FLOODPLAIN HABITAT RESTORATION 2005 MONITORING FINAL REPORT GREEN RIVER, UTAH

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Executive Summary

This document presents the results of sedimentation/erosion and discharge monitoring conducted in 2005 at five restored floodplain sites (Thunder Ranch (TR), Bonanza Bridge (BB), Stirrup (ST), Baeser (BA) and Above Brennan (AB)), along the Green River near Vernal, Utah. Levees were breached at these sites to allow for both flow-through and backwater flooding during spring runoff.

The goal of this monitoring effort was to quantify discharges through levee breaches and document observable erosion/sedimentation at the restored bottomland sites during the 2005 runoff event. In addition, post runoff surveys were conducted at Thunder Ranch to quantify erosion/sedimentation in the inlets and outlets. Results of the monitoring studies will give the Recovery Program a better idea of how different floodplain restoration site configurations respond during spring runoff, and how site configurations may be improved to better entrain drifting razorback sucker larvae.

This report presents the field results for flows measured at all five sites, cross sectional surveys and trends in the inlets and outlets for degradation and aggradation, documentation of visual observations, plots of inflow to the bottomland sites versus flows in the Green River and recommendations for future efforts.

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1.0 INTRODUCTION

The Upper Colorado River Endangered Fish Recovery Program (Recovery Program) seeks to re-establish self-sustaining populations of four endangered fishes endemic to the system. One method of meeting this objective is to restore or enhance natural floodplain functions that support recovery of endangered fishes in the basin. During 1997, 1998, 2000, and 2004 the physical inundation parameters of nine bottomlands located along the Green River near Vernal, Utah were modified. Levee breaching and/or bank lowering reduced the flood elevations and discharges required to inundate these sites. These reduced flood elevations allow floodplain inundation to occur at frequencies that mimic historic patterns under the current flow regime influenced by the Flaming Gorge dam and other water resources projects in the basin.

This document presents the results of sedimentation/erosion and discharge monitoring conducted in 2005 at five restored floodplain sites (Thunder Ranch (TR), Bonanza Bridge (BB), Stirrup (ST), Baeser (BA) and Above Brennan (AB)), along the Green River near Vernal, Utah. Levees were breached at these sites to allow for both flow-through and backwater flooding during spring runoff.

The goal of this monitoring effort is to quantify discharges through levee breaches and document observable erosion/sedimentation at the restored bottomland sites during the 2005 runoff event. In addition, post runoff surveys were conducted at Thunder Ranch to quantify erosion/sedimentation in the inlets and outlets. Results of the monitoring studies will give the Recovery Program a better idea of how different floodplain restoration site configurations respond during spring runoff. Ideally, these sites will provide adequate fish utilization through entrainment of larval fish to the floodplain habitats at frequencies and durations that mimic historic patterns utilizing current spring flows. A second goal of this monitoring effort is to assess the needs for site improvements for better connectivity with the Green River.

Specific objectives of this report are to:

- Present levee breach discharge results for all five sites.
- Present pre-runoff and post-runoff cross section surveys for Thunder Ranch.
- Present pre-runoff cross section surveys for Bonanza Bridge, Stirrup, Baeser and Above Brennan.
- Present qualitative, observed erosion and sedimentation trends at all sites from the 2005 spring runoff event.
- Provide recommendations, where applicable, to improve connectivity of the bottomland sites to the Green River.
- Develop a photo documentation record to monitor changes at the restoration sites.
- Provide surveys as baseline data for future erosion and sedimentation monitoring.

A more detailed discussion of the initial design objectives, river hydraulics and hydrology, specific site configurations, and locations of these sites are presented in the “Green River Floodplain Habitat Restoration Investigation, Bureau of Land Management Sites, and Ouray National Wildlife Refuge Sites near Vernal, Utah, Final Report (FLO, 1997).”

2.0 OVERVIEW OF 2005 FIELD DATA COLLECTION EFFORT

During 2005, data were collected during the spring runoff event in May, 2005. The spring runoff consisted of timed releases from Flaming Gorge Reservoir coinciding with the runoff from the Yampa River, which confluences with the Green River upstream of the study sites (approximately 42.25 miles upstream of Jensen Bridge). The spring runoff event for the Green River in 2005 was consistent with average spring runoff events for the Green River. Spring runoff events for several years prior to 2005 have been relatively low due to drought conditions. Terms used in this report related to “flood” and “flooding” refer to inundation that occurred during the 2005 spring runoff flows.

Discharge measurements through the levee notches were to be conducted during three flow stages in the Green River as reported at the Jensen Gage. One round of measurements was to coincide with 14,000 cfs in the Green River on the ascending limb of the hydrograph, one round was to coincide with the peak of 18,000 cfs, and one round was to coincide with 16,000 cfs in the Green River on the descending limb of the hydrograph. Actual discharge measurements were conducted three times during the runoff event at each inlet/outlet but at slightly different flows noted as follows; once on the ascending limb of the hydrograph at approximately 14,000 cfs between May 19th and May 20th, once at the peak at approximately 20,000 cfs between May 24th and May 25th, and once on the descending limb at approximately 17,000 cfs between May 30th and May 31st.

Post-runoff cross section monitoring and observations were also performed at the Thunder Ranch site between August 11 and August 12, 2005. In contrast to previous years, river cross section surveys adjacent to the bottomlands and cross section surveys of the bottomlands themselves were not conducted. The elimination of these tasks allowed for more field data collection efforts at new bottomland sites where floodability studies involving quantification of inflows and outflows was the priority for this year’s data collection. In addition, data from previous years indicated that most areas with notable changes tended to be at the inlets and outlets of the bottomland sites and that the interior portions of the bottomland sites did not exhibit significant changes. Initial measurements have indicated that the rate of sedimentation in the interior portions of the bottomlands is slow and surveys at intervals of several years or more are appropriate for tracking potential filling of the bottomlands from sedimentation. Re-surveying of the river cross sections was not performed this year but should be considered as part of upcoming data collection efforts. See Section 6.0 for recommendations of future monitoring efforts.

The 2005 data and cross section plots at the inlets and outlets of the monitored bottomland sites are appended to this report. Cross section data for the inlets and outlets are plotted against previous year’s data for comparing erosion and sedimentation at the levee openings. Corresponding mapping showing the cross section locations can be found on Figures 1 through 6 in **Appendix B**. The 1999 monitoring report (FLO, 1999) provides a summary of the methodology of erosion/sedimentation monitoring at each site.

Endpoint and cross section length information for all cross sections at all monitored sites is provided in **Appendix A.** The field notes for establishing vertical control at the Thunder Ranch cross sections, the reset LEP on BB-IN-2, and the reset LEP on AB-OUT are also provided in Appendix A. Figures 2 through 6 in **Appendix B** show the site plans with locations of the various monitoring sections for all five bottomland sites.

3.0 METHODS FOR DISCHARGE MONITORING AND EROSION AND SEDIMENTATION DOCUMENTATION

Discharge measurements in all inlets/outlets at each site were conducted three times, as previously discussed in Section 2.0 of this report. The time at which measurements were to be taken at the bottomland sites were to correspond to the time when flows at Jensen Gage reached 14,000 cfs on the ascending limb of the hydrograph, 18,000 cfs at the peak, and 16,000 cfs on the descending limb. Flows at the bottomland sites, however, were not directly equivalent to the flows reported at the Jensen Gage due to the travel time needed for flows at the gage to reach the bottomland sites, and due to flows from Ashley Creek. Ashley Creek confluences with the Green River approximately 17.5 miles downstream of the Jensen Gage. The creek was observed to have significant flows at the time of data collection. Discharges from Ashley Creek are added to the Jensen Gage discharges at the appropriate time intervals and a composite discharge obtained. The added discharge from Ashley Creek affects the bottomland sites downstream of the confluence, namely Bonanza Bridge, Stirrup, Baeser, and Above Brennan. Detailed information regarding the stream gages, river miles, composite discharges and lag times is located in **Appendix D**.

A Marsh-McBirney, Inc. Flow-Mate Model 2000 Portable Flowmeter and a wading rod were used to collect velocity measurements for determination of discharge.

Two staff gages were installed along the flow line of each inlet and outlet at all five sites. One gage was installed at or near the inlet/outlet cross section and one gage was installed inland, further toward the bottomland. The original intent of these staff gages was to help determine the hydraulic gradient in each inlet and outlet while flow was moving in and out of the bottomlands. Some readings were made during the survey efforts, however many of the gages were inaccessible, covered with debris, underwater, or washed away, making it difficult to take systematic and meaningful readings. The staff gages were useful, however, in making visual observations of erosion and sedimentation in the inlets and outlets during the post-runoff monitoring which is presented in later in this report.

At the inlets and outlets with previously monumented cross sections, pre-runoff cross section surveys were used to compare the erosion and sedimentation magnitudes from previous years. At the Thunder Ranch site, monitoring cross sections were established and surveyed across the mouth of each inlet and outlet before the spring runoff and surveyed again after the spring runoff in order to compare as-built conditions with post runoff conditions. Monitoring cross sections are designated by a two letter site identification followed by a short (usually two or three letter) feature description and feature number if there is more than one of its type. For example TR-IN-1 denotes Thunder Ranch inlet number 1. Multiple features are numbered sequentially from upstream to downstream.

Qualitative observations of the site characteristics are also reported and photo documentation serves as references for erosion/sedimentation monitoring. During 2005, all of the sites were connected for approximately 25 days, from May 19 to June 12.

4.0 DISCHARGE RESULTS AND CROSS SECTION SURVEYS

A site by site summary of discharge monitoring results and erosion and sedimentation measurements is presented in this section. Each site analysis includes comparisons of discharge between the inlets and outlet and the Jensen Gage, comparisons of erosion and sedimentation from previous years or as-built surveys, and general observations.

4.1 Thunder Ranch

All elevations used at the Thunder Ranch site including those use in construction drawings, HEC-RAS analysis, cross-section surveys, and discharge measurements are based on a datum that is 99.30 feet higher than the USGS mapping. See the memo in **Appendix D** for further information.

Information regarding the Thunder Ranch site contained within this report represents the first monitoring effort for the site. The Thunder Ranch site (RM 305 to 306.2) is located approximately 3 river miles upstream of the U.S. Highway 40 crossing of the Green River near the town of Jensen, Utah (a.k.a. Jensen Bridge). The site consists of seven constructed inlets along the length of the bottomland and one constructed outlet at the southern end of the bottomland to provide flow through conditions. These inlets and outlet are designed to connect with the Green River when flows in the river range between approximately 12,000 and 16,000 cfs. Reclamation crews from Provo performed the construction of features at Thunder Ranch in May/June 2004. Thus 2005 is the first time the inlets and outlet have received connection flows.

At the Thunder Ranch site all the inlets and outlet had fairly flat and uniform inverts. No aggradation or degradation appeared to have occurred prior to the spring 2005. Most inlets/outlets exhibited moderate (around 40%) regrowth of vegetation. Fences have been erected across the mouths of TR-IN-1, TR-IN-2 and TR-IN-3 reportedly to prevent cattle from accessing the river. TR-IN-4, TR-IN-5, TR-IN-6, TR-IN-7 and TR-OUT had no fences; however TR-IN-5 had signs of cattle accessing the river at its location. There is an existing ditch which drains the fields that lie in the vicinity of TR-IN-1 and TR-IN-2. The ditch may have an effect on the function of these two inlets.

4.1.1 Discharge Monitoring

Three sets of discharge measurements were taken at each of the inlets and outlet. The results of the measurements are presented in Table 1 and discussed below. Estimates of flow in the Green River, noted in Table 1 are determined from the Jensen Gage, adjusted for travel time. Computations are presented in Appendix D

On May 19, 2005 the Thunder Ranch site started to fill when the Green River reached flows of approximately 14,000 cfs on the ascending limb of the hydrograph. Prior to hydraulic connectivity the bottomland had some ponded water at the south end which is most likely due to ground water connection and a perched aquifer that seeps out of a bluff on the east side of the bottomland. The north end of the bottomland was dry. On May 19th through four inlets (TR-IN-3, TR-IN-5, TR-IN-6 and TR-IN-7) and the outlet, TR-OUT water was flowing into the bottomland. The highest inflows were recorded at TR-IN-3, TR-IN-6, and TR-IN-7. TR-IN-2 remained dry while TR-IN-1 and TR-IN-4 were inundated but there was no detectable velocity. A sum total of approximately 125 cfs was flowing into the bottomland at this stage. At the location of the seep conveyance pipe water was overtopping the road constructed parallel to the pipe in two places and erosion was beginning to occur. The road had been constructed with excess material generated onsite and as a result is elevated above the existing ground. This elevated area is what was observed to be eroding.

Table 1. Discharges at Thunder Ranch Site (RM 305.0 to 306.2)

5/19/2005								
LOCATION	TIME	DEPTH RANGE (ft)	AVG. DEPTH (ft)	WIDTH @ WATER SURFACE (ft)	AVG. VEL. (ft/sec)	FEATURE Q (cfs)	JENSEN Q (cfs)*	APPROX. SITE Q (cfs)
TR-IN-1	13:30	-	-	-	-	0	14100	14100
TR-IN-2	13:45	-	-	-	-	0	14100	14100
TR-IN-3	14:15	0.7	0.7	54	0.39	14	14200	14200
TR-IN-4	14:45	-	-	-	-	0	14200	14200
TR-IN-5	15:00	0.3-0.4	0.35	29	0.17	3	14200	14200
TR-IN-6	15:45	1.0-1.7	1.35	56	0.19	14	14100	14100
TR-IN-7	16:15	1.5-2.3	1.9	66	0.12	23	14100	14100
TR-OUT	11:45	1.3-3.0	2.15	46	0.66	71	13700	13700
					NET Q IN=	125		

5/24/2005								
LOCATION	TIME	DEPTH RANGE (ft)	AVG. DEPTH (ft)	WIDTH @ WATER SURFACE (ft)	AVG. VEL. (ft/sec)	FEATURE Q (cfs)	JENSEN Q (cfs)*	APPROX. SITE Q (cfs)
TR-IN-1	10:30	1.2-2.6	1.9	68	0.15	22	19200	19200
TR-IN-2	11:45	0.6-1.1	0.85	57	0.11	6	19400	19400
TR-IN-3	12:30	0.9-1.4	1.15	67	1.16	88	19500	19500
TR-IN-4	13:00	1.6-3.2	2.4	74	0.20	-10	19500	19500
TR-IN-5	14:30	0.8-2.3	1.55	60	1.43	166	19600	19600
TR-IN-6	15:15	1.4-2.8	2.1	68	1.21	188	19600	19600
TR-IN-7	16:00	2.4-3.4	2.9	74	-0.26	-58	19600	19600
TR-OUT	17:15	1.1-4.6	2.85	63	-1.64	-319	19600	19600
					NET Q IN=	83		

5/30/2005								
LOCATION	TIME	DEPTH RANGE (ft)	AVG. DEPTH (ft)	WIDTH @ WATER SURFACE (ft)	AVG. VEL. (ft/sec)	FEATURE Q (cfs)	JENSEN Q (cfs)*	APPROX. SITE Q (cfs)
TR-IN-1	9:15	0.3-1.8	1.05	60	-0.02	-1	16800	16800
TR-IN-2	9:45	-	-	-	-	0	16700	16700
TR-IN-3	10:15	0.4-1.4	0.9	37	1.24	40	16700	16700
TR-IN-4	10:45	0.4-2.1	1.25	50	0.21	4	16700	16700
TR-IN-5	11:15	0.6-1.7	1.15	51	0.57	32	16700	16700
TR-IN-6	11:45	0.2-1.1	0.65	46	0.70	28	16800	16800
TR-IN-7	12:15	0.8-2.3	1.55	69	0.96	82	16800	16800
TR-OUT	13:15	1.4-3.5	2.45	49	-0.76	-100	16800	16800
					NET Q IN=	85		

* NOTES:

1. FEATURE Q with positive values indicate flow into the bottomland, negative values indicate flow out of the bottomland.
2. Estimated flows at Jensen Gage account for time lag between the bottomland site and the gage

On May 24th discharge measurements were taken to represent the runoff peak of approximately 19,600 cfs in the Green River. All inlets/outlets were hydraulically connected at this stage and flow-through was achieved. Flows were being returned to the river from the bottomland through the outlet (TR-OUT). Through two inlets (TR-IN-7 and TR-IN-4) water was also flowing out from the bottomland to the river. The highest inflows were recorded at TR-IN-3, TR-IN-5 and TR-IN-6. A total of approximately 470 cfs was flowing into the bottomland while approximately 390 cfs was flowing out. The 80cfs reduction is most likely the result of natural flow attenuation within the bottomland. It is also possible that there may be minor errors in flow measurements, changes in flows over the time period of measurements, and minor losses within the bottomland such as evaporation, infiltration into the banks, etc.

On May 30th discharge measurements were taken to capture the descending limb of the hydrograph. Flows in the Green River were approximately 16,700 cfs at the time of measurement. Through five inlets water was still flowing into the bottomland (TR-IN-3, TR-IN-4, TR-IN-5, TR-IN-6 and TR-IN-7) with the highest inflows recorded at TR-IN-3, TR-IN-5 and TR-IN-7. TR-IN-2 had some ponding but no moving water. Water was flowing out of the bottomland through TR-OUT as well as slightly through TR-IN-1.

A sum total of approximately 190 cfs was measured flowing into the bottomland while approximately 100 cfs was measured flowing out of the bottomland. It is important to note that prior to these final flow measurements water overtopped the south levee and downcutting eroded notches in the levee. This may account for some of the difference in inflow and outflow measurements. In addition the difference in flows may be due to natural flow attenuation within the bottomland, minor errors in flow measurements, changes in flows over the time period of measurements, and minor losses within the bottomland such as evaporation, infiltration into the banks, etc

All inlets and the outlet connected as predicted by preconstruction analyses. Table 2 summarizes constructed versus post runoff invert elevations as well as target flows for connection and observed flow-connection conditions.

Table 2. As Constructed vs. 2005 Surveyed Conditions at Thunder Ranch Inlets/Outlets

Feature	As Constructed Invert Elevation	Post Runoff Invert Elevation 2005	Target Q For Connection (cfs)	Observations of flow at Features			
				Flow @ Site < 10,000 cfs	Flow @ Site Approx. 14,000 cfs	Flow @ Site Approx. 19,600 cfs	Flow @ Site Approx. 16,700 cfs
TR-IN-1	4833.65	4833.71	11500	Not Connected	Flow In	Flow In	Flow Out
TR-IN-2	4835.00	4834.81	16800	Not Connected	Not Connected	Flow In	Ponded
TR-IN-3	4833.40	4833.67	11900	Not Connected	Flow In	Flow In	Flow In
TR-IN-4	4833.45	4833.36	12933	Not Connected	Flow In	Flow In	Flow In
TR-IN-5	4832.75	4833.05	12000	Not Connected	Flow In	Flow In	Flow In
TR-IN-6	4832.25	4831.91	11166	Not Connected	Flow In	Flow In	Flow In
TR-IN-7	4832.25	4832.00	12000	Not Connected	Flow In	Flow In	Flow In
TR-OUT	4831.30	4829.06	12433	Not Connected	Flow In	Flow Out	Flow Out

4.1.2 Erosion and Sedimentation Monitoring

Post runoff surveys at Thunder Ranch were conducted on August 11, 2005 to assess sedimentation and erosion at each of the inlets and the outlet. When the post-runoff cross section data from the Thunder Ranch site is compared with the pre-runoff/as built data, a trend of deposition can be seen in most of the inlet/outlet bottoms. Overall, the trend of deposition in the Thunder Ranch inlet/outlet bottoms followed a pattern of mounding in the center with drain channels developing along the right and left sides. The inlets/outlets that experienced the most deposition appear to be those that had the highest inflows during runoff. The exception to this appears to be TR-IN-3 which experienced some fairly significant scour along the right and left sides of the inlet bottom. However, TR-IN-3 did have some mounded deposition in the middle of the inlet bottom. TR-IN-2 experienced almost no change overall which was probably due to the near lack of inflows throughout the runoff event. Minor scour occurred along the right side of TR-IN-2 which may be attributed to a slow eddy that was observed to form in the inlet. The outlet (TR-OUT) exhibited some slight mounded deposition around the center of the outlet bottom and almost no scour. The absence of scour in TR-OUT may indicate that the grade control structures are functioning per plan. Table 3 presents a summary of the survey results. Cross section plots are also presented in **Appendix C**.

Table 3. Comparison of Scour (-) and Deposition (+) for the Thunder Ranch Inlet Cross Sections May 2005 to August 2005 (See Appendix C).

Cross Section	Range of Scour (-) & Deposition (+) in feet						Comments
	Left side slope	Left 1/3rd of bottom	Center 1/3rd of bottom	Right 1/3rd of bottom	Right side slope	Average Change in Bottom	
TR-IN-1	0 to +0.5	+0.5	+0.5 to +0.75	+0.75 to +1.5	0 to +1.5	+0.75	Most deposition along middle to right side
TR-IN-2	0	0	0	0	0 to -0.25	0	Some minor bank erosion along right side
TR-IN-3	-3.5 to +1.25	+1.25	+0.75 to +1.25	+0.25 to +0.75	-1.5 to +0.25	+1.0	Significant bank erosion along left and right sides with mounding deposition in center
TR-IN-4	0 to +0.5	+0.5 to +1.75	+1.75 to +2.0	+2.0 to +2.25	0 to +2.0	+1.75	Significant deposition along middle and right side
TR-IN-5	0	0 to +0.25	+0.25 to +0.5	0 to +0.5	0 to -0.75	+0.25	Minor deposition in middle, bank erosion along right side
TR-IN-6	0 to +1.25	+1.25 to +1.75	+1.75 to +2.0	+1.75 to +1.0	-0.75 to +1.0	+1.75	Mounded deposition in bottom of inlet with small drain channel developing along right side
TR-IN-7	0 to +2.0	+1.5 to +2.0	+1.5 to +1.75	+1.5 to 0	0 to -1.0	+1.5	Deposition in bottom of inlet with small drain channel developing along right side
TR-OUT	0	0 to +0.25	+0.25 to +0.75	+0.5 to +0.75	-0.5 to +0.5	+0.5	Small amount of mounded deposition in middle of outlet bottom

4.1.3 Post Runoff Visual Observations

In addition to the cross sectional surveys, visual observations were made on August 11, 2005. The following summarizes these observations. Some of these observations refer to staff gages that were installed in the notches in an attempt to read the water surface slope during flood events. These staff gages were installed at all notches in all five sites. However, many of the gages were inaccessible, covered with debris, underwater, or washed away, making it difficult to take systematic and meaningful readings. The staff gages were useful, however, in making visual observations of erosion and sedimentation in the inlets and outlets during the post-runoff monitoring which is presented in the visual observations section for each site.

TR-IN 1

- Deposition berm has formed across inlet bottom at bank with a small channel scoured along left (upstream) toe of inlet
- Staff gage toward bottomland not showing deposition or aggradation
- Staff gage at cross section has some deposition
- Inlet has some new vegetation growth/also lots of cattle tracks
- Fence is in place, located at the bank of the river across the excavated opening
- Vegetative cover in overbanks and areas outside of inlet unchanged from pre-runoff conditions

TR-IN 2

- Approximately 50% new vegetation cover consisting of short vegetation
- Staff gages not showing deposition or aggradation
- No obvious signs of aggradation or degradation in any area of the inlet
- Fence is in place, located at the bank of the river across the excavated opening
- Vegetative cover in overbanks and areas outside of inlet has not changed from pre-runoff conditions

TR-IN 3

- No vegetation across bottom of inlet
- Sediment is relatively uniform along the length of the inlet bottom with a mound in the middle
- Staff gage toward bottomland ground at 0.6 ft on gage (some deposition)
- Staff gage at cross-section ground at 0.08 ft on gage (little deposition)
- Fence is down (probably during floods)
- Debris snag at inlet along river bank

TR-IN 4

- Sandy notch bottom, less than 50% vegetation cover consisting of short vegetation
- Deposition is visible in notch at the surveyed cross section
- Ground further inland appears to be unaltered
- Banks along the Green between TR-IN 3 and TR-IN 4 has eroded whereby the bank has lost at least 10 feet of bank and accompanying vegetation. Notch appears to be relatively unaffected.

TR-IN 5

- No vegetation across bottom of inlet
- Cross-section staff gage missing
- Staff gage toward bottomland ground at 0.5 ft on gage (some deposition)

TR-IN 6

- Cross-section staff gage reading 1.16 ft at ground (deposition)
- Staff gage toward bottomland ground level at 2.06 feet deep

TR-IN 7

- Cross-section staff gage reading 0.58 ft at ground (deposition)
- Staff gage toward bottomland ground level at 0.09 ft.(little deposition)
- Vegetation growth at least 50% coverage consisting of short vegetation
- Large sand bar has developed in Green River adjacent to inlet. Sand bar was not visible prior to spring runoff.

TR-OUT

- Channel has new cottonwood growth (0.1-0.4 ft tall) throughout notch from the upper grade control at the road crossing, to river
- 2 scour holes developed just upstream (toward the bottomland) of the upper grade control structure
- Lower grade control structure is mostly buried (deposition)
- Staff gage S16A (upper staff gage toward bottomland) has almost fallen over
- Staff gage S16 (lower staff gage toward bottomland) reading 0.70 ft at ground (some deposition)
- Staff gage S15A (upper staff gage at cross-section) reading 0.48 ft at ground (some deposition)
- Staff gage S15 (lower staff gage at cross-section) reading 0.70 ft at ground (some deposition)

Visual observations at TR also include inspection of the siphon, cleanout stand pipes and access road over the top of the seepage pipe located in the center of the property. Based on visual observation, including observations of the siphon vault and downstream manhole, the siphon and seepage pipe appear to be functioning as designed and show no signs of changes due to the flooding. There was some minor erosion at the top of the cleanout stand pipes along the portion of access road. The access road had two locations that eroded from inland flows moving from the upstream inlets to the downstream bottomland and outlet. The sections that eroded appeared to be elevated above the ground on each side of the road. The erosion did not appear to have affected or lowered the ground adjacent to the access road.

4.2 Bonanza Bridge

The Bonanza Bridge site (RM 288.9 to 289.6) is located immediately downstream of the Utah State Highway 45 crossing of the Green River (a.k.a. Bonanza Bridge) and approximately 26.5 miles downstream of the Jensen Gage (RM 316.5). The outlet at Bonanza Bridge was constructed in 1997 with inlets being added in April 2000. Previous monitoring efforts at the Bonanza Bridge site are as follows:

- Erosion and sedimentation monitoring of the river cross sections during the spring of 1996, 1997, and 1998
- Erosion and sedimentation monitoring of the bottomland cross sections during the spring and fall of 1997, spring of 1998 and summer of 2003.
- Erosion and sedimentation monitoring of the outlet cross sections during the spring and summer of 1997, the spring of 1998, the summer of 1999, and the summer of 2003.
- Erosion and sedimentation monitoring of the inlet cross sections during the summer of 2003.

The site has three narrow constructed inlets at its upper end and one constructed outlet to provide flow through conditions. In 2005 connection occurred when the Green River at Jensen reached approximately 14,000 cfs.

Site observations were made prior to runoff in 2005. Each inlet/outlet had very different characteristics. BB-5B, the outlet, is heavily vegetated with young cottonwoods and grasses. BB-IN-1 has less vegetative cover with about 30% to 35% coverage. BB-IN-2 is a deep v-notch constructed through a dune of wind-deposited sand. The sand is quite loose and highly mobile, particularly along the left bank of the inlet. There is very little vegetation along the left bank of this inlet. During the discharge measurements the left bank was observed to be eroding very quickly with large chunks falling into the inlet bottom. BB-IN-3 is also a deep v-notch with denser vegetative cover. In the bottom of the inlet, large Russian Olives have grown near the mouth of the inlet and a stand of dense Salt Cedars have grown further in towards the bottomland. There is evidence of some scour in the bottom of this inlet.

4.2.1 Discharge Monitoring

Three sets of discharge measurements were taken at each of the inlets and outlet. The results of the measurements are presented in Table 4 and discussed below. The flows in the Green River have been estimated by adding flows from Ashley Creek, a tributary to the Green River below Jensen, and lagging the hydrograph for the appropriate time between Jensen and this bottomland site. Details of this analysis are presented in **Appendix D**.

Table 4. Discharges at Bonanza Bridge Site (RM 288.9 to 289.6)

5/19/2005								
LOCATION	TIME	DEPTH RANGE (ft)	AVG. DEPTH (ft)	WIDTH @ WATER SURFACE (ft)	AVG. VEL. (ft/sec)	FEATURE Q (cfs)	JENSEN Q (cfs)*	APPROX. SITE Q (cfs)
BB-IN-1	18:45	-	-	-	-	0	13900	13900
BB-IN-2	18:30	-	-	-	-	0	13900	13900
BB-IN-3	18:00	0.6-1.0	0.8	4	1.26	5	13800	13800
BB-5B	19:00	-	-	-	-	0	14000	14000
					NET Q IN=	5		

5/25/2005								
LOCATION	TIME	DEPTH RANGE (ft)	AVG. DEPTH (ft)	WIDTH @ WATER SURFACE (ft)	AVG. VEL. (ft/sec)	FEATURE Q (cfs)	JENSEN Q (cfs)*	APPROX. SITE Q (cfs)
BB-IN-1	9:30	0.3-1.5	0.9	8	0.64	8	19300	21998
BB-IN-2	10:15	0.8-3.4	2.1	27	1.41	82	19300	21849
BB-IN-3	10:45	1.0-2.9	1.95	12	1.45	32	19300	21750
BB-5B	8:30	0.5-2.6	1.55	148	-0.32	-112	19300	22196
					NET Q IN=	10		

5/30/2005								
LOCATION	TIME	DEPTH RANGE (ft)	AVG. DEPTH (ft)	WIDTH @ WATER SURFACE (ft)	AVG. VEL. (ft/sec)	FEATURE Q (cfs)	JENSEN Q (cfs)*	APPROX. SITE Q (cfs)
BB-IN-1	17:30	-	-	-	-	0	16800	18538
BB-IN-2	17:45	0.7-2.3	1.5	12	0.85	22	16700	18432
BB-IN-3	18:15	0.5-2.1	1.3	11	1.21	19	16800	18521
BB-5B	17:00	0.7-1.8	1.25	128	-0.09	-19	16800	18549
					NET Q IN=	22		

*NOTES:

1. FEATURE Q with positive values indicate flow into the bottomland, negative values indicate flow out of the bottomland.
2. Estimated flows at Jensen Gage account for time lag between the bottomland site and the gage
3. Flows at the bottomland site include additional flows from Ashley Creek. See Appendix D.

Prior to surface water connection, the Bonanza Bridge site had some shallow ponded water which could have been the result of heavier than usual spring rains and/or ground water connectivity. The Bonanza Bridge site began to fill on May 19th with approximately 13,900 cfs in the Green River at the site. BB-IN-3 was the only inlet with measurable inflow at a rate of 5 cfs. BB-IN-2 was starting to flow but not enough to facilitate data collection. BB-IN-1 was dry (water surface measurements indicated the invert of the inlet remained approximately 0.5 feet above the water level adjacent to the inlet). BB-5B (the outlet cross section) was also dry.

On May 25th with approximately 21,900 cfs in the Green River at the site, all the inlets/outlets were hydraulically connected and flow through was achieved. Water was flowing into the bottomland through all three of the inlets and out of the bottomland through the outlet. The highest flows recorded were at BB-IN-2 and BB-IN-3. An approximate total of 120 cfs was flowing into the bottomland and approximately 110 cfs was flowing out. The 10 cfs reduction is most likely the result of natural flow attenuation within the bottomland. It is also possible that there may be minor errors in flow measurements, changes in flows over the time period measurements were taken as well as minor losses within the bottomland such as evaporation, infiltration into the banks, etc.

On May 30th with approximately 18,500 cfs in the Green River at the site, BB-IN-1 became disconnected. Inflow was occurring at BB-IN-2 and BB-IN-3. Flows were being returned to the river from the bottomland through the outlet (BB-5B). An approximate total of 40 cfs was flowing into the bottomland and approximately 20 cfs of outflow was measured at the outlet.

The outlet, BB-5B, connected at a higher discharge than predicted by preconstruction analyses. Table 5 summarizes constructed versus post runoff invert elevations as well as target flows for connection and observed overtopping conditions. Inlets BB-IN-2 and BB-IN-3 connected under slightly higher flows than anticipated, while BB-IN-1 is not connecting until flows are in excess of 18,500 cfs. Based on review of past notes and data collection, BB-IN-1 may have been set too high. Further discussion is presented in the following section.

Table 5. As Constructed vs. 2005 Surveyed Conditions at Bonanza Bridge Site

Feature	As Constructed Invert Elevation	Pre-Runoff Invert Elevation 2005	Target Q For Connection (cfs)	Observations of flow at Features			
				Flow @ Site < 10,000 cfs	Flow @ Site Approx. 13,900 cfs	Flow @ Site Approx. 19,700 cfs	Flow @ Site Approx. 18,500 cfs
BB-IN-1	4705.62	4705.26	13000	Not Connected	Not Connected	Flow In	Not Connected
BB-IN-2	4705.05	4704.22	13000	Not Connected	Not Connected	Flow In	Flow In
BB-IN-3	4704.63	4703.94	13000	Not Connected	Flow In	Flow In	Flow In
BB-5B	4704.83	4704.84	13000	Not Connected	Not Connected	Flow Out	Flow Out

4.2.2 Erosion and Sedimentation Monitoring
Only pre-runoff surveys at Bonanza Bridge were conducted in 2005 and compared with as-constructed surveys and observations made since 1998. Cross sections plots are presented in Appendix C and discussed below.

Based on cross section surveys, it appears that the outlet, BB-5B, overall is lower in elevation since it was constructed in 1997. However, comparisons of current conditions with July 2003 show relatively little change. A small drain channel toward the left side of the cross section experienced some deposition, and minor scour along the right side of the cross section created a new invert around station 1+50. Since 1997, the outlet area has established dense young cottonwoods throughout its entire width.

Comparison of surveys since construction for inlets BB-IN-2, and BB-IN-3 show an overall trend of degradation, although inverts in 2005 where slightly higher than 2003. Since it is unlikely that connectivity (flooding of the bottomland site) has occurred between July 2003 and May 2005, it is probable the aggradation is due to aeolian deposits. Aeolian deposition may also be causing a slight upstream migration (horizontal shift) of inlet BB-IN-2. Human activities may also have contributed to changes in the inlet configurations as there were signs of ATV use in the area. BB-IN-2 and BB-IN-3 are developing dense vegetation in their channels. Large sand deposits projecting from BB-IN-2, and BB-IN-3 toward the bottomland, first noted during the July 2003 monitoring effort (Tetra Tech, Inc. 2003) still project from the inlets 2 and 3 into the bottomland. It appears that the narrow inlet channels maintain sand transport in the flows, depositing sediment as flows slow down upon entering the bottomland. The missing LEP of BB-IN-2 was reset.

BB-IN-1 shows little sign of change since construction and since 2003 and appears to be too high for proper connection at the desired flows of 13,000 cfs (at Jensen). The original design for BB included only an outlet. To establish an invert elevation at the outlet a rating curve was developed using surveyed information for a range of flows. Unfortunately this information was only collected at the outlet. Thus it appears the inlets were designed using a HECRAS model and surveyed cross sections but without calibration measurements. The estimated rating curve for flow versus elevation for the inlets appears to be too high. However, current surveys indicate that inlets BB-IN-2 and BB-IN-3 have scoured to lower elevations, and are currently connecting at 14,000 cfs. BB-IN-1 however, has not had sufficient flow to create a scoured invert.

4.2.3 Post Runoff Observations
No cross-sectional surveys were performed following this years' runoff, however, visual observations were made on August 11, 2005. The following summarizes these observations:

<u>BB-IN-1</u>
BB-IN-1 showed little change from this years' runoff. Some very minor scour and localized aggradation occurred but not enough to disturb the existing vegetation.

<u>BB-IN-2</u>
BB-IN-2 also appeared to have experienced little change from this years flooding. Observations made during the runoff indicate that this area may scour during inflows (while the bottomland is filling) and aggrade following the peak flows. Based on visual observations it appears that there may be some aggradation overall with localized scour along the right side of the inlet bottom. It is also possible that some brush and grass vegetation may have been removed near the river bank during the flooding.

<u>BB-IN-3</u>
BB-IN-3 showed little change from this years' runoff. The ground elevation at the staff gage is relatively unchanged, although observations made during runoff indicate that this area may scour during inflows (while the bottomland is filling) and aggrade following the peak flows. Along the inlet area closer to the bottomlands there is a thick Russian Olive stand which should be removed to maintain good channel conveyance into the bottomlands.

BB-5B

The condition of this outlet area following runoff appeared to be very similar to conditions before runoff. There were no notable areas of degradation or aggradation and the ground cover and vegetation appeared to be in similar conditions as pre-flooding.

4.3 Stirrup

The Stirrup site (RM 275.7) is located at the upstream end of a geologic formation known as The Stirrup, approximately 14 river miles downstream of Bonanza Bridge. The site has one constructed inlet/outlet to provide backwater conditions for discharges above approximately 13,000 cfs. Previous monitoring efforts at the Stirrup site are as follows:

- Erosion and sedimentation monitoring of the river cross sections during the spring of 1996, 1997, and 1998
- Erosion and sedimentation monitoring of the bottomland cross sections during the spring of 1997, spring of 1998 and summer of 1999.
- Erosion and sedimentation monitoring of the inlet/outlet cross section during the spring of 1997, spring of 1998, and summer of 1999.

At the Stirrup site the single inlet/outlet is a deep v-notch. There is moderate to sparse vegetation in the inlet/outlet. The Stirrup bottomland was nearly full with water when the site was visited prior to runoff.

During the runoff measurements it was observed that water moves very slowly into the bottomland area. Since the bottomland was nearly full prior to connection through the inlet/outlet, the reduced hydraulic head between the river and the bottomland at the time of connection explains the slow movement of water into the bottomland.

4.3.1 Discharge Monitoring

Three sets of discharge measurements were taken at the single inlet/outlet. The results of the measurements are presented in Table 6 and discussed below. The flows in the Green River have been estimated by adding flows from Ashley Creek, a tributary to the Green River below Jensen, and lagging the hydrograph for the appropriate time between Jensen and this bottomland site. Details of this analysis are presented in **Appendix D**.

Table 6. Discharges at Stirrup Site (RM 275.7)

5/20/2005								
LOCATION	TIME	DEPTH RANGE (ft)	AVG. DEPTH (ft)	WIDTH @ WATER SURFACE (ft)	AVG. VEL. (ft/sec)	FEATURE Q (cfs)	JENSEN Q (cfs)*	APPROX. SITE Q (cfs)
ST-OUT	11:45	3.0-3.5	3.25	13	0.32	6	13900	13900
					NET Q IN=	6		
5/25/2005								
LOCATION	TIME	DEPTH RANGE (ft)	AVG. DEPTH (ft)	WIDTH @ WATER SURFACE (ft)	AVG. VEL. (ft/sec)	FEATURE Q (cfs)	JENSEN Q (cfs)*	APPROX. SITE Q (cfs)
ST-OUT	18:30	1.5-3.4	2.45	22	0.11	7	19500	21596
					NET Q IN=	7		
5/30/2005								
LOCATION	TIME	DEPTH RANGE (ft)	AVG. DEPTH (ft)	WIDTH @ WATER SURFACE (ft)	AVG. VEL. (ft/sec)	FEATURE Q (cfs)	JENSEN Q (cfs)*	APPROX. SITE Q (cfs)
ST-OUT	15:45	1.0-2.4	1.7	17	0.09	3	16700	18500
					NET Q IN=	3		

*NOTES:

1 FEATURE Q with positive values indicate flow into the bottomland, negative values indicate flow out of the bottomland.
2 Estimated flows at Jensen Gage account for time lag between the bottomland site and the gage
3 Flows at the bottomland site include additional flows from Ashley Creek. See Appendix D.

The site became hydraulically connected somewhere between 11,000 and 13,400 cfs. On May 20th the site was filling at a rate of 6 cfs through its only inlet/outlet (ST-OUT). This corresponded to a discharge in the Green River of 13,900 cfs. On May 25th the bottomland was still filling slowly at a rate of 7 cfs. Discharge at the Jensen Gage at this time was 19,500 cfs with an estimated 21,600 cfs at the site.

On May 30th, inflows were observed at the Stirrup site at a rate of 3 cfs. Inflows were not expected but were probably caused by diurnal fluctuations in the river discharge. A small upturn in the hydrograph could cause flows to move into the bottomland site versus out.

The inlet/outlet connected as predicted by preconstruction analyses, although there appears to be some erosion in the inlet/outlet resulting in slightly lower flows required to overtop. Table 7 summarizes constructed versus post runoff invert elevations as well as target flows for connection and observed overtopping conditions.

Table 7. As Constructed vs. 2005 Surveyed Conditions at Stirrup Site

Feature	As Constructed Invert Elevation	Pre-Runoff Invert Elevation 2005	Target Q For Connection (cfs)	Observations of flow at Features			
				Flow @ Site < 10,000 cfs	Flow @ Site Approx. 13,900 cfs	Flow @ Site Approx. 21,600 cfs	Flow @ Site Approx. 18,500 cfs
ST-OUT	4686.80	4685.46	13000	Not Connected	Flow In	Flow In	Flow In

4.3.2 Erosion and Sedimentation Monitoring:

Only pre-runoff surveys at Stirrup were conducted in 2005 and compared with as-constructed surveys and observations made since 1998. Cross sections plots are presented in Appendix C and discussed below.

Comparison of this years pre runoff surveys with as constructed elevation shows the invert to have degraded by approximately 1 ½ feet with a slight narrowing of the inlet/outlet. Note that true cross section endpoints were established for the first time this year. Thus comparison of future surveys should be a more accurate and reliable representation of the cross section.

4.3.3 Post Runoff Observations

No cross sectional surveys were performed following this year's flooding, however, visual observations were made on August 12, 2005. The following summarizes these observations.

<u>ST-OUT</u>

It is possible that there may be a trend toward degradation in this inlet/outlet. However, the condition of the outlet area following flooding appeared to be very similar to conditions before flooding. There were no notable areas of scour and the ground cover and vegetation appeared to be in similar conditions as pre-flooding. The bottomland was filling during all site visits and could be the result of the immediate response (and relatively small size) of the bottomland to the diurnal fluctuations of the river and upturn of the hydrograph.

4.4 Baeser

The Baeser site (RM 272.7) is located at the downstream end of the geologic formation known as The Stirrup, approximately 17 river miles downstream of Bonanza Bridge. Like the Stirrup site, the Baeser site has one constructed inlet/outlet to provide backwater conditions for discharges above approximately 13,000 cfs. The Baeser inlet/outlet was constructed in the fall of 1997. Previous monitoring efforts at the Baeser site are as follows:

- Erosion and sedimentation monitoring of the river cross sections during the spring of 1996, 1997, and 1998
- Erosion and sedimentation monitoring of the bottomland cross section during the spring of 1998.
- Erosion and sedimentation monitoring of the inlet/outlet cross section during the spring of 1998 and the summer of 1999.

The Baeser inlet/outlet consists of a deep v-notch with erosion in the inlet near the river and along the river bank. There are some grasses growing in the inlet near the river and heavy grass and Russian Olive growth farther in toward the bottomland. There was water standing in the bottomland prior to the runoff and rows of nets have been installed in the bottomland for larval survival studies. A broad crested weir about 1.8 feet wide made of sandbags had been placed across the inlet for unknown reasons.

4.4.1 Discharge Monitoring

Three sets of discharge measurements were taken at each of the inlets and outlet. The results of the measurements are presented in Table 8 and discussed below. The flows in the Green River have been estimated by adding flows from Ashley Creek, a tributary to the Green River below Jensen, and lagging the hydrograph for the appropriate time between Jensen and this bottomland site. Details of this analysis are presented in **Appendix D**.

Table 8. Discharges at Baeser Site (RM 272.7)

5/20/2005								
LOCATION	TIME	DEPTH RANGE (ft)	AVG. DEPTH (ft)	WIDTH @ WATER SURFACE (ft)	AVG. VEL. (ft/sec)	FEATURE Q (cfs)	JENSEN Q (cfs)*	APPROX. SITE Q (cfs)
BA-MON-INLET	12:45	1.7-3.2	2.45	19	0.2	10	13600	13700
					NET Q IN=	10		

5/25/2005								
LOCATION	TIME	DEPTH RANGE (ft)	AVG. DEPTH (ft)	WIDTH @ WATER SURFACE (ft)	AVG. VEL. (ft/sec)	FEATURE Q (cfs)	JENSEN Q (cfs)*	APPROX. SITE Q (cfs)
BA-MON-INLET	17:30	1.3-3.4	2.35	33	0.22	26	19400	21578
					NET Q IN=	26		

5/31/2005								
LOCATION	TIME	DEPTH RANGE (ft)	AVG. DEPTH (ft)	WIDTH @ WATER SURFACE (ft)	AVG. VEL. (ft/sec)	FEATURE Q (cfs)	JENSEN Q (cfs)*	APPROX. SITE Q (cfs)
BA-MON-INLET	11:15	0.3-1.2	0.75	30	0.16	5	17000	18434
					NET Q IN=	5		

*NOTES:
1 FEATURE Q with positive values indicate flow into the bottomland, negative values indicate flow out of the bottomland.
2 Estimated flows at Jensen Gage account for time lag between the bottomland site and the gage
3 Flows at the bottomland site include additional flows from Ashley Creek. See Appendix D.

On May 18th during the pre-runoff survey the inlet/outlet at the Baeser site was already flowing into the bottomland. This corresponded to a river discharge of approximately 11,500 cfs. On May 20th the first discharge measurement was taken in the inlet/outlet. Water was flowing into the bottomland at a rate of 10 cfs. Discharges in the river, at the site were approximately 13,700 cfs. Scour holes had formed in the inlet/outlet indicating high velocities while the bottomland is filling.

On May 25th, at a river discharge at the site of approximately 21,600 cfs water was flowing slow and deep into the bottomland at a rate of 26 cfs.

The final discharge measurement at the Baeser site was conducted on May 30th. Discharges in the river at the site were approximately 18,400 cfs. Like the Stirrup site, water was still flowing slowly into the bottomland at a rate of 5 cfs despite being on the descending limb of the hydrograph. This could be the result of the immediate response (and relatively small size) of the bottomland to the diurnal fluctuations of the river and upturn of the hydrograph.

The inlet/outlet connected as predicted by preconstruction analyses. Table 9 summarizes constructed versus pre-runoff invert elevations as well as target flows for connection and observed overtopping conditions.

Table 9. As Constructed vs. 2005 Surveyed Conditions at Baeser Site

Feature	As Constructed Invert Elevation	Pre-Runoff Invert Elevation 2005	Target Q For Connection (cfs)	Observations of flow at Features			
				Flow @ Site < 10,000 cfs	Flow @ Site Approx. 13,700 cfs	Flow @ Site Approx. 21,600 cfs	Flow @ Site Approx. 18,400 cfs
BA-MON-INLET	4682.60	4680.68	14000	Not Connected	Flow In	Flow In	Flow In

4.4.2 Erosion and Sedimentation Monitoring
Only pre-runoff surveys at Baeser were conducted in 2005 and compared with as-constructed surveys and observations made since 1998. Cross sections plots are presented in Appendix C and discussed below.

The bottom of the Baeser inlet has scoured several feet since the last monitoring data were collected. This was visually evident by the fact that water was already flowing into the bottomland at the time of pre-runoff data collection. A fairly deep drain channel has developed near the center of the inlet/outlet bottom. Review of several years' data indicate the inlet/outlet may experience fluctuations in aggradation and degradation, however, overall there appears to be a long term trend for degradation.

4.4.3 Post Runoff Observations
No cross-sectional surveys were performed following this years flooding, however, visual observations were made on August 12, 2005. The following summarizes these observations:

<u>BA-MON-INLET</u>
During visual post runoff observations it was noted that the scoured drain channel evident in the cross section surveys had filled with sediment. Fine sediment appeared to have been deposited throughout the entire inlet/outlet. The condition of the outlet area following this years flooding indicates some loss of vegetation; primarily shrubs and grasses, however, there were no notable areas of scour left behind. The inlet/outlet was filling during each site visit and could be the result of the immediate response (and relatively small size) of the bottomland to the diurnal fluctuations of the river and upturn of the Green River hydrograph.

This inlet/outlet also had been reconfigured in a previous year with the construction of a sand bag weir. This weir may have caused localized scour during the flood event but appeared to be demolished by the completion of this years flood.

4.5 Above Brennan

The Above Brennan site (RM 267.9 to 269.0) is located approximately 21 river miles downstream of Bonanza Bridge. Similar to the Bonanza Bridge site, the Above Brennan site has three narrow constructed inlets at its upper end and one constructed outlet to provide flow through conditions. Flow-through conditions occur above approximately 13,000 cfs. The outlet at Above Brennan was constructed in 1997. Inlets at this site were constructed in April 2000. Previous monitoring efforts at the Above Brennan site are as follows:

- Erosion and sedimentation monitoring of the river cross sections during the spring of 1996, 1997, and 1998
- Erosion and sedimentation monitoring of the bottomland cross sections during the summer of 2003.
- Erosion and sedimentation monitoring of the outlet cross section during spring and fall of 1998 and the summer of 2003.
- Erosion and sedimentation monitoring of the inlet cross sections during the summer of 2003.

The Above Brennan bottomland was dry and covered with young vegetation prior to runoff. Each inlet and outlet at the Above Brennan site had very distinct characteristics. At AB-IN-1 a considerable amount of erosion was observed. Two large scour holes have developed in the bottom of the inlet. The banks along the inlet have been eroding and there is very little vegetation in the inlet. A sand bag weir had been placed across the mouth of the inlet similar to that of the Baeser site. There is a thick stand of young willows at the mouth of AB-IN-2. Farther in towards the bottomland there is less growth with about 50% coverage with no notable aggradation or degradation visible by observation. At AB-IN-3 there were thick stands of young willows near the river. From the endpoints and farther back toward the bottomland the AB-IN-3 inlet is sandy with little vegetation. The outlet, AB-OUT, is located in a wooded area at the south end of the bottomland site. There are large cottonwoods and some scattered debris around the outlet. There are no signs of significant aggradation or degradation. Under growth is relatively thin or non-existent in the outlet and the adjacent area, which may be due to the heavy canopy from the cottonwood trees. Note that the drawing of AB (Appendix A) shows four inlets. However, only three have been constructed and are being monitored.

4.5.1 Discharge Monitoring

Three sets of discharge measurements were taken at each of the inlets and outlet. The results of the measurements are presented in Table 10 and discussed below. The flows in the Green River have been estimated by adding flows from Ashley Creek, a tributary to the Green River below Jensen, and lagging the hydrograph for the appropriate time between Jensen and this bottomland site. Details of this analysis are presented in **Appendix D**.

Table 10. Discharges at Above Brennan Site (RM 267.9 to 269.0)

5/20/2005								
LOCATION	TIME	DEPTH RANGE (ft)	AVG. DEPTH (ft)	WIDTH @ WATER SURFACE (ft)	AVG. VEL. (ft/sec)	FEATURE Q (cfs)	JENSEN Q (cfs)*	APPROX. SITE Q (cfs)
AB-IN-1	10:30	1.3-3.2	2.25	18	1.45	53	14100	15131
AB-IN-2	10:15	0.3-0.4	0.7	4	0.45	1	14000	15012
AB-IN-3	9:45	0.2-0.6	0.4	12	0.69	4	14100	15073
AB-OUT	7:45	0.9-2.9	1.9	33	0.7	48	14200	15017
					NET Q IN=	105		

5/25/2005								
LOCATION	TIME	DEPTH RANGE (ft)	AVG. DEPTH (ft)	WIDTH @ WATER SURFACE (ft)	AVG. VEL. (ft/sec)	FEATURE Q (cfs)	JENSEN Q (cfs)*	APPROX. SITE Q (cfs)
AB-IN-1	13:30	0.6-4.9	2.75	25	1.68	151	19600	21948
AB-IN-2	14:30	0.7-2.8	1.75	82	0.36	32	19500	21824
AB-IN-3	15:30	1.4-3.2	2.3	21	1.42	84	19600	21900
AB-OUT	16:30	0.9-5.5	3.2	49	1.46	-223	19400	21671
					NET Q IN=	43		

5/31/2005								
LOCATION	TIME	DEPTH RANGE (ft)	AVG. DEPTH (ft)	WIDTH @ WATER SURFACE (ft)	AVG. VEL. (ft/sec)	FEATURE Q (cfs)	JENSEN Q (cfs)*	APPROX. SITE Q (cfs)
AB-IN-1	8:45	1.9-3.9	2.9	19	1.37	74	16900	18462
AB-IN-2	9:30	0.6-1.1	0.85	12	0.97	11	16800	18341
AB-IN-3	9:45	1.1-2.0	1.55	19	0.75	26	16700	18233
AB-OUT	10:30	1.1-4.4	2.75	39	0.72	-104	16800	18312
					NET Q IN=	7		

*NOTES:

1 FEATURE Q with positive values indicate flow into the bottomland, negative values indicate flow out of the bottomland.
2 Estimated flows at Jensen Gage account for time lag between the bottomland site and the gage
3 Flows at the bottomland site include additional flows from Ashley Creek. See Appendix D.

At the time of the pre-runoff survey on May 18th water was observed to be flowing into the bottomland through the outlet (AB-OUT). Discharges in the river at this time were 11,100 cfs. There was no standing water in the inlets and the bottomland area was dry. The bottomland area was covered by vegetation and appeared to have been dry for an extended period of time. The Above Brennan site became hydraulically connected somewhere between river discharges at the site of 11,000 cfs and 13,400 cfs. On May 20th the first round of discharge measurements were taken. All inlets and outlets were flowing into the bottomland. The highest flows were recorded at AB-IN-1 and AB-OUT. A total of approximately 105 cfs was flowing into the bottomland. River discharges at this time were approximately 15,000 cfs.

On May 25th discharge measurements were taken to capture conditions at the peak discharge. Flow through conditions had been achieved with all three inlets flowing into the bottomland and flows returning to the river through the outlet. The highest inflow was coming through AB-IN-1 which was flowing fast and deep. AB-IN-3 was also flowing fairly fast and deep. The monitoring cross section for AB-IN-2 was completely inundated as was the case for most of the overbank areas around the bottomland. An approximate total of 270 cfs was flowing into the bottomland while approximately 225 cfs was flowing out. The 45 cfs reduction is most likely the result of natural flow attenuation within the bottomland. It is also possible that there may be minor errors in flow measurements, changes in flows over the time period measurements were taken as well as minor losses within the bottomland such as evaporation, infiltration into the banks, etc. Flows in the Green River at this time were estimated at the site to be approximately 21,800 cfs.

The descending limb discharge measurements were taken on May 31st with flows in the river at the site of approximately 18,300 cfs. Flow through conditions still existed in the bottomland. The highest inflow was through AB-IN-1 which was flowing fast and deep. AB-IN-3 was also still flowing fairly fast and deep. A total of approximately 110 cfs was flowing into the bottomland while approximately 105 cfs was flowing out. Much of the wooded areas surrounding the bottomland were still inundated.

All inlets connected as predicted by preconstruction analyses. Table 11 summarizes constructed versus post runoff invert elevations as well as target flows for connection and observed overtopping conditions.

Table 11. As Constructed vs. 2005 Surveyed Conditions at Above Brennan Site

Feature	As Constructed Invert Elevation	Pre-Runoff Invert Elevation 2005	Target Q For Connection (cfs)	Observations of flow at Features			
				Flow @ Site < 10,000 cfs	Flow @ Site Approx. 15,000 cfs	Flow @ Site Approx. 21,800 cfs	Flow @ Site Approx. 18,300 cfs
AB-IN-1	4675.93	4674.94	13000	Not Connected	Flow In	Flow In	Flow In
AB-IN-2	4675.90	4675.48	13000	Not Connected	Flow In	Flow In	Flow In
AB-IN-3	4676.00	4675.10	13000	Not Connected	Flow In	Flow In	Flow In
AB-OUT	4674.32	4672.48	13000	Not Connected	Flow In	Flow Out	Flow Out

4.5.2 Erosion and Sedimentation Monitoring

Only pre-runoff surveys at Above Brennan were conducted in 2005 and compared with as-constructed surveys and observations made since 2000. Cross sections plots are presented in Appendix C and discussed below.

The invert of AB-IN-1 showed some signs of erosion. As seen in the cross section survey (Appendix C) there appears to be one foot of erosion which has occurred since 2003. However, flows in the Green River only reached 11,400 cfs in 2004, which should not have been high enough to overtop the invert. The inlet erosion could be accounted for in two ways. First, there has been some modification done to the inlet as made evident by the placement of sandbags across the mouth of the inlet. Installation of these sandbags may have involved some minor excavation. Second, some error may have been incurred during data collection as the banks of AB-IN-1 are steep and difficult to survey. AB-IN-2 showed no significant change. AB-IN-3 showed minor deposition through the bottom of the inlet. This deposition may be due to wind deposited sand as this inlet is cut through a sandy portion of the levee. The outlet at the Above Brennan site had not been fully surveyed since the summer of 1999. Since that time the Green River has exceeded 13,000 cfs, and potentially achieved flow-through conditions, three times; once in 2000, once in 2001, and once in 2003. When compared with the 1999 survey, this years survey shows approximately 1 ½ feet of scour around the invert of the channel. Minor deposition occurred along the right bank.

4.5.3 Post Runoff Observations

No cross sectional surveys were performed following this years' flooding, however, visual observations were made on August 12, 2005. The following summarizes these observations.

AB-IN-1

This inlet showed little change from this years flooding between pre and post flood events. However, observations made during the flood event indicate that this area may scour from inflows while the bottomland is filling, and aggrade following the peak flows. It is also possible that some brush and grass vegetation may have been removed near the river bank during the flooding. This inlet also had been reconfigured in a previous year with the installation of sandbags. These sandbags may have caused localized scour during the flood event but appeared to be demolished by the completion of this years flood.

AB-IN-2

This inlet showed little change from this years flooding.

AB-IN-3

This inlet showed little change from this years flooding. The ground elevation at the staff gage is relatively unchanged.

AB-OUTLET

The condition of the outlet area following flooding appeared to be very similar to conditions before flooding. There were no notable areas of degradation or aggradation and the ground cover and vegetation appeared to be in similar conditions as pre-flooding.

5.0 RELATIONSHIP OF GREEN RIVER FLOWS AND FLOWS AT BOTTOMLAND SITES

The purpose of comparing inflows to the bottomlands versus flows in the Green River is to evaluate the effectiveness of the inlets and outlets in diverting flows from the main stem, and in particular, the relative importance of having both inlets and outlets in a bottomlands area versus a single opening. The relationship between flows in the Green River and inflows/outflows to a bottomland site is a complex system dependent on many factors, some of which include Green River flows and temporal location on the hydrograph (ascending, descending or peak), depth of water in the river and at the inlets and outlets, depth of water in the bottomlands, hydraulic gradient across the bottomland site, volume of water in the bottomlands or volume of storage available, and rate of change in discharges in the river. These factors are discussed briefly, below. Because sites with multiple openings appear to be behaving differently than those with single openings, they are addressed separately.

5.1 Bottomlands with Inlets and Outlets

The expected performance of these sites is that all openings (inlets and outlets) initially capture flows. Flows, or volumetric rate, are a function of the elevation of the river at the inlets and outlets, geometry of the opening, and level and volume of water already contained in the wetlands, either from earlier flooding or from groundwater connectivity. Once the site is full the outlets begin to discharge into the river and a flow-through is achieved between the inlets and outlets with volumetric rates being controlled by hydraulic gradient of the river, and attenuating factors of the bottomland.

Of the five sites that were monitored for flow rates in 2005, three have inlets and outlets (TR, BB and AB). All three responded relatively closely to expectations. Initially, inflows were measured at the outlets of both TR and AB, which each appeared to fill rapidly. It is possible that BB also experienced inflow through the outlet, but if this occurred, it happened between the first and second monitoring efforts and therefore was not observed or measured. Based on the three sets of measurements taken this year, the maximum net inflow at TR and AB was achieved prior to the river peak. Once the site was at or above the elevation of the outlet, the net flow-through at these two sites was controlled by the hydraulic gradient in the river. TR measured relatively high flow-through rates on the descending limb of the hydrograph, however, the south levee had overtopped prior to the May 30 measurements. Thus it is possible that the high flow-through was due, in part, to the levee overtopping.

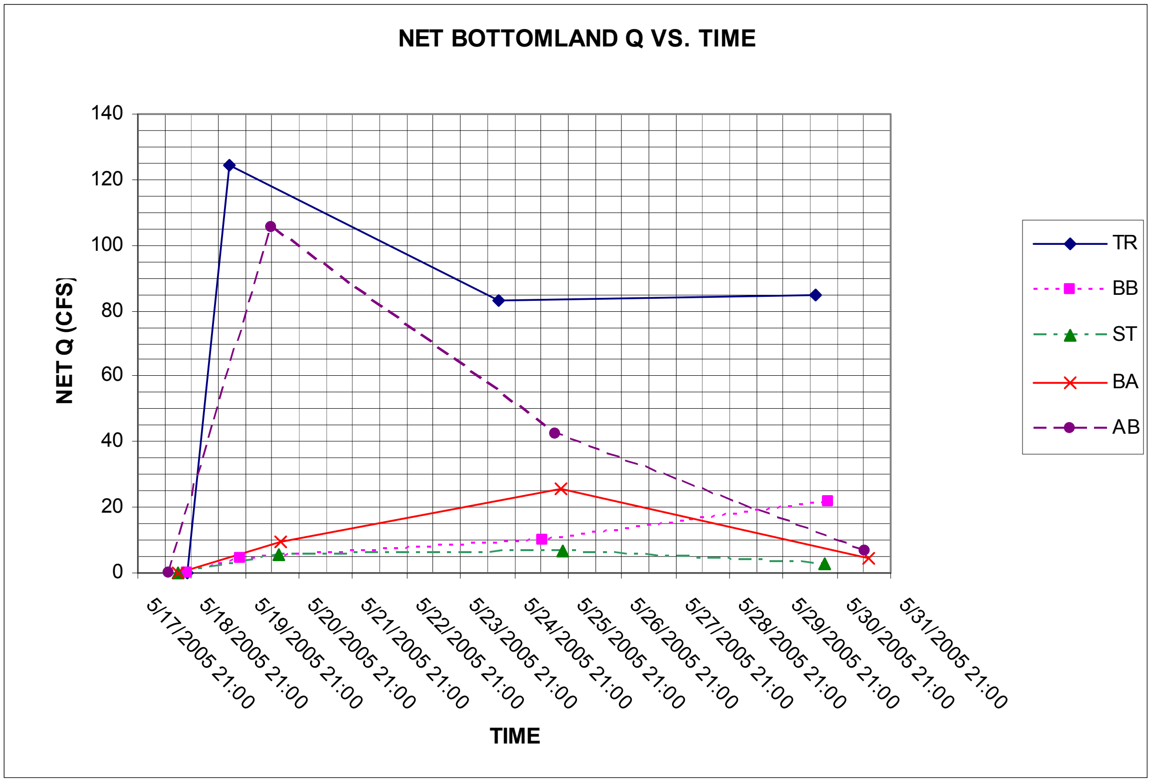
5.2 Bottomlands with Single Notches

At the bottomland sites with single openings (ST and BA) the sites appeared to fill rapidly, and achieved a slow or low inflow rate once filled. During 2005 ST and BA sites both had flows moving into the bottomlands for all recorded flow conditions, even on the descending limb of the hydrograph. This was not expected. However, a review of the Green River flows on May 30 to 31, during the time period flows where measured at ST and BA, indicate that flows rose slightly accounting for the increase in river elevations and inflow to these two sites.

5.3 Functional Trends/Conclusions

Figures 1 and 2 are plots of inflow versus time for all five sites. These plots are placed below the Green River hydrograph to show the relative timing of peak flows on the Green River versus the five monitored sites. Figure 1 depicts net inflow (inflow minus outflow) to each site; Figure 2 depicts total inflow. Based on this plot and other data presented herein it appears that the multiple openings (inlets and outlets) have several advantages over single notch opening in diverting flows from the main stem. First, the relatively high inflows achieved early in test period, at Thunder Ranch and Above Brennan is due to rapid filling through all the inlets plus filling through the outlet. With these high inflows occurring early in the runoff hydrograph, it is possible that a higher percentage of river flow is captured, which in turn, increases the likelihood for entraining drifting larvae if they are present. Second, these sites will achieve a steady flow-through condition as river flows equalize which, in turn increases the potential for capturing drifting larvae by increasing the time and amount of flows being diverted into the bottomland site. Perhaps the most dominant factor observed this year is depth and volume of water in the bottomlands. This impacts the hydraulic gradient within the site and ability of the site to capture flows. Figure 2 clearly shows the relative differences in volumes of flow-through for the multiple opening sites versus the single opening sites with ST and BA showing relatively low volumes of inflow in comparison.

Figure 1. Net Inflow to Bottomland Sites versus Time



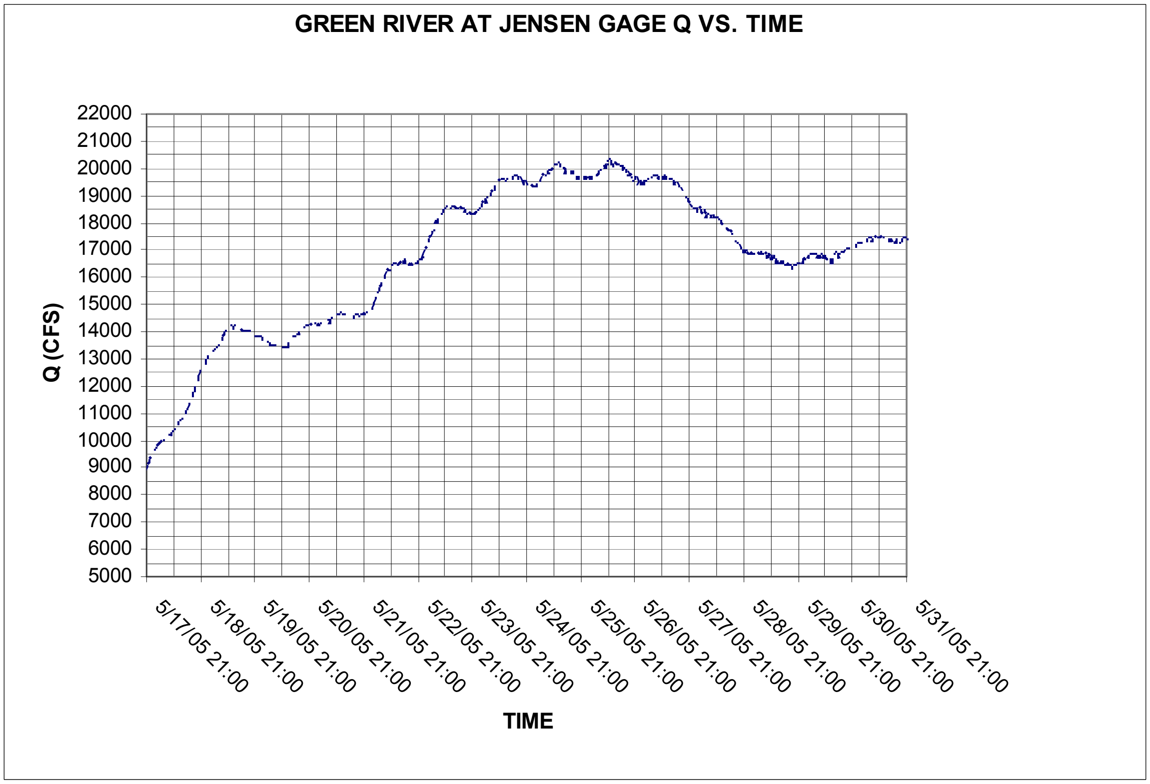
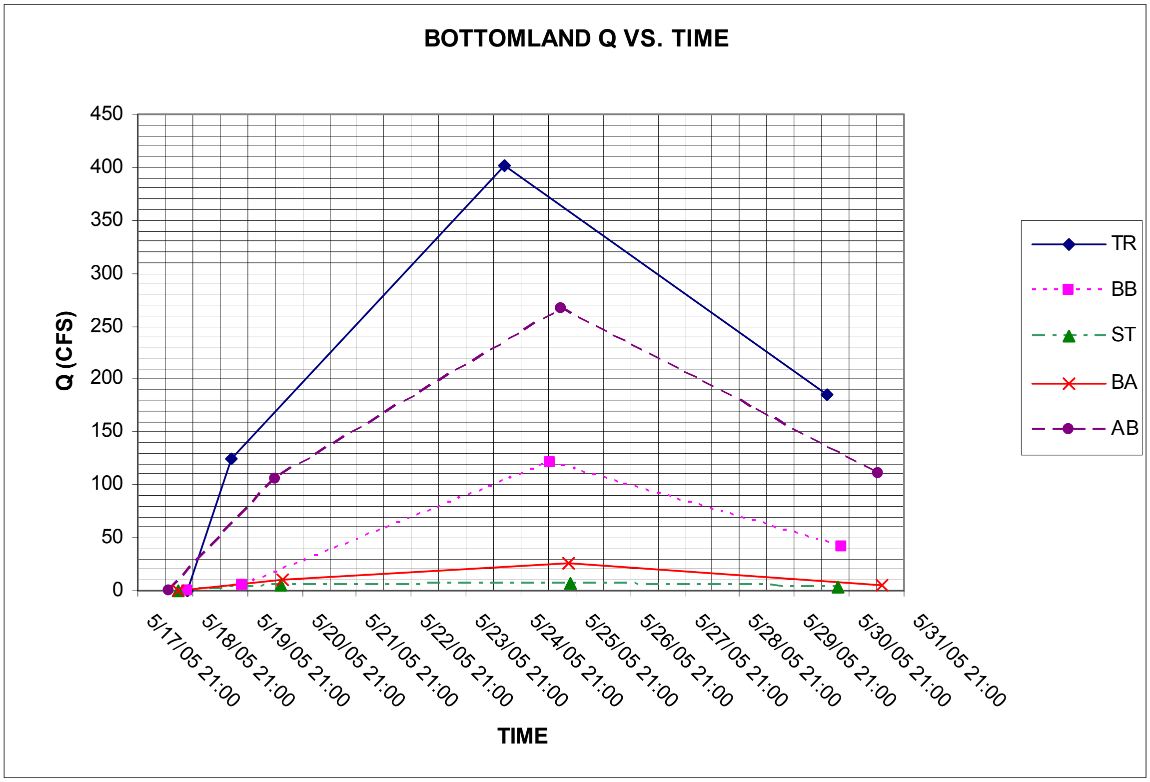
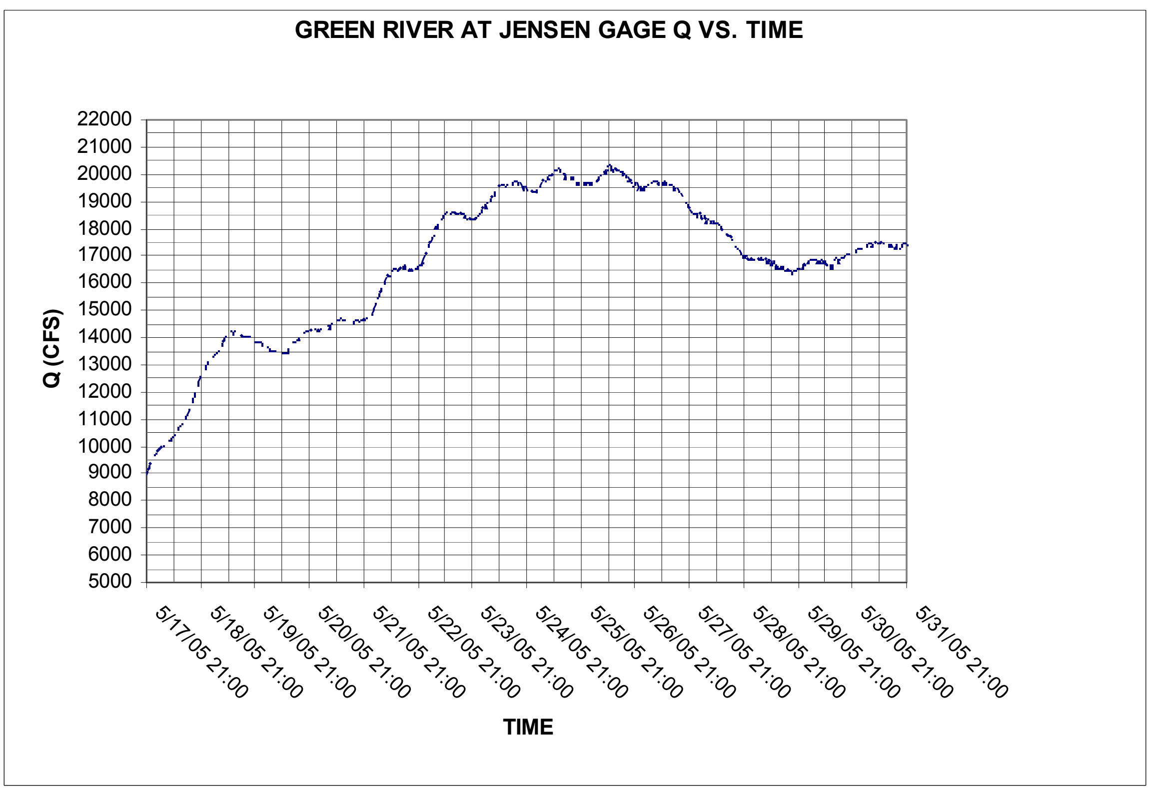


Figure 2. Total Inflow to Bottomland Sites versus Time





6.0 RECOMMENDATIONS

6.1 Thunder Ranch

The Thunder Ranch inlets/outlet all connected in 2005, within close proximity of expected flows in the Green River. TR-IN Inlets 1 and 2 had relatively low flow measurements during all three monitoring efforts. The poor connectivity may be due to the long travel distance between the inlets and bottomlands and the relatively flat gradient available for transporting flows. In addition, there is an existing ditch with a fairly flat slope that drains the adjacent hay fields. This ditch directs flows, collected from the fields, towards the river, discharging at a point between TR-IN 1 and 2 and approximately 200 feet inland. The ditch is relatively low and prone to flooding. Field surveys indicate that the invert elevation of the ditch, which controls backwater into the ditch is approximately 1 foot lower than the invert elevation of TR-IN-1, approximately 2.25 feet lower than the invert elevation of TR-IN-2 and approximately 1 foot lower than the invert of TR-IN-3. It is possible that inlet 3 is isolated from the ditch by higher ground located between TR-IN-3 and the ditch; however, there still remains the potential for backwater. Several options exist to prevent future flood flows from entering the ditch. The first is to close all three inlets. This would be achieved by backfilling and reconstructing the excavated openings. Based on this years discharge measurements closing inlets TR-IN-1 and TR-IN-2 will have little effect on the total and net inflows to the bottomland. TR-IN-3 however, diverted between 10 and 20% of the total inflows to Thunder Ranch. Thus, a second option is to close TR-IN-1 and TR-IN-2 and install a slide gate in the ditch to restrict backwater entering the ditch from TR-3. Note that the slide gate will also restrict backwater from TR-IN-1 and TR-IN-2 however, because inlets TR-IN-1 and TR-IN-2 had little connectivity, and given their close proximity to the fields (cattle access and backwater on the access road) we recommend closing inlets TR-IN-1 and TR-IN-2 in addition to installing the slide gate.

Aside from inlets 1 and 2, low inflow rates were also recorded at Inlet 4. This may be partially due to the mounded or elevated road constructed from the river to the siphon over the drainage pipe. This mound on the road causes the flows to backwater, reducing the available gradient for transporting flows into the bottomland areas immediately downstream (south). Thus it is recommended to remove the excess fill on top of the road. The road should be graded flush with the adjacent ground and wetlands. In addition, the cleanout stand pipes that experienced minor erosion around the concrete caps should be backfilled and stabilized.

As a final note for TR, the south levee breached in two sections after overtopping during this years flood event, each approximately 25 to 35 feet wide along the eastern portion of the levee. Reclamation has a proposal to reconstruct this levee later this year.

6.2 Bonanza Bridge

Based on visual observations the inlets appear to be connecting at higher flows than originally designed. BB-IN-1 in particular, since it has not degraded, connected only at 20,100 cfs. BB-IN-2 and BB-IN-3 have both degraded by approximately one (1) foot and are therefore connecting closer to the intended target flows. The outlet BB-5B has also degraded by approximately one foot since constructed and is connecting close to intended target flows. At BB-IN-1 however, it is projected that approximately 16,000 cfs (2-year event) is currently required for BB-IN-1 to connect flows to the bottomlands. To improve connectivity BB-IN-1 should be lowered. To determine a new invert elevation for BB-IN-1 the existing rating curve should be extended upstream to include the inlets. Rating curve data could utilize the surface water elevations surveyed this year. Several river cross sections would also be valuable for calibrating the hydraulic analysis. Monitoring these inlets/outlets should continue, especially for indications of long term trends. We also recommend the Russian Olives in BB-IN-3 be removed.

6.3 Stirrup

Based on visual observations, the Stirrup site appeared to be nearly full prior to inflow through the inlet/outlet. This may be indicative of a strong groundwater connection. This bottomland appeared to respond quickly to changes in the river flows which may also be due to the strong groundwater connection and/or the relatively small size of the bottomland, but the volume of inflow is small compared to the other sites monitored this year. Thus ST should be considered for reconfiguring to multiple openings. ST currently has a single opening located on the downstream end of the site and is angled in the downstream direction. Larval capture is anticipated to be greatly improved if several notches are installed upstream and the existing notch utilized for outflow. Note that this site was originally configured with one opening because there was some concern about erosion around the power line towers as a result of the opening. Since it appears that the inlet/outlet here and at all the other sites have not created or experienced adverse erosion and scour impacts, it may be feasible to install additional openings to serve as inlet(s). The biological results (drift capture) should be reviewed for this site to ascertain if inlet channels might be desirable to improve larval entrainment. Long term monitoring should continue for aggradation or degradation trends in the inlet/outlet.

6.4 Baeser

BA should be considered for reconfiguring to multiple openings. BA currently has a single notch which is located in the middle of the bottomlands and placed at approximately 90 degrees to the river flow. Again, larval capture is anticipated to be improved if several notches are installed upstream. In the case of BA an outlet may also improve flow-through if placed downstream of the existing notch. Long term monitoring should continue for aggradation or degradation trends in the inlet/outlet.

6.5 Above Brennan

Overall this site appeared to have good connectivity with the river. The bottomland, prior to the flood, was dry and had non-wetlands vegetation growing in the old channel bottom. It is possible that this bottomland is too shallow to be connected to the river through groundwater and that it could dry up between seasons. Yearly monitoring in late summer or early fall (visual observations) would help determine if this site can provide adequate over-winter habitat, and may also provide insight for corrective measures, if applicable.

6.6 Monitoring and Field Work

2005 measurements of inflow to the bottomland sites have proven invaluable for review of design considerations, not only for reconfiguration of sites but for future designs. Inflow monitoring should continue at all sites being considered for alteration including ST, BA and TR. Other sites that have been reconfigured but not monitored for inflow should be considered for future inflow monitoring. In addition the following site-specific recommendations are presented for additional field work.

- Extend section AB-5 to the east so that it crosses the side channel where inlet AB-IN-1 is located.
- Horizontal coordinates should be established for the remaining endpoints including AB-IN-1 REP and LEP, AB-IN-2 REP and LEP and AB-IN-3 REP, AB-OUT REP and LEP, BB-IN-2 LEP, and all of the inlet and outlet endpoints at Thunder Ranch.
- Continue to monitor the dimensions of the sand deposits noted at the Bonanza Bridge site for future comparisons and watch for the development of similar deposits at the Above Brennan bottomland site.
- Consider installing water level loggers for continuous elevations of the bottomlands during the next flood event, or alternatively measure water elevations in the bottomlands to develop and calibrate a rating curve through the bottomland sites.
- Extend rating curve at BB with river elevation surveys.
- River cross sections at all sites to review changes in the main stem as part of the post runoff monitoring efforts.

6.7 Additional Recommendations

- Several inlets/outlets had sand bags placed at the river banks for unknown reasons. These sand bags appeared to cause localized scour and channel reconfiguration. It is recommended that they be removed and that use of sandbags in the future is limited.

- Ultimately an analysis of impacts to the bottomland sites should be made, including trends for deposition, and scour. For the smaller older sites including Baeser, Above Brennen, Stirrup and Bonanza, existing topography was developed at the time of the initial site work including the establishment of monitoring cross sections. Thunder Ranch, however, is a very large site with only limited field survey information, performed primarily along the river edge. Thus analysis of the internal bottomlands area at Thunder Ranch would be best performed using topographic data from aerial photography. Topography of existing conditions should be established before the next runoff event exceeding 12,000 cfs in the Green River.

- It may be possible to develop a mathematical relationship to route flows from the river through the bottomlands. This model could be utilized for predicting inflow and flow-through conditions and may be of value for evaluating flow recommendations, on the Green River, for optimizing inflow and entrainment of drifting larvae. Input required for the model includes stage-volume relationships for the bottomlands, Green River hydrograph for the duration of the spring runoff, river elevations at the inlets and outlets, and geometry of the inlets and outlets. Based on current available information, most of the data are available or could be easily obtained and utilized to develop a model. Additional data collection may be required to calibrate the model, above and beyond the data collected this year.

- The analysis presented herein is restricted to the effectiveness of the inlets and outlets as they pertain to capturing flows. Ideally this information would be interfaced with the biologist's data collection efforts to develop a better understanding of the effectiveness of capturing larval drift. In particular, an attempt should be made to correlate the inflows to the bottomland sites with timing of larval drift.

7.0 REFERENCES

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