MONITORING OF THE LITTLE SNAKE RIVER AND TRIBUTARIES

YEAR 5 – FINAL REPORT

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Monitoring of the Little Snake River and Tributaries

Year 5 – Final Report

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TABLE OF CONTENTS

ADDITIONAL APPENDICES (included on CD ROM data supplement)

- *Continuous Temperatures*
- *Continuous Flow Records*
- *Photo Points*
- *Monitoring Location Descriptions*
- *Erosion Pins*
- *Crest Gages*
- *Aggradation / Degradation*
- *Cross Section Surveys*
- *Pebble Counts*
- *Benthic Macroinvertebrates*

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

An extensive restoration plan for approximately 14.4 miles of the Little Snake River and its tributaries was implemented by Wildland Hydrology of Pagosa Springs, Colorado, in the Summer and Fall of 2000. A Clean Water Act §404 permit to carry out the work was issued by the U.S. Army Corps of Engineers (USACE), Sacramento District. Colorado State University (CSU) is pleased to report results and accomplishments from the fifth and final year of the five-year monitoring effort to assess the results of the stream-restoration project on the Little Snake River and tributaries in Routt County, Colorado.

PROJECT LOCATION

The project is located in the Upper Yampa River Basin in Northwestern Colorado on the Little Snake River and tributaries. The specific project location is within Township 11 and 12 N, R 86 W, in Routt County on the property of Three Forks Ranch Corporation, located at County Road 129 near Savery, Wyoming.

OBJECTIVES

In accordance with the §404 permit, CSU is fulfilling the following monitoring objectives:

- For a period of five years after construction, monitor the effectiveness and success of the restoration project in meeting the objectives of stream stability and fish habitat improvement;

- Identify any necessary corrective actions and report these to Porzak, Browning, and Bushong LLP (PBB) and the permittee;

- Provide annual letter reports describing the monitoring effort and results for PBB and submittal to the USACE, Sacramento District;

- Make technical recommendations to the permittee should remedial action be required; and

- Provide a comprehensive report on the effectiveness and success of the project in achieving the intended objectives at the end of the five-year monitoring effort.

SUMMARY OF 2004-2005 MONITORING RESULTS

The Little Snake River at Slater, Colorado, yielded mean daily peak discharges near the 51st percentile of the period of record in 2005. Since the beginning of monitoring, the 2005 peak mean daily discharge was the second highest, and lower than the 2003 peak by 50 cubic feet per second (cfs). However, the hydrograph of the 2005 water year indicates that runoff *duration and* *volume* in 2005 were greater than those of 2003, the previous high-water year during the monitoring period. The nearby Whiskey Park Snow Telemetry (SNOTEL) site reported 3.4 inches less precipitation during the 2005 water year than the 2003 water year. In 2005, the area received more early season snowfall (prior to March) and more late-spring and early summer precipitation (May and June). However, the 2003 water year yielded more spring rain and snow (March and April). Average daily air temperatures in 2005 remained lower than the 2003 temperatures through most of the runoff period, resulting in a longer duration of runoff. In contrast to the U.S. Geological Survey (USGS) data from the Slater gage, crest gages installed throughout the ranch recorded a higher peak discharge in 2005 than in 2003 at the three flow-meter locations along the South Fork and at the Middle Fork bridge. The North Fork crest gage recorded a higher peak in 2003.

The restored reaches throughout the project site remained stable during 2005 with no system-wide instability or large-scale channel adjustments. The majority of the structures continued to perform as intended, despite relatively long durations of high flows and shear stresses. After five years of observation, monitoring results indicate that the constructed project continues to successfully meet standard definitions of stream and river stability (Mackin 1948, Schumm 1977, Leopold and Bull 1979, Rosgen 1996, Biedenharn *et al*. 1997). As in other years, some channel adjustments inevitably occurred in 2005; however, these adjustments are not thought to exceed the range of variability observed in comparable, least disturbed natural systems of the region, particularly during system evolution to a new equilibrium state.

Because streams and rivers dynamically adjust to the flows of water and sediment delivered from the upstream watershed, year-to-year variation is an essential, defining characteristic of natural fluvial systems. Even with the high flows of 2005, no major or widespread changes to the project site occurred in 2005. Adjustments in 2005 were primarily limited to further sealing of structures, local pool scour and infilling at structures resulting in net aggradation on the South Fork, and minor localized bank erosion. However, these changes are within a reasonably expected range of variability and are typical of successful stream-restoration projects of this scale. At the rates of change observed, no remedial action is recommended at this time. Of approximately 580 structures, the high flows necessitated repair of two structures along the South Fork and one structure along the Middle Fork. Furthermore, one additional structure was constructed by Wildland Hydrology at the downstream end of the project (see Appendix A).

Point measurements of vertical and horizontal channel adjustments indicate that minor cross-sectional changes are ongoing due to sediment sorting and structure sealing. Similar to 2003 and 2004, locations established for vertical monitoring, located primarily a few meters upstream of structures, revealed a general trend of aggradation. Vertical adjustments at these sites appear to be smaller than adjustments in 2003 but greater than adjustments in 2004. A comparison of cross-section surveys from 2001 and 2004 also suggests a trend of aggradation as expected. Monitoring of horizontal stability revealed that localized bank erosion continued to occur over the year, with an average of 1.9 inches (± 1.7 inches standard deviation) erosion at nine targeted locations.

As described in previous annual reports, the restoration effort has clearly resulted in substantially more pool volume and deep-water habitat with improved potential for riparian shading, lower instream temperatures, and higher dissolved oxygen content. Scour by the high flows of 2005 maintained pool volume at a majority of the structures located throughout the project. These pools continue to adequately support the stocked trout population in each of the three major forks of the Little Snake and along the Main Stem of the river. Furthermore, there has been continuing development and re-establishment of riparian vegetation throughout the project due to streamside plantings and improved grazing practices.

In 2005, ambient temperatures and recorded stream temperatures at most locations in late summer were comparable to previous years. Fish were further protected from high water temperatures by the cold-water refugia provided by the deep pools created throughout the project. No substantial fish mortality was reported by Three Forks Ranch personnel who frequently observed the fish throughout the most critical summer period.

A CD ROM data supplement containing an organized set of monitoring data from the fifth year is provided with this report. The compiled data sets include cross-section surveys, pebble counts, crest gage measurements, vertical and horizontal stability measurements, continuous water temperatures, continuous flow data, and several hundred documented photographs.

SUMMARY OF 2005 MONITORING ACTIVITIES

The following monitoring tasks were completed in the fifth year of monitoring:

- We continuously recorded stage and velocity with data loggers at six sites on the project. Each logger records stage and velocity at one to three points at each site on the main stem and the three upstream forks of the Little Snake (three sites on the South Fork). Gaging stations use American Sigma, Inc. transducers to provide a continuous record that is correlated with the downstream USGS gaging station 09253000 located on the Little Snake River near Slater, Colorado. The American Sigma, Inc. instruments were provided at no cost to the project. The map in Figure 1 shows the location of flow loggers and temperature sensors throughout the project.

- Ongoing maintenance associated with the American Sigma, Inc. flow loggers included periodic cleaning, calibrating, and adjusting the pressure transducers and velocity probes.

- Crest gages were monitored at the six gaging locations to determine peak stage values. Maximum stage during snowmelt was recorded at each location except on the Main Stem where the crest gage was overtopped.

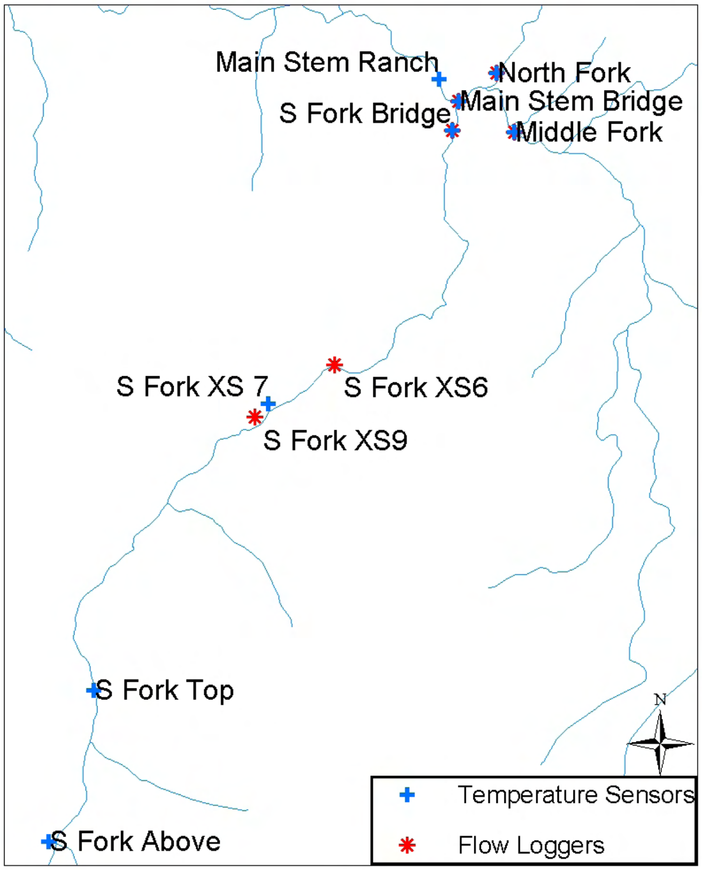


Figure 1: Map of flow logger and temperature sensor locations on the Little Snake.

- We re-visited the fifty-seven permanent photo points, located at 1,000-ft intervals throughout the entire project. Photographs were taken to document permanent photo-point locations, looking both upstream and downstream. The photographs from this and previous years were compiled to compare changes from year to year.

- We walked and visually assessed the entire length of the project. Locations of noteworthy morphologic adjustments were photographed and global positioning system (GPS) coordinates were recorded in order to assess future conditions at these locations. These sites are located at points where localized channel adjustments are occurring in various forms. These adjustments include locations with higher potential for bank erosion, structures where higher flows have begun to flank a structure, structures where the bed-material load has not completely filled gaps in structures, large woody debris deposits, locations where a point bar has expanded into the center of the channel and filled in structures, locations of concentrated overbank and return flow, shifts in the thalweg to the outside of bends, and locations with noteworthy riparian vegetation and healthy cut banks. These are not locations where ongoing maintenance is deemed necessary, but rather sites marked for future observation to ensure that adjustments continue to have only localized affects with no impact at larger spatial scales. Similar monitoring sites from 2002, 2003, and 2004 were revisited to assess current conditions.

- Additional photographs were taken to document features of interest at various locations and times during the year. Most of these photographs were geo-referenced with a GPS unit.

- Rates of bank erosion or accretion were measured at eight locations using rebar erosion pins driven into the stream banks. The erosion pins were revisited and assessed following the 2003, 2004, and 2005 peak flows.

- Vertical channel adjustments were monitored by taking measurements at each flow-meter site. These data are used to estimate aggradation or degradation, and to adjust flow-meter stage measurements.

- Hourly temperature data from July to September were measured at seven locations throughout the project and one location above the project on the South Fork.

- We applied the U.S. Environmental Protection Agency's *Rapid Bioassessment Protocols For Use in Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish* (Barbour *et al*. 1999) to perform a visual assessment of physical habitat quality.

- Pebble counts were conducted at forty-nine sites during the summer of 2004 following Wolman (1954) and Rosgen (1996) procedures to determine particle size distribution and substrate characteristics in a minimum of ten reaches in each of the following: Main Stem Little Snake, South Fork, North Fork, and Middle Fork. Seven pebble counts were performed in the Roaring Fork. Three of the original fifty-one locations were not sampled and one additional location was sampled downstream of the project site.

- Detailed cross-section surveys were completed in 2004 at twenty-five locations to assess changes in channel morphology and stability. All survey measurements of channel cross sections were recorded at a resolution of 0.01 ft.

Channel Stability Monitoring

Any restoration effort of the magnitude of the Three Forks Ranch project inherently involves post-construction adjustment of the channel. Monitoring channel stability in 2005 included: (1) assessing flow conditions using flow meters located throughout the project, (2) measuring vertical and horizontal channel adjustments through the use of fixed t-post and erosion pins, and (3) analyzing vegetation establishments through time series photographs.

2005 Flow Conditions

The 2005 water year yielded peak flows comparable to 2003, the previous high-water year since construction. A comparison of the mean daily peak discharge at the USGS gage (USGS gage 09253000) near Slater, Colorado, with the historic record indicates that peak discharge was just above the median peak in the 59-year period of record (50.8% non-exceedance probability). However, the hydrograph for the 2005 water year indicates that the volume and duration of runoff was greater than the 2003 water year (Figure 3). This increased volume and extended duration is partially attributed to more early winter snowfall and cooler temperatures in 2005 compared to 2003. Table 1 provides a summary of the estimated peak flows on each segment of the river.

Table 1: Estimated annual maximum mean daily discharge values since project construction.

Location	Maximum mean daily discharge (m^3/s)				
	2001	**2002**	**2003**	**2004**	**2005**
South Fork	6.0	2.4	4.5	1.6	6.7
Middle Fork	27.5	10.2	27.0	--**	24.8
North Fork	8.9	6.6	13.7	3.5	7.0
Main Stem	36.4	12.3*	40.7	12.8	40.4

*the North and Middle Forks peaked on different dates in 2002; thus the peak discharges of these segments do not sum to the peak discharge on the Main Stem.

**none of the three flow meters at the Middle Fork site properly functioned during peak runoff in 2004 and the data could be suspect for 2005 due to intermittent problems with this flow meter.

To verify the flow-meter data and to compare trends in peak flow at the USGS gage near Slater, Colorado, with trends occurring locally on the ranch, crest gages were installed at the beginning of the project to measure the maximum stage at or near the flow meters. The crest gages recorded a higher stage in 2005 than in 2003 at the three flow-meter sites along the South Fork and at the Middle Fork bridge. On the North Fork, the crest gage recorded a higher peak in 2003. The high flows in 2003 damaged the crest gage at the Main Stem bridge site and flows overtopped the gage in 2005.

Figure 2 depicts the results of year 2005 continuous flow monitoring. Flows in the Main Stem Little Snake River near the Ranch entrance are compared with the USGS gaging station (USGS gage 09253000) near Slater, Colorado, in Figure 3. Stage-discharge measurements collected in 2003 updated the rating curves used to determine discharge at each flow-meter site.

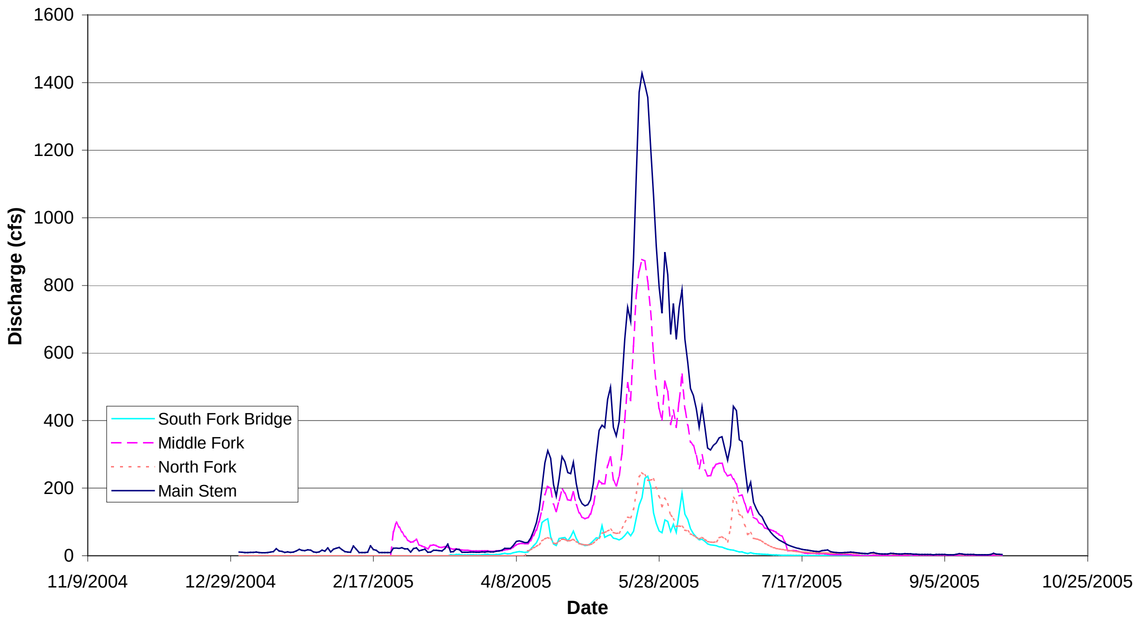


Figure 2: Little Snake River flows measured in 2005 at Three Forks Ranch.

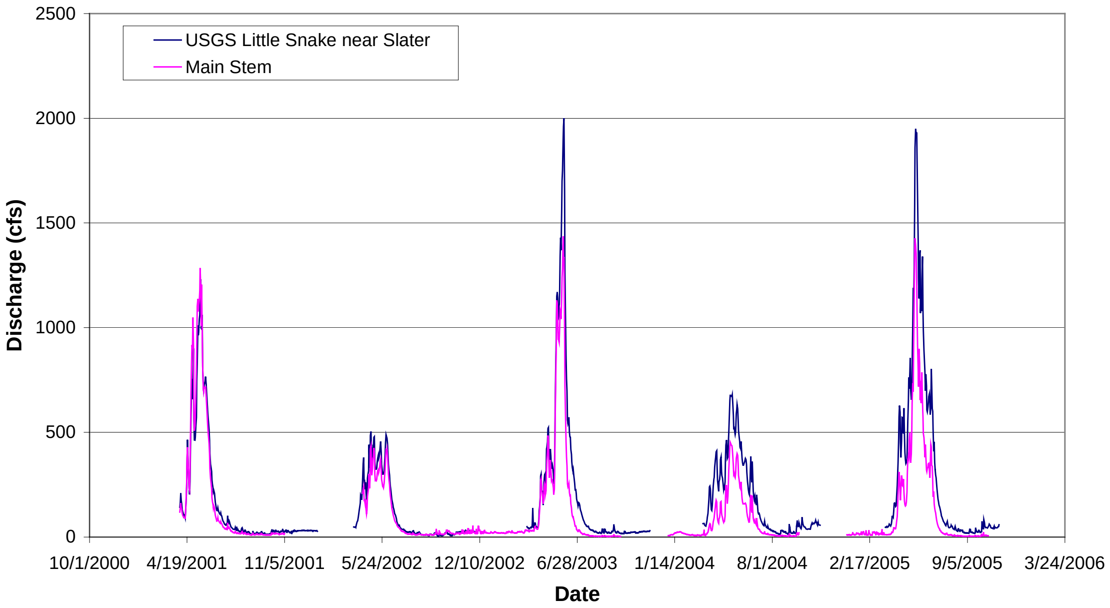


Figure 3: Main Stem mean daily flow record at CSU gages and mean daily flow at USGS gage 09253000 near Slater, Colorado, 2001 through 2005.

Figure 4 compares discharges measured at the Main Stem bridge flow-meter site with the USGS gage near Slater, Colorado and conveys the relative magnitude of flows over the project duration. The 2004 and 2005 flow-meter data are consistently lower than the USGS data through the runoff period as expected. However, differences in flow are likely too large to be realistic. This discrepancy is due to a combination of effects. First, the stage-discharge relationship was last surveyed in 2003. Geomorphic changes since that survey introduce systematic error. Secondly, stage-discharge relationships are not adequately calibrated at high flows. Differences in channel entrenchment and floodplain morphology between the two sites also preclude accurate extrapolation of the observed rating relationships. As previously reported, the computed Main Stem flows exceed downstream flows recorded at the USGS gage in 2001 (Figure 3). During the 2001 runoff, adjustments in channel cross-sectional shape and roughness characteristics affected the stage-discharge relationship over time. Thus, the current rating curve is less accurate for the 2001 data relative to current conditions and these data should be used with caution.

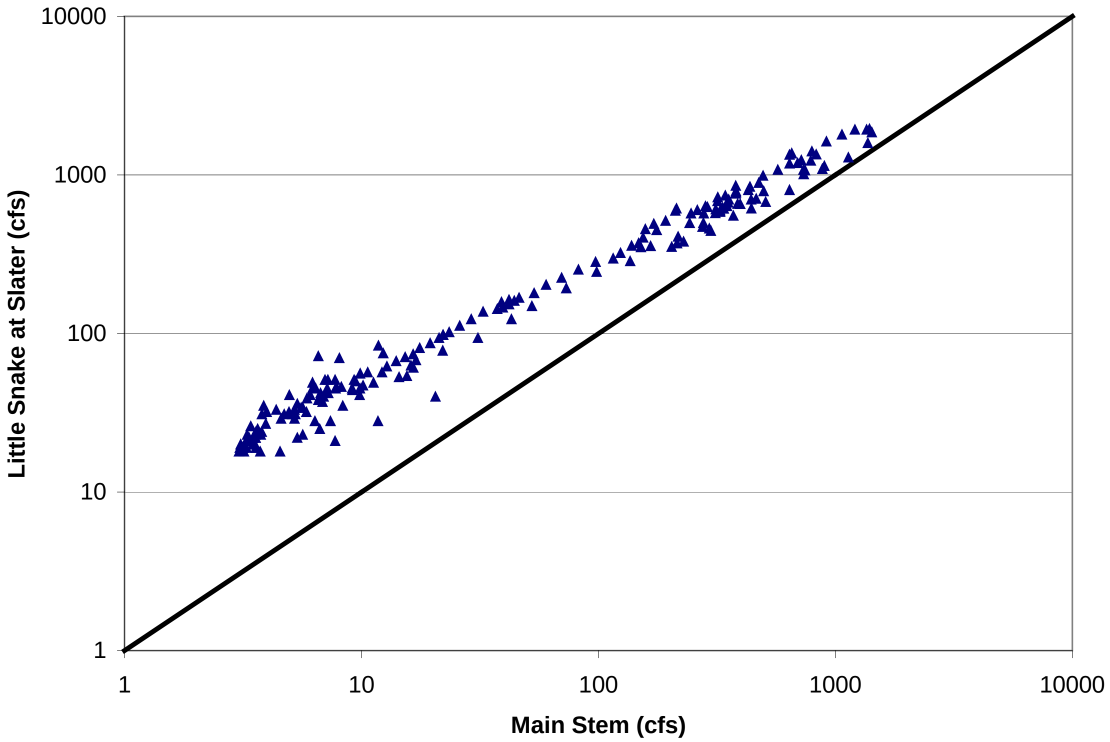


Figure 4: A comparison of the USGS mean daily data at the gage on the Little Snake near Slater, Colorado, with the mean daily flow measurement at the Main Stem bridge site. The data are from April 1, 2005 to October 18, 2005.

Figure 5 compares precipitation recorded at the Whiskey Park SNOTEL site in the 2003 and 2005 water years. Early winter snowfall prior to March 1 was greater in 2005 than in 2003. Rain and snow through March and April were greater in 2003. These spring events during the beginning of runoff likely resulted in the steeper and higher peak of the 2003 hydrograph. Rainfall through May and June was greater in 2005. This rain, coupled with cooler temperatures during the runoff period in 2005, likely resulted in the extended duration of the 2005 runoff. This comparison of peak flow between 2003 and 2005 applies only to the Main Stem. The crest gage data suggest that peak flow along the Middle and South Forks was higher in 2005 than in 2003.

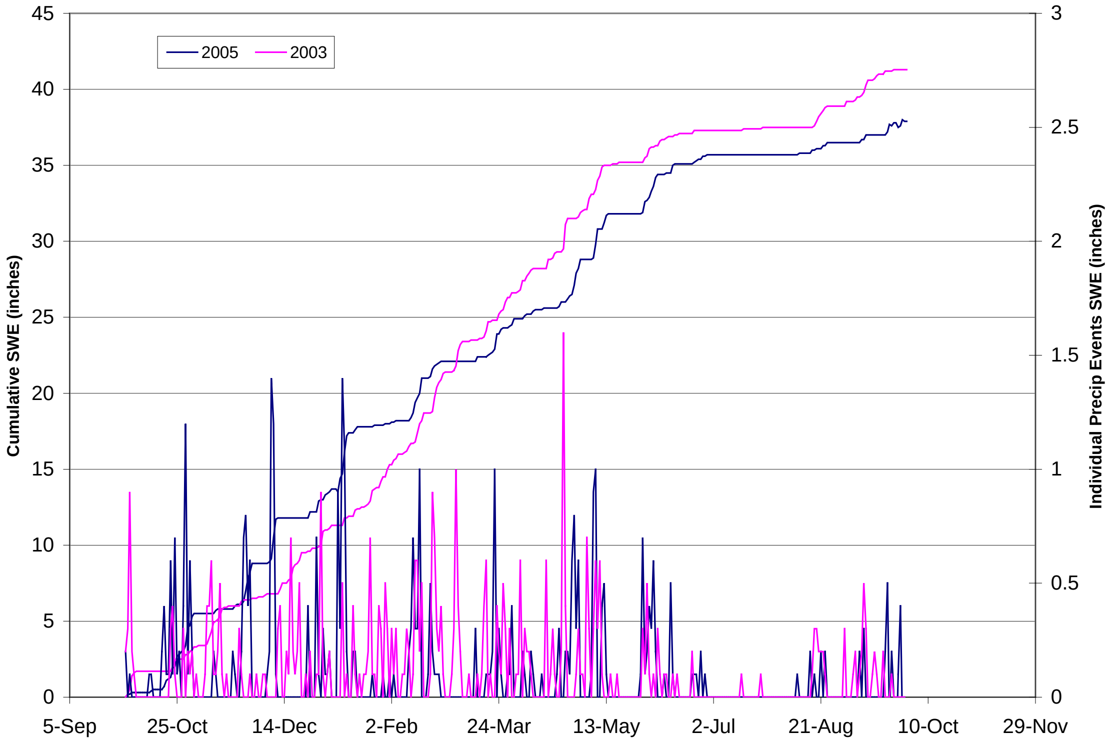


Figure 5: Precipitation comparison at the nearby Whiskey Park SNOTEL site between the 2003 and 2005 water years.

Horizontal and Vertical Adjustments

Point measurements of vertical channel adjustments were collected at sixteen locations throughout the project (Table 2). The magnitude of vertical adjustment that occurred in 2005 was greater than in 2004 but less than in 2003. The greater adjustment compared to 2004 was due to the higher cumulative sediment transport capacity of flows in 2005. Smaller adjustments in 2005 compared to 2003 could reflect a trend towards equilibrium as the project evolves. Although the results indicate an gradational trend, this response does not warrant remedial action. Monitoring of vertical adjustments was conducted at each of the flow-meter sites, which were selected for accuracy of flow measurement, and thus are generally located in zones upstream of cross-vane structures. The net aggradation is a result of continued sealing and storage of bed material behind the structures.

Table 2: Summary of vertical channel adjustments during the period 2003 through 2005. Positive values indicate aggradation, negative values indicate degradation.

Flow Meter	Location	Change in Bed Elevation 2003 (ft)	Change in Bed Elevation 2004 (ft)	Change in Bed Elevation 2005 (ft)
South Fork cross section 9	A	0.01	0.05	-0.03
	B	0.40	0.09	0.13
	C	0.06	0.08	-0.09
South Fork cross section 6	A	0.23	0.09	-0.07
	B	0.08	0.01	-0.08
South Fork Bridge	A	0.09	0.03	0.04
	B	0.17	0.15	0.26
	C	0.31	-0.05	0.04
Middle Fork	A	0.79	0.08	0.26
	B	0.41	0.12	0.01
	C	0.14	-0.08	0.15
North Fork	A	0.27	0.13	0.22
	B	-0.02	0.09	-0.09
	C	0.33	0.00	0.08
Main Stem	A	0.31	-0.12	0.05
	B	-0.31	0.00	--
	C	0.80	-0.01	0.01
Average		**0.24**	**0.04**	**0.06**

Horizontal channel adjustments were measured using erosion pins located throughout the project. Between 2001 and 2002, twenty erosion pins were installed. The erosion pins were revisited following the 2003, 2004, and 2005 runoffs to quantify horizontal adjustment at the monitoring locations as summarized in Table 3. At the end of the project, nine erosion pins were locatable. Several factors account for the loss of pins including fluvial detachment or slab failure of the bank, dense vegetation regeneration, or the accuracy of GPS locations.

Table 3: Summary of horizontal channel adjustments measured at erosion pins. Positive values indicate accretion, negative values indicate erosion.

River	Erosion Pin	Change 2001-2002 (ft)	Change 2002-2003 (ft)	Change 2003-2004 (ft)	Change 2004-2005 (ft)
South Fork	1	-0.45	-0.50	--	--
	2	-0.33	-0.39	-0.13	--
	3	-0.05	-0.45	-0.03	-0.23
	4	0.41	0.14	-0.05	-0.11
	5	0.36	-0.70	--	--
	7		-0.32	--	--
	8		-0.19	-0.27	-0.12
	9		-0.11	0.04	--
	10		0.39	0.17	--
North Fork	11		0.01	-0.04	-0.04
	12		-0.01	-0.10	-0.13
	13		-0.27	-0.35	-0.12
Middle Fork	14		-0.02	-0.05	--
	15		over 1 ft	0.10	-0.50
	16		over 1 ft	--	--
Main Stem	17		-0.19	0.09	--
	18		over 1 ft	--	--
	19		over 1 ft	-0.68	-0.09
	20		-0.44	-0.02	-0.07
Average		**-0.01**	**-0.37**	**-0.09**	**-0.16**

These results indicate that some adjustment is occurring along the channel banks as occurs in natural meandering channels. The trend in magnitudes of horizontal adjustment between 2003, 2004, and 2005 is of similar order to that of the vertical adjustment. The greater adjustments in 2005 compared to 2004 were likely due to the higher and longer duration shear stresses. As with the vertical adjustments, smaller changes in 2005 relative to 2003 could reflect a trend towards equilibrium.

Despite the inability to relocate some erosion pins described above, we are confident that the reported data are representative of the upper limit of lateral adjustment rates among the project reaches. Erosion pin placement was intentionally biased towards locations where shear stresses were expected to be higher and erosion was a potential concern. Therefore, the rates in erosion as measured by the pins are likely maximum rates occurring throughout the project. The banks are generally stable and their adjustment is consistent with what would be expected in stable river environments (Knighton 1998).

As noted previously, the vast majority of structures and habitat enhancement features are performing as intended, and overall the project is stable. Locations marked in previous years for more in-depth monitoring and/or maintenance were revisited in 2005. Additional locations of interest identified after the 2005 runoff were also noted. Appendix A includes detailed descriptions of the most notable of these locations. All of the locations are presented in the *2005-*

Monitoring Locations.xls spreadsheet included on the CD ROM data supplement. The types of adjustments described in Appendix A are encountered in successful stream-restoration projects of this scale and are acceptable, given the inherent variability of natural river systems.

Cross-section Survey Comparison

Detailed cross-section surveys were completed at twenty-five locations in the summers of 2001 and 2004 to assess changes in channel morphology and stability. All survey measurements of channel cross sections were recorded at a vertical resolution of 0.01 ft. The horizontal resolution of the 2004 cross sections was increased relative to the 2001 cross sections. Comparisons of thalweg elevations from each year reveal a general trend of aggradation at the cross sections, as shown by the representative cross section presented in Figure 6. The average amount of aggradation among all cross sections is 0.66 ft, with a standard deviation of 0.65 ft.

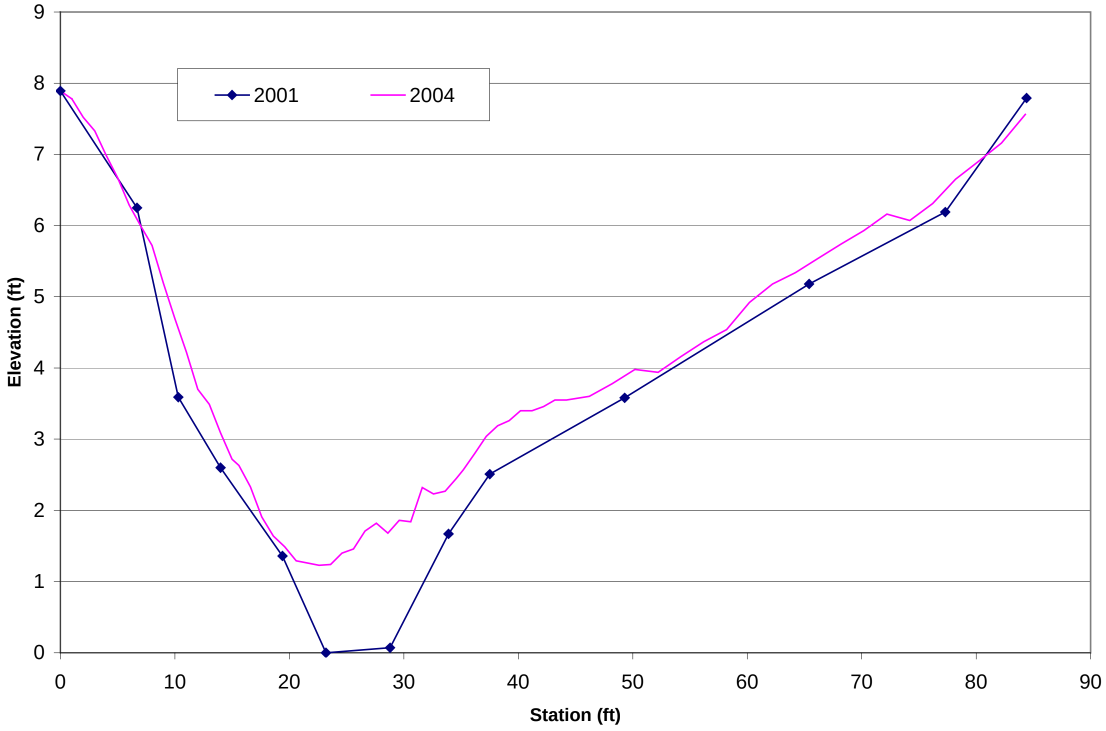


Figure 6: **A representative cross section comparison between 2001 and 2004 surveys indicating aggradation at SF XS6A.**

This trend in aggradation is consistent with the trend identified by the point measurements made at the flow-meter locations. The magnitudes of the adjustments are within the range of variability expected after emplacement of several hundred grade control structures intended to reduce slopes and dissipate energy. Furthermore, the flow conditions between the two surveys would also point towards aggradation. Runoff between 2001 and 2004 includes two historically low-water years and one peak in the middle of the historical record. The system has had a relatively short period over which to transport sediment at effective discharge levels.

Bed-material Sampling

Pebble counts were conducted during the summer of 2001 following Wolman (1954) and Rosgen (1996) procedures to determine particle size distribution and substrate characteristics at ten reaches along the Main Stem, North Fork, and Middle Fork; fourteen reaches along the South Fork; and seven reaches along the Roaring Fork. These same locations were re-sampled in the summer of 2004 to assess bed material sizes and gradation. Forty-seven of the original locations were sampled and one additional location was sampled downstream of the project site. Table 4 summarizes changes in average median grain size of bed material for each tributary from 2001 to 2005. For all tributaries except the Roaring Fork, pebble counts indicate a trend of bed material coarsening. Excluding the Roaring Fork sites, the D_{50} value increased from 2001 to 2004 for all but one site along the North Fork, one site along the Middle Fork, and two sites along the South Fork.

Table 4: Average median grain size of the 2001 and 2004 pebble counts.

Tributary	2001 D_{50} (mm)	2004 D_{50} (mm)
Main Stem	42.7	69.3
Middle Fork	58.0	74.8
North Fork	56.6	68.9
South Fork	45.5	62.0
Roaring Fork	62.0	55.3

The results of the pebble count comparison suggest that armoring is occurring throughout the project. Sediment sorting and armoring, particularly on the falling limbs of high flows of 2003 and 2005, are responsible for increases in bed-material size. The material comprising the channel immediately following construction was similar to that of the pre-project channel, except in the vicinity of the structures. With the increased shear stresses of the narrower and deeper post-project channel, the high flows of 2003 moved much of the finer material through the system and below the armor layer. Thus, larger material was left behind and the sampled D_{50} was larger in 2004 than in 2001. These trends in grain size bode well for the observed aggradational patterns in that substrate quality has improved despite deposition resulting from structure sealing and slope reductions.

Vegetation Establishment

In addition to sorting of bed material, vegetation succession is another ongoing response to the restoration activities. In the fifth full growing season following construction, vegetation continues to re-establish along channel margins and floodplain surfaces. Grasses and forbs are the primary vegetation types colonizing the banks and riparian zone. This is evident along most of the project, even along many of the reshaped gravel and cobble bars. Willows (*Salix* spp.) are the predominant woody vegetation establishing along channel margins, and gravel and cobble bars. Changes in the willow assemblages can be characterized in two general ways. First, many transplanted willows have experienced some dieback, but there is new growth at the bases of the plants. This was first noted in previous years along the project and new growth of transplanted willows has continued. We expect that, given relatively normal precipitation and flow conditions, these plants will continue to successfully regenerate with proper grazing practices. Second, willows are colonizing many of the exposed gravel bars and cobble bars. While many of the early colonizers have established in locations that will not support perennial vegetation over the long term (i.e., too low into the active channel where excessive periods of inundation and high shear stresses preclude long-term establishment), a large number of more suitable sites have been successfully colonized. These locations are expected to develop into an important functional component of the riparian community. Willow, grass, and forb establishment will increasingly contribute to the overall geomorphic stability of the channel, as well as improve the available cover for aquatic fauna, input coarse particulate matter for desirable aquatic insects, and reduce water temperatures through shading.

Photo points located throughout the project provide a means to observe changes in vegetation over time. Figures 7 through 11 depict a representative progression of vegetation colonization along a cobble bar of the South Fork of the Little Snake, while Figures 12 through 16 depict a similar representative progression along the Main Stem. Although this vegetation establishment is encouraging, it is not limited to reaches within the project. At an additional photo point located downstream of the end of the project, similar colonization is occurring (see Figures 17 through 21). This could be related to upstream restoration activities, or could be an indicator that vegetative changes are partially due to climatic factors. Vegetation colonization in lower levels of the channel may reflect successive low-flow years during the drought cycle. Vegetation has thrived throughout the restoration project since construction, despite drought conditions. Much of this improvement is attributable to improved grazing practices and enhanced hydrologic connectivity of the riparian corridor resulting from the restoration project.

2001

2002

2003

2004

2005

Figures 7-11: Sequence of vegetation establishment along the South Fork (photo-point SFPP18, looking downstream).

2001

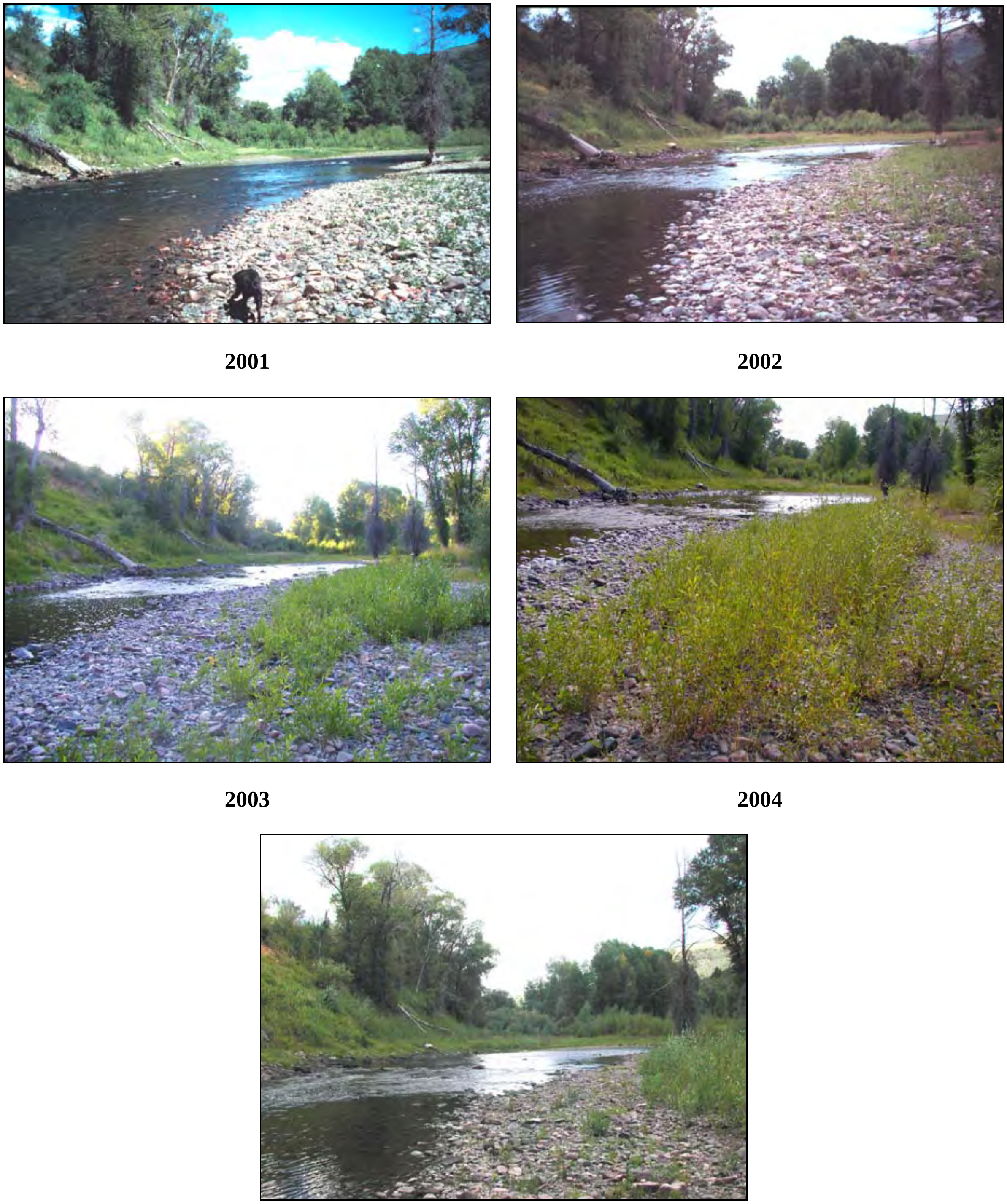
2002

2003

2004

2005

Figures 12-16: Sequence of vegetation establishment along the Main Stem (photo-point MSPP4, looking upstream).



2001

2002

2003

2004

2005

Figures 17-21: Sequence of vegetation establishment along the Main Stem, downstream of the project boundary (photo-point MSPP10, looking upstream).

Riparian vegetation was denser in 2005 than in previous years, especially along the lower South Fork, with the high flows and wet early summer. Figure 22 shows one representative location on the lower South Fork in the pasture immediately upstream of the South Fork Bridge flow-meter site.

Figure 22: Representative riparian vegetation along the lower South Fork. Note the shading provided to the bend pool by willow establishment.

The restoration reaches, like all streams, continue to be influenced by upstream land-management practices. Upstream of the South Fork restoration reach and beyond the Three Forks Ranch property boundary, existing grazing practices increase fine sediment loading and channel instability through continual disturbance of streamside vegetation and soils. The restoration reaches cannot be assessed without considering the overall watershed, and the potential effects of upstream grazing practices on downstream reaches are a continuing point of concern. A sediment trap constructed above the project on the South Fork will require periodic maintenance to ensure its long-term effectiveness.

Fish Habitat Monitoring

The restoration effort has resulted in substantially more pool volume and deep-water habitat with improved potential for riparian shading, lower instream temperatures, and higher dissolved oxygen content. The fish habitat monitoring effort for 2005 has primarily focused on:

- Determining changes in the stream temperature regime as a result of the project.
- Assessing the benthic macroinvertebrate community through sampling using standard techniques. Dr. Leroy Poff's lab in the CSU Department of Biology performed taxonomic analysis on the benthic macroinvertebrate samples collected in 2001, 2002, and 2004. The results of these analyses are presented below.
- Applying the U.S. Environmental Protection Agency's *Rapid Bioassessment Protocols For Use in Streams and Rivers: Periphyton, Benthic Macroinvertebrates,*

and Fish (Barbour *et al*. 1999) to perform a visual assessment of physical habitat quality. The Rapid Bioassessment Protocol (RBP) approach is widely utilized across the U.S. to provide a multi-scale, rapid, visually-based assessment of stream habitat quality.

Temperature Monitoring

Continuous records of hourly stream temperatures were monitored at seven locations within the restored reaches and one location upstream of the project on the South Fork. Plots of the daily maximum, minimum, and average temperatures recorded during the 2005 low-flow season are provided in Appendix B. Instream water temperatures are heavily influenced by ambient air temperatures. The 2005 late summer ambient and stream temperatures were comparable to the previous four years (see Figures 23 through 25). Plots comparing stream temperatures between years for the remaining locations are provided in Appendix B. As in the previous three years, the maximum water temperatures for 2005 reached near-lethal levels for trout at some locations, however no notable fish mortality resulted from the elevated water temperatures through summer 2005. This suggests that there continues to be adequate volume and redundancy of cold-water refugia in deep pools created by structures throughout the restoration project. We hypothesize that hyporheic exchange is greatly increased due to the restoration project.

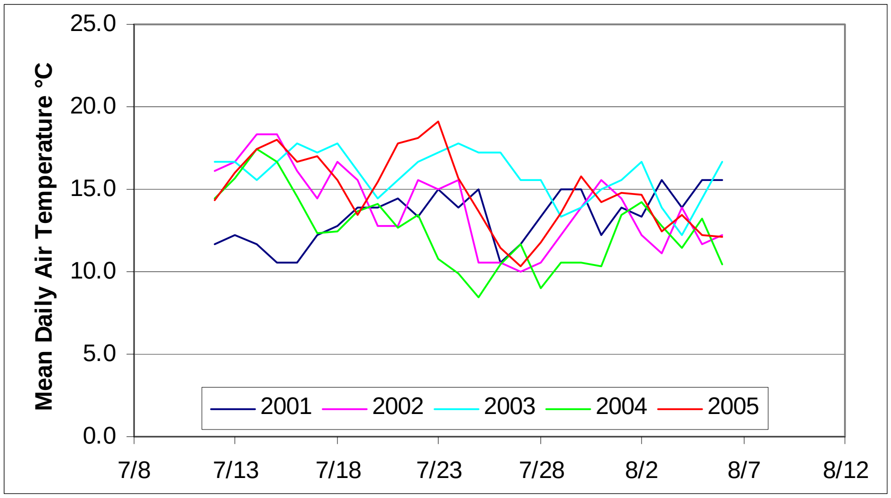
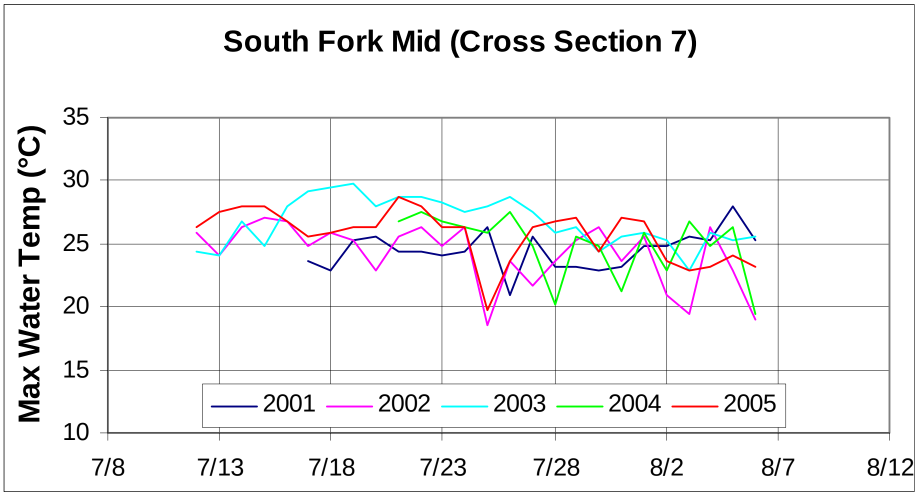
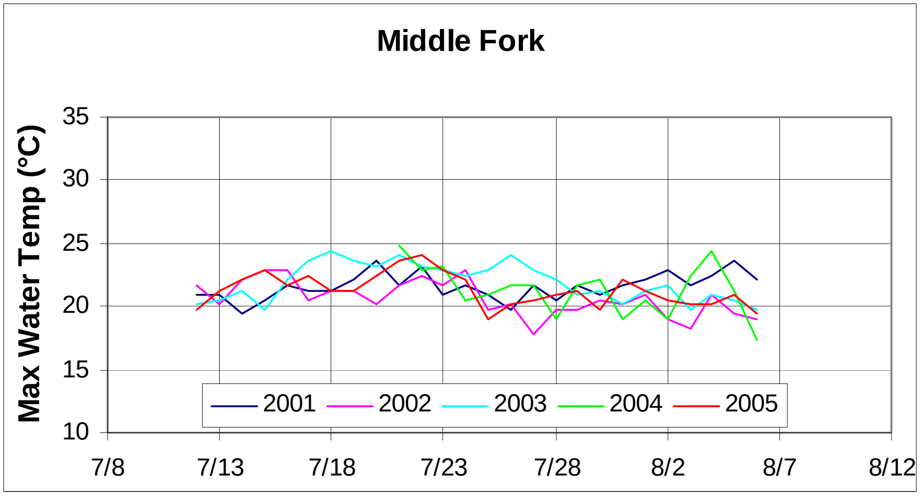


Figure 23: Comparison of 2001 through 2005 average air temperatures at the nearby Whiskey Park SNOTEL station for mid-summer (corresponding to Figures 18 and 19).





Figures 24-25: Comparison of 2001 through 2005 maximum water temperatures along the South and Middle Forks (see Appendix B for remaining temperature sensor location comparisons).

Spatial trends in temperature from location to location over the 2005 season are slightly different than those observed in 2004. Figures 26 and 27 present mean daily temperatures along the North, Middle, and South Forks, as well as Main Stem of the Little Snake River (refer to Figure 1 for a map of the temperature sensor locations). As in other years, North Fork temperatures are substantially colder than all other locations (Figure 26). The South Fork temperatures are the highest of all locations, as expected, and the Middle Fork temperatures are between those of the South and North Forks. The Main Stem “bridge” probe is located downstream of the confluence of the North and Middle Forks, and the Main Stem “ranch” probe is located downstream of the confluence with the South Fork. With the elevated temperatures of the South Fork, the Main Stem “ranch” temperatures were higher than the Main Stem “bridge” temperatures, as expected.

South Fork temperatures drop from above the project to the top of the project due to a cold water spring at that location. Unlike 2004, the middle and lower segments of the South Fork had lower temperatures than above the project. These temperatures are influenced by the “resetting” effect of the spring at the top of the project and remained lower than temperatures above the project through the South Fork project segment.

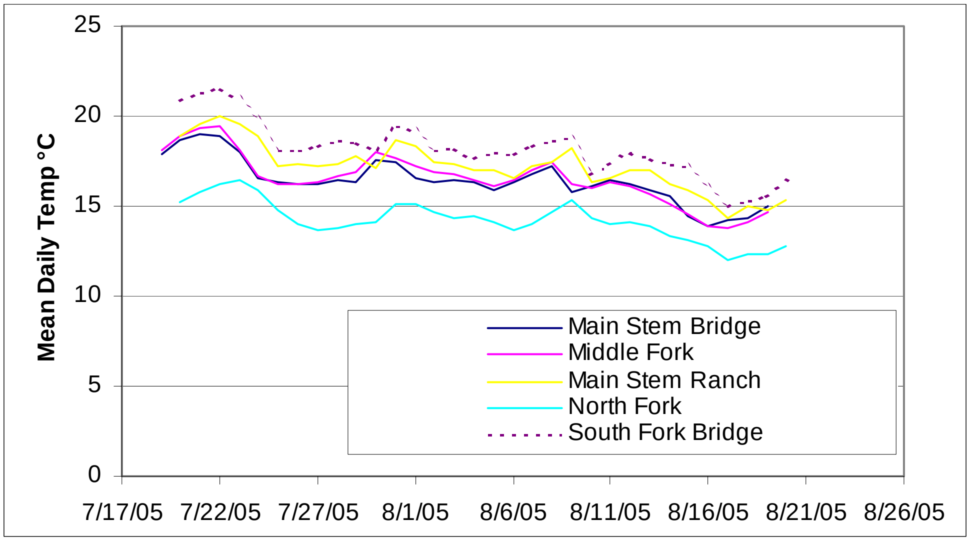


Figure 26: Mean daily temperatures on the Little Snake River at Three Forks Ranch in 2005.

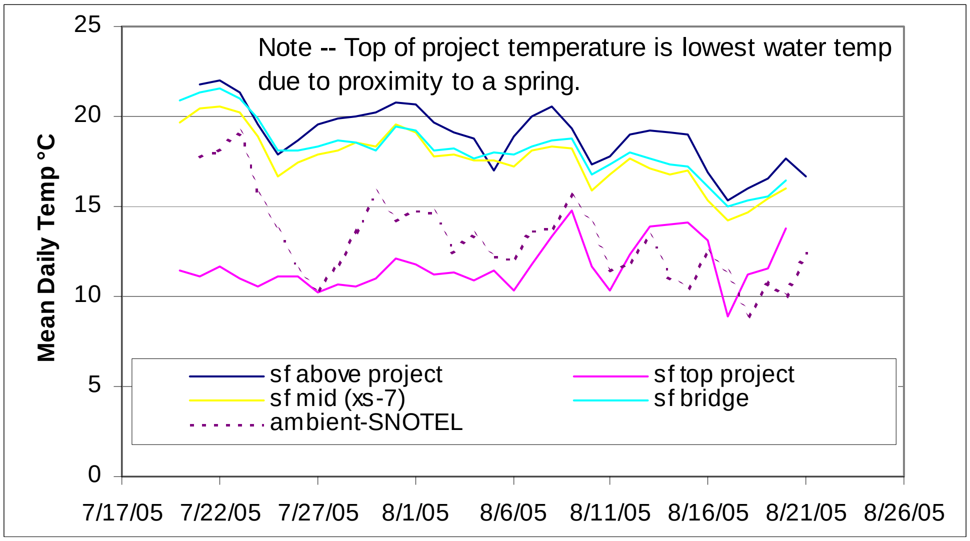


Figure 27: Mean daily temperatures along the South Fork Little Snake River in 2005.

Although late-summer temperatures have sometimes reached levels of concern for fish populations in shallower habitat units along the South Fork and Main Stem of the Little Snake, the large number of deep pools created and sustained by the project is apparently providing adequate protection from excessive temperatures during summer low-flow periods. Table 5 provides the average time of day that maximum stream temperatures occurred at each location during the 2005 monitoring period. This time is affected by where the sensor is located at the site, which is also provided in Table 5.

Table 5: Average time of day of the maximum temperature at each monitoring location in 2005 (July 12, 2005 to October 18, 2005).

Location	Average Time of Maximum Temperature	Sensor Location
South Fork above the project	1:25 pm	pool
South Fork top of the project	3:09 pm	pool
South Fork middle (cross section 7)	2:31 pm	pool
South Fork bridge	3:11 pm	riffle
North Fork	3:28 pm	riffle
Middle Fork	2:35 pm	riffle
Main Stem at flow meter	2:15 pm	riffle
Main Stem at ranch entrance	2:55 pm	pool

Benthic Macroinvertebrate Monitoring

Benthic macroinvertebrate assemblages were monitored at multiple locations in 2000, 2001, and 2004 (Table 6). Composites of three quantitative Surber samples (2,700 cm^2) were collected in relatively fast-flowing habitats at each site and preserved in the field with ethanol. Samples were subsequently sorted and identified to the lowest practicable taxonomic level (genus in most cases) in Dr. LeRoy Poff's Stream Ecology Laboratory at Colorado State University.

Table 6: Benthic macroinvertebrate monitoring locations.

Location Description	Type	2000 July 25-26	2001 June 26-28	2004 September 7-10
South Fork near bridge at flow-meter location / cross section 15+12	Project	X	X	X
South Fork ca. 30 m above top of the project	Reference	X	X	X
South Fork ca. 1 km above temperature sensor located above the project	Impacted	X	X	X
Middle Fork just above the project boundary	Project		X	X
Middle Fork project upstream of W-weir	Reference		X	X
North Fork between flow meter and confluence	Project		X	X
North Fork upstream of the project	Reference	X	X	X
Main Stem at downstream project buffer	Impacted	X		X

The results of these surveys (Table 7) suggest that densities of sensitive taxa (Ephemeroptera [mayflies], Plecoptera [stoneflies], and Tricoptera [caddisflies] (EPT)) have increased at monitoring locations on the Middle and North Forks since 2001, despite decreases at upstream reference locations on these tributaries and late season sampling in 2004. Caddisfly densities and relative densities have also increased dramatically in the South, Middle, and North Forks since 2001. EPT density in the South Fork project area shows a decline from 2001 to 2004 but is consistently higher than upstream reference and impacted reaches, which also exhibit a decline in this metric. The increased dominance of caddisfly taxa in the South Fork is associated with lower relative densities of Ephemeroptera and Plecoptera taxa.

Table 7: Benthic macroinvertebrate survey results.

Variables	Year	South Fork			Middle Fork		North Fork		Main Stem
		Project	Reference	Impacted	Project	Reference	Project	Reference	
EPT Relative Density	2000	78%	46%	45%	--	--	--	22%	74%
	2001	56%	17%	25%	52%	43%	42%	57%	
	2004	29%	21%	21%	77%	26%	61%	38%	38%
EPT Density (per m^2)	2000	3666.67	850.00	1511.11	--	--	--	1462.96	355.56
	2001	688.89	461.11	608.33	181.48	507.41	259.26	792.59	
	2004	214.81	66.67	66.67	362.96	70.37	562.96	222.22	537.04
Tricoptera Relative Density	2000	58%	34%	42%	--	--	--	9%	23%
	2001	1%	2%	9%	3%	11%	6%	15%	
	2004	23%	12%	12%	66%	19%	45%	35%	13%
Tricoptera Density (per m^2)	2000	2722.2	644.4	1422.2	--	--	--	733.3	111.1
	2001	14.8	72.2	225.0	7.4	133.3	33.3	259.3	
	2004	170.4	37.0	37.0	314.8	51.9	414.8	203.7	181.5
EPT/C	2000	55.0	1.1	2.0	--	--	--	22.2	16.0
	2001	5.3	7.6	1.0	1.9	1.1	0.8	1.2	
	2004	0.7	0.4	0.4	4.1	0.5	1.7	0.8	1.6
% Plecoptera	2000	13%	16%	7%	--	--	--	25%	23%
	2001	10%	15%	15%	9%	11%	20%	15%	
	2004	0%	11%	11%	29%	29%	29%	13%	15%
Total Richness	2000	15	19	15	--	--	--	24	13
	2001	10	13	13	11	18	10	13	
	2004	7	9	9	7	7	7	8	13
EPT Richness	2000	10	11	8	--	--	--	17	8
	2001	6	8	10	6	13	7	8	
	2004	3	5	5	4	4	4	5	8

Total taxa richness values in project reaches were comparable to least disturbed upstream reference sites in all three forks of the Little Snake in 2004. Percentages of stoneflies (generally the most sensitive order of stream insects) appear to have increased since 2001 in the Middle and North Forks. EPT taxa richness values in project sites were comparable but slightly lower than reference locations on the South and North Forks in 2004, with the Middle Fork project site and upstream reference having equal values of EPT richness.

Overall, these results suggest that invertebrate productivity has generally increased since 2001 and that sensitive taxa have recolonized the study sites following construction as the channel bed has sorted and stabilized. This process may have occurred more rapidly on the Middle and North Forks due to smaller project extents relative to the South Fork, and due to the presence of minimally impacted upstream segments on the Middle and North Forks. Reduced numbers of total taxa and EPT taxa in 2004 are likely the result of sampling later in the season after certain taxa have largely emerged. As described above, these samples were collected in riffle habitats. The project has resulted in both less embedded substrates and a tremendous increase in pool habitat relative to run and glide habitat units. The net effect of this redistribution of habitat units on project-wide productivity of benthic macroinvertebrates remains unclear. Differing low-flow conditions and sampling dates, sediment basin effects on the South Fork, and increased drift to downstream segments of the South Fork and Main Stem during construction in 2000 complicate interpretation of these data as a time series. Moreover, the South Fork, as the smallest tributary to the Little Snake, probably exhibits the greatest inter-annual and intra-annual variations in macroinvertebrate assemblages due to greater ranges of temperatures and base-flow conditions. Nonetheless, the marked improvements in channel substrates, low-flow depths, and summer temperatures resulting from the restoration project have undoubtedly improved these key aspects of benthic habitat. This conclusion is supported by numerous anecdotal reports by fishing guides of marked increases in insect hatches and abundance.

Rapid Bioassessment Protocols

In 2005, visual habitat assessments based on the RBPs by Barbour *et al*. (1999) were conducted at the benthic macroinvertebrate sampling locations of 2001 and 2004 as well as the ten locations where they were conducted in 2002 and 2003. The scores in 2005 were nearly identical to the scores in 2004. Even though peak flows were relatively high compared to 2004, physical habitat was not appreciably altered. Changes in RBP score from year to year are partly due to variability in the scoring process from different observer interpretations of habitat at different flow levels. However, changes in RBP scores have diminished every year. The habitat features assessed by the forms are too broad to be sensitive to the small-scale changes occurring in the restoration areas. In general, the RBP assessments indicate improvements in the following stream characteristics in all restored reaches since the start of the project:

- Epifuanal substrate / available cover (increase)
- Embeddedness (decrease)
- Velocity / depth combinations (increase)
- Sediment deposition (decrease)
- Channel alteration (decrease)
- Bank stability (increase)
- Bank vegetative protection (increase)
- Riparian vegetative zone width (increase)
- Habitat complexity and cover, both instream and overhead (increase)
- Depth during extended base-flow periods in late summer / early fall (increase)

In 2002, extensive amounts of algae and periphyton growth were noted throughout the project. In 2003, 2004, and 2005, there were still isolated locations with substantial amounts of primary production, but overall reductions in periphyton and algae were noted. The elevated algae and periphyton levels in 2002 were likely the result of unusually low flows and greater light penetration occurring in the system.

There has been a continuing development and re-establishment of riparian vegetation throughout the project, as noted in the channel stability summaries. The establishment of new vegetation along the banks of the channel will increasingly provide shade and cover, thereby reducing in-stream temperatures and improving aquatic habitat.

PERSONNEL

The following is a list of names, titles, and affiliations of all persons who contributed to the content of this report (in alphabetical order):

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APPENDIX A

Locations Noted for Continued Monitoring by Ranch Personnel

The project site remained largely stable during the 2005 runoff season, and no large-scale channel adjustments were identified along any portion of the project. Areas that may require future maintenance were noted in the 2003 and 2004 annual reports. These areas were revisited in 2005 and new photographs are presented. Also presented, are additional areas of interest identified in 2005.

During walk-throughs of the entire restoration area over the five-year monitoring period, numerous locations were marked for detailed monitoring and potential future maintenance. In 2002, twenty locations were marked; these locations were revisited and photographed in subsequent years. An additional nineteen locations were marked for detailed monitoring during the 2003 walk-through; an additional eight locations were identified in 2004; and an additional fifteen locations were identified in 2005. The majority of these locations are points where structures have shifted or minor bank erosion is occurring. We recommend that these locations be monitored by ranch personnel to ensure that no channel avulsions or channel adjustment outside the range of natural variability occur. Selected noteworthy locations are described in the following sections. See the *2005-Monitoring Locations.xls* spreadsheet included on the CD ROM data supplement, for photographs and GPS coordinates of other locations marked for focused monitoring.

Main Stem

One location was noted in 2004 on the Main Stem upstream of the structure at XS4569 (40° 59.832' N, 107° 03.463' W). The left bank is eroding above the structure, as shown in Figures 28 and 29. This area was revisited in 2005. The bank appears to be slumping due to cantilevering, but dense vegetation on the failure will likely continue to protect it. No action is necessary at this time.

2004 **2005**

Figures 28-29: 2004 and 2005 photographs taken of bank erosion on the left bank upstream of the structure at XS4569 (40° 59.832' N, 107° 03.463' W).

In the Fall of 2005, Wildland Hydrology added a structure at the downstream end of the project (Figure 30). The new structure is a J-hook extending from the left bank composed of log along the leg of the structure reinforced by boulders along the bank and at the tip of the structure.

Figure 30: Photograph taken on October 20, 2005 of the new structure at the downstream end of the project site.

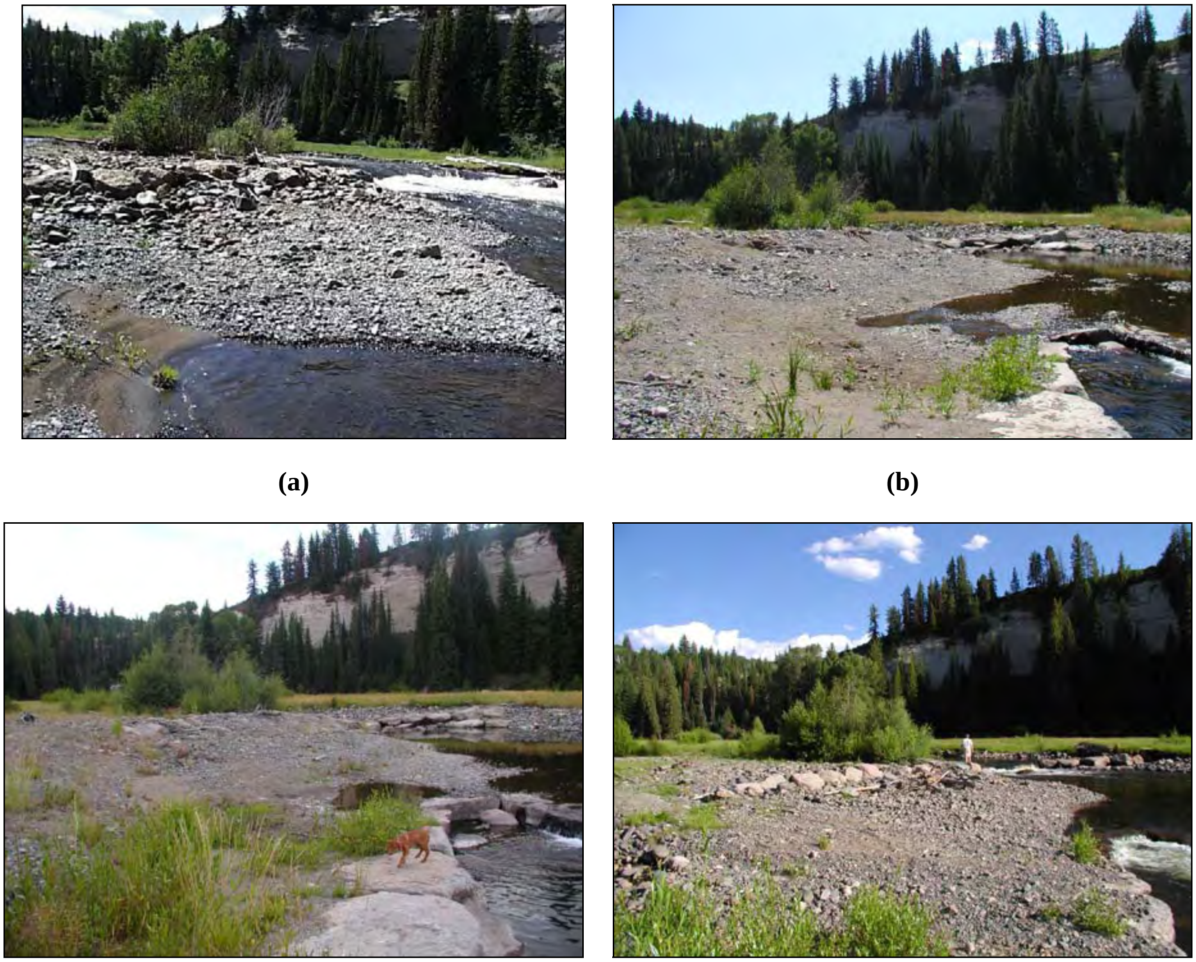
North Fork

No new locations were identified along the North Fork in 2005. The side channel that flows around the left side of the flow-meter island was purposely cutoff from the main flow during construction. However, the flow did get high enough in 2005 to enter this side channel (Figure 31), but this did not result in any stability problems at the island.

Figure 31: Flow in the channel behind the North Fork flow-meter island in 2005.

Middle Fork

Two locations on the Middle Fork had been targeted for maintenance activities in the past. The first is in the vicinity of the W-weir on the Middle Fork (40° 59.211' N, 107° 2.283' W) (Figures 32a-d). During high flows in 2003, tie-in rocks of the structure above the W-weir were exposed due to overbank flows and erosion of material covering the right tie-in boulders (Figure 32a). This resulted in downstream deposition of cobbles and gravels in the right side of the W-weir. After recession of the high flows, Three Forks Ranch personnel removed the deposited materials surrounding the W-weir and re-covered the tie-in boulders of the upstream structure (Figure 32b). This location was revisited in 2004 and 2005. Figure 32c shows that the deposition in 2004 is similar to that shown in Figure 32b. Figure 32d shows some uncovering of the tie-in boulders from the high flows in 2005. However, the structure remains stable and no action is required at this time.



(a) (b)

(c) (d)

Figures 32a-d: (a) Photograph taken on June 11, 2003, after high flows, showing the exposed tie-in boulders of the structure above the W-weir on the Middle Fork. Note the newly deposited material below the structure. (b) Photograph taken on August 15, 2003, after material removal and re-covering the tie-in rock. (c) Photograph taken on August 16, 2004, showing similar deposition as in (b) (40° 59.211' N, 107° 2.283' W). (d) Photograph taken on July 11, 2005, showing some uncovering of tie-in boulders during 2005 runoff. All photographs are looking upstream.

Near the upstream end of the project on the Middle Fork (40° 59.196' N, 107° 2.094' W), the boulders of a structure have shifted into a position that focuses flows on the left bank (Figures 33 through 36). Mass wasting during high flows in 2003 removed an 8-ft section of the willows from the bank. In 2005, the failure is still evident although new vegetation has established on the bank. Filling in this eroded section and emplacing additional boulders or other roughness elements along the bank would improve the stability of this location.

2002

2003

2004

2005

Figures 33-36: 2002, 2003, 2004, 2005 comparison of the 8-ft section where bank erosion removed willows (40° 59.196' N, 107° 2.094' W).

High flows in the spring of 2005 flanked the left side of the structure immediately upstream of the W-weir (Figure 37a). This structure was repaired by Wildland Hydrology in the fall of 2005 (Figure 37b).

(a) (b)

Figures 37a-b: (a) Photograph taken on July 11, 2005, of flanking of the left side of the structure upstream of W-weir. (b) Photograph taken on October 20, 2005, of the same structure after repair.

South Fork

Several locations were marked along the South Fork for detailed monitoring in 2002, 2003, 2004, and 2005. There are a few isolated areas where some maintenance is recommended.

First, at a location identified in 2002 (40° 56.409' N, 107° 06.042' W), high flows continue to erode the left side of a structure and have removed a small tree from the bank. This erosion is associated with eddying, resulting from flow under the structure at the bank toe. The site remains largely unchanged in 2005, with the exception of some new grasses on the left side of the structure in the failure.

2002

2003

2004

2005

Figures 38-41: Flow concentrated on the left bank took out small tree on the bank (40° 56.409' N, 107° 06.042' W). The site remains largely unchanged in 2005 (photograph taken on August 17, 2004).

A few other locations along the South Fork exhibit similar erosion characteristics occurring where flow is concentrated on one side of a structure and is beginning to flank the structure. Figure 42 shows a location identified in 2005 where flow is flanking a structure on the right bank (40° 58.327' N, 107° 03.151' W).

Figure 42: Photograph taken on August 23, 2005, showing a South Fork structure flanked on the right bank (40° 58.327' N, 107° 03.151' W).

There are numerous locations along the South Fork where a point bar on the inside of a bend has migrated toward the channel centerline and resulted in filling of structures and thalweg shifts toward the outside of the bend (Figure 43). This results in greater shear stresses but has not resulted in substantial amounts of bank erosion due to vegetation established along the banks.

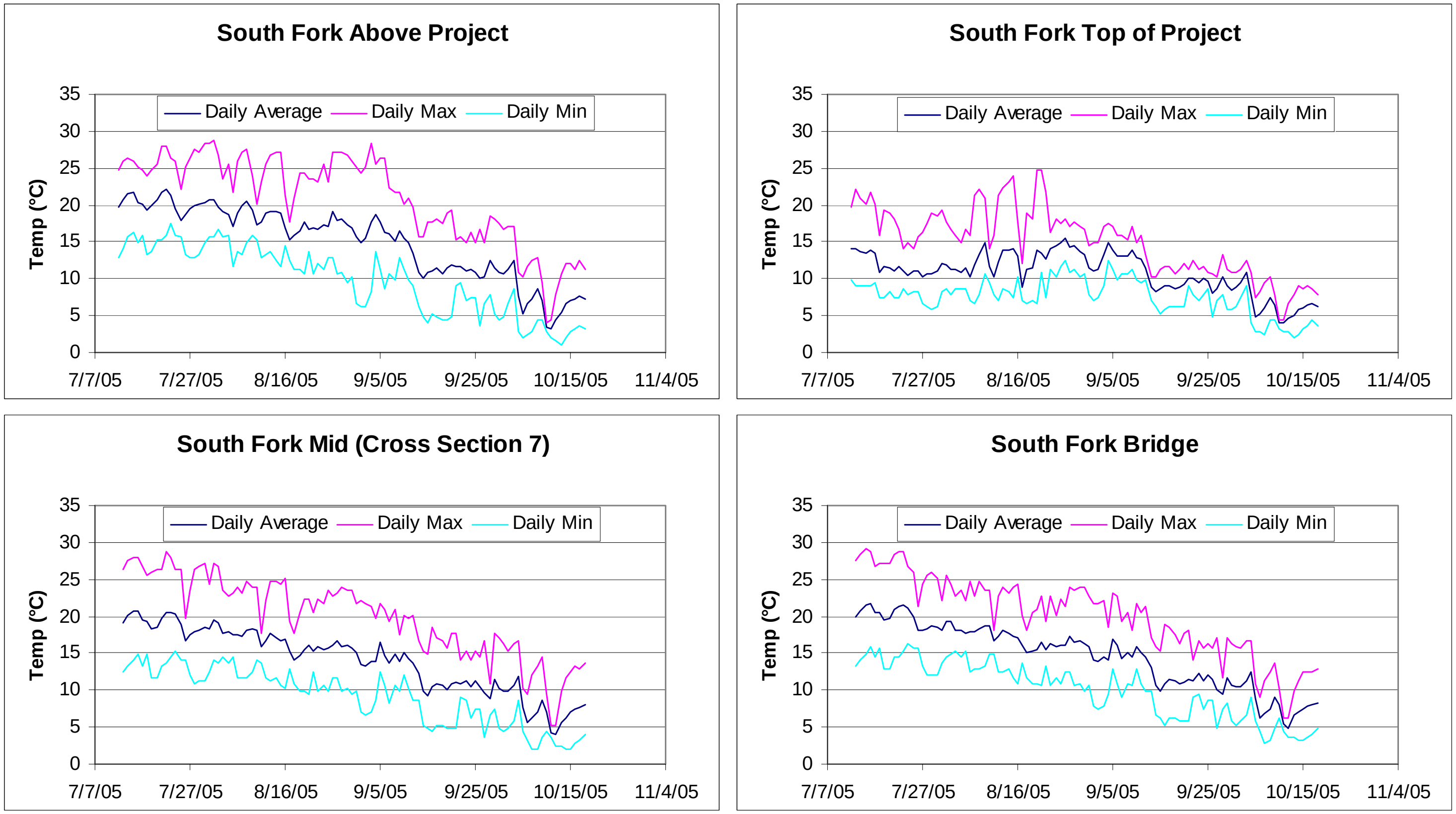
Figure 43: J-hook structure on the South Fork filling in by a point bar on the left bank opposite the tie-in (40° 57.203' N, 107° 05.163' W).

Visual inspection of pools along the South Fork during late summer in 2003, 2004, and 2005 suggests that residual pool volume is reduced relative to post-construction conditions in some locations. Structures that have sealed and formed the expected upstream wedge of stored sediment can affect pool volume upstream depending on the distance the wedge extends upstream relative to structure spacing. In particular, sediment storage upstream of sealed structures spaced at one to three channel widths on relatively low gradients of the South Fork has encroached into and reduced the volume of pools excavated in 2000.

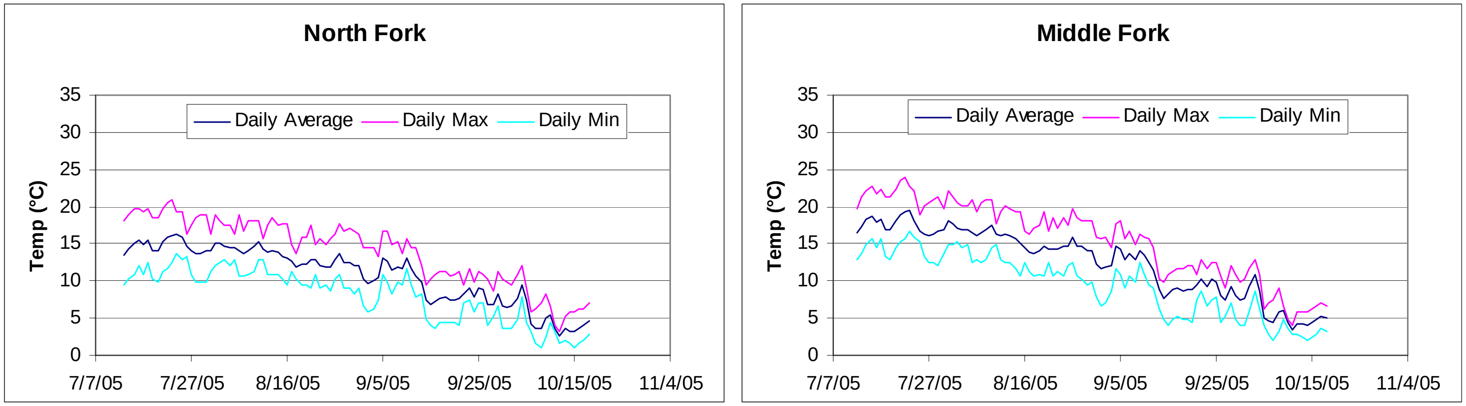
APPENDIX B

The plots in Figures 44 through 51 depict daily maximum and minimum temperatures collected along the Little Snake River. The one-hour data used to create these plots are included in the *temperature_data_2005.xls* spreadsheet on the CD ROM data supplement.

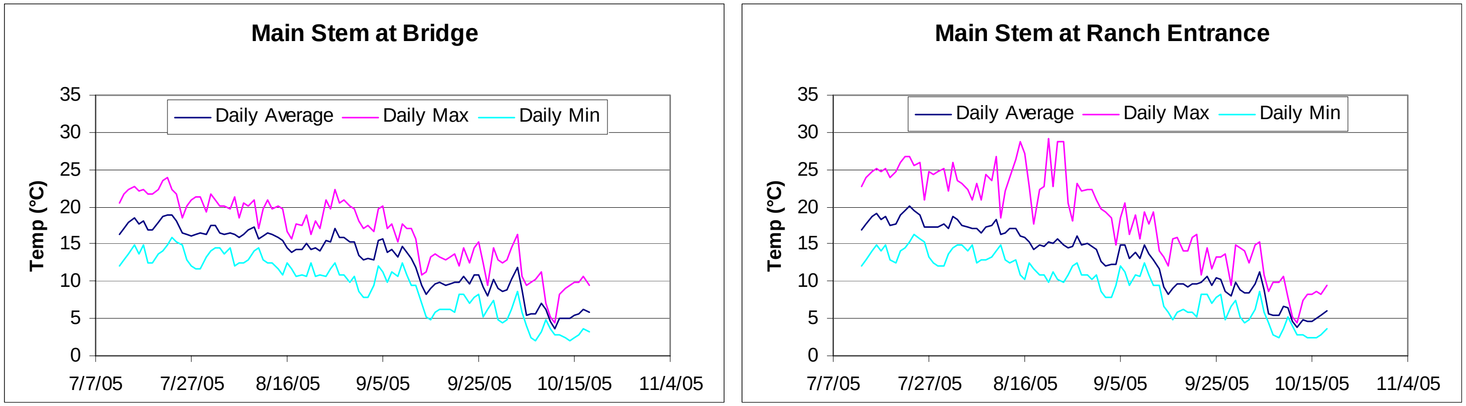
The plots in Figures 52 through 59 compare temperatures between years during a critical high temperature period at each location.



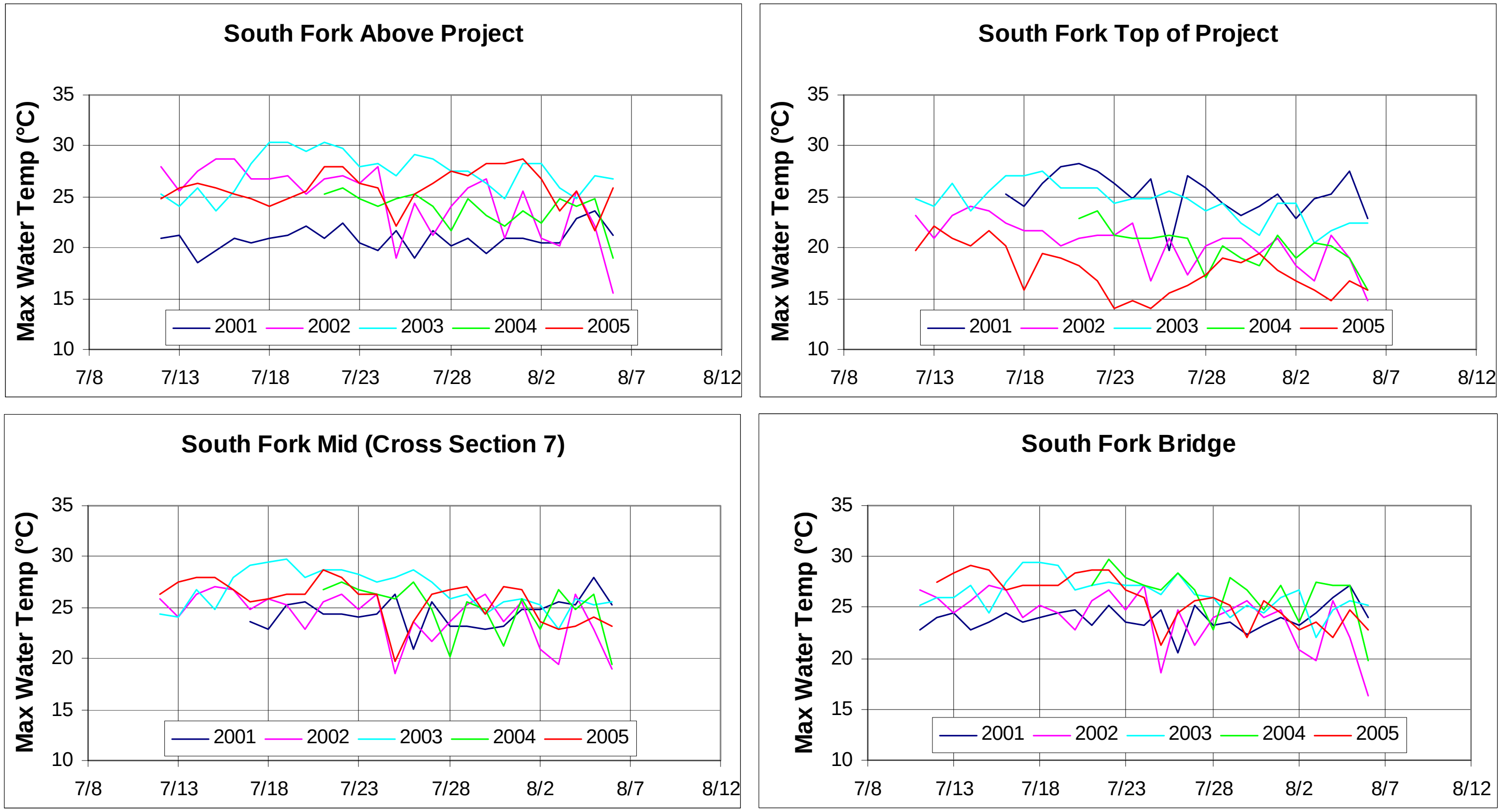
Figures 44-47: Comparison of 2005 temperature data collected along the South Fork.



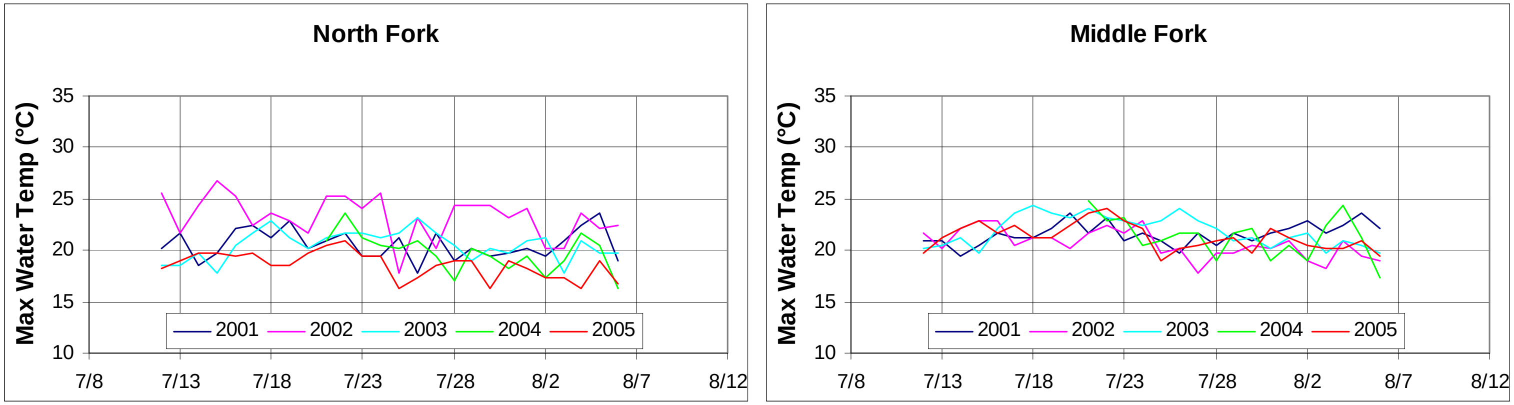
Figures 48-49: Comparison of 2005 temperature data collected along the North and Middle Forks.



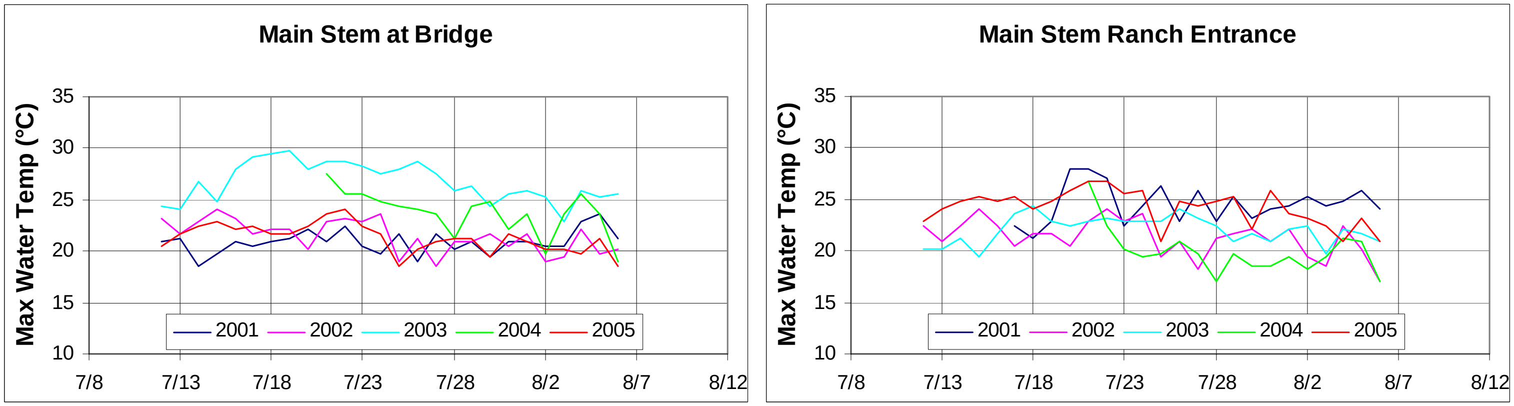
Figures 50-51: Comparison of 2005 temperature data collected along the Main Stem.



Figures 52-55: Comparison of 2001 through 2005 maximum water temperatures along the South Fork.



Figures 56-57: Comparison of 2001 through 2005 maximum water temperatures along the North and Middle Forks.



Figures 58-59: Comparison of 2001 through 2005 maximum water temperatures along the Main Stem.