2012 Reassessment of Floodplain Wetland Connections in the Middle Green River, Utah

Environmental Science Division

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2012 Reassessment of Floodplain Wetland Connections in the Middle Green River, Utah

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prepared for

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NOTATION

ACRONYMS, INITIALISMS, AND ABBREVIATIONS

Argonne	Argonne National Laboratory
Reclamation	Bureau of Reclamation
Recovery Program	Upper Colorado River Endangered Fish Recovery Program
USGS	U.S. Geological Survey
WAPA	Western Area Power Administration

UNITS OF MEASURE

cfs	cubic foot (feet) per second
cm	centimeter(s)
ft	foot/feet
h	hour(s)
km	kilometers(s)
mi	mile(s)
m ³	cubic meter(s)
s	second(s)

METRIC UNIT CONVERSIONS

1 cfs	0.0283 m ³ /s
1 ft	30 cm
1 mi	1.61 km
1 river mi	1.61 river km

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EXECUTIVE SUMMARY

The frequency, magnitude, and duration of seasonal overbank flooding in the Green River have been substantially reduced since closure of Flaming Gorge Dam. Flow recommendations (Muth et al. 2000) were developed to assist with conservation and recovery of endangered fish species in the Green River downstream from Flaming Gorge Dam. Among the objectives of these recommendations was to provide for floodplain wetland connection to the river at sufficient frequency and duration to support sustained recruitment of the endangered razorback sucker (*Xyrauchen texanus*). Although floodplain habitats are important for all four of the endangered Colorado River fishes, the inundation of floodplain wetlands along the middle Green River is particularly important for providing important nursery habitat for young-of-the-year razorback suckers. Restoring or enhancing floodplain wetland connections to the river would provide access to these productive habitats and is expected to support the recovery of the four endangered fish species in the basin.

An uncertainty identified in the Larval Trigger Study Plan (Larval Trigger Study Plan Ad Hoc Committee 2012), a report that identified priorities for geomorphology research in the Upper Colorado River Basin (LaGory et al. 2003), and in the Green River Study Plan (Green River Study Plan Ad Hoc Committee 2007) was interannual variability in the flow needed to connect floodplain wetlands, and the effect of peak flows on these connecting flows. The present study was developed to address this uncertainty.

This report presents the results of floodplain wetland connection surveys conducted in 2012 at eight priority floodplain wetlands along the middle Green River between Jensen and Ouray, Utah. Surveys were conducted at levee breaches and within channels leading from the breaches to the wetlands (referred to here as connection channels) to characterize the flows needed to connect the river's main channel with the floodplain wetlands. Specific objectives of this work were to:

- Determine the minimum flow that would connect floodplain wetlands to the main channel river and allow for the entrainment of larval razorback suckers;
- Determine the minimum flow that would allow the passage of subadult and adult razorback suckers (minimum depth of 1 ft [30 cm] based on Burdick 1997) between the wetlands and the river; and
- Compare our 2012 survey results with previously reported results from Tetra Tech (2005) and Bestgen et al. (2011) to determine if and how conditions have changed since 2005.

Our survey results will be used in conjunction with the results of other studies conducted under the Larval Trigger Study Plan and Green River Study Plan plans to resolve uncertainties associated with razorback sucker floodplain nursery habitats and factors contributing to recruitment of this species. The evaluation summarized here also will provide important input to the Upper Colorado River Endangered Fish Recovery Program's ongoing evaluation of the Muth et al. (2000) flow recommendations.

Topographic surveys to determine the flows that would connect the main channel of the Green River to eight priority floodplain wetlands were conducted along the middle Green River from October 22 through 25, 2012, between the U.S. Geological Survey (USGS) Jensen gage (USGS 09261000) and the USGS Ouray gage (USGS 9272400). At each wetland location, topographic surveys were conducted of the river surface elevation and at cross sections at the breaches and along the connection channels. This topographic information was used with current USGS stage-discharge relationships to determine minimum flows needed to overtop breaches and connect the floodplain wetlands to the river main channel.

Our 2012 survey identified substantial changes since 2005 at most of the levee breaches and connection channels evaluated. The most recent reported values represented conditions in 2005 (Tetra Tech 2005 and Bestgen et al. 2011), and these values were mostly based on the design specifications of levee breaches made to intentionally entrain water at specific high flows.

The average minimum floodplain connection flow (i.e., the lowest connecting breach) among the seven floodplains surveyed in 2012 was 13,503 cfs. This is a relatively small mean increase (826 cfs) compared to estimated connection flows in 2005. However, there was considerable variation among the wetlands in estimated minimum connection flow, ranging from 9,430 cfs at Old Charlie Wash to 17,400 cfs at Bonanza Bridge. There was much less variation in estimated minimum connection flow in 2005 (11,166 to 13,000 cfs).

Changes in connection flows differed between upstream and downstream breaches with upstream breaches showing a much larger increase since 2005 compared to downstream breaches. The mean connection flow of upstream breaches in 2012 was 17,267 cfs (15,300 to 20,100 cfs) compared to 12,389 cfs (11,166 to 13,000 cfs) in 2005, and represents an increase of 4,878 cfs (3,400 to 7,100 cfs) for upstream breaches. The mean connection flow of downstream breaches in 2012 was 13,503 cfs (9,430 to 17,400 cfs) compared to the 2005 mean of 13,056 cfs (12,433 to 13,900 cfs), and represents an increase of 465 cfs (-3,570 to +3,900 cfs) for downstream breaches.

Estimated fish passage flows in 2012 were approximately 2,300 to 2,600 cfs higher than connection flows in the Ouray National Wildlife Refuge wetlands (Johnson Bottom, Leota Bottom, and Old Charlie Wash) and 3,300 to 3,600 cfs higher than connection flows in the wetlands further upstream. In 2012, the mean minimum fish passage flow for the floodplain wetlands surveyed was 19,900 cfs (11,600 to 27,900 cfs). In 2012, the mean minimum fish passage flow for the floodplain wetlands surveyed (i.e., the lowest of all levee breaches in each wetland) was approximately 16,343 cfs (11,600 to 20,800 cfs).

Our results indicate that there is a need for periodic reassessments of levee breaches and connection channels especially following very high peak flows. Changes in estimated floodplain connection flows since 2005 were related to the amount of scour and sediment deposition in levee breaches and the intervening connection channels that connect the wetlands to the river's main channel at high flows. In general, connection flows for upstream breaches increased, and connection flows for downstream breaches decreased since 2005. In the wetlands studied, upstream breaches were topographically higher than the wetland, while downstream breaches were lower than the wetland. This topographic variation results in the deposition and scour patterns we observed.

Downstream breaches also serve as inlets for flood water at lower flows. Water depth in downstream connection channels increase as flows rise until connection with the wetland margin occurs, at which time the wetland begins to fill. Downstream breaches can be depositional areas during this filling process, but when peak flows recede, scour of new deposits would occur as water flows out of the wetland and the wetland water surface stabilizes to a lower elevation.

Our observations support those of Heitmeyer and Fredrickson (2005), who stated that high flows may increase sedimentation and debris build up in upstream breaches, resulting in higher subsequent connection flows in these breaches, but would tend to scour downstream breaches, resulting in maintenance or reduction of connection flows. Our results suggest that for upstream breaches to remain as viable connections to floodplain wetlands over the long term, regular breach and connection channel inspection and maintenance may be required.

We recommend the following:

- Resurvey floodplain wetland breaches and their connection channels following peak flows that exceed previously determined connection flows to determine if those peak flows have altered connection flows.
- Determine connection of floodplain wetlands annually by direct observation. Ideally, determinations would be made of initial connection flows at upstream and downstream breaches and the degree of filling and draining through the peak flow cycle.
- Measure the surface area of floodplain wetlands after peak flows recede and through the summer and winter to determine if floodplain wetlands provide suitable habitat for razorback suckers between flooding events that reconnect the wetlands to the main channel.
- Consider modification of floodplain wetland breaches and connection channels to provide connection to the main channel river at a return frequency of 1.5 years (probability of about 67%) to mimic pre-dam flooding frequency.

- Consider modifications of wetlands to prevent sediment deposition from blocking inflow. These modifications could include (1) actively reconfiguring levee breaches, connection channels, and wetland topography to minimize the blockage of connection channels; (2) filling or allowing the filling of upstream breaches; (3) creating control structures such as those that have been successfully deployed at Stewart Lake, Johnson Bottom, and Old Charlie Wash; and (4) managing vegetation encroachment that exacerbates sediment deposition in breaches and channels.

1 INTRODUCTION

The frequency, magnitude, and duration of seasonal overbank flooding in the Green River have been substantially reduced since closure of Flaming Gorge Dam. Flow recommendations (Muth et al. 2000) were developed to assist with conservation and recovery of endangered fish species in the Green River downstream from Flaming Gorge Dam. These recommendations identified target instantaneous annual spring peak flows in the middle Green River between the confluences of the Yampa River and White River of at least 18,600 cubic feet per second (cfs) (as measured at the Jensen gage) in 1 of 2 years, and flows of at least 18,600 cfs for at least 2 weeks in 4 of 10 years (Table 1). No upper limits were placed on recommended annual spring peak flows in any hydrologic condition. The intent of these recommendations was to provide floodplain wetland connection to the river at sufficient frequency and duration to support sustained recruitment of the endangered razorback sucker (*Xyrauchen texanus*).

Although floodplain habitats are important for all four of the endangered Colorado River fishes, the inundation of floodplain wetlands along the middle Green River is particularly important for providing important nursery habitat for young-of-the-year razorback suckers. Restoring or enhancing floodplain wetland connections to the river would provide access to these productive habitats and is expected to improve the recovery of the four endangered fish species in the Green River Basin.

In implementing the flow recommendations to achieve recommended peak flow magnitudes and durations prior to 2011, the Bureau of Reclamation (Reclamation) timed the releases of water from Flaming Gorge Reservoir to match the peak flows in the Yampa River in accordance with the Flaming Gorge Dam Environmental Impact Statement Record of Decision (Reclamation 2006). The primary purpose of those spring operations at Flaming Gorge Dam was to provide access to floodplain wetland nursery habitat for young-of-the-year razorback sucker in the middle Green River. Despite Reclamation's success in meeting or exceeding peak-flow magnitudes and durations in the middle Green River since the flow recommendations were published, consistent and substantial razorback sucker recruitment had not been observed.

In a recently completed synthesis report (Bestgen et al. 2011), researchers concluded that in most years since 1993, releases from Flaming Gorge Dam occurred too early relative to the presence of drifting razorback sucker larvae in the Green River. The researchers recommended that the Colorado River Endangered Fish Recovery Program (Recovery Program) and Reclamation implement an altered schedule to match the timing of flow releases from Flaming Gorge Dam with the presence of razorback sucker larvae in the middle Green River. The Recovery Program proposed that Reclamation use the occurrence of razorback sucker larvae in channel margin habitats (as determined by real-time monitoring) as the trigger to determine when peak releases from Flaming Gorge Dam should occur.

TABLE 1 Annual Spring Peak Flow Recommendations for the Green River between the Confluences of the Yampa and White Rivers (Muth et al. 2000)^a

	Hydrologic Condition				
	Wet (0 to 10% Exceedance)	Moderately Wet (10 to 30% Exceedance)	Average (30 to 70% Exceedance)	Moderately Dry (70 to 90% Exceedance)	Dry (90 to 100% Exceedance)
Peak-flow magnitude	≥26,400 cfs	≥20,300 cfs	≥18,600 cfs in 1 of 2 average years; ≥8,300 cfs in other average years	≥8,300 cfs	
Peak-flow duration	Flows >22,700 cfs should be maintained for 2 weeks or more, and flows >18,600 cfs for 4 weeks or more	Flows >18,600 cfs should be maintained for 2 weeks or more	Flows >18,600 cfs should be maintained for at least 2 weeks in at least 1 of 4 average years	Flows >8,300 cfs should be maintained for at least 1 week	Flows >8,300 cfs should be maintained for 2 days or more, except in extremely dry years (≥98% exceedance)

^a All flow targets are as measured at the Jensen, Utah, gage (USGS 09261000).

Determining the effectiveness of this larval trigger in promoting the recruitment of razorback suckers is the primary focus of a study plan developed by the Larval Trigger Study Plan Ad Hoc Committee (2012) (referred to here as the “Larval Trigger Study Plan”). One uncertainty identified in the Larval Trigger Study Plan, a report that identified priorities for geomorphology research in the Upper Colorado River Basin (LaGory et al. 2003), and the Green River Study Plan (Green River Study Plan Ad Hoc Committee 2007) was inter-annual variability in the flow needed to connect floodplain wetlands and the effect of peak flows on these connecting flows. As noted in the Larval Trigger Study Plan:

A new field study would be needed to collect these data, but could tier from ongoing project C6-hydro to assess actual connection flow (i.e., when river flow begins to enter wetlands) at each study wetland at the beginning of the study, and perhaps every year thereafter until study completion. It may be necessary to develop new river flow and entrainment relationships at the beginning of the study, and periodically during the study, if breach elevations are altered by annual high flows. Green River researchers have noted the poor concordance between published (i.e., Valdez and Nelson 2004; Bestgen et al. 2011) connecting flows and actual connecting flows following high-flow years. These differences

between actual and published connecting flows may be especially noticeable following the very high flows in 2011.¹

The present study was developed to address this uncertainty. Surveys were conducted at eight priority floodplain wetland sites along the middle Green River between Jensen and Ouray, Utah, at levee breaches and within channels leading from the breaches to the wetlands (referred to here as connection channels) to characterize the flows needed to connect the river's main channel with the floodplain wetlands. Specific objectives of this work were to:

- Determine the minimum flow that would connect floodplain wetlands to the main channel river and allow for the entrainment of larval razorback suckers;
- Determine the minimum flow that would allow the passage of subadult and adult razorback suckers (minimum depth of 1 ft [30 cm] based on Burdick 1997) between the wetlands and the river; and
- Compare our 2012 survey results with previously reported results from Tetra Tech (2005) and Bestgen et al. (2011)² to determine if and how conditions have changed since 2005.

The annual peak flows at the Green River Jensen gage since 2005 are shown in Table 2. In three years (2008, 2010, and 2011), annual peak flows were higher than the flows that occurred in 2005, and, thus, had the potential to either scour sediment deposited in levee breaches and connection channels in 2005 or deposit more sediment in those areas.

Our survey results will be used in conjunction with the results of other studies conducted under the Larval Trigger Study Plan and Green River Study Plan to resolve uncertainties associated with razorback sucker floodplain nursery habitats and factors contributing to recruitment of this species. The evaluation summarized here also will provide important input to the Upper Colorado River Endangered Fish Recovery Program's ongoing evaluation of the Muth et al. (2000) flow recommendations.

¹ In 2011, flows were >18,000 cfs from May 16 to July 12 (58 days). The maximum mean daily flow of 32,200 cfs was reached on June 11. These high flows resulted in widespread inundation of floodplain wetlands in the middle Green River.

² Bestgen (2011) reported connection flows based on several information sources including TetraTech (2005).

TABLE 2 Green River Annual Peak Flow at Jensen, Utah, from 2005-2012

Year	Peak Flow (cfs)
2005	19,900
2006	19,200
2007	12,700
2008	24,000
2009	19,600
2010	20,500
2011	32,200
2012	10,600

2 METHODS

Topographic surveys to determine the flows that would connect the main channel of the Green River to eight priority floodplain wetlands were conducted along the middle Green River from October 22 through 25, 2012, between the U.S. Geological Survey (USGS) Jensen gage (9261000) and the USGS Ouray gage (9272400) (Figure 1). We surveyed a total of 24 levee breach locations at the eight floodplain wetland sites using standard surveying techniques to characterize the topography of the area between the river edge and the floodplain wetland including the full width of the levee breach, adjacent portions of the levee, and the connecting channel from the breach to the wetland. A survey base station was setup at a permanent USGS or Bureau of Land Management (BLM) benchmark with known longitude, latitude, and elevation values. Global Positioning System (GPS) rover units were used (various TopCon digital UHF units including Models Ga/Gb, Hyper II, and Hyper Vs) communicated with the base station to determine the coordinates of survey points with ± 1 cm horizontal and vertical accuracy. Example photographs of the surveying locations and effort are shown in Figure 2.

The river water surface elevation near each levee breach was surveyed and used to determine the elevation associated with the specific flow at the time of the survey. A summary of survey times and flow conditions at each of the floodplain areas is provided in Table 3. Local flow conditions were estimated from USGS gage data using calculated flow travel times (lag-adjusted flows) and distance from the nearest Green River USGS gage sites (Jensen or Ouray; Table 3). For sites closer to the Jensen gage and downstream from the Ashley Creek confluence, Ashley Creek flows (USGS gage 9266500) were added to Jensen flows to determine flow at the site. Flows were relatively steady during the survey period. Jensen flow ranged from 1,160 to 1,220 cfs; Ashley Creek flow ranged from 20 to 25 cfs; and Ouray flow ranged from 1,120 to 1,300 cfs.

FIGURE 1 Green River Floodplain Wetland Survey Locations, October 2012. Note that Escalante Ranch was referred to as Thunder Ranch in many previous reports.

TABLE 3 Summary of Survey Dates and Modeled Local Flow Conditions for Eight Floodplain Wetland Sites on the Middle Green River, Utah, in 2012

Floodplain Wetland	Date	Time (h)	USGS Gage (distance, mi) ^a	Lag-Adjusted Gage Flow (cfs) ^b	Ashley Creek Flow (cfs)	Estimated Local Flow (cfs) ^c	Estimated Local Stage (ft) ^d
Escalante Ranch	October 23, 2012	16:00	Jensen (10)	1,190	NA ^e	1,190	1.98
Bonanza Bridge	October 25, 2012	10:45	Jensen (24)	1,210	25	1,235	2.03
Stirrup	October 22, 2012	12:00	Jensen (38)	1,170	23	1,193	1.98
Above Brennan	October 22, 2012	14:30	Jensen (44)	1,160	20	1,180	1.97
Johnson Bottom	October 25, 2012	13:45	Ouray (-12)	1,250	NA ^f	1,250	15.24
Leota Bottom	October 23, 2012	11:00	Ouray (-9)	1,190	NA ^f	1,190	15.18
Sheppard Bottom	October 24, 2012	13:50	Ouray (-3)	1,190	NA ^f	1,190	15.18
Old Charlie Wash	October 24, 2012	11:00	Ouray (-1)	1,190	NA ^f	1,190	15.18

^a Values in parentheses indicate distance (mi) away from the nearest USGS stream gage. Positive values are locations downstream from the gage; negative values are locations upstream from the nearest gage.

^b The lag-adjusted flow was determined by offsetting the gage flow by the lag time from the gage to the site. The lag time (hours [h]) was calculated as $h = 8.9441 \times D_w \times Q_{max}^{-0.3231}$, where D_w is the distance (mi) of the wetland from the nearest gage and Q_{max} is the maximum hourly flow (cfs) at the gage on the day of the survey.

^c For sites associated with the Jensen gage, the local lag-adjusted flow was determined by adding the lag-adjusted Jensen flow (column 5) with the Ashley Creek flow (column 6).

^d The local lag-adjusted stage was determined using the stage-flow tables provided by the USGS for the Jensen and Ouray gages. Stage-flow tables are provided in Appendix A. Since the stage-flow tables provide discrete values, the closest associated stage value was identified for each flow.

^e NA = not applicable; Ashley Creek is downstream of the Escalante Ranch site and its flow is already included in the Ouray gage flow.

^f NA = not applicable; Ashley Creek flow is included in the Ouray gage flow.

Survey base station equipment

Surveying connection channel with GPS rover at Above Brennan (AB-IN-1)

Levee breach at Bonanza Bridge (BB-IN-2) with large deposit of sand obstructing connection channel

Surveying water's edge and river surface elevation at Above Brennan (AB-OUT)

FIGURE 2 2012 Floodplain Wetland Survey Photographs

Flow values corresponding to the elevation of all survey points were determined based on their elevation relative to the river elevation and flow at the time of survey and stage-flow tables provided by USGS for the nearest USGS gage (Jensen or Ouray gage). Stage-flow tables for each of the gages are provided in Appendix A. For wetlands closer to the Jensen gage and downstream of the Ashley Creek confluence, Ashley Creek flows (USGS 9266500) were added to Jensen flows to determine flow at the site. Flows were relatively steady during the survey period. Jensen flow ranged from 1,160 and 1,210 cfs; Ashley Creek flows were approximately 23 cfs; and Ouray flows ranged from 1,190 and 2,250 cfs.

Cross sectional transects of levee breaches and connection channels were used to capture all features that could affect the conveyance of water between the river and the wetland, focusing on areas of noticeable elevation change, such as shorelines, sandbars, levee breaches, sand deposits within levee breaches and connecting channels, roads that crossed connecting channels, and scoured areas within breaches and connecting channels. Using the survey data, a topographical surface was spatially interpolated for each location and a spatial model was developed to determine the minimum flow that would provide connection between the river and floodplain wetland. Fish passage flows (i.e., the minimum depth needed for passage of subadult and adult razorback suckers estimated by Burdick [1997] as 1 ft [30 cm]) have not been previously reported for Green River floodplain wetland breaches. These values were estimated starting with the elevations associated with the estimated connection flow, adding 1 ft to those elevations, and determining the associated flow in the stage-flow tables provided by the USGS..

Connection channel surveys were conducted at all but three levee breach locations: Escalante Ranch Inlet 1 (ER-IN-1), Escalante Ranch Inlet 2 (ER-IN-2), and Sheppard Bottom Inlet (SB-IN). After 2005, the two Escalante Ranch breaches had been purposely filled with riprap to prevent connection. The breach location at the Sheppard Bottom site was adjacent to the wetland edge and did not possess a connecting channel. However, the breach was not adjacent to the river and the flow path between the river and breach was not determined. This prevented us from being able to determine the flows that would inundate the Sheppard Bottom wetland.

At each floodplain wetland, the minimum flow needed for connection and fish passage were determined for all breach locations and associated connection channels and compared to floodplain connections reported by Tetra Tech in 2005 (Tetra Tech 2005), if applicable.

3 RESULTS

Characteristics of floodplain wetland connections in 2012 and changes since 2005 are provided in this section. Sites are discussed in order of location along the Green River (upstream to downstream) (Figure 1). A summary of survey results, with comparisons to previous reported values (Tetra Tech 2005; Bestgen et al. 2011) is provided in Table 4. Table 5 summarizes minimum connection flows at each floodplain area and at upstream and downstream breaches. Table 6 presents the fish passage flows for each breach in 2005 and 2012. For each levee breach, maps of the connection channel between the river and the floodplain wetland at the minimum connection flow are provided in Appendix B.

TABLE 4 Breach and Connection Flows at Surveyed Breaches in October 2012 and Comparison to Previously Reported Connection Flows

Floodplain Wetland	Breach Name	2012 Breach Flow (cfs)	2012 Connection Flow (cfs)	2005 Connection Flow (cfs) ^a	Difference between 2012 and 2005 (cfs) ^b	Notes
Escalante Ranch	ER-IN-1	22,000	22,000	11,500	+10,500	Prior to the October 2012 survey, the levee breach was filled with rip rap to prevent connection to the river.
	ER-IN-2	23,000	23,000	16,800	+6,200	Prior to the October 2012 survey, the levee breach was filled with rip rap to prevent connection to the river.
	ER-IN-3	14,500	18,100	11,900	+6,200	Breach was well-defined, but connection flow was higher than previous values due to deposition of sand and debris in previous floods. Tetra Tech (2005) noted significant bank erosion and deposition in the center of the breach, and inflow at 14,000 cfs.
	ER-IN-4	17,600	20,300	12,933	+7,367	Connection flow was higher than previous values due to deposition of sand and debris in previous floods. Tetra Tech (2005) noted a general trend of deposition, and inflow at 14,000 cfs.
	ER-IN-5	15,200	16,800	12,000	+4,800	Connection flow was higher than previous values due to deposition of sand and debris in previous floods. Tetra Tech (2005) noted minor bank erosion and deposition in the center of the breach, and inflow at 14,000 cfs.
	ER-IN-6	15,100	19,200	11,166	+8,034	Connection flow was higher than previous values due to deposition of sand and debris in previous floods. Tetra Tech (2005) noted a general trend of deposition, and inflow at 14,000 cfs.

Table 4 (Cont.)

Floodplain Wetland	Breach Name	2012 Breach Flow (cfs)	2012 Connection Flow (cfs)	2005 Connection Flow (cfs) ^a	Difference between 2012 and 2005 (cfs) ^b	Notes
Escalante Ranch (cont.)	ER-IN-7	13,800	15,300	12,000	+3,300	Connection flow was higher than previous values due to deposition of sand and debris in previous floods. Tetra Tech (2005) noted a general trend of deposition, and inflow at 14,000 cfs.
	ER-OUT	10,800	11,300	12,433	-1,133	Connection flow at this downstream breach was lower than previous reported values apparently resulting from scour during previous floods. Tetra Tech (2005) observed some scouring upstream of the upper control structure, and inflow at 14,000 cfs.
Bonanza Bridge	BB-IN-1	17,400	20,100	13,000 (actual >18,500)	+7,100 (< +1,600 compared to actual)	Connection flow was similar to previous observed values. Large deposit of sand where inlet feeds into wetland. Tetra Tech (2005) stated that the breach elevation is too high for proper connection at design flows of 13,000 cfs, and noted that the inlet was dry at 18,500 cfs, but connected at 19,700 cfs.
	BB-IN-2	16,300	21,100	13,000 (actual >13,900)	+8,100 (< +7,200 compared to actual)	Connection flow was higher than previous values. Large deposit of sand where inlet feeds into wetland. Tetra Tech (2005) observed some scouring, and noted that connection was just beginning at 13,900 cfs.
	BB-IN-3	24,100	24,100	13,000	+11,100	Connection flow was higher than previous values due to vegetation growth and deposition of sand and debris in previous floods. Tetra Tech (2005) observed a thick stand of Russian olive in breach, and noted measurable inflow at 13,900 cfs.
	BB-OUT	13,100	17,400	13,000 (actual >13,900)	+4,400 (< +3,500 compared to actual)	Connection flow was higher than previous values. Tetra Tech (2005) noted that BB-OUT was dry at 13,900 cfs, but draining the wetland at 18,500 cfs.

Table 4 (Cont.)

Floodplain Wetland	Breach Name	2012 Breach Flow (cfs)	2012 Connection Flow (cfs)	2005 Connection Flow (cfs) ^a	Difference between 2012 and 2005 (cfs) ^b	Notes
Stirrup	ST-OUT	11,000	16,900	13,000	+3,900	Connection flow was higher than previous values, although levee breach elevation was lower than previous reported values. No deposits of loose sand or debris were noted at the time of survey. Tetra Tech (2005) noted filling of the wetland at 13,900 cfs, and a decrease in elevation from previous surveys of about 1.5 ft.
Above Brennan	AB-IN-1	10,300	16,400	13,000	+3,400	Connection flow was higher than previous values, although levee breach elevation was lower than previous reported values. Tetra Tech (2005) noted a general trend in erosion, and inflow at 15,000 cfs.
	AB-IN-2	15,500	19,500	13,000	+6,500	Breach was very narrow, and connection flow was higher than previous values. Tetra Tech (2005) did not report any changes at this breach, and noted inflow at 15,000 cfs.
	AB-IN-3	16,400	18,500	13,000	+5,500	Connection flow was higher than previous values. Tetra Tech (2005) noted a general trend of deposition, and inflow at 15,000 cfs.
	AB-OUT	9,990	9,990	13,000	-3,010	Connection flow was lower than previously reported values. Tetra Tech (2005) noted erosion and a decrease in elevation from previous surveys of about 1.5 ft, and inflow at 15,000 cfs.
Johnson Bottom	JB-OUT-1	16,100	16,100	13,000 ^c	+3,100	Breach and connection channel were not surveyed by Tetra Tech (2005). Measured connection flow was higher than value reported by Bestgen et al. (2011). Flow entry is controlled by gate that is located at the end of a connection channel. Channel was overgrown with vegetation.

Table 4 (Cont.)

Floodplain Wetland	Breach Name	2012 Breach Flow (cfs)	2012 Connection Flow (cfs)	2005 Connection Flow (cfs) ^a	Difference between 2012 and 2005 (cfs) ^b	Notes
Johnson Bottom (cont.)	JB-OUT-2	11,100	16,400	13,000 ^c	+3,400	Connection flow at this wide downstream breach was higher than the reported value in Bestgen et al. (2011) as a result of deposition of sand during previous floods.
Leota Bottom	LB7-IN	17,200	17,600	NA ^d	NA	Large deposits of sand in wide breach. Not reported in previous surveys.
	LB7A-IN	13,300	13,400	NA	NA	Connection flow not reported in previous surveys.
Sheppard Bottom ^e	SB-IN	11,800	NA	NA	NA	Broad breach away from river edge. Potential obstructions to connection between breach and river not determined. Refuge staff noted that Sheppard Bottom did not connect in 2014 when flows reached 17,800 cfs at the Ouray gage on June 9.
Old Charlie Wash	OC-OUT-1	12,400	14,300	13,000 ^c	+1,300	Breach and connection channel were not surveyed by Tetra Tech (2005). No apparent deposition in breach, but measured connection flow was higher than previous value reported by Bestgen et al. (2011).
	OC-OUT-2	3,850	9,430	13,000 ^c	-3,570	Breach and connection channel were not surveyed by Tetra Tech (2005). Measured connection flow was lower than value reported by Bestgen et al. (2011). Entry to wetland is controlled by gate.
Mean for all breaches		14,050	16,772	13,091	+3,815	

Table 4 (Cont.)

- ^a Values reported in Tetra Tech (2005) except where noted. 2005 connection flows are the flows that were targeted for connection when levee breaches were constructed. Tetra Tech (2005) made observations during the peak runoff period of 2005 to determine if connection was actually occurring at these flows by visiting sites at the following flows: Escalante Ranch: <10,000 cfs, 14,000 cfs, 16,700 cfs, and 19,600 cfs; Bonanza Bridge: <10,000 cfs, 13,900 cfs, 18,500 cfs, and 19,700 cfs; Stirrup: <10,000 cfs, 13,900 cfs, 18,500 cfs, and 21,600 cfs; and Above Brennan: <10,000 cfs, 15,000 cfs, 18,300 cfs, and 21,800 cfs. These visits allowed verification of target flows. In some cases (as noted), actual connection flows were higher than the target.
- ^b Comparisons of 2014 connection flows were made to actual estimates of connection in 2005 as reported in Tetra Tech (2005) where available.
- ^c 2005 connection flow from Bestgen (2011) is presented because connection flow was not presented in Tetra Tech (2005).
- ^d NA = not available.
- ^e Surveyed breach had been created shortly before survey, and had not been previously surveyed. Connection channel was not identified or surveyed.

TABLE 5 Minimum Connection Flows at Floodplain Wetlands in 2005 and 2012 for Any Breach, Upstream Breaches Only, and Downstream Breaches Only

Floodplain Wetland ^a	2012 Connection Flow (cfs) ^b	2005 Connection Flow (cfs) ^{bc}	Change from 2005 to 2012 (cfs)
Minimum Connection Flows of any Breach			
Escalante Ranch	11,300 (ER-OUT)	11,166 (ER-IN-6)	+134
Bonanza Bridge	17,400 (BB-OUT)	13,000 (BB-IN-3)	+4,400
Stirrup	16,900 (ST-OUT)	13,000 (ST-OUT)	+3,900
Above Brennan	9,990 (AB-OUT)	13,000 (all breaches)	-3,010
Johnson Bottom	16,100 (JB-OUT-1)	13,000 (all breaches)	+3,100
Leota Bottom	13,400 (LB7A-IN)	NA ^d	NA
Old Charlie Wash	9,430 (OC-OUT-2)	13,000 (all breaches)	-3,570
Mean	13,503 (13,520) ^d	12,694	+826
Minimum Connection Flows of Upstream Breaches			
Escalante Ranch	15,300 (ER-IN-7)	11,166 (ER-IN-6)	+4,134
Bonanza Bridge	20,100 (BB-IN-1)	13,000 (BB-IN-3)	+7,100
Above Brennan	16,400 (AB-IN-1)	13,000 (all breaches)	+3,400
Mean	17,267	12,389	+4,878
Minimum Connection Flows of Downstream Breaches			
Escalante Ranch	11,300 (ER-OUT)	12,433 (ER-OUT)	-1,133
Bonanza Bridge	17,400 (BB-OUT)	13,900 (BB-OUT)	+3,500
Stirrup	16,900 (ST-OUT)	13,000 (ST-OUT)	+3,900
Above Brennan	9,990 (AB-OUT)	13,000 (AB-OUT)	-3,010
Johnson Bottom	16,100 (JB-OUT-1)	13,000 (all breaches) ^c	+3,100
Leota Bottom	13,400 (LB7A-IN)	NA	NA
Old Charlie Wash	9,430 (OC-OUT-2)	13,000 (all breaches)	-3,570
Mean	13,503 (13,520) ^e	13,056	+465

^a Sheppard Bottom was not included in this comparison because connection flow was not determined.

^b Breaches associated with connection flows are presented in parentheses.

^c 2005 connection flow values are from Tetra Tech (2005) for all wetlands except for Johnson Bottom and Old Charlie Wash, which are from Bestgen et al. (2011). When 2005 target connection flows were known to be incorrect (based on Tetra Tech 2005 observations noted in Table 4), comparisons are made to observed connection flows.

^d NA = not available because connection flow in 2005 was not determined.

^e Value in parentheses represents the mean of flows without Leota Bottom to enable comparison with the 2005 mean.

TABLE 6 Fish Passage Flows^a at Surveyed Breaches in October 2012 and Comparison to Estimated 2005 Fish Passage Flows

Floodplain Wetland ^b	Breach Name	2012 Fish Passage Flow (cfs)	2005 Fish Passage Flow (cfs) ^c	Change from 2005 to 2012 (cfs)
Escalante Ranch	ER-IN-1	NA ^d	14,600	NA
	ER-IN-2	NA	20,500	NA
	ER-IN-3	21,500	15,100	+6,400
	ER-IN-4	23,900	16,200	+7,700
	ER-IN-5	20,100	15,200	+4,900
	ER-IN-6	22,600	14,200	+8,400
	ER-IN-7	18,500	15,200	+3,300
	ER-OUT	14,300	15,600	-1,300
Bonanza Bridge	BB-IN-1	23,700	22,300	+1,400
	BB-IN-2	24,700	17,300	+7,400
	BB-IN-3	27,900	16,300	+11,600
	BB-OUT	20,800	17,300	+3,500
Stirrup	ST-OUT	20,200	16,300	+3,900
Above Brennan	AB-IN-1	19,700	16,300	+3,400
	AB-IN-2	23,000	16,300	+6,700
	AB-IN-3	21,900	16,300	+5,600
	AB-OUT	13,000	16,300	-3,300
Johnson Bottom	JB-OUT-1	18,700	15,400	+3,300
	JB-OUT-2	19,000	15,400	+3,600
Leota Bottom	LB7-IN	20,300	NA	NA
	LB7A-IN	15,800	NA	NA
Old Charlie Wash	OC-OUT-1	16,700	15,400	+1,300
	OC-OUT-2	11,600	15,400	-3,800
Mean		19,900	16,200	+3,895

^a Based on minimum fish passage depth of 1 ft reported in Burdick (1997).

^b Sheppard Bottom was not included in this comparison because fish passage flow was not determined.

^c Fish passage flows for 2005 were estimated by the authors using the elevations associated with reported 2005 connection flows in Tetra Tech (2005) and Bestgen et al. (2011), adding 1 ft to the elevation, and determining the associated flow in the stage-flow table provided by USGS for 2005. Since the Ouray gage was not in place in 2005, we used the 2012 stage flow table for the Ouray gage to estimate fish passage flows for Johnson Bottom, Leota Bottom, and Old Charlie Wash.

^d NA = not available.

In the descriptions below, the following critical elevations and associated estimated flows are identified for each levee breach and its connection channel:

- *River water surface elevation (flow)*: water surface elevation and associated flow as surveyed at river's edge nearest each levee breach.
- *Breach elevation (flow)*: minimum elevation and associated flow measured along levee breach cross section, representing the elevation and flow at which river flow would begin to enter the levee breach.
- *Connection elevation (flow)*: minimum elevation and associated flow in the connection channel that would allow water to flow between the river and floodplain wetland as determined from a series of cross sections measured between the levee breach and the entrance to the floodplain wetland.
- *Fish passage elevation (flow)*: minimum water surface elevation and associated flow that would provide at least 1 ft (30 cm) of depth along the entire connection channel. This is considered to be the minimum depth that would allow subadult and adult razorback suckers to swim between the wetland and river (Burdick 1997).

3.1 ESCALANTE RANCH

The Escalante Ranch wetland, formerly known as Thunder Ranch, was surveyed on October 23, 2012. Table 3 summarizes the dates and times of the floodplain surveys, with corresponding lag-adjusted local flow conditions at the time of the survey. The local flow at Escalante Ranch at the time of the survey was estimated to be 1,190 cfs (Table 3).

Eight locations were surveyed at Escalante Ranch: seven upstream inlets and one downstream outlet (Figure 3). The approximate distance between the upstream-most inlet (ER-IN-1) and the outlet (ER-OUT) was 1.3 river miles (2 river km). Characterization of levee breaches and connection channel elevations at each of these locations is provided below. As summarized in Table 5, the 2012 minimum connection flow at Escalante Ranch was estimated to be 11,300 cfs (ER-OUT), which was about a 134 cfs increase from estimates at the lowest connecting breach in 2005 (ER-IN-6; Table 5). Estimated connection flows among upstream breaches increased by about 4,134 cfs, whereas connection flows for the downstream breach, ER-OUT, decreased by about 1,133 cfs in 2012. Estimated minimum fish passage flows for Escalante Ranch showed the same pattern as connection flows, but were on average 3,317 cfs higher than connection flows (Table 5).

ER-IN-1. ER-IN-1 had been intentionally filled with rip-rap prior to our survey and was no longer a functioning levee breach. Nine locations were surveyed at ER-IN-1 (Figure 4). River water surface elevation was not recorded for this site; therefore, the estimated mean water surface elevation for the nearest site (ER-IN-3) was used: 4,730.55 ft. Based on our survey, the

FIGURE 3 Escalante Ranch Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

FIGURE 4 ER-IN-1 Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

estimated breach flow at ER-IN-1 in 2012 was about 22,000 cfs (Table 4). No floodplain and channel elevation surveys were conducted at ER-IN-1, but any channel between the filled breach and the wetland is expected to be at a lower elevation than the filled breach elevation. Therefore, the breach flow for ER-IN-1 is expected to be equivalent to the connection flow. The estimated 2012 breach flow for ER-IN-1 was approximately 10,500 cfs higher than flow reported by Tetra Tech (2005).

ER-IN-2. ER-IN-2 also had been intentionally filled with rip-rap prior to our survey and was no longer a functioning levee breach. Six locations were surveyed at ER-IN-2 (Figure 5). River water surface elevation was not recorded for this site; therefore, the estimated mean water elevation for the nearest site (ER-IN-3) was used: 4,730.55 ft. Based on our survey, the estimated breach flow at ER-IN-2 in 2012 was about 23,000 cfs (Table 4). No floodplain and channel elevation surveys were conducted at ER-IN-2, but any channel between the filled breach and the wetland is expected to be a lower elevation than the filled breach elevation. Therefore, the breach flow for ER-IN-2 is expected to equal the connection flow. The estimated 2012 breach flow for ER-IN-2 was approximately 6,200 cfs higher than the flow reported by Tetra Tech (2005).

ER-IN-3. Seventy-four locations were surveyed at ER-IN-3 (Figure 6). The estimated mean river water surface elevation near ER-IN-3 was 4,730.55 ft. At the time of the survey, ER-IN-3 was a well-defined sandy breach with willows and annual plants growing in the breach area. Based on our survey, the estimated breach flow at ER-IN-3 in 2012 was 14,500 cfs (Table 4). The connection flow was estimated to be 18,100 cfs, and the highest portion of the channel that limited connection was located approximately two-thirds of the way up the channel from the breach (Figure B-1). This estimated connection flow was approximately 6,200 cfs higher than the connection flow reported by Tetra Tech (2005). Tetra Tech (2005) noted significant bank erosion and deposition within the breach at this site in 2005 (Table 4). The estimated fish passage flow for ER-IN-3 in 2012 was estimated at 21,500 cfs, which is 6,400 cfs higher than in 2005 (Table 6).

ER-IN-4. A total of 101 locations were surveyed at ER-IN-4 (Figure 7). The estimated mean river water surface elevation near ER-IN-4 was 4,730.45 ft. At the time of the survey, ER-IN-4 was completely blocked by sand with no apparent cut in the levee. Based on our survey, the estimated breach flow at ER-IN-4 in 2012 was 17,600 cfs (Table 4). The connection flow for ER-IN-4 in 2012 was estimated to be 20,300 cfs, and the highest portion of the channel that limited connection was located near the wetland edge (Figure B-2). The estimated connection flow for ER-IN-4 was approximately 7,367 cfs higher than the connection flow reported by Tetra Tech (2005). Tetra Tech (2005) noted a general trend of sand deposition at this site (Table 4). The estimated fish passage flow for ER-IN-4 in 2012 was estimated at 23,900 cfs, which is 7,700 cfs higher than in 2005 (Table 6).

ER-IN-5. A total of 112 locations were surveyed at ER-IN-5 (Figure 8). The estimated mean river water surface elevation at ER-IN-5 was 4,730.04 ft. At the time of the survey, ER-IN-5 was a shallow breach (approximately 3 ft in depth) with loose sand. Based on our survey, the breach flow at ER-IN-5 in 2012 was estimated to be 15,200 cfs (Table 4). The connection flow was estimated to be 16,800 cfs, and the highest portion of the channel that

FIGURE 5 ER-IN-2 Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

FIGURE 6 ER-IN-3 Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

FIGURE 7 ER-IN-4 Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

FIGURE 8 ER-IN-5 Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

limited connection was near the wetland edge (Figure B-3). This estimated connection flow was approximately 4,800 cfs higher than the connection flow reported by Tetra Tech (2005). Tetra Tech (2005) noted minor bank erosion and sand deposition at this site (Table 4). The estimated fish passage flow for ER-IN-5 in 2012 was estimated at 20,100 cfs, which is 4,900 cfs higher than in 2005 (Table 6).

ER-IN-6. A total of 104 locations were surveyed at ER-IN-6 (Figure 9). The estimated mean river water surface elevation at ER-IN-6 was 4,729.67 ft. At the time of the survey, ER-IN-6 was a shallow breach (approximately 3 ft in depth) with loose sand. Based on our survey, the breach flow at ER-IN-6 in 2012 was estimated to be 15,100 cfs (Table 4). The connection flow was estimated to be 19,200 cfs, and the highest portion of the channel that limited connection was located approximately one-third of the way up the channel from the breach (Figure B-4). This estimated connection flow was approximately 8,034 cfs higher than the connection flow reported by Tetra Tech (2005). Tetra Tech (2005) noted a general trend of sand deposition at this site (Table 4). The estimated fish passage flow for ER-IN-6 in 2012 was 22,600 cfs, which is 8,400 cfs higher than in 2005 (Table 6).

ER-IN-7. A total of 109 locations were surveyed at ER-IN-7 (Figure 10). The estimated mean river water surface elevation at ER-IN-7 was 4,729.80 ft. At the time of the survey, ER IN 7 was a broad, low, sandy breach. Based on our survey, the breach flow at ER IN-7 in 2012 was estimated to be 13,800 cfs (Table 4). The connection flow was estimated to be 15,300 cfs, and the highest portion of the channel that limited connection was located approximately two-thirds of the way up the channel from the breach (Figure B-5). This estimated connection flow was approximately 3,300 cfs higher than the connection flow reported by Tetra Tech (2005). Tetra Tech (2005) noted a general trend of sand deposition at this site (Table 4). The estimated fish passage flow for ER-IN-7 in 2012 was 18,500 cfs, which is 3,300 cfs higher than in 2005 (Table 6).

ER-OUT. A total of 123 locations were surveyed at ER-OUT (Figure 11). The estimated mean river water surface elevation at ER-OUT was 4,728.90 ft. At the time of the survey, ER OUT was a long broad channel extending from the river to the wetland. Several areas of scour were noted in the channel both near the levee breach and where the channel changes direction from east-west to northeast-southwest (Figure 11). This scour presumably occurred during periods when high flows passed through the wetland from upstream breaches through the outlet during peak flow, and as the wetland drained during flood recession. Based on our survey, the breach flow at ER-OUT in 2012 was estimated to be 10,800 cfs. The connection flow was estimated to be 11,300 cfs, and the highest portion of the channel that limited connection was located approximately two-thirds of the way up the channel from the breach (Figure B-6). This estimated connection flow was approximately 1,133 cfs lower than the connection flow reported by Tetra Tech (2005). Tetra Tech (2005) noted some scouring upstream of the upper control structure that exists at this site (Table 4). The estimated fish passage flow for ER-OUT in 2012 was 14,300 cfs, which is 1,300 cfs lower than in 2005 (Table 6).

Escalante Ranch ER-IN-6

- GPS Waypoints (n = 9)
- Survey Locations
- Breach Cross Section Axis

f062

FIGURE 9 ER-IN-6 Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

FIGURE 10 ER-IN-7 Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

Escalante Ranch ER-OUT

- GPS Waypoints (n = 12)
- Survey Locations
- Breach Cross Section Axis

f064

FIGURE 11 ER-OUT Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

3.2 BONANZA BRIDGE

The Bonanza Bridge wetland was surveyed on October 25, 2012. Table 3 summarizes the dates and times of the floodplain surveys, with corresponding lag-adjusted local flow conditions at the time of the survey. The local flow at Bonanza Bridge at the time of the survey was calculated to be 1,235 cfs (Table 3).

Four breach locations were surveyed at Bonanza Bridge: three upstream inlets and a downstream outlet (Figure 12). The approximate distance between the upstream-most inlet (BB-IN-1) and the outlet (BB-OUT) was 0.7 river miles (1.1 river km). Characterization of levee and floodplain elevations at each of these locations is provided below. The 2012 minimum connection flow at Bonanza Bridge was estimated to be 17,400 cfs (BB-OUT), which was about a 4,400 cfs increase from estimates at the lowest connecting breach in 2005 (BB-IN-3; Table 5). Estimated connection flows among upstream breaches increased by about 7,100 cfs, and the estimated connection flow at the outlet increased by about 3,500 cfs. Fish passage flow estimates for Bonanza Bridge showed the same pattern as connection flow, but were on average 3,475 cfs higher than connection flows (Table 6).

BB-IN-1. Fifty-six locations were surveyed at BB-IN-1 (Figure 13). The estimated mean river water surface elevation at BB-IN-1 was 4,703.1 ft. At the time of the survey, the levee breach at BB-IN-1 was partially blocked with loose sand, but led to a relatively narrow, mostly grassy channel. Based on our survey, the breach and connection flows at BB-IN-1 were estimated to be 17,400 cfs and 20,100 cfs, respectively (Table 4), and the highest portion of the channel that limited connection was located approximately one-third of the way up the channel from the breach (Figure B-7). This connection flow was approximately 1,600 cfs higher than the connection flows reported by Tetra Tech (2005). The increase in connection flow resulted from the accumulation of sand deposits and debris in the levee and along the connection channel, including a very large deposit of sand at the wetland end of the channel that appeared to originate from inflow through BB-IN-2 (see description under BB-IN-2) (Figure 13). In addition, portions of the channel were partially blocked with cut brush, although flow could pass through this material. Two sand roads crossed portions of the channel including near the breach and midway between the breach and the wetland (Figure 13). These roads did not appear to affect the magnitude of connection flow at the time of the survey. Tetra Tech (2005) suggested that the breach elevation was too high for proper connection at reported flows of 13,000 cfs and actual connection occurred at flows between 18,500 and 19,700 cfs (Table 4). The estimated fish passage flow for BB-IN-1 in 2012 was 23,700 cfs, which is 1,400 cfs higher than in 2005 (Table 6).

BB-IN-2. Sixty locations were surveyed at BB-IN-2 (Figure 14). The estimated mean river water surface elevation at BB-IN-2 was 4,702.9 ft. At the time of survey, BB-IN-2 was partially blocked with a deposit of loose sand. Based on our survey, the breach and connection flows at BB-IN-2 were estimated to be 16,300 cfs and 21,100 cfs, respectively (Table 4), and the highest portion of the channel that limited connection was located approximately half way up the channel from the breach (Figure B-8). This connection flow was approximately 7,200 cfs higher than the connection flow reported by Tetra Tech (2005). The increase in connection flow resulted from the accumulation of sand deposits and debris in the levee breach, including a very

FIGURE 12 Bonanza Bridge Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

FIGURE 13 BB-IN-1 Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

FIGURE 14 BB-IN-2 Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

large deposit of sand at the wetland end of the channel that, based on a review of aerial imagery, was deposited during the high peak flows of 2008 and 2011 (Figure 14). This deposit was estimated to be approximately 6 ft (2 m) higher than the wetland surface at the time of the survey. The sand deposit first appears in Google Earth images in 2009 at the end of the connection channel of BB-IN-2, but then increases greatly in size after the 2011 peak flow. A sand road (continuation of the road through BB-IN-1) passed through the levee breach (Figure 14), but did not appear to affect the magnitude of connection flow at the time of the survey. Tetra Tech (2005) suggested that the breach elevation was too high for proper connection at reported flows of 13,000 cfs and that actual connection occurred at flows greater than 13,900 cfs (Table 4). The estimated fish passage flow for BB-IN-2 in 2012 was 24,700 cfs, which is 7,400 cfs higher than in 2005 (Table 6).

BB-IN-3. Forty-nine locations were surveyed at BB-IN-3 (Figure 15). The estimated mean river water surface elevation at BB-IN-3 was 4,702.8 ft. At the time of survey, BB-IN-3 contained large sand deposits and stands of Russian thistle (*Salsola* sp.). Based on our survey, the breach and connection flows at BB-IN-3 were both estimated to be 24,100 cfs (Table 4), and the highest portion of the channel that limited connection was located at the breach (Figure B-9). This connection flow was approximately 11,100 cfs higher than the connection flow reported by Tetra Tech (2005). Tetra Tech (2005) also noted thick stands of vegetation in the breach and channel (Table 4). The estimated fish passage flow for BB-IN-3 in 2012 was 27,900 cfs, which is 11,600 cfs higher than in 2005 (Table 6).

BB-OUT. One hundred sixteen locations were surveyed at the two breaches of BB-OUT (Figure 16). This breach was referred to as BB-5B in the Tetra Tech (2005) report. Two breaches of hard packed sand near the river lead to a network of unimproved dirt and gravel roads that serve as connection channels to the wetland through a broad low woodland. The estimated mean river water surface elevation was 4,702.0 ft at both breach locations. Based on our survey, the estimated breach and connection flows at BB-OUT in 2012 were 13,100 cfs and 17,400 cfs, respectively (Table 4), and the highest portion of the channel that limited connection was located approximately half way up the channel from the breach (Figure B-10). This connection flow was approximately 3,500 cfs higher than the connection flows reported by Tetra Tech (2005). Tetra Tech (2005) suggested that the breach elevation was too high for proper connection at reported flows of 13,000 cfs and that actual connection occurred at flows between 13,900 and 18,500 cfs (Table 4). The estimated fish passage flow for BB-OUT in 2012 was estimated at 20,800 cfs, which is 3,500 cfs higher than in 2005 (Table 6).

3.3 STIRRUP

The Stirrup wetland was surveyed on October 22, 2012. Table 3 summarizes the dates and times of the floodplain surveys, with corresponding lag-adjusted local flow conditions at the time of the survey. The local flow at Stirrup at the time of the survey was calculated to be 1,193 cfs (Table 3).

FIGURE 15 BB-IN-3 Breach Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

Bonanza Bridge BB-IN-OUT

- GPS Waypoints (n = 13)
- Survey Locations
- Breach Cross Section Axis

1069

FIGURE 16 BB-OUT Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

There is only one breach location at Stirrup (ST-OUT, Figure 17). A total of 193 locations were surveyed at ST-OUT (Figure 17). The estimated mean river water surface elevation at ST-OUT was 4,683.1 ft. Based on our survey, the breach and connection flows at ST-OUT in 2012 was estimated to be 11,000 cfs and 16,900 cfs, respectively (Table 4), and the highest portion of the channel that limited connection was located approximately two-thirds of the way up the channel from the breach (Figure B-11). This estimated connection flow was approximately 3,900 cfs higher than the connection flow reported by Tetra Tech (2005). At the time of the survey, no deposits of loose sand or other material that might obstruct flow were seen. The estimated breach flow was lower than previous estimates, but Tetra Tech (2005) noted a decrease in elevation from previous surveys of about 1.5 ft (Table 4). Estimated fish passage flow for ST-OUT in 2012 was 20,200 cfs, which is a 3,900 cfs increase from 2005 (Table 6).

3.4 ABOVE BRENNAN

The Above Brennan wetland was surveyed on October 22, 2012. Table 3 summarizes the dates and times of the surveys with corresponding lag-adjusted local flow conditions at the time of the survey. The local flow at Above Brennan at the time of the survey was calculated to be 1,180 cfs (Table 3).

Four breach locations were surveyed at Above Brennan: three upstream inlets and a downstream outlet (Figure 18). The approximate distance between the upstream-most inlet (AB-IN-1) and the outlet (AB-OUT) was 0.8 river mi (1.3 river km). Characterizations of levee and floodplain connection elevations at each of these locations are provided below. As summarized in Table 5, the 2012 minimum connection flow at Above Brennan was estimated to be 9,990 cfs (AB-OUT), which was about a 3,010 cfs decrease from connection flow observations made by Tetra Tech (2005). Estimated 2012 connection flows among upstream breaches increased by about 3,400 cfs, whereas connection flows at the downstream breach (AB-OUT) decreased by about 3,010 cfs. Fish passage flow estimates for Above Brennan showed the same pattern as connection flow, but were on average 3,300 cfs higher (Table 6).

AB-IN-1. A total of 131 locations were surveyed at AB-IN-1 (Figure 19). The estimated mean river water surface elevation at AB-IN-1 was 4,673.5 ft. At the time of survey, AB-IN-1 was a fairly narrow breach and channel with little apparent obstruction to flow. Based on our survey, breach and connection flows at AB-IN-1 in 2012 were estimated to be 10,300 cfs and 16,400 cfs, respectively (Table 4), and the highest portion of the channel that limited connection was located approximately one-third of the way up the channel from the breach (Figure B-12). This estimated connection flow was approximately 3,400 cfs higher than the connection flow reported by Tetra Tech (2005). The 2012 estimated breach flow was lower than previous estimates, but Tetra Tech (2005) noted a general trend in erosion at this site. The estimated fish passage flow for AB-IN-1 in 2012 was 19,700 cfs, which is a 3,400 cfs increase from 2005 (Table 6).

AB-IN-2. Fifty-four locations were surveyed at AB-IN-2 (Figure 20). The estimated mean river water surface elevation at AB-IN-2 was 4,673.2 ft. At the time of survey, AB-IN-2 was a very narrow channel (approximately 3 ft wide) that widened as it approached the wetland.

FIGURE 17 Stirrup Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

f071

FIGURE 18 Above Brennan Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

FIGURE 19 AB-IN-1 Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

Above Brennan AB-IN-2

- GPS Waypoints (n = 3)
- Survey Locations
- Breach Cross Section Axis

#073

FIGURE 20 AB-IN-2 Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

Based on our survey, the breach and connection flows at AB-IN-2 in 2012 were estimated to be 15,500 cfs and 19,500 cfs, respectively (Table 4), and the highest portion of the channel that limited connection was located near the breach (Figure B-13). This estimated connection flow was approximately 6,500 cfs higher than the connection flows previously reported by Tetra Tech (2005). Tetra Tech (2005) did not observe any trends at this site. Estimated fish passage flow for AB-IN-2 in 2012 was 23,000 cfs, which is a 6,700 cfs increase from 2005 (Table 6).

AB-IN-3. Fifty-eight locations were surveyed at AB-IN-3 (Figure 21). The estimated mean river water surface elevation at AB-IN-3 was 4,672.9 ft. At the time of survey, AB-IN-3 was a narrow channel with packed sand. Based on our survey, the breach and connection flows at AB-IN-3 in 2012 were estimated to be 16,400 cfs and 18,500 cfs, respectively (Table 4), and the highest portion of the channel that limited connection was located near the breach (Figure B-14). This estimated connection flow was approximately 5,500 cfs higher than the connection flows previously reported by Tetra Tech (2005). Tetra Tech (2005) noted a general trend of deposition at this site. The estimated fish passage flow for AB-IN-3 in 2012 was 21,900 cfs, which is a 5,600 cfs increase from 2005 (Table 6).

AB-OUT. Seventy-nine locations were surveyed at AB-OUT (Figure 22). The estimated mean river water surface elevation at AB-OUT was 4,672.5 ft. AB-OUT consisted of a fairly wide breach (approximately 45 ft in width) with a narrow, more deeply incised notch. This breach led to a broad short channel with many downed trees that have collected near the outlet. This downed wood and a nearby degraded beaver dam could obstruct the inflow of water at high flows. Based on our survey, the breach and connection flows at AB-OUT in 2012 were both estimated to be 9,990 cfs (Table 4), and the highest portion of the channel that limited connection was located near the breach (Figure B-15). This estimated connection flow was approximately 3,010 cfs lower than the connection flows reported by Tetra Tech (2005). Tetra Tech (2005) noted a general trend of erosion at this site. The fish passage flow for AB-OUT in 2012 was estimated to be 13,000 cfs, which is a 3,300 cfs decrease from 2005 (Table 6).

3.5 JOHNSON BOTTOM

Johnson Bottom was surveyed on October 25, 2012. Table 3 summarizes the dates and times of the floodplain surveys with corresponding lag-adjusted local flow conditions at the time of the survey. The local flow at Johnson Bottom at the time of the survey was calculated to be 1,250 cfs (Table 3).

Two downstream breach locations were surveyed at Johnson Bottom (Figure 23). The approximate distance between the upstream-most breach (JB-OUT-1) and the downstream-most breach (JB-OUT-2) was 0.3 river mi (0.5 river km). Characterizations of levee and floodplain elevations at each of these locations are provided below. As summarized in Table 5, the 2012 minimum connection flow at Johnson Bottom was estimated to be 16,100 cfs (JB-OUT-1), which was about a 3,100 cfs higher than the connection flow presented in Bestgen et al. (2011). Fish passage flow estimates for Johnson Bottom showed the same pattern as connection flow, but were on average 2,600 cfs higher (Table 6).

FIGURE 21 AB-IN-3 Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

Above Brennan AB-OUT

- GPS Waypoints (n = 6)
- Survey Locations
- Breach Cross Section Axis

1075

FIGURE 22 AB-OUT Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

FIGURE 23 Johnson Bottom Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

JB-OUT-1. JB-OUT-1 is a concrete and metal gated drain structure and fish kettle that was constructed in 1999 (Heitmeyer and Fredrickson 2005). Seventy-five locations were surveyed at the breach and connection channel leading to the JB-OUT-1 structure (Figure 24). The estimated mean river water surface elevation at JB-OUT-1 was 4,663.5 ft. JB-OUT-1 was a fairly narrow breach through hard sand that leads to a well-defined mostly vegetated channel that slopes down toward the gated inlet structure. Based on our survey, the breach and connection flows at JB-OUT-1 in 2012 were both estimated to be 16,100 cfs (Table 4), indicating that the breach represented the highest elevation along the connection channel (Figure B-16). Estimated connection flows in 2012 were approximately 3,100 cfs higher than the connection flows reported by Bestgen et al. (2011). The fish passage flow at JB-OUT-1 was estimated to be 18,700 cfs, which is a 3,300 cfs increase from 2005 (Table 6). Tetra Tech (2005) did not evaluate this site.

JB-OUT-2. JB-OUT-2 is a wide channel breach that was created when a 200 ft portion of levee was removed in 1998 (Heitmeyer and Fredrickson 2005). Ninety-eight locations were surveyed at JB-OUT-2 (Figure 25). The estimated mean river water surface elevation at JB-OUT-2 was 4,663.5 ft. This very broad low sandy breach led to a complex connection channel and the wetland. A sand road crosses the length of the breach. Based on our survey, the breach and connection flows at JB-OUT-2 in 2012 were estimated to be 11,100 cfs and 16,400 cfs, respectively (Table 4), and the highest portion of the channel that limited connection was located approximately half way up the channel from the breach (Figure B-17). This estimated connection flow was approximately 3,400 cfs higher than the connection flow reported by Bestgen et al. (2011). The increase in connection flow resulted from the accumulation of debris and sand deposits along the connection channel that, based on a review of aerial imagery, was deposited during the high peak flows of 2005 and 2011. The estimated fish passage flow for JB-OUT-2 in 2012 was 19,000 cfs, which is a 3,600 cfs increase from 2005 (Table 6). Tetra Tech (2005) did not evaluate this site.

3.6 LEOTA BOTTOM

Leota Bottom is separated into 11 units each with levees and water-control structures (Heitmeyer and Fredrickson 2005). Leota Bottom was surveyed on October 23, 2012. Table 3 summarizes the dates and times of the floodplain surveys with corresponding lag-adjusted local flow conditions at the time of the survey. The local flow at Leota Bottom at the time of the survey was calculated to be 1,190 cfs (Table 3).

Two downstream breach locations were surveyed at Leota Bottom: LB7-IN and LB7A-IN (Figure 26). In 1998, short portions of the levee along the Green River adjacent to units L7 and L7A were breached to allow flood flows of 15,000 to 20,000 cfs to enter Leota Bottom. The approximate distance between LB7-IN and LB7A-IN was 0.3 river mi (0.5 river km). Characterizations of levee and floodplain elevations at each of these locations are provided below. As summarized in Table 5, the 2012 minimum connection flow at Leota Bottom was estimated to be 13,400 cfs (LB7A-IN). This wetland was not surveyed by Tetra Tech (2005) or reported in Bestgen et al. (2011); therefore, comparisons to 2005 connection flows could not be

FIGURE 24 JB-OUT-1 Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

FIGURE 25 JB-OUT-2 Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

Leota Bottom

● Survey Locations

1079

FIGURE 26 Leota Bottom Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

made. Fish passage flow estimates for Leota Bottom showed the same pattern as connection flow, but were on average 2,550 cfs higher (Table 6).

LB7-IN. Ninety-seven locations were surveyed at LB7-IN (Figure 27). The estimated mean river water surface elevation at LB7-IN was 4,659.9 ft. LB7-IN was a broad breach of loose sand that led to a broad connection channel to the wetland; a sand road traversed the length of the breach. There was a large sandbar between the breach and the river edge. Based on our survey, the breach and connection flows at LB7-IN were estimated to be 17,200 cfs and 17,600 cfs, respectively (Table 4), and the highest portion of the channel that limited connection was located near the wetland edge (Figure B-18). This breach was not surveyed by Tetra Tech (2005) or reported in Bestgen et al. (2011); therefore, comparisons to 2005 connection flows could not be made. In 2012, a large deposit of sand within the connection channel was apparent from the 2011 inflow. The estimated fish passage flow for LB7-IN in 2012 was 20,300 cfs (Table 6).

LB7A-IN. Eighty-two locations were surveyed at LB7A-IN (Figure 28). The estimated mean river water surface elevation at LB7A-IN was 4,658.8 ft. LB7A-IN was a broad breach that led to a broad connection channel to the wetland; a road traversed the length of the breach, part of which was paved concrete with the rest loose sand. There was a large sandbar between the breach and the river edge. Based on our survey, the breach and connection flows at LB7A-IN in 2012 were estimated to be 13,300 cfs and 13,400 cfs, respectively (Table 4), and the highest portion of the channel that limited connection was located near the wetland edge (Figure B-19). This breach was not surveyed by Tetra Tech (2005) or reported in Bestgen et al. (2011); therefore, comparisons to 2005 connection flows could not be made. The estimated fish passage flow for LB7A-IN in 2012 was 15,800 cfs (Table 6).

3.7 SHEPPARD BOTTOM

Sheppard Bottom was surveyed on October 24, 2012. Table 3 summarizes the dates and times of the floodplain surveys with corresponding lag-adjusted local flow conditions at the time of the survey. The local flow at Sheppard Bottom at the time of the survey was calculated to be 1,190 cfs (Table 3).

One downstream breach location was surveyed at Sheppard Bottom (Figure 29). Tetra Tech (2005) did not evaluate this site (Table 4). This location was identified by the Ouray National Wildlife Refuge Manager (D. Shaad) as a potential connection recently created by the Refuge to facilitate connection during peak runoff. Twenty-four locations were surveyed at SB-IN (Figure 29). No river water surface elevations were recorded at Sheppard Bottom because of the distance to the river from the breach and the lack of access to the river's edge. Instead, river water surface elevations were interpolated from the nearest upstream survey location (LB7A-IN) and downstream survey location (OC-OUT-1). Based upon this interpolation, the estimated water surface elevation at SB-IN was calculated to be 4,651.74 ft. Based on our survey, the breach flow at SB-IN in 2012 was estimated to be 11,800 cfs. However, because the surveyed breach was far from the river (straight line distance 0.25 mi), and no clear connection channel led to the river, we did not survey the area between the breach and the river (Figure 29).

Leota Bottom LB7-IN

- GPS Waypoints (n = 8)
- Survey Locations
- Breach Cross Section Axis

1080

FIGURE 27 LB7-IN Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

Leota Bottom LB7A-IN

- GPS Waypoints (n = 8)
- Survey Locations
- Breach Cross Section Axis

f081

FIGURE 28 LB7A-IN Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

Sheppard Bottom

- GPS Waypoints (n = 8)
- Survey Locations
- Breach Cross Section Axis

f082

FIGURE 29 Sheppard Bottom Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

Refuge staff (D. Shaad, personal communication) noted that Sheppard Bottom did not connect through this breach in 2014 when flows reached 17,800 cfs at the Ouray gage on June 9, indicating that obstruction to inflow does occur somewhere between the breach and the river, and that connection flow is considerably higher than the breach flow at this location. A more extensive survey would be needed to identify the most likely connection channel between the river and wetland.

3.8 OLD CHARLIE WASH

Old Charlie Wash (referred to as Woods Bottom in Heitmeyer and Fredrickson 2005) was surveyed on October 24, 2012. Table 3 summarizes the dates and times of the floodplain surveys, with corresponding lag-adjusted local flow conditions at the time of the survey. The local flow at Old Charlie Wash at the time of the survey was calculated to be 1,190 cfs (Table 3).

Two downstream breach locations were surveyed at Old Charlie Wash (Figure 30). The approximate distance between OC-OUT-1 and OC-OUT-2 was 0.3 river mi (0.5 river km). Characterizations of levee and floodplain elevations at each of these locations are provided below. As summarized in Table 5, the 2012 minimum connection flow at Old Charlie Wash was estimated to be 9,430 cfs (OC-OUT-2), which is 3,570 cfs lower than the connection flow reported in Bestgen et al. (2011). Fish passage flow estimates for Leota Bottom showed the same pattern as connection flow, but were on average 2,285 cfs higher (Table 6).

OC-OUT-1. In 1997, a 100-ft-wide section of the south levee of the backside unit along the Green River was removed to allow overbank flooding at about 13,000 cfs. Fifty-two locations were surveyed at OC-OUT-1 (Figure 31). The estimated mean river water surface elevation at OC-OUT-1 was 4,650.5 ft. Based on our survey, the breach and connection flows at OC-OUT-1 in 2012 was estimated to be 12,400 cfs and 14,300 cfs, respectively (Table 4), and the highest portion of the channel that limited connection was located approximately half way up the channel from the breach (Figure B-20). This estimated connection flow was approximately 1,300 cfs higher than the connection flow reported by Bestgen et al. (2011). The fish passage flow at OC-OUT-1 in 2012 was estimated to be 16,700 cfs, which is a 1,300 cfs increase from 2005 (Table 6).

OC-OUT-2. OC-OUT-2 is a concrete and metal gated drain structure that was modified in 1993 with a fish kettle and a bottom elevation of about 4,000 cfs (Heitmeyer and Fredrickson 2005). This breach to Old Charlie Wash can be opened or closed to allow river water to enter the site or be retained as river flows recede. Forty three locations were surveyed at OC-OUT-2 (Figure 32). The estimated mean river water surface elevation at OC-OUT-2 was 4,650.2 ft. Based on our survey, the estimated breach and connection flows at OC-OUT-2 in 2012 were approximately 3,850 cfs and 9,430 cfs, respectively (Table 4), and the highest portion of the channel that limited connection was about one-third of the distance between the river edge and the gate structure (Figure B-21). This connection flow is 3,570 cfs lower than the connection

FIGURE 30 Old Charlie Wash Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

FIGURE 31 OC-OUT-1 Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

FIGURE 32 OC-OUT-2 Survey Locations. The date of the aerial imagery differs from the date of the survey; aerial imagery does not depict exact conditions at the time of the survey.

1 flow reported by Bestgen et al. (2011). The estimated fish passage flow at the gate structure in
2 2012 was estimated to be 11,600 cfs, which is a 3,800 cfs decrease from 2005 (Table 6).

3.9 RESULTS SUMMARY

7 Our 2012 survey identified substantial changes since 2005 at most of the levee breaches
8 and connection channels evaluated (Table 4). Original reported values were largely based on
9 design specifications of levee breaches made to intentionally entrain water at specific high flows.
10 However, as noted by Tetra Tech (2005) during the high flows of 2005, there were
11 inconsistencies in the design connection flow and the actual connection flow at several of the
12 Bonanza Bridge breaches (BB-IN-1, BB-IN-2, BB-OUT); each of these breaches did not connect
13 until flows were higher than the design flow (Table 4).

15 The average estimated minimum floodplain connection flow (i.e., the lowest connection
16 flow of any breach at a particular wetland) among the seven floodplain wetlands surveyed in
17 2012 was 13,503 cfs (Table 5). This is a relatively small mean increase (826 cfs) compared to
18 estimated connection flows in 2005. However, there was considerable variation among the
19 wetlands in estimated minimum connection flow, ranging from 9,430 cfs at Old Charlie Wash to
20 17,400 cfs at Bonanza Bridge. There was much less variation in 2005 (11,166 to 13,000 cfs).

22 Changes in connection flows differed between upstream and downstream breaches with
23 upstream breaches showing a much larger increase since 2005 compared to downstream breaches
24 (Table 5). The mean connection flow of upstream breaches in 2012 was 17,267 cfs (15,300 to
25 20,100 cfs) compared to 12,389 cfs (11,166 to 13,000 cfs) in 2005, and represents an increase of
26 4,878 cfs (3,400 to 7,100 cfs) for upstream breaches. The mean connection flow of downstream
27 breaches in 2012 was 13,503 cfs (9,430 to 17,400 cfs) compared to the 2005 mean of 13,056 cfs
28 (12,433 to 13,900 cfs), and represents an increase of 465 cfs (-3,570 to 3,900 cfs) for
29 downstream breaches.

31 Estimated fish passage flows in 2012 were approximately 2,300 to 2,600 cfs higher than
32 connection flows in the Ouray National Wildlife Refuge wetlands (Johnson Bottom, Leota
33 Bottom, and Old Charlie Wash) and 3,300 to 3,600 cfs higher than connection flows in the
34 wetlands further upstream. In 2012, the mean passage flow for the floodplain wetlands surveyed
35 was 19,900 cfs (11,600 to 27,900 cfs; Table 6). In 2012, the mean minimum passage flow for the
36 floodplain wetlands surveyed (i.e., the lowest of all levee breaches in each wetland) was
37 approximately 16,343 cfs (11,600 to 20,800 cfs).

4 DISCUSSION

We reassessed floodplain wetland connection of eight priority wetlands in the Middle Green River in 2012 to determine if high magnitude peak flows since 2005 had resulted in changes in the levee breaches and connection channels of the se wetlands. Knowing the actual connection flows in any given year is critical to defining the target peak flows during the runoff season to meet the biological objectives identified in Muth et al. (2000) and in the Larval Trigger Study Plan (Larval Trigger Study Plan Ad Hoc Committee 2012).

Our results indicate that there is a need for periodic reassessments of levee breaches and connection channels especially following very high peak flows. In 2012, there were considerable differences from connection flows measured or estimated in 2005 at most of the levee breaches and connection channels we surveyed. Differences between 2012 and 2005 floodplain connection flows were related to the amount of scour and sediment deposition in levee breaches and the intervening channels that connect the wetlands to the river's main channel at high flows. In general, the flows needed to connect floodplain wetlands at upstream breaches increased, and connection flows for downstream breaches either increased less or decreased since 2005. In the wetlands studied, upstream breaches were topographically higher than the wetland, while downstream breaches were lower than the wetland. This topographic variation likely explains the deposition patterns we observed. Water flowing into an upstream breach would deposit sediment once it encountered the low velocity water of the wetland, and, as a consequence, upstream breaches and channels would accumulate fine sediment. The wetland and connection channels serve as traps for sediment, and water exiting through the downstream breach would have a lower sediment load and would more likely scour during flow-through or as flows recede after the peak.

The configuration and length of the connection channel of upstream inlets can affect where deposition occurs and would likely affect connection in later years. Water flowing into longer channels (i.e., when the wetland is further from the breach) would retain its sediment load in suspension until the low-velocity water of the wetland was encountered. This was apparent at Bonanza Bridge where large sediment deposits formed near the edge of the wetland boundary in 2008 and 2011 (Figures 13 and B-7). These deposits may not restrict future connection because the channel is sufficiently wide to allow water to flow around the deposit. In contrast, and as another example, BB-IN-3 has a much shorter connection channel, and sediment deposition occurred much closer to the breach (Figures 15 and B-9).

Downstream breaches also serve as inlets for flood water. Water depth in downstream connection channels increase as flows rise until connection with the wetland margin occurs, at which time the wetland begins to fill. Downstream breaches can be depositional areas during this filling process, but when peak flows recede, scour of new deposits would occur as water flows out of the wetland and the wetland water surface stabilizes to a lower elevation.

Our observations support those of Heitmeyer and Fredrickson (2005), who stated that high flows may increase sedimentation and debris build up in upstream breaches, resulting in higher subsequent connection flows in these breaches, but would tend to scour downstream

breaches, resulting in maintenance or reduction of connection flows. Our results suggest that for upstream breaches to remain as viable connections to floodplain wetlands over the long term, regular breach and connection channel inspection and maintenance may be required.

5 CONCLUSIONS

- Substantial changes from 2005 in estimated connection flows at levee breaches of seven priority floodplain wetlands in the middle Green River were observed in 2012, and these changes resulted from significant deposition of sediment in breaches and connection channels during intervening high peak flows.
- Mean connection flow for surveyed wetlands in 2012 was 13,503 cfs compared to 12,694 cfs in 2005, an increase of 826 cfs.
- Most individual breaches showed an increase in the flow needed to connect the wetland to the main channel. The mean change was an increase of 3,815 cfs; only three breaches showed a decrease (ER-OUT, AB-OUT, and OC-OUT-2) with decreases of 1,133 cfs, 3,010 cfs, and 3,570 cfs, respectively.
- Sediment deposition was apparent in most upstream breaches but not downstream breaches, and this deposition resulted in an increase in estimated connection flows. In 2012, mean connection flow of upstream breaches was 17,267 cfs compared to 12,389 cfs in 2005, an increase of 4,878 cfs. In 2012, mean minimum connection flow of downstream breaches was 13,503 cfs compared to 13,056 cfs in 2005, an increase of 465 cfs.
- Estimated fish passage flows (those flows needed to allow passage of subadult and adult fish) were approximately 2,300 to 2,600 cfs higher than connection flows in the Ouray National Wildlife Refuge wetlands (Johnson Bottom, Leota Bottom, and Old Charlie Wash) and 3,300 to 3,600 cfs higher than estimated connection flows in the wetlands further upstream. In 2012, the mean estimated fish passage flow for the floodplain wetlands surveyed was 19,900 cfs (11,600 to 27,900 cfs). The mean estimated minimum fish passage flow for the floodplain wetlands surveyed (i.e., the lowest of all levee breaches in each wetland) was approximately 16,343 cfs (11,600 to 20,800 cfs).

6 RECOMMENDATIONS

- Resurvey floodplain wetland breaches and their connection channels following peak flows that exceed previously determined connection flows to determine if those peak flows have altered connection flows.
- Determine connection of floodplain wetlands annually by direct observation. Ideally, determinations would be made annually of initial connection flows at upstream and downstream breaches and the degree of filling and draining through the peak flow cycle.
- Measure the surface area of floodplain wetlands after peak flows recede and through the summer and winter to determine if floodplain wetlands provide suitable habitat for razorback suckers between flooding events that reconnect the wetlands to the main channel.
- Consider modification of floodplain wetland breaches and connection channels to provide connection to the main channel river at a return frequency of 1.5 years (probability of about 67%) to mimic pre-dam flooding frequency.
- Consider modifications of wetlands to prevent sediment deposition from blocking inflow. These modifications could include (1) actively reconfiguring levee breaches, connection channels, and wetland topography to minimize the blockage of connection channels; (2) filling or allowing the filling of upstream breaches; (3) creating control structures such as those that have been successfully deployed at Stewart Lake, Johnson Bottom, and Old Charlie Wash; and (4) managing vegetation encroachment that exacerbates sediment deposition in breaches and channels.

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APPENDIX A:
USGS STAGE-FLOW TABLES FOR THE JENSEN AND OURAY GAGES

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APPENDIX A:**USGS STAGE-FLOW TABLES FOR THE JENSEN AND OURAY GAGES**

This appendix presents the stage-flow tables for the Jensen gage (USGS 09261000) and Ouray gage (USGS 9272400) developed by the U.S. Geological Survey (USGS) (Tables A-1 and A-2, respectively). These tables were used as the basis for determining the flows that would connect wetlands and allow passage of fish at surveyed levee breaches and connection channels.

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TABLE A-1 USGS Stage-Flow Table for the Jensen Gage (USGS 09261000) in 2005 and 2012

Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)	Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)	Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)
1.87	795	1,080	2.35	1,210	1,620	2.83	1,720	2,260
1.88	803	1,090	2.36	1,220	1,630	2.84	1,730	2,270
1.89	811	1,100	2.37	1,230	1,640	2.85	1,740	2,290
1.90	818	1,110	2.38	1,240	1,650	2.86	1,750	2,300
1.91	826	1,120	2.39	1,250	1,670	2.87	1,760	2,320
1.92	834	1,130	2.40	1,260	1,680	2.88	1,780	2,330
1.93	842	1,140	2.41	1,270	1,690	2.89	1,790	2,350
1.94	850	1,150	2.42	1,280	1,700	2.90	1,800	2,360
1.95	858	1,160	2.43	1,290	1,720	2.91	1,810	2,380
1.96	865	1,170	2.44	1,290	1,730	2.92	1,820	2,390
1.97	873	1,180	2.45	1,300	1,740	2.93	1,840	2,410
1.98	881	1,190	2.46	1,310	1,750	2.94	1,850	2,420
1.99	889	1,200	2.47	1,330	1,770	2.95	1,860	2,440
2.00	898	1,210	2.48	1,340	1,780	2.96	1,870	2,450
2.01	906	1,220	2.49	1,350	1,790	2.97	1,880	2,470
2.02	914	1,230	2.50	1,360	1,810	2.98	1,900	2,480
2.03	922	1,240	2.51	1,370	1,820	2.99	1,910	2,500
2.04	930	1,260	2.52	1,380	1,830	3.00	1,920	2,510
2.05	939	1,270	2.53	1,390	1,850	3.01	1,930	2,530
2.06	947	1,280	2.54	1,400	1,860	3.02	1,950	2,540
2.07	955	1,290	2.55	1,410	1,870	3.03	1,960	2,560
2.08	964	1,300	2.56	1,420	1,890	3.04	1,970	2,570
2.09	972	1,310	2.57	1,430	1,900	3.05	1,980	2,590
2.10	981	1,320	2.58	1,440	1,910	3.06	2,000	2,600
2.11	989	1,330	2.59	1,450	1,930	3.07	2,010	2,620
2.12	998	1,340	2.60	1,460	1,940	3.08	2,020	2,630
2.13	1,010	1,360	2.61	1,470	1,950	3.09	2,030	2,650
2.14	1,020	1,370	2.62	1,480	1,970	3.10	2,050	2,670
2.15	1,020	1,380	2.63	1,490	1,980	3.11	2,060	2,680
2.16	1,030	1,390	2.64	1,500	1,990	3.12	2,070	2,700
2.17	1,040	1,400	2.65	1,510	2,010	3.13	2,090	2,710
2.18	1,050	1,410	2.66	1,520	2,020	3.14	2,100	2,730
2.19	1,060	1,420	2.67	1,540	2,030	3.15	2,110	2,740
2.20	1,070	1,440	2.68	1,550	2,050	3.16	2,130	2,760
2.21	1,080	1,450	2.69	1,560	2,060	3.17	2,140	2,780
2.22	1,090	1,460	2.70	1,570	2,080	3.18	2,150	2,790
2.23	1,100	1,470	2.71	1,580	2,090	3.19	2,160	2,810
2.24	1,100	1,480	2.72	1,590	2,100	3.20	2,180	2,820
2.25	1,110	1,500	2.73	1,600	2,120	3.21	2,190	2,840
2.26	1,120	1,510	2.74	1,610	2,130	3.22	2,200	2,860
2.27	1,130	1,520	2.75	1,620	2,150	3.23	2,220	2,870
2.28	1,140	1,530	2.76	1,640	2,160	3.24	2,230	2,890
2.29	1,150	1,540	2.77	1,650	2,170	3.25	2,250	2,900
2.30	1,160	1,560	2.78	1,660	2,190	3.26	2,260	2,920
2.31	1,170	1,570	2.79	1,670	2,200	3.27	2,270	2,940
2.32	1,180	1,580	2.80	1,680	2,220	3.28	2,290	2,950
2.33	1,190	1,590	2.81	1,690	2,230	3.29	2,300	2,970
2.34	1,200	1,600	2.82	1,700	2,240	3.30	2,310	2,990

Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)	Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)	Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)
3.31	2,330	3,000	3.81	3,080	3,860	4.31	3,940	4,790
3.32	2,340	3,020	3.82	3,090	3,880	4.32	3,960	4,810
3.33	2,350	3,040	3.83	3,110	3,900	4.33	3,980	4,830
3.34	2,370	3,050	3.84	3,120	3,920	4.34	4,000	4,850
3.35	2,380	3,070	3.85	3,140	3,920	4.35	4,020	4,870
3.36	2,400	3,090	3.86	3,160	3,940	4.36	4,030	4,890
3.37	2,410	3,100	3.87	3,170	3,960	4.37	4,050	4,910
3.38	2,420	3,120	3.88	3,190	3,980	4.38	4,070	4,930
3.39	2,440	3,140	3.89	3,210	4,000	4.39	4,090	4,950
3.40	2,450	3,150	3.90	3,220	4,010	4.40	4,110	4,970
3.41	2,470	3,170	3.91	3,240	4,030	4.41	4,130	4,990
3.42	2,480	3,190	3.92	3,260	4,050	4.42	4,150	5,010
3.43	2,500	3,200	3.93	3,270	4,070	4.43	4,170	5,040
3.44	2,510	3,220	3.94	3,290	4,090	4.44	4,190	5,060
3.45	2,520	3,240	3.95	3,310	4,110	4.45	4,210	5,080
3.46	2,540	3,260	3.96	3,320	4,130	4.46	4,230	5,100
3.47	2,550	3,270	3.97	3,340	4,150	4.47	4,240	5,120
3.48	2,570	3,290	3.98	3,360	4,170	4.48	4,260	5,140
3.49	2,580	3,310	3.99	3,370	4,190	4.49	4,280	5,160
3.50	2,600	3,320	4.00	3,390	4,210	4.50	4,300	5,180
3.51	2,610	3,340	4.01	3,410	4,230	4.51	4,320	5,210
3.52	2,630	3,360	4.02	3,420	4,240	4.52	4,340	5,230
3.53	2,640	3,380	4.03	3,440	4,260	4.53	4,360	5,250
3.54	2,660	3,390	4.04	3,460	4,280	4.54	4,380	5,250
3.55	2,670	3,410	4.05	3,480	4,300	4.55	4,400	5,270
3.56	2,690	3,430	4.06	3,490	4,320	4.56	4,420	5,290
3.57	2,700	3,450	4.07	3,510	4,340	4.57	4,440	5,310
3.58	2,720	3,460	4.08	3,530	4,340	4.58	4,460	5,330
3.59	2,730	3,480	4.09	3,550	4,360	4.59	4,480	5,360
3.60	2,750	3,500	4.10	3,560	4,380	4.60	4,500	5,380
3.61	2,760	3,520	4.11	3,580	4,400	4.61	4,520	5,400
3.62	2,780	3,520	4.12	3,600	4,420	4.62	4,540	5,420
3.63	2,790	3,540	4.13	3,620	4,440	4.63	4,560	5,440
3.64	2,810	3,550	4.14	3,630	4,460	4.64	4,580	5,470
3.65	2,820	3,570	4.15	3,650	4,480	4.65	4,600	5,490
3.66	2,840	3,590	4.16	3,670	4,500	4.66	4,620	5,510
3.67	2,850	3,610	4.17	3,690	4,520	4.67	4,640	5,530
3.68	2,870	3,630	4.18	3,700	4,540	4.68	4,660	5,550
3.69	2,890	3,640	4.19	3,720	4,560	4.69	4,680	5,580
3.70	2,900	3,660	4.20	3,740	4,580	4.70	4,700	5,600
3.71	2,920	3,680	4.21	3,760	4,600	4.71	4,720	5,620
3.72	2,930	3,700	4.22	3,780	4,620	4.72	4,740	5,640
3.73	2,950	3,720	4.23	3,790	4,640	4.73	4,760	5,660
3.74	2,960	3,730	4.24	3,810	4,660	4.74	4,780	5,690
3.75	2,980	3,750	4.25	3,830	4,680	4.75	4,810	5,710
3.76	3,000	3,770	4.26	3,850	4,700	4.76	4,830	5,730
3.77	3,010	3,790	4.27	3,870	4,720	4.77	4,850	5,730
3.78	3,030	3,810	4.28	3,890	4,740	4.78	4,870	5,750
3.79	3,040	3,830	4.29	3,900	4,760	4.79	4,890	5,780
3.80	3,060	3,850	4.30	3,920	4,790	4.80	4,920	5,800

Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)	Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)	Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)
4.81	4,940	5,820	5.31	6,110	6,950	5.81	7,410	8,180
4.82	4,960	5,840	5.32	6,130	6,980	5.82	7,440	8,210
4.83	4,980	5,870	5.33	6,160	7,000	5.83	7,470	8,230
4.84	5,000	5,890	5.34	6,180	7,030	5.84	7,490	8,260
4.85	5,030	5,910	5.35	6,210	7,050	5.85	7,520	8,290
4.86	5,050	5,940	5.36	6,230	7,080	5.86	7,550	8,310
4.87	5,070	5,960	5.37	6,260	7,100	5.87	7,580	8,340
4.88	5,090	5,980	5.38	6,280	7,130	5.88	7,610	8,370
4.89	5,120	6,000	5.39	6,310	7,150	5.89	7,630	8,390
4.9	5,140	6,030	5.40	6,330	7,180	5.90	7,660	8,420
4.91	5,160	6,050	5.41	6,360	7,200	5.91	7,690	8,450
4.92	5,180	6,070	5.42	6,380	7,230	5.92	7,720	8,470
4.93	5,210	6,100	5.43	6,410	7,250	5.93	7,750	8,470
4.94	5,230	6,120	5.44	6,430	7,280	5.94	7,770	8,500
4.95	5,250	6,140	5.45	6,460	7,300	5.95	7,800	8,530
4.96	5,280	6,170	5.46	6,490	7,330	5.96	7,830	8,550
4.97	5,300	6,190	5.47	6,510	7,330	5.97	7,860	8,580
4.98	5,320	6,210	5.48	6,540	7,350	5.98	7,890	8,610
4.99	5,340	6,230	5.49	6,560	7,380	5.99	7,920	8,640
5.00	5,370	6,230	5.50	6,590	7,400	6.00	7,940	8,660
5.01	5,390	6,260	5.51	6,610	7,430	6.01	7,970	8,690
5.02	5,410	6,280	5.52	6,640	7,450	6.02	8,000	8,720
5.03	5,440	6,300	5.53	6,670	7,480	6.03	8,030	8,740
5.04	5,460	6,330	5.54	6,690	7,500	6.04	8,060	8,770
5.05	5,480	6,350	5.55	6,720	7,530	6.05	8,090	8,800
5.06	5,510	6,380	5.56	6,740	7,550	6.06	8,120	8,830
5.07	5,530	6,400	5.57	6,770	7,580	6.07	8,140	8,850
5.08	5,550	6,420	5.58	6,800	7,610	6.08	8,170	8,880
5.09	5,580	6,450	5.59	6,820	7,630	6.09	8,200	8,910
5.10	5,600	6,470	5.60	6,850	7,660	6.10	8,230	8,940
5.11	5,620	6,490	5.61	6,870	7,680	6.11	8,260	8,970
5.12	5,650	6,520	5.62	6,900	7,710	6.12	8,290	8,990
5.13	5,670	6,540	5.63	6,930	7,730	6.13	8,320	9,020
5.14	5,700	6,570	5.64	6,950	7,760	6.14	8,350	9,050
5.15	5,720	6,590	5.65	6,980	7,790	6.15	8,380	9,080
5.16	5,740	6,610	5.66	7,010	7,810	6.16	8,410	9,080
5.17	5,770	6,640	5.67	7,030	7,840	6.17	8,440	9,100
5.18	5,790	6,660	5.68	7,060	7,860	6.18	8,460	9,130
5.19	5,820	6,690	5.69	7,090	7,890	6.19	8,490	9,160
5.20	5,840	6,710	5.70	7,110	7,890	6.20	8,520	9,190
5.21	5,860	6,730	5.71	7,140	7,920	6.21	8,550	9,220
5.22	5,890	6,760	5.72	7,170	7,940	6.22	8,580	9,240
5.23	5,910	6,780	5.73	7,190	7,970	6.23	8,610	9,270
5.24	5,940	6,780	5.74	7,220	7,990	6.24	8,640	9,300
5.25	5,960	6,810	5.75	7,250	8,020	6.25	8,670	9,330
5.26	5,990	6,830	5.76	7,280	8,050	6.26	8,700	9,360
5.27	6,010	6,860	5.77	7,300	8,070	6.27	8,730	9,380
5.28	6,030	6,880	5.78	7,330	8,100	6.28	8,760	9,410
5.29	6,060	6,900	5.79	7,360	8,130	6.29	8,790	9,440
5.30	6,080	6,930	5.80	7,380	8,150	6.30	8,820	9,470

Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)	Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)	Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)
6.31	8,850	9,500	6.81	10,200	10,900	7.31	11,700	12,400
6.32	8,880	9,530	6.82	10,300	11,000	7.32	11,700	12,500
6.33	8,910	9,560	6.83	10,300	11,000	7.33	11,700	12,500
6.34	8,940	9,580	6.84	10,300	11,000	7.34	11,700	12,500
6.35	8,970	9,610	6.85	10,300	11,100	7.35	11,800	12,600
6.36	9,000	9,640	6.86	10,400	11,100	7.36	11,800	12,600
6.37	9,030	9,670	6.87	10,400	11,100	7.37	11,800	12,600
6.38	9,060	9,700	6.88	10,400	11,100	7.38	11,900	12,600
6.39	9,090	9,700	6.89	10,500	11,200	7.39	11,900	12,700
6.40	9,120	9,730	6.90	10,500	11,200	7.40	11,900	12,700
6.41	9,140	9,760	6.91	10,500	11,200	7.41	12,000	12,700
6.42	9,170	9,780	6.92	10,500	11,300	7.42	12,000	12,800
6.43	9,200	9,810	6.93	10,600	11,300	7.43	12,000	12,800
6.44	9,220	9,840	6.94	10,600	11,300	7.44	12,000	12,800
6.45	9,250	9,870	6.95	10,600	11,400	7.45	12,100	12,900
6.46	9,280	9,900	6.96	10,600	11,400	7.46	12,100	12,900
6.47	9,300	9,930	6.97	10,700	11,400	7.47	12,100	12,900
6.48	9,330	9,960	6.98	10,700	11,400	7.48	12,200	12,900
6.49	9,360	9,990	6.99	10,700	11,500	7.49	12,200	13,000
6.50	9,380	10,000	7.00	10,800	11,500	7.50	12,200	13,000
6.51	9,410	10,000	7.01	10,800	11,500	7.51	12,300	13,000
6.52	9,440	10,100	7.02	10,800	11,600	7.52	12,300	13,100
6.53	9,460	10,100	7.03	10,800	11,600	7.53	12,300	13,100
6.54	9,490	10,100	7.04	10,900	11,600	7.54	12,300	13,100
6.55	9,520	10,200	7.05	10,900	11,700	7.55	12,400	13,100
6.56	9,540	10,200	7.06	10,900	11,700	7.56	12,400	13,200
6.57	9,570	10,200	7.07	11,000	11,700	7.57	12,400	13,200
6.58	9,600	10,300	7.08	11,000	11,700	7.58	12,500	13,200
6.59	9,620	10,300	7.09	11,000	11,800	7.59	12,500	13,300
6.60	9,650	10,300	7.1	11,000	11,800	7.60	12,500	13,300
6.61	9,680	10,300	7.11	11,100	11,800	7.61	12,600	13,300
6.62	9,710	10,400	7.12	11,100	11,900	7.62	12,600	13,300
6.63	9,730	10,400	7.13	11,100	11,900	7.63	12,600	13,400
6.64	9,760	10,400	7.14	11,200	11,900	7.64	12,700	13,400
6.65	9,790	10,500	7.15	11,200	12,000	7.65	12,700	13,400
6.66	9,810	10,500	7.16	11,200	12,000	7.66	12,700	13,500
6.67	9,840	10,500	7.17	11,200	12,000	7.67	12,700	13,500
6.68	9,870	10,500	7.18	11,300	12,000	7.68	12,800	13,500
6.69	9,900	10,600	7.19	11,300	12,100	7.69	12,800	13,500
6.70	9,920	10,600	7.20	11,300	12,100	7.70	12,800	13,600
6.71	9,950	10,600	7.21	11,400	12,100	7.71	12,900	13,600
6.72	9,980	10,700	7.22	11,400	12,200	7.72	12,900	13,600
6.73	10,000	10,700	7.23	11,400	12,200	7.73	12,900	13,700
6.74	10,000	10,700	7.24	11,500	12,200	7.74	13,000	13,700
6.75	10,100	10,800	7.25	11,500	12,300	7.75	13,000	13,700
6.76	10,100	10,800	7.26	11,500	12,300	7.76	13,000	13,800
6.77	10,100	10,800	7.27	11,500	12,300	7.77	13,100	13,800
6.78	10,100	10,800	7.28	11,600	12,300	7.78	13,100	13,800
6.79	10,200	10,900	7.29	11,600	12,400	7.79	13,100	13,800
6.80	10,200	10,900	7.30	11,600	12,400	7.80	13,100	13,900

Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)	Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)	Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)
7.81	13,200	13,900	8.31	14,800	15,400	8.81	16,500	17,000
7.82	13,200	13,900	8.32	14,800	15,400	8.82	16,500	17,000
7.83	13,200	14,000	8.33	14,800	15,500	8.83	16,500	17,100
7.84	13,300	14,000	8.34	14,900	15,500	8.84	16,600	17,100
7.85	13,300	14,000	8.35	14,900	15,500	8.85	16,600	17,100
7.86	13,300	14,000	8.36	14,900	15,600	8.86	16,600	17,100
7.87	13,400	14,100	8.37	15,000	15,600	8.87	16,700	17,200
7.88	13,400	14,100	8.38	15,000	15,600	8.88	16,700	17,200
7.89	13,400	14,100	8.39	15,000	15,700	8.89	16,700	17,200
7.90	13,500	14,200	8.40	15,100	15,700	8.90	16,800	17,300
7.91	13,500	14,200	8.41	15,100	15,700	8.91	16,800	17,300
7.92	13,500	14,200	8.42	15,100	15,800	8.92	16,800	17,300
7.93	13,600	14,300	8.43	15,200	15,800	8.93	16,900	17,400
7.94	13,600	14,300	8.44	15,200	15,800	8.94	16,900	17,400
7.95	13,600	14,300	8.45	15,200	15,800	8.95	17,000	17,400
7.96	13,600	14,300	8.46	15,300	15,900	8.96	17,000	17,500
7.97	13,700	14,400	8.47	15,300	15,900	8.97	17,000	17,500
7.98	13,700	14,400	8.48	15,300	15,900	8.98	17,100	17,500
7.99	13,700	14,400	8.49	15,400	16,000	8.99	17,100	17,600
8.00	13,800	14,500	8.50	15,400	16,000	9.00	17,100	17,600
8.01	13,800	14,500	8.51	15,400	16,000	9.01	17,200	17,600
8.02	13,800	14,500	8.52	15,500	16,100	9.02	17,200	17,700
8.03	13,900	14,600	8.53	15,500	16,100	9.03	17,200	17,700
8.04	13,900	14,600	8.54	15,500	16,100	9.04	17,300	17,700
8.05	13,900	14,600	8.55	15,600	16,200	9.05	17,300	17,800
8.06	14,000	14,600	8.56	15,600	16,200	9.06	17,300	17,800
8.07	14,000	14,700	8.57	15,600	16,200	9.07	17,400	17,800
8.08	14,000	14,700	8.58	15,700	16,300	9.08	17,400	17,900
8.09	14,100	14,700	8.59	15,700	16,300	9.09	17,400	17,900
8.10	14,100	14,800	8.60	15,700	16,300	9.10	17,500	17,900
8.11	14,100	14,800	8.61	15,800	16,300	9.11	17,500	18,000
8.12	14,200	14,800	8.62	15,800	16,400	9.12	17,600	18,000
8.13	14,200	14,900	8.63	15,800	16,400	9.13	17,600	18,000
8.14	14,200	14,900	8.64	15,900	16,400	9.14	17,600	18,100
8.15	14,300	14,900	8.65	15,900	16,500	9.15	17,700	18,100
8.16	14,300	15,000	8.66	16,000	16,500	9.16	17,700	18,100
8.17	14,300	15,000	8.67	16,000	16,500	9.17	17,700	18,200
8.18	14,400	15,000	8.68	16,000	16,600	9.18	17,800	18,200
8.19	14,400	15,000	8.69	16,100	16,600	9.19	17,800	18,200
8.20	14,400	15,100	8.70	16,100	16,600	9.20	17,800	18,300
8.21	14,500	15,100	8.71	16,100	16,700	9.21	17,900	18,300
8.22	14,500	15,100	8.72	16,200	16,700	9.22	17,900	18,300
8.23	14,500	15,200	8.73	16,200	16,700	9.23	17,900	18,400
8.24	14,600	15,200	8.74	16,200	16,800	9.24	18,000	18,400
8.25	14,600	15,200	8.75	16,300	16,800	9.25	18,000	18,400
8.26	14,600	15,300	8.76	16,300	16,800	9.26	18,100	18,500
8.27	14,600	15,300	8.77	16,300	16,900	9.27	18,100	18,500
8.28	14,700	15,300	8.78	16,400	16,900	9.28	18,100	18,500
8.29	14,700	15,400	8.79	16,400	16,900	9.29	18,200	18,600
8.30	14,700	15,400	8.80	16,400	17,000	9.30	18,200	18,600

Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)	Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)	Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)
9.31	18,200	18,600	9.81	20,100	20,300	10.31	22,000	22,100
9.32	18,300	18,700	9.82	20,100	20,300	10.32	22,100	22,100
9.33	18,300	18,700	9.83	20,200	20,400	10.33	22,100	22,100
9.34	18,300	18,700	9.84	20,200	20,400	10.34	22,100	22,200
9.35	18,400	18,800	9.85	20,200	20,500	10.35	22,200	22,200
9.36	18,400	18,800	9.86	20,300	20,500	10.36	22,200	22,200
9.37	18,500	18,800	9.87	20,300	20,500	10.37	22,300	22,300
9.38	18,500	18,900	9.88	20,400	20,600	10.38	22,300	22,300
9.39	18,500	18,900	9.89	20,400	20,600	10.39	22,300	22,300
9.40	18,600	18,900	9.90	20,400	20,600	10.40	22,400	22,400
9.41	18,600	19,000	9.91	20,500	20,700	10.41	22,400	22,400
9.42	18,600	19,000	9.92	20,500	20,700	10.42	22,500	22,500
9.43	18,700	19,000	9.93	20,500	20,700	10.43	22,500	22,500
9.44	18,700	19,100	9.94	20,600	20,800	10.44	22,500	22,500
9.45	18,700	19,100	9.95	20,600	20,800	10.45	22,600	22,600
9.46	18,800	19,100	9.96	20,700	20,800	10.46	22,600	22,600
9.47	18,800	19,200	9.97	20,700	20,900	10.47	22,700	22,600
9.48	18,900	19,200	9.98	20,700	20,900	10.48	22,700	22,700
9.49	18,900	19,200	9.99	20,800	20,900	10.49	22,700	22,700
9.50	18,900	19,300	10.00	20,800	21,000	10.50	22,800	22,700
9.51	19,000	19,300	10.01	20,900	21,000	10.51	22,800	22,800
9.52	19,000	19,300	10.02	20,900	21,000	10.52	22,900	22,800
9.53	19,000	19,400	10.03	20,900	21,100	10.53	22,900	22,900
9.54	19,100	19,400	10.04	21,000	21,100	10.54	22,900	22,900
9.55	19,100	19,400	10.05	21,000	21,100	10.55	23,000	22,900
9.56	19,200	19,500	10.06	21,000	21,200	10.56	23,000	23,000
9.57	19,200	19,500	10.07	21,100	21,200	10.57	23,100	23,000
9.58	19,200	19,500	10.08	21,100	21,300	10.58	23,100	23,000
9.59	19,300	19,600	10.09	21,200	21,300	10.59	23,100	23,100
9.60	19,300	19,600	10.10	21,200	21,300	10.60	23,200	23,100
9.61	19,300	19,600	10.11	21,200	21,400	10.61	23,200	23,100
9.62	19,400	19,700	10.12	21,300	21,400	10.62	23,300	23,200
9.63	19,400	19,700	10.13	21,300	21,400	10.63	23,300	23,200
9.64	19,500	19,700	10.14	21,400	21,500	10.64	23,300	23,300
9.65	19,500	19,800	10.15	21,400	21,500	10.65	23,400	23,300
9.66	19,500	19,800	10.16	21,400	21,500	10.66	23,400	23,300
9.67	19,600	19,800	10.17	21,500	21,600	10.67	23,500	23,400
9.68	19,600	19,900	10.18	21,500	21,600	10.68	23,500	23,400
9.69	19,600	19,900	10.19	21,600	21,600	10.69	23,500	23,400
9.70	19,700	19,900	10.20	21,600	21,700	10.70	23,600	23,500
9.71	19,700	20,000	10.21	21,600	21,700	10.71	23,600	23,500
9.72	19,800	20,000	10.22	21,700	21,700	10.72	23,700	23,500
9.73	19,800	20,000	10.23	21,700	21,800	10.73	23,700	23,600
9.74	19,800	20,100	10.24	21,700	21,800	10.74	23,800	23,600
9.75	19,900	20,100	10.25	21,800	21,900	10.75	23,800	23,700
9.76	19,900	20,100	10.26	21,800	21,900	10.76	23,800	23,700
9.77	19,900	20,200	10.27	21,900	21,900	10.77	23,900	23,700
9.78	20,000	20,200	10.28	21,900	22,000	10.78	23,900	23,800
9.79	20,000	20,200	10.29	21,900	22,000	10.79	24,000	23,800
9.80	20,100	20,300	10.30	22,000	22,000	10.80	24,000	23,800

Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)	Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)	Stage (ft)	2005 Flow (cfs)	2012 Flow (cfs)
10.81	24,000	23,900	11.28	25,800	25,600	11.75	27,600	27,400
10.82	24,100	23,900	11.29	25,800	25,700	11.76	27,700	27,500
10.83	24,100	23,900	11.30	25,900	25,700	11.77	27,700	27,500
10.84	24,100	24,000	11.31	25,900	25,700	11.78	27,700	27,500
10.85	24,200	24,000	11.32	26,000	25,800	11.79	27,800	27,600
10.86	24,200	24,100	11.33	26,000	25,800	11.80	27,800	27,600
10.87	24,300	24,100	11.34	26,000	25,900	11.81	27,900	27,700
10.88	24,300	24,100	11.35	26,100	25,900	11.82	27,900	27,700
10.89	24,300	24,200	11.36	26,100	25,900	11.83	27,900	27,700
10.90	24,400	24,200	11.37	26,100	26,000	11.84	28,000	27,800
10.91	24,400	24,200	11.38	26,200	26,000	11.85	28,000	27,800
10.92	24,400	24,300	11.39	26,200	26,000	11.86	28,100	27,900
10.93	24,500	24,300	11.40	26,300	26,100	11.87	28,100	27,900
10.94	24,500	24,400	11.41	26,300	26,100	11.88	28,100	27,900
10.95	24,600	24,400	11.42	26,300	26,200	11.89	28,200	28,000
10.96	24,600	24,400	11.43	26,400	26,200	11.90	28,200	28,000
10.97	24,600	24,500	11.44	26,400	26,200	11.91	28,200	28,000
10.98	24,700	24,500	11.45	26,500	26,300	11.92	28,300	28,100
10.99	24,700	24,500	11.46	26,500	26,300	11.93	28,300	28,100
11.00	24,700	24,600	11.47	26,500	26,300	11.94	28,400	28,200
11.01	24,800	24,600	11.48	26,600	26,400	11.95	28,400	28,200
11.02	24,800	24,600	11.49	26,600	26,400	11.96	28,400	28,200
11.03	24,900	24,700	11.50	26,600	26,500	11.97	28,500	28,300
11.04	24,900	24,700	11.51	26,700	26,500	11.98	28,500	28,300
11.05	24,900	24,800	11.52	26,700	26,500	11.99	28,600	28,400
11.06	25,000	24,800	11.53	26,800	26,600	12.00	28,600	28,400
11.07	25,000	24,800	11.54	26,800	26,600	12.01	28,600	28,400
11.08	25,000	24,900	11.55	26,800	26,700	12.02	28,700	28,500
11.09	25,100	24,900	11.56	26,900	26,700	12.03	28,700	28,500
11.10	25,100	24,900	11.57	26,900	26,700	12.04	28,800	28,600
11.11	25,200	25,000	11.58	27,000	26,800	12.05	28,800	28,600
11.12	25,200	25,000	11.59	27,000	26,800	12.06	28,800	28,600
11.13	25,200	25,100	11.60	27,000	26,800	12.07	28,900	28,700
11.14	25,300	25,100	11.61	27,100	26,900	12.08	28,900	28,700
11.15	25,300	25,100	11.62	27,100	26,900	12.09	29,000	28,800
11.16	25,300	25,200	11.63	27,200	27,000	12.10	29,000	28,800
11.17	25,400	25,200	11.64	27,200	27,000	12.11	29,000	28,800
11.18	25,400	25,200	11.65	27,200	27,000	12.12	29,100	28,900
11.19	25,500	25,300	11.66	27,300	27,100	12.13	29,100	28,900
11.20	25,500	25,300	11.67	27,300	27,100	12.14	29,200	29,000
11.21	25,500	25,400	11.68	27,300	27,200	12.15	29,200	29,000
11.22	25,600	25,400	11.69	27,400	27,200	12.16	29,200	29,000
11.23	25,600	25,400	11.70	27,400	27,200	12.17	29,300	29,100
11.24	25,700	25,500	11.71	27,500	27,300	12.18	29,300	29,100
11.25	25,700	25,500	11.72	27,500	27,300	12.19	29,400	29,200
11.26	25,700	25,500	11.73	27,500	27,300	12.20	29,400	29,200
11.27	25,800	25,600	11.74	27,600	27,400	12.21	29,400	29,200

TABLE A-2 USGS Stage-Flow Table for the Ouray Gage (USGS 9272400) in 2012

Stage (ft)	Flow (cfs)	Stage (ft)	Flow (cfs)	Stage (ft)	Flow (cfs)
14.94	930	15.42	1,460	15.90	2,060
14.95	940	15.43	1,470	15.91	2,080
14.96	951	15.44	1,490	15.92	2,090
14.97	961	15.45	1,500	15.93	2,100
14.98	972	15.46	1,510	15.94	2,120
14.99	982	15.47	1,520	15.95	2,130
15.00	992	15.48	1,530	15.96	2,140
15.01	1,000	15.49	1,550	15.97	2,160
15.02	1,010	15.50	1,560	15.98	2,170
15.03	1,020	15.51	1,570	15.99	2,180
15.04	1,030	15.52	1,580	16.00	2,200
15.05	1,050	15.53	1,590	16.01	2,210
15.06	1,060	15.54	1,610	16.02	2,220
15.07	1,070	15.55	1,620	16.03	2,240
15.08	1,080	15.56	1,630	16.04	2,250
15.09	1,090	15.57	1,640	16.05	2,270
15.10	1,100	15.58	1,660	16.06	2,280
15.11	1,110	15.59	1,670	16.07	2,290
15.12	1,120	15.60	1,680	16.08	2,310
15.13	1,130	15.61	1,690	16.09	2,320
15.14	1,140	15.62	1,710	16.10	2,330
15.15	1,150	15.63	1,720	16.11	2,350
15.16	1,160	15.64	1,730	16.12	2,360
15.17	1,180	15.65	1,740	16.13	2,370
15.18	1,190	15.66	1,760	16.14	2,390
15.19	1,200	15.67	1,770	16.15	2,400
15.20	1,210	15.68	1,780	16.16	2,420
15.21	1,220	15.69	1,790	16.17	2,430
15.22	1,230	15.70	1,810	16.18	2,440
15.23	1,240	15.71	1,820	16.19	2,460
15.24	1,250	15.72	1,830	16.20	2,470
15.25	1,270	15.73	1,840	16.21	2,490
15.26	1,280	15.74	1,860	16.22	2,500
15.27	1,290	15.75	1,870	16.23	2,510
15.28	1,300	15.76	1,880	16.24	2,530
15.29	1,310	15.77	1,900	16.25	2,540
15.30	1,320	15.78	1,910	16.26	2,560
15.31	1,330	15.79	1,920	16.27	2,570
15.32	1,350	15.80	1,930	16.28	2,580
15.33	1,360	15.81	1,950	16.29	2,600
15.34	1,370	15.82	1,960	16.30	2,610
15.35	1,380	15.83	1,970	16.31	2,630
15.36	1,390	15.84	1,990	16.32	2,640
15.37	1,400	15.85	2,000	16.33	2,660
15.38	1,420	15.86	2,010	16.34	2,670
15.39	1,430	15.87	2,030	16.35	2,680
15.40	1,440	15.88	2,040	16.36	2,700
15.41	1,450	15.89	2,050	16.37	2,710

Stage (ft)	Flow (cfs)	Stage (ft)	Flow (cfs)	Stage (ft)	Flow (cfs)
16.38	2,730	16.88	3,470	17.38	4,280
16.39	2,740	16.89	3,490	17.39	4,290
16.40	2,760	16.90	3,510	17.40	4,310
16.41	2,770	16.91	3,520	17.41	4,330
16.42	2,780	16.92	3,540	17.42	4,340
16.43	2,800	16.93	3,550	17.43	4,360
16.44	2,810	16.94	3,570	17.44	4,380
16.45	2,830	16.95	3,580	17.45	4,390
16.46	2,840	16.96	3,600	17.46	4,410
16.47	2,860	16.97	3,620	17.47	4,430
16.48	2,870	16.98	3,630	17.48	4,440
16.49	2,890	16.99	3,650	17.49	4,460
16.50	2,900	17.00	3,660	17.50	4,480
16.51	2,920	17.01	3,680	17.51	4,490
16.52	2,930	17.02	3,690	17.52	4,510
16.53	2,950	17.03	3,710	17.53	4,530
16.54	2,960	17.04	3,730	17.54	4,540
16.55	2,970	17.05	3,740	17.55	4,560
16.56	2,990	17.06	3,760	17.56	4,580
16.57	3,000	17.07	3,770	17.57	4,590
16.58	3,020	17.08	3,790	17.58	4,610
16.59	3,030	17.09	3,810	17.59	4,630
16.60	3,050	17.10	3,820	17.60	4,640
16.61	3,060	17.11	3,840	17.61	4,660
16.62	3,080	17.12	3,850	17.62	4,680
16.63	3,090	17.13	3,870	17.63	4,700
16.64	3,110	17.14	3,890	17.64	4,710
16.65	3,120	17.15	3,900	17.65	4,730
16.66	3,140	17.16	3,920	17.66	4,750
16.67	3,150	17.17	3,930	17.67	4,760
16.68	3,170	17.18	3,950	17.68	4,780
16.69	3,180	17.19	3,970	17.69	4,800
16.70	3,200	17.20	3,980	17.70	4,820
16.71	3,210	17.21	4,000	17.71	4,830
16.72	3,230	17.22	4,010	17.72	4,850
16.73	3,240	17.23	4,030	17.73	4,870
16.74	3,260	17.24	4,050	17.74	4,880
16.75	3,270	17.25	4,060	17.75	4,900
16.76	3,290	17.26	4,080	17.76	4,920
16.77	3,310	17.27	4,100	17.77	4,940
16.78	3,320	17.28	4,110	17.78	4,950
16.79	3,340	17.29	4,130	17.79	4,970
16.80	3,350	17.30	4,140	17.80	4,990
16.81	3,370	17.31	4,160	17.81	5,010
16.82	3,380	17.32	4,180	17.82	5,020
16.83	3,400	17.33	4,190	17.83	5,040
16.84	3,410	17.34	4,210	17.84	5,060
16.85	3,430	17.35	4,230	17.85	5,080
16.86	3,440	17.36	4,240	17.86	5,090
16.87	3,460	17.37	4,260	17.87	5,110

Stage (ft)	Flow (cfs)	Stage (ft)	Flow (cfs)	Stage (ft)	Flow (cfs)
17.88	5,130	18.38	6,030	18.88	6,970
17.89	5,150	18.39	6,040	18.89	6,990
17.9	5,160	18.40	6,060	18.90	7,010
17.91	5,180	18.41	6,080	18.91	7,020
17.92	5,200	18.42	6,100	18.92	7,040
17.93	5,220	18.43	6,120	18.93	7,060
17.94	5,230	18.44	6,140	18.94	7,080
17.95	5,250	18.45	6,150	18.95	7,100
17.96	5,270	18.46	6,170	18.96	7,120
17.97	5,290	18.47	6,190	18.97	7,140
17.98	5,300	18.48	6,210	18.98	7,160
17.99	5,320	18.49	6,230	18.99	7,180
18	5,340	18.50	6,250	19.00	7,200
18.01	5,360	18.51	6,270	19.01	7,220
18.02	5,370	18.52	6,280	19.02	7,240
18.03	5,390	18.53	6,300	19.03	7,260
18.04	5,410	18.54	6,320	19.04	7,280
18.05	5,430	18.55	6,340	19.05	7,300
18.06	5,450	18.56	6,360	19.06	7,320
18.07	5,460	18.57	6,380	19.07	7,340
18.08	5,480	18.58	6,400	19.08	7,360
18.09	5,500	18.59	6,420	19.09	7,370
18.10	5,520	18.60	6,430	19.10	7,390
18.11	5,540	18.61	6,450	19.11	7,410
18.12	5,550	18.62	6,470	19.12	7,430
18.13	5,570	18.63	6,490	19.13	7,450
18.14	5,590	18.64	6,510	19.14	7,470
18.15	5,610	18.65	6,530	19.15	7,490
18.16	5,620	18.66	6,550	19.16	7,510
18.17	5,640	18.67	6,570	19.17	7,530
18.18	5,660	18.68	6,590	19.18	7,550
18.19	5,680	18.69	6,600	19.19	7,570
18.20	5,700	18.70	6,620	19.20	7,590
18.21	5,720	18.71	6,640	19.21	7,610
18.22	5,730	18.72	6,660	19.22	7,630
18.23	5,750	18.73	6,680	19.23	7,650
18.24	5,770	18.74	6,700	19.24	7,670
18.25	5,790	18.75	6,720	19.25	7,690
18.26	5,810	18.76	6,740	19.26	7,710
18.27	5,820	18.77	6,760	19.27	7,730
18.28	5,840	18.78	6,780	19.28	7,750
18.29	5,860	18.79	6,790	19.29	7,770
18.30	5,880	18.80	6,810	19.30	7,790
18.31	5,900	18.81	6,830	19.31	7,810
18.32	5,920	18.82	6,850	19.32	7,830
18.33	5,930	18.83	6,870	19.33	7,850
18.34	5,950	18.84	6,890	19.34	7,870
18.35	5,970	18.85	6,910	19.35	7,890
18.36	5,990	18.86	6,930	19.36	7,910
18.37	6,010	18.87	6,950	19.37	7,930

Stage (ft)	Flow (cfs)	Stage (ft)	Flow (cfs)	Stage (ft)	Flow (cfs)
19.38	7,950	19.88	8,970	20.38	10,000
19.39	7,970	19.89	8,990	20.39	10,100
19.40	7,990	19.90	9,010	20.40	10,100
19.41	8,010	19.91	9,030	20.41	10,100
19.42	8,030	19.92	9,060	20.42	10,100
19.43	8,050	19.93	9,080	20.43	10,100
19.44	8,070	19.94	9,100	20.44	10,200
19.45	8,090	19.95	9,120	20.45	10,200
19.46	8,110	19.96	9,140	20.46	10,200
19.47	8,130	19.97	9,160	20.47	10,200
19.48	8,150	19.98	9,180	20.48	10,200
19.49	8,170	19.99	9,200	20.49	10,300
19.50	8,190	20.00	9,220	20.50	10,300
19.51	8,210	20.01	9,240	20.51	10,300
19.52	8,230	20.02	9,260	20.52	10,300
19.53	8,250	20.03	9,290	20.53	10,400
19.54	8,270	20.04	9,310	20.54	10,400
19.55	8,290	20.05	9,330	20.55	10,400
19.56	8,310	20.06	9,350	20.56	10,400
19.57	8,330	20.07	9,370	20.57	10,400
19.58	8,350	20.08	9,390	20.58	10,500
19.59	8,370	20.09	9,410	20.59	10,500
19.60	8,390	20.10	9,430	20.60	10,500
19.61	8,410	20.11	9,450	20.61	10,500
19.62	8,440	20.12	9,480	20.62	10,600
19.63	8,460	20.13	9,500	20.63	10,600
19.64	8,480	20.14	9,520	20.64	10,600
19.65	8,500	20.15	9,540	20.65	10,600
19.66	8,520	20.16	9,560	20.66	10,600
19.67	8,540	20.17	9,580	20.67	10,700
19.68	8,560	20.18	9,600	20.68	10,700
19.69	8,580	20.19	9,620	20.69	10,700
19.70	8,600	20.20	9,650	20.70	10,700
19.71	8,620	20.21	9,670	20.71	10,800
19.72	8,640	20.22	9,690	20.72	10,800
19.73	8,660	20.23	9,710	20.73	10,800
19.74	8,680	20.24	9,730	20.74	10,800
19.75	8,700	20.25	9,750	20.75	10,800
19.76	8,720	20.26	9,770	20.76	10,900
19.77	8,740	20.27	9,800	20.77	10,900
19.78	8,760	20.28	9,820	20.78	10,900
19.79	8,780	20.29	9,840	20.79	10,900
19.80	8,810	20.30	9,860	20.80	10,900
19.81	8,830	20.31	9,880	20.81	11,000
19.82	8,850	20.32	9,900	20.82	11,000
19.83	8,870	20.33	9,920	20.83	11,000
19.84	8,890	20.34	9,950	20.84	11,000
19.85	8,910	20.35	9,970	20.85	11,100
19.86	8,930	20.36	9,990	20.86	11,100
19.87	8,950	20.37	10,000	20.87	11,100

Stage (ft)	Flow (cfs)	Stage (ft)	Flow (cfs)	Stage (ft)	Flow (cfs)
20.88	11,100	21.38	12,300	21.88	13,400
20.89	11,100	21.39	12,300	21.89	13,400
20.90	11,200	21.40	12,300	21.90	13,500
20.91	11,200	21.41	12,300	21.91	13,500
20.92	11,200	21.42	12,300	21.92	13,500
20.93	11,200	21.43	12,400	21.93	13,500
20.94	11,300	21.44	12,400	21.94	13,600
20.95	11,300	21.45	12,400	21.95	13,600
20.96	11,300	21.46	12,400	21.96	13,600
20.97	11,300	21.47	12,500	21.97	13,600
20.98	11,400	21.48	12,500	21.98	13,700
20.99	11,400	21.49	12,500	21.99	13,700
21.00	11,400	21.50	12,500	22.00	13,700
21.01	11,400	21.51	12,600	22.01	13,700
21.02	11,400	21.52	12,600	22.02	13,800
21.03	11,500	21.53	12,600	22.03	13,800
21.04	11,500	21.54	12,600	22.04	13,800
21.05	11,500	21.55	12,600	22.05	13,800
21.06	11,500	21.56	12,700	22.06	13,800
21.07	11,600	21.57	12,700	22.07	13,900
21.08	11,600	21.58	12,700	22.08	13,900
21.09	11,600	21.59	12,700	22.09	13,900
21.10	11,600	21.60	12,800	22.10	13,900
21.11	11,600	21.61	12,800	22.11	14,000
21.12	11,700	21.62	12,800	22.12	14,000
21.13	11,700	21.63	12,800	22.13	14,000
21.14	11,700	21.64	12,900	22.14	14,000
21.15	11,700	21.65	12,900	22.15	14,100
21.16	11,800	21.66	12,900	22.16	14,100
21.17	11,800	21.67	12,900	22.17	14,100
21.18	11,800	21.68	13,000	22.18	14,100
21.19	11,800	21.69	13,000	22.19	14,200
21.20	11,800	21.70	13,000	22.20	14,200
21.21	11,900	21.71	13,000	22.21	14,200
21.22	11,900	21.72	13,000	22.22	14,200
21.23	11,900	21.73	13,100	22.23	14,300
21.24	11,900	21.74	13,100	22.24	14,300
21.25	12,000	21.75	13,100	22.25	14,300
21.26	12,000	21.76	13,100	22.26	14,300
21.27	12,000	21.77	13,200	22.27	14,400
21.28	12,000	21.78	13,200	22.28	14,400
21.29	12,100	21.79	13,200	22.29	14,400
21.30	12,100	21.80	13,200	22.30	14,400
21.31	12,100	21.81	13,300	22.31	14,400
21.32	12,100	21.82	13,300	22.32	14,500
21.33	12,100	21.83	13,300	22.33	14,500
21.34	12,200	21.84	13,300	22.34	14,500
21.35	12,200	21.85	13,300	22.35	14,500
21.36	12,200	21.86	13,400	22.36	14,600
21.37	12,200	21.87	13,400	22.37	14,600

Stage (ft)	Flow (cfs)	Stage (ft)	Flow (cfs)	Stage (ft)	Flow (cfs)
22.38	14,600	22.88	15,800	23.38	17,100
22.39	14,600	22.89	15,900	23.39	17,100
22.40	14,700	22.90	15,900	23.40	17,200
22.41	14,700	22.91	15,900	23.41	17,200
22.42	14,700	22.92	15,900	23.42	17,200
22.43	14,700	22.93	16,000	23.43	17,200
22.44	14,800	22.94	16,000	23.44	17,300
22.45	14,800	22.95	16,000	23.45	17,300
22.46	14,800	22.96	16,000	23.46	17,300
22.47	14,800	22.97	16,100	23.47	17,300
22.48	14,900	22.98	16,100	23.48	17,400
22.49	14,900	22.99	16,100	23.49	17,400
22.50	14,900	23.00	16,100	23.50	17,400
22.51	14,900	23.01	16,200	23.51	17,400
22.52	15,000	23.02	16,200	23.52	17,500
22.53	15,000	23.03	16,200	23.53	17,500
22.54	15,000	23.04	16,200	23.54	17,500
22.55	15,000	23.05	16,300	23.55	17,500
22.56	15,100	23.06	16,300	23.56	17,600
22.57	15,100	23.07	16,300	23.57	17,600
22.58	15,100	23.08	16,300	23.58	17,600
22.59	15,100	23.09	16,400	23.59	17,600
22.60	15,200	23.10	16,400	23.60	17,700
22.61	15,200	23.11	16,400	23.61	17,700
22.62	15,200	23.12	16,400	23.62	17,700
22.63	15,200	23.13	16,500	23.63	17,700
22.64	15,300	23.14	16,500	23.64	17,800
22.65	15,300	23.15	16,500	23.65	17,800
22.66	15,300	23.16	16,500	23.66	17,800
22.67	15,300	23.17	16,600	23.67	17,800
22.68	15,300	23.18	16,600	23.68	17,900
22.69	15,400	23.19	16,600	23.69	17,900
22.70	15,400	23.20	16,600	23.70	17,900
22.71	15,400	23.21	16,700	23.71	17,900
22.72	15,400	23.22	16,700	23.72	18,000
22.73	15,500	23.23	16,700	23.73	18,000
22.74	15,500	23.24	16,700	23.74	18,000
22.75	15,500	23.25	16,800	23.75	18,000
22.76	15,500	23.26	16,800	23.76	18,100
22.77	15,600	23.27	16,800	23.77	18,100
22.78	15,600	23.28	16,800	23.78	18,100
22.79	15,600	23.29	16,900	23.79	18,200
22.80	15,600	23.30	16,900	23.80	18,200
22.81	15,700	23.31	16,900	23.81	18,200
22.82	15,700	23.32	16,900	23.82	18,200
22.83	15,700	23.33	17,000	23.83	18,300
22.84	15,700	23.34	17,000	23.84	18,300
22.85	15,800	23.35	17,000	23.85	18,300
22.86	15,800	23.36	17,000	23.86	18,300
22.87	15,800	23.37	17,100	23.87	18,400

Stage (ft)	Flow (cfs)	Stage (ft)	Flow (cfs)	Stage (ft)	Flow (cfs)
23.88	18,400	24.38	19,700	24.88	21,000
23.89	18,400	24.39	19,700	24.89	21,100
23.90	18,400	24.40	19,800	24.90	21,100
23.91	18,500	24.41	19,800	24.91	21,100
23.92	18,500	24.42	19,800	24.92	21,200
23.93	18,500	24.43	19,800	24.93	21,200
23.94	18,500	24.44	19,900	24.94	21,200
23.95	18,600	24.45	19,900	24.95	21,200
23.96	18,600	24.46	19,900	24.96	21,300
23.97	18,600	24.47	19,900	24.97	21,300
23.98	18,600	24.48	20,000	24.98	21,300
23.99	18,700	24.49	20,000	24.99	21,300
24.00	18,700	24.50	20,000	25.00	21,400
24.01	18,700	24.51	20,000	25.01	21,400
24.02	18,800	24.52	20,100	25.02	21,400
24.03	18,800	24.53	20,100	25.03	21,500
24.04	18,800	24.54	20,100	25.04	21,500
24.05	18,800	24.55	20,200	25.05	21,500
24.06	18,900	24.56	20,200	25.06	21,500
24.07	18,900	24.57	20,200	25.07	21,600
24.08	18,900	24.58	20,200	25.08	21,600
24.09	18,900	24.59	20,300	25.09	21,600
24.10	19,000	24.60	20,300	25.10	21,600
24.11	19,000	24.61	20,300	25.11	21,700
24.12	19,000	24.62	20,300	25.12	21,700
24.13	19,000	24.63	20,400	25.13	21,700
24.14	19,100	24.64	20,400	25.14	21,800
24.15	19,100	24.65	20,400	25.15	21,800
24.16	19,100	24.66	20,500	25.16	21,800
24.17	19,100	24.67	20,500	25.17	21,800
24.18	19,200	24.68	20,500	25.18	21,900
24.19	19,200	24.69	20,500	25.19	21,900
24.20	19,200	24.70	20,600	25.20	21,900
24.21	19,300	24.71	20,600	25.21	21,900
24.22	19,300	24.72	20,600	25.22	22,000
24.23	19,300	24.73	20,600	25.23	22,000
24.24	19,300	24.74	20,700	25.24	22,000
24.25	19,400	24.75	20,700	25.25	22,100
24.26	19,400	24.76	20,700	25.26	22,100
24.27	19,400	24.77	20,700	25.27	22,100
24.28	19,400	24.78	20,800	25.28	22,100
24.29	19,500	24.79	20,800	25.29	22,200
24.30	19,500	24.80	20,800	25.30	22,200
24.31	19,500	24.81	20,900	25.31	22,200
24.32	19,500	24.82	20,900	25.32	22,200
24.33	19,600	24.83	20,900	25.33	22,300
24.34	19,600	24.84	20,900	25.34	22,300
24.35	19,600	24.85	21,000	25.35	22,300
24.36	19,600	24.86	21,000	25.36	22,400
24.37	19,700	24.87	21,000	25.37	22,400

Stage (ft)	Flow (cfs)	Stage (ft)	Flow (cfs)	Stage (ft)	Flow (cfs)
25.38	22,400	25.88	23,900	26.38	25,500
25.39	22,400	25.89	23,900	26.39	25,500
25.40	22,500	25.90	24,000	26.40	25,600
25.41	22,500	25.91	24,000	26.41	25,600
25.42	22,500	25.92	24,000	26.42	25,600
25.43	22,600	25.93	24,100	26.43	25,700
25.44	22,600	25.94	24,100	26.44	25,700
25.45	22,600	25.95	24,100	26.45	25,700
25.46	22,600	25.96	24,200	26.46	25,800
25.47	22,700	25.97	24,200	26.47	25,800
25.48	22,700	25.98	24,200	26.48	25,800
25.49	22,700	25.99	24,200	26.49	25,800
25.50	22,700	26.00	24,300	26.50	25,900
25.51	22,800	26.01	24,300	26.51	25,900
25.52	22,800	26.02	24,300	26.52	25,900
25.53	22,800	26.03	24,400	26.53	26,000
25.54	22,900	26.04	24,400	26.54	26,000
25.55	22,900	26.05	24,400	26.55	26,000
25.56	22,900	26.06	24,500	26.56	26,000
25.57	22,900	26.07	24,500	26.57	26,100
25.58	23,000	26.08	24,500	26.58	26,100
25.59	23,000	26.09	24,600	26.59	26,200
25.60	23,000	26.10	24,600	26.60	26,200
25.61	23,100	26.11	24,600	26.61	26,200
25.62	23,100	26.12	24,700	26.62	26,300
25.63	23,100	26.13	24,700	26.63	26,300
25.64	23,100	26.14	24,700	26.64	26,400
25.65	23,200	26.15	24,800	26.65	26,400
25.66	23,200	26.16	24,800	26.66	26,500
25.67	23,200	26.17	24,800	26.67	26,500
25.68	23,300	26.18	24,900	26.68	26,600
25.69	23,300	26.19	24,900	26.69	26,600
25.70	23,300	26.20	24,900	26.70	26,600
25.71	23,400	26.21	25,000	26.71	26,700
25.72	23,400	26.22	25,000	26.72	26,700
25.73	23,400	26.23	25,000	26.73	26,800
25.74	23,400	26.24	25,100	26.74	26,800
25.75	23,500	26.25	25,100	26.75	26,900
25.76	23,500	26.26	25,100	26.76	26,900
25.77	23,500	26.27	25,200	26.77	26,900
25.78	23,600	26.28	25,200	26.78	27,000
25.79	23,600	26.29	25,200	26.79	27,000
25.80	23,600	26.30	25,300	26.80	27,100
25.81	23,700	26.31	25,300	26.81	27,100
25.82	23,700	26.32	25,300	26.82	27,200
25.83	23,700	26.33	25,300	26.83	27,200
25.84	23,800	26.34	25,400	26.84	27,300
25.85	23,800	26.35	25,400	26.85	27,300
25.86	23,800	26.36	25,400	26.86	27,300
25.87	23,900	26.37	25,500	26.87	27,400

Stage (ft)	Flow (cfs)
26.88	27,400
26.89	27,500
26.90	27,500
26.91	27,600
26.92	27,600
26.93	27,700
26.94	27,700
26.95	27,700
26.96	27,800
26.97	27,800
26.98	27,900
26.99	27,900
27.00	28,000
27.01	28,000
27.02	28,100

Stage (ft)	Flow (cfs)
27.03	28,100
27.04	28,200
27.05	28,200
27.06	28,200
27.07	28,300
27.08	28,300
27.09	28,400
27.10	28,400
27.11	28,500
27.12	28,500
27.13	28,600
27.14	28,600
27.15	28,700
27.16	28,700
27.17	28,700

Stage (ft)	Flow (cfs)
27.18	28,800
27.19	28,800
27.20	28,900
27.21	28,900
27.22	29,000
27.23	29,000
27.24	29,100
27.25	29,100
27.26	29,200
27.27	29,200
27.28	29,200
27.29	29,300
27.30	29,300
27.31	29,400
27.32	29,400

APPENDIX B:

MIDDLE GREEN RIVER FLOODPLAIN WETLAND CONNECTION MAPS FOR 2012

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APPENDIX B:**MIDDLE GREEN RIVER FLOODPLAIN WETLAND CONNECTION MAPS FOR 2012**

This appendix presents overlays of modeled flow connections on aerial imagery of levee breaches and connection channels for floodplain wetlands surveyed in October 2012. The flow and cross section at which connection is estimated to occur is presented on each figure. For all images shown in the following figures, the date of the aerial imagery differs from the date of the survey, and aerial imagery does not depict exact conditions at the time of the survey.

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Escalante Ranch ER-IN-3

- Breach survey locations
- Floodplain connection cross section

f035

FIGURE B-1 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for ER-IN-3 at 18,100 cfs in 2012

Escalante Ranch
ER-IN-4

● Breach survey locations
— Floodplain connection cross section

1036

FIGURE B-2 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for ER-IN-4 at 20,300 cfs in 2012

Escalante Ranch
ER-IN-5

- Breach survey locations
- Floodplain connection cross section

1037

FIGURE B-3 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for ER-IN-5 at 16,800 cfs in 2012

Escalante Ranch
ER-IN-6

- Breach survey locations
- | Floodplain connection cross section

1038

FIGURE B-4 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for ER-IN-6 at 19,200 cfs in 2012

Escalante Ranch
ER-IN-7

- Breach survey locations
- / Floodplain connection cross section

FIGURE B-5 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for ER-IN-7 at 15,300 cfs in 2012

FIGURE B-6 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for ER-OUT at 11,300 cfs in 2012

FIGURE B-7 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for BB-IN-1 at 20,100 cfs in 2012

Bonanza Bridge BB-IN-2

● Breach survey locations

— Floodplain connection cross section

1042

FIGURE B-8 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for BB-IN-2 at 21,100 cfs in 2012

Bonanza Bridge BB-IN-3

- Breach survey locations
- Floodplain connection cross section

1043

FIGURE B-9 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for BB-IN-3 at 24,100 cfs in 2012

FIGURE B-10 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for BB-OUT at 17,400 cfs in 2012

FIGURE B-11 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for ST-OUT at 16,900 cfs in 2012

Above Brennan
AB-IN-1

- Breach survey locations
- Floodplain connection cross section

1047

FIGURE B-12 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for AB-IN-1 at 16,400 cfs in 2012

FIGURE B-13 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for AB-IN-2 at 19,500 cfs in 2012

FIGURE B-14 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for AB-IN-3 at 18,500 cfs in 2012

Above Brennan
AB-OUT

- Breach survey locations
- Floodplain connection cross section

1050

FIGURE B-15 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for AB-OUT at 9,990 cfs in 2012

FIGURE B-16 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for JB-OUT-1 at 16,100 cfs in 2012

Johnson Bottom JB-OUT-2

- Breach survey locations
- Floodplain connection cross section

1051a

FIGURE B-17 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for JB-OUT-2 at 16,400 cfs in 2012

FIGURE B-18 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for LB7-IN at 17,600 cfs in 2012

FIGURE B-19 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for LB7A-IN at 13,400 cfs in 2012

FIGURE B-20 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for OC-OUT-1 at 14,300 cfs in 2012

FIGURE B-21 Floodplain Wetland Connection Channel and Minimum Connection Cross Section for OC-OUT-2 at 9,430 cfs in 2012.

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