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Managing Water in the West

As-Built Survey Report at San Felipe Phase 2 Downstream Sites

Research and Development Office
Science and Technology Program
Final Report ST-2016-2645-01

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Bureau of Reclamation
Research and Development Office

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Mission Statements

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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The Pueblo of San Felipe has granted Reclamation permission for the data collection trip in August 2015. The data presented in this report was collected with the help from Suzanne Devergie and Rosanne Vigil. The floodplain and bankline data were collected with a total station by Cord Everetts of Reclamation.

Executive Summary

In 2011, a river maintenance project along the Rio Grande at San Felipe from rivermile 210.0 (RM 210.0) to RM 210.3 was initiated with two visits to the three priority sites with bank erosion problems. A multi-disciplinary team was formed that included Reclamation’s staff, Pueblo of San Felipe, and Tetra Tech Inc. to develop six to eight feasible alternatives for these three sites. These alternatives were reviewed and ranked by the project team to select the preferred alternative designs in 2012. Because of the close proximity of the three sites on two consecutive meander bends, it was decided that the river maintenance project would evaluate the three sites as one comprehensive project to facilitate the evaluation of adverse impacts between the sites for the final design phase. The selected preferred alternative was a combination of the longitudinal fill stone toe protection (LFSTP) and bendway weir alternatives coupled with the removal and/or destabilization of bars as illustrated in Figure 1.

Since September 2014, construction of the design at the project site has been performed with a break between April 15 and August 15 under restrictions for the bird migratory season. The majority of the project components were completed by April 15 with only some minor work on levee road improvement and re-vegetation that need to be finished after August 15, 2015. All 28 bendway weirs and the 600-foot long LFSTP were placed along the outside of the two meander bends before April 15, 2015. An as-built survey of the channel bathymetry was planned to occur during the construction break after April 15, 2015. This data collection effort aimed to provide a snapshot of the channel geometry with the constructed project components such as the bendway weirs and bar removal immediately after construction to serve as the baseline bathymetry for subsequent performance evaluation of transverse features per Reclamation’s monitoring guidelines (Reclamation 2015).

The snowmelt runoff season of 2015 had instantaneous discharges up to 3,200 cfs at the Rio Grande at San Felipe Gauge (USGS 08319000) in late May 2015. A strong and earlier than usual monsoon season immediately followed the snowmelt runoff season of 2015 that caused a subsequent peak discharge of 2,500 cfs for two weeks in June and another peak discharge of 2,000 cfs for one week in July at the Rio Grande at San Felipe Gauge. Daily average discharges at the Rio Grande at San Felipe Gauge have been stable around 1,000 cfs since mid July 2015. It was determined that the data collection crew should take advantage of the break

in this year's monsoonal rainfalls to perform the as-built data collection since additional monsoonal peak discharges would bring arroyo sediments that would significantly change the bathymetry of the as-built channel conditions. On August 13-14 and August 17, 2015, a crew of three Reclamation's staff, Suzanne Devergie, Rosanne Vigil, and Chi Bui, carried out an as-built data collection at San Felipe phase 2 downstream sites from the upstream end at RM 210.3 to the downstream end RM 210.0. Bed elevation data of the reach and velocities at three bendway weirs were collected and reported in this data collection summary.

The as-built survey report summarizes the data collected approximately four months after construction. This data set serves as the baseline for any future analysis of the hydraulic, geomorphic, biological responses of the river due to the installation of the bendway weirs.

Contents

Page

Tables

Page

Figures

Page

Background

The Bureau of Reclamation (Reclamation) has authority for river channel maintenance on the Rio Grande between Velarde, New Mexico, and the headwaters of Caballo Reservoir. Reclamation regularly monitors changes in the river channel and evaluates channel and levee capacity in an effort to identify river maintenance priority sites where there are concerns about possible damage to riverside facilities.

In 2011, a river maintenance project along the Rio Grande at San Felipe from rivermile 210.0 (RM 210.0) to RM 210.3 was initiated with two visits to the three priority sites with bank erosion problems. A multi-disciplinary team was formed that included Reclamation's staff, Pueblo of San Felipe, and Tetra Tech Inc. to develop six to eight feasible alternatives for these three sites. These alternatives were reviewed and ranked by the project team to select the preferred alternative designs in 2012. Because of the close proximity of the three sites on two consecutive meander bends, it was decided that the river maintenance project would evaluate the three sites as one comprehensive project to facilitate the evaluation of adverse impacts between the sites for the final design phase. The selected preferred alternative was a combination of the longitudinal fill stone toe protection (LFSTP) and bendway weir alternatives coupled with the removal and/or destabilization of bars as illustrated in Figure 1.

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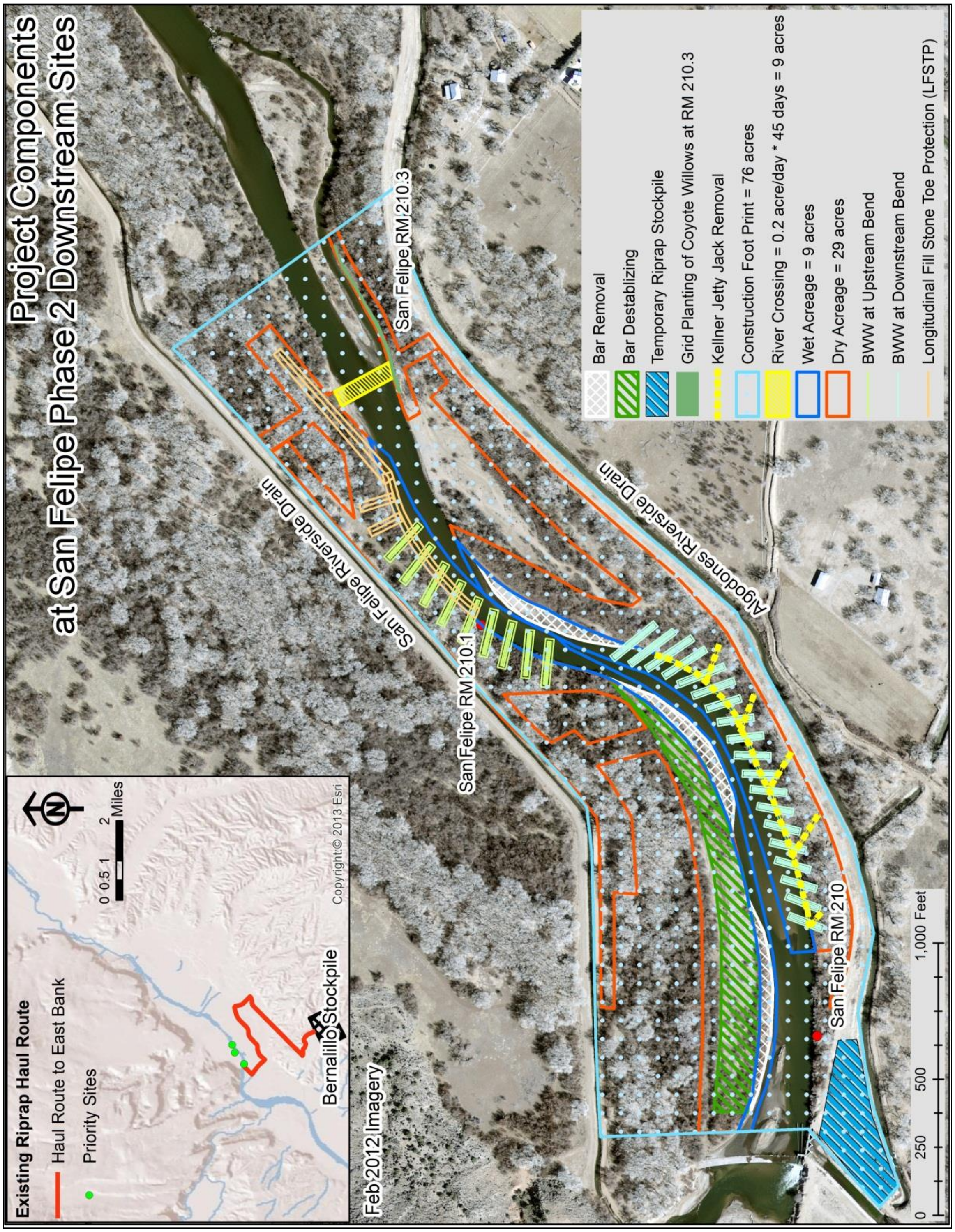

Figure 1: Project Components at San Felipe Phase 2 Downstream Sites

As-Built Data Collection

Survey Equipment

The as-built data collection at San Felipe phase 2 downstream sites planned to utilize a real time kinematics global positioning system (RTK GPS) and an acoustic doppler current profiler (ADCP) equipment to collect depths from the water surface elevation (WSE) to the river bed and instantaneous depth-average velocities where depth data were recorded, and locations and elevations of points where velocities and water depths were taken.

RTK GPS systems are comprised of a base station and one or multiple rover units to capture the x, y, and z values of points on the earth surface. These x-y-z values collected in the field are raw data which are calculated by at least four satellites with unobstructed lines of sight to the rover unit. The raw data need to be compared and corrected accordingly with known control monuments in the field that are maintained frequently with a third order of horizontal and vertical accuracy by one of Reclamation's contractors.

An ADCP unit is a hydro-acoustic current meter able to measure depth from the WSE to the bottom of a river by calculating the returning time of sound waves sent from the four beams at the bottom of the device. This unit is also capable of measuring instantaneous depth-average velocities of the stream. An ADCP is controlled by the WinRiver II software on a laptop computer that records beam depths and instantaneous depth-average velocities. The WinRiver II software has a Bluetooth function that allows both devices to communicate the data they collect and integrate the RTK GPS system to the ADCP unit so that for every point where velocities and beam depths are collected, the x-y-z values of the point at the WSE are also automatically captured by the RTK GPS system so that the final data are compatible with the ArcGIS software. Beam depths from the WSE to the river bed help to calculate the bed elevation of the point where beam depths and velocities data were collected.

The ADCP unit and the RTK GPS system that the survey crew used had some Bluetooth connectivity problems that prevented reliable communications between the two devices. Without stable communications, the RTK GPS system did not automatically acquire x-y-z values of points where beam depths were collected by the ADCP unit; in the meantime the ADCP unit could not acquire water velocity data either, and only beam depths data were collected by the ADCP. In order to utilize beam depth data of the ADCP unit collected at approximately one-second intervals, the one-second interval auto-point function of the RTK GPS system was deployed so that the approximate x-y-z data of the point where beam depth data were recorded was assigned as the location and WSE of the point. Assigning the x-y-z data to a beam depth value occurred during data post-processing by matching the time stamp of an x-y-z data point at the WSE collected by the RTK

GPS system with the time stamp of a beam depth data point collected by the ADCP unit. By doing this, elevation data of the river channel was created for the as-built data collection in August 2015.

Without reliable communications between the RTK GPS system and the ADCP unit, the survey crew was not able to collect instantaneous depth-average velocities with the ADCP unit. A hand-held one-dimensional Flo-Mate Marsh-McBirney flow meter was used to collect velocity data at discrete points in the water column of three bendway weirs along the downstream bendway. The Flow-Mate instrument uses voltage to generate a magnetic field so when a cluster of sediment particles moves through the magnetic field, it generates a voltage which is directly proportional to the velocity of the water that is transporting the sediment particles.

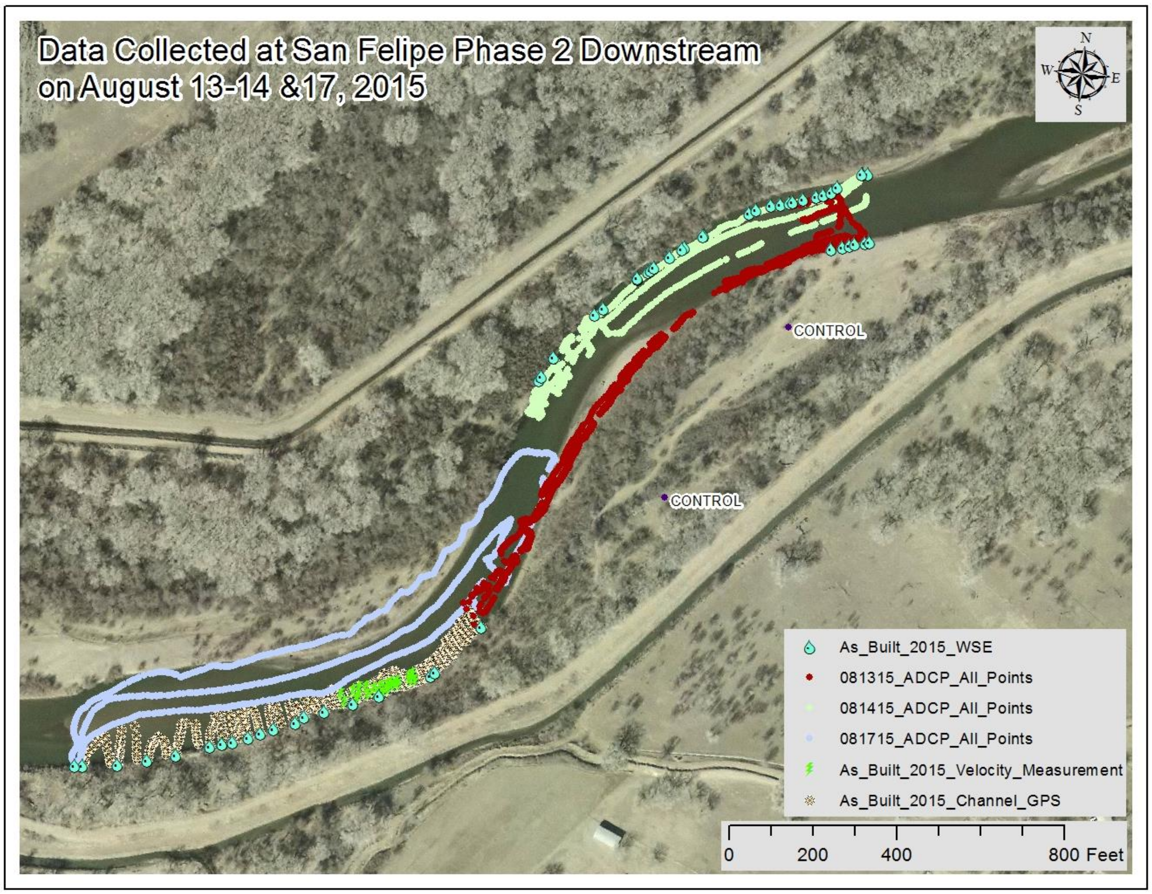

Figure 2: As-built Data Collected in August 2015 at San Felipe Downstream Sites

A combination of an RTK GPS system, an ADCP unit, and a Marsh-McBirney flow meter was used in the field in order to work around the Bluetooth communication problems for the 2015 as-built data collection at San Felipe phase 2 downstream sites. The 2015 as-built data collected from the trip are illustrated in Figure 2.

Data Collection and Correction

GPS Data

Data collection with an RTK GPS system comprised of a base station and a rover provides a location and elevation reading for a point taken by the rover unit. The location and elevation of a point are calculated from at least four satellites using timing signals. Since each of the timing signals that goes into a position calculation has some degree of error, calculation of the location and elevation reading of a point is going to be a compounding of those errors. Correction for each location and elevation reading of a point is necessary to obtain accurate readings of the point. Corrections were made by comparison between the location and elevation readings of the two control monuments in the field, AR-230.5 and AR-231.5, with the known locations and elevations of these two monuments checked in April 2015 by one of Reclamation's contractors. The average difference between the measured and known locations and elevations of the two control monuments on each survey day was applied to all as-built survey points collected on that day by the RTK GPS with both the auto-point mode and the manual mode, and this procedure is called data correction for the RTK GPS system. The corrected RTK GPS 2015 as-built data at San Felipe phase 2 downstream sites are located at this location on Reclamation's network in Albuquerque Area Office (AAO): T:\ALB240\PUBLIC\TSD_Works\10Projects\10_MRG_Priority_Sites\San_Felipe(six)\1.0_Pre-Construction\Surveys\As Built 2015\GPS. The data are only released if Reclamation gets written permission from the Pueblo of San Felipe.

ADCP Data

Data collection by an ADCP unit provides depths from the WSE to the river bed and instantaneous depth-average velocities at an approximate one-second interval along the course of the StreamPro boat where the ADCP unit is mounted on, and without the location and elevation information of the boat course, the beam depth and velocity data would be not useable. If an RTK GPS system could be integrated to an ADCP unit and mounted on the same StreamPro boat, for every point where the ADCP takes a measurement of the beam depth and velocity, the RTK GPS would automatically record the location and WSE. The auto-point function of the RTK GPS could be deployed to record the course of the boat if the two pieces of survey equipment could not communicate. However, that would require corrections of the ADCP data to match the time stamps of the depth data with the time stamps of the RTK GPS x-y-z data. The beam depth information would be used to convert the RTK GPS z-data at the WSE to the channel bed elevation. The corrected ADCP 2015 as-built data at San Felipe phase 2 downstream sites are located at this location on Reclamation's network in AAO: T:\ALB240\PUBLIC\TSD_Works\10Projects\10_MRG_Priority_Sites\San_Felipe(six)\1.0_Pre-Construction\Surveys\As Built 2015\GPS. The data are only released if Reclamation gets written permission from the Pueblo of San Felipe.

Marsh-McBirney Flo-Mate Data

Point velocity measurements around three bendway weirs were taken using a Marsh-McBirney Flo-Mate flow meter. With reference to USGS guidelines for discharge measurements (http://md.water.usgs.gov/publications/presentations/md-de-dc_rt98/sld013.htm), if the water depth in a water column where a point velocity measurement would be collected was less than 2.5 ft, one point velocity measurement was taken at the depth of 60% of the total depth from the water surface. If the water depth in the water column was greater than 2.5 ft, two point velocity measurements were taken at the depths of 20% and 80% of the total depth from the water surface. The point velocity measurement was the average of the velocities found at the 20% and 80% depths. At each point velocity measurement location, an RTK GPS point was also taken for future reference of repeated locations for data collection (Reclamation 2015).

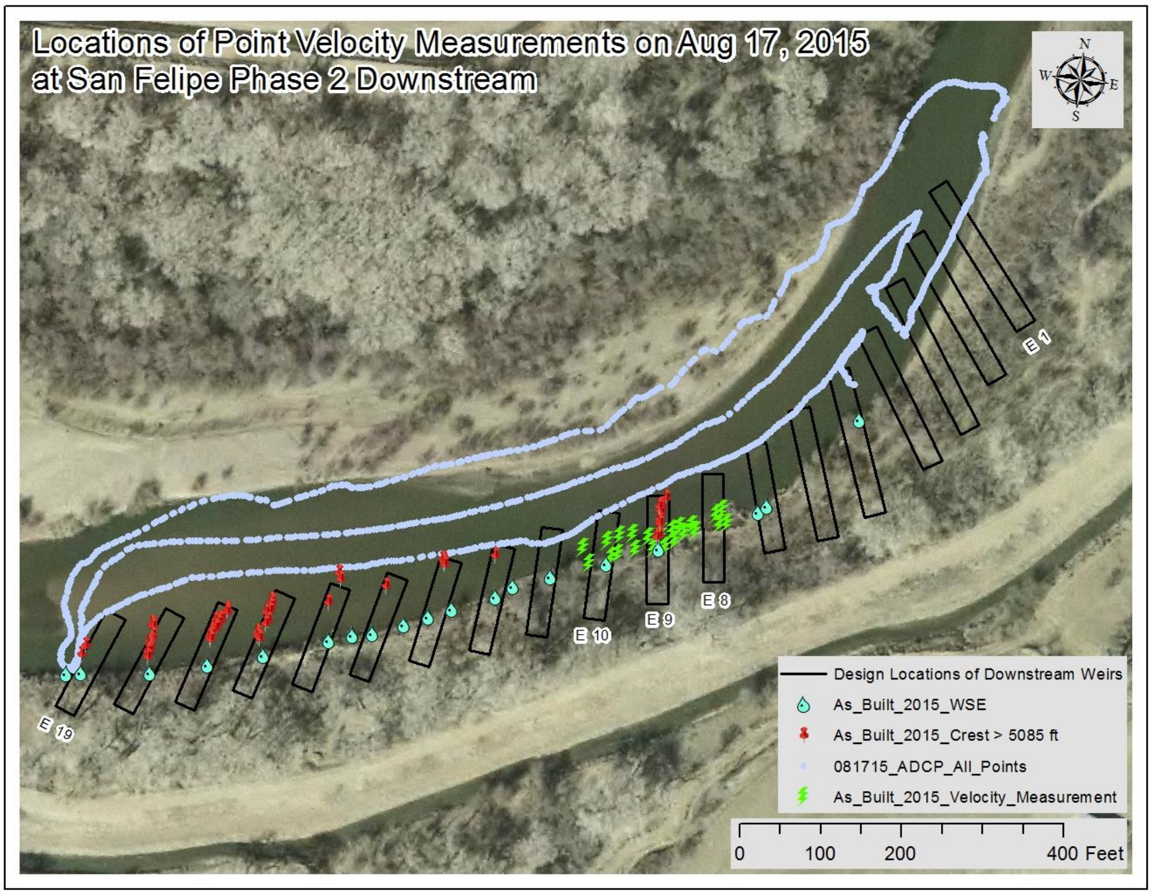

Figure 3: Locations of Point Velocity Measurements in the Downstream Weir Field

The general locations of the point velocity measurements were selected in the downstream weir field with wadable depths. The specific locations of the downstream weirs where the point velocity measurements were taken were determined by their crest elevations. The design elevation of the downstream weirs was 5,084 feet so that the weirs would be submerged at flows higher than

500 cfs (measured at the Rio Grande at San Felipe Gauge). Construction of the project components occurred during flows higher than 500 cfs, causing difficulties in placing rock at the design elevation. It was observed by the survey crew that several weirs had the crest elevations as high as the WSE of the 1,200-cfs discharge (measured at the Rio Grande at San Felipe Gauge) though these weirs were designed to be submerged at flows higher than 500 cfs. Those high weir crests are marked by the red pins in Figure 3.

Higher weir crests in the downstream weir field have been observed to cause flows of different magnitudes accelerating over the crests and a small stream of unusually high velocities in the near bank areas shooting downstream in the longitudinal direction. A specific location where this flow pattern has been frequently observed is around weir E9 as illustrated in Figure 3 with the crest elevation along the length of the crest 1.1-2.6 feet higher than the design elevation. It was determined that point velocity measurements would be taken at three consecutive weirs, E8, E9 (with the crest elevation higher than the design elevation), and E10. Velocities around weir E8 feature typical flow patterns around bendway weirs where velocities are slowed down in the near bank areas of the outer bank (Acharya and Gautam 2012). Velocities around weirs E9 and E10 feature another common flow pattern with eddies and scalloping of the bankline of the outer bank between two weirs caused by those eddies (Abad et al. 2009; Kinzli and Myrick 2009; Reclamation 2015).

Table 1: Point Velocity Measurements at Discharge of 1,100 cfs

Point Locations	Rod Depth	Velocity 60%	Velocity 80%	Velocity 20%	Velocity (ft/s)
Near bank, upstream of E8	0.7	0.61			0.61
Half of crest length from bank, upstream of E8	2.65		1.54	1.20	1.37
Half of crest length from bank, on weir crest of E8	2.4	1.67			1.67
Near bank, on weir crest of E8	1.0	0.87			0.87
Near bank, downstream of E8	1.6	0.71			0.71
Half of crest length from bank, downstream of E8	2.8		1.37	0.96	1.17
Half of crest length from bank, in between E8 and E9	2.6		1.19	1.00	1.10
Near bank, in between E8 and E9	3.5		1.28	0.69	0.99
Near bank, upstream of E9	1.2	1.22			1.22
Half of crest length from bank, upstream of E9	3.0		1.44	1.20	1.32
Half of crest length from bank, on weir crest of E9	1.1	2.75			2.75
Near bank, on weir crest of E9	0.3	1.27			1.27
Near bank, downstream of E9	1.3	1.47			1.47
Half of crest length from bank, downstream of E9	2.8		2.37	1.49	1.93
Half of crest length from bank, in between E9 and E10	2.4	1.04			1.04

Near bank, in between E9 and E10	3.4		1.87	0.91	1.39
Near bank, upstream of E10	2.9		2.02	1.46	1.74
Half of crest length from bank, upstream of E10	2.1	0.86			0.86
Half of crest length from bank, on weir crest of E10	2.4	1.00			1.00
Near bank, on weir crest of E10	2.3	2.32			2.32
Near bank, downstream of E10	2.6		1.75	0.93	1.34
Half of crest length from bank, downstream of E10	1.7	0.77			0.77

There were 11 point velocity measurements taken along the bankline toe, and 11 point velocity measurements taken at a distance of half of the crest length from the bankline toe. These velocities were measured with the Marsh-McBirney 1-D velocity probe. These 11 sets of points were distributed upstream of a weir structure, on the crest of a weir structure, downstream of a weir structure, and midway between two weir structures, as summarized in Table 1. This distribution of 2015 as-built point velocity measurements follows Reclamation’s guidelines for monitoring transverse features (Reclamation 2015). Due to the channel depth and high velocities making conditions unwadable, the survey crew was not able to collect point velocity measurements at the weir tips and at a distance of 12 feet from the weir tips as recommended by Reclamation’s guidelines (Reclamation 2015). Once the Bluetooth communication problem between the ADCP unit and the RTK GPS system could be fixed, this would help the crew to collect those point velocity missing from the 2015 as-built data.

Observations from 2015 as-built data and photos

The majority of data collected for the 2015 as-built plan was done by floating the StreamPro boat with the mounted ADCP unit and RTK GPS system in areas where there was at least one foot of depth beneath the boat. For areas such as bendway weirs constructed higher than design elevation, only the RTK GPS was used to record bed elevations. The 2015 as-built data are categorized by water depths of flows between 1,000 cfs and 1,100 cfs as illustrated in Figure 4. Riprap in the design of these bendway weirs was sized to withstand discharges up to 10,000 cfs which is equivalent to a 25-year flood frequency discharge magnitude (Wright 2010). The height of the bendway weir was designed so that the weirs would be submerged at flows greater than 500 cfs. A 500-cfs flow has a 90-percent probability of being exceeded at the Rio Grande at San Felipe (USGS 08319000).

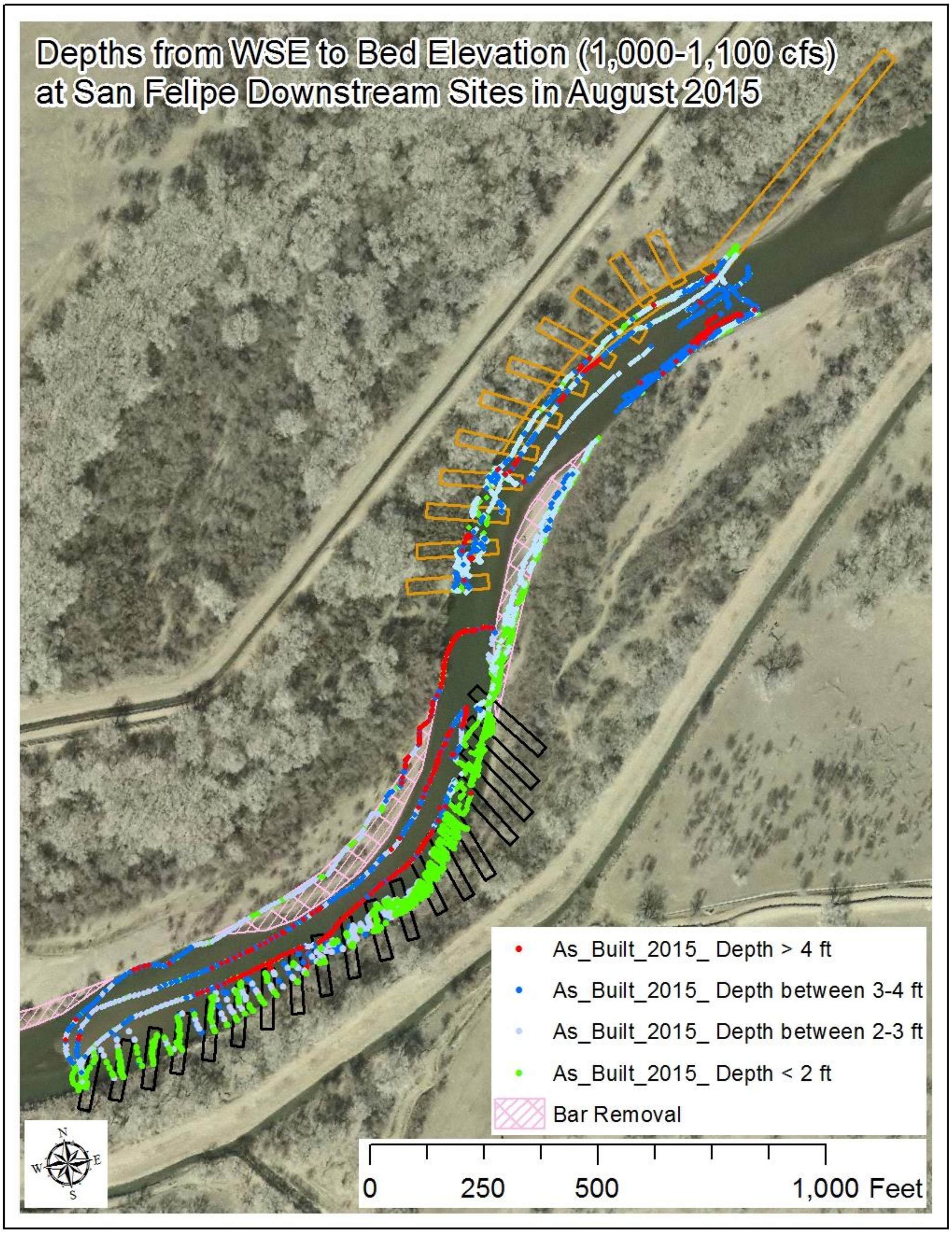

Figure 4: Depths to Bed Elevation of Flows between 1,000 cfs and 1,100 cfs

In the upstream weir field, there are not a lot of areas with only shallow water depths (< 2 feet); however, in the downstream weir field, the majority of the near bank areas have depths less than 2 feet. The areas of depths greater than 4 feet (4-7 feet) are found mostly at the tips of the downstream bendway weirs, whereas in the upstream weir field those extreme depths are located from near bank areas to 30 feet from the bankline toe of the outer bank (the length of the in-stream weir portion is 60 feet). In the upstream weir field, depths in the range of 2-4 feet are also more frequently found in areas in between the near bank and 30 feet from the bankline toe of the outer bank; and there is no distinct thalweg profile off the tips of the upstream weirs. The close-up views of the distribution of water depths in the upstream and downstream weir fields are illustrated in Figure 5 & Figure 8.

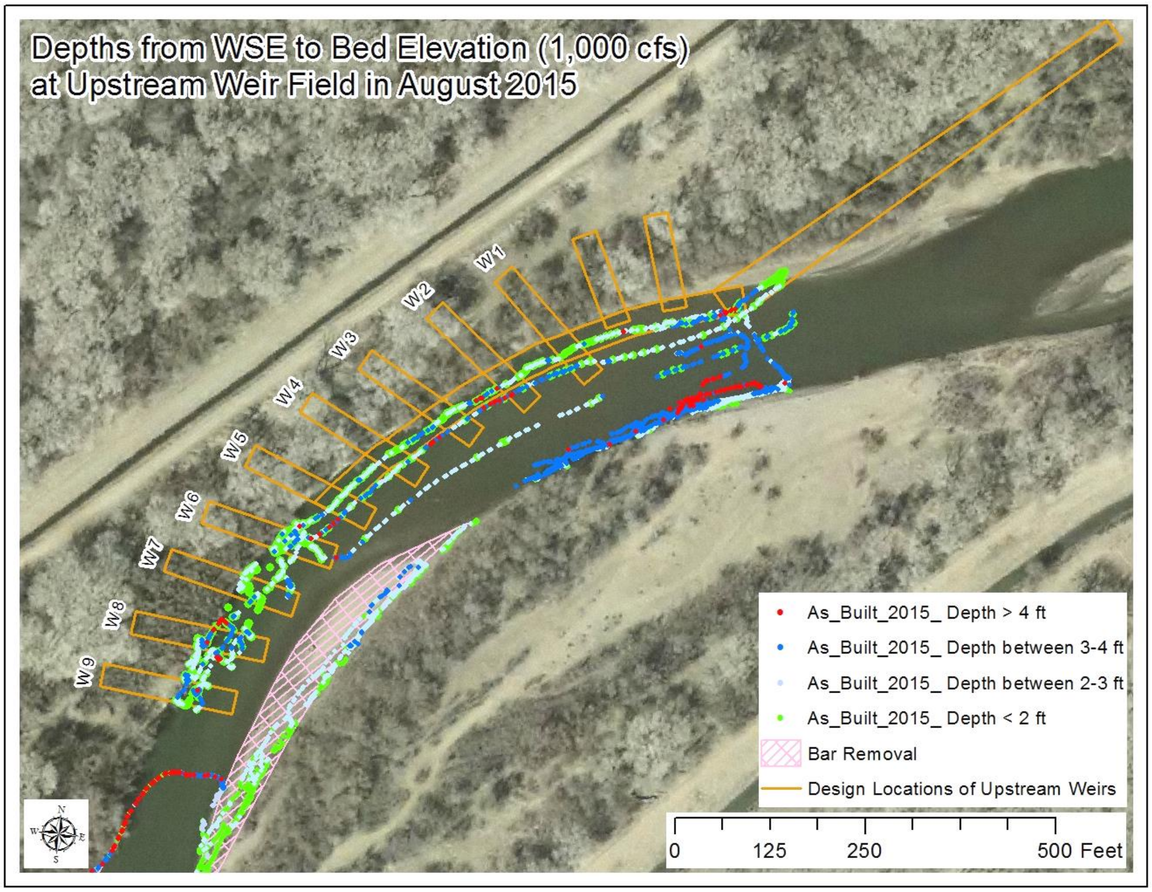

Figure 5: Distribution of Water Depths of 1,000 cfs in Upstream Weir Field

The distribution of water depths along the upstream weir field is not consistent with the typical depth distribution around a submerged weir characterized by high rates of sediment deposition in near bank areas and scour holes at the riverward end of weirs (Papanicolaou et al. 2011). There are pockets with water depths larger than 4 feet (4-6 feet) in the near bank areas of the upstream weir field. The areas off the tips of the upstream bendway weirs do not have the greatest water depths compared to areas between the tips and the outer bankline of the upstream field. Scour holes occurred in areas between the tips and the outer bankline. On any float path of the StreamPro boat in the upstream weir field, the data show that points ranging from depths less than 2 feet to greater than 4 feet are found in the very close vicinity of each other. Two clusters of such data point range are located in between weirs W5-W6 and weirs W7-W8. Scour holes developed in these two areas have also caused some bankline scalloping which is illustrated in Figure 6. The bankline scalloping between weirs W5-W6 marks the transition from continuous bank protection (LFSTP) coupled with directive bank protection (bendway weirs) to only directive bank protection. The keys of the upstream bendway weirs have a length of 100 feet from the bankline into the floodplain. This key length would help to prevent high flows from flanking the upstream weirs if scalloping progresses between these weirs. Also re-vegetation of the right bankline in this project area is scheduled to occur in the coming dormant winter months by the Pueblo, which also will help to stabilize the bankline.

Water depths along the upstream end of the excavated point bar opposite the upstream weir field are mostly above 2 feet. The downstream end of the excavated bar have water depths less than 2 feet leading into areas of significant deposition in the downstream left weir field. If this deposition trend moves upstream along the inner left bankline, it could narrow down the river width around weirs W5-W9, which could increase the hydraulic pressure along the right bankline of the upstream weir field. Monitoring of the right bankline scalloping around weirs W5-W9 will be necessary in future data collection trips.

Figure 6: Scalloping of Right Bankline in between Weirs 5-6 and Weirs 7-8 (looking upstream)

The near bank areas from weirs E1-E8 of the downstream weir field have a lot of very recent deposition of very fine materials and with minimal velocities as featured in Figure 7. The majority of the 1,100-cfs water depths in this area are less than 1 foot. Areas above the crests of these first eight weirs and in between weirs have been filled in, which completely cover the riprap. In the near bank areas from weirs E9-E19, water depths below 2 feet are not caused by deposition, but because of weir crest elevations being constructed higher than the design elevation of 5,084 feet at weirs E9, E16, E17, and E18 as marked by the yellow pins in Figure 8. The depositional pattern in the near bank areas shifts to shallow depths on the weir crests and deep pools in front of and behind these high weirs. Velocities next to the toe of the left bankline increased two to three times in the vicinity of the high crests.

Figure 9 shows streamwise flows accelerating over the visible high crest of weir E9 with a small stream of water shooting from the bankline toe at a velocity of 1.3 ft/s at 1,100 cfs, increasing from 0.7 ft/s in the vicinity of weir E8. The velocity on the high crest of weir E9 was 2.8 ft/s, increasing from 1.7 ft/s on the crest of weir E8. The small stream of flow next to the bankline toe continued to the next downstream weir E10 with a velocity of 2.3 ft/s. A small amount of bankline scalloping between weirs E9-E10 was detected during the as-built data collection trip as the left bankline in this project area had not been re-vegetated before snowmelt runoff and monsoon peaks occurred from May through July 2015. This scalloping trend has been observed for weirs with higher crest elevations (Reclamation 2015). Re-vegetation of the right bankline in this project area is scheduled to occur in the coming dormant winter months by the Pueblo, which also will help to stabilize the bankline.

Figure 7: New Deposition along Left Bank Line of Weirs E1-E8 (flow = 1,700 cfs)

The data from the float by the StreamPro boat along the tips of the downstream weir field show that the thalweg location has been relocated off the tips of the weirs with one scour hole as deep as 7 feet near weir E9 with flows at approximately 1,100 cfs. A preliminary survey before this year's runoff season in March 2015 also found a 7-foot deep scour hole off the tip of weir E9 at a discharge of 860 cfs (measured at the Rio Grande of San Felipe Gauge). The relocation of the thalweg away from the eroded bank is one of the expected geomorphic responses after the installations of the bendway weirs.

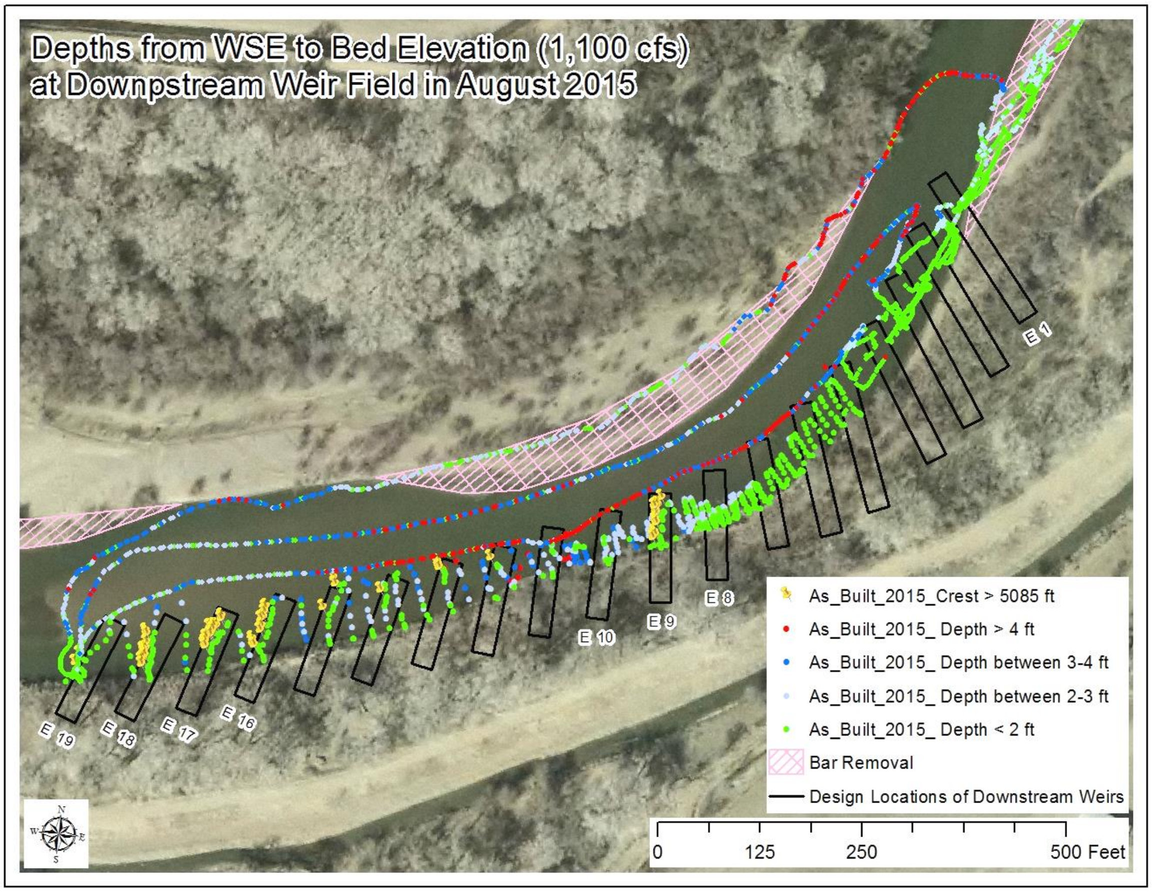

Figure 8: Distribution of Water Depths of 1,100 cfs in Downstream Weir Field

The data of the float along the middle of the channel indicates that water depths are not as deep as those around the weir tip areas, mostly 3-4 foot deep. The float next to the right bankline has a mix of water depths with sections deeper than 4 feet at the bend transition area, between 2-3 feet along the bar excavation area, and between 3-4 feet downstream of the bar excavation area. Bar excavation was one of the project components to maintain the existing river width after placing bendway weirs. It was desirable that higher inner bank velocities would help to prevent the bars from growing back (Reclamation 2013). With shallower depths along the left bankline and greater depths between the weir tips and the right bankline, the bulk of the river flow remains on the right side of channel, and this geomorphic response might be able to prevent the opposite bars from growing back.


Figure 9: Flow pattern at weir E9 – Photo taken on August 27, 2015 – Flow = 930 cfs

Summary and Recommendations

After the completion of bendway weir construction at San Felipe phase 2 downstream sites in April 2015, an as-built data collection was performed in August 2015. The bendway weirs were evaluated on their functionality with some snowmelt runoff peaks and monsoonal rain peaks between May and July 2015. The 2015 as-built data does not reflect the channel conditions immediately after constructions as some geomorphic changes occurred during periods of peak discharges. Post-project field measurements and evaluation protocols for transverse features such as bendway weirs recommended by Reclamation (Reclamation 2015) have five different levels of complexity for data collection to perform evaluation of river responses and structure performances. The 2015 as-built data collection was intended for a tier 4 of complexity of the protocols. Tier 4 of field monitoring consists of channel and structure topography sufficient to develop a terrain surface for determination of topographic changes and potential future application of a 2-D numerical model for calibration and validation of the original design. Other measurement requirements of tier 4 include transverse feature length, rock dislodgement, scour location and topography, bank line scalloping or deposition using an RTK GPS system. Most of the data required for tier 4 were collected in August 2015. The bankline and floodplain data collected separately by a total station are not discussed in this report as the crew did not take part in that data collection effort. Once the data collected by the two crews are available, they will be integrated to construct a topographic representation of the as-built conditions of the reach.

The as-built data collection occurred four months after the completion of construction of the bendway weirs. The 2015 as-built data showed that there had been geomorphic responses induced by the installations of the bendway weirs. The thalweg profile along the downstream weirs was relocated along the tips of the bendway weirs and a depositional trend has occurred along the toe of the right bankline. Various depths along the excavated bars on the inner bankline indicate that there is enough energy on the inner bank that the excavated bars may not build back up. However, there are some bendway weirs that were constructed higher than the design elevation that caused some scour holes in front of and behind the weirs and higher velocities along the toe of the outer bank. The crest elevation of weir E9 was recommended to the construction crew to be lowered down as it is located at the bend apex that could trigger undesirable erosion of the outer bankline. Weirs E16, E17, and E18 are located at the end of weir field, so frequent visual monitoring is necessary to timely detect any trend of bank scalloping that could undermine the keys of those weirs.

The 2015 as-built data at the upstream bend showed different responses of the upstream bendway weir field. There is no distinct thalweg profile along the weir tips. The length of the LFSTP has helped most of the bankline from being eroded from last spring runoff. However as the bank protection method transitions from a continuous to directive method, scour holes developed near the bankline have caused scalloping between weirs W5 and W6, and between weirs W7 and W8. After the construction crew came back in August 2015, the outer bankline along the upstream bend has been reshaped. It is hoped that coyote willow planting this coming dormant winter season will help to strengthen the rest of the bankline without the continuous bank protection. Monitoring of these scalloping areas is necessary as there is some trend of deposition along the excavated bar on the opposite side of the upstream bend which may narrow down the channel width and increase hydraulic pressure along the scalloping bankline areas.

A general observation on vegetation growth after construction shows that coyote willows have come back strongly on areas of bar lowering along the inner bankline of the upstream bend. This is an area that was inundated during the 2015 spring runoff. The upland floodplain along the right bankline of the downstream has seen cottonwood seedlings in September 2015. A 3-year monitoring plan to assess responses of terrestrial and aquatic indicator species induced by the installations of bendway weirs has been developed in conjunction with AAO biologists to formally understand ecological benefits of bendway weirs, such as creating habitat for certain life-stages of native fishes, and potentially promoting riparian habitat revegetation (Kinzli and Myrick 2009).

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