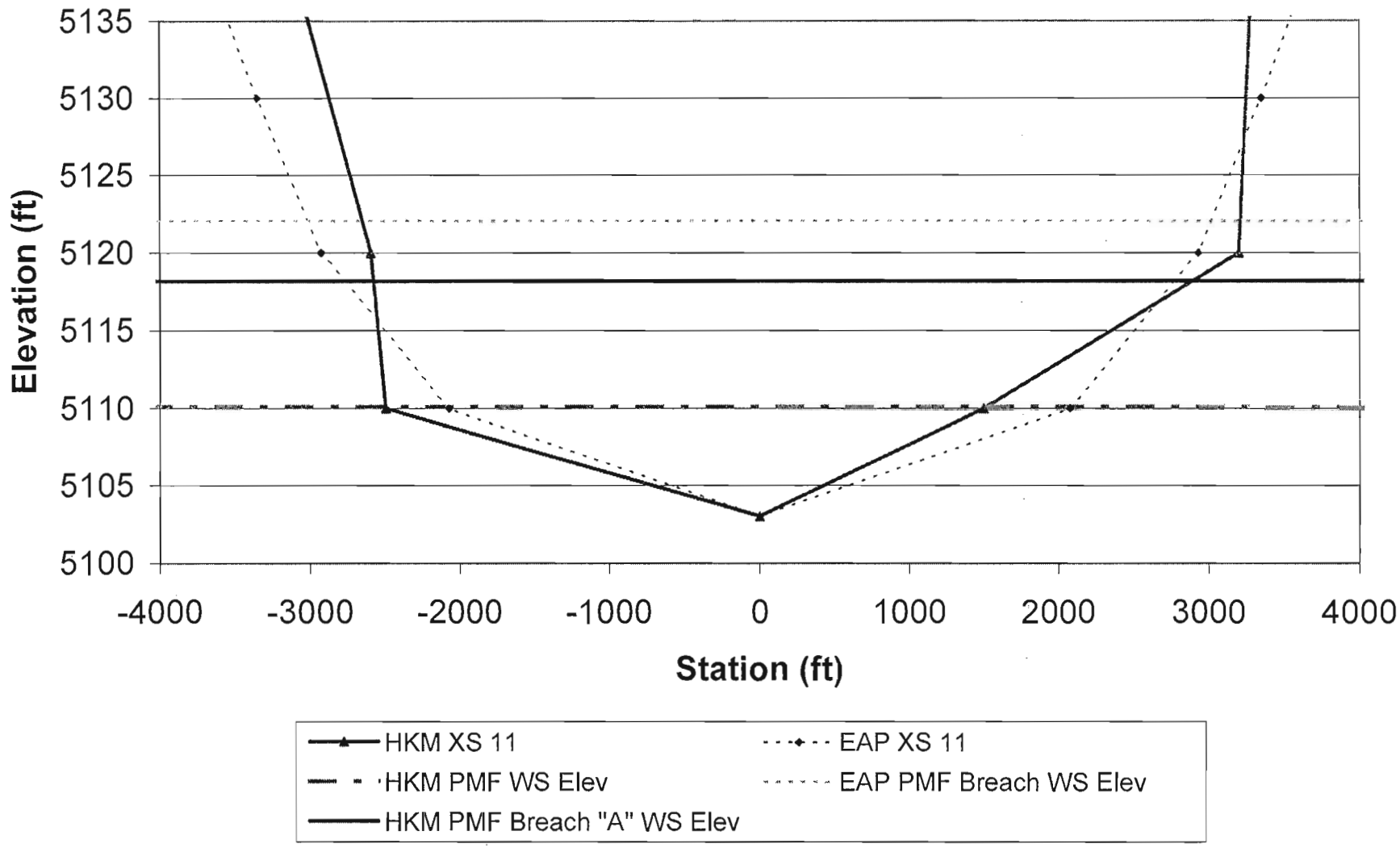
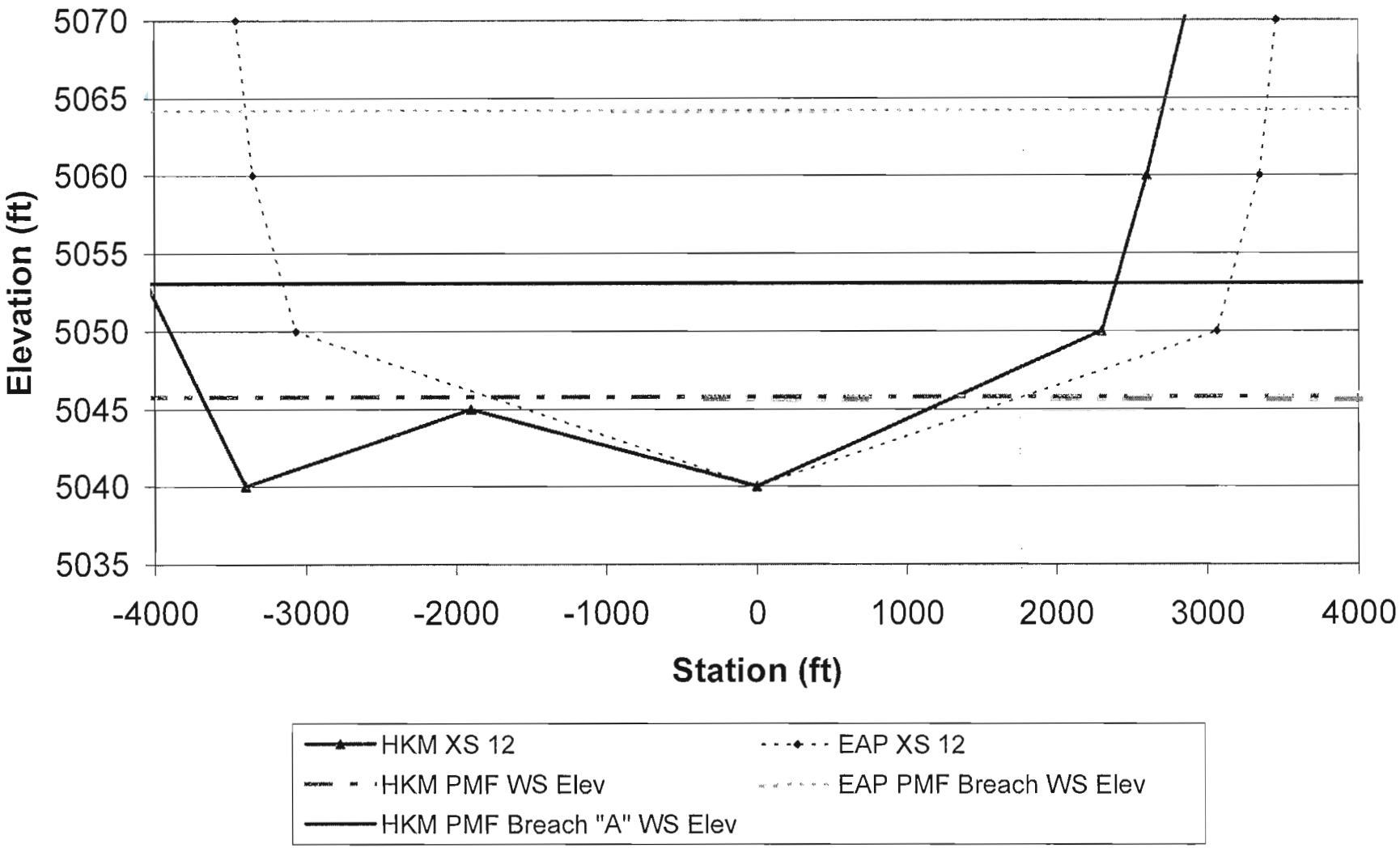


Figure 6 - Water Surface Elevation near Laurin, MT (XS 12)

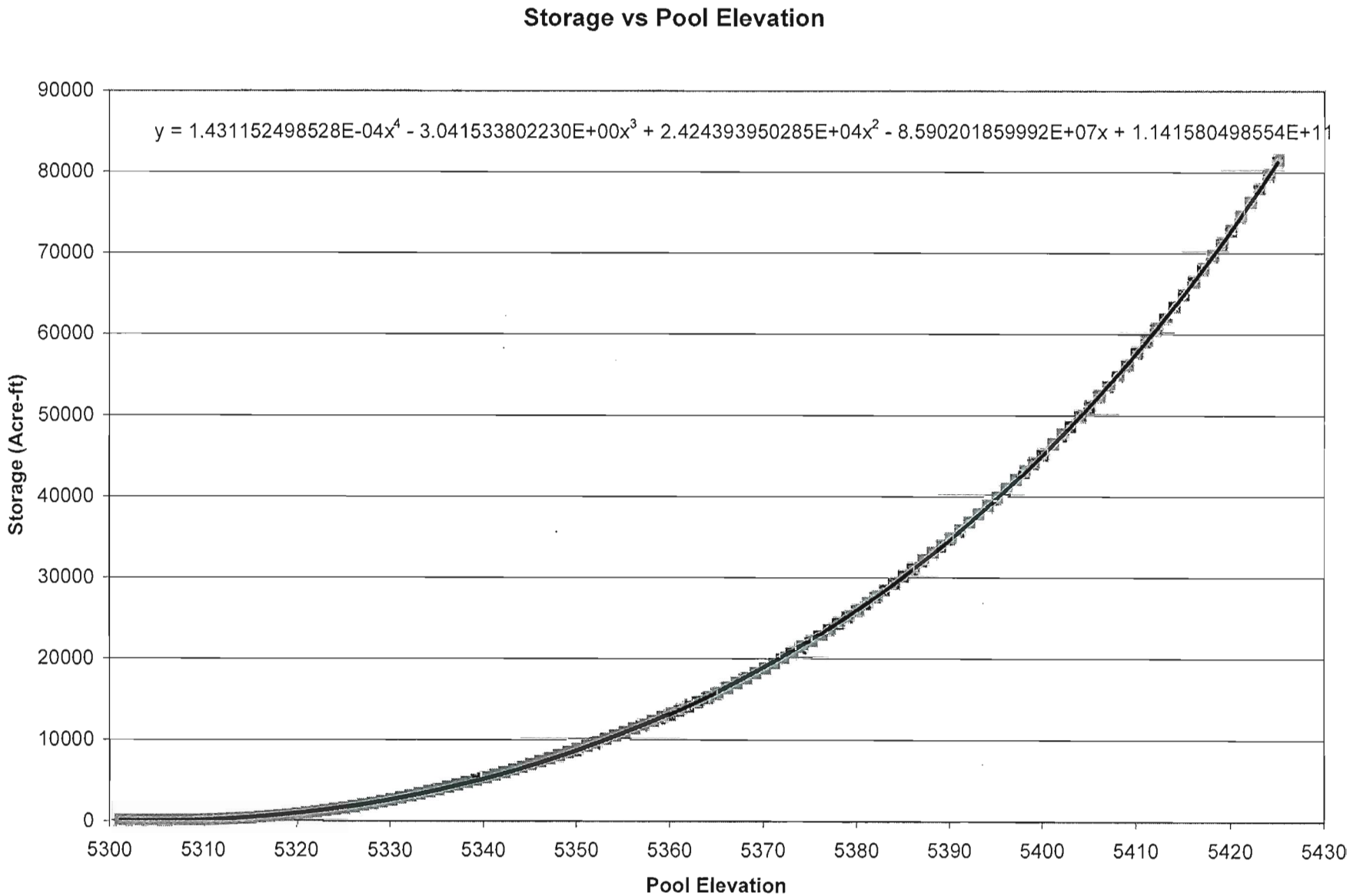


Ruby Dam
Incremental Hazard Screening Study

APPENDIX A

RESERVOIR ELEVATION-CAPACITY DATA

Ruby Dam Rehabilitation



H:\08\M087175\Water Availability\Storage vs El.xls

Ruby Dam Storage

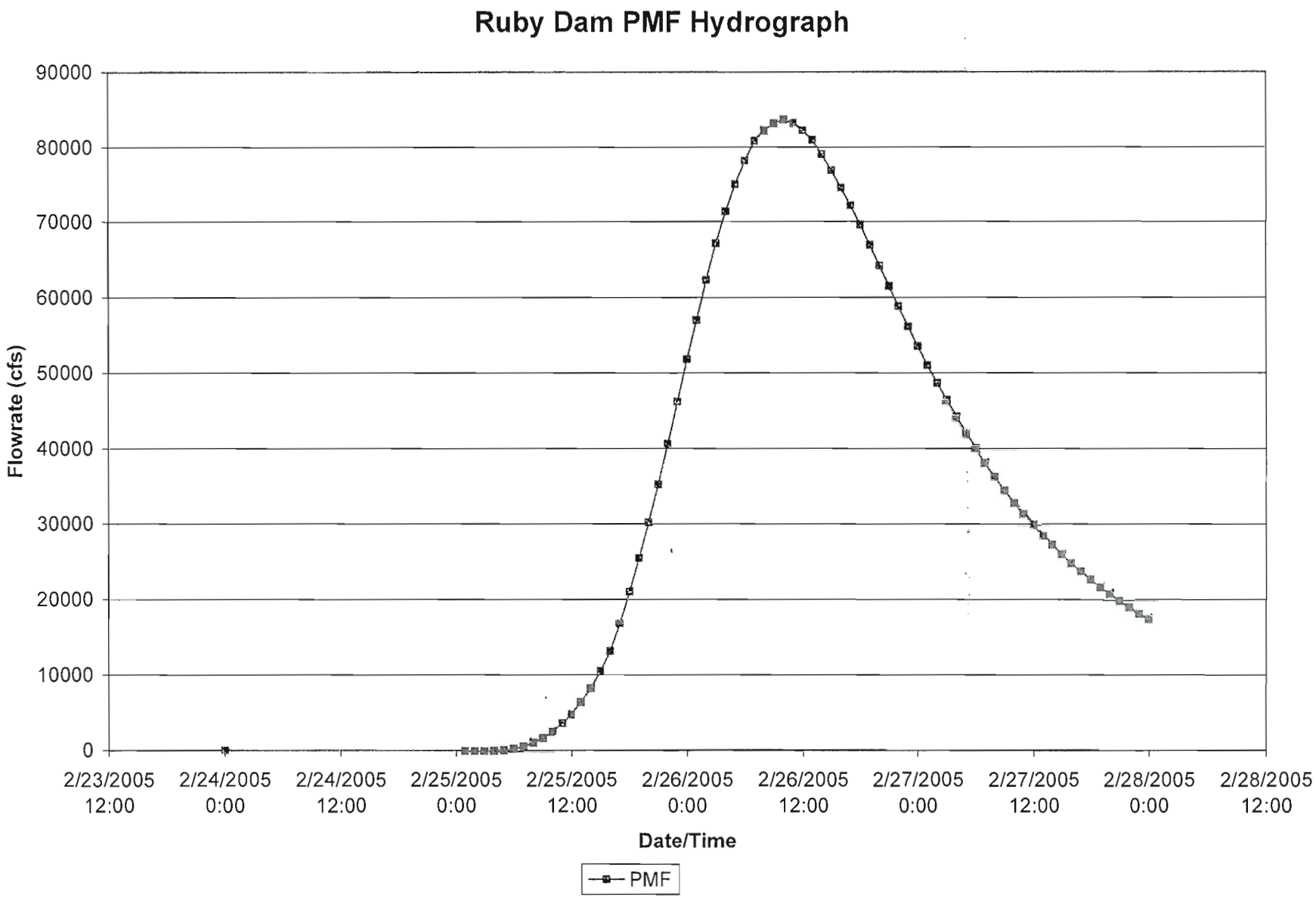
Projected above Elev. 5410

Pool El.	Storage	Pool El.	Storage	Pool El.	Storage	Pool El.	Storage	Pool El.	Storage
5301	0	5326	1724	5351	9119	5376	22743	5401	46296
5302	1	5327	1927	5352	9529	5377	23516	5402	47478
5303	1	5328	2129	5353	9939	5378	24289	5403	48659
5304	2	5329	2332	5354	10349	5379	25062	5404	49841
5305	3	5330	2535	5355	10759	5380	25835	5405	51023
5306	13	5331	2786	5356	11220	5381	26691	5406	52292
5307	24	5332	3038	5357	11682	5382	27548	5407	53562
5308	34	5333	3289	5358	12143	5383	28404	5408	54831
5309	45	5334	3541	5359	12605	5384	29261	5409	56101
5310	56	5335	3793	5360	13067	5385	30118	5410	57683
5311	102	5336	4082	5361	13591	5386	31035	5411	59071
5312	148	5337	4372	5362	14115	5387	31952	5412	60484
5313	194	5338	4661	5363	14639	5388	32869	5413	61921
5314	240	5339	4951	5364	15163	5389	33786	5414	63384
5315	286	5340	5241	5365	15687	5390	34703	5415	64873
5316	384	5341	5568	5366	16274	5391	35668	5416	66387
5317	483	5342	5895	5367	16862	5392	36633	5417	67928
5318	581	5343	6222	5368	17449	5393	37642	5418	69495
5319	680	5344	6549	5369	18037	5394	38652	5419	71090
5320	779	5345	6876	5370	18625	5395	39662	5420	72711
5321	927	5346	7242	5371	19294	5396	40752	5421	74361
5322	1076	5347	7609	5372	19963	5397	41843	5422	76039
5323	1224	5348	7975	5373	20632	5398	42933	5423	77745
5324	1373	5349	8342	5374	21301	5399	44024	5424	79480
5325	1522	5350	8709	5375	21970	5400	45115	5425	81244

Ruby Dam
Incremental Hazard Screening Study

APPENDIX B

PMF FLOOD HYDROGRAPH AND CONCURRENT FLOOD ESTIMATION


Ruby Dam PMF Hydrograph
Flowrate (cfs)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
2/23/2005 12:00
2/24/2005 0:00
2/24/2005 12:00
2/25/2005 0:00
2/25/2005 12:00
2/26/2005 0:00
2/26/2005 12:00
2/27/2005 0:00
2/27/2005 12:00
2/28/2005 0:00
2/28/2005 12:00
Date/Time
PMF

PMF Inflow Hydrograph

Date/Time	Reservoir Storage (Ac-Ft)	Reservoir Elevation (ft)	Inflow (cfs)
2/24/2005 0:00	41516	5396.7	0
2/25/2005 1:00	41516	5396.7	0
2/25/2005 2:00	41516	5396.7	3
2/25/2005 3:00	41517	5396.7	12
2/25/2005 4:00	41519	5396.7	55
2/25/2005 5:00	41527	5396.7	142
2/25/2005 6:00	41545	5396.7	333
2/25/2005 7:00	41583	5396.8	653
2/25/2005 8:00	41651	5396.8	1114
2/25/2005 9:00	41758	5396.9	1727
2/25/2005 10:00	41916	5397.1	2540
2/25/2005 11:00	42141	5397.3	3589
2/25/2005 12:00	42448	5397.6	4890
2/25/2005 13:00	42854	5397.9	6471
2/25/2005 14:00	43376	5398.4	8329
2/25/2005 15:00	44033	5399	10532
2/25/2005 16:00	44828	5399.7	13151
2/25/2005 17:00	45790	5400.6	16811
2/25/2005 18:00	46961	5401.6	20997
2/25/2005 19:00	48343	5402.7	25480
2/25/2005 20:00	49922	5404.1	30188
2/25/2005 21:00	51691	5405.5	35235
2/25/2005 22:00	53644	5407.1	40621
2/25/2005 23:00	55760	5408.7	46212
2/26/2005 0:00	57981	5410.4	51812
2/26/2005 1:00	60243	5411.8	57016
2/26/2005 2:00	62466	5413.4	62272
2/26/2005 3:00	64574	5414.8	67115
2/26/2005 4:00	66529	5416.1	71386
2/26/2005 5:00	68341	5417.3	74997
2/26/2005 6:00	70049	5418.3	78178
2/26/2005 7:00	71734	5419.4	80817
2/26/2005 8:00	73461	5420.5	82288
2/26/2005 9:00	75212	5421.5	83233
2/26/2005 10:00	76949	5422.5	83727
2/26/2005 11:00	78613	5423.5	83215
2/26/2005 12:00	80150	5424.4	82222
2/26/2005 13:00	81533	5425.2	80943
2/26/2005 14:00	82733	5425.8	79047
2/26/2005 15:00	83722	5426.4	76877
2/26/2005 16:00	84490	5426.8	74534
2/26/2005 17:00	85038	5427.1	72178
2/26/2005 18:00	85365	5427.3	69588
2/26/2005 19:00	85464	5427.3	66877
2/26/2005 20:00	85340	5427.3	64156
2/26/2005 21:00	85001	5427.1	61478
2/26/2005 22:00	84459	5426.8	58810
2/26/2005 23:00	83721	5426.4	56143
2/27/2005 0:00	82798	5425.9	53546
2/27/2005 1:00	81704	5425.3	51043
2/27/2005 2:00	80457	5424.6	48687
2/27/2005 3:00	79072	5423.8	46438
2/27/2005 4:00	77563	5422.9	44253
2/27/2005 5:00	75941	5421.9	42121
2/27/2005 6:00	74219	5420.9	40102
2/27/2005 7:00	72410	5419.8	38205
2/27/2005 8:00	70556	5418.7	36393
2/27/2005 9:00	68782	5417.5	34646
2/27/2005 10:00	67210	5416.5	33003
2/27/2005 11:00	65855	5415.6	31456
2/27/2005 12:00	64697	5414.9	29996
2/27/2005 13:00	63709	5414.2	28616
2/27/2005 14:00	62851	5413.6	27318
2/27/2005 15:00	62090	5413.1	26088
2/27/2005 16:00	61403	5412.6	24918
2/27/2005 17:00	60776	5412.2	23806
2/27/2005 18:00	60199	5411.8	22759
2/27/2005 19:00	59663	5411.4	21768
2/27/2005 20:00	59161	5411.1	20825
2/27/2005 21:00	58678	5410.8	19934
2/27/2005 22:00	58198	5410.5	19097
2/27/2005 23:00	57721	5410.2	18308
2/28/2005 0:00	57254	5409.9	17574

USGS

Montana Flood-Frequency and Basin-Characteristic Data

Estimate Flood Discharges at Ungaged Sites in Montana -- (continued)

Summary of Estimation Parameters Selected:

Name for this estimation: Ruby Drainage Estimate
Region: Southwest
Estimation method: Basin and Climatic Characteristics Only
Drainage area in square miles: 54
Percent basin above 6,000 feet: 5

Flood Discharge Estimation:

(In the Flood Discharge table, RI is the Recurrence Interval, in years; STD ERR is the Standard Error; and 90% PRED. INTERVAL is the 90% Prediction Interval, in cubic feet per second)

```
 METHOD: Regression on basin characteristics
 Flood frequency estimates for
 Ruby Drainage Estimate
Southwest Region: A =     54.00 E6 =     5.
```

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	121.	100.7	29.7	495.
5	346.	85.3	99.9	1200.
10	604.	82.9	179.1	2040.
25	1090.	83.9	320.9	3730.
50	1610.	86.8	456.0	5660.
100	2270.	90.7	616.5	8340.
200	3100.	95.5	800.3	12000.
500	4520.	103.3	1080.0	18900.

Ruby Dam
Incremental Hazard Screening Study

APPENDIX C

CROSS SECTION DATA AND LOCATIONS

Ruby Dam
Incremental Hazard Evaluation
08M087.175

HKM XS 4

Station	Elevation
-950	5440
-900	5400
-750	5360
-300	5320
0	5280
200	5320
250	5360
300	5400
350	5440

HKM XS 7

Station	Elevation
-800	5340
-700	5320
-600	5300
-450	5280
-350	5260
0	5246
300	5260
380	5280
400	5300
700	5320
850	5340

HKM XS 8

Station	Elevation
-2100	5300
-1750	5280
-1150	5260
-800	5240
-600	5220
0	5214
400	5220
3700	5230
4350	5240
4850	5260
5400	5280
6200	5300

HKM XS 10

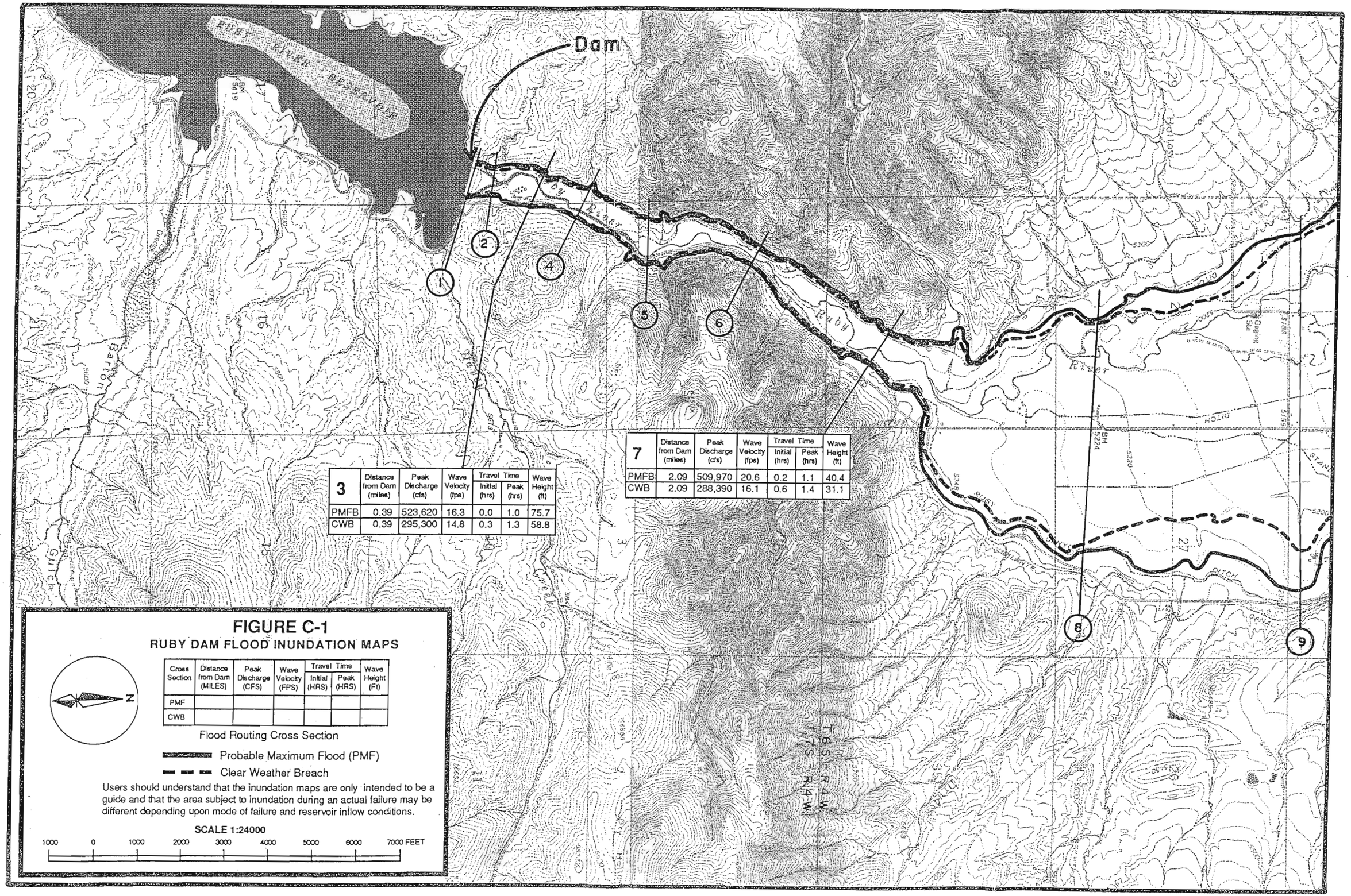
Station	Elevation
-2500	5200
-2000	5180
-1850	5170
-1700	5160
-500	5150
0	5142
1600	5150
7100	5160
7250	5170
7300	5180
7400	5200

HKM XS 11

Station	Elevation
-3700	5160
-2600	5120
-2500	5110
0	5103
1500	5110
3200	5120
3300	5140
3400	5160

HKM XS 12

Station	Elevation
-4800	5100
-4500	5080
-4400	5060
-3400	5040
-1900	5045
0	5040
2300	5050
2600	5060
3100	5080
3600	5100
3920	5120



3	Distance from Dam (miles)	Peak Discharge (cfs)	Wave Velocity (fps)	Travel Time Initial (hrs)	Travel Time Peak (hrs)	Wave Height (ft)
PMFB	0.39	523,620	16.3	0.0	1.0	75.7
CWB	0.39	295,300	14.8	0.3	1.3	58.8

7	Distance from Dam (miles)	Peak Discharge (cfs)	Wave Velocity (fps)	Travel Time Initial (hrs)	Travel Time Peak (hrs)	Wave Height (ft)
PMFB	2.09	509,970	20.6	0.2	1.1	40.4
CWB	2.09	288,390	16.1	0.6	1.4	31.1

FIGURE C-1

RUBY DAM FLOOD INUNDATION MAPS

Cross Section	Distance from Dam (MILES)	Peak Discharge (CFS)	Wave Velocity (FPS)	Travel Time Initial (HRS)	Travel Time Peak (HRS)	Wave Height (Ft)
PMF						
CWB						

Flood Routing Cross Section

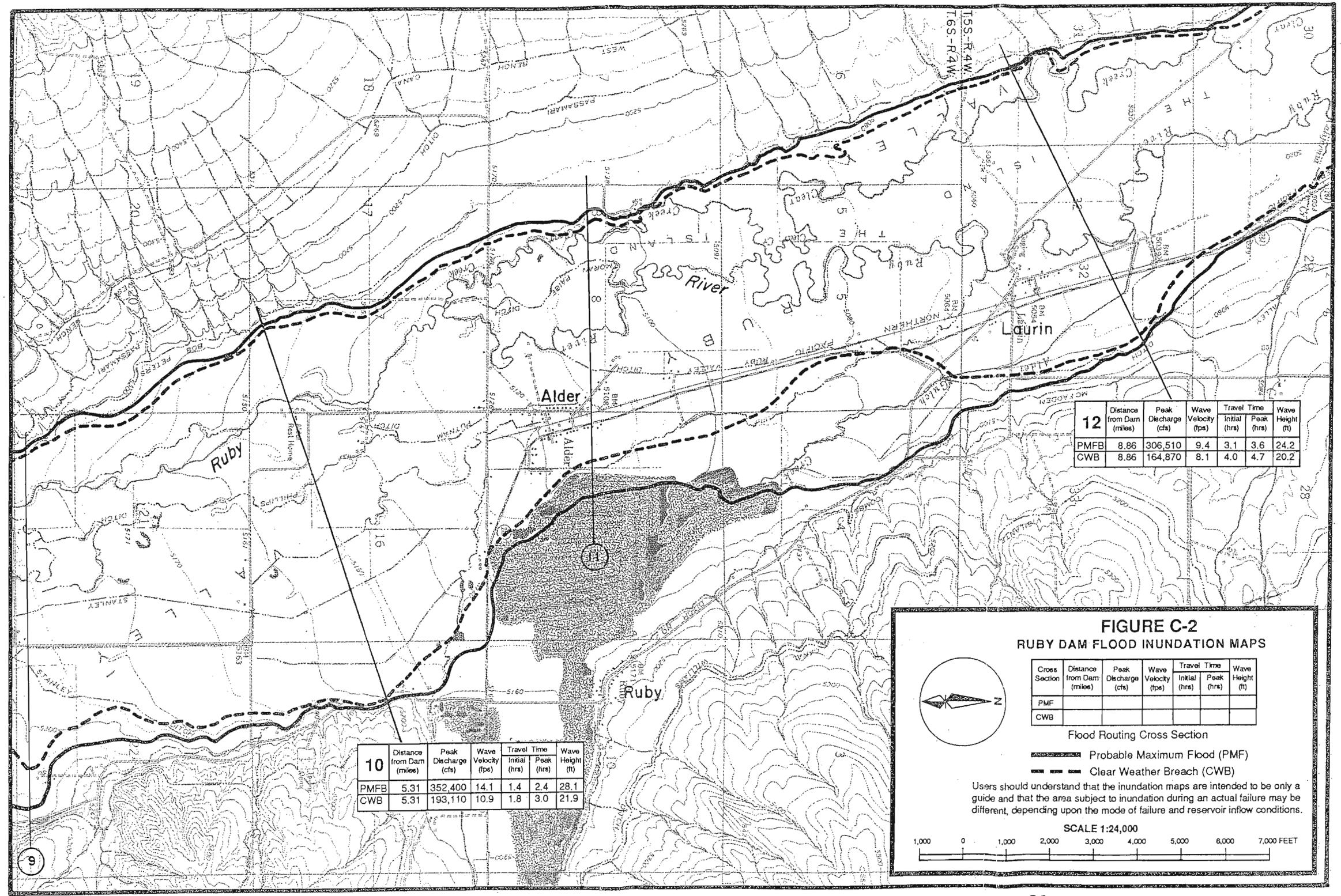
Probable Maximum Flood (PMF)

Clear Weather Breach

Users should understand that the inundation maps are only intended to be a guide and that the area subject to inundation during an actual failure may be different depending upon mode of failure and reservoir inflow conditions.

SCALE 1:24000

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET



12	Distance from Dam (miles)	Peak Discharge (cfs)	Wave Velocity (fps)	Travel Time Initial (hrs)	Travel Time Peak (hrs)	Wave Height (ft)
PMFB	8.86	306,510	9.4	3.1	3.6	24.2
CWB	8.86	164,870	8.1	4.0	4.7	20.2

10	Distance from Dam (miles)	Peak Discharge (cfs)	Wave Velocity (fps)	Travel Time Initial (hrs)	Travel Time Peak (hrs)	Wave Height (ft)
PMFB	5.31	352,400	14.1	1.4	2.4	28.1
CWB	5.31	193,110	10.9	1.8	3.0	21.9

FIGURE C-2

RUBY DAM FLOOD INUNDATION MAPS

N

Cross Section	Distance from Dam (miles)	Peak Discharge (cfs)	Wave Velocity (fps)	Travel Time Initial (hrs)	Travel Time Peak (hrs)	Wave Height (ft)
PMF						
CWB						

Flood Routing Cross Section

Probable Maximum Flood (PMF)

Clear Weather Breach (CWB)

Users should understand that the inundation maps are intended to be only a guide and that the area subject to inundation during an actual failure may be different, depending upon the mode of failure and reservoir inflow conditions.

SCALE 1:24,000

1,000 0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 FEET

Ruby Dam
Incremental Hazard Screening Study

APPENDIX D

HEC-RAS MODELING DATA

HEC-RAS INPUT DATA REPORT

Ruby.rep

HEC-RAS Version 3.1.3 May 2005
U.S. Army Corp of Engineers
Hydrologic Engineering Center
609 Second Street
Davis, California

```
X     X  XXXXXX    XXXX        XXXX       XX      XXXX
X     X  X        X    X      X   X     X  X    X
X     X  X        X           X   X    X    X   X
XXXXXXX  XXXX     X       XXX XXXX     XXXXXX    XXXX
X     X  X        X           X  X     X    X        X
X     X  X        X    X      X   X    X    X        X
X     X  XXXXXX    XXXX       X    X   X    X   XXXXX
```

PROJECT DATA
Project Title: Ruby
Project File : Ruby.prj
Run Date and Time: 5/25/2006 3:59:47 PM

Project in English units

PLAN DATA

Plan Title: Ruby
Plan File : h:\08\M087175\Flood Hydrology\Incremental Hazard Evaluation\HEC-RAS\Ruby.p01

Geometry Title: Ruby
Geometry File : h:\08\M087175\Flood Hydrology\Incremental Hazard Evaluation\HEC-RAS\Ruby.g01

Flow Title : Ruby
Flow File : h:\08\M087175\Flood Hydrology\Incremental Hazard Evaluation\HEC-RAS\Ruby.f01

Plan Summary Information:

Number of:					
Cross Sections	=	6	Multiple Openings	=	0
Culverts	=	0	Inline Structures	=	0
Bridges	=	0	Lateral Structures	=	0

Computational Information

Water surface calculation tolerance	=	0.01
Critical depth calculation tolerance	=	0.01
Maximum number of iterations	=	20
Maximum difference tolerance	=	0.3
Flow tolerance factor	=	0.001

Computation Options
Critical depth computed only where necessary
Conveyance Calculation Method: At breaks in n values only
Friction Slope Method: Average Conveyance
Computational Flow Regime: Subcritical Flow

FLOW DATA

Flow Title: Ruby
Flow File : h:\08\M087175\Flood Hydrology\Incremental Hazard Evaluation\HEC-RAS\Ruby.f01

Flow Data (cfs)

River	Reach	RS	PF 1	PF 2	PF 3	PF 4	PF 5	PF 6	PF 7	PF 8
Ruby River	DS Ruby Dam	6	20000	40000	60000	80000	100000	120000	140000	160000

River	Reach	RS	PF 9	PF 10	PF 11	PF 12	PF 13	PF 14	PF 15	PF 16
Ruby River	DS Ruby Dam	6	180000	200000	220000	240000	260000	280000	300000	320000

Boundary Conditions

River	Reach	Profile	Upstream	Downstream
Ruby River	DS Ruby Dam	PF 1	Normal S = 0.0044	Normal S = 0.00544
Ruby River	DS Ruby Dam	PF 2	Normal S = 0.0044	Normal S = 0.00544

GEOMETRY DATA

Geometry Title: Ruby
Geometry File : h:\08\M087175\Flood Hydrology\Incremental Hazard Evaluation\HEC-RAS\Ruby.g01

CROSS SECTION

RIVER: Ruby River
REACH: DS Ruby Dam RS: 6

INPUT
Description: XS 4
Station Elevation Data num= 9

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
-950	5440	-900	5400	-750	5360	-300	5320	0	5280
200	5320	250	5360	300	5400	350	5440		

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
-950	.06	-300	.05	200	.06

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
-300	200	7709	7709	7709	.1	.3

CROSS SECTION

RIVER: Ruby River
REACH: DS Ruby Dam RS: 5

INPUT
Description: XS 7
Station Elevation Data num= 11

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
-800	5340	-700	5320	-600	5300	-450	5280	-350	5260
0	5246	300	5260	380	5280	400	5300	700	5320
850	5340								

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
-800	.06	-350	.05	300	.06

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
-350	300	5544	5544	5544	.1	.3

CROSS SECTION

RIVER: Ruby River
REACH: DS Ruby Dam RS: 4

INPUT
Description: XS 8
Station Elevation Data num= 12

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
-2100	5300	-1750	5280	-1150	5260	-800	5240	-600	5220
0	5214	400	5220	3700	5230	4350	5240	4850	5260
5400	5280	6200	5300						

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
-2100	.06	-600	.05	400	.06

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
-600	400	11458	11458	11458	.1	.3

CROSS SECTION

RIVER: Ruby River
REACH: DS Ruby Dam RS: 3

INPUT
Description: XS 10 - Alder Resthome
Station Elevation Data num= 11

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev

-2500	5200	-2000	5180	-1850	5170	-1700	5160	-500	5150
0	5142	1600	5150	7100	5160	7250	5170	7300	5180
7400	5200								

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
-2500	.06	-500	.05	1600	.06

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
-500	1600	7603	7603	7603	.1	.3

CROSS SECTION

RIVER: Ruby River
REACH: DS Ruby Dam RS: 2

INPUT
Description: XS 11 - Alder
Station Elevation Data num= 8

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
-3700	5160	-2600	5120	-2500	5110	0	5103	1500	5110
3200	5120	3300	5140	3400	5160				

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
-3700	.06	-2500	.05	1500	.06

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
-2500	1500	11141	11141	11141	.1	.3

CROSS SECTION

RIVER: Ruby River
REACH: DS Ruby Dam RS: 1

INPUT
Description: XS 12 - Laurin
Station Elevation Data num= 11

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
-4800	5100	-4500	5080	-4400	5060	-3400	5040	-1900	5045
0	5040	2300	5050	2600	5060	3100	5080	3600	5100
3920	5120								

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
-4800	.06	-1900	.05	2300	.06

Bank Sta: Left	Right	Coeff Contr.	Expan.
-1900	2300	.1	.3

SUMMARY OF MANNING'S N VALUES

River:Ruby River

Reach	River Sta.	n1	n2	n3
DS Ruby Dam	6	.06	.05	.06
DS Ruby Dam	5	.06	.05	.06
DS Ruby Dam	4	.06	.05	.06

DS Ruby Dam	3	.06	.05	.06
DS Ruby Dam	2	.06	.05	.06
DS Ruby Dam	1	.06	.05	.06

SUMMARY OF REACH LENGTHS

River: Ruby River

Reach	River Sta.	Left	Channel	Right
DS Ruby Dam	6	7709	7709	7709
DS Ruby Dam	5	5544	5544	5544
DS Ruby Dam	4	11458	11458	11458
DS Ruby Dam	3	7603	7603	7603
DS Ruby Dam	2	11141	11141	11141
DS Ruby Dam	1			

HEC-RAS Plan: Ruby River: Ruby River Reach: DS Ruby Dam

Reach	River Sta	Q Total	W.S. Elev	Crit W.S.	Vel Total	Flow Area	Top Width	Froude # Chl	Crit Depth	Max Chl Dpth
		(cfs)	(ft)	(ft)	(ft/s)	(sq.ft)	(ft)		(ft)	(ft)
XS 4										
DS Ruby Dam	6	20000.00	5298.32	5294.44	9.53	2098.16	229.03	0.55	14.44	18.32
DS Ruby Dam	6	40000.00	5303.62	5299.06	11.48	3485.64	295.20	0.59	19.06	23.62
DS Ruby Dam	6	60000.00	5307.29	5302.40	12.89	4653.33	341.08	0.62	22.40	27.29
DS Ruby Dam	6	80000.00	5310.28	5305.14	13.96	5729.12	378.45	0.63	25.14	30.28
DS Ruby Dam	6	100000.00	5312.87	5307.53	14.81	6753.98	410.91	0.64	27.53	32.87
DS Ruby Dam	6	120000.00	5315.17	5309.58	15.52	7730.77	439.62	0.65	29.58	35.17
DS Ruby Dam	6	140000.00	5317.26	5311.46	16.13	8677.50	465.77	0.66	31.46	37.26
DS Ruby Dam	6	160000.00	5319.18	5313.22	16.68	9592.85	489.72	0.66	33.22	39.18
DS Ruby Dam	6	180000.00	5320.80	5314.82	17.30	10403.90	510.00	0.67	34.82	40.80
DS Ruby Dam	6	200000.00	5322.21	5316.31	17.96	11134.99	527.61	0.67	36.31	42.21
DS Ruby Dam	6	220000.00	5323.56	5317.69	18.55	11861.10	544.54	0.68	37.69	43.56
DS Ruby Dam	6	240000.00	5324.85	5319.07	19.09	12574.53	560.68	0.68	39.07	44.85
DS Ruby Dam	6	260000.00	5326.10	5320.19	19.57	13283.18	576.26	0.68	40.19	46.10
DS Ruby Dam	6	280000.00	5327.31	5321.19	20.02	13986.99	591.33	0.69	41.19	47.31
DS Ruby Dam	6	300000.00	5328.48	5322.27	20.42	14692.09	606.05	0.69	42.27	48.48
DS Ruby Dam	6	320000.00	5329.64	5323.32	20.78	15399.99	620.48	0.69	43.32	49.64
DS Ruby Dam	6	340000.00	5330.76	5324.34	21.12	16101.91	634.47	0.69	44.34	50.76
DS Ruby Dam	6	360000.00	5331.84	5325.39	21.43	16798.91	648.05	0.70	45.39	51.84
DS Ruby Dam	6	380000.00	5332.91	5326.43	21.72	17496.46	661.37	0.70	46.43	52.91
DS Ruby Dam	6	400000.00	5333.94	5327.43	21.99	18187.12	674.30	0.70	47.43	53.94
DS Ruby Dam	6	420000.00	5334.96	5328.38	22.25	18879.40	687.01	0.70	48.38	54.96
DS Ruby Dam	6	440000.00	5335.95	5329.28	22.49	19563.10	699.34	0.70	49.28	55.95
DS Ruby Dam	6	460000.00	5336.92	5330.21	22.72	20247.85	711.47	0.70	50.21	56.92
DS Ruby Dam	6	480000.00	5337.87	5331.15	22.93	20930.94	723.38	0.70	51.15	57.87
DS Ruby Dam	6	500000.00	5338.81	5332.08	23.13	21614.24	735.09	0.70	52.08	58.81
DS Ruby Dam	6	520000.00	5339.72	5332.96	23.33	22291.74	746.52	0.70	52.96	59.72
DS Ruby Dam	6	540000.00	5340.61	5333.83	23.52	22960.83	757.64	0.70	53.82	60.61
DS Ruby Dam	6	560000.00	5341.49	5334.79	23.70	23630.43	768.61	0.71	54.79	61.49
DS Ruby Dam	6	580000.00	5342.27	5335.66	23.93	24235.86	778.39	0.71	55.66	62.27
DS Ruby Dam	6	600000.00	5342.98	5336.48	24.20	24793.95	787.30	0.71	56.48	62.98
DS Ruby Dam	6	620000.00	5343.68	5337.27	24.46	25344.78	796.00	0.72	57.27	63.68
DS Ruby Dam	6	640000.00	5344.37	5338.01	24.72	25894.20	804.58	0.72	58.01	64.37
DS Ruby Dam	6	660000.00	5345.02	5338.85	24.98	26420.53	812.72	0.73	58.85	65.02
DS Ruby Dam	6	680000.00	5345.66	5339.57	25.24	26942.54	820.71	0.73	59.57	65.66
DS Ruby Dam	6	700000.00	5346.28	5340.37	25.49	27459.14	828.54	0.73	60.37	66.28
DS Ruby Dam	6	720000.00	5346.90	5341.07	25.74	27973.71	836.27	0.74	61.07	66.90
DS Ruby Dam	6	740000.00	5347.51	5341.79	25.98	28485.21	843.88	0.74	61.79	67.51
DS Ruby Dam	6	760000.00	5347.91	5342.55	26.36	28826.58	848.92	0.75	62.55	67.91
DS Ruby Dam	6	780000.00	5348.52	5343.22	26.58	29342.87	856.49	0.76	63.21	68.52
DS Ruby Dam	6	800000.00	5349.10	5343.98	26.80	29846.02	863.80	0.76	63.98	69.10
DS Ruby Dam	6	820000.00	5349.64	5344.67	27.05	30308.80	870.47	0.76	64.67	69.64
DS Ruby Dam	6	840000.00	5350.23	5345.36	27.25	30826.56	877.87	0.77	65.36	70.23
DS Ruby Dam	6	860000.00	5350.79	5346.00	27.46	31322.78	884.91	0.77	66.00	70.79
DS Ruby Dam	6	880000.00	5351.36	5346.67	27.65	31825.13	891.98	0.77	66.67	71.36
DS Ruby Dam	6	900000.00	5351.85	5347.30	27.89	32266.54	898.14	0.78	67.30	71.85
DS Ruby Dam	6	920000.00	5352.36	5348.01	28.11	32724.69	904.50	0.78	68.01	72.36
DS Ruby Dam	6	940000.00	5352.89	5348.64	28.31	33205.63	911.12	0.79	68.64	72.89
DS Ruby Dam	6	960000.00	5353.40	5349.24	28.51	33671.27	917.49	0.79	69.24	73.40
DS Ruby Dam	6	980000.00	5353.93	5349.91	28.69	34156.38	924.07	0.79	69.91	73.93
DS Ruby Dam	6	1000000.00	5354.53	5350.51	28.80	34719.54	931.66	0.79	70.51	74.53
DS Ruby Dam	6	1020000.00	5354.91	5351.06	29.08	35070.24	936.35	0.80	71.06	74.91
DS Ruby Dam	6	1040000.00	5355.41	5351.74	29.27	35537.22	942.57	0.80	71.74	75.41
DS Ruby Dam	6	1060000.00	5355.88	5352.27	29.46	35983.20	948.46	0.80	72.27	75.88
DS Ruby Dam	6	1080000.00	5356.34	5352.92	29.65	36426.84	954.29	0.81	72.92	76.34
DS Ruby Dam	6	1100000.00	5356.82	5353.51	29.82	36884.44	960.27	0.81	73.51	76.82
DS Ruby Dam	6	1120000.00	5357.26	5354.11	30.02	37304.81	965.72	0.81	74.11	77.26
DS Ruby Dam	6	1140000.00	5357.76	5354.60	30.16	37794.93	972.05	0.82	74.60	77.76
DS Ruby Dam	6	1160000.00	5358.18	5355.22	30.37	38197.54	977.21	0.82	75.22	78.18
DS Ruby Dam	6	1180000.00	5358.63	5355.81	30.54	38636.82	982.81	0.82	75.81	78.63
DS Ruby Dam	6	1200000.00	5359.12	5356.36	30.67	39128.34	989.04	0.82	76.36	79.12
XS 7										
DS Ruby Dam	5	20000.00	5257.22		6.84	2922.01	520.89	0.51		11.22
DS Ruby Dam	5	40000.00	5260.27	5257.27	8.47	4724.57	652.41	0.55	11.27	14.27
DS Ruby Dam	5	60000.00	5262.15	5259.25	10.05	5969.22	669.36	0.59	13.25	16.15
DS Ruby Dam	5	80000.00	5263.74	5260.74	11.36	7041.77	683.63	0.62	14.74	17.74
DS Ruby Dam	5	100000.00	5265.11	5262.00	12.52	7986.53	695.96	0.64	16.00	19.11
DS Ruby Dam	5	120000.00	5266.34	5263.19	13.56	8851.08	707.05	0.66	17.19	20.34
DS Ruby Dam	5	140000.00	5267.45	5264.32	14.52	9644.85	717.08	0.68	18.32	21.45
DS Ruby Dam	5	160000.00	5268.49	5265.39	15.40	10392.32	726.40	0.70	19.39	22.49
DS Ruby Dam	5	180000.00	5269.45	5266.38	16.23	11093.07	735.03	0.72	20.38	23.45
DS Ruby Dam	5	200000.00	5270.35	5267.34	17.01	11758.54	743.14	0.74	21.34	24.35
DS Ruby Dam	5	220000.00	5271.19	5268.27	17.76	12389.86	750.74	0.76	22.27	25.19
DS Ruby Dam	5	240000.00	5272.00	5269.17	18.46	13000.59	758.03	0.77	23.17	26.00
DS Ruby Dam	5	260000.00	5272.77	5270.06	19.14	13582.10	764.90	0.78	24.06	26.77

HEC-RAS Plan: Ruby River: Ruby River Reach: DS Ruby Dam (Continued)

Reach	River Sta	Q Total	W.S. Elev	Crit W.S.	Vel Total	Flow Area	Top Width	Froude # Chl	Crit Depth	Max Chl Dpth
		(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)		(ft)	(ft)
DS Ruby Dam	5	280000.00	5273.50	5270.92	19.80	14142.49	771.47	0.80	24.92	27.50
DS Ruby Dam	5	300000.00	5274.19	5271.76	20.43	14682.97	777.75	0.81	25.76	28.19
DS Ruby Dam	5	320000.00	5274.85	5272.57	21.05	15198.37	783.69	0.83	26.57	28.85
DS Ruby Dam	5	340000.00	5275.49	5273.38	21.66	15699.96	789.43	0.84	27.38	29.49
DS Ruby Dam	5	360000.00	5276.11	5274.17	22.24	16187.34	794.97	0.85	28.17	30.11
DS Ruby Dam	5	380000.00	5276.70	5274.92	22.81	16657.43	800.27	0.86	28.92	30.70
DS Ruby Dam	5	400000.00	5277.27	5275.67	23.36	17120.80	805.47	0.88	29.67	31.27
DS Ruby Dam	5	420000.00	5277.83	5276.40	23.91	17567.78	810.44	0.89	30.40	31.83
DS Ruby Dam	5	440000.00	5278.37	5277.12	24.43	18012.34	815.37	0.90	31.12	32.37
DS Ruby Dam	5	460000.00	5278.90	5277.82	24.94	18442.77	820.10	0.91	31.82	32.90
DS Ruby Dam	5	480000.00	5279.41	5278.52	25.45	18864.01	824.71	0.92	32.52	33.41
DS Ruby Dam	5	500000.00	5279.91	5279.21	25.94	19273.85	829.17	0.93	33.21	33.91
DS Ruby Dam	5	520000.00	5280.40	5279.86	26.42	19681.78	833.39	0.94	33.85	34.40
DS Ruby Dam	5	540000.00	5280.89	5280.54	26.88	20088.09	837.52	0.95	34.54	34.89
DS Ruby Dam	5	560000.00	5281.36	5281.25	27.33	20487.37	841.57	0.96	35.25	35.36
DS Ruby Dam	5	580000.00	5281.92	5281.92	27.68	20955.07	846.28	0.96	35.92	35.92
DS Ruby Dam	5	600000.00	5282.52	5282.52	27.95	21469.02	851.42	0.96	36.52	36.52
DS Ruby Dam	5	620000.00	5283.12	5283.12	28.21	21981.91	856.53	0.97	37.12	37.12
DS Ruby Dam	5	640000.00	5283.71	5283.71	28.46	22485.24	861.51	0.97	37.71	37.71
DS Ruby Dam	5	660000.00	5284.32	5284.32	28.68	23010.53	866.68	0.97	38.31	38.31
DS Ruby Dam	5	680000.00	5284.91	5284.91	28.90	23530.88	871.77	0.97	38.91	38.91
DS Ruby Dam	5	700000.00	5285.51	5285.51	29.11	24049.13	876.80	0.96	39.51	39.51
DS Ruby Dam	5	720000.00	5286.09	5286.09	29.31	24561.33	881.76	0.96	40.09	40.09
DS Ruby Dam	5	740000.00	5286.66	5286.66	29.52	25069.48	886.64	0.96	40.66	40.66
DS Ruby Dam	5	760000.00	5287.44	5287.44	29.50	25761.27	893.25	0.95	41.44	41.44
DS Ruby Dam	5	780000.00	5287.99	5287.99	29.72	26249.29	897.88	0.96	41.99	41.99
DS Ruby Dam	5	800000.00	5288.54	5288.54	29.91	26744.67	902.56	0.96	42.54	42.54
DS Ruby Dam	5	820000.00	5289.12	5289.12	30.06	27276.74	907.55	0.95	43.12	43.12
DS Ruby Dam	5	840000.00	5289.64	5289.64	30.28	27741.38	911.90	0.96	43.63	43.63
DS Ruby Dam	5	860000.00	5290.17	5290.17	30.47	28226.13	916.40	0.96	44.17	44.17
DS Ruby Dam	5	880000.00	5290.68	5290.68	30.66	28702.03	920.81	0.96	44.68	44.68
DS Ruby Dam	5	900000.00	5291.26	5291.26	30.79	29232.62	925.69	0.95	45.26	45.26
DS Ruby Dam	5	920000.00	5291.81	5291.81	30.93	29741.95	930.36	0.95	45.81	45.81
DS Ruby Dam	5	940000.00	5292.32	5292.32	31.11	30220.05	934.71	0.95	46.32	46.32
DS Ruby Dam	5	960000.00	5292.84	5292.84	31.26	30708.65	939.15	0.95	46.84	46.84
DS Ruby Dam	5	980000.00	5293.33	5293.33	31.44	31173.30	943.34	0.95	47.33	47.33
DS Ruby Dam	5	1000000.00	5293.74	5293.74	31.69	31552.15	946.75	0.96	47.74	47.74
DS Ruby Dam	5	1020000.00	5294.36	5294.36	31.73	32148.31	952.09	0.95	48.36	48.36
DS Ruby Dam	5	1040000.00	5294.86	5294.86	31.88	32617.48	956.27	0.95	48.85	48.85
DS Ruby Dam	5	1060000.00	5295.36	5295.36	32.02	33104.18	960.58	0.95	49.36	49.36
DS Ruby Dam	5	1080000.00	5295.87	5295.87	32.15	33588.84	964.86	0.95	49.87	49.87
DS Ruby Dam	5	1100000.00	5296.35	5296.35	32.30	34054.35	968.96	0.95	50.35	50.35
DS Ruby Dam	5	1120000.00	5296.86	5296.86	32.41	34554.15	973.33	0.95	50.86	50.86
DS Ruby Dam	5	1140000.00	5297.30	5297.30	32.59	34979.84	977.04	0.95	51.30	51.30
DS Ruby Dam	5	1160000.00	5297.82	5297.82	32.69	35489.55	981.46	0.95	51.82	51.82
DS Ruby Dam	5	1180000.00	5298.30	5298.30	32.82	35958.24	985.52	0.95	52.30	52.30
DS Ruby Dam	5	1200000.00	5298.72	5298.72	32.99	36372.83	989.08	0.95	52.72	52.72
DS Ruby Dam	4	20000.00	5220.28		6.07	3293.63	1095.29	0.59		6.28
DS Ruby Dam	4	40000.00	5221.89		7.27	5500.69	1643.31	0.63		7.89
DS Ruby Dam	4	60000.00	5223.06		7.84	7649.94	2040.09	0.65		9.06
DS Ruby Dam	4	80000.00	5224.00		8.23	9721.15	2360.17	0.67		10.00
DS Ruby Dam	4	100000.00	5224.81		8.51	11753.59	2636.75	0.68		10.81
DS Ruby Dam	4	120000.00	5225.53		8.75	13714.08	2878.47	0.69		11.52
DS Ruby Dam	4	140000.00	5226.17		8.96	15630.88	3096.61	0.69		12.17
DS Ruby Dam	4	160000.00	5226.74		9.16	17473.11	3292.68	0.70		12.74
DS Ruby Dam	4	180000.00	5227.28		9.33	19283.89	3474.63	0.71		13.28
DS Ruby Dam	4	200000.00	5227.77		9.50	21045.91	3642.97	0.71		13.77
DS Ruby Dam	4	220000.00	5228.24		9.66	22776.06	3801.02	0.72		14.24
DS Ruby Dam	4	240000.00	5228.67		9.82	24446.48	3947.61	0.72		14.67
DS Ruby Dam	4	260000.00	5229.08		9.96	26098.20	4087.39	0.73		15.08
DS Ruby Dam	4	280000.00	5229.47		10.10	27718.72	4220.04	0.73		15.47
DS Ruby Dam	4	300000.00	5229.84		10.24	29303.92	4345.88	0.73		15.84
DS Ruby Dam	4	320000.00	5230.18		10.39	30787.53	4413.40	0.74		16.18
DS Ruby Dam	4	340000.00	5230.49		10.57	32155.21	4436.58	0.74		16.49
DS Ruby Dam	4	360000.00	5230.79		10.75	33479.98	4458.92	0.75		16.79
DS Ruby Dam	4	380000.00	5231.08		10.93	34780.77	4480.75	0.75		17.08
DS Ruby Dam	4	400000.00	5231.36		11.10	36035.16	4501.70	0.75		17.36
DS Ruby Dam	4	420000.00	5231.63		11.27	37275.52	4522.31	0.76		17.63
DS Ruby Dam	4	440000.00	5231.90		11.44	38470.54	4542.09	0.76		17.89
DS Ruby Dam	4	460000.00	5232.15		11.60	39648.49	4561.50	0.77		18.15
DS Ruby Dam	4	480000.00	5232.41		11.76	40804.63	4580.47	0.77		18.41
DS Ruby Dam	4	500000.00	5232.65		11.92	41943.11	4599.07	0.77		18.65
DS Ruby Dam	4	520000.00	5232.89		12.08	43045.62	4617.02	0.78		18.89

X8

HEC-RAS Plan: Ruby River: Ruby River Reach: DS Ruby Dam (Continued)

Reach	River Sta	Q Total	W.S. Elev	Crit W.S.	Vel Total	Flow Area	Top Width	Froude # Chl	Crit Depth	Max Chl Dpth
		(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)		(ft)	(ft)
DS Ruby Dam	4	540000.00	5233.13		12.24	44113.95	4634.34	0.78		19.12
DS Ruby Dam	4	560000.00	5233.35		12.40	45161.30	4651.26	0.78		19.35
DS Ruby Dam	4	580000.00	5233.57		12.56	46189.67	4667.81	0.79		19.57
DS Ruby Dam	4	600000.00	5233.79		12.71	47189.68	4683.85	0.79		19.78
DS Ruby Dam	4	620000.00	5233.99		12.87	48158.70	4699.34	0.80		19.99
DS Ruby Dam	4	640000.00	5234.20		13.02	49137.82	4714.94	0.80		20.20
DS Ruby Dam	4	660000.00	5234.40		13.18	50083.23	4729.96	0.80		20.40
DS Ruby Dam	4	680000.00	5234.60		13.33	51029.33	4744.93	0.81		20.60
DS Ruby Dam	4	700000.00	5234.79		13.47	51952.86	4759.51	0.81		20.79
DS Ruby Dam	4	720000.00	5234.99		13.62	52876.89	4774.05	0.82		20.99
DS Ruby Dam	4	740000.00	5235.18		13.76	53778.02	4788.18	0.82		21.18
DS Ruby Dam	4	760000.00	5235.36		13.90	54681.80	4802.32	0.82		21.36
DS Ruby Dam	4	780000.00	5235.55		14.04	55574.15	4816.24	0.83		21.55
DS Ruby Dam	4	800000.00	5235.73		14.17	56454.93	4829.93	0.83		21.73
DS Ruby Dam	4	820000.00	5235.92		14.30	57350.04	4843.81	0.83		21.92
DS Ruby Dam	4	840000.00	5236.10		14.43	58223.99	4857.32	0.84		22.10
DS Ruby Dam	4	860000.00	5236.27		14.56	59055.20	4870.14	0.84		22.27
DS Ruby Dam	4	880000.00	5236.44		14.69	59910.05	4883.29	0.84		22.44
DS Ruby Dam	4	900000.00	5236.62	5235.58	14.81	60781.55	4896.66	0.85	21.58	22.62
DS Ruby Dam	4	920000.00	5236.79	5235.71	14.93	61607.50	4909.29	0.85	21.71	22.79
DS Ruby Dam	4	940000.00	5236.97	5235.83	15.05	62464.40	4922.36	0.85	21.83	22.96
DS Ruby Dam	4	960000.00	5237.13	5235.98	15.18	63260.94	4934.49	0.85	21.98	23.13
DS Ruby Dam	4	980000.00	5237.29	5236.16	15.30	64061.85	4946.64	0.86	22.16	23.29
DS Ruby Dam	4	1000000.00	5237.45	5236.33	15.42	64859.89	4958.73	0.86	22.33	23.45
DS Ruby Dam	4	1020000.00	5237.62	5236.49	15.53	65679.30	4971.11	0.86	22.49	23.61
DS Ruby Dam	4	1040000.00	5237.77	5236.69	15.65	66469.11	4983.01	0.87	22.69	23.77
DS Ruby Dam	4	1060000.00	5237.93	5236.86	15.76	67260.81	4994.91	0.87	22.86	23.93
DS Ruby Dam	4	1080000.00	5238.09	5236.99	15.87	68037.30	5006.56	0.87	22.99	24.09
DS Ruby Dam	4	1100000.00	5238.24	5237.15	15.99	68795.98	5017.91	0.87	23.15	24.24
DS Ruby Dam	4	1120000.00	5238.40	5237.30	16.10	69580.95	5029.63	0.88	23.30	24.40
DS Ruby Dam	4	1140000.00	5238.55	5237.45	16.21	70335.75	5040.87	0.88	23.45	24.54
DS Ruby Dam	4	1160000.00	5238.70	5237.57	16.32	71092.23	5052.11	0.88	23.57	24.69
DS Ruby Dam	4	1180000.00	5238.85	5237.75	16.42	71852.87	5063.39	0.88	23.75	24.85
DS Ruby Dam	4	1200000.00	5238.99	5237.90	16.54	72570.59	5074.01	0.89	23.90	24.99
DS Ruby Dam	3	20000.00	5147.96	5146.26	4.28	4669.03	1565.64	0.44	4.26	5.96
DS Ruby Dam	3	40000.00	5149.72	5147.63	5.11	7820.75	2026.30	0.46	5.63	7.72
DS Ruby Dam	3	60000.00	5150.80	5148.62	5.83	10297.75	2636.85	0.48	6.62	8.80
DS Ruby Dam	3	80000.00	5151.65	5149.44	6.26	12776.72	3205.44	0.49	7.44	9.65
DS Ruby Dam	3	100000.00	5152.37	5150.11	6.56	15241.09	3684.71	0.50	8.11	10.37
DS Ruby Dam	3	120000.00	5153.00	5150.73	6.78	17698.95	4107.38	0.51	8.73	11.00
DS Ruby Dam	3	140000.00	5153.56	5151.33	6.96	20117.54	4484.59	0.52	9.33	11.56
DS Ruby Dam	3	160000.00	5154.08	5151.89	7.10	22523.69	4830.71	0.53	9.89	12.08
DS Ruby Dam	3	180000.00	5154.55	5152.41	7.23	24884.30	5147.72	0.53	10.41	12.55
DS Ruby Dam	3	200000.00	5154.99	5152.88	7.35	27224.47	5443.78	0.54	10.88	12.99
DS Ruby Dam	3	220000.00	5155.40	5153.30	7.45	29524.80	5719.90	0.54	11.30	13.40
DS Ruby Dam	3	240000.00	5155.80	5153.70	7.54	31824.85	5983.25	0.55	11.70	13.80
DS Ruby Dam	3	260000.00	5156.17	5154.08	7.63	34079.16	6230.58	0.55	12.07	14.17
DS Ruby Dam	3	280000.00	5156.52	5154.42	7.71	36314.16	6466.45	0.55	12.42	14.52
DS Ruby Dam	3	300000.00	5156.85	5154.75	7.79	38534.09	6692.51	0.56	12.75	14.85
DS Ruby Dam	3	320000.00	5157.18	5155.07	7.86	40732.40	6909.08	0.56	13.07	15.18
DS Ruby Dam	3	340000.00	5157.49	5155.37	7.92	42924.20	7118.46	0.56	13.37	15.49
DS Ruby Dam	3	360000.00	5157.79	5155.65	7.98	45106.33	7320.96	0.58	13.65	15.79
DS Ruby Dam	3	380000.00	5158.08	5155.92	8.04	47261.55	7515.62	0.56	13.92	16.08
DS Ruby Dam	3	400000.00	5158.37	5156.19	8.09	49416.86	7705.36	0.57	14.19	16.37
DS Ruby Dam	3	420000.00	5158.64	5156.44	8.15	51541.14	7887.91	0.57	14.44	16.64
DS Ruby Dam	3	440000.00	5158.91	5156.68	8.20	53667.88	8066.53	0.57	14.68	16.91
DS Ruby Dam	3	460000.00	5159.16	5156.92	8.25	55773.82	8239.60	0.57	14.92	17.16
DS Ruby Dam	3	480000.00	5159.41	5157.14	8.30	57858.77	8407.42	0.57	15.14	17.41
DS Ruby Dam	3	500000.00	5159.66	5157.36	8.34	59935.51	8571.32	0.57	15.36	17.66
DS Ruby Dam	3	520000.00	5159.90	5157.58	8.39	62009.70	8731.95	0.57	15.58	17.90
DS Ruby Dam	3	540000.00	5160.12	5157.79	8.44	63952.95	8803.59	0.57	15.79	18.12
DS Ruby Dam	3	560000.00	5160.33	5158.03	8.51	65771.91	8809.79	0.57	16.03	18.33
DS Ruby Dam	3	580000.00	5160.53	5158.19	8.58	67562.02	8815.88	0.57	16.19	18.53
DS Ruby Dam	3	600000.00	5160.73	5158.40	8.65	69340.44	8821.93	0.57	16.40	18.73
DS Ruby Dam	3	620000.00	5160.93	5158.57	8.72	71102.84	8827.92	0.57	16.57	18.93
DS Ruby Dam	3	640000.00	5161.13	5158.69	8.79	72823.30	8833.77	0.57	16.69	19.13
DS Ruby Dam	3	660000.00	5161.32	5158.89	8.85	74540.58	8839.60	0.58	16.89	19.32
DS Ruby Dam	3	680000.00	5161.51	5158.97	8.92	76211.49	8845.26	0.58	16.97	19.51
DS Ruby Dam	3	700000.00	5161.70	5159.31	8.99	77892.12	8850.96	0.58	17.31	19.70
DS Ruby Dam	3	720000.00	5161.88	5159.57	9.05	79517.60	8856.47	0.58	17.57	19.88
DS Ruby Dam	3	740000.00	5162.07	5159.73	9.12	81148.42	8861.99	0.58	17.73	20.07
DS Ruby Dam	3	760000.00	5162.25	5160.15	9.18	82754.29	8867.43	0.58	18.15	20.25
DS Ruby Dam	3	780000.00	5162.43	5160.31	9.25	84335.14	8872.77	0.58	18.31	20.43

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HEC-RAS Plan: Ruby River: Ruby River Reach: DS Ruby Dam (Continued)

Reach	River Sta	Q Total	W.S. Elev	Crit W.S.	Vel Total	Flow Area	Top Width	Froude # Chl	Crit Depth	Max Chl Dpth
		(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)		(ft)	(ft)
DS Ruby Dam	3	800000.00	5162.60	5160.45	9.31	85890.94	8878.03	0.58	18.45	20.60
DS Ruby Dam	3	820000.00	5162.77	5160.57	9.38	87417.29	8883.19	0.58	18.57	20.77
DS Ruby Dam	3	840000.00	5162.94	5160.68	9.44	88940.20	8888.33	0.58	18.68	20.94
DS Ruby Dam	3	860000.00	5163.12	5160.80	9.51	90477.00	8893.52	0.58	18.79	21.12
DS Ruby Dam	3	880000.00	5163.29	5160.91	9.57	91975.60	8898.57	0.58	18.91	21.29
DS Ruby Dam	3	900000.00	5163.45	5161.02	9.63	93435.93	8903.49	0.58	19.02	21.45
DS Ruby Dam	3	920000.00	5163.62	5161.17	9.69	94905.76	8908.44	0.58	19.17	21.61
DS Ruby Dam	3	940000.00	5163.78	5161.27	9.76	96341.59	8913.28	0.58	19.27	21.78
DS Ruby Dam	3	960000.00	5163.94	5161.37	9.82	97808.69	8918.21	0.58	19.37	21.94
DS Ruby Dam	3	980000.00	5164.10	5161.47	9.87	99254.80	8923.08	0.58	19.47	22.10
DS Ruby Dam	3	1000000.00	5164.26	5161.57	9.93	100684.30	8927.88	0.58	19.57	22.26
DS Ruby Dam	3	1020000.00	5164.42	5161.66	9.99	102079.60	8932.57	0.58	19.66	22.42
DS Ruby Dam	3	1040000.00	5164.58	5161.79	10.05	103488.80	8937.30	0.58	19.79	22.58
DS Ruby Dam	3	1060000.00	5164.73	5161.91	10.11	104872.50	8941.94	0.58	19.91	22.73
DS Ruby Dam	3	1080000.00	5164.89	5162.00	10.16	106257.00	8946.59	0.58	20.00	22.89
DS Ruby Dam	3	1100000.00	5165.04	5162.03	10.22	107633.40	8951.20	0.58	20.03	23.04
DS Ruby Dam	3	1120000.00	5165.19	5162.16	10.28	108984.30	8955.73	0.58	20.16	23.19
DS Ruby Dam	3	1140000.00	5165.34	5162.30	10.33	110344.60	8960.28	0.58	20.29	23.34
DS Ruby Dam	3	1160000.00	5165.49	5162.38	10.39	111675.00	8964.74	0.58	20.38	23.49
DS Ruby Dam	3	1180000.00	5165.64	5162.49	10.44	113010.40	8969.20	0.58	20.49	23.64
DS Ruby Dam	3	1200000.00	5165.79	5162.59	10.49	114368.40	8973.75	0.58	20.59	23.79
DS Ruby Dam	2	20000.00	5107.29		3.81	5246.45	2448.66	0.46		4.29
DS Ruby Dam	2	40000.00	5108.54		4.56	8775.34	3166.85	0.48		5.54
DS Ruby Dam	2	60000.00	5109.44		5.06	11865.56	3682.48	0.50		6.44
DS Ruby Dam	2	80000.00	5110.14	5108.44	5.50	14558.38	4025.05	0.51	5.44	7.14
DS Ruby Dam	2	100000.00	5110.66	5108.95	6.00	16677.84	4118.74	0.52	5.95	7.66
DS Ruby Dam	2	120000.00	5111.14	5109.42	6.43	18659.06	4204.43	0.53	6.42	8.14
DS Ruby Dam	2	140000.00	5111.58	5109.82	6.81	20551.29	4284.68	0.54	6.82	8.58
DS Ruby Dam	2	160000.00	5112.00	5110.16	7.16	22345.10	4359.39	0.54	7.16	9.00
DS Ruby Dam	2	180000.00	5112.39	5110.47	7.48	24079.02	4430.40	0.55	7.47	9.39
DS Ruby Dam	2	200000.00	5112.77	5110.76	7.77	25755.27	4497.99	0.56	7.76	9.77
DS Ruby Dam	2	220000.00	5113.13	5111.05	8.03	27392.27	4563.03	0.56	8.05	10.13
DS Ruby Dam	2	240000.00	5113.47	5111.33	8.29	28955.64	4624.29	0.57	8.33	10.47
DS Ruby Dam	2	260000.00	5113.80	5111.60	8.52	30500.97	4684.05	0.57	8.60	10.80
DS Ruby Dam	2	280000.00	5114.12	5111.86	8.75	32010.57	4741.71	0.58	8.86	11.12
DS Ruby Dam	2	300000.00	5114.43	5112.12	8.96	33480.06	4797.17	0.58	9.12	11.43
DS Ruby Dam	2	320000.00	5114.73	5112.37	9.17	34912.15	4850.61	0.58	9.37	11.73
DS Ruby Dam	2	340000.00	5115.01	5112.62	9.36	36319.40	4902.55	0.59	9.61	12.01
DS Ruby Dam	2	360000.00	5115.30	5112.85	9.55	37705.36	4953.17	0.59	9.85	12.30
DS Ruby Dam	2	380000.00	5115.57	5113.09	9.73	39066.48	5002.39	0.60	10.09	12.57
DS Ruby Dam	2	400000.00	5115.84	5113.32	9.90	40408.98	5050.47	0.60	10.32	12.84
DS Ruby Dam	2	420000.00	5116.10	5113.54	10.06	41734.46	5097.49	0.60	10.54	13.10
DS Ruby Dam	2	440000.00	5116.35	5113.77	10.22	43039.57	5143.37	0.61	10.77	13.35
DS Ruby Dam	2	460000.00	5116.60	5113.98	10.38	44328.51	5188.28	0.61	10.98	13.60
DS Ruby Dam	2	480000.00	5116.85	5114.20	10.53	45603.10	5232.31	0.61	11.20	13.85
DS Ruby Dam	2	500000.00	5117.09	5114.41	10.67	46862.70	5275.47	0.61	11.41	14.09
DS Ruby Dam	2	520000.00	5117.32	5114.62	10.81	48104.08	5317.66	0.62	11.62	14.32
DS Ruby Dam	2	540000.00	5117.55	5114.82	10.95	49337.03	5359.23	0.62	11.82	14.55
DS Ruby Dam	2	560000.00	5117.78	5115.02	11.07	50576.95	5400.71	0.62	12.02	14.78
DS Ruby Dam	2	580000.00	5118.01	5115.22	11.20	51786.57	5440.88	0.62	12.22	15.00
DS Ruby Dam	2	600000.00	5118.22	5115.41	11.32	52981.06	5480.25	0.62	12.41	15.22
DS Ruby Dam	2	620000.00	5118.44	5115.60	11.45	54159.92	5518.84	0.63	12.60	15.44
DS Ruby Dam	2	640000.00	5118.65	5115.80	11.57	55333.48	5556.98	0.63	12.80	15.65
DS Ruby Dam	2	660000.00	5118.86	5115.97	11.68	56490.54	5594.34	0.63	12.97	15.86
DS Ruby Dam	2	680000.00	5119.06	5116.14	11.80	57644.35	5631.34	0.63	13.14	16.06
DS Ruby Dam	2	700000.00	5119.27	5116.33	11.91	58791.93	5667.90	0.64	13.33	16.27
DS Ruby Dam	2	720000.00	5119.47	5116.53	12.01	59933.01	5704.02	0.64	13.53	16.47
DS Ruby Dam	2	740000.00	5119.66	5116.71	12.12	61058.92	5739.44	0.64	13.71	16.66
DS Ruby Dam	2	760000.00	5119.86	5116.89	12.22	62174.88	5774.34	0.64	13.89	16.86
DS Ruby Dam	2	780000.00	5120.05	5117.06	12.33	63283.24	5801.59	0.64	14.06	17.05
DS Ruby Dam	2	800000.00	5120.23	5117.24	12.43	64360.27	5807.62	0.64	14.24	17.23
DS Ruby Dam	2	820000.00	5120.42	5117.40	12.53	65432.73	5813.62	0.65	14.40	17.42
DS Ruby Dam	2	840000.00	5120.60	5117.56	12.64	66480.73	5819.47	0.65	14.56	17.60
DS Ruby Dam	2	860000.00	5120.78	5117.72	12.74	67518.41	5825.26	0.65	14.72	17.78
DS Ruby Dam	2	880000.00	5120.96	5117.91	12.84	68554.27	5831.04	0.65	14.91	17.96
DS Ruby Dam	2	900000.00	5121.13	5118.08	12.93	69594.02	5836.83	0.65	15.08	18.13
DS Ruby Dam	2	920000.00	5121.31	5118.25	13.03	70611.96	5842.50	0.65	15.25	18.31
DS Ruby Dam	2	940000.00	5121.48	5118.42	13.12	71633.76	5848.18	0.65	15.42	18.48
DS Ruby Dam	2	960000.00	5121.65	5118.56	13.22	72605.09	5853.57	0.66	15.55	18.65
DS Ruby Dam	2	980000.00	5121.82	5118.74	13.32	73594.49	5859.07	0.66	15.74	18.82
DS Ruby Dam	2	1000000.00	5121.98	5118.86	13.41	74567.63	5864.46	0.66	15.86	18.98
DS Ruby Dam	2	1020000.00	5122.15	5119.02	13.50	75553.14	5869.92	0.66	16.02	19.15
DS Ruby Dam	2	1040000.00	5122.32	5119.17	13.59	76513.74	5875.24	0.66	16.17	19.31

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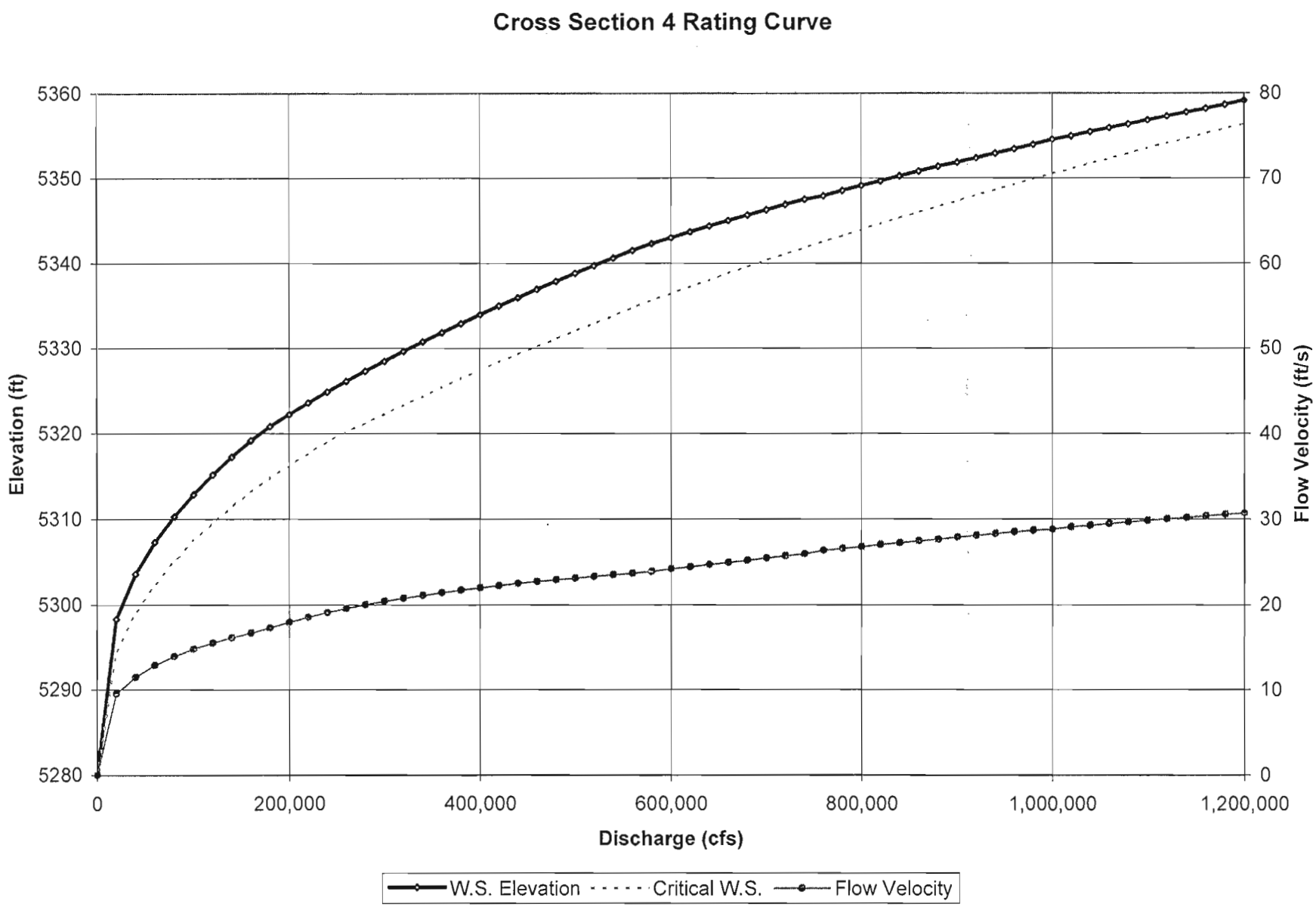
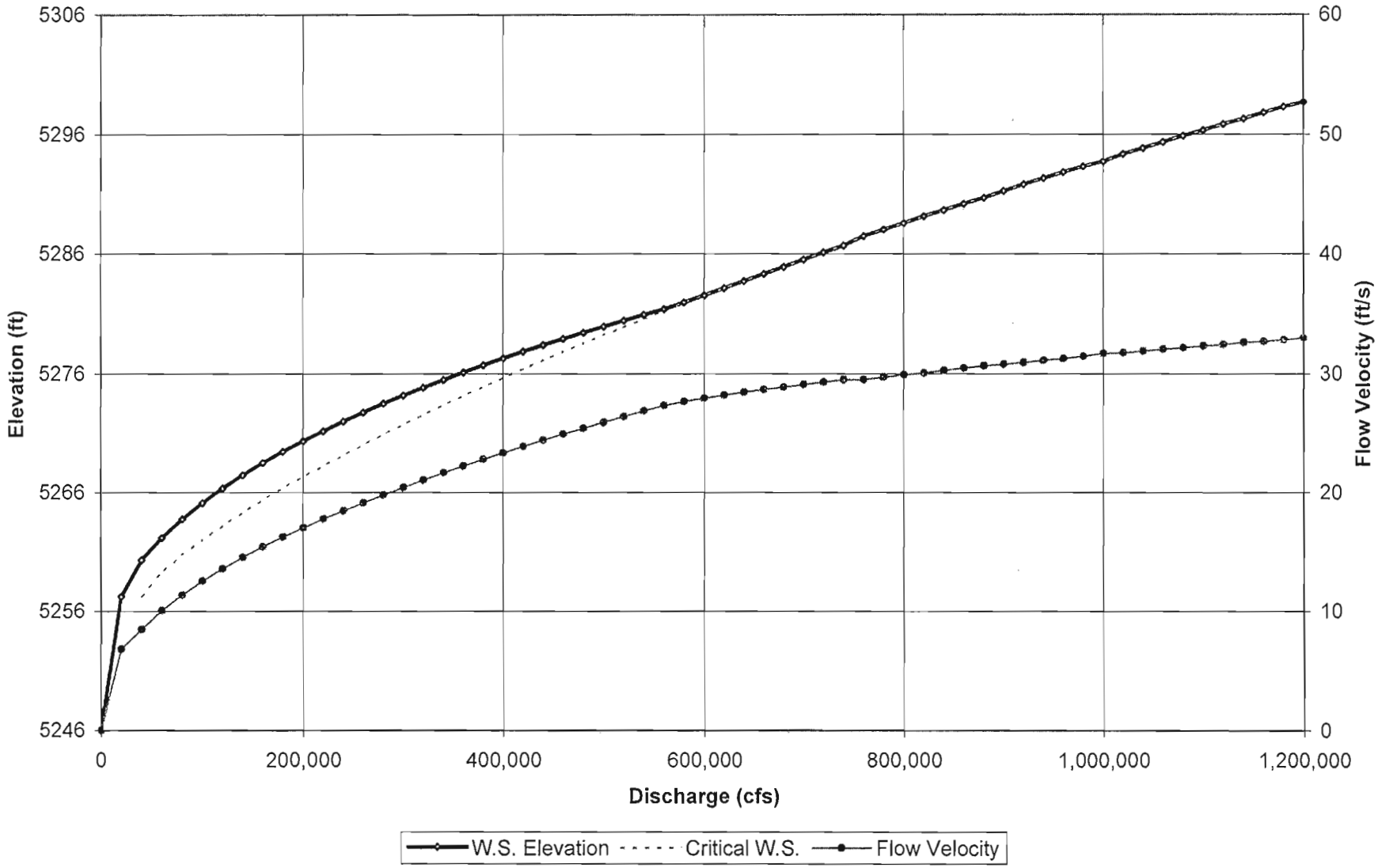
HEC-RAS Plan: Ruby River: Ruby River Reach: DS Ruby Dam (Continued)

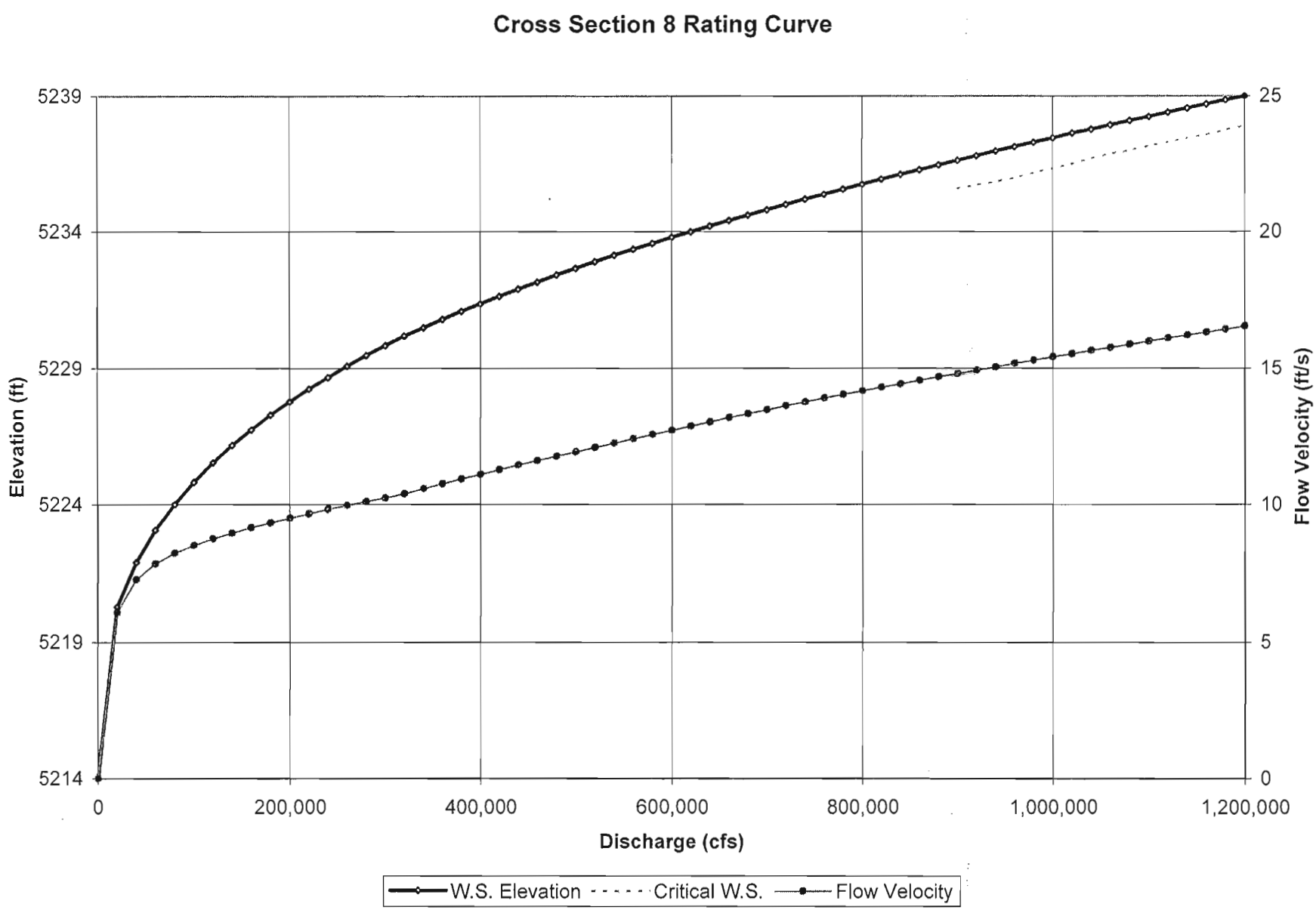
Reach	River Sta	Q Total	W.S. Elev	Crit W.S.	Vel Total	Flow Area	Top Width	Froude # Chl	Crit Depth	Max Chl Dpth
		(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)		(ft)	(ft)
DS Ruby Dam	2	1060000.00	5122.48	5119.37	13.68	77475.22	5880.55	0.66	16.37	19.48
DS Ruby Dam	2	1080000.00	5122.64	5119.52	13.77	78428.94	5885.82	0.66	16.52	19.64
DS Ruby Dam	2	1100000.00	5122.80	5119.74	13.86	79366.25	5890.99	0.66	16.74	19.80
DS Ruby Dam	2	1120000.00	5122.96	5119.92	13.95	80310.15	5896.20	0.67	16.92	19.96
DS Ruby Dam	2	1140000.00	5123.12	5120.11	14.03	81228.95	5901.26	0.67	17.11	20.12
DS Ruby Dam	2	1160000.00	5123.27	5120.25	14.12	82151.41	5906.34	0.67	17.24	20.27
DS Ruby Dam	2	1180000.00	5123.43	5120.40	14.21	83068.90	5911.39	0.67	17.40	20.43
DS Ruby Dam	2	1200000.00	5123.58	5120.53	14.29	83966.95	5916.32	0.67	17.53	20.58
DS Ruby Dam	1	20000.00	5043.67	5042.55	3.09	6475.12	3525.94	0.43	2.55	3.67
DS Ruby Dam	1	40000.00	5044.76	5043.37	3.67	10890.20	4572.66	0.45	3.37	4.76
DS Ruby Dam	1	60000.00	5045.48	5043.96	4.19	14324.11	4933.71	0.46	3.96	5.48
DS Ruby Dam	1	80000.00	5046.06	5044.44	4.64	17245.60	5096.82	0.47	4.44	6.06
DS Ruby Dam	1	100000.00	5046.58	5044.88	5.01	19941.59	5242.83	0.48	4.88	6.58
DS Ruby Dam	1	120000.00	5047.06	5045.22	5.34	22471.92	5376.27	0.49	5.22	7.06
DS Ruby Dam	1	140000.00	5047.50	5045.50	5.63	24864.26	5499.45	0.49	5.50	7.50
DS Ruby Dam	1	160000.00	5047.91	5045.81	5.89	27165.38	5615.39	0.50	5.81	7.91
DS Ruby Dam	1	180000.00	5048.30	5046.08	6.13	29377.46	5724.63	0.50	6.08	8.30
DS Ruby Dam	1	200000.00	5048.67	5046.32	6.35	31509.73	5827.99	0.51	6.32	8.67
DS Ruby Dam	1	220000.00	5049.02	5046.59	6.55	33570.14	5926.15	0.51	6.59	9.02
DS Ruby Dam	1	240000.00	5049.36	5046.84	6.74	35606.16	6021.58	0.52	6.84	9.36
DS Ruby Dam	1	260000.00	5049.69	5047.07	6.92	37573.19	6112.36	0.52	7.07	9.69
DS Ruby Dam	1	280000.00	5050.00	5047.28	7.09	39496.97	6199.86	0.52	7.28	10.00
DS Ruby Dam	1	300000.00	5050.27	5047.49	7.28	41195.27	6221.84	0.53	7.49	10.27
DS Ruby Dam	1	320000.00	5050.54	5047.74	7.47	42862.96	6243.24	0.53	7.74	10.54
DS Ruby Dam	1	340000.00	5050.80	5047.95	7.64	44490.49	6264.06	0.53	7.95	10.80
DS Ruby Dam	1	360000.00	5051.06	5048.15	7.81	46083.55	6284.38	0.54	8.15	11.05
DS Ruby Dam	1	380000.00	5051.30	5048.32	7.98	47644.84	6304.22	0.54	8.32	11.30
DS Ruby Dam	1	400000.00	5051.55	5048.52	8.13	49177.07	6323.63	0.54	8.52	11.55
DS Ruby Dam	1	420000.00	5051.78	5048.72	8.29	50683.05	6342.66	0.55	8.72	11.78
DS Ruby Dam	1	440000.00	5052.02	5048.89	8.44	52159.38	6361.25	0.55	8.89	12.02
DS Ruby Dam	1	460000.00	5052.24	5049.10	8.58	53615.12	6379.53	0.55	9.10	12.24
DS Ruby Dam	1	480000.00	5052.47	5049.26	8.72	55050.04	6397.50	0.55	9.26	12.47
DS Ruby Dam	1	500000.00	5052.69	5049.45	8.86	56460.80	6415.12	0.56	9.45	12.69
DS Ruby Dam	1	520000.00	5052.91	5049.62	8.99	57853.46	6432.46	0.56	9.61	12.91
DS Ruby Dam	1	540000.00	5053.12	5049.78	9.12	59224.68	6449.49	0.56	9.78	13.12
DS Ruby Dam	1	560000.00	5053.32	5049.97	9.25	60552.18	6465.94	0.56	9.97	13.32
DS Ruby Dam	1	580000.00	5053.53	5050.08	9.37	61895.70	6482.54	0.56	10.08	13.53
DS Ruby Dam	1	600000.00	5053.74	5050.23	9.49	63220.46	6498.87	0.57	10.23	13.74
DS Ruby Dam	1	620000.00	5053.94	5050.38	9.61	64532.66	6515.00	0.57	10.38	13.94
DS Ruby Dam	1	640000.00	5054.14	5050.51	9.72	65828.97	6530.90	0.57	10.51	14.14
DS Ruby Dam	1	660000.00	5054.33	5050.68	9.83	67109.25	6546.56	0.57	10.67	14.33
DS Ruby Dam	1	680000.00	5054.53	5050.83	9.94	68376.59	6562.03	0.57	10.83	14.53
DS Ruby Dam	1	700000.00	5054.72	5050.94	10.05	69630.86	6577.31	0.57	10.94	14.72
DS Ruby Dam	1	720000.00	5054.91	5051.08	10.16	70871.95	6592.38	0.58	11.08	14.90
DS Ruby Dam	1	740000.00	5055.09	5051.25	10.26	72102.97	6607.31	0.58	11.25	15.09
DS Ruby Dam	1	760000.00	5055.28	5051.38	10.37	73320.61	6622.03	0.58	11.38	15.28
DS Ruby Dam	1	780000.00	5055.46	5051.54	10.47	74528.00	6636.60	0.58	11.54	15.46
DS Ruby Dam	1	800000.00	5055.64	5051.66	10.56	75725.05	6651.02	0.58	11.66	15.64
DS Ruby Dam	1	820000.00	5055.82	5051.80	10.66	76908.43	6665.23	0.58	11.80	15.82
DS Ruby Dam	1	840000.00	5055.99	5051.94	10.76	78084.55	6679.34	0.59	11.94	15.99
DS Ruby Dam	1	860000.00	5056.17	5052.06	10.85	79253.35	6693.32	0.59	12.06	16.17
DS Ruby Dam	1	880000.00	5056.34	5052.20	10.94	80408.23	6707.11	0.59	12.20	16.34
DS Ruby Dam	1	900000.00	5056.51	5052.31	11.04	81535.94	6720.55	0.59	12.30	16.51
DS Ruby Dam	1	920000.00	5056.68	5052.44	11.13	82682.35	6734.18	0.59	12.44	16.68
DS Ruby Dam	1	940000.00	5056.84	5052.57	11.22	83781.66	6747.23	0.59	12.57	16.84
DS Ruby Dam	1	960000.00	5057.01	5052.70	11.30	84942.52	6760.98	0.59	12.70	17.01
DS Ruby Dam	1	980000.00	5057.18	5052.85	11.39	86056.13	6774.14	0.59	12.85	17.18
DS Ruby Dam	1	1000000.00	5057.34	5052.98	11.47	87161.96	6787.19	0.60	12.98	17.34
DS Ruby Dam	1	1020000.00	5057.50	5053.10	11.56	88256.64	6800.08	0.60	13.10	17.50
DS Ruby Dam	1	1040000.00	5057.66	5053.21	11.64	89346.74	6812.89	0.60	13.21	17.66
DS Ruby Dam	1	1060000.00	5057.82	5053.36	11.72	90432.23	6825.63	0.60	13.36	17.82
DS Ruby Dam	1	1080000.00	5057.98	5053.48	11.80	91506.38	6838.20	0.60	13.48	17.98
DS Ruby Dam	1	1100000.00	5058.13	5053.61	11.88	92572.49	6850.66	0.60	13.61	18.13
DS Ruby Dam	1	1120000.00	5058.29	5053.73	11.96	93637.18	6863.09	0.60	13.73	18.29
DS Ruby Dam	1	1140000.00	5058.44	5053.85	12.04	94697.09	6875.43	0.60	13.85	18.44
DS Ruby Dam	1	1160000.00	5058.60	5053.97	12.11	95752.16	6887.70	0.61	13.97	18.60
DS Ruby Dam	1	1180000.00	5058.75	5054.09	12.19	96799.02	6899.84	0.61	14.09	18.75
DS Ruby Dam	1	1200000.00	5058.90	5054.21	12.26	97840.98	6911.91	0.61	14.20	18.90

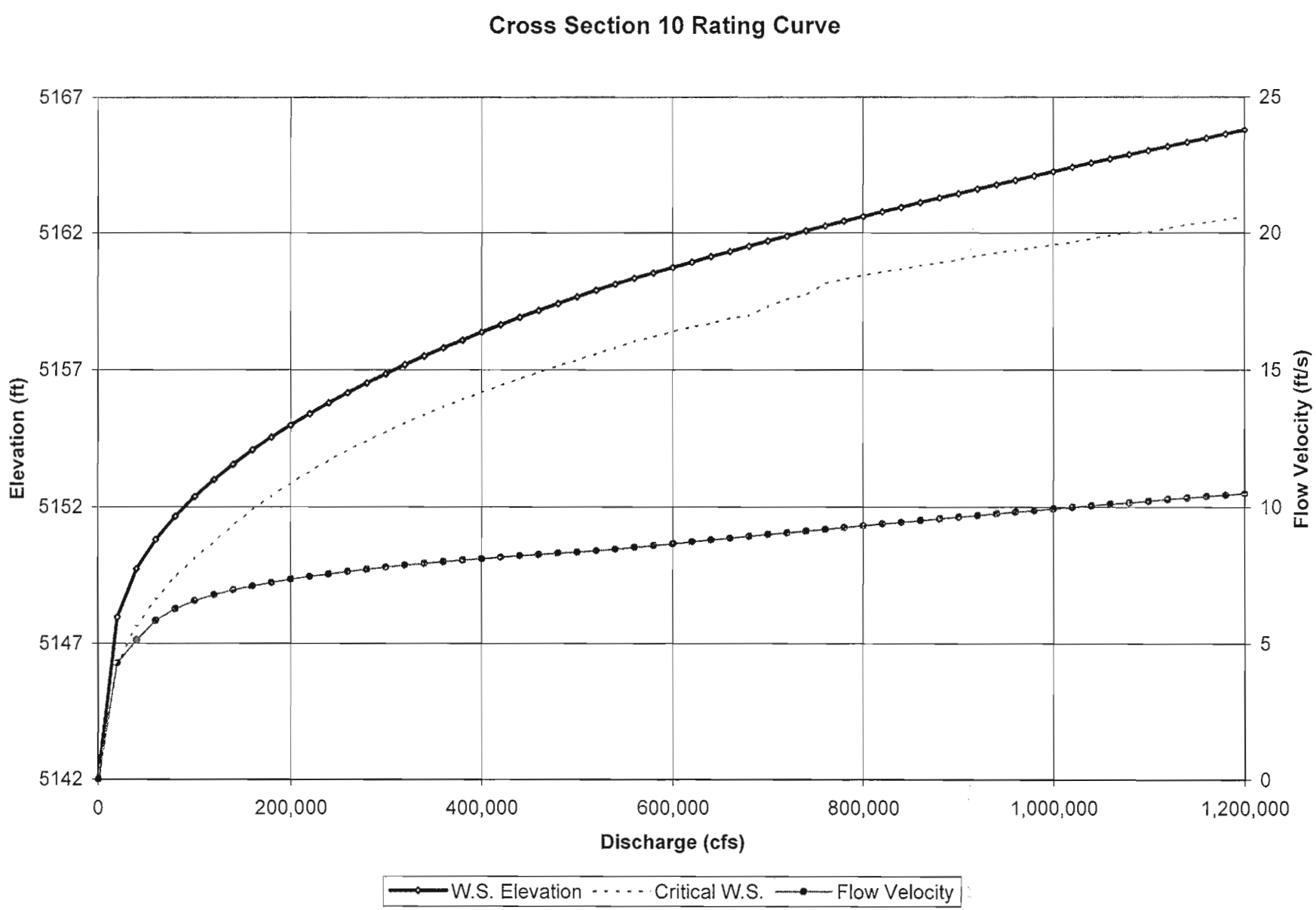
XS 12
Lauvik

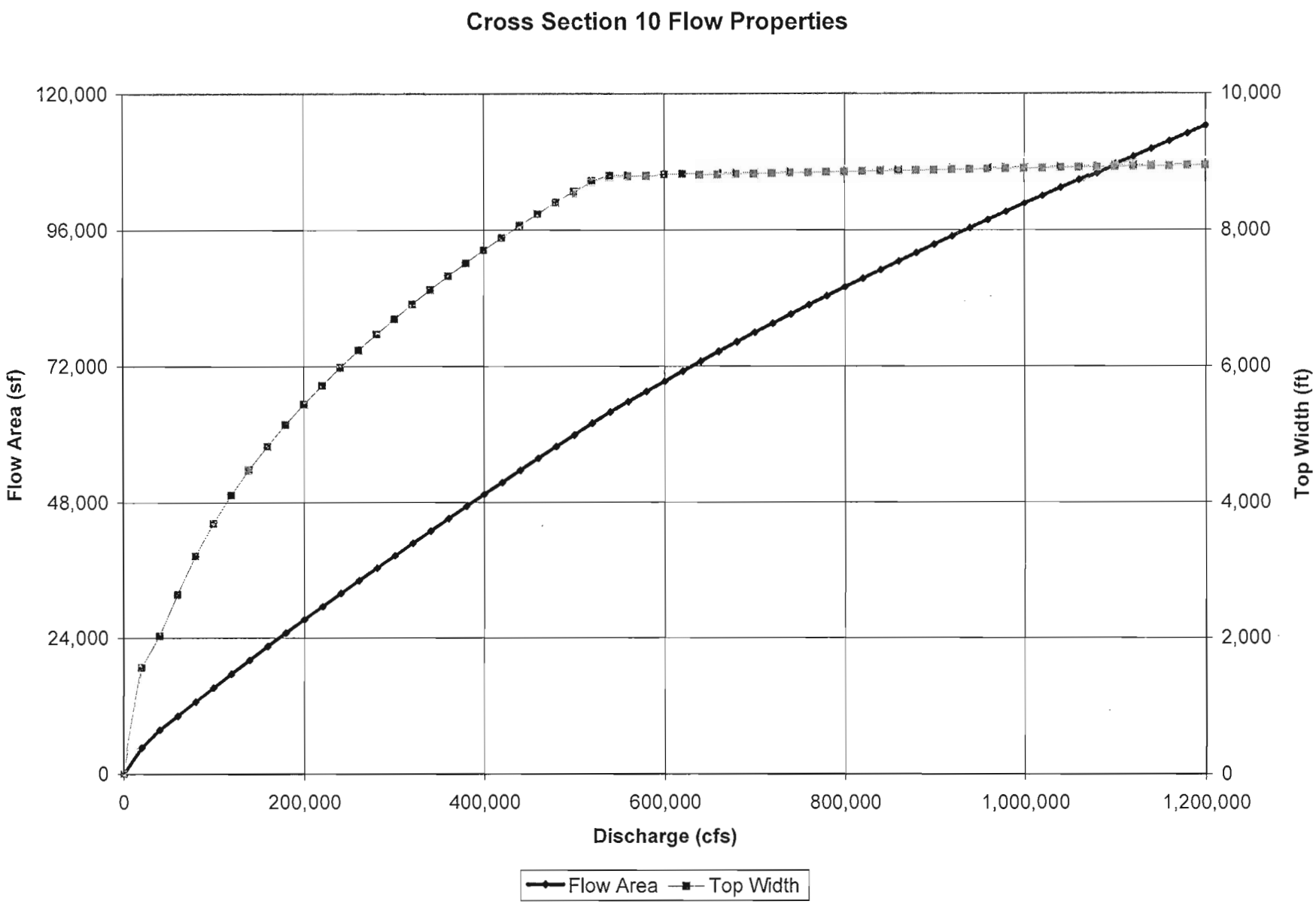

Cross Section 4 Rating Curve
Elevation (ft)
5360
5350
5340
5330
5320
5310
5300
5290
5280
Flow Velocity (ft/s)
80
70
60
50
40
30
20
10
0
0
200,000
400,000
600,000
800,000
1,000,000
1,200,000
Discharge (cfs)
W.S. Elevation
Critical W.S.
Flow Velocity

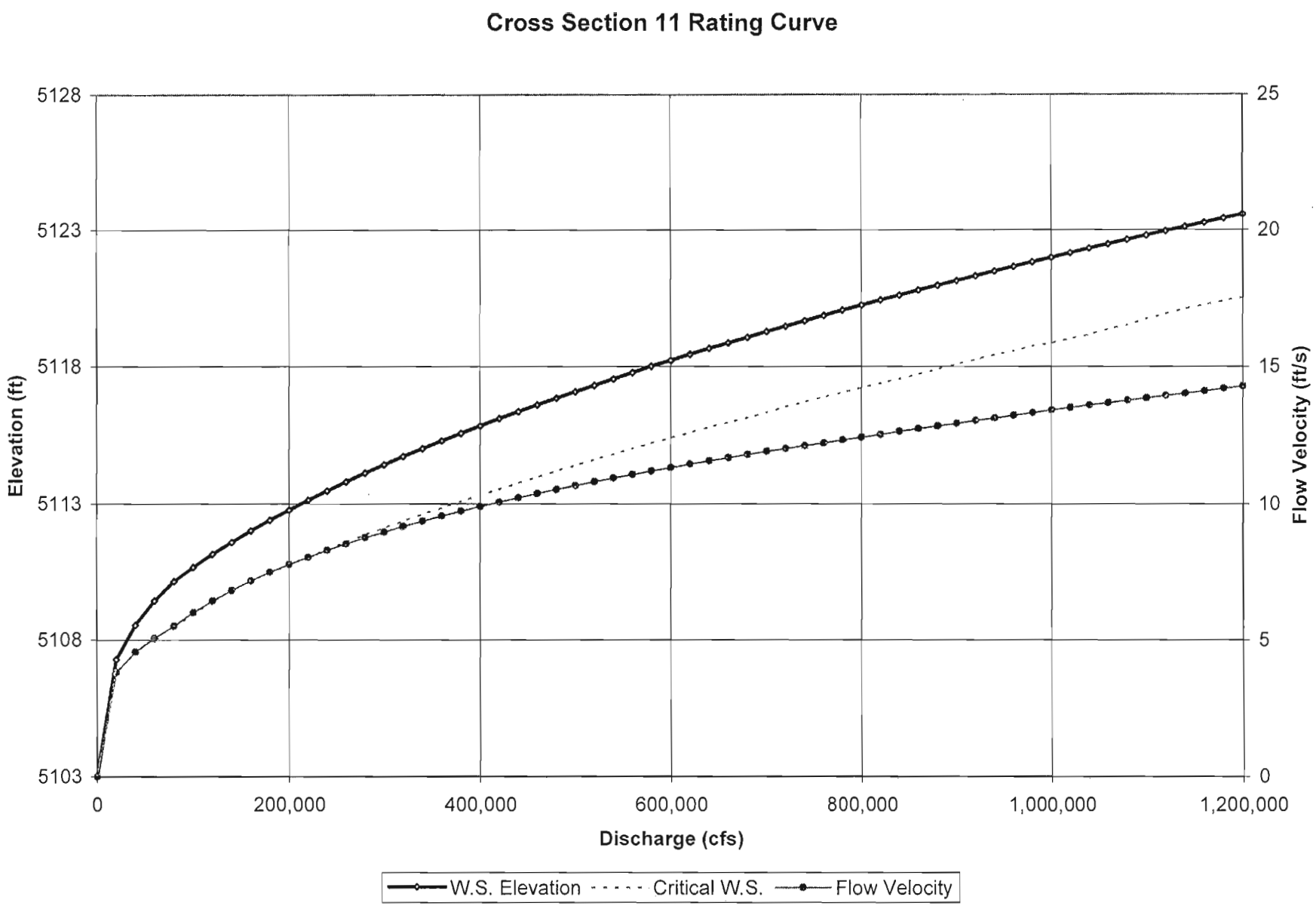
Cross Section 7 Rating Curve

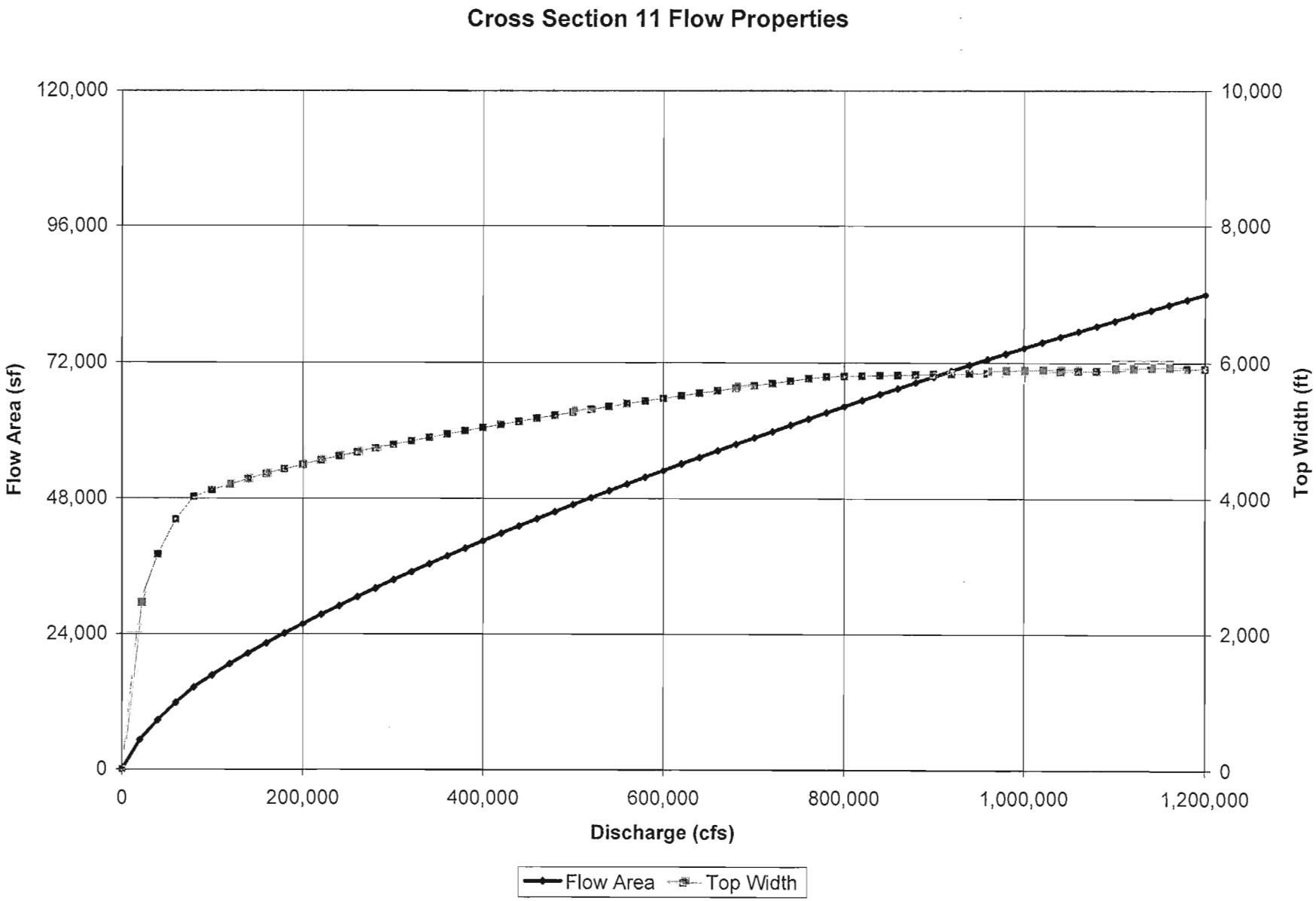


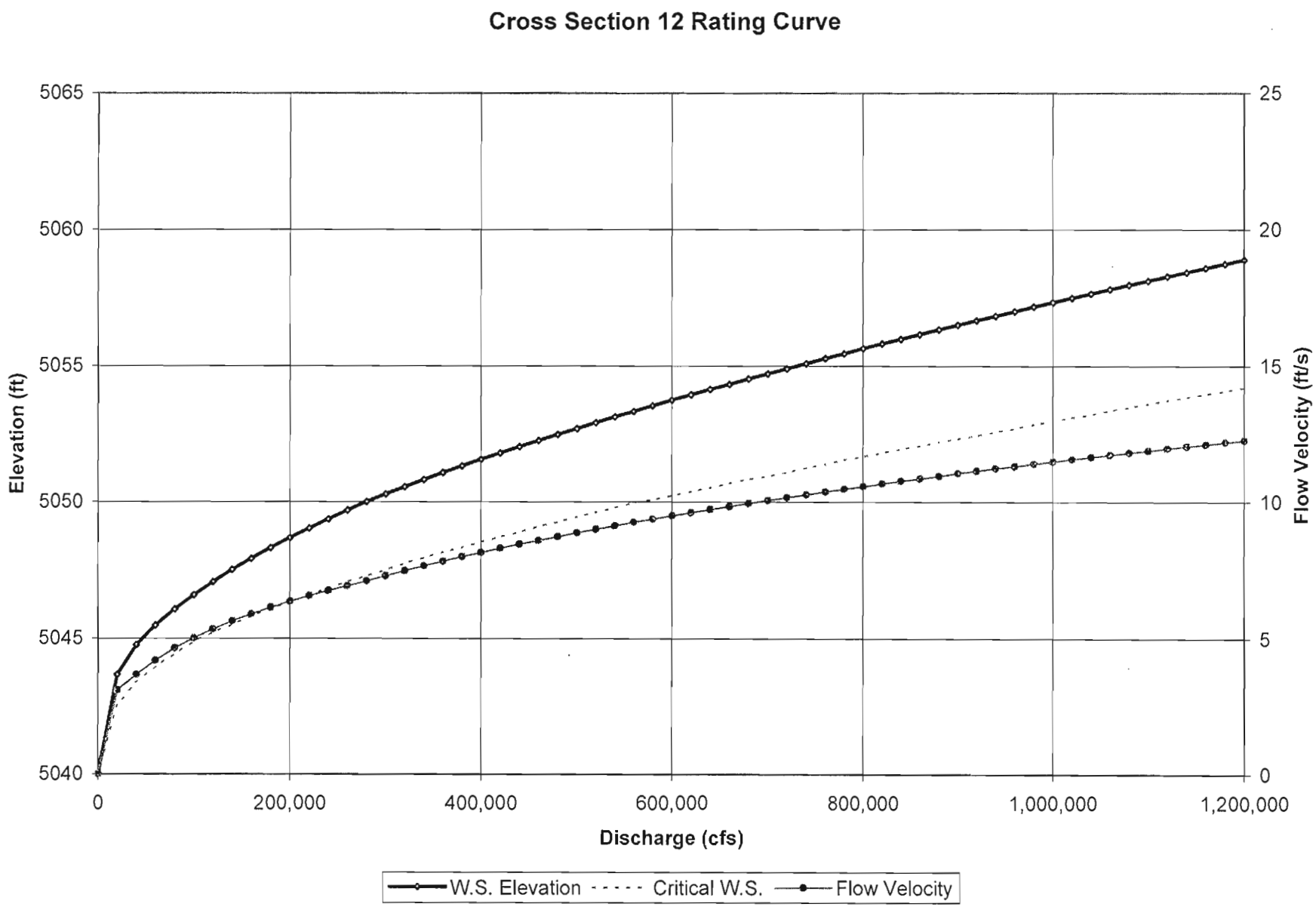

Cross Section 8 Rating Curve
Elevation (ft)
5239
5234
5229
5224
5219
5214
Flow Velocity (ft/s)
25
20
15
10
5
0
0
200,000
400,000
600,000
800,000
1,000,000
1,200,000
Discharge (cfs)
W.S. Elevation
Critical W.S.
Flow Velocity


Cross Section 10 Rating Curve
5167
5162
5157
5152
5147
5142
Elevation (ft)
25
20
15
10
5
0
Flow Velocity (ft/s)
0
200,000
400,000
600,000
800,000
1,000,000
1,200,000
Discharge (cfs)
W.S. Elevation
Critical W.S.
Flow Velocity

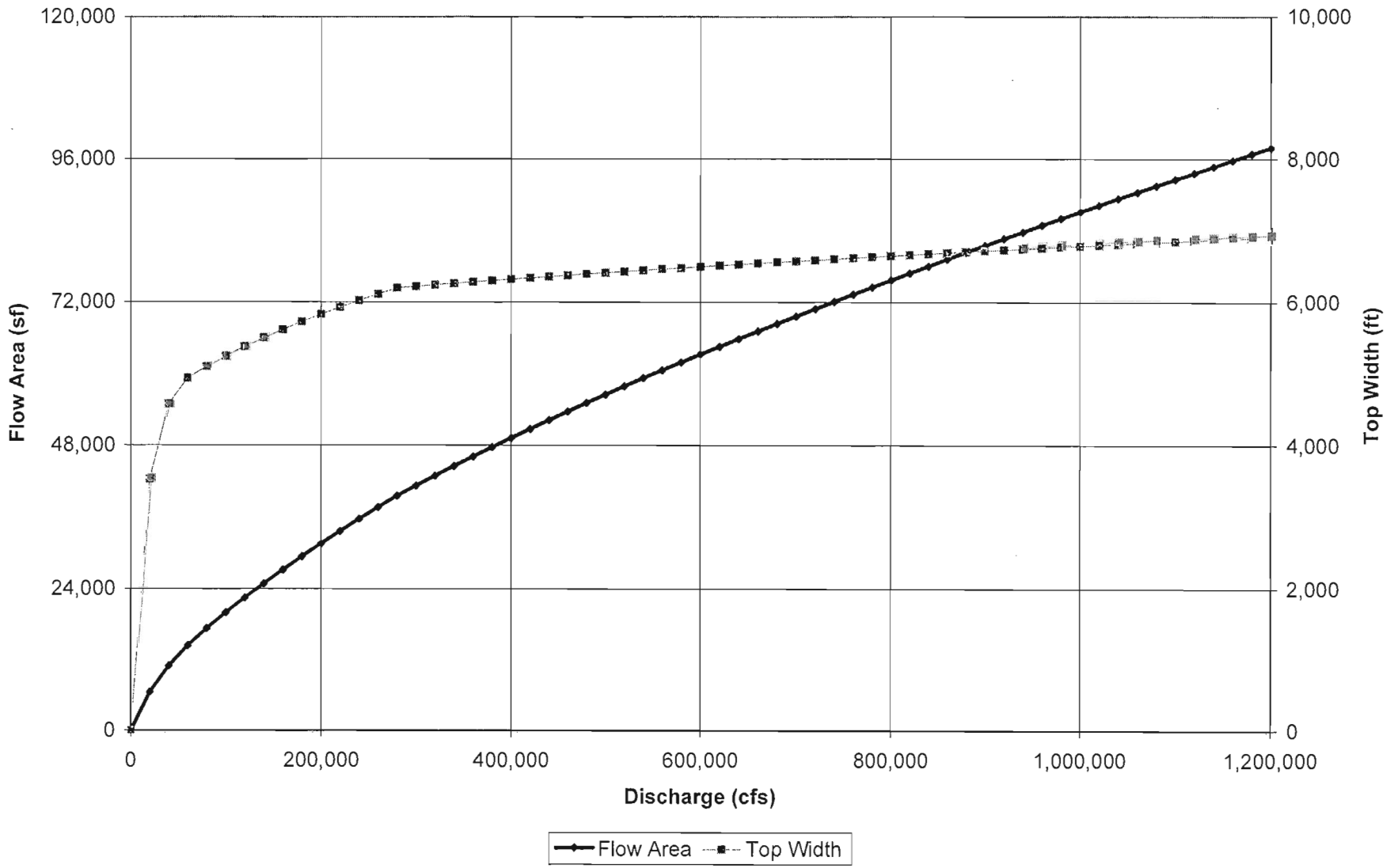

Cross Section 10 Flow Properties
120,000
96,000
72,000
48,000
24,000
0
Flow Area (sf)
10,000
8,000
6,000
4,000
2,000
0
Top Width (ft)
0
200,000
400,000
600,000
800,000
1,000,000
1,200,000
Discharge (cfs)
Flow Area
Top Width


Cross Section 11 Rating Curve
Elevation (ft)
5128
5123
5118
5113
5108
5103
Flow Velocity (ft/s)
25
20
15
10
5
0
0
200,000
400,000
600,000
800,000
1,000,000
1,200,000
Discharge (cfs)
W.S. Elevation
Critical W.S.
Flow Velocity


Cross Section 11 Flow Properties
120,000
96,000
72,000
48,000
24,000
0
Flow Area (sf)
10,000
8,000
6,000
4,000
2,000
0
Top Width (ft)
0
200,000
400,000
600,000
800,000
1,000,000
1,200,000
Discharge (cfs)
Flow Area
Top Width


Cross Section 12 Rating Curve
5065
5060
5055
5050
5045
5040
Elevation (ft)
25
20
15
10
5
0
Flow Velocity (ft/s)
0
200,000
400,000
600,000
800,000
1,000,000
1,200,000
Discharge (cfs)
W.S. Elevation
Critical W.S.
Flow Velocity

Cross Section 12 Flow Properties



Ruby Dam
Incremental Hazard Screening Study

APPENDIX E

HEC-HMS INPUT DATA AND PMF ROUTING WITH NO DAM BREACH

RUN 1 - BASIN: RUBY-PMF
METEOR.: 24-HR PMP
CONTROL: 24-Hour

RUBY BASIN:

LOSS RATE - METHOD: INITIAL / CONSTANT
INITIAL LOSS: 0 IN
CONST. RATE: 0.22 IN/HR
IMPERV.: 10%
AREA = 595 SQ MI

TRANSFORM - METHOD: USER-SPECIFIED UH
HYDROGRAPH: DIMLESS-1-FINAL

BASEFLOW - METHOD: NO BASEFLOW

RUBY RESERVOIR:

STORAGE: METHOD: ELEVATION-STORAGE (RESERVOIR INPUT DATA ON PAGE 2)

D.S. REACHES:

METHOD: MUSKINGUM CUNGE 8 POINT
MANNING n: LT O.B. = 0.06
CHANNEL = 0.05
RT O.B. = 0.06
SAME FOR ALL REACHES

REACH	REACH LENGTH (FT)	SLOPE (FT/FT)
XS4	3326.4	0.00440
XS7	7709	0.00540
XS8	5544	0.00544
XS10	11458	0.00544
XS11	7603	0.00544
XS12	11141	0.00544

100-YR CONCURRENT:

AREA: 54 SQ MI (INC. DRAINAGE AREA BETWEEN XS 12 AND RUBY RESERVOIR OUTLET)
METHOD: CONSTANT FLOW
CONSTANT DISCHARGE: 2270 CFS (PER APPENDIX C)

RUN 1 - (CONT.)

RUBY RESERVOIR:

STORAGE- METHOD: ELEVATION-STORAGE
INITIAL ELEVATION: 5396.7 FT

OUTLET- METHOD: NO OUTLET

SPILLWAY- METHOD: BROAD-CRESTED
CREST ELEV: 5396.7 FT
CREST WIDTH: 100 FT
DIS. COEFF.: 3.3 (PER ORIGINAL PMF MODEL)

OVERFLOW- METHOD: LEVEL OVERFLOW
CREST ELEV.: 5415 FT (OPTION P1-100-96.7 TOP OF DAM)
CREST WIDTH: 750 FT (TOP OF DAM LENGTH - SPILLWAY LENGTH)
DIS. COEFF.: 2.6 (PER HEC-HMS USERS MANUAL)

DAM BREAK- METHOD: NO DAM BREAK

RUN 2 - BASIN: RUBY - PMF BREACH
METEOR: 24-HR PMP
CONTROL: 24-Hour

RUBY BASIN: SAME AS RUN 1

RUBY RESERVOIR:
STORAGE- METHOD: ELEVATION-STORAGE
INITIAL ELEVATION: 5396.7 FT
OUTLET: METHOD: NO OUTLET
SPILLWAY: METHOD: BROADCRESTED
CREST ELEV: 5396.7 FT
CREST WIDTH: 100 FT
DISCH. COEFF: 3.3 (PER ORIGINAL PMF MODEL)
OVERFLOW: METHOD: LEVEL OVERFLOW
CREST ELEV: 5415 FT (OPTION P1-100-96.7 TOP OF DAM)
CREST WIDTH: 750 FT (DAM LENGTH - SPILLWAY LENGTH)
DISCH. COEFF: 2.6 (PER HEC-HMS USERS MANUAL)
DAM BREAK: METHOD: OVERTOP FAILURE
BREACH BOT ELEV: 5299 FT
BREACH BOT WIDTH: 285 FT
SIDE SLOPE: 1:1
BREACH TOP ELEV: 5415 FT
DEVELOP. TIME: 0.5 HRS
TRIGGER ELEV: 5422.2 FT (PER TRIAL + ERROR TO GET DAM TO BREACH AS CLOSE TO HYDROGRAPH PEAK AS POSSIBLE)

D.S. REACHES: SAME AS RUN 1

100-YR CONCURRENT: SAME AS RUN 1

RUN 3 - BASIN: RUBY - PMFLOWDISCHARGE
METEOR.: 24-HR PMP
CONTROL: 24-Hour

RUBY BASIN: SAME AS RUN 1

RUBY RESERVOIR: SAME AS RUN 2, EXCEPT:
DAM BREAK:
BREACH BOT WIDTH: 75 FT
SIDE SLOPE ½:1
DEVELOP TIME: 1.0 HRS
TRIGGER ELEV: 5422.2 FT

D.S. REACHES: SAME AS RUN 1

100-YR CONCURRENT: SAME AS RUN 1

HMS * Summary of Results

Project : Ruby Run Name : Run 1

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1459 Control Specs : 24-Hour

Hydrologic Element	Discharge Peak (cfs)	Stage Peak (ft)	Time of Peak	e (ac ft)	Drainage Area (sq mi)
Ruby Basin	83727		26 Feb 05 1000	229761	595.000
Ruby Reservoir	81941		26 Feb 05 1200	208307	595.000
XS 4	81908	5311.1	26 Feb 05 1200	208139	595.000
XS 7	81835	5264.1	26 Feb 05 1200	207739	595.000
XS 8	81818	5225.0	26 Feb 05 1300	207202	595.000
100 yr Concurrent	2270.0		24 Feb 05 2400	13507	54.000
XS 10 - Ald Restho	84040	5151.9	26 Feb 05 1300	219714	649.000
XS 11 - Alder	83933	5110.1	26 Feb 05 1300	218905	649.000
XS 12 - Laurin	83886	5045.8	26 Feb 05 1400	217553	649.000

HMS * Summary of Results for Ruby Basin

Project : Ruby Run Name : Run 1

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1459 Control Specs : 24-Hour

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
24 Feb 05	2400				0	0	0
25 Feb 05	0100	0.01	0.01	0.00	0	0	0
25 Feb 05	0200	0.03	0.03	0.00	3	0	3
25 Feb 05	0300	0.13	0.11	0.01	12	0	12
25 Feb 05	0400	0.26	0.20	0.06	55	0	55
25 Feb 05	0500	0.26	0.20	0.06	142	0	142
25 Feb 05	0600	0.38	0.20	0.18	333	0	333
25 Feb 05	0700	0.38	0.20	0.18	653	0	653
25 Feb 05	0800	0.38	0.20	0.18	1114	0	1114
25 Feb 05	0900	0.38	0.20	0.18	1727	0	1727
25 Feb 05	1000	0.43	0.20	0.24	2540	0	2540
25 Feb 05	1100	0.43	0.20	0.24	3589	0	3589
25 Feb 05	1200	0.46	0.20	0.26	4890	0	4890
25 Feb 05	1300	0.47	0.20	0.28	6471	0	6471
25 Feb 05	1400	0.51	0.20	0.31	8329	0	8329
25 Feb 05	1500	0.60	0.20	0.40	10532	0	10532
25 Feb 05	1600	0.74	0.20	0.54	13151	0	13151
25 Feb 05	1700	1.97	0.20	1.77	16811	0	16811
25 Feb 05	1800	0.51	0.20	0.31	20997	0	20997
25 Feb 05	1900	0.51	0.20	0.31	25480	0	25480
25 Feb 05	2000	0.47	0.20	0.28	30188	0	30188
25 Feb 05	2100	0.47	0.20	0.28	35235	0	35235
25 Feb 05	2200	0.46	0.20	0.26	40621	0	40621
25 Feb 05	2300	0.46	0.20	0.26	46212	0	46212
25 Feb 05	2400	0.43	0.20	0.24	51812	0	51812
26 Feb 05	0100	0.43	0.20	0.24	57016	0	57016
26 Feb 05	0200	0.43	0.20	0.24	62272	0	62272
26 Feb 05	0300	0.43	0.20	0.24	67115	0	67115
26 Feb 05	0400	0.38	0.20	0.18	71386	0	71386
26 Feb 05	0500	0.38	0.20	0.18	74997	0	74997
26 Feb 05	0600	0.26	0.20	0.06	78178	0	78178
26 Feb 05	0700	0.26	0.20	0.06	80817	0	80817
26 Feb 05	0800	0.26	0.20	0.06	82288	0	82288
26 Feb 05	0900	0.26	0.20	0.06	83233	0	83233
26 Feb 05	1000	0.26	0.20	0.06	83727	0	83727
26 Feb 05	1100	0.26	0.20	0.06	83215	0	83215
26 Feb 05	1200	0.26	0.20	0.06	82222	0	82222
26 Feb 05	1300	0.26	0.20	0.06	80943	0	80943
26 Feb 05	1400	0.26	0.20	0.06	79047	0	79047
26 Feb 05	1500	0.26	0.20	0.06	76877	0	76877
26 Feb 05	1600	0.13	0.11	0.01	74534	0	74534

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
26 Feb 05	1700	0.13	0.11	0.01	72178	0	72178
26 Feb 05	1800	0.13	0.11	0.01	69588	0	69588
26 Feb 05	1900	0.13	0.11	0.01	66877	0	66877
26 Feb 05	2000	0.13	0.11	0.01	64156	0	64156
26 Feb 05	2100	0.13	0.11	0.01	61478	0	61478
26 Feb 05	2200	0.13	0.11	0.01	58810	0	58810
26 Feb 05	2300	0.13	0.11	0.01	56143	0	56143
26 Feb 05	2400	0.13	0.11	0.01	53546	0	53546
27 Feb 05	0100	0.13	0.11	0.01	51043	0	51043
27 Feb 05	0200	0.13	0.11	0.01	48687	0	48687
27 Feb 05	0300	0.03	0.03	0.00	46438	0	46438
27 Feb 05	0400	0.03	0.03	0.00	44253	0	44253
27 Feb 05	0500	0.03	0.03	0.00	42121	0	42121
27 Feb 05	0600	0.03	0.03	0.00	40102	0	40102
27 Feb 05	0700	0.03	0.03	0.00	38205	0	38205
27 Feb 05	0800	0.03	0.03	0.00	36393	0	36393
27 Feb 05	0900	0.03	0.03	0.00	34646	0	34646
27 Feb 05	1000	0.03	0.03	0.00	33003	0	33003
27 Feb 05	1100	0.03	0.03	0.00	31456	0	31456
27 Feb 05	1200	0.03	0.03	0.00	29996	0	29996
27 Feb 05	1300	0.03	0.03	0.00	28616	0	28616
27 Feb 05	1400	0.01	0.01	0.00	27318	0	27318
27 Feb 05	1500	0.01	0.01	0.00	26088	0	26088
27 Feb 05	1600	0.01	0.01	0.00	24918	0	24918
27 Feb 05	1700	0.01	0.01	0.00	23806	0	23806
27 Feb 05	1800	0.01	0.01	0.00	22759	0	22759
27 Feb 05	1900	0.01	0.01	0.00	21768	0	21768
27 Feb 05	2000	0.01	0.01	0.00	20825	0	20825
27 Feb 05	2100	0.01	0.01	0.00	19934	0	19934
27 Feb 05	2200	0.01	0.01	0.00	19097	0	19097
27 Feb 05	2300	0.01	0.01	0.00	18308	0	18308
27 Feb 05	2400	0.01	0.01	0.00	17574	0	17574

HMS * Summary of Results for Ruby Reservoir

Project : Ruby Run Name : Run 1

Start of Run	: 25Feb05 0000	Basin Model	: Ruby-PMF
End of Run	: 28Feb05 0000	Met. Model	: 24 HR, PMP
Execution Time	: 31May06 1459	Control Specs	: 24-Hour

Computed Results

Peak Inflow	: 83727 (cfs)	Date/Time of Peak Inflow	: 26 Feb 05 1000
Peak Outflow	: 81941 (cfs)	Date/Time of Peak Outflow	: 26 Feb 05 1200
Total Inflow	: 7.24 (in)	Peak Storage	: 76671(ac-ft)
Total Outflow	: 6.56 (in)	Peak Elevation	: 5422.4(ft)

HMS * Summary of Results for Ruby Reservoir

Project : Ruby Run Name : Run 1

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1459 Control Specs : 24-Hour

Date	Time	Reservoir Storage (ac-ft)	Reservoir Elevation (ft)	Inflow (cfs)	Outflow (cfs)
24 Feb 05	2400	41516	5396.7	0	0
25 Feb 05	0100	41516	5396.7	0	0
25 Feb 05	0200	41516	5396.7	3	0
25 Feb 05	0300	41517	5396.7	12	0
25 Feb 05	0400	41519	5396.7	55	0
25 Feb 05	0500	41527	5396.7	142	0
25 Feb 05	0600	41547	5396.7	333	2
25 Feb 05	0700	41587	5396.8	653	6
25 Feb 05	0800	41660	5396.8	1114	16
25 Feb 05	0900	41775	5396.9	1727	38
25 Feb 05	1000	41946	5397.1	2540	82
25 Feb 05	1100	42189	5397.3	3589	160
25 Feb 05	1200	42521	5397.6	4890	292
25 Feb 05	1300	42958	5398.0	6471	502
25 Feb 05	1400	43515	5398.5	8329	819
25 Feb 05	1500	44207	5399.2	10532	1280
25 Feb 05	1600	45053	5399.9	13151	1928
25 Feb 05	1700	46097	5400.8	16811	2772
25 Feb 05	1800	47383	5401.9	20997	3935
25 Feb 05	1900	48914	5403.2	25480	5488
25 Feb 05	2000	50678	5404.7	30188	7479
25 Feb 05	2100	52667	5406.3	35235	9809
25 Feb 05	2200	54876	5408.0	40621	12594
25 Feb 05	2300	57287	5409.9	46212	15887
25 Feb 05	2400	59898	5411.6	51812	18952
26 Feb 05	0100	62672	5413.5	57016	22751
26 Feb 05	0200	65532	5415.4	62272	27321
26 Feb 05	0300	68224	5417.2	67115	36920
26 Feb 05	0400	70470	5418.6	71386	47229
26 Feb 05	0500	72239	5419.7	74997	56346
26 Feb 05	0600	73602	5420.5	78178	63840
26 Feb 05	0700	74648	5421.2	80817	69841
26 Feb 05	0800	75427	5421.6	82288	74418
26 Feb 05	0900	75979	5422.0	83233	77743
26 Feb 05	1000	76358	5422.2	83727	80034
26 Feb 05	1100	76585	5422.3	83215	81415
26 Feb 05	1200	76671	5422.4	82222	81941
26 Feb 05	1300	76648	5422.4	80943	81796
26 Feb 05	1400	76529	5422.3	79047	81071
26 Feb 05	1500	76323	5422.2	76877	79823

Date	Time	Reservoir Storage (ac-ft)	Reservoir Elevation (ft)	Inflow (cfs)	Outflow (cfs)
26 Feb 05	1600	76051	5422.0	74534	78181
26 Feb 05	1700	75732	5421.8	72178	76249
26 Feb 05	1800	75377	5421.6	69588	74119
26 Feb 05	1900	74986	5421.4	66877	71808
26 Feb 05	2000	74566	5421.1	64156	69369
26 Feb 05	2100	74129	5420.9	61478	66846
26 Feb 05	2200	73681	5420.6	58810	64286
26 Feb 05	2300	73224	5420.3	56143	61727
26 Feb 05	2400	72760	5420.0	53546	59184
27 Feb 05	0100	72296	5419.7	51043	56651
27 Feb 05	0200	71836	5419.5	48687	54201
27 Feb 05	0300	71384	5419.2	46438	51851
27 Feb 05	0400	70940	5418.9	44253	49587
27 Feb 05	0500	70502	5418.6	42121	47388
27 Feb 05	0600	70071	5418.4	40102	45282
27 Feb 05	0700	69647	5418.1	38205	43277
27 Feb 05	0800	69232	5417.8	36393	41353
27 Feb 05	0900	68826	5417.6	34646	39518
27 Feb 05	1000	68427	5417.3	33003	37781
27 Feb 05	1100	68036	5417.1	31456	36141
27 Feb 05	1200	67653	5416.8	29996	34581
27 Feb 05	1300	67278	5416.6	28616	33113
27 Feb 05	1400	66909	5416.3	27318	31742
27 Feb 05	1500	66546	5416.1	26088	30463
27 Feb 05	1600	66185	5415.9	24918	29265
27 Feb 05	1700	65826	5415.6	23806	28152
27 Feb 05	1800	65465	5415.4	22759	27144
27 Feb 05	1900	65098	5415.1	21768	26262
27 Feb 05	2000	64715	5414.9	20825	25609
27 Feb 05	2100	64307	5414.6	19934	25033
27 Feb 05	2200	63876	5414.3	19097	24428
27 Feb 05	2300	63428	5414.0	18308	23806
27 Feb 05	2400	62970	5413.7	17574	23165

HMS * Summary of Results for XS 4

Project : Ruby Run Name : Run 1

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1459 Control Specs : 24-Hour

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
24 Feb 05	2400	0	0	5280.00
25 Feb 05	0100	0	0	5280.00
25 Feb 05	0200	0	0	5280.00
25 Feb 05	0300	0	0	5280.00
25 Feb 05	0400	0	0	5280.00
25 Feb 05	0500	0	0	5280.00
25 Feb 05	0600	2	1	5280.00
25 Feb 05	0700	6	5	5280.00
25 Feb 05	0800	16	15	5280.01
25 Feb 05	0900	38	36	5280.03
25 Feb 05	1000	82	77	5280.07
25 Feb 05	1100	160	152	5280.14
25 Feb 05	1200	292	279	5280.26
25 Feb 05	1300	502	481	5280.44
25 Feb 05	1400	819	787	5280.72
25 Feb 05	1500	1280	1233	5281.13
25 Feb 05	1600	1928	1863	5281.71
25 Feb 05	1700	2772	2687	5282.46
25 Feb 05	1800	3935	3819	5283.50
25 Feb 05	1900	5488	5333	5284.89
25 Feb 05	2000	7479	7280	5286.68
25 Feb 05	2100	9809	9588	5288.79
25 Feb 05	2200	12594	12346	5291.32
25 Feb 05	2300	15887	15611	5294.32
25 Feb 05	2400	18952	18708	5297.15
26 Feb 05	0100	22751	22462	5299.01
26 Feb 05	0200	27321	27000	5300.25
26 Feb 05	0300	36920	36269	5302.77
26 Feb 05	0400	47229	46569	5305.07
26 Feb 05	0500	56346	55784	5306.87
26 Feb 05	0600	63840	63390	5308.23
26 Feb 05	0700	69841	69488	5309.19
26 Feb 05	0800	74418	74154	5309.93
26 Feb 05	0900	77743	77556	5310.46
26 Feb 05	1000	80034	79904	5310.83
26 Feb 05	1100	81415	81334	5311.03
26 Feb 05	1200	81941	81908	5311.11
26 Feb 05	1300	81796	81802	5311.09
26 Feb 05	1400	81071	81109	5311.00
26 Feb 05	1500	79823	79892	5310.83
26 Feb 05	1600	78181	78272	5310.58
26 Feb 05	1700	76249	76357	5310.27

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
26 Feb 05	1800	74119	74239	5309.94
26 Feb 05	1900	71808	71940	5309.58
26 Feb 05	2000	69369	69510	5309.19
26 Feb 05	2100	66846	66992	5308.79
26 Feb 05	2200	64286	64437	5308.39
26 Feb 05	2300	61727	61879	5307.99
26 Feb 05	2400	59184	59337	5307.56
27 Feb 05	0100	56651	56805	5307.07
27 Feb 05	0200	54201	54351	5306.59
27 Feb 05	0300	51851	51997	5306.13
27 Feb 05	0400	49587	49729	5305.69
27 Feb 05	0500	47388	47528	5305.26
27 Feb 05	0600	45282	45418	5304.85
27 Feb 05	0700	43277	43407	5304.45
27 Feb 05	0800	41353	41480	5304.08
27 Feb 05	0900	39518	39640	5303.69
27 Feb 05	1000	37781	37898	5303.22
27 Feb 05	1100	36141	36252	5302.77
27 Feb 05	1200	34581	34688	5302.34
27 Feb 05	1300	33113	33215	5301.94
27 Feb 05	1400	31742	31838	5301.57
27 Feb 05	1500	30463	30554	5301.22
27 Feb 05	1600	29265	29351	5300.89
27 Feb 05	1700	28152	28233	5300.58
27 Feb 05	1800	27144	27218	5300.31
27 Feb 05	1900	26262	26327	5300.06
27 Feb 05	2000	25609	25658	5299.88
27 Feb 05	2100	25033	25075	5299.72
27 Feb 05	2200	24428	24474	5299.56
27 Feb 05	2300	23806	23853	5299.39
27 Feb 05	2400	23165	23214	5299.22

HMS * Summary of Results for XS 7

Project : Ruby Run Name : Run 1

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1459 Control Specs : 24-Hour

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
24 Feb 05	2400	0	0	5246.00
25 Feb 05	0100	0	0	5246.00
25 Feb 05	0200	0	0	5246.00
25 Feb 05	0300	0	0	5246.00
25 Feb 05	0400	0	0	5246.00
25 Feb 05	0500	0	0	5246.00
25 Feb 05	0600	1	1	5246.00
25 Feb 05	0700	5	4	5246.00
25 Feb 05	0800	15	12	5246.01
25 Feb 05	0900	36	30	5246.02
25 Feb 05	1000	77	66	5246.04
25 Feb 05	1100	152	133	5246.07
25 Feb 05	1200	279	247	5246.13
25 Feb 05	1300	481	432	5246.24
25 Feb 05	1400	787	714	5246.39
25 Feb 05	1500	1233	1129	5246.62
25 Feb 05	1600	1863	1718	5246.94
25 Feb 05	1700	2687	2500	5247.36
25 Feb 05	1800	3819	3565	5247.95
25 Feb 05	1900	5333	4998	5248.73
25 Feb 05	2000	7280	6853	5249.74
25 Feb 05	2100	9588	9087	5250.96
25 Feb 05	2200	12346	11752	5252.41
25 Feb 05	2300	15611	14912	5254.13
25 Feb 05	2400	18708	18048	5255.85
26 Feb 05	0100	22462	21665	5257.18
26 Feb 05	0200	27000	26041	5257.88
26 Feb 05	0300	36269	34343	5259.22
26 Feb 05	0400	46569	44965	5260.63
26 Feb 05	0500	55784	54441	5261.60
26 Feb 05	0600	63390	62333	5262.37
26 Feb 05	0700	69488	68667	5262.93
26 Feb 05	0800	74154	73540	5263.36
26 Feb 05	0900	77556	77116	5263.67
26 Feb 05	1000	79904	79603	5263.90
26 Feb 05	1100	81334	81153	5264.02
26 Feb 05	1200	81908	81835	5264.08
26 Feb 05	1300	81802	81815	5264.07
26 Feb 05	1400	81109	81197	5264.02
26 Feb 05	1500	79892	80047	5263.93
26 Feb 05	1600	78272	78480	5263.80
26 Feb 05	1700	76357	76604	5263.63

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
26 Feb 05	1800	74239	74516	5263.44
26 Feb 05	1900	71940	72243	5263.24
26 Feb 05	2000	69510	69834	5263.03
26 Feb 05	2100	66992	67333	5262.81
26 Feb 05	2200	64437	64787	5262.58
26 Feb 05	2300	61879	62234	5262.36
26 Feb 05	2400	59337	59695	5262.13
27 Feb 05	0100	56805	57168	5261.87
27 Feb 05	0200	54351	54708	5261.62
27 Feb 05	0300	51997	52345	5261.38
27 Feb 05	0400	49729	50069	5261.15
27 Feb 05	0500	47528	47863	5260.93
27 Feb 05	0600	45418	45744	5260.71
27 Feb 05	0700	43407	43723	5260.51
27 Feb 05	0800	41480	41787	5260.31
27 Feb 05	0900	39640	39939	5260.12
27 Feb 05	1000	37898	38250	5259.85
27 Feb 05	1100	36252	36588	5259.58
27 Feb 05	1200	34688	35011	5259.33
27 Feb 05	1300	33215	33522	5259.09
27 Feb 05	1400	31838	32128	5258.86
27 Feb 05	1500	30554	30825	5258.65
27 Feb 05	1600	29351	29604	5258.46
27 Feb 05	1700	28233	28469	5258.27
27 Feb 05	1800	27218	27432	5258.11
27 Feb 05	1900	26327	26515	5257.96
27 Feb 05	2000	25658	25799	5257.84
27 Feb 05	2100	25075	25199	5257.75
27 Feb 05	2200	24474	24601	5257.65
27 Feb 05	2300	23853	23985	5257.55
27 Feb 05	2400	23214	23349	5257.45

HMS * Summary of Results for XS 8

Project : Ruby Run Name : Run 1

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1459 Control Specs : 24-Hour

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
24 Feb 05	2400	0	0	5214.00
25 Feb 05	0100	0	0	5214.00
25 Feb 05	0200	0	0	5214.00
25 Feb 05	0300	0	0	5214.00
25 Feb 05	0400	0	0	5214.00
25 Feb 05	0500	0	0	5214.00
25 Feb 05	0600	1	1	5214.00
25 Feb 05	0700	4	3	5214.00
25 Feb 05	0800	12	9	5214.00
25 Feb 05	0900	30	24	5214.01
25 Feb 05	1000	66	54	5214.02
25 Feb 05	1100	133	111	5214.04
25 Feb 05	1200	247	210	5214.07
25 Feb 05	1300	432	373	5214.13
25 Feb 05	1400	714	627	5214.21
25 Feb 05	1500	1129	1004	5214.34
25 Feb 05	1600	1718	1545	5214.52
25 Feb 05	1700	2500	2275	5214.77
25 Feb 05	1800	3565	3264	5215.11
25 Feb 05	1900	4998	4598	5215.56
25 Feb 05	2000	6853	6343	5216.15
25 Feb 05	2100	9087	8480	5216.87
25 Feb 05	2200	11752	11041	5217.74
25 Feb 05	2300	14912	13990	5218.74
25 Feb 05	2400	18048	17137	5219.81
26 Feb 05	0100	21665	20643	5220.84
26 Feb 05	0200	26041	24872	5221.25
26 Feb 05	0300	34343	32281	5221.97
26 Feb 05	0400	44965	42513	5222.87
26 Feb 05	0500	54441	52369	5223.48
26 Feb 05	0600	62333	60670	5223.99
26 Feb 05	0700	68667	67368	5224.31
26 Feb 05	0800	73540	72559	5224.56
26 Feb 05	0900	77116	76405	5224.75
26 Feb 05	1000	79603	79113	5224.88
26 Feb 05	1100	81153	80849	5224.95
26 Feb 05	1200	81835	81702	5224.99
26 Feb 05	1300	81815	81818	5224.99
26 Feb 05	1400	81197	81317	5224.97
26 Feb 05	1500	80047	80272	5224.93
26 Feb 05	1600	78480	78788	5224.86
26 Feb 05	1700	76604	76976	5224.77

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
26 Feb 05	1800	74516	74932	5224.68
26 Feb 05	1900	72243	72700	5224.57
26 Feb 05	2000	69834	70323	5224.46
26 Feb 05	2100	67333	67844	5224.34
26 Feb 05	2200	64787	65313	5224.21
26 Feb 05	2300	62234	62767	5224.09
26 Feb 05	2400	59695	60230	5223.97
27 Feb 05	0100	57168	57706	5223.82
27 Feb 05	0200	54708	55238	5223.66
27 Feb 05	0300	52345	52860	5223.51
27 Feb 05	0400	50069	50571	5223.37
27 Feb 05	0500	47863	48355	5223.23
27 Feb 05	0600	45744	46222	5223.10
27 Feb 05	0700	43723	44184	5222.97
27 Feb 05	0800	41787	42234	5222.85
27 Feb 05	0900	39939	40371	5222.73
27 Feb 05	1000	38250	38649	5222.58
27 Feb 05	1100	36588	36986	5222.42
27 Feb 05	1200	35011	35393	5222.27
27 Feb 05	1300	33522	33887	5222.12
27 Feb 05	1400	32128	32473	5221.98
27 Feb 05	1500	30825	31151	5221.86
27 Feb 05	1600	29604	29913	5221.74
27 Feb 05	1700	28469	28760	5221.63
27 Feb 05	1800	27432	27700	5221.52
27 Feb 05	1900	26515	26755	5221.43
27 Feb 05	2000	25799	25988	5221.36
27 Feb 05	2100	25199	25358	5221.30
27 Feb 05	2200	24601	24761	5221.24
27 Feb 05	2300	23985	24151	5221.18
27 Feb 05	2400	23349	23522	5221.12

HMS * Summary of Results for 100 yr
Concurrent

Project : Ruby Run Name : Run 1

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF
End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP
Execution Time : 31May06 1459 Control Specs : 24-Hour

Date	Time	Discharge (cfs)
24 Feb 05	2400	2270.0
25 Feb 05	0100	2270.0
25 Feb 05	0200	2270.0
25 Feb 05	0300	2270.0
25 Feb 05	0400	2270.0
25 Feb 05	0500	2270.0
25 Feb 05	0600	2270.0
25 Feb 05	0700	2270.0
25 Feb 05	0800	2270.0
25 Feb 05	0900	2270.0
25 Feb 05	1000	2270.0
25 Feb 05	1100	2270.0
25 Feb 05	1200	2270.0
25 Feb 05	1300	2270.0
25 Feb 05	1400	2270.0
25 Feb 05	1500	2270.0
25 Feb 05	1600	2270.0
25 Feb 05	1700	2270.0
25 Feb 05	1800	2270.0
25 Feb 05	1900	2270.0
25 Feb 05	2000	2270.0
25 Feb 05	2100	2270.0
25 Feb 05	2200	2270.0
25 Feb 05	2300	2270.0
25 Feb 05	2400	2270.0
26 Feb 05	0100	2270.0
26 Feb 05	0200	2270.0
26 Feb 05	0300	2270.0
26 Feb 05	0400	2270.0
26 Feb 05	0500	2270.0
26 Feb 05	0600	2270.0
26 Feb 05	0700	2270.0
26 Feb 05	0800	2270.0
26 Feb 05	0900	2270.0
26 Feb 05	1000	2270.0
26 Feb 05	1100	2270.0
26 Feb 05	1200	2270.0
26 Feb 05	1300	2270.0
26 Feb 05	1400	2270.0
26 Feb 05	1500	2270.0
26 Feb 05	1600	2270.0

Date	Time	Discharge (cfs)
26 Feb 05	1700	2270.0
26 Feb 05	1800	2270.0
26 Feb 05	1900	2270.0
26 Feb 05	2000	2270.0
26 Feb 05	2100	2270.0
26 Feb 05	2200	2270.0
26 Feb 05	2300	2270.0
26 Feb 05	2400	2270.0
27 Feb 05	0100	2270.0
27 Feb 05	0200	2270.0
27 Feb 05	0300	2270.0
27 Feb 05	0400	2270.0
27 Feb 05	0500	2270.0
27 Feb 05	0600	2270.0
27 Feb 05	0700	2270.0
27 Feb 05	0800	2270.0
27 Feb 05	0900	2270.0
27 Feb 05	1000	2270.0
27 Feb 05	1100	2270.0
27 Feb 05	1200	2270.0
27 Feb 05	1300	2270.0
27 Feb 05	1400	2270.0
27 Feb 05	1500	2270.0
27 Feb 05	1600	2270.0
27 Feb 05	1700	2270.0
27 Feb 05	1800	2270.0
27 Feb 05	1900	2270.0
27 Feb 05	2000	2270.0
27 Feb 05	2100	2270.0
27 Feb 05	2200	2270.0
27 Feb 05	2300	2270.0
27 Feb 05	2400	2270.0

HMS * Summary of Results for XS 10 - Ald Resthome

Project : Ruby Run Name : Run 1

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1459 Control Specs : 24-Hour

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
24 Feb 05	2400	2270	2270	5142.64
25 Feb 05	0100	2270	2270	5142.64
25 Feb 05	0200	2270	2270	5142.64
25 Feb 05	0300	2270	2270	5142.64
25 Feb 05	0400	2270	2270	5142.64
25 Feb 05	0500	2270	2270	5142.64
25 Feb 05	0600	2271	2270	5142.64
25 Feb 05	0700	2273	2272	5142.64
25 Feb 05	0800	2279	2276	5142.64
25 Feb 05	0900	2294	2286	5142.64
25 Feb 05	1000	2324	2307	5142.65
25 Feb 05	1100	2381	2349	5142.66
25 Feb 05	1200	2480	2425	5142.68
25 Feb 05	1300	2643	2553	5142.72
25 Feb 05	1400	2897	2758	5142.77
25 Feb 05	1500	3274	3068	5142.86
25 Feb 05	1600	3815	3522	5142.99
25 Feb 05	1700	4545	4153	5143.16
25 Feb 05	1800	5534	5008	5143.40
25 Feb 05	1900	6868	6167	5143.73
25 Feb 05	2000	8613	7707	5144.16
25 Feb 05	2100	10750	9653	5144.71
25 Feb 05	2200	13311	12012	5145.37
25 Feb 05	2300	16260	14780	5146.15
25 Feb 05	2400	19407	17843	5147.00
26 Feb 05	0100	22913	21186	5147.71
26 Feb 05	0200	27142	25077	5148.03
26 Feb 05	0300	34551	31015	5148.52
26 Feb 05	0400	44783	40202	5149.28
26 Feb 05	0500	54639	50771	5150.02
26 Feb 05	0600	62940	59568	5150.63
26 Feb 05	0700	69638	66876	5151.03
26 Feb 05	0800	74829	72674	5151.34
26 Feb 05	0900	78675	77074	5151.57
26 Feb 05	1000	81383	80255	5151.74
26 Feb 05	1100	83119	82395	5151.82
26 Feb 05	1200	83972	83616	5151.87
26 Feb 05	1300	84088	84040	5151.89
26 Feb 05	1400	83587	83796	5151.88
26 Feb 05	1500	82542	82978	5151.85
26 Feb 05	1600	81058	81677	5151.80

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
26 Feb 05	1700	79246	80001	5151.73
26 Feb 05	1800	77202	78053	5151.63
26 Feb 05	1900	74970	75899	5151.51
26 Feb 05	2000	72593	73580	5151.39
26 Feb 05	2100	70114	71142	5151.26
26 Feb 05	2200	67583	68629	5151.12
26 Feb 05	2300	65037	66086	5150.99
26 Feb 05	2400	62500	63541	5150.85
27 Feb 05	0100	59976	61006	5150.71
27 Feb 05	0200	57508	58508	5150.56
27 Feb 05	0300	55130	56086	5150.39
27 Feb 05	0400	52841	53753	5150.23
27 Feb 05	0500	50625	51498	5150.07
27 Feb 05	0600	48492	49323	5149.92
27 Feb 05	0700	46454	47237	5149.77
27 Feb 05	0800	44504	45351	5149.64
27 Feb 05	0900	42641	43458	5149.51
27 Feb 05	1000	40919	41682	5149.39
27 Feb 05	1100	39256	40001	5149.27
27 Feb 05	1200	37663	38384	5149.14
27 Feb 05	1300	36157	36845	5149.01
27 Feb 05	1400	34743	35396	5148.89
27 Feb 05	1500	33421	34038	5148.78
27 Feb 05	1600	32183	32766	5148.67
27 Feb 05	1700	31030	31578	5148.57
27 Feb 05	1800	29970	30478	5148.48
27 Feb 05	1900	29025	29482	5148.40
27 Feb 05	2000	28258	28630	5148.33
27 Feb 05	2100	27628	27934	5148.27
27 Feb 05	2200	27031	27321	5148.22
27 Feb 05	2300	26421	26718	5148.17
27 Feb 05	2400	25792	26098	5148.12

HMS * Summary of Results for XS 11 - Alder

Project : Ruby Run Name : Run 1

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1459 Control Specs : 24-Hour

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
24 Feb 05	2400	2270	2270	5103.48
25 Feb 05	0100	2270	2270	5103.48
25 Feb 05	0200	2270	2270	5103.48
25 Feb 05	0300	2270	2270	5103.48
25 Feb 05	0400	2270	2270	5103.48
25 Feb 05	0500	2270	2270	5103.48
25 Feb 05	0600	2270	2270	5103.48
25 Feb 05	0700	2272	2271	5103.48
25 Feb 05	0800	2276	2274	5103.48
25 Feb 05	0900	2286	2281	5103.48
25 Feb 05	1000	2307	2297	5103.48
25 Feb 05	1100	2349	2330	5103.49
25 Feb 05	1200	2425	2391	5103.50
25 Feb 05	1300	2553	2496	5103.52
25 Feb 05	1400	2758	2667	5103.56
25 Feb 05	1500	3068	2931	5103.61
25 Feb 05	1600	3522	3322	5103.70
25 Feb 05	1700	4153	3877	5103.81
25 Feb 05	1800	5008	4638	5103.97
25 Feb 05	1900	6167	5671	5104.19
25 Feb 05	2000	7707	7055	5104.48
25 Feb 05	2100	9653	8839	5104.85
25 Feb 05	2200	12012	11037	5105.31
25 Feb 05	2300	14780	13649	5105.86
25 Feb 05	2400	17843	16604	5106.48
26 Feb 05	0100	21186	19845	5107.16
26 Feb 05	0200	25077	23529	5107.41
26 Feb 05	0300	31015	28687	5107.73
26 Feb 05	0400	40202	36816	5108.23
26 Feb 05	0500	50771	47107	5108.75
26 Feb 05	0600	59568	56656	5109.18
26 Feb 05	0700	66876	64533	5109.49
26 Feb 05	0800	72674	70937	5109.72
26 Feb 05	0900	77074	75929	5109.90
26 Feb 05	1000	80255	79438	5110.02
26 Feb 05	1100	82395	81852	5110.09
26 Feb 05	1200	83616	83306	5110.13
26 Feb 05	1300	84040	83933	5110.15
26 Feb 05	1400	83796	83856	5110.14
26 Feb 05	1500	82978	83184	5110.13
26 Feb 05	1600	81677	82006	5110.09

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
26 Feb 05	1700	80001	80428	5110.05
26 Feb 05	1800	78053	78554	5109.99
26 Feb 05	1900	75899	76457	5109.91
26 Feb 05	2000	73580	74187	5109.83
26 Feb 05	2100	71142	71787	5109.75
26 Feb 05	2200	68629	69419	5109.66
26 Feb 05	2300	66086	66893	5109.57
26 Feb 05	2400	63541	64356	5109.48
27 Feb 05	0100	61006	61826	5109.39
27 Feb 05	0200	58508	59325	5109.30
27 Feb 05	0300	56086	56886	5109.19
27 Feb 05	0400	53753	54532	5109.08
27 Feb 05	0500	51498	52259	5108.98
27 Feb 05	0600	49323	50065	5108.88
27 Feb 05	0700	47237	47956	5108.79
27 Feb 05	0800	45351	46008	5108.70
27 Feb 05	0900	43458	44124	5108.62
27 Feb 05	1000	41682	42314	5108.53
27 Feb 05	1100	40001	40605	5108.46
27 Feb 05	1200	38384	38971	5108.37
27 Feb 05	1300	36845	37409	5108.27
27 Feb 05	1400	35396	35933	5108.18
27 Feb 05	1500	34038	34546	5108.09
27 Feb 05	1600	32766	33246	5108.01
27 Feb 05	1700	31578	32031	5107.94
27 Feb 05	1800	30478	30901	5107.87
27 Feb 05	1900	29482	29868	5107.80
27 Feb 05	2000	28630	28963	5107.75
27 Feb 05	2100	27934	28208	5107.70
27 Feb 05	2200	27321	27563	5107.66
27 Feb 05	2300	26718	26956	5107.62
27 Feb 05	2400	26098	26343	5107.58

HMS * Summary of Results for XS 12 -
Laurin

Project : Ruby Run Name : Run 1

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF
End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP
Execution Time : 31May06 1459 Control Specs : 24-Hour

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
24 Feb 05	2400	2270	2270	5040.39
25 Feb 05	0100	2270	2270	5040.39
25 Feb 05	0200	2270	2270	5040.39
25 Feb 05	0300	2270	2270	5040.39
25 Feb 05	0400	2270	2270	5040.39
25 Feb 05	0500	2270	2270	5040.39
25 Feb 05	0600	2270	2270	5040.39
25 Feb 05	0700	2271	2271	5040.39
25 Feb 05	0800	2274	2272	5040.39
25 Feb 05	0900	2281	2276	5040.39
25 Feb 05	1000	2297	2286	5040.39
25 Feb 05	1100	2330	2306	5040.40
25 Feb 05	1200	2391	2347	5040.40
25 Feb 05	1300	2496	2419	5040.42
25 Feb 05	1400	2667	2542	5040.44
25 Feb 05	1500	2931	2739	5040.47
25 Feb 05	1600	3322	3039	5040.52
25 Feb 05	1700	3877	3478	5040.60
25 Feb 05	1800	4638	4096	5040.71
25 Feb 05	1900	5671	4942	5040.85
25 Feb 05	2000	7055	6088	5041.05
25 Feb 05	2100	8839	7608	5041.31
25 Feb 05	2200	11037	9540	5041.65
25 Feb 05	2300	13649	11887	5042.05
25 Feb 05	2400	16604	14633	5042.52
26 Feb 05	0100	19845	17707	5043.05
26 Feb 05	0200	23529	21122	5043.51
26 Feb 05	0300	28687	25353	5043.72
26 Feb 05	0400	36816	31643	5044.04
26 Feb 05	0500	47107	40909	5044.50
26 Feb 05	0600	56656	52183	5044.90
26 Feb 05	0700	64533	60958	5045.21
26 Feb 05	0800	70937	68136	5045.40
26 Feb 05	0900	75929	73791	5045.55
26 Feb 05	1000	79438	77961	5045.66
26 Feb 05	1100	81852	80852	5045.73
26 Feb 05	1200	83306	82702	5045.77
26 Feb 05	1300	83933	83668	5045.80
26 Feb 05	1400	83856	83886	5045.80
26 Feb 05	1500	83184	83456	5045.79
26 Feb 05	1600	82006	82485	5045.77

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
26 Feb 05	1700	80428	81079	5045.74
26 Feb 05	1800	78554	79332	5045.69
26 Feb 05	1900	76457	77334	5045.64
26 Feb 05	2000	74187	75147	5045.58
26 Feb 05	2100	71787	72813	5045.52
26 Feb 05	2200	69419	70443	5045.46
26 Feb 05	2300	66893	67997	5045.39
26 Feb 05	2400	64356	65479	5045.33
27 Feb 05	0100	61826	62960	5045.26
27 Feb 05	0200	59325	60461	5045.19
27 Feb 05	0300	56886	58009	5045.11
27 Feb 05	0400	54532	55631	5045.03
27 Feb 05	0500	52259	53335	5044.94
27 Feb 05	0600	50065	51118	5044.86
27 Feb 05	0700	47956	48983	5044.79
27 Feb 05	0800	46008	47145	5044.72
27 Feb 05	0900	44124	45231	5044.66
27 Feb 05	1000	42314	43388	5044.59
27 Feb 05	1100	40605	41630	5044.53
27 Feb 05	1200	38971	39961	5044.47
27 Feb 05	1300	37409	38365	5044.39
27 Feb 05	1400	35933	36846	5044.31
27 Feb 05	1500	34546	35412	5044.24
27 Feb 05	1600	33246	34066	5044.17
27 Feb 05	1700	32031	32804	5044.10
27 Feb 05	1800	30901	31624	5044.04
27 Feb 05	1900	29868	30531	5043.99
27 Feb 05	2000	28963	29545	5043.94
27 Feb 05	2100	28208	28694	5043.89
27 Feb 05	2200	27563	27979	5043.86
27 Feb 05	2300	26956	27348	5043.82
27 Feb 05	2400	26343	26739	5043.79

Ruby Dam
Incremental Hazard Screening Study

APPENDIX F

BREACH PARAMETER CALCULATIONS

(FERC, 1993)
Chapter 2

TABLE 1
SUGGESTED BREACH PARAMETERS
(Definition Sketch Shown in Figure 1)

Parameter	Value	Type of Dam
Average width of Breach (BR) (See Comment No. 1)*	$\overline{BR}$ = Crest Length	Arch
	$\overline{BR}$ = Multiple Slabs	Buttress
	$\overline{BR}$ = Width of 1 or more	Masonry, Gravity Monoliths,
	Usually $\overline{BR} \leq 0.5$ W	
	HD $\leq \overline{BR} \leq$ 5HD ..... (usually between ..... 2HD & 4HD)	Earthen, Rockfill, Timber Crib
	$\overline{BR} \geq$ 0.8 x Crest Length	Slag, Refuse
Horizontal Component of Side Slope of Breach (Z) (See Comment No. 2)*	$0 \leq Z \leq$ slope of valley walls ...	Arch
	Z = O	Masonry, Gravity Timber Crib, Buttress
	$\frac{1}{4} \leq Z \leq 1$	Earthen (Engineered, Compacted)
	$1 \leq Z \leq 2$	Slag, Refuse (Non-Engineered)
Time to Failure (TFH) (in hours) (See Comment No. 3)*	TFH ≤ 0.1	Arch
	$0.1 \leq$ TFH ≤ 0.3	Masonry, Gravity, Buttress
	$0.1 \leq$ TFH ≤ 1.0	Earthen (Engineered, Compacted) Timber Crib
	$0.1 \leq$ TFH ≤ 0.5	Earthen (Non Engineered Poor Construction)
	$0.1 \leq$ TFH ≤ 0.3	Slag, Refuse

Definition:

- HD - Height of Dam
- Z - Horizontal Component of Side Slope of Breach
- BR - Average Width of Breach
- TFH - Time to Fully Form the Breach
- W - Crest Length

Note: See Page 2-A-12 for definition Sketch

**Comments: See Page 2-A-10 - 2-A-11*

Comments:

1. $\overline{BR}$ is the average breach width, which is not necessarily the bottom width. $\overline{BR}$ is the bottom width for a rectangle, but $\overline{BR}$ is not the bottom width for a trapezoid.

2. Whether the shape is rectangular, trapezoidal, or triangular is not generally critical if the average breach width for each shape is the same. What is critical is the assumed average width of the breach.

3. Time to failure is a function of height of dam and location of breach. Therefore, the longer the time to failure, the wider the breach should be. Also, the greater the height of the dam and the storage volume, the greater the time to failure and average breach width will probably be. Time to failure is the time from the start of the breach formation until the complete breach is formed. It does not include the time leading up to the start of the breach formation. For example, the time to erode away the downstream slope of an earth dam is not included. In this situation, the time to failure commences after sufficient erosion of the downstream slope has occurred and actual formation of the breach (the lowering of the crest) has begun.

4. The bottom of the breach should be at the foundation elevation.

5. Breach width assumptions should be based on the type of dam, the height of dam, the volume of the reservoir, and the type of failure (e.g. piping, sustained overtopping, etc.). Slab and buttress dams require sensitivity analyses that vary the number of slabs assumed to fail.

6. For a worst-case scenario, the average breach width should be in the upper portion of the recommended range, the time to failure should be in the lower portion of the range, and the Manning's "n" value should be in the upper portion of the recommended range. In order to fully evaluate the impacts of a failure on downstream areas, a sensitivity analysis is required to estimate the confidence and relative differences resulting from varying assumptions.

   a. To compare relative differences in peak elevation based on variations in breach widths, the sensitivity analysis should be based on the following assumptions:

      1. Assume a probable (reasonable) maximum breach width, a probable minimum time to failure, and a probable maximum Manning's "n" value. Manning's "n" values for sections immediately below the dam and up to several thousand feet or more downstream of the dam should be assumed to be larger than the maximum value suggested by field investigations in

order to account for uncertainties of high energy losses, velocities, turbulence, etc., resulting from the initial failure.

2. Assume a probable minimum breach width, a probable maximum time to failure, and a probable minimum Manning's "n" value.

Plot the resulting water surface elevation at selected locations downstream from the dam for each run on the same graph. Compare the differences in elevation with respect to distance downstream from the dam for the two cases.

b. To compare differences in travel time of the flood wave, the sensitivity analysis should be based on the following assumptions:

1. Use criteria in a. 1.

2. Assume a probable maximum breach width, a probable minimum time to failure, and a probable minimum Manning's "n" value.

Plot the results (elevation-distance downstream) of both runs on the same graph to compare the changes in travel time with respect to distance downstream from the dam.

c. To compare differences in elevation between natural flood conditions and natural flood conditions plus dambreak, the sensitivity analysis should be based on the following assumptions:

1. Route natural flood without dambreak assuming maximum probable Manning's "n" value.

2. Use criteria in a. 1.

Plot the results (elevation-distance downstream) of both runs on the same graph to compare the changes in elevation with respect to distance downstream from the dam.

7. When dams are assumed to fail from overtopping, wider breach widths than those suggested in Table 1 should be considered if overtopping is sustained for a long period of time.

PMF BREACH MODEL - BREACH PARAMETERS

- PARAMETERS CALCULATED FOR 100' LABYRINTH CREST @ 5396.7 ft

BREACH FORMATION FACTOR:

V_W = VOLUME OF WATER THAT WILL FLOW THROUGH BREACH

PMF STORM VOL = 229,761 AC-FT (PER HEC-HMS TOTAL INFLOW - RUBY-PMF BASIN - RUN 1)

RES. VOLUME @ 5396.7 = 41,516 AC-FT

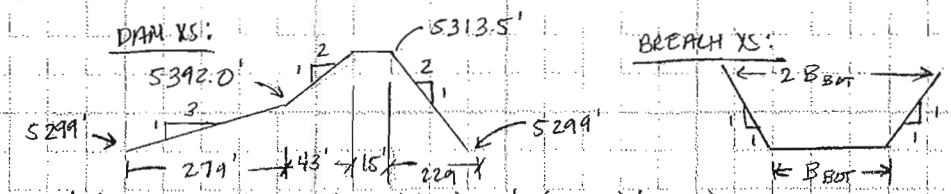
$V_W = 229{,}761 + 41{,}516 \Rightarrow \underline{V_W = 271{,}277 \text{ AC-FT}}$

h = (PEAK W.S. ELEV - BREACH BASE ELEV.) = (HEC-HMS MAX W.S. ELEV. RUN 1 - DAM BASE ELEV)
$= 5427.3 \text{ ft} - 5299 \text{ ft} \Rightarrow \underline{h = 128.3 \text{ ft}}$

$BFF = V_W h = (271{,}277)(128.3) \Rightarrow \underline{BFF = 3.50 \times 10^7}$

- FROM FIG 1: $V_m \approx 2 \times 10^6$ cy
- FROM FIG 2: $T \approx 3.0$ hrs

BREACH XS AREA:



XS AREA $= \frac{1}{2}(93')(279') + \frac{1}{2}(93' + 114.5')(43') + (114.5')(15') + \frac{1}{2}(114.5')(229') \Rightarrow \underline{\text{XS AREA} = 32262.5 \text{ ft}^2}$

$V_m = 2B_{BOT}(\text{XS AREA}) \Rightarrow 2B_{BOT}(32{,}262.5 \text{ ft}) = (2{,}000{,}000 \text{ cy})\left(\frac{27 \text{ ft}^3}{1 \text{ cy}}\right)$

THESE VALUES REPRESENT A BREACH THAT IS LARGER THAN THE DAM.

$B_{BOT} = 836.9$ ft
$B_{TOP} = 2B_{BOT} = 1673.8$ ft

- IT WAS ASSUMED MOST OF THE DAM EMBANKMENT IS BLOWN OUT DURING A BREACH. THE BREACH WAS ASSUMED TO HAVE 1:1 SIDE SLOPES FOR ENGINEERED, EARTHEN MATERIAL. A MORE LIBERAL RUN WAS ALSO USED.

HEC-HMS RUN 2:
$B_{BOT} = 425$ FT
$B_{TOP} = 850$ FT
SIDESLOPE = 1H:1V
T = 3.0 hrs

HEC-HMS RUN 3:
$B_{BOT} = 255$ FT
$B_{TOP} = 383$ FT
SIDESLOPE = ½H:1V
T = 4.0 hrs

- HEC-HMS TRIGGER ELEV SET AT 5428.7

BFF = the Breach Formation Factor ($V_w \times n$);
h = maximum reservoir water surface elevation minus base elevation of breach;
Q_P = peak rate of outflow;
T = time for breach to develop;
V_M = volume of material removed during the breach; and
V_W = volume of outflow that formed the breach.

Breaching Characteristics of Dam Failures

By Thomas C. MacDonald[1] and Jennifer Langridge-Monopolis[2]

Abstract: Computer programs developed for dam safety analyses are limited by the accuracy of the input data for the geometric and temporal dam breach characteristics. Data on a number of historical dam failures were collected and analyzed and graphical relationships for predicting breach characteristics were developed for erosion type breaches. The data provides a basis for selecting a breach shape and calculating the breach size and the time for breach development. A relationship is also developed for estimating peak outflows from dam failures. This relationship can be used to verify the methodology and the results of dam safety studies.

Introduction

In recent years significant effort has been directed at determining the safety of dams in the United States and abroad. One aspect of dam safety is the potential for loss of life and damages in the downstream floodplain that would result in the event of a dam failure. To assess the potential hazards of dam failures, sophisticated computer programs have been developed that simulate dam break hydrographs, and route these hydrographs downstream so that inundated areas, flow depths, and flow velocities can be estimated. Two of the commonly used computer programs for dam break analyses are the U.S. Army Corps of Engineers' HEC-1 program and the U.S. National Weather Service's program entitled DAMBRK.

Although the available computer programs utilize state-of-the-art hydrograph development and routing techniques, they are dependent on certain inputs regarding the geometric and temporal characteristics of the dam breach. The state-of-the-art in estimating these breach characteristics is not as advanced as the computer techniques they are used with and, therefore, they are limiting factors in dam safety analyses.

The purpose of this paper is to present the results of studies that were made to develop a methodology for estimating breach characteristics for certain types of dams. The results of these initial studies are promising and, with further research, may provide a sound basis for estimating dam breach characteristics.

The studies presented in this paper are based on reported case histories of dams that have failed. The limited number of case histories that were studied represent only a small portion of the dams that have failed and for which data are available. The data presented in the case histories were limited and, in some cases, needed interpretation before they could be used. Collection of additional data on the dam failures presented in

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Note.—Discussion open until October 1, 1984. To extend the closing date one month, a written request must be filed with the ASCE Manager of Technical and Professional Publications. The manuscript for this paper was submitted for review and possible publication on November 5, 1982. This paper is part of the *Journal of Hydraulic Engineering*, Vol. 110, No. 5, May, 1984. ©ASCE, ISSN 0733-9429/84/0005-0567/$01.00. Paper No. 18795.

dependent relationship that can be used to verify the methodology and to verify the results of dam safety studies. These analyses and their results are described in the following paragraphs.

Breach Shape.—With the exception of Baldwin Hills Dam, all of the data indicate an approximate trapezoidal breach shape with the bottom of the breach at the base of the embankment. The breach through Baldwin Hills Dam was triangular in shape and extended down to the base of the embankment.

These data suggest the following sequence of development for breaches caused by overtopping. The breach is initiated at a low or weak point in the embankment. Water flowing over the embankment at this point causes downcutting at the embankment crest and erosion of material from the downstream slope of the embankment. After sufficient downcutting and erosion has occurred a weak section is formed in the dam. The dam may "burst" at this weak section or the downcutting may continue until the breach reaches the base of the embankment. When the breach reaches the natural ground, which is less erodable and large in extent, further downcutting is prevented. Subsequent outflows attack the sides of the breach and cause it to grow laterally until the abutments of the embankment are reached. Generally, the abutments prevent further growth of the breach because they are less erodable and large in extent.

For breaches caused by piping, material is first eroded from the downstream slope at the point where the piping flows exit the embankment. A cavity is formed in the embankment at this point. As the cavity grows adjacent embankment material sloughs into the cavity and is washed away. Eventually material from the embankment crest sloughs into the cavity and forms a low point where water can flow over the embankment. During this process the dam may "burst" at the weak section of the dam to form the breach or the breach may form by downcutting. Subsequent development of a piping breach is similar to a breach formed by overtopping.

The methodology developed in these studies assumes these sequences of breach development. Thus, depending on the amount of material removed during the breach and the geometry of the embankment, the breach would be either triangular or trapezoidal in shape.

To fully define breach shape, an estimate of the most likely breach side slope is needed. The data presented in Table 2 indicate a range of side slopes with the most common slope being about 2V:1H. This side slope is assumed in the methodology that is developed.

Breach Size.—As already mentioned, the maximum size of a breach is limited by the abutments of the embankment and the natural ground. Therefore, the following methodology for estimating breach size only applied to breaches where less than the total embankment is washed away. If the methodology estimates a breach size that is greater than the entire embankment, then the size and shape of the actual embankment should be used in the dam safety analysis.

Adopting the breach shape described, the breach size can be calculated from the embankment geometry, if the volume of embankment material that would be washed away during breaching can be predicted. Thus, a relationship to predict breach volume is needed.

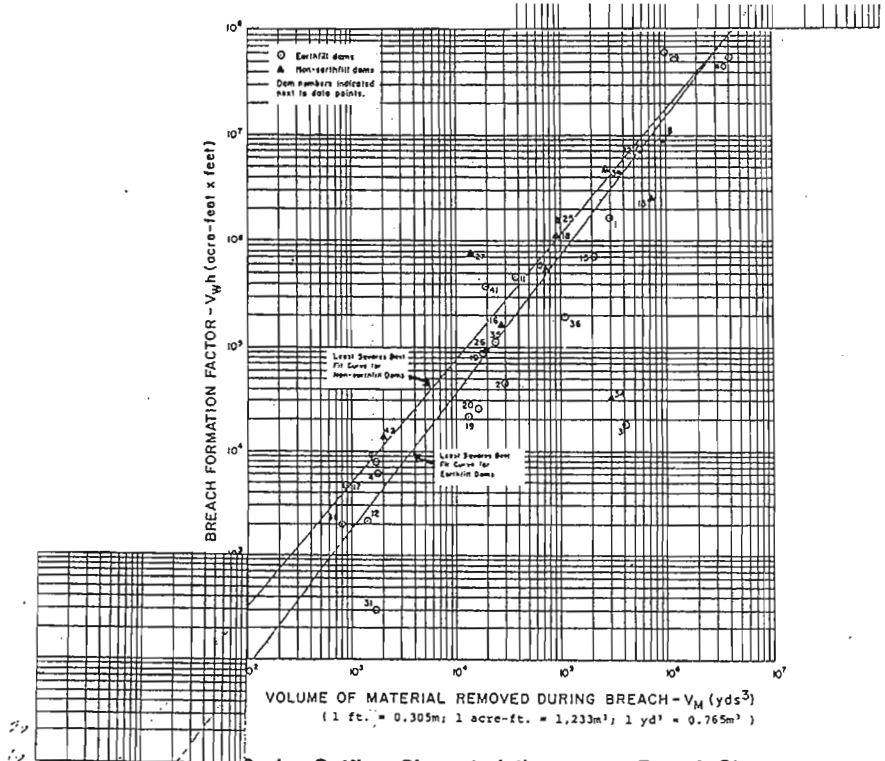


FIG. 1.—Outflow Characteristics versus Breach Size

Various combinations of the variables presented in Table 2 that describe flow characteristics during the breach were plotted against the estimated volume of breach material that was removed. It was found that the product of the outflow volume of water and the difference in elevation of the peak reservoir water surface and breach base ($V_w \times h$), when plotted against the volume of breach material removed, resulted in a minimum amount of scatter of the data and is a reasonably consistent variable for predicting breach volume. Hereinafter this variable for predicting breach volume is called the Breach Formation Factor (BFF).

A plot of the BFF versus breach volume, is presented in Fig. 1 for both the "earthfill" and "non-earthfill" dams. As shown in Fig. 1, the breach volumes for "non-earthfill" dams are, in general, less than "earthfill" dams. This can be explained by the more erosion resistant nature of the "non-earthfill" types of dams that are included in the analyses.

There is a large amount of scatter in the data plotted in Fig. 1. A large amount of scatter is not surprising, considering the number of factors not considered in the variable used to predict breach volume. Probably one of the more important variables not considered is the structural properties of the embankment material. For example, easily erodable embankment materials may be the explanation of why more material was washed away during failure of Rio Manzanares Dam (dam number 31), Buffalo Creek Dam (dam number 3), and Schaeffer Dam (dam num-

34) than would be predicted from the data for the other "earthfill" dams. The literature indicates that the embankment material of Rio Manzanares Dam was "highly susceptible to erosion." Buffalo Creek Dam was a coal waste embankment. The material was cohesionless, had a low specific gravity, and minimum compaction. Schaeffer Dam was initially constructed by hydraulic fill but when it was observed that the placed material was more nearly liquid than solid, the liquid material was replaced. If some of the hydraulic fill had not been replaced, it could have acted as a thixotropic lens that suddenly liquefied due to the high hydraulic loading conditions.

Two least squares best fit curves are shown in Fig. 1, one for the "non-earthfill" dams and one for all of the "earthfill" dams except Rio Manzanares, Buffalo Creek, and Schaeffer Dams. This latter curve may be appropriate for "earthfill" dams whose embankment materials have average structural properties but may not be appropriate for easily erodable embankments or embankments with thixotropic characteristics.

Breach Development Time.—Analyses of the data in Table 2 indicate that, except for Buffalo Creek and Schaeffer Dams, the maximum breach development times of "earthfill" dams varied in a consistent manner with the volumes of material removed during the breach. Plots of the maximum breach development times versus breach volumes are presented in Fig. 2 along with an envelope curve that includes all "earthfill" dams except Buffalo Creek and Schaeffer Dams. This curve is probably more indicative of actual breach development times but, because it is an envelope of maximums, may still give high estimates of actual development times. The data for Buffalo Creek and Schaeffer Dams are not included in the envelope curve because it is suspected that these dams failed unusually fast for the reasons presented in the preceding section.

Plots of the maximum breach development times for the "non-earthfill" dams are also shown in Fig. 2. These plots do not vary in a consistent manner with breach volumes. One explanation for this is that the breaching mechanism may have been only partially due to erosion and partially due to structural instabilities that developed in the embankment during breaching.

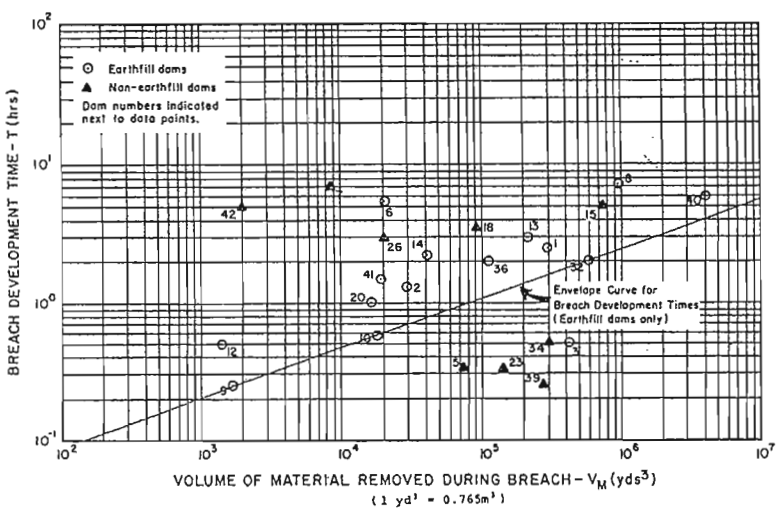


FIG. 2.—Breach Size versus Breach Development Time

Peak Outflows.—Analyses of the estimated peak outflows from dam failures presented in Table 2 were made to develop a relationship that can be used to verify the methodology and to verify results of dam safety studies. Studies by Hagen (24) found that there is a good correlation between the peak rate of outflow from a dam breach and a variable very similar to the BFF. The data in Table 2 were used to develop the relationship between peak outflow and the BFF presented in Fig. 3. This relationship is essentially identical to that developed by Hagen.

The estimated peak outflows from Buffalo Creek and Schaeffer Dams are plotted in Fig. 3 but are not included in the calculated least squares best fit curve for "earthfill" dams. As previously reviewed, these two dams apparently failed very quickly, and washed out unusually large amounts of embankment material. Thus, it would be reasonable to expect unusually large peak outflows from these dam failures but, the data indicate that these outflows are only on the high side of the scatter of data. This could probably be explained by the large scatter of the data, i.e., had the breaches been smaller and developed at a slower rate, the

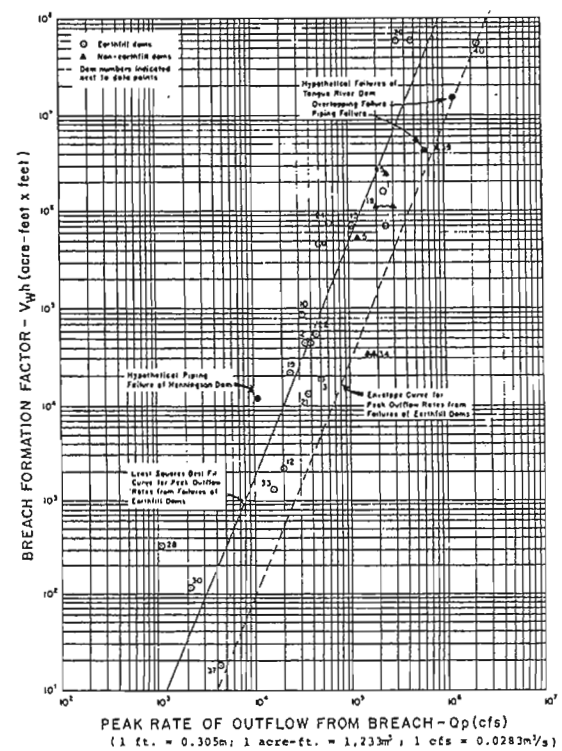


FIG. 3.—Outflow Characteristics versus Peak Rate of Outflow

ervoir shape and other factors influencing outflow may have resulted in peak outflows that are only half of what were estimated, which would still be well within the scatter of data. However, the literature on Buffalo Creek Dam provides an additional explanation for a lower peak outflow. The dam crest was about 450 ft wide and, although a large amount of material washed out very rapidly, the cross-sectional area of the breach was relatively small and restricted the rate of outflow.

Also plotted in Fig. 3 are estimated peak outflows from "non-earthfill" dams. In general, peak rates of outflow from the "non-earthfill" dam failures are higher than would be predicted from the data on "earthfill" dam failures. This would be expected if the breaches were formed partly by erosion and partly by the sudden collapse of a section of the embankment. A least squares best fit curve for "non-earthfill" dams is not presented in Fig. 3 because of the limited amount of data.

Application of Results

The breach parameters required as input to computer programs that analyze dam failures are: the width and elevation of the base of the breach, the breach side slopes, the time for breach development, and the reservoir water surface elevation at which failure begins. Figs. 1 and 2 are used to predict all of these parameters except the reservoir water surface elevation at the beginning of failure. Reasonable assumptions for the reservoir water surface elevation at the beginning of failure are the dam crest elevation for dams assumed to fail by overtopping, and the spillway crest, or maximum normal pool elevation, for dams that are assumed to fail by piping, seepage, or other causes.

To use Fig. 1, the volume of water that will be released by the breach (V_w) must first be estimated. This volume of water is the change in reservoir storage for assumed nonovertopping failures. For failures caused by overtopping, the outflow volume is estimated as the change in reservoir storage during the breach, plus inflows into the reservoir that occur after breaching begins and continue until the reservoir water surface is essentially at the base of the breach. It may be necessary to estimate this outflow volume by trial-and-error routings of the inflow hydrograph through the reservoir and breach. The trial-and-error estimate of outflow volume is made by first assuming the outflow volume, calculating the breach characteristics as described previously, routing the inflow hydrograph through the reservoir and trial breach, and comparing the assumed outflow volume with the volume that is determined from the calculated outflow and storage hydrographs.

The difference in elevation between the peak reservoir water surface during the breach and the base of the ultimate breach (h) is also needed to use Fig. 1. The peak reservoir water surface elevation can usually be assumed to be the water surface elevation at which breaching begins. For breaches caused by overtopping the validity of this assumption can be confirmed by the trial-and-error routings described previously.

These estimates of outflow volume, and the elevation difference between the breach base and the maximum reservoir water surface, are used to calculate the BFF. This calculated BFF is then used in Fig. 1 to obtain the breach volume. Knowing the breach volume and geometry

of the dam being analyzed, and assuming a triangular or trapezoidal breach shape with 2V:1H side slopes, the parameters of breach geometry needed as input to the computer programs can be calculated.

The remaining variable needed as input for the computer analysis is the development time of the breach. This development time is estimated using the breach volume determined from Fig. 1 and the envelope curve shown in Fig. 2.

Verification of Methodology

The relationships presented in Figs. 1 and 2 for predicting breach characteristics were used with the HEC-1 computer program to calculate outflow hydrographs for three hypothetical failures of two dams and reservoirs. The peak outflows of the calculated hydrographs are shown on Fig. 3 for comparison with the peak outflows of historical dam failures. These comparisons indicate that the methodology that was developed provides reasonable estimates of dam failure flood hydrographs. The analyses and results of these verification studies are described in the following paragraphs.

TABLE 3.—Hypothetical Dam Failure Analyses

Reservoir, breach and outflow characteristics (1)	Tongue River Dam: Overtopping failure (2)	Tongue River Dam: Piping failure (3)	Henningson Dam: Piping failure (4)
Spillway crest elevation, feet	3,424.4	3,424.4	10,014
Dam crest elevation, feet	3,442.4	3,442.2	10,017.6
Base elevation of dam, feet	3,364.4	3,364.4	9,988.6
Assumed WSEL at beginning of breach, feet	3,442.9	3,424.4	10,014
Reservoir storage at beginning of breach, acre-feet	156,500	69,440	469
Inflow during breach, acre-feet	30,000	0	0
Outflow volume (5 + 6), acre-feet	186,500	69,400	469
Base elevation of ultimate breach, feet	3,364.4	3,364.4	9,988.6
Maximum water surface height above breach (4–8), feet	78.5	60.0	25.4
Breach formation factor, (7 × 9) acre-feet	1.5×10^7	4.2×10^6	1.2×10^4
Breach volume (from Fig. 1), cubic yards	1.5×10^6	5.5×10^5	1.5×10^3
Breach base width, feet	1,375	555	33
Breach side slopes, vertical:horizontal	1:2.88[a]	2:1	2:1
Breach development time (from Fig. 2), hours	3.0	2.0	0.35
HEC-1-calculated peak outflow, cubic feet per second	1,285,500	622,800	10,979

[a]Abutment side slopes used because breach volume = volume of entire dam.

Note: 1 ft = 0.305 m; 1 acre-ft = 1,233 m^3; 1 yd^3 = 0.765 m^3; 1 cfs = 0.0283 m^3/s.

Ruby Dam
Incremental Hazard Screening Study

APPENDIX G

HEC-HMS PMF ROUTING
WITH DAM BREACH "A"

HMS * Summary of Results

Project : Ruby Run Name : Run 2

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF Breach

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1504 Control Specs : 24-Hour

Hydrologic Element	Discharge Peak (cfs)	Stage Peak (ft)	Time of Peak		e (ac ft)	Drainage Area (sq mi)
Ruby Basin	83727		26 Feb 05	1000	229761	595.000
Ruby Reservoir	1016644		26 Feb 05	1200	283788	595.000
XS 4	985433	5354.1	26 Feb 05	1200	284579	595.000
XS 7	934064	5292.2	26 Feb 05	1200	286688	595.000
XS 8	867471	5236.3	26 Feb 05	1200	288992	595.000
100 yr Concurrent	2270.0		24 Feb 05	2400	13507	54.000
XS 10-Ald Resthome	682584	5161.5	26 Feb 05	1200	307275	649.000
XS 11 - Alder	597818	5118.2	26 Feb 05	1200	308463	649.000
XS 12 - Laurin	536047	5053.1	26 Feb 05	1300	309796	649.000

HMS * Summary of Results for Ruby Basin

Project : Ruby Run Name : Run 2

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF Breach

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1504 Control Specs : 24-Hour

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
24 Feb 05	2400				0	0	0
25 Feb 05	0100	0.01	0.01	0.00	0	0	0
25 Feb 05	0200	0.03	0.03	0.00	3	0	3
25 Feb 05	0300	0.13	0.11	0.01	12	0	12
25 Feb 05	0400	0.26	0.20	0.06	55	0	55
25 Feb 05	0500	0.26	0.20	0.06	142	0	142
25 Feb 05	0600	0.38	0.20	0.18	333	0	333
25 Feb 05	0700	0.38	0.20	0.18	653	0	653
25 Feb 05	0800	0.38	0.20	0.18	1114	0	1114
25 Feb 05	0900	0.38	0.20	0.18	1727	0	1727
25 Feb 05	1000	0.43	0.20	0.24	2540	0	2540
25 Feb 05	1100	0.43	0.20	0.24	3589	0	3589
25 Feb 05	1200	0.46	0.20	0.26	4890	0	4890
25 Feb 05	1300	0.47	0.20	0.28	6471	0	6471
25 Feb 05	1400	0.51	0.20	0.31	8329	0	8329
25 Feb 05	1500	0.60	0.20	0.40	10532	0	10532
25 Feb 05	1600	0.74	0.20	0.54	13151	0	13151
25 Feb 05	1700	1.97	0.20	1.77	16811	0	16811
25 Feb 05	1800	0.51	0.20	0.31	20997	0	20997
25 Feb 05	1900	0.51	0.20	0.31	25480	0	25480
25 Feb 05	2000	0.47	0.20	0.28	30188	0	30188
25 Feb 05	2100	0.47	0.20	0.28	35235	0	35235
25 Feb 05	2200	0.46	0.20	0.26	40621	0	40621
25 Feb 05	2300	0.46	0.20	0.26	46212	0	46212
25 Feb 05	2400	0.43	0.20	0.24	51812	0	51812
26 Feb 05	0100	0.43	0.20	0.24	57016	0	57016
26 Feb 05	0200	0.43	0.20	0.24	62272	0	62272
26 Feb 05	0300	0.43	0.20	0.24	67115	0	67115
26 Feb 05	0400	0.38	0.20	0.18	71386	0	71386
26 Feb 05	0500	0.38	0.20	0.18	74997	0	74997
26 Feb 05	0600	0.26	0.20	0.06	78178	0	78178
26 Feb 05	0700	0.26	0.20	0.06	80817	0	80817
26 Feb 05	0800	0.26	0.20	0.06	82288	0	82288
26 Feb 05	0900	0.26	0.20	0.06	83233	0	83233
26 Feb 05	1000	0.26	0.20	0.06	83727	0	83727
26 Feb 05	1100	0.26	0.20	0.06	83215	0	83215
26 Feb 05	1200	0.26	0.20	0.06	82222	0	82222
26 Feb 05	1300	0.26	0.20	0.06	80943	0	80943
26 Feb 05	1400	0.26	0.20	0.06	79047	0	79047
26 Feb 05	1500	0.26	0.20	0.06	76877	0	76877
26 Feb 05	1600	0.13	0.11	0.01	74534	0	74534

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
26 Feb 05	1700	0.13	0.11	0.01	72178	0	72178
26 Feb 05	1800	0.13	0.11	0.01	69588	0	69588
26 Feb 05	1900	0.13	0.11	0.01	66877	0	66877
26 Feb 05	2000	0.13	0.11	0.01	64156	0	64156
26 Feb 05	2100	0.13	0.11	0.01	61478	0	61478
26 Feb 05	2200	0.13	0.11	0.01	58810	0	58810
26 Feb 05	2300	0.13	0.11	0.01	56143	0	56143
26 Feb 05	2400	0.13	0.11	0.01	53546	0	53546
27 Feb 05	0100	0.13	0.11	0.01	51043	0	51043
27 Feb 05	0200	0.13	0.11	0.01	48687	0	48687
27 Feb 05	0300	0.03	0.03	0.00	46438	0	46438
27 Feb 05	0400	0.03	0.03	0.00	44253	0	44253
27 Feb 05	0500	0.03	0.03	0.00	42121	0	42121
27 Feb 05	0600	0.03	0.03	0.00	40102	0	40102
27 Feb 05	0700	0.03	0.03	0.00	38205	0	38205
27 Feb 05	0800	0.03	0.03	0.00	36393	0	36393
27 Feb 05	0900	0.03	0.03	0.00	34646	0	34646
27 Feb 05	1000	0.03	0.03	0.00	33003	0	33003
27 Feb 05	1100	0.03	0.03	0.00	31456	0	31456
27 Feb 05	1200	0.03	0.03	0.00	29996	0	29996
27 Feb 05	1300	0.03	0.03	0.00	28616	0	28616
27 Feb 05	1400	0.01	0.01	0.00	27318	0	27318
27 Feb 05	1500	0.01	0.01	0.00	26088	0	26088
27 Feb 05	1600	0.01	0.01	0.00	24918	0	24918
27 Feb 05	1700	0.01	0.01	0.00	23806	0	23806
27 Feb 05	1800	0.01	0.01	0.00	22759	0	22759
27 Feb 05	1900	0.01	0.01	0.00	21768	0	21768
27 Feb 05	2000	0.01	0.01	0.00	20825	0	20825
27 Feb 05	2100	0.01	0.01	0.00	19934	0	19934
27 Feb 05	2200	0.01	0.01	0.00	19097	0	19097
27 Feb 05	2300	0.01	0.01	0.00	18308	0	18308
27 Feb 05	2400	0.01	0.01	0.00	17574	0	17574

HMS * Summary of Results for Ruby Reservoir

Project : Ruby Run Name : Run 2

Start of Run	: 25Feb05 0000	Basin Model	: Ruby-PMF Breach
End of Run	: 28Feb05 0000	Met. Model	: 24 HR, PMP
Execution Time	: 31May06 1504	Control Specs	: 24-Hour

Computed Results

Peak Inflow	: 83727 (cfs)	Date/Time of Peak Inflow	: 26 Feb 05 1000
Peak Outflow	: 1016644 (cfs)	Date/Time of Peak Outflow	: 26 Feb 05 1200
Total Inflow	: 7.24 (in)	Peak Storage	: 76585 (ac-ft)
Total Outflow	: 8.94 (in)	Peak Elevation	: 5422.3 (ft)

HMS * Summary of Results for Ruby Reservoir

Project : Ruby Run Name : Run 2

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF Breach

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1504 Control Specs : 24-Hour

Date	Time	Reservoir Storage (ac-ft)	Reservoir Elevation (ft)	Inflow (cfs)	Outflow (cfs)
24 Feb 05	2400	41516	5396.7	0	0
25 Feb 05	0100	41516	5396.7	0	0
25 Feb 05	0200	41516	5396.7	3	0
25 Feb 05	0300	41517	5396.7	12	0
25 Feb 05	0400	41519	5396.7	55	0
25 Feb 05	0500	41527	5396.7	142	0
25 Feb 05	0600	41547	5396.7	333	2
25 Feb 05	0700	41587	5396.8	653	6
25 Feb 05	0800	41660	5396.8	1114	16
25 Feb 05	0900	41775	5396.9	1727	38
25 Feb 05	1000	41946	5397.1	2540	82
25 Feb 05	1100	42189	5397.3	3589	160
25 Feb 05	1200	42521	5397.6	4890	292
25 Feb 05	1300	42958	5398.0	6471	502
25 Feb 05	1400	43515	5398.5	8329	819
25 Feb 05	1500	44207	5399.2	10532	1280
25 Feb 05	1600	45053	5399.9	13151	1928
25 Feb 05	1700	46097	5400.8	16811	2772
25 Feb 05	1800	47383	5401.9	20997	3935
25 Feb 05	1900	48914	5403.2	25480	5488
25 Feb 05	2000	50678	5404.7	30188	7479
25 Feb 05	2100	52667	5406.3	35235	9809
25 Feb 05	2200	54876	5408.0	40621	12594
25 Feb 05	2300	57287	5409.9	46212	15887
25 Feb 05	2400	59898	5411.6	51812	18952
26 Feb 05	0100	62672	5413.5	57016	22751
26 Feb 05	0200	65532	5415.4	62272	27321
26 Feb 05	0300	68224	5417.2	67115	36920
26 Feb 05	0400	70470	5418.6	71386	47229
26 Feb 05	0500	72239	5419.7	74997	56346
26 Feb 05	0600	73602	5420.5	78178	63840
26 Feb 05	0700	74648	5421.2	80817	69841
26 Feb 05	0800	75427	5421.6	82288	74418
26 Feb 05	0900	75979	5422.0	83233	77743
26 Feb 05	1000	76358	5422.2	83727	80034
26 Feb 05	1100	76585	5422.3	83215	81415
26 Feb 05	1200	38047	5393.4	82222	1016644
26 Feb 05	1300	11809	5329.0	80943	156096
26 Feb 05	1400	8275	5320.0	79047	89439
26 Feb 05	1500	7710	5318.6	76877	80143

Date	Time	Reservoir Storage (ac-ft)	Reservoir Elevation (ft)	Inflow (cfs)	Outflow (cfs)
26 Feb 05	1600	7489	5318.0	74534	76612
26 Feb 05	1700	7326	5317.6	72178	74044
26 Feb 05	1800	7167	5317.2	69588	71570
26 Feb 05	1900	6999	5316.8	66877	68979
26 Feb 05	2000	6823	5316.3	64156	66314
26 Feb 05	2100	6644	5315.9	61478	63647
26 Feb 05	2200	6464	5315.4	58810	61001
26 Feb 05	2300	6281	5314.9	56143	58366
26 Feb 05	2400	6098	5314.5	53546	55760
27 Feb 05	0100	5916	5314.0	51043	53223
27 Feb 05	0200	5739	5313.6	48687	50791
27 Feb 05	0300	5568	5313.1	46438	48478
27 Feb 05	0400	5401	5312.7	44253	46259
27 Feb 05	0500	5236	5312.3	42121	44106
27 Feb 05	0600	5074	5311.9	40102	42031
27 Feb 05	0700	4918	5311.5	38205	40060
27 Feb 05	0800	4767	5311.1	36393	38191
27 Feb 05	0900	4620	5310.7	34646	36403
27 Feb 05	1000	4477	5310.4	33003	34697
27 Feb 05	1100	4340	5310.0	31456	33083
27 Feb 05	1200	4208	5309.7	29996	31559
27 Feb 05	1300	4082	5309.4	28616	30118
27 Feb 05	1400	3960	5309.1	27318	28759
27 Feb 05	1500	3843	5308.8	26088	27474
27 Feb 05	1600	3731	5308.5	24918	26255
27 Feb 05	1700	3622	5308.2	23806	25098
27 Feb 05	1800	3517	5307.9	22759	24000
27 Feb 05	1900	3417	5307.7	21768	22962
27 Feb 05	2000	3320	5307.4	20825	21977
27 Feb 05	2100	3226	5307.2	19934	21042
27 Feb 05	2200	3137	5307.0	19097	20159
27 Feb 05	2300	3051	5306.7	18308	19325
27 Feb 05	2400	2969	5306.5	17574	18541

HMS * Summary of Results for XS 4

Project : Ruby Run Name : Run 2

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF Breach

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1504 Control Specs : 24-Hour

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
24 Feb 05	2400	0	0	5280.00
25 Feb 05	0100	0	0	5280.00
25 Feb 05	0200	0	0	5280.00
25 Feb 05	0300	0	0	5280.00
25 Feb 05	0400	0	0	5280.00
25 Feb 05	0500	0	0	5280.00
25 Feb 05	0600	2	2	5280.00
25 Feb 05	0700	6	5	5280.00
25 Feb 05	0800	16	15	5280.01
25 Feb 05	0900	38	37	5280.03
25 Feb 05	1000	82	79	5280.07
25 Feb 05	1100	160	155	5280.14
25 Feb 05	1200	292	284	5280.26
25 Feb 05	1300	502	488	5280.45
25 Feb 05	1400	819	798	5280.73
25 Feb 05	1500	1280	1249	5281.14
25 Feb 05	1600	1928	1885	5281.73
25 Feb 05	1700	2772	2715	5282.49
25 Feb 05	1800	3935	3857	5283.53
25 Feb 05	1900	5488	5382	5284.93
25 Feb 05	2000	7479	7341	5286.72
25 Feb 05	2100	9809	9645	5288.84
25 Feb 05	2200	12594	12396	5291.35
25 Feb 05	2300	15887	15650	5294.34
25 Feb 05	2400	18952	18728	5297.15
26 Feb 05	0100	22751	22470	5298.97
26 Feb 05	0200	27321	26987	5300.17
26 Feb 05	0300	36920	36268	5302.63
26 Feb 05	0400	47229	46570	5304.83
26 Feb 05	0500	56346	55788	5306.52
26 Feb 05	0600	63840	63397	5307.80
26 Feb 05	0700	69841	69493	5308.71
26 Feb 05	0800	74418	74157	5309.41
26 Feb 05	0900	77743	77556	5309.91
26 Feb 05	1000	80034	79905	5310.27
26 Feb 05	1100	81415	81735	5310.50
26 Feb 05	1200	1016644	985433	5354.09
26 Feb 05	1300	156096	193628	5321.76
26 Feb 05	1400	89439	93098	5311.98
26 Feb 05	1500	80143	80666	5310.37
26 Feb 05	1600	76612	76811	5309.80
26 Feb 05	1700	74044	74190	5309.41

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
26 Feb 05	1800	71570	71712	5309.04
26 Feb 05	1900	68979	69128	5308.65
26 Feb 05	2000	66314	66469	5308.26
26 Feb 05	2100	63647	63804	5307.86
26 Feb 05	2200	61001	61159	5307.46
26 Feb 05	2300	58366	58524	5307.02
26 Feb 05	2400	55760	55919	5306.54
27 Feb 05	0100	53223	53379	5306.08
27 Feb 05	0200	50791	50943	5305.63
27 Feb 05	0300	48478	48624	5305.20
27 Feb 05	0400	46259	46400	5304.79
27 Feb 05	0500	44106	44245	5304.40
27 Feb 05	0600	42031	42167	5304.02
27 Feb 05	0700	40060	40191	5303.66
27 Feb 05	0800	38191	38316	5303.17
27 Feb 05	0900	36403	36524	5302.70
27 Feb 05	1000	34697	34814	5302.25
27 Feb 05	1100	33083	33195	5301.82
27 Feb 05	1200	31559	31666	5301.41
27 Feb 05	1300	30118	30221	5301.03
27 Feb 05	1400	28759	28856	5300.67
27 Feb 05	1500	27474	27567	5300.33
27 Feb 05	1600	26255	26345	5300.00
27 Feb 05	1700	25098	25184	5299.69
27 Feb 05	1800	24000	24082	5299.40
27 Feb 05	1900	22962	23039	5299.13
27 Feb 05	2000	21977	22049	5298.86
27 Feb 05	2100	21042	21111	5298.61
27 Feb 05	2200	20159	20223	5298.38
27 Feb 05	2300	19325	19386	5297.76
27 Feb 05	2400	18541	18598	5297.04

HMS * Summary of Results for XS 7

Project : Ruby Run Name : Run 2

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF Breach

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1504 Control Specs : 24-Hour

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
24 Feb 05	2400	0	0	5246.00
25 Feb 05	0100	0	0	5246.00
25 Feb 05	0200	0	0	5246.00
25 Feb 05	0300	0	0	5246.00
25 Feb 05	0400	0	0	5246.00
25 Feb 05	0500	0	0	5246.00
25 Feb 05	0600	2	1	5246.00
25 Feb 05	0700	5	5	5246.00
25 Feb 05	0800	15	14	5246.01
25 Feb 05	0900	37	34	5246.02
25 Feb 05	1000	79	74	5246.04
25 Feb 05	1100	155	146	5246.08
25 Feb 05	1200	284	268	5246.15
25 Feb 05	1300	488	464	5246.26
25 Feb 05	1400	798	762	5246.43
25 Feb 05	1500	1249	1197	5246.67
25 Feb 05	1600	1885	1813	5247.02
25 Feb 05	1700	2715	2622	5247.47
25 Feb 05	1800	3857	3729	5248.09
25 Feb 05	1900	5382	5213	5248.92
25 Feb 05	2000	7341	7125	5250.00
25 Feb 05	2100	9645	9394	5251.27
25 Feb 05	2200	12396	12098	5252.79
25 Feb 05	2300	15650	15299	5254.58
25 Feb 05	2400	18728	18397	5256.32
26 Feb 05	0100	22470	22069	5257.54
26 Feb 05	0200	26987	26506	5258.21
26 Feb 05	0300	36268	35284	5259.55
26 Feb 05	0400	46570	45582	5260.79
26 Feb 05	0500	55788	54909	5261.67
26 Feb 05	0600	63397	62675	5262.36
26 Feb 05	0700	69493	68916	5262.86
26 Feb 05	0800	74157	73716	5263.24
26 Feb 05	0900	77556	77235	5263.52
26 Feb 05	1000	79905	79684	5263.72
26 Feb 05	1100	81735	81563	5263.85
26 Feb 05	1200	985433	934064	5292.17
26 Feb 05	1300	193628	262051	5272.84
26 Feb 05	1400	93098	102525	5265.27
26 Feb 05	1500	80666	81837	5263.87
26 Feb 05	1600	76811	77175	5263.52
26 Feb 05	1700	74190	74437	5263.30

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
26 Feb 05	1800	71712	71946	5263.10
26 Feb 05	1900	69128	69373	5262.90
26 Feb 05	2000	66469	66721	5262.68
26 Feb 05	2100	63804	64057	5262.47
26 Feb 05	2200	61159	61410	5262.26
26 Feb 05	2300	58524	58775	5262.03
26 Feb 05	2400	55919	56167	5261.79
27 Feb 05	0100	53379	53621	5261.55
27 Feb 05	0200	50943	51175	5261.32
27 Feb 05	0300	48624	48846	5261.10
27 Feb 05	0400	46400	46614	5260.89
27 Feb 05	0500	44245	44452	5260.69
27 Feb 05	0600	42167	42367	5260.49
27 Feb 05	0700	40191	40381	5260.31
27 Feb 05	0800	38316	38514	5260.04
27 Feb 05	0900	36524	36714	5259.77
27 Feb 05	1000	34814	34995	5259.51
27 Feb 05	1100	33195	33367	5259.26
27 Feb 05	1200	31666	31828	5259.02
27 Feb 05	1300	30221	30374	5258.80
27 Feb 05	1400	28856	29001	5258.59
27 Feb 05	1500	27567	27704	5258.40
27 Feb 05	1600	26345	26475	5258.21
27 Feb 05	1700	25184	25308	5258.03
27 Feb 05	1800	24082	24200	5257.86
27 Feb 05	1900	23039	23150	5257.70
27 Feb 05	2000	22049	22155	5257.55
27 Feb 05	2100	21111	21212	5257.40
27 Feb 05	2200	20223	20319	5257.27
27 Feb 05	2300	19386	19476	5256.93
27 Feb 05	2400	18598	18683	5256.48

HMS * Summary of Results for XS 8

Project : Ruby Run Name : Run 2

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF Breach

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1504 Control Specs : 24-Hour

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
24 Feb 05	2400	0	0	5214.00
25 Feb 05	0100	0	0	5214.00
25 Feb 05	0200	0	0	5214.00
25 Feb 05	0300	0	0	5214.00
25 Feb 05	0400	0	0	5214.00
25 Feb 05	0500	0	0	5214.00
25 Feb 05	0600	1	1	5214.00
25 Feb 05	0700	5	4	5214.00
25 Feb 05	0800	14	12	5214.00
25 Feb 05	0900	34	31	5214.01
25 Feb 05	1000	74	67	5214.02
25 Feb 05	1100	146	134	5214.04
25 Feb 05	1200	268	249	5214.08
25 Feb 05	1300	464	433	5214.14
25 Feb 05	1400	762	716	5214.22
25 Feb 05	1500	1197	1130	5214.35
25 Feb 05	1600	1813	1719	5214.54
25 Feb 05	1700	2622	2499	5214.78
25 Feb 05	1800	3729	3563	5215.12
25 Feb 05	1900	5213	4992	5215.57
25 Feb 05	2000	7125	6842	5216.15
25 Feb 05	2100	9394	9060	5216.84
25 Feb 05	2200	12098	11701	5217.67
25 Feb 05	2300	15299	14767	5218.64
25 Feb 05	2400	18397	17902	5219.62
26 Feb 05	0100	22069	21494	5220.40
26 Feb 05	0200	26506	25821	5220.75
26 Feb 05	0300	35284	33952	5221.40
26 Feb 05	0400	45582	44036	5222.13
26 Feb 05	0500	54909	53518	5222.68
26 Feb 05	0600	62675	61521	5223.13
26 Feb 05	0700	68916	67991	5223.44
26 Feb 05	0800	73716	73006	5223.67
26 Feb 05	0900	77235	76715	5223.85
26 Feb 05	1000	79684	79322	5223.97
26 Feb 05	1100	81563	81285	5224.05
26 Feb 05	1200	934064	867471	5236.33
26 Feb 05	1300	262051	332930	5230.38
26 Feb 05	1400	102525	125936	5225.72
26 Feb 05	1500	81837	84890	5224.20
26 Feb 05	1600	77175	77864	5223.90
26 Feb 05	1700	74437	74842	5223.76

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
26 Feb 05	1800	71946	72315	5223.64
26 Feb 05	1900	69373	69754	5223.52
26 Feb 05	2000	66721	67114	5223.39
26 Feb 05	2100	64057	64453	5223.27
26 Feb 05	2200	61410	61803	5223.14
26 Feb 05	2300	58775	59167	5223.01
26 Feb 05	2400	56167	56555	5222.86
27 Feb 05	0100	53621	54001	5222.71
27 Feb 05	0200	51175	51541	5222.57
27 Feb 05	0300	48846	49194	5222.43
27 Feb 05	0400	46614	46948	5222.30
27 Feb 05	0500	44452	44777	5222.17
27 Feb 05	0600	42367	42681	5222.05
27 Feb 05	0700	40381	40680	5221.93
27 Feb 05	0800	38514	38796	5221.79
27 Feb 05	0900	36714	36986	5221.65
27 Feb 05	1000	34995	35255	5221.51
27 Feb 05	1100	33367	33614	5221.38
27 Feb 05	1200	31828	32062	5221.25
27 Feb 05	1300	30374	30596	5221.13
27 Feb 05	1400	29001	29212	5221.02
27 Feb 05	1500	27704	27903	5220.92
27 Feb 05	1600	26475	26664	5220.82
27 Feb 05	1700	25308	25488	5220.72
27 Feb 05	1800	24200	24371	5220.63
27 Feb 05	1900	23150	23313	5220.55
27 Feb 05	2000	22155	22311	5220.47
27 Feb 05	2100	21212	21359	5220.39
27 Feb 05	2200	20319	20459	5220.32
27 Feb 05	2300	19476	19609	5220.16
27 Feb 05	2400	18683	18809	5219.91

HMS * Summary of Results for 100 yr

Concurrent

Project : Ruby Run Name : Run 2

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF Breach

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1504 Control Specs : 24-Hour

Date	Time	Discharge (cfs)
24 Feb 05	2400	2270.0
25 Feb 05	0100	2270.0
25 Feb 05	0200	2270.0
25 Feb 05	0300	2270.0
25 Feb 05	0400	2270.0
25 Feb 05	0500	2270.0
25 Feb 05	0600	2270.0
25 Feb 05	0700	2270.0
25 Feb 05	0800	2270.0
25 Feb 05	0900	2270.0
25 Feb 05	1000	2270.0
25 Feb 05	1100	2270.0
25 Feb 05	1200	2270.0
25 Feb 05	1300	2270.0
25 Feb 05	1400	2270.0
25 Feb 05	1500	2270.0
25 Feb 05	1600	2270.0
25 Feb 05	1700	2270.0
25 Feb 05	1800	2270.0
25 Feb 05	1900	2270.0
25 Feb 05	2000	2270.0
25 Feb 05	2100	2270.0
25 Feb 05	2200	2270.0
25 Feb 05	2300	2270.0
25 Feb 05	2400	2270.0
26 Feb 05	0100	2270.0
26 Feb 05	0200	2270.0
26 Feb 05	0300	2270.0
26 Feb 05	0400	2270.0
26 Feb 05	0500	2270.0
26 Feb 05	0600	2270.0
26 Feb 05	0700	2270.0
26 Feb 05	0800	2270.0
26 Feb 05	0900	2270.0
26 Feb 05	1000	2270.0
26 Feb 05	1100	2270.0
26 Feb 05	1200	2270.0
26 Feb 05	1300	2270.0
26 Feb 05	1400	2270.0
26 Feb 05	1500	2270.0
26 Feb 05	1600	2270.0

Date	Time	Discharge (cfs)
26 Feb 05	1700	2270.0
26 Feb 05	1800	2270.0
26 Feb 05	1900	2270.0
26 Feb 05	2000	2270.0
26 Feb 05	2100	2270.0
26 Feb 05	2200	2270.0
26 Feb 05	2300	2270.0
26 Feb 05	2400	2270.0
27 Feb 05	0100	2270.0
27 Feb 05	0200	2270.0
27 Feb 05	0300	2270.0
27 Feb 05	0400	2270.0
27 Feb 05	0500	2270.0
27 Feb 05	0600	2270.0
27 Feb 05	0700	2270.0
27 Feb 05	0800	2270.0
27 Feb 05	0900	2270.0
27 Feb 05	1000	2270.0
27 Feb 05	1100	2270.0
27 Feb 05	1200	2270.0
27 Feb 05	1300	2270.0
27 Feb 05	1400	2270.0
27 Feb 05	1500	2270.0
27 Feb 05	1600	2270.0
27 Feb 05	1700	2270.0
27 Feb 05	1800	2270.0
27 Feb 05	1900	2270.0
27 Feb 05	2000	2270.0
27 Feb 05	2100	2270.0
27 Feb 05	2200	2270.0
27 Feb 05	2300	2270.0
27 Feb 05	2400	2270.0

HMS * Summary of Results for XS 10-Ald

Resthome

Project : Ruby Run Name : Run 2

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF Breach

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1504 Control Specs : 24-Hour

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
24 Feb 05	2400	2270	2270	5142.68
25 Feb 05	0100	2270	2270	5142.68
25 Feb 05	0200	2270	2270	5142.68
25 Feb 05	0300	2270	2270	5142.68
25 Feb 05	0400	2270	2270	5142.68
25 Feb 05	0500	2270	2270	5142.68
25 Feb 05	0600	2271	2271	5142.68
25 Feb 05	0700	2274	2273	5142.68
25 Feb 05	0800	2282	2279	5142.68
25 Feb 05	0900	2301	2292	5142.68
25 Feb 05	1000	2337	2321	5142.69
25 Feb 05	1100	2404	2374	5142.71
25 Feb 05	1200	2519	2468	5142.74
25 Feb 05	1300	2703	2621	5142.78
25 Feb 05	1400	2986	2861	5142.85
25 Feb 05	1500	3400	3218	5142.96
25 Feb 05	1600	3989	3732	5143.11
25 Feb 05	1700	4769	4432	5143.32
25 Feb 05	1800	5833	5378	5143.60
25 Feb 05	1900	7262	6658	5143.98
25 Feb 05	2000	9112	8340	5144.49
25 Feb 05	2100	11330	10414	5145.10
25 Feb 05	2200	13971	12893	5145.84
25 Feb 05	2300	17037	15798	5146.71
25 Feb 05	2400	20172	18916	5147.64
26 Feb 05	0100	23764	22337	5148.17
26 Feb 05	0200	28091	26386	5148.52
26 Feb 05	0300	36222	33053	5149.11
26 Feb 05	0400	46306	42420	5149.85
26 Feb 05	0500	55788	52263	5150.38
26 Feb 05	0600	63791	60775	5150.83
26 Feb 05	0700	70261	67804	5151.13
26 Feb 05	0800	75276	73364	5151.37
26 Feb 05	0900	78985	77567	5151.55
26 Feb 05	1000	81592	80594	5151.67
26 Feb 05	1100	83555	82803	5151.75
26 Feb 05	1200	869741	682584	5161.53
26 Feb 05	1300	335200	492592	5159.57
26 Feb 05	1400	128206	206496	5155.12
26 Feb 05	1500	87160	102964	5152.46
26 Feb 05	1600	80134	82828	5151.75

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
26 Feb 05	1700	77112	78268	5151.58
26 Feb 05	1800	74585	75549	5151.46
26 Feb 05	1900	72024	73000	5151.35
26 Feb 05	2000	69384	70389	5151.24
26 Feb 05	2100	66723	67733	5151.13
26 Feb 05	2200	64073	65077	5151.02
26 Feb 05	2300	61437	62433	5150.90
26 Feb 05	2400	58825	59808	5150.79
27 Feb 05	0100	56271	57229	5150.65
27 Feb 05	0200	53811	54730	5150.52
27 Feb 05	0300	51464	52337	5150.39
27 Feb 05	0400	49218	50049	5150.26
27 Feb 05	0500	47047	47845	5150.14
27 Feb 05	0600	44951	45755	5150.03
27 Feb 05	0700	42950	43720	5149.92
27 Feb 05	0800	41066	41792	5149.82
27 Feb 05	0900	39256	39955	5149.72
27 Feb 05	1000	37525	38195	5149.56
27 Feb 05	1100	35884	36521	5149.41
27 Feb 05	1200	34332	34936	5149.27
27 Feb 05	1300	32866	33437	5149.14
27 Feb 05	1400	31482	32022	5149.02
27 Feb 05	1500	30173	30685	5148.90
27 Feb 05	1600	28934	29420	5148.79
27 Feb 05	1700	27758	28220	5148.68
27 Feb 05	1800	26641	27081	5148.58
27 Feb 05	1900	25583	26001	5148.49
27 Feb 05	2000	24581	24977	5148.40
27 Feb 05	2100	23629	24006	5148.31
27 Feb 05	2200	22729	23086	5148.23
27 Feb 05	2300	21879	22217	5148.16
27 Feb 05	2400	21079	21397	5148.08

HMS * Summary of Results for XS 11 -
Alder

Project : Ruby Run Name : Run 2

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF Breach
End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP
Execution Time : 31May06 1504 Control Specs : 24-Hour

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
24 Feb 05	2400	2270	2270	5103.49
25 Feb 05	0100	2270	2270	5103.49
25 Feb 05	0200	2270	2270	5103.49
25 Feb 05	0300	2270	2270	5103.49
25 Feb 05	0400	2270	2270	5103.49
25 Feb 05	0500	2270	2270	5103.49
25 Feb 05	0600	2271	2271	5103.49
25 Feb 05	0700	2273	2272	5103.49
25 Feb 05	0800	2279	2277	5103.49
25 Feb 05	0900	2292	2289	5103.49
25 Feb 05	1000	2321	2314	5103.50
25 Feb 05	1100	2374	2361	5103.51
25 Feb 05	1200	2468	2444	5103.52
25 Feb 05	1300	2621	2583	5103.55
25 Feb 05	1400	2861	2801	5103.60
25 Feb 05	1500	3218	3129	5103.67
25 Feb 05	1600	3732	3604	5103.77
25 Feb 05	1700	4432	4259	5103.91
25 Feb 05	1800	5378	5146	5104.10
25 Feb 05	1900	6658	6347	5104.36
25 Feb 05	2000	8340	7934	5104.70
25 Feb 05	2100	10414	9918	5105.13
25 Feb 05	2200	12893	12305	5105.64
25 Feb 05	2300	15798	15115	5106.24
25 Feb 05	2400	18916	18188	5106.90
26 Feb 05	0100	22337	21544	5107.39
26 Feb 05	0200	26386	25453	5107.63
26 Feb 05	0300	33053	31529	5108.01
26 Feb 05	0400	42420	40298	5108.55
26 Feb 05	0500	52263	50051	5108.99
26 Feb 05	0600	60775	58872	5109.39
26 Feb 05	0700	67804	66239	5109.66
26 Feb 05	0800	73364	72214	5109.87
26 Feb 05	0900	77567	76701	5110.02
26 Feb 05	1000	80594	79971	5110.14
26 Feb 05	1100	82803	82349	5110.20
26 Feb 05	1200	682584	597818	5118.20
26 Feb 05	1300	492592	520297	5117.32
26 Feb 05	1400	206496	257431	5113.76
26 Feb 05	1500	102964	123918	5111.23
26 Feb 05	1600	82828	86957	5110.32

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
26 Feb 05	1700	78268	79206	5110.11
26 Feb 05	1800	75549	76110	5110.00
26 Feb 05	1900	73000	73526	5109.91
26 Feb 05	2000	70389	70932	5109.82
26 Feb 05	2100	67733	68323	5109.73
26 Feb 05	2200	65077	65668	5109.64
26 Feb 05	2300	62433	63022	5109.55
26 Feb 05	2400	59808	60394	5109.45
27 Feb 05	0100	57229	57806	5109.34
27 Feb 05	0200	54730	55289	5109.23
27 Feb 05	0300	52337	52873	5109.12
27 Feb 05	0400	50049	50563	5109.02
27 Feb 05	0500	47845	48341	5108.92
27 Feb 05	0600	45755	46226	5108.82
27 Feb 05	0700	43720	44179	5108.73
27 Feb 05	0800	41792	42228	5108.64
27 Feb 05	0900	39955	40371	5108.56
27 Feb 05	1000	38195	38594	5108.45
27 Feb 05	1100	36521	36901	5108.35
27 Feb 05	1200	34936	35296	5108.25
27 Feb 05	1300	33437	33779	5108.15
27 Feb 05	1400	32022	32345	5108.06
27 Feb 05	1500	30685	30991	5107.98
27 Feb 05	1600	29420	29710	5107.90
27 Feb 05	1700	28220	28495	5107.82
27 Feb 05	1800	27081	27343	5107.75
27 Feb 05	1900	26001	26249	5107.68
27 Feb 05	2000	24977	25213	5107.62
27 Feb 05	2100	24006	24230	5107.55
27 Feb 05	2200	23086	23299	5107.50
27 Feb 05	2300	22217	22418	5107.44
27 Feb 05	2400	21397	21587	5107.39

HMS * Summary of Results for XS 12 -
Laurin

Project : Ruby Run Name : Run 2

Start of Run : 25Feb05 0000 Basin Model : Ruby-PMF Breach
End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP
Execution Time : 31May06 1504 Control Specs : 24-Hour

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
24 Feb 05	2400	2270	2270	5040.42
25 Feb 05	0100	2270	2270	5040.42
25 Feb 05	0200	2270	2270	5040.42
25 Feb 05	0300	2270	2270	5040.42
25 Feb 05	0400	2270	2270	5040.42
25 Feb 05	0500	2270	2270	5040.42
25 Feb 05	0600	2271	2270	5040.42
25 Feb 05	0700	2272	2272	5040.42
25 Feb 05	0800	2277	2275	5040.42
25 Feb 05	0900	2289	2284	5040.42
25 Feb 05	1000	2314	2304	5040.42
25 Feb 05	1100	2361	2343	5040.43
25 Feb 05	1200	2444	2412	5040.44
25 Feb 05	1300	2583	2529	5040.46
25 Feb 05	1400	2801	2717	5040.50
25 Feb 05	1500	3129	3004	5040.55
25 Feb 05	1600	3604	3424	5040.63
25 Feb 05	1700	4259	4012	5040.74
25 Feb 05	1800	5146	4814	5040.88
25 Feb 05	1900	6347	5902	5041.08
25 Feb 05	2000	7934	7351	5041.35
25 Feb 05	2100	9918	9198	5041.69
25 Feb 05	2200	12305	11447	5042.10
25 Feb 05	2300	15115	14115	5042.59
25 Feb 05	2400	18188	17104	5043.14
26 Feb 05	0100	21544	20370	5043.69
26 Feb 05	0200	25453	24097	5043.89
26 Feb 05	0300	31529	29441	5044.18
26 Feb 05	0400	40298	37317	5044.61
26 Feb 05	0500	50051	46791	5045.00
26 Feb 05	0600	58872	56105	5045.34
26 Feb 05	0700	66239	63947	5045.59
26 Feb 05	0800	72214	70366	5045.78
26 Feb 05	0900	76701	75319	5045.92
26 Feb 05	1000	79971	78967	5046.03
26 Feb 05	1100	82349	81620	5046.10
26 Feb 05	1200	597818	488840	5052.57
26 Feb 05	1300	520297	536047	5053.08
26 Feb 05	1400	257431	321762	5050.56
26 Feb 05	1500	123918	163408	5047.98
26 Feb 05	1600	86957	98170	5046.53

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
26 Feb 05	1700	79206	81583	5046.10
26 Feb 05	1800	76110	77063	5045.97
26 Feb 05	1900	73526	74323	5045.90
26 Feb 05	2000	70932	71733	5045.82
26 Feb 05	2100	68323	69131	5045.74
26 Feb 05	2200	65668	66492	5045.67
26 Feb 05	2300	63022	63845	5045.59
26 Feb 05	2400	60394	61214	5045.52
27 Feb 05	0100	57806	58615	5045.43
27 Feb 05	0200	55289	56079	5045.34
27 Feb 05	0300	52873	53633	5045.25
27 Feb 05	0400	50563	51292	5045.17
27 Feb 05	0500	48341	49044	5045.09
27 Feb 05	0600	46226	46937	5045.01
27 Feb 05	0700	44179	44869	5044.94
27 Feb 05	0800	42228	42887	5044.86
27 Feb 05	0900	40371	40999	5044.80
27 Feb 05	1000	38594	39197	5044.72
27 Feb 05	1100	36901	37477	5044.62
27 Feb 05	1200	35296	35843	5044.53
27 Feb 05	1300	33779	34297	5044.45
27 Feb 05	1400	32345	32835	5044.37
27 Feb 05	1500	30991	31455	5044.29
27 Feb 05	1600	29710	30150	5044.22
27 Feb 05	1700	28495	28913	5044.16
27 Feb 05	1800	27343	27740	5044.09
27 Feb 05	1900	26249	26627	5044.03
27 Feb 05	2000	25213	25571	5043.97
27 Feb 05	2100	24230	24571	5043.92
27 Feb 05	2200	23299	23622	5043.87
27 Feb 05	2300	22418	22724	5043.82
27 Feb 05	2400	21587	21877	5043.77

Ruby Dam
Incremental Hazard Screening Study

APPENDIX H

HEC-HMS PMF ROUTING WITH DAM BREACH "B"

HMS * Summary of Results

Project : Ruby Run Name : Run 3

Start of Run : 25Feb05 0000 Basin Model : RUby-PMFLowDischarge

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1507 Control Specs : 24-Hour

Hydrologic Element	Discharge Peak (cfs)	Stage Peak (ft)	Time of Peak	e (ac ft)	Drainage Area (sq mi)
Ruby Basin	83727		26 Feb 05 1000	229761	595.000
Ruby Reservoir	465343		26 Feb 05 1200	264073	595.000
XS 4	451439	5336.5	26 Feb 05 1200	264297	595.000
XS 7	424194	5277.9	26 Feb 05 1200	264730	595.000
XS 8	389682	5231.2	26 Feb 05 1200	265687	595.000
100 yr Concurrent	2270.0		24 Feb 05 2400	13507	54.000
XS 10-Ald Resthome	352012	5157.7	26 Feb 05 1300	278770	649.000
XS 11 - Alder	340033	5115.0	26 Feb 05 1300	278757	649.000
XS 12 - Laurin	316285	5050.5	26 Feb 05 1300	278537	649.000

HMS * Summary of Results for Ruby Basin

Project : Ruby Run Name : Run 3

Start of Run : 25Feb05 0000 Basin Model : RUby-PMFLowDischarge

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1507 Control Specs : 24-Hour

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
24 Feb 05	2400				0	0	0
25 Feb 05	0100	0.01	0.01	0.00	0	0	0
25 Feb 05	0200	0.03	0.03	0.00	3	0	3
25 Feb 05	0300	0.13	0.11	0.01	12	0	12
25 Feb 05	0400	0.26	0.20	0.06	55	0	55
25 Feb 05	0500	0.26	0.20	0.06	142	0	142
25 Feb 05	0600	0.38	0.20	0.18	333	0	333
25 Feb 05	0700	0.38	0.20	0.18	653	0	653
25 Feb 05	0800	0.38	0.20	0.18	1114	0	1114
25 Feb 05	0900	0.38	0.20	0.18	1727	0	1727
25 Feb 05	1000	0.43	0.20	0.24	2540	0	2540
25 Feb 05	1100	0.43	0.20	0.24	3589	0	3589
25 Feb 05	1200	0.46	0.20	0.26	4890	0	4890
25 Feb 05	1300	0.47	0.20	0.28	6471	0	6471
25 Feb 05	1400	0.51	0.20	0.31	8329	0	8329
25 Feb 05	1500	0.60	0.20	0.40	10532	0	10532
25 Feb 05	1600	0.74	0.20	0.54	13151	0	13151
25 Feb 05	1700	1.97	0.20	1.77	16811	0	16811
25 Feb 05	1800	0.51	0.20	0.31	20997	0	20997
25 Feb 05	1900	0.51	0.20	0.31	25480	0	25480
25 Feb 05	2000	0.47	0.20	0.28	30188	0	30188
25 Feb 05	2100	0.47	0.20	0.28	35235	0	35235
25 Feb 05	2200	0.46	0.20	0.26	40621	0	40621
25 Feb 05	2300	0.46	0.20	0.26	46212	0	46212
25 Feb 05	2400	0.43	0.20	0.24	51812	0	51812
26 Feb 05	0100	0.43	0.20	0.24	57016	0	57016
26 Feb 05	0200	0.43	0.20	0.24	62272	0	62272
26 Feb 05	0300	0.43	0.20	0.24	67115	0	67115
26 Feb 05	0400	0.38	0.20	0.18	71386	0	71386
26 Feb 05	0500	0.38	0.20	0.18	74997	0	74997
26 Feb 05	0600	0.26	0.20	0.06	78178	0	78178
26 Feb 05	0700	0.26	0.20	0.06	80817	0	80817
26 Feb 05	0800	0.26	0.20	0.06	82288	0	82288
26 Feb 05	0900	0.26	0.20	0.06	83233	0	83233
26 Feb 05	1000	0.26	0.20	0.06	83727	0	83727
26 Feb 05	1100	0.26	0.20	0.06	83215	0	83215
26 Feb 05	1200	0.26	0.20	0.06	82222	0	82222
26 Feb 05	1300	0.26	0.20	0.06	80943	0	80943
26 Feb 05	1400	0.26	0.20	0.06	79047	0	79047
26 Feb 05	1500	0.26	0.20	0.06	76877	0	76877
26 Feb 05	1600	0.13	0.11	0.01	74534	0	74534

Date	Time	Precip. (in)	Loss (in)	Excess (in)	Direct Q (cfs)	Base-flow (cfs)	Total Q (cfs)
26 Feb 05	1700	0.13	0.11	0.01	72178	0	72178
26 Feb 05	1800	0.13	0.11	0.01	69588	0	69588
26 Feb 05	1900	0.13	0.11	0.01	66877	0	66877
26 Feb 05	2000	0.13	0.11	0.01	64156	0	64156
26 Feb 05	2100	0.13	0.11	0.01	61478	0	61478
26 Feb 05	2200	0.13	0.11	0.01	58810	0	58810
26 Feb 05	2300	0.13	0.11	0.01	56143	0	56143
26 Feb 05	2400	0.13	0.11	0.01	53546	0	53546
27 Feb 05	0100	0.13	0.11	0.01	51043	0	51043
27 Feb 05	0200	0.13	0.11	0.01	48687	0	48687
27 Feb 05	0300	0.03	0.03	0.00	46438	0	46438
27 Feb 05	0400	0.03	0.03	0.00	44253	0	44253
27 Feb 05	0500	0.03	0.03	0.00	42121	0	42121
27 Feb 05	0600	0.03	0.03	0.00	40102	0	40102
27 Feb 05	0700	0.03	0.03	0.00	38205	0	38205
27 Feb 05	0800	0.03	0.03	0.00	36393	0	36393
27 Feb 05	0900	0.03	0.03	0.00	34646	0	34646
27 Feb 05	1000	0.03	0.03	0.00	33003	0	33003
27 Feb 05	1100	0.03	0.03	0.00	31456	0	31456
27 Feb 05	1200	0.03	0.03	0.00	29996	0	29996
27 Feb 05	1300	0.03	0.03	0.00	28616	0	28616
27 Feb 05	1400	0.01	0.01	0.00	27318	0	27318
27 Feb 05	1500	0.01	0.01	0.00	26088	0	26088
27 Feb 05	1600	0.01	0.01	0.00	24918	0	24918
27 Feb 05	1700	0.01	0.01	0.00	23806	0	23806
27 Feb 05	1800	0.01	0.01	0.00	22759	0	22759
27 Feb 05	1900	0.01	0.01	0.00	21768	0	21768
27 Feb 05	2000	0.01	0.01	0.00	20825	0	20825
27 Feb 05	2100	0.01	0.01	0.00	19934	0	19934
27 Feb 05	2200	0.01	0.01	0.00	19097	0	19097
27 Feb 05	2300	0.01	0.01	0.00	18308	0	18308
27 Feb 05	2400	0.01	0.01	0.00	17574	0	17574

HMS * Summary of Results for Ruby Reservoir

Project : Ruby Run Name : Run 3

Start of Run	: 25Feb05 0000	Basin Model	: RUby-PMFLowDischarge
End of Run	: 28Feb05 0000	Met. Model	: 24 HR, PMP
Execution Time	: 31May06 1507	Control Specs	: 24-Hour

Computed Results

Peak Inflow	: 83727 (cfs)	Date/Time of Peak Inflow	: 26 Feb 05 1000
Peak Outflow	: 465343 (cfs)	Date/Time of Peak Outflow	: 26 Feb 05 1200
Total Inflow	: 7.24 (in)	Peak Storage	: 76585(ac-ft)
Total Outflow	: 8.32 (in)	Peak Elevation	: 5422.3(ft)

HMS * Summary of Results for Ruby Reservoir

Project : Ruby Run Name : Run 3

Start of Run : 25Feb05 0000 Basin Model : RUby-PMFLowDischarge

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1507 Control Specs : 24-Hour

Date	Time	Reservoir Storage (ac-ft)	Reservoir Elevation (ft)	Inflow (cfs)	Outflow (cfs)
24 Feb 05	2400	41516	5396.7	0	0
25 Feb 05	0100	41516	5396.7	0	0
25 Feb 05	0200	41516	5396.7	3	0
25 Feb 05	0300	41517	5396.7	12	0
25 Feb 05	0400	41519	5396.7	55	0
25 Feb 05	0500	41527	5396.7	142	0
25 Feb 05	0600	41547	5396.7	333	2
25 Feb 05	0700	41587	5396.8	653	6
25 Feb 05	0800	41660	5396.8	1114	16
25 Feb 05	0900	41775	5396.9	1727	38
25 Feb 05	1000	41946	5397.1	2540	82
25 Feb 05	1100	42189	5397.3	3589	160
25 Feb 05	1200	42521	5397.6	4890	292
25 Feb 05	1300	42958	5398.0	6471	502
25 Feb 05	1400	43515	5398.5	8329	819
25 Feb 05	1500	44207	5399.2	10532	1280
25 Feb 05	1600	45053	5399.9	13151	1928
25 Feb 05	1700	46097	5400.8	16811	2772
25 Feb 05	1800	47383	5401.9	20997	3935
25 Feb 05	1900	48914	5403.2	25480	5488
25 Feb 05	2000	50678	5404.7	30188	7479
25 Feb 05	2100	52667	5406.3	35235	9809
25 Feb 05	2200	54876	5408.0	40621	12594
25 Feb 05	2300	57287	5409.9	46212	15887
25 Feb 05	2400	59898	5411.6	51812	18952
26 Feb 05	0100	62672	5413.5	57016	22751
26 Feb 05	0200	65532	5415.4	62272	27321
26 Feb 05	0300	68224	5417.2	67115	36920
26 Feb 05	0400	70470	5418.6	71386	47229
26 Feb 05	0500	72239	5419.7	74997	56346
26 Feb 05	0600	73602	5420.5	78178	63840
26 Feb 05	0700	74648	5421.2	80817	69841
26 Feb 05	0800	75427	5421.6	82288	74418
26 Feb 05	0900	75979	5422.0	83233	77743
26 Feb 05	1000	76358	5422.2	83727	80034
26 Feb 05	1100	76585	5422.3	83215	81415
26 Feb 05	1200	60828	5412.2	82222	465343
26 Feb 05	1300	35981	5390.3	80943	299121
26 Feb 05	1400	24160	5360.3	79047	146952
26 Feb 05	1500	20109	5350.1	76877	107002

Date	Time	Reservoir Storage (ac-ft)	Reservoir Elevation (ft)	Inflow (cfs)	Outflow (cfs)
26 Feb 05	1600	18210	5345.2	74534	90358
26 Feb 05	1700	17161	5342.6	72178	81731
26 Feb 05	1800	16486	5340.9	69588	76385
26 Feb 05	1900	15975	5339.6	66877	72450
26 Feb 05	2000	15538	5338.4	64156	69161
26 Feb 05	2100	15136	5337.4	61478	66198
26 Feb 05	2200	14751	5336.4	58810	63413
26 Feb 05	2300	14371	5335.5	56143	60722
26 Feb 05	2400	13994	5334.5	53546	58098
27 Feb 05	0100	13619	5333.6	51043	55547
27 Feb 05	0200	13251	5332.6	48687	53088
27 Feb 05	0300	12892	5331.7	46438	50734
27 Feb 05	0400	12540	5330.8	44253	48475
27 Feb 05	0500	12193	5330.0	42121	46292
27 Feb 05	0600	11852	5329.1	40102	44188
27 Feb 05	0700	11519	5328.2	38205	42176
27 Feb 05	0800	11195	5327.4	36393	40258
27 Feb 05	0900	10880	5326.6	34646	38424
27 Feb 05	1000	10572	5325.8	33003	36673
27 Feb 05	1100	10273	5325.1	31456	35008
27 Feb 05	1200	9985	5324.3	29996	33429
27 Feb 05	1300	9706	5323.6	28616	31932
27 Feb 05	1400	9437	5323.0	27318	30515
27 Feb 05	1500	9177	5322.3	26088	29174
27 Feb 05	1600	8926	5321.7	24918	27902
27 Feb 05	1700	8684	5321.0	23806	26694
27 Feb 05	1800	8449	5320.4	22759	25547
27 Feb 05	1900	8223	5319.9	21768	24460
27 Feb 05	2000	8004	5319.3	20825	23428
27 Feb 05	2100	7792	5318.8	19934	22448
27 Feb 05	2200	7588	5318.3	19097	21519
27 Feb 05	2300	7392	5317.8	18308	20639
27 Feb 05	2400	7203	5317.3	17574	19808

HMS * Summary of Results for XS 4

Project : Ruby Run Name : Run 3

Start of Run : 25Feb05 0000 Basin Model : RUby-PMFLowDischarge

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1507 Control Specs : 24-Hour

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
24 Feb 05	2400	0	0	5280.00
25 Feb 05	0100	0	0	5280.00
25 Feb 05	0200	0	0	5280.00
25 Feb 05	0300	0	0	5280.00
25 Feb 05	0400	0	0	5280.00
25 Feb 05	0500	0	0	5280.00
25 Feb 05	0600	2	1	5280.00
25 Feb 05	0700	6	5	5280.00
25 Feb 05	0800	16	15	5280.01
25 Feb 05	0900	38	36	5280.03
25 Feb 05	1000	82	79	5280.07
25 Feb 05	1100	160	154	5280.14
25 Feb 05	1200	292	282	5280.26
25 Feb 05	1300	502	486	5280.45
25 Feb 05	1400	819	796	5280.73
25 Feb 05	1500	1280	1245	5281.14
25 Feb 05	1600	1928	1879	5281.72
25 Feb 05	1700	2772	2708	5282.48
25 Feb 05	1800	3935	3847	5283.52
25 Feb 05	1900	5488	5370	5284.92
25 Feb 05	2000	7479	7325	5286.71
25 Feb 05	2100	9809	9627	5288.82
25 Feb 05	2200	12594	12375	5291.34
25 Feb 05	2300	15887	15626	5294.31
25 Feb 05	2400	18952	18707	5297.14
26 Feb 05	0100	22751	22460	5298.97
26 Feb 05	0200	27321	26989	5300.17
26 Feb 05	0300	36920	36268	5302.63
26 Feb 05	0400	47229	46569	5304.83
26 Feb 05	0500	56346	55787	5306.52
26 Feb 05	0600	63840	63395	5307.80
26 Feb 05	0700	69841	69494	5308.71
26 Feb 05	0800	74418	74157	5309.41
26 Feb 05	0900	77743	77555	5309.91
26 Feb 05	1000	80034	79905	5310.27
26 Feb 05	1100	81415	81987	5310.54
26 Feb 05	1200	465343	451439	5336.50
26 Feb 05	1300	299121	305701	5328.81
26 Feb 05	1400	146952	154311	5318.63
26 Feb 05	1500	107002	109117	5313.92
26 Feb 05	1600	90358	91263	5311.74
26 Feb 05	1700	81731	82211	5310.57

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
26 Feb 05	1800	76385	76688	5309.78
26 Feb 05	1900	72450	72676	5309.18
26 Feb 05	2000	69161	69351	5308.69
26 Feb 05	2100	66198	66371	5308.24
26 Feb 05	2200	63413	63577	5307.82
26 Feb 05	2300	60722	60883	5307.42
26 Feb 05	2400	58098	58257	5306.97
27 Feb 05	0100	55547	55703	5306.50
27 Feb 05	0200	53088	53240	5306.05
27 Feb 05	0300	50734	50881	5305.62
27 Feb 05	0400	48475	48617	5305.20
27 Feb 05	0500	46292	46431	5304.80
27 Feb 05	0600	44188	44324	5304.41
27 Feb 05	0700	42176	42307	5304.04
27 Feb 05	0800	40258	40385	5303.69
27 Feb 05	0900	38424	38547	5303.23
27 Feb 05	1000	36673	36791	5302.77
27 Feb 05	1100	35008	35122	5302.33
27 Feb 05	1200	33429	33538	5301.91
27 Feb 05	1300	31932	32037	5301.51
27 Feb 05	1400	30515	30616	5301.13
27 Feb 05	1500	29174	29270	5300.78
27 Feb 05	1600	27902	27994	5300.44
27 Feb 05	1700	26694	26783	5300.12
27 Feb 05	1800	25547	25632	5299.81
27 Feb 05	1900	24460	24541	5299.52
27 Feb 05	2000	23428	23506	5299.25
27 Feb 05	2100	22448	22523	5298.99
27 Feb 05	2200	21519	21591	5298.74
27 Feb 05	2300	20639	20708	5298.51
27 Feb 05	2400	19808	19874	5298.20

HMS * Summary of Results for XS 7

Project : Ruby Run Name : Run 3

Start of Run : 25Feb05 0000 Basin Model : RUby-PMFLowDischarge

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1507 Control Specs : 24-Hour

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
24 Feb 05	2400	0	0	5246.00
25 Feb 05	0100	0	0	5246.00
25 Feb 05	0200	0	0	5246.00
25 Feb 05	0300	0	0	5246.00
25 Feb 05	0400	0	0	5246.00
25 Feb 05	0500	0	0	5246.00
25 Feb 05	0600	1	1	5246.00
25 Feb 05	0700	5	5	5246.00
25 Feb 05	0800	15	13	5246.01
25 Feb 05	0900	36	33	5246.02
25 Feb 05	1000	79	72	5246.04
25 Feb 05	1100	154	142	5246.08
25 Feb 05	1200	282	262	5246.15
25 Feb 05	1300	486	455	5246.26
25 Feb 05	1400	796	748	5246.42
25 Feb 05	1500	1245	1177	5246.66
25 Feb 05	1600	1879	1783	5247.00
25 Feb 05	1700	2708	2584	5247.45
25 Feb 05	1800	3847	3677	5248.06
25 Feb 05	1900	5370	5143	5248.89
25 Feb 05	2000	7325	7036	5249.95
25 Feb 05	2100	9627	9287	5251.21
25 Feb 05	2200	12375	11970	5252.72
25 Feb 05	2300	15626	15147	5254.50
25 Feb 05	2400	18707	18253	5256.24
26 Feb 05	0100	22460	21908	5257.51
26 Feb 05	0200	26989	26323	5258.18
26 Feb 05	0300	36268	34902	5259.49
26 Feb 05	0400	46569	45231	5260.76
26 Feb 05	0500	55787	54590	5261.64
26 Feb 05	0600	63395	62406	5262.34
26 Feb 05	0700	69494	68701	5262.84
26 Feb 05	0800	74157	73550	5263.23
26 Feb 05	0900	77555	77116	5263.51
26 Feb 05	1000	79905	79604	5263.71
26 Feb 05	1100	81987	81725	5263.86
26 Feb 05	1200	451439	424194	5277.94
26 Feb 05	1300	305701	317619	5274.77
26 Feb 05	1400	154311	169369	5268.94
26 Feb 05	1500	109117	114228	5265.98
26 Feb 05	1600	91263	93423	5264.66
26 Feb 05	1700	82211	83349	5263.97

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
26 Feb 05	1800	76688	77401	5263.53
26 Feb 05	1900	72676	73198	5263.20
26 Feb 05	2000	69351	69783	5262.93
26 Feb 05	2100	66371	66758	5262.69
26 Feb 05	2200	63577	63940	5262.46
26 Feb 05	2300	60883	61233	5262.25
26 Feb 05	2400	58257	58598	5262.02
27 Feb 05	0100	55703	56035	5261.78
27 Feb 05	0200	53240	53560	5261.54
27 Feb 05	0300	50881	51188	5261.32
27 Feb 05	0400	48617	48911	5261.11
27 Feb 05	0500	46431	46715	5260.90
27 Feb 05	0600	44324	44597	5260.70
27 Feb 05	0700	42307	42569	5260.51
27 Feb 05	0800	40385	40634	5260.33
27 Feb 05	0900	38547	38817	5260.09
27 Feb 05	1000	36791	37049	5259.82
27 Feb 05	1100	35122	35367	5259.56
27 Feb 05	1200	33538	33771	5259.32
27 Feb 05	1300	32037	32258	5259.09
27 Feb 05	1400	30616	30825	5258.87
27 Feb 05	1500	29270	29468	5258.66
27 Feb 05	1600	27994	28182	5258.47
27 Feb 05	1700	26783	26961	5258.28
27 Feb 05	1800	25632	25802	5258.10
27 Feb 05	1900	24541	24702	5257.94
27 Feb 05	2000	23506	23658	5257.78
27 Feb 05	2100	22523	22667	5257.63
27 Feb 05	2200	21591	21728	5257.48
27 Feb 05	2300	20708	20838	5257.35
27 Feb 05	2400	19874	19997	5257.22

HMS * Summary of Results for XS 8

Project : Ruby Run Name : Run 3

Start of Run : 25Feb05 0000 Basin Model : RUby-PMFLowDischarge

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1507 Control Specs : 24-Hour

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
24 Feb 05	2400	0	0	5214.00
25 Feb 05	0100	0	0	5214.00
25 Feb 05	0200	0	0	5214.00
25 Feb 05	0300	0	0	5214.00
25 Feb 05	0400	0	0	5214.00
25 Feb 05	0500	0	0	5214.00
25 Feb 05	0600	1	1	5214.00
25 Feb 05	0700	5	4	5214.00
25 Feb 05	0800	13	11	5214.00
25 Feb 05	0900	33	28	5214.01
25 Feb 05	1000	72	62	5214.02
25 Feb 05	1100	142	125	5214.04
25 Feb 05	1200	262	234	5214.07
25 Feb 05	1300	455	410	5214.13
25 Feb 05	1400	748	682	5214.21
25 Feb 05	1500	1177	1081	5214.34
25 Feb 05	1600	1783	1651	5214.52
25 Feb 05	1700	2584	2412	5214.76
25 Feb 05	1800	3677	3445	5215.08
25 Feb 05	1900	5143	4836	5215.52
25 Feb 05	2000	7036	6644	5216.09
25 Feb 05	2100	9287	8826	5216.77
25 Feb 05	2200	11970	11425	5217.59
25 Feb 05	2300	15147	14419	5218.53
25 Feb 05	2400	18253	17567	5219.52
26 Feb 05	0100	21908	21119	5220.37
26 Feb 05	0200	26323	25387	5220.71
26 Feb 05	0300	34902	33116	5221.34
26 Feb 05	0400	45231	43113	5222.07
26 Feb 05	0500	54590	52688	5222.63
26 Feb 05	0600	62406	60827	5223.10
26 Feb 05	0700	68701	67434	5223.41
26 Feb 05	0800	73550	72577	5223.65
26 Feb 05	0900	77116	76408	5223.83
26 Feb 05	1000	79604	79115	5223.96
26 Feb 05	1100	81725	81311	5224.05
26 Feb 05	1200	424194	389682	5231.22
26 Feb 05	1300	317619	328931	5230.32
26 Feb 05	1400	169369	192655	5227.59
26 Feb 05	1500	114228	123910	5225.65
26 Feb 05	1600	93423	97307	5224.70
26 Feb 05	1700	83349	85294	5224.21

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
26 Feb 05	1800	77401	78573	5223.93
26 Feb 05	1900	73198	74039	5223.72
26 Feb 05	2000	69783	70469	5223.55
26 Feb 05	2100	66758	67367	5223.41
26 Feb 05	2200	63940	64508	5223.27
26 Feb 05	2300	61233	61779	5223.14
26 Feb 05	2400	58598	59131	5223.01
27 Feb 05	0100	56035	56554	5222.86
27 Feb 05	0200	53560	54062	5222.71
27 Feb 05	0300	51188	51670	5222.57
27 Feb 05	0400	48911	49375	5222.44
27 Feb 05	0500	46715	47164	5222.31
27 Feb 05	0600	44597	45031	5222.18
27 Feb 05	0700	42569	42985	5222.06
27 Feb 05	0800	40634	41032	5221.95
27 Feb 05	0900	38817	39191	5221.83
27 Feb 05	1000	37049	37415	5221.68
27 Feb 05	1100	35367	35716	5221.55
27 Feb 05	1200	33771	34102	5221.42
27 Feb 05	1300	32258	32573	5221.29
27 Feb 05	1400	30825	31124	5221.18
27 Feb 05	1500	29468	29752	5221.07
27 Feb 05	1600	28182	28452	5220.96
27 Feb 05	1700	26961	27218	5220.86
27 Feb 05	1800	25802	26047	5220.77
27 Feb 05	1900	24702	24935	5220.68
27 Feb 05	2000	23658	23881	5220.59
27 Feb 05	2100	22667	22879	5220.51
27 Feb 05	2200	21728	21930	5220.44
27 Feb 05	2300	20838	21030	5220.36
27 Feb 05	2400	19997	20179	5220.29

HMS * Summary of Results for 100 yr

Concurrent

Project : Ruby Run Name : Run 3

Start of Run : 25Feb05 0000 Basin Model : RUby-PMFLowDischarge

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1507 Control Specs : 24-Hour

Date	Time	Discharge (cfs)
24 Feb 05	2400	2270.0
25 Feb 05	0100	2270.0
25 Feb 05	0200	2270.0
25 Feb 05	0300	2270.0
25 Feb 05	0400	2270.0
25 Feb 05	0500	2270.0
25 Feb 05	0600	2270.0
25 Feb 05	0700	2270.0
25 Feb 05	0800	2270.0
25 Feb 05	0900	2270.0
25 Feb 05	1000	2270.0
25 Feb 05	1100	2270.0
25 Feb 05	1200	2270.0
25 Feb 05	1300	2270.0
25 Feb 05	1400	2270.0
25 Feb 05	1500	2270.0
25 Feb 05	1600	2270.0
25 Feb 05	1700	2270.0
25 Feb 05	1800	2270.0
25 Feb 05	1900	2270.0
25 Feb 05	2000	2270.0
25 Feb 05	2100	2270.0
25 Feb 05	2200	2270.0
25 Feb 05	2300	2270.0
25 Feb 05	2400	2270.0
26 Feb 05	0100	2270.0
26 Feb 05	0200	2270.0
26 Feb 05	0300	2270.0
26 Feb 05	0400	2270.0
26 Feb 05	0500	2270.0
26 Feb 05	0600	2270.0
26 Feb 05	0700	2270.0
26 Feb 05	0800	2270.0
26 Feb 05	0900	2270.0
26 Feb 05	1000	2270.0
26 Feb 05	1100	2270.0
26 Feb 05	1200	2270.0
26 Feb 05	1300	2270.0
26 Feb 05	1400	2270.0
26 Feb 05	1500	2270.0
26 Feb 05	1600	2270.0

Date	Time	Discharge (cfs)
26 Feb 05	1700	2270.0
26 Feb 05	1800	2270.0
26 Feb 05	1900	2270.0
26 Feb 05	2000	2270.0
26 Feb 05	2100	2270.0
26 Feb 05	2200	2270.0
26 Feb 05	2300	2270.0
26 Feb 05	2400	2270.0
27 Feb 05	0100	2270.0
27 Feb 05	0200	2270.0
27 Feb 05	0300	2270.0
27 Feb 05	0400	2270.0
27 Feb 05	0500	2270.0
27 Feb 05	0600	2270.0
27 Feb 05	0700	2270.0
27 Feb 05	0800	2270.0
27 Feb 05	0900	2270.0
27 Feb 05	1000	2270.0
27 Feb 05	1100	2270.0
27 Feb 05	1200	2270.0
27 Feb 05	1300	2270.0
27 Feb 05	1400	2270.0
27 Feb 05	1500	2270.0
27 Feb 05	1600	2270.0
27 Feb 05	1700	2270.0
27 Feb 05	1800	2270.0
27 Feb 05	1900	2270.0
27 Feb 05	2000	2270.0
27 Feb 05	2100	2270.0
27 Feb 05	2200	2270.0
27 Feb 05	2300	2270.0
27 Feb 05	2400	2270.0

HMS * Summary of Results for XS 10-Ald

Resthome

Project : Ruby Run Name : Run 3

Start of Run : 25Feb05 0000 Basin Model : RUby-PMFLowDischarge

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1507 Control Specs : 24-Hour

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
24 Feb 05	2400	2270	2270	5142.68
25 Feb 05	0100	2270	2270	5142.68
25 Feb 05	0200	2270	2270	5142.68
25 Feb 05	0300	2270	2270	5142.68
25 Feb 05	0400	2270	2270	5142.68
25 Feb 05	0500	2270	2270	5142.68
25 Feb 05	0600	2271	2271	5142.68
25 Feb 05	0700	2274	2272	5142.68
25 Feb 05	0800	2281	2277	5142.68
25 Feb 05	0900	2298	2290	5142.68
25 Feb 05	1000	2332	2315	5142.69
25 Feb 05	1100	2395	2364	5142.70
25 Feb 05	1200	2504	2450	5142.73
25 Feb 05	1300	2680	2593	5142.77
25 Feb 05	1400	2952	2818	5142.84
25 Feb 05	1500	3351	3155	5142.94
25 Feb 05	1600	3921	3644	5143.09
25 Feb 05	1700	4682	4315	5143.29
25 Feb 05	1800	5715	5222	5143.56
25 Feb 05	1900	7106	6450	5143.92
25 Feb 05	2000	8914	8071	5144.41
25 Feb 05	2100	11096	10090	5145.01
25 Feb 05	2200	13695	12511	5145.73
25 Feb 05	2300	16689	15339	5146.57
25 Feb 05	2400	19837	18431	5147.49
26 Feb 05	0100	23389	21817	5148.12
26 Feb 05	0200	27657	25783	5148.47
26 Feb 05	0300	35386	32029	5149.02
26 Feb 05	0400	45383	41091	5149.78
26 Feb 05	0500	54958	51192	5150.32
26 Feb 05	0600	63097	59789	5150.79
26 Feb 05	0700	69704	66979	5151.10
26 Feb 05	0800	74847	72712	5151.34
26 Feb 05	0900	78678	77083	5151.53
26 Feb 05	1000	81385	80257	5151.66
26 Feb 05	1100	83581	82668	5151.75
26 Feb 05	1200	391952	280314	5156.53
26 Feb 05	1300	331201	352012	5157.67
26 Feb 05	1400	194925	245087	5155.89
26 Feb 05	1500	126180	153500	5153.91
26 Feb 05	1600	99577	110543	5152.70

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
26 Feb 05	1700	87564	92566	5152.10
26 Feb 05	1800	80843	83645	5151.78
26 Feb 05	1900	76309	78197	5151.57
26 Feb 05	2000	72739	74223	5151.40
26 Feb 05	2100	69637	70923	5151.26
26 Feb 05	2200	66778	67959	5151.14
26 Feb 05	2300	64049	65172	5151.02
26 Feb 05	2400	61401	62485	5150.91
27 Feb 05	0100	58824	59872	5150.79
27 Feb 05	0200	56332	57338	5150.66
27 Feb 05	0300	53940	54897	5150.52
27 Feb 05	0400	51645	52554	5150.40
27 Feb 05	0500	49434	50300	5150.28
27 Feb 05	0600	47301	48125	5150.16
27 Feb 05	0700	45255	46121	5150.05
27 Feb 05	0800	43302	44138	5149.94
27 Feb 05	0900	41461	42251	5149.84
27 Feb 05	1000	39685	40448	5149.74
27 Feb 05	1100	37986	38717	5149.61
27 Feb 05	1200	36372	37068	5149.46
27 Feb 05	1300	34843	35504	5149.32
27 Feb 05	1400	33394	34022	5149.19
27 Feb 05	1500	32022	32618	5149.07
27 Feb 05	1600	30722	31288	5148.95
27 Feb 05	1700	29488	30026	5148.84
27 Feb 05	1800	28317	28828	5148.74
27 Feb 05	1900	27205	27692	5148.64
27 Feb 05	2000	26151	26613	5148.54
27 Feb 05	2100	25149	25589	5148.45
27 Feb 05	2200	24200	24618	5148.37
27 Feb 05	2300	23300	23696	5148.29
27 Feb 05	2400	22449	22825	5148.21

HMS * Summary of Results for XS 11 - Alder

Project : Ruby Run Name : Run 3

Start of Run : 25Feb05 0000 Basin Model : RUby-PMFLowDischarge

End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP

Execution Time : 31May06 1507 Control Specs : 24-Hour

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
24 Feb 05	2400	2270	2270	5103.49
25 Feb 05	0100	2270	2270	5103.49
25 Feb 05	0200	2270	2270	5103.49
25 Feb 05	0300	2270	2270	5103.49
25 Feb 05	0400	2270	2270	5103.49
25 Feb 05	0500	2270	2270	5103.49
25 Feb 05	0600	2271	2271	5103.49
25 Feb 05	0700	2272	2272	5103.49
25 Feb 05	0800	2277	2276	5103.49
25 Feb 05	0900	2290	2286	5103.49
25 Feb 05	1000	2315	2308	5103.49
25 Feb 05	1100	2364	2350	5103.50
25 Feb 05	1200	2450	2425	5103.52
25 Feb 05	1300	2593	2551	5103.55
25 Feb 05	1400	2818	2752	5103.59
25 Feb 05	1500	3155	3057	5103.66
25 Feb 05	1600	3644	3503	5103.75
25 Feb 05	1700	4315	4123	5103.88
25 Feb 05	1800	5222	4964	5104.06
25 Feb 05	1900	6450	6104	5104.31
25 Feb 05	2000	8071	7620	5104.63
25 Feb 05	2100	10090	9534	5105.05
25 Feb 05	2200	12511	11850	5105.54
25 Feb 05	2300	15339	14575	5106.13
25 Feb 05	2400	18431	17602	5106.78
26 Feb 05	0100	21817	20916	5107.35
26 Feb 05	0200	25783	24735	5107.59
26 Feb 05	0300	32029	30393	5107.94
26 Feb 05	0400	41091	38740	5108.46
26 Feb 05	0500	51192	48596	5108.93
26 Feb 05	0600	59789	57594	5109.33
26 Feb 05	0700	66979	65151	5109.62
26 Feb 05	0800	72712	71345	5109.84
26 Feb 05	0900	77083	76053	5110.00
26 Feb 05	1000	80257	79510	5110.12
26 Feb 05	1100	82668	82102	5110.19
26 Feb 05	1200	280314	244326	5113.54
26 Feb 05	1300	352012	340033	5115.01
26 Feb 05	1400	245087	264000	5113.86
26 Feb 05	1500	153500	171901	5112.23
26 Feb 05	1600	110543	120182	5111.14

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
26 Feb 05	1700	92566	96757	5110.58
26 Feb 05	1800	83645	85736	5110.29
26 Feb 05	1900	78197	79478	5110.12
26 Feb 05	2000	74223	75160	5109.97
26 Feb 05	2100	70923	71703	5109.85
26 Feb 05	2200	67959	68711	5109.74
26 Feb 05	2300	65172	65880	5109.65
26 Feb 05	2400	62485	63168	5109.55
27 Feb 05	0100	59872	60538	5109.46
27 Feb 05	0200	57338	57985	5109.35
27 Feb 05	0300	54897	55521	5109.24
27 Feb 05	0400	52554	53154	5109.13
27 Feb 05	0500	50300	50878	5109.03
27 Feb 05	0600	48125	48684	5108.93
27 Feb 05	0700	46121	46637	5108.84
27 Feb 05	0800	44138	44649	5108.75
27 Feb 05	0900	42251	42738	5108.66
27 Feb 05	1000	40448	40914	5108.58
27 Feb 05	1100	38717	39166	5108.49
27 Feb 05	1200	37068	37497	5108.38
27 Feb 05	1300	35504	35911	5108.28
27 Feb 05	1400	34022	34408	5108.19
27 Feb 05	1500	32618	32984	5108.10
27 Feb 05	1600	31288	31635	5108.02
27 Feb 05	1700	30026	30356	5107.94
27 Feb 05	1800	28828	29143	5107.86
27 Feb 05	1900	27692	27990	5107.79
27 Feb 05	2000	26613	26897	5107.72
27 Feb 05	2100	25589	25859	5107.66
27 Feb 05	2200	24618	24874	5107.59
27 Feb 05	2300	23696	23940	5107.54
27 Feb 05	2400	22825	23056	5107.48

HMS * Summary of Results for XS 12 -
Laurin

Project : Ruby Run Name : Run 3

Start of Run : 25Feb05 0000 Basin Model : RUby-PMFLowDischarge
End of Run : 28Feb05 0000 Met. Model : 24 HR, PMP
Execution Time : 31May06 1507 Control Specs : 24-Hour

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
24 Feb 05	2400	2270	2270	5040.42
25 Feb 05	0100	2270	2270	5040.42
25 Feb 05	0200	2270	2270	5040.42
25 Feb 05	0300	2270	2270	5040.42
25 Feb 05	0400	2270	2270	5040.42
25 Feb 05	0500	2270	2270	5040.42
25 Feb 05	0600	2271	2270	5040.42
25 Feb 05	0700	2272	2271	5040.42
25 Feb 05	0800	2276	2274	5040.42
25 Feb 05	0900	2286	2281	5040.42
25 Feb 05	1000	2308	2297	5040.42
25 Feb 05	1100	2350	2330	5040.43
25 Feb 05	1200	2425	2389	5040.44
25 Feb 05	1300	2551	2491	5040.46
25 Feb 05	1400	2752	2657	5040.49
25 Feb 05	1500	3057	2914	5040.53
25 Feb 05	1600	3503	3295	5040.60
25 Feb 05	1700	4123	3836	5040.70
25 Feb 05	1800	4964	4578	5040.84
25 Feb 05	1900	6104	5587	5041.03
25 Feb 05	2000	7620	6939	5041.27
25 Feb 05	2100	9534	8684	5041.59
25 Feb 05	2200	11850	10834	5041.99
25 Feb 05	2300	14575	13392	5042.46
25 Feb 05	2400	17602	16301	5042.99
26 Feb 05	0100	20916	19505	5043.58
26 Feb 05	0200	24735	23124	5043.84
26 Feb 05	0300	30393	28031	5044.11
26 Feb 05	0400	38740	35296	5044.50
26 Feb 05	0500	48596	44577	5044.92
26 Feb 05	0600	57594	54171	5045.27
26 Feb 05	0700	65151	62304	5045.55
26 Feb 05	0800	71345	69026	5045.74
26 Feb 05	0900	76053	74299	5045.89
26 Feb 05	1000	79510	78226	5046.01
26 Feb 05	1100	82102	81141	5046.09
26 Feb 05	1200	244326	192652	5048.53
26 Feb 05	1300	340033	316285	5050.49
26 Feb 05	1400	264000	285181	5050.07
26 Feb 05	1500	171901	200711	5048.68
26 Feb 05	1600	120182	138268	5047.46

Date	Time	Inflow (cfs)	Outflow (cfs)	Stage (ft)
26 Feb 05	1700	96757	105306	5046.71
26 Feb 05	1800	85736	89795	5046.31
26 Feb 05	1900	79478	81796	5046.11
26 Feb 05	2000	75160	76765	5045.97
26 Feb 05	2100	71703	72992	5045.86
26 Feb 05	2200	68711	69830	5045.77
26 Feb 05	2300	65880	66941	5045.68
26 Feb 05	2400	63168	64188	5045.60
27 Feb 05	0100	60538	61530	5045.52
27 Feb 05	0200	57985	58950	5045.44
27 Feb 05	0300	55521	56455	5045.35
27 Feb 05	0400	53154	54054	5045.27
27 Feb 05	0500	50878	51746	5045.18
27 Feb 05	0600	48684	49523	5045.10
27 Feb 05	0700	46637	47468	5045.03
27 Feb 05	0800	44649	45459	5044.96
27 Feb 05	0900	42738	43518	5044.89
27 Feb 05	1000	40914	41660	5044.82
27 Feb 05	1100	39166	39883	5044.75
27 Feb 05	1200	37497	38182	5044.66
27 Feb 05	1300	35911	36564	5044.57
27 Feb 05	1400	34408	35028	5044.49
27 Feb 05	1500	32984	33573	5044.41
27 Feb 05	1600	31635	32195	5044.33
27 Feb 05	1700	30356	30888	5044.26
27 Feb 05	1800	29143	29648	5044.20
27 Feb 05	1900	27990	28471	5044.13
27 Feb 05	2000	26897	27354	5044.07
27 Feb 05	2100	25859	26294	5044.01
27 Feb 05	2200	24874	25288	5043.96
27 Feb 05	2300	23940	24333	5043.91
27 Feb 05	2400	23056	23429	5043.86

Ruby Dam
Incremental Hazard Screening Study

APPENDIX I

HKM AND EAP COMPARISON

I. Comparison to EAP Inundation Maps

After completing the downstream flood hazard evaluation, results were compared to the Emergency Action Plan (EAP) inundation maps to verify HKM computations. Breach parameters utilized in the HKM study were selected based on Federal Energy Regulatory Commission (FERC) guidelines. Table I-1 presents the parameters used by HKM in this evaluation and the parameters used in the EAP.

Table I-1. Breach Parameters

Parameter	Breach "A" Parameters	Breach "B" Parameters	EAP Parameters
Dam Break Mode	Overtopping	Overtopping	Overtopping
Breach Bottom Elevation (ft)	5299	5299	5299.1
Breach Bottom Width (ft)	285	75	320
Breach Side Slopes	1 H:1V	½ H:1V	0 H:1 V
Breach Top Elevation (ft)	5415	5415	5410
Breach Development Time (hrs)	0.5	1	1.7
Breach Trigger Elevation (ft)	5422.2	5422.2	5392.9
Initial Reservoir Elevation (ft)	5396.7	5396.7	5392.9

FERC guidelines recommend a breach development time of 1.0 hours or less for embankment dams. The half hour breach "A" development time (versus 1.7 hours in the EAP) results in a higher peak flow than reported in the EAP. Model results from the breach "B" analysis were similar to the results reported in the EAP. Downstream routing computations were performed for each set of breach parameters, and a summary of the results is presented in Table I-2.

Table I-2. Downstream Routing Comparison

Hydrologic Element	Element Type	Breach "A" Peak Discharge	Breach "A" Stage Peak	EAP Peak Discharge	EAP Peak Stage
		(cfs)	(ft)	(cfs)	(ft)
Ruby Basin	Basin	83,727			
Ruby Reservoir	Reservoir	1,016,644	5,422.3	527,932	
XS 4	Reach	985,433	5,354.1	518,240	5,352.5
XS 7	Reach	934,064	5,292.2	509,968	5,286.4
XS 8	Reach	867,471	5,236.3	488,400	5,246.8
XS 10 - Ald Resthome	Reach	682,584	5,161.5	352,398	5,170.1
XS 11 - Alder	Reach	597,818	5,118.2	326,229	5,122.1
XS 12 - Laurin	Reach	536,047	5,053.1	306,510	5,064.2

The results of this evaluation and those reported in the EAP were quite different. The main cause of concern was that in this study, higher flow rates produced lower flow depths. After verifying that flows were subcritical at each location in the HKM evaluation, EAP cross section data was entered into FlowMaster 2005 software as a basis of comparison for cross section locations near Alder and Laurin. The intent of using FlowMaster to model the EAP cross sections was to determine the channel parameters (Manning's n and channel slope) required to replicate the depths reported in the EAP. The same flow rate as reported in the EAP during a PMF breach event at each cross section was entered along with the slope approximated from USGS 7.5-minute series topographic maps and Manning's n used for HKM cross section rating curves. The FlowMaster normal depths for EAP cross sections 10, 11, and 12 are reported in the table below.

Table I-3. HKM versus EAP Flow Depth

Cross Section Location	PMF Breach "A" HKM Flow Depth (ft)	PMF Breach EAP Flow Depth (ft)	FlowMaster Depth with EAP Cross Sections (ft)
XS 4	74.1	72.5	NE*
XS 7	46.2	40.4	NE
XS 8	22.3	32.8	NE
XS 10 - Alder Resthome	19.5	28.1	14.9
XS 11 - Alder	15.2	19.1	12.2
XS 12 - Laurin	13.1	24.2	11.6

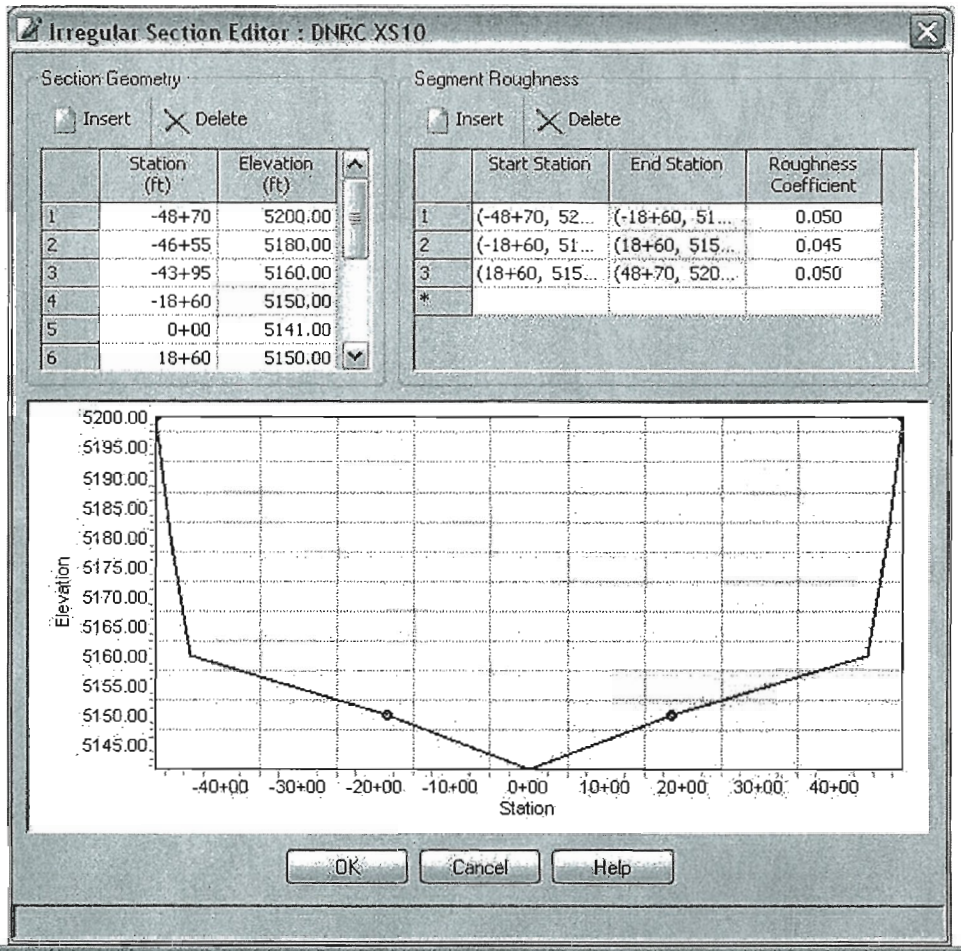
*NE = Not Evaluated

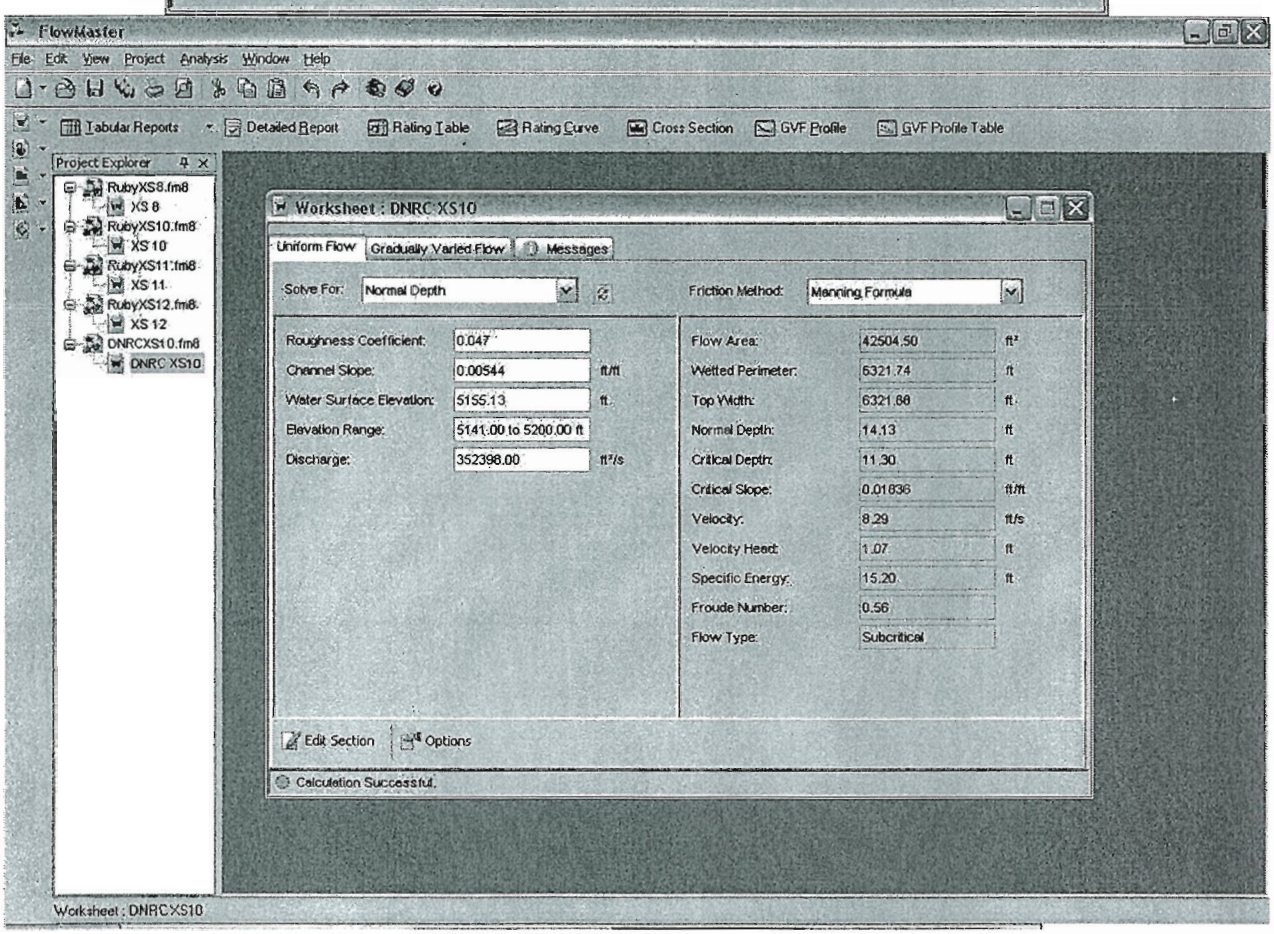
Manning's n and channel slope were varied in FlowMaster in an attempt to create channel conditions that would provide depths similar to the flow depth reported on EAP inundation maps. In order to compute similar depths, the channel slope had to be lessened by an order of magnitude and Manning's n increased to 0.100. EAP cross sections evaluated in FlowMaster are presented in the following pages. A graphical comparison of HKM cross section geometry and flow depths versus EAP cross section geometry and flow depths is presented in the main text of this report (Figures 4, 5, and 6).

HKM cross section geometry and flow depths were used in the final downstream flood hazard evaluation. Based on the brief review discussed above, it is clear the HKM and EAP evaluations are not in concurrence. Major modeling and methodology differences between the HKM and

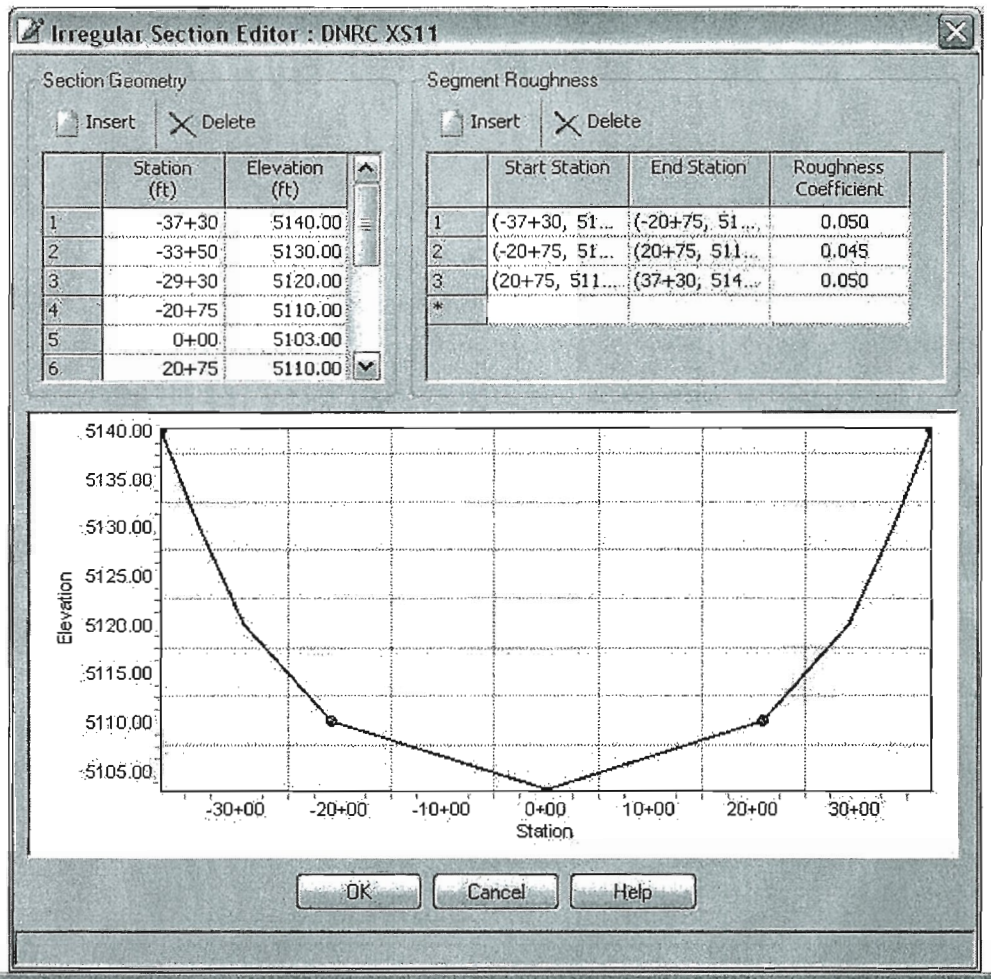
EAP evaluation were not determined in association with this analysis. Thorough comparison of the models and review of the EAP flood inundation study were outside of the scope of this task and the Ruby Dam Rehabilitation Feasibility Study, and were not performed. HKM recommends DNRC review and verify the EAP flood inundation analysis and mapping as it appears the EPA inundation boundaries may be inaccurate.

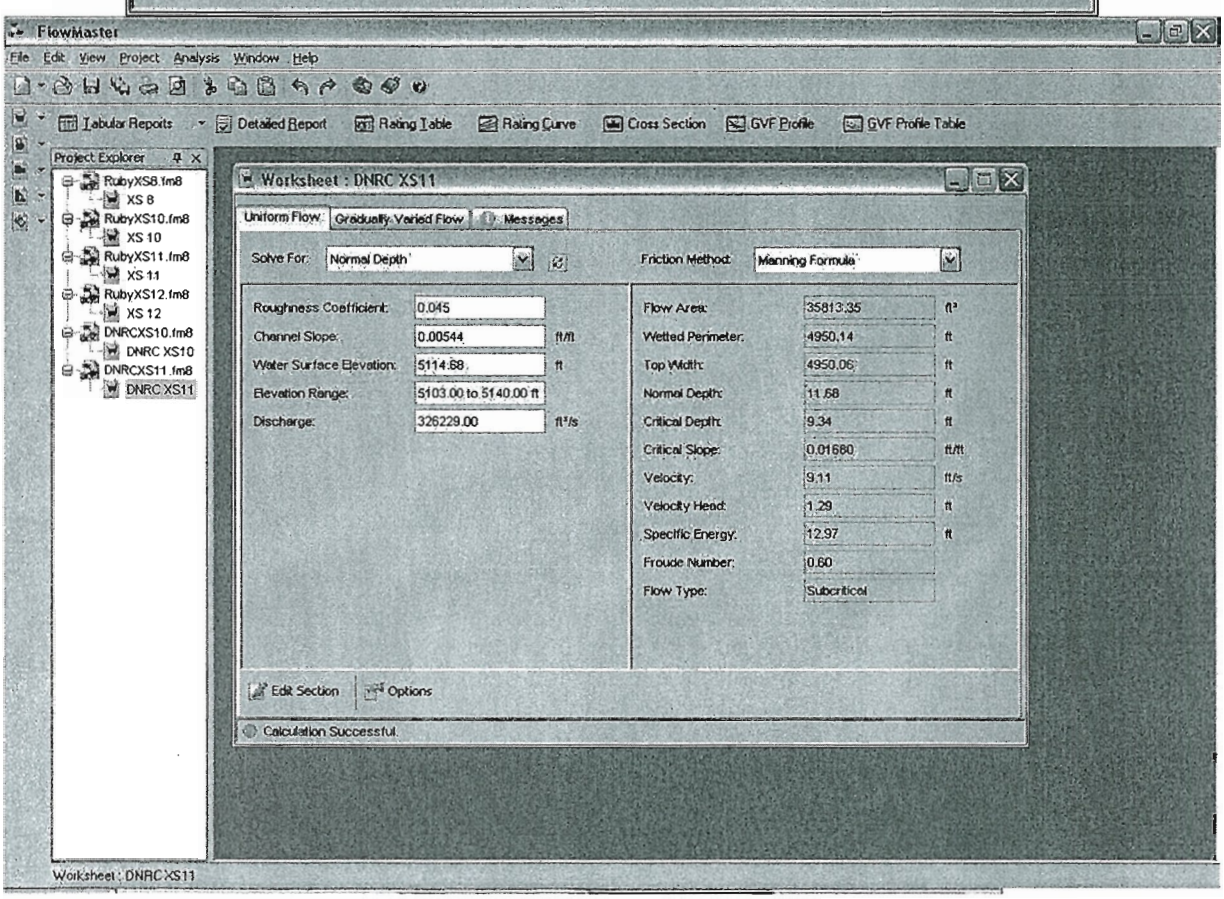
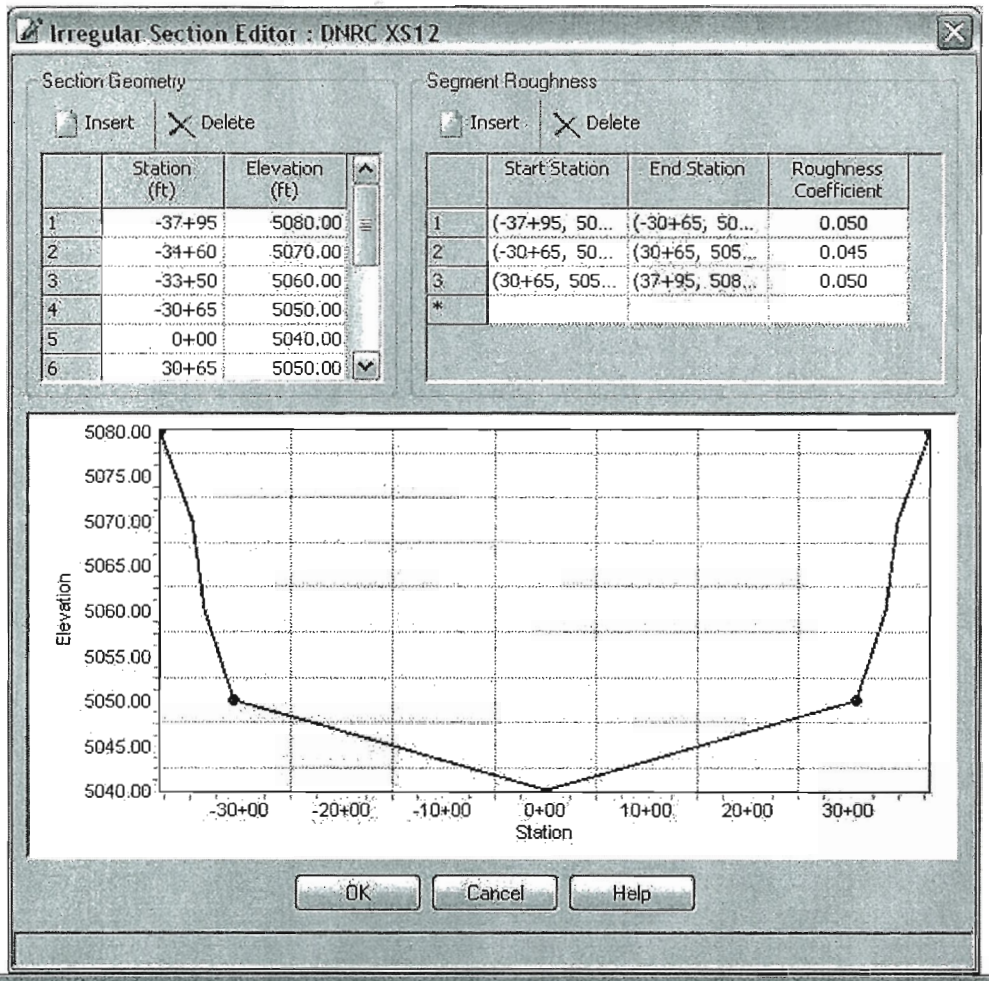
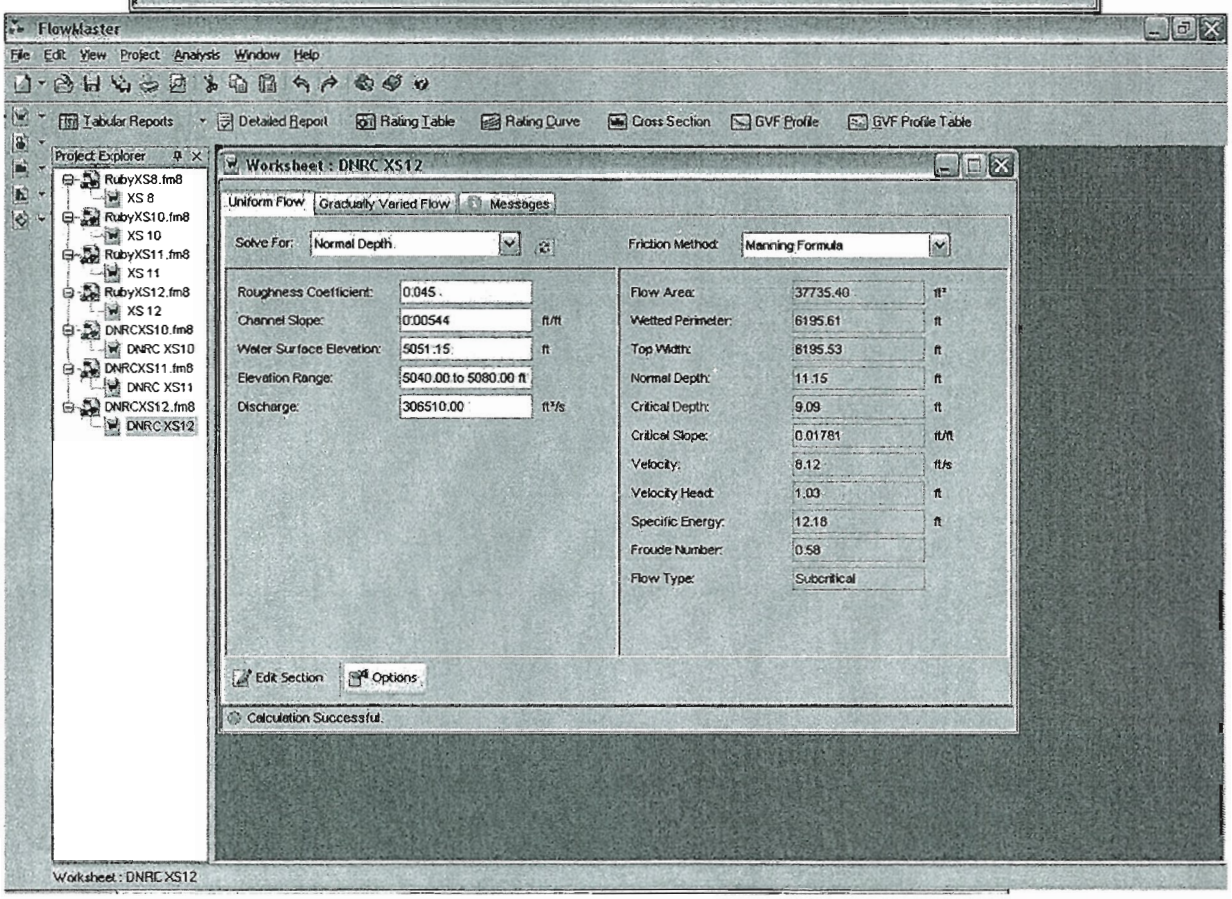
DNRC Cross Section 10





DNRC Cross Section 11





DNRC Cross Section 12