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Sediment Erosion Analysis of San Acacia Diversion Dam Removal Alternative – Final Report

San Acacia, NM

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center

August 2005

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1. Project Description

The Technical Service Center (TSC) of the Bureau of Reclamation (Reclamation) was requested by the Albuquerque Area Office (AAO) to study potential sediment erosion resulting from the removal of San Acacia Diversion Dam on the Rio Grande in the county of Socorro, New Mexico. This document describes the work tasks and the deliverables associated with this work effort. The analysis presented in this document only addresses the impacts associated with the removal of San Acacia Diversion Dam. It does not analyze or address changes to the river that are occurring as a results of other effects such as decreases in peak flows and sediment supply caused by dams along the Rio Grande and its tributaries.

AAO is performing an alternative analysis for fish passage at San Acacia Diversion Dam. The work effort described herein will address the dam removal alternative. The project study area is from the confluence of Arroyo Abo with the Rio Grande to the Arroyo Alamillo confluence (Figure 1). Figure 2 shows an overview of the project reach. Figure 3 is a smaller scale map of the area just upstream of San Acacia Diversion dam and Figure 4 is an orthophotograph of the project reach. In this report, Agg/Deg line numbers are used to refer to specific cross sections along the Rio Grande and in terms of Agg/Deg numbers the reach extends from Agg/Deg # 964 to 1243. Agg/Deg lines are approximately 500 feet apart. For the purposes of this report, River Miles (RM) are measured upstream from the Arroyo Alamillo confluence. The reach extends from RM 26.12 to RM 0. The location of various landmarks in the project reach is given in Table 1.

Table 1. Location of Landmarks in Study Reach by RM and Agg/Deg #.

Agg/Deg #	RM	Landmark
964	26.12	Arroyo Abo Confluence
1016	21.24	Beginning of San Francisco Riverside Drain (Abeytas Heading)
1053	17.7	Highway 60 Bridge
1097	13.78	Rio Puerco Confluence
1115	12.13	La Joya Community
1151 - 1170	8.68 – 6.86	Constriction near Los Cañonitos
1182	5.74	Rio Salado Confluence
1206	3.43	San Acacia Diversion Dam
1243	0	Confluence with Arroyo Alamillo

2. Stream Description

Plots of the river bed profile are given in Figure 5 and Figure 6. Figure 5 shows the thalweg profile in 2002, 1992, and 1972. The average stream slope is also shown on the figure. Figure 6 is a plot of the mean bed elevation for several years since 1936.

The Rio Grande from the upstream end of the project reach (Arroyo Abo) to Agg/Deg #1100 (Rio Puerco) has a stream slope between 0.00072 and 0.00083. At Agg/Deg #1100, immediately downstream where Rio Puerco enters from the West and Arroyo Salas enters from the east, the Rio Grande narrows; perhaps due to the presence of tributaries. The stream slope decreases to 0.0007 in this reach.

The river widens again at Agg/Deg #1110, but the stream slope continues to decrease in the downstream direction. The continued decrease in slope at this point may be caused by three different factors: 1. the large sediment supply from the Rio Salado, 2. San Acacia Dam, and 3. the geological controls of the canyon through Los Cañonitos. At Agg/Deg #1150, the river is constricted by the presence of terraces on either side of the river. The river exits the constricted section at Agg/Deg #1170, and the Rio Salado confluence is at Agg/Deg #1180. The reach from Agg/Deg #1180 to #1206, is wide and greatly influenced by the presence of San Acacia Diversion Dam at Agg/Deg #1206 and the coarse sediment supply from the Rio Salado.

The bed material in this reach was sampled in 2003 by Travis Bauer and Robert Hilldale and in 2004 by Travis Bauer of the Technical Service Center. The data collected are found in Appendix A. The sample locations are shown in Figure 2. Special effort was made to sample the coarse bed material that underlies the sand moving through the river. The samples can be divided into two groups: the sand samples and the coarse bed material samples. It is assumed that the coarse bed material samples are representative of the bed material important to the morphology of the channel. The sand samples are representative of the material moving through the river, but not necessarily of the bed material which controls net erosion and deposition. The plots of the average size fractions information of the sand samples and the coarse bed material samples are shown in Figure 7 and Figure 8. In these figures, Belen refers to the Rio Grande reach from Railroad Bridge at Agg/Deg #877 to Hwy 60 at Agg/Deg #1050. The samples labeled Rio Salado were collected near the Rio Salado Delta. The samples labeled San Acacia were collected on the Rio Grande downstream of San Acacia Dam from San Acacia Dam to Arroyo de la Parida.

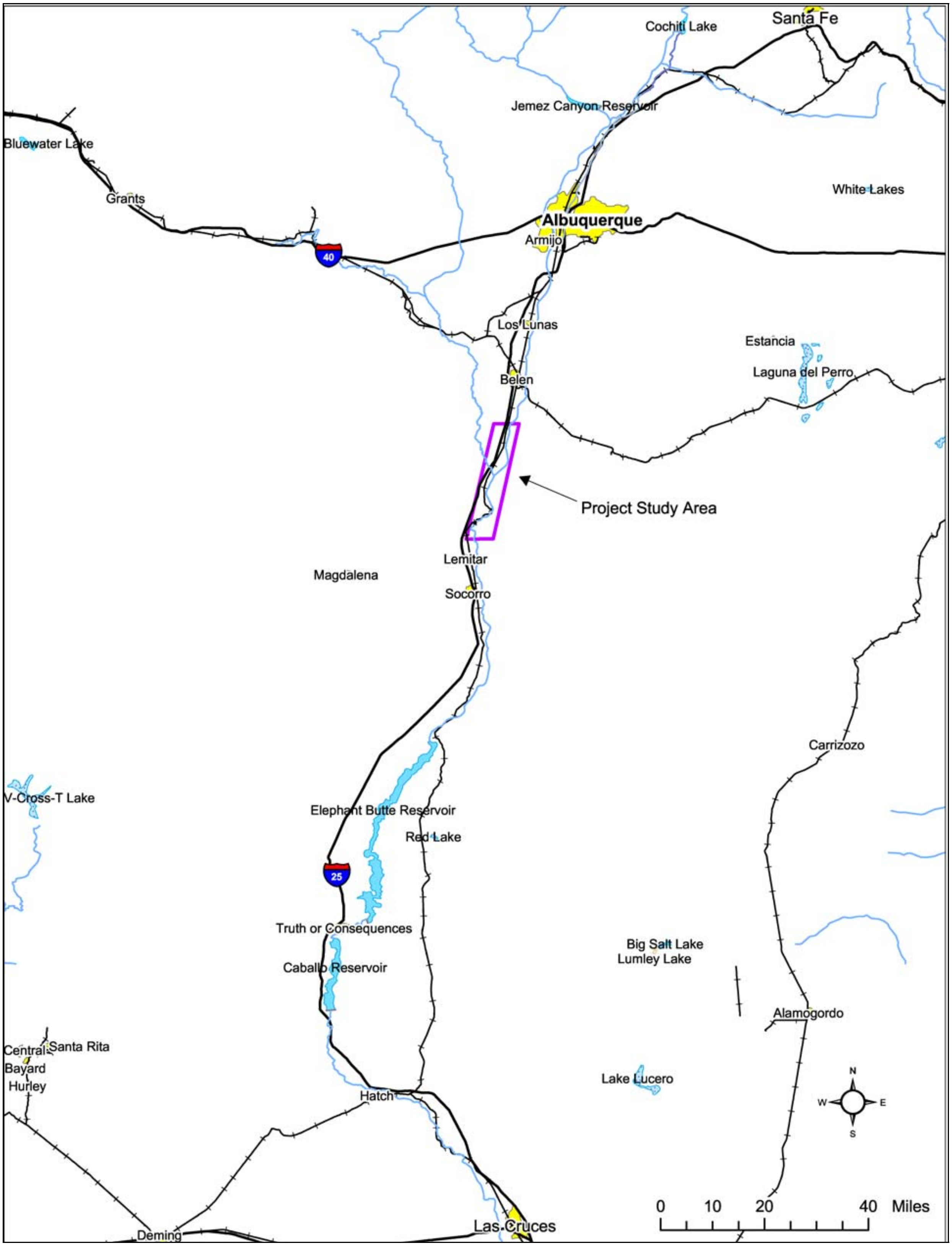

Figure 1. Project Location.

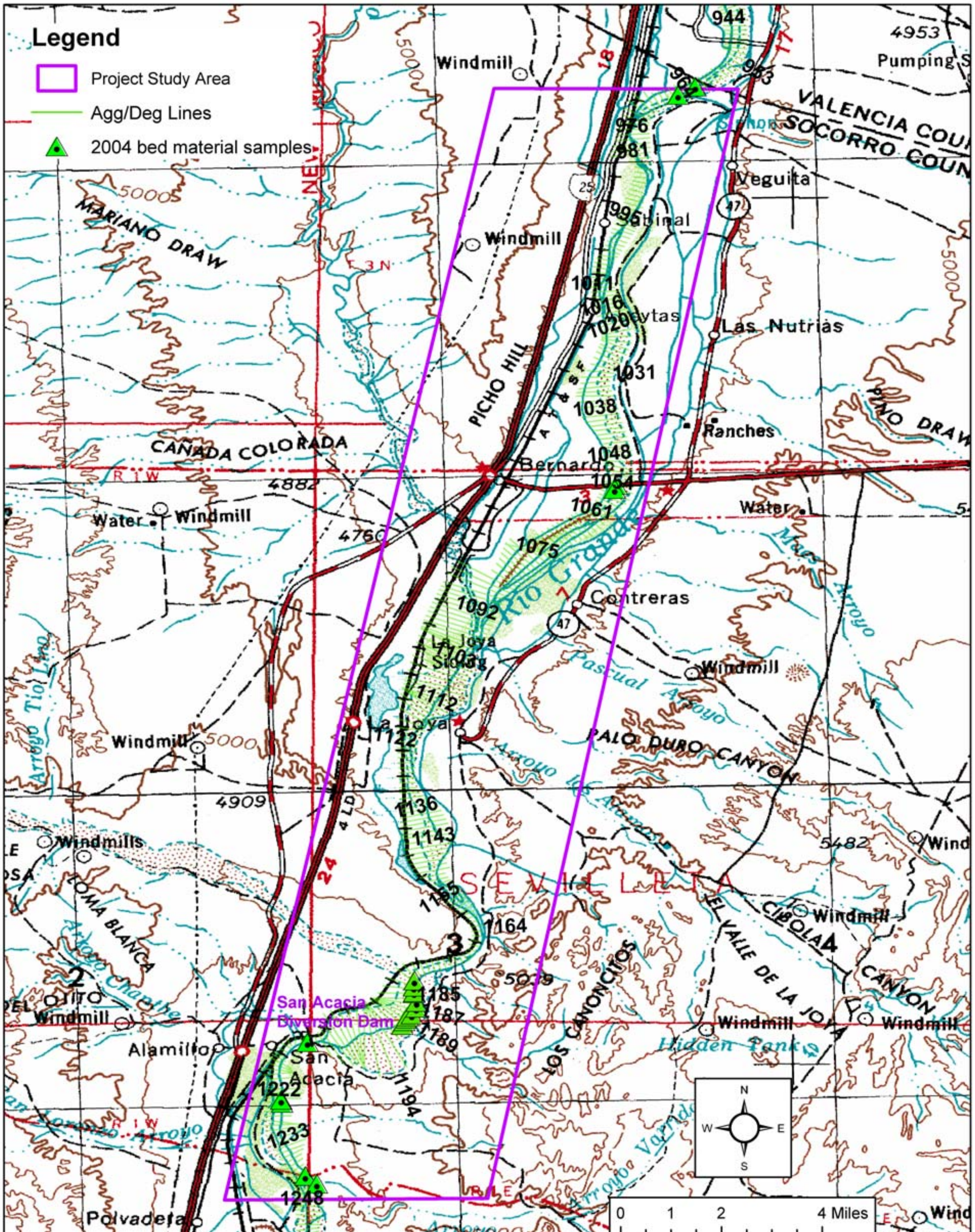

Figure 2. Project Reach including Agg/Deg Lines. Green Triangles are location of Bed Material Samples.

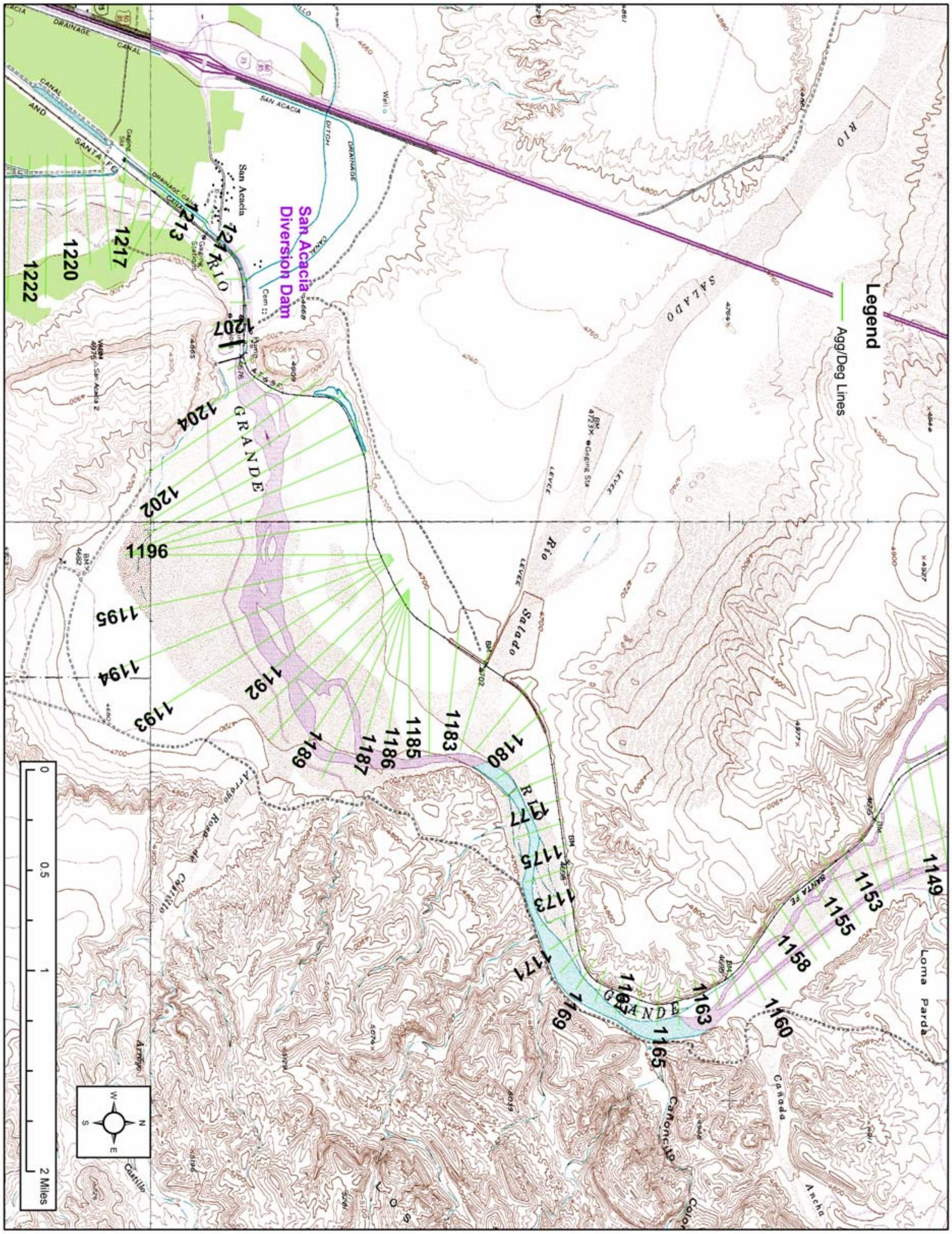

Figure 3. Area upstream of San Acacia Dam. The Agg/Deg lines are labeled.

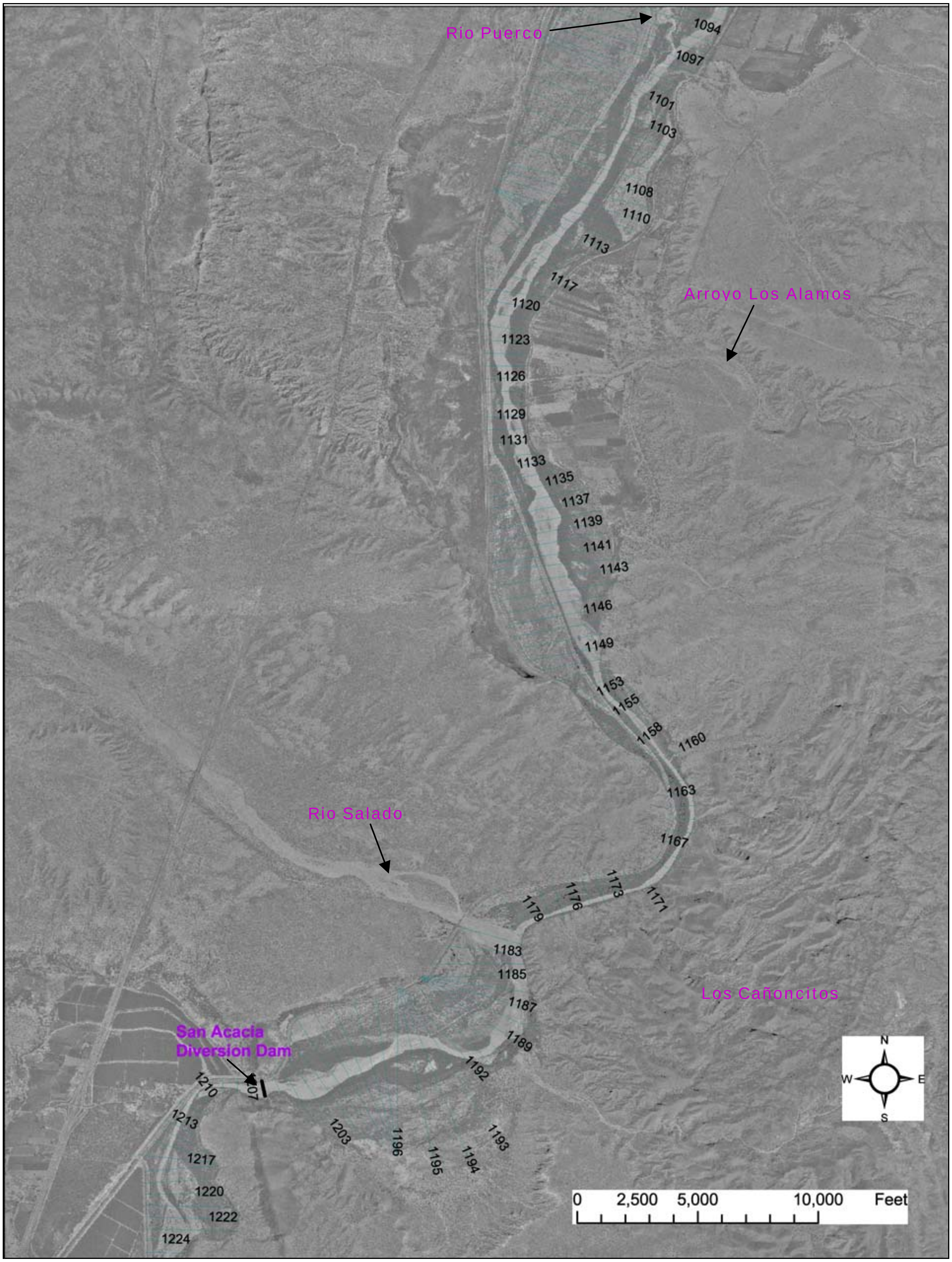

Figure 4. 1996 USGS Ortho-photograph of Area Upstream of San Acacia Diversion Dam.

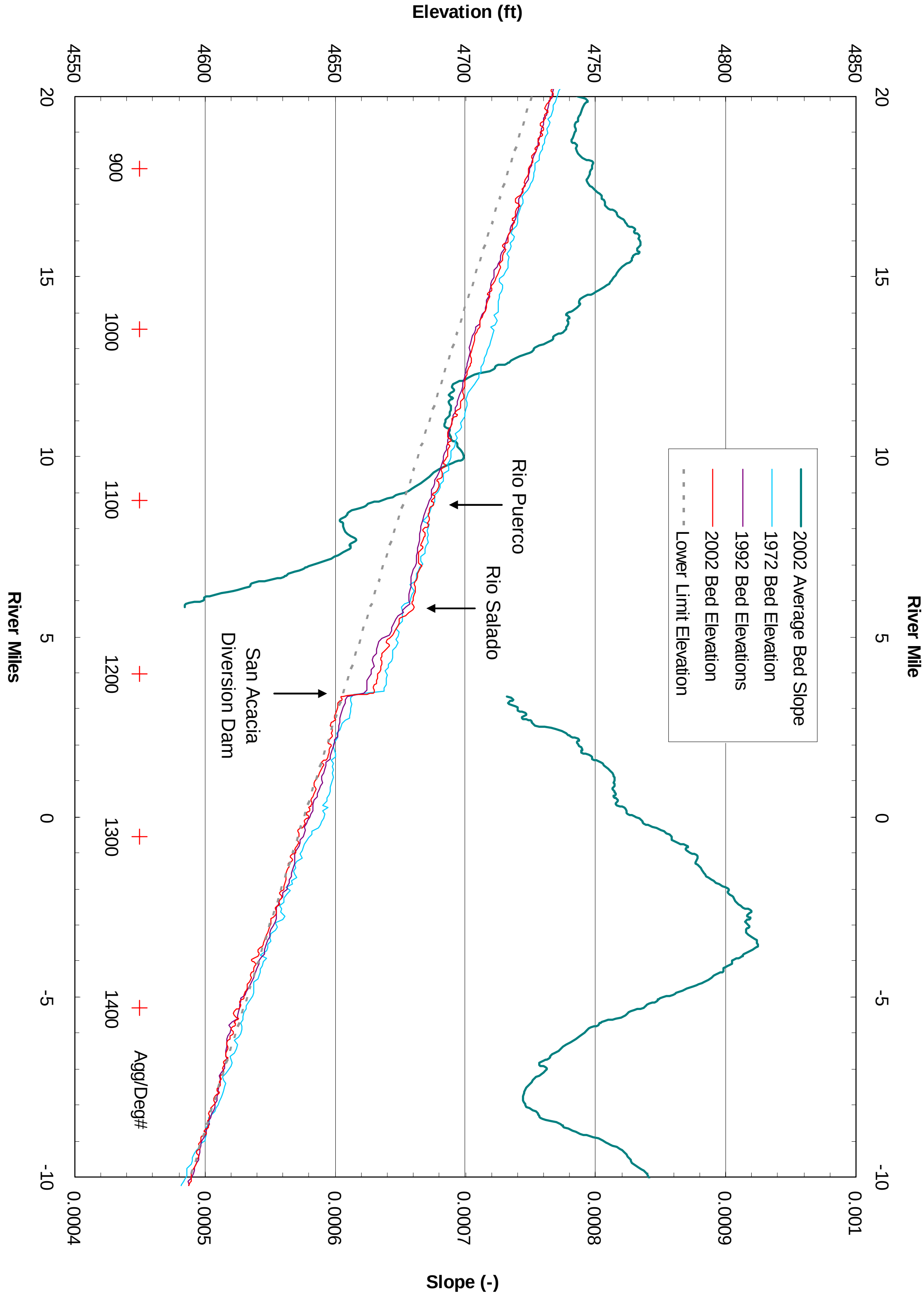

Figure 5. Bed Profile in Project Reach. Bed Slope is Average Stream Slope Over 5 Mile Reach.

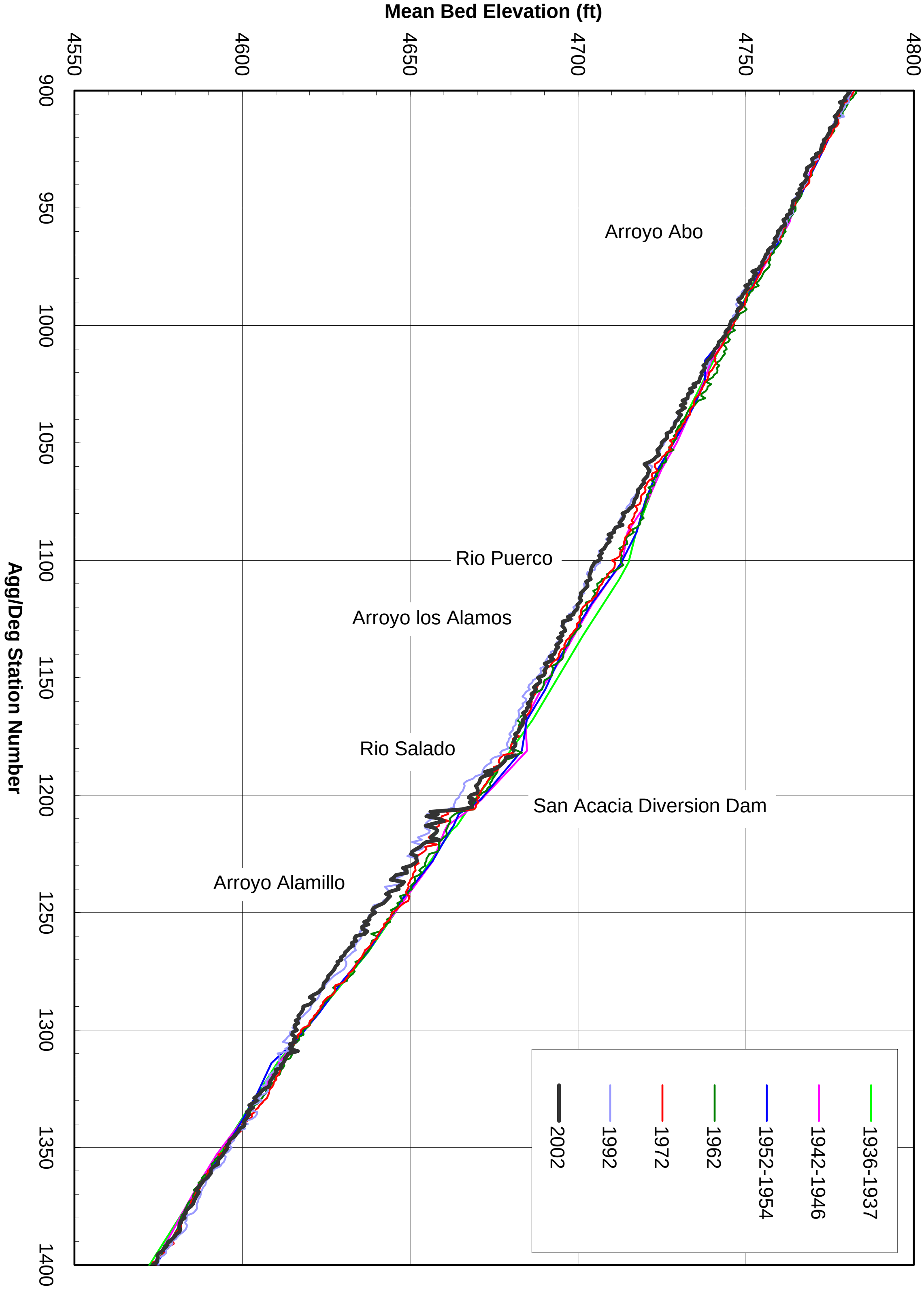

Figure 6. Mean Bed Profiles in Reach since 1936.

Table 2. Definition of Particles Sizes for Sediment Analyses.

Size Class	Sub class	Abbreviation	Size range (mm)
clay	--	clay	0.00024 – 0.004
silt	--	silt	0.004 – 0.062
sand	very fine	vfs	0.062 – 0.125
	fine	fs	0.125 – 0.25
	medium	ms	0.25 – 0.5
	coarse	cs	0.5 – 1
	very coarse	vcs	1 – 2
gravel	very fine	vfgr	2 – 4
	fine	vgr	4 – 8
	medium	gr	8 – 16
	coarse	cgr	16 – 32
	very coarse	vcgr	32 – 64
cobble	small	sc	64 – 128
	large	lc	128 – 256
boulder	--	b	256 – 4096

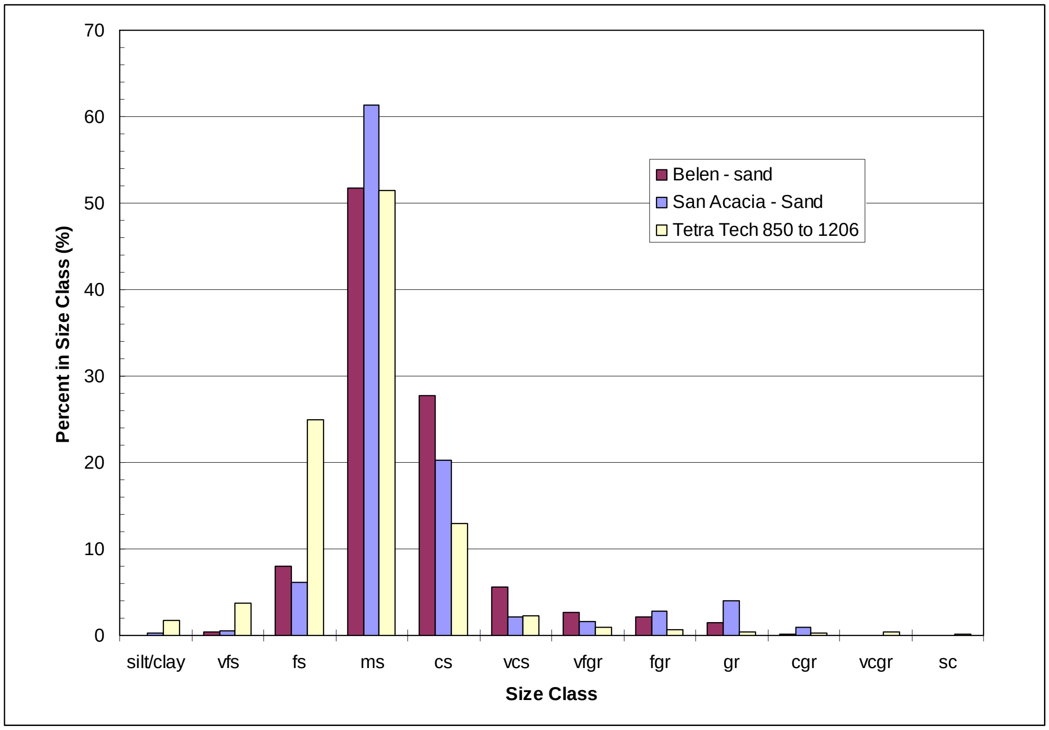

Figure 7. Average Gradations from Sand Samples Collected in Project Reach.

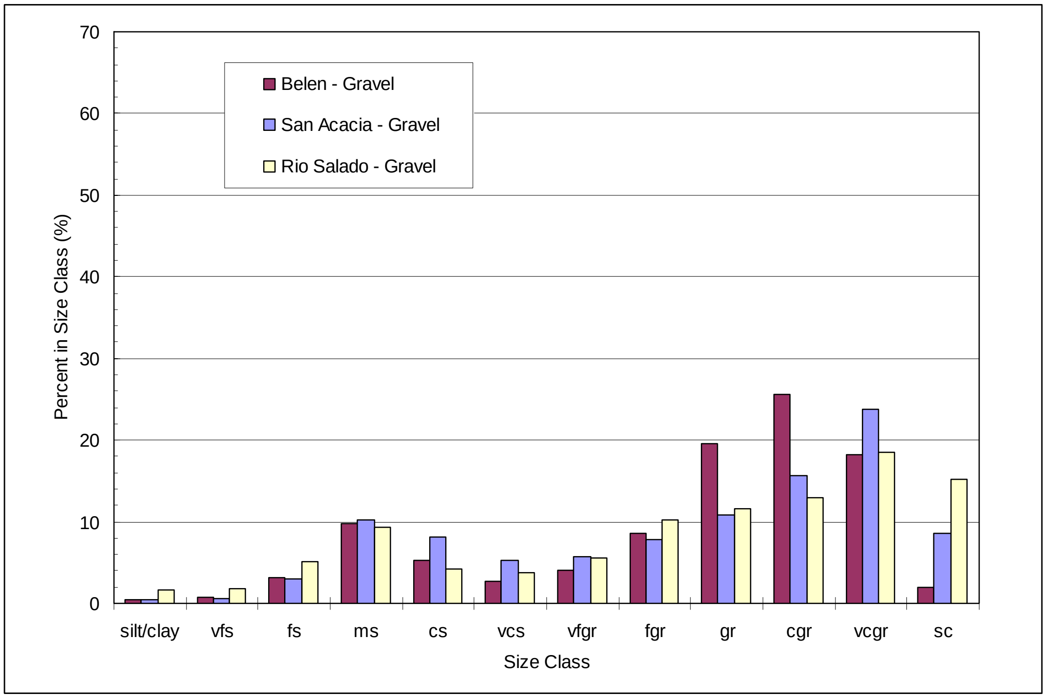

Figure 8. Coarse Bed Material Samples Collected in 2004.

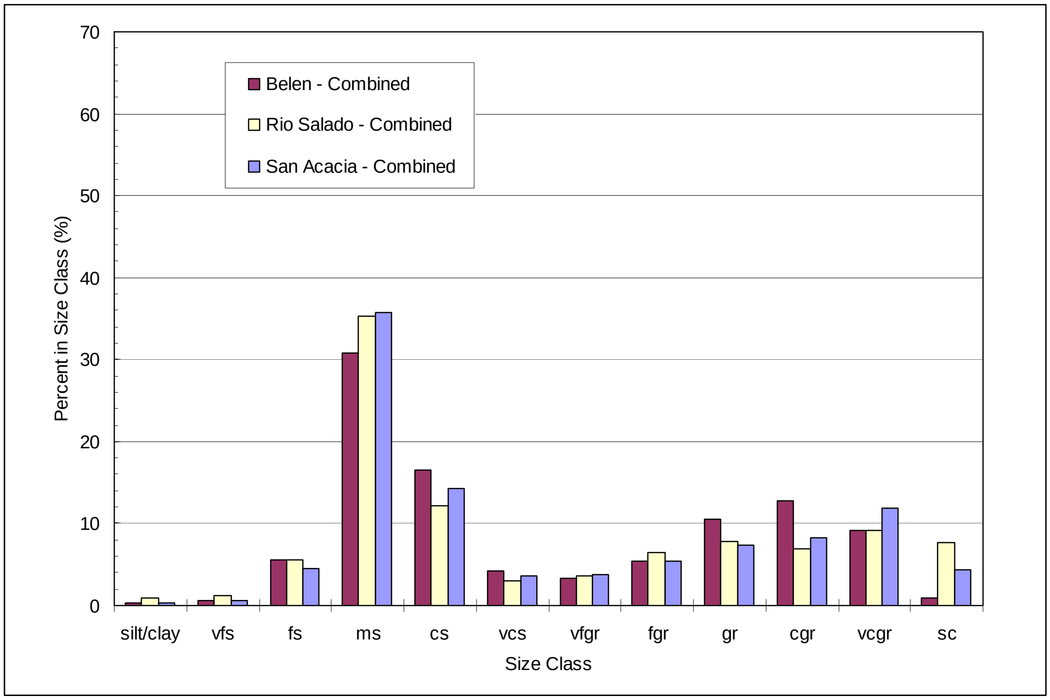

Figure 9. Combination of Coarse Bed Material Samples and Sand Samples (50% of each).

3. Analysis Methods

GSTAR-1D 1.0 (Yang et al., 2005) is used to estimate the response of the stream channel to the removal of San Acacia Diversion Dam. GSTAR-1D is a one-dimensional hydraulic and sediment transport model that has been used on previous studies on the Rio Grande. It has also been used to calculate stream response due to the removal of Matilija Dam on the Ventura River, CA (Reclamation, 2004) and several diversion dams on Battle Creek, CA. The data requirements for GSTAR-1D are: channel geometry, stream flows, sediment inflows, initial bed material, and several different sediment transport parameters. The data input will be described in the next section.

One-dimensional models segment the river channel into a series of cross sections and calculate average hydraulic properties for each section. Because properties are averaged over the cross section, several phenomena are ignored. These include effects due to channel curvature, the variation in shear stress across the cross section, main channel interactions with the floodplain, and secondary currents.

Three alternatives are considered: the No Action, the Natural Erosion Alternative, and the Stabilization Alternative. The No Action Alternative assumes that the dam remains in place and normal diversions continue. The Natural Erosion Alternative assumes that the dam is removed all at once and the river is allowed to naturally erode the sediment behind the dam. The Stabilization Alternative assumes the dam is removed, but grade control structures are placed in the river behind the dam to reduce erosion of the upstream channel.

4. Input Data Description

4.1 Channel Geometry

The channel geometry used for this study is taken from the 2002 Agg/Deg Surveys. The surveys did not obtain channel geometry below the water. To approximate the below water geometry, a rectangular area was added to the below the water portion by assuming normal depth at the average stream slope.

The reach from Agg/Deg # 900 to 1350 was simulated. The reach simulated was larger than the project reach so that the boundary conditions did not affect the results in the vicinity of San Acacia Diversion Dam. Not every cross section was used and the cross section spacing was gradually increased with distance from diversion dam (see Table 3). The Manning's roughness coefficient (*n*) used for the main channel was 0.02 for the entire reach. As a sensitivity test, a simulation is also performed with a roughness coefficient of 0.025. The floodplain roughness was set to 0.1 and was not varied.

Table 3. Cross Sections Used in Study.

Reach (Agg/Deg#)	Number of cross sections used
900 to 1100	Every 5th
1100 to 1150	Every 3rd
1150 to 1170	Every 2nd
1170 to 1215	All
1215 to 1240	Every 2nd
1240 to 1350	Every 3rd

4.2 Stream Flows

Four different flow scenarios were used (Table 4). The first three scenarios used a constant flow rate of 1,000, 3,000 and 7,000 cfs for 120 days. The fourth flow scenario used the stream flows from October 1, 1991 to September 30, 2002 as measured by the USGS at San Acacia Stream Gage (USGS gage # 08354900). The last 10 years of record was used because it would be fairly representative of current river operations and was wet enough to cause significant erosion. Additional flow scenarios could be simulated in the future.

Table 4. Flow Scenarios Used in Simulations.

Flow Scenario #	Flow Scenario Name
1	Constant 1,000 cfs flow for 120 days
2	Constant 3,000 cfs flow for 120 days
3	Constant 7,000 cfs flow for 120 days
4	Flows at San Acacia Stream gage #08354900 from October 1, 1991 to September 30, 2002

4.3 Sediment Inflows

The sediment inflow to the simulated reach is set to equilibrium supply as calculated by the Engelund-Hansen (1972) transport equation at the upstream section. Therefore, the model assumes the reach upstream of the project reach is in equilibrium. Prediction of the long term river stability upstream of the project reach is considered outside the scope of this study. The Engelund-Hansen formula was chosen to predict the inflow because it is used to predict the transport capacity within the project reach for all simulations. Furthermore, the Engelund-Hansen has shown to reasonably predict the bed material transport in this reach of the Rio Grande (see Section 4.5.1 titled “Transport Formula”).

4.4 Bed Material Gradation and Thickness

In GSTAR-1D any number of layers can be used to represent the bed material. A three layer model of the bed material was used. The first layer is the active layer and is comprised of the same material as in Layer 2. The active layer is assumed to be 1.5 feet thick based upon previous calibrations of the active layer thickness in the Rio Grande (Reclamation, 2004b). The model sensitivity to active layer thickness is analyzed later in this document.

The thickness of Layer 2 was set to 1.5 feet for all reaches except for the 10 miles upstream of the dam. Beginning 10 miles upstream of the dam (Agg/Deg #1100), the thickness of layer 2 increases linearly with distance from 1.5 to 18.5 feet at the face of the dam. Based upon the current bed profile (Figure 5), there is approximately 20 feet of deposition behind San Acacia Dam. Therefore the total thickness of the first two layers was assumed to be 20 feet. It is assumed that the deposition thickness due to the dam gradually decreases as one goes upstream from the dam. The third layer is assumed to have infinite thickness. All the layer thicknesses are shown in Figure 10.

The gradations used for the bed layers are shown in Table 5. The sediment gradation in layer 3 is assumed to be an average of the sand and coarse bed material samples throughout the entire simulated reach. Upstream of the influence of the San Acacia Dam, the bed material in layers 1 and 2 is computed by averaging the sand and coarse sediment samples collected by Bauer (2004). This gradation is also shown in Figure 9. In the area immediately upstream of San Acacia Dam the sediment gradation in layers 1 and 2 is assumed to have the composition of the sand samples. There has been no sediment sampling in the area directly behind the dam. Therefore, the gradation of the material stored behind the dam is uncertain. If the material is finer than assumed in the analysis, the erosion rates may be higher than predicted. Also, the downstream sediment concentrations may be higher.

Downstream of San Acacia Dam the sediment gradations in layers 1 and 2 are assumed fine so that the model does not predict artificial deposition. The model predicts sediment transport capacity based upon the amount of sediment in each size class present in the bed and with little sand present in the bed at the start of the model, the model may predict excessive deposition. Riprap has been placed on the apron of the dam to prevent further erosion of the river bed. Because the riprap apron is not included in the model, erosion for the No Action alternative is likely over predicted. However, excluding the riprap apron will not significantly affect the simulations of dam removal because deposition is predicted downstream of the dam. As deposition occurs, the original bed material, whatever its composition, is quickly covered and the original surface bed material no longer affects the amount of deposition.

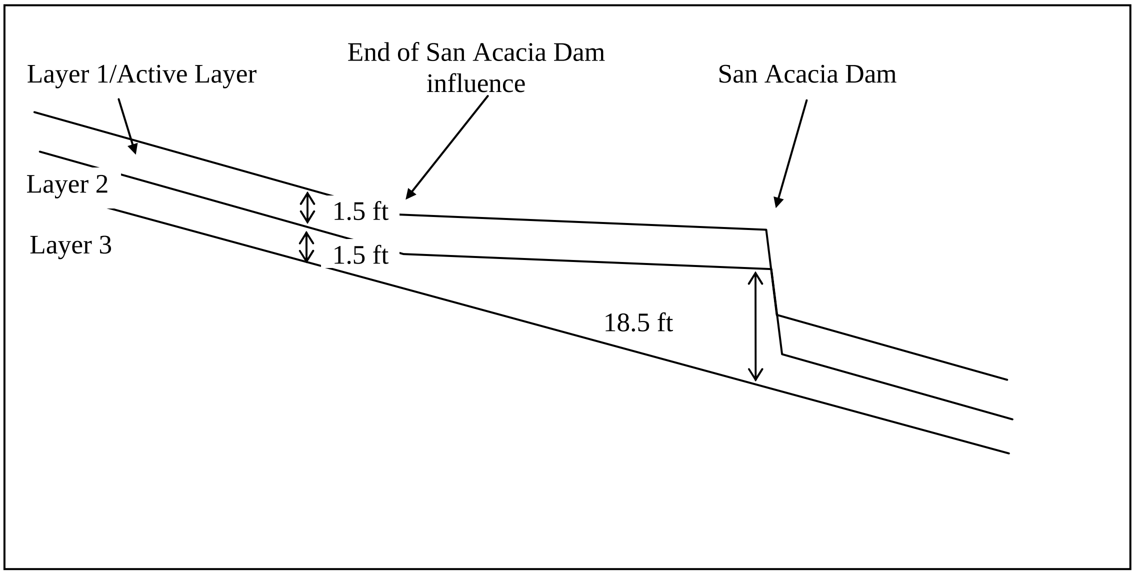

Figure 10. Bed Layer Thicknesses Used in GSTAR-1D Simulations.

Table 5. Bed Material Percentages Used in the GSTAR-1D Simulations. Numbers in first column refer to Agg/Deg numbers.

	silt/clay	**vfs**	**fs**	**ms**	**cs**	**vcs**	**vfgr**	**fgr**	**gr**	**cgr**	**vcgr**	**sc**
Layers 1 & 2												
Upstream of Agg/Deg #900	0.2	0.6	5.6	30.8	16.5	4.2	3.3	5.4	10.5	12.8	9.1	0.9
End of SA influence, at Agg/Deg #1100	0.2	0.6	5.6	30.8	16.5	4.2	3.3	5.4	10.5	12.8	9.1	0.9
San Acacia Dam, at Agg/Deg #1206	0.0	0.5	8.0	51.7	27.8	5.6	2.6	2.2	1.4	0.1	0.0	0.0
Downstream of San Acacia Dam, at Agg/Deg #1207	0.2	0.6	6.1	61.4	20.3	2.1	1.6	2.8	3.9	0.9	0.0	0.0
Layer 3												
Upstream of Agg/Deg #900	0.2	0.6	5.6	30.8	16.5	4.2	3.3	5.4	10.5	12.8	9.1	0.9
end of SA influence, at Agg/Deg #1100	0.2	0.6	5.6	30.8	16.5	4.2	3.3	5.4	10.5	12.8	9.1	0.9
San Acacia Dam, at Agg/Deg #1206	0.3	0.6	4.6	35.8	14.2	3.7	3.7	5.4	7.4	8.2	11.9	4.3
d/s San Acacia Dam, at Agg/Deg #1207	0.3	0.6	4.6	35.8	14.2	3.7	3.7	5.4	7.4	8.2	11.9	4.3

4.5 Sediment Transport Parameters

4.5.1 Transport Formula

The Engelund-Hansen (1972) transport formula has been used in previous analysis of sediment transport on the Rio Grande (Reclamation, 2005). A comparison between the Engelund-Hansen formula and the measured sand and gravel loads at San Acacia stream gage is given in Figure 11 and Figure 12. HEC-RAS 3.1.1 was used to compute the hydraulic properties in the reach where the gage was present. The average hydraulic properties over a two mile reach downstream of San Acacia Diversion dam were used. The bed material gradations used in the transport capacity computations were taken from the average gradation of the sand and coarse bed material samples of Bauer (2004) found in Figure 9.

The total sediment concentrations plotted against flow rate are given in Figure 13. One can see that the concentrations are not well correlated with flow rate as the R squared value of the fitted power function between concentration and flow has a value of 0.09, indicating that flow explains approximately only 9% of the variation in sediment concentration. Therefore, many other factors affect sediment concentration. Some tributaries, such as the Rio Puerco, supply large amounts of fine-grained sediment, but the flow in the Rio Puerco is not always correlated to large flows in the Rio Grande.

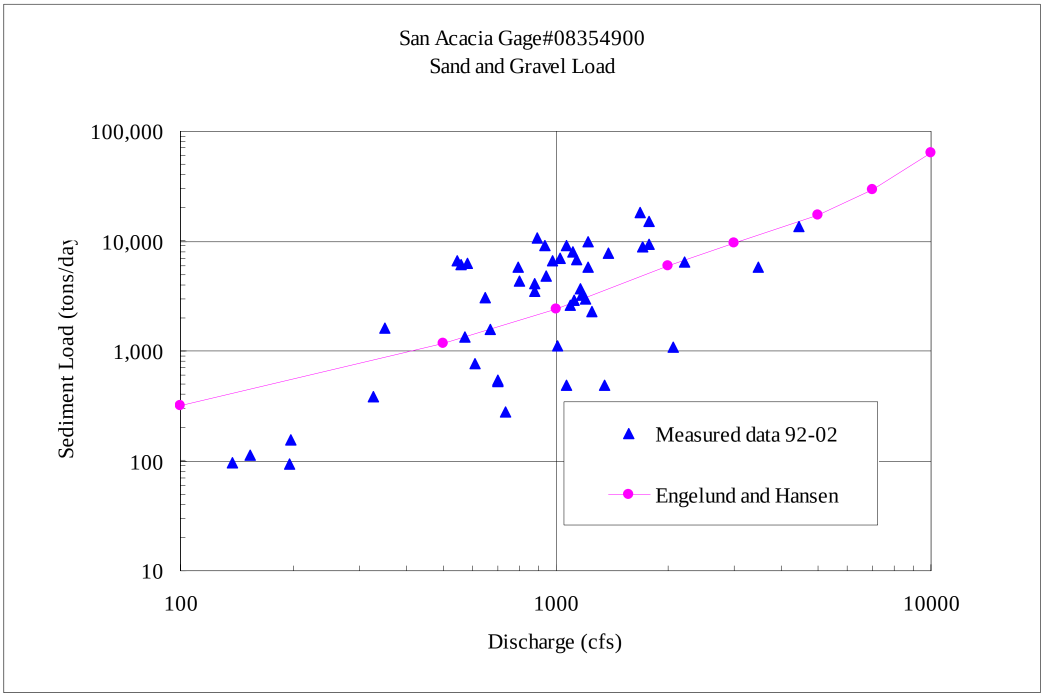

Figure 11. Comparison between predicted and measured sand and gravel load at San Acacia USGS stream gage.

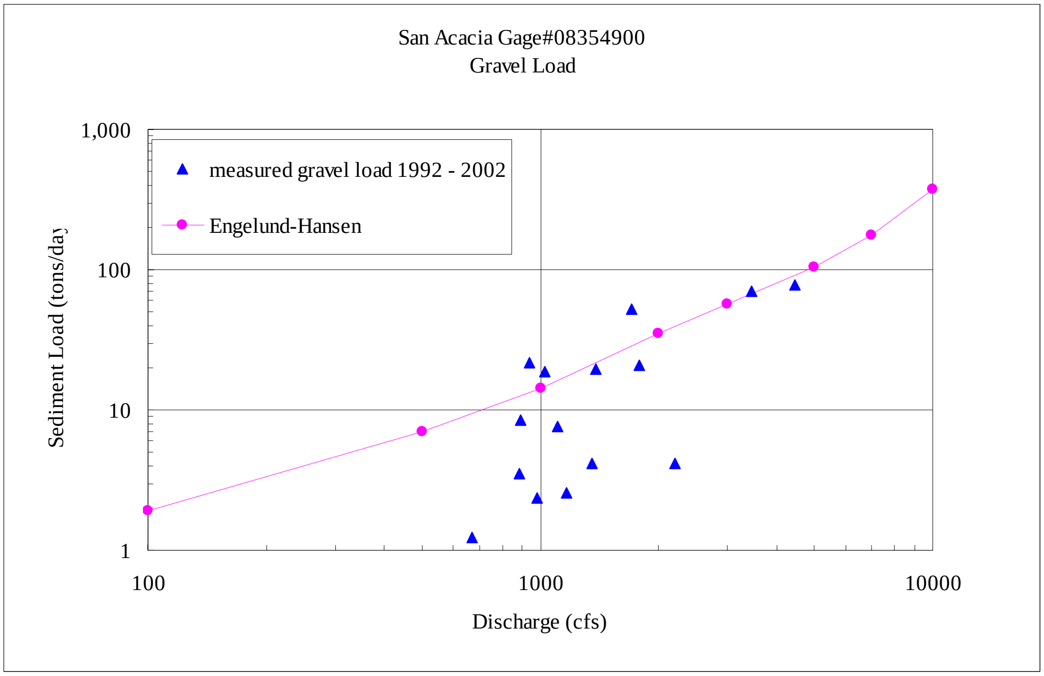

Figure 12. Comparison between predicted and measured gravel load at San Acacia USGS stream gage.

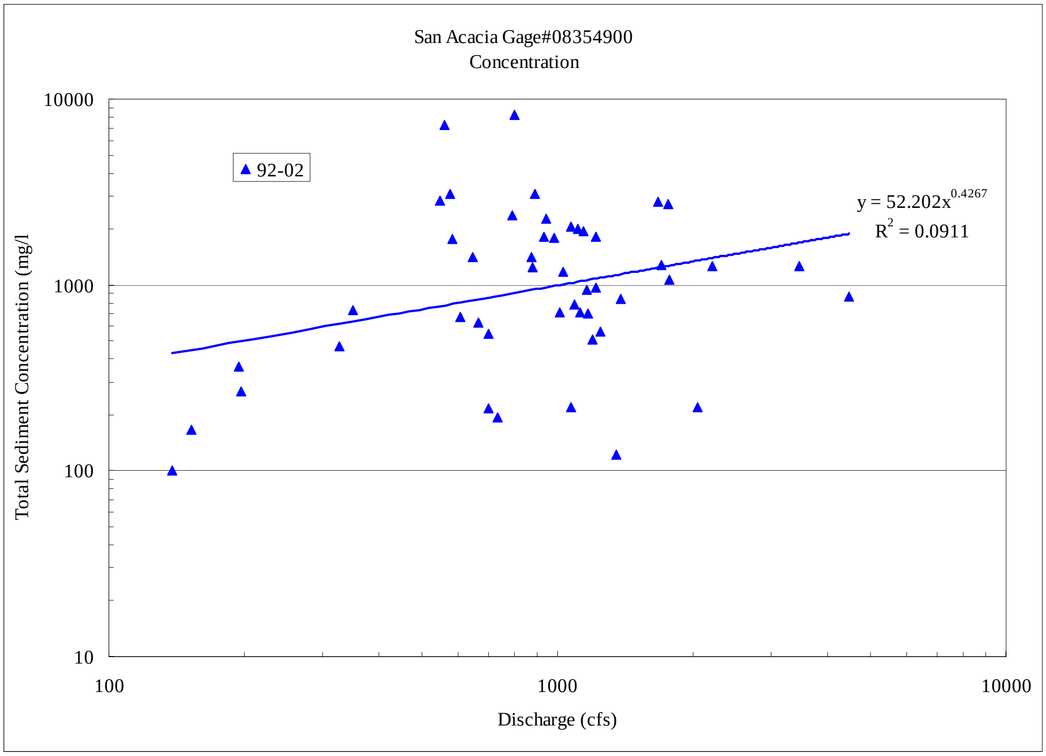

Figure 13. Total sediment concentration at San Acacia Gage for period 1992 to 2002.

4.5.2 Active Layer

The active layer is an important parameter in controlling the rate at which armoring occurs. Based upon previous calibrations in the reach from San Acacia to Elephant Butte a value of 1.5 ft is used (Reclamation, 2005). A sensitivity analysis of this value is conducted as part of this study.

4.5.3 Angle of Repose

The angle of repose for the bed material was set to 25 degrees below water and 45 degrees above water. Because of the relatively large width to depth ratios, the erosion and deposition volumes are not sensitive to the angle of repose chosen in the model.

5. Simulations Results

Three different alternatives were simulated using GSTAR-1D: the No Action Alternative, the Natural Erosion Alternative, and Stabilization Alternative. Under the No Action Alternative, San Acacia Diversion Dam is left in place. Under the Natural Erosion Alternative the dam is removed and the sediment behind the dam is eroded naturally by the river. Under the Stabilization Alternative the dam is removed, but one or more grade control structures are placed in the Rio Grande upstream of the dam location. The simulation results from these alternatives are described in the following sections.

5.1 No Action Alternative

A simulation leaving the dam in place was run as a baseline case (called the No-Action Alternative). The only difference between the No-Action Alternative and the Natural Erosion Alternative is the internal boundary condition set at the diversion dam. In the No Action Alternative, the diversion dam is represented by a weir with a sill elevation of 4668.5 ft and a width of 500 ft. The weir coefficient was set to 3. For the Natural Erosion Alternative, the weir is removed and there is no internal boundary condition set at the diversion dam. The hydrologic period simulated is the period from 1992 to 2002.

The simulation results show that the reach upstream of the dam remains relatively stable (Figure 14). There is some erosion from Agg/Deg #1150 to #1185 (upstream of the Los Cañonitos Constriction to the Rio Salado Confluence) and some deposition from #1185 to #1206 (at the dam face). The starting profile has a steep slope just downstream of the Rio Salado (Agg/Deg #1185) and the model will tend to smooth out this steep slope causing erosion upstream of the steep slope and deposition downstream of the steep slope. The cause of this steep slope is the sediment supply from Rio Salado. The Rio Salado has formed a delta as it enters the Rio Grande because the Rio Grande is unable to carry all the sediment entering from the Rio Salado. The present model does not account for additional sediment entering from the Rio Salado. To estimate the sediment contributions it would be necessary to obtain geometry information from the Rio Salado and construct a hydraulic model of the river. These activities are considered to be beyond the scope of this study. If the sediment input from the Rio Salado was included, the delta forming at the mouth of the Rio Salado would continue and the profile would remain similar to the 2002 profile. In other words, the erosion from Agg/Deg #1150 to #1185 is a result of ignoring the Rio Salado in the simulation.

Downstream of San Acacia Diversion Dam, there is substantial erosion (Figure 14). Just downstream of the dam, the model predicts that 7 feet occurs during the 10 year simulation period. The amount of erosion at each cross section gradually decreases in the downstream direction until where at Agg/Deg #1300, where the erosion is approximately 1 foot. The volume of erosion from the dam to Agg/Deg #1300 is approximately 1100 ac-ft.

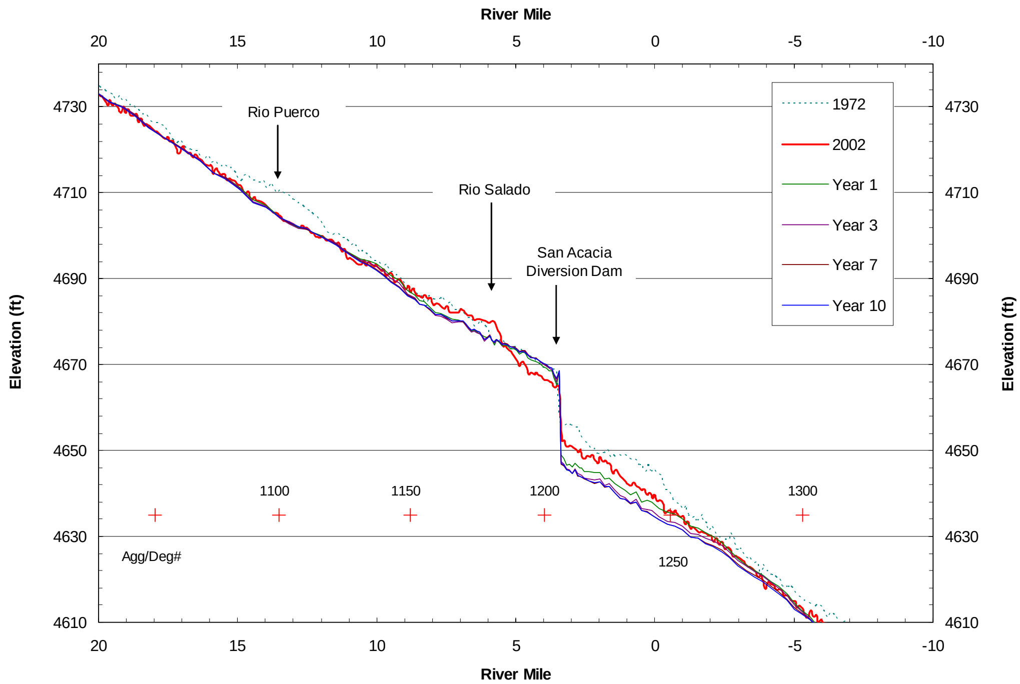

Figure 14. Bed Profile in Reach at Various Times in the Simulation of the No Action Alternative. The 1972 and 2002 bed profiles are also given for comparison.

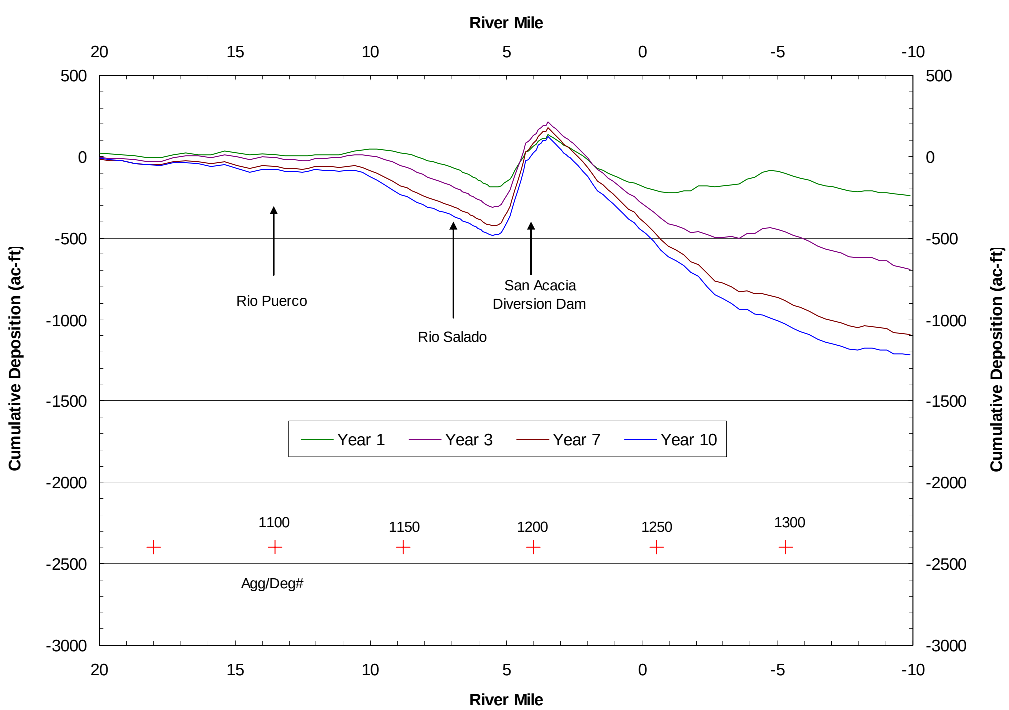

Figure 15. Cumulative Erosion or Deposition in Reach for the No Action Alternative. Summation Begins Upstream and Proceeds Downstream.

5.2 Natural Erosion Alternative

There were 4 hydrologic scenarios simulated: a constant 1000 cfs flow, a constant 3000 cfs flow, a constant 4000 cfs flow, and the hydrologic period from October 1, 1991 to September 30, 2002. The constant flows are simulated to explicitly show the effect that flow magnitude has on the sediment transport after dam removal. The hydrologic period from October 1, 1991 to September 30, 2002 was chosen as a fairly representative flow period to show the long term impacts of dam removal.

The sensitivity of the model to various parameter sets and conditions was also tested. The list of runs is given in Table 6.

Table 6. Description of Model Runs Used to Analyze the Natural Erosion Alternative and Stabilization Alternative.

Model Run	Description
1	1992 – 2002 Hydrology, Original parameter set
2	1992 – 2002 Hydrology, change in bed material distribution
3	1992 – 2002 Hydrology, Active layer thickness of 1.5 ft throughout entire reach
4	1992 – 2002 Hydrology, Active layer thickness of 7.4 ft throughout entire reach
5	Constant 1000 cfs flow, Original parameter set
6	Constant 3000 cfs flow, Original parameter set
7	Constant 7000 cfs flow, Original parameter set
8	1992 – 2002 Hydrology, Original parameter set, grade control at Agg/Deg #1150
9	1992 – 2002 Hydrology, Original parameter set, a series of grade controls from Agg/Deg #1150 to dam
10	1992 – 2002 Hydrology, Increase in Manning's Roughness

5.2.1 1992 to 2002 Hydrologic Period

The hydrologic period 1992 to 2002 was simulated using the same input parameters as in the No Action Alternative and this simulation is term Run 1. The 1992 to 2002 had a peak flow of 6800 cfs in 1995 and an average flow of 1130 cfs. The simulated bed profile and cumulative erosion volumes are shown in Figure 16 and Figure 17, respectively.

There is significant erosion upstream of San Acacia Dam following removal of the dam. The erosion after dam removal will occur rapidly and after the first year there will be no significant vertical barrier to fish passage. The simulations shows that after the first year the bed and water surface slopes through the entire reach are similar to natural river conditions. Over the entire 10 year simulation, approximately 2500 ac-ft of sediment is eroded upstream of San Acacia Dam. The majority of this sediment is eroded in the first three years. The erosion rate gradually decreases over time and after 10 years the reach is near equilibrium, meaning that the net erosion or deposition is near zero.

After 10 years of simulation, the maximum erosion depth occurs at Agg/Deg #1183 (Rio Salado Confluence) and is approximately 15 feet. Just upstream of the diversion dam it is approximately 10 feet. The erosion depth gradually decreases going upstream from Agg/Deg #1180. At Agg/Deg #1150 (just upstream of Los Cañonitos Constriction), the erosion depth is approximately 7 to 8 feet. At Agg/Deg #1100 (the Rio Puerco Confluence), the change in elevation is less than 2 feet, which is similar to the erosion simulated in this reach under the No Action Alternative. Agg/Deg #1100 is approximately 10 miles upstream of San Acacia Diversion Dam.

As mentioned previously, the flow and sediment input from the Rio Salado is not included into the simulation. Currently, the Rio Salado is forming a large delta at its confluence with the Rio Grande. Based upon the current bed profile the delta causes the bed to rise approximately 5 feet upstream of confluence of the Rio Salado and the Rio Grande (Figure 16). If the flow and sediment input were included into the simulation, the predicted erosion on the Rio Grande upstream of the Rio Salado would be less because the delta would continue to form. It is estimated that neglecting the flow and sediment input from the Rio Salado results in an over prediction of erosion between Agg/Deg #1185 to 1150 of 5 feet or less.

Another factor not considered in this impact analysis is the erosion that may occur on the Rio Salado itself. The bed of the Rio Grande at the confluence with the Rio Salado will be lowered approximately 10 feet and this will cause an erosion front to progress up the Rio Salado. The analysis of this erosion on the Salado is beyond the scope of this report. To analyze this situation, bed material and geometry data of the Salado would need to be collected.

There will be large terraces formed as a result of the erosion after dam removal. However, depending upon the strength of the sediment in the banks, these terraces may slump. Further sediment sampling of the reservoir and bank material is necessary to evaluate the strength of the sediment. Of particular importance is the gradation and degree of consolidation of the sediment. If the sediment is consolidated, then the high banks may remain relatively high and steep, however, if the sediment is loose the banks will collapse and will not be as high or as steep. The simulations performed in this report do not consider slumping of the reservoir sediments. An example cross section that is approximately 3 miles upstream of San Acacia Dam is shown in Figure 18. The initial bank height is approximately 10 feet and after dam removal the bank height increased to 20 feet. The simulations are considered to give the maximum bank height. It is possible that the banks are unable to sustain a 20 foot height and will fail, forming a series of smaller terraces. The final height of the banks will depend upon the sediment composition and degree of consolidation of the sediments. Further sediment sampling of the sediment behind San Acacia Dam would be required to evaluate the ultimate bank height. The increase is bank height is expected to be most severe in the 5 miles immediately upstream of San Acacia Dam. Ten miles upstream of the dam, the increase in bank height gradually decreases to zero.

Some of the sediment eroded from behind San Acacia Dam will deposit in the reach downstream. Based upon the mean bed elevations of Figure 6, the reach downstream of San Acacia Dam has been experiencing erosion since the 1950's. The large supply of sediment upstream of San Acacia Dam may temporarily reverse this trend and aggradation may occur downstream of San Acacia Dam if it is removed. The aggradation is expected to be most significant in the first three years, after which time the reach will be fairly stable for at least 10 years. After 10 years the reach downstream of San Acacia may again start to degrade, but the simulation was only for a period of 10 years and a larger study would have to be conducted to estimate the long term trends in this reach after dam removal. The reach downstream of San Acacia Dam has also become significantly coarser and the simulations indicate that the removal of the San Acacia Dam will at reverse trend for the 10 year simulation period.

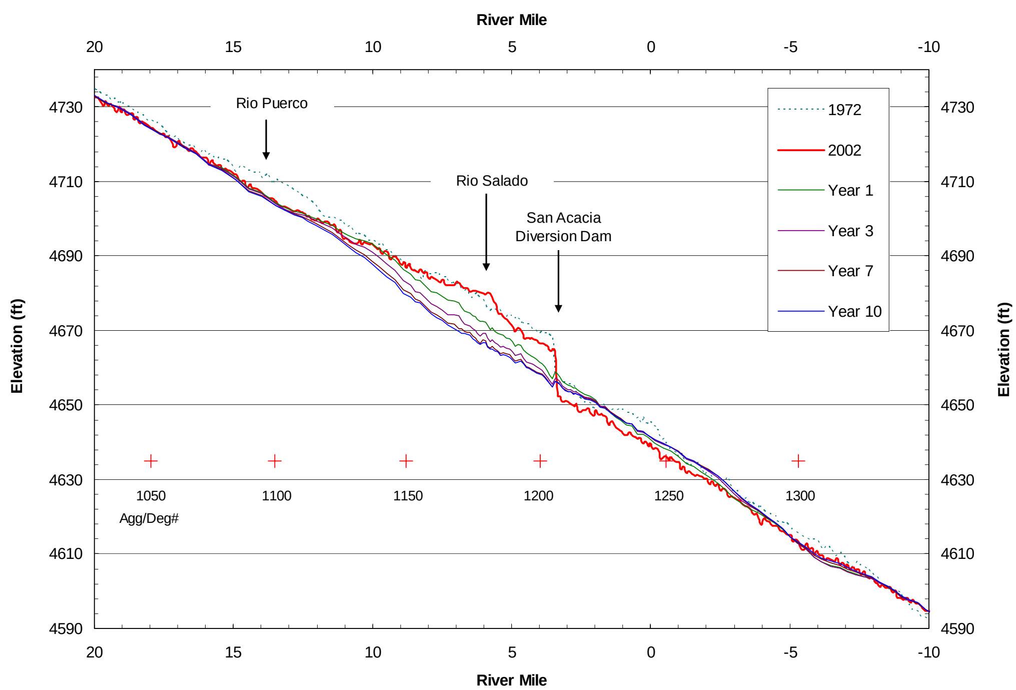

Figure 16. Bed profile in reach at various times in the simulation, Run 1. The 1972 and 2002 bed profiles are also given for comparison.

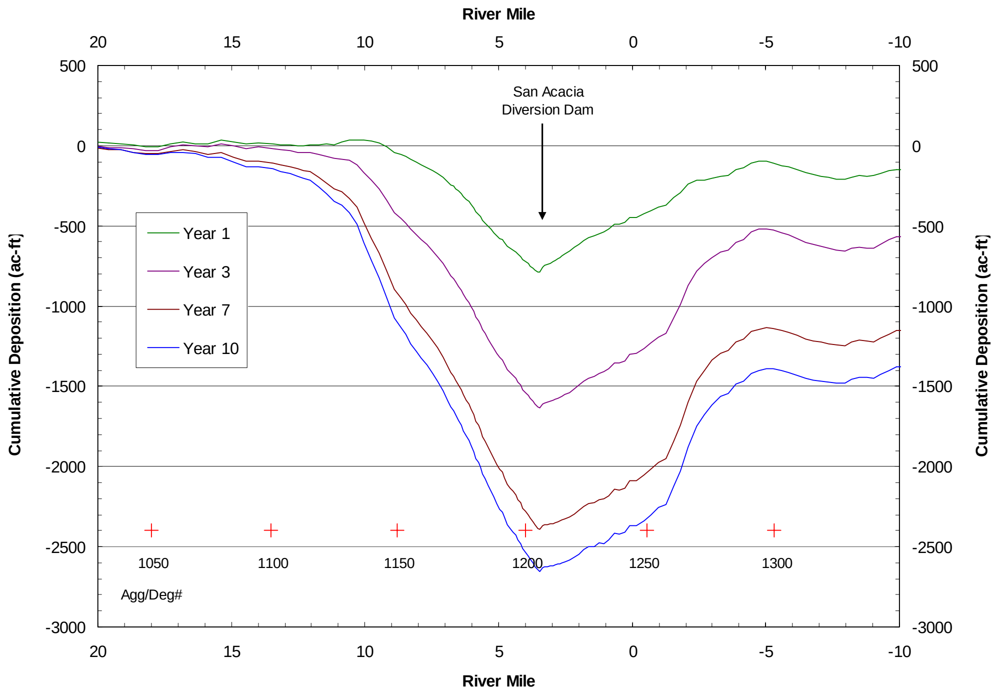

Figure 17. Cumulative Erosion or Deposition in Reach, Run 1. Summation Begins Upstream and Proceeds Downstream.

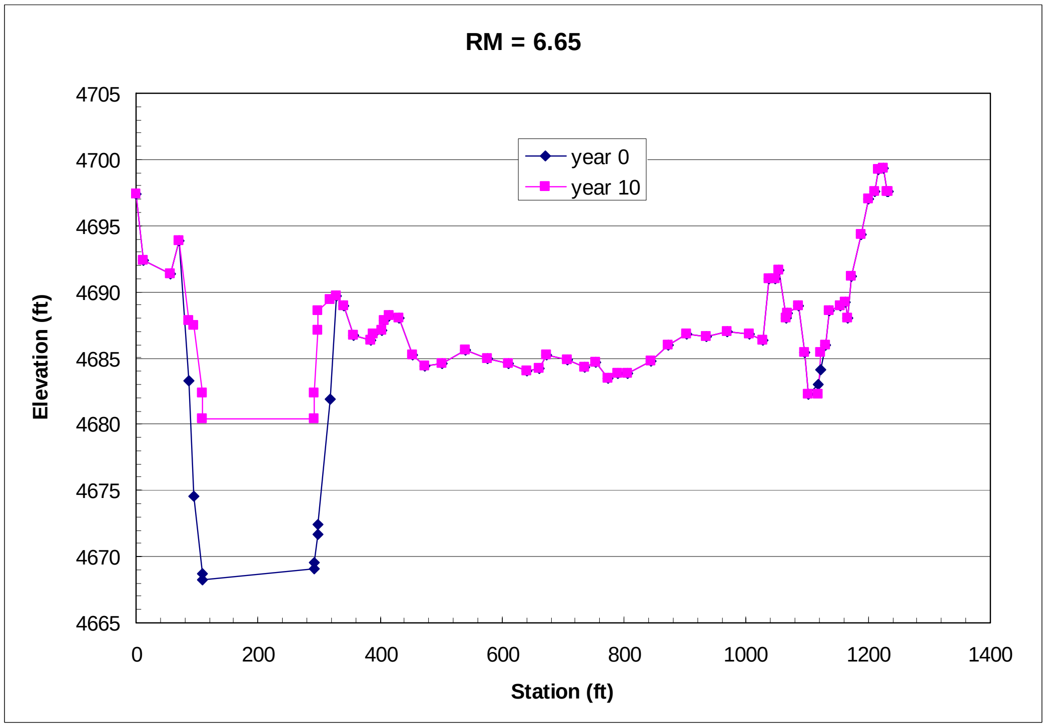

Figure 18. Cross Section geometry at River Mile 6.65, 3 miles upstream of San Acacia Dam, Run 1.

5.2.2 Sensitivity to Bed Material Distribution

In Run 2, the distribution of bed material was altered. In Run 1, the fine sediment was assumed to extend 10 miles upstream of San Acacia Dam. In Run 2, the fine sediment was assumed to extend 5 miles upstream (Agg/Deg #1153). The effect of this change is shown in Figure 19 and Figure 20.

The erosion in Run 2 did not extend as far upstream as in Run 1. The erosion caused by the removal of San Acacia Dam in Run 2 did not extend upstream of Agg/Deg #1130. However, downstream of Agg/Deg #1150, the simulated erosion in Run 2 was actually more than in Run 1. The total volume eroded upstream of San Acacia Dam was approximately 400 ac-ft less in Run 2 than in Run 1. The reason Run 2 erodes more than Run 1 downstream of Agg/Deg #1150 is that Run 2 eroded less upstream of Agg/Deg #1150 and is more ‘sediment hungry’ than Run 1 at this point.

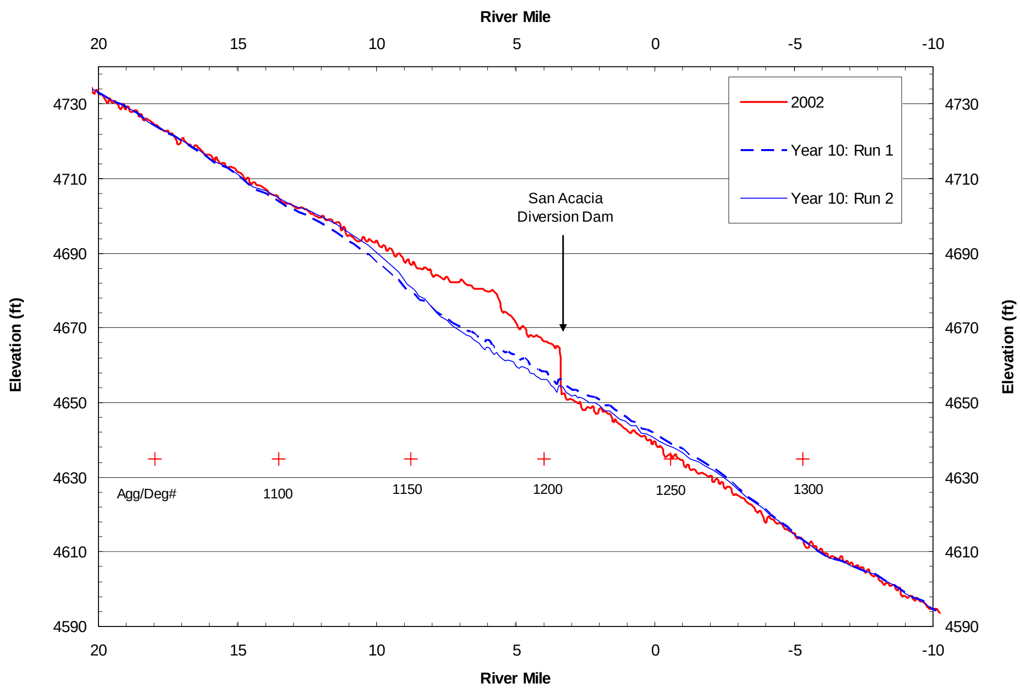

Figure 19. Comparison between Simulated Bed Profiles of Run 1 and Run 2.

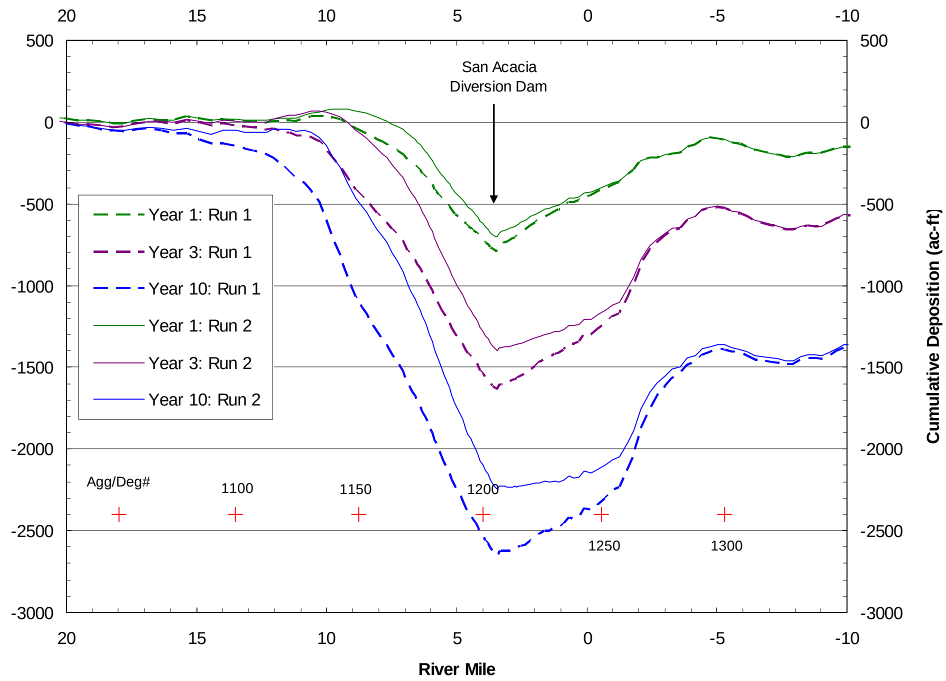

Figure 20. Comparison between Simulated Deposition or Erosion Volumes of Run 1 and Run 2.

5.2.3 Sensitivity to Active Layer Thickness

Two different active layer thickness combinations were simulated to assess model sensitivity to this parameter. Run 3 used an active layer thickness of 1.55 ft throughout the simulated reach. Run 4 used an active layer thickness of 7.4 ft throughout the simulated reach. In general, the model was relatively insensitive to active layer thickness. There was however, slightly less erosion predicted with smaller active layer thicknesses. Overall, the model is not considered sensitive to active layer thickness.

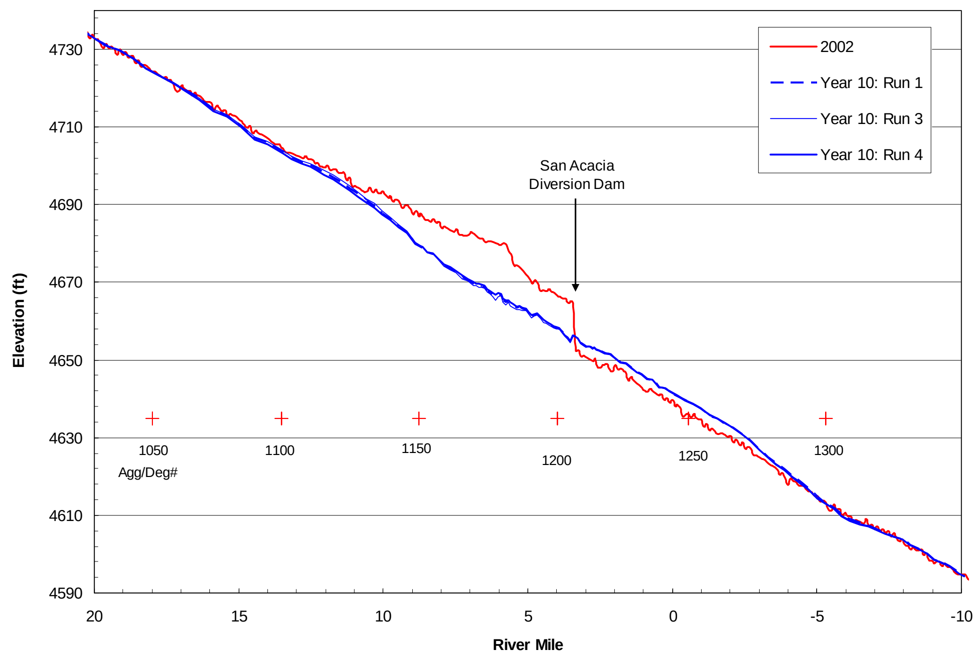

Figure 21. Comparison between Simulated Bed Profiles of Run 1, Run 3, and Run 4.

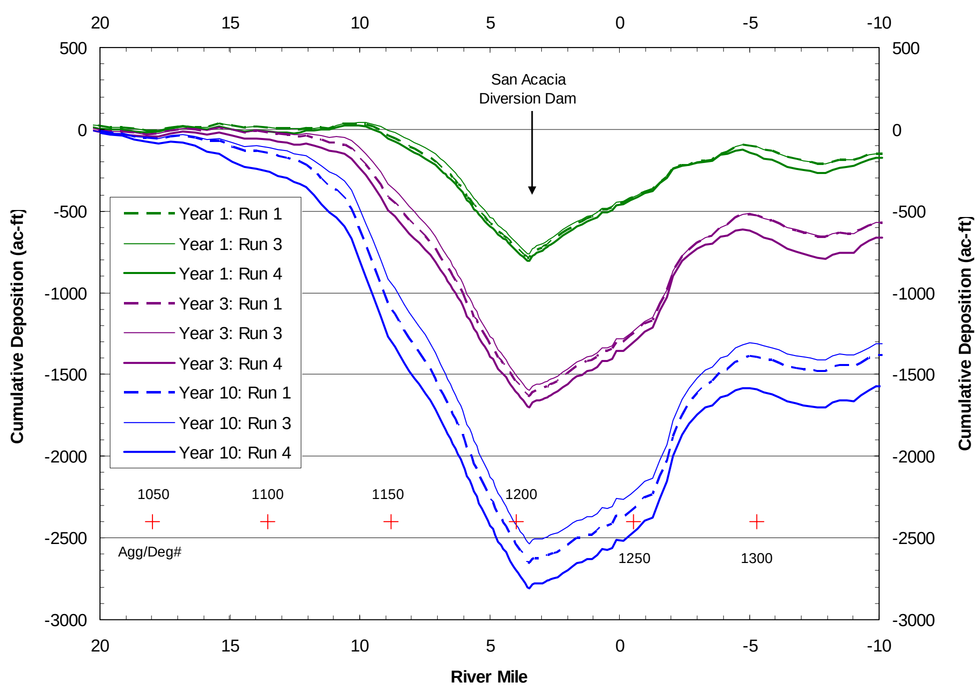

Figure 22. Comparison between Simulated Erosion or Deposition Volumes of Run 1, Run 3, and Run 4.

5.2.4 Sensitivity to Manning's Roughness Coefficient

The value of Manning's roughness coefficient was increased to 0.025 to test the sensitivity of the model to its value. The profile comparison between the base simulation (Run 1) and the simulation with the increased Manning's roughness coefficient of 0.025 (Run 10) is given in Figure 23. The erosion volume comparison is given in Figure 26. There is slightly less erosion predicted when Manning's roughness coefficient is increased, but the difference is insignificant.

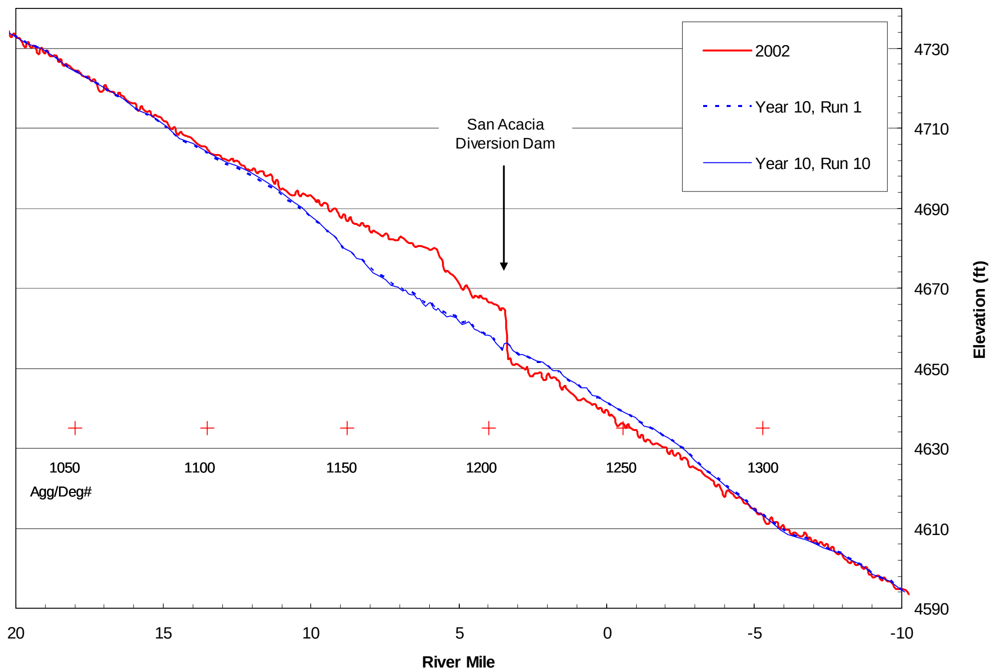

Figure 23. Comparison between Simulated Bed Profiles of Run 1 and Run 10.

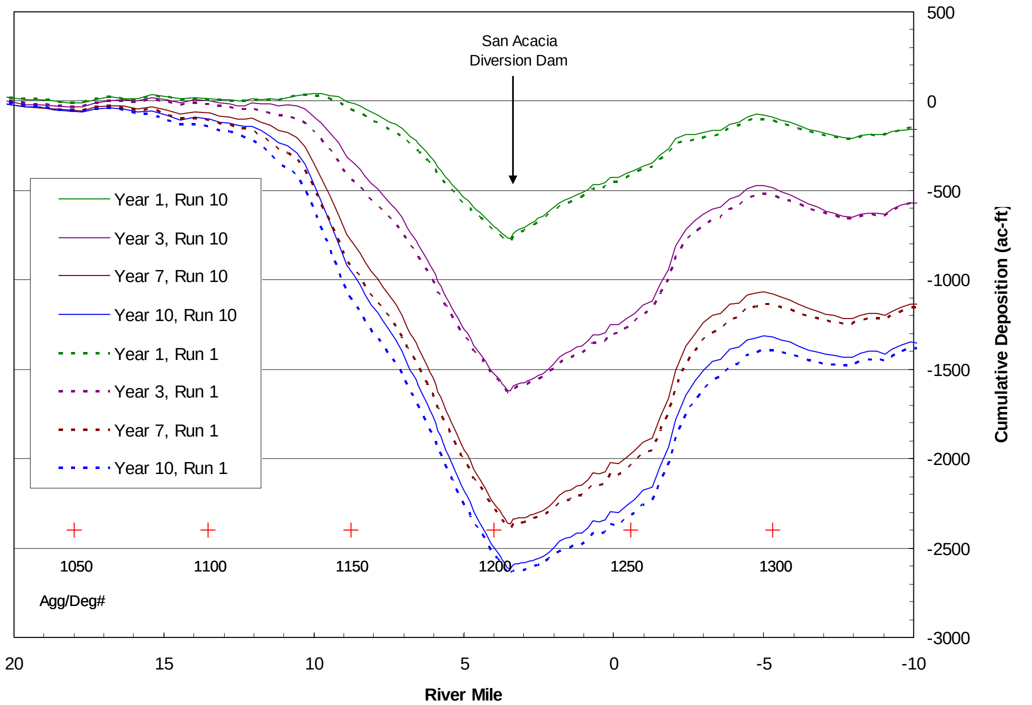

Figure 24. Comparison between Simulated Erosion or Deposition Volumes of Run 1 and Run 10.

5.2.5 Constant 1000 cfs flow

A constant flow of 1000 cfs was simulated for a period of 120 days. The constant flows are simulated to show the change to impacts with increasing flow rate. The results are shown in Figure 25 and Figure 26. The erosion is limited to the 3 to 4 miles upstream of the dam and less than 300 ac-ft of sediment is eroded upstream of the dam. Even at this relatively small flow, the water is able to produce a smooth profile and the steep front at the dam is eroded away.

The sediment concentrations upstream and downstream of San Acacia Dam following its removal during the 1000 cfs flow are given in Figure 27. The upstream concentration is the average concentration computed from RM 14 to 24 (approximately the reach starting at 10 miles upstream of the dam and extending 10 miles further upstream). The upstream sediment concentration can be thought of as the background concentration. The downstream sediment concentration is the concentration averaged over the 5 mile reach immediately downstream of the dam. It should be noted that there was less than 1 % of silt and clay measured in the sand samples collected by Bauer (2004) and therefore there was very little silt and clay is assumed in the sediment storage behind San Acacia Diversion Dam. Further sediment sampling of the sediment behind San Acacia Diversion Dam would be necessary to improve the accuracy of the predicted sediment concentrations. The simulations with a constant flow of 1000 cfs showed that the downstream concentrations were initially 1200 mg/l higher than the concentration upstream of the dam or the background concentrations. After 120 days of a flow of 1000 cfs, the downstream concentrations were approximately 650 mg/l higher.

It should be noted that an increase of 1200 mg/l is a relatively minor increase in sediment concentration considering the large natural variability in sediment concentrations (see Figure 13). Sediment concentrations currently vary between 100 and 8000 mg/l.

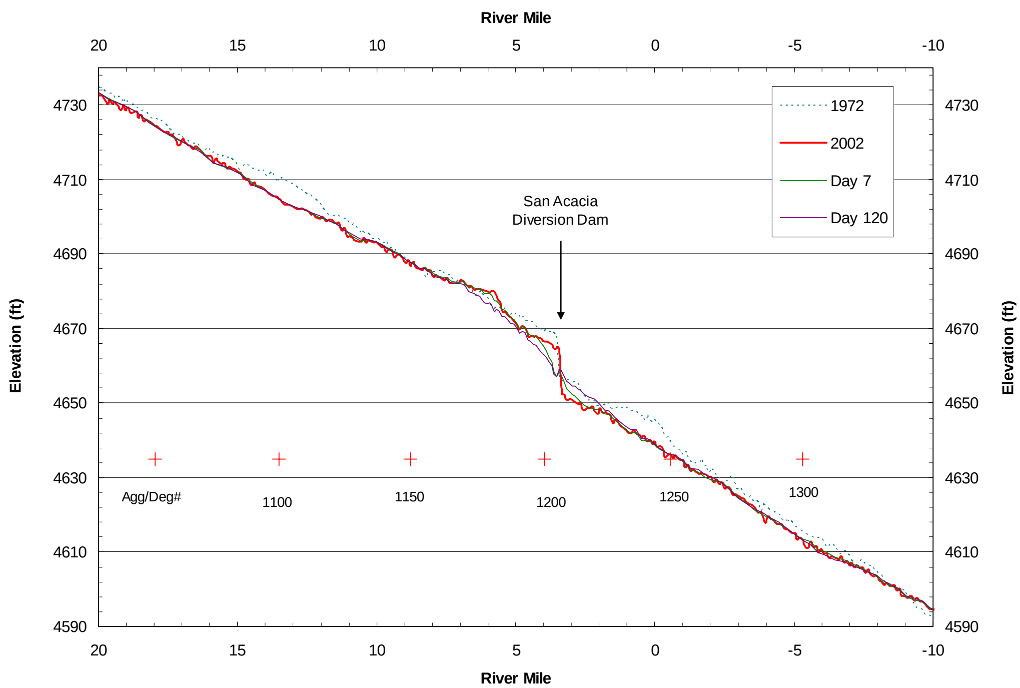

Figure 25. Simulated Bed Profile Assuming a Constant 1000 cfs flow for a period of 120 days.

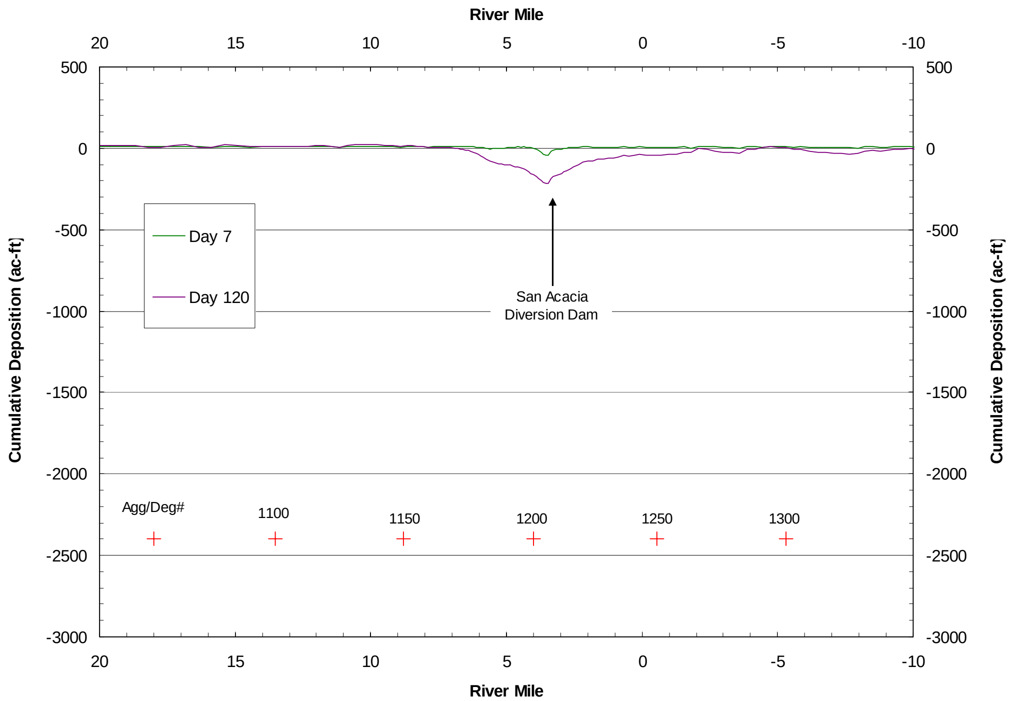

Figure 26. Simulated Cumulative Erosion or Deposition Assuming a Constant 1000 cfs flow for a period of 120 days.

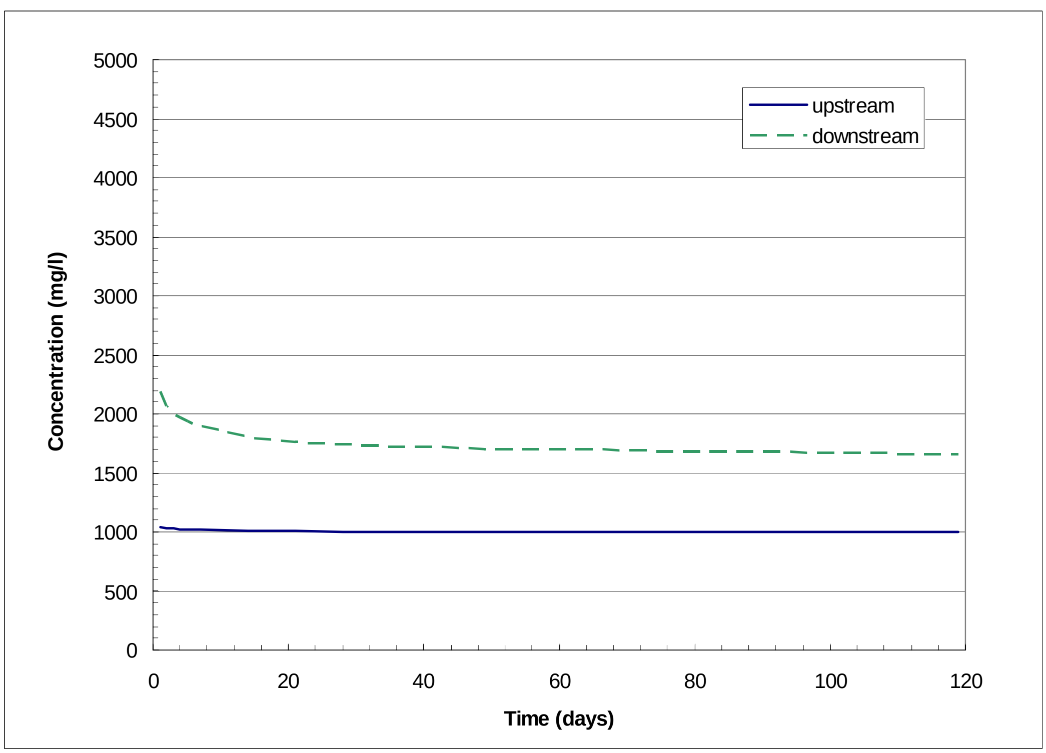

Figure 27. Simulated Sediment Concentrations after Dam Removal Assuming a Constant 1000 cfs Flow.

5.2.6 Constant 3000 cfs flow

The erosion zone for the constant flow of 3000 cfs extended approximately 6 miles upstream of the dam, near Agg/Deg #1143 (Figure 28). The constant flow of 3000 cfs eroded approximately twice as much sediment as the 1000 cfs flow (600 ac-ft versus 300 ac-ft, see Figure 29).

The sediment concentrations following removal are given in Figure 30. The concentration upstream of the dam, which can be thought of as the background concentration, stabilizes at approximately 1600 mg/l. The downstream concentrations immediately after dam removal are 3800 mg/l (1850 mg/l higher than upstream concentrations). After 120 days, the downstream concentration was 850 mg/l higher than that upstream.

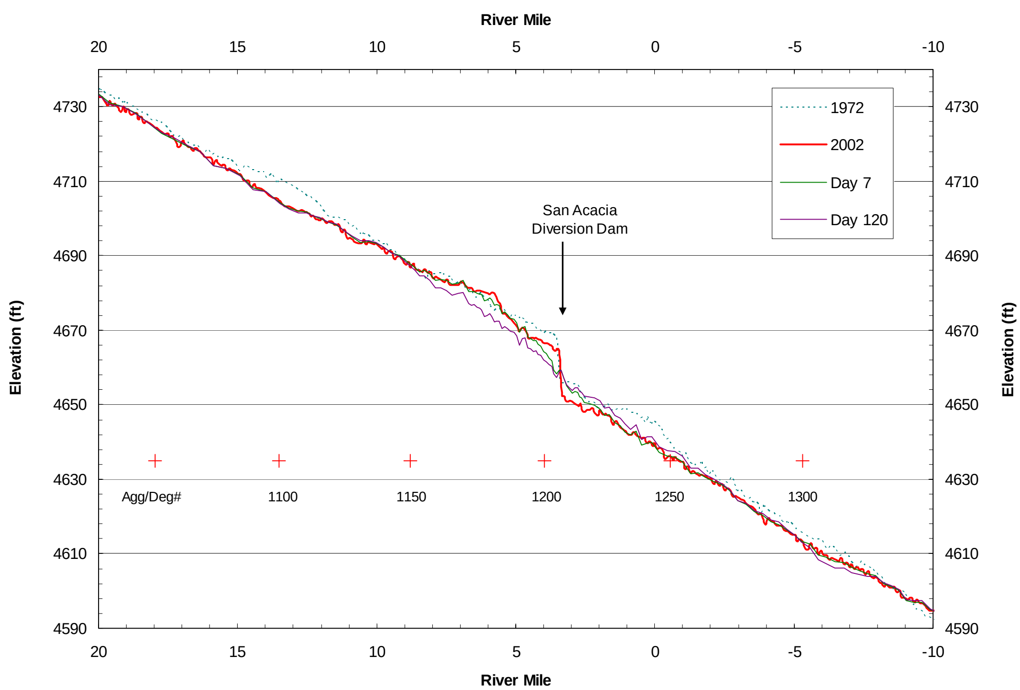

Figure 28. Simulated Bed Profile Assuming a Constant 3000 cfs flow for a period of 120 days.

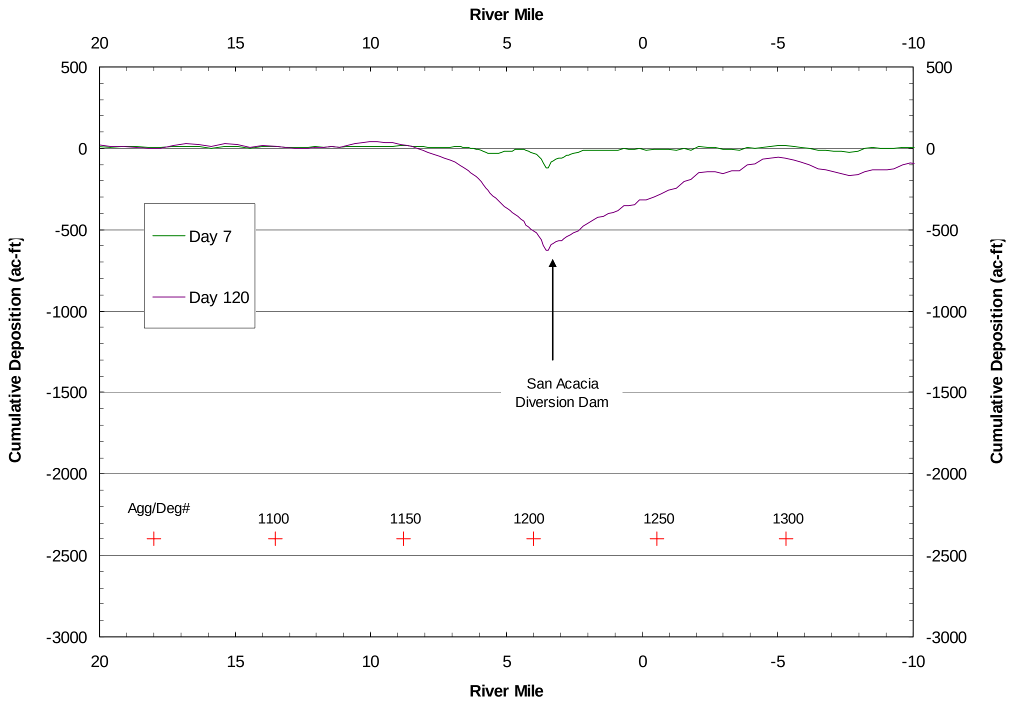

Figure 29. Simulated Cumulative Erosion or Deposition Assuming a Constant 3000 cfs flow for a period of 120 days.

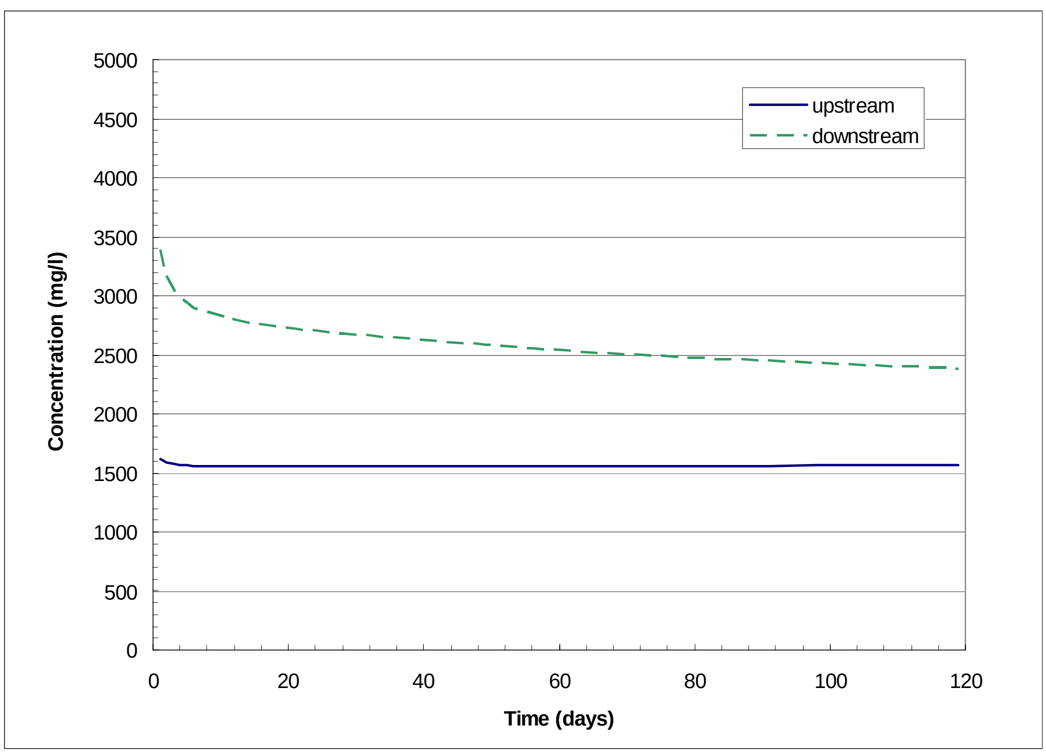

Figure 30. Simulated Sediment Concentrations after Dam Removal Assuming a Constant 3000 cfs Flow.

5.2.7 Constant 7000 cfs flow

The erosion zone predicted as the result of a 7000 cfs flow for 120 days extended approximately 6 miles upstream of the dam, near Agg/Deg #1143 (Figure 31). This is a similar erosion distance as predicted for the 3000 cfs flow. However, the volume eroded during the 7000 cfs was much greater, approximately 1400 ac-ft (Figure 32).

The sediment concentration upstream of the dam stabilizes at approximately 2300 mg/l. The downstream concentrations immediately after dam removal are 4400 mg/l (2100 mg/l higher than upstream concentrations). After 120 days, the downstream concentration was 800 mg/l higher than that upstream. It should be noted that these variations are within those presently occurring.

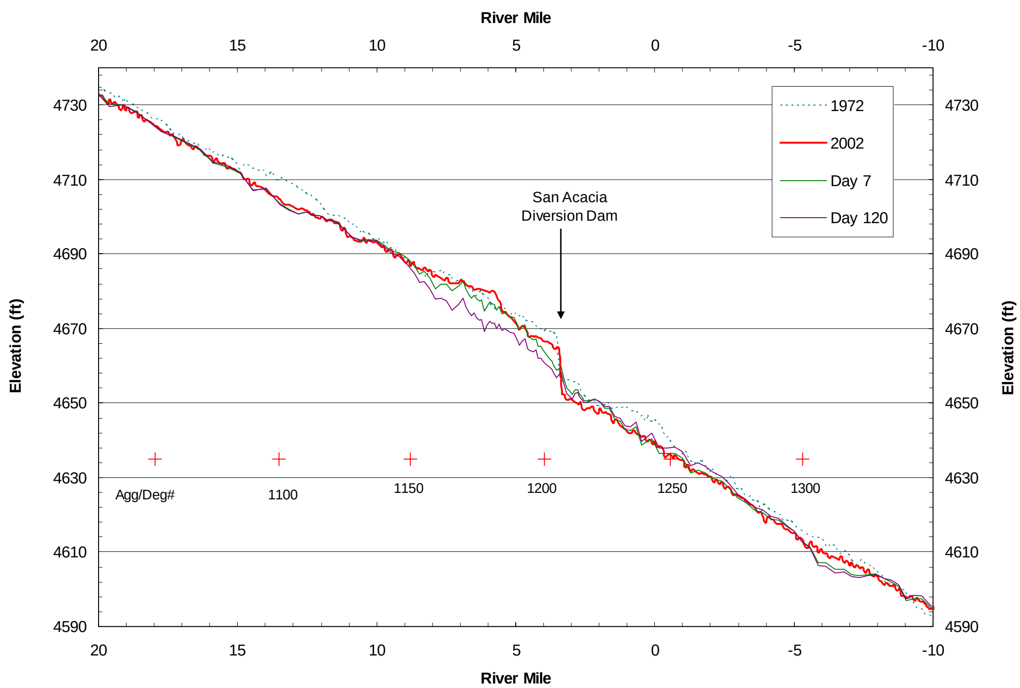

Figure 31. Simulated Bed Profile Assuming a Constant 7000 cfs flow for a period of 120 days.

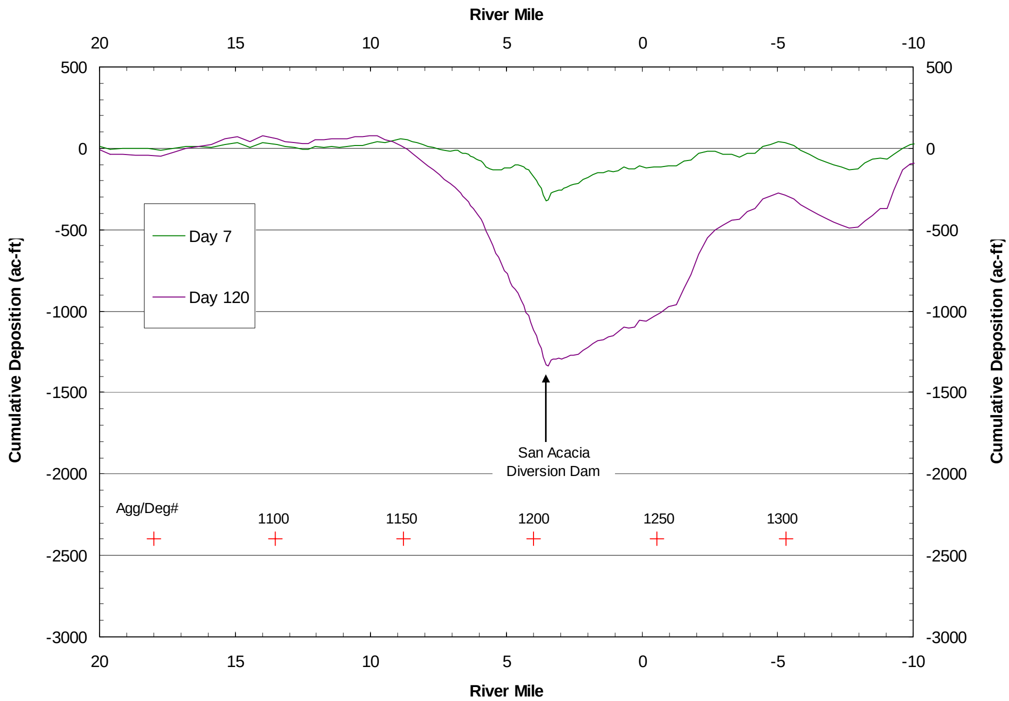

Figure 32. Simulated Cumulative Erosion or Deposition Assuming a Constant 7000 cfs flow for a period of 120 days.

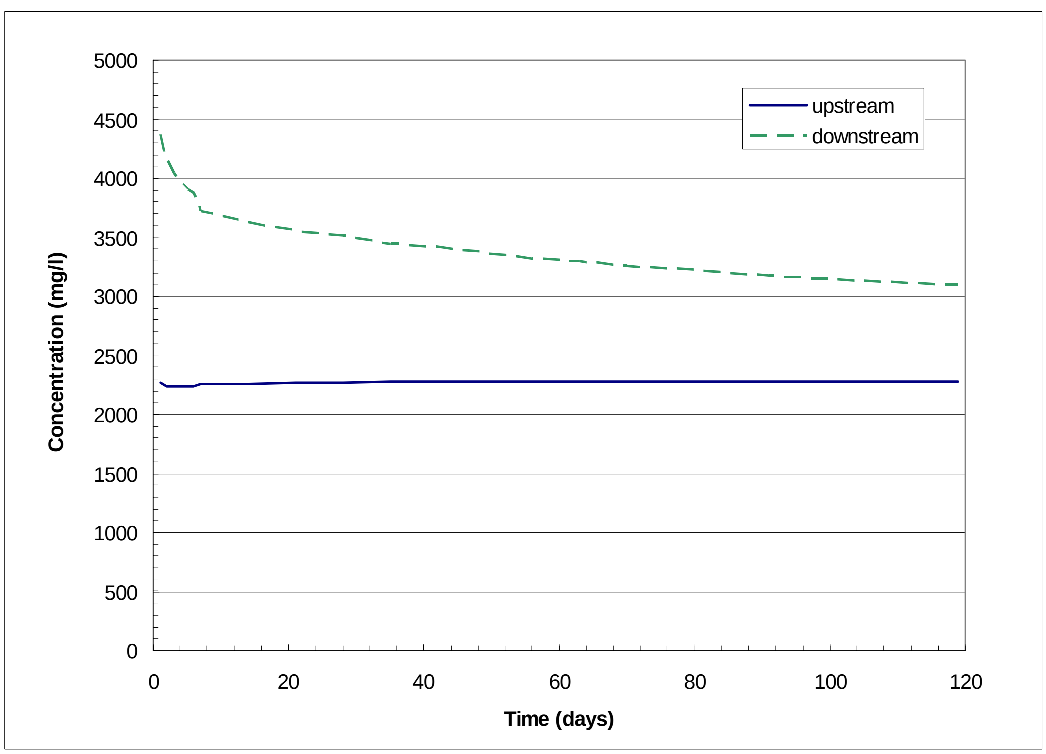

Figure 33. Simulated Sediment Concentrations after Dam Removal Assuming a Constant 7000 cfs Flow.

5.3 Stabilization Alternative

The construction of grade control structures after the removal of San Acacia Diversion Dam is termed the “Stabilization Alternative.” These grade control structures could decrease the magnitude of the upstream progression of the erosion. However, if a single grade control structure is used it may itself become a hindrance to fish passage as erosion occurs downstream from the grade control. To demonstrate the erosion downstream of the grade control, a simulation (Run 8) was performed in which a fixed grade control structure is assumed at Agg/Deg #1150 at an elevation of 4688 ft. The bed profile upstream of the grade control located at Agg/Deg #1150 remains stable throughout the 10 year simulation. However, downstream of the grade control extensive erosion occurs. The simulation predicts over 15 feet of erosion downstream of the grade control structure at the end of the 10 year period.

A series of grade control structures could be installed to prevent excessive erosion downstream of any single structure. The height of each grade control structure would be dependent upon fish passage requirements. The bed slope between the grade control structures could be the natural stream slope in this area, which is approximately 0.0008 (Figure 5). For example, if each grade control structure can have a 1.5 foot drop, and the structures extend from the dam face to Agg/Deg #1150, there would need to be 10 structures spaced approximately 2600 feet apart. However, to construct these grade controls extensive channel excavation would need to be performed. Also, the sediment that would have been eroded and transported downstream would be either stabilized or excavated and removed from the system. With less sediment coming downstream, less deposition would occur in the reach downstream of the dam. A simulation (Run 9) was performed assuming that a series of grade control structures as described above are installed between Agg/Deg #1150 and the dam. The results are shown in Figure 36 and Figure 37. The results downstream of San Acacia Diversion Dam location are similar to the case with one grade control structure and the river remains relatively stable downstream of the grade control structures. The amount of material eroded from behind the dam was also similar to the case of one grade control structure. The simulation assumes that the sediment excavated during the construction of the grade control structures is returned to the river system. If the sediment excavated during the construction is not returned to the river system, then some erosion may occur downstream of the grade control structures.

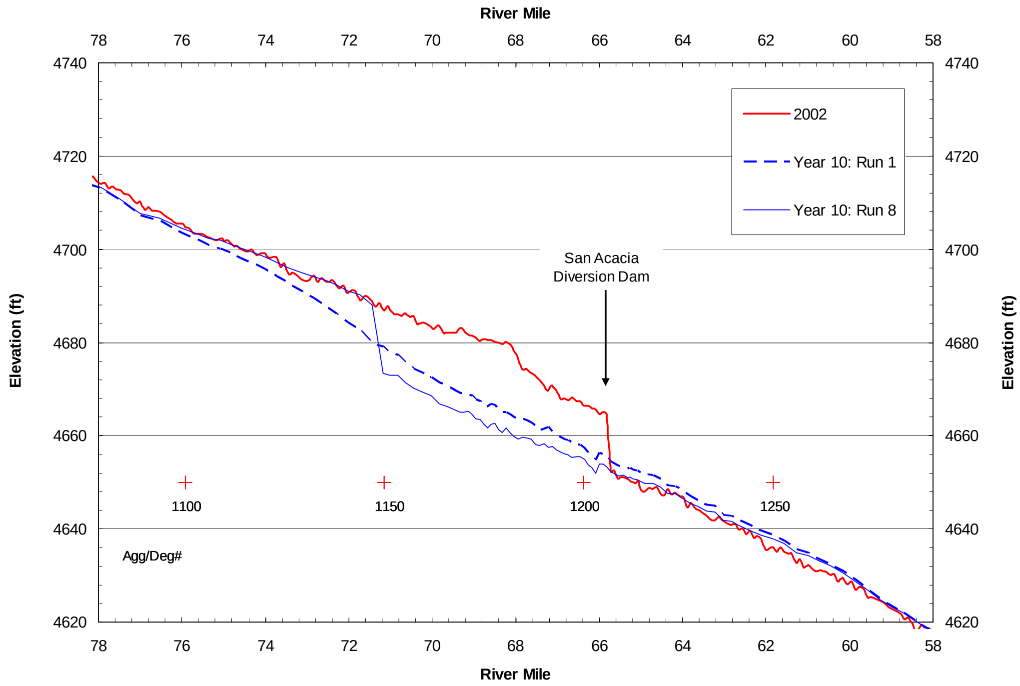

Figure 34. Comparison between Simulated Bed Profiles of Run 1 and Run 8.

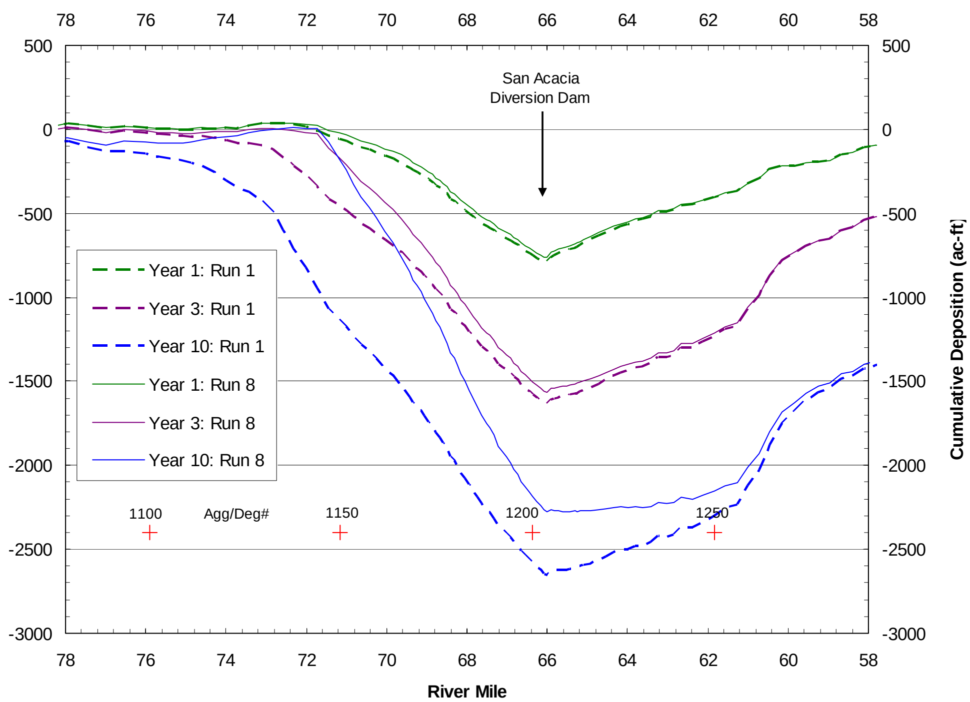

Figure 35. Comparison between Simulated Erosion or Deposition Volumes of Run 1 and Run 8 (Single Grade Control Structure at Agg/Deg #1150).

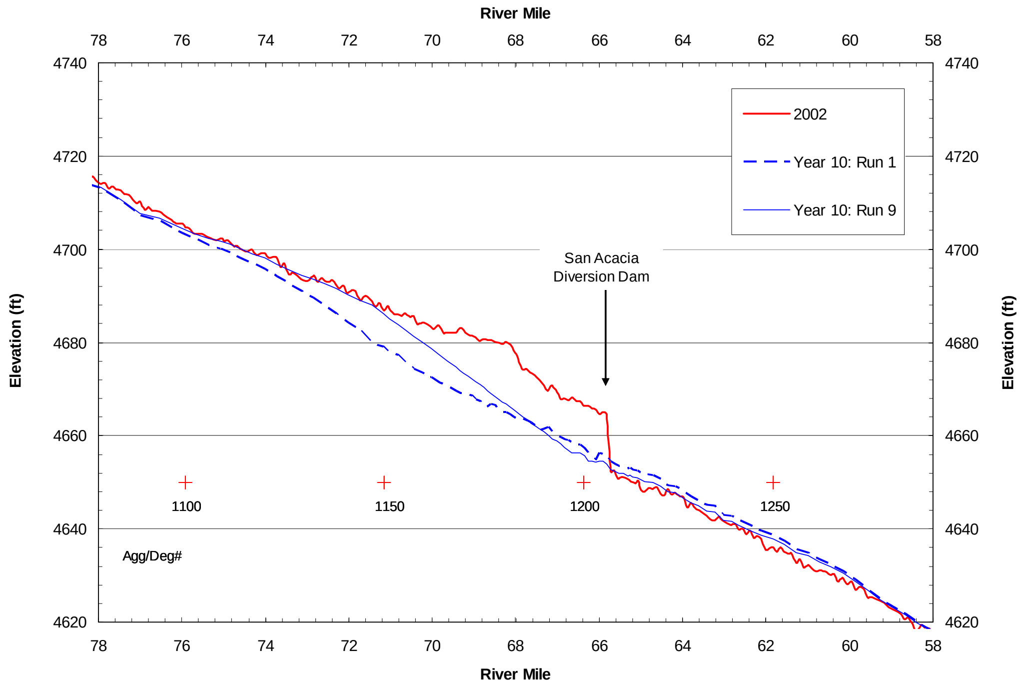

Figure 36. Comparison between Simulated Bed Profiles of Run 1 and Run 9 (Multiple Grade Control Structure between Agg/Deg #1150 and Agg/Deg #1206).

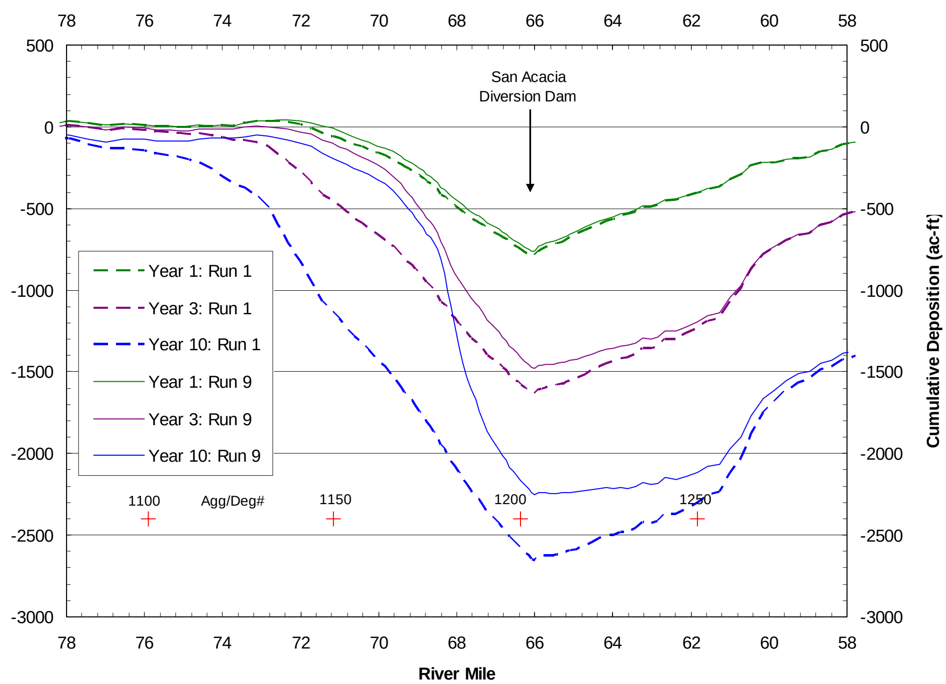

Figure 37. Comparison between Simulated Erosion or Deposition Volumes of Run 1 and Run 9.

6. Summary

The one dimensional hydraulic and sediment transport model GSTAR-1D was used to predict the sediment transport resulting from the removal of San Acacia Diversion Dam. Several different scenarios were modeled.

To provide a baseline from which to compare the results from the dam removal simulations, the No Action Alternative was simulated. The No Action Alternative leaves the dam in place and the San Acacia Diversion Dam continues to operate. The hydrologic period from October 1992 to September 2002 was simulated. Under this alternative, the river upstream of the dam remains relatively stable with some minor reworking of the sediment immediately upstream of the dam. The reach downstream of the dam continues to degrade as it has since 1972. Up to 7 feet of additional degradation was predicted downstream of San Acacia Diversion Dam for the No Action Alternative.

The Natural Erosion Alternative was simulated by removing the hydraulic and grade control at San Acacia Diversion Dam and allowing the sediment to erode naturally. Four different hydrologic scenarios were simulated. The hydrologic period from October 1992 to September 2002 was simulated (termed Run 1). In addition, three different constant flow rates (1000, 3000, and 7000 cfs) were simulated for a period of 120 days (termed Runs 5, 6, and 7). The analysis does not consider the sediment or flow inputs from the Rio Salado or other tributaries. This report also does not analyze any impacts of dam removal on the Rio Salado or other tributaries. Additional bed material and geometry data should be collected on the Rio Salado so that impacts to this tributary could be analyzed.

For the base 10 year simulation (Run 1), the GSTAR-1D model predicts that approximately 2500 ac-ft of sediment is eroded from behind San Acacia Diversion Dam over the 10 year hydrologic period from 1992 to 2002. The erosion after dam removal will occur rapidly and after the first year there will be no significant vertical barrier to fish passage. The erosion zone upstream of San Acacia Diversion extends approximately 10 miles upstream of the dam. Just upstream of the diversion dam the erosion depth is approximately 10 feet. The erosion depth gradually decreases going upstream from the Rio Salado. At Los Cañonitos (Agg/Deg #1150), the erosion depth is approximately 7 to 8 feet. At the confluence of the Rio Puerco (Agg/Deg #1100) the change in elevation is less than 2 feet, which is similar to the erosion simulated in this reach under the No Action Alternative. The 2500 ac-ft of sediment eroded from behind San Acacia Diversion Dam will provide a substantial quantity of sediment to the downstream reach and may reverse the current trend of erosion to cause deposition downstream of San Acacia Dam for at least one decade. Also, the current trend of bed coarsening may reverse downstream of San Acacia Dam after removal for at least one decade.

An analysis was performed to determine the model sensitivity to bed material distribution and active layer thickness. The hydrologic period from October 1992 to September 2002 was used for this analysis. The model is not sensitive to the active layer thickness chosen. However, it was found that the erosion upstream of San Acacia Dam is sensitive to the bed material distribution assumed. The simulated erosion upstream of San Acacia Diversion was 400 ac-ft less if it is assumed the influence of San Acacia Diversion Dam on the bed material size distribution extends 5 miles instead of 10 miles. There is some uncertainty regarding the sediment gradation below the surface layer because no sediment cores were obtained of the sediment deposited behind San Acacia Diversion Dam. Before the dam is removed, it is *strongly* recommended that sediment cores through the entire depth of the sediment deposit are obtained and analyzed. The sediment core data could improve the estimate of the sediment erosion and transport following dam removal.

Another uncertainty of the erosion and transport following dam removal is the presence of consolidated clay layers or gravel layers. A consolidated clay layer would act to slow and/or reduce erosion of sediment from behind the dam. Gravel layers could have the same effect. A large layer of gravel or consolidated clay could cause a headcut to form in the reservoir sediments. Again, the uncertainty regarding the presence of clay and gravel layers could be reduced or effectively eliminated by obtaining the sediment core data. The degree to which the clay is consolidated will also affect the final shape of the cross sections. If the clay is fairly well consolidated, the banks may remain relatively steep, however, if the clay is not consolidated, the banks may collapse and the bank height will be much less.

The constant flow simulations demonstrated the effect on increasing the flow rate on the sediment erosion and transport. Also, the sediment concentration was analyzed. The sediment concentration downstream of the dam immediately following dam removal will be significantly higher than upstream. It is estimated that the initial concentrations after dam removal will be approximately 1000 m/l higher at a flow of 1000 cfs and almost 3000 mg/l higher at a flow of 7000 cfs. The sediment concentrations will eventually return to normal levels, but it is expected to take more than one year to reach near background sediment concentrations. It should be noted, however, that the measured concentrations have varied between 100 to 8000 mg/l on the Rio Grande during the period 1992 to 2002 and the additional concentration caused by the removal of San Acacia Dam is expected to fall within this range.

The Stabilization Alternative consists of installing one or more grade control structures in the stream channel after the dam is removed. These grade control structures would reduce the upstream erosion. A single grade control structure placed upstream of the dam at the current bed elevation, however, would cause substantial erosion downstream of the structure. This erosion would cause a drop of more than 10 feet in water surface elevation across the single structure and most likely prevent fish passage. To ensure fish passage, it would be necessary to install a series of grade control structures. For the purposes of this report, it was assumed that a series of 10 grade controls structures were built, each with a 1.5 foot drop across them. If the sediment excavated during the construction of the structures is returned to the river system, the Rio Grande downstream of the grade control structures will likely remain relatively stable over a ten year period. However, if the sediment excavated during the construction of the structures is not returned to the river system, then erosion downstream of the dam may continue to occur.

7. References

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Yang, C.T, Huang, J., and (2005). *User's Manual for GSTAR-1D 1.0 (Generalized Sediment Transport for Alluvial Rivers – One Dimension, Version 1.0)*, Draft publication of Reclamation, Technical Service Center, Denver, CO.

8. Appendix A

Bed Material Data Collection Trip Report

Rio Grande, New Mexico

July and August 2004

By Travis Bauer

Bed material samples were collected on two separate trips to the Rio Grande in July and August 2004. The first trip was on July 21, 2004 to July 23, 2004 in support of the Albuquerque Area Transition Zone modeling. The second trip was from August 3, to August 6, 2004 in support of the Rio Grande sediment models. Between the two trips the area between Angostura Diversion Dam and Silver Canyon in Elephant Butte Reservoir were covered. This report will relay field observations and note what data were collected. The report will describe sites from upstream to downstream regardless of when they were visited.

Angostura Site 1 8/6/2004

This site is located a few hundred meters downstream from Angostura Diversion Dam. Access to the site was through the Baca property. Three bed material samples were collected from the gravel bar at the upstream end of the property. There was a low bar that was just recently exposed. The bar has a thin covering of clay from recent arroyo activity upstream. The bar is unvegetated but it looks like some aquatic plants may have been rooted on the surface when flows were higher. The surface of the bar was pretty coarse being mostly coarse gravel and cobble but the subsurface was much finer (sand and pea gravel). I was surprised to find it relatively easy to get a shovel into the bed here. Based on how easily the material was disturbed I think the material was recently (this spring) reworked or deposited from upstream. The landowner said that the riverbed was still dropping just a little ways downstream (mouth of Las Huertas Creek). The bed material samples were taken to represent the surface armor and not the bulk bed material.

Santa Ana Construction Site 8/3/2004

We were able to access the Santa Ana construction site (BOR project) to do dynamic cone penetrometer work. We were not allowed to take bed material samples at this time. We began working at the upstream end of the project reach near CO 24. The low bar surfaces in this area (down to the mouth of the Jemez River confluence) were covered with gravel. I would guess that most of the gravel was in the coarse to very coarse gravel range. This material either came from the riverbed immediately upstream (below angostura diversion dam) or upstream of the diversion dam. Some of the low bars are beginning to vegetate immediately upstream from the mouth of the Jemez River. The willows planted as part of the project are doing very well. The river is beginning to meander to the west near range line 255 (dike 1 area). There are gravel deposits on the point bar but DCP results show that it is very thin. None of the gravel deposits through the construction site seem very solid and are easily disrupted. There is also a lot of coarse material in the spoils material along the riverbanks from the floodplain lowering. Just as a note the construction work for the 2 additional GRF's and Rock Sill has begun downstream of the BOR project area.

Site 1 7/21/2004

This site is located upstream from the Hwy 550 Bridge in Bernalillo, NM adjacent to the Coronado Monument. Specifically the site is located about 100 m upstream from the first set of wooden bridge pilings upstream from the bridge on the right side channel. One bed material sample was collected from a gravel deposit in the side channel. The deposit was still working downstream similar to a macrodune. The leading edge of the deposit was about 1 food deep and very loose. I think the material was mostly fine gravel. It was kind of impressive to see gravel being transported down such a small side channel. The larger side channel on the left side is beginning to fill in. It doesn't seem like much water is coming down anymore.

Site 2 7/21/2004

This site is located near agg/deg line 307 downstream from the Hwy 550 Bridge. One sample was collected from a small riffle on the right bank of the wetted channel. A pebble count was also done on the bar to the right of the edge of water. The gravel in the channel is very dense. It was difficult to get a shovel into the gravel to collect a sample. The subsurface was still mostly gravel. The only sand was filling the voids. The sample was collected from water less than knee deep (18 inches). Another interesting is that the color IR photos show all the gravel patches on the bars. They show up as gray patches. The gravel on the bars appears to have a uniform size distribution; it seems to be mostly coarse gravel. The pebble count location was approximately 2 feet above the water surface and was gently sloped toward the channel. Banks not covered with gravel were more vertical even if they had some gravel in them.

Site 3 7/21/2004

This site is located about 250 meters downstream from the Hwy 550 Bridge. Two samples were collected from the gravel deposit to the left of the former island along the left edge of the active channel. The site is several feet above the water surface and does not appear to have been overtopped by this year's high flow. The samples were collected from the surface but include some sub-surface material (a few coarse particles deep).

Site 4 7/21/2004

This site is located just upstream from agg/deg line 324. Two bed material samples were collected from this site. The first samples was collected from the surface of the right most bar. The second sample was collected from the bed in the riffle. There is a well-developed riffle across the channel in this location. The bars in this location are growing in the upstream direction. There are more sand dunes here than at the previous sites and they are passing over a gravel bed. The gravel is mostly coarse but there is some recently deposited sand on the bars. There are high sand banks upstream (left bank) that are eroding and could be a potential source of sand for the dunes.

Site 5 7/21/2004

This site is located near the old Bernalillo USGS gauge (downstream from agg/deg 335) on the leading edge of a point bar on the left bank. There was small gravel pushed onto the surface of the bar. There were well-developed dunes along the right bank (outside of bend) that go down to the fan at Arroyo de la Baranca. There are poorly formed macro dunes in the center of the channel. This area is much more depositional that the previous sites. One bed material sample was taken from point bar on the left bank.

Site 10 7/22/2004

This site is located at the mouth of Arroyo de la Baranca near the Rio Rancho Waste Water Treatment Plant. Two samples were collected here. The first sample was collected from the riffle on the right bank. The second sample was collected from the arroyo approximately 200 m upstream from the river. The sample is probably not representative of the material in the riffle because most of the material is too coarse to sample. This site really needs to have a pebble count done but we did not have the time. The bed seems to be mostly cobbles with occasional boulders. The arroyo fan has pushed out about half way into the channel. This site is very coarse with a dense imbricated armor layer. This should be a very stable point in the bed.

Site 6 7/22/2004

This site is located along the right bank of agg/deg line 342. The thalweg follows the right bank and a point bar starts right near the sample location. Coarse gravel was found on the surface of the point bar and in strip about 20 feet wide on the right bank. The center of the channel is mostly sand and has several depositional sand bars. The dunes are not well developed in this location. The side channel on the left bank (just upstream) is all gravel and cobble. A small riffle was starting to develop upstream near agg/deg line 340. One of the side channels running across the large bar downstream from Arroyo de la Baranca had dumped gravel into the channel just downstream from the developing riffle. The sand bars in this area except for the ones created behind woody debris had small gravel on the surface. The sandbars along the left bank at agg/deg 242 were gently sloped into the river at the upstream end and were covered with small gravel. The gravel at the sample location was dense and hard to penetrate with a shovel. Gravel deposits on the more developed bars (point bars) were also dense and at least 1 foot deep. More gravel was found at the upstream end of the point bars than the downstream end. The sample was taken from about 2 feet of water and material was removed from the upper 6 inches of the riverbed.

Site 7 7/22/2004

This site is located near agg/deg line 345. One bed material sample was collected from the head of the point bar. Gravel was pushed up onto the bar and extended about 30 feet into the channel. The gravel deposits in the channel were dense and difficult to penetrate with a shovel. There was not a lot of sand mixed with the gravel. The gravel layer was a competent layer, not just a layer a few grains thick. There were dunes starting at the edge of the gravel. There is probably gravel under the dunes but we could not detect it. The sample was collected from the upper 6 inches of the riverbed.

Site 8 7/22/2004

This site is located at the downstream end of the point bar from the previous site between agg/deg lines 347 and 348. There is a series of low bars extending out from the downstream end of the point bar. These bars are generally very coarse but have some sand covering the gravel. The sample was taken from the shallow riffle between the first bar and point bar. The gravel is similar to the other sites upstream in that it is dense and difficult to penetrate with a shovel. The right part of the channel is depositional. Some woody debris has collected here and there are lots of sand bars.

Site 9 7/22/2004

This site is located at the outfall for the Harvey Jones Channel (Arroyo Montoyas). One sample was collected from the right bank near agg/deg 354. There bed was very hard and it was difficult to retrieve a sample. There is a riffle all the way across the channel and a large island extends downstream from the settling basin. Gravel can be found in the side channel to the right of the island, on the island, and in the main channel along the left edge of the island. Upstream from the outfall, the channel is more depositional and there is not much gravel present on the surface of the bars or in the channel. There is a large point bar on the right bank upstream from the outfall that is well vegetated. Most of the sediment is sand sized or finer. There seems to be a lot of clay and silt deposition in the side channel between the bar and riverbank (cutoff channel).

Site 11 7/22/2004

This site is located downstream from the outfall near agg/deg line 360. This site is at the downstream end of the outfall island where the side channel and main channel join back up. The side channel had at least one small gravel riffle with pea to medium gravel being moved. There were a few unvegetated patches on the island that were covered with gravel. The left bank of the island was lined with medium to coarse gravel. The sample site was a gravel patch located between the large island and a smaller island just downstream. This part of the channel was mostly gravel with a little sand moving over the top. A small riffle was forming and gravel was found on top of and around the small bar.

Site 12 7/22/2004

This site is located near agg/deg 363. At this site the channel splits around an island. The left channel is mostly sand, but the right channel has a gravel riffle most of the way across. The gravel is mostly coarse and the bed is competent as it was difficult to retrieve a sample. The riffle extended diagonally across the channel for more than 300 feet. We found a little more gravel downstream but it was in isolated pockets and did not travel past agg/deg line 369. The rest of this reach should be walked to verify existing conditions.

Site 13 7/23/2004

This site is located near agg/deg line 415 upstream from Alameda Bridge. A lot of gravel was found at this site. Unlike the previous two day, the river was very muddy. Heavy rain the night before caused several arroyos to run. There was a lot of horse manure floating in the water. We entered the channel just downstream from the first small side channel upstream from the bridge and crossed to the island under the bridge. There was gravel covering most of the channel to the island. There were sand dunes moving over the gravel but gravel could be felt in between the dunes and under the sand (probing with the shovel). At the island there was some grave pushed onto the leading edge of the bar but there was also a lot of recent deposition from the storm peak so it was difficult to see patches of gravel. Further upstream gravel was found on and around several small bars. The sample was collected along right edge of a bar on the edge of the main channel. Most of the gravel seemed to be in the fine to medium size range. Closer to the left bank, gravel was also found on several of the smaller bars and on the left floodplain (active floodplain). There was also a small riffle across the large side channel near agg/deg 416. The gravel in this area was very similar to the sample and the gravel first encountered upstream from the bridge. This gravel is not real solid and could be moved if the flow got high enough.

Site 15 7/23/2004

This site is located upstream from Montano Bridge (agg/deg line 456) and is characterized by isolated patches of gravel that follow the thalweg just like site 14. Unlike site 14, the gravel at this site is a little larger and seems to be in the medium to coarse size range. This site is located along the right bank just as the thalweg shifts from the right bank back to the left bank. The photos show a point bar forming around the island just downstream. Some gravel was found on the surface of the bar but it was mostly fine gravel. The gravel at the toe of the bank is much coarser and is more competent. It is not real dense but there is at least six inches of gravel on the bed. Gravel could be found at least 50 feet into the channel at which point dunes became much more prevalent and gravel could not be found.

Site 14 7/23/2004

This site is located upstream from Montano Bridge and is characterized by isolated patches of gravel that follow the thalweg. One sample of fine to medium gravel was collected from the right bank of a small bar near agg/deg 462. At this site the gravel was found in a small scour hole at the head of the bar, on top of the bar and a short distance (maybe 5 feet) into the channel. More gravel was found on both sides of the island upstream from this site. The gravel sample was fine to medium and is mostly a surface sample.

Site 17 7/23/2004

This site is located just downstream from the I-40 Bridge and is completely dominated by gravel and small cobble. The point bar downstream from the bridge has gravel along the entire length. The gravel extends over 50 feet from the bar into the channel. The gravel eventually gives way to dunes but some gravel could be found in the dunes. The water got too deep to really see how far the gravel extended. It's likely that most of the channel is gravel. The point bar also has a lot of gravel on and in it. There were a few places were there were gravel deposits at least 18 inches deep that extended all the way to the edge of the bar. Most of these deposits were covered with a thin layer of sand. Two samples were collected from the lower riffle near agg/deg line 497. The gravel on the bar was very dense and difficult to dig through. The gravel in the river seemed very dense at first but once I started collecting the sample I found that it was much looser than I first thought. It is probably because the material was so large that it just didn't move much when walking on it. While collecting the sample I found a lot of sand under the top layer of gravel and cobbles. This gravel was probably recently reworked, loosened, or deposited. It's hard to say where this gravel came from but based on the size it could be a lag deposit from the west mesa or possibly from Arroyo Calabacillas. The gravel sample is a surface sample.

Site 16 7/23/2004

This site is located just downstream from the point bar downstream from the I-40 Bridge at agg/deg line 499. This site is basically the downstream extension of the site 17 riffle. From site 17, gravel extends diagonally across the entire channel. The bars in the middle of the channel mark the edge of the riffle. The gravel at site 16 is generally a medium gravel and most of the gravel along the bars is much looser than many of the other sites in the Albuquerque area. This gravel layer is generally only one or two particles thick and is easily disturbed. It actually feels similar to the gravel layers found on the Santa Ana construction site except that it is much smaller. In the center of the channel there are dunes passing over the gravel but the gravel seems to limit full dune formation so the dunes are somewhat misshaped. The sample was taken mostly from the gravel surface to the right of the vegetated bar.

Rio Bravo Bridge 7/23/2004

At Rio Bravo Bridge, we did not collect any samples. The channel was almost completely sand here. We did find a small amount of fine gravel along one of the bars just upstream from the bridge but it did not seem like there was enough to really influence channel characteristics. The sand bars in this location had nearly vertical banks and were generally only covered with grass. The scour holes at the leading edges of vegetated bars were very deep. It seems like the gravel found upstream in similar locations limited the depth of scour. The dunes were also much deeper and better developed than other locations with gravel. The vegetation along the left bank was growing very well. There is a dense stand of willows and cottonwoods growing just below the high terrace.

AMAFCA South Diversion Channel Outfall 7/23/2004

We walked into the channel immediately downstream from the outfall channel. There was a thin veneer of medium to coarse gravel on the bank, channel bottom and low bars on the left side of the channel. Across the main channel to the right, there was some fine gravel as well. I suspect that the gravel is from the outfall but did not have the time to investigate the reach more. It would be nice to spend more time in this area to really see what's going on. The vegetation in this area is doing incredibly well. I'm not sure but it looked like there was a stand of false bamboo growing on the island across from the outfall. We did not collect a sample from this location because it was hard to tell if it was representative of the reach or just a local phenomenon. It was also about to storm so we were in kind of a hurry to get out of the channel. It turned out to be a very good thing because there was some very bad flooding less than an hour later.

Los Lunas Site 3 8/4/2004

This site is located near the downstream boundary of Isleta Pueblo. Two samples were collected. This site is mostly sand but there was small to medium gravel pushed onto the leading edge the sand bar on the right bank. This bar is starting to look like a point bar. The channel to the right of the low vegetated island is starting to fill in. The first sample was from the surface and is mostly gravel. The second is a bulk sample of surface and subsurface. Both samples were taken near the right bank. Most of the vegetation on the bars here is still grass, but some cottonwoods are starting to grow on the three foot terrace on the left bank.

Los Lunas Site 2 8/4/2004

This site is located near agg/deg line 722 upstream from the Los Lunas Bridge. This was a very interesting site. When I first walked out of the trees onto the floodplain the first thing I saw was a bar covered with medium to coarse gravel. The side channel (50 feet wide) running close to the bank at this point turned back to the right and where it joined the main channel. As it turned there was a large gravel deposit. It was like the momentum of the gravel just kept it going straight instead of making the turn. Another striking thing about this site was the amount of sand deposition on top of the existing bars. Some of the bars had been partially eroded by the spring flows, but it seems like most of them were still there but had an extra layer of clean sand on them. In some places it seems like some of the smaller channels between the bars were filled in and buried with sand. Two samples were taken at this location. The first was a surface sample from the gravel deposit. The second sample was a bulk sample from the sand deposits along the main channel. Sand deposits were more prevalent along the main channel and larger side channels and the gravel was only a surface layer.

Los Lunas Site 1 8/4/2004

This site is located near agg/deg line 728. This site was very similar to site 2 except there wasn't a large surface deposit. This site had similar sand deposition and gravel was found along the left bank of the main channel. Two samples were taken. The first sample was taken from the sand deposits along the main channel and the second sample was a surface sample from the gravel deposit along the bank. In both sites 1 and 2, some of the sand deposits were very thick and could have been between 18 and 24 inches deep (above the low water surface). These deposits were also around existing vegetation, which shows some signs of burial and preferential deposition.

Los Lunas Site 4 8/4/2004

This site is located near the outfall for the Los Lunas Waste Water Treatment Plant and near agg/deg line 761. Once again, this site is mostly sand but in certain locations gravel was present. I found a large deposit of fine to medium gravel at the entrance to a large secondary channel. Where the channel split off the main channel there was gravel along the bank in the main channel and all over the surface of the dry secondary channel. This site also had a significant amount of sand deposition on top of the bars. At this site it seems like the sand moved onto the bars a macrodunes. Some of the bars had woody vegetation but most of the plant life in the channel was grasses. Upon closer inspection, however, there were a lot of small cottonwoods mixed in with the grass, about 18 inches high. One bed surface sample was taken from the gravel deposit. The sand seems to be same as upstream samples.

Los Lunas Site 5 8/4/2004

This site is located at the Los Lunas Habitat Restoration site. Two samples were collected near agg/deg lines 775 and 779. The first sample was a surface sample collected from the side channel that runs along the far left bank at this site. The sample was collected from several small gravel deposits in the channel just downstream from a split where part of the side channel flow went back to the main channel. The gravel in the side channel was mostly fine gravel and only covered the surface. The second sample was collected from a portion of the main channel that had just gone dry. At the sampling site there were many small gravel deposits. Each lobe, or small dune in the bed had some gravel on the surface. This fine gravel material was clearly being transported downstream. This site was similar to all the other sites in the Los Lunas reach in that there was a lot of sand deposition on top of existing bars. Because the channel is so low (almost dry) it is difficult to tell just how many of the side channels have filled in, but it seems like a lot of the smaller ones have filled in the bars have and extra 8 to 12 inches of sand on them.

Los Lunas Site 6 8/4/2004

This site is located near agg/deg line 793. One bed material sample was collected at this site from the active channel. This is another site where it seems like the bars are growing higher because of sand deposition on top of them. In some locations it seems like there was at least 3 feet of sand deposition along the channel.

Los Lunas Site 7 8/4/2004

This site is located near agg/deg line 828 and just upstream from where the Peralta Main Canal returns to the river. This area had some very tall islands that were at least 4 feet higher than the riverbed. There was also a lot of sand deposition at this site similar to the upstream sites. The bed was mostly sand but a large patch of gravel was found on the downstream side of a large scour hole. The scour hole was over 3 feet deep (standing water). Small to medium gravel was strewn across most of the bed downstream from the scour hole. One sample was collected from the surface of the gravel. The depth of scour hole just gives an indication of how much potential there is for vertical change in this reach.

Belen Site 1 8/4/2004

This site is located just upstream from the Belen Bridge. There was a little water in the river from drain returns but the water was still very low and extremely warm. The channel is mostly sand but some gravel was found on a bar adjacent to the main channel. Fine to medium sized gravel was found on top and around the bar. One sample was collected from the gravel patch. Some woody vegetation is starting to grow in this location. There is a mixture of saltcedar and cottonwood growing on some of the taller bar surfaces. The gravel was found on a grassy bar at least 2 feet above the channel bed.

Belen Site 2 8/4/2004

This site is located at the outfall of the Lower Peralta Riverside Drain. There was a beaver dam near the mouth of the drain and a large pile of gravel and cobble just downstream from the drain. The drain enters into a secondary channel that is separated from the main channel by a small island that is perhaps two to three feet high. There was a lot of sand deposition on the island. There was a gravel riffle in the main channel. Gravel in the riffle was coarse to very coarse. The secondary channel that was right of the main channel was almost completely filled with sand. There was also some small gravel on the leading edges of the bars. The gravel in the riffle and at the mouth of the drain is somewhat loose and not very dense. It was fairly easy to sample with the shovel. One sample was collected from the gravel in the riffle and a second sample was collected from sand deposits on the bars.

Belen Site 3 8/4/2004

This site is located at the upstream aerial gas line near agg/deg line 918. There is woody vegetation growing at least half way across the channel. There is a dense line of Russian olive along the left bank with tall willows growing along a side channel along the left bank. There are patches of willow and cottonwood that are between 10 and 20 feet high and cattails are giving way to trees. There are saltcedar about 5 feet high growing on the downstream half of the point bar under the gas line. The main channel is pretty narrow under the gas line and there were piles of gravel along the left bank. Most of this gravel is medium to coarse gravel. There was gravel in the channel but it was difficult to determine the size or extent because of sand dunes moving over the top. The gravel along the edge seemed to have been recently deposited. At the downstream end of the pipe point bar the entrance to a secondary channel between another island was covered with gravel. One bulk sample was taken from this material. The gravel in this area was mostly medium with some coarse particles. There was also some grass growing with the gravel. It also looks like a large macro dune started moving onto the gravel deposit and then was partially eroded by flows into the secondary channel. There could be a lot of buried gravel in this location.

Belen Site 4 8/4/2004

This site is located downstream from the gas lines near agg/deg line 930. This site is mostly san but there is some fine to medium gravel moving through. There were a few scattered patches of gravel. The channel was mostly dry at this location but there was a very deep hole upstream from one of the bars on the right bank. A good point bar pattern was setting up here with cutoff chutes. One sample was collected from an active sandbar in the main channel.

Belen Site 5 8/4/2004

This site is located at Arroyo Abo. I first went upstream of the arroyo to see if there was gravel being transported to this area. There was a lot of clay all over this site. Anything that had been recently covered in water had clay on it. I crossed the channel about 350 meters upstream from the mouth and found gravel on the left bank of the river and on top of the bar on the left bank. The gravel on the bar was fine to medium gravel on top of sand deposits. This material was definitely transported downstream by the river, but it is still hard to say where it came from. One sample was collected from this area from the surface gravel. The side channel where the gravel was collected was nearly filled with several feet of sand just like the sites upstream. The gravel along the left bank most likely came from Arroyo Abo. It was over two feet below the water but when I pulled a shovel full up a red cloud of water rushed around the shovel. Since the bed surface was not red and the material was only released when the bed was disturbed, it is likely that the material is from an arroyo deposit. The water upstream from the mouth was almost standing still. There was a large amount of sediment deposited in the main channel of the Rio Grande. There were cobbles and gravel on the surface of the deposit but a lot of the material was sand and clay. There was also a truck buried up to the windows in the middle of the river. I did not walk into the riffle to see what the bed was like because it was getting late and the water was moving very fast. The bed was also kind of loose and I would sometimes sink in up to my knees. I took a second sample just upstream from a small vegetated bar downstream from the mouth. This was mostly a surface sample of the gravel armor. The subsurface was mostly sand with very few large particles. Based on the looseness of the deposits, I think this is a very recent deposit and is maybe only a few weeks old. I only walked a short distance downstream and did not verify how much gravel is being transported downstream from the arroyo. This would be a good reach to spend more time in.

Belen Site 6 8/4/2004

This site is located at the Hwy 60 Bridge in Bernardo. The channel has shifted a little in this area. There used to be a small bar next to the gauge house, but now there is a small side channel next to the bank. Upon first inspection this site was mostly all sand. There were sand deposits on most of the bars just like upstream. The left bank of the main channel provided a good look into the sand deposition. I dug a strat column into the bank where I found about 8 inches of recently deposited sand on top of a clay layer that was on top of more sand. There were roots in the clay layer. The clay is probably from a summer storm from the year before. One sample was collected from a sand deposit on the right side of the channel. Further downstream gravel was found along the left bank and at the entrance to a dry secondary side channel. The camera memory card was full so I couldn't take more pictures, but the gravel deposition was similar to other deposits in the Los Lunas and Belen reach and was medium to coarse gravel. A second surface sample was collected from the gravel along the left bank. It started to thunder and lightning strikes were getting closer so it was time to get out of the river. I did not have the chance to see any more of the reach between Bernardo and San Acacia but it would be interesting to see how the arroyos were affected by runoff and if gravel was being transported downstream into and through this reach.

San Acacia Site 1 8/5/2004

This site is located immediately downstream from San Acacia Diversion Dam. This site showed lots of evidence of downstream movement of sediment. The large island in the center of the channel had new sand and gravel deposits along the upstream third of the island. There were sand deposits with thin gravel armor that were several (2 to 3) feet high on top of the previous surface. The left side channel was covered in silt and clay but the subsurface was mostly round basalt cobble. The main channel was also very coarse consisting mainly of gravel and cobble. The right bank of the main channel was very coarse and was all cobbles. The left bank of the main channel was covered in coarse angular gravel with red clay deposits. This material was most likely transported downstream from one of the upstream arroyos. Previous visits to this site have not revealed the coarse nature of the channel bed. During other visits, the coarse substrate was covered with fine to medium gravel. The material was large enough that it could not be adequately sampled without heavy equipment. A pebble count should be done at this site to more adequately determine the bed material size. The sample collected from the left bank of the main channel doesn't really represent the controlling bed material at this site but is representative of material that is being transported downstream.

San Acacia Site 2 8/5/2004

This site is located between range lines 1223 and 1224 just upstream from the basalt outcrop. At first glance this site is entirely sand. The channel tends to shift around a lot at this site depending on the flow level. There is an inset bar on the left bank upstream from the basalt that is becoming vegetated with willows and cottonwoods. It seems like the channel is incising a little because the side channel at 1223 seems to be abandoned. At least there is not a defined entrance anymore. There were a lot of sand bars in the channel. The low surfaces (above the water) were covered with clay deposits from recent arroyo events. There were a few gravel deposits (mostly fine gravel) on top of some of the sand bars and behind some of the wood snags in the channel. One sample was collected from a sand bar (sand). The right bank was still gravel. There was still some sand over the top of the gravel but it was exposed for at least 10 feet into the channel. This gravel layer seems to be getting coarser and is very solid as it was difficult to penetrate with a shovel. The bed seemed to be very coarse gravel to small cobble. Several small boulders were also found. These were slightly larger than a 10 by 18 inch sample bag when completely filled. Two samples were collected from the gravel layer. The samples are mostly from the surface because the shovel could not penetrate more than a few grain diameters into the bed. The side channel at 1223 might also be closed off because the point bar in that area is either getting larger or is moving downstream. Coarse gravel was also observed on the surface of the point bar at Rivermile 114.

San Acacia Site 3 8/5/2004

This site is located near Arroyo Alamillo. At this site two general areas were sampled. The first was upstream from the arroyo and the second was at the mouth of the arroyo. I did not look downstream from the arroyo because of time constraints. About five years ago, the channel upstream from the arroyo was split and the main channel flowed through the left channel. A few years ago the left channel started to fill and both channels merged into the right channel. The left channel now has signs of significant sand deposition. A soil pit was dug in the upstream third of the bar in freshly deposited sand. The pit was excavated at a small saltcedar. The tree was a few feet high above the ground surface and was growing straight up. When I started digging, I discovered that the tree had been bent over and there was about 18 inches of sand deposition on top of the clay germination surface. Below the new sand there was a clay layer probably from a previous arroyo event overlying more sand. This was very similar to sand deposition and bar building seen in the Los Lunas and Belen reaches. Further upstream at the head of the former island there are a few smaller islands with mature woody vegetation. The current low flow channel is mostly concentrated between the right bank and these islands and is less than 50 feet wide. Because the channel is so narrow it is pretty deep for the discharge. The bed of the channel here was all gravel with some poorly formed dunes passing over the top. The surface of the right bank consisted of coarse angular gravel. Excavation of the bank revealed that the entire bank was made up of coarse gravel with coarse sand and fine gravel filling the voids. This surface is similar to and is most likely a downstream extension of the 5-foot terrace found near range line 1221. One sample was collected from the bulk mixture in the bank. There was another freshly exposed bar about 200 feet upstream that was completely covered with very coarse gravel and cobbles. The right bank of the channel is very coarse in this area. The left bank is mostly sand but shows signs of downstream gravel migration. There were scattered patches small gravel on the surface of the low bars and in the dry bed forms. The mouth of the arroyo was not as pronounced as it has been at other times. I think a lot of material was removed during runoff but there was still a lot of coarse material left. One sample was taken from the surface of the gravel on the left bank near the mouth of the arroyo. The riverbed near the mouth was very coarse with some sand dunes washing through. There have been exposed boulders at this site for a long time but I found several that were at least 2 feet across and mostly buried in the bed. There was a lot of very coarse gravel and small cobbles mixed between the boulders. The bar along the right bank is now vegetated with a mixture of willow cottonwood and Russian olive and some are over 10 feet tall. The low terrace on the right bank upstream from the arroyo (3 to 5 feet high) also has dense willow growth along the channel margin.

San Acacia Site 4 8/5/2004

This site is located near rangeline 1268. The channel is narrowing at this location at the active channel width is now less than half of the previous unvegetated width. The large bar on the right side of the channel has become heavily vegetated with willow, cottonwood and Russian olive. Most of the trees are between 5 and 10 feet high but there are a few that are more mature and are maybe as high as 15 to 20 feet high. The more mature trees are mostly Russian olives. The active channel is mostly sand. There are a lot of active sand bars but there is some small to medium flat platy gravel on the leading edges of some of the sand bars. Most of the gravel was found on the outside of a bend as the channel moved from the left bank to the right bank. There was a series of bars and each of them had a small amount of gravel pushed up onto the tops of the bars. The bars were also graded into the river so that they did not have vertical faces. They were very low but other bars without the gravel coating had vertical faces and edges. One sample was collected from the gravel surface from several of the bars.

San Acacia Site 5 8/5/2004

This site is located near rangeline 1298. The non-vegetated width of this area has decreased in the past few years. The left side of the channel has become vegetated and there is no longer a rapid decrease in width as the channel enters the constriction upstream from Escondida. There is now a much more gradual reduction in width as the channel approaches Escondida. In addition to the vegetated bars along the left side of the channel, there are recent sand deposits along both banks. Many of the bars between agg/deg lines 1296 and 1298 are now connected and are part of one large sand bar. The bar is about 18 inches high and is mostly all sand. Because the bar is mostly sand, the edge closest to the water is nearly vertical. Despite the high sand content, there was a strip of gravel along the right bank that kind of followed the thalweg. This material was fine to coarse gravel and was only a few particle diameters thick. The strip only extended a few feet into the channel before it was covered with sand dunes. One sample was collected from the surface of the gravel. On the other side of the main channel (inside of the bend) there were deposits of fine to medium gravel on the upstream edges of several bars as well as small gravel deposits in the dry bedforms. A second sample was collected form the material on the left bank bars and is more of a bulk sample that includes the subsurface material. There were also clay deposits on some of the low bars. The clay was just a coating and was probably from an arroyo event.

San Acacia Site 6 8/5/2004

This site is located at the mouth of Arroyo de la Parida. This arroyo has been building a fan for the past 3 years. Occasionally, arroyo deposits are washed out and transported downstream. Material too large to be transported downstream has been collecting here for several years now. At and downstream from the arroyo mouth the entire channel is covered with gravel and cobbles. The channel is very narrow here to begin with but the arroyo fan constricts the channel even more. During low flows the water upstream from the arroyo is pooled and moves very slow. The bed material in the deepest part of the channel is very coarse gravel and cobbles. Most of the gravel brought into the channel from the arroyo is angular gravel. The arroyo fan appears to have been recently deposited. It is likely that portions of the fan were removed during spring runoff and the recent rains caused flooding on the arroyo leading to more deposition in the channel. The gravel in the main riffle seems to be stable as it is competent and imbricated. The gravel on the exposed bar was much less stable and was very loosely packed. In one spot I stepped into a pile of gravel and sank up to my knee and the material was all small gravel. I took one sample from the exposed bar. This sample is a good representation of the sediment brought in form the arroyo. One other thing I observed at this site is that in previous visits arroyo deposits were layered with river deposits on the exposed bar. At this time there were no river deposits on or in the bar. I dug several pits on the bar and the subsurface was very similar to the surface. There was a good mixture of gravel ranging from fine gravel to cobbles. Surprisingly, there really wasn’t much sand or clay. The void spaces were filled with small gravel and not sand. Also when the material was disturbed the water in the hole would clear very quickly indicating a lack of clay in the deposit. This is clearly a clast supported bed but one that could be mobilized with high enough flow.

Arroyo de las Canas 8/5/2004

I stopped at Arroyo de las Canas late this day and just made some observations. I did not collect any samples because of the time of day (almost 8:00 pm) and the storms that were overhead. The main thing I noticed at this site is that some of the arroyo fan had been removed. The downstream fan was partially cut and part of the can was now an exposed gravel bank. It doesn't look like the bed incised and it is still coarse gravel and cobble with sand dunes passing over the top. There is actually a pretty large sand bar between the two arroyo outlets. There was not enough time to go upstream to the upper outlet. It would have been nice to spend more time in this reach to really see what's going on and what impact the recent work on the east side arroyos has had on gravel supply to the reach.

Socorro Site 1 8/5/2004

This site is located upstream from the San Antonio constriction near agg/deg line 1452. This site has narrowed considerably since 1992. The most of the channel is now vegetated and the active channel is around 200 feet wide. The channel is pretty much all sand here. I was able to find some flat platy gravel in some scour holes around woody debris, but it was very isolated and not significant. There was a significant amount of sand deposition on many of the bar surfaces. All the low surfaces had clay deposition from the recent arroyo events. One sample was collected from the sand. The clay on top of the sand was excluded from the sample.

San Antonio Site 1 8/5/2004

This site is located downstream from the Hwy 380 Bridge near agg/deg line 1499. This site is located between two narrow sections in the river. This area used to be quite wide but has been narrowing in the past few years. After vegetation growth and some incision, this site has narrowed to the point that it has a similar width as the upstream and downstream reaches. There was a significant amount of clay covering all the low surfaces in this reach. The vegetation on the bars ranged in height from 2 to 15 feet and was composed of willow, cottonwood, saltcedar, and some Russian olive. One sample was collected from the bed of the active channel to avoid sampling the clay deposits.

BDANWR Site 1 8/5/2004

This site is located at the south boundary of the Bosque del Apache National Wildlife Refuge. The only water in the river at this site was coming from pumps at the south boundary. The channel here is very narrow and there is clay covering pretty much everything. The channel bed is sand but the floodplain and banks have a lot of silt and clay in them. One sample was collected from the bed. The dried clay was removed from the sample site prior to collecting the sample.

San Marcial Site 4 8/5/2004

This site is located at the San Marcial Railroad Bridge. The channel is pretty much all sand at this location with clay deposits from arroyo events covering the lower exposed surfaces. Immediately downstream from the bridge there are alternate point bars formed with some vegetation growing on them. It seems like there is between 2 and 3 feet of clearance under the bridge and that the bars under the bridge have not vegetated. One sample was collected from the active channel downstream from the bridge.

San Marcial Site 3 8/5/2004

This site is located at the downstream end of the San Marcial berm, which is a few hundred meters upstream from rangeline EB10.5. The channel is pretty narrow here and is mostly sand with clay deposits covering a lot of the bar surfaces. There seemed to be a lot of alternate bars setting up in this area that were becoming vegetated mostly with willow. One sample was collected from this site.

San Marcial Site 2 8/5/2004

This site is located at the Fort Craig pumping station downstream from rangeline EB17. This site is mostly sand and is similar to the other San Marcial sites. There are alternate bars upstream and downstream that are becoming vegetated with willows. One sample was collected from the surface of a bar. The sample is a mixture of sand and fines as there were multiple layers in the bar. It was raining at this site and I lost the sole off one of my boots so I didn't spend a lot of time here.

San Marcial Site 1 8/5/2004

This site is located near station 1800 just upstream from rangeline EB24. One sample was collected from the riverbed along the right bank. The channel is mostly sand but there is a lot of silt and clay covering everything. The banks are very slippery because of all the clay. It was raining and lighting so I got the sample very quickly. There was a lot of vegetation in the way so I couldn't see very far downstream. The channel seems to be dominated by sand but is forming alternate bars that are vegetating with willows.

Temporary Channel Site 4 8/5/2004

This site is the current location of a large headcut that progressing upstream from the temporary channel into Elephant Butte Reservoir. The headcut is currently located between rangelines EB27 and EB28. The total height of the headcut is between 6 and 8 feet high. The bed material is a fat clay that is at least 8 feet thick and possibly more. The clay has alternate layers of red and brown. I would guess that it is the difference between Rio Puerco (brown) flows and arroyo events (red). The bed and banks through the headcut are clay but there are a few sand deposits in some slackwater areas. Most of the flow is along the left bank where the water cascades down the 6 to 8 feet over perhaps a distance of 150 meters. At the downstream end of the cascade there is a second channel that drops a smaller portion of the flow over a 6-foot drop. A very small channel continues downstream and drops down to the channel after another 180 meters in a series of drops about 3 feet each. One sample was collected from this site from the large drop near rangeline EB27D. There are also many trees in the channel throughout the headcut area. These trees were buried by sediment when the reservoir last filled. They appear to be mostly saltcedar. In some places the trees are very thick. It is difficult to determine if the cascade section has any trees in it that could be slowing the upstream migration. As it is, the clay appears to be very resistant to erosion so it could be a long time before the headcut passes through the clay deposits.

Temporary Channel Site 3 8/5/2004

This site is located about 400 meters downstream from rangeline EB28 and is in a section of channel that has completely incised. The incised channel is very narrow and the banks are composed of desiccated and cracked clay. The clay banks are very brittle and fall apart very easily. The channel is more than 6 feet below the top of bank. There are a few small sand bars within the channel at this location. One sample was collected from the top of the clay banks.

Temporary Channel Site 2 8/5/2004

This site is located approximately 400 meters upstream from rangeline EB31. It looks like this might be one of the wide sections of the temporary channel. The channel is pretty narrow but there is a much larger floodplain than in other locations. There is a dense matte of cocklebur growing over everything so it is hard to really get a good look at things. The channel bottom through this reach is actually sand and there are alternating sand bars within the channel. One sample was collected from one of the sand bars. The riverbanks and floodplain (and probably the riverbed under the sand) are made up of clay. Since the clay is no longer wet it has cracked. Most of the cracks are several inches wide (almost as wide as your foot) and several feet deep. There was also some sand deposition on top of the floodplain. It is likely to continue depositing on the floodplain until the banks are too high. It could be difficult to maintain floodplain in this reach without active maintenance.

Temporary Channel Site 1 8/5/2004

This site is located at the downstream end of the San Marcial access road at the confluence of the low-flow water about 200 meters upstream from rangeline EB33 or at the mouth of Silver Canyon. This site has a mixture of sand and clay but it looks like it has been worked on since runoff so it is hard to say what it is really like. Two samples were collected here. One sample was collected from sandy material on the right bank and another sample was collected from the clay material in the riverbed. The clay was very loose and plastic.

Table 7. Laboratory Data from Sediment Samples Collected in 2004 by Bauer.

LAB I.D.	FIELD I.D.	<0.062 (Pan)	0.062	0.125	0.25	0.50	1.0	2.0	4.0	8.0	16.0	32.0	64.0	128
F143	Site 1	0.00	1.09	3.27	9.42	17.21	36.09	46.11	51.23	58.96	74.27	93.05	100.00	
F144	Site 2	0.00	0.04	0.20	1.36	7.59	15.28	18.99	23.06	29.98	42.13	60.69	96.63	100.00
F145	Site 3 (1 of 2)	0.00	1.90	3.92	8.75	19.14	25.27	29.09	33.98	41.15	51.25	75.91	100.00	
F146	Site 3 (2 of 2)	0.00	0.85	2.05	5.46	13.48	20.50	24.64	29.49	36.99	48.23	70.84	100.00	
F147	Site 4	0.00	0.34	1.44	5.24	15.29	19.98	23.22	29.34	39.22	54.08	67.75	100.00	
F148	Site 5	0.00	0.53	2.24	8.60	28.13	38.36	46.69	58.60	80.88	99.30	100.00		
F149	Site 7	0.00	0.15	0.54	2.51	7.31	11.46	14.34	17.91	23.78	32.51	49.27	79.32	100.00
F150	Site 8	0.00	0.15	0.79	3.45	10.41	16.01	19.44	24.39	32.76	44.97	72.30	100.00	
F151	Site 9	0.00	0.34	1.55	5.55	12.79	20.92	24.39	28.33	34.51	42.25	59.09	93.40	100.00
F152	Site 10	0.00	0.09	0.36	1.56	4.28	6.35	7.68	9.47	12.70	18.33	25.15	62.07	100.00
F153	Site 6	0.00	0.12	0.56	2.40	8.63	19.27	27.73	36.25	47.72	62.39	80.75	100.00	
F154	Site 11	0.00	0.05	0.29	3.00	10.13	16.43	20.51	26.05	34.39	46.92	69.25	100.00	
F155	Site 12	0.00	0.07	0.31	1.91	9.00	16.51	21.75	27.47	34.85	49.28	79.59	100.00	
F156	Site 13	0.00	0.19	1.12	5.30	14.40	22.76	27.86	34.28	46.04	65.82	91.22	100.00	
F157	Site 14	0.00	0.31	1.36	4.28	13.19	21.39	26.76	33.63	44.81	72.37	100.00		
F158	Site 15	0.00	0.20	1.05	2.82	11.30	21.60	28.17	36.24	47.54	67.95	94.18	100.00	
F159	Site 16	0.00	0.22	0.98	4.44	15.76	24.90	30.63	39.24	52.53	77.76	95.52	100.00	
F160	Site 17 (1 of 2)	0.00	0.17	0.66	3.16	13.22	20.04	22.41	25.25	30.43	39.20	62.44	90.00	100.00
F161	Site 17 (2 of 2)	0.00	0.08	0.42	2.42	10.93	18.15	22.91	28.06	35.35	47.83	73.85	100.00	
F162	Site 4 (riffle)	0.00	0.11	0.45	2.42	12.50	17.81	20.65	24.39	30.75	41.01	59.17	100.00	
F163	Site 10 (arroyo)	0.00	0.07	0.62	4.00	15.74	23.63	27.83	32.57	39.25	49.78	72.10	92.27	100.00
F164	Angostura # 1	0.00	1.53	2.82	6.62	10.06	11.02	11.85	13.40	16.17	22.25	33.96	60.13	100.00
F165	Angostura # 2	0.00	0.95	2.25	7.51	11.67	16.34	20.77	25.35	30.48	37.01	48.28	75.47	100.00

F166	Angostura # 3	0.00	2.12	4.10	9.58	12.21	13.47	14.85	17.17	21.94	28.05	37.40	80.96	100.00
F167	Belem site 1-1	0.00	0.00	0.26	8.00	65.45	96.58	99.32	100.00					
F168	Belem site 2-1	0.00	0.14	0.65	4.03	13.73	17.19	19.52	24.44	35.32	53.24	88.84	100.00	
F169	Belem site 2-2	0.00	0.06	0.75	16.92	92.25	98.96	99.70	100.00					
F170	Belem site 3-1	0.00	0.09	0.48	5.35	34.25	67.10	80.10	87.56	93.92	99.53	100.00		
F171	Belem site 4-1	0.00	0.01	0.52	5.56	47.21	88.25	97.33	99.34	99.97	100.00			
F172	Belem site 5-1	0.00	0.04	0.57	8.76	66.59	84.28	88.58	92.24	97.17	99.73	100.00		
F173	Belem site 5-2	0.00	1.12	2.67	6.17	15.52	20.32	23.17	26.53	31.71	42.43	53.65	94.35	100.00
F174	Belem site 6-1	0.00	0.05	0.38	6.67	55.78	93.06	96.97	98.47	99.71	100.00			
F175	Belem site 6-2	0.00	0.07	0.27	3.01	13.52	20.97	23.85	27.80	37.29	67.28	97.11	100.00	
F176	Basque site 1-1	0.00	0.46	3.29	21.59	99.61	99.80	99.89	100.00					
F177	Los Lunas site 1-1	0.00	0.10	0.52	7.74	76.79	95.53	98.75	100.00					
F178	Los Lunas site 1-2	0.00	0.45	1.41	9.41	36.62	50.74	60.73	68.88	78.94	93.78	100.00		
F179	Los Lunas site 2-1	0.00	0.63	1.46	5.04	20.29	32.77	39.05	48.54	65.67	93.26	100.00		
F180	Los Lunas site 2-2	0.00	0.89	2.26	6.08	90.71	99.21	99.95	100.00					
F181	Los Lunas site 3-1	0.00	0.23	0.56	4.08	28.47	60.80	73.06	84.16	95.55	99.25	100.00		
F182	Los Lunas site 3-2	0.00	0.02	0.24	4.33	39.89	83.59	92.34	96.01	98.45	99.83	100.00		
F183	Los Lunas site 4-1	0.00	0.04	0.14	3.27	36.34	79.45	92.65	97.19	99.77	100.00			
F184	Los Lunas site 4-2	0.00	0.15	0.41	3.59	12.16	17.62	22.01	31.61	58.17	92.11	99.07	100.00	
F185	Los Lunas site 5-1	0.00	0.44	1.82	11.09	50.47	67.98	75.19	81.45	90.86	99.30	100.00		
F186	Los Lunas site 5-2	0.00	0.02	0.27	3.93	24.18	82.37	96.24	99.02	99.88	100.00			
F187	Los Lunas site 6-1	0.00	0.03	0.09	3.25	31.18	78.59	93.85	98.45	99.81	100.00			
F188	Los Lunas site 7-1	0.00	0.01	0.28	6.24	44.37	81.58	91.48	95.88	98.59	99.77	100.00		
F189	San Acacia site 1-1	0.00	0.39	0.80	1.99	8.99	18.91	25.14	31.39	40.72	54.13	74.12	94.63	100.00
F190	San Acacia site 2-1	0.00	0.04	0.20	4.69	88.23	99.12	99.74	99.95	100.00				
F191	San Acacia site 2-2	0.00	0.18	0.68	3.17	10.92	14.53	16.26	19.42	26.88	40.05	58.88	100.00	
F192	San Acacia site 2-2	0.00	0.09	0.41	1.93	5.90	7.61	8.54	10.56	14.93	21.41	31.69	66.05	100.00
F193	San Acacia site 3-1	0.00	0.82	1.62	5.02	17.96	32.98	43.35	52.96	61.67	69.99	81.80	100.00	

F194	San Acacia site 3-2	0.00	0.86	1.46	4.78	19.10	25.85	31.43	39.10	48.97	60.47	71.80	87.94	100.00
F195	San Acacia site 4-1	0.00	0.47	1.17	6.50	39.41	69.35	73.41	77.60	85.72	97.36	100.00		
F196	San Acacia site 5-1	0.00	0.08	0.96	7.02	22.39	34.32	40.86	46.52	54.14	66.39	87.72	100.00	
F197	San Acacia site 5-2	0.00	0.18	1.10	9.73	77.38	97.36	98.98	99.53	99.81	100.00			
F198	San Acacia site 6-1	0.00	1.84	3.67	7.68	9.57	12.05	17.27	32.54	59.02	87.27	99.44	100.00	
F199	San Antonio site 1-1	0.00	0.25	2.03	15.31	99.49	99.90	99.95	99.99	100.00				
F200	San Mareial site 1-1	0.00	0.22	2.30	10.53	97.36	99.07	99.75	100.00					
F201	San Mareial site 2-1	0.00	0.72	6.22	34.68	96.83	98.43	99.71	100.00					
F202	San Mareial site 3-1	0.00	0.17	2.30	9.59	52.04	98.26	98.89	99.41	99.96	100.00			
F203	San Mareial site 4-1	0.00	0.82	4.80	17.76	93.88	95.70	97.77	98.86	100.00				
F204	Socorro site 1-1	0.00	1.11	4.02	29.89	81.41	91.05	92.20	92.88	94.09	96.26	98.65	100.00	
F205	Temp Chan. site 1-1	0.00	1.25	5.21	20.54	84.98	88.89	92.41	96.22	99.83	100.00			
F207	Temp Chan. site 2-1	0.00	0.31	1.89	11.70	84.09	94.52	97.30	98.07	99.07	100.00			

Table 8. Tetra Tech Bed Material Sample Data.

Reach	Cross Section	Sample Number	Date Collected	Station	Int from	Int to	B or S	5.0" 125 mm	2.5" 63 mm	1.25" 32 mm	5/8" 16 mm	5/16" 8 mm	no.5 4 mm	no.10 2 mm	no.18 1 mm	no.35 .5 mm	no.60 .25 mm	no.120 .125 mm	no.230 .063 mm
CO	1091	1	09/26/00	CM-100	70	130	B	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.0	93.9	52.4	3.7	0.0
				CM-230	190	293													
CO	1091	2	09/26/00	170	160	190	B	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.4	95.5	33.2	4.7	1.4
CO	1091	3	09/26/00	330	300	354	B	100.0	100.0	100.0	100.0	100.0	100.0	99.8	98.6	85.0	11.1	0.2	0.0
CO	1104	1	10/05/00	CM-80	70	95	B	100.0	100.0	100.0	100.0	100.0	99.8	99.5	97.7	80.6	17.1	0.9	0.1
				CM-110	95	125													
				CM-140	125	155													
				CM-170	155	210													
CO	1104	2	10/05/00	210	210	225	B	100.0	100.0	71.4	71.4	71.4	71.4	70.9	61.9	42.4	28.7	18.8	10.9
CO	1164	1	09/29/00	CM-50	30	70	B	100.0	100.0	100.0	100.0	100.0	100.0	99.6	98.4	86.3	31.3	5.5	0.4
				CM-90	70	110													
				CM-130	110	175													
CO	1179	1	09/29/00	CM-50	35	65	B	100.0	100.0	100.0	100.0	100.0	100.0	99.7	98.9	92.5	28.3	0.8	0.1
				CM-140	125	155													
				CM-170	155	182													
CO	1179	2	09/29/00	CM-80	65	90	B	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.4	95.3	44.8	3.0	0.3
				CM-100	90	125													
CO	1194	1	09/29/00	CM-80	65	100	B	100.0	100.0	100.0	100.0	100.0	100.0	99.5	97.6	87.6	35.1	1.2	0.1
				CM-110	100	125													
CO	1194	2	09/29/00	CM-130	125	140	B	100.0	92.7	89.5	78.3	70.8	63.5	58.7	53.8	40.5	9.9	1.7	0.2

Reach	Cross Section	Sample Number	Date Collected	Station	Int from	Int to	B or S	5.0" 125 mm	2.5" 63 mm	1.25" 32 mm	5/8" 16 mm	5/16" 8 mm	no.5 4 mm	no.10 2 mm	no.18 1 mm	no.35 .5 mm	no.60 .25 mm	no.120 .125 mm	no.230 .063 mm
				CM-150	140	160													
RP	1100	1	10/05/00	CM-100	77	110	B	100.0	100.0	100.0	100.0	100.0	100.0	99.2	95.4	78.6	27.9	3.8	0.3
				CM-120	110	130													
				CM-140	130	150													
				CM-160	150	180													
RP	1100	2	10/05/00	CM-330	320	350	B	100.0	100.0	100.0	100.0	100.0	100.0	99.3	95.4	72.1	21.5	0.5	0.0
				CM-390	380	410													
				CM-420	410	420													
RP	1128	1	09/26/00	CM-100	50	125	B	100.0	100.0	100.0	100.0	100.0	99.5	97.7	94.0	78.2	35.4	5.5	0.7
				CM-150	125	175													
				CM-200	175	210													
RP	1128	2	09/26/00	CM-250	210	265	B	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.0	90.7	32.2	1.2	0.1
				CM-280	265	295													
				CM-310	295	330													
RP	1150	1	10/05/00	140	132	155	B	100.0	100.0	100.0	100.0	100.0	100.0	99.7	98.7	84.7	17.3	1.3	0.3
RP	1150	2	10/05/00	CM-190	155	225	B	100.0	100.0	100.0	100.0	100.0	99.8	99.5	98.1	84.8	23.9	2.2	0.1
				CM-260	225	290													
				CM-320	290	340													
				CM-360	340	385													
RP	1190	1	10/05/00	CM-65	58	73	B	100.0	100.0	100.0	100.0	100.0	99.6	98.9	96.6	82.9	17.2	0.4	0.0
				CM-80	73	90													
				CM-100	90	125													
RP	1190	2	11/05/00	CM-130	125	135	B	100.0	100.0	100.0	98.8	84.3	60.6	43.9	34.7	25.4	6.8	0.7	0.1

Reach	Cross Section	Sample Number	Date Collected	Station	Int from	Int to	B or S	5.0" 125 mm	2.5" 63 mm	1.25" 32 mm	5/8" 16 mm	5/16" 8 mm	no.5 4 mm	no.10 2 mm	no.18 1 mm	no.35 .5 mm	no.60 .25 mm	no.120 .125 mm	no.230 .063 mm
				CM-140	135	145													
CO	833	1	08/23/98	30	21	40	B	100.0	100.0	100.0	100.0	100.0	100.0	99.7	97.1	70.5	9.7	0.4	0.1
CO	833	2	08/23/98	70	40	105	B	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	93.5	14.1	1.6	0.4
CO	833	3	08/23/98	450	402	500	B	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.1	94.8	43.0	10.1	3.1
CO	833	4	08/23/98	530	500	560	B	100.0	100.0	100.0	100.0	100.0	99.7	98.9	96.9	82.9	21.4	1.0	0.5
CO	877	1	08/31/98	140	122	184	B	100.0	100.0	100.0	100.0	100.0	99.8	99.4	98.0	90.8	30.7	2.9	0.3
CO	877	2	08/31/98	200	184	281	B	100.0	100.0	100.0	100.0	100.0	99.9	99.7	98.6	86.2	29.0	4.6	0.6
CO	877	3	08/31/98	370	281	405	B	100.0	100.0	100.0	100.0	100.0	99.2	97.2	89.3	52.1	6.9	0.6	0.2
CO	877	4	08/31/98	440	405	490	B	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	98.2	75.7	13.8	1.6
CO	877	5	08/31/98	500	490	510	B	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.4	93.9	33.0	3.7	0.5
CO	1006	1	09/01/98	100	48	150	B	100.0	100.0	100.0	100.0	100.0	100.0	99.5	98.0	86.8	16.0	0.4	0.1
CO	1006	2	09/01/98	200	150	250	B	100.0	100.0	100.0	100.0	100.0	99.8	99.6	98.6	88.3	19.0	0.5	0.1
CO	1006	3	09/01/98	300	250	391	B	100.0	100.0	100.0	100.0	100.0	99.9	99.6	98.2	86.5	21.3	1.0	0.2
CO	1006	4	09/01/98	400	391	490	B	100.0	100.0	100.0	100.0	100.0	100.0	99.7	98.8	94.1	56.5	4.4	2.5
CO	1006	5	09/01/98	590	490	601	B	100.0	100.0	100.0	100.0	100.0	99.9	98.8	93.9	70.0	19.8	2.0	0.3
CO	1044	1	09/01/98	40	16	80	B	100.0	100.0	100.0	100.0	100.0	100.0	99.8	98.5	83.3	15.8	0.5	0.1
CO	1044	2	09/01/98	100	80	200	B	100.0	100.0	100.0	100.0	100.0	99.9	99.8	99.6	97.6	34.0	2.8	0.6
CO	1044	3	09/01/98	300	200	400	B	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	97.7	81.8	38.9	10.6
CO	1044	4	09/01/98	550	400	600	B	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.5	96.4	58.3	5.2	1.4
CO	1044	5	09/01/98	680	600	690	B	100.0	100.0	100.0	100.0	100.0	99.4	95.5	84.4	41.3	3.2	0.3	0.1
CO	1091	4	09/02/98	320	311	343	B	100.0	100.0	100.0	100.0	100.0	99.9	99.8	99.6	94.6	48.9	21.6	10.5
CO	1194	4	09/02/98	500	400	625	B	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.2	91.6	56.5
CO	877	1	8/5/1995	160	-	-	B	100	100	100	100	99.7	99.6	99.1	97	81	21	3	0.2

Reach	Cross Section	Sample Number	Date Collected	Station	Int from	Int to	B or S	5.0" 125 mm	2.5" 63 mm	1.25" 32 mm	5/8" 16 mm	5/16" 8 mm	no.5 4 mm	no.10 2 mm	no.18 1 mm	no.35 .5 mm	no.60 .25 mm	no.120 .125 mm	no.230 .063 mm
CO	877	2	8/5/1995	250	-	-	B	100	100	100	100	99.8	99.6	99.2	98	84	19	1	0.1
CO	877	3	8/5/1995	370	-	-	B	100	100	100	100	100	100	100	100	99.9	53	4	0.6
CO	877	4	8/5/1995	450	-	-	B	100	100	100	100	100	100	99.9	99.7	98	22	0.4	0
CO	877	5	8/5/1995	500	-	-	B	100	100	100	100	100	99.9	99.9	99.8	99.5	80	6	0.3
CO	966	1	8/6/1995	80	-	-	B	100	100	100	100	100	99.9	99	95	69	8	0.5	0.1
CO	966	2	8/6/1995	250	-	-	B	100	100	100	100	100	100	99.6	98	90	33	6	0.8
CO	966	3	8/6/1995	420	-	-	B	100	100	100	100	100	100	99.9	99.7	98	60	6	0.6
CO	966	4	8/6/1995	500	-	-	B	100	100	100	100	100	100	100	99.9	96	24	0.6	0.1
CO	966	5	8/6/1995	540	-	-	B	100	100	100	100	100	99.7	99.2	96	63	7	0.2	0.1
CO	1006	1	8/6/1995	60	-	-	B	100	100	100	100	100	100	100	99.9	98	58	18	4.2
CO	1006	2	8/6/1995	100	-	-	B	100	100	100	100	100	99.9	99.4	97	83	36	2	0.2
CO	1006	3	8/6/1995	150	-	-	B	100	100	100	100	100	100	100	99.9	99.3	32	4	0.3
CO	1006	4	8/6/1995	250	-	-	B	100	100	100	100	100	100	99.9	99.7	97	38	2	0.3
CO	1006	5	8/6/1995	450	-	-	B	100	100	100	100	100	99.9	99.5	97	80	23	0.9	0.1
CO	1044	1	7/30/1995	70	-	-	B	100	100	100	100	100	99.8	99.5	98	85	11	0.2	0.1
CO	1044	2	7/30/1995	120	-	-	B	100	100	100	100	99.9	99.4	99	96	77	11	0.3	0.1
CO	1044	3	7/30/1995	200	-	-	B	100	100	100	100	100	99.2	98	91	61	13	0.7	0.1
CO	1044	4	7/30/1995	320	-	-	B	100	100	100	100	100	99.8	99.4	97	82	21	0.9	0.1
CO	1044	5	7/30/1995	500	-	-	B	100	100	100	100	99.7	99.5	99.4	99.1	93	24	0.7	0.1
CO	1044	6	7/30/1995	620	-	-	B	100	100	100	98	96	95	94	88	47	6	0.1	0.1
CO	1091	1	7/20/1995	100	-	-	B	100	100	100	100	99	99	98	97	68	13	0.7	0.1
CO	1091	2	7/30/1995	170	-	-	B	100	100	100	100	99.9	99.7	99.1	96	77	18	0.7	0.1
CO	1091	3	7/30/1995	300	-	-	B	100	100	100	100	100	99.9	99.9	99.7	95	39	3	0.1
CO	1091	4	7/30/1995	420	-	-	B	100	100	100	100	100	99.6	99	97	79	33	4	0.3
CO	1091	5	7/30/1995	486	-	-	B	100	100	100	100	99.9	99.5	99.2	97	91	61	43	13.3

Reach	Cross	Sample	Date	Station	Int	Int	B or S	5.0"	2.5"	1.25"	5/8"	5/16"	no.5	no.10	no.18	no.35	no.60	no.120	no.230
	Section	Number	Collected		from	to		125 mm	63 mm	32 mm	16 mm	8 mm	4 mm	2 mm	1 mm	.5 mm	.25 mm	.125 mm	.063 mm
CO	1104	2	7/31/1995	130	-	-	B	100	100	100	100	100	99.4	99.1	99	89	18	0.7	0.1
CO	1104	4	7/31/1995	200	-	-	B	100	100	100	100	100	99.7	97	87	45	9	0.4	0.1
CO	1164	1	7/31/1995	40	-	-	B	100	100	100	100	100	100	100	100	99.8	44	1	0
CO	1164	2	7/30/1995	70	-	-	B	100	100	100	100	99.7	99.3	99	96	79	29	0.3	0
CO	1164	3	7/31/1995	110	-	-	B	100	100	100	100	99.6	99.2	99	99	91	16	0.6	0.1
CO	1164	4	7/31/1995	140	-	-	B	100	100	100	100	100	100	100	99.9	91	21	1	0.1
CO	1164	5	7/31/1995	180	-	-	B	100	100	100	100	99.4	99	98	97	75	23	2	0.1
CO	1194	1	7/31/1995	70	-	-	B	100	100	100	99.1	95	88	79	65	38	6	0.5	0.1
CO	1194	2	7/31/1995	120	-	-	B	100	100	100	100	99.9	98	93	85	59	9	0.4	0
CO	1194	3	7/31/1995	210	-	-	B	100	100	100	100	99.5	99	92	95	68	17	1	0.1
CO	1194	4	7/31/1995	330	-	-	B	100	100	100	100	100	100	100	99.9	99.4	80	31	4.8
CO	1194	6	7/31/1995	540	-	-	B	100	100	100	100	100	100	100	100	99.9	67	5	0.1