San Juan River Basin
Recovery Implementation Program

HYDROLOGY/GEOMORPHOLOGY/HABITAT STUDIES
2004
ANNUAL REPORT

prepared by

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CHAPTER 1: INTRODUCTION

Hydrology, geomorphology and habitat studies of the San Juan River began in 1992 as a part of the San Juan River Basin Recovery Implementation Program (SJRIP). The activities changed from research to monitoring beginning in 1999. This report summarizes data collected in 2004 as a part of the long-term monitoring program and compares this data to that collected since 1992. Data collected in the following areas are summarized here:

- Hydrology
- River Cross-Section Measurement
- Turbidity
- Water Temperature
- Water Quality
- Aquatic Habitat Mapping from the confluence of the San Juan and Animas Rivers (RM180) to the confluence with Lake Powell (RM 0)
- Potential Razorback Spawning Bar Characterization

All data sets are from the 2004 field season except habitat mapping. Due to the long data analysis time after the late fall data collection, there is a one-year lag in the habitat data.

Methods for each data set are covered in the Long-Term Monitoring Plan and are not described in detail in this annual progress report. The report concentrates on data reporting with a minimum of data analysis, particularly between data sets.

SAN JUAN RIVER STUDY AREA

The seven-year research program defined 8 geomorphically distinct reaches in the San Juan River (Bliesner and Lamara, 1999). Figure 1.1 shows these reach locations. The bulk of the studies reported here occur within Reaches 1-6, as this encompasses the critical habitat for the endangered Colorado Pikeminnow and razorback sucker. Some studies extend outside this range where necessary to define processes that effect the critical habitat. The study area for each data set is described with the summary of that data set.

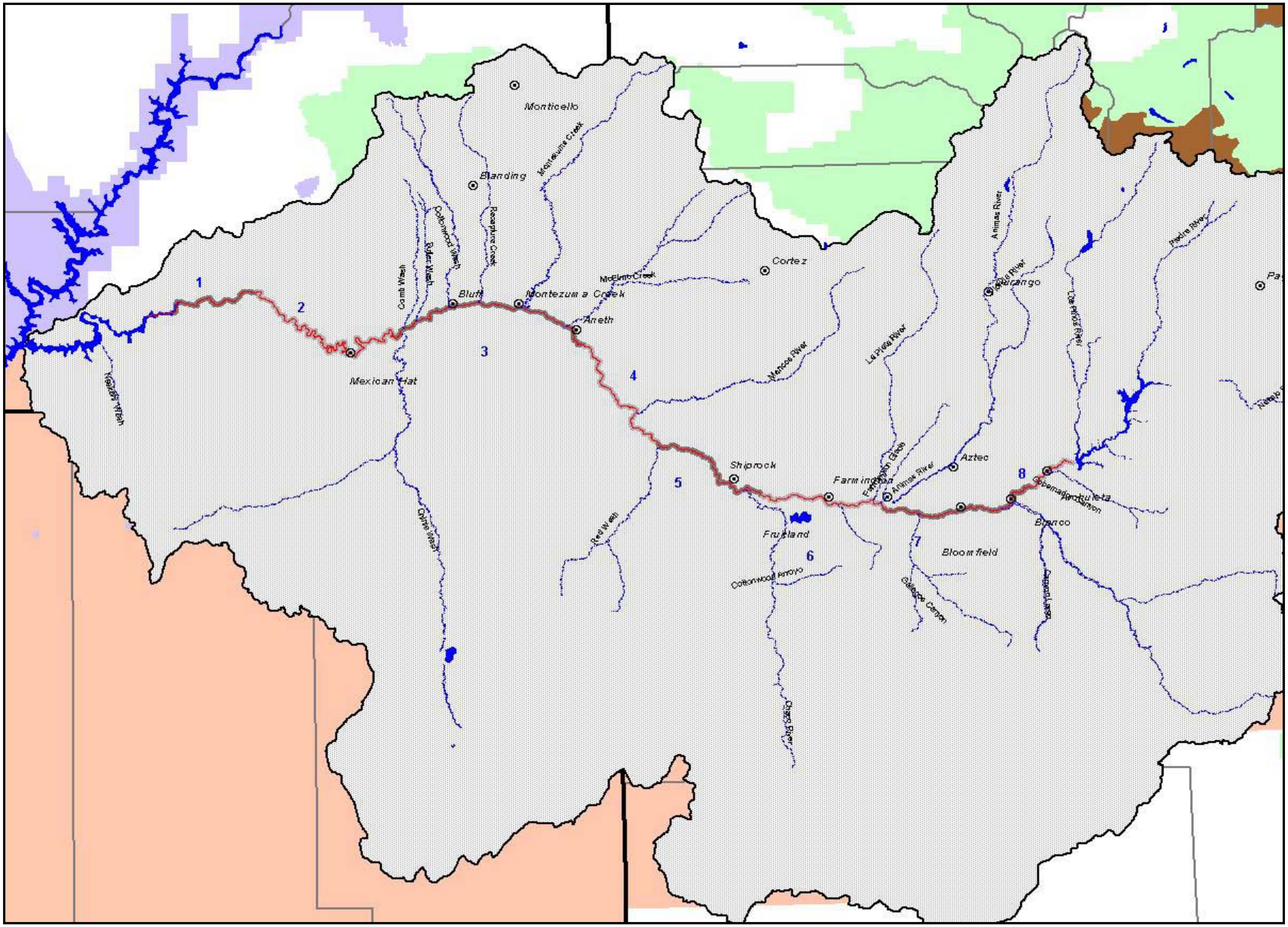

Figure 1.1. San Juan Basin Location Map Showing Geomorphic Reaches

CHAPTER 2: HYDROLOGY

BACKGROUND

United States Geological Survey (USGS) flow records for the San Juan River begin in 1911, but are not consistent or complete until about 1929. By this time substantial irrigation development had occurred. While the pre-Navajo Dam hydrology is natural in shape, it is depleted in volume by about 16 percent from natural conditions due to this irrigation development, with most of the depletion coming during the summer months. Since the depletion prior to Navajo Dam was relatively small and the flow was not regulated by major storage reservoirs, the conditions during the pre-dam period (1929-1961) are used to judge effects of later development and the value of future modification of the hydrology for the benefit of the endangered fishes.

Daily flow data recorded by the USGS from 1929 through the present are available for the key points on the San Juan River. These data have been used to analyze the 2004 hydrology and compare the statistics to other years. The foundation of comparison are the flow statistics in the SJRIP Flow Recommendation Report (Holden, 1999).

METHODS

Beginning in 1999, the operating rules recommended in the Flow Recommendation Report have been employed by Reclamation as far as restrictions would allow. USGS gage records were used to assess the resulting hydrograph at Archuleta, Farmington, Shiprock, Four Corners and Bluff.

For each release year, the operating rules are evaluated utilizing the anticipated water supply and the release criteria set. The design release pattern and the actual releases are compared. The statistics of each year are computed and the flow recommendation conditions that were met indicated.

RESULTS

Research releases from Navajo Dam were made every year from 1992 through 1998 (1991 was a control year with no modification to the release) to augment the unregulated flows from the Animas River and provide peak spring runoff flows mimicking a natural hydrograph in the San Juan River below Farmington, NM. Beginning in 1999, the operating rules presented in the Flow Recommendation Report were implemented. There was no fish release in 2000. A release of 166,000 acre-feet (based on a 600 cfs base flow) over 27 days was called for in early Spring 2001 per the Navajo Fish Release Decision Tree. Higher forecasted inflows and the need to complete dam maintenance caused Reclamation to increase the planned release to 300,000 acre-feet to reach a pool elevation of 6,074 feet by the end of September.

One of the 72-inch Hollow Jet Valves experienced hydraulic control problems and was shut down on May 30th. At that time flows were reduced to about 4,300 cfs. Not all of the forecasted inflows materialized and hence there was an over release, resulting in the reservoir being about 10 ft lower than planned, even though the release was terminated early in response to the smaller runoff volume. The release was about 130,000 acre-feet greater than needed to achieve the desired reservoir elevation.

If water year 2002 had been a normal runoff year the over-release in 2001 would not have been a source for much concern. However, 2002 was a record-breaking dry year. There is a continuous gage record for the San Juan near Bluff starting in 1927. Sporadic records exist back as far as 1915. The March to July runoff at Bluff for each year were summed and ranked for years 1927 to 2004 for a total of 78 years. The driest year on record, which is 2002, receives a rank of 1. As measured at the Bluff gage, the 2002 March through July runoff was only 92% of 1977, the previous driest year on record and now ranked number 2.

Without extra releases from Navajo Reservoir to maintain flows for the endangered fish, the flow at Bluff would have been even lower. The inflow to Navajo Reservoir was only 52% of the driest year, having a 2.5% recurrence frequency over the period of record.

Water year 2003 was another extremely dry year. The Bluff March through July runoff was 274,000 ac-ft and ranking as the fourth driest year on record. Water year 2004 brought yet another dry year but not as bad as 2002 and 2003. The March through July runoff at Bluff was 427,000 ac-ft and is ranked at number 14. For comparison purposes the wettest year on record was 1941 and had a March through July runoff of nearly 3.4 million acre feet (rank = 78). The average is approximately 1.1 million acre feet.

Table 2.1 describes the nature of the release each year since 1991. The volume of water released in excess of an assumed base release of 600 cfs, the typical minimum historical release. In 2002, 2003 and 2004 there was not sufficient water to make a fish release.

Table 2.2 compares the flow statistics from 2004 to those of the 1994-2003 period for each non-base flow category identified in the Flow Recommendation Report. Also indicated are the desired conditions that were met. Table 2.3 shows a summary of the base flow conditions for 2004, including the statistics resulting from applying the 3-gage rule approved by the SJRIP. In 2004, the 500 cfs minimum was altered due to drought conditions as follows: *"For 2004, recognizing the need to conserve water and provide sufficient water for a spring peak release at the earliest possible time, the Biology Committee recommends that the normal summer release minimum for April through October be set to 400 cfs for 2004 only. Any shortage would be computed based upon 400 cfs rather than 500 cfs. To protect the fish from possible harm, we further recommend that the flows be allowed to fall below 350 cfs for no more than 50 cumulative days and below 300 cfs for no more than 40 cumulative days for this period under implementation of the shortage sharing rules. As determined last spring, the 7-day average flow in the habitat should not fall below 250 cfs. All compliance calculations are to be made using the three-gauge rule."* (Miller, 2003). These criteria were met.

Table 2.1. Summary of Navajo Dam Release Hydrograph Characteristics since the Beginning of the Research Period, 1992 to 2004

Year	Ascending Limb	Peak	Descending Limb	Matched Animas River Peak	Volume Above 600 CFS Base - AF
1992	6 weeks starting April 13	2 weeks at 4,500 cfs	4 weeks ending July 15	Yes	409,740
1993	Starting March 1, rapid increase to 4,500 (compare with 1987)	split peak, 45 days at 4,500 cfs, 7 days at 4,500 cfs	4 weeks ending July 13	No	773,820
1994	4 weeks starting April 23	3 weeks at 4,500 cfs	6 weeks ending July 28	Yes	486,620
1995	3 weeks at 2,000 cfs in March, ramp to 4,500 over 6 weeks starting April 1	3 weeks at 5,000 cfs	4 weeks ending July 14 (summer flow increased by 200 cfs)	Yes	675,810
1996	1 week starting May 27	3 weeks at 2,500 cfs	1 week ending June 29	No	100,320
1997	3 weeks at 2,000 cfs in March, return to 600-cfs base for 31 days, 10 days starting May 12	2 weeks at 5,000 cfs	6 weeks ending July 16	Yes	433,580
1998	30 days starting April 23	3 weeks at 5,000 cfs	1 week ending June 18	Yes	340,850
1999	9 days starting May 24	8 days at 5000 cfs	9 days ending June 18	No	166,189
2000	8 days starting May 30	1 day at 4580	7 days ending June 13	No	61,484
2001	10 days starting May 15	26 days at 4300-5300 cfs	10 days ending June 28	No	265,527
2002	none	none	none	No	-
2003	none	none	none	No	-
2004	none	none	none	No	-

Table 2.2. Flow Statistics Met in Each Year

Flow Condition	Std	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
10,000 cfs or more	5	0	**11**	0	**10**	0	0	0	0	0	0	0
8,000 cfs or more	10	**13**	**27**	0	**33**	2	0	0	0	0	0	0
5,000 cfs or more	21	**49**	**72**	0	**50**	**34**	**29**	3	**33**	0	0	1
2,500 cfs or more	10	**67**	**135**	**36**	**100**	**65**	**70**	**37**	**55**	0	**13**	**23**
Yrs w/o meeting 10,000cfs	10	8	0	1	0	1	2	3	4	5	6	7
Yrs w/o meeting 8,000 cfs	6	0	0	1	0	1	2	3	4	5	6	7
Yrs w/o meeting 5,000 cfs	4	0	0	1	0	0	0	1	0	1	2	3
Yrs w/o meeting 2,500 cfs	2	0	0	0	0	0	0	0	0	1	0	0

The 2004 hydrographs for the San Juan River at Archuleta (release hydrograph), Four Corners, Bluff and the Animas River at Farmington are presented in Figure 2.1. Figures 2.2 and 2.3 show hydrographs for Four Corners for water years 1992 to 2004. The flow statistics that apply to these hydrographs appear in Table 2.4. The Four Corners gage is considered the most representative gage for the habitat range and is used in all correlations reported here.

Table 2.3. 2004 Base Flow Statistics Using a 7-day Running Average

Gage	Minimum 7-Day Average Flow	Days below Given Flow Rate		
		500 cfs	400 cfs	300 cfs
Farmington	474	39	0	0
Shiprock	305	90	27	0
Four Corners	321	73	15	0
Bluff	270	103	22	6
3-gage rule	304	92	15	0

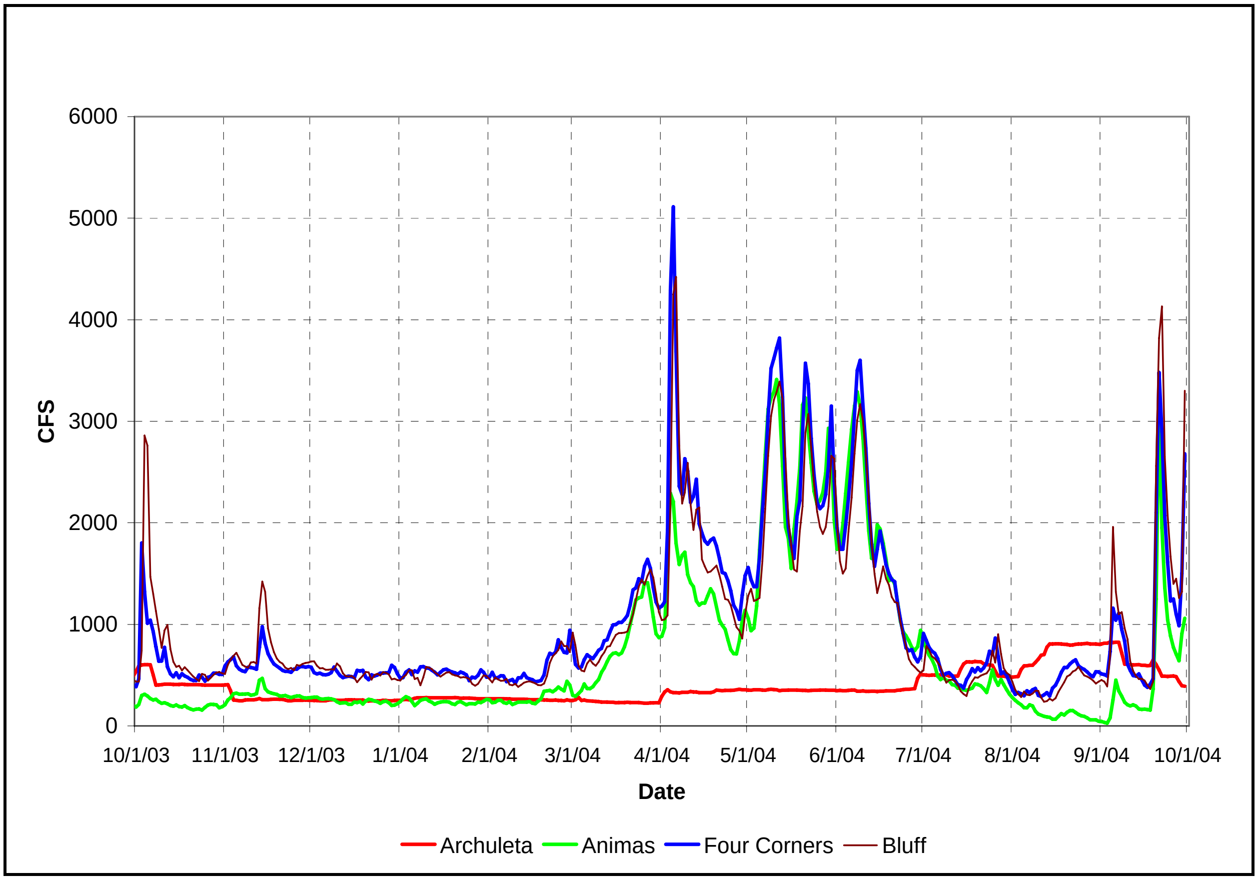

Figure 2.1 Hydrographs for San Juan River near Archuleta, Four Corners and Bluff and Animas near Farmington

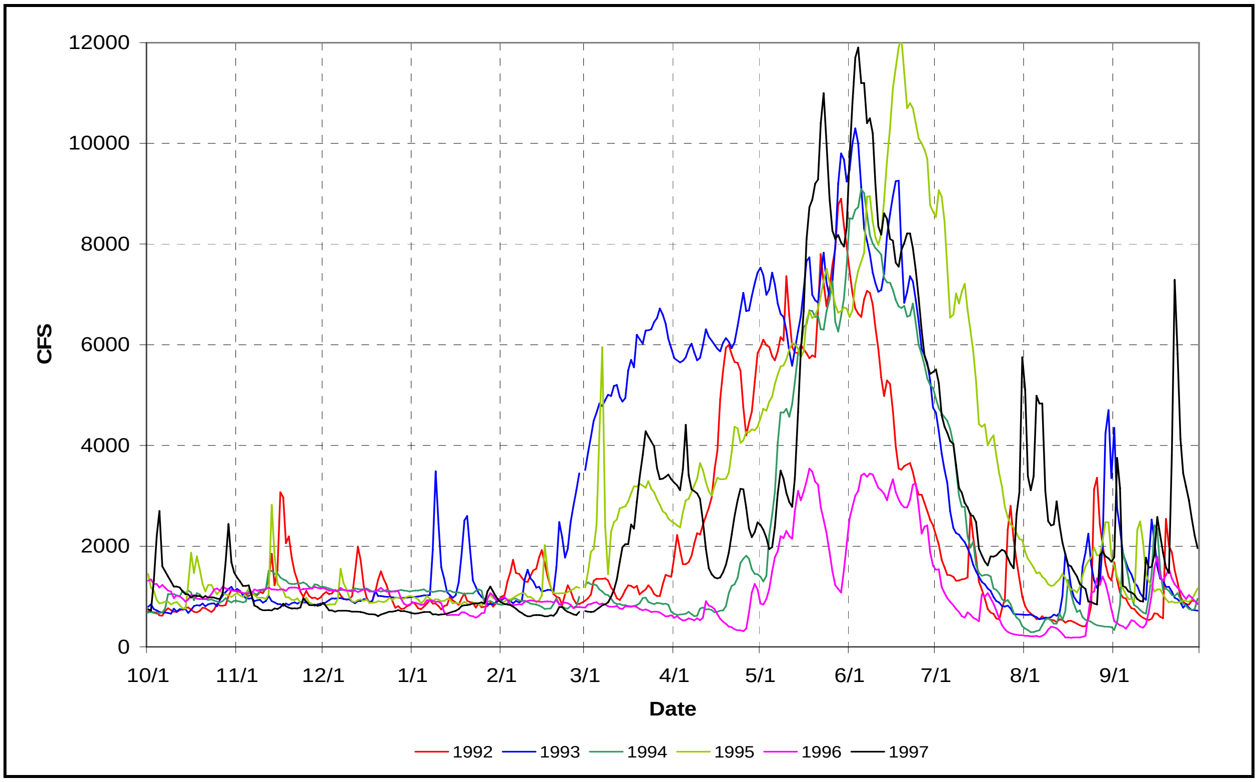

Figure 2.2. Hydrographs for San Juan River near Four Corners 1992 to 1997

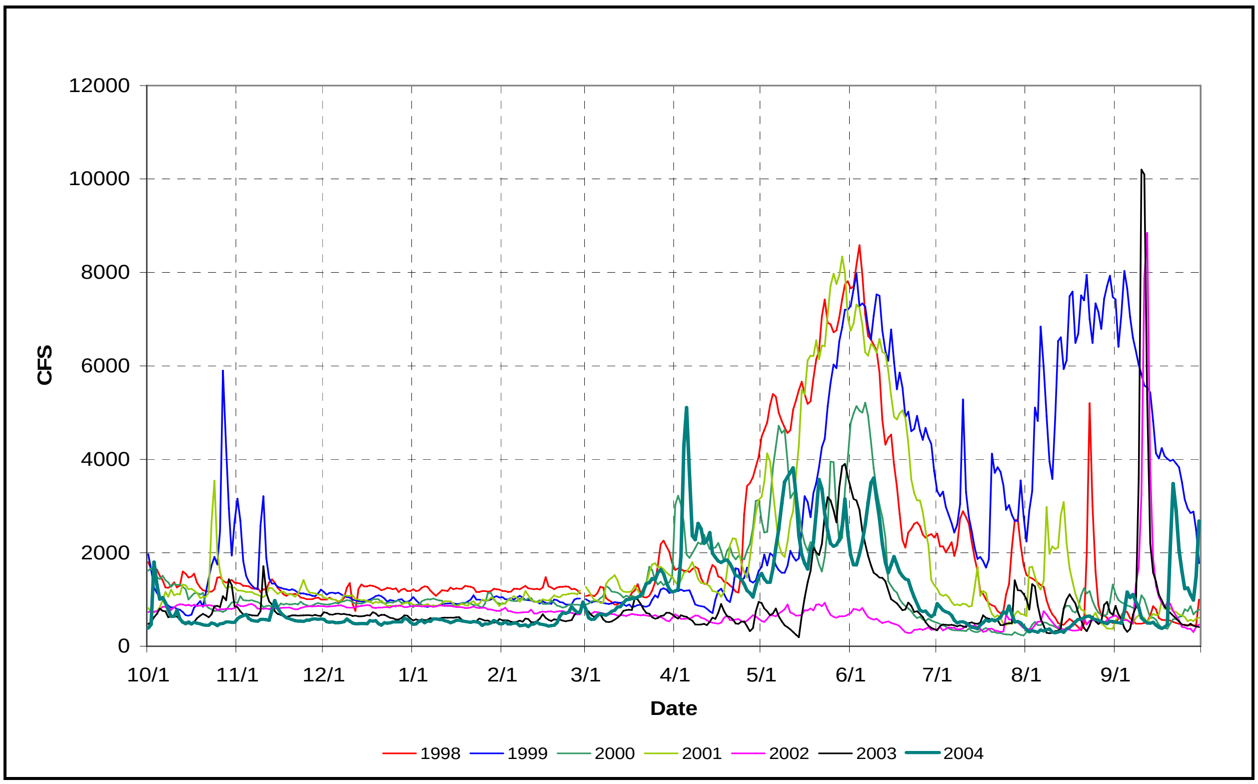

Figure 2.3. Hydrographs for San Juan River near Four Corners 1998 to 2004

Table 2.4. Summary of Flows for the Research (1991-1998) and Monitoring (1999-2004) Periods, San Juan River at Four Corners, New Mexico

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Peak Runoff-cfs	5,160	8,900	10,300	9,090	12,100	3,540	11,900	8,580	7,970	5,210	8,340	926	3,900	5,110
Runoff - af (Mar - Jul)	600,510	1,076,680	1,717,333	1,004,047	1,627,775	432,670	1,340,886	931,107	876,847	548,424	848,626	174,282	294,401	475,970
Runoff - af (total annual)	1,086,676	1,512,795	2,216,820	1,410,706	2,102,229	815,796	1,884,020	1,401,536	1,901,804	928,808	1,288,346	534,643	627,396	739,950
Peak Date	16-May	29-May	3-Jun	5-Jun	19-Jun	18-May	4-Jun	4-Jun	3-Jun	6-Jun	29-May	23-May	30-May	5-Apr
Days >10,000	0	0	1	0	11	0	10	0	0	0	0	0	0	0
Days >.8,000	0	3	16	9	27	0	33	2	0	0	1	0	0	0
Days >5,000	2	54	109	49	72	0	51	34	29	3	33	0	0	1
Days >2,500	46	81	126	68	135	36	103	65	72	37	55	0	13	23
Average Daily Flow For Month-cfs														
Oct	1,447	767	826	919	1,107	1,089	1,273	1,404	1,533	1,141	1,273	829	720	633
Nov	1,125	1,354	909	1,202	1,076	1,137	881	1,175	1,494	910	1,154	836	744	612
Dec	1,078	1,086	955	1,129	958	1,087	700	1,154	1,031	940	966	848	657	517
Jan	1,171	858	1,356	1,056	916	783	788	1,208	947	935	915	835	569	524
Feb	1,299	1,263	1,522	852	1,084	874	695	1,239	976	931	1,039	732	574	578
Mar	994	1,171	5,454	948	2,777	765	2,251	1,267	969	1,186	1,329	663	698	1,016
Apr	1,807	3,716	6,178	984	3,472	606	2,524	1,910	1,174	2,263	1,680	582	580	2,020
May	3,733	6,622	7,285	5,255	6,108	2,146	5,990	5,831	3,439	2,995	5,146	713	1,619	2,485
Jun	2,575	4,835	7,688	7,212	9,351	2,920	8,499	4,542	5,986	2,293	4,984	501	1,371	1,754
Jul	799	1,442	1,773	2,195	5,178	714	2,899	1,802	2,925	330	877	411	583	586
Aug	555	925	1,346	534	1,561	491	2,306	1,073	6,135	708	1,315	482	672	440
Sep	1,441	997	1,432	1,078	1,193	891	2,361	574	4,852	733	646	1,443	1,611	1,100
Uniqueness														
	Control	Early Ave.	Early ascent	Late Ave.	Late Peak	Dry	narrow runoff	Early Ave.	Large summer release	Dry	Early Ave.	Record Dry	Very Dry	Dry
		Storm@ spawn					Storm@ spawn	Storm@ spawn	Storm@ spawn				Sept Peak >10,000	

CHAPTER 3. GEOMORPHOLOGY

INTRODUCTION

Through 2004, river transect information was collected twice yearly, pre- and post-runoff. As a result of data integration in 2004, the Biology Committee and Peer Review Panel concluded that, while this information has been very helpful in monitoring gross channel change, the rate of change has not been such that bi-annual readings are necessary. The frequency has now changed to once every 5 years, to coincide with the valley-wide transects. This will be the last report that includes cross-section survey analysis until 2009.

Through 2003, cobble bar survey data were included in this report. In 2004 it was determined that the bar survey should be terminated due to the change in the bars that had been surveyed, with a synoptic survey of reaches 5 and 6 to identify other potential sites. Since 2004 is the final year for these studies, a separate report will be generated including the findings through the project duration and the results of the synoptic survey that will be completed in April 2005. Therefore, no cobble bar data are reported here.

METHODS

Channel Morphology - River Transects

Cross sections have been identified in five of the six geomorphic reaches for monitoring of bed elevation change with time. Reach 2 (RM 67 to RM 17) is canyon-bound and is not subject to major channel change so it is not monitored. Two to three cross-sections in each geomorphic reach were identified for monitoring. Each cross-section is surveyed across the active river channel pre- and post-runoff each year. At lease one cross-section in the reach spans the floodplain and the full width is surveyed every fifth year to monitor the effect of high flows on the floodplain. These were first surveyed in 1999 and then again in late 2004.

Table 3.1 lists the cross-sections in each geomorphic reach as identified in the Long-Term Monitoring Plan. The cross sections were selected from those established in 1962 (lettered cross-sections), those established in 1992, and new cross-sections (where existing cross-sections were not representative of a geomorphic reach). Monitoring program cross-sections are coded by geomorphic reach (e.g., CS6-02 = second cross-section in geomorphic Reach 6).

Water and channel depth are obtained by stretching a marked cable across river between anchor points for each transect and measuring the channel depth relative to a local bench mark. River depths are measured with a survey level and rod at 5 ft increments unless cross-section length exceeds approximately 300 ft. In such situations, areas of the cross-section that have a change in depth of less than 0.5 ft in 10 ft may be surveyed in 10 ft increments. Substrate type at each survey point is characterized as sand or gravel/cobble and recorded. The full-width floodplain surveys were completed with a total station outside the active channel. The points surveyed correspond to grade breaks such as a change in slope, top of a hill or edge of a channel or bank.

Table 3.1. San Juan River Channel Morphology Monitoring Cross-section Locations by Geomorphic Reach

Geomorphic Reach	X-Section No.	Former Identification	River mile
6	CS6-01	Section T	175.0
	CS6-02	RT-01	168.3
	CS6-03	RT-02	154.4
5	CS5-01	RT-03	142.7
	CS5-02	RT-04	136.6
	CS5-03*	RT-05	132.7
4	CS4-01	RT-06	124.0
	CS4-02	RT-07	122.1
	CS4-03*	Section E	118.2
3	CS3-01	RT-09	90.8
	CS3-02*	RT-10	82.3**
	CS3-03	RT-11	70.0
1	CS1-01	C-01	12.7
	CS1-02	C-02	4.1

*Valley-wide cross-sections surveyed every fifth year to monitor floodplain changes
**Valley-wide cross-section located at RM 82.2

RESULTS

Channel Morphology - River Transects

Cross-section plots referenced in Table 3.1 are contained in Appendix A. The figures show the pre- and post-runoff cross-section of each transect. The bars with the various hatch patterns show the substrate conditions at the time of survey.

The average relative bed elevation for each of the Reach 3-6 transects since the initial survey in 1992 is shown in Figure 3.1. In this plot, the average bed elevation of the first survey in 1992 was normalized to one meter. The initial survey of CS6-01 and CS4-03 were normalized to the average of the other cross-sections, as of Spring 2000, their first survey date. The change with subsequent surveys is then reported as a relative difference. Bed elevation greater than one indicates net deposition since the first survey. Conversely, a bed elevation less than one shows scour. Figure 3.2 shows the minimum relative bed elevation. It shows how the minimum elevation in each of the transects has changed since the first survey in 1992.

The variability between cross-sections in Figures 3.1 and 3.2 makes it difficult to determine a trend for the entire reach. Figures 3.3 and 3.4 are the average relative and minimum relative bed elevation, respectively. The values represented in Figures 3.3 and 3.4 are calculated by averaging the individual bed elevations shown in Figures 3.1 and 3.2 for each survey date. Figure 3.5 shows the cumulative deposition and scour for the Reach 3-6 transects for 1992 to 2004. This plot shows that cumulative deposition exceeded scour for the first time in the spring 2004. This is likely due to a large sediment laden runoff event that occurred in September 2003 that produced average daily flows in excess of 20,000 cfs at the Bluff gage.

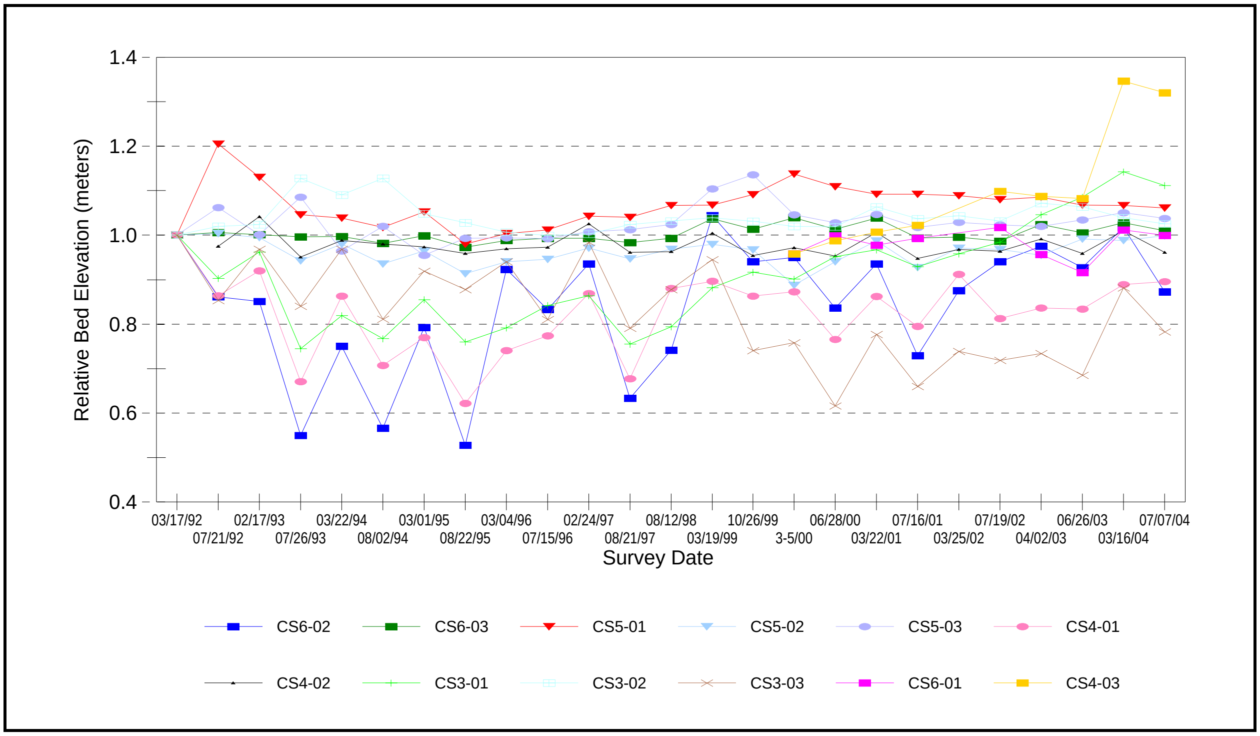

Figure 3.1. Average Relative Bed Elevation for Reach 3-6 Transects, 1992-2004

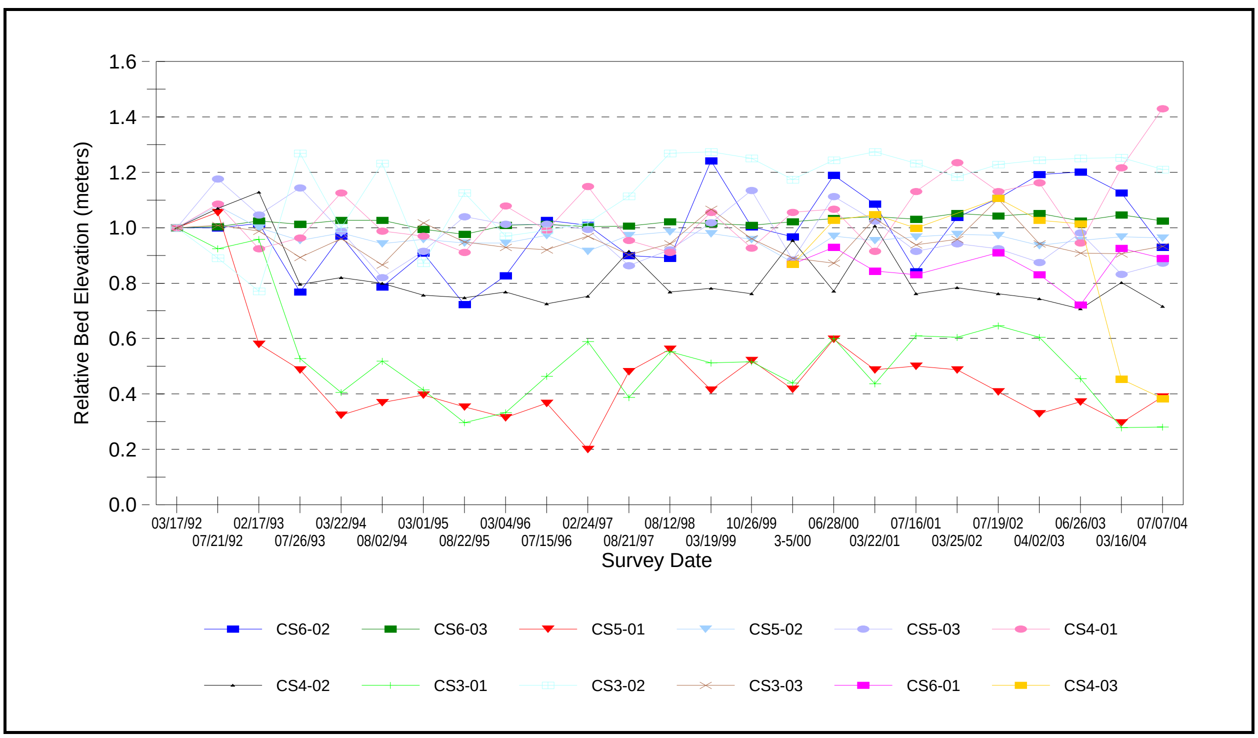

Figure 3.2. Minimum Relative Bed Elevation for Reach 3-6 Transects, 1992-2004

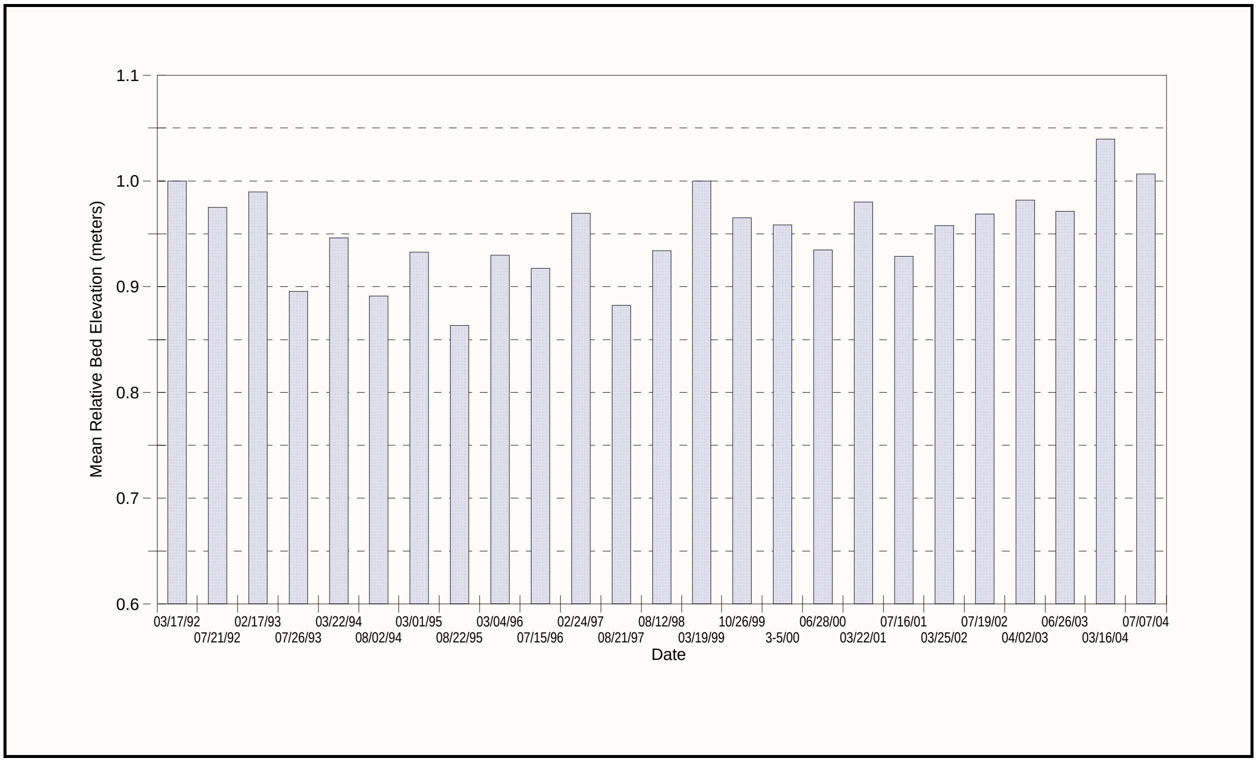

Figure 3.3. **Mean Relative Bed Elevation for Reach 3-6 Transects, 1992-2004**

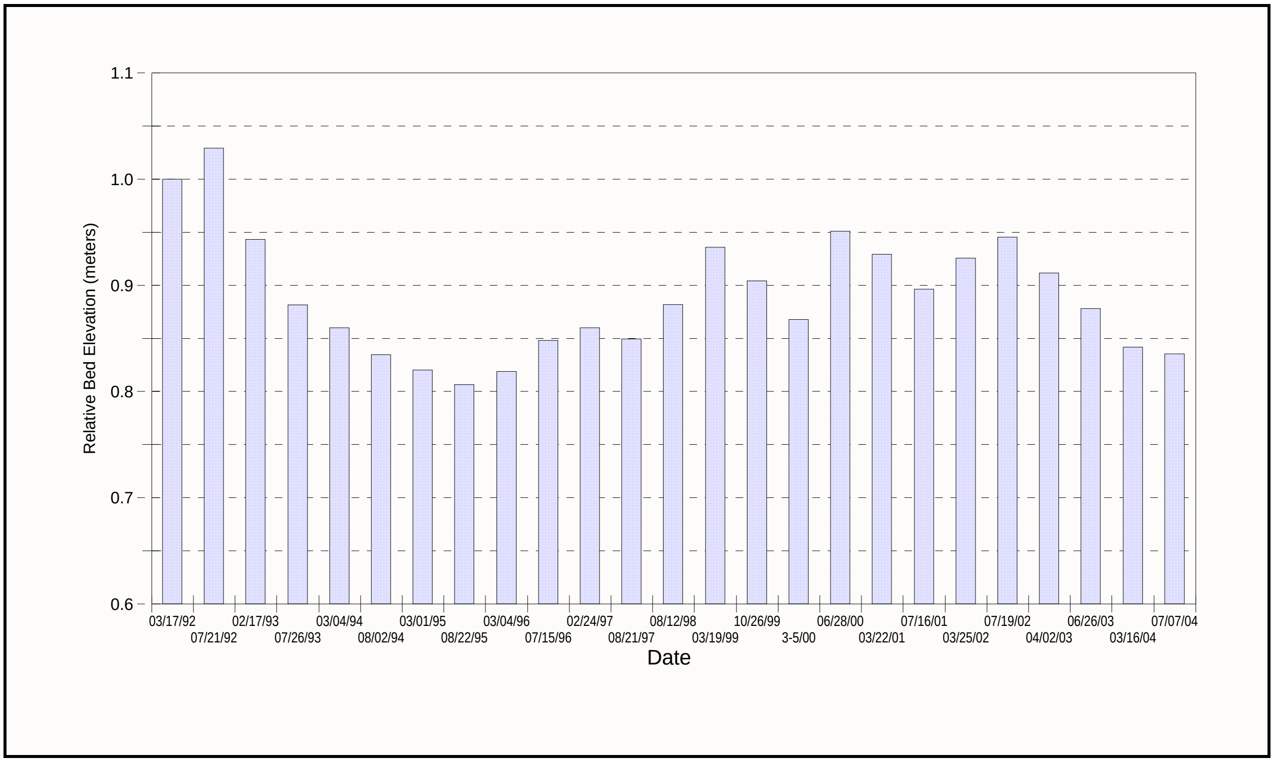

Figure 3.4. **Minimum Relative Bed Elevation Averaged for Reach 3-6 Transects, 1992-2004**

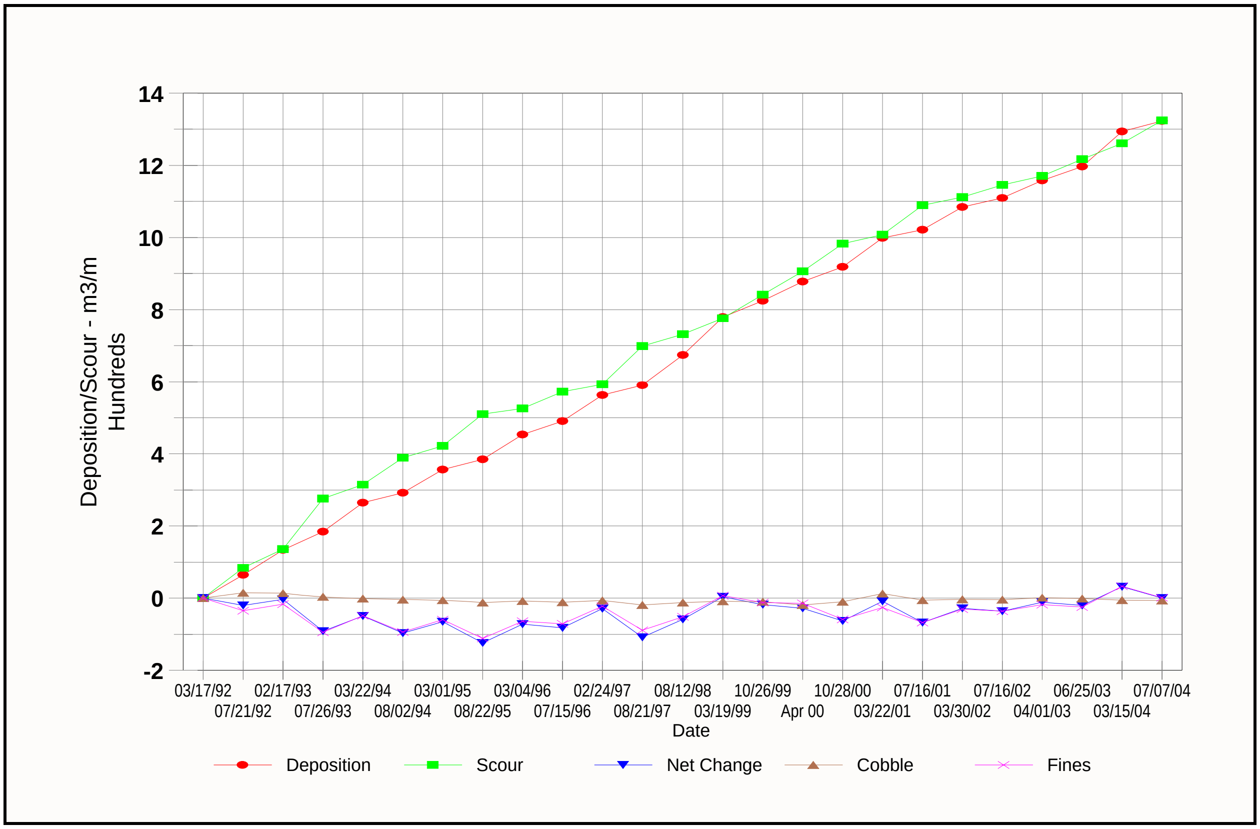

Figure 3.5. Net Change in Reach 3-6 Transects, 1992-2004

The cross-sections accumulated an average of 6.8 cm of material between the post-runoff 2003 and pre-runoff 2004 surveys. An average of approximately 3 cm of material was scoured between the pre- and post-runoff 2004 surveys. Table 3.2 shows the peak runoff season discharge and volume at Bluff for the last 14 years. The peak flow during the 2004 runoff season was 4420 cfs while that in 2003 was 847 cfs. The 20,000 cfs fall 2003 flow event is outside what is considered the runoff season and hence the smaller flows.

The general hypothesis is that spring runoff scours fine sediments from the system. This scour is important in maintaining backwater habitats. One of the questions that has gone unanswered is whether large magnitude storm events are as effective as large magnitude snow-melt runoff events in maintaining backwater habitat. The large deposition that occurred during the September 2003 runoff event indicates that fall storms have a much different effect on the system than spring snow-melt events. Not only did the fall storm put a lot of sediment in the system, the thalweg subsequently eroded through the fine sediments (see Figure 3.4), leaving large sediment deposition on the sides of the channel and a diminished water surface elevation relative to the bed elevation where the sediment was deposited(see individual plots in appendix A). The lower velocity areas typically had the most deposition. Therefore, it appears that the procedure of counting only spring runoff volumes to test compliance with flow recommendations is valid.

Table 3.2. Peak Discharge and Volume at Bluff (1991 - 2004)

Year	March to July Runoff Volume (ac-ft)	Peak Flow (cfs)
1991	575,000	4,530
1992	1,027,000	8,510
1993	1,681,000	9,650
1994	889,000	8,290
1995	1,506,000	11,600
1996	422,000	3,280
1997	1,281,000	11,300
1998	873,000	8,070
1999	814,000	7,420
2000	462,000	5,120
2001	754,000	7,630
2002	163,000	847
2003	274,000	3,590
2004	427,000	4,420

Floodplain Monitoring

There are four cross-sections, CS6-01, CS5-03, CS4-03 and CS3-02 that extend across the floodplain and are surveyed at 5-year intervals. The intent of the surveys is to document changes in the flood plain as a result of large flow events. The only out-of-bank flow event between the two surveys was the September 2003 event and then only below Shiprock. Therefore, the real change in floodplain would be expected to be minor.

The first survey was completed in 1999 and the second in December 2004. The cross-sections are shown in Figures 3.6 to 3.9. These surveys are difficult to complete due to the challenge of trying to survey through thick vegetation over long distances. A total station is used to survey the floodplain. It is typically set as high as possible so you can attempt to shoot over the top of obstructions such as trees. The survey rod is height adjustable with a prism attached to the top. In areas of thick vegetation, the rod is extended up through the canopy so the prism may be seen by the total station. An infrared beam of light emitted by the total station determines the slope distance to the rod. This is used with the angles turned by the instrument to determine the 3-d coordinates relative to the instrument location. The higher the rod is extended, the more difficult it is to get an accurate reading due to the difficulty of keeping the rod vertical and stable during the shot.

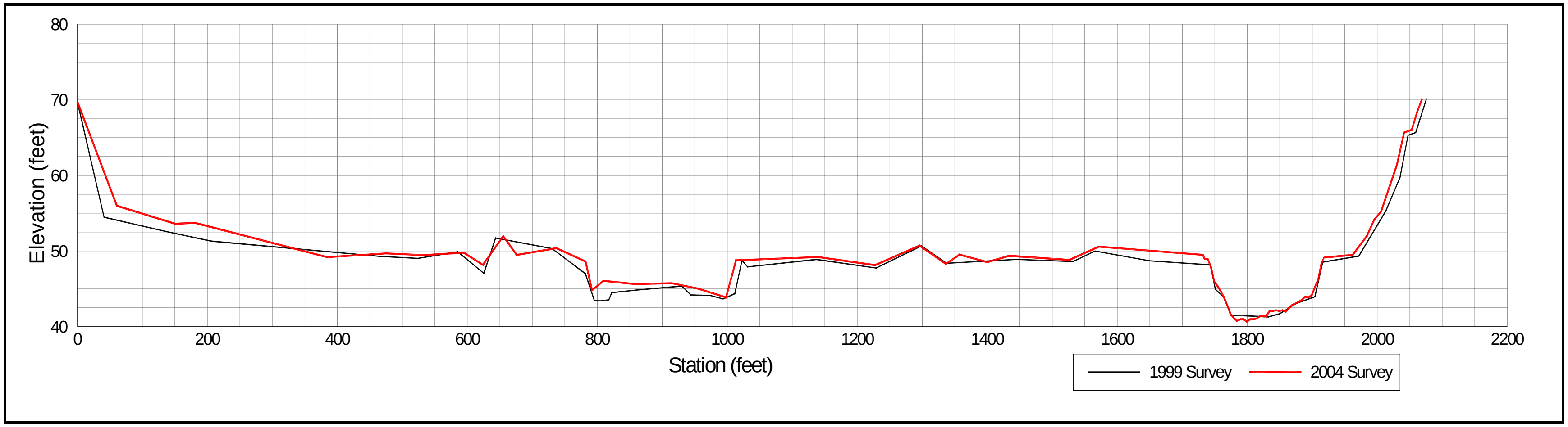

Figure 3.6. 1999 and 2004 Surveys of CS6-01 near Farmington

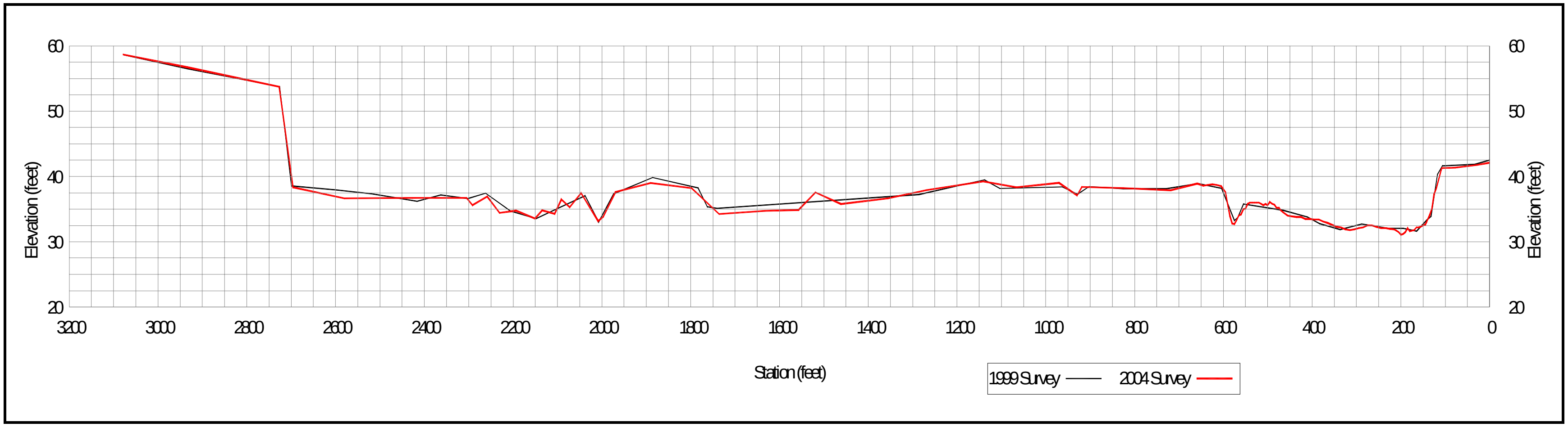

Figure 3.7. 1999 and 2004 Surveys of CS5-03 (at RT-05)

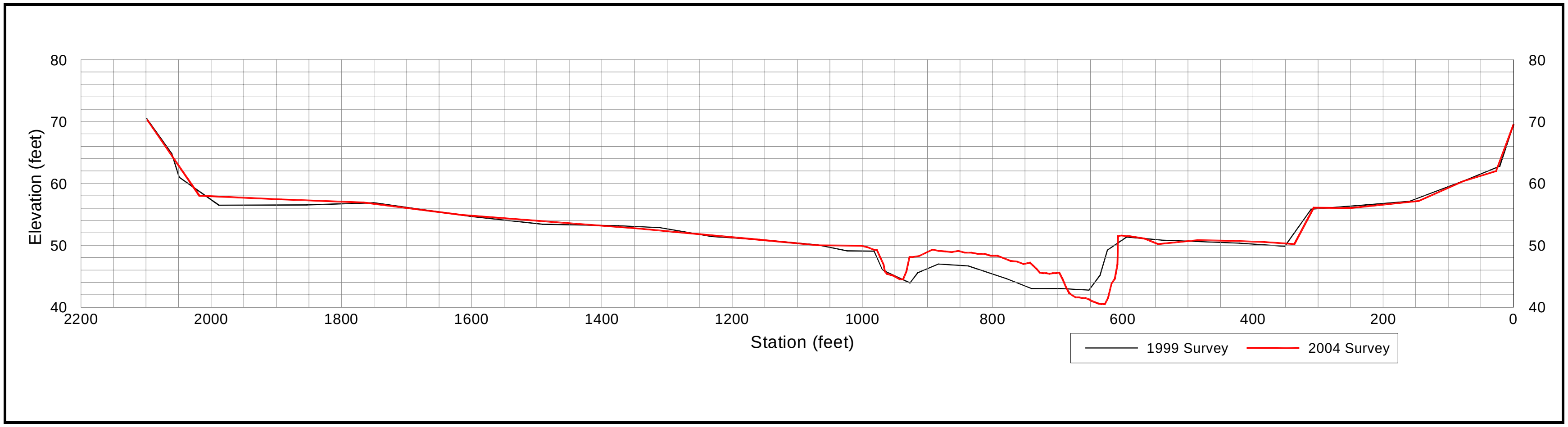

Figure 3.8. 1999 and 2004 Surveys of CS4-03 (near Four Corners Bridge)

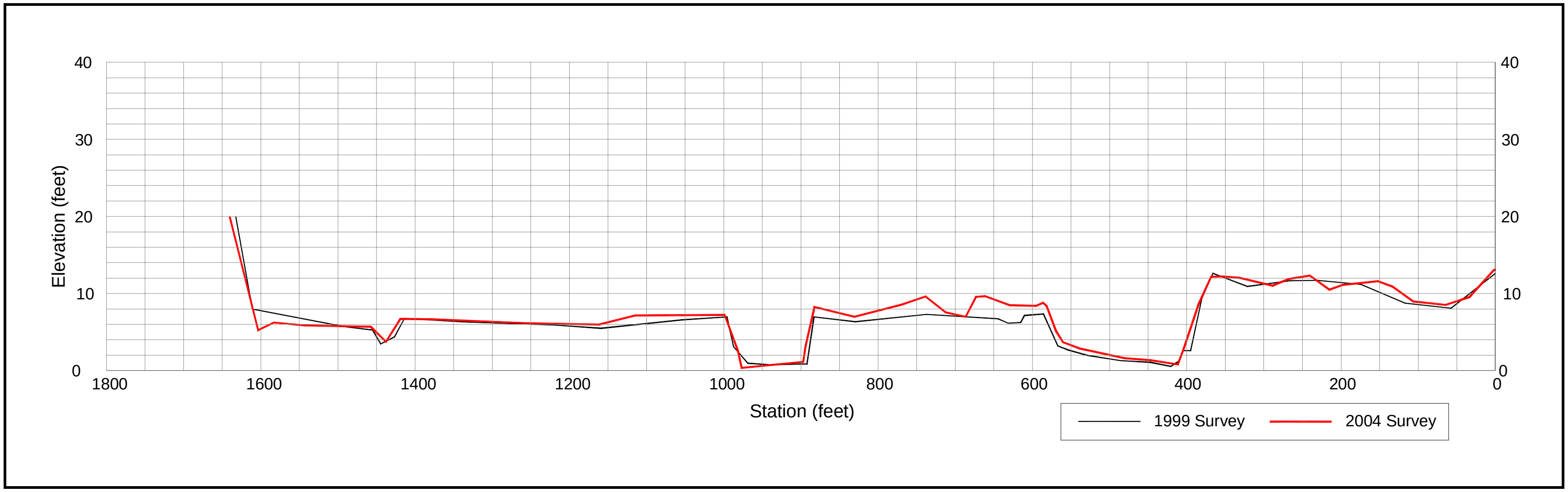

Figure 3.9. 1999 and 2004 Surveys of CS3-02 (near Bluff)

Surveys done under these conditions tend to be less accurate than the river cross section surveys conducted with a rod and level and in the clear with relatively short shot distances.. Some of the variability in the profiles shown in Appendix A are due to survey accuracy issues. Also, the floodplain tends to be rough. Just the point selection by the rod man will produce some differences in the survey results. The individual surveys are discussed in the following sections.

CS6-01

Section CS6-01 is located near Farmington and is shown in Figure 3.6. Comparing the two survey results, there appears to be a significant difference between the two surveys between stations 50 and 350. This is above the high water line so it is unlikely the apparent change was caused by the San Juan River. The most probably explanation for the difference between the two surveys is the point selection. This area is heavily vegetated with a rough ground surface. Except as noted, the rest of CS6-01 appears to be quite stable. There is some variability in and along the banks of the river channel, representing real channel change.

CS5-03

Section CS5-03 is located downstream of Shiprock and is shown in Figure 3.7. There has been very little change between the 1990 and 2004 surveys.

CS4-03

Section CS4-03 is located downstream of the Four Corners Bridge and is shown in Figure 3.8. The main river channel is located between stations 600 and 1000 and has seen substantial change between the 1999 and 2004 surveys. Some areas show in excess of 3-feet of change. The river potion of this cross section is surveyed pre- and post-runoff. These data show a large change occurred between June 2003 and March 2004. This is probably due to the September 2003 storm event which resulted in an average daily flow of 10,200 cfs (September 10, 2003) at the Four Corners gage.

There is also change shown between stations 1800 and 2000. It is unknown if this was caused by the September 2003 storm event or if it is localized deposition due to flow from a nearby arroyo. During the December 2004 survey this area was reported as wet by the surveyors indicating that is was probably affected by the arroyo.

CS3-02

Section CS3-02 is located near Bluff, Utah and is shown in Figure 3.9. The September 10, 2003 flow at the Bluff gage registered an average daily flow of 20,700 cfs. This is the highest flow measured at the Bluff gage since October 1972. The changes shown in Figure 3.9 are likely due to this event.

Measurement of Change in Reach 1 Cross-Sections

The average bed elevation for each Reach 1 transect is shown in Figure 3.10. The mean bed elevation for both transects is shown in Figure 3.11. All data were normalized to use the October 1993 survey as the baseline and the relative elevation of each transect was set to 1.0 meter for that survey. These transects are located in a canyon reach that is influenced by Lake Powell. There is approximately 12-m (40-ft) of sediment, primarily sand, deposited in the bottom of the canyon in this location. This makes the river bottom very mobile. The thalweg is constantly shifting by eroding and depositing sand shoals. Most of the change in the two cross-sections through July 1996 is a result of this erosion and deposition within the cross-sections.

In 1996, the elevation of the downstream cross-section (CS1-02) began increasing. CS1-01 began increasing in 1997. CS1-02 was at maximum in the fall of 1999, CS1-01 reached maximum in 2002. Prior to 1995, Lake Powell levels were sufficiently low to not influence this reach. Even though the lake levels were low, rerouting of the channel at RM 0 placed the channel on a sandstone ledge, preventing erosion upstream. In 1995 lake levels reached a level sufficient to submerge the waterfall that had developed at the ledge, but did not markedly impact channel elevations upstream until 1996. Between 1996 and the 1999, the bed elevation gradually increased in response to this backwater effect.

The drought that began in 2000 initiated a declining period for Lake Powell water surface elevation. There was a small water surface elevation increase during the runoff season and then a continued fall through the end of 2000. By the end of 2000, the water fall was no longer submerged. The 2001 runoff increased the water surface elevation almost to the waterfall elevation again and then continued to fall through the end of 2004. By the end of 2004 the water surface elevation was lower than it had been since the early 70's. Lake Powell water surface elevations are shown in Figure 3.12.

Since 2000 CS1-01 and CS1-02 have responded differently. CS1-01 continued to aggrade until the Fall of 2002 and has degraded since. CS1-01 showed its maximum elevation during 1999 when it was still affected by the backwater effect of Lake Powell. It degraded nearly 0.8 meters between 1999 and 2001 and it has been fairly stable since.

Characterization of Bed Material

Table 3.4 shows the surface cobble substrate composition for the 2004 pre- and post-runoff surveys of the Reach 3-6 cross-sections. The pre-runoff 2004 survey averaged 67% sand and 33% cobble. The post-runoff 2004 survey averaged 48% sand and 52% cobble. The increase in the cobble percentage in the post-runoff 2004 survey shows that there was some flushing of fines from the system. A fall 2003 storm event filled the system with sediment and even the low runoff of the 2004 season flushed some sediment from the system. Figure 3.13 shows the composition of the scour and deposition that occurred at each of the Reach 3-6 transects between pre- and post runoff 2004. Most of the material moved during 2004 was fines. Figure 3.14 and 3.15 show surface cobble percentages for all the surveyed cross-sections with time. These figures show how the surface cobble can vary with time. In general, the variability is caused by sand depositing and scouring off an underlying cobble bed.

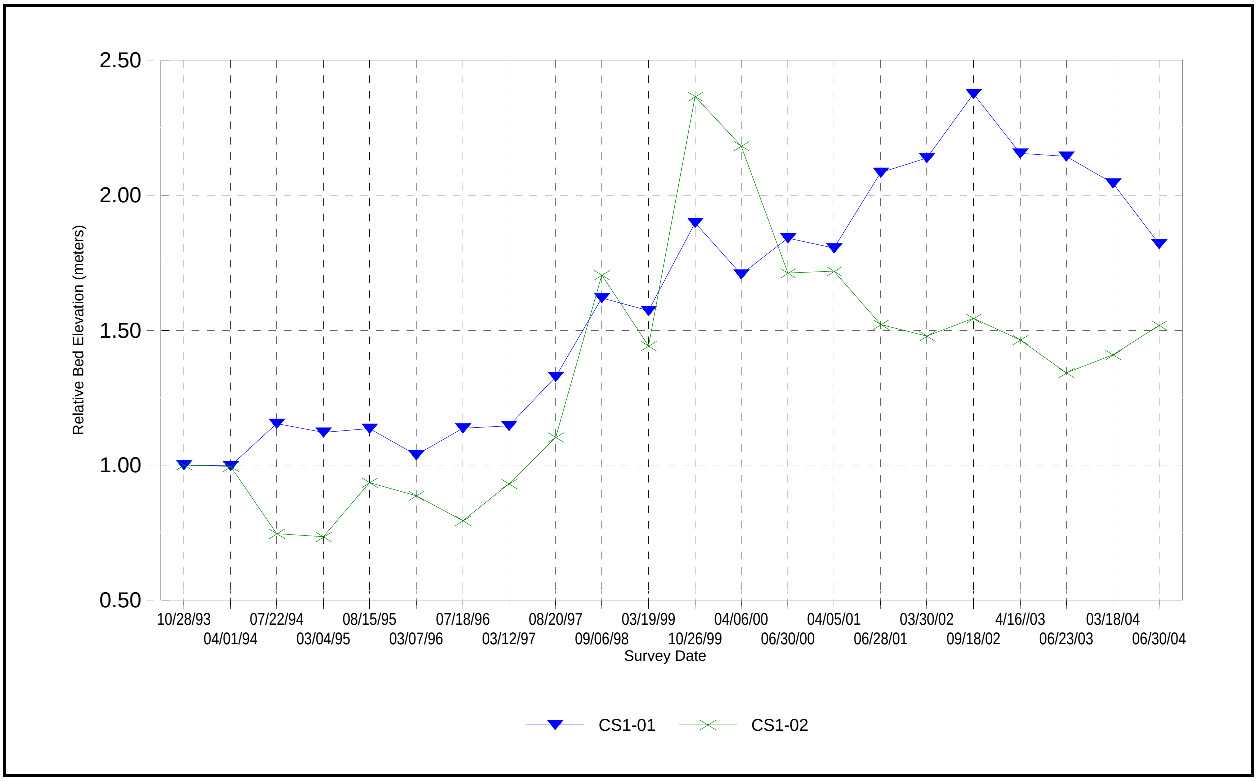

Figure 3.10. Average Relative Bed Elevation for Reach 1 Transects

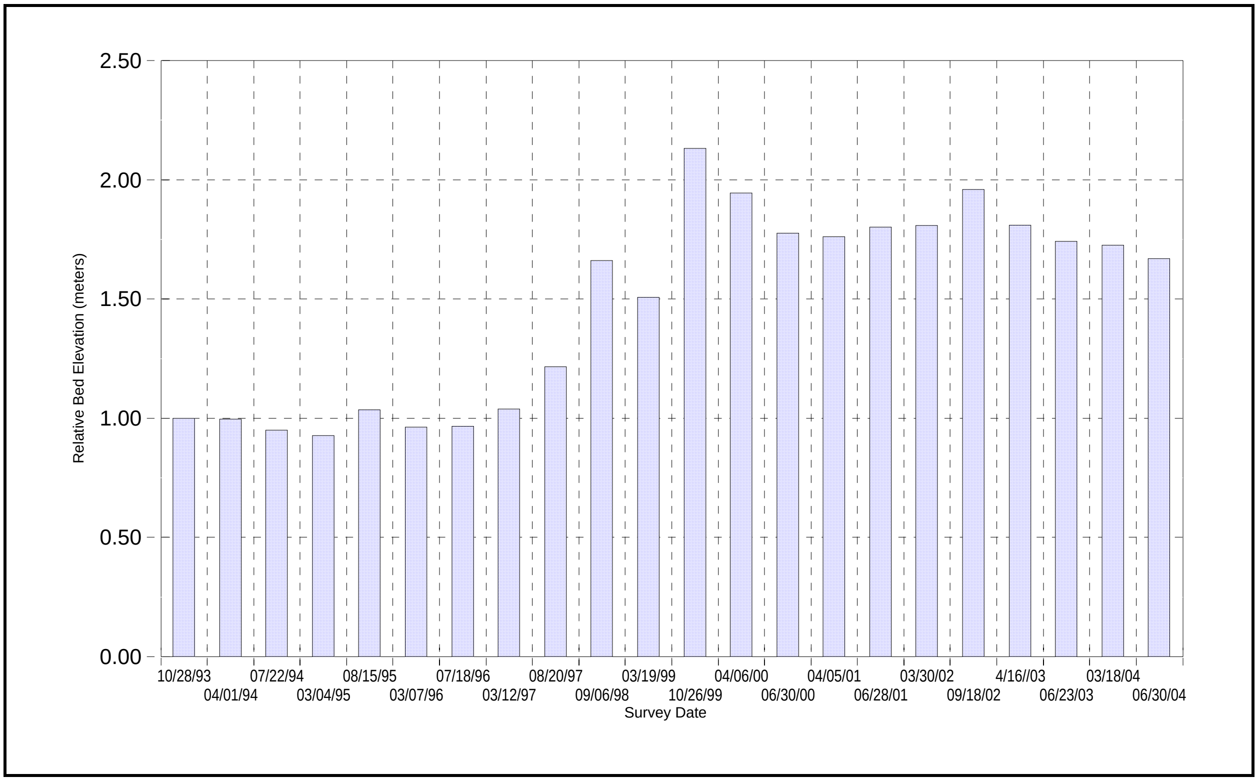

Figure 3.11. Mean Relative Bed Elevation for Reach 1 Transects

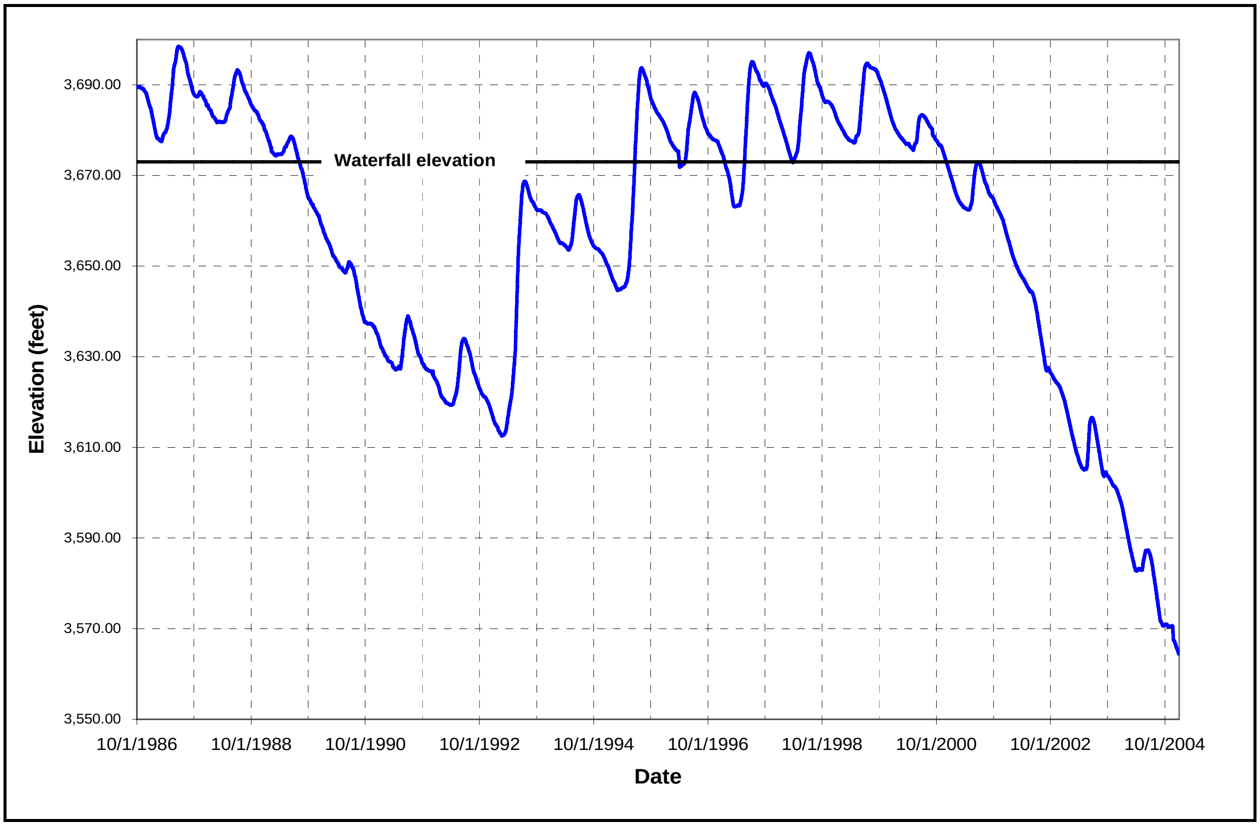

Figure 3.12. Lake Powell Water Surface Elevation, 1986 to 2004

Table 3.4. Summary of Percent Cobble Substrate, Pre- and Post-runoff, 2004 for Reach 3-6 Transects

Transect	3/15/04	7/07/04
CS6-01	67%	74%
CS6-02	9%	22%
CS6-03	53%	70%
CS5-01	60%	66%
CS5-02	42%	72%
CS5-03	40%	45%
CS4-01	3%	14%
CS4-02	52%	75%
CS4-03	27%	65%
CS3-01	10%	13%
CS3-02	25%	73%
CS3-03	3%	34%
Average	33%	52%

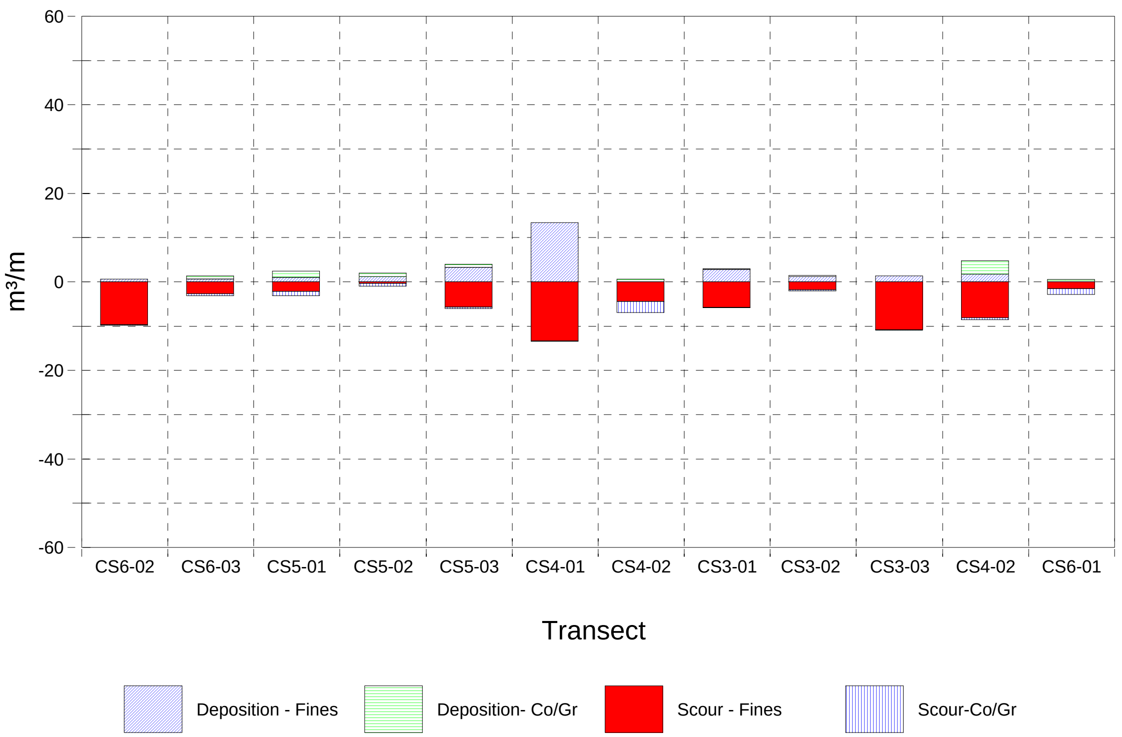

Figure 3.13. Comparison of Deposition and Scour Between Pre- and Post-Runoff 2004 for Reach 3 to Reach 6 Cross Sections

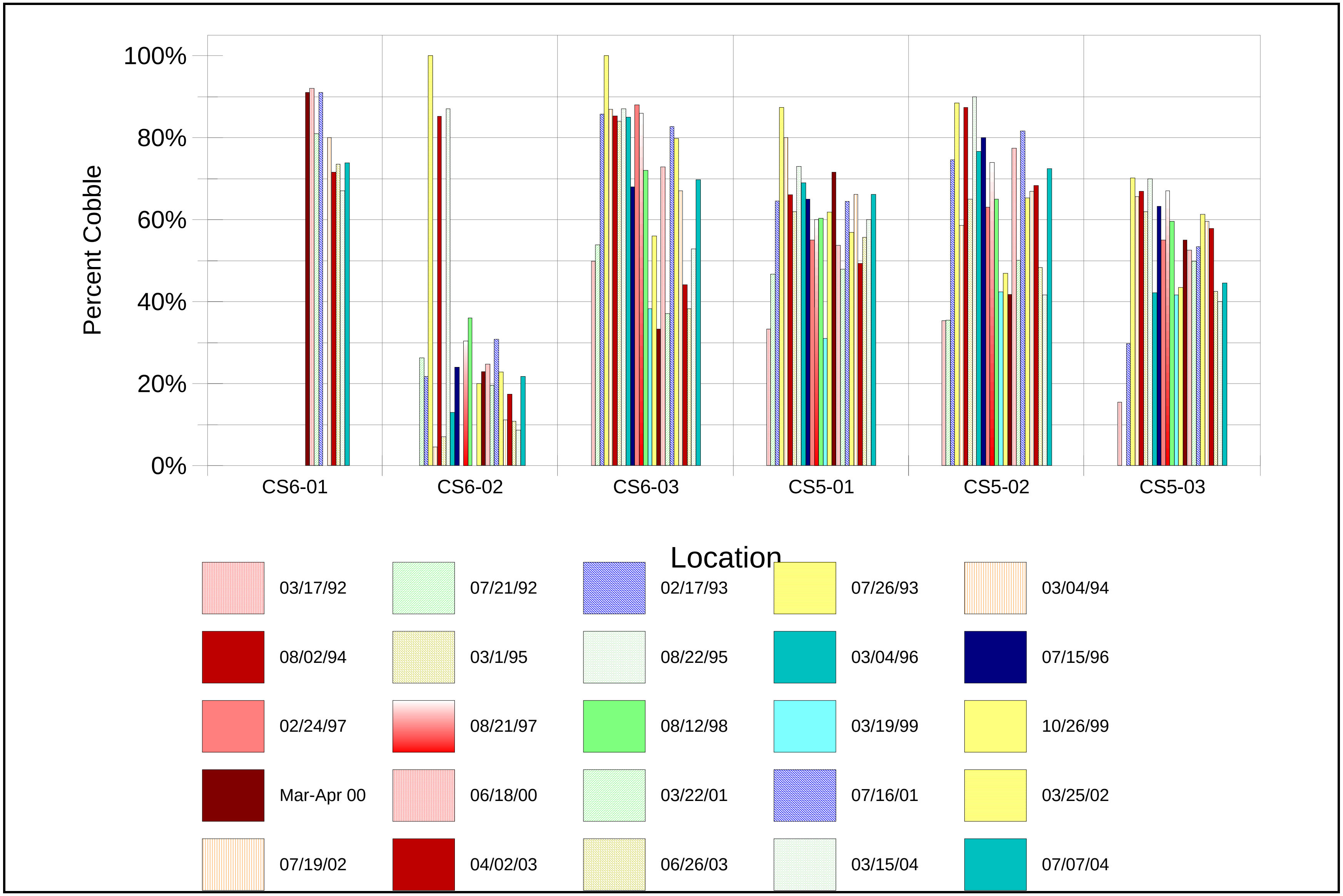

Figure 3.14. Cobble Percentage at CS6 and CS5 Transects, 1992-2004

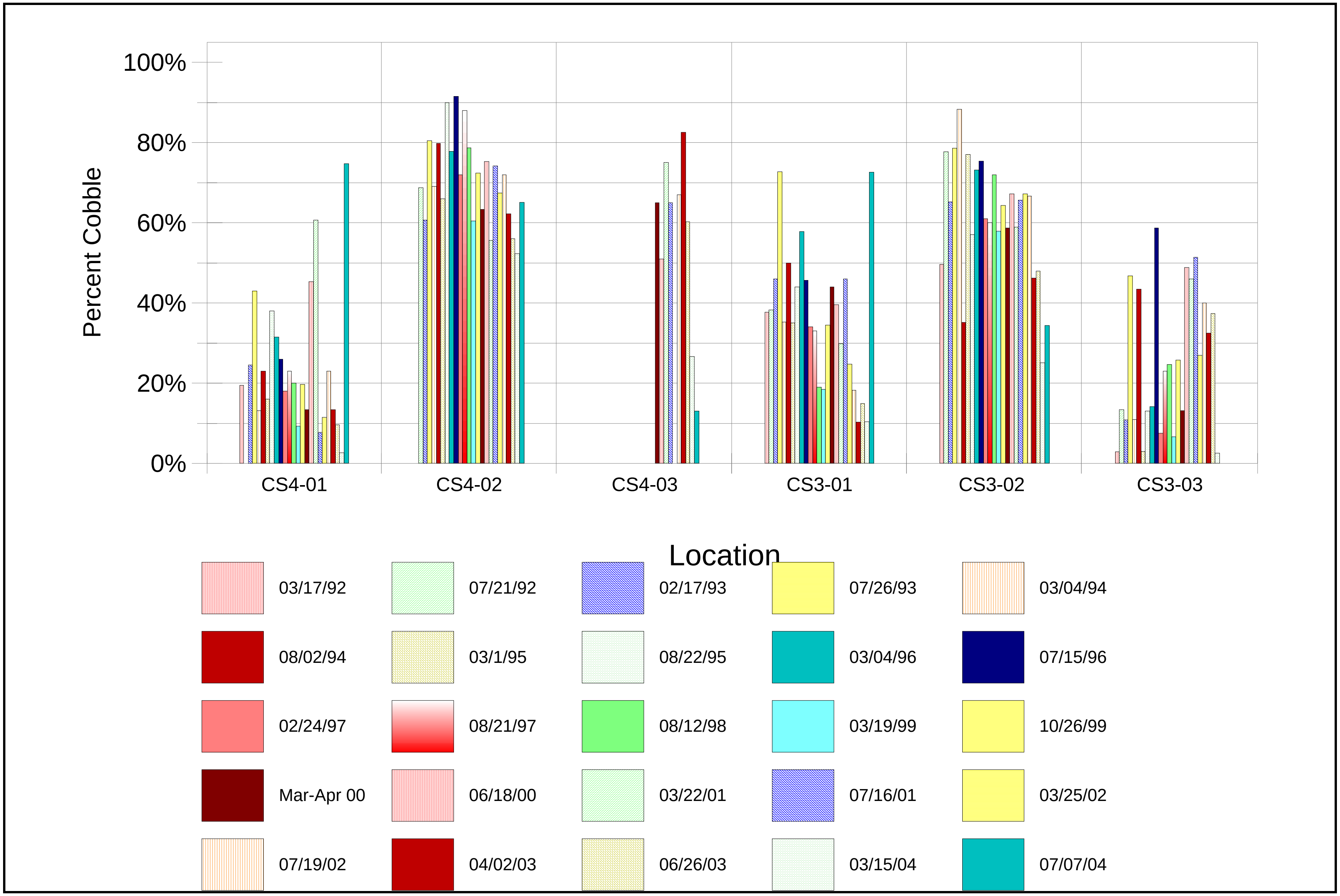

Figure 3.15. Cobble Percentage at CS4 and CS3 Transects, 1992-2004

CHAPTER 4: WATER QUALITY

INTRODUCTION

Water temperature, turbidity and chemistry data have been collected in the San Juan River as a part of the long-term monitoring program since 1999. As a result of the findings of the 1999 to 2003 integration studies, the SJRIP Biology Committee elected to terminate funding of water chemistry and turbidity and remove these studies from the long-term monitoring plan. This will be the last report to include turbidity and chemistry data.

METHODS

Water Temperature

Nine temperature recorders were originally installed in the San Juan and Animas rivers in July and August of 1992 at the locations shown in Table 4.1. Each station consisted of a temperature sensor, lead wires and an OMNIDATA DP-230 data pod. The temperature was sampled every 10 minutes and stored every 24 hours as a maximum, minimum and mean temperature for the day. Table 4.1 also shows the periods of record at each site. The missing data were caused by equipment problems. Due to equipment problems and other maintenance challenges, the temperature recorders were replaced in July 1999 with the Optic StowAway temperature loggers. These are manufactured by Onset Computer Corporation and are factory sealed, submersible units that communicate via an optic interface. The temperature sensor is embedded in the body of the unit, eliminating any external wires. Water temperature is currently recorded every 15-minutes. The “in place” phrase in Table 4.1 indicates that StowAway’s are monitoring temperature at the indicated sites.

Water Chemistry

Ten water quality monitoring sites (Table 4.2) were identified as necessary to characterize water quality in the San Juan River and key tributaries. Sampling intervals are quarterly (tri-monthly) in February, May, August, and November. This temporal spacing was adopted to ensure water sampling occurs during spring runoff in the upper portion of the San Juan River basin and during winter base flows.

Chemical analyses performed are listed in Table 4.3. Parameters listed in left column were measured quarterly. In addition, field measurements of water temperature, pH, redox potential, specific conductance, and dissolved oxygen were made. Annually, during low-flow periods in February, water samples were analyzed for all parameters listed in Table 4.3.

Table 4.1. Water Temperature Monitoring Locations and Period of Record

Location	RM	Period of Record
Near Navajo Dam	225	7/9/1999 to 7/9/04 (in place)
Archuleta - San Juan at USGS Gage Location	218.6	7/23/92 to 7/9/04 (in place)
Blanco - San Juan at US-64 Bridge	207.1	8/7/92 to 2/28/95 (missing 11/21 - 12/9/92)
Bloomfield - San Juan at Highway 44 Bridge	195.6	2/27/93 to 7/17/98
Lee Acres - San Juan at Lee Acres Bridge	188.9	8/8/92 to 12/2/92, 2/26/93 to 4/15/93, 5/27/93 to 9/6/94, 3/9/95 to 10/10/95
Farmington - San Juan at USGS Gage Location	180.1	8/5/92 to 1/16/96, 7/8/99 to 11/4/01, 10/3/02 to 12/9/04 (in place)
Shiprock - San Juan at USGS Gage Location	148.0	7/8/99 to 12/7/04 (in place)
Four Corners - San Juan at USGS Gage Location	119.4	10/7/94 to 3/11/96*, 7/9/99 to 12/7/04 (in place)
Montezuma Creek - San Juan at Montezuma Creek Bridge	93.6	8/9/92 to 1/11/93, 2/25 to 3/14/93, 4/14 to 5/10/93, 5/28/93 to 12/9/04 (in place)
Mexican Hat - San Juan near Bluff Gage Location	52.1	7/9/99 to 3/27/02 , 9/18/02 to 7/8/04 (in place)
Cedar Hill - Animas at USGS Gage nr Cedar Hill	n/a	8/7/92 to 9/22/98
Farmington - Animas at USGS Gage Location	n/a	8/5/92 to 4/14/97, 5/7/97 to 8/26/97, 10/15/97 to 6/4/98, 7/8/99 to 12/9/04 (in place)
USGS Data - San Juan at Archuleta	218.6	10/1/50 - 9/30/68 with some missing data
USGS Data - San Juan at Shiprock	148.0	10/1/51 - 9/30/86,9/7/91 - 3/3/93 with some missing data
USGS Data - Animas	n/a	10/1/52 - 9/30/90 with some missing data

Note: all locations missing October 1992 data
* installed 8/10/92 but bad data were logged until thermistor was changed in October 1994. Prior to this time it was thought sediment accumulation was causing the warmer readings instead of bad thermistor.

Table 4.2. San Juan River Water Quality Monitoring Sites

Station Name	USGS ID	USGS Record	BIA Record
San Juan River near Archuleta Bridge	9355500	1958 -1984	1991-2004
Animas River @ Farmington	9364500	1958 -1992	1991-2004
San Juan River @ Farmington	9365000	1974 -1991	1991-2004
LaPlata River near Farmington	9367500	1977-1991	1994-2004
San Juan River @ Shiprock	9368000	1958 -1992	1991-2004
Mancos River near Four Corners	9371005		1991-2004
San Juan River @ Four Corners	9371010	1977-1990	1991-2004
San Juan River @ Montezuma Creek	9378610		1991-2004
San Juan River @ Bluff	9379495		1991-2004
San Juan River near Bluff (@ Mex. Hat)	9379500	1974 -1993	1991-2004

Table 4.3. San Juan River Monitoring Program Water Quality Parameters

Quarterly	Detection	Annually	Detection
Arsenic (total & dissolved)	*0.2 µg/L*	Aluminum (total & dissolved)	*0.03 mg/L*
Calcium (dissolved)	*0.2 mg/L*	Barium (total & dissolved)	*3 µg/L*
Copper (dissolved)	*1.0 µg/L*	Manganese (total & dissolved)	*5 µg/L*
Copper (total)	*0.5 µg/L*	Nickel (total & dissolved)	*10 µg/L*
Lead (total & dissolved)	*0.2 µg/L*	Potassium (total & dissolved)	*0.3 mg/L*
Magnesium (dissolved)	*0.2 mg/L*	Strontium (total & dissolved)	*10 µg/L*
Mercury (total & dissolved)	*0.2 µg/L*	Orthophosphate (total & dissolved)	*5 mg/L*
Sodium (dissolved)	*0.3 mg/L*	Chloride (dissolved)	*10 mg/L*
Selenium (total, dissolved, & total recoverable)	*1 µg/L*	Ammonia (dissolved)	*50 µg/L*
Zinc (total & dissolved)	*10 µg/L*	Nitrate (dissolved)	*20 µg/L*
Alkalinity (HCO_3)	*2 mg/L*	Nitrite (dissolved)	*10 µg/L*
Hardness	*1 mg/L*	Silica (total & dissolved)	*0.2 mg/L*
TDS	*10 mg/L*	Sulfate (dissolved)	*10 mg/L*
TSS	*5 mg/L*		
Turbidity	*0.1 NTU*		

Turbidity Monitoring

The continuous turbidity monitoring equipment installed at Shiprock and Montezuma Creek is used to monitor sediment producing events. The turbidity monitoring equipment at both Shiprock and Montezuma Creek consists of a D&A OBS-3 turbidity probe connected to a Campbell Scientific CR-510 data logger. The probes are calibrated to read between 0 and 4000 NTU's. Turbidity is measured every hour.

In the spring of 2003, the data logger and battery were stolen from the Montezuma Creek site. This equipment was replaced in April 2004 and was installed at the same location, under the Montezuma Creek Bridge crossing the San Juan River. During this installation it was noted that the sheet piling underneath the bridge was failing and allowing the bank under the bridge to slough into the river. Since the turbidity probe is attached to the sheet piling, this was a concern. The sheet piling at the installation location was still unaffected at the time of installation. We notified the responsible party of the problem and assumed it would be fixed. On May 5, 2004 the site was checked again and conditions had continued to worsen. At this point the equipment was removed before it was lost.

RESULTS

Water Temperature

The plots of the 2004 water temperature data for all monitored sites are shown in Figure 4.1. The equipment performed well but there was some problem at low flow with the Archuleta sensor becoming exposed to the air. Figures 4.2 and 4.3 show the maximum, minimum and average water temperatures for Archuleta and Montezuma Creek respectively. The missing data in Figure 4.2 were excluded because it was believed the temperature probe was not submerged. The Archuleta sensor was lowered in March 2005 to help prevent this problem.

Water Chemistry

Tables 4.4 through 4.13 summarize the water quality data for the 10 permanent stations, comparing the 1994-2003 statistics to those for 2004. In each case the minimum, maximum, mean and standard deviation are given for each parameter in Table 4.3. When values fall below detection, they are shown at ½ detection limit and included in the summary statistics shown in Tables 4.4 through 4.13. The values for the annual parameters shown in Table 4.3 are presented in Table 4.14 through 4.23.

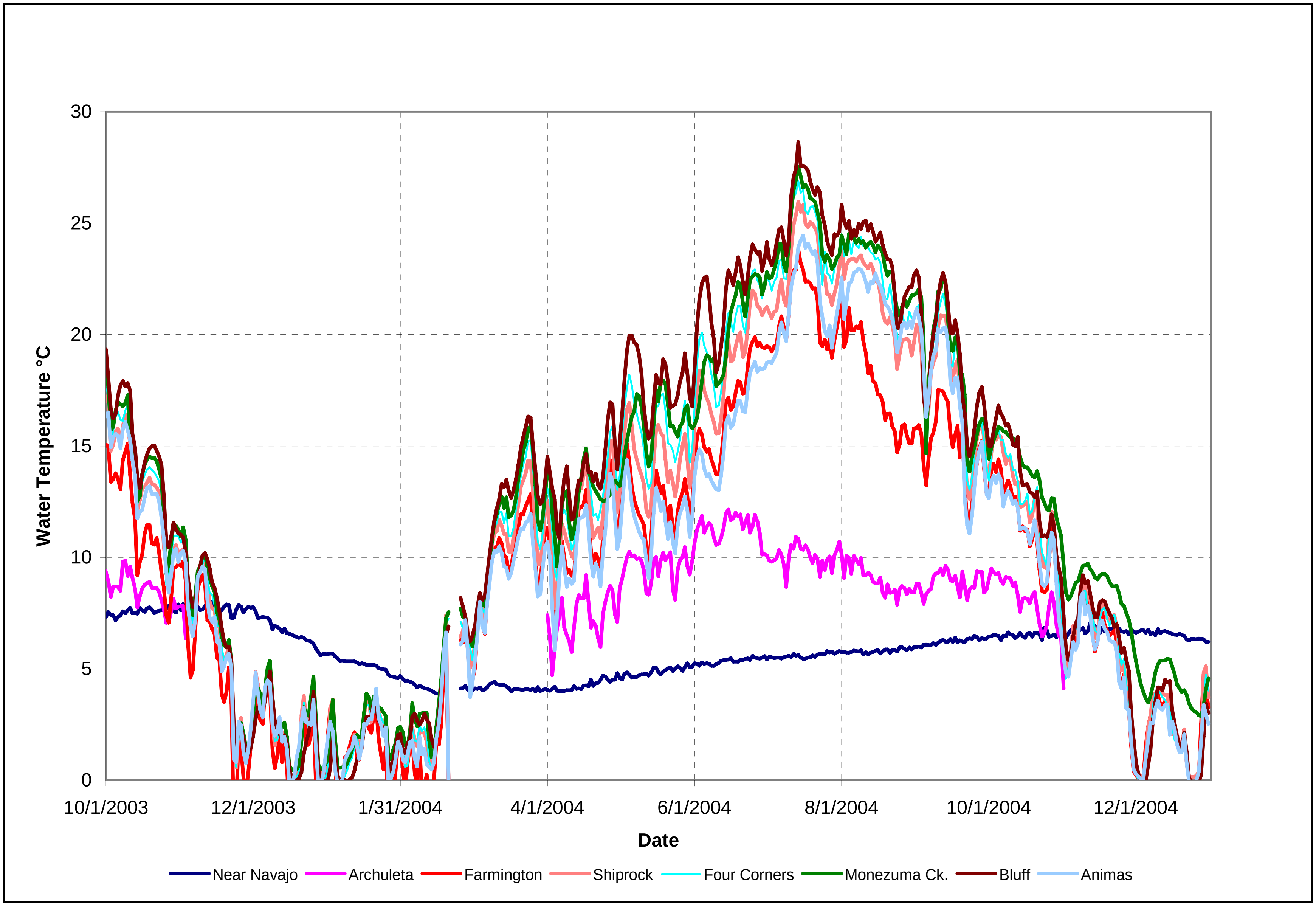

Figure 4.1. San Juan Basin Average Water Temperature Data, 2004

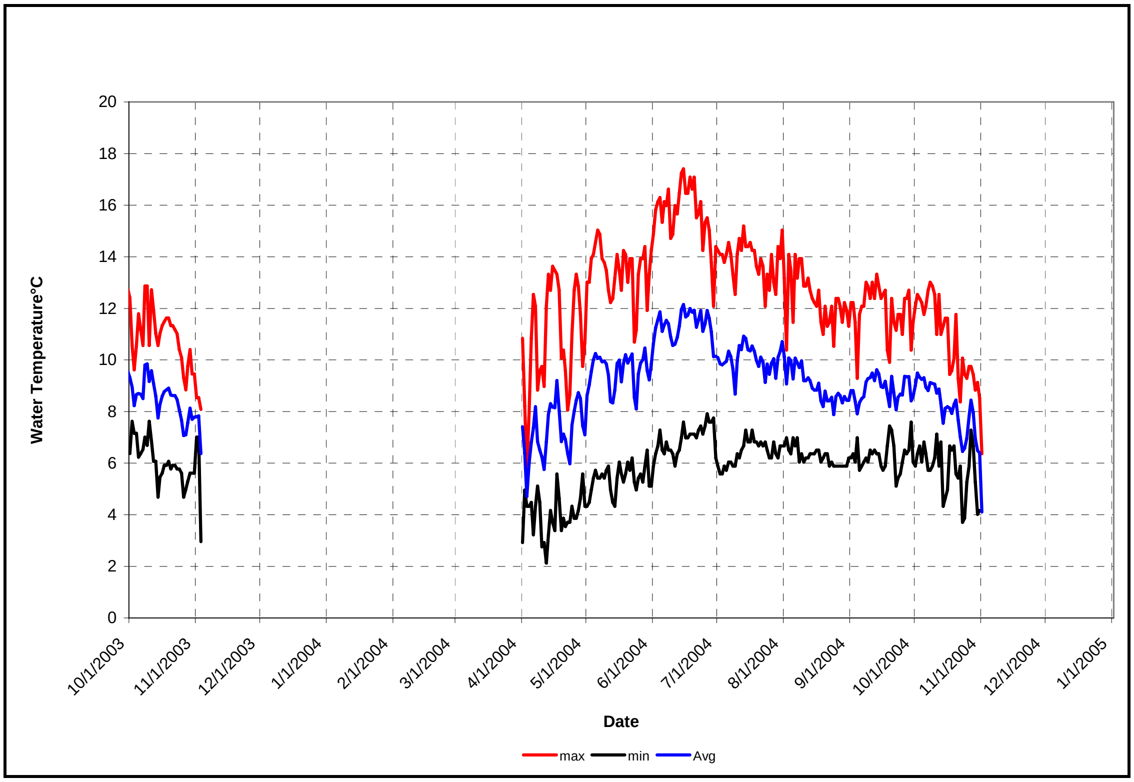

Figure 4.2 Archuleta Maximum, Minimum and Average 2004 Water Temperature

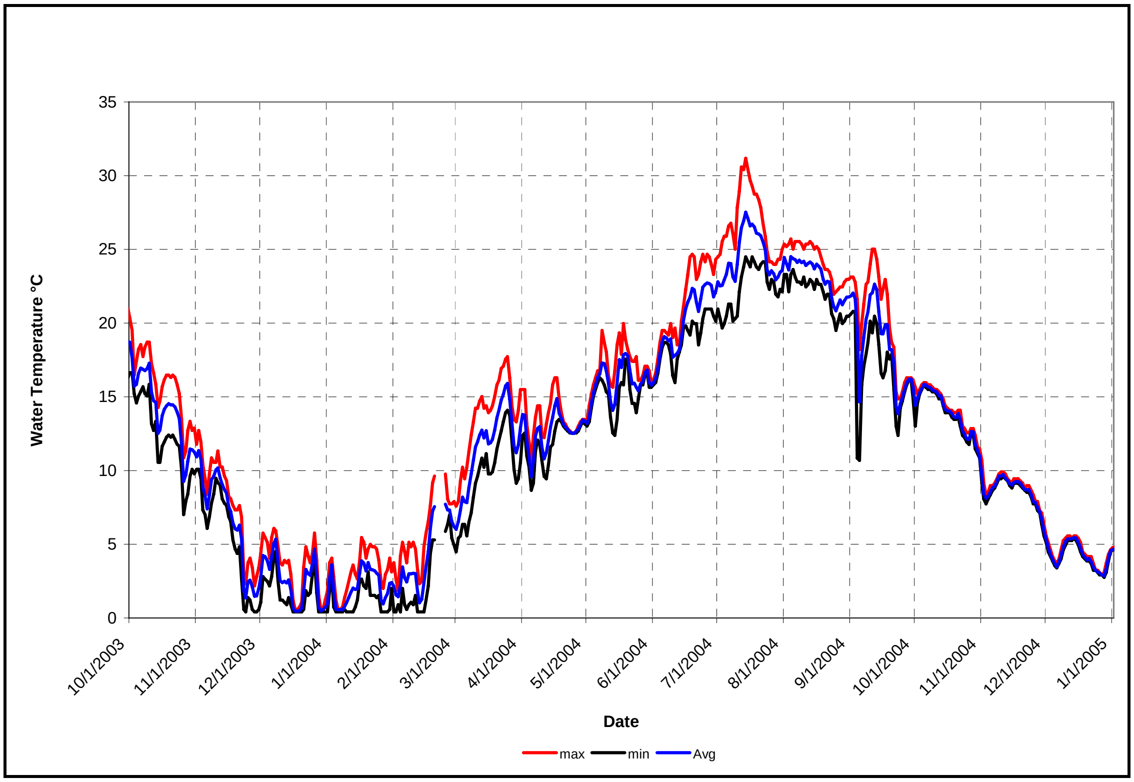

Figure 4.3 Montezuma Creek Maximum, Minimum and Average 2004 Water Temperature

Table 4.4. Water Chemistry Data for San Juan River at Archuleta Bridge

Parameter	1994-2003 N of Cases	Minimum	Maximum	Mean	Standard Dev	2004 N of Cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	50	43.0	124.0	76.7	11.8	4	81.0	100.0	91.8	8.9
Alkalinity (mg/l)	50	43.0	124.0	77.1	11.8	4	81.0	100.0	91.8	8.9
Arsenic dissolved (μg/l)	78	0.3	2.5	1.7	0.8	4	0.8	1.1	1.0	0.1
Arsenic total (μg/l)	78	0.3	642.0	10.7	72.5	4	0.6	2.5	1.2	0.9
Calcium dissolved (mg/l)	50	25.1	38.1	29.8	3.1	4	37.4	39.8	38.2	1.1
Copper dissolved (μg/l)	50	*0.9*	21.0	3.1	3.1	4	*0.9*	1.2	1.1	0.1
Copper total (μg/l)	50	1.0	41.0	6.2	8.7	4	1.0	15.0	4.9	6.7
Hardness ((mg/l)	50	83.0	124.0	97.6	10.1	4	123.0	128.0	124.5	2.4
Mercury dissolved (μg/l)	78	*0.1*	0.5	*0.1*	0	4	*0.1*	*0.1*	*0.1*	0
Mercury total (μg/l)	78	*0.1*	*0.1*	*0.1*	0	4	*0.1*	*0.1*	*0.1*	0
Magnesium dissolved (mg/l)	20	4.8	7.0	5.7	0.6	4	6.9	7.1	7.0	0.1
Sodium dissolved (mg/l)	27	10.7	18.7	13.6	2.0	4	18.5	19.9	19.2	0.8
Lead dissolved (μg/l)	78	*0.1*	5.7	0.5	0.8	4	*0.1*	0.2	*0.1*	0.1
Lead total (μg/l)	78	0.1	19.2	1.2	2.5	4	0.1	0.5	0.3	0.2
Selenium dissolved (μg/l)	78	*0.5*	*0.5*	*0.5*	0	4	*0.5*	*0.5*	*0.5*	0
Selenium total (μg/l)	78	*0.5*	3.0	*0.5*	0.3	4	*0.5*	*0.5*	*0.5*	0
Selenium total recoverable (μg/l)	28	*0.5*	1.0	*0.5*	0.1	4	*0.5*	*0.5*	*0.5*	0
Total dissolved solids (mg/l)	48	90.0	280.0	159.2	35.5	4	200.0	210.0	207.5	5.0
Total suspended solids (mg/l)	77	*1.0*	57.0	8.3	9.5	4	2.5	10.0	*4.4*	3.8
Turbidity (NTU)	75	0.0	33.0	5.8	5.1	4	2.0	8.9	5.8	3.1
Zinc dissolved (μg/l)	78	*5.0*	70.0	*8.1*	8.8	4	*5.0*	*5.0*	*5.0*	0
Zinc total (μg/l)	78	*5.0*	360.0	23.5	48.2	4	*5.0*	*5.0*	*5.0*	0
Temperature ($^\circ$C)	78	3.1	14.3	7.7	2.5	2	7.8	8.3	8.0	0.4
pH	78	6.1	9.1	8.1	0.5	2	8.5	8.6	8.5	0.1
Conductance (μmhos/cm)	78	199.0	305.0	240.6	25.7	2	302.0	314.0	308.0	8.5
Redox Potential (mv)	77	138.0	527.0	372.1	81.6	2	345.0	509.0	427.0	116.0
Oxygen dissolved (mg/l)	77	5.4	14.3	10.6	1.4	2	10.4	12.1	11.3	1.2

Note: *Italics* indicate “below detection”

Table 4.5. Water Chemistry Data for Animas River at Farmington

Parameter	1994-2003 N of Cases	Minimum	Maximum	Mean	Standard Dev	2004 N of Cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	50	43.0	246.0	124.3	39.3	4	76.0	151.0	124.3	35.0
Alkalinity (mg/l)	50	43.0	246.0	125.1	39.3	4	76.0	151.0	126.0	34.9
Arsenic dissolved (μg/l)	79	0.3	2.5	1.6	0.9	4	0.3	0.6	0.4	0.2
Arsenic total (μg/l)	79	0.5	25.8	2.6	3.1	4	0.3	2.5	1.1	1.0
Calcium dissolved (mg/l)	50	27.6	107.0	73.4	24.4	4	37.8	117.0	84.0	34.1
Copper dissolved (μg/l)	50	*0.7*	9.0	3.3	2.0	4	*0.7*	2.9	1.9	1.1
Copper total (μg/l)	50	1.5	73.87	13.5	15.7	4	2.0	18.0	8.4	7.7
Hardness ((mg/l)	50	85.0	334.0	232.1	78.1	4	116.0	376.0	263.8	111.1
Mercury dissolved (μg/l)	79	*0.1*	*0.1*	*0.1*	0	4	*0.1*	*0.1*	*0.1*	0
Mercury total (μg/l)	79	*0.1*	0.9	0.1	0.1	4	*0.1*	*0.1*	*0.1*	0
Magnesium dissolved (mg/l)	50	3.8	19.2	11.8	4.3	4	5.3	20.2	13.1	6.3
Sodium dissolved (mg/l)	27	4.9	46.1	28.6	12.9	4	7.3	63.3	32.3	23.7
Lead dissolved (μg/l)	79	*0.1*	4.5	0.5	0.6	4	*0.1*	1.1	0.4	0.5
Lead total (μg/l)	79	0.5	80.0	14.2	19.4	4	0.5	14.8	4.3	7.0
Selenium dissolved (μg/l)	79	*0.5*	3.0	*0.6*	0.3	4	*0.5*	*0.5*	*0.5*	0
Selenium total (μg/l)	79	*0.5*	6.0	*0.7*	0.8	4	*0.5*	*0.5*	*0.5*	0
Selenium total recoverable (μg/l)	29	*0.5*	1.5	*0.6*	0.2	4	*0.5*	*0.5*	*0.5*	0
Total dissolved solids (mg/l)	49	110.0	520.0	345.5	129.3	4	150.0	590.0	392.5	189.1
Total suspended solids (mg/l)	78	*0.1*	2940.0	165.0	430.1	4	*2.5*	56.0	23.6	23.3
Turbidity (NTU)	76	0.9	3720.0	126.2	464.1	4	1.6	26.1	13.1	12.9
Zinc dissolved (μg/l)	79	*5.0*	40	10.8	7.8	4	*5.0*	20.0	*8.8*	7.5
Zinc total (μg/l)	79	*5.0*	430.0	87.0	88.1	4	*5.0*	90.0	31.3	39.7
Temperature (°C)	79	0.1	27.3	11.7	7.1	3	2.9	24.0	13.2	10.5
pH	79	6.9	8.9	8.2	0.3	3	8.2	8.8	8.4	0.3
Conductance (μmhos/cm)	79	196.0	969.0	562.1	186.3	3	255.0	911.0	567.0	329.2
Redox Potential (mv)	78	137.0	545.0	385.2	81.4	3	422.0	424.0	423.0	1.0
Oxygen dissolved (mg/l)	78	3.7	13.2	9.6	2.1	3	7.6	9.0	8.4	0.8

Note: *Italics* indicate "below detection"

Table 4.6. Water Chemistry Data for San Juan River at Farmington Bridge

Parameter	1994-2003 N of Cases	Minimum	Maximum	Mean	Standard Dev	2004 N of Cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	50	49.0	143.0	103.8	21.7	4	78.0	163.0	117.5	37.1
Alkalinity (mg/l)	50	49.0	143.0	104.0	21.5	4	78.0	163.0	117.5	37.1
Arsenic dissolved (µg/l)	80	0.3	5.0	1.8	0.9	4	0.3	1.0	0.6	0.3
Arsenic total (µg/l)	80	0.5	7.0	2.4	1.3	4	0.6	5.0	2.0	2.0
Calcium dissolved (mg/l)	50	28.8	83.5	54.9	14.9	4	40.8	80.9	60.2	19.2
Copper dissolved (µg/l)	50	*0.8*	10.0	3.4	2.2	4	*0.8*	2.9	1.7	1.0
Copper total (µg/l)	50	2.5	106.0	18.6	20.2	4	2.4	50.0	18.2	21.7
Hardness ((mg/l)	50	91.0	265.0	173.1	46.7	4	126.0	255.0	189.3	59.9
Mercury dissolved (µg/l)	80	*0.1*	0.2	*0.1*	0	4	*0.1*	*0.1*	*0.1*	0
Mercury total (µg/l)	80	*0.1*	0.2	*0.1*	0	4	*0.1*	*0.1*	*0.1*	0
Magnesium dissolved (mg/l)	50	4.6	13.9	8.7	2.4	4	5.8	12.8	9.4	3.0
Sodium dissolved (mg/l)	27	9.5	46.7	31.6	10.9	4	12.1	45.9	29.7	14.0
Lead dissolved (µg/l)	80	*0.1*	4.0	0.5	0.5	4	0.2	1.1	0.5	0.4
Lead total (µg/l)	80	0.5	105.0	12.6	16.3	4	1	14.0	7.3	5.9
Selenium dissolved (µg/l)	80	*0.5*	2.0	*0.5*	0.2	4	*0.5*	*0.5*	*0.5*	0
Selenium total (µg/l)	80	*0.5*	2.5	*0.6*	0.3	4	*0.5*	*0.5*	*0.5*	0
Selenium total recoverable (µg/l)	30	*0.5*	*0.5*	*0.5*	0	4	*0.5*	*0.5*	*0.5*	0
Total dissolved solids (mg/l)	50	90.0	450.0	290.2	89.3	4	90.0	460.0	312.5	121.5
Total suspended solids (mg/l)	79	*2.5*	2660.0	246.0	375.4	4	34.0	118.0	72.0	34.8
Turbidity (NTU)	77	2.5	7400.0	203.8	867.0	4	12.0	37.6	28.6	12.1
Zinc dissolved (µg/l)	80	*5*	30.0	*8.8*	6.4	4	*5.0*	10.0	*6.3*	2.5
Zinc total (µg/l)	80	*5*	330.0	65.2	62.3	4	*5.0*	70.0	26.3	29.8
Temperature (°C)	50	0.1	24.3	10.5	6.3	3	3.0	13.7	9.9	6.0
pH	80	6.8	8.8	8.1	0.4	3	8.3	8.7	8.4	0.2
Conductance (µmhos/cm)	80	203.0	704.0	437.7	123.7	3	281.0	562.0	419.3	140.6
Redox Potential (mv)	78	144.0	535.0	390.2	78.9	3	397.0	451.0	417.0	29.6
Oxygen dissolved (mg/l)	77	0	12.9	8.9	2.3	3	7.2	8.2	7.5	0.6

Note: *Italics* indicate "below detection"

Table 4.7. Water Chemistry Data for La Plata River near Farmington

Parameter	1994-2003 N of Cases	Minimum	Maximum	Mean	Standard Dev	2004 N of Cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	33	111.0	861.0	252.9	120.6	3	204.0	270.0	231.7	34.3
Alkalinity (mg/l)	33	111.0	861.0	253.2	120.5	3	208.0	270.0	233.0	32.7
Arsenic dissolved (μg/l)	62	0	5.0	2.2	0.9	3	0.3	0.6	0.4	0.2
Arsenic total (μg/l)	62	0.5	105.0	5.7	13.7	3	0.6	2.8	1.4	1.2
Calcium dissolved (mg/l)	33	65.4	507.0	189.2	90.9	3	153.0	230.0	190.7	38.5
Copper dissolved (μg/l)	33	1.0	20.0	7.7	5.5	3	*0.7*	1.4	1.0	0.4
Copper total (μg/l)	33	1.5	395.0	31.9	69.9	3	2.6	10.7	5.4	4.6
Hardness ((mg/l)	33	279.0	2120.0	824.2	387.7	3	650.0	1040.0	845.3	195.0
Mercury dissolved (μg/l)	62	*0.1*	*0.1*	*0.1*	0	3	*0.1*	*0.1*	*0.1*	0
Mercury total (μg/l)	62	*0.1*	1.7	0.2	0.3	3	*0.1*	*0.1*	*0.1*	0
Magnesium dissolved (mg/l)	33	18.1	208.0	85.3	42.2	3	65.2	114.0	90.0	24.4
Sodium dissolved (mg/l)	13	36.6	546.0	201.6	159.4	3	099.0	255.0	218.3	31.8
Lead dissolved (μg/l)	62	*0.1*	1.0	0.4	0.2	3	*0.1*	0.2	*0.1*	0.1
Lead total (μg/l)	62	0.3	408.0	20.3	66.4	3	0.2	6.6	2.8	3.4
Selenium dissolved (μg/l)	62	*0.5*	4.0	1.2	0.9	3	*0.5*	*0.5*	*0.5*	0
Selenium total (μg/l)	62	*0.5*	10.0	1.5	1.8	3	*0.5*	*0.5*	*0.5*	0
Selenium total recoverable (μg/l)	17	*0.5*	3.0	1.2	0.7	3	*0.5*	*0.5*	*0.5*	0
Total dissolved solids (mg/l)	33	80.0	3780.0	1481.2	826.2	3	1430.0	2080.0	1750.0	325.1
Total suspended solids (mg/l)	62	*2.0*	65600.0	2087.0	9013.9	3	*2.5*	358.0	146.2	187.3
Turbidity (NTU)	62	0.1	24300.0	899.1	3870.5	3	2.9	418.0	159.9	225.2
Zinc dissolved (μg/l)	62	*5.0*	20.0	*6.9*	4.0	3	*5.0*	*5.0*	*5.0*	0
Zinc total (μg/l)	62	*5.0*	1850.0	104.1	329.7	3	*5.0*	30.0	20.0	13.2
Temperature (°C)	62	0	32.2	13.2	9.2	2	2.7	24.8	13.8	15.6
pH	62	6.8	8.5	8.0	0.3	2	8.3	8.5	8.4	0.2
Conductance (μmhos/cm)	62	274.0	4190.0	1756.2	782.8	2	1960.0	2110.0	2035.0	106.1
Redox Potential (mv)	61	230.0	498.0	388.1	65.4	2	429.0	441.0	435.0	8.5
Oxygen dissolved (mg/l)	61	3.1	12.8	8.8	2.2	2	6.4	7.0	6.7	0.1

Note: *Italics* indicate “below detection”

Table 4.8. Water Chemistry Data for San Juan River at Shiprock Bridge

Parameter	1994-2003 N of Cases	Minimum	Maximum	Mean	Standard Dev	2004 N of Cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	92	1.0	359.0	110.5	41.1	8	85.0	125.0	110.9	16.3
Alkalinity (mg/l)	92	*1.0*	359.0	111.4	41.3	8	85.0	133.0	116.0	20.1
Arsenic dissolved (μg/l)	151	0.3	5.0	1.8	0.8	8	0.3	1.1	0.7	0.3
Arsenic total (μg/l)	150	0.3	44.0	4.1	6.0	8	0.6	5.0	2.0	1.9
Calcium dissolved (mg/l)	92	30.8	96.3	61.3	16.5	8	44.1	83.9	67.2	16.9
Copper dissolved (μg/l)	92	1.0	18.0	4.0	3.0	8	*0.6*	4.2	2.0	1.5
Copper total (μg/l)	92	2.5	298.0	30.1	44.5	8	1.7	50.0	18.4	20.0
Hardness ((mg/l)	92	98.0	317.0	199.1	55.3	8	137.0	272.0	216.8	56.6
Mercury dissolved (μg/l)	151	*0.1*	0.3	*0.1*	0	8	*0.1*	*0.1*	*0.1*	0
Mercury total (μg/l)	151	*0.1*	1.6	*0.1*	0.2	8	*0.1*	*0.1*	*0.1*	0
Magnesium dissolved (mg/l)	92	5.2	18.6	11.2	3.6	8	6.5	15.2	11.8	3.5
Sodium dissolved (mg/l)	45	11.4	125.0	42.0	19.0	8	15.4	55.8	38.5	16.1
Lead dissolved (μg/l)	151	*0.1*	18.0	0.9	2.3	8	*0.1*	0.8	0.4	0.3
Lead total (μg/l)	150	0.5	323.0	26.1	42.3	8	1.0	11.3	5.0	4.4
Selenium dissolved (μg/l)	151	*0.5*	1.0	*0.5*	0.1	8	*0.5*	*0.5*	*0.5*	0
Selenium total (μg/l)	151	*0.5*	7.0	*0.7*	0.7	8	*0.5*	*0.5*	*0.5*	0
Selenium total recoverable (∧g/l)	55	*0.5*	2.0	*0.6*	0.4	8	*0.5*	*0.5*	*0.5*	0
Total dissolved solids (mg/l)	91	130.0	590.0	352.2	109.7	8	180.0	500.0	360.0	126.7
Total suspended solids (mg/l)	149	*2.5*	20200.0	1074.7	3165.3	8	12.0	128.0	57.5	36.2
Turbidity (NTU)	147	3.8	22300.0	746.3	2488.8	8	7.9	46.2	30.1	16.5
Zinc dissolved (∧g/l)	151	*5.0*	50.0	*8.3*	6.4	8	*5.0*	*5.0*	*5.0*	0
Zinc total (μg/l)	151	*5.0*	2000.0	126.5	257.3	8	*5.0*	70.0	21.9	26.9
Temperature (°C)	151	0.1	26.1	12.2	6.9	6	2.1	23.3	13.6	9.6
pH	151	6.9	9.0	8.2	0.3	6	8.3	8.8	8.6	0.2
Conductance (μmhos/cm)	151	244.0	921.0	527.9	151.8	6	317.0	654.0	495.7	151.5
Redox Potential (mv)	150	202.0	544.0	400.8	76.4	6	396.0	472.0	433.3	34.0
Oxygen dissolved (mg/l)	149	3.6	13.9	9.7	2.3	6	8.4	9.1	8.7	0.4

Note: *Italics* indicate “below detection”

Table 4.9 Water Chemistry Data for Mancos River near Four Corners

Parameter	1994-2003 N of Cases	Minimum	Maximum	Mean	Standard Dev	2004 N of Cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	40	92.0	360.0	176.1	54.7	3	144.0	223.0	188.0	40.3
Alkalinity (mg/l)	40	92.0	360.0	178.5	54.3	3	151.0	223.0	190.3	36.5
Arsenic dissolved (μg/l)	63	0.5	5.0	2.0	0.9	3	0.3	0.8	0.5	0.3
Arsenic total (μg/l)	63	0.7	45.0	5.7	8.7	3	0.6	1.3	0.9	0.4
Calcium dissolved (mg/l)	40	43.6	284.0	149.5	58.4	3	105.0	226.0	180.7	66.0
Copper dissolved (μg/l)	40	1.2	20.0	7.6	5.4	3	0.8	3.6	1.8	1.6
Copper total (μg/l)	40	1.5	198.0	30.6	42.2	3	1.6	7.0	3.4	3.1
Hardness ((mg/l)	40	165.0	1110.0	703.7	291.7	3	447.0	1120.0	847.3	354.2
Mercury dissolved (μg/l)	63	*0.1*	*0.1*	*0.1*	0	3	*0.1*	*0.1*	*0.1*	0
Mercury total (μg/l)	63	*0.1*	2.0	*0.1*	0.2	3	*0.1*	*0.1*	*0.1*	0
Magnesium dissolved (mg/l)	40	13.7	145.0	80.2	39.0	3	45.0	134.0	96.0	45.9
Sodium dissolved (mg/l)	17	22.0	206.0	122.9	52.1	3	51.8	149.0	104.3	49.1
Lead dissolved (μg/l)	63	*0.1*	1.0	0.4	0.2	3	*0.1*	0.3	0.2	0.1
Lead total (μg/l)	63	0.2	135.0	12.3	24.1	3	0.6	1.7	1.0	0.6
Selenium dissolved (μg/l)	63	*0.5*	30.0	7.9	6.2	3	*0.5*	2.0	1.2	0.8
Selenium total (μg/l)	63	*0.5*	30.0	8.0	6.1	3	*0.5*	2.0	1.5	0.9
Selenium total recoverable (μg/l)	24	*0.5*	26.0	9.3	5.9	3	*0.5*	2.0	1.0	0.9
Total dissolved solids (mg/l)	39	240.0	2100.0	1280.0	544.9	3	680.0	1880.0	1386.7	627.8
Total suspended solids (mg/l)	62	*2.5*	33500.0	1191.4	4409.5	3	40.0	48.0	43.3	4.2
Turbidity (NTU)	62	3.9	18500.0	734.2	2405.2	3	35.1	58.5	45.0	12.1
Zinc dissolved (μg/l)	63	*5.0*	40.0	7.3	5.9	3	*5.0*	*5.0*	*5.0*	0
Zinc total (μg/l)	63	*5.0*	2300.0	99.8	306.1	3	*5.0*	40.0	18.3	18.9
Temperature (°C)	63	0	32.3	12.0	8.5	1	18.0	18.0	18.0	
pH	63	6.8	8.8	8.2	0.3	1	8.6	8.6	8.6	
Conductance (μmhos/cm)	63	381.0	2450.0	1574.5	581.6	1	946.0	946.0	946.0	
Redox Potential (mv)	62	4.2	548.0	400.5	86.4	1	437.0	437.0	437.0	
Oxygen dissolved (mg/l)	62	4.8	13.3	9.5	2.1	1	7.6	7.6	7.6	

Note: *Italics* indicate “below detection”

Table 4.10. Water Chemistry Data for San Juan River at Four Corners Bridge

Parameter	1994-2003 N of Cases	Minimum	Maximum	Mean	Standard Dev	2004 N of Cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	53	67.0	214.0	118.8	29.9	4	84.0	146.0	125.5	28.4
Alkalinity (mg/l)	53	67.0	214.0	119.3	30.1	4	84.0	148.0	126.8	29.1
Arsenic dissolved (μg/l)	82	0.3	17.2	1.9	1.9	4	0.3	1.0	0.6	0.3
Arsenic total (μg/l)	82	0.5	19.0	3.9	3.9	4	0.6	5.0	2.0	2.1
Calcium dissolved (mg/l)	53	31.7	99.9	66.4	18.8	4	43.9	86.1	70.7	19.6
Copper dissolved (μg/l)	53	1.0	16.2	4.2	3.0	4	*0.6*	1.5	1.2	0.4
Copper total (μg/l)	53	2.5	130.0	25.4	25.2	4	1.8	50.0	15.9	23.0
Hardness ((mg/l)	53	103.0	340.0	222.6	66.4	4	139.0	293.0	234.3	69.3
Mercury dissolved (μg/l)	82	*0.1*	0.3	*0.1*	0	4	*0.1*	*0.1*	*0.1*	0
Mercury total (μg/l)	82	*0.1*	0.8	*0.1*	0.1	4	*0.1*	*0.1*	*0.1*	0
Magnesium dissolved (mg/l)	53	5.5	23.8	13.8	5.1	4	7.0	19.0	14.0	5.1
Sodium dissolved (mg/l)	30	12.6	70.3	44.6	16.7	4	16.1	60.9	46.8	21.1
Lead dissolved (μg/l)	82	*0.1*	14.4	0.7	1.7	4	*0.1*	0.7	0.3	0.3
Lead total (μg/l)	82	0.5	271.0	21.9	40.6	4	1.0	11.6	6.3	4.4
Selenium dissolved (μg/l)	82	*0.5*	2.0	*0.8*	0.5	4	*0.5*	*0.5*	*0.5*	0
Selenium total (μg/l)	82	*0.5*	4.0	1.0	0.6	4	*0.5*	1.0	*0.6*	0.3
Selenium total recoverable (μg/l)	32	*0.5*	2.0	*0.8*	1.4	4	*0.5*	1.0	*0.6*	0.3
Total dissolved solids (mg/l)	52	110.0	640.0	389.2	131.9	4	190.0	540.0	405.0	151.5
Total suspended solids (mg/l)	82	*2.5*	11700.0	750.5	1822.4	4	38.0	348.0	132.5	146.1
Turbidity (NTU)	80	2.0	60500.0	1230.5	6834.5	4	17.9	277.0	91.0	124.7
Zinc dissolved (μg/l)	82	5.0	30.0	7.6	5.5	4	5.0	5.0	5.0	0
Zinc total (μg/l)	82	*5.0*	920.0	88.2	131.8	4	*5.0*	60.0	25.0	26.1
Temperature (°C)	82	0	26.3	12.5	7.5	2	15.4	22.5	19.0	5.0
pH	82	6.8	8.8	8.2	0.4	2	8.3	8.5	8.4	0.1
Conductance (μmhos/cm)	82	251.0	870.0	587.3	177.3	2	339.0	656.0	497.5	224.2
Redox Potential (mv)	80	189.0	592.0	395.3	82.6	2	401.0	422.0	411.5	14.8
Oxygen dissolved (mg/l)	81	4.3	12.7	9.3	2.1	2	8.1	8.4	8.2	0.2

Note: *Italics* indicate "below detection"

Table 4.11. Water Chemistry Data for San Juan River at Montezuma Creek Bridge

Parameter	1994-2003 N of Cases	Minimum	Maximum	Mean	Standard Dev	2004 N of Cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	46	59.0	205.0	126.4	32.9	3	85.0	143.0	133.7	29.0
Alkalinity (mg/l)	46	59.0	205.0	126.9	33.1	3	85.0	143.0	116.0	29.2
Arsenic dissolved (μg/l)	74	0.5	3.2	1.8	0.8	3	0.3	1.1	0.6	0.4
Arsenic total (μg/l)	74	0.5	55.0	4.4	7.2	3	0.6	5.0	2.5	2.3
Calcium dissolved (mg/l)	46	33.9	132.0	74.03	23.5	3	43.6	96.9	71.2	26.7
Copper dissolved (μg/l)	46	1.5	15.0	4.2	3.1	3	*0.7*	1.5	1.1	0.4
Copper total (μg/l)	46	1.5	234.0	29.0	41.6	3	1.7	50.0	20.6	25.8
Hardness ((mg/l)	46	110.0	465.0	265.4	91.7	3	139.0	344.0	249.3	103.4
Mercury dissolved (μg/l)	74	*0.1*	0.2	*0.1*	0	3	*0.1*	*0.1*	*0.1*	0
Mercury total (μg/l)	74	*0.1*	0.8	*0.1*	0.1	3	*0.1*	*0.1*	*0.1*	0
Magnesium dissolved (mg/l)	46	6.2	40.5	19.4	8.5	3	7.3	24.8	17.3	9.0
Sodium dissolved (mg/l)	22	12.8	196.0	54.6	37.2	3	15.2	57.3	40.3	22.2
Lead dissolved (μg/l)	74	0.1	4.0	0.4	0.5	3	0.1	0.4	0.2	0.2
Lead total (μg/l)	74	0.5	211.0	20.5	34.0	3	0.8	13.2	5.2	7.0
Selenium dissolved (μg/l)	74	*0.5*	4.0	*0.9*	0.6	3	*0.5*	*0.5*	*0.5*	0
Selenium total (μg/l)	74	*0.5*	6.0	1.1	0.9	3	*0.5*	1.0	*0.7*	0.3
Selenium total recoverable (μg/l)	28	*0.5*	2.0	*0.9*	0.5	3	*0.5*	*0.5*	*0.5*	0
Total dissolved solids (mg/l)	44	170.0	800.0	454.3	163.7	3	200.0	590.0	403.3	195.5
Total suspended solids (mg/l)	73	*2.5*	13000.0	880.4	2048.3	3	28.0	146.0	78.7	60.7
Turbidity (NTU)	73	3.9	17200.0	686.1	2243.2	3	15.4	62.9	42.3	24.4
Zinc dissolved (μg/l)	74	*5.0*	60.0	*7.9*	7.5	3	*5.0*	*5.0*	*5.0*	0
Zinc total (μg/l)	74	*5.0*	860.0	95.2	140.9	3	*5.0*	60.0	23.3	31.8
Temperature (°C)	74	0.1	27.8	12.7	7.5	2	14.6	22.2	18.4	5.4
pH	74	6.9	8.7	8.2	0.3	2	8.2	8.6	8.4	0.3
Conductance (μmhos/cm)	74	274.0	1160.0	674.1	216.7	2	344.0	654.0	499.0	219.2
Redox Potential (mv)	73	186.0	520.0	394.8	78.9	2	399.0	439.0	419.0	28.3
Oxygen dissolved (mg/l)	73	4.8	12.6	9.1	2.0	2	7.9	9.0	8.4	0.8

Note: *Italics* indicate “below detection”

Table 4.12. Water Chemistry Data for San Juan River at Bluff Bridge

Parameter	1994-2003 N of Cases	Minimum	Maximum	Mean	Standard Dev	2004 N of Cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	96	47.0	349.0	126.9	43.0	8	75.0	145.0	122.1	29.1
Alkalinity (mg/l)	96	47.0	349.0	127.0	43.0	8	75.0	145.0	123.4	29.1
Arsenic dissolved (μg/l)	153	0.5	2.5	1.8	0.8	8	0.3	1.0	0.6	0.3
Arsenic total (μg/l)	152	0.5	35.8	4.7	6.4	8	0.7	5.0	2.1	1.9
Calcium dissolved (mg/l)	96	32.3	121.0	74.8	21.4	8	42.9	105.0	79.3	26.3
Copper dissolved (μg/l)	96	1.0	13.0	4.7	3.1	8	*0.7*	1.5	1.1	0.3
Copper total (μg/l)	96	1.5	200.0	32.2	39.4	8	1.9	60.0	16.6	21.7
Hardness ((mg/l)	96	106.0	507.0	268.3	86.2	8	137.0	381.0	282.4	102.0
Mercury dissolved (μg/l)	153	*0.1*	0.5	*0.1*	0	8	*0.1*	*0.1*	*0.1*	0
Mercury total (μg/l)	153	*0.1*	0.7	*0.1*	0.1	8	*0.1*	*0.1*	*0.1*	0
Magnesium dissolved (mg/l)	96	6.2	49.8	19.9	8.5	8	7.2	28.9	20.5	8.9
Sodium dissolved (mg/l)	49	12.6	83.0	50.4	19.9	8	15.0	81.8	50.2	25.4
Lead dissolved (μg/l)	153	*0.1*	4.0	0.5	0.7	8	*0.1*	0.4	0.2	0.1
Lead total (μg/l)	152	0.5	144.0	22.4	32.4	8	1.1	15.6	5.1	6.3
Selenium dissolved (μg/l)	153	*0.5*	3.0	*0.8*	0.5	8	*0.5*	*0.5*	*0.5*	0
Selenium total (μg/l)	153	*0.5*	8.0	1.1	1.0	8	*0.5*	1.0	*0.6*	0.2
Selenium total recoverable (μg/l)	57	*0.5*	2.0	*0.8*	0.3	8	*0.5*	*0.5*	*0.5*	0
Total dissolved solids (mg/l)	93	150.0	990.0	475.9	167.7	8	200.0	660.0	472.5	188.1
Total suspended solids (mg/l)	153	*1.0*	9820.0	923.2	1803.4	8	30.0	298.0	109.0	116.6
Turbidity (NTU)	151	2.0	7900.0	677.6	1510.2	8	14.7	84.3	42.5	27.8
Zinc dissolved (μg/l)	153	*5.0*	40.0	7.9	5.8	8	*5.0*	*5.0*	*5.0*	0
Zinc total (μg/l)	153	*5.0*	650.0	104.1	142.6	8	*5.0*	70.0	29.4	27.7
Temperature (°C)	153	0.1	29.4	12.3	7.7	6	0.6	20.4	12.0	9.1
pH	153	6.9	8.6	8.2	0.2	6	8.3	8.7	8.5	0.2
Conductance (μmhos/cm)	153	270.0	1145.0	690.8	219.2	6	336.0	842.0	613.3	229.4
Redox Potential (mv)	152	4.0	535.0	391.5	93.2	6	331.0	486.0	419.7	71.4
Oxygen dissolved (mg/l)	151	5.4	12.7	9.1	2.0	6	7.9	8.4	8.1	0.3

Note: *Italics* indicate "below detection"

Table 4.13. Water Chemistry Data for San Juan River at Mexican Hat Bridge

	1994-2003					2004				
Parameter	**N of Cases**	**Minimum**	**Maximum**	**Mean**	**Standard Dev**	**N of Cases**	**Minimum**	**Maximum**	**Mean**	**Standard Dev**
Bicarbonate (mg/l)	50	71.0	1070.0	147.6	135.6	4	86.0	144.0	122.5	27.7
Alkalinity (mg/l)	50	71.0	1070.0	147.6	135.6	4	86.0	144.0	124.0	27.4
Arsenic dissolved (μg/l)	79	0.5	2.5	1.8	0.8	4	0.3	1.0	0.6	0.3
Arsenic total (μg/l)	79	0.8	75.7	5.6	10.3	4	0.8	5.0	2.2	2.0
Calcium dissolved (mg/l)	50	32.7	164.0	76.6	24.9	4	46.5	103.0	80.1	28.0
Copper dissolved (μg/l)	50	1.5	13.0	4.3	3.0	4	*0.7*	1.8	1.2	0.5
Copper total (μg/l)	50	1.5	255.0	26.5	43.4	4	1.9	50.0	16.6	22.8
Hardness ((mg/l)	50	108.0	530.0	275.8	95.6	4	139.0	369.0	285.5	108.4
Mercury dissolved (μg/l)	79	*0.1*	*0.1*	*0.1*	0	4	*0.1*	*0.1*	*0.1*	0
Mercury total (μg/l)	79	*0.1*	1.1	*0.1*	0.2	4	*0.1*	*0.1*	*0.1*	0
Magnesium dissolved (mg/l)	50	6.2	43.8	20.5	8.9	4	7.4	28.4	20.8	9.4
Sodium dissolved (mg/l)	27	12.8	113	52.9	22.5	4	15.1	72.7	49.1	24.6
Lead dissolved (μg/l)	79	*0.1*	1.0	0.4	0.2	4	*0.1*	0.6	0.3	0.2
Lead total (μg/l)	79	0.5	327.0	23.4	51.0	4	0.3	15.3	4.6	7.2
Selenium dissolved (μg/l)	79	*0.5*	4.0	*0.9*	0.6	4	*0.5*	*0.5*	*0.5*	0
Selenium total (μg/l)	79	*0.5*	7.0	1.2	1.1	4	*0.5*	1.0	*0.6*	0.3
Selenium total recoverable (μg/l)	29	*0.5*	9.0	1.5	1.9	4	*0.5*	*0.5*	*0.5*	0
Total dissolved solids (mg/l)	49	170.0	1050.0	487.3	181.8	4	220.0	640.0	477.5	196.0
Total suspended solids (mg/l)	79	*1.0*	18800.0	1385.8	3170.4	4	14.0	254.0	92.5	109.1
Turbidity (NTU)	77	1.0	24700.0	1057.2	3244.4	4	13.4	91.3	61.5	33.1
Zinc dissolved (μg/l)	79	*5.0*	100.0	9.0	12.0	4	*5.0*	*5.0*	*5.0*	0
Zinc total (μg/l)	79	*5.0*	1620.0	118.0	249.2	4	*5.0*	80.0	23.8	37.5
Temperature ($^{\circ}$C)	79	0.1	29.8	12.6	7.9	2	16.3	22.4	19.3	4.4
pH	79	7.0	8.6	8.1	0.3	2	8.3	8.6	8.4	0.2
Conductance (μmhos/cm)	79	273.0	1452.0	701.8	226.8	2	335.0	669.0	502.0	236.2
Redox Potential (mv)	78	140.0	537.0	392.3	89.0	2	373.0	390.0	381.5	12.0
Oxygen dissolved (mg/l)	78	5.8	12.9	9.1	2.0	2	7.7	8.3	8.0	0.4

Note: *Italics* indicate “below detection”

Table 4.14. Annual Sampling Parameters for San Juan River at Archuleta Bridge, 1997-2004

	Sampling Date					
Parameter	**2/19/1997**	**2/18/1998**	**2/28/2001**	**2/13/2002**	**2/20/2003**	**2/18/2004**
Aluminum (dissolved) mg/l	*0.015*	*0.015*	*0.015*	*0.015*	*0.015*	*0.015*
Aluminum (total) mg/l	0.23	0.31	0.16	0.29	0.5	0.33
Barium (dissolved) mg/l	0.07		0.072	0.071	0.089	0.098
Barium (total) mg/l	0.073		0.073	0.074	0.089	0.101
Manganese (dissolved) mg/l	0.015		0.011	0.006	0.009	0.018
Manganese (total) mg/l	0.016		0.01	0.011	0.01	0.024
Nickel (dissolved) mg/l	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Nickel (total) mg/l	*0.005*	*0.005*	*0.005*	*0.005*	0.01	*0.005*
Potassium (dissolved) mg/l	1.7		1.7	1.7	2.1	2
Potassium (total) mg/l	2		1.7	1.8	2	2
Strontium (dissolved) mg/l	0.29		0.28	0.26	0.32	0.38
Strontium (total) mg/l	0.3		0.27	0.27	0.34	0.36
Chloride (dissolved) mg/l	2		3	2	3	4
Nitrogen as NH_3 mg/l	0.025		0.025	0.025	0.05	0.025
Nitrogen as NO_3 mg/l	0.01		0.03	0.05	0.09	0.56
Nitrogen as NO_2 mg/l	*0.005*		*0.005*	*0.005*	*0.005*	*0.005*
Silica (dissolved) mg/l	11.2		11.2	10.4	10.2	10.6
Silica (total) mg/l	12		11.1	12.7	11.8	12.0
Sulfate (dissolved) mg/l	50		40	40	60	60

Note: *Italics* indicate “below detection”

Table 4.15. Annual Sampling Parameters for Animas River at Farmington, 1997-2004

	Sampling Date					
Parameter	**2/19/1997**	**2/17/1998**	**2/28/2001**	**2/13/2002**	**2/19/2003**	**2/18/2004**
Aluminum (dissolved) mg/l	*0.015*	*0.015*	*0.015*	*0.015*	*0.015*	0.07
Aluminum (total) mg/l	3.19	0.3	4.91	*0.22*	3.24	0.5
Barium (dissolved) mg/l	0.083		0.071	0.066	0.097	0.067
Barium (total) mg/l	0.116		0.048	0.069	0.13	0.073
Manganese (dissolved) mg/l	0.072		0.059	0.088	0.034	0.062
Manganese (total) mg/l	0.274		0.132	0.109	0.117	0.083
Nickel (dissolved) mg/l	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Nickel (total) mg/l	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Potassium (dissolved) mg/l	2.7		3	3	3.3	3.4
Potassium (total) mg/l	3.6		2.5	3.1	4.1	3.4
Strontium (dissolved) mg/l	1.07		1.08	1.19	1.23	1.27
Strontium (total) mg/l	1.03		0.08	1.22	1.26	1.22
Chloride (dissolved) mg/l	16		27	25	28	27
Nitrogen as NH_3 mg/l	0.025		0.025	0.025	0.05	0.025
Nitrogen as NO_3 mg/l	0.35		0.26	0.23	0.11	0.85
Nitrogen as NO_2 mg/l	*0.005*		0.01	*0.005*	*0.005*	*0.005*
Silica (dissolved) mg/l	6.3		5.8	6	4.8	6.9
Silica (total) mg/l	17.4		39	7.2	16.9	9.2
Sulfate (dissolved) mg/l	150		170	190	210	200

Note: *Italics* indicate “below detection”

Table 4.16. Annual Sampling Parameters for San Juan River at Highway 371 Bridge, 1997-2004

	Sampling Date					
Parameter	**2/19/1997**	**3/17/1998**	**2/28/2001**	**2/13/2002**	**2/20/2003**	**2/18/2004**
Aluminum (dissolved) mg/l	*0.015*	*0.015*	*0.015*	*0.015*	*0.015*	*0.015*
Aluminum (total) mg/l	1.72	4.37	5.81	0.86	2.98	1.93
Barium (dissolved) mg/l	0.074		0.067	0.064	0.08	0.064
Barium (total) mg/l	0.103		0.112	0.086	0.111	0.098
Manganese (dissolved) mg/l	0.056		0.027	0.031	0.017	0.031
Manganese (total) mg/l	0.214		0.166	0.08	0.088	0.087
Nickel (dissolved) mg/l	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Nickel (total) mg/l	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Potassium (dissolved) mg/l	2.6		2.4	2.3	2.6	4
Potassium (total) mg/l	2.8		3.5	2.5	3.3	4.2
Strontium (dissolved) mg/l	1		0.81	0.74	0.87	1.06
Strontium (total) mg/l	0.99		0.83	0.74	0.94	1.03
Chloride (dissolved) mg/l	15		15	14	16	24
Nitrogen as NH_3 mg/l	0.2		0.11	0.24	0.3	0.5
Nitrogen as NO_3 mg/l	2.3		0.45	0.2	0.25	1.15
Nitrogen as NO_2 mg/l	0.01		0.01	*0.005*	*0.005*	0.02
Silica (dissolved) mg/l	7.3		9	8.4	7.7	8.4
Silica (total) mg/l	13.5		32.6	12.3	18.9	17
Sulfate (dissolved) mg/l	170		150	130	170	190

Note: *Italics* indicate “below detection”

Table 4.17. Annual Sampling Parameters for LaPlata River at Mouth, 1997-2004

	Sampling Date				
	3/18/1997	2/17/1998	2/28/2001	2/13/2002	2/18/2004
Aluminum (dissolved) mg/l	*0.015*	0.03	*0.015*	*0.015*	*0.015*
Aluminum (total) mg/l	66.5	1.1	11.7	25.9	3.24
Barium (dissolved) mg/l			0.031	0.032	0.022
Barium (total) mg/l			0.17	0.286	0.044
Manganese (dissolved) mg/l			0.007	0.012	0.204
Manganese (total) mg/l			0.312	0.55	0.249
Nickel (dissolved) mg/l	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Nickel (total) mg/l	0.06	*0.005*	*0.005*	0.01	*0.005*
Potassium (dissolved) mg/l			2.4	2.5	3.4
Potassium (total) mg/l			4.6	7.1	3.7
Strontium (dissolved) mg/l			1.51	1.64	2.97
Strontium (total) mg/l			1.53	1.76	2.74
Chloride (dissolved) mg/l			36	38	89
Nitrogen as NH_3 mg/l			0.025	0.025	0.07
Nitrogen as NO_3 mg/l			0.29	0.57	0.33
Nitrogen as NO_2 mg/l			*0.005*	*0.005*	*0.005*
Silica (dissolved) mg/l			10.8	14.5	11
Silica (total) mg/l			46.8	103	26.7
Sulfate (dissolved) mg/l			680	700	1130

Note: *Italics* indicate “below detection”

Table 4.18. Annual Sampling Parameters for San Juan River at Shiprock Bridge, 1997-2004

	Sampling Date										
Parameter	**2/20/1997**	**2/19/1998**	**2/19/1998**	**3/1/2001**	**3/1/2001**	**2/14/2002**	**2/14/2002**	**2/20/2003**	**2/20/2003**	**2/18/2004**	**2/18/2004**
Aluminum (dissolved) mg/l	*0.015*	*0.015*	*0.015*	*0.015*	*0.015*	*0.015*	0.04	0.07	0.05	*0.015*	*0.015*
Aluminum (total) mg/l	1.92	1.73	4.12	5.25	5.56	1.31	1.05	2.11	2.04	0.43	0.37
Barium (dissolved) mg/l	0.066			0.069	0.069	0.064	0.064	0.089	0.088	0.059	0.06
Barium (total) mg/l	0.173			0.127	0.115	0.074	0.07	0.099	0.102	0.065	0.067
Manganese (dissolved) mg/l	0.021			0.008	0.006	0.02	0.02	0.121	0.122	0.019	0.019
Manganese (total) mg/l	0.314			0.147	0.136	0.06	0.056	0.156	0.144	0.035	0.035
Nickel (dissolved) mg/l	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Nickel (total) mg/l	0.01	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Potassium (dissolved) mg/l	2.5			2.7	2.6	2.6	2.6	2.9	2.8	3	3
Potassium (total) mg/l	2.7			3.5	3.4	2.6	2.5	3.3	3.4	2.9	3
Strontium (dissolved) mg/l	0.99			0.89	0.89	0.85	0.86	1.05	1.05	1.09	1.11
Strontium (total) mg/l	1.04			0.99	0.88	0.8	0.77	1	1.04	1.05	1.08
Chloride (dissolved) mg/l	17			18	18	16	16	23	22	23	23
Nitrogen as NH_3 mg/l	0.025			0.025	0.025	0.025	0.025	0.05	0.05	0.025	0.025
Nitrogen as NO_3 mg/l	0.26			0.4	0.41	0.23	0.32			0.67	0.67
Nitrogen as NO_2 mg/l	0.01			*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	0.01	0.01
Silica (dissolved) mg/l	6.4			8.9	8.8	5.4	5.4	6.1	6	6.2	6.1
Silica (total) mg/l	11.5			30.6	31.8	11.6	10	17.2	12.8	7.6	7.5
Sulfate (dissolved) mg/l	200			180	190	170	170	220	220	230	220

Notes: *Italics* indicate “below detection”, This site has blind replicate samples for lab QA/QC. Both values are shown.

Table 4.19. Annual Sampling Parameters for Mancos River near Four Corners, 1997-2004

	Sampling Date					
Parameter	**2/26/1997**	**3/19/1998**	**3/1/2001**	**2/14/2002**	**2/209/2003**	**2/19/2004**
Aluminum (dissolved) mg/l	*0.015*	*0.015*	*0.015*	*0.015*	0.18	*0.015*
Aluminum (total) mg/l	4.3	28.8	1.32	1.19	7.61	1.87
Barium (dissolved) mg/l			0.061	0.062	0.071	0.044
Barium (total) mg/l			0.074	0.065	0.097	0.051
Manganese (dissolved) mg/l			0.075	0.043	0.018	0.041
Manganese (total) mg/l			0.11	0.059	0.05	0.065
Nickel (dissolved) mg/l	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Nickel (total) mg/l	*0.005*	0.04	*0.005*	*0.005*	*0.005*	*0.005*
Potassium (dissolved) mg/l			5	4.1	6.5	3.9
Potassium (total) mg/l			5.1	4	8.2	4.9
Strontium (dissolved) mg/l			1.87	1.82	1.53	2.02
Strontium (total) mg/l			1.91	1.74	1.46	2.01
Chloride (dissolved) mg/l			21	18	19	23
Nitrogen as NH_3 mg/l			0.025	0.025	0.2	0.025
Nitrogen as NO_3 mg/l			0.75	0.74	0.77	0.06
Nitrogen as NO_2 mg/l			*0.005*	*0.005*	0.01	*0.005*
Silica (dissolved) mg/l			1.1	4.5	6.6	6
Silica (total) mg/l			6.4	10.2	18.5	11.5
Sulfate (dissolved) mg/l			1080	1080	990	1180

Note: *Italics* indicate “below detection”

Table 4.20 Annual Sampling Parameters for San Juan River at Four Corners Bridge, 1997-2004

	Sampling Date					
Parameter	**2/20/1997**	**2/19/1998**	**3/1/2001**	**2/13/2002**	**2/21/2003**	**2/19/2004**
Aluminum (dissolved) mg/l	*0.015*	*0.015*	0.03	*0.015*	*0.015*	*0.015*
Aluminum (total) mg/l	0.64	3.74	13.2	1.27	1.67	0.6
Barium (dissolved) mg/l	0.06		0.074	0.063	0.069	0.056
Barium (total) mg/l	0.072		0.175	0.074	0.076	0.07
Manganese (dissolved) mg/l	0.016		0.006	0.007	0.005	0.012
Manganese (total) mg/l	0.045		0.259	0.044	0.052	0.031
Nickel (dissolved) mg/l	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Nickel (total) mg/l	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Potassium (dissolved) mg/l	2.6		2.6	2.6	2.7	2.9
Potassium (total) mg/l	3.1		4.7	2.8	3.1	3.1
Strontium (dissolved) mg/l	1.07		0.98	0.89	1.1	1.13
Strontium (total) mg/l	1.1		1.04	0.87	0.99	1.18
Chloride (dissolved) mg/l	18		16	16	24	23
Nitrogen as NH_3 mg/l	0.025		0.025	0.025	0.05	0.025
Nitrogen as NO_3 mg/l	0.16		0.47	0.37	0.49	0.47
Nitrogen as NO_2 mg/l	*0.005*		*0.005*	*0.005*	0.02	0.01
Silica (dissolved) mg/l	3.9		8.2	3.7	4.9	2.9
Silica (total) mg/l	6.9		60.7	9.9	10.6	5.7
Sulfate (dissolved) mg/l	270		230	210	240	250

Note: *Italics* indicate “below detection”

Table 4.21. Annual Sampling Parameters for San Juan River at Montezuma Creek Bridge, 1997-2003

	Sampling Date				
	2/26/1997	2/19/1998	3/1/2001	2/13/2002	2/21/2003
Aluminum (dissolved) mg/l	*0.015*	0.25		*0.015*	*0.015*
Aluminum (total) mg/l	9.68	10.1	24.8	1.02	1.67
Barium (dissolved) mg/l			0.073	0.064	0.072
Barium (total) mg/l			0.203	0.074	0.077
Manganese (dissolved) mg/l			*0.0025*	*0.0025*	*0.0025*
Manganese (total) mg/l			0.332	0.035	0.039
Nickel (dissolved) mg/l	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Nickel (total) mg/l	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Potassium (dissolved) mg/l			2.8	2.7	3.1
Potassium (total) mg/l			5.8	2.6	3.3
Strontium (dissolved) mg/l			1.05	1.03	1.28
Strontium (total) mg/l			1.16	0.96	1.15
Chloride (dissolved) mg/l			18	17	27
Nitrogen as NH_3 mg/l			0.025	0.025	0.05
Nitrogen as NO_3 mg/l			0.58	0.24	0.57
Nitrogen as NO_2 mg/l			*0.005*	*0.005*	*0.005*
Silica (dissolved) mg/l			7.1	4.1	5.1
Silica (total) mg/l			96	9.2	10.6
Sulfate (dissolved) mg/l			280	250	300

Note: *Italics* indicate "below detection"

Table 4.22. Annual Sampling Parameters for San Juan River at Bluff Bridge, 1997-2003

	Sampling Date										
Parameter	**2/20/1997**	**2/19/1998**	**2/19/1998**	**3/1/2001**	**3/1/2001**	**2/14/2002**	**2/14/2002**	**2/21/2003**	**2/21/2003**	**2/19/2004**	**2/19/2004**
Aluminum (dissolved) mg/l	*0.015*	*0.015*	*0.015*	*0.015*	*0.015*	0.05	0.04	*0.015*	*0.015*	*0.015*	*0.015*
Aluminum (total) mg/l	0.92	6.91	6.29	5.91	6.59	1.13	1.11	2.08	2.82	0.5	0.55
Barium (dissolved) mg/l	0.075			0.072	0.073	0.063	0.063	0.077	0.079	0.069	0.068
Barium (total) mg/l	0.101			0.123	0.12	0.072	0.072	0.084	0.088	0.071	0.073
Manganese (dissolved) mg/l	0.01			*0.0025*	*0.0025*	0.005	*0.0025*	0.011	0.011	0.013	0.013
Manganese (total) mg/l	0.119			0.138	0.136	0.06	0.061	0.057	0.055	0.026	0.026
Nickel (dissolved) mg/l	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Nickel (total) mg/l	0.01	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Potassium (dissolved) mg/l	3.1			2.7	2.8	2.7	2.7	3.3	3.2	3.4	3.5
Potassium (total) mg/l	3.1			3.7	3.8	2.7	2.5	3.3	3.8	3.3	3.2
Strontium (dissolved) mg/l	1.63			1.04	1.04	0.99	1	1.29	1.31	1.48	1.48
Strontium (total) mg/l	1.65			1.08	1.07	0.93	0.92	1.16	1.18	1.36	1.36
Chloride (dissolved) mg/l	23			20	20	17	17	26	26	29	29
Nitrogen as NH_3 mg/l	0.025			0.025	0.025	0.025	0.025	0.05	0.05	0.025	0.025
Nitrogen as NO_3 mg/l	0.17			0.41	0.38	0.25	0.25			0.63	0.74
Nitrogen as NO_2 mg/l	*0.005*			*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	0.01	0.01
Silica (dissolved) mg/l	4.1			7.1	7.2	4	4	5.7	5.8	2.8	2.9
Silica (total) mg/l	7.5			31.3	31.7	10.3	9.4	12.8	14.9	5.2	5.4
Sulfate (dissolved) mg/l	450			260	260	230	230	300	310	340	340

Notes: *Italics* indicate “below detection”, This site has blind replicate samples for lab QA/QC. Both values are shown.

Table 4.23. Annual Sampling Parameters for San Juan River at Mexican Hat Bridge, 1997-2003

	Sampling Date					
Parameter	**2/20/1997**	**2/19/1998**	**3/1/2001**	**2/14/2002**	**2/21/2003**	**2/19/2004**
Aluminum (dissolved) mg/l	*0.015*	*0.015*	*0.015*	*0.015*	*0.015*	*0.015*
Aluminum (total) mg/l	2.14	35.7	8.73	0.76	5.91	0.29
Barium (dissolved) mg/l	0.077		0.065	0.065	0.079	0.069
Barium (total) mg/l	0.101		0.125	0.071	0.101	0.067
Manganese (dissolved) mg/l	*0.0025*		0.011	*0.0025*	*0.0025*	0.009
Manganese (total) mg/l	0.077		0.155	0.027	0.083	0.047
Nickel (dissolved) mg/l	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Nickel (total) mg/l	*0.005*	0.02	*0.005*	*0.005*	*0.005*	*0.005*
Potassium (dissolved) mg/l	3		2.6	2.7	3.1	3.3
Potassium (total) mg/l	4.1		4.2	2.7	4.1	3.5
Strontium (dissolved) mg/l	1.49		0.99	1.04	1.31	1.35
Strontium (total) mg/l	1.51		1.02	0.99	1.22	1.34
Chloride (dissolved) mg/l	22		17	19	23	29
Nitrogen as NH_3 mg/l	0.025		0.025	0.025	0.05	0.025
Nitrogen as NO_3 mg/l	0.12		0.39	0.23	0.48	0.88
Nitrogen as NO_2 mg/l	*0.005*		*0.005*	*0.005*	*0.005*	0.01
Silica (dissolved) mg/l	3.4		7.8	3.9	7.1	3.5
Silica (total) mg/l	13		43	7.6	25	4.7
Sulfate (dissolved) mg/l	420		240	240	280	330

Note: *Italics* indicate “below detection”

Turbidity Monitoring

Turbidity equipment is installed at the USGS gage site at Shiprock. The OBS-3 turbidity probe measures the optical properties of the water by emitting an infrared beam of light and measuring the backscatter. The sediment concentration and particle size distributions affect the back scatter. The probes are calibrated to read between 0-4000 NTU's (Nephelometric Turbidity Unit). The turbidity data collected for water year 2004 are shown plotted with USGS gage flow in Figure 3.16.

The turbidity equipment is used to continuously monitor sediment producing events. These events can result in large inflows of sediment that can fill open interstitial space in cobble bars and collect in backwaters, diminishing habitat quality. By monitoring these events, reservoir operations the next year may be modified to provide flushing flows in an attempt to flush the sediment through the system. These sediment producing events have been defined as storm event days. The definition of a storm event day is flow based. The following algorithm is used to determine Storm Event Days.

The storm event day calculation for Bluff is shown below. The subscripted numbers are day indicators. A 0 represents day 0 (today), -1 represents the previous day (yesterday), +1 represents the following day (tomorrow).

$\text{Gain}_0 = \text{Bluff}_0 - \text{Animas}_{-1} - \text{Archuleta}_{-2}$

If [$\text{Gain}_0 - \text{AverageGain}_{(-2, -1, 0, 1, 2)} > 150$ cfs] then
　　If [$\text{Bluff}_0 - \text{AverageBluff}_{(-2, -1, 0, 1, 2)} > 150$ cfs] then
　　　　　If [$Gain_0 - AverageGain_{(-2, -1, 0, 1, 2)} > 3000$ cfs] then
　　Storm Event Day Flag = 2
　　　　　else
　　　　　Storm Event Day Flag =1
　　　　　End if
　　　　else
　　　　　　Storm Event Day Flag = 0
　　　　End if
　　else
　　　　Storm Event Day Flag = 0
　End if

Where,
Gain_0 = The flow gain in cfs between Archuleta and Bluff.
Bluff_0 = The flow at Bluff today
Animas_{-1} = The Animas contribution to the San Juan in cfs yesterday.
Archuleta_{-2} = The flow at Archuleta two days ago in cfs.
$\text{AverageGain}_{(-2, -1, 0, 1, 2)}$ = The average gain over a 5-day period.
$\text{AverageBluff}_{(-2, -1, 0, 1, 2)}$ = The average flow at Bluff over a 5-day period.

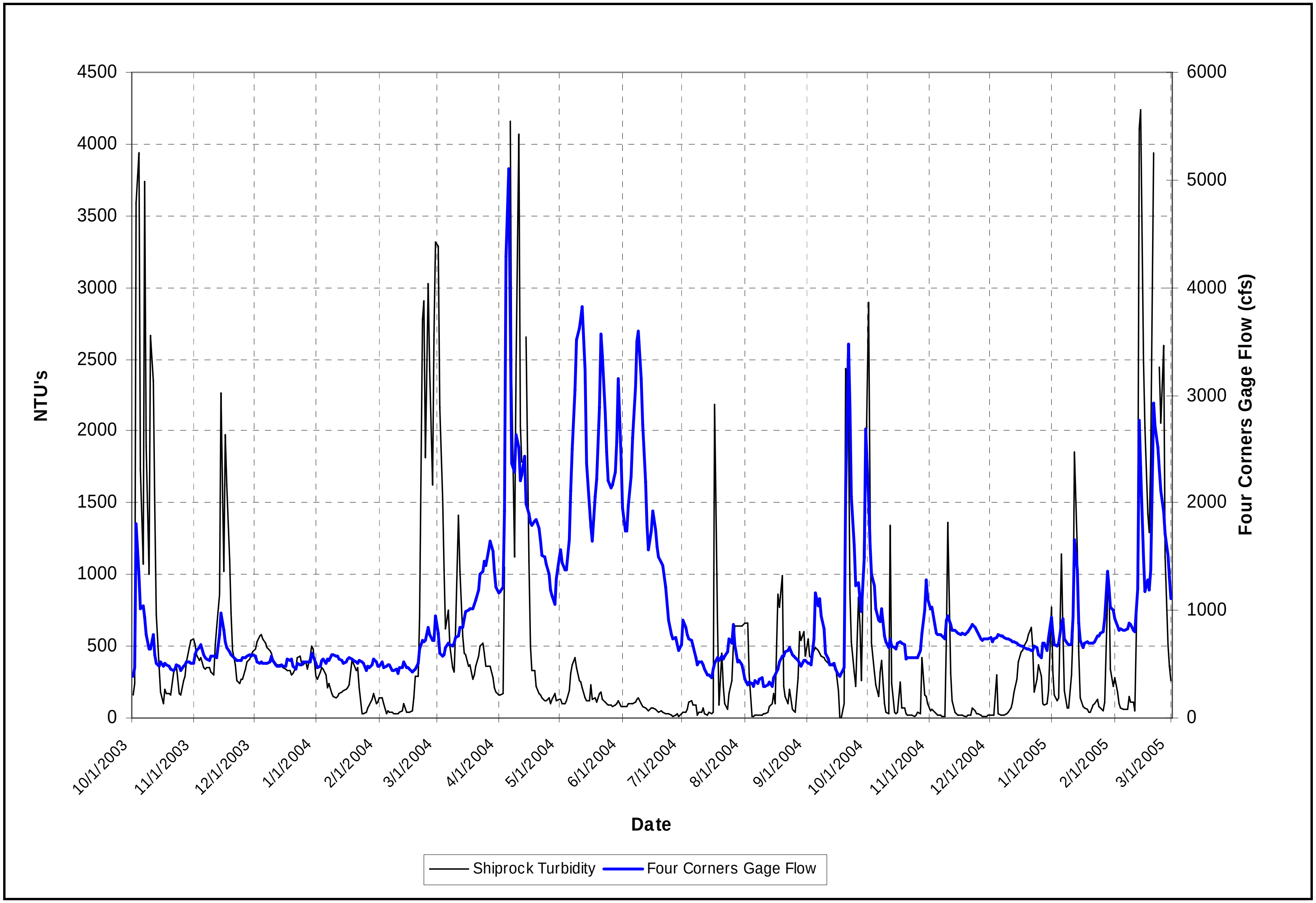

Figure 4.4. Shiprock Turbidity Data and Four Corners Gage Flow

The above algorithm may be described as follows: The gain in flow between Bluff and Archuleta is determined after subtracting the Animas contribution. All other tributaries are ignored. The flow of the Animas is lagged one day and the flow at Archuleta is lagged two days. If this average gain is more than 150 cfs than the 5-day average and the average flow at Bluff is more than 150 cfs greater than the 5-day average, the day is flagged as a storm event day. If the Gain is greater than 3,000 cfs, the day is given extra weight and counted as two days. The "End if" statements in the algorithm are used to separate if-then blocks. A perturbating year is determined by summing the storm event days between July 25 and the end of February. If the number of storm event days is greater than 12 then the year is flagged as a perturbating year and additional flushing releases from Navajo may be necessary the following season.

In 1999, turbidity data were correlated to the sediment event days calculated by the flow method described above. This analysis determined that using 2600 NTU's as the limit to define a sediment event day was a good approximation. This analysis has been conducted each year since 1999 using the Shiprock turbidity data. The results are summarized in Table 3.5. The year designation is the ending year of the data set. For example, 2000 is from July 25, 1999 to February 29, 2000. The 2000 data would be used to determine the perturbation condition between the 1999 and the 2000 runoff season and the desired release for 2000.

The correlation between days greater than 2600 NTU's and flow based sediment event days correlate reasonably well until 2005. Figure 4.5 shows a plot of the relationship between the two calculations. For every year except 2005, the turbidity based method predicted more sediment days than the flow based method, although the determination of a perturbated year would have only been different in 2002. Using all the data through 2004 suggests that using a turbidity threshold of 3,000 NTU's would improve the agreement between the two methods, but makes the relationship worse in 2005. Changing the threshold value would not have improved the accuracy of predicting perturbating years, so no change is recommended.

Table 4.24 Flow Based Sediment Event Days and Turbidity Based Sediment Days

Year	Days > 2600 NTU's	Flow Based Sediment Event Days	Concurrent Days*
2000	16	14	8
2001	6	4	4
2002	13	6	5
2003	17	12	7
2004	22	14	8
2005	6	22	6

* Concurrent or within 1-day

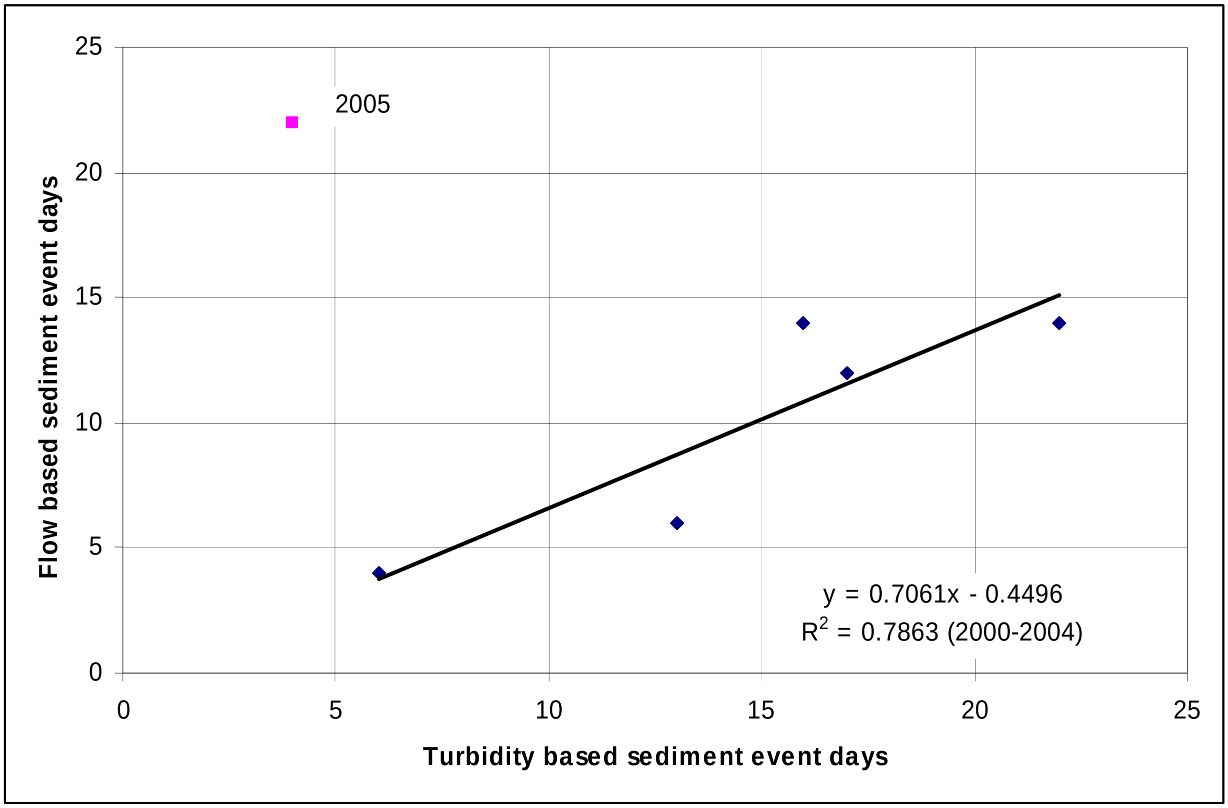

Figure 4.5. Sediment Event Day Calculation Comparison using the Turbidity and Flow Methods for 2000 through 2005

The marked difference in relationship for 2005 can be partially explained by the nature of the runoff events since July 25, 2004. Most years accumulate most of the sediment event days in the fall during the normal monsoon season. For the 2004-2005 season, most of the flow based event days came during the winter from mid-November through February. Further, more of the events were created by inflow below Shiprock than in previous years. It appears that there was truly less sediment generated by the events this year than in other years due to the timing and nature of the storm, but it is also likely that using Shiprock as the measurement point is not adequate to predict sediment events in the system. The original plan to have a turbidity meter at Shiprock and at Montezuma Creek or some other lower location is advisable.

Since the collection of turbidity data is no longer funded by the program, future predictions of perturbation must be made based on flow or observation of habitat. It appears that the flow based perturbation estimate agrees sufficiently well for most conditions that it will be an adequate estimator of perturbation. In years when most of the peak flow events are winter events, it may over-estimate sediment events. If turbidity data are deemed necessary in the future, a minimum of two stations should be established.

CHAPTER 5: HABITAT

HABITAT QUANTITY

Habitat quantity was determined using airborne videography as previously described by Bliesner and Lamarra (1999) and established as part of the Long Range Monitoring Program. Habitat types mapped can be seen in Table 5.1 with habitat categories summarized into seven general categories. In 2003, mapping between RM 2 and RM 180 occurred between October 20th and October 24th. Flows during the 2003 habitat mapping ranged between 340 and 941 cfs. In 2002, mapping occurred between July 28th and August 4th. Flows during the 2002 habitat mapping ranged between 329 and 842 cfs. The 2002 data have been previously described and are shown here as a comparison.

In 2002 and 2003, the sequence of dominant to subdominant habitat types based upon the amount of surface area between RM 2 to RM 180 had exactly the same distribution. These distributions can be seen in Figure 5.1. Run habitats for both 2002 and 2003 had the most surface area with 82% of the total wetted area (TWA) of the San Juan River in 2002 and 80.5% of TWA in 2003. Riffles had the second largest surface area (9% in 2002 and 11% in 2003), followed by shoals (6.4% in 2002 and 4.8% in 2003) and slackwaters (1.6% in 2002 and 2.3% in 2003). Backwaters made up only 0.17% of the surface area of habitats in 2002 and 0.13% of the surface area in 2003.

The spatial distribution of these same general categories can be seen in Figures 5.2 and 5.3 for 2002 and 2003. Figure 5.4 shows a more detailed spatial distribution of the subdominant categories in 2003 excluding the run type habitats.

Table 5.1. Seven General Categories Of Habitat Types On The San Juan River

LOW VELOCITY TYPES	RUN TYPES	RIFFLE TYPES	BACK-WATER TYPES	SHOAL TYPES	SLACK-WATER TYPES	VEGETATION ASSOCIATED HABITAT TYPES
pool	shoal/run	riffle	backwater	sand shoal	slackwater	overhanging vegetation
debris pool	run	shore riffle	backwater pool	cobble shoal	pocket water	Inundated vegetation
rootwad pool	scour run	riffle chute	embayment			
eddy	shore run	shoal/riffle				
edge pool	undercut run	chute				
riffle eddy	run/riffle	rapid				

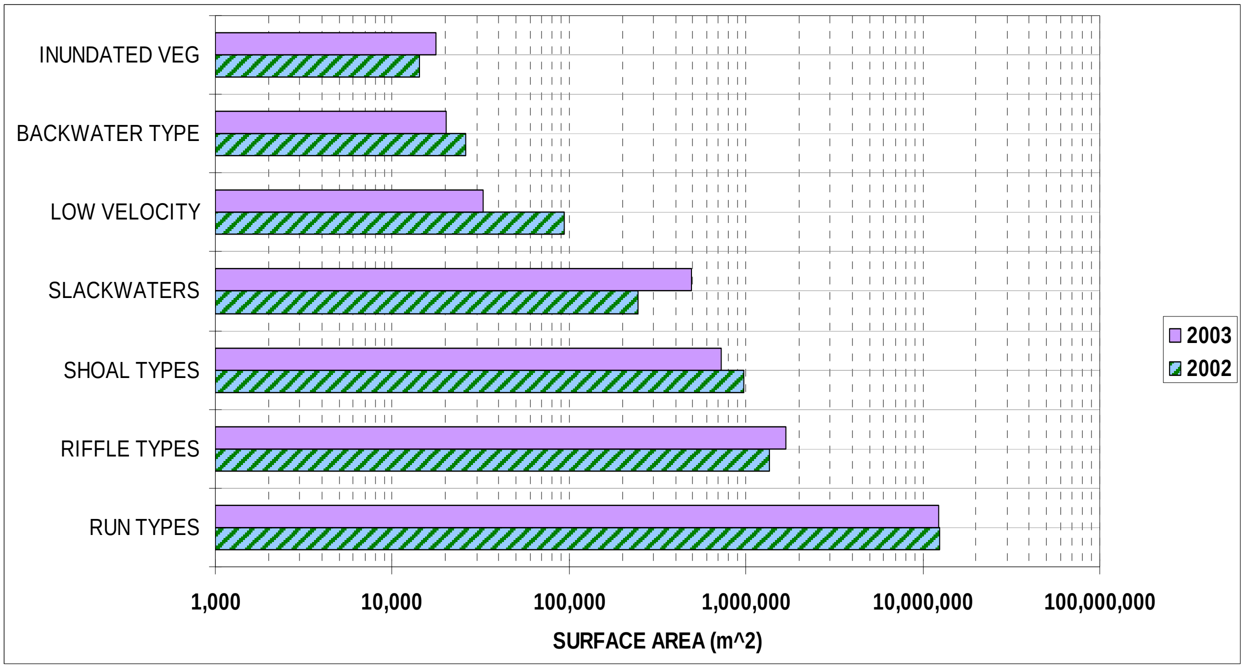

Figure 5.1. A Comparison of the Amount of Surface Areas by General Habitat Type in the San Juan River (RM2 to RM180) for 2002 and 2003

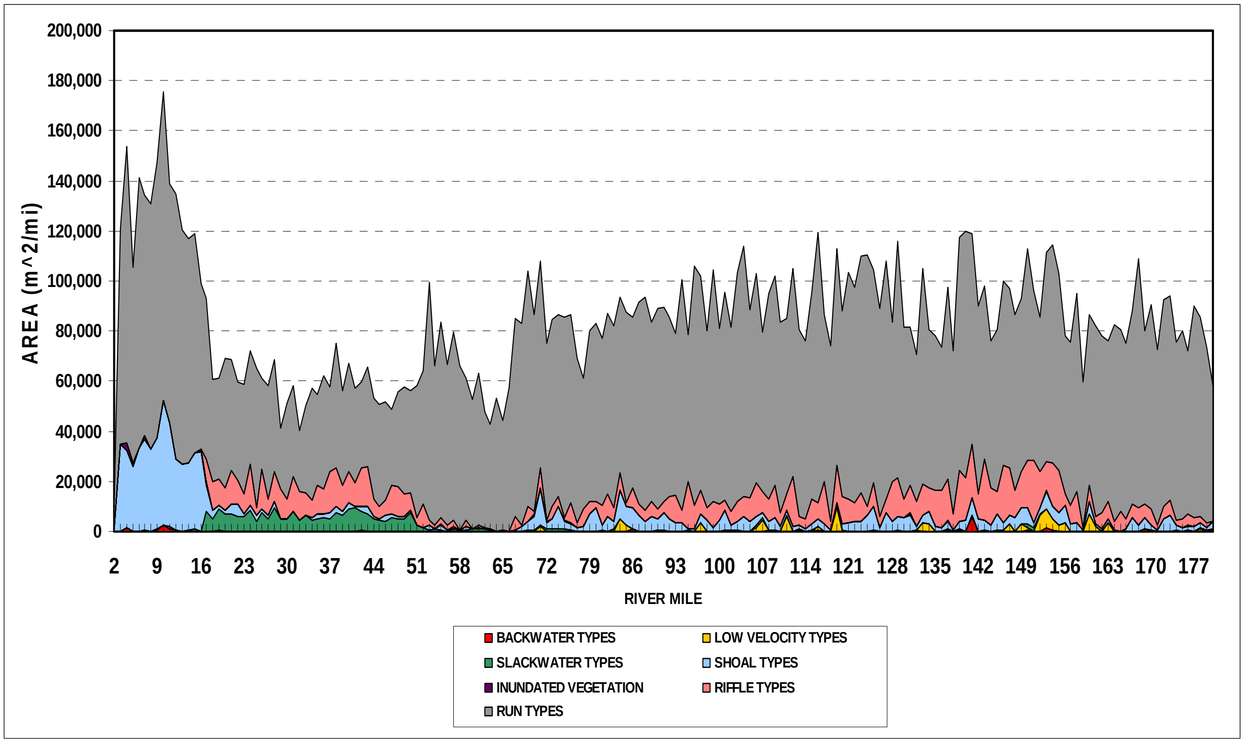

Figure 5.2. The Spatial Distribution of Major Habitat Types in the San Juan River for 2002

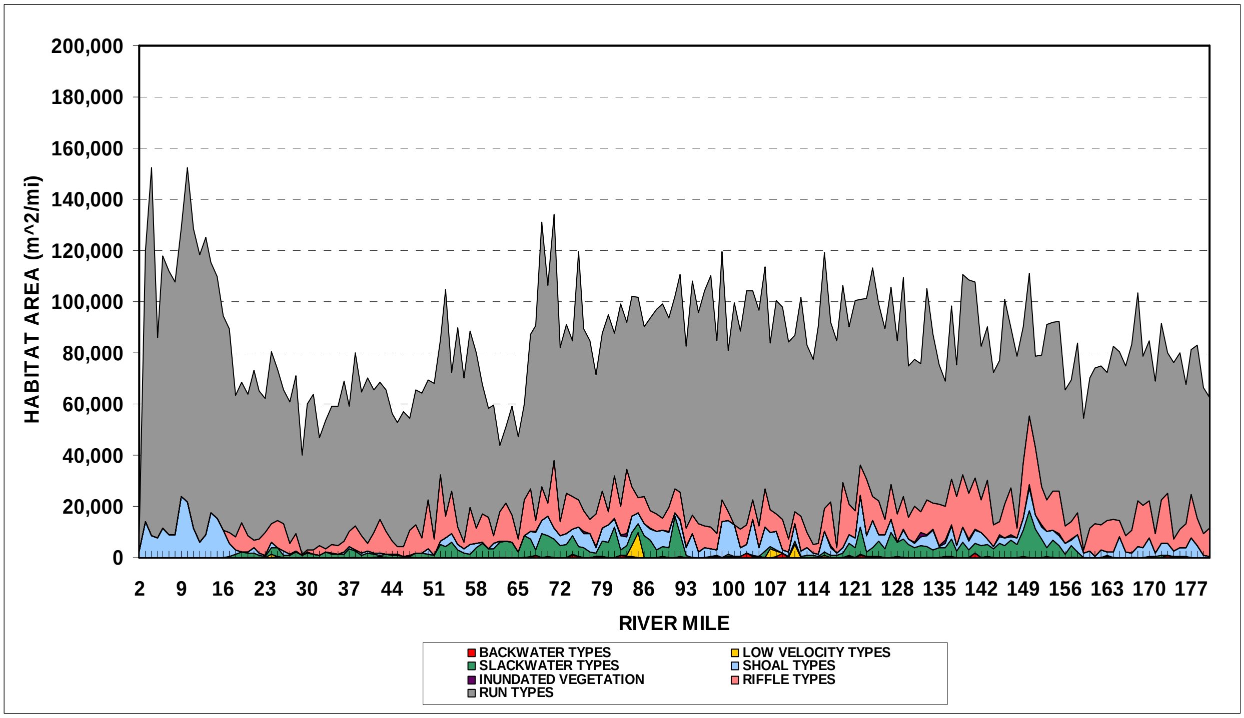

Figure 5.3. The Spatial Distribution of Major Habitat Types in the San Juan River in 2003

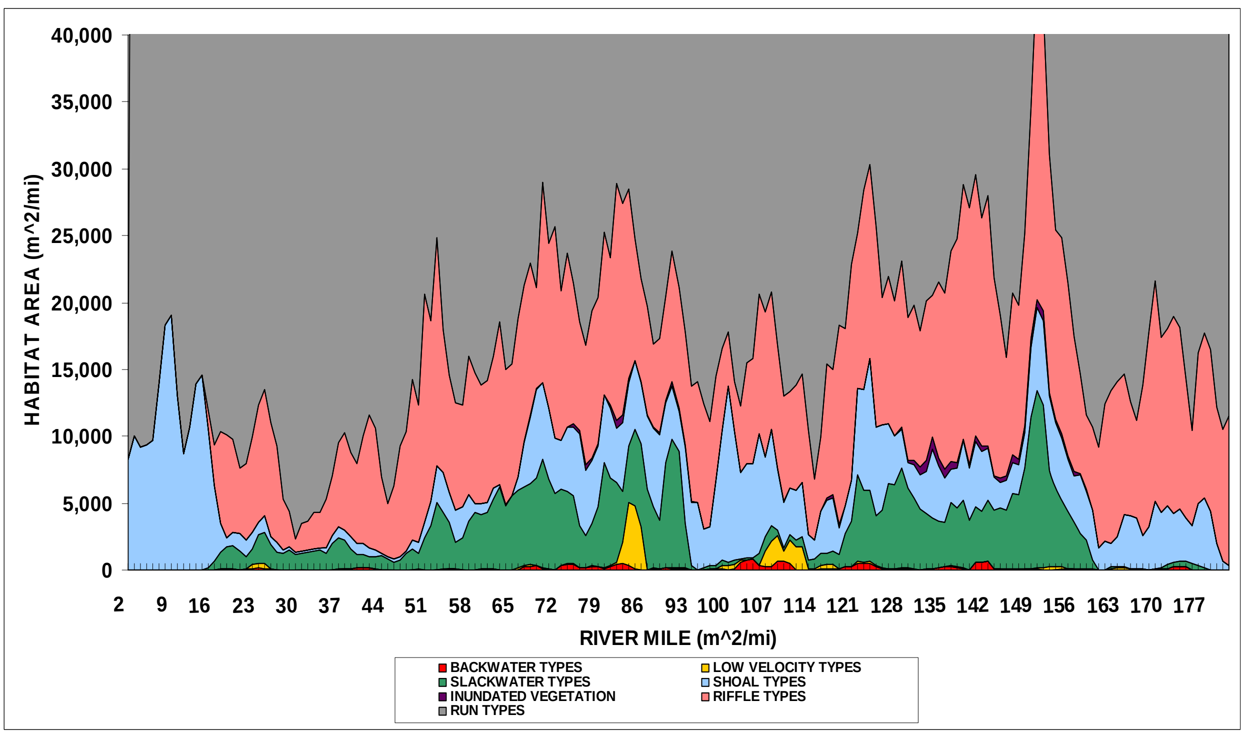

Figure 5.4. The Detailed Spatial Distribution of the Major Habitat Types in the San Juan River During 2003

Riffle habitat is the most dominant habitat in the San Juan River when runs are excluded. This habitat type contains mostly cobble substrate in all river miles except the bottom 14 miles where the river substrate is exclusively sand.

Excluding run habitat, shoals are the second most dense habitat type and are also found throughout the river system but are a major habitat feature in the lower 19 miles of the San Juan River where it is influenced by the backwater effects of Lake Powell and between Rm 98 and 115 where the gradient of the river is low. Slackwater habitats are mostly found between RM 20 and RM 160 and are associated with riffle complexes.

In 2003, low velocity and backwater habitats were distributed throughout the river in low numbers, but were in highest magnitude in Reaches 3 and 4, between RM 68 and RM 130. This was in contrast to 2002, where the highest amount of backwater habitat (10,450 m^2) was found in Reach 5. In 2003 the surface area of backwaters in Reach 5 was only 3,380 m^2, while in Reaches 3 and 4 the area was 8,360 m^2 and 5,300 m^2, respectively.

Backwater habitats represent an important component of the life cycle of many of the native species found in the San Juan River. Because of this fact, the temporal trend in the magnitude of surface area of this habitat type is used as a monitoring indicator to assess influences of flows on habitat quantity. As noted in previous investigations (Bliesner and Lamarra 1999), the magnitude of backwater habitats are influenced by their location in the river, flow magnitude, and summer storm events. A summary and breakdown by Reach of the total backwater areas for 2003 (20,290 m^2) compared to previous years with similar flows are shown in Figure 5.5 for surface area and in Figure 5.6 for the number of backwaters. The data indicated that after reaching a maximum surface area of 143,000 m^2 (373 backwaters) between RM 2 and RM 180 in 1995, there has been a decrease down to 20,290 m^2 (53 backwaters) in the summer of 2003. The loss of almost 120,000 m^2, or 320 backwaters, primarily occurred in reaches 3, 4 and 5.

Even though all these mappings occurred at low flow, there was still a relatively large range in flow (450 to 1,200 cfs). To better determine the change with time, the values were normalized by regressing habitat area against flow at mapping and then plotting the residuals of these relationships (adjusted to be all positive) with time. Only habitat runs with flows under 1,200 cfs and for which all reaches were sampled are included. This relationship is shown in Figure 5.7. The relationship is significant with a downward trend, showing loss of habitat with time. When corrected for flow, the trend from October 1996 through October 2003 is nearly flat. The very low numbers in the last two years reflect the low flow at mapping as well as loss with time.

HABITAT QUALITY

The depths of backwaters is an important attribute relative to use by native endangered species. In the San Juan River system, backwater depths are affected by sediment laden summer storms. Bed sediment depths in backwaters have been periodically measured since August 1995. In 2003, backwater habitat quality was discontinued because of the difficulty of measuring the same backwater over time. Because the San Juan River has been losing backwaters as noted the previous discussion, the measurements collected over the last three years proved ineffective as a monitoring parameter.

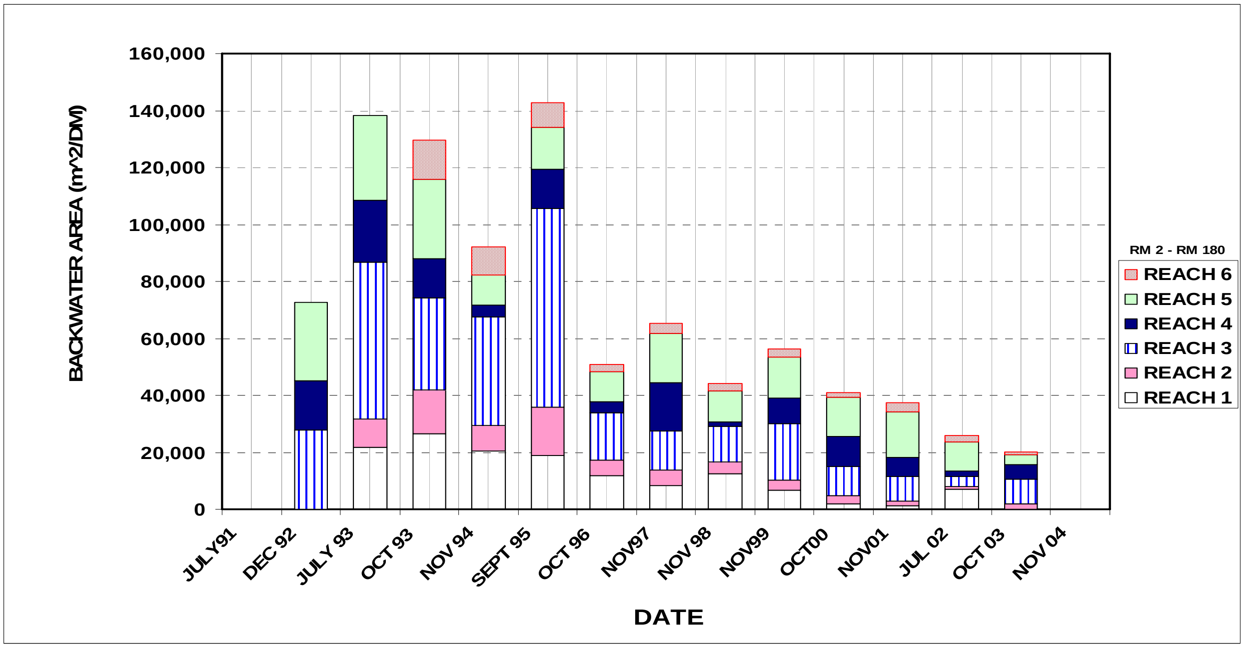

Figure 5.5. **A Comparison of the Backwater Surface Areas Mapped at Approximately the Same Flow in the San Juan River Since 1991 (450-1200 cfs)**[1]

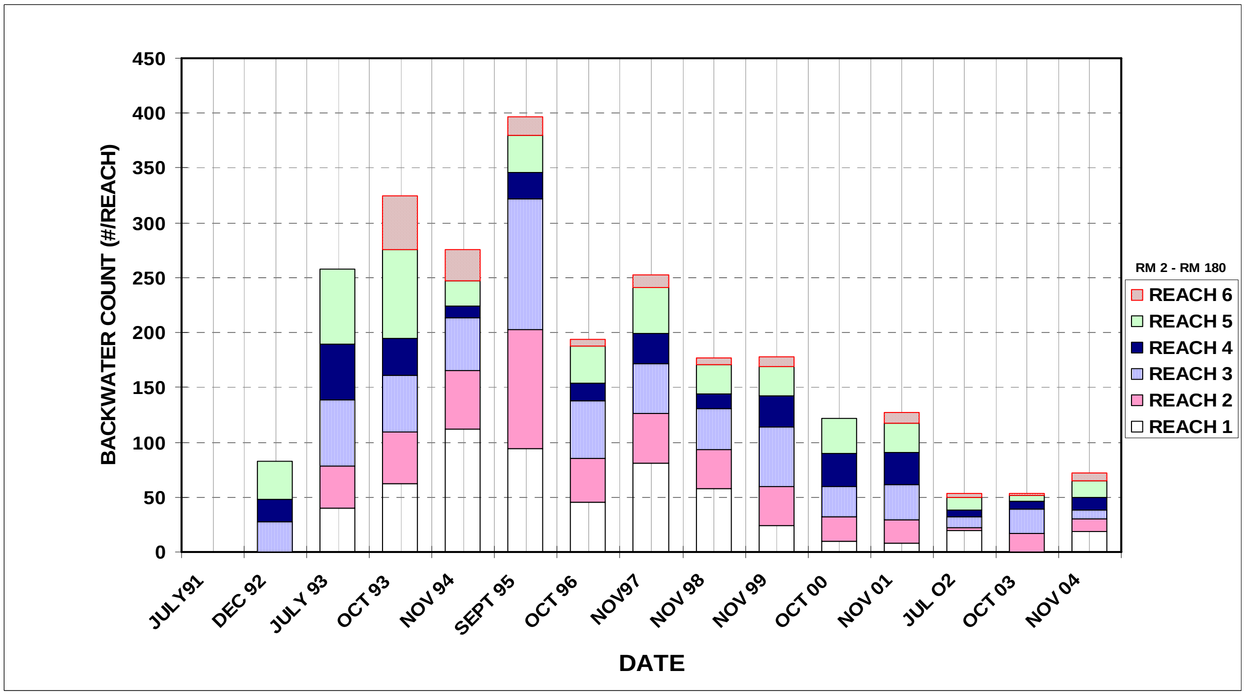

Figure 5.6. **A Comparison of the Number of Backwaters in the San Juan River Mapped at Approximately the Same Flow Since 1991 (450-1200 cfs).** [1]

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[1] Reach 1 not surveyed in December 92. Reach 6 not surveyed in December 92 or July 93.

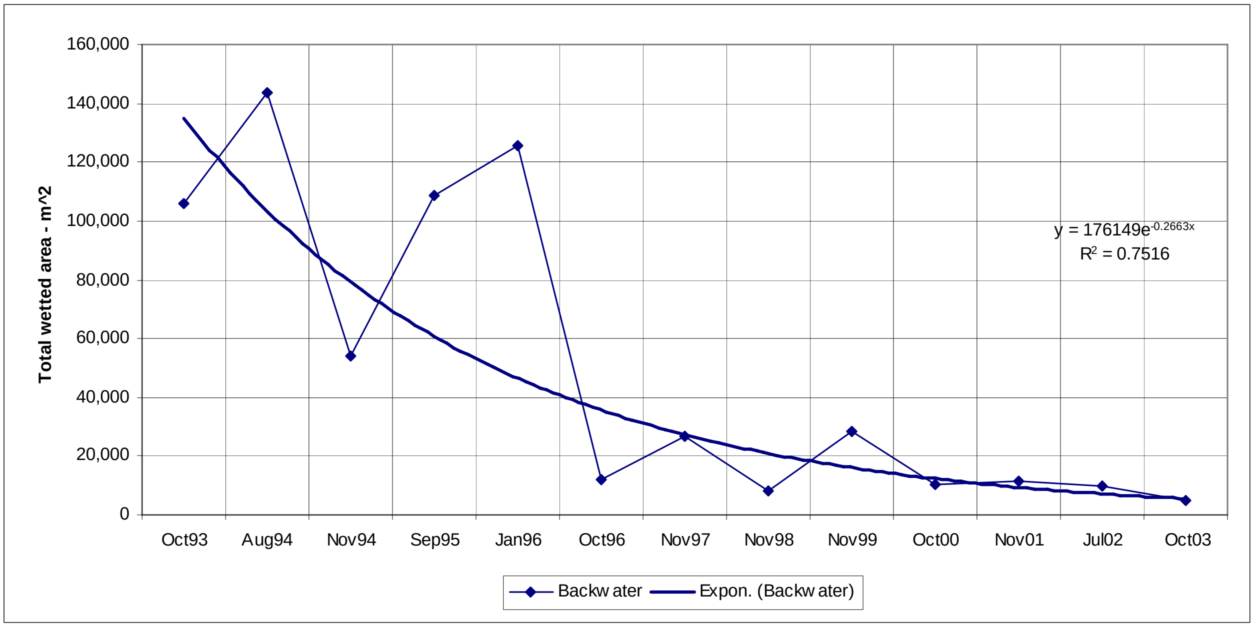

Figure 5.7. Backwater Area Residual (Transposed to Eliminate Negative Values) from Habitat-Flow Regression

CHAPTER 6: RAZORBACK SUCKER SPAWNING BAR ANALYSIS

SPAWNING BAR ANAYLSIS

In the spring of 2004, Dale Ryden (USFWS) discovered a potential spawning site for razorback suckers at RM 154.4. Immediately after notification of the discovery, a geomorphic characterization of the site was undertaken. This characterization, which included the determination of particle size and the depth to embeddedness was repeated after runoff. The second survey was done in order to determine if physical substrate features changed due to spring runoff. This becomes important because if the physical feature changes due to spring run off, future characterizations of potential sites must therefore be done prior to runoff.

The initial survey was conducted on May 5, 2004 prior to spring runoff. Two individual areas were sampled (denoted as sites “A” and “B” in Figure 6.1). Site “B” was the actual bar where Ryden (2004) collected a ripe female razorback sucker. In this first survey, a second bar was also sampled. This second site (denoted as “A” in Figure 6.1) was immediately upstream of the potential spawning bar and did not yield spawning razorbacks when sampled by Ryden (2004). The second survey occurred on July 13, 2004 and consisted of sampling the physical features at the two previously mentioned riffles as well as two additional adjacent sites (denoted as “C” and “D” in Figure 6.1).

The physical data collected on the potential razorback sucker spawning bar compared to adjacent similar sites not used by razorbacks, indicated differences in the substrate D50, depth to the embedded layer (DTE), and bed particle distribution. In addition there were significant changes in the bed composition before and after spring runoff for both the sites sampled. The results of the pre and post runoff sampling can be seen in Figures 6.2 through 6.6.

The D_{50} particle size (Figure 6.2) in the potential spawning bar was calculated to be 3.7 cm before and after spring runoff. The D_{50} of the adjacent riffle was initially 11.0 cm and measured 8.9 cm after runoff, a difference likely due as much to sampling method as to change in the bar. The distributions of the bed particles can be seen in Figure 6.3.

The major changes in the bed material corresponded to the amount of interstial space and the depth to the embedded layer. Several parameters indicated both initial differences between the two sites and changes in the sites over the runoff time period. Inspection of Figure 6.4 shows the differences in the depth to the embedded layer for each site before and after spring runoff. At sites “A”, the riffle adjacent to the suspected spawning bar, the DTE did not significantly change. This riffle averaged 15.2 cm before runoff and 15.0 cm after runoff. However, an inspection of the DTE data collected at site “B”, the suspected spawning bar, did show significant differences over time. Prior to runoff, site “B” had an average DTE of 9.9 cm which was reduced to 4.0 cm.

The DTE distance was also expressed as a ratio to the mean rock diameter (DTE/D_{50}). This relative index is shown in Figure 6.5. Site "B" had overall higher relative depths of void space compared to any of the sites investigated, averaging 2.7 prior to runoff and 1.1 post runoff. The main reason for the reduction in the (DTE/D_{50}) index was the intrusion of sand or fine sediments into the bars. This can be seen in Figure 6.6 which documents the per cent of observations (during the Wolman pebble counts) where sand and fine sediments were encountered. Prior to runoff, there were no fines observed. However, after runoff site "A" had 6% and site "B" had 8% of the observations as fine materials. This sediment reduced the interstial void space in the bed of both riffles sampled.

Figure 6-1. The Location of the Potential Razorback Sucker Spawning Bar in the San Juan River in 2004.

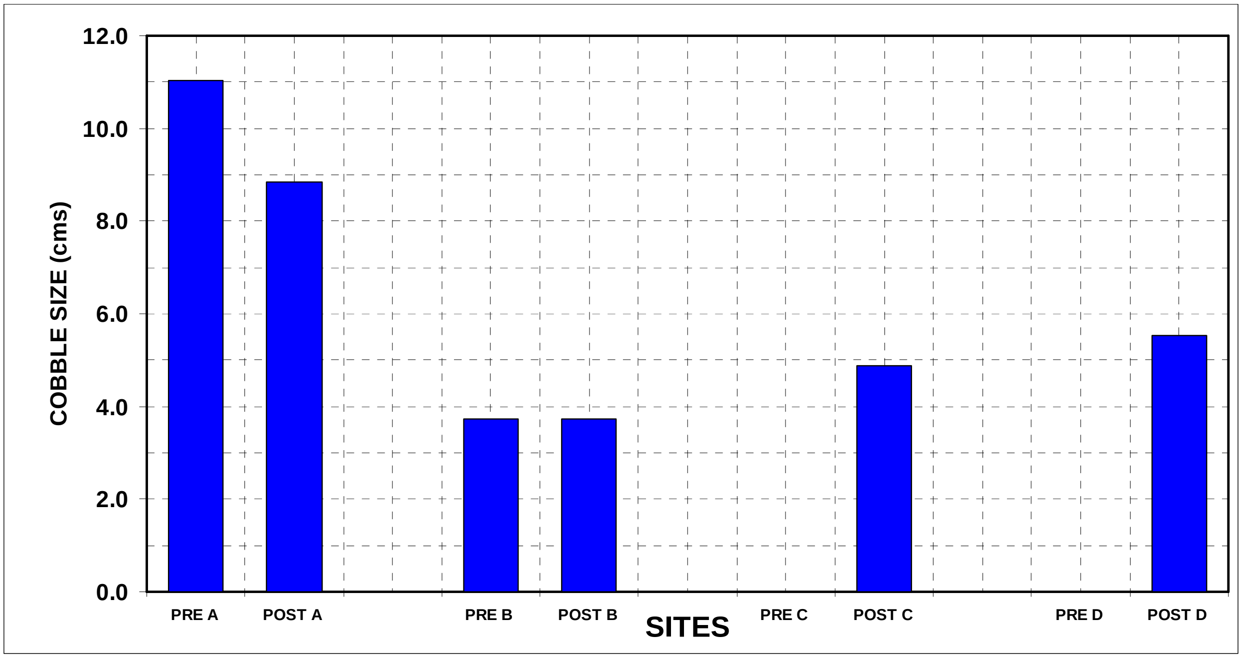

Figure 6.2. The Average Substrate Size in Four Riffles at RM 154.4 in the San Juan River in 2004

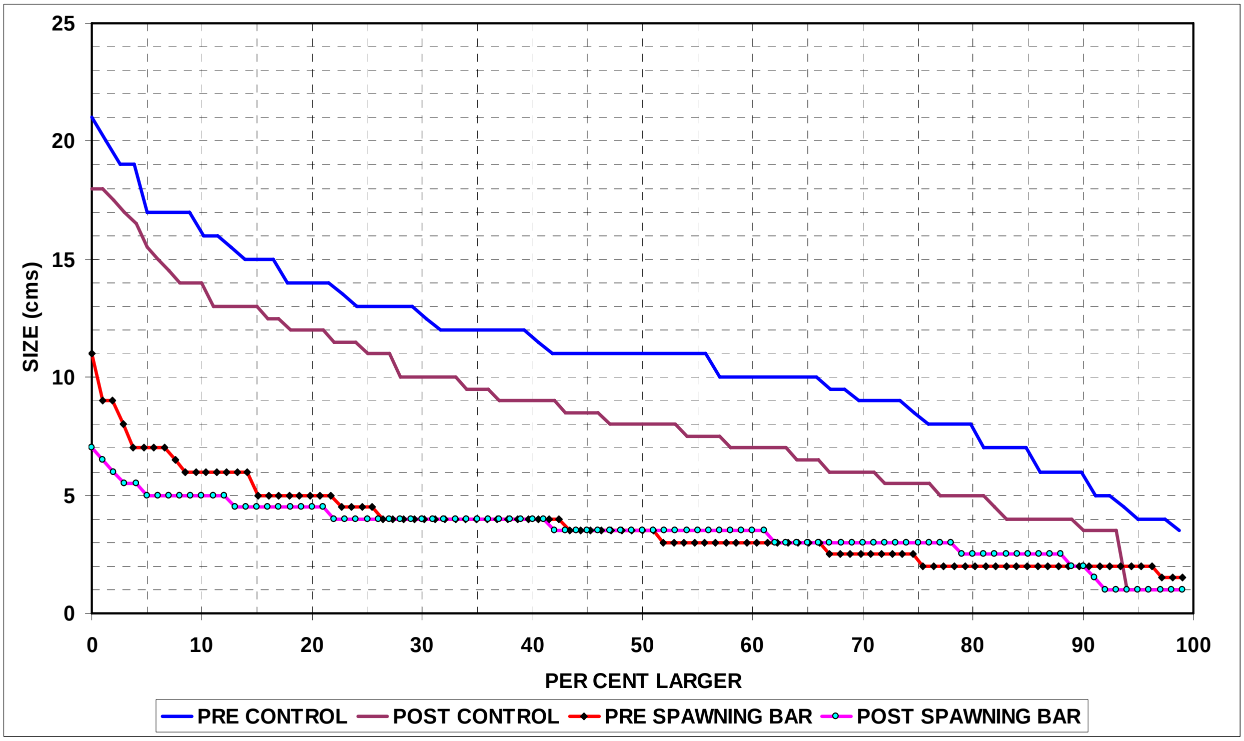

Figure 6.3. The Size Distributions of Substrate Materials at Two Riffles at RM 154.4 in the San Juan River in 2004

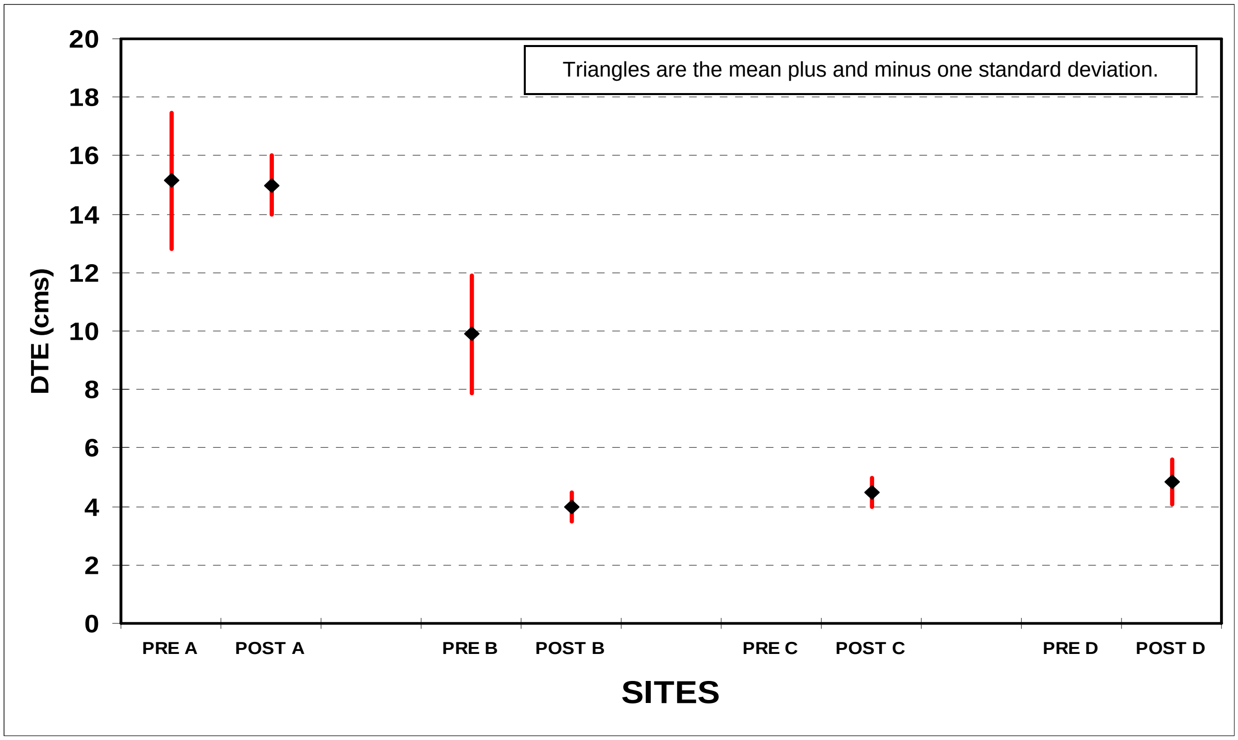

Figure 6.4. **The Average Depth to the Embedded Layer(DTE) at Four Riffles near RM 154.4 in the San Juan River.**

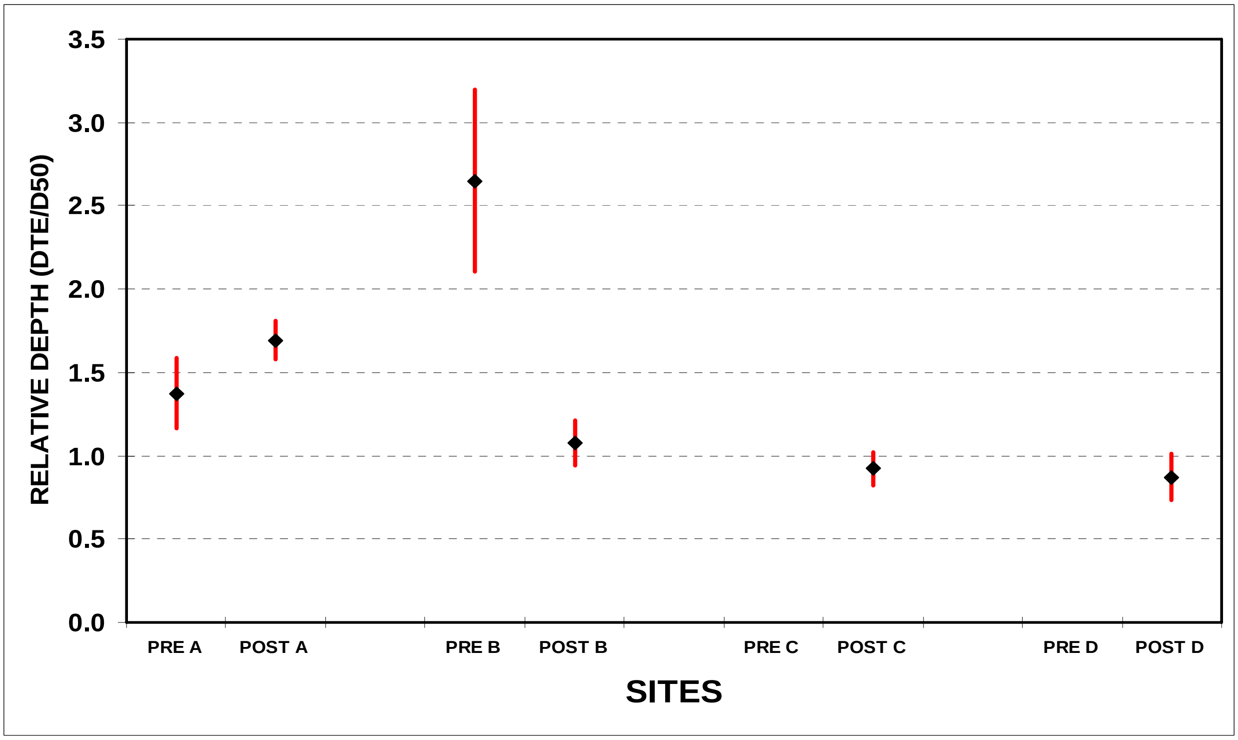

Figure 6.5. **The Relative Depth (DTE/D50) for Four Riffles at RM 154.4 in the San Juan River During 2004**

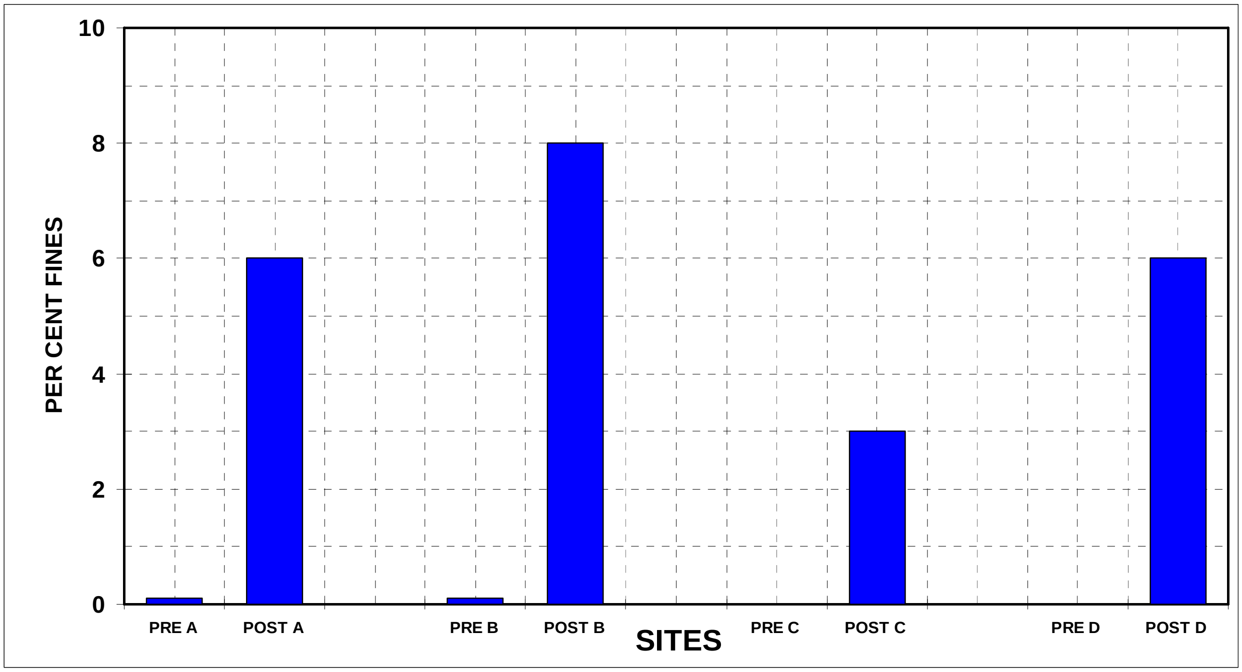

Figure 6.6. The Percent of the Observations During the Wolman Pebble Counts Where Fine Materials were Encountered on the Sites Investigated in the San Juan River During 2004

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