Phase II San Juan River Channel Restoration Monitoring

Final Report 2016

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Executive Summary:

A number of analytic tools were used to address the project objectives and determine the effectiveness of the secondary channel restoration effort at the Phase II site, located at river mile (RM) 137. At the site, the restored main secondary channel was sampled at a number of locations or throughout its entire length depending on the data set (see below). In addition, two tributaries to the main secondary channel were also sampled, Tertiary A and Tertiary B, and as well as a control or reference secondary channel. The sampling design was to collect data before and after spring runoff (April and August) and before and after the summer monsoon season (August and October).

Results for each of the major data sets collected were as follows:

Flow and Stage in the Restored Channels

- Stage and flow data in the Phase II secondary channel indicated that the restoration effort was successful. Prior to restoration (1993 – 2012), the Phase II channel never flowed when discharge was less than 659 cfs, while after restoration, the Phase II main channel flowed continuously during 2016, even when discharges were 397 cfs. The restored tertiary channels showed mixed results. Tertiary A only flowed during spring runoff and during some monsoon storm events, while Tertiary B flowed continuously.
- Pressure sensors were placed at each transect location and self-corrected for changing atmospheric barometric pressures, providing 15-minute stage data in both the San Juan River and the restored secondary and tertiary channels. These stage data mirrored flow (discharge) data recorded at the San Juan River USGS station in Shiprock New Mexico (Station No. 09368000).

Across-Channel Profiles (Transects)

- Six locations (i.e. across-channel transects) were surveyed in the restored secondary channel complex.
- High spring flows generally caused restored channels to deepen and widen.
- Monsoon floods resulted in sediment deposition in the channels.
- High spring flows are necessary to maintain the restored Phase II channel.

Habitat Data

- Within the Phase II main secondary channel, runs and shoals dominated on a percent of wetted area basis compared to other habitat types.
- Low-velocity habitats such as backwaters, embayments, pools and eddies had very low relative cover (expressed as a percent of total wetted area) but were present during all sample dates.
- Habitat counts, expressed as a percent of the total habitat count, were used in lieu of habitat area to track changes in habitat richness and the relative abundance of low-

velocity habitats. Percent habitat counts show a more even distribution (i.e. abundance) across habitat types than the relative cover (area) of different meso-habitats.

- Low-velocity habitat counts, when summed, comprised approximately 50% of available habitats in the Phase II main secondary channel and the control channel.
- Habitat richness in the Phase II restored channels increased in 2016 compared to 2015, whereas habitat richness in the control was more variable compared to 2015, indicating each channel has its own independent processes and trajectory of habitat change.

Fisheries Data

- Catch per unit effort (density) of native fishes was greatest in October, whereas catch per unit effort of non-native fishes was greatest in August.
- Native fishes made up more than 80% of the total catch for 2016.
- Native fish density varied by mesohabitat with significantly more individuals caught per unit effort in riffles than any other habitats. Non-native fish density showed no statistically significant differences among meso-habitats.
- Four age 1+ Colorado Pikeminnow *Ptychocheilus lucius* were caught in the Phase II restored channel in two sampling periods, representing 11% to < 1% of the total catch. Thus, the Phase II site continues to provide suitable habitat for juvenile endangered fishes.

1.0 Introduction

In November 2010, The Nature Conservancy (TNC), in cooperation with the U.S. Fish and Wildlife (USFWS), the San Juan River Basin Recovery Implementation Program (SJRIP), and, the Bureau of Reclamation (BOR) started a restoration project on secondary channels, backwaters, and low velocity habitats in the San Juan River near Shiprock, New Mexico. Evidence collected by the SJRIP suggested that restoring these critical habitat types would aid in the recovery of endangered species (Holden, 1977, Joseph et al 1977, Tyus and Karp, 1989, 1990, Wick et al. 1982.) and help restore a natural geomorphic process to the San Juan River. Backwaters and secondary channels are critical to the survival of young of the year and juvenile native fish, including Colorado Pikeminnow *Ptychocheilus lucius* and Razorback Sucker *Xyrauchen texanus* (Propst and Hobbes 1999; Archer et al. 2000). Retention studies after stocking Colorado Pikeminnow and Razorback Sucker showed that secondary channels were important habitats for stocked endangered fish, especially during the first initial months after stocking (Golden and Holden 2005).

The initial restoration project proposed habitat enhancement and restoration at six abandoned secondary channel sites on the San Juan River. The proposed construction methods were to: 1) excavate the inlets of previously selected abandoned secondary channels in order to re-establish continuous flow into the channel and create sustainable critical habitat that would be accessible to endangered species; and 2) remove non-native russian olive and saltcedar from the banks of the restored channels using mechanical and chemical methods. A total of six River Ecosystem Restoration Initiative (RERI) sites were restored by December 2011 re-connecting 2.2 miles of previously abandoned secondary channels and removing 26 acres of non-native riparian vegetation. Cooperative monitoring of the RERI sites for flow, habitat availability, and the presence of small bodied and larval fishes began in early 2012 and continues to the present.

With the observed persistence of the RERI sites, staff from The Nature Conservancy, Bureau of Reclamation, U.S. Fish and Wildlife Service, Ecosystems Research Institute (ERI), Keller-Bleisner Engineering (KBE), and American Southwest Ichthyological Researchers (ASIR) met in Albuquerque, New Mexico in August 2013 to identify suitable sites for Phase II of the channel restoration project. The interdisciplinary team identified twelve sites for field investigation. KBE performed preliminary investigation of these sites in October 2013, and later that month, a small team visited the top five sites, recommending the rehabilitation of a complex of abandoned channels located at approximately river mile 134.5 to river mile 137.1 (Figure 3.1). KBE started the permitting process, survey work, site design and archeological surveys in January 2014. Site construction work by the San Juan Dineh Water Users and the Southwest Conservation Corps began in October 2014 and was completed in November 2014.

Monitoring for fish presence, habitat, flow, and stage began in April 2015 through November 2015, and continued again in April 2016, followed by two repeat monitoring trips in August and October of 2016. The monitoring design included sampling pre- and post-spring runoff and pre- and post-monsoon season.

2.0 Project Objectives

The following five objectives were identified to: (1) address potential changes in aquatic habitat, channel geomorphology and fish assemblages at the Phase II channel restoration site; and (2) evaluate the overall success (or failure) of the restoration effort.

- **Objective 1**. Measure changes in habitat features, channel geomorphology, larval fish abundance, and small-bodied fish abundance in the restored channels over three years following completion of the restoration treatments.
- **Objective 2.** Measure seasonal changes in habitat features, channel geomorphology larval fish abundance, and small-bodied fish abundance, in the restored channels, from prior to spring runoff to late fall during each of the three years following completion of restoration treatments.
- **Objective 3**. Compare the relative abundance of small-bodied fishes collected in different meso-habitats within the restored site to determine whether or not there are preferences for specific meso-habitats.
- **Objective 4**. Measure changes in habitat features and channel geomorphology of the restored channels associated with environmental flow releases or large floods that may occur over the three years following completion of restoration treatments.
- **Objective 5.** Compare habitat features, channel geomorphology, larval fish abundance and small-bodied fish abundance between restored channels and a control or reference secondary channel site.

These five objectives support several goals and actions identified in the 2016 Long Range Plan of the San Juan River Basin Recovery Implementation Program. They are:

- **Goal 4.2:** Monitor habitat use and availability.
  - **Action 4.2.3 and 4.2.4:** Identify, characterize, and quantify suitable habitat; identify and refine habitat/fish relationships.
- **Goal 4.3:** Evaluate habitat restoration strategies and monitor habitat restoration strategies and monitor habitat restoration projects.
  - **Action 4.3.1 and 4.3.2:** Evaluate and implement habitat restoration strategies; monitor habitat restoration projects.

3.0 Study Area

The Phase II channel restoration site is located on the San Juan River at river mile 134 through river mile 137, approximately 10 miles west of Shiprock, New Mexico (Figure 3.1). The Phase II site consists of one main secondary channel and two tertiary channels. The main secondary channel is approximately 2.3 miles long and has a potential wetted area of 34,400 m^2. The main channel is made up of multiple complex island areas connected by reaches of run to riffle complexes. Tertiary A, a previously abandoned channel, is approximately 0.7 miles long with a potential wetted area of 2,500 m^2. Tertiary A only flowed during spring runoff from May 14 to July 10 and very briefly during several monsoon flood events in 2016. Tertiary B, also a previously abandoned channel, is approximately 0.6 miles long and has a potential wetted area of 2,900 m^2. Tertiary B has flowed continuously over the duration of the study period. It is made up of mostly run to riffle complexes with a single newly constructed island. Overall, the Phase II restoration site is approximately 3.7 miles in total length, and has a potential total wetted area of approximately 37,330 m^2. In addition to the Phase II restoration site, a consistently flowing natural secondary channel located at river mile 129 was monitored as a control or reference site. The control site is approximately 0.4 miles long, with an average wetted area of 6,915 m^2. This site has been monitored periodically since April 2012 as part of the Phase I RERI project.

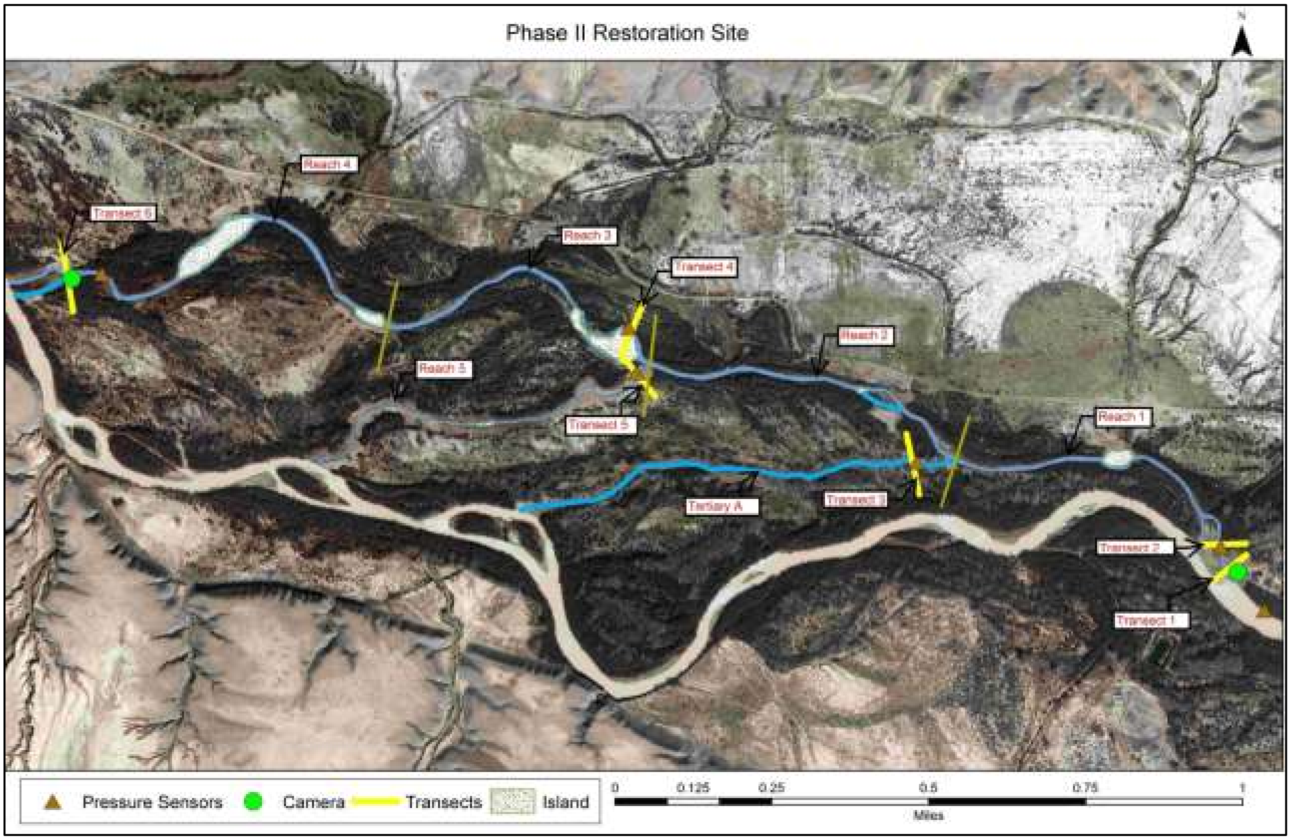

Figure 3.1: Restoration site showing the location of cross-channel transects, temperature-pressure sensors, and field cameras. Reach designations and island complexes also indicated.

4.0 Methods

4.1 Methods of Habitat Monitoring

Post-construction aerial imagery was acquired from Digital Globe Incorporated for the Phase II and control sites; images were taken on February 4, 2015, with a pixel resolution of approximately 40 cm. The flows at the time of image capture were between 804 CFS and 828 CFS. At the time of image capture, all channels, (constructed and natural) were flowing.

Using ESRI ArcMap 10.0, digital images of the channels were geo-referenced and transformed into portable document format (pdf) files and printed with a 1:200 inch ratio. The prints were placed in transparent Mylar page covers and assembled into map books.

During each sampling period, all channels (if flowing) were walked and their habitats were mapped by drawing representative polygons on the Mylar-covered maps in the attempt to duplicate the distribution and cover of habitats in the channel. Each polygon was coded using 14 established San Juan River habitat types (Table 4.1)

Habitat Code	Habitat Type
1	Backwater
2	Embayment
3	Riffle
4	Run
5	Rapid
6	Slack Water
7	Pocket Water
8a	Pool
8b	Eddy
9	Shoal
11a	Overhanging Vegetation
11b	Inundated Vegetation
15	Island
13	In Channel Cobble/Sand Bar

Table 4.1: The 14 habitat types mapped in this investigation.

Laboratory post-processing consisted of scanning all hand mapped Mylar sleeves into digital high-resolution Joint Photographic Experts Group (JPEG) files using an EPSON 4490 photo-scanner. All individual JPEG files were geo-referenced onto the previously mentioned satellite acquired base map. Wetted area and individual habitat polygons were subsequently digitized to quantify habitat count, habitat area, and habitat perimeter for each geo-referenced location. Following rasterization, the habitat polygons were exported from ArcMap 10.0 into Microsoft Excel for statistical analysis.

4.2 Methods for Channel Monitoring

Six cross-channel transects were established at various locations in the Phase II main secondary channel, the two tertiary channels, and the control channel (Figure 3.1). The bed elevations of the across-stream transects were measured every 0.5 meter and at all major landform topographical breaks including the water's edge. All measurements were made to the nearest two centimeters using a metered stadia rod and a Spectra Precision LL 300N self-leveling laser transit. Transit data were transcribed in field and post processed in the laboratory using Microsoft Excel.

4.3 Methods for Channel Stage Monitoring

An Onset HOBO Water Level and Temperature series U20L probe was installed near each transect location, as well as in the main stem of the San Juan River near the mouth of the Phase II channel (Figure 3.1), in order to assess the presence or absence of inundation and flow. Each probe recorded pressure and temperature every 15 minutes. In order to obtain site-specific water depths, and temperature, each probe was calibrated in the laboratory in order to convert pressure to water depth. The initial pressure measurements were corrected for atmospheric pressure changes using a reference probe that was installed at the site but not submerged in the channels. The barometric pressure reference probe collected data at the same time step as the submerged probes. Probes were launched on April 29, 2015 and have provided nearly continuous stage and temperature data for each channel over the course of the project. A flow history of the Phase II restoration site was constructed prior to the restoration effort through a retrospective analysis of aerial imagery from 1993 through 2013. This past habitat mapping data was combined with an analysis of Google Earth images to create a binary data set (i.e. flowing or not flowing). The data were then referenced to the San Juan River flows recorded at the USGS gauge site at Shiprock, New Mexico (Station No. 09368000) at the time of observation.

4.4 Fish Collection Methods

The Phase II restoration site fish assemblage was monitored using the small-bodied fishes sampling protocol established by the SJRIP. The Phase II restoration site was divided into six distinct reaches. Four of these reaches make up the main secondary channel and ranged in linear distance from 1620 meters to 774 meters. Each tertiary channel and the control channel were considered individual reaches. The reaches were delineated by distinct geographic landmark breaks such as, the tertiary channels diverging from the main channel, or large island complexes (Figure 3.1). Water quality (pH, dissolved oxygen, temperature, and conductivity) were measured and recorded at the beginning of each reach. The meso-habitats were sampled for fish within each reach in the same proportion as their overall occurrence in that reach (Table 4.1). Data from each meso-habitat sampled was also recorded separately within each reach. If present, all meso-habitat types were sampled within reaches, with a target sample size of 8 seine hauls per reach. Each seine haul sample was recorded on the habitat maps for the purpose of data integration and redundancy.

Fishes were collected with a 3.0 m x 1.8 m (3.0 mm heavy Delta mesh) drag seine. All captured native fish were identified by species and enumerated. In addition, each fish was measured, recorded and released. Non-native fishes were removed from the river system after measurements were taken and recorded.

Following fish collection, the seine area (length x width), target habitat type, water depth and dominant substrate (measured at 5 generalized locations within the area of the seine haul) were measured and recorded for each seine haul sample.

Due to low catch rates during small-bodied fishes sampling, the number of fish captured by species were grouped into native and non-native species. Density of native and non-native fishes for each individual seine haul was then calculated as the number of fish captured per square meter (fish/m^2) sampled. The calculated densities were then used to test differences between sampling dates (i.e.: April, July, and November), channel type (i.e.: Phase II-Main, Phase II-Tertiary B, Control), and meso-habitat (e.g.: riffle, run, pool) for both natives and non-natives. Data failed to meet the assumptions of one-way ANOVA test even after log (x+0001) transformation, so differences were tested using the non-parametric Kruskal-Wallis ANOVA for Ranks Test. Post-hoc Dunn's Test for multiple comparisons was used to determine differences between groups following a statistically significant Kruskal-Wallis Test (Dunn 1964). Due to the natural variability often observed in age-0 fish populations, an α of 0.10 was used to determine statistically significant differences (Brown and Guy 2007). An α of 0.05 was used when assessing the assumptions of normality (Shapiro-Wilk Test) and homogeneity of variance (Bartlett's Test). All statistical analyses were performed using R3.2.1 (R Core Team 2015).

4.5 Larval Fish Sampling Methods

Available low-velocity nursery type habitats (e.g.: backwater, embayment, shoals) were sampled according to larval fish collection protocols established by the SJRIP Larval Fish Monitoring Program. Nursery type habitats were sampled with a fine mesh larval seine measuring 1m x 1m (0.8 mm mesh). All captured fishes large enough to be field identified were measured, counted, recorded and, depending on status (native or non-native), returned to the river or removed from the system. Fishes too small to field identify were labeled and preserved in 10% formalin, and returned to the laboratory for identification by personnel from ASIR. Following larval fish collection, seine haul locations were recorded on habitat maps. Area seined, relative depth, dominant substrate and habitat type were also recorded.

5.0 Results and Disscussion

5.1 Habitat

Habitat abundance in the Phase II channel in 2016 was disproportionately distributed in terms of area; habitat types such as run and shoal dominated in terms of their overall percent coverage in all three of the active channels monitored, representing approximately 70% to 85% of total habitat area observed (Figure 5.1.1). Habitat counts, expressed as a percent of the total count, show a more even distribution across meso-habitats (Figure 5.1.1) and this more sensitive metric will be used in this section to describe changes in habitat abundance in 2016.

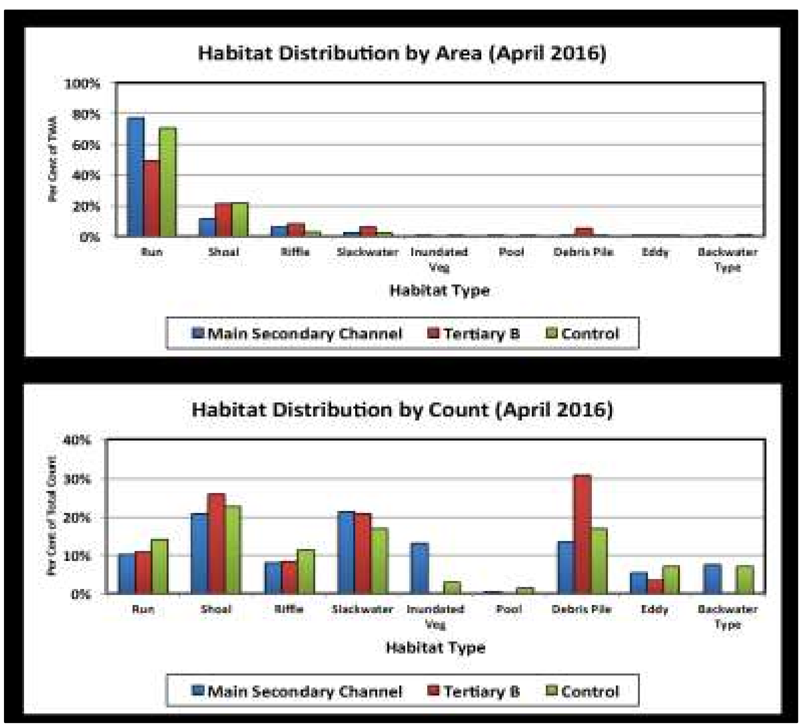

Figure 5.1.1: Habitat distribution by area and count for April 2016.

When low velocity habitat (LVH) counts (e.g. slackwater, pool, debris pile, eddy, backwater and embayment) are summed, LVH represent 48% of the total habitat count in the main channel and 49% in the control channel in April 2016 (Figure 5.1.1). In August 2016, LVH increased in the Phase II main channel to 51% and decreased in the control channel to 44%; the increase in the main channel can be attributed to an increase in slackwater counts, and a decrease in shoals (Figure 5.1.2). October (post-monsoon) 2016 showed a decrease in LVH from August 2016 back down to 48% for the main channel and an increase for the control channel to 47%. Main channel LVH losses can be attributed to slight decreases in the percent count of backwater type habitats (Figure 5.1.2). In summary, on a percent count basis, the Phase II main secondary channel is providing a relatively stable abundance of LVH throughout the year for endangered fishes consistent with the control channel.

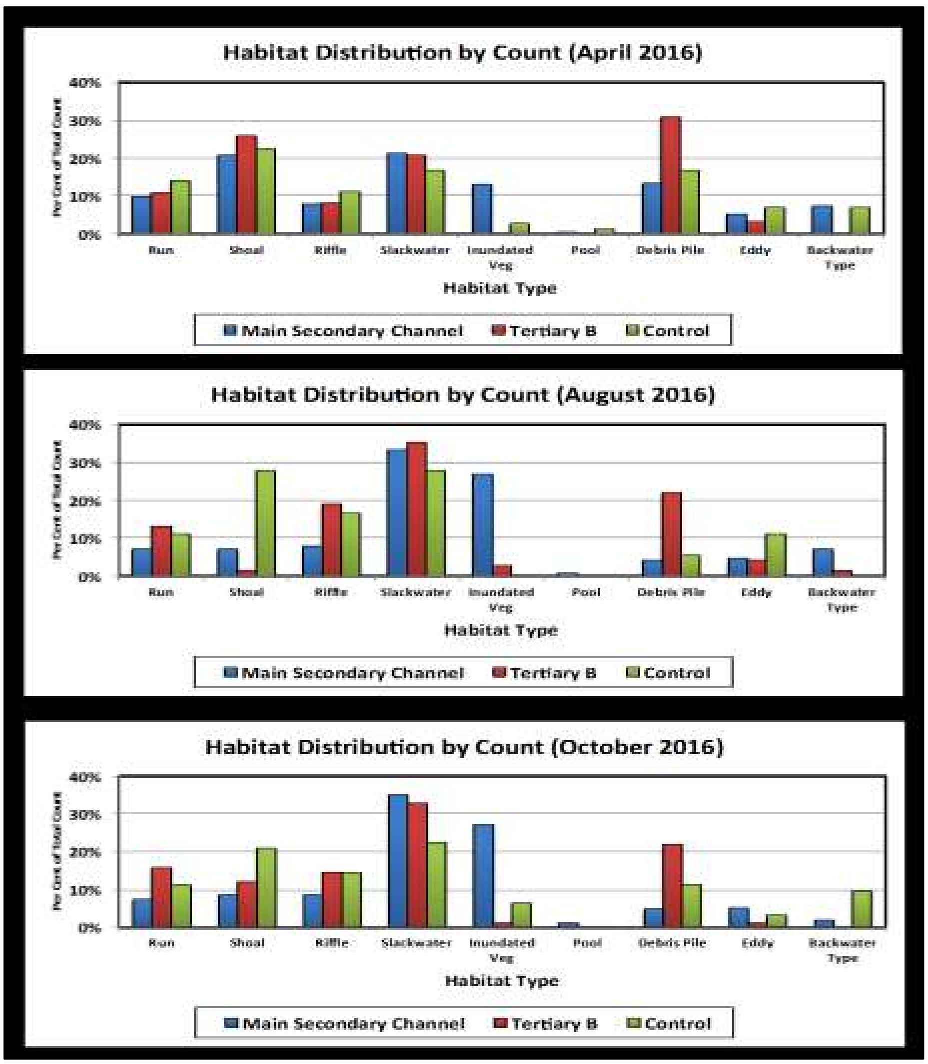

Figure 5.1.2: Habitat distribution by count for all channels monitored during the 2016 study period.

Habitat richness was calculated for each channel type as the total number of habitats per 100 meters of linear distance. For the phase II site (main channel, Tertiary B), habitat richness increased in 2016 compared to 2015. In contrast, the control site saw decreases in habitat richness in August and October 2016 compared to November 2015 and April 2016. By October 2016, however, habitat richness in the control channel was again greater than in the restored channels, although the difference was not as great as the previous fall. Together these results suggest that that, although LVH percentages remained similar between the two channels in 2016, each channel followed its own trajectory of habitat change based on antecedent flow conditions and flows at the time of mapping (Figure 5.1.3).

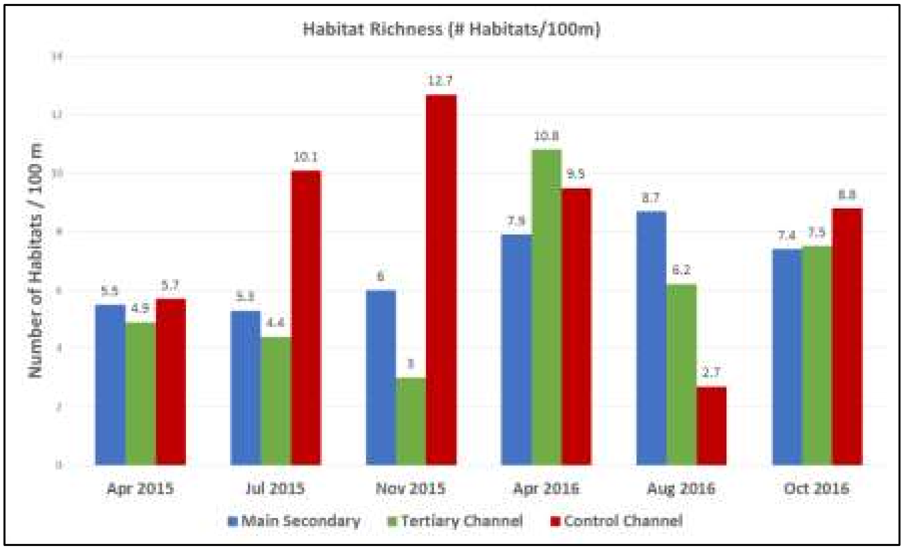

Figure 5.1.3: Habitat richness for all channels monitored from 2015 to 2016.

Total wetted area (TWA) is a general metric representing the amount of aquatic habitat in each channel type. Like habitat richness, TWA was calculated per 100 meters of each channel to control for differences in their lengths. Over the course of the study period, the control channel had greater TWA per 100 meters than the Phase II main channel and Tertiary B when flows were above 800 cfs, though the control channel was more variable over time than the main channel. TWA per 100 meters in the Phase II restored channels remained relatively stable in August 2016 and October 2016 but showed a slight increase compared to previous sampling trips, presumably as a result of high spring flows (Figure 5.1.4).

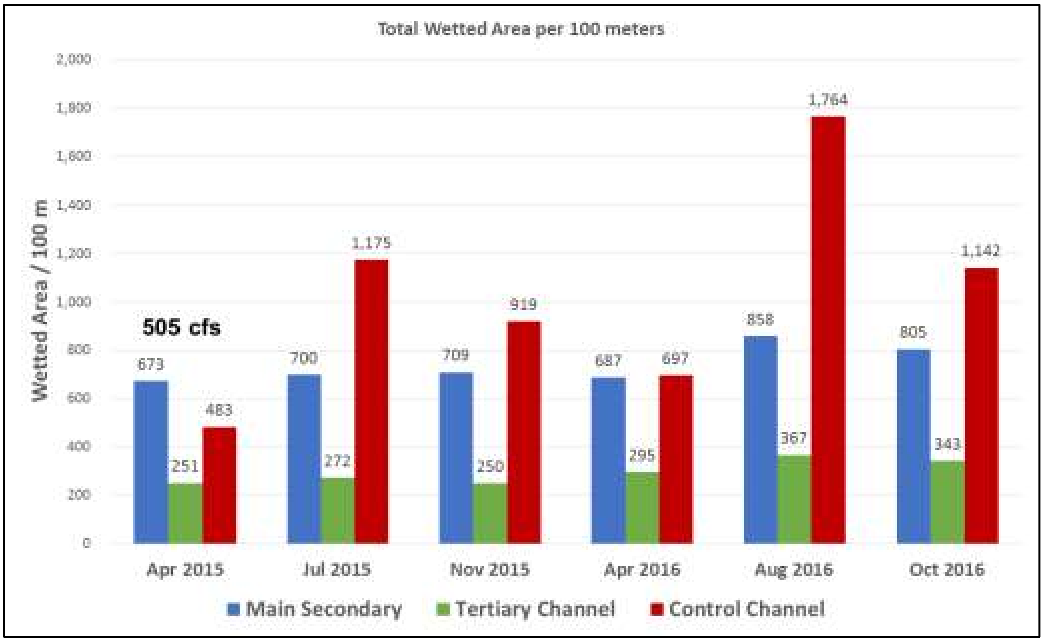

Figure 5.1.4: Total wetted area per 100 meters of all channels monitored from 2015-2016.

5.2 Stage

At the Phase II site, the water stage was measured at six locations using Onset HOBO Water Level and Temperature Series U20L probes (Figure 3.1). Three probes were installed in the secondary channel at the inflow, outflow, and near the linear center of the channel. Tertiary channels each had a single probe installed near their confluence with the main secondary channel. In addition to monitoring the Phase II channels, a single water level sensor was also installed on the main stem of the San Juan River immediately upstream of the secondary channel.

Once corrected for changes in atmospheric barometric pressure, water depths and water temperatures were recorded every 15 minutes at each site. In addition, the flow in the San Juan River was also collected in 15-minute time intervals from the USGS gauge (Station No. 09368000) at Shiprock, New Mexico. This station is immediately upstream from the study site. The flow data at Shiprock was adjusted for travel time and compared to the stage data in the San Juan at the secondary channel entrance (Figure 5.2.1). Flow and stage in the San Juan River at the Phase II site in 2016 was characterized by a moderate spring run-off event culminating on June 7, 2016 with a peak instantaneous flow of 8,511 cfs. Flows remained over 8,000 cfs for seven days. The peak flows were followed by a long period of elevated but declining flows until the end of July. On August 6, 2016, a large monsoonal event caused flows in the San Juan River to exceed 11,800 cfs with an increase in stage of 5.1 feet in only a few hours. Additional monsoon events in late August and September resulted in stage changes of approximately one foot (Figure 5.2.1).

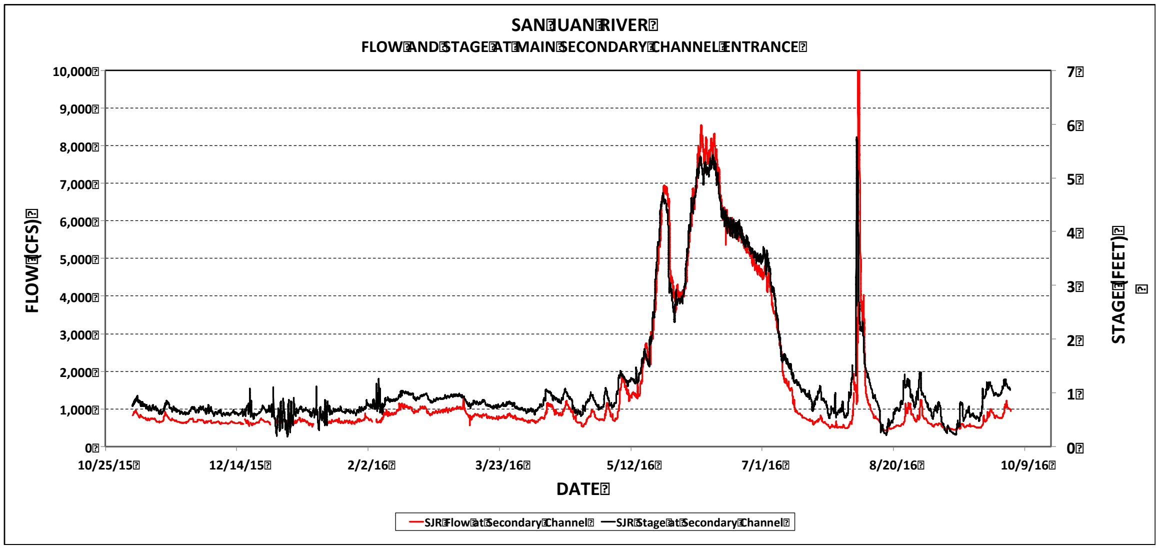

Figure 5.2.1: Stage (feet) and flow (cfs) in the San Juan River immediately upstream of the restored secondary channel inflow at the Phase II site. Data are for 2016.

Stage in the main secondary channel was also measured at the outflow transect site (T-6) near the confluence with the San Juan River. Hydrograph patterns for the secondary channel mimicked the hydrograph for the main stem of the San Juan River with a maximum stage and flow on June 7, 2016 with subsequent changes in stage resulting from snowmelt runoff, Navajo reservoir releases and monsoonal events throughout the rest of the year. Flow in the main secondary channel was continuous throughout the water year and ranged from the peak of 8,511 cfs in the main stem of the San Juan, to a minimum base flow of 409 cfs on August 17, 2016, indicating that the restoration effort achieved its goal of restoring continuous flow to the Phase II main secondary channel (Figure 5.2.2).

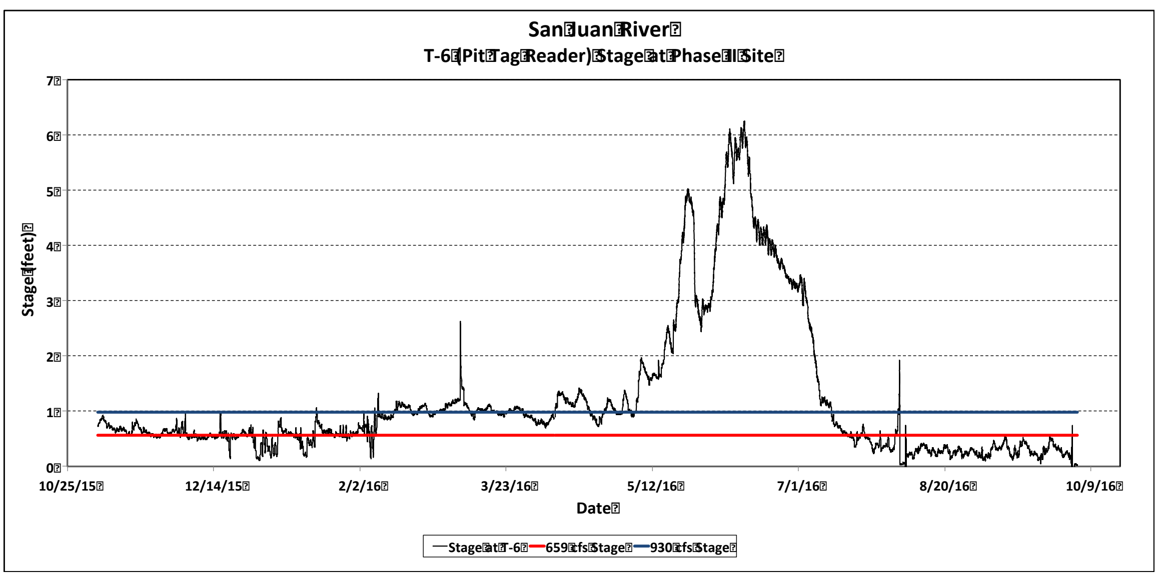

Figure 5.2.2: Stage (feet) in the outflow area (at Transect T-6) of the Phase II main secondary channel.

Stage for the Tertiary A channel was measured at the divergence of the tertiary channel and the main secondary channel of the Phase II site. Tertiary A consistently flowed from May 20, 2016 to July 12, 2016 with a maximum increase in stage of 4.8 feet on June 7, 2016. This corresponded to the spring peak flow in the San Juan River of approximately 8,511 cfs. Tertiary A started to flow when a threshold volume of 3,200 CFS occurred in the San Juan on May 20, 2016 and stopped flowing when San Juan River flows were 2,030 cfs on July 12, 2016. The reason for this channel flowing at a lower stage on the decreasing hydrograph was likely due to the 0.5 feet of sediment erosion that occurred between pre- and post-runoff sampling visits (Figure 5.5.5) at this site. In total, the channel flowed for most of the spring runoff, as well as, during the large monsoonal event on August 6, 2016 (Figure 5.2.3).

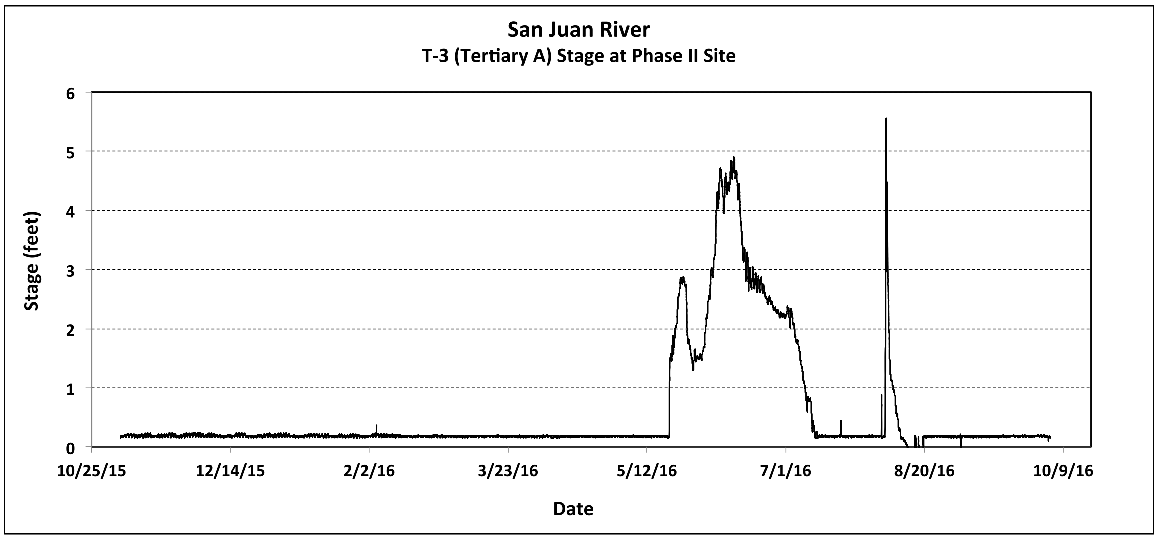

Figure 5.2.3: Stage (feet) in Tertiary A at Transect T-3 at the Phase II Site.

The stage of Tertiary B was measured at Transect T-5, located 20 meters below the divergence from the main secondary channel. Tertiary B had a maximum stage increase of 3.9 feet on June 7, 2016 corresponding to the 8,511 cfs flow measured in the main channel of the San Juan River. Tertiary B flowed for the entire study period (Figure 5.2.4). In the fall of 2015, the stilling well containing the pressure sensor was deepened to offset channel erosion. The resetting of the sensor was successful, and the stage was accurately measured during spring runoff and during summer and fall monsoonal storm events.

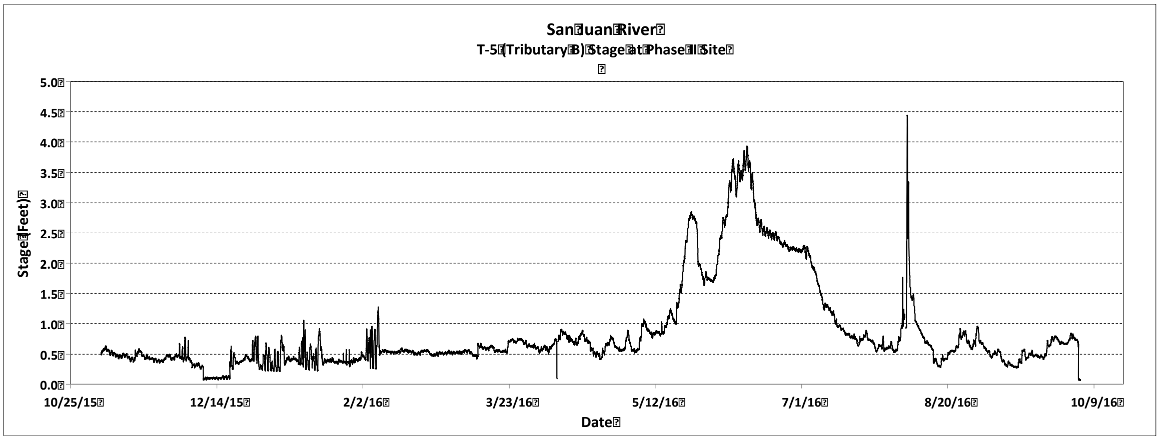

Figure 5.2.4: Stage (feet) in Tertiary B recorded at Transect T-5 at the Phase II Site.

In addition to water depth, temperature was also monitored at each site every 15 minutes, and paired with the stage data. The ranges of water temperatures in the Phase II main secondary channel (inflow and mid-channel) were comparable to the upstream site in the main stem of the San Juan River. The San Juan River temperatures ranged from 37° F to 76° F over the period of observation. The main secondary channel temperatures at the outflow station ranged from 42°F to 68°F. However, subtle differences in temperatures were evident between this most downstream station in the main secondary channel and the station located in the main stem of the San Juan River. Specifically, the main secondary channel outflow station (T-6) recorded consistently higher temperatures in the fall and winter and consistently lower temperatures (up to 5°F colder) in the summer compared to the inflowing river (Figure 5.2.5).

Consistently colder temperatures in the lower main secondary channel site were most likely the result of colder hyporheic flow from the adjacent main stem of the San Juan River into the Phase II secondary channel. Direct observations indicated that the groundwater depth in the adjacent floodplain alluvial aquifer was at the same elevation as the secondary channel water elevation between the two temperature stations, T4 and T6 (V. Lamarra, personal communication). The groundwater temperature was 45° F on April 10, 2016 and increased linearly to 66° F on August 2, 2016.

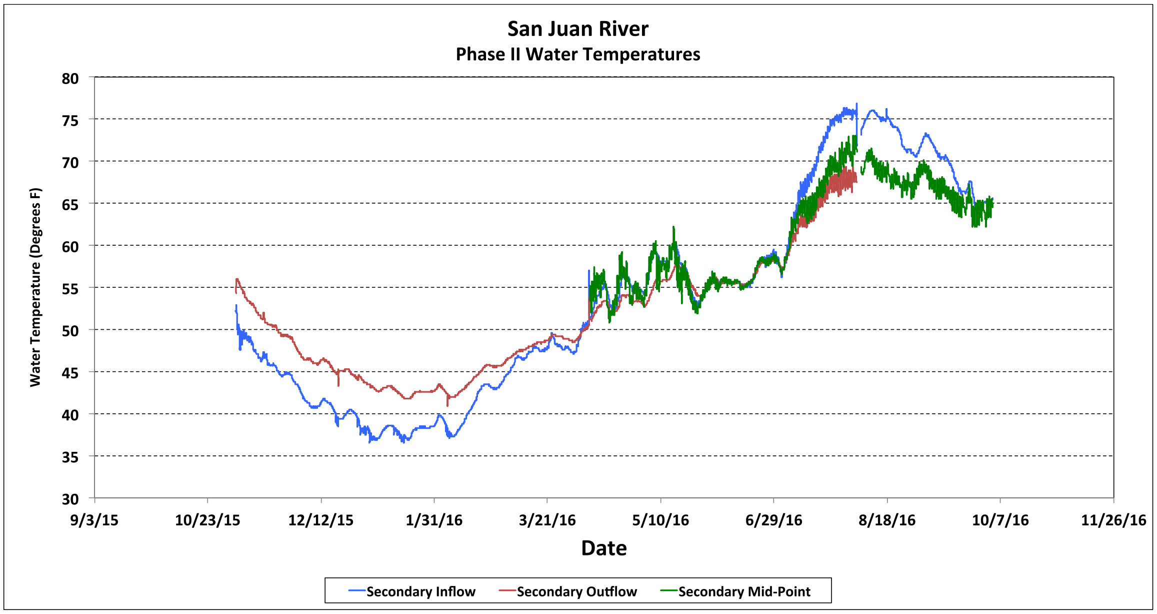

Figure 5.2.5: Water temperatures in the restored main secondary channel at the channel entrance from the San Juan, at the mid-point in the secondary channel, and at the outflow into the San Juan. Data are in degrees Fahrenheit.

In summary, pressure sensors were placed at each transect location, corrected for changing atmospheric barometric pressures and provided 15-minute stage data in the San Juan River and in the restored main secondary and tertiary channels. The stage data mirrored San Juan River flows recorded at the USGS station at Shiprock New Mexico, 10 miles upstream of the restored site. After restoration, water flowed in the main secondary channel at all times, including at river flows of 409 cfs. The lowermost station, located just above the secondary's outflow back into the San Juan River displayed the same stage pattern as the inflow station (T2) sensor, indicating that the entire secondary channel was continuously wetted during the study period. The tertiary channels showed mixed results. Tributary A was dry except for periods of high flow (spring runoff) and large monsoonal storm events, whereas Tributary B flowed continuously at all flows between fall 2015 and fall 2016.

5.3 Cross-Channel Transect Profiles

The uppermost secondary channel transect (Transect T-1) was located at the mouth of the Phase II main secondary channel and the San Juan River; this transect originated on the northeast bank of the secondary channel and terminated on a large cobble bar in the main stem of the San Juan River. This was the location of the channel excavation. All elevation values were calculated as negative values (feet) relative to the transect benchmark (stake) which was located on the floodplain adjacent to the channel bank. Over the three sample periods in 2016, April 7th, August 5th, and October 2rd, Transect T-1 had maximum relative depths ranging from -4.81 to -5.30 feet with an average maximum depth of -5.11 feet below the survey benchmark (Figure 5.3.1).

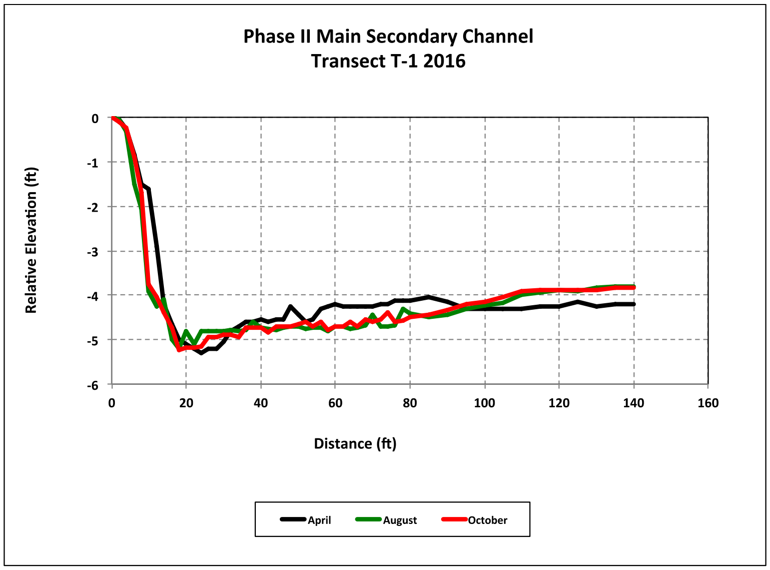

Figure 5.3.1: Elevations of the stream bed relative to a 0 benchmark at Transect T-1, Phase II main secondary channel. Data are for April. August, and October, 2016.

Comparison of the cross-sectional areas before and after spring runoff, before and after the monsoon season, and for the entire year are shown in Table 5.3.1. After spring runoff, the channel profile increased by 14.3 ft^2, a 2.5% change in cross-sectional area, presumably the result of erosion caused by high spring runoff flows. During the interval between August and October (i.e. the monsoon season), the channel lost capacity (deposition) by -4.04 ft^2. Over the entire study period, the channel showed a net increase in cross-sectional area of 10.2 ft^2, corresponding to an 1.8 % increase between April and October. Although the magnitude of the change was different, Transect T-1 responded in the same way in 2015 as in 2016, showing a net erosion between pre-spring runoff and fall.

Transect T-2 was located in the Phase II main secondary channel approximately 90 meters downstream from the inflow (Transect T-1). This transect originated on the east bank of the Phase II inflow channel and ended on a large cobble bar on the west side of the channel. The wetted width of T-2 ranged from 12.3 to 16 feet, and it had maximum depths ranging from -5.06 to -5.20 feet. The average maximum depth was -5.15 feet (Figure 5.3.2)

Name	Transect Location	X-Section (ft^2) Difference & % of Total	X-Section (ft^2) Difference & % of Total	X-Section (ft^2) Difference & % of Total
Transect		April-Aug	Aug - Oct	April-Oct
T-1	River Confluence	14.3 (2.5%)	-4.04 (-0.69%)	10.2 (1.8%)
T-2	Mouth of Secondary	-10.5 (-6.6%)	-12.2 (-8.2)	-22.7 (-14.2)
T-4	Mid-Point	-9.17 (-4.6%)	-45.3 (-23.8%)	-54.4 (-27.3)
T-6	Bottom of Secondary	97.5 (48.5%)	-75.5 (-25.2%)	22.0 (10.9%)
T-3	Tertiary A	4.1 (16.7%)	0.69 (2.5%)	4.79 (19.5%)
T-5	Tertiary B	22.0 (95.7%)	2.1 (4.9%)	24.1 (104.8%)
T-C	Control			-41.1 (-18.8%)

=Erosion
=Deposition

Table 5.3.1: A summary of the changes in cross-sectional area at each transect during 2016. Positive values represent a gain in area (erosion) while negative values represent a loss in area (deposition). Values in parenthesis indicate the percent gain or loss based on the initial cross-sectional area (April 2016).

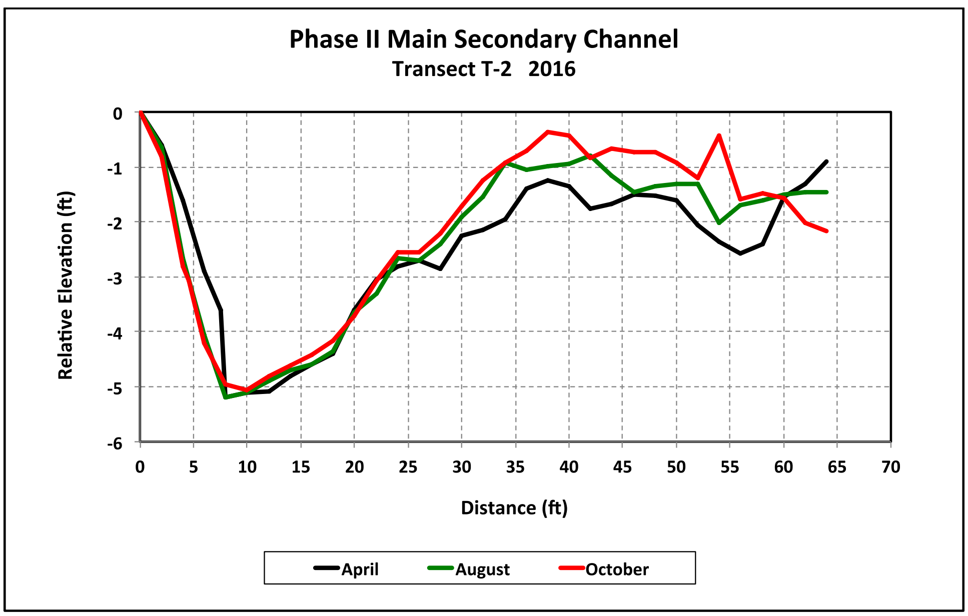

Figure 5.3.2: Elevations of the streambed relative to a 0 benchmark at Transect T-2, Phase II main secondary channel. Data are for April, August and October, 2016.

The cross-sectional channel area at Transect T-2 decreased during both spring runoff and the summer monsoon period (Table 5.3.1), resulting in an overall loss of 22.7 ft^2 (or 14.2% of the initial area) between April and October. Although channel depth remained roughly constant, deposition on the east bank resulted in a net decrease in cross-sectional area in August and October (Figure 5.3.2). A similar pattern was observed in 2015.

Transect T-4 (Mid-point) was located in the main secondary channel near a large island complex, approximately 1,900 meters downstream from the inflow of the Phase II channel. The wetted width of the secondary channel at this site ranged from 17 feet in April, to 18.8 feet in October 2016. Relative maximum depths ranged from -7.31 to -5.98 feet with an average max depth of -6.69 feet (Figure 5.3.3).

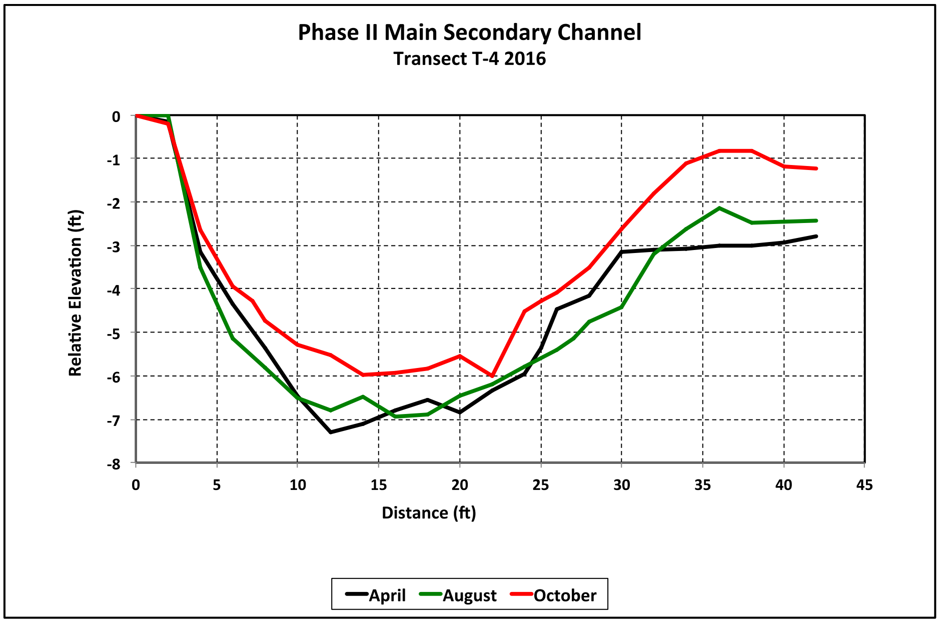

Figure 5.3.3: Elevations of the stream bed relative to a 0 benchmark at Transect T-4, Phase II main secondary channel. Data are for April, August, and October, 2016.

The seasonal pattern in 2016 on Transect T-4 was similar to that on Transect T-2, with net deposition in both the spring and fall. However, deposition on Transect T-4 in the fall was greater in magnitude than on Transect 2, resulting in a 27.3 % net loss in cross-sectional area during the study period (Table 5.3.1).

The most downstream main secondary channel transect, Transect T-6, was located 170 meters upstream from the confluence of the Phase II channel with the San Juan River. This transect had wetted widths that were constant for each survey period (41.2 feet). However, the relative maximum depth ranged from -4.65 to -7.40 feet, with an average maximum depth of -4.76 feet (Figure 5.3.4).

Transect T-6 showed the same seasonal pattern of erosion and deposition as Transect T-1. However, the extent of spring erosion and summer/fall deposition, expressed as a percent of the original cross-sectional area, was an order of magnitude greater at Transect T-6. This transect had an initial increase in cross-sectional area of 48.5% followed by a loss of area of -25.5%. Over the entire year, there was a net gain in cross-sectional area of 22% between April and October.

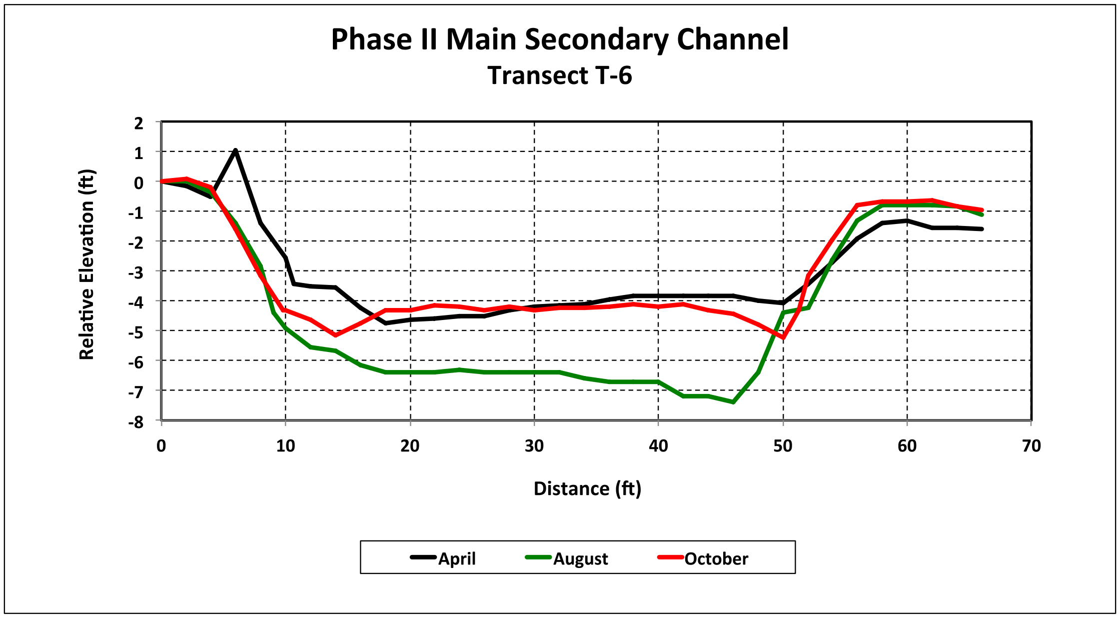

Figure 5.3.4: Elevations of the streambed relative to a 0 benchmark at Transect T-6, Phase II main secondary channel. Data are for April, August, and October, 2016.

The two secondary channel tributaries (i.e. restored tertiary channels) responded similarly to spring runoff and monsoon season flows. Transect T-3 was located on Tertiary Channel A, 50 meters from its confluence with the main channel and approximately 920 meters downstream of the inflow to the Phase II main secondary channel. At each sampling period, there was no flow at Transect T-3, so surveys were undertaken without a wetted channel. The width of the bed was constant at approximately 6 feet and the maximum bed depth ranged from only -2.9 feet to -3.1 feet (Figure 5.3.5). After an initial deposition in the summer of 2015, this channel has been relatively stable. This observation is consistent with the minor gains in cross-sectional area at this transect, which occurred during both time periods (i.e. pre/post runoff and pre/post monsoons). Overall, this transect gained 4.79 ft^2, a 19.5% of its cross-sectional area, between April and October (Table 5.3.1).

Transect T-5 was located on Tertiary Channel B, approximately 20 meters from its confluence with the main secondary channel and approximately 1,800 meters from the inflow of the main secondary channel to the San Juan River. Transect T-5 was flowing during all three sampling events. In addition to continuous flow, Transect T-5 was also strongly influenced by spring runoff and flow releases from Navajo Dam. The channel depth at the transect location increased by 1.3 feet, indicating that down-cutting was continuing to occur in response to high flows as it did in 2015. The wetted channel width ranged from 9.4 to 10 feet with maximum depths ranging from -3.4 feet to -4.71 feet; the average depth was -4.23 feet (Figure 5.3.6). Tertiary channel B had consistent gains in cross-sectional area over both spring runoff and summer/fall monsoon periods. Overall, the channel more than doubled its cross-sectional area (104.8% increase) between April and October 2016. These data are consistent with the pressure sensor data collected at this site in

2015 which indicated channel downcutting in spring, summer and fall and the need to reset the pressure probe on the channel bottom in November. This process has continued through 2016 (Table 5.3.1).

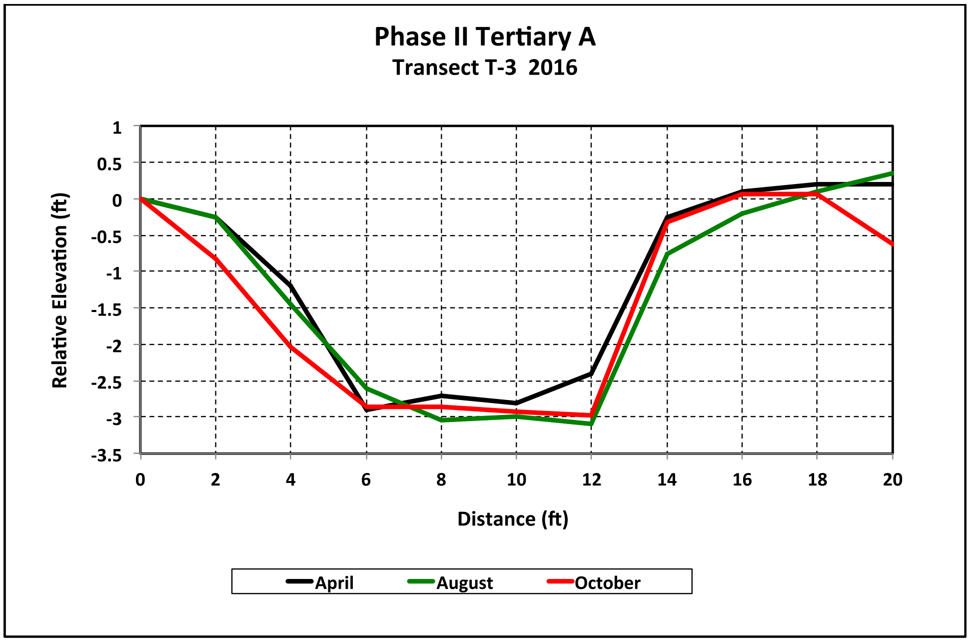

Figure 5.3.5: Elevations of the streambed relative to a 0 benchmark at Transect T-3, Phase II Tertiary A. Data are for April, August, and October, 2016.

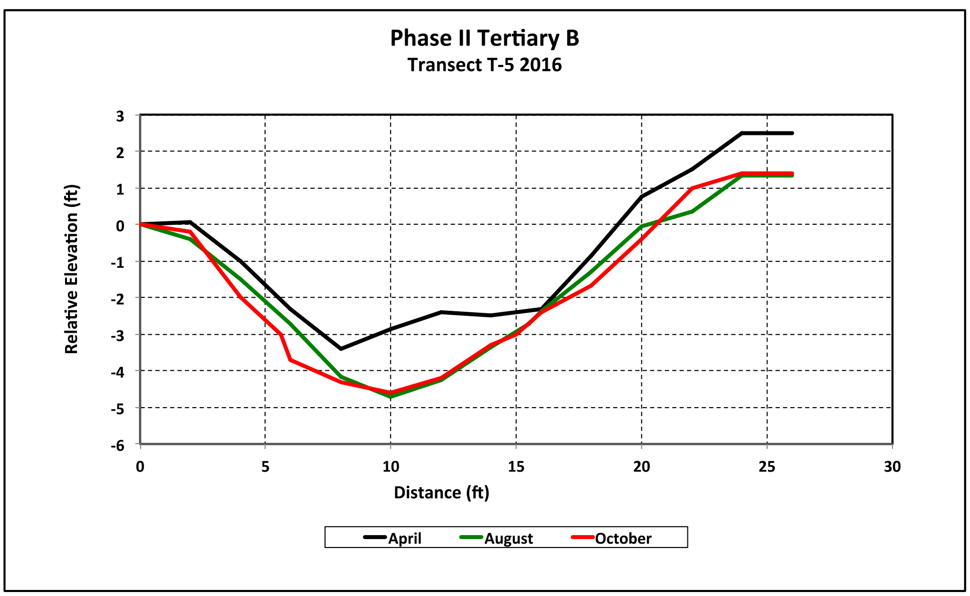

Figure 5.3.6: Elevations of the streambed relative to a 0 benchmark at Transect T-5, Phase II Tertiary B. Data area for April, August, and October, 2016.

The Control channel transect (Transect T-C) was located at river mile 129; it has flowed continuously since 1993 based on past observations. This secondary channel runs from east to west across a large debris pile that has created a complex braided inflow channel (Figure 5.3.7). In 2016, the width of the cross-section at Transect T-C ranged from 76 to 86 feet with a braided wetted channel width of 40.8 feet in April and 20.6 feet in October. Maximum relative depth ranged from -4.91 to -5.56 feet. Due to weather conditions (heavy monsoon rains) and muddy roads, this transect was not surveyed in August 2016. Overall, the channel cross-section experienced deposition during 2016 (mostly as sand adjacent to a large root wad pile at the entrance of the channel) and extensive erosion on one bank (Table 5.3.1). The result was net deposition at this transect during the study period, corresponding to an 18.8 % loss in cross-sectional area).

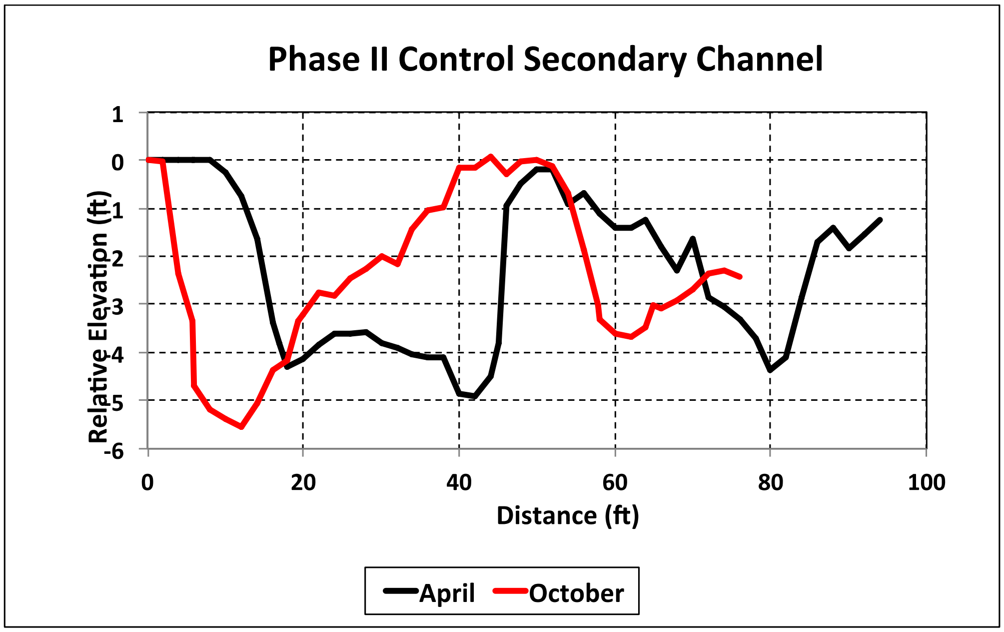

Figure 5.3.7: Elevations of the streambed relative to a 0 benchmark at the control site, Transect T-C. Data are for April, and October, 2016.

In summary, the across-channel profiles were surveyed at six locations in the Phase II restoration complex in 2016. The sites corresponded to the locations of the pressure sensors. The transect data indicated that: (1) the main secondary entrance tended to be eroded by spring runoff and filled by monsoon season flows, resulting in a net overall gain in cross-sectional area; (2) the same pattern was observed at the most downstream transect in the main secondary channel; and (3) in the remaining two secondary channel transects, deposition occurred during both spring runoff and the summer/fall monsoon season (April-October). The tertiary channels showed different results. Channel A only flowed during spring runoff and for very brief periods during the summer monsoon season. It has remained filled with sediment, although some erosion occurred in 2016, primarily in the spring. In contrast, Tertiary B flowed continuously in 2016 and continued down-cutting as it did in 2015.

5.4 Fish Assemblage

During 2016, native fishes were proportionately dominant, and the percentage of native fishes never fell below 83% of the total catch. Additionally, native the proportion of native fish captured was significantly greater in 2016 than 2015 (X^2:197.1, $p<0.001$) (Figure 5.4.1).

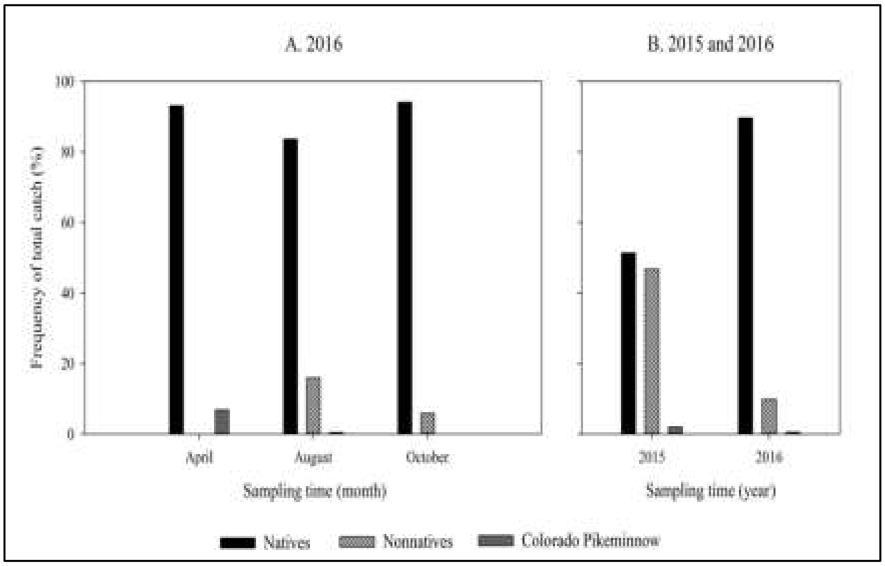

Figure 5.4.1: Fish Capture expressed as percent of total catch.

Speckled Dace *Rhinichthys osculus* were the most common species captured in 2016 (n=492), followed by Channel Catfish *Ictalurus punctatus* (n=24) and Flannelmouth Sucker *Catostomus latipinnis* (n=23). The density of native and non-native fishes, expressed as catch per unit effort (CPUE), varied significantly across the three sampling periods in 2016. The greatest density of native fishes occurred in October followed by August, whereas non-native density was greatest in August followed by October (Figure 5.4.2)

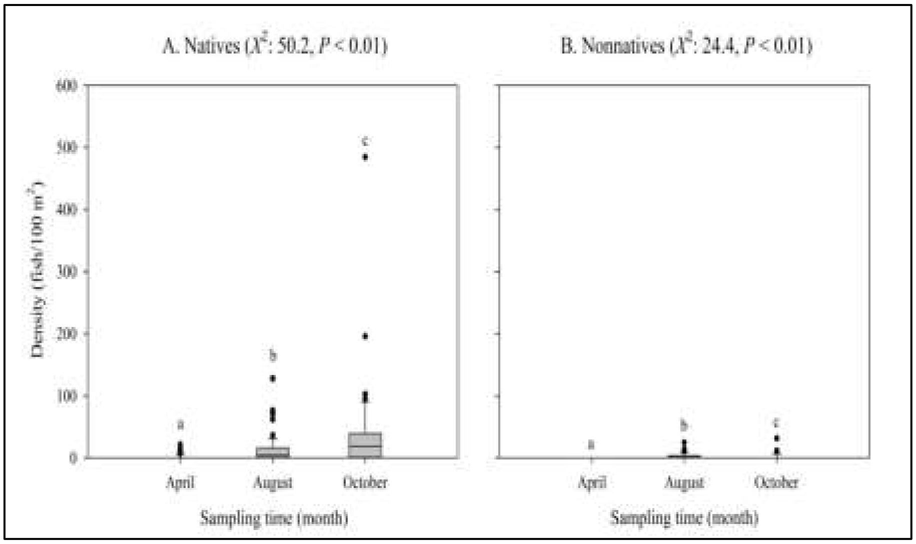

Figure 5.4.2: Density (CPUE) of fish captured by sampling time in 2016.

Fish density did not differ significantly between channel types (i.e. Phase II Main Secondary, Tertiary B, and Control) for natives or non-natives, similar to the results observed in 2015 (Figure 5.4.3).

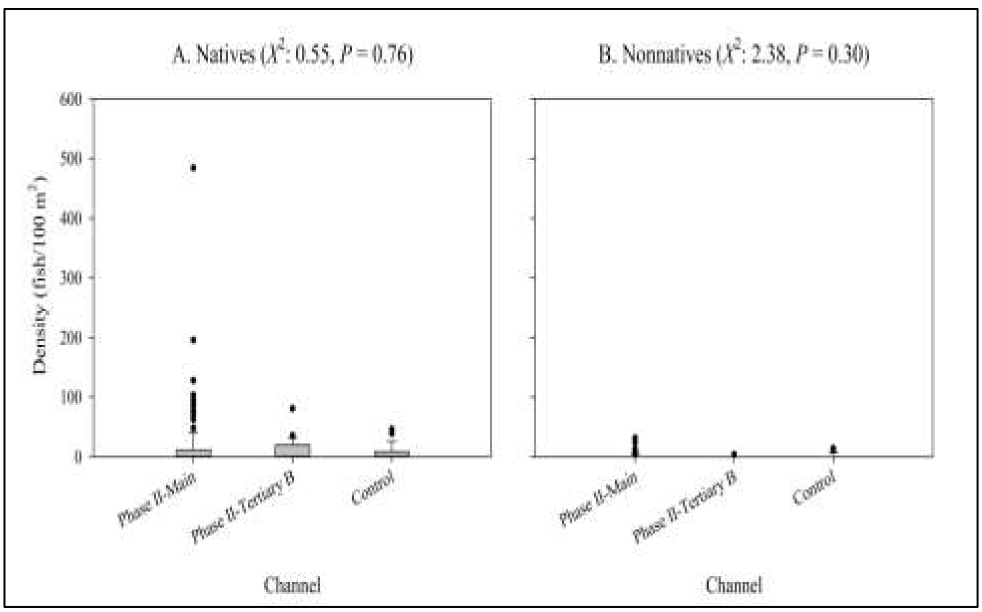

Figure 5.4.3: Density (CPUE) of Fish captured by channel type in 2016.

In 2016, there were significant differences in the density of native fishes captured in different habitat types, but no differences for non-natives. Many of the habitat types sampled contained similar densities of native fishes, although slackwater habitats had higher densities than did runs (Figure 5.4.4).

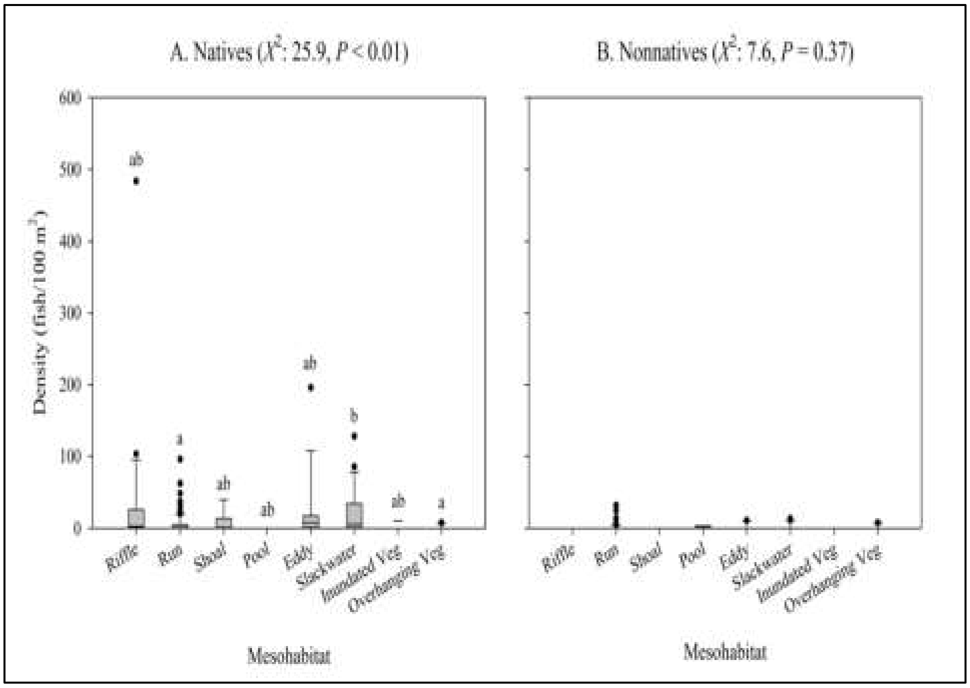

Figure 5.4.4: Density (CPUE) of fish captured by habitat type in 2016.

Four Colorado pikeminnow (CPM) were captured in 2016, two in the pre-spring run-off (April) and two in the post-runoff (August) samplings. All individuals were captured in different locations and reaches compared to 2015, including a capture in Tertiary B (Figure 5.4.5). All CPM are presumed to be stocked fishes from the previous fall. CPM captures represented 11% of the total number of native fishes caught in April but less than 1% in August.

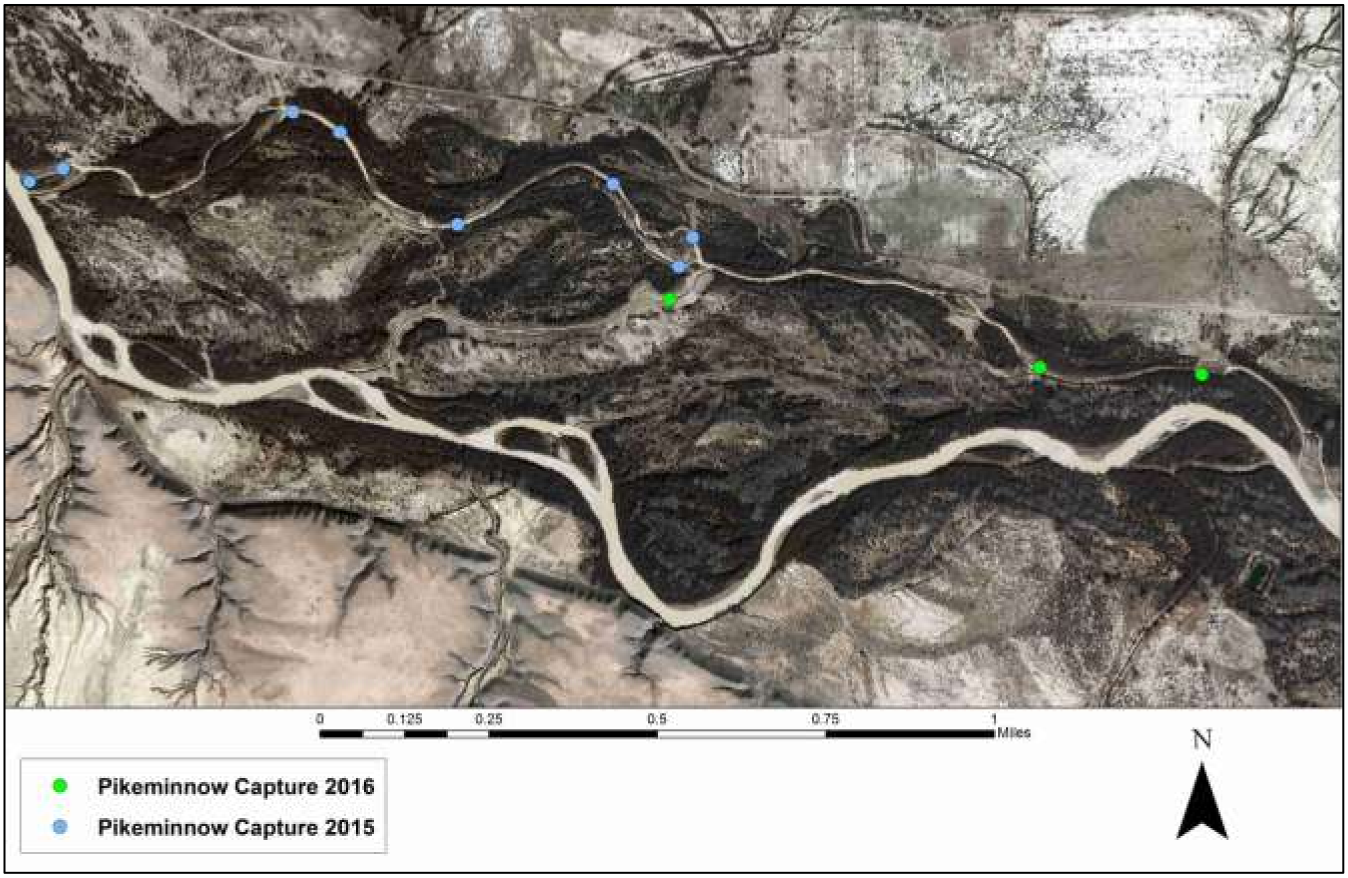

Figure 5.4.5: Capture locations of Colorado Pikeminnow from 2015 and 2016.

6.0 Conclusion

In conclusion, all stage-flow relationship data shows that the Phase II site was successful for 2016. High spring flows caused restored channels to deepen and widen, while monsoon floods caused sediment deposition in the channels. High spring flows are needed to maintain the restored Phase II channel. The combined percent count of low velocity habitats in the Phase II main secondary channel and the control channel were similar in April, and high flows in the spring resulted in an increase, be it small, in low velocity habitat counts in the restored main secondary channel and a decrease in the control channel. Both the control channel and the Phase II channel appeared to stabilize by the end of the season returning to values similar to April. From 2015-2016 habitat richness was greater in the controlled channel to that in the main channel of the Phase II site in five of six sampling events; but habitat richness in the main channel has increased significantly in 2016 to that of 2015. The total wetted area per 100 meters of linear distance in the restored channels has increased since 2015, increasing the potential for habitat growth for the future. Catch per unit effort of native fishes was greatest in October, whereas density of the non-native fishes was greatest in August. Native fish densities varied significantly by habitat type with greater numbers captured in slackwaters than in runs; there were no detectable differences in native densities in the other habitat types. In contrast, non-natives had similar densities across all habitat types. Four Colorado pikeminnow were captured at the Phase II site in 2016, making up 11% of the total catch in April and less than 1% of the catch in August, all pikeminnow were presumed to be stocked the previous fall.

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Appendix 1. Response to Reviewers' Comments

Reviewer: Tom Wesche

1. Tom made a number of editorial revisions in "Track Changes" in the report text, in the figure captions, and in the *List of Figures and Tables*; all of his suggested changes were made to the document.
2. Pg. 9, Section 4.3 *Methods for Channel Stage Monitoring*, first sentence in the paragraph. Comment: "6 (probes) at each transect or 6 total?"
   Response: Sentence was revised to indicate that there is one probe near each transect and one in the main stem of the San Juan R., that is, a total of 6 probes.
3. Pg. 15. Figure 5.2.1 caption. Comment: "When I print out some of these figures, the labelling turns to jibberish. Same goes for Figures 5.2.2, 5.2.4, and Table 5.3.1".
   Response: We printed the document on both the TNC and ERI office printers and the axis labels and captions printed accurately.
4. Pg. 24, paragraph 1, 2nd sentence. Comment: When you refer to transect length, "is this total width of the cross-section?
   Response: Yes, the sentence was re-written to clarify that the width of the cross-section at Transect T-C ranged from 76 to 86 feet in 2016.
5. Pg. 27. Comment: "Should there be a section on larval fish sampling results?"
   Response: Although backwater, eddy, slackwater and embayment habitats were sampled for larval fish in 2016, few individuals were captured. We will summarize/analyze the larval fish capture data in the 2017 final report, i.e. next year's report.
6. Figure 5.4.5. Comment: "I only see 3 green dots" although the text indicates four Colorado pikeminnow were captured in 2016.
   Response: One of the four pikeminnow was captured in Reach 4 very close to where a pikeminnow capture was made in 2015; the 2016 blue dot is covering the 2017 green dot.
7. P. 28, Section 6.0 *Conclusion*, second sentence in section. Comment: Does this refer to the secondary channel.
   Response: Yes, it does; sentence revised to clarify this point.
8. P. 28, Section 6.0 *Conclusion*. Comment: Sentence pertaining to the density of natives by habitat type, "something seems to be missing here."
   Response: Sentence re-written to clarify as: "Native densities varied significantly by habitat type with greater numbers captured in slackwaters than in runs; there were no detectable differences in native fish densities in the other habitat types."
9. Pg. 28. Comment: "Will monitoring continue in 2017? Can a recommendation be added here at the end [of the report] regarding what you feel is needed for future monitoring? Can you provide your thoughts regarding is this type of restoration an effective management tool from a river-wide and population level perspective? Your thoughts would be appreciated."
   Response: Monitoring will continue in 2017 which is the last year of the project. These questions will be addressed in the 2017 final report.