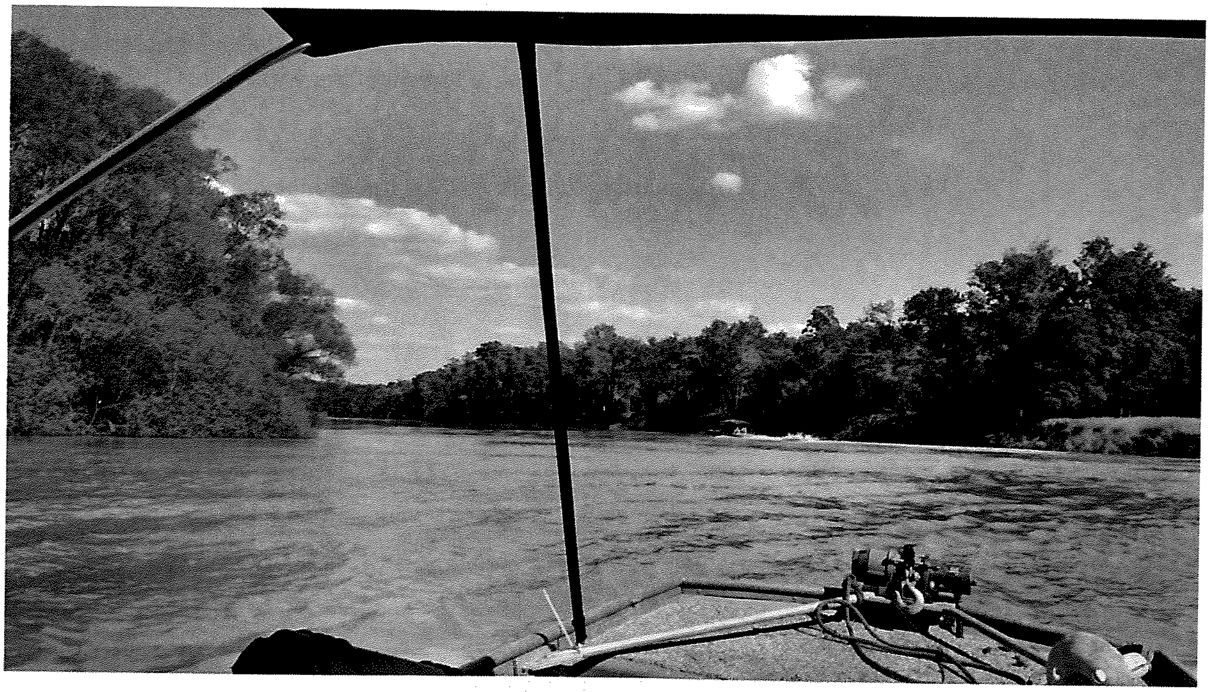
LiDAR Acquisition and Flow Assessment for the Middle Trinity River

by:

Webster Mangham
Tim Osting
David Flores



For: Trinity and San Jacinto Rivers and Galveston Bay Stakeholder Committee through the Texas Water Development Board

"PURSUANT TO SENATE BILL 1 AS APPROVED BY THE 83RD TEXAS LEGISLATURE, THIS STUDY REPORT WAS FUNDED FOR THE PURPOSE OF STUDYING ENVIRONMENTAL FLOW NEEDS FOR TEXAS RIVERS AND ESTUARIES AS PART OF THE ADAPTIVE MANAGEMENT PHASE OF THE SENATE BILL 3 PROCESS FOR ENVIRONMENTAL FLOWS ESTABLISHED BY THE 80TH TEXAS LEGISLATURE. THE VIEWS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE AUTHOR(S) AND DO NOT NECESSARILY REFLECT THE VIEWS OF THE TEXAS WATER DEVELOPMENT BOARD."

Contract No. 1400011696

Final Report – October 15, 2015

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Contributors

TNRIS

Trinity River Authority

RPS

Aqua Strategies Inc.

Arroyo Environmental Consultants, Inc.

Acknowledgements

This work could not have been completed without the hard work, blood, sweat, teeth, and grit given up by the dedicated field staff and dedicated advisors who blaze new trails and push the limits so we can all get to know the Trinity River a little better:

Trinity River Authority – Kelly McKnight, Austin Dudley, James Fox

Texas Water Development Board – Mike Vielleux, Nathan Brock

RPS – Dr. Bill Espey

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List of Acronyms

ADP – Acoustic Doppler Profiler
af – acre-feet
BBASC – Basin and Bay Area Stakeholder Committee
BBEST – Basin and Bay Expert Science Team
cfs – cubic feet per second
DEM – Digital Elevation Model
DO – Dissolved Oxygen
DTM – Digital Terrain Model
H&H – Hydrology & Hydraulics
HEC–RAS – Hydrologic Engineering Centers River Analysis System
HSC – Habitat Suitability Criteria
LiDAR – Light Detection and Ranging
NAD83 – North American Datum of 1983
NAVD88 – North American Vertical Datum of 1988
NOAA – National Oceanic and Atmospheric Administration
NGS – National Geodetic Survey
ppsm – pulses per square meter
PT – Pressure Transducer
RTK – Real Time Kinematic
SB3 – Texas Senate Bill 3
TAC – Texas Administrative Code
TCEQ – Texas Commission on Environmental Quality
TESCP – Texas Ecological Systems Classification Project
TIFP – Texas Instream Flow Program
TNRIS – Texas Natural Resources Information System
TRA – Trinity River Authority
TRWD – Tarrant Regional Water District
USGS – United States Geological Survey
WQ – Water Quality
WSP – Water Surface Profile

1 Introduction

In 2007, the 80th Texas Legislature passed Senate Bill 3 (SB3) which created a stakeholder driven process designed to establish environmental flow standards for all of the major river basins in Texas. For the Trinity River, the Trinity and San Jacinto and Galveston Bay Basin and Bay Area Stakeholder Committee (BBASC) and Expert Science Team (BBEST) were created and tasked with recommending flow standards to the Texas Commission on Environmental Quality (TCEQ). On April 20, 2011, the TCEQ adopted flow standards for the Trinity River at four measurement points (30 TAC § 298.225, 2011) (Table 1) (Figure 1).

Table 1. Trinity River Senate Bill 3 Measurement Points and the accompanying study site location as described by the Trinity River basin number and the river mile.

Measurement Point USGS Gage Number	Measurement Point USGS Gage Name	Representative Site (Basin Number and River Mile)
08049500	West Fork Trinity River near Grand Prairie	N/A
08057000	Trinity River at Dallas	080444
08065000	Trinity River at Oakwood	080295
08066500	Trinity River at Romayor	080075

During the SB3 process, instream habitat, hydraulics, geomorphology, and ecology data gaps were identified in the Trinity basin. In response, the BBASC and BBEST created a Work Plan Report that outlined what additional data was needed to prepare for the adaptive management provisions of the SB3 legislation (BBASC, BBEST, 2012). The adaptive management phase is designed to provide for a periodic review of the standards at a maximum interval of every ten years. This current project was designed to focus on high flow pulses and address data gaps identified in the Work Plan Report by completing the following four tasks:

1. Create a data archive structure for field and modeling data;
2. Collect additional field data from representative sites that represent three of the SB3 measurement points (Table 1);
3. Complete data processing and modeling at each of the representative sites;
4. Provide data analysis (to illuminate field characteristics at SB3 pulse flow levels) and issue a final report.

The complete scope of work is provided in Appendix 1, and each of these tasks is further discussed in detail in the appropriate section of this report. Methods used to measure river data for this project are described in Section 2. Work conducted for each representative site is summarized in Sections 3, 4 and 5, respectively. The data archive is described in Section 6 and conclusions, including recommended next steps, are included in Section 7.

As part of the initial data collection phase of this project, the Trinity River Authority (TRA) and the Tarrant Regional Water District (TRWD) provided additional funding to have new LiDAR, Light Detection and Ranging, flown along approximately 50 river miles in order to fill an existing data gap along the Trinity River mainstem near the 080295 Oakwood representative site (see Section 1.1).

This report was submitted in draft form to the TWDB on August 31, 2015. Comments received from the TWDB and other reviewers on September 23, 2015, were incorporated into this report.

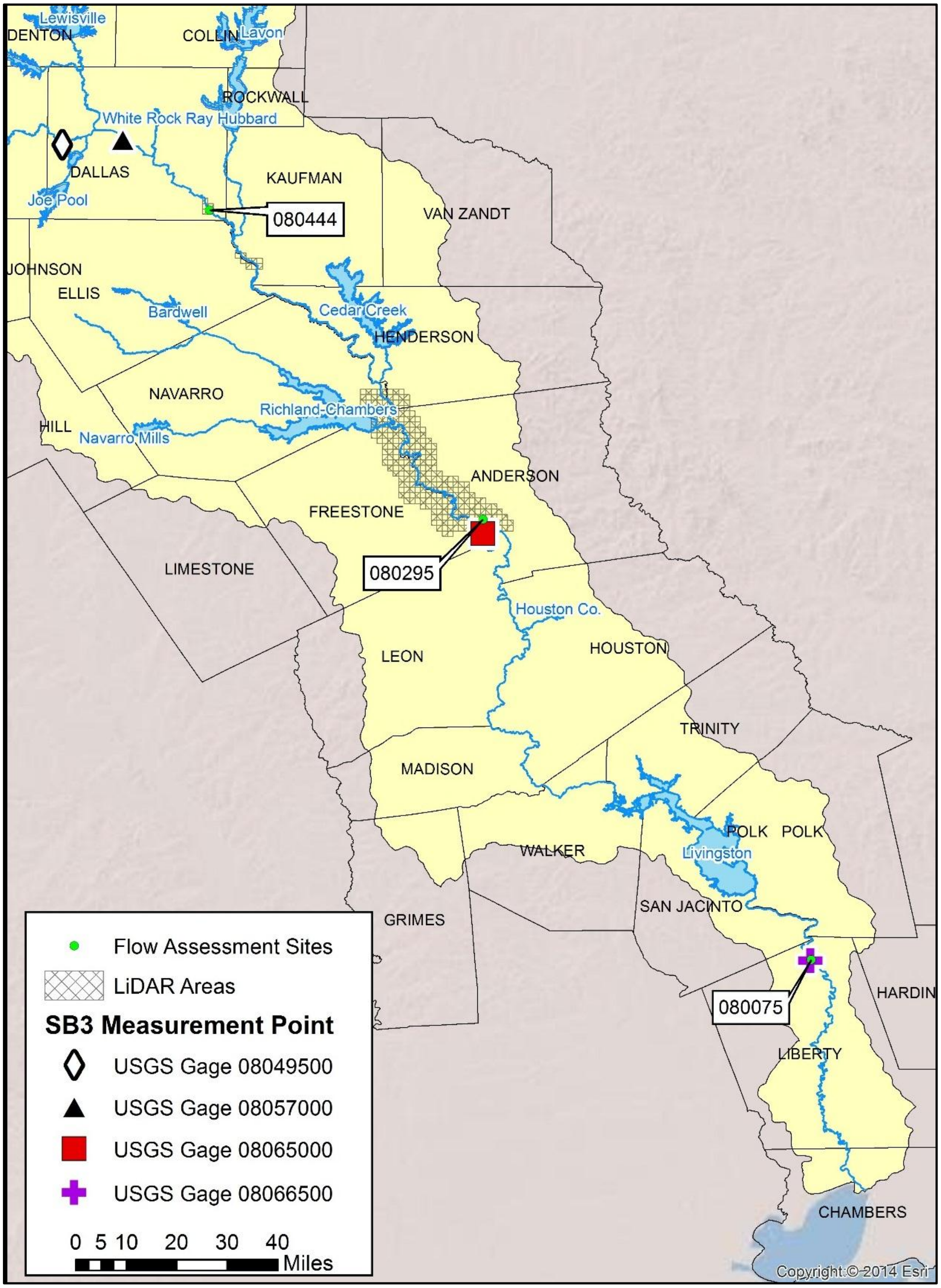
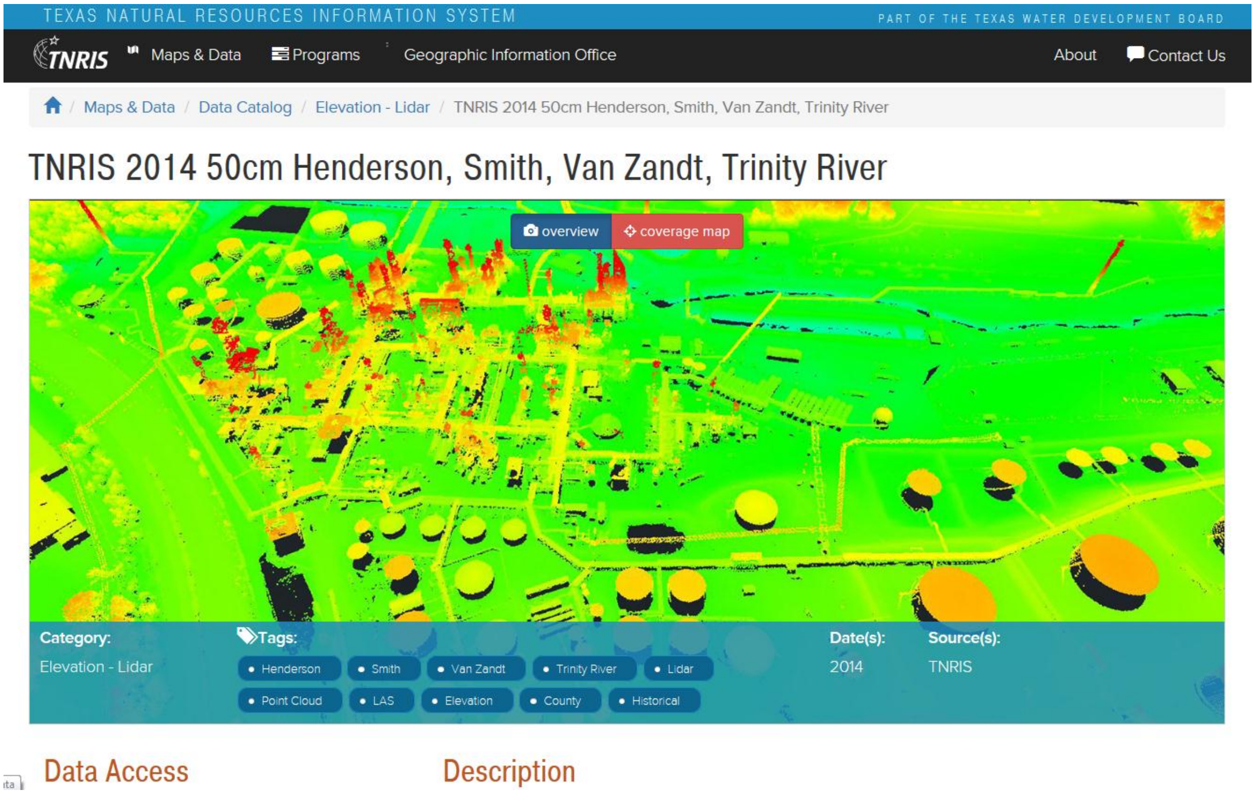


Figure 1. Study Area map showing SB3 measurement points, LiDAR collection areas, and SB3 study sites.

1.1 LiDAR Data Collection for this project

LiDAR-derived Digital Terrain Models (DTM) have been shown to be the recommended approach for large river basin management because accurate and precise river geometry data serve as basis to properly identify terrestrial and aquatic habitat types (Marchamalo, Bejarano, Garcia de Jalon, & Marin, 2007) (Hauer, Mandlburger, & Habersack, 2008). The new DTM allowed for the refinement of existing hydraulic models near site 080295, and existing LiDAR-derived DTMs allowed for the creation of new models at sites 080444 and 080075 (Figure 1). The LiDAR near site 080295 was flown during the leaf off period at 8 ppsm in February of 2014, and the collection, processing, and quality assurance was completed under a contract managed by the Texas Natural Resource Information System (TNRIS). The data are uploaded and publically available for order from the TNRIS website (Figure 2).



TNRIS 2014 50cm Henderson, Smith, Van Zandt, Trinity River

Category: Elevation - Lidar

Date(s): 2014

Source(s): TNRIS

Figure 2. Screen capture showing the availability of the 2014 50 cm LiDAR data collected for this project on the TNRIS website. Data can be accessed here: http://tnris.org/data-catalog/elevation-lidar/tnris-2014-50cm-henderson-smith-van-zandt-trinity-river/

1.2 Related Recent Studies

Several studies have taken place along the Trinity River mainstem since 2011 which provide an excellent source for background data relative to this project. Those studies include:

1. Trinity River Reconnaissance Survey, 2011 (TRA & RPS Espey, 2013a);
2. The Trinity River Long-term Study (TRA & RPS Espey, 2013b);
3. Trinity River Long-Term Study Master Report, Revision 03 (TRA & RPS Espey Consultants Inc., 2013c)
4. Supplemental Biological Data Collection, Middle Trinity River Priority Instream Flow Study (TRA and TPWD, 2014);
5. Trinity River Miles (TRA, 2012); and
6. Instream Flow Study of the Middle Trinity River, Draft Study Design (TIFP and TRA, 2014, in review) (*field data component in progress*).

This current study fits into the TRA's Long-term Monitoring Plan (TRA & RPS Espey, 2013a). The overarching objectives of this plan include the creation of a long-term high quality dataset that covers, but is not limited to, the biology, hydrology, geology, geomorphology, geography, water quality, and riparian attributes of the Trinity River basin. The plan objectives, timeline, and status are detailed in Table 2.

1.3 Related Historical Studies

The USACE 1899 Trinity River Survey contains some of the most pertinent planning information (Figure 3) and survey data types (Figure 4) which are comparable to the cross-sectional data measured for this SB3 project. However, due to the scale of the available cross-sections and the lack of flow data from the USACE 1899 Trinity River Survey, no comparisons to the site specific data collected during this, or any of the recent studies, was possible under the scope of this project. However, further analysis of the USACE 1899 Trinity River Survey data would be useful on a reach or segment scale if the entire dataset could be location-referenced. Further analysis on this expanded scale could allow for comparison of historical cross-section geometry and WSP information with current-day reach averages and could allow for valuable comparison between an unmanaged (or minimally managed) river as it existed in 1899 and current-day physical river characteristics that have developed as a result of numerous flood control projects and water use patterns. Even if location referencing is not possible, the dimensions and configurations (e.g., wetted-width vs. cross-sectional area, average depth vs. thalweg depth, etc.) of each 1899 measured cross-section may be compared to modern-day measurements to illuminate the degree of change that has occurred over the last 100+ years.

Location referencing of the historical dataset may be possible, within reasonable tolerances conducive to comparison to new survey data. In the horizontal (plan view), it may not be possible to estimate the location of some historical cross-section measurements with any degree of accuracy given that river miles, bridge crossing and farm references from 1899 may be difficult to pinpoint in the modern day. In contrast, it may be possible to estimate the location of other cross-sections with high precision within the vicinity of hard references that are able to be clearly identified. In the vertical, the elevation datum would need to be referenced to current-day datums (e.g., NAVD88). Of all the bay and estuary systems in Texas, historical data from the Trinity River system may be most conducive to accurate translation to current-day elevation datum considering the pivotal role that tide levels in Galveston Bay play in the origin and definition of current-day elevation datums.

1.4 Trinity River Flooding, Spring and Summer 2015

In the spring of 2015 during the prosecution of this current study, Texas experienced record rainfall amounts which ended years of extended drought (Figure 5). According to the National Oceanic and

Atmospheric Administrations (NOAA), the Dallas/Fort Worth area recorded a record 16.96 inches of rainfall in May, 2015 (Figure 6). The extended heavy rainfall filled all of the north Texas reservoirs above their conservation pool, with many filling their flood pools, resulting in uncontrolled releases for several weeks in May, June, and July 2015.

Reservoir releases and rainfall created very high flows along the entire mainstem of the Trinity River. Between January 1, 2015 and June 7 , 2015, the cumulative flows at the USGS gage near Rosser (08062500) were 8 times higher than the same timeframe in 2014 (USGS, 2015) (Figure 7). The USGS gage at Oakwood (08065000), just downstream of site 080295, showed that the spring and summer of 2015 was marked by pulse events and extended high flows. Two “Action Level” pulse events (30 ft. stage at the Oakwood gage) occurred on March 14, 2015 and May 1, 2015 which were immediately followed by 54 consecutive days of “Flood Stage” (35 ft. stage at the gage).

Table 2. TRA's Long-term Monitoring Plan objectives, timeline, and status. This table was updated in August 2015 for this report from the Long-Term Plan (TRA & RPS Espey, 2013b).

Fiscal Year Target	UPDATED Schedule outlook	Study	Focus Area
2012	**Complete**	Establish statement of study goals	All
2012	**Complete**	Continue data processing of 2011 survey	All
2012	**Complete**	Reach Re-segmentation	All
2012	**Complete**	Updated / New River Miles	All
2012	**5 sites identified**	Identify long-term study sites	All
2012	**In progress**	TIFP coordination	All
2012	**Continual**	Landowner coordination	All
2012 & 2015	**4 sites measured 2012** **2 sites added in 2015 (This Report)**	Cross-sectional measurements and elevation reference	Physical Processes
2012	**6 sites sampled 2012 (with TIFP)**	Baseline biological sampling – Fish, Mussels, Invasives	Biological – instream
2014	**Complete**	1-month diurnal sonde data DO/Temp	Water Quality
2013	**Complete**	Reconnaissance downstream of Livingston	Habitat
2013	Near-term	Historical timeline for each segment	Physical Processes
2013 2015	**3 Sites Complete** **3 Sites Complete (6 total)**	1D hydraulic model for pulse inundation	H&H
2014	**1 Site Complete**	Baseline riparian study	Biological – riparian
2014 2015	**1 Site Complete** **2 Sites Complete**	Riparian inundation study	Biological - riparian
2015	**2 Sites Complete**	Sediment load and transport	Physical Processes
	Baseline	Large Woody Debris study	Physical Processes
2014	**In Progress**	Impact of lock and dam bank failure	Physical Processes
	Mid-Term	Recreation uses	Rec. and Eco.
	Mid-Term	Economic value	Rec. and Eco.
2015	**In Progress**	Fish HSC development	Biological - instream
2014	Mid-term	2D hydraulic models for habitat	H&H
2015	Mid-term	Instream habitat models	Habitat
2015	**In Progress (TIFP project)**	Determine WQ goal values and assess	Water quality
	Initiated 2012	Baseline biological sampling – Tribs	Biological - instream
2015	Baseline	High base flow habitat study for tribs and riffles	Habitat
	Long-term	Repeated area-wide recon – high base	Habitat
	Long-term	Repeated area-wide recon – low base	Habitat
	Long-term	Long-term cross-section monitoring	Physical Processes

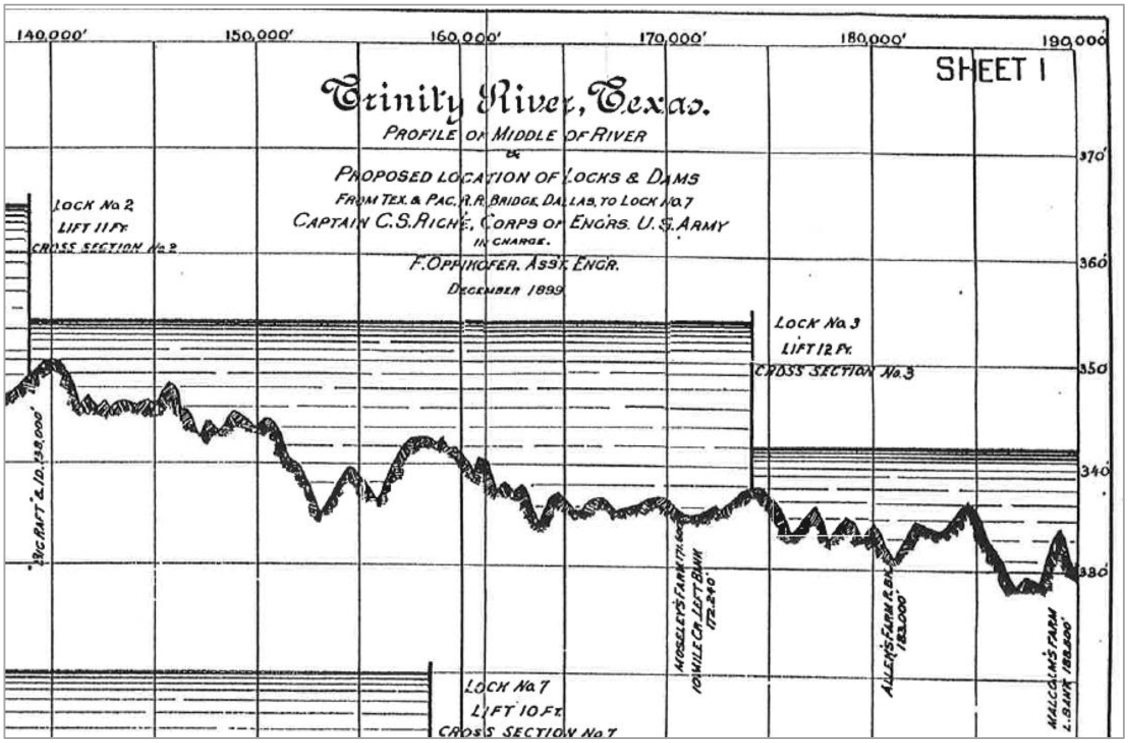


Figure 3. USACE 1899 Trinity River Survey and proposed lock and dam water profiles (datum uncertain).

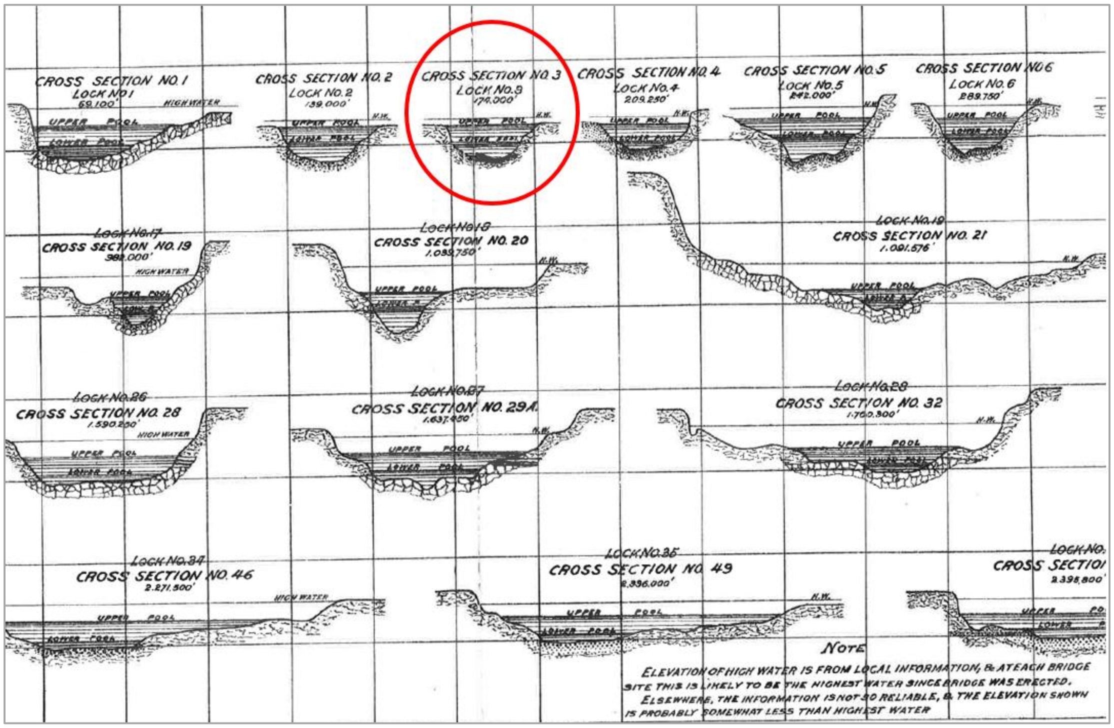


Figure 4. USACE 1899 Trinity River Survey cross-sections at proposed lock and dam locations. The red circle indicates the 1899 cross-section that is estimated to be nearest to site 080444.

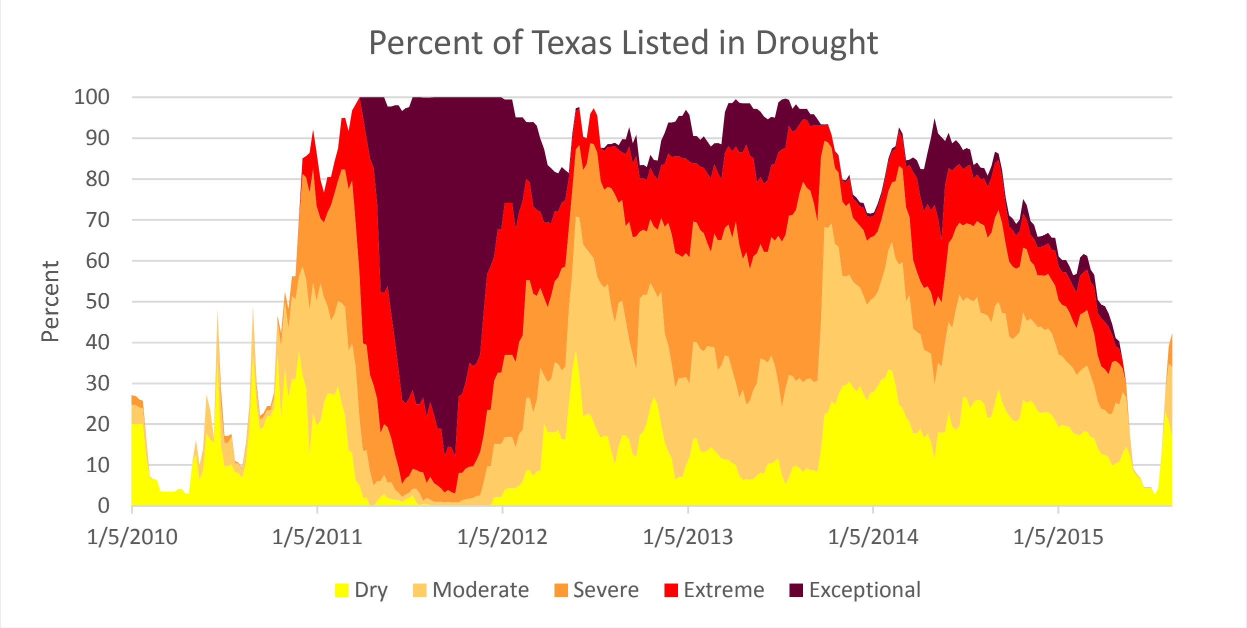


Figure 5. Percent of Texas listed in drought according to data from the U.S. Drought Monitor between January 2010 and August 2015. (Data from: http://droughtmonitor.unl.edu/Home/StateDroughtMonitor.aspx?TX)

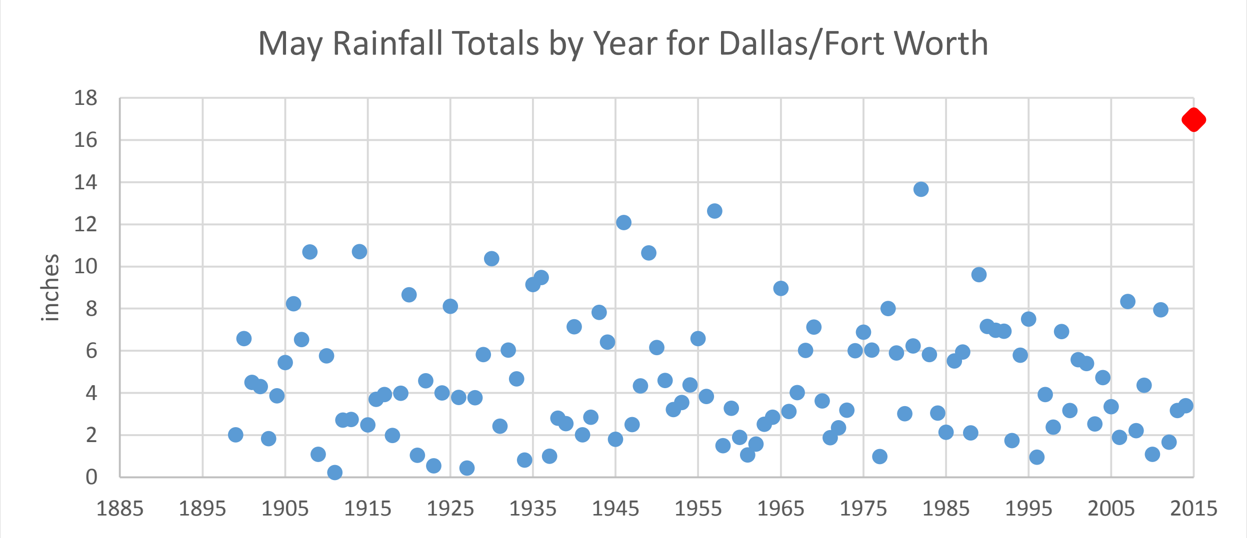


Figure 6. May Rainfall Totals by Year for Dallas/Fort Worth. Source: NOAA, 2015 http://www.srh.noaa.gov/fwd/?n=dmoprecip

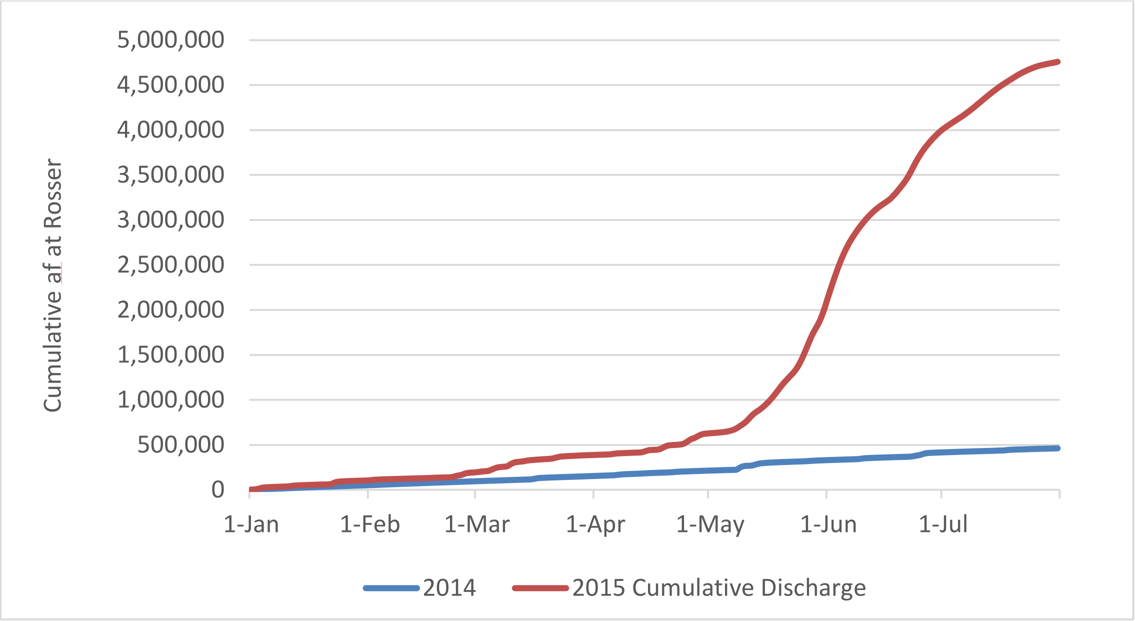


Figure 7. Graph of the cumulative flows (af/day) at the USGS gage near Rosser for the first 6 months of 2014 and 2015 (USGS, 2015).

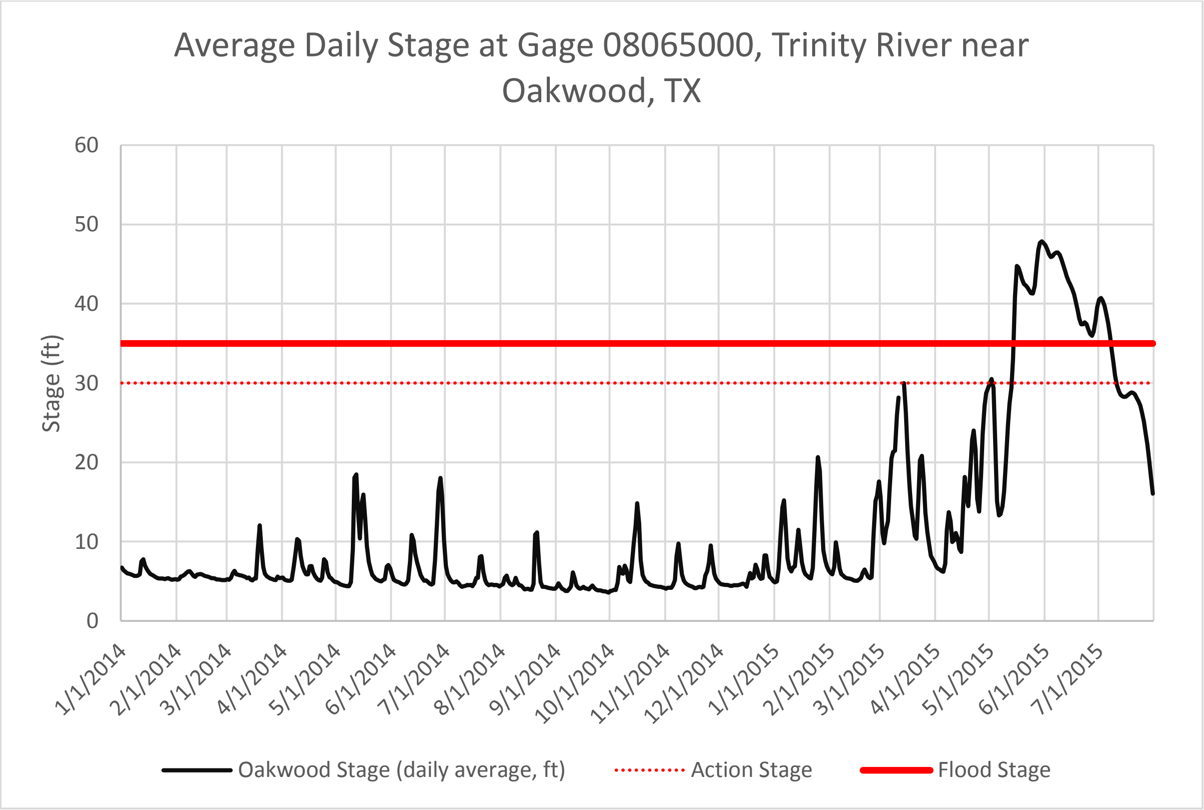


Figure 8. Graph showing the Average Daily Stage between January 1, 2015 and July 31, 2015 at USGS gage 08065000, Trinity River near Oakwood, TX (USGS, 2015).

Because the high flows prevented the collection of riparian tree data at all sites, the project scope was adjusted and resources were focused on collection of data that would characterize the system at these atypical high flows. Each site was visited at least one time and site specific information is included in the overbanking sections for sites 080444, 080295, and 080075. A previous study at site 080444 included riparian data collection, but not analysis. As part of this project, that riparian data was processed and is discussed in Section 3.6.

On June 4, 2015, TRA staff completed a low altitude aerial reconnaissance flight along the Trinity River from Arlington, TX to Trinity Bay. This reconnaissance resulted in a better understanding of the scale of the flooding and extent of floodplain inundation along the river. Geotagged photographs from this flight are included in the accompanying data archive. Near US 79/84 (also the USGS gage 08065000, Trinity River near Oakwood) aerial reconnaissance showed inundation of the river that caused large meander bends to be bypassed completely as large volumes of water passed through the floodplain. TRA staff returned to this location on June 11, 2015 and collected a single boat mounted acoustic Doppler profiler (ADP) flow transect upstream of the US79/84 bridge (red line shown in Figure 9) which measured a wetted width of 10,341 feet. Under normal summer flow conditions, the average cross-sectional wetted width in this segment is 129.8 feet (TRA & RPS Espey, 2013a). During the overbank event, the ADP results showed that approximately 36% of the flow was being conveyed by the channel with an average velocity of 2.01 ft/sec and 64% of the flow was moving in the overbank with an average velocity of 0.90 ft/sec.

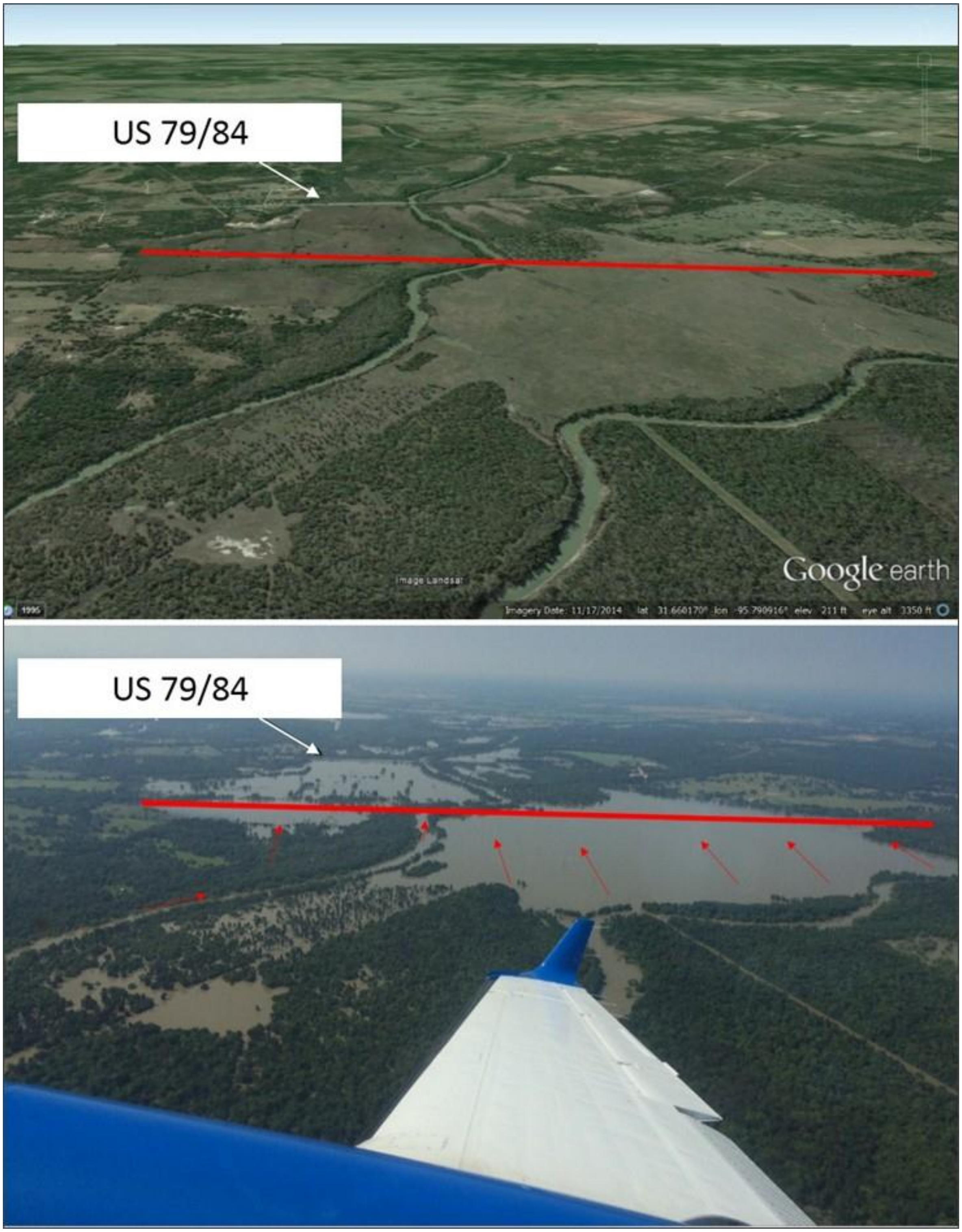


Figure 9. Top: Google Earth image from November 17, 2014 at approximately 618 cfs. Bottom: Aerial photograph taken upstream of the US 79/84 bridge (also USGS gage 08065000, Trinity River near Oakwood) looking downstream. Photograph take approximately 10:00 am on 6/4/2015 with a corresponding gage flow of 59,900 cfs and stage of 45.92 ft. (provisional) (USGS, 2015). Red arrows represent the flow direction.

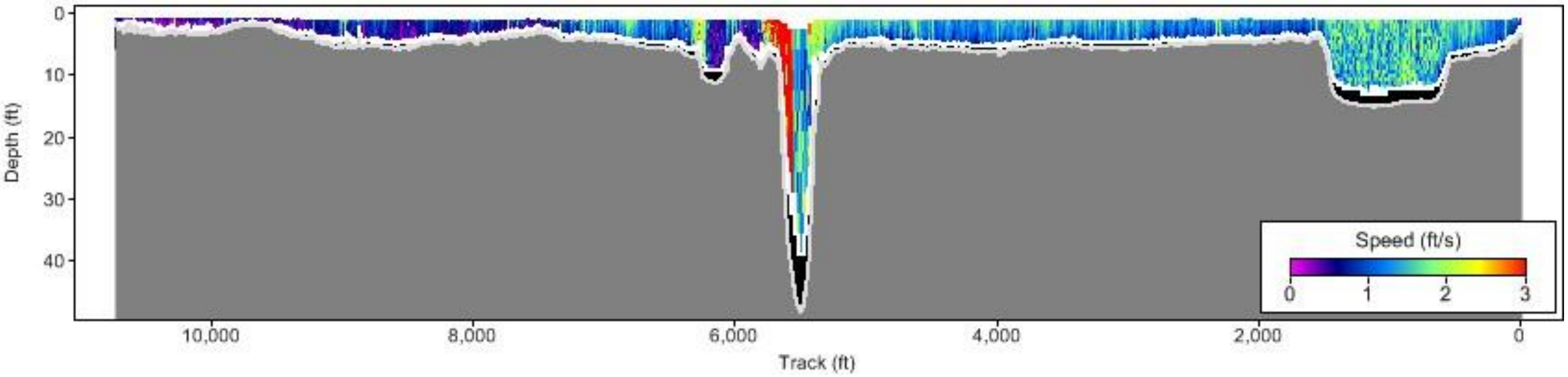


Figure 10. Cross-section taken with a boat mounted acoustic Doppler profiler just upstream of the US 79/84 bridge (also USGS gage 08065000, Trinity River near Oakwood). **Station 0 is the right bank** and the transect line follows the approximate location of the red line in Figure 9. The cross-section was started at approximately 10:30 on June 11, 2015 and measured a wetted width of 10,341 ft. with a corresponding USGS gage flow reading of 53,600 cfs and a stage of 44.96 ft. (provisional) (USGS, 2015).

2 Field Data Collection

Field data was measured at three sites to better characterize the biology, geomorphology, and hydrology of each study site. Hardened benchmarks were installed at each site and mapped with RTK GPS points to facilitate future studies and confirmation of modeling efforts associated with this project, if needed. Data was collected in accordance with standard industry practices and includes:

1. Photographic (automated time-lapse camera and standard photographs);
2. Sediment (suspended and substrate/bed);
3. Flow (Acoustic Doppler and wading rod, as required);
4. Cross-section field survey (benchmarks, cross-section, water surface profile, and longitudinal);
5. Pressure transducers (PT) (water level time-series on-site);
6. Riparian (tree, sapling and seedling counts along a cross-section transect);
7. Field observations and notes.

Table 3. Field data collected by site and data type.

Site	Photos	Time-lapse Photographs	Sediment	Flow	Bench-marks	Cross-section Survey	PTs	Riparian	Base Flow	High Flow
080075	X	X		X	X	X	X			X
080295	X	X	X	X	X	X	X		X	X
080444	X	X	X	X	X	X	X	X	X	X

2.1 Accuracy Goals

Successful long-term monitoring depends heavily on repeatability. Particularly important in assessment of geometric changes in cross-sections are positional accuracy and repeatability of measuring known locations. English units (e.g., feet, cfs, miles, etc.) are used for this assessment for consistency with available USGS flow data. Geographic coordinate projection is Texas State Plane (4202, 4203) NAD83 and elevation datum is NAVD88 GEOID03.

The accuracy goal of this study was to detect morphological changes in the river due to deposition or erosion at magnitudes (of change) of between 3 and 6 inches. While that goal is easily attainable for relative accuracy for any single-day data collection event, the goal for absolute accuracy may be somewhat larger, closer to 1 foot. The absolute accuracy goal is in consideration of using GPS equipment for expedient survey of many locations throughout a site, in lieu of installing additional benchmarks (ideally, 2 benchmarks per cross-section are required for optimum accuracy).

Typically, the relative accuracy of any single-day GPS data collection event is high (less than one inch precision); however, the absolute accuracy is more difficult to quantify and may be less accurate (less than one foot). Positional shifts are difficult to assess and correct when compiling multiple datasets from multi-day field data collection events (Osting, 2007). To maximize both precision and accuracy, state-of-the-art survey technologies and techniques were incorporated into the study methods to help achieve accuracy goals, and established national reference points were surveyed where available.

As future studies, including the TRA Long-term Study, progress, the installation and incorporation of additional fixed benchmark locations at each cross-section will contribute considerably to achieving the data accuracy goals. The next phase of work will further evaluate data collected during the 2012 survey to estimate the level of accuracy, and to evaluate an appropriate balance between level of accuracy and level of field effort.

2.1.1 Survey Reference Marks

At sites 080444 and 080075, hardened benchmarks were installed on the left and right banks of each cross-section. At 080295, hardened benchmarks had previously been installed on both the left and right banks of Cross-section 1, but high flows prevented installing them at other cross-sections before the end of this project. Benchmark installation consists typically of cementing rebar with a survey cap flush with ground elevation (Figure 2) on a high point of a cross-section, thus reducing potential disturbance.

Figure 11. Typical survey reference mark.

2.1.2 Trimble RTK GPS Surveying

A Trimble RTK GPS Surveying system is typically used to collect cross-section data points, temporary benchmark points and established National Geodetic Survey (NGS) reference cap points. This system utilizes the deployment of an on-site base-station at each site which allowed for RTK surveying to be conducted with a rover receiver. The base station was deployed on temporary benchmarks when terrain or access allowed.

The Trimble RTK GPS Surveying system was also used to tie each site survey to established National Geodetic Survey (NGS) reference caps. All data collected with the Trimble RTK GPS Surveying system was post processed using the Trimble Business Center software.

2.2 Cross-section Field Data Methods

Each individual cross-section is targeted for data collection according to study objectives and in consideration of circumstances encountered in the field. In some instances, the entire cross-section can be surveyed with one instrument/technique, and in others, several methods must be combined in order to accurately represent the channel and bathymetry. The methods are described in the sections below.

2.2.2 Trimble VX Spatial Station and Laser Scanner, and S6 Total Station

A Trimble VX Spatial Station (VX) and S6 were used to collect cross-sectional data and water surface elevation data at each site along with a traditional Auto-Level. The VX has several different operation settings which were utilized during data collection efforts. The total station setting (accuracy of VX - 0.08 inches, prism rod to 0.156 inches, direct reflection; and S6 - .078 inches) in conjunction with a prism rod, or direct reflection (if terrain was not accessible) was used to collect cross-section data for some of the cross-sections at each site. This method collected all cross-section data at wadeable cross-sections. At non-wadeable cross-sections, this method only collected the above water portion of the cross-section and a Sontek M9 Echosounder was used to collect the submerged portion of the cross-section. The prism rod was used to collect water surface elevation data which was used to determine water surface slope and water surface profiles.

2.2.3 Traditional Auto-Level Survey

A traditional auto level (accuracy of 0.7mm per 1km level loop) with survey rod was used to collect cross-sectional data and water surface profiles at each site. This method is capable of measuring all cross-sectional data at wadeable cross-sections. At non-wadeable cross-sections this method only collected the above water portion of the cross-section and a Sontek M9 Echosounder was used to collect the submerged portion of the cross-section. The water surface elevation data was used to determine water surface slope and water surface profiles. Selected reference points along each auto-level cross-section were also measured with either the VX or RTK GPS.

2.2.4 Sontek M9 Echosounding and Flow Measurement

A Sontek M9 Acoustic Doppler Profiler (ADP) was used to collect flow measurements at each site on the day the cross-sectional survey was conducted. The M9 unit was also used to collect submerged portions of cross-sections as well as additional bathymetry within the site. A longitudinal bathymetry profile was collected through each site. This profile collected data from the most upstream cross-section through the most downstream cross-section following the centerline of the stream (unless debris prevented this course).

Accuracy of the M9 device is 1% of the measured depth and 0.25% of the measured velocity. Data collected with the M9 unit was post processed using Sontek’s RiverSurveyor Live software.

2.3 Sediment

2.3.1 Sediment Samples

Bed sediment samples were collected at selected cross-sections. Typically, 5 samples were collected by hand or by dredge, depending on depth, along a sampled cross-section: 1) right bank (out of water), 2) left bank (out of water), 3) left channel (in channel; submerged), 4) middle channel (in channel; submerged), and 5) right channel (in channel; submerged). Additional sediment samples were taken if significant substrate changes were observed. Additionally, if substrate could not be collected due to size or type (e.g. bedrock or large boulder), notes and/or size measurements were recorded. At site 080444, after an overbanking pulse, sediment samples were collected from on top of the hardened benchmarks located on the top of bank (Figure 12). Additionally, suspended sediment samples were collected within the top 4 feet of the water column with a depth integrated suspended sediment sampler (Figure 13).

Figure 12. Deposition on top of a benchmark at 080444.

Figure 13. Suspended sediment sampling at site 080444.

2.3.2 Water level and slope data

Water level data is available at USGS gage locations, but water level changes at these locations may not be the same as water level changes at each site. During each site survey, while the survey crew was on site, water level change was monitored using a temporary staff gauge. Additionally, pressure transducers (PTs) were installed to measure water level at 5 to 15 minute increments. PT deployments typically span at least a month but have been successfully deployed as long as six months.

2.4 Riparian Survey

Due to flooding at the sites, the riparian field survey portion of this project was not completed. In 2013, riparian data was collected, but not processed, at site 080444. For this report, those data were processed and analyzed in order to estimate riparian population composition, forest diversity, and density. A riparian transect consisted of a 30-foot width from the water's edge to the cross-section benchmark at Cross-sections 4 and 2. Data collected included: 1) identification of tree species, 2) general categorization of life stage (seedling, sapling or tree), 3) species density counts, 4) canopy coverage estimates, and 5) diameter at breast heights (DBH) measurement for trees (>2 inches DBH; (Duke, 2011).

Different riparian vegetation types were considered during the development of this riparian study plan. Herbaceous bank vegetation usually has an annual life-span, is susceptible to natural disturbances (e.g. sedimentation, browsing, etc.), and is heavily influenced by tree canopy (Bagstad & Stromberg, 2005). Due to these factors, herbaceous bank vegetation was not considered a good indicator of long-term change, or establishing relationships to long-term hydrology patterns. Trees are a more permanent fixture in the riparian community and can be more tolerable to natural and anthropogenic disturbances. This creates an opportunity to collect data at fixed locations along rivers over long periods of time, which is essential for estimating long-term changes and relationships to hydrology patterns.

2.5 High Flow – Overbank Observation

At least one high flow field event was completed at each of the three sites. Data collected during this observation included water surface elevation data points marked with nails, river discharge, geo-referenced photographs, cross-section surveys (M9), moving bed estimates (M9), flood plain deposition estimates near benchmarks, suspended sediment water samples, and one bed sample. Additional bed samples were planned, but the equipment was destroyed by the high flows.

An experimental method to identify moving bed (i.e. transport of river bed particles) processes was conducted within the Trinity River channel. This experiment was conducted at 080295 and 080444 and consisted of fixing the M9 to a tethered rope, which spanned the Trinity River channel from right bank tree line to left bank tree line (Figure 15). The purpose of this M9 deployment is to investigate the instrument motion output (bottom track) to determine if the instrument detected movement while tethered immobile in the center of the stream. Results of this experiment are described in more detail in the site-specific sections.

Figure 14. Site 080444 low flow (620 cfs) and high flow (45,100 cfs). Note: Lock is completely submerged at high flow.

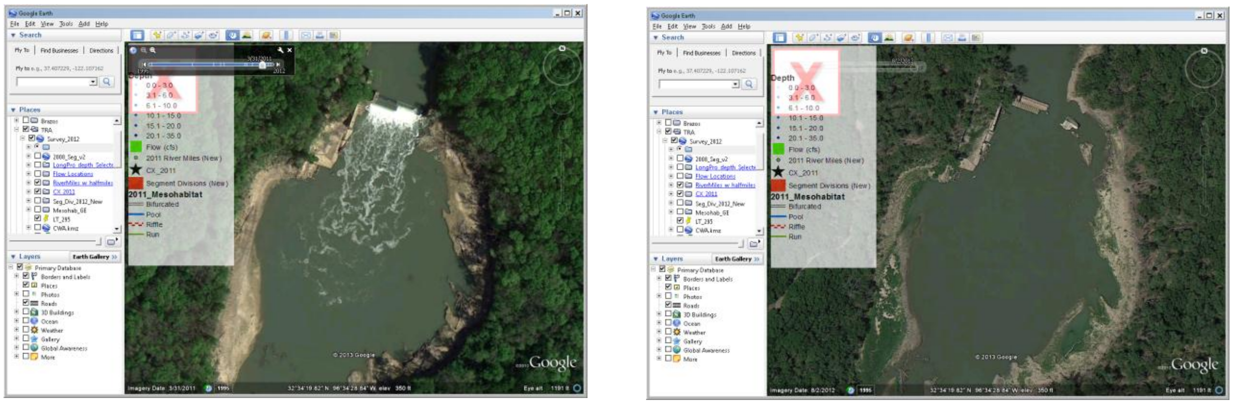
Figure 15. Tethered M9 measuring moving bed at Cross-section 1 at 080295.

3 Site 080444 – Downstream of SB3 Trinity River at Dallas measurement point

3.1 080444 - Site description

This representative site area is located approximately 27 river miles downstream of the Trinity River at Dallas SB3 measurement point. The site is located at the boundary between segment B1 and B2 (TRA and RPS 2013), approximately 2 miles downstream of Malloy Bridge Road. Between the site and the upstream SB3 measurement point, two wastewater discharges, one lock structure, and significant flood control management (levees) occur.

In the immediate vicinity of the site, a lock and dam structure (Lock 3) failed between July 2011 and April 2012. Prior to the failure, the lock served as a local grade control with water surface drop of 5 ft to 7 ft. A long term monitoring effort is being conducted at this site to quantify geomorphic response to the change in grade control. Five permanent benchmarks have been installed for each of five cross-sections.



03/31/2011

08/02/2012 (breach is apparent 04/04/2012)

Figure 16. 080444 – Flanking of Lock 3.

Figure 17. 080444 – Looking upstream at left bank, from below USACE Lock 3; July 2011, prior to flanking.

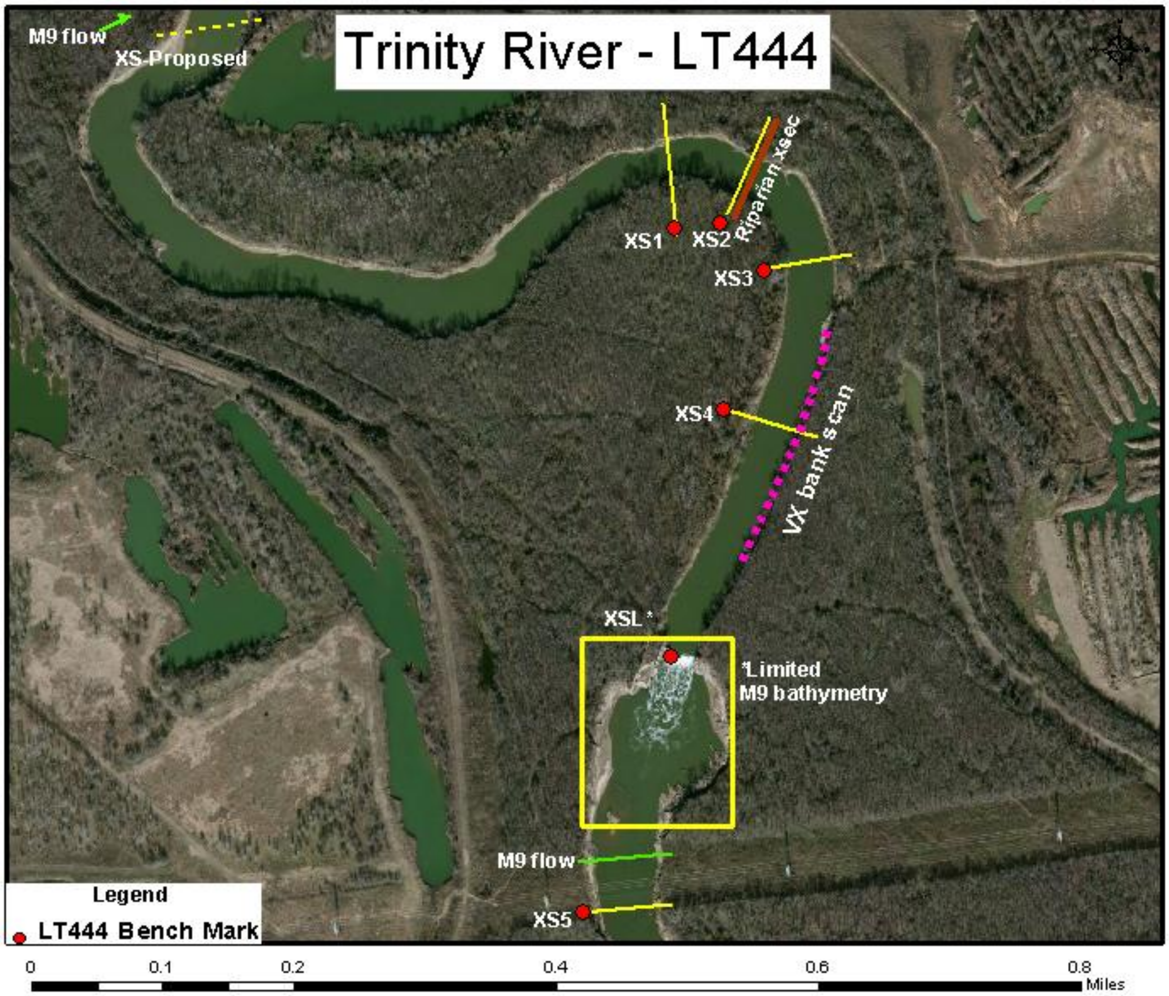


Figure 18. 080444 – Lock3 site with 2013 and 2015 field work locations. The VX scan was competed in 2013.

3.2 080444 - Cross-section comparisons

The initial survey was collected in 2014 at 667 cfs. As mentioned above, a second survey was conducted during a high flow event on June 9, 2015 at 25,198 cfs (measured onsite with M9). High rainfall in the Trinity River Basin during May and June caused elevated flows in the Trinity River and the river overtopped its banks and connected with the floodplain. The entire lock structure was submerged during the high flow sampling event (Figure 14). During the June 9, 2015 field effort, survey was completed on the channel portions of Cross-sections 1, 2, 4, and 5; velocity in the flooded riparian timber on both banks hampered measurements of overbank portions of the cross-sections.

Cross-sectional surveys are depicted the figures below and illustrate changes to the river channel at each cross-section. The river channel at Cross-sections 2 and 5 exhibited changes of less than 3 feet; however, the river channel exhibited more significant change at Cross-sections 1 and 4. At Cross-section 1, the thalweg appeared to migrate laterally (approximately 10 feet) toward the center of the river channel with sediment deposition (approximately 20 feet) on the right bank. At Cross-section 4 some deposition occurred along the right side of the channel as well as erosion on the left bank (approximately 28 feet).

Significant changes in the channel were observed and are expected to continue as the system adjusts to the recent slope changes caused by the failure of the relic USACE Lock 3 structure located between Cross-sections 4 and 5 within this site (Figure 23).

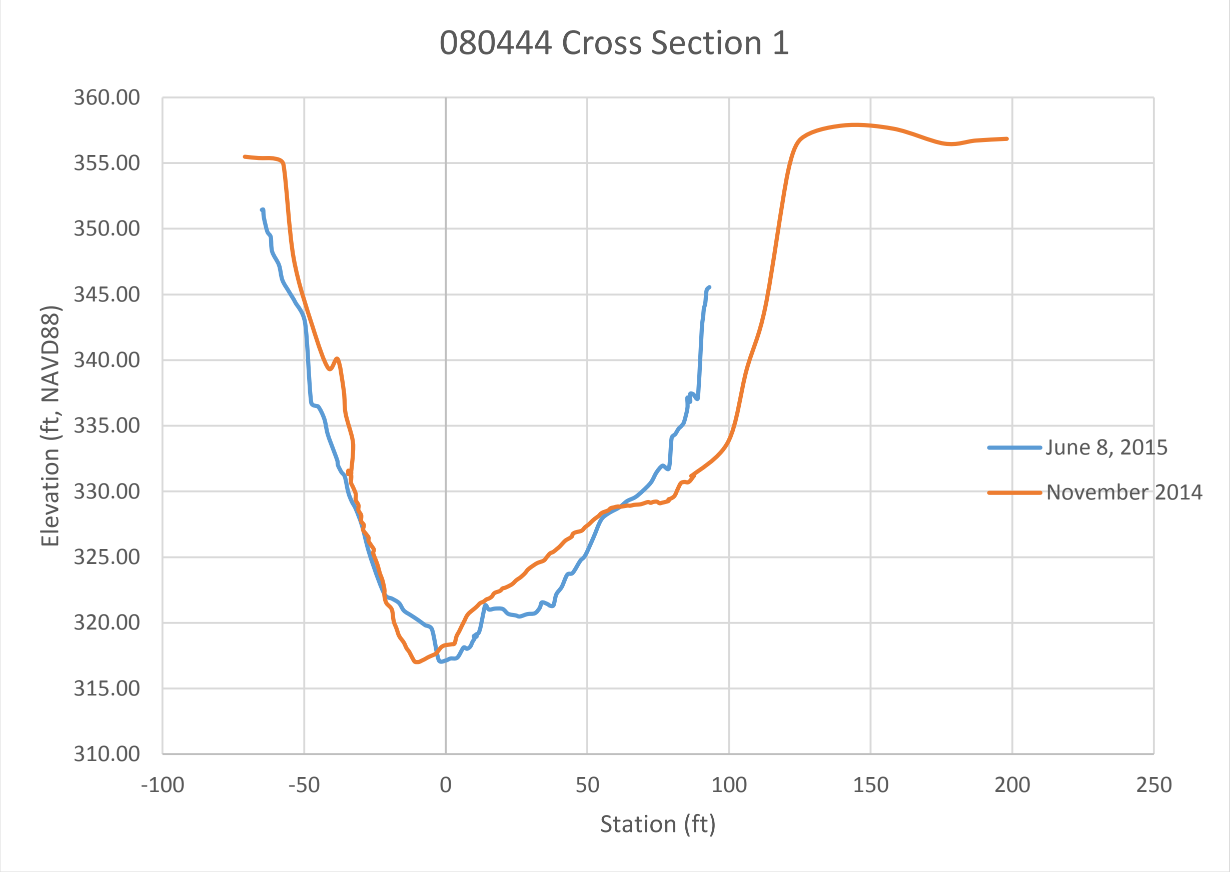


Figure 19. 080444 -- Cross-section 1 time comparison.

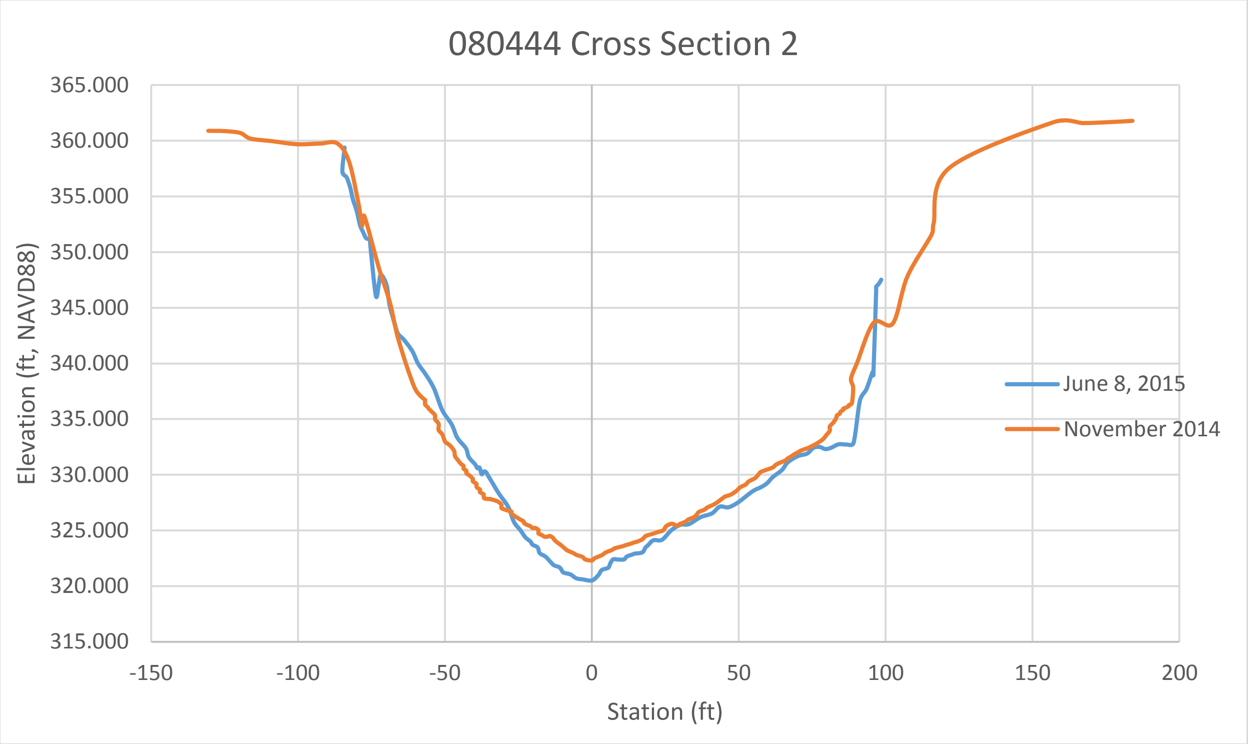


Figure 20. Cross-section 2 time comparison.

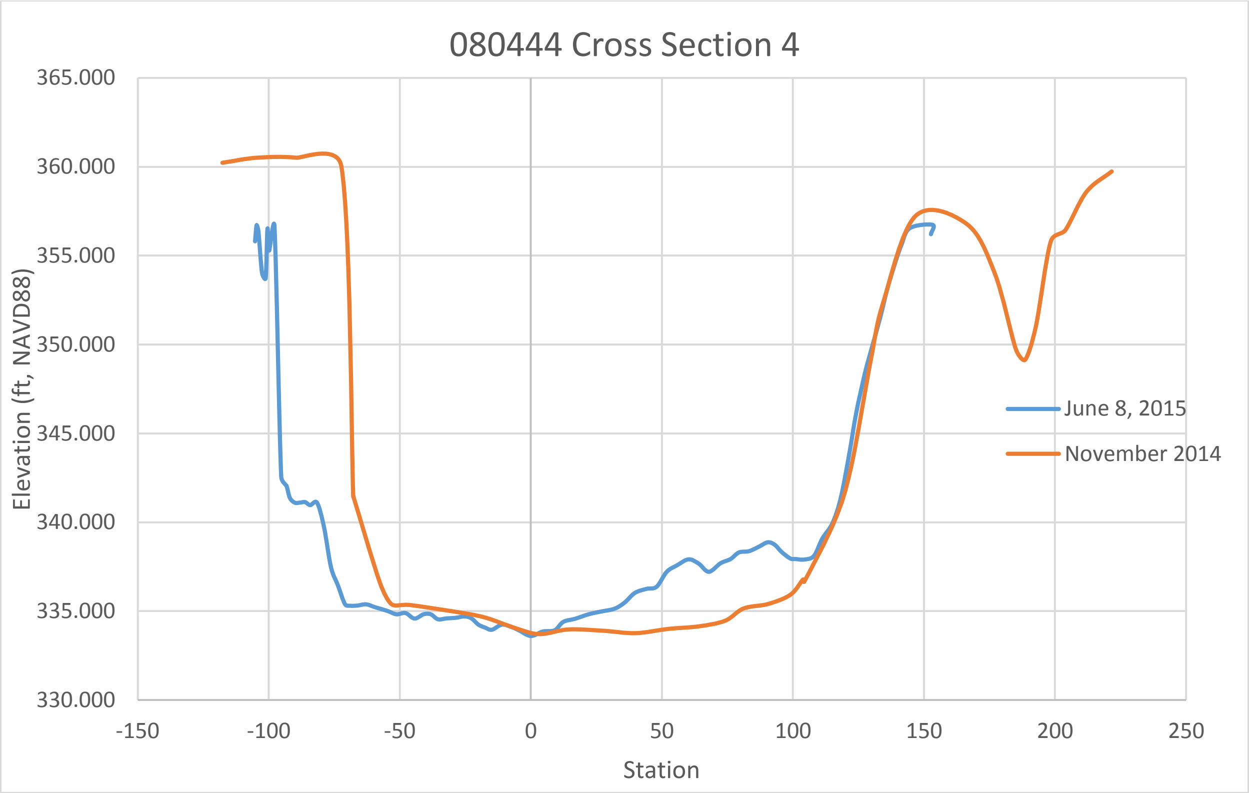


Figure 21. Cross-section 4 time comparison.

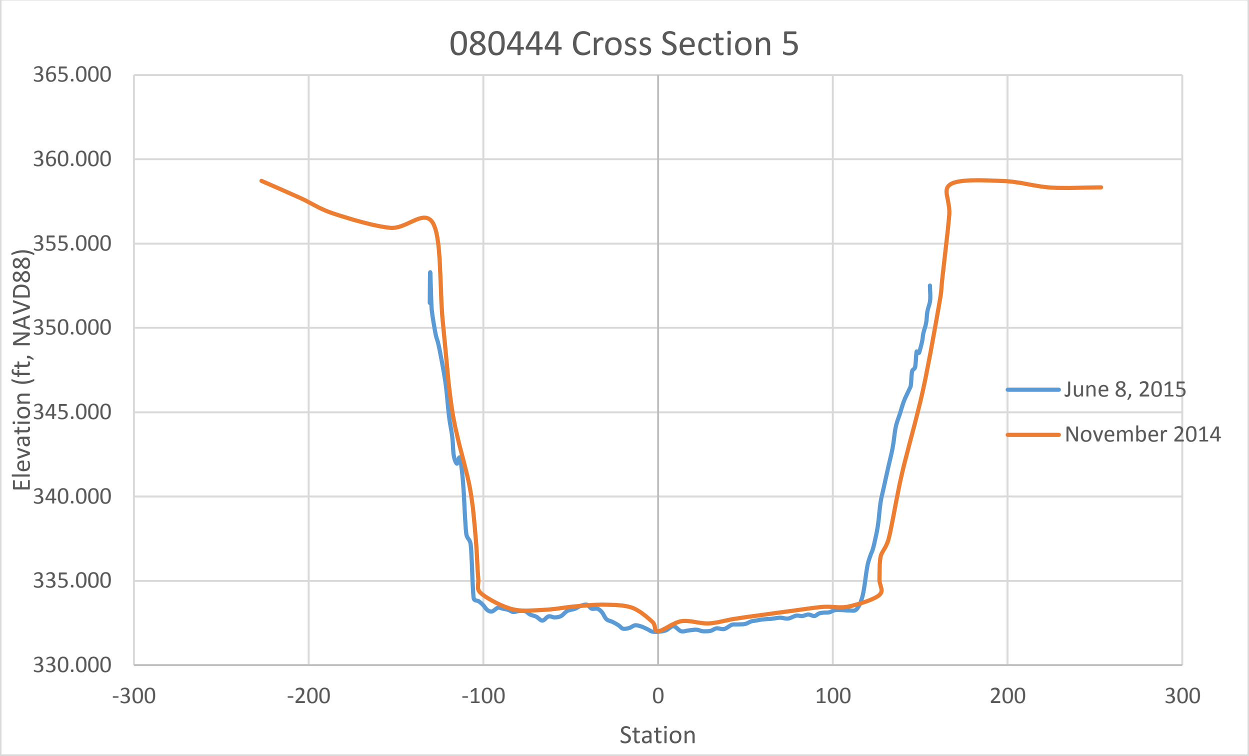


Figure 22. Cross-section 5 time comparison.

Figure 23. Photograph showing the river flanking the historic lock structure. Downstream is towards the right.

3.3 080444 - Water surface profiles

3.3.1 Data Sources

The primary existing data used to develop the HEC-RAS water surface profile (WSP) models are summarized in Table 4.

Table 4. 080444 HEC-RAS cross-section elevation data sources.

RAS Station (ft)	Overbank Data	In-channel Data	Notes
92.8	2014 LiDAR	2014 topographic survey and bathymetric survey	Downstream boundary condition from PT data and calculated flows inferred from the USGS gage TR below Dallas
92.8 -3,929.048	2014 LiDAR	2014 topographic survey and bathymetric survey	Combined from bathymetry, M9 cross-section and bathymetry data, and PT adjusted water surface elevation tie in
4140.052 – 17860.6	2014 LiDAR	Inferred in-channel to match observed WSP, 2011 cross-sections during (TRA & RPS Espey, 2013a)	

3.3.2 Model Development

The downstream boundary of the model for site 080444 is immediately upstream of the confluence of Ten Mile Creek and the upstream boundary is just upstream of Malloy Bridge Road in south east Dallas County (Figure 24). The elevations across each cross-section were assigned by combining floodplain LiDAR data with the low flow, on-site survey based on the benchmark locations at each cross-section. For cross-sections upstream of the upstream site boundary, centerline elevations from a 2011 longitudinal survey (TRA & RPS Espey, 2013a) were used for thalweg depth. The LiDAR and benchmark elevations lined up well with an average error of approximately +/- 0.3 feet (Figure 25).

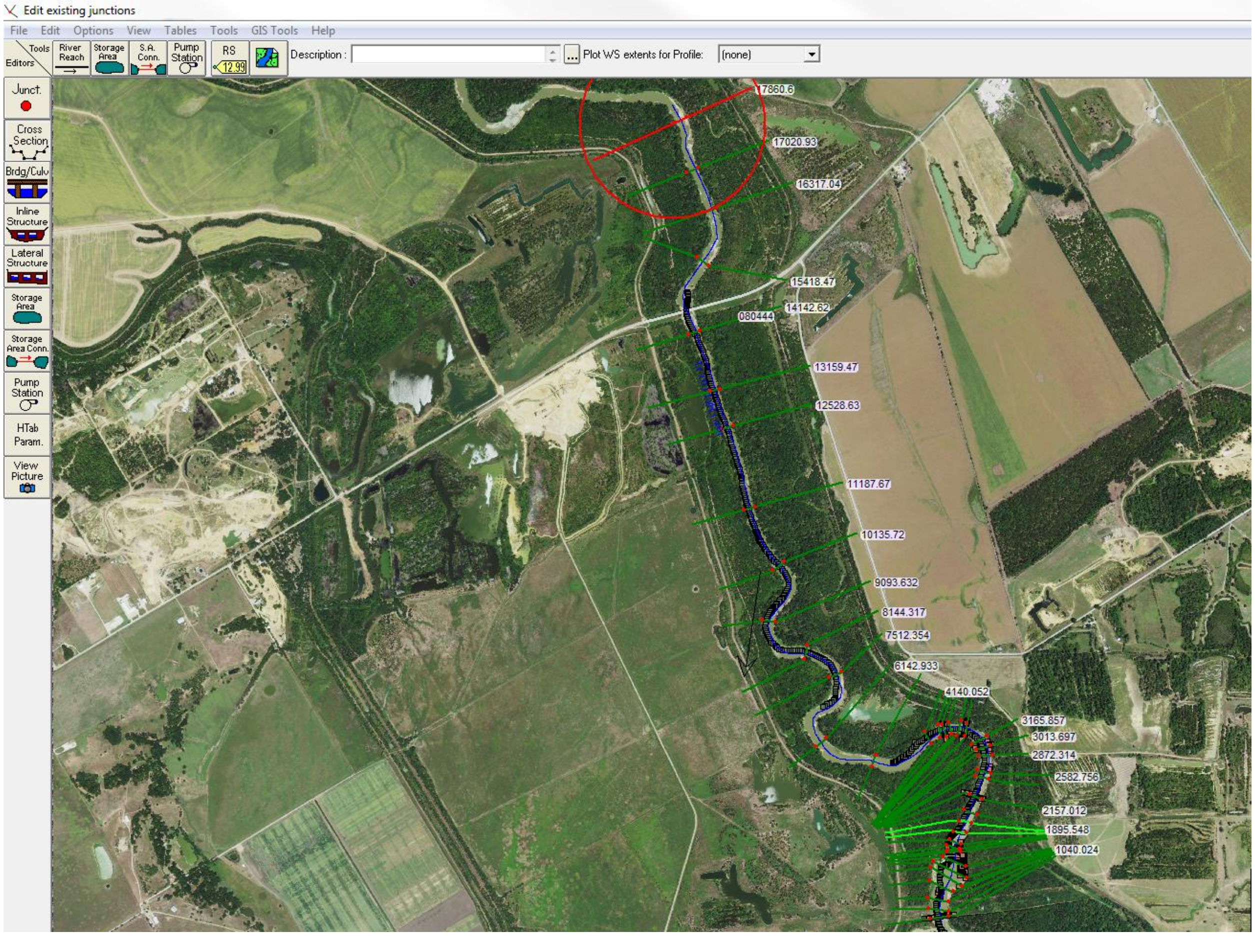


Figure 24. HEC-RAS planview for site 080444. The squares represent depth measurements taken during the 2011 Longitudinal Survey.

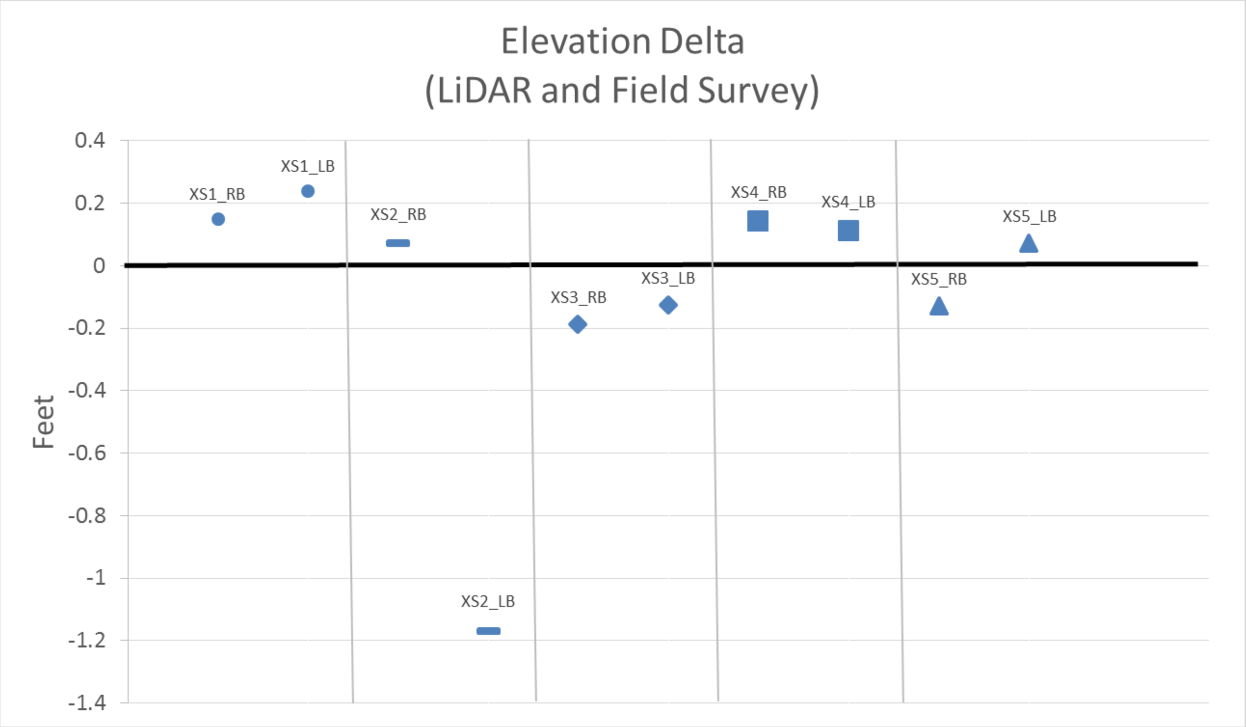


Figure 25. Graph showing the delta in feet between surveyed bench mark elevations and the LiDAR elevations at site 080444. Note: Each symbol represents a cross-section within the 080444 site and the naming convention describes the specific location. For example, the circles represent cross-section 1 (XS1) left bank (LB) and right bank (RB).

3.3.3 Calibration

The 080444 HEC-RAS model was calibrated based upon water surface profile observation data at 526 cfs and 4540 cfs (Figure 26). Model predictions were calibrated by adjusting the roughness factors and inferring cross-section bathymetry in an area near the lock at station 1539 ft. and 1717 ft. Manning’s roughness factors used are

- n=0.05 – Overbank floodplain areas (no flows in the overbank were modeled)
- n=0.03 – In-channel areas between the banks for all cross-sections except as noted below

For the 4 cross-sections immediately upstream of the failed lock, the Manning’s roughness factors were increased to 0.35, 0.04, 0.14, and 0.14 from upstream to downstream due to the lock failure which is creating complex flow patterns, pushing water to the left of the relic lock, and splitting the flow around a large concrete obstruction which used to be part of the lock (Figure 27).

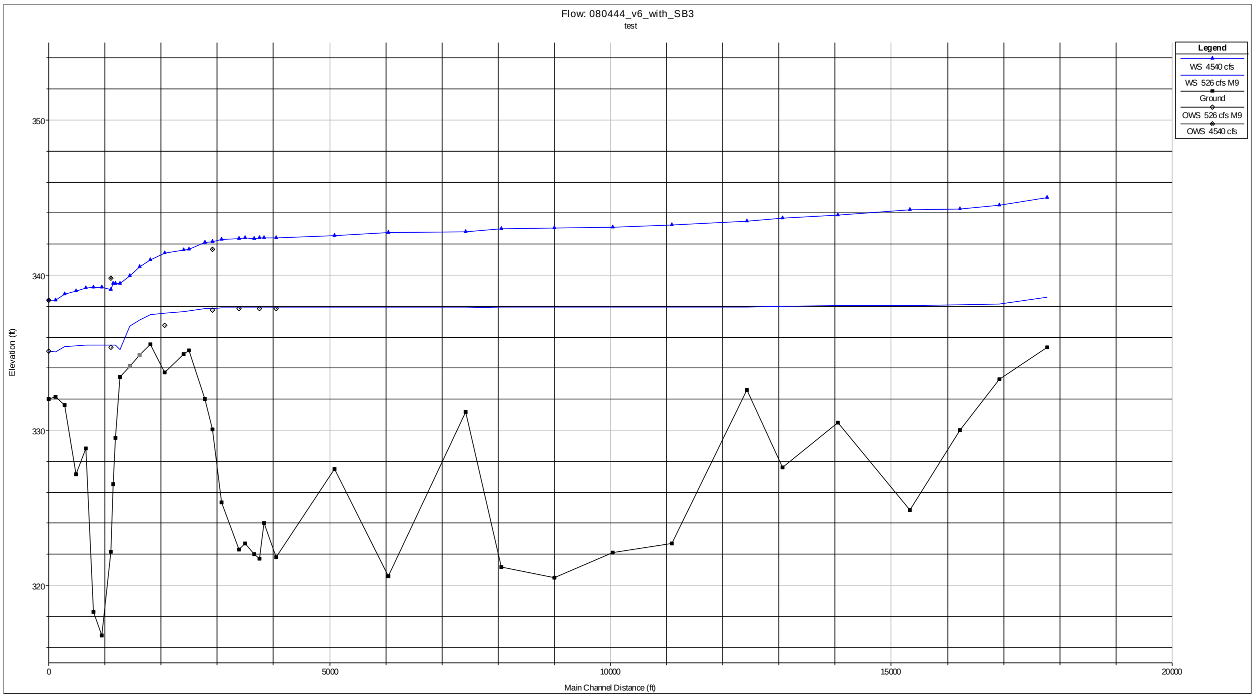


Figure 26. 080444 water surface profiles at 556 cfs and 4540 cfs. Observed water surface measurements are shown in diamonds.

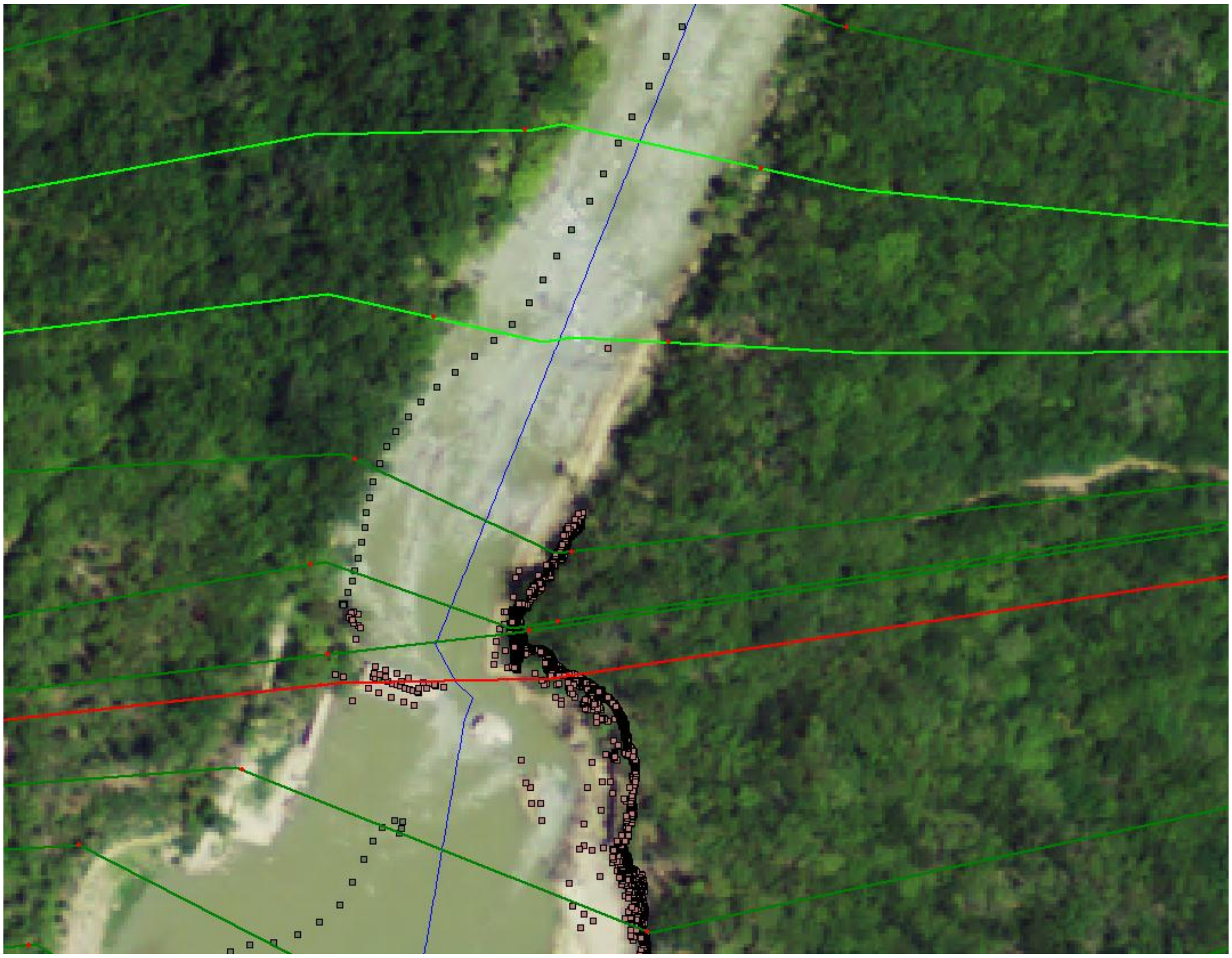


Figure 27. 080444 HEC-RAS model showing the failed lock structure, large concrete obstruction, and immediate movement of water to the left of the channel around the relic lock. The green squares show depth measurement locations during the 2011 Longitudinal Survey and the pink squares show the locations of topographic survey measurement points.

3.3.4 HEC-RAS Water Surface Profile (WSP) Results

A series of steady-state flow rates were modeled as part of this project, ranging from 526 cfs to 10,042 cfs. The flow data were selected from peak pulse data (except for 526 cfs which was measured in the field) from the USGS gage 08057410 - Trinity River below Dallas. Observed water surface elevations were surveyed onsite, or measured by long-term PT deployments on site. The RTs were not deployed during the spring and summer flooding, and the overbank flows were not modeled due to the lack of data and the leveed nature of this site.

Table 5. 080444 HEC-RAS modeled steady-state flows.

Flow Rate (cfs)	Description
526	Observed WSP
700	SB3 - Winter Trigger
1000	SB3 - Summer Trigger
1167	Observed from PT
1411	Observed from PT
1900	Observed from PT
2503	Observed from PT
4000	SB3 - Spring Trigger
4540	Observed from PT
6470	Observed from PT
10042	Observed from PT

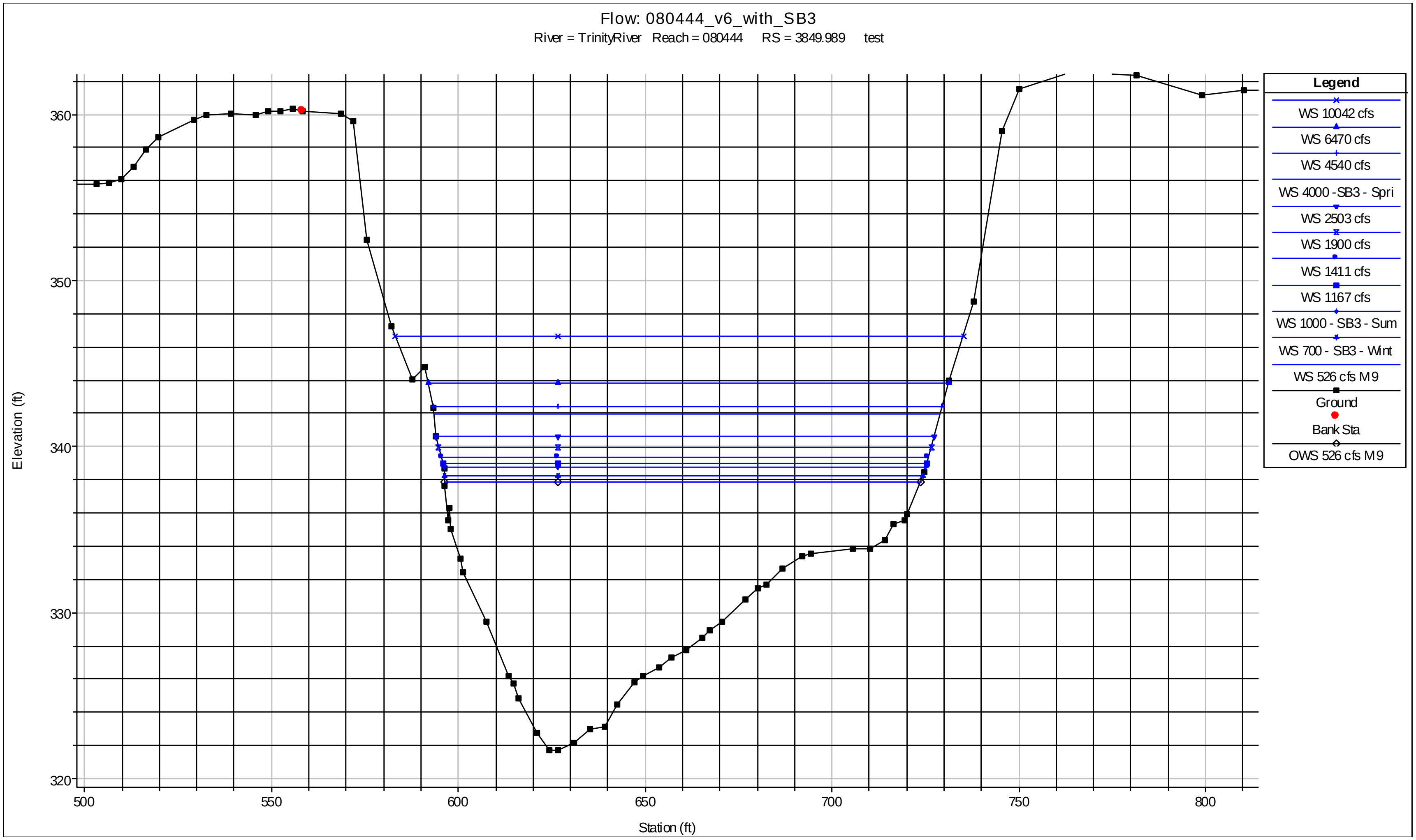


Figure 28. 080444 XS1 - Upstream benchmark cross-section.

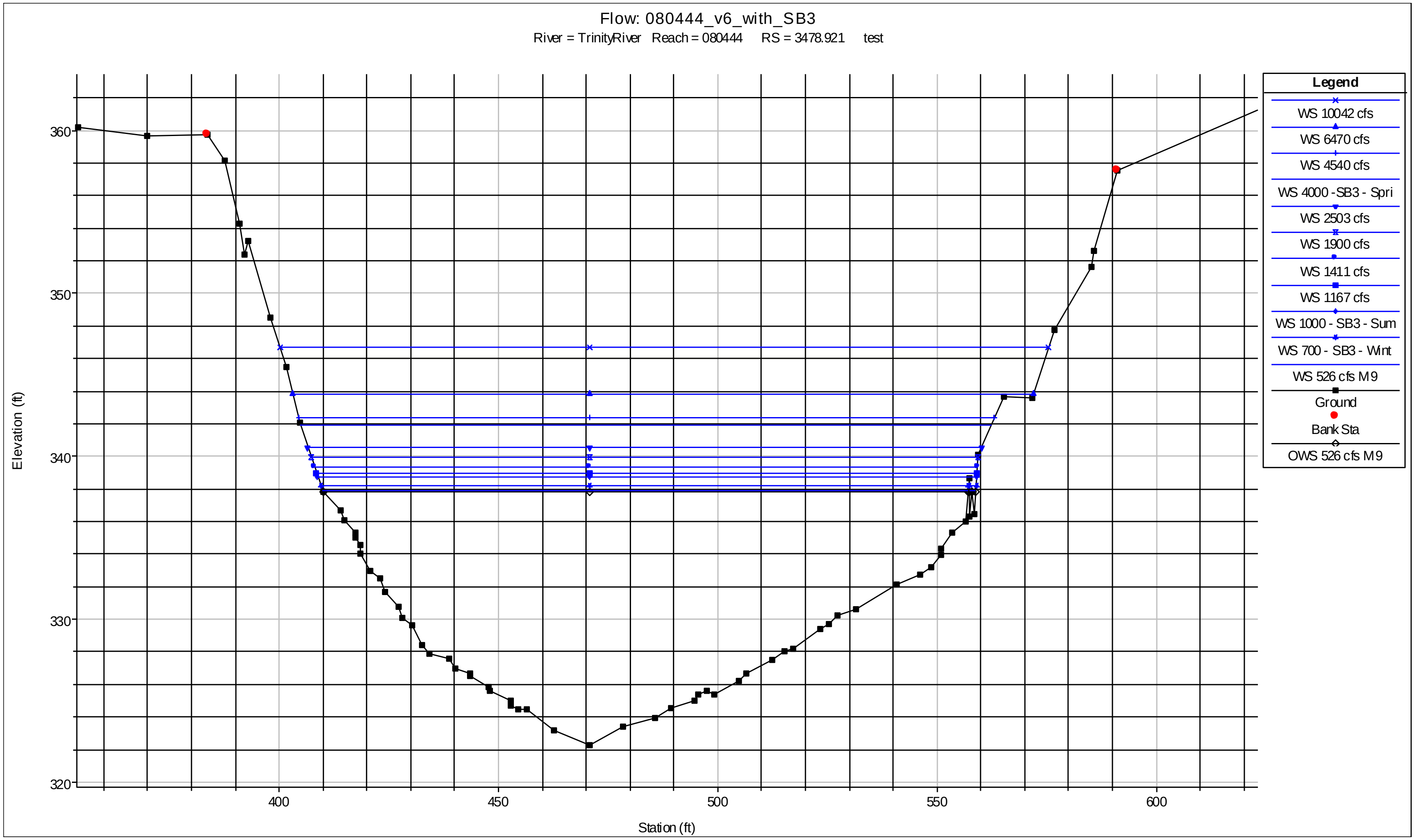


Figure 29. 080444 XS2 cross-section.

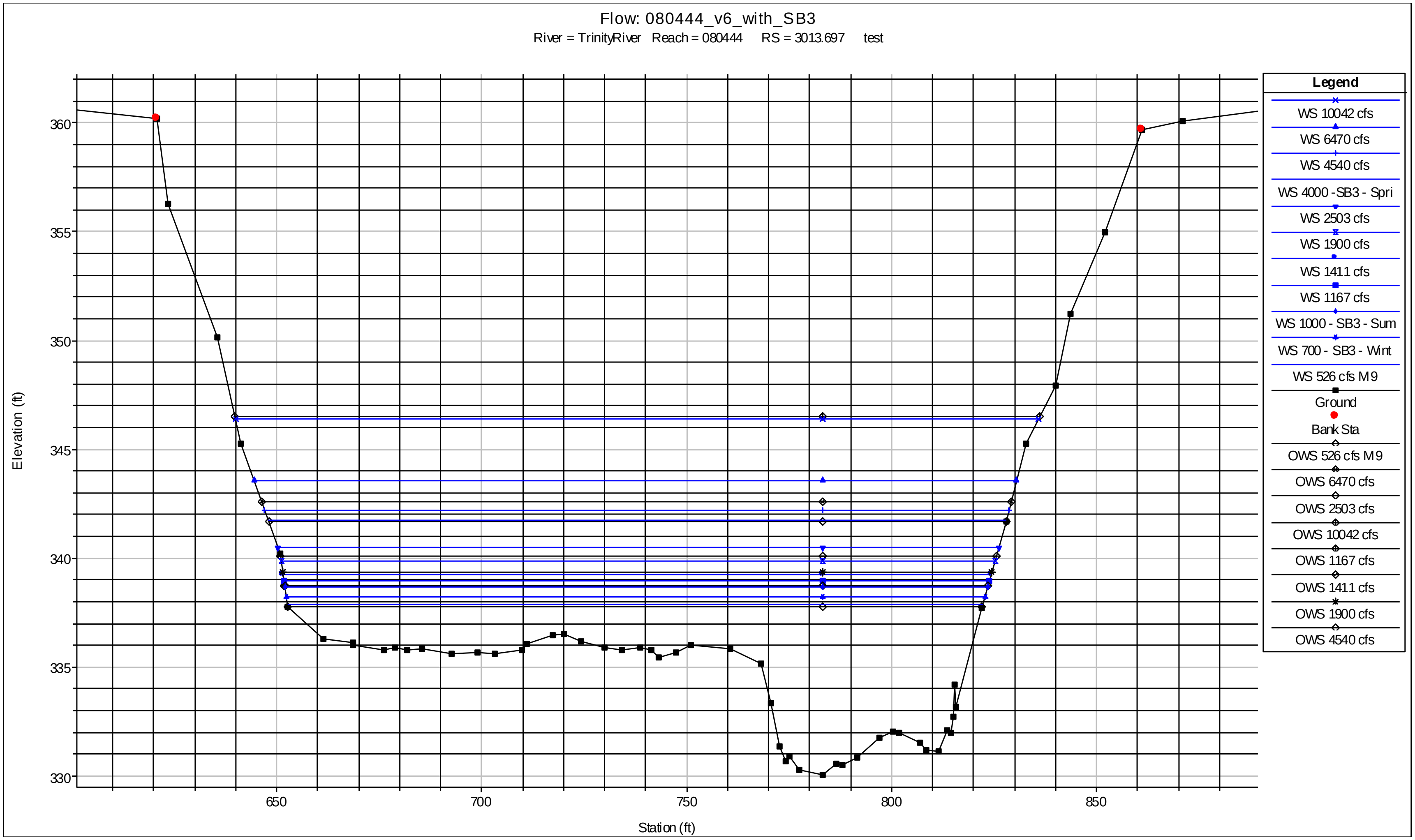


Figure 30. 080444 XS3 cross-section.

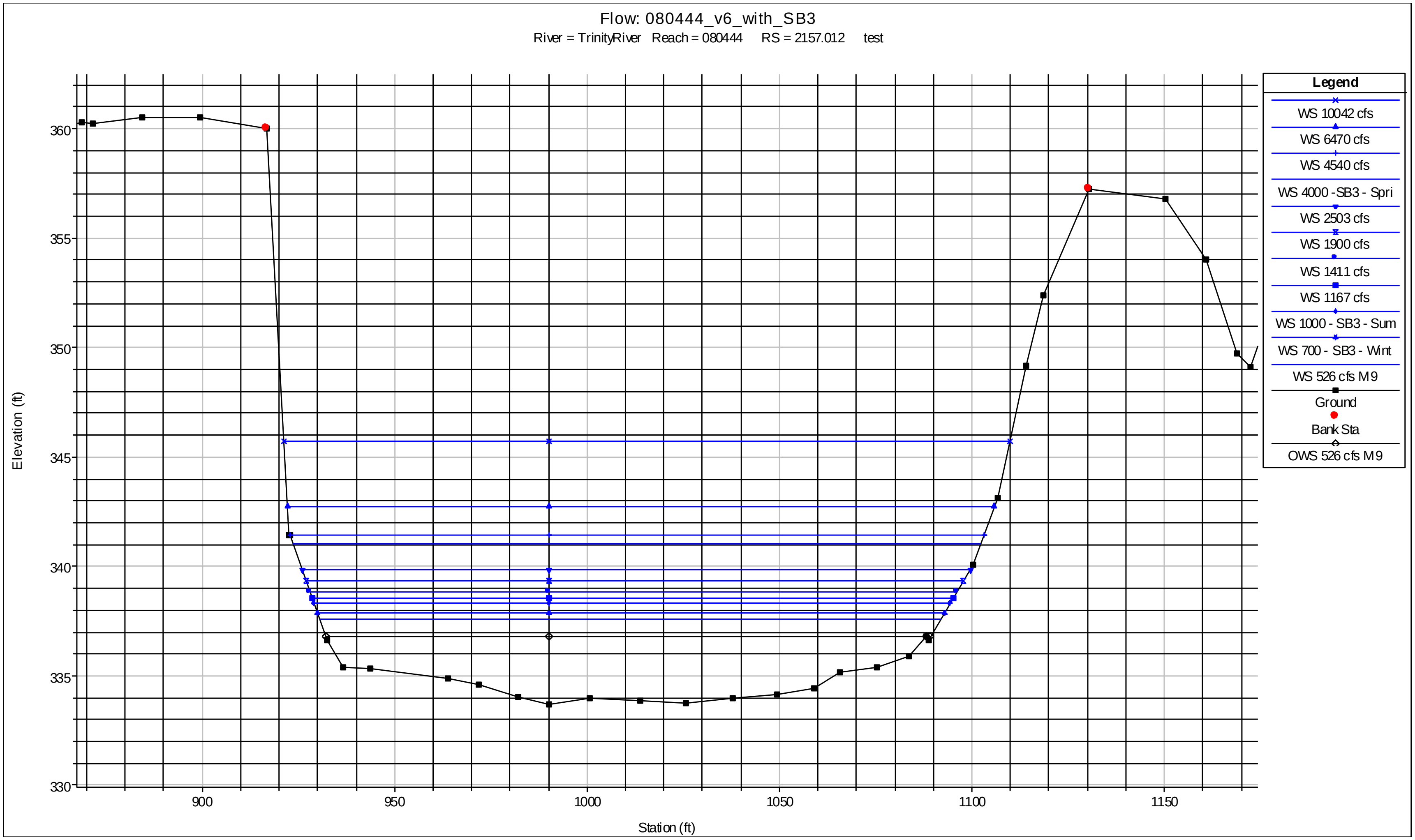


Figure 31. 080444 XS4 cross-section.

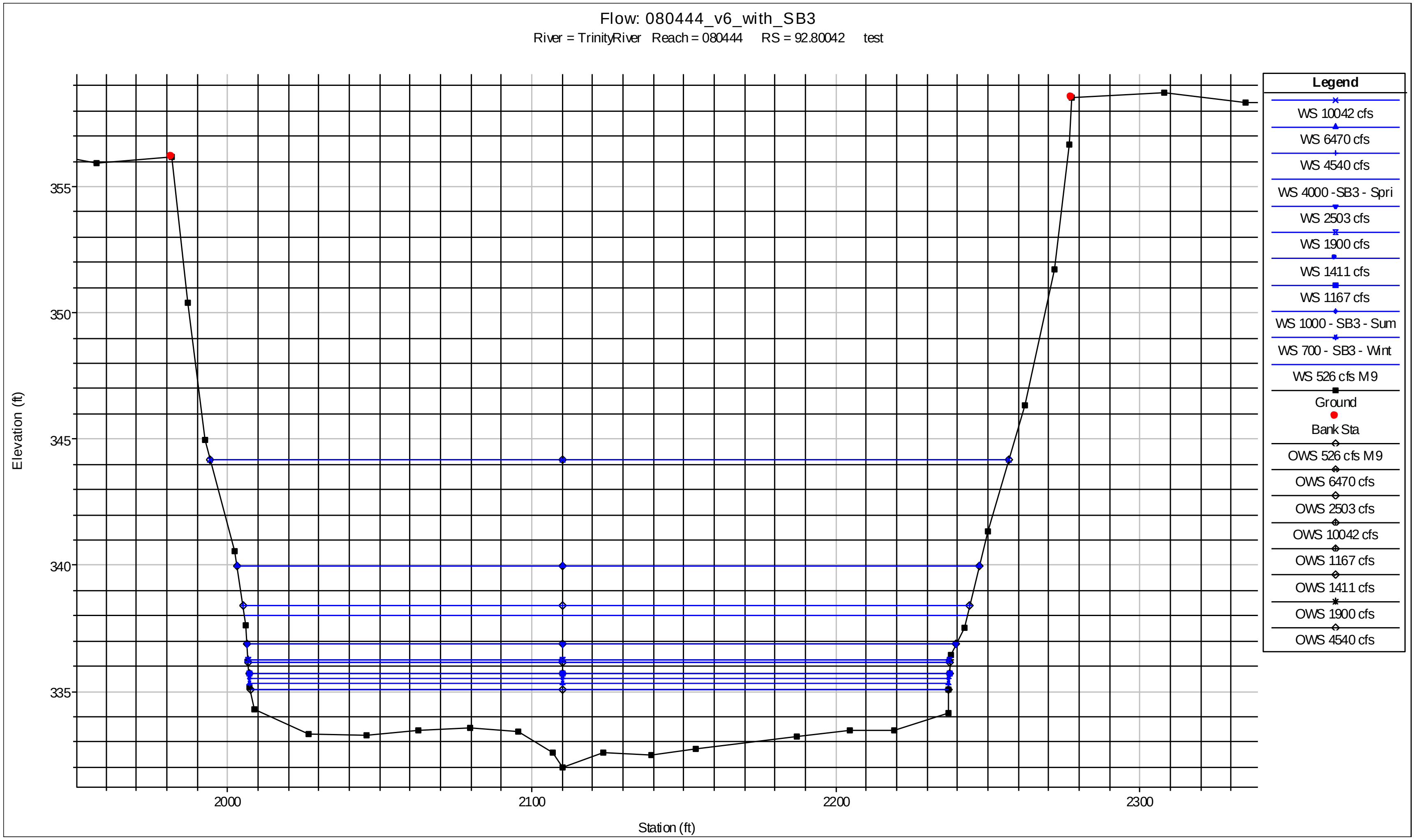


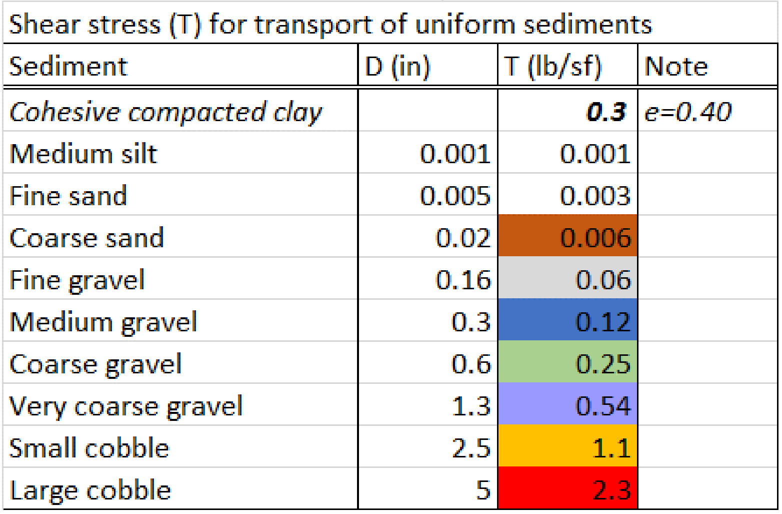
Figure 32. 080444 XS5 cross-section, downstream boundary condition.

3.4 080444 - Sediment

Sediment samples were collected on-site at 080444 during the 2013 and 2014 field efforts. Five sediment samples were collected and grain size analysis was performed. Sediment grain size analysis at Cross-section 2 revealed bank substrates are primarily sand (>70% finer than 0.003 inch) (Figure 33) and are similar to right bank substrates at Cross-section 4 (Figure 34). Submerged sediments in the mid-channel of Cross-section 2 are primarily sand. Cross-section 4 is located at an outcrop exhibiting a bedrock bottom with primarily coarse gravel and larger sediments on top of the smooth bedrock.

Shear stress predictions can be used as a first step to investigate sediment mobilization. The shear stress necessary to cause incipient motion across a range of grain size classes was identified in Table 6. Using HEC-RAS model, shear stress was predicted in the channel at each of the 080444 cross-sections (Table 7). Color shading is used for convenience in the tables for relating transportable grain size to flow ranges for each cross-section.

Table 6. Shear stress causing incipient motion



Shear stress (T) for transport of uniform sediments			
Sediment	D (in)	T (lb/sf)	Note
Cohesive compacted clay		***0.3***	*e=0.40*
Medium silt	0.001	0.001	
Fine sand	0.005	0.003	
Coarse sand	0.02	0.006	
Fine gravel	0.16	0.06	
Medium gravel	0.3	0.12	
Coarse gravel	0.6	0.25	
Very coarse gravel	1.3	0.54	
Small cobble	2.5	1.1	
Large cobble	5	2.3	

Sand transport is predicted for all flow levels above 700 cfs, with Cross-section 2 being the location where sand may be deposited during low flow conditions (Table 7). Model predictions are consistent with on-site sediment sample grain size analysis from bed material described above.

Cross-section 2 is typical of many pool and run reaches where shear stress is sufficient for gravel transport at flows above 4,000 cfs. At Cross-section 4, coarse gravel transport is predicted (Table 7) and is consistent with the substrate found onsite. Erosion of cohesive sediments (compacted clay) is predicted for flows above 2,500 cfs at Cross-section 4 (Table 7) which is also consistent with the steep eroding left bank at the Cross-section. Maximum shear is predicted at 6,470 cfs for Cross-section 5 and Cross-section 4, and maximum shear of the flow levels analyzed is predicted at 10,000 cfs for Cross-section 2.

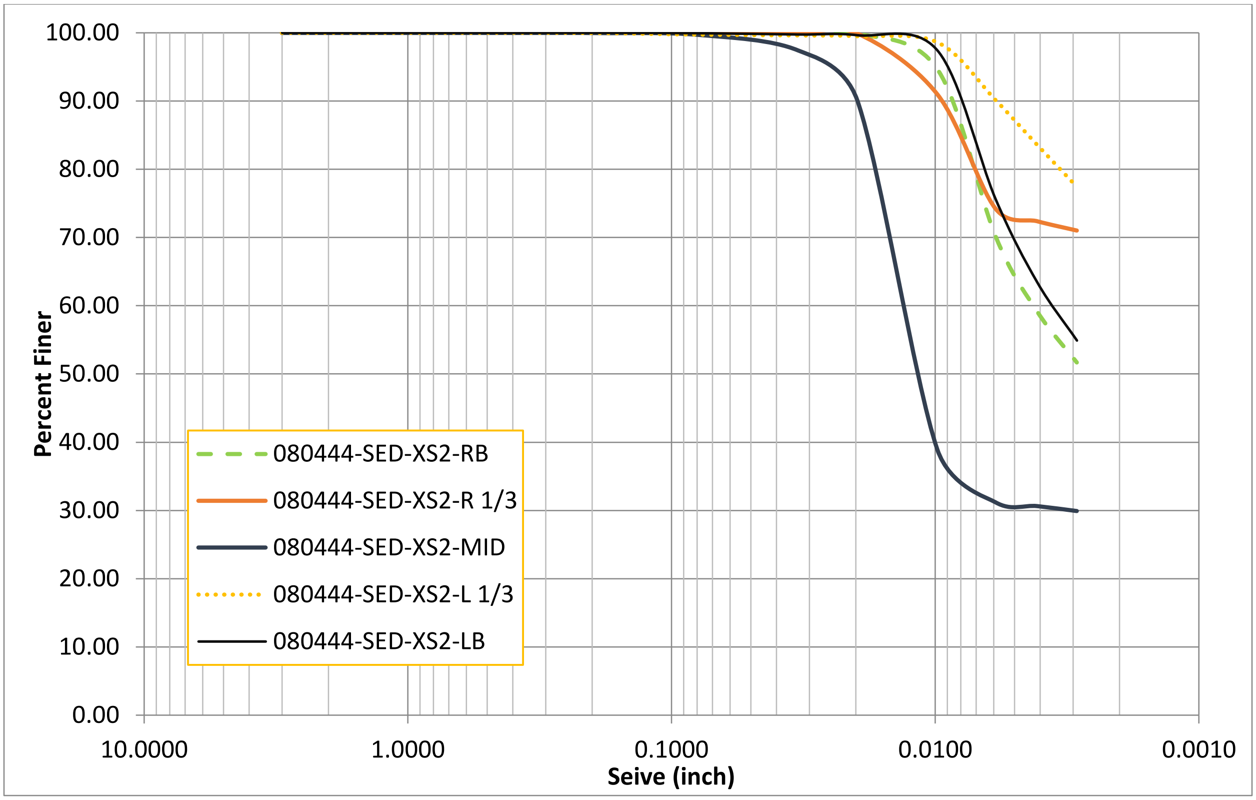


Figure 33. Sediment gradations at 080444 Cross-section 2.

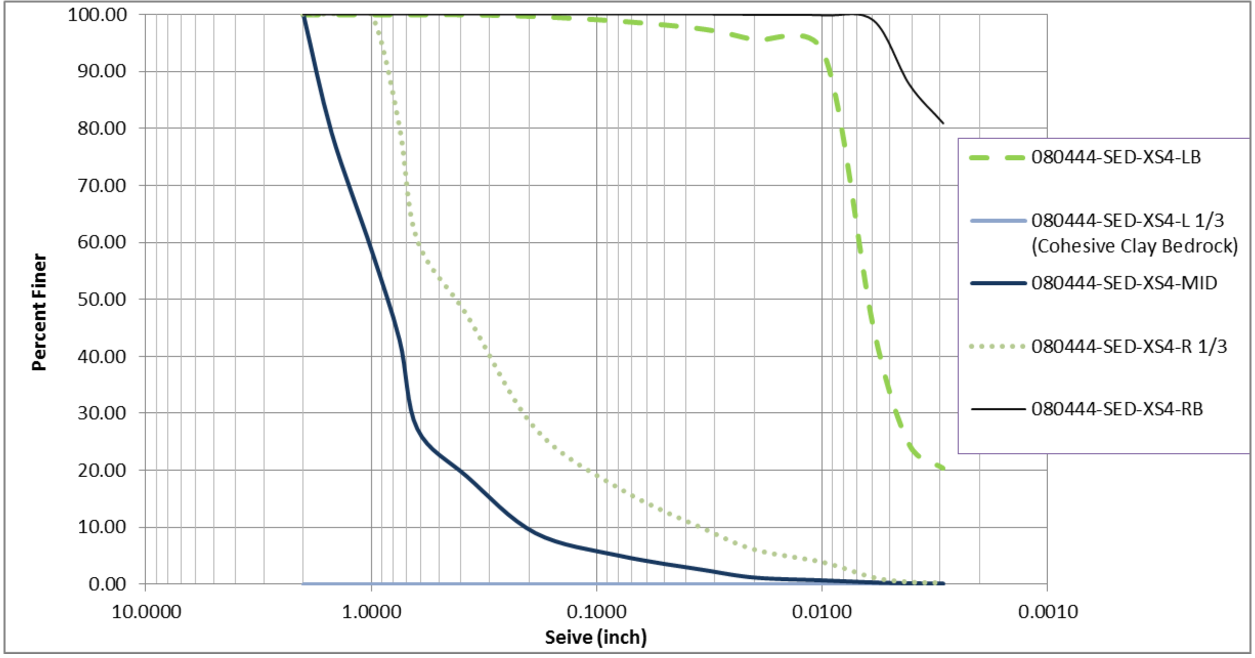
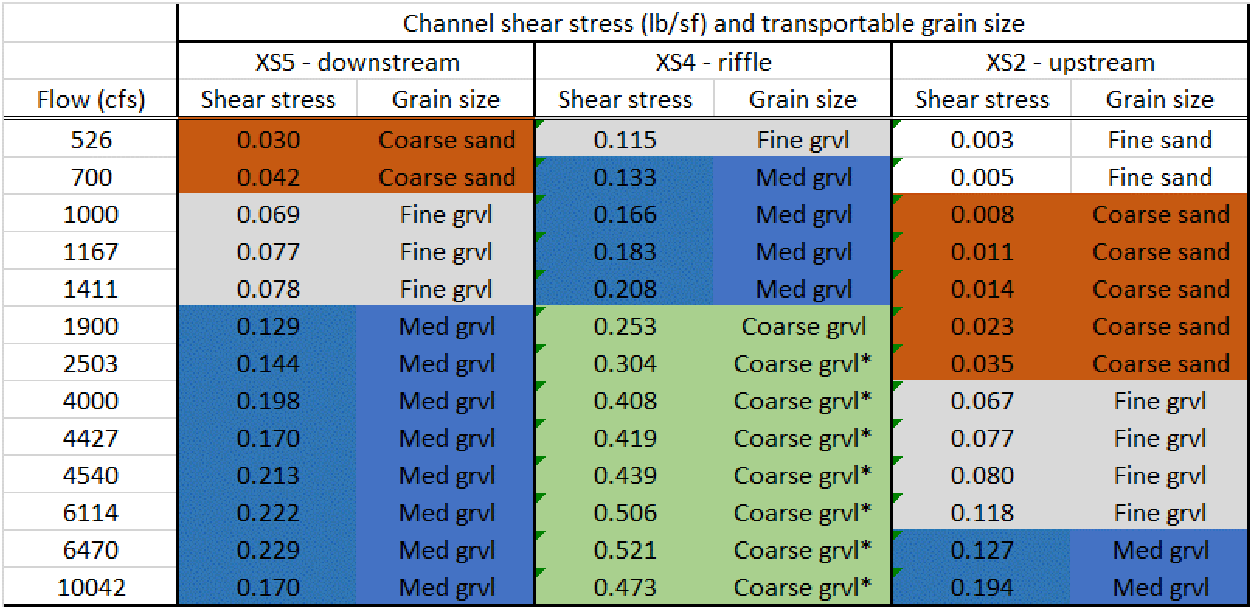


Figure 34. Sediment gradations at 080444 Cross-section 4.

Table 7. 080444 HEC-RAS predicted channel sheer stress (lb./ft).



	Channel shear stress (lb/sf) and transportable grain size					
	XS5 - downstream		XS4 - riffle		XS2 - upstream	
Flow (cfs)	Shear stress	Grain size	Shear stress	Grain size	Shear stress	Grain size
526	0.030	Coarse sand	0.115	Fine grvl	0.003	Fine sand
700	0.042	Coarse sand	0.133	Med grvl	0.005	Fine sand
1000	0.069	Fine grvl	0.166	Med grvl	0.008	Coarse sand
1167	0.077	Fine grvl	0.183	Med grvl	0.011	Coarse sand
1411	0.078	Fine grvl	0.208	Med grvl	0.014	Coarse sand
1900	0.129	Med grvl	0.253	Coarse grvl	0.023	Coarse sand
2503	0.144	Med grvl	0.304	Coarse grvl*	0.035	Coarse sand
4000	0.198	Med grvl	0.408	Coarse grvl*	0.067	Fine grvl
4427	0.170	Med grvl	0.419	Coarse grvl*	0.077	Fine grvl
4540	0.213	Med grvl	0.439	Coarse grvl*	0.080	Fine grvl
6114	0.222	Med grvl	0.506	Coarse grvl*	0.118	Fine grvl
6470	0.229	Med grvl	0.521	Coarse grvl*	0.127	Med grvl
10042	0.170	Med grvl	0.473	Coarse grvl*	0.194	Med grvl

3.5 Riparian area cross-section photos

Inundation of river bank riparian areas was documented during this study using commercially-available game cameras. The cameras logged photographs of the river each hour during the deployment period. At site 080444, the game camera was set at Cross-section 2, looking downstream towards Cross-section 3. Inundation photos indicate limited connectivity with herbaceous river bank vegetation (e.g., grasses) at flow levels below 700 cfs. For higher flows above 6,000 cfs captured on the camera, some herbaceous vegetation and limited, if any, woody vegetation is inundated (Figure 52). The camera was consistent with the on-site riparian surveys.

3.6 080444 - Riparian

Riparian woody vegetation was surveyed in November 2013 at site 080444 at Cross-sections 2 and 4. Vegetation found along these cross-sections consisted of hydrophilic species: Black Willow, *Salix nigra*; Green Ash, *Fraxinus pennsylvanica* at lower elevations (i.e. moist soils near normal water surface elevations), and flood plain species: Cedar Elm, *Ulmus crassifolia*; Southern Hackberry, *Celtis laevigata*; Pecan, *Carya illinoinensis* at higher elevations with mesic species in between.

Riparian data included in the following section is presented in metric units which is customary for this type of scientific information. Also following methods employed for similar assessments, the station 0.0 of each transect is used to identify the water's edge at time of riparian survey.

3.6.1 Cross-section 2

Cross-section 2 is located on the apex of a right curve (Figure 18). During the vegetation survey, some fallen trees and bank mass failures along the left bank were observed as well as some evidence of deposition of the right bank. The river channel did not change significantly after large amounts of precipitation and stream flow were observed during the two cross-sectional surveys.

Seven woody species were identified on the left bank of Cross-section 2 (Table 8). The most common woody riparian species identified on the left bank were Southern Hackberry (*Celtis laevigata*), Slippery Elm (*Ulmus rubra*), and Roughleaf Dogwood (*Cornus drummondii*). The location of each individual is shown in Figure 35, Figure 36 and Figure 37.

Table 8. 080444 – Cross-section 2 left bank woody vegetation counts

Cross-section 2 Left Bank

Common Name	**Scientific Name**	**Total Individuals**
Trees		
Boxelder	*Acer negundo*	5
Hackberry	*Celtis laevigata*	6
Slippery Elm	*Ulmus rubra*	3
Roughleaf Dogwood	*Cornus drummondii*	2
Green Ash	*Fraxinus pennsylvanica*	1
Saplings		
Blackwillow	*Salix nigra*	2
Hackberry	*Celtis laevigata*	16
Roughleaf Dogwood	*Cornus drummondii*	36
Slippery Elm	*Ulmus rubra*	6
Pecan	*Carya illinoinensis*	1
Seedlings		
Roughleaf Dogwood	*Cornus drummondii*	3
Pecan	*Carya illinoinensis*	1
Slippery Elm	*Ulmus rubra*	1
Hackberry	*Celtis laevigata*	12

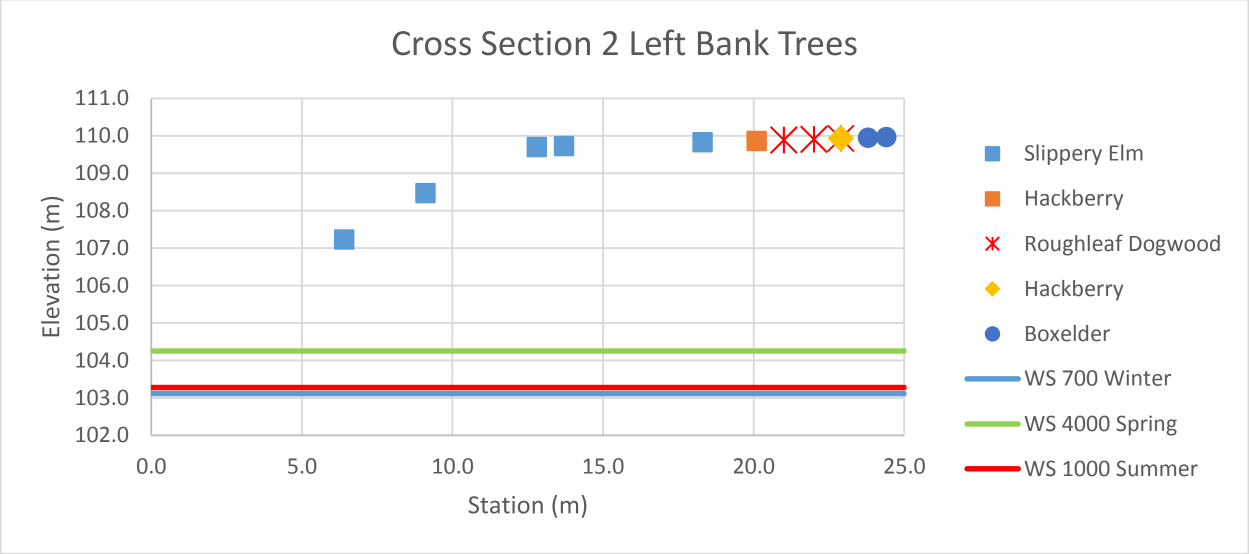


Figure 35. 080444 – Cross-section 2 – Left Bank – Trees – Location along cross-section.

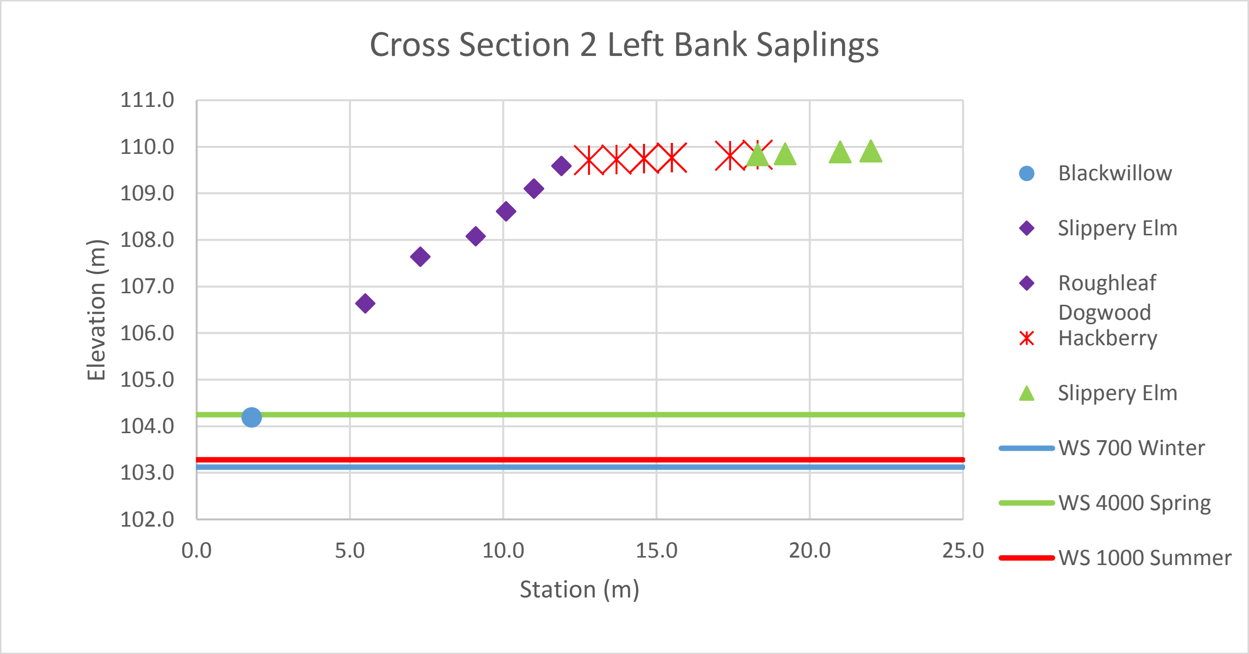


Figure 36. 080444 – Cross-section 2 – Left Bank – Saplings – Location along cross-section.

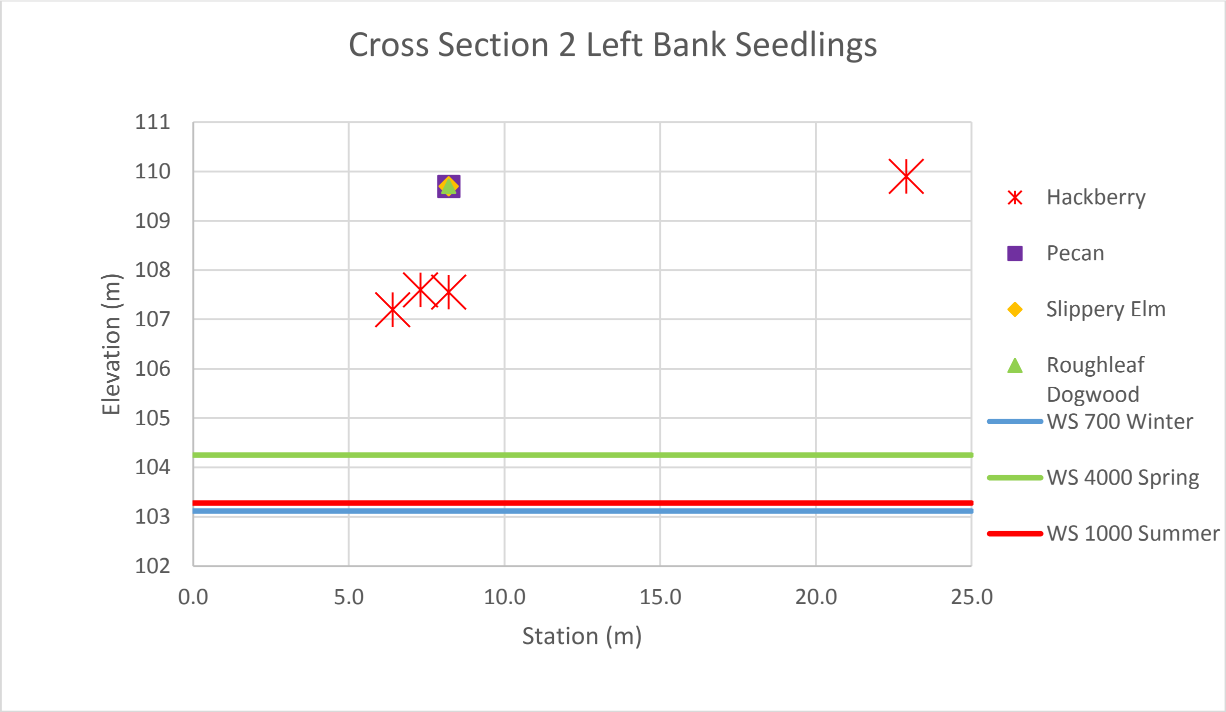


Figure 37. 080444 – Cross-section 2 – Left Bank – Seedlings – Location along cross-section.

Twelve woody species were identified on the right bank of Cross-section 2. The most common woody riparian species identified on the right bank were Green Ash (*Fraxinus pennsylvanica*), Winged sumac (*Rhus copallinum*), and Roughleaf Dogwood (*Cornus drummondii*).

Table 9. 080444 – Cross-section 2 right bank woody vegetation counts

Cross-section 2 Right Bank		
Common Name	**Scientific Name**	**Total Individuals**
Trees		
Hackberry	*Celtis laevigata*	2
Pecan	*Carya illinoinensis*	2
Boxelder	*Acer negundo*	4
Cottonwood	*Populus deltoides*	1
Green Ash	*Fraxinus pennsylvanica*	2
Roughleaf Dogwood	*Cornus drummondii*	2
Slippery Elm	*Ulmus rubra*	1
Sapplings		

Hackberry	*Celtis laevigata*	3
Winged Sumac	*Rhus copallinum*	12
Chinese Privet	*ligustrum spp.*	2
Decidous Holly	*Illex decidua*	2
Blackwillow	*Salix nigra*	2
Boxelder	*Acer negundo*	4
Roughleaf Dogwood	*Cornus drummondii*	13
Green Ash	*Fraxinus pennsylvanica*	8
Cedar Elm	*Ulmus crassifolia*	1
Slippery Elm	*Ulmus rubra*	9
Seedlings		
Cedar Elm	*Ulmus crassifolia*	3
Pecan	*Carya illinoinensis*	6

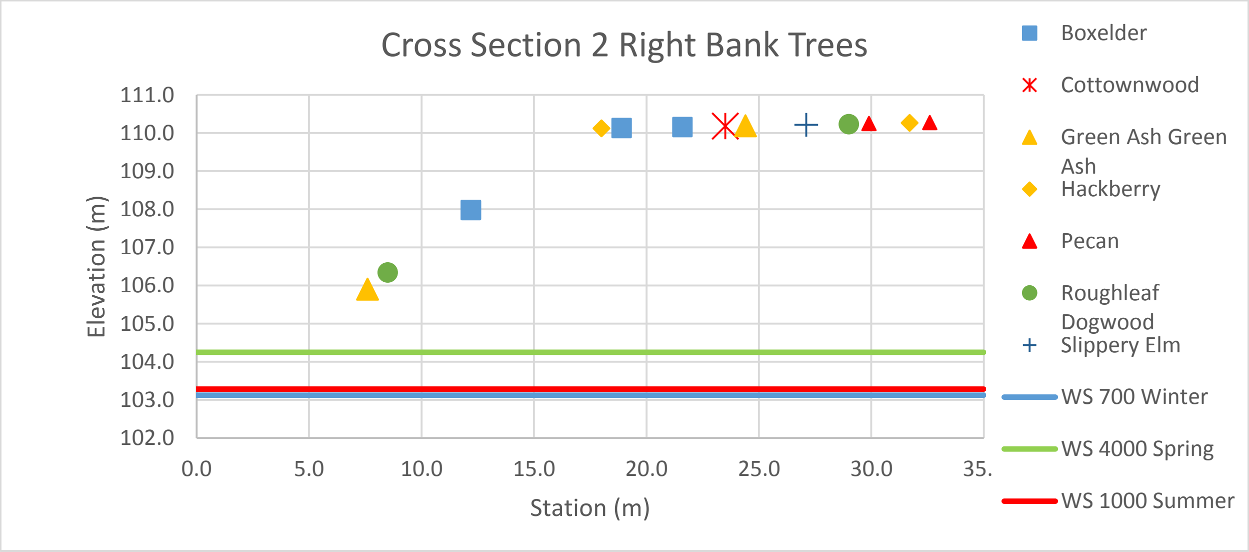


Figure 38. 080444 – Cross-section 2 – Right Bank – Trees – Location along cross-section.

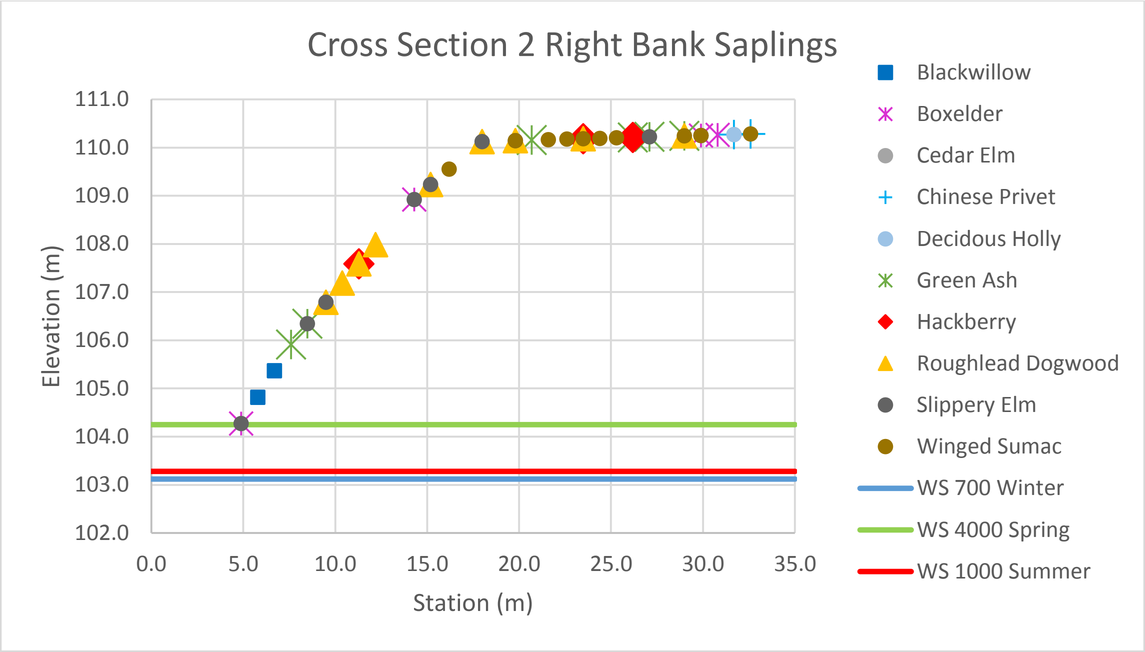


Figure 39. 080444 – Cross-section 2 – Right Bank – Saplings – Location along cross-section.

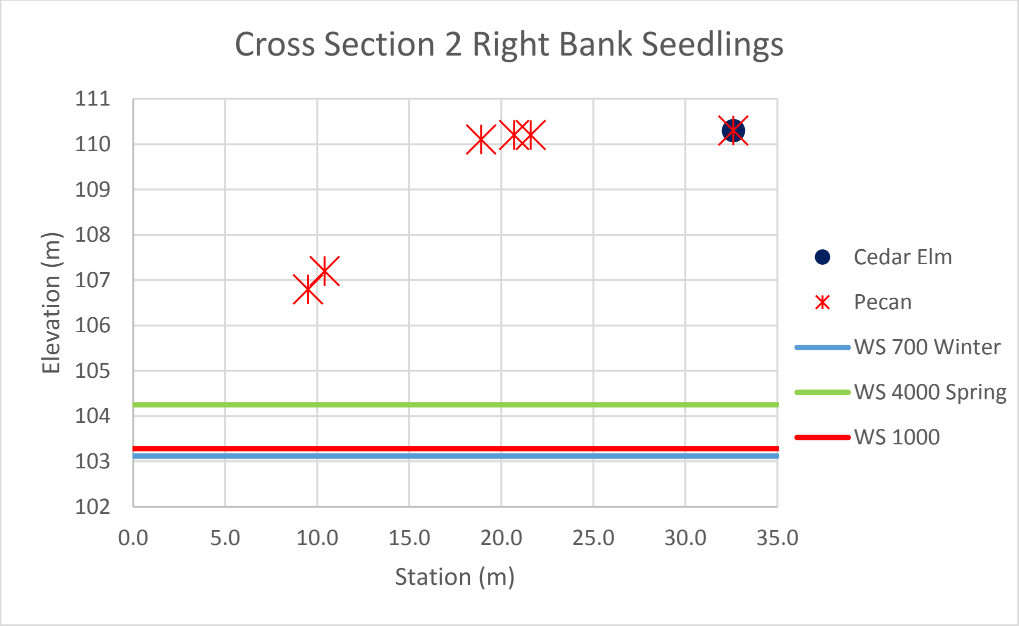


Figure 40. 080444 – Cross-section 2 – Right Bank – Seedlings – Location along cross-section.

3.6.2 080444 - Cross-section 4

Cross-section 4 is located downstream of a river meander bend. The river channel is steep along the left bank with observed bank failures and falling trees and more moderately steep on the right bank. There is also a back channel located on the right bank.

Eight woody species were identified on the left bank of Cross-section 4. The most common woody riparian species identified on the left bank were Southern Hackberry (*Celtis laevigata*), Cedar Elm (*Ulmus crassifolia*) and Roughleaf Dogwood (*Cornus drummondii*). Active erosional forces along the left bank could impact riparian vegetation by reducing the effectiveness of vegetation recruitment.

Table 10. 080444 – Cross-section 4 Left bank woody vegetation counts

Cross-section 4 Left Bank

Common Name	**Scientific Name**	**Total Individuals**
Trees		
Cedar Elm	*Ulmus crassifolia*	8
Hackberry	*Celtis laevigata*	8
Slippery Elm	*Ulmus rubra*	1
Osage Orange	*Maclura pomifera*	3
Green Ash	*Fraxinus pennsylvanica*	5
Pecan	*Carya illinoinensis*	1
Saplings		
Cedar Elm	*Ulmus crassifolia*	3
Hackberry	*Celtis laevigata*	1
Roughleaf Dogwood	*Cornus drummondii*	40
Eastern Red Cedar	*Juniperus virginiana*	2
Pecan	*Carya illinoinensis*	2
Seedlings		
Hackberry	*Celtis laevigata*	4

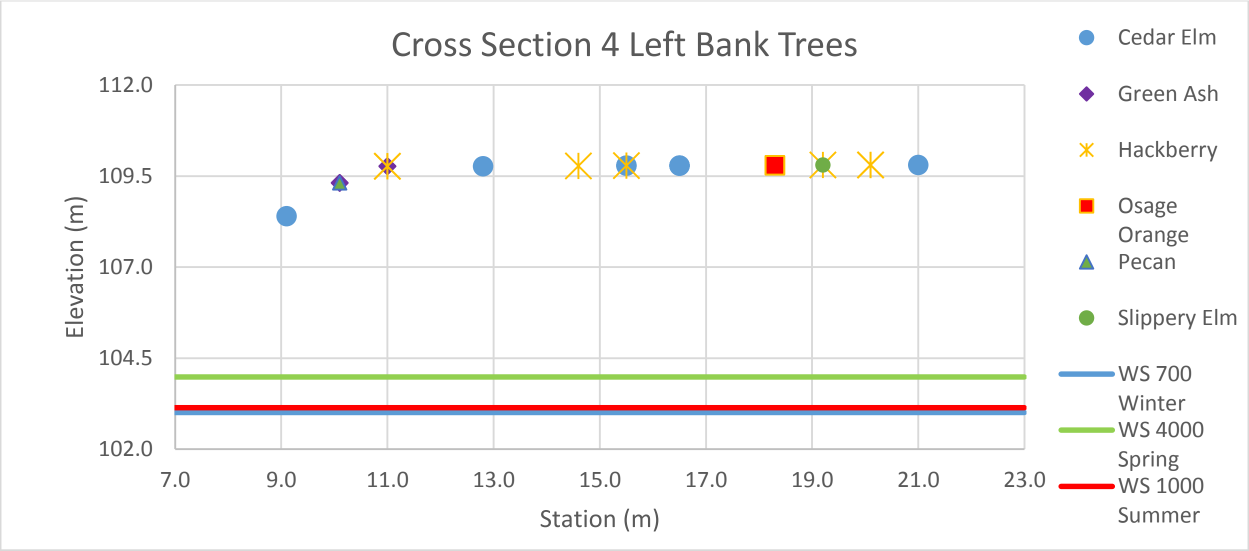


Figure 41. 080444 – Cross-section 4 – Left Bank – Trees – Location along cross-section.

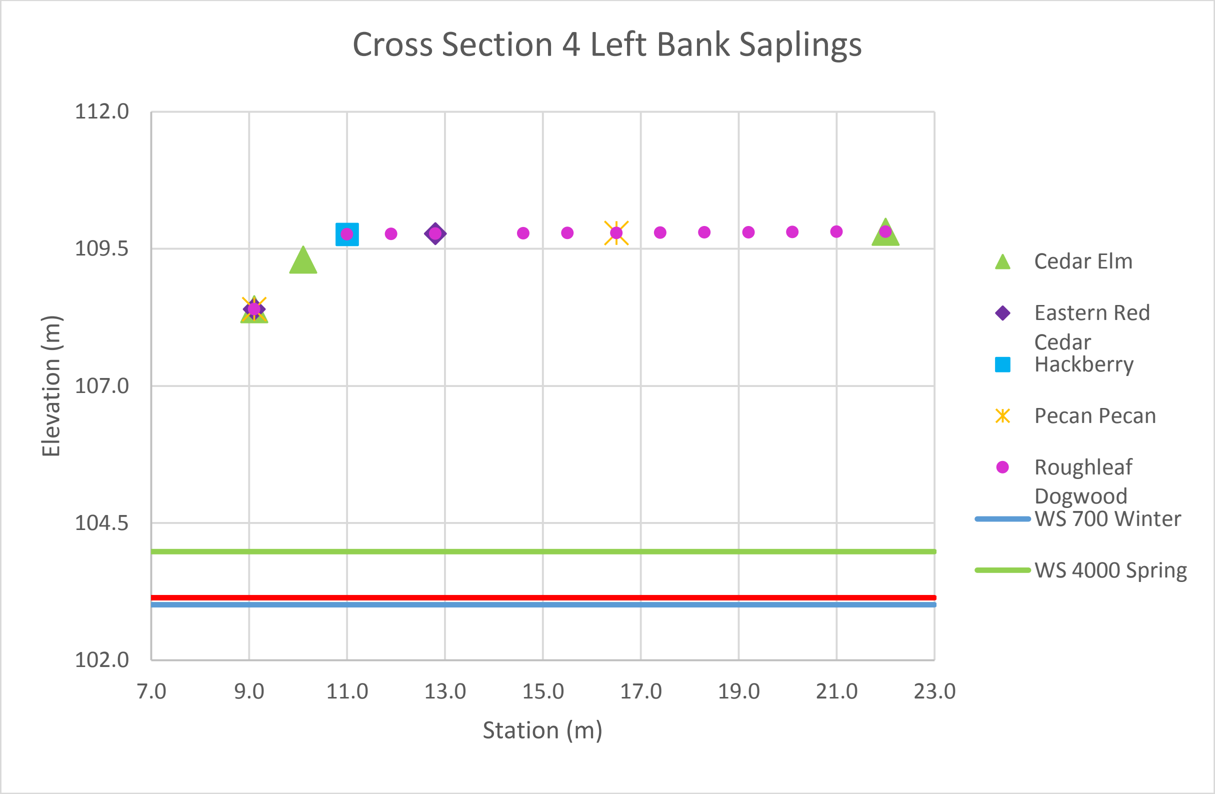


Figure 42. 080444 – Cross-section 4 – Left Bank – Seedlings – Location along cross-section.

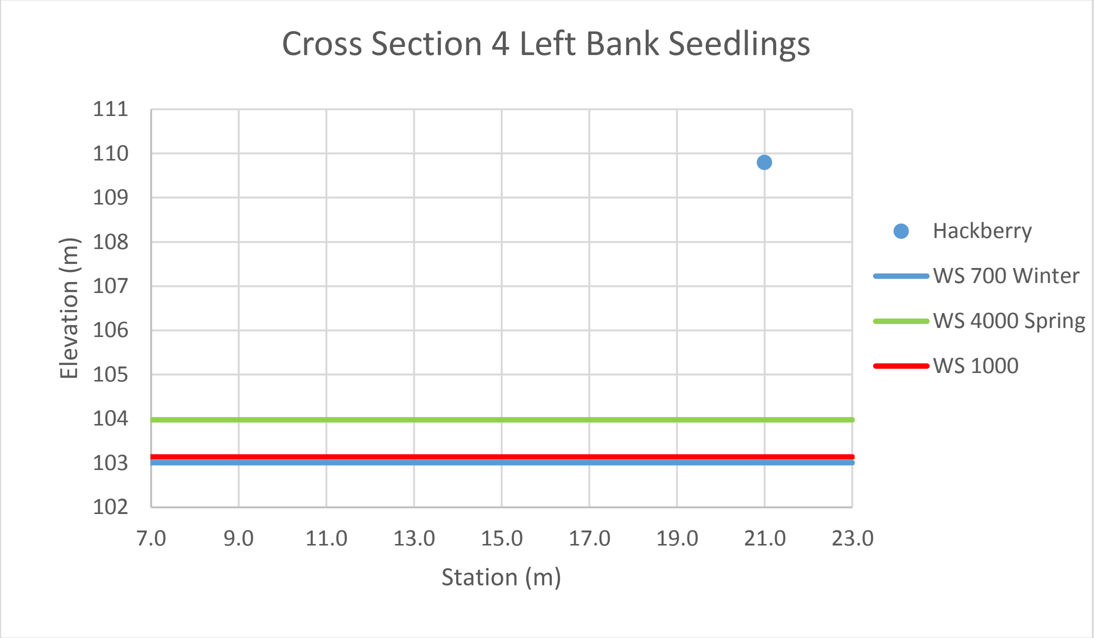


Figure 43. 080444 – Cross-section 4 – Left Bank – Seedlings – Location along cross-section.

Eight woody species were identified on right bank of Cross-section 4. The most common woody riparian species identified on the right bank were Southern Hackberry (*Celtis laevigata*), Slippery Elm (*Ulmus rubra*), and Boxelder (*Acer negundo*).

Table 11. 080444 – Cross-section 4 right bank woody vegetation counts

Cross-section 4 Right Bank

Common Name	**Scientific Name**	**Total Individuals**
Trees		
Hackberry	*Celtis laevigata*	7
Willowoak	*Quercus phellos*	1
Boxelder	*Acer negundo*	15
Blackwillow	*Salix nigra*	2
Slippery elm	*Ulmus rubra*	5
Saplings		
Hackberry	*Celtis laevigata*	11
Winged Sumac	*Rhus copallinum*	15
Boxelder	*Acer negundo*	4

Roughleaf Dogwood	*Cornus drummondii*	5
Green Ash	*Fraxinus pennsylvanica*	1
Slippery Elm	*Ulmus rubra*	39
Seedlings		
Hackberry	*Celtis laevigata*	5
Green Ash	*Fraxinus pennsylvanica*	1

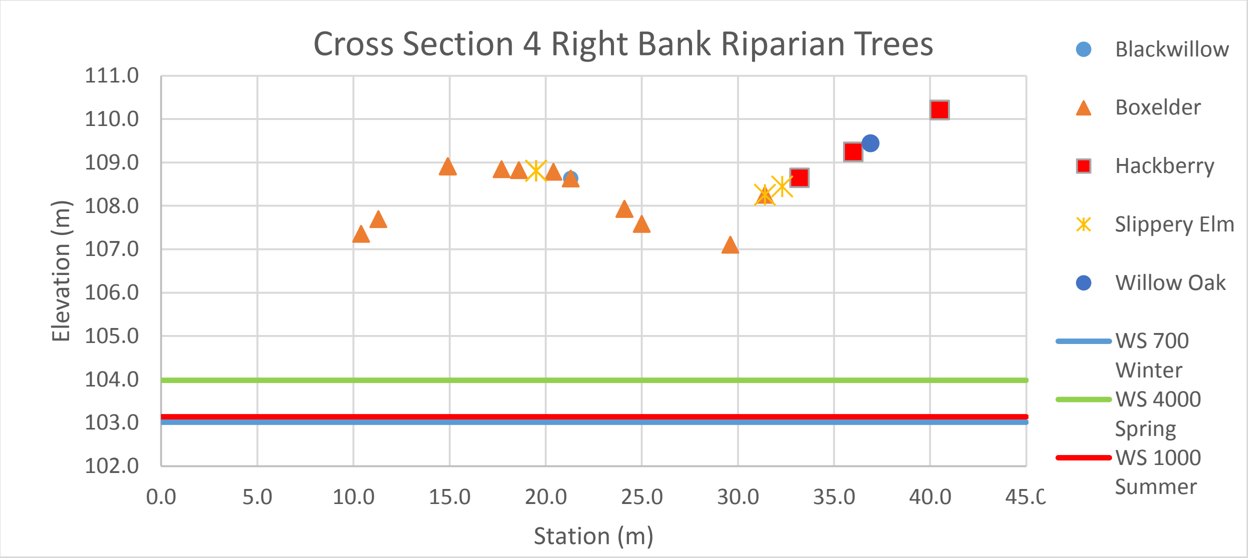


Figure 44. 080444 – Cross-section 4 – Right Bank – Trees – Location along cross-section.

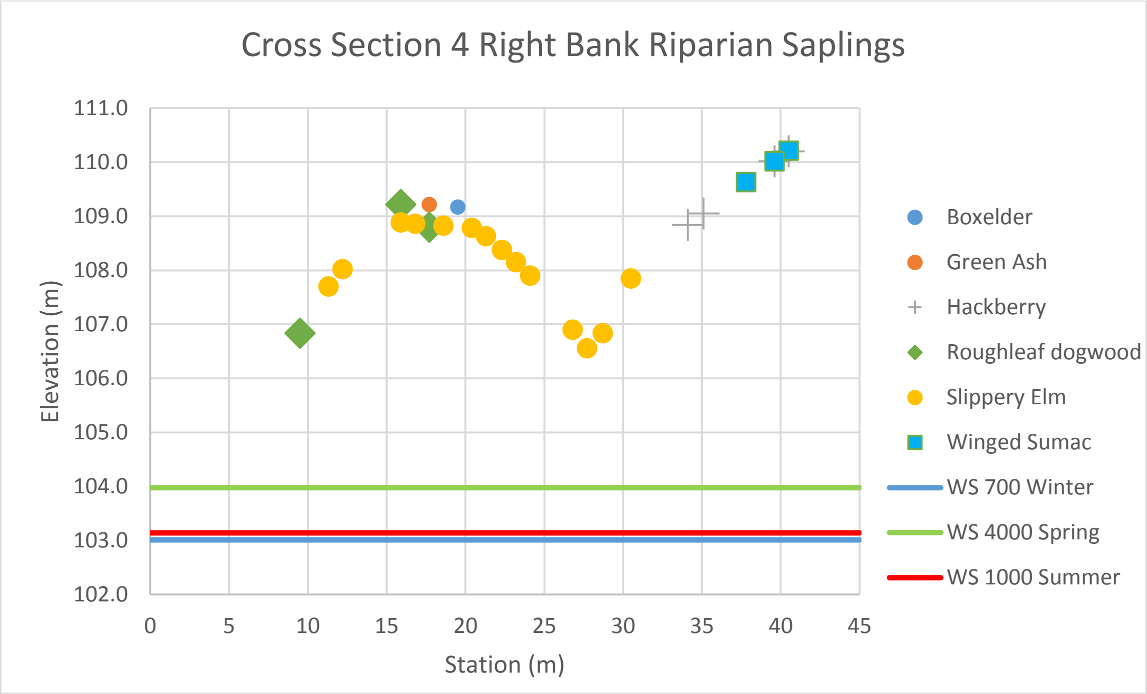


Figure 45. 080444 – Cross-section 4 – Right Bank – Saplings – Location along cross-section.

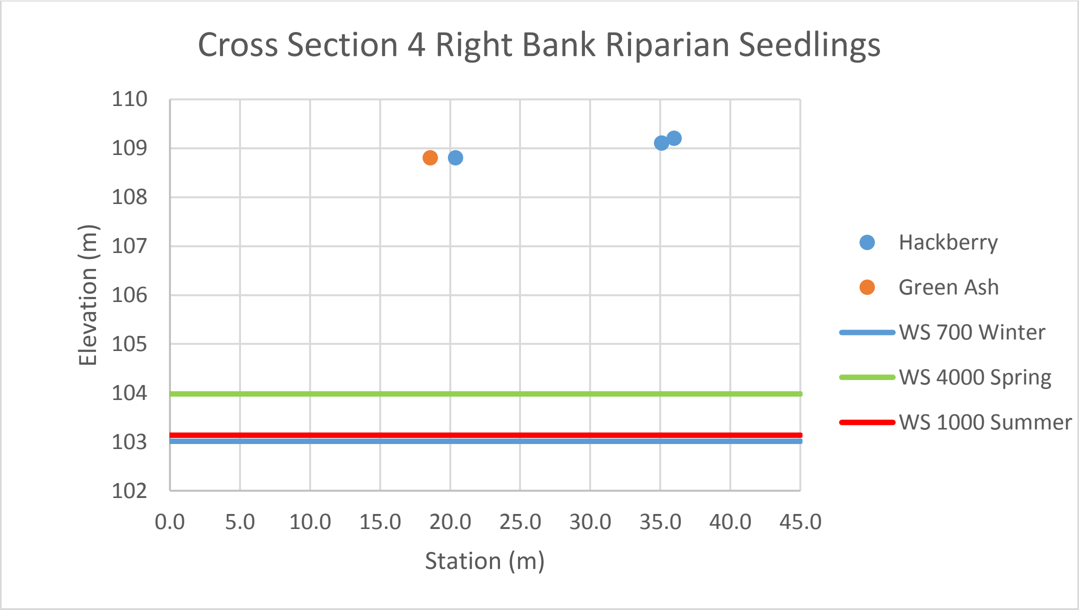


Figure 46. 080444 – Cross-section 4 – Right Bank – Seedlings – Location along cross-section.

3.6.3 Riparian area cross-section photos

Figure 47. 080444 - Cross-section 2 at 557 cfs 2014-8-11.

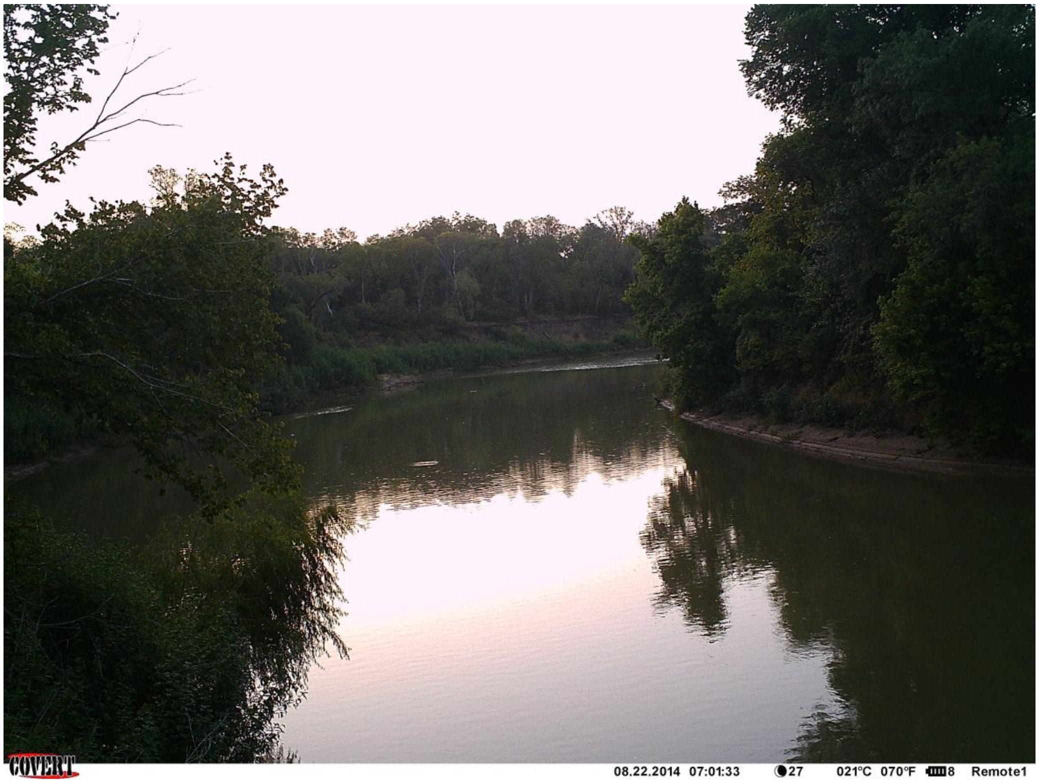


Figure 48. 080444 - Cross-section 2 at 700 cfs 2014-8-22.

Figure 49. 080444 - Cross-section 2 at 1150 cfs 2014-8-19.

Figure 50. 080444 – Cross-section 2 at 4150 cfs 2014-8-17.

Figure 51. 080444 - Cross-section 2 at 6300 cfs 2014-8-18.

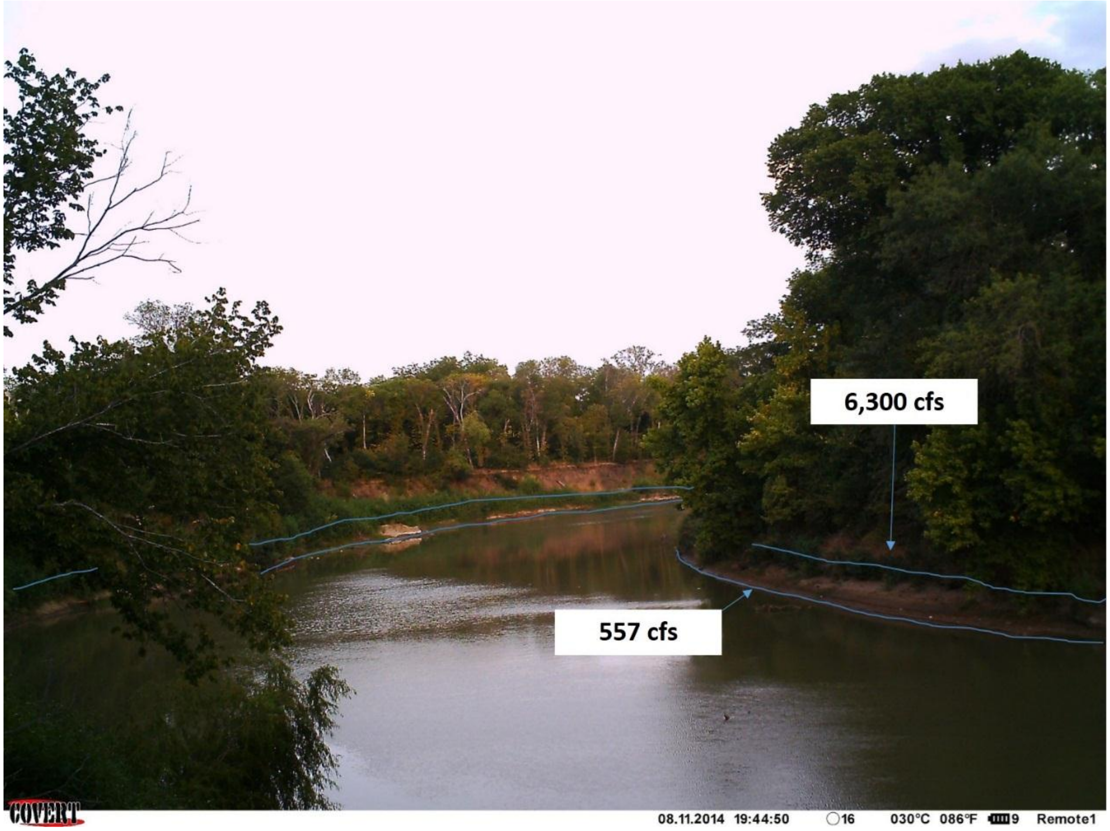


Figure 52. 080444 Game Camera Comparison between the waterline at 557 cfs and 6,300 cfs.

3.6.4 Riparian Discussion

The overall ecological goal of a regulated flow regime is to protect both the natural physical processes of a river and the biological communities which depend on such processes. Riparian areas are directly connected to a river via the water table (normal flows) and surface water inundation (high flows) (Duke, 2011) (Winward, 2000) (Trinity, San Jacinto, and Glaveston BBEST, 2009). Therefore, riparian areas offer an opportunity to establish long-term monitoring of riparian vegetation and its changes under different flows. All major life stages of woody riparian vegetation (seedlings, saplings and trees) were studied to help identify what these changes might be.

Within the boundaries of this site, adopted flow levels do not appear to provide substantial inundation to the riparian community on an annual basis. Only water surface elevations associated with the highest SB3 pulse trigger flow rates (Spring, 4000 cfs) may provide some inundation of the sapling riparian community (Figure 36). Inundation connection of these flows is limited to three species of the riparian community (Black Willow, Boxelder and Slippery Elm) that typically inhabit areas nearest the water's edge. Older trees were typically located over 8 feet higher in elevation than the 4,000 cfs flow level. It is important to note that this reach is leveed on both sides, which is common in the upper Trinity River basin.

The adopted flow standards trigger levels correspond most to the hydrophilic species. Lack of inundation connectivity with other mesic species (e.g. Pecan, Oak, and Ash) can limit riparian recruitment by limiting seed dispersal and nutrient recycling. Many of the riparian woody species provide nutritional benefits to the biological communities that inhabit these areas as well as provide shelter (Winward, 2000) (Duke, 2011) (TPWD).

The complexity of riparian community health and its relationship with the river's flow regime make it difficult to recommend specific flow regimes when this relationship is not fully understood. The riparian dataset developed as part of this project represents a baseline riparian dataset that can inform on future river management and water policy.

3.7 080444 - Overbanking

During the June 2015 field efforts, high flows were observed within the left bank of the river channel; however, flood waters dispersed laterally along the right bank and connected with the floodplain within the levees. There was evidence of water flow above the left bank (i.e. small wet pools and flood debris). Water surface elevations were still elevated enough to completely submerge the lock structure at this site.

After flooding, sediment data were collected from on top of the benchmarks at this site. One benchmark in a low area was still submerged, though no longer connected to the river, and others had between 0.02 – 0.35 ft. of fine sand, silt, and clay deposition on top of the benchmark survey caps (Figure 53).

Moving bed is an important aspect of sediment transport. At high flows, rivers typically scour and clean the pools and build the riffles. To get an idea of the moving bed at high flows at 080444, the experimental bed movement method was employed where the M9 was tethered with rope across the channel. The data showed the M9 moving upstream 135 linear feet in 23 minutes and 47 seconds at 25,198 cfs (Figure 54). This movement upstream indicates that the bed load is mobile since the instrument bottom tracking function is "tricked" into thinking it is moving as it maps the bottom of the channel.

Figure 53. TRA staff collection sand and clay from on top of benchmark at 080444 Cross-section 4, left bank.

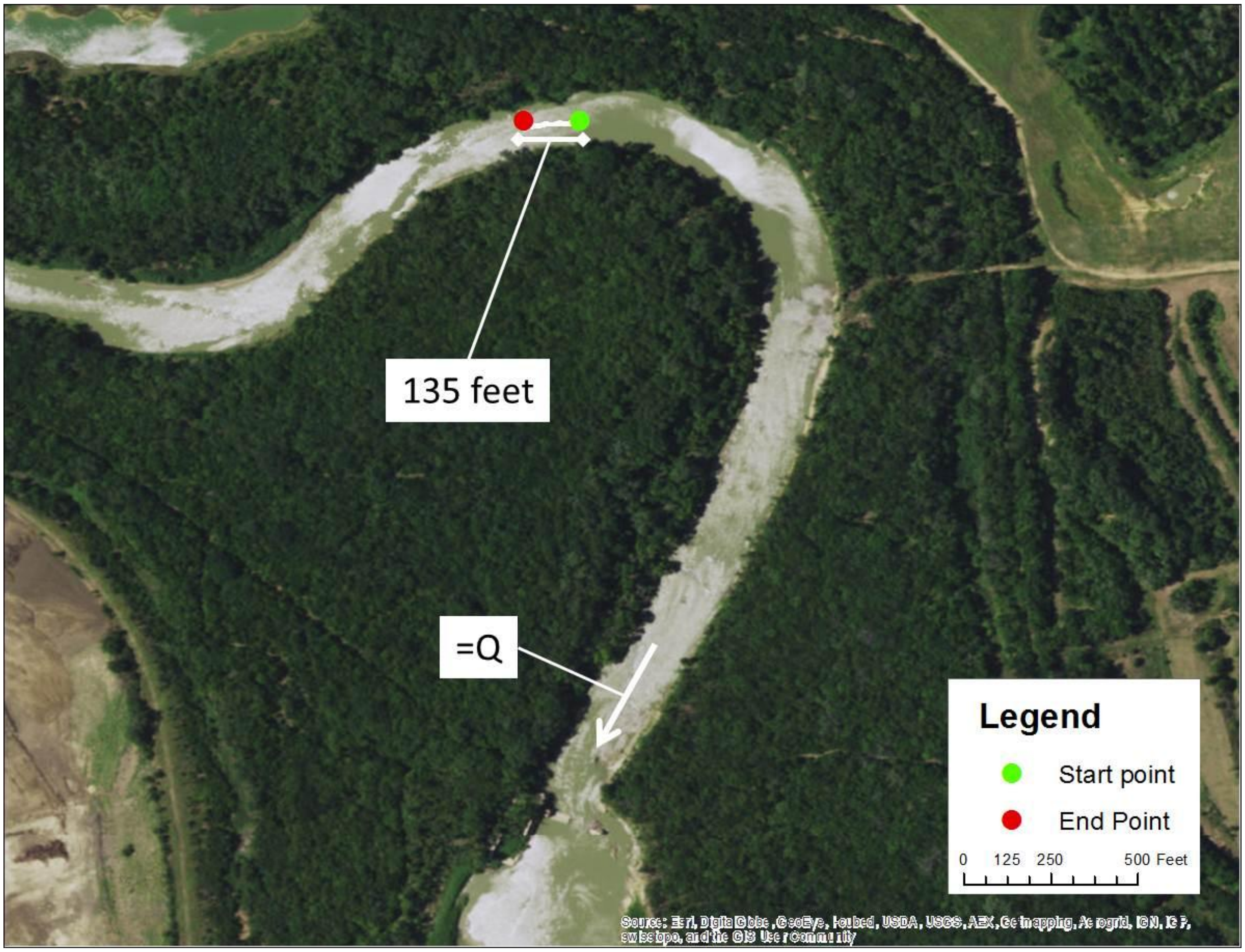
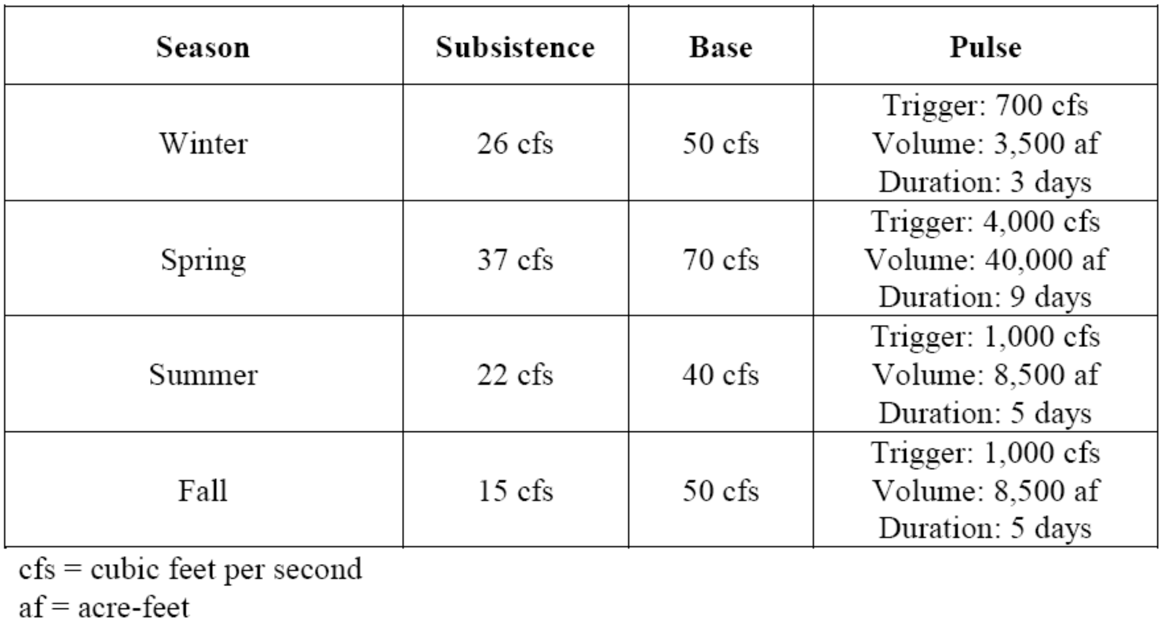


Figure 54. Map showing the M9 moving upstream 135 linear feet in 23 minutes and 47 seconds during a high flow event (25,198 cfs). This movement upstream indicates that the bed load is mobile at this site during high flows.

3.8 080444 - Site summary

080444 was the only site which benefitted from riparian tree, sapling, and seeding data collection.

This site is designed to be a surrogate site to the SB3 measurement point located at the USGS gage Trinity River at Dallas. The Dallas gage is located directly in the Dallas Floodway and the channel is constantly maintained to prevent flooding in downtown and south Dallas. The SB3 flows associated with this measurement point are shown in Figure 55.



Season	Subsistence	Base	Pulse
Winter	26 cfs	50 cfs	Trigger: 700 cfs Volume: 3,500 af Duration: 3 days
Spring	37 cfs	70 cfs	Trigger: 4,000 cfs Volume: 40,000 af Duration: 9 days
Summer	22 cfs	40 cfs	Trigger: 1,000 cfs Volume: 8,500 af Duration: 5 days
Fall	15 cfs	50 cfs	Trigger: 1,000 cfs Volume: 8,500 af Duration: 5 days

cfs = cubic feet per second
af = acre-feet

Figure 55. SB3 flow standards at the measurement point Trinity River at Dallas.

3.9 080444 - Site Next Steps

It is important to understand the effects of the lock failure at this site and follow-up monitoring is essential to both monitor the site and prepare, if needed, for the eventual failure of the four additional relic locks on Trinity River mainstem. These structures built in the middle 19-teens provide grade control points through the middle and upper Trinity River basin. Upon a failure, the channel will adjust its slope as quickly as possible and could cause excessive widening and over-steepening of banks. Additionally, head cuts could further change the slope and river morphology in the area which can damage infrastructure like bridges or roads and can create detrimental impacts to water quality and instream habitat availability.

4 Site 080295 – SB3 Trinity River near Oakwood measurement point

4.1 080295 - Site description

This representative site on the Trinity River is located approximately four river miles upstream of USGS gage 08065000 - Trinity River near Oakwood which is a TCEQ SB3 measurement point. The site is located near the confluence with Keechi Creek (also known as Long Creek). The upstream end is within the Big Lake Bottom WMP. Riparian areas are intact on both banks, with large tracts of adjacent forest (Figure 56). Near the channel, the condition of willows indicates recent channel change; willows on a lower terrace near the upstream cross-section lean over toward side channels indicating historical widening. The downstream end of the site is at the creek confluence, where there is also a large riffle at a shale outcrop.

A significant amount of data has been measured at this site as part of the TRA Long Term study, as reported in TRA and RPS Espey 2013, and this site is coincident with a SB2 TIFP instream flow study site.

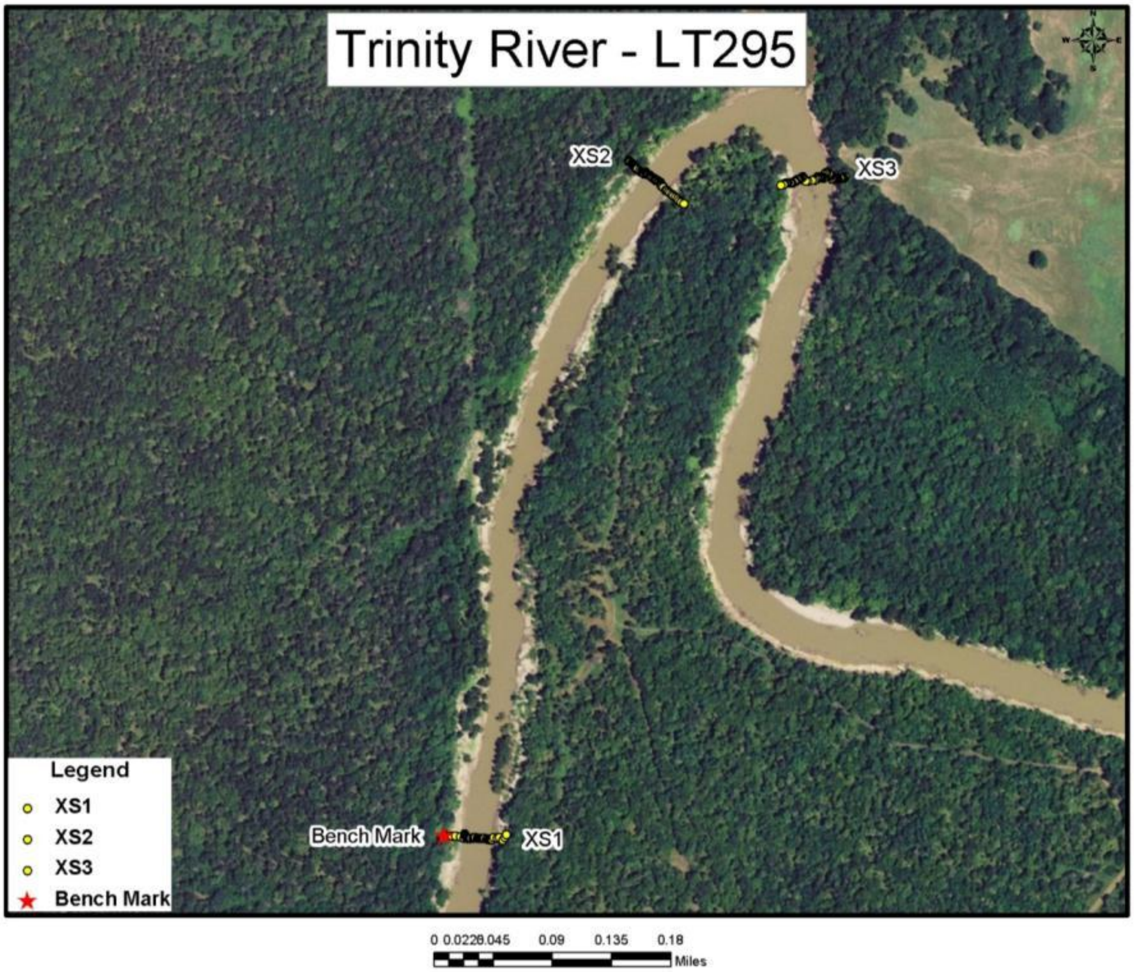


Figure 56. 080295 – Oakwood/Keechi Creek Site (Segment C3) (TRA and RPS Espey 2013).

4.2 080295 - Cross-section comparisons

Repeat measurements of Trinity River cross-sections at the 080295 site allow for identification of differences between survey results.

4.2.1 In-channel comparison at base flow

High-resolution, on-site cross-sectional surveys were conducted in 2012 at 815 cfs using at total station for exposed bank areas and an echosounder for submerged areas. During the overbank event in June 2015, an echosounder was used to survey each cross-section since the cross-sections were completely inundated. Based upon positioning provided by survey-grade RTK GPS equipment used to characterize data for both sampling events, observed differences were less than 10 feet in cross-sectional movement in the horizontal and less than two feet in the vertical.

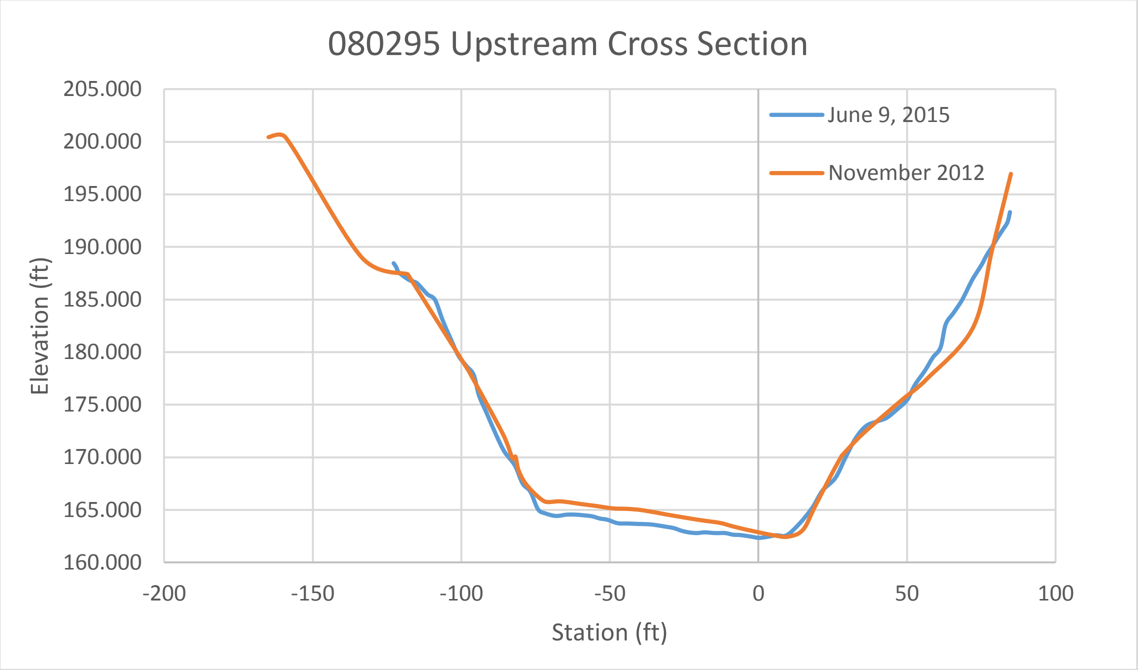


Figure 57. 080295 upstream (xs1) cross-section comparison (elevations in feet above NAVD88).

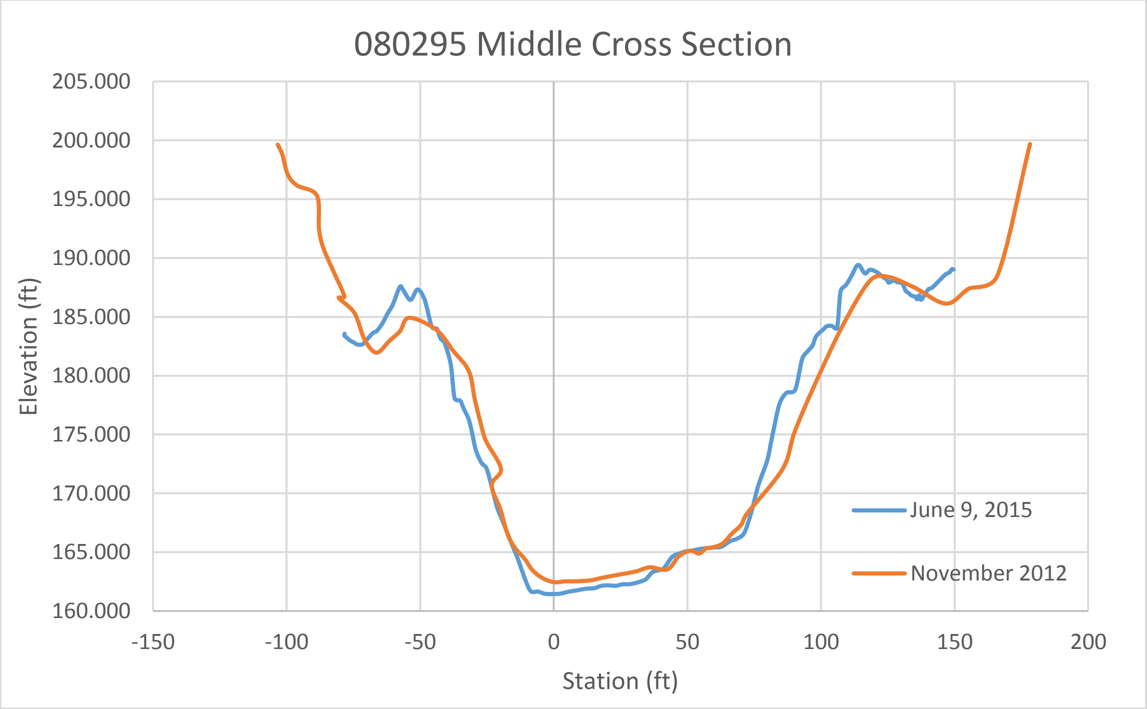


Figure 58. 080295 middle (xs2) cross-section comparison (elevations in feet above NAVD88).

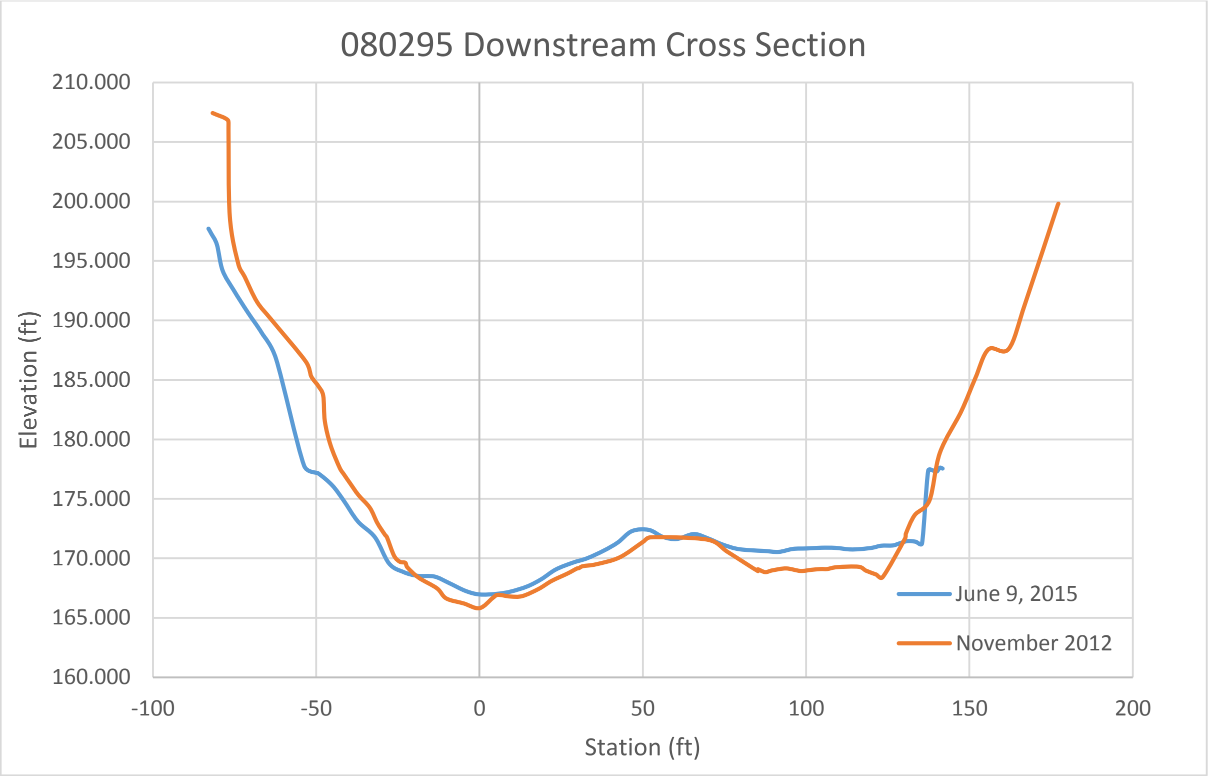


Figure 59. 080295 (xs3) downstream cross-section comparison (elevations in feet above NAVD88).

4.2.2 Valley comparison between low-resolution DEM and high-resolution 2014 LiDAR

To develop the 2013 HEC-RAS model at this site (TRA and RPS Espey 2013), USGS DEM (digital elevation model) digital terrain models were used to characterize the overbank terrain. Comparison of that DEM surface along cross-sections to the new 2014 LiDAR data collected as part of this project reveals significant differences in ground level. In many locations, the new 2014 LiDAR is four to five feet higher than the DEM dataset (e.g., station 7000 in Figure 60, station 2000 in Figure 61), although is also lower by three to four feet in other areas (station -3000 in Figure 62). The new 2014 LiDAR data shows reasonable correspondence to on-the-ground survey data in bare ground areas; highly vegetated areas away from the river channel were not verified.

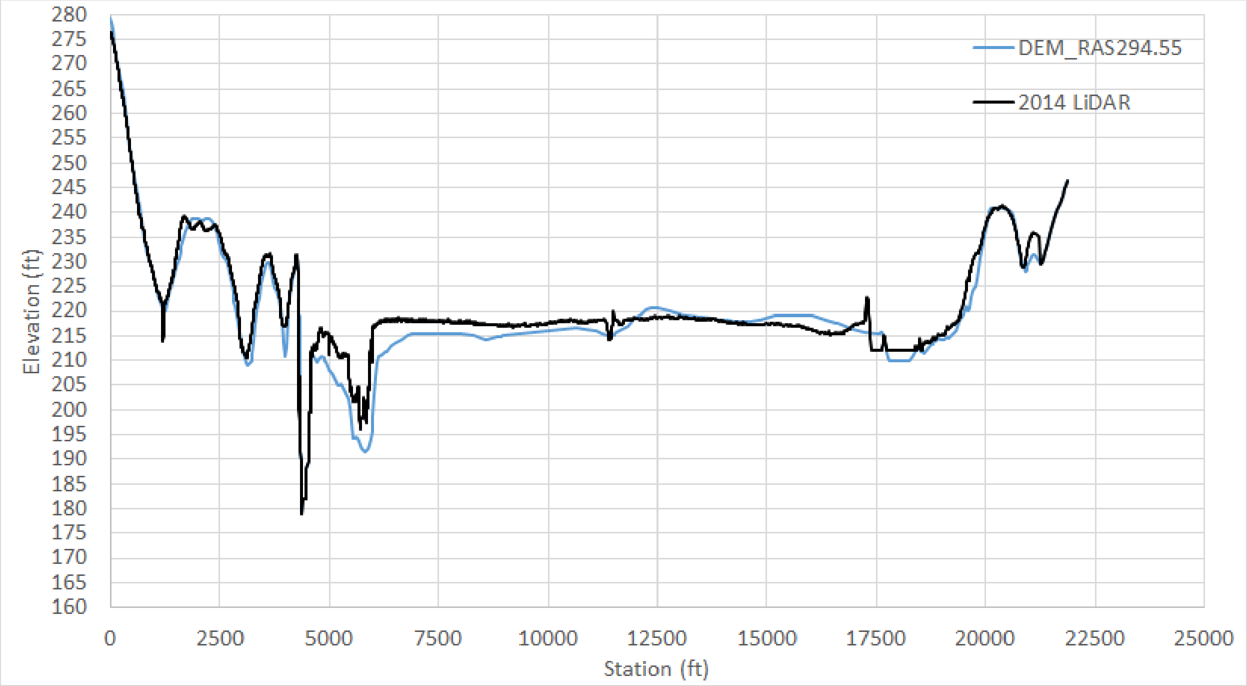


Figure 60. 080295 (xs3) downstream cross-section comparison.

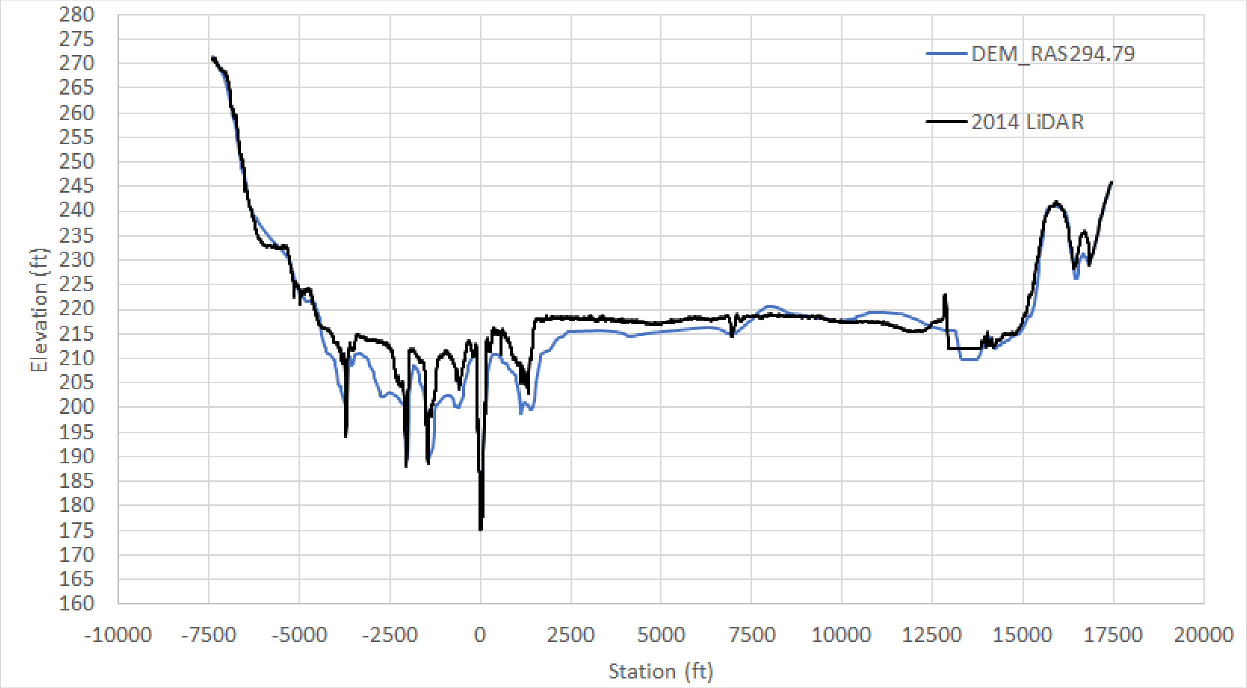


Figure 61. 080295 (xs2) middle cross-section comparison.

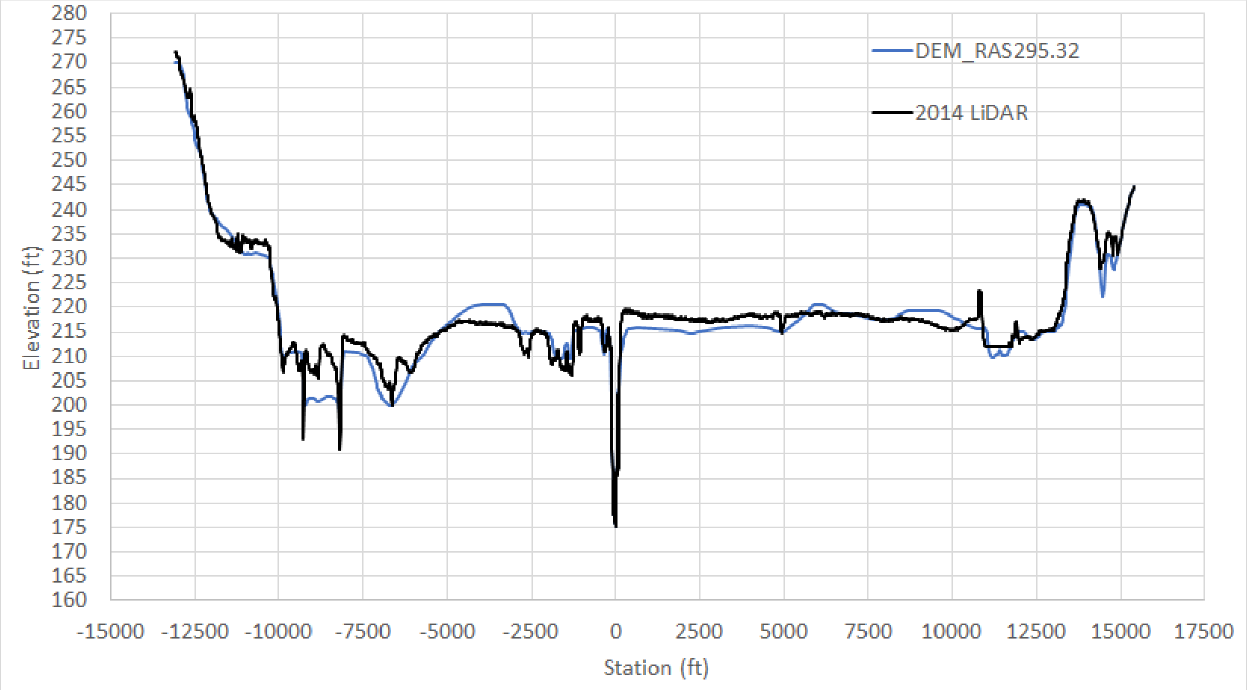


Figure 62. 080295 (xs1) upstream cross-section comparison.

4.3 080295 - Water surface profiles and inundation mapping

4.3.1 Data sources

The primary existing data used to develop the HEC-RAS water surface profile models are summarized in Table 12 , as updated from TRA and RPS Espey 2013.

Table 12. 080295 HEC-RAS cross-section elevation data sources

River Mile	Overbank data	In-channel data	Notes
289.04	10m DEM	2011 M9 xsec + 2011 WSP	Downstream boundary condition from adjusted Oakwood rating curve
291.16	10m DEM	2011 M9 xsec + 2013 WSP	Just upstream of USGS Oakwood gage
293.13	2014 LiDAR	2011 M9 xsec + 2013 WSP	
293.59	2014 LiDAR	Inferred in-channel to match observed WSP	
293.73	2014 LiDAR	Inferred in-channel to match observed WSP	Riffle downstream from 080295
293.905*	*interpolated 293.73-294.43 to match water surface profile		
294.08*			
294.255*			

294.43	2014 LiDAR	Inferred in-channel to match observed WSP	
294.55	2014 LiDAR	2012 VX survey + M9 + WSP	080295 XS3 - The main riffle
294.79	2014 LiDAR	2012 VX survey + M9 + WSP	080295 XS2
295.15	2014 LiDAR	2011 M9 xsec + 2013 WSP	
295.32	2014 LiDAR	2012 level survey + M9 + WSP	080295 XS1 - Onsite benchmark
297.04	2014 LiDAR	2011 M9 xsec + 2013 WSP	

4.3.2 Model development

Development of the 080295 site HEC-RAS model (Figure 63) is documented in TRA and RPS Espey 2013. The overbank portions of the model were updated using the new 2014 LiDAR data.

Elevations across each section were assigned by combining floodplain geospatial elevation data (e.g., the new 2014 LiDAR data) with low-flow on-site survey data (Figure 64).

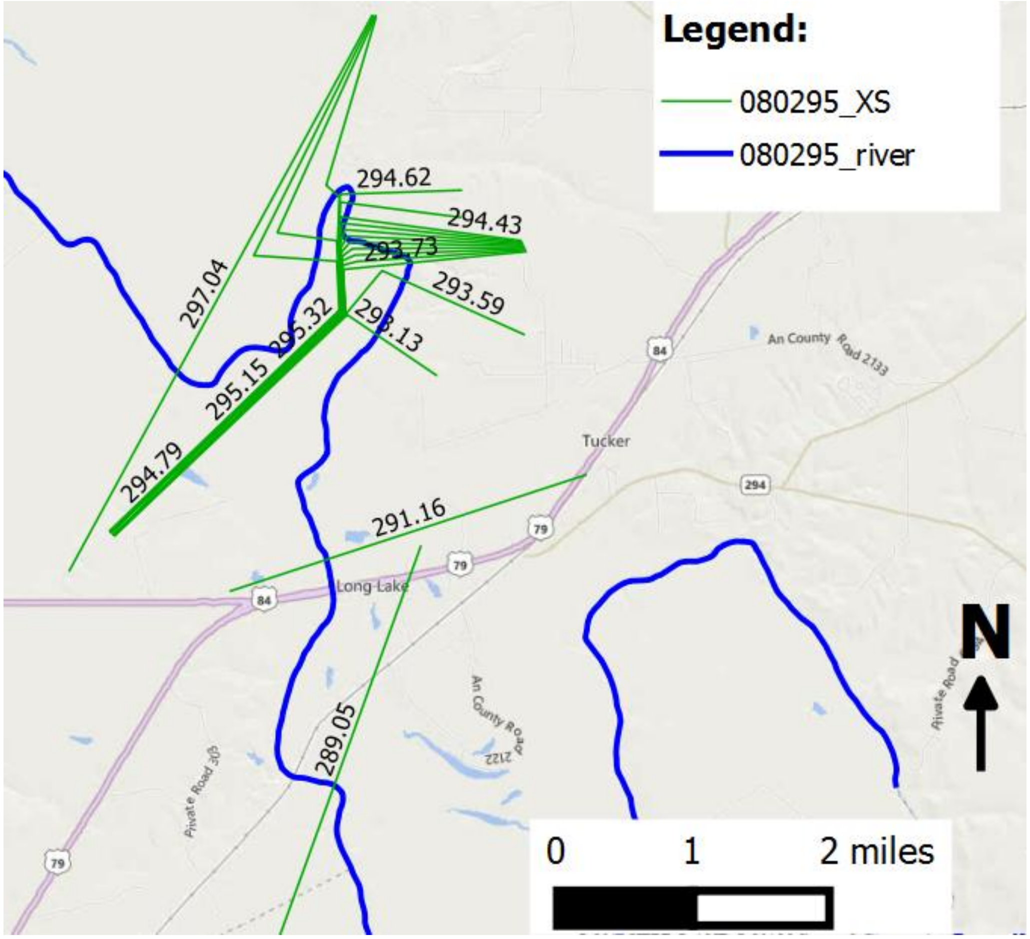
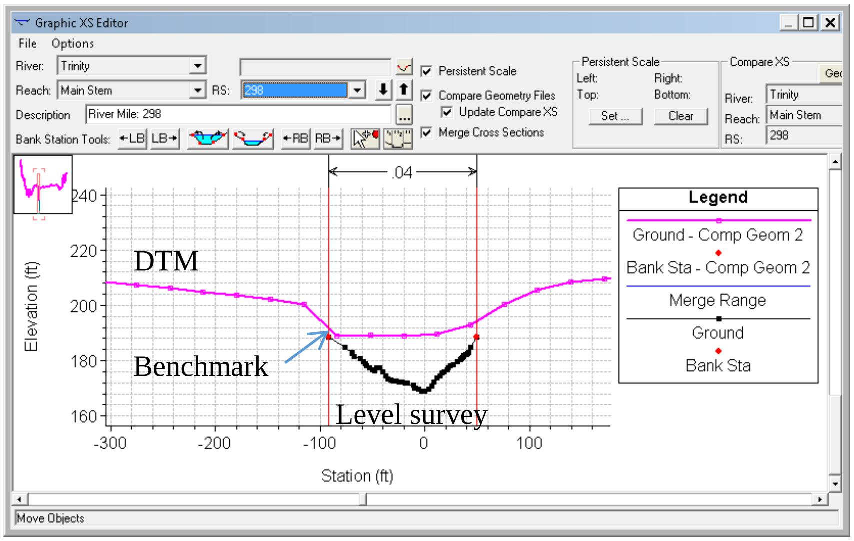


Figure 63. 080295 HEC-RAS cross-section locations upstream of the USGS Oakwood gage (at SH 79/84).



River: Trinity
Reach: Main Stem
RS: 298
Description: River Mile: 298
☑ Persistent Scale
☑ Compare Geometry Files
☑ Update Compare XS
☑ Merge Cross Sections
Left:
Right:
Top:
Bottom:
River: Trinity
Reach: Main Stem
RS: 298

Figure 64. 080295 XS1 - Merging DTM and survey cross-sections

4.3.3 Calibration

The 080295 HECRAS model was calibrated based upon available water surface profile observation data at 668 cfs and 2,670 cfs (TRA and RPS Espey 2013). While the new cross-sections affected higher flow events, the existing calibration did not significantly impact calibration of base or lower pulse flows (Figure 65).

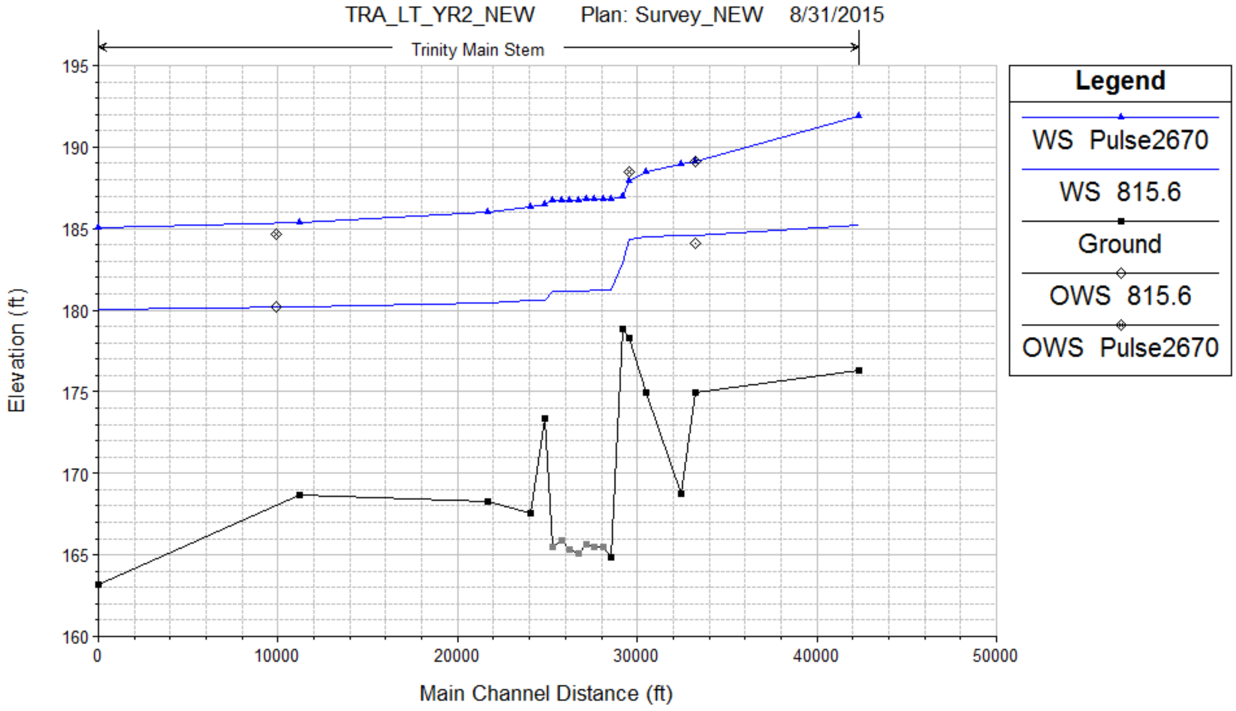


Figure 65. 080295 – HEC-RAS water surface profile plot for calibration flows (diamonds are observed water surface).

4.3.4 HEC-RAS Water Surface Profile Results

A series of steady-state flow rates were modeled as part of this project, ranging from low-flow (668 cfs) to highest recorded flow (106,000 cfs at Oakwood) (Figure 66). Water levels from each of the three study-site cross-sections are presented in Figure 67, Figure 68, and Figure 69.

Table 13. Table 12. 080295 - HEC-RAS modeled steady-state flows.

Flow Rate (cfs)	**Description**
668	Observed WSP August 2013
815	Observed WSP September 2013
1,250	Typical recent high baseflow
2,500	SB3 Summer/Fall pulse trigger flow standard at USGS Oakwood
2,670	Observed peak from PT data August 2013
3,000	SB3 Winter pulse trigger flow standard at USGS Oakwood
5,000	
6,180	Oakwood pulse 10/03/2012
7,000	SB3 Spring pulse trigger flow standard at USGS Oakwood
10,000	
11,800	Crockett pulse 09/30/2012
16,500	Typical (1/season) recent Jan-Jun pulse
21,000	Typical (1/season) recent Jul-Dec pulse
30,000	
40,000	
49,900	Oakwood flood peak 10/31/2010
71,600	Oakwood flood peak 07/10/2007
106,000	Oakwood flood peak 12/24/1991 (maximum 107,000 cfs 05/07/1990)

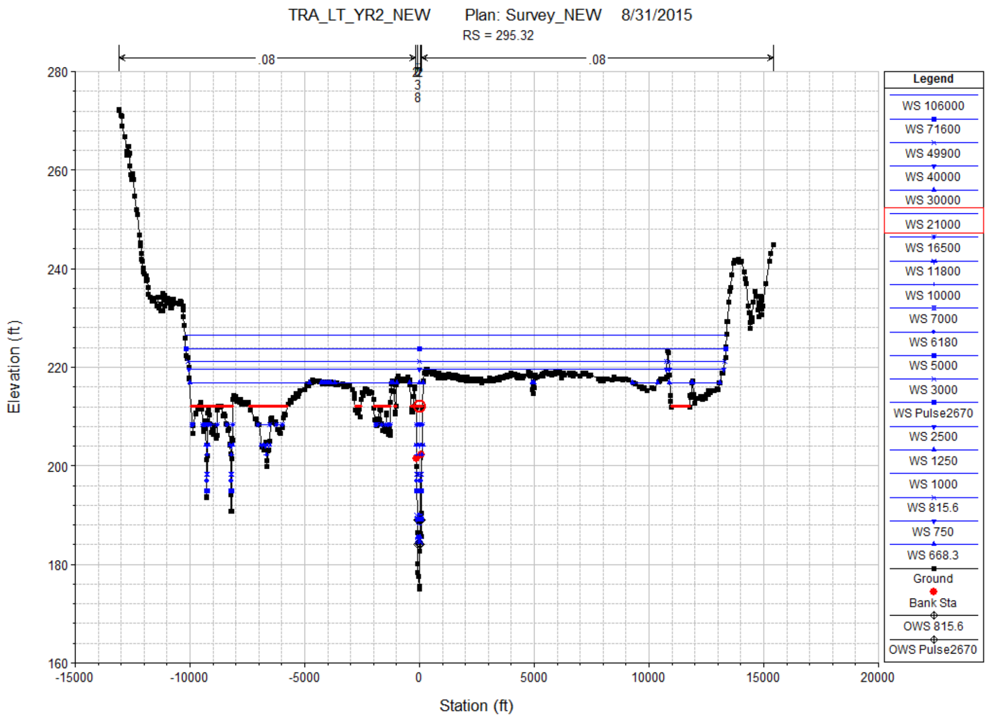


Figure 66. 080295 XS1 - Upstream benchmark cross-section floodplain

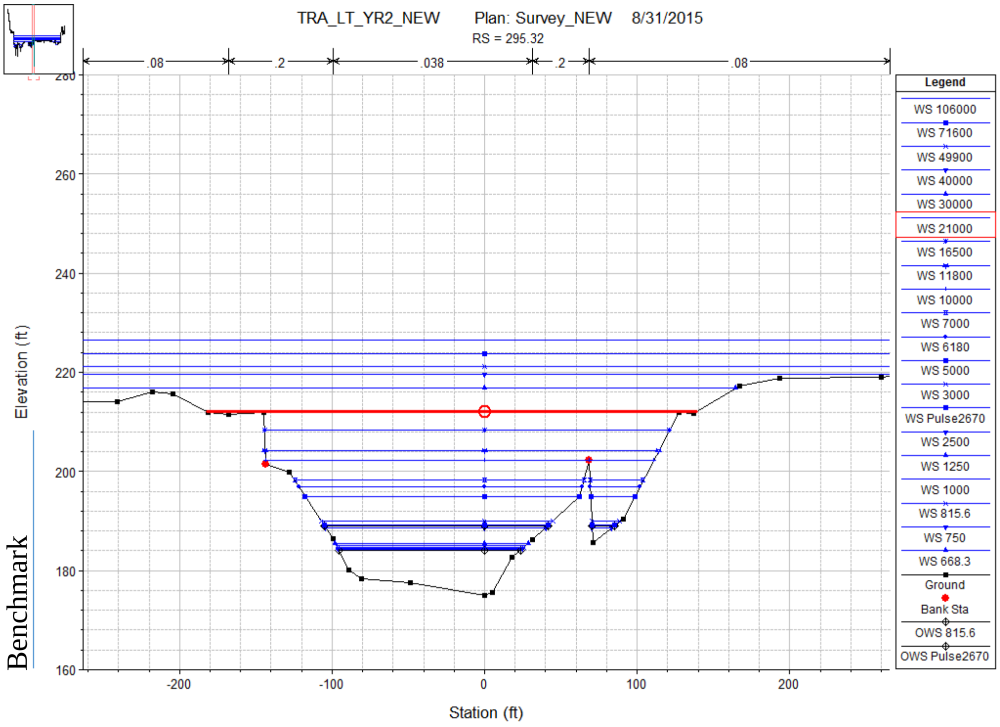


Figure 67. 080295 XS1 - Upstream benchmark cross-section near-channel

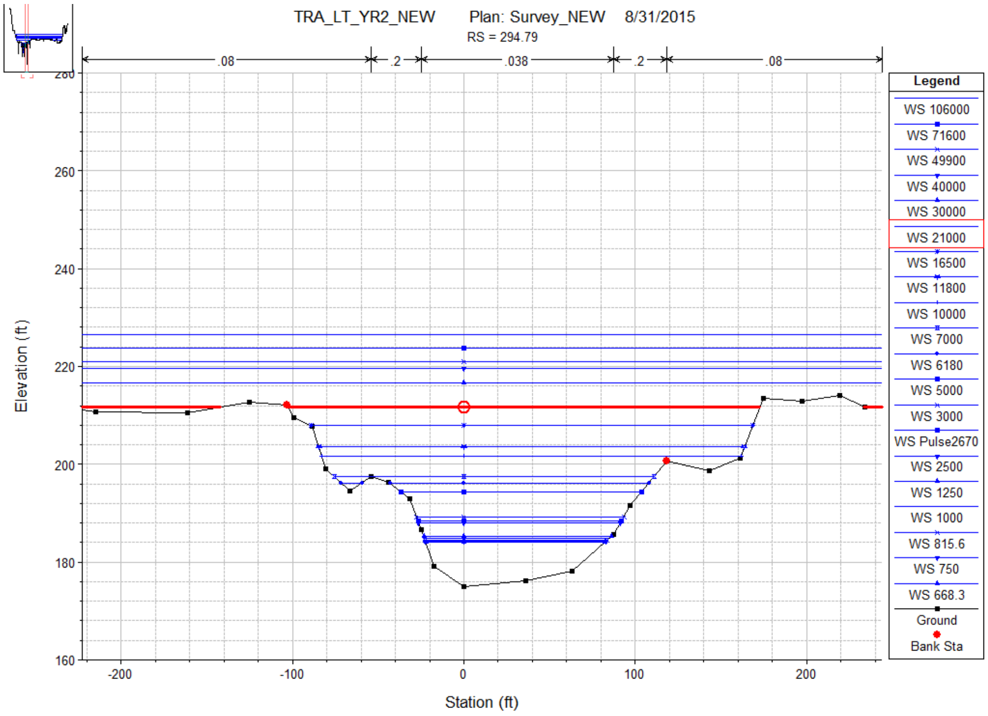


Figure 68. 080295 XS2 - Middle cross-section near-channel

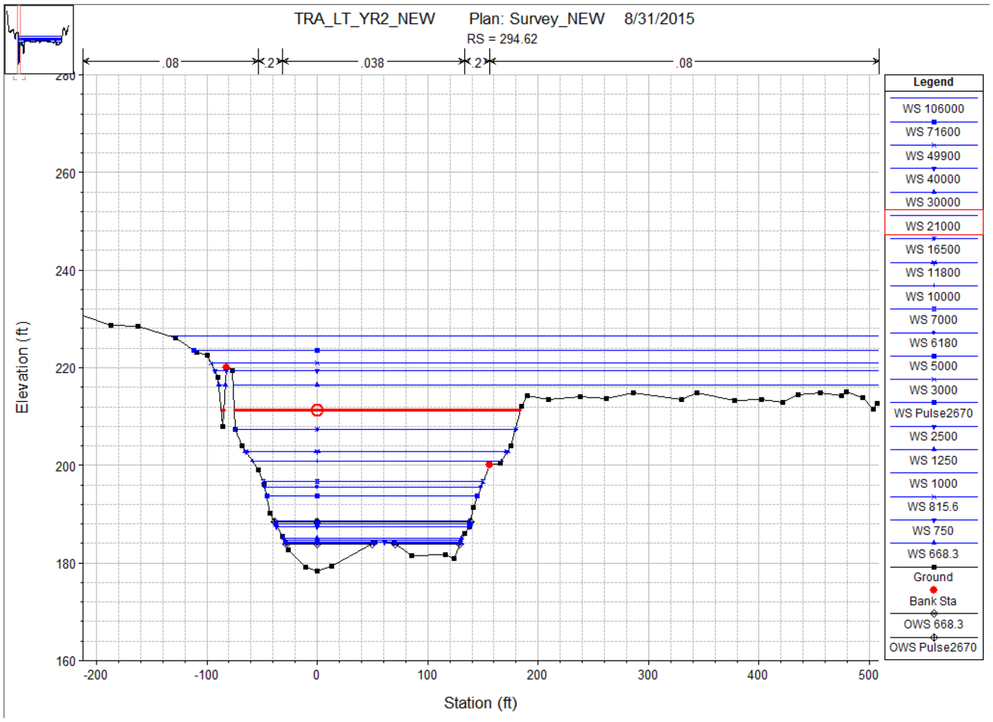


Figure 69. 080295 XS3 - Downstream riffle cross-section near-channel

4.3.5 Inundation mapping

Water edge inundation maps were created using the RAS Mapper function in HEC-RAS. The water surface elevation predictions for each modeled flow level were intersected with the DTM topographic surface. The 6,180 cfs pulse flow remains largely in the main channel and is the lowest flow for which an inundation surface was generated. Flow lower than 30,000 cfs are conveyed primarily within the banks of the main channel; flows of 40,000 cfs and higher represent overbank events (Figure 70).

Using the new high-resolution LiDAR data has a significant effect on the inundation extent. At 21,000 cfs, the inundation surfaces exhibit a similar footprint, with the exception of increased detail on the LiDAR set around the edges (and extending up into small runoff confluences) and to the west of the Keechi Creek confluence (Figure 71). At 30,000 cfs, the difference is dramatic, where the LiDAR map exhibits less inundation area than the DEM map (Figure 72).

The benefit of increased topographic resolution is clear when estimating near-bank inundation for riparian areas. However, the riparian SB3 pulse trigger flows are contained within the channel, so the increased resolution has limited impacted on assessing characteristics at SB3 flow levels.

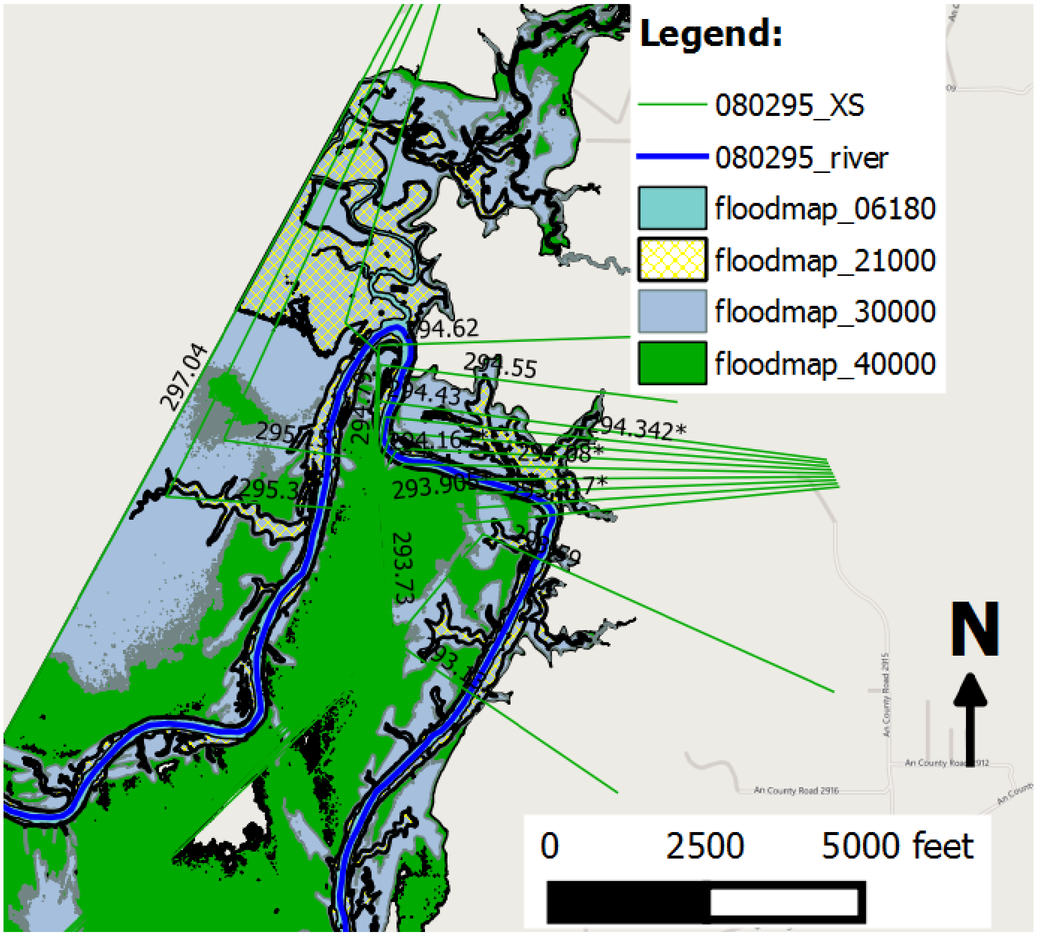


Figure 70. 080295 – Inundation extent up to 40,000 cfs.

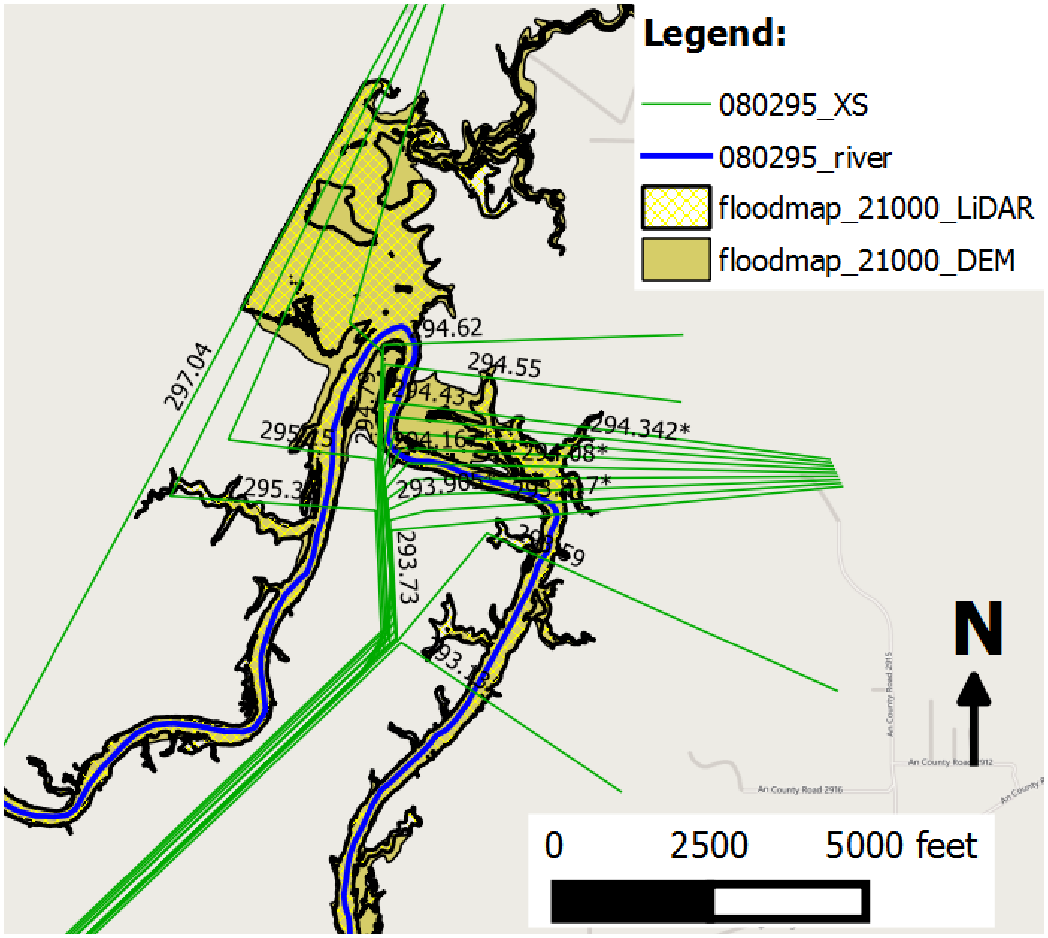


Figure 71. 080295 – Comparing inundation extent at 21,000 cfs based on LiDAR topography set (yellow hatch) to DEM topography set (solid).

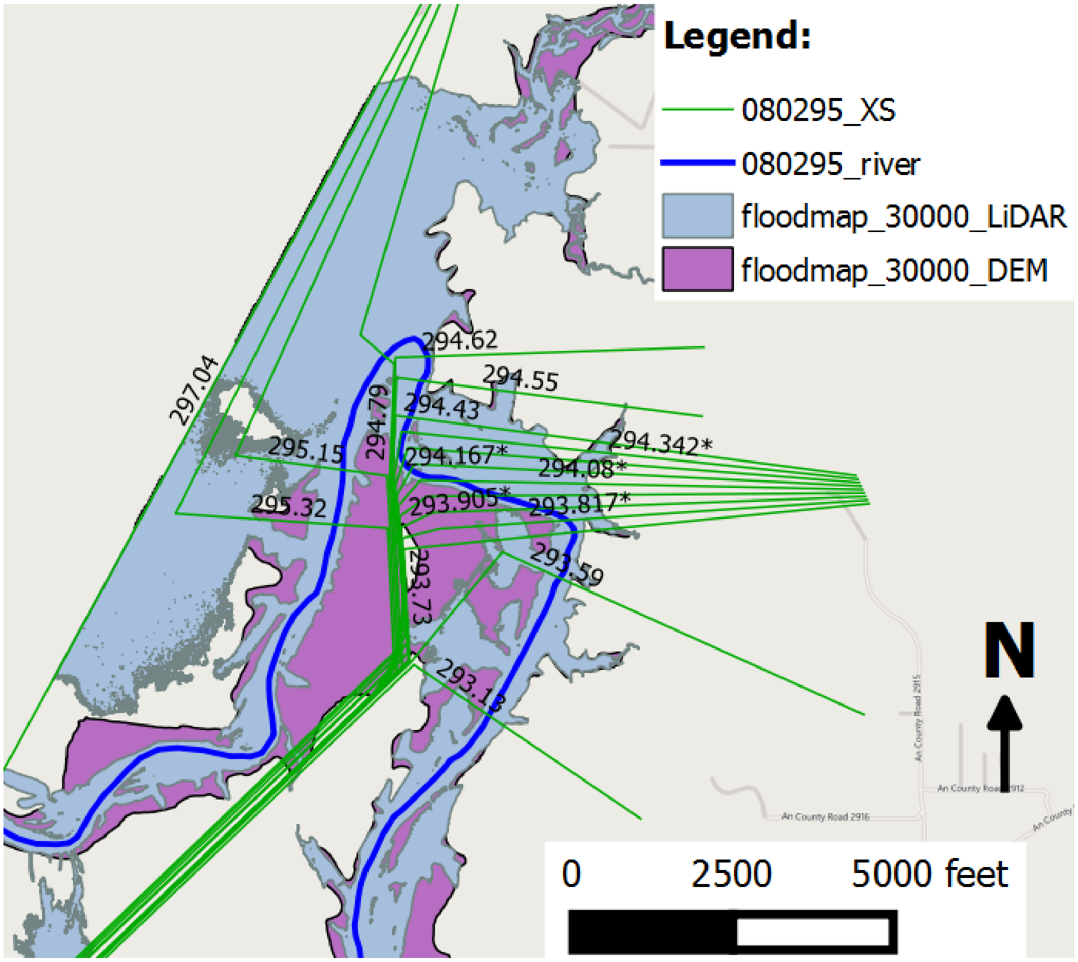


Figure 72. 080295 – Comparing inundation extent at 30,000 cfs based on LiDAR topography set (blue) to DEM topography set (purple).

4.4 080295 - Sediment

Sediment samples were collected on-site at LT295 XS1 during the 2012 field efforts. Five sediment samples were collected and grain size analysis was performed. Sediment grain size analysis reveals bank and right channel substrates are primarily fine sand (>60% finer than 0.003 inch) (Figure 73). Submerged sediments near the left bank are primarily coarse sand (Figure 73), and no material was recoverable from the center of channel (clean clay) (TRA and RPS Espey 2013).

Shear stress predictions can be used to investigate sediment mobilization. The shear stress necessary to cause incipient motion across a range of grain size classes was identified in Table 6. Using the revised HEC-RAS model, shear stress was predicted in the channel at each of the 080295 cross-sections (Table 14). Color shading is used for convenience in the tables for relating transportable grain size to flow ranges for each cross-section.

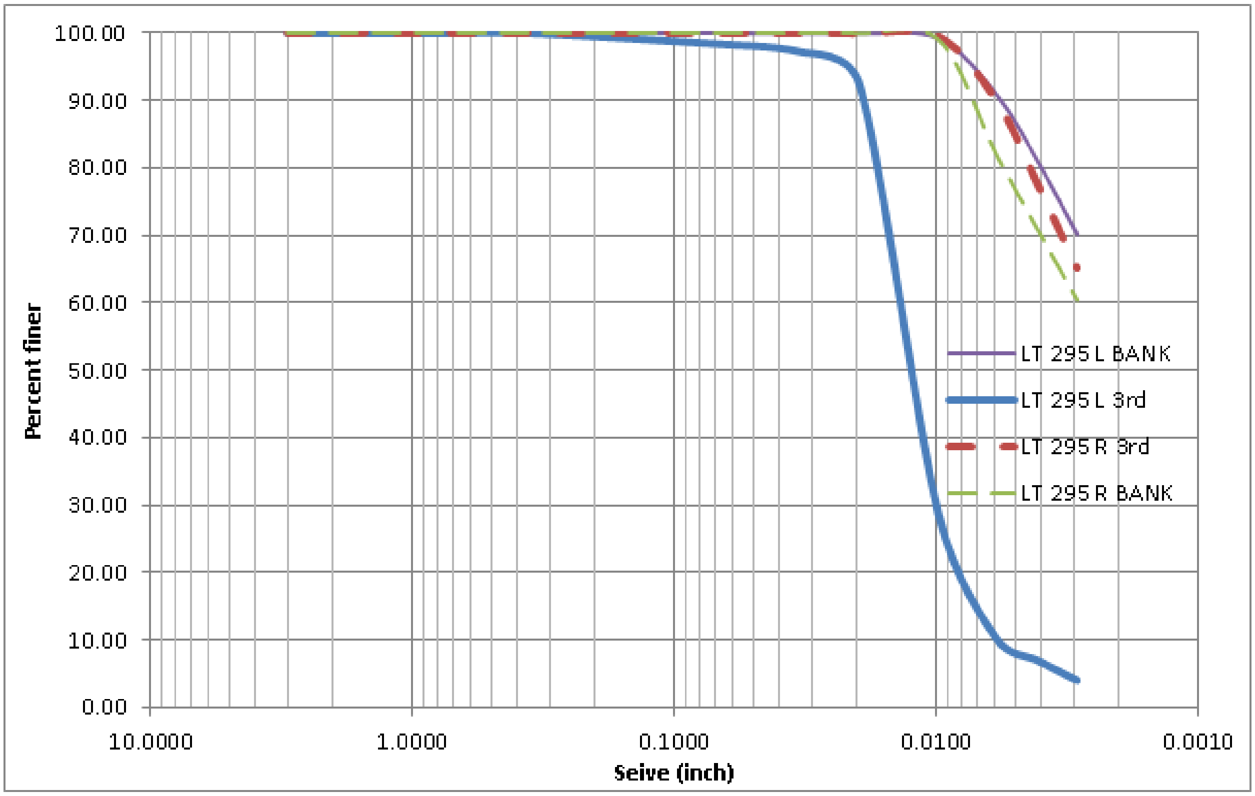


Figure 73. Grain size analysis of sediments at 080295_XS1 (no recovery at channel center) (TRA and RPS Espey 2013).

Sand transport is predicted for all flow levels, including down to minimum flow modeled of 668 cfs (Table 14). Model predictions of all-sand transport are consistent with on-site sediment sample grain size analysis from bed material at 080295_XS1. At this cross-section, as in many other mid-channel areas of the Trinity River, the primary bed material substrate was clean compacted clay. Mid-channel Ponar dredge samples returned empty or limited sample volumes comprised largely of organic material. As velocity and energy decreases away from channel center towards the banks, some deposition of sand-size particles is evident in the sediment field samples (Table 14).

Table 14. Shear stress for 080295 cross-sections, in channel

	Channel shear stress (lb/sf) and transportable grain size					
	XS3-riffle		XS2		XS1-upstream	
Flow (cfs)	Shear stress	Grain size	Shear stress	Grain size	Shear stress	Grain size
668.3	1.510	Sm cobble*	0.021	Coarse sand	0.017	Coarse sand
750	1.566	Sm cobble*	0.024	Coarse sand	0.020	Coarse sand
815.6	1.602	Sm cobble*	0.027	Coarse sand	0.022	Coarse sand
1000	1.740	Sm cobble*	0.037	Coarse sand	0.029	Coarse sand
1250	1.887	Sm cobble*	0.051	Coarse sand	0.040	Coarse sand
2500	1.388	Sm cobble*	0.181	Med grvl	0.176	Med grvl
2670	1.403	Sm cobble*	0.206	Med grvl	0.201	Med grvl
3000	1.477	Sm cobble*	0.257	Coarse grvl	0.250	Coarse grvl
5000	2.348	Lg cobble*	0.525	Coarse grvl*	0.442	Coarse grvl*
6180	2.419	Lg cobble*	0.666	Vry crs grvl*	0.508	Coarse grvl*
7000	2.389	Lg cobble*	0.734	Vry crs grvl*	0.533	Coarse grvl*
10000	2.312	Lg cobble*	0.644	Vry crs grvl*	0.665	Vry crs grvl*
11800	2.083	Sm cobble*	0.580	Vry crs grvl*	0.680	Vry crs grvl*
16500	1.318	Sm cobble*	0.431	Coarse grvl*	0.584	Vry crs grvl*
21000	0.880	Vry crs grvl*	0.321	Coarse grvl*	0.303	Coarse grvl*
30000	0.494	Coarse grvl*	0.124	Med grvl	0.100	Fine grvl
40000	0.339	Coarse grvl*	0.076	Fine grvl	0.059	Coarse sand
49900	0.209	Med grvl	0.060	Fine grvl	0.047	Coarse sand
71600	0.131	Med grvl	0.050	Coarse sand	0.038	Coarse sand
106000	0.113	Fine grvl	0.051	Coarse sand	0.038	Coarse sand

Note: * = erosion of compacted clay

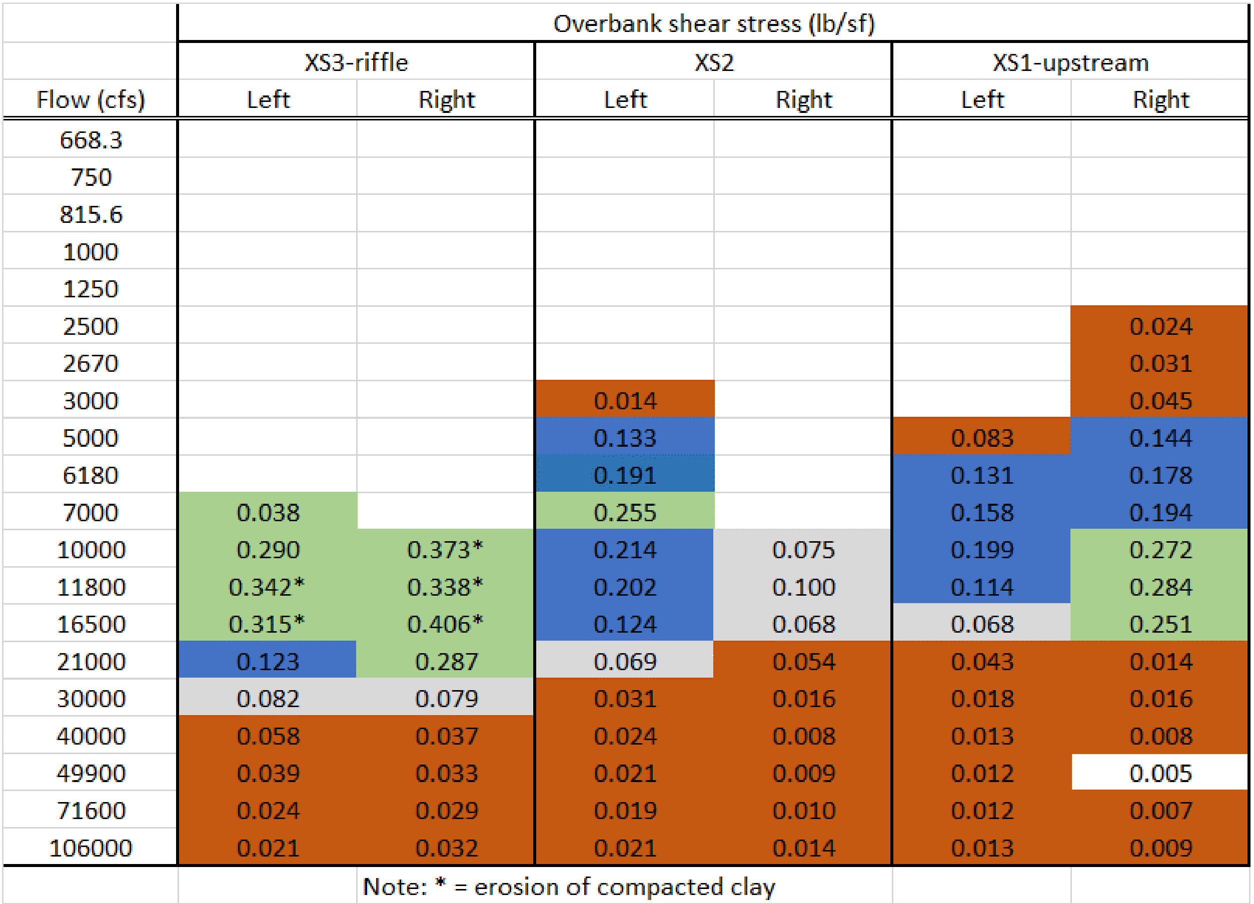
Cross-sections 080295_XS2 and LT295_XS1 are typical of many pool and run reaches in Area C of the Trinity River. At Cross-sections XS1 and XS2, shear stress sufficient for gravel transport is predicted between 2,500 cfs and 30,000 cfs, but no cobble transport is predicted (Table 14). Erosion of cohesive sediments (compacted clay) is predicted for flows between 5,000 cfs and 12,000 cfs (Table 14). Maximum shear is predicted at 7,000 cfs for XS2 and 10,000 cfs for XS1.

At the riffle cross-section immediately downstream of the confluence of Keechi (Town) Creek (LT295 XS3), it is not surprising that higher shear stresses are predicted than at XS1 and XS2 (Table 14). On-site, the observed bed material at XS3 ranges from coarse gravel to large cobble, and this is consistent with the shear stress predictions between 0.49 lb/sf and 2.42 lb/sf for all flows below 30,000 cfs. These shear stress values are sufficient to mobilize coarse gravels and cobbles up to 5” diameter. Maximum shear of stress of 2.42 lb/sf is predicted at 6,180 cfs. The decrease in shear stress within the channel at higher flows is consistent with on-site observations; flow direction in this study site was transverse to the direction of the channel (flow generally traveling south, down-valley) during the high overbank flow site visit.

For overbank areas, deposition of sands and fine gravel is expected for flow levels higher than 10,000 cfs (Table 15). Color coding follows Table 14. Erosion of compacted clay material (shear stress higher than 0.3 lb/sf) is predicted at overbank areas of Cross-section 3 for flow levels between 7,000 and 16,500 cfs. The topographically lower overbank level on the right of XS3 allows for inundation at flows between

5,000 cfs and 21,000 cfs, and shear stress is sufficient to transport gravel material in the overbank (Table 15). Similarly, the topographically lower overbank level on the left banks of XS2 allows for inundation at flows between 5,000 cfs and 16,500 cfs with shear stress sufficient to transport gravels (Table 15).

Table 15. Shear stress for 080295 cross-sections, overbank areas.



	Overbank shear stress (lb/sf)					
	XS3-riffle		XS2		XS1-upstream	
Flow (cfs)	Left	Right	Left	Right	Left	Right
668.3						
750						
815.6						
1000						
1250						
2500						0.024
2670						0.031
3000			0.014			0.045
5000			0.133		0.083	0.144
6180			0.191		0.131	0.178
7000	0.038		0.255		0.158	0.194
10000	0.290	0.373*	0.214	0.075	0.199	0.272
11800	0.342*	0.338*	0.202	0.100	0.114	0.284
16500	0.315*	0.406*	0.124	0.068	0.068	0.251
21000	0.123	0.287	0.069	0.054	0.043	0.014
30000	0.082	0.079	0.031	0.016	0.018	0.016
40000	0.058	0.037	0.024	0.008	0.013	0.008
49900	0.039	0.033	0.021	0.009	0.012	0.005
71600	0.024	0.029	0.019	0.010	0.012	0.007
106000	0.021	0.032	0.021	0.014	0.013	0.009
		Note: * = erosion of compacted clay				

Bed load sediment transport capacity for Cross-sections XS1 and XS2 was calculated using the Ackers-White equation (Figure 74). Transport occurs between 2,500 cfs and 30,000 cfs for the grain sizes appropriate to an Ackers-White analysis. Maximum transport is predicted at XS2, and for both XS1 and XS2 the maximum transport occurs between 7,000 and 16,500 cfs.

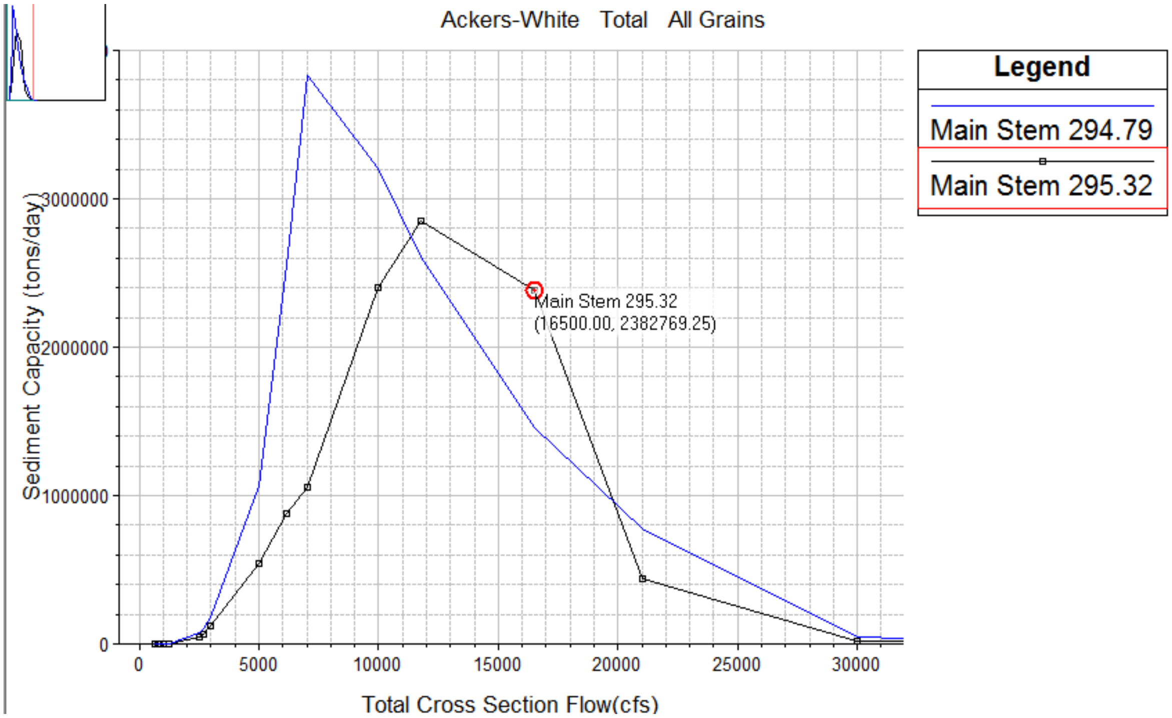


Figure 74. 080295 bed-load capacity

4.5 080295 - Riparian

Inundation of river bank riparian areas was documented during this study using commercially-available game cameras. The cameras logged photographs of the river each hour during the deployment period. At site 080295, the game camera was set between Cross-section 1 and 2, looking downstream towards Cross-section 2 (Figure 75). Inundation photos indicate limited connectivity with herbaceous river bank vegetation (e.g., grasses) at flow levels below 3,000 cfs (Figure 76, Figure 77, Figure 78 and Figure 79). For higher flows captured on the camera, some herbaceous vegetation and limited, if any, woody vegetation is inundated (Figure 80 and Figure 81). On May 28, 2015, the camera was submerged for five days at approximately 70,000 cfs. (Figure 82). Figure 83 shows a waterline comparison between 1,000 cfs and approximately 11,000 cfs.

Figure 75. 080295 - Automated game camera deployment location.

Figure 76. 080295 – Cross-section 2 at 750 cfs 2014-12-09.

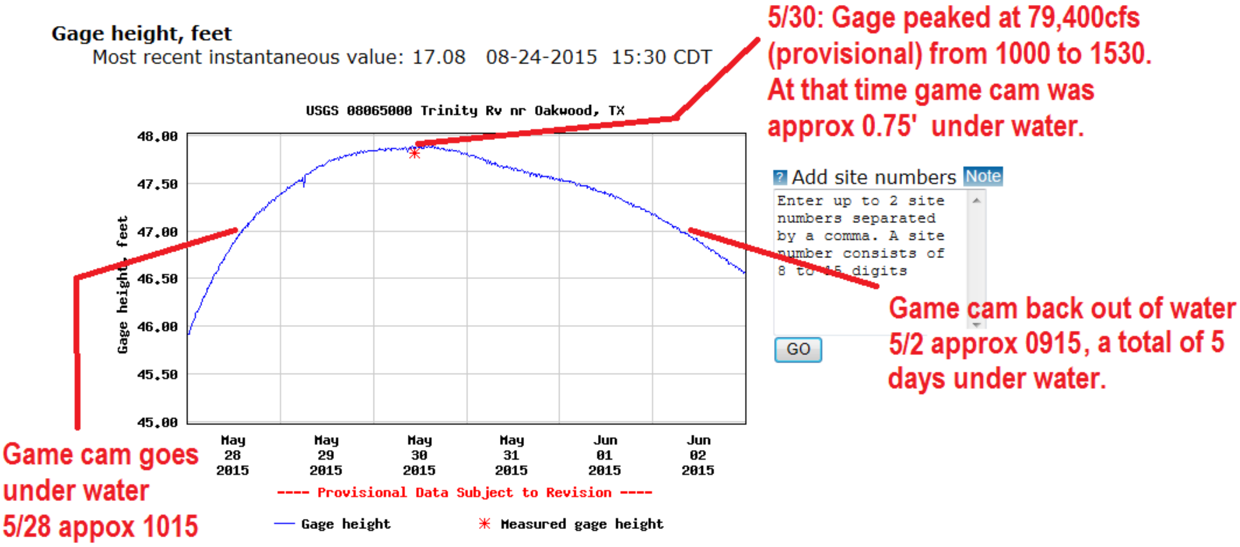
Figure 77. 080295 – Cross-section 2 at 1240 cfs, 2015-01-18.

Figure 78. 080295 – Cross-section 2 at 2470 cfs, 2015-002-03.

Figure 79. 080295 – Cross-section 2 at 3070 cfs, 2014-11-08.

Figure 80. 080295 – Cross-section 2 at 7770 cfs, 2015-01-26.

Figure 81. 080295 – Cross-section 1 at 10200 cfs, 2015-01-25.



Gage height, feet

Most recent instantaneous value: 17.08 08-24-2015 15:30 CDT

Add site numbers Note

Enter up to 2 site numbers separated by a comma. A site number consists of 8 to 15 digits

5/30: Gage peaked at 79,400cfs (provisional) from 1000 to 1530. At that time game cam was approx 0.75' under water.

Game cam goes under water 5/28 appox 1015

Game cam back out of water 5/2 approx 0915, a total of 5 days under water.

Figure 82. 080295 – Game camera inundated.

Figure 83. Game camera photograph showing the water line at 1,000 cfs and approximately11,000 cfs.

4.6 080295 - Overbanking

During a high overbank flow event (see Section 1.4), a field survey event was conducted on June 9, 2015, at 45,159 cfs. High rainfall in the Trinity River Basin during May and June cause elevated flows in the Trinity River (Figure 84), and the river overtopped its banks and connected with the floodplain.

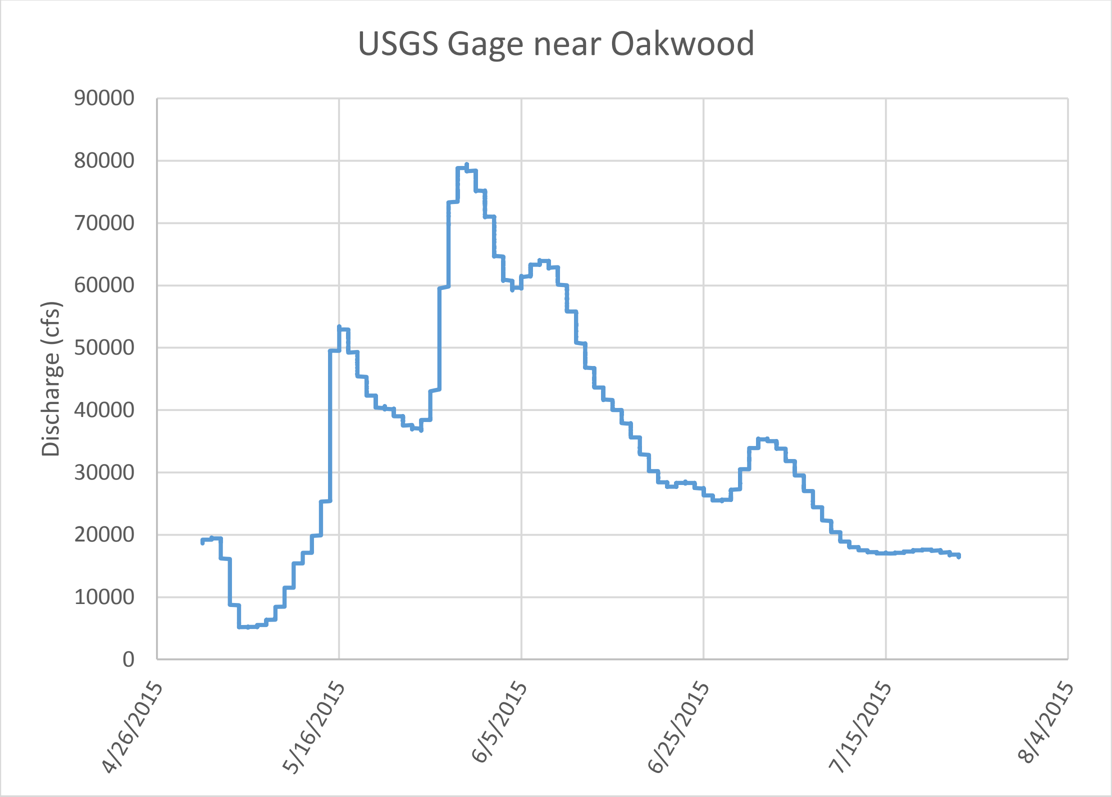


Figure 84. USGS Oakwood gage discharge hydrograph, spring overbanking 2015.

This site was unique in that predominant flow direction was transverse or slightly reverse to the direction of typical river channel flows, predominantly overtopping the right bank to flow southward through a large agriculture area (Figure 85). Flow generally bypassed the meander bend and riffle at Cross-section 3. Channel flow appeared to slow considerably and reverse at the confluence with Keechi Creek, creating a large backwater area upstream of the confluence. However, flow in the down-channel direction was observed in the Trinity River channel downstream of Keechi Creek. An attempt to collect an extended discharge cross-section across the inundated agriculture field and the Trinity River channel accounted for the majority of the flow within this part of the Trinity River (Figure 86).

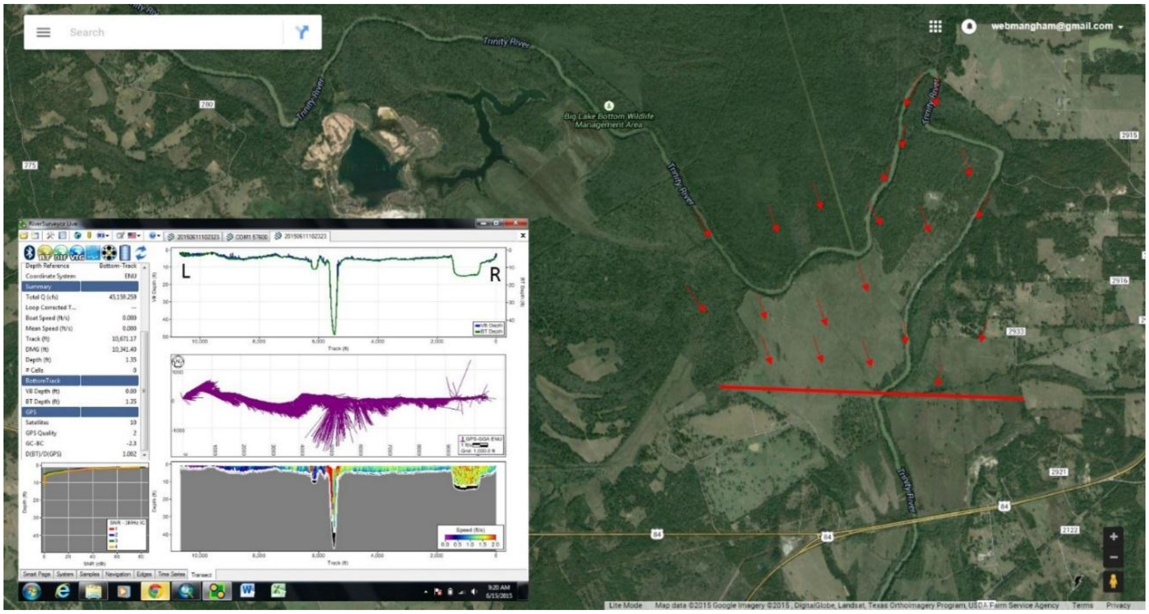


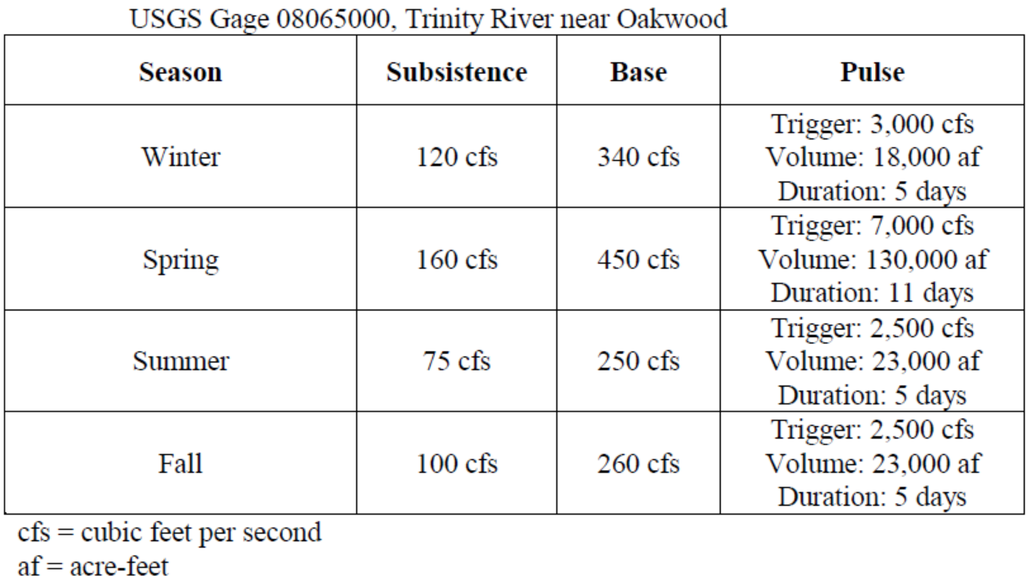
Figure 85. 080295 – Overbanking event flow velocity direction and cross-section measurement.

Figure 86. 080295 – Overbank flow condition and velocity direction, at same cross-section. The river reach under the airplane wing is experiencing reverse flow; the reach behind the wing is experiencing transverse flow.

4.7 080295 - Site summary

Adopted SB3 rules for the Trinity River environmental flows at the Oakwood measurement point include pulse trigger flow levels at 2500 cfs (Summer/Fall), 3000 cfs (Winter), and 7000 cfs (Spring) (Table 16).

Table 16. SB3 environmental flow standards, Trinity River near Oakwood



USGS Gage 08065000, Trinity River near Oakwood

Season	Subsistence	Base	Pulse
Winter	120 cfs	340 cfs	Trigger: 3,000 cfs Volume: 18,000 af Duration: 5 days
Spring	160 cfs	450 cfs	Trigger: 7,000 cfs Volume: 130,000 af Duration: 11 days
Summer	75 cfs	250 cfs	Trigger: 2,500 cfs Volume: 23,000 af Duration: 5 days
Fall	100 cfs	260 cfs	Trigger: 2,500 cfs Volume: 23,000 af Duration: 5 days

cfs = cubic feet per second
af = acre-feet

Riparian areas

Pulse flows between 5,000 cfs and 21,000 cfs are confined to the near-banks of the river. The analysis did, however, tell us about higher seasonal flows, particularly that flows tend to spread out overbank at levels higher than 21,000 cfs. Hydrology analysis indicates that flows approach 21,000 cfs perhaps two times per year on average (Table 13). Using the Texas Ecological Systems Classification Program (TESCP) geospatial dataset of land use/land cover data, earlier analysis indicates that areas classified as riparian and floodplain trees are mostly inundated for flows >30,000 cfs (TRA and RPS Espey 2013). While some difference is evident in water surface profiles and inundation extent comparing the earlier 2013 work with the 2015 work, the overall assessment of riparian areas is that additional site-specific riparian vegetation data is needed to better determine how intermediate flow levels (between 2,500 cfs and 30,000 cfs) inundate different near-channel components of the riparian community. More specifically, as flow increases, when does it inundate willow, then ash, then sycamore, then cottonwood, then pecan, and then oak.

Sediment

Flow levels between 7,000 cfs and 16,500 cfs are important to the river as these flow levels represent the greatest sediment transport capacity.

Predicted gravel transport is initiated at flows as low as 2,500 cfs, consistent with the SB3 pulse trigger flow, and tapers off at flows higher than 21,000 cfs, the level when flood waters begin to crest into overbank areas. A range of gravel size sediments are predicted to be transported by these flow pulses, and would represent refreshment of substrates in riffle habitats potentially important for some lotic fish species and mussels.

Sand transport is predicted at all flow levels modeled higher than 668 cfs.

Instream aquatic habitat

Sand is continually being transported at the flow levels currently exhibited. Different, more sandy edge habitats may have existed under lower base flow levels considering lower shear stress (potentially low enough to deposit sand) would be expected at lower flow levels. Lower flow levels should be evaluated for sand transport.

Current public datasets (10m DEM) were found to be coarse and provided limited utility in the near-bank areas for mapping inundation below 5,000 cfs. Improved near-bank topography (e.g., LiDAR or photogrammetry) improved ability to predict flood surface profiles for flows lower than 30,000 cfs.

Cohesive sediments are predicted to erode between flow levels of 5,000 cfs and 21,000 cfs.

4.8 080295 - Site Next Steps

The following tasks would augment this analysis:

1. Complete a riparian tree, sapling, seedling transect count consistent with the effort at site 080444.
2. Revise the TESCP analysis by updating the flow to riparian area relationships using the updated HEC-RAS inundation maps based upon 2014 LiDAR.
3. Measure cross-sections during a base flow condition, after the pulse event has subsided, to determine degree of change in channel caused by the pulse event.
4. Install water table monitoring wells to better understand the sub-surface connectivity of riparian species to river water levels.

5 Site 080075 – Downstream of SB3 Trinity River near Romayor measurement point

5.1 080075 - Site description

This study site is located approximately 10 river miles downstream of the USGS gage 08066500 - Trinity River near Romayor Senate Bill 3 (SB3) measurement point at FM787 and approximately 8 miles upstream of SH105 (Figure 87). No flood control or channel modification is believed to be in the vicinity; flow at the site is primarily controlled by releases from Lake Livingston 40 river miles upstream, a water supply and flood control reservoir. Work conducted for this 2015 project included installation of eight permanent benchmarks marking endpoints of four cross-sections (Table 17).

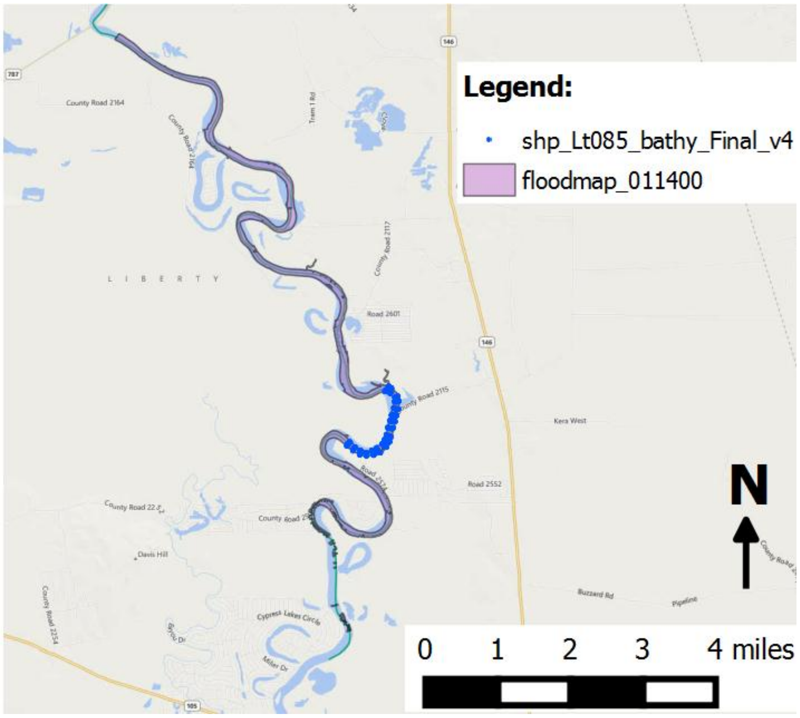


Figure 87. 080075 – Site vicinity map between FM797 and SH105; blue dots denote study site.

Table 17. 080075 – On-site survey reference marks

080075 Reference Marks

Point	Easting	Northing	Elevation	Comments
xs1_bmrb	4047026.032	10134184.314	52.753	VX (20150114)
xs1_bm_lb	4048185.077	10134417.432	56.751	VX (20150114)
xs2_rbbm	4047238.161	10131905.501	56.546	VX (20150114)
xs2_lbbm	4047882.500	10131761.082	55.682	VX (20150114)
xs3_bm_rb	4046973.967	10130958.020	54.473	VX (20150114)
xs_3_bm_lb	4047542.556	10130691.475	55.806	GPS (20150114)
xs_4_bm_rb	4045063.211	10130936.697	53.046	VX (20150114)
xs4_bm_lb	4044561.069	10130060.538	54.041	GPS (20150114)

5.2 080075 - Cross-section comparisons

Repeat cross-section surveys were conducted on this site. The initial survey was collected in January of 2015, during a Lake Livingston flood control release at 11,400 cfs. A second survey was conducted on June 10, 2015 during a high flow event (Figure 88); flow measured on-site using an ADP was 58,766 cfs.

Cross-section 1 exhibited some erosion along the left bank (Figure 89, blue line is later measurement) which was confirmed via interview with a landowner near the cross-section; significant accretion of the point bar along the right bank is also exhibited at this cross-section. Large amounts of deposition were observed during field efforts at 080075, as one of the PTs installed at cross-section 1, along the right bank, became buried by shifting sand sediment between field visits.

A distinct thalweg formed at Cross-section 2 as flows increased at this site (Figure 90). At Cross-section 3, the June 2015 survey was downstream of the original cross-section. This slight shift in survey location resulting from high flow field conditions may account for some differences seen in Cross-section 3, however, significant erosion appears to have occurred along the right bank (Figure 91). The river channel at Cross-section 4 did not exhibit much change along the left and right banks, but scour (or deepening) of the cross-section was evident (Figure 92).

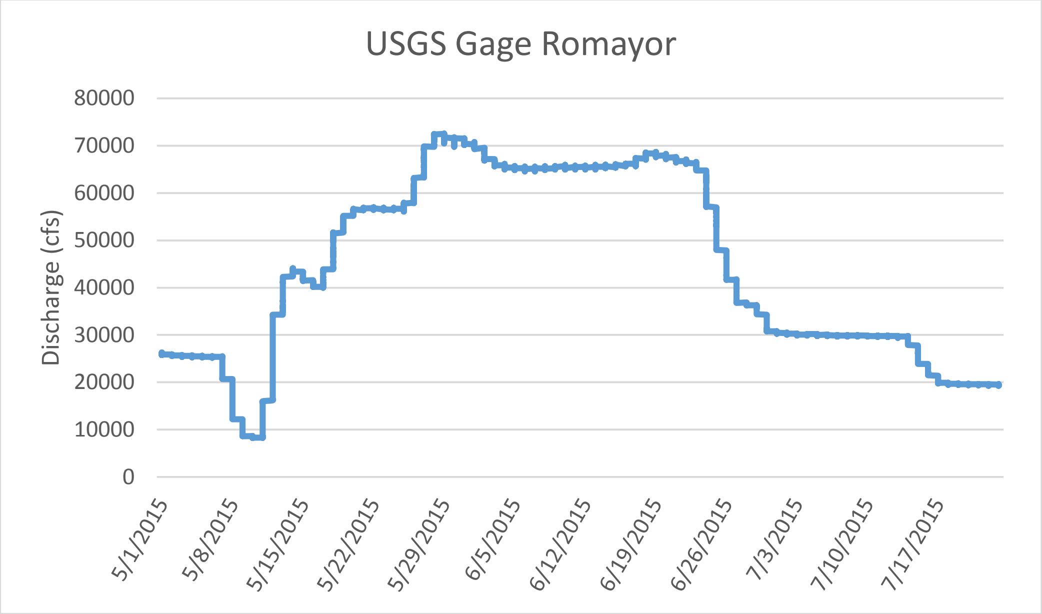


Figure 88. USGS Romayor gage during spring/summer 2015.

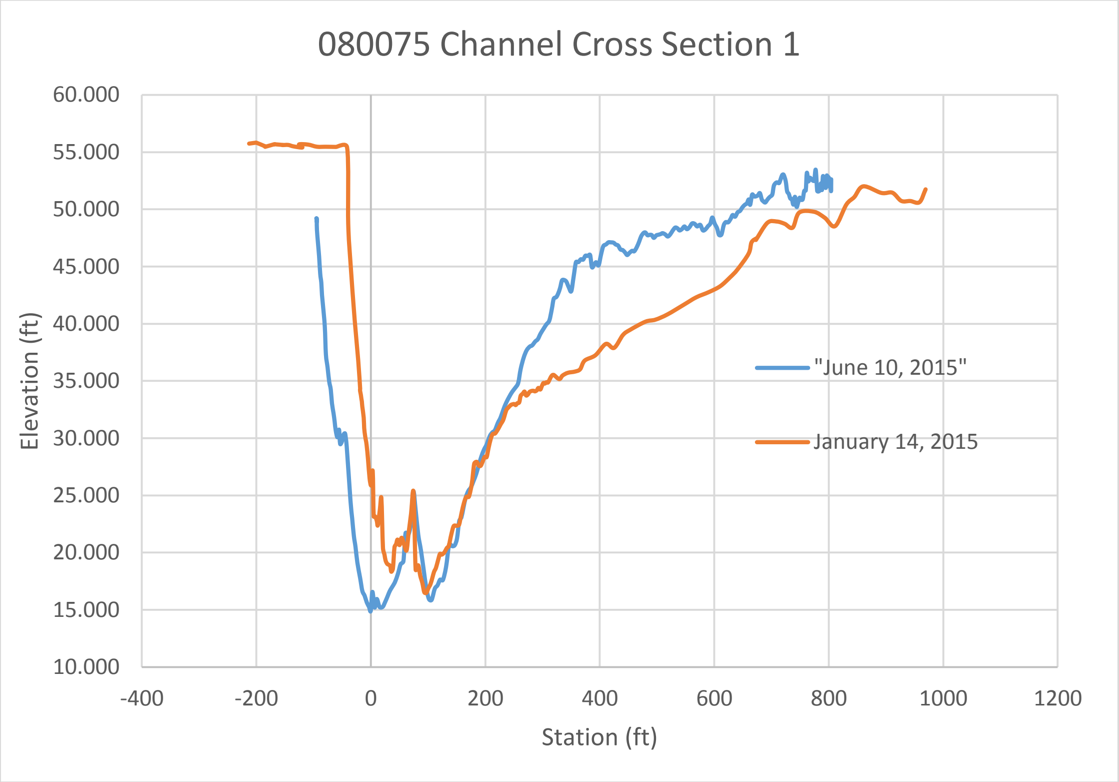


Figure 89. 080075 Cross-section 1 before and after high flows.

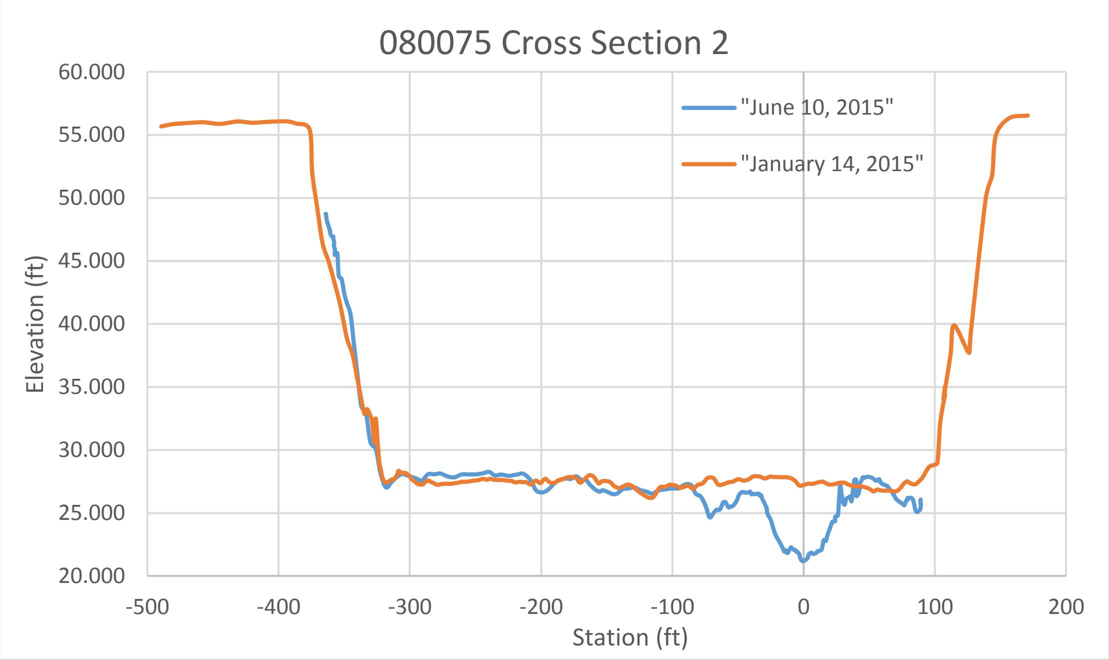


Figure 90. 080075 Cross-section 2 before and after high flows.

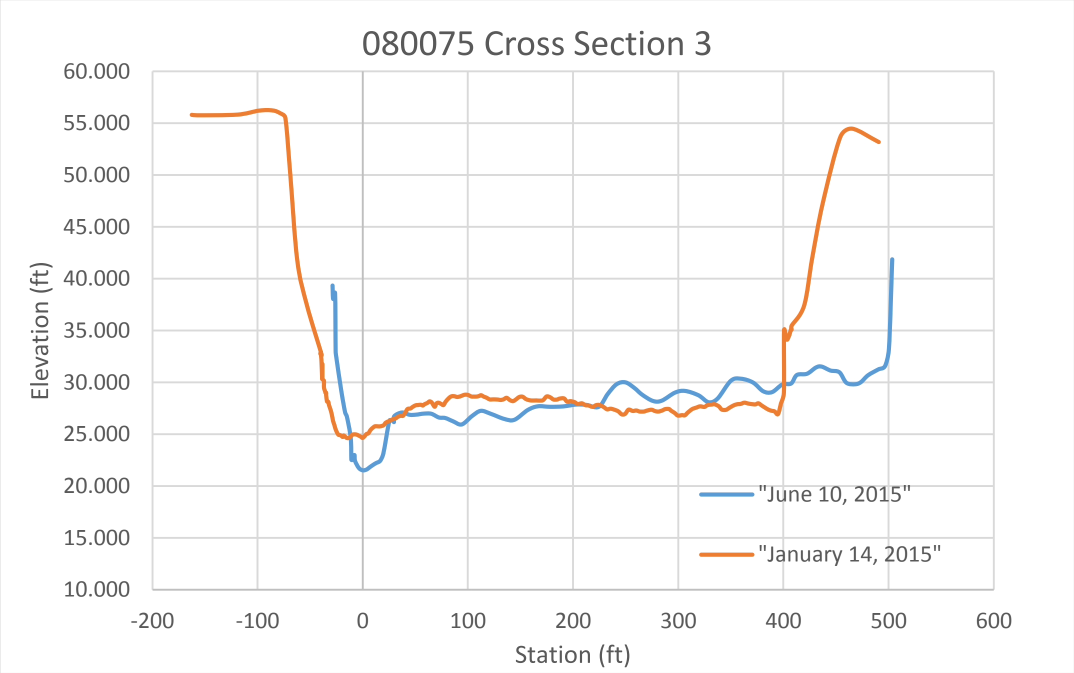


Figure 91. 080075 Cross-section 3 before and after high flows.

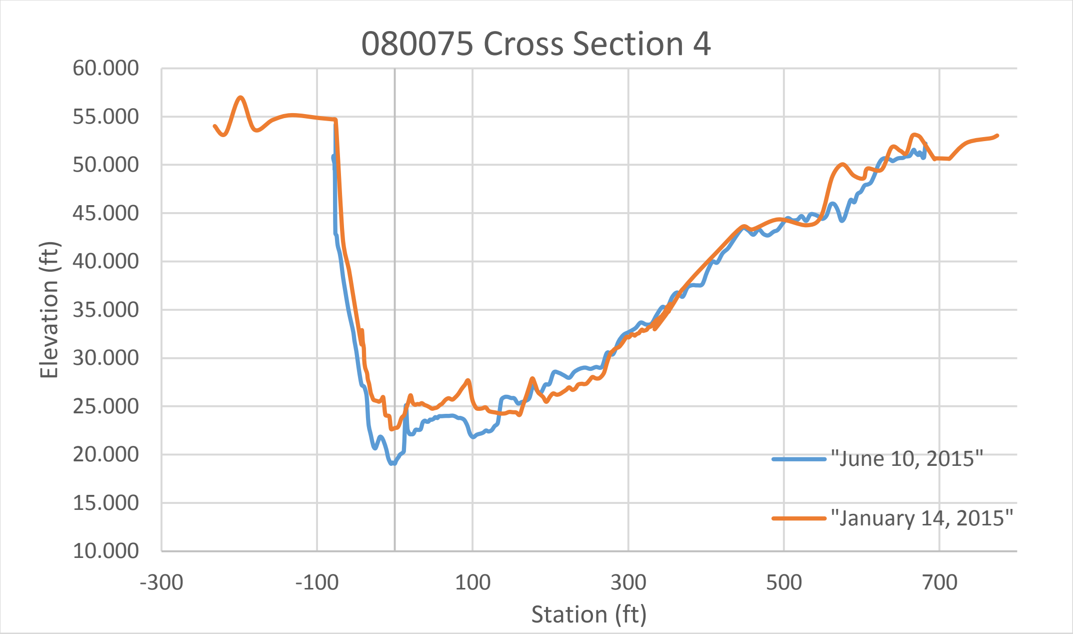


Figure 92. 080075 Cross-section 4 before and after high flows.

5.3 080075 - Water surface profiles and inundation mapping

To investigate water surface profiles at the site, a HEC-RAS model was developed using existing and new field data (Table 18). Flood plain overbank areas were based upon LiDAR data provided by TNRIS. In-channel cross-sections were based upon field survey data from the 2013 Longitudinal Survey (Lake Livingston to the Trinity Bay) and from data collected at the 080075 site during 2015 for this project.

Table 18. 080075 HEC-RAS cross-section elevation data sources

River Mile	RAS Station	Overbank data	In-channel data	Notes
85.8	87417	2011 LiDAR	2013 M9 xsec + USGS WSP	
85.2	84733	2011 LiDAR	Inferred in-channel to match observed WSP	
83.8	78474	2011 LiDAR	Inferred in-channel to match observed WSP	
83.0	74749	2011 LiDAR	2013 M9 xsec + USGS WSP	
81.4	67464	2011 LiDAR	Inferred in-channel to match observed WSP	
79.5	59194	2011 LiDAR	2013 M9 xsec + USGS WSP	
77.7	51083	2011 LiDAR	Inferred in-channel to match observed WSP	
76.6	45916	2011 LiDAR	Inferred in-channel to match observed WSP	
76.1	43086	2011 LiDAR	Inferred in-channel to match observed WSP	
75.0	38440	2011 LiDAR	2015 M9 xsec + 2015 VX TDS survey	Site xsec1
74.4	35823	2011 LiDAR	2015 M9 xsec + 2015 VX TDS survey	Site xsec2
74.2	34773	2011 LiDAR	2015 M9 xsec + 2015 VX TDS survey	Site xsec3
73.8	32995	2011 LiDAR	2015 M9 xsec + 2015 WSP	
73.6	31840	2011 LiDAR	2015 M9 xsec + 2015 VX TDS survey	Site xsec4
72.6	27293	2011 LiDAR	2013 M9 xsec + USGS WSP	

69.1	11192	2011 LiDAR	2013 M9 xsec + USGS WSP	
67.2	2805	2011 LiDAR	2013 M9 xsec + USGS WSP	

Water surface profiles were adjusted to water surface elevation based upon a tie to the elevation of the established benchmark, or based upon the water surface elevation of the USGS gage. The water surface elevations were used to determine the elevation of cross-sections where depth echosoundings were collected in the field.

5.3.1 Model development

The HEC-RAS model consisted of 17 cross-sections spanning the valley (Figure 93 and Figure 94).

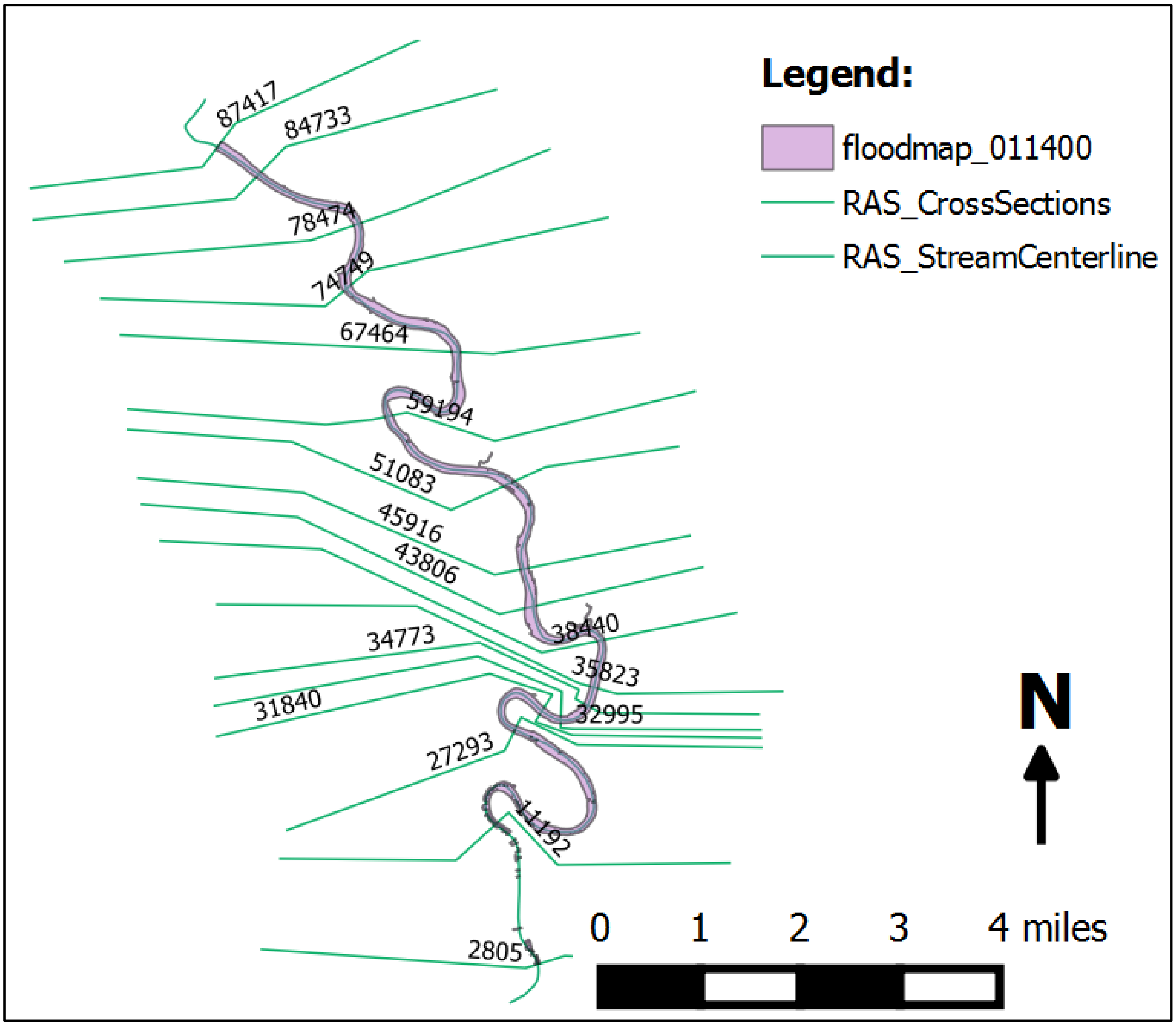


Figure 93. 080075 – HEC-RAS cross-section locations.

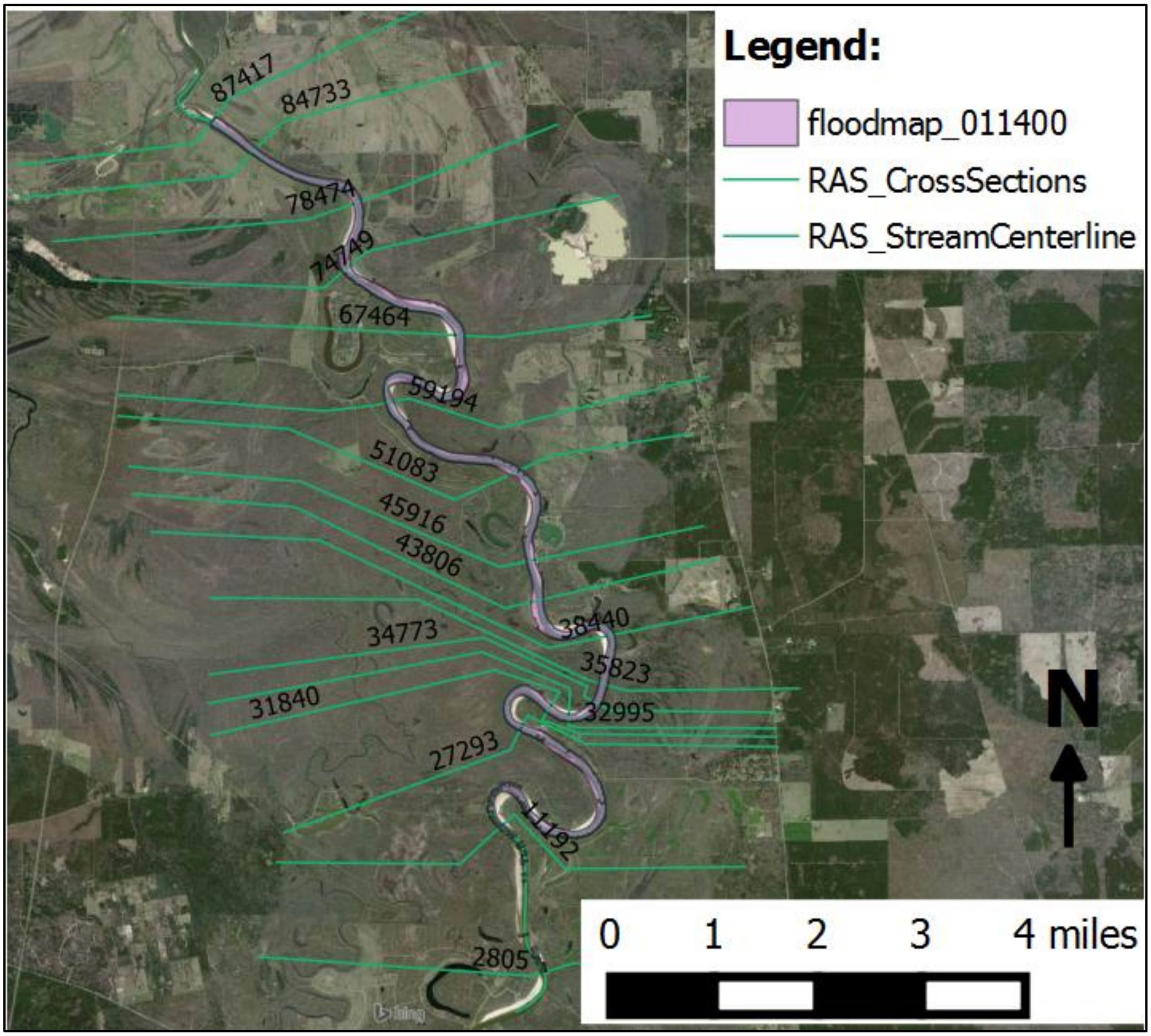


Figure 94. 080075 HEC-RAS cross-section locations over aerial imagery.

5.3.2 Calibration

The 080075 HEC-RAS model was calibrated based upon available water surface profile observation data at 1,150 cfs, 6,380 cfs, 11,400 cfs, and 18,700 cfs. Model predictions were calibrated by adjusting roughness factors and by inferring cross-section bathymetry where data was sparse (see below). Calibrated Manning’s roughness factors used are:

- n=0.08 - Overbank flood plain areas
- n=0.023 - In-channel areas between the banks.

In areas without measured in-channel cross-section information, interpreted cross-sections were added (Table 18). These additions were included to promote model prediction of observed water surface profiles, and observed field conditions.

The results of calibration efforts to match predicted water surface elevation with observed water surface elevation are favorable. At both the site (between stations 31,000 feet. and 38,000 feet) and at the Romayor USGS gage (near station 88,000 feet), the model results are comparable to the observation values and generally within one foot of elevation (Figure 95). After marrying the predicted water surface profile with the LiDAR DTM topographic surface, inundation predictions at 11,400 cfs match water edge observations within a couple feet in the horizontal; the blue dots in Figure 96 represent echosounder measurements from 11,400 cfs and the white circles represent water edge measurements at the same flow. Many differences can be attributed to the mobile nature of the sand banks between the 2011 LiDAR flight and the 2015 field measurements.

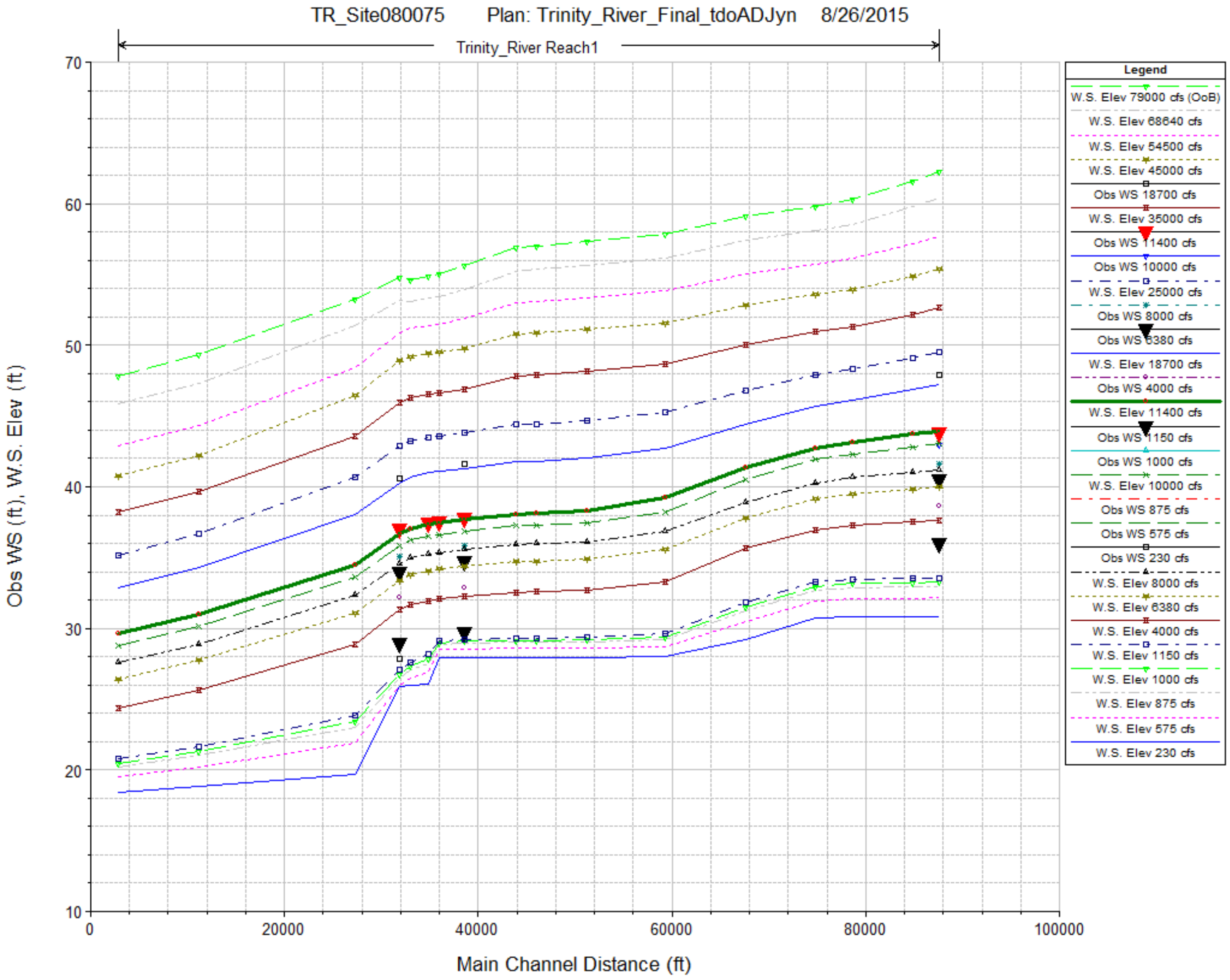


Figure 95. 080075 water surface profile calibration

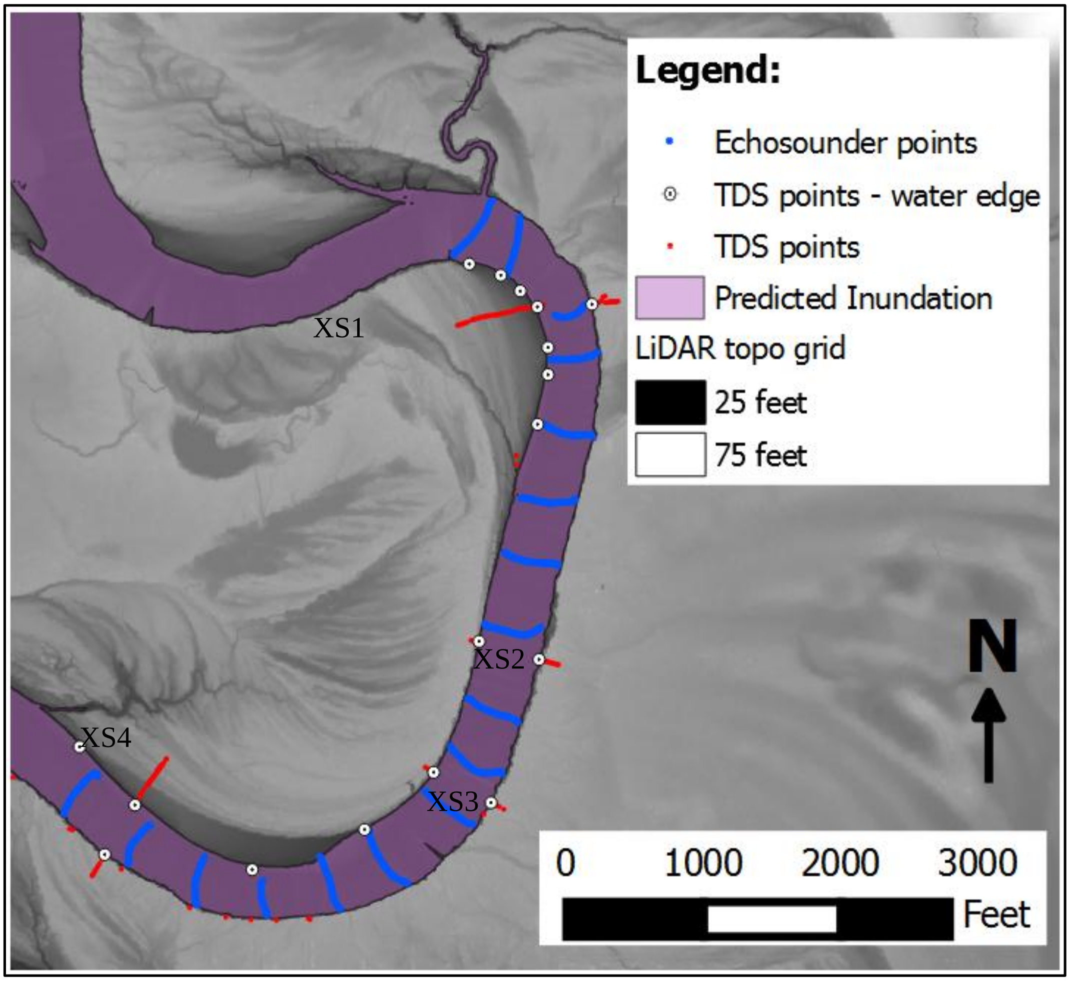


Figure 96. 080075 Predicted inundation surface near site, 11,400 cfs with observed survey points.

5.3.3 HEC-RAS Water Surface Profile Results

A series of steady-state flow rates were modeled at this site, ranging from low-flow (230 cfs SB3 flow) to a high flood flow (79,000 cfs at Romayor) (Table 19). Water levels from each of the four study-site cross-sections are presented in Figure 97, Figure 98, Figure 99, Figure 100 and Figure 101.

Table 19. 080075 - HEC-RAS modeled steady-state flows

Flow Rate (cfs)	**Description**
230	SB3
575	SB3
875	SB3
1000	
1150	SB3 and field observation data
4000	SB3 trigger Romayor
6380	Field observation data
8000	SB3 trigger Romayor

10000	SB3 trigger Romayor
11400	Field visit and observation data
18700	Field observation data
54500	
68640	Pulse flow event during study period.
79000	

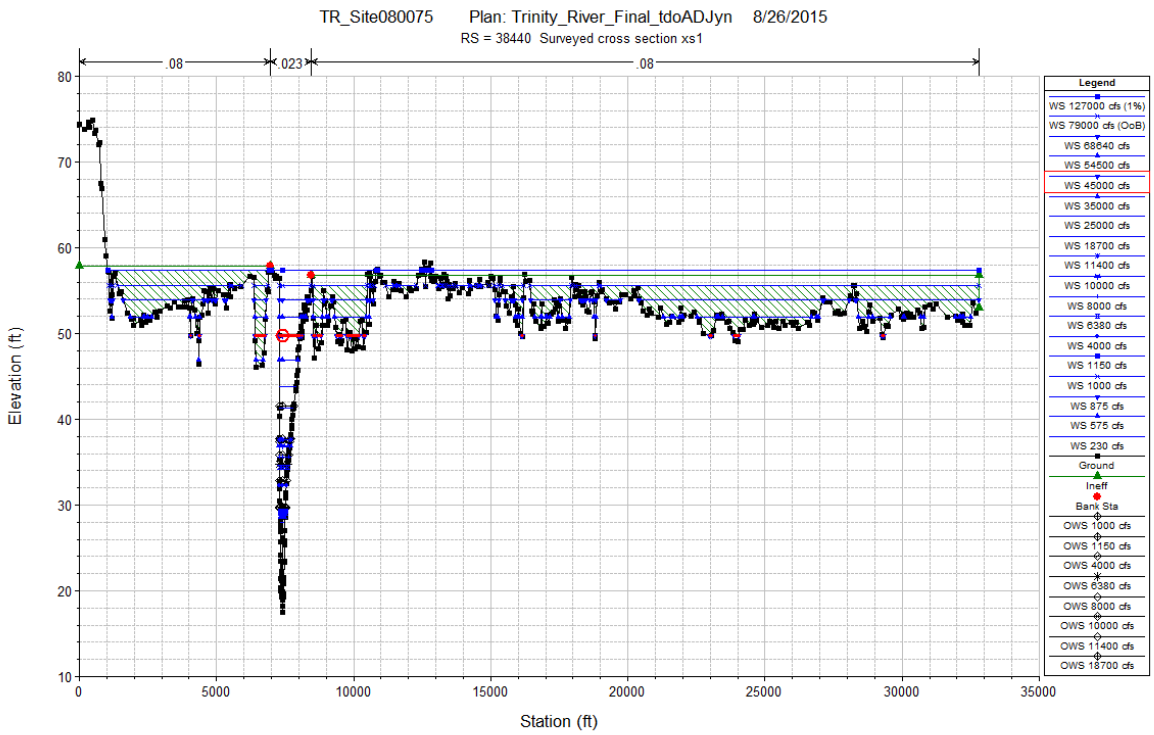


Figure 97. 080075 XS1 - Upstream cross-section floodplain

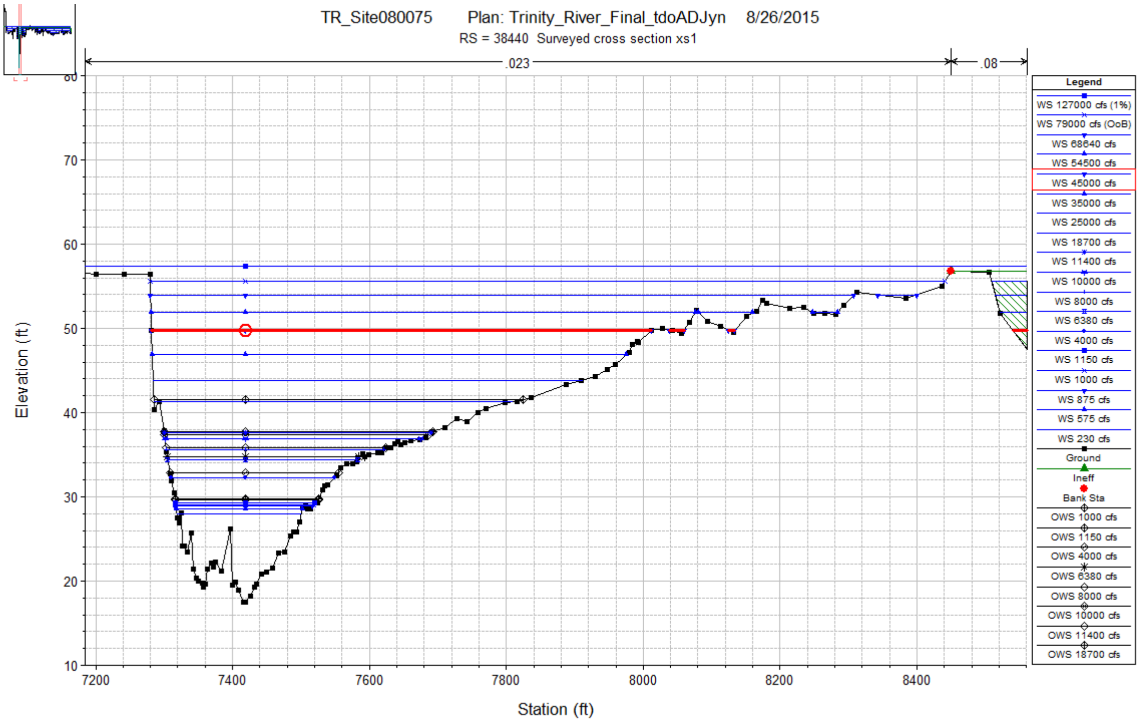


Figure 98. 080075 XS1 - Upstream cross-section near-channel

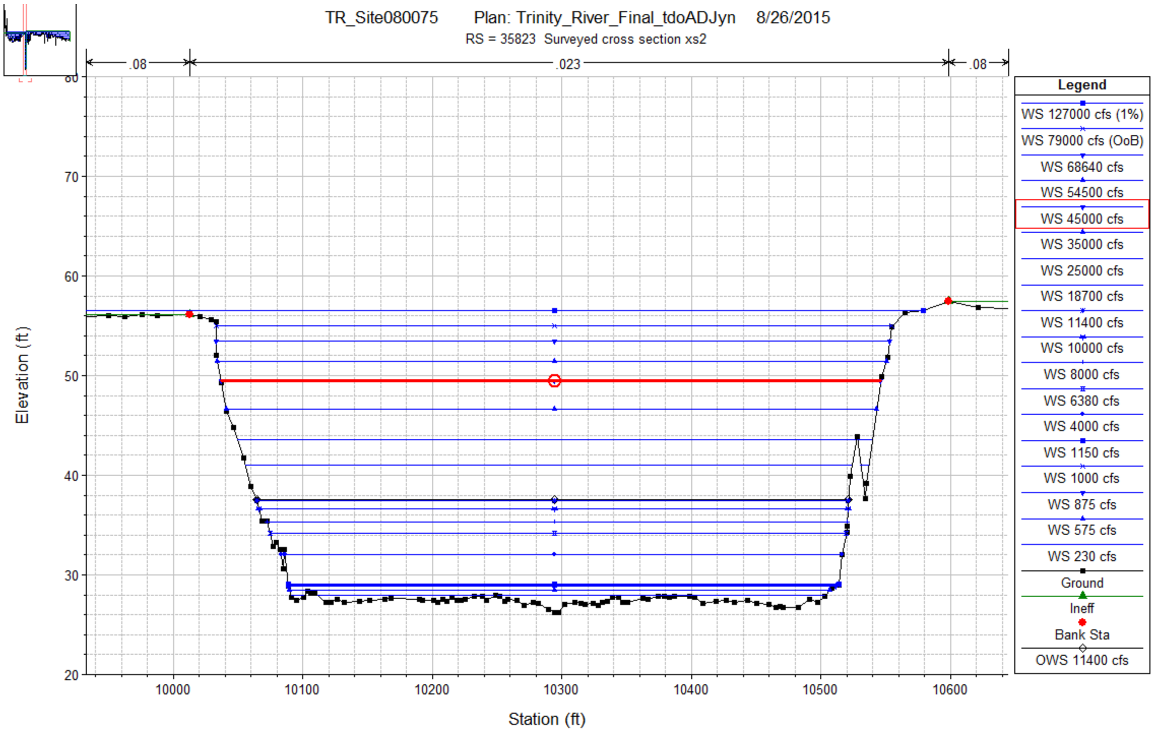


Figure 99. 080075 XS2 - Middle up stream cross-section near-channel

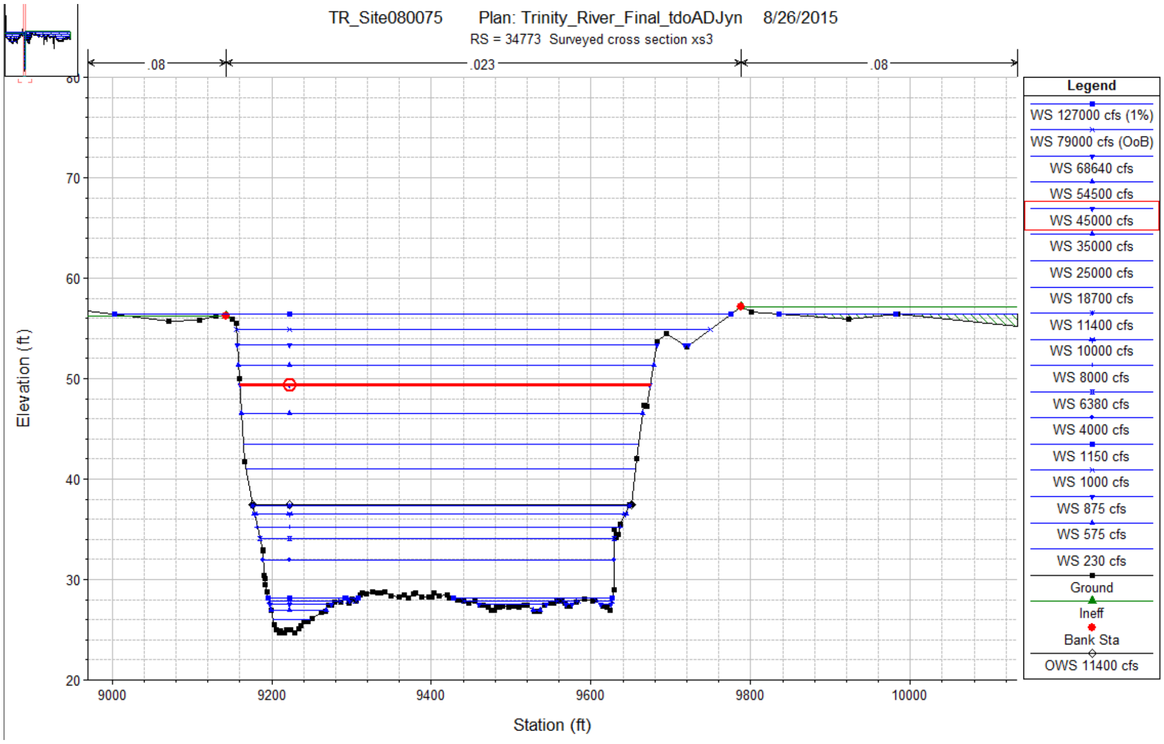


Figure 100. 080075 XS3 - Middle downstream cross-section near-channel

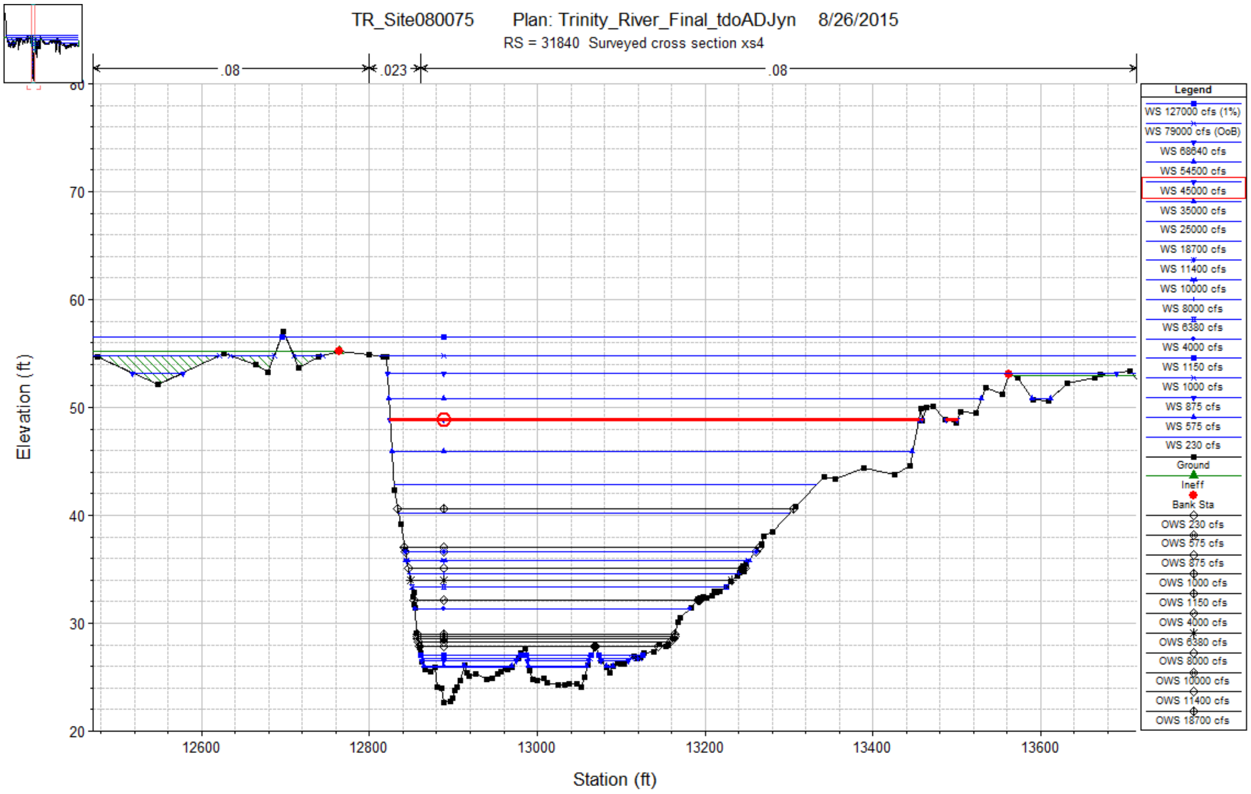


Figure 101. 080075 XS4 - Downstream cross-section near-channel

5.3.4 Inundation mapping

As conducted for the 080295 site, water edge inundation maps were created using the RAS Mapper function in HEC-RAS. The water surface elevation predictions for each modeled flow level were intersected with the TNRIS LiDAR topographic surface thus allowing delineation of the water edge of each flood event (Figure 102).

The spatial resolution of LiDAR elevation did not include the in-channel portion, so water edges for flow levels less than 11,400 cfs were not mapped. The higher flow levels like 65,280 cfs illustrate the complex drainage patterns and meander scrolling of this Gulf coastal area. While the inundation of areas adjacent to the river bank is limited even for the 65,280 cfs inundation surface, significant inundation is apparent in the overbank areas away from the natural river levees (Figure 103).

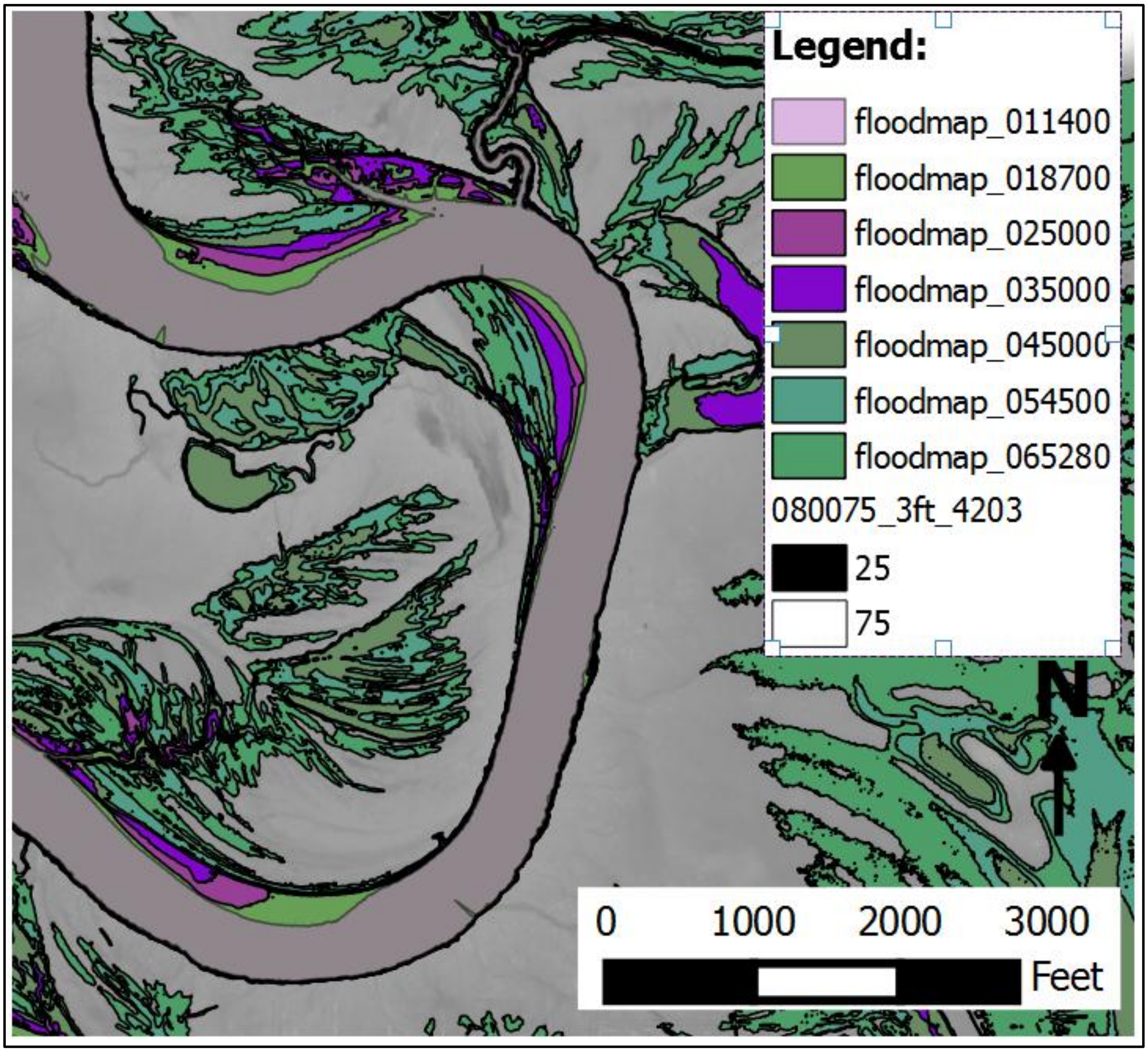


Figure 102. 080075 Predicted inundation surfaces near site

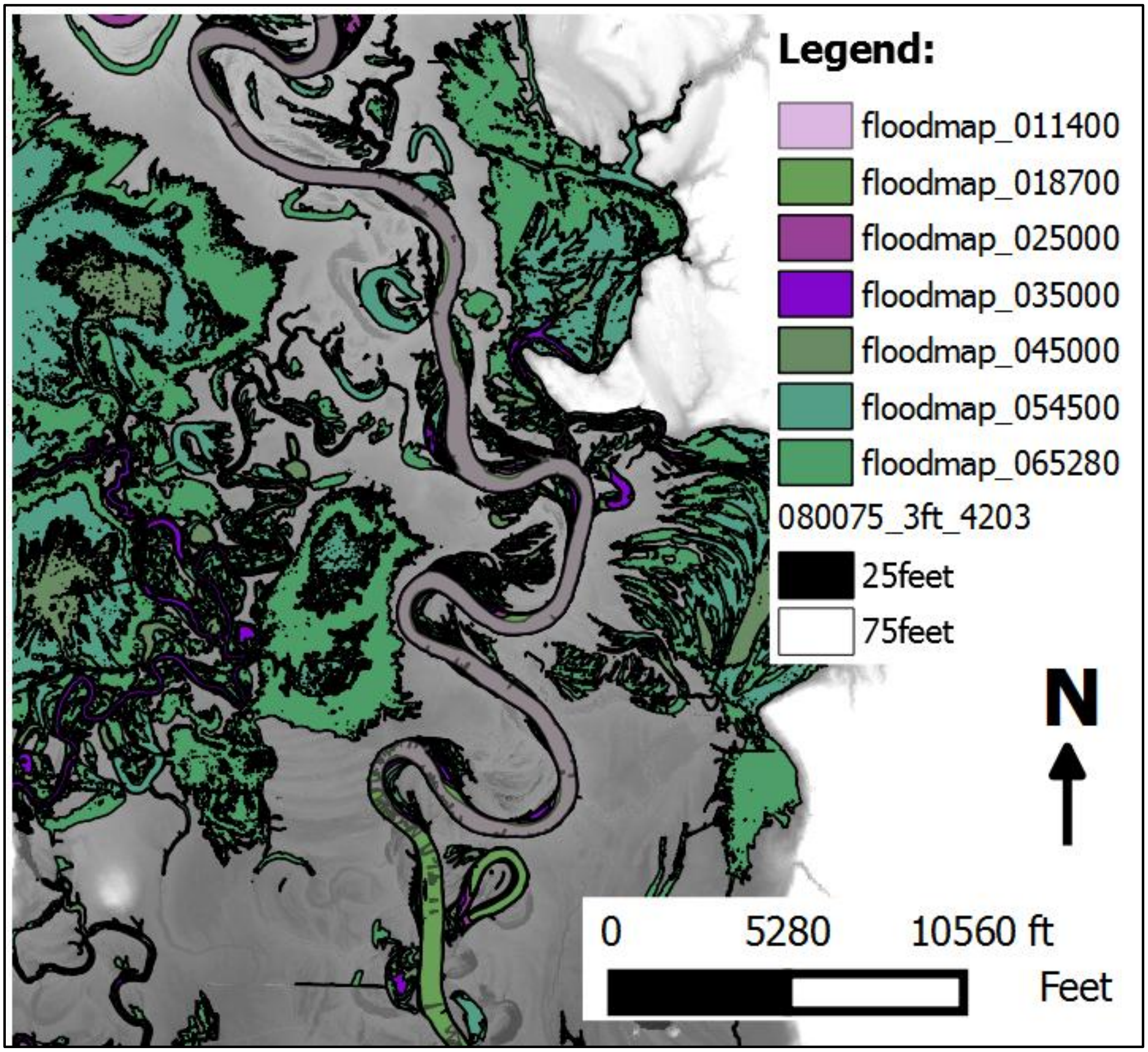


Figure 103. 080075 Predicted inundation surfaces in vicinity of site

5.4 080075 - Sediment

As with site 080295, shear stress predictions are used to investigate sediment mobilization at site 080075. The shear stress necessary to cause incipient motion across a range of grain size classes was identified in Table 6. Color shading according to transportable grain sizes is according to Table 7. Using the revised HEC-RAS model, shear stress was predicted in the channel at each of the 080075 cross-sections (Table 20).

Sand transport is predicted for all flow levels, except the very low base and subsistence flows below 575 cfs (Table 20). Lower shear stress at Cross-section 1 is consistent with its relatively large cross-section (Figure 98) and placement along a large point bar (Figure 96). For overbank areas, limited erosion capacity is exhibited for any of the cross-sections (Table 21) because of the expansive flood plain. Limited transport of coarse material is anticipated to occur in the overbank.

Table 20. Shear stress for 080075 cross-sections, in-channel areas.

	Channel shear stress (lb/sf) and transportable grain size					
	XS4 - downstream		XS3 - mid-downstream		XS1 - upstream	
Flow (cfs)	Shear stress	Grain size	Shear stress	Grain size	Shear stress	Grain size
230	0.234	Med grvl	0.447	Coarse grvl*	0.000	#N/A
575	1.205	Sm cobble*	0.543	Vry crs grvl*	0.002	Med silt
875	1.148	Sm cobble*	0.448	Coarse grvl*	0.004	Fine sand
1000	1.056	Vry crs grvl*	0.283	Coarse grvl	0.005	Fine sand
1150	0.957	Vry crs grvl*	0.191	Med grvl	0.006	Coarse sand
4000	0.543	Vry crs grvl*	0.039	Coarse sand	0.031	Coarse sand
6380	0.628	Vry crs grvl*	0.039	Coarse sand	0.047	Coarse sand
8000	0.672	Vry crs grvl*	0.042	Coarse sand	0.057	Coarse sand
10000	0.722	Vry crs grvl*	0.046	Coarse sand	0.068	Fine grvl
11400	0.756	Vry crs grvl*	0.049	Coarse sand	0.072	Fine grvl
18700	0.922	Vry crs grvl*	0.060	Fine grvl	0.089	Fine grvl
25000	1.012	Vry crs grvl*	0.071	Fine grvl	0.095	Fine grvl
35000	1.234	Sm cobble*	0.090	Fine grvl	0.104	Fine grvl
45000	1.294	Sm cobble*	0.105	Fine grvl	0.108	Fine grvl
54500	1.476	Sm cobble*	0.125	Med grvl	0.119	Fine grvl
68640	0.264	Coarse grvl	0.163	Med grvl	0.140	Med grvl
79000	0.164	Med grvl	0.191	Med grvl	0.142	Med grvl
127000	0.118	Fine grvl	0.255	Coarse grvl	0.082	Fine grvl
		Note: * = erosion of compacted clay				

Table 21. Shear stress for 080075 cross-sections, overbank areas.

	Overbank shear stress (lb/sf)					
	XS4 - downstream		XS3 - mid-downstream		XS1 - upstream	
Flow (cfs)	Left	Right	Left	Right	Left	Right
230						
575						
875						
1000						
1150						
4000						
6380						
8000						
10000						
11400						
18700						
25000						
35000						
45000						
54500						
68640		0.051				
79000		0.041				
127000	0.028	0.039	0.055			0.030
		Note: * = erosion of compacted clay				

5.5 080075 - Riparian

Commercially-available automated game cameras were installed on this site to log photographs of the river each hour during the deployment period. At site 080755, the game camera was set just upstream of Cross-section 1, looking downstream across Cross-section 1 towards Cross-section 2. Inundation photos indicate limited connectivity with herbaceous river bank vegetation (e.g., grasses) at flow levels below 68,000 cfs (Figure 104, Figure 105, Figure 106, Figure 107 and Figure 108). At the highest flow captured on the camera, some riparian vegetation appears inundated (Figure 109) along with the entire sand bar to river right at Cross-section 1.

Figure 104. 080075 - Cross-section 1 at 1,380 cfs 2015-2-4.

Figure 105. 080075 - Cross-section 1 at 4,220 cfs 2015-1-22.

Figure 106. 080075 - Cross-section 1 at 8,040 cfs 2015-1-31.

Figure 107. 080075 - Cross-section 1 at 10,000 cfs 2015-1-23.

Figure 108. 080075 - Cross-section 1 at 11,400 cfs 2015-1-23.

Figure 109. 080075 - Cross-section 1 at 68,000 cfs 2015-6-19.

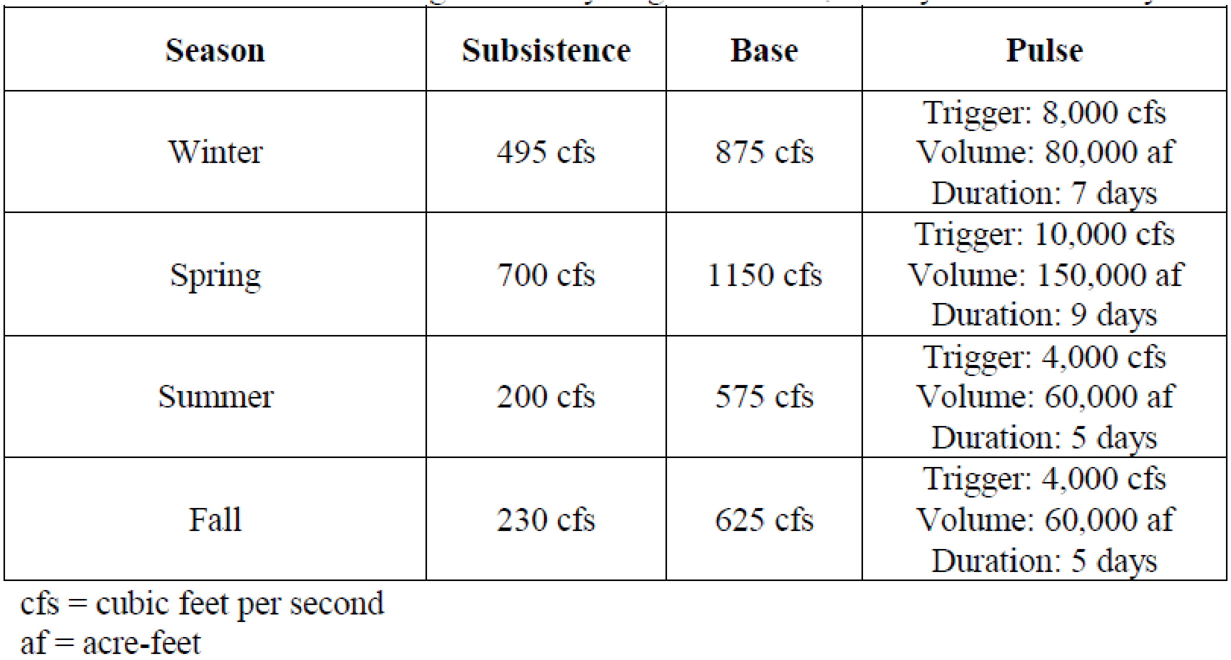
5.6 080075 - Overbanking

During the June 2015 field efforts, high flows (greater than 70,000 cfs) were observed (Figure 88). Throughout the study site, velocity was observed over the left bank of the river channel although flood waters dispersed more prominently towards the west, laterally along the right bank and connected with the floodplain. There was evidence of flowing water above the left bank (i.e. small wet pools and flood debris), and discussions with adjacent landowner suggested significant amount of erosion were taking place along the left bank of the river channel.

5.7 080075 - Site summary

Adopted SB3 rules for the Trinity River environmental flows at the USGS Romayor measurement point include pulse trigger flow levels at 4000 cfs (Summer/Fall), 8000 cfs (Winter) and 10000 cfs (Spring) (Table 22).

Table 22. SB3 environmental flow standards, Trinity River at Romayor (USGS 08066500)



Season	Subsistence	Base	Pulse
Winter	495 cfs	875 cfs	Trigger: 8,000 cfs Volume: 80,000 af Duration: 7 days
Spring	700 cfs	1150 cfs	Trigger: 10,000 cfs Volume: 150,000 af Duration: 9 days
Summer	200 cfs	575 cfs	Trigger: 4,000 cfs Volume: 60,000 af Duration: 5 days
Fall	230 cfs	625 cfs	Trigger: 4,000 cfs Volume: 60,000 af Duration: 5 days

cfs = cubic feet per second
af = acre-feet

Riparian areas

The riparian zone near this 080075 study site and in the coastal plain exhibits more complex drainage and inundation connection patterns than the riparian zone farther north at sites 080295 and 080444. Instead of spilling over the river banks, the natural levee forms a high spot and the low flat overbank areas near the study site are more likely to become inundated by local runoff and slow drainage than by high river flows. A regional model more closely investigating the relationship between the TESCP dataset and the inundation prediction of this RAS model could help illuminate whether tree populations in the near-river riparian zone differs from the ecological makeup of habitat and trees in other frequently inundated areas that are removed from the river.

Sediment

Flow levels between 2,000 cfs and 10,000 cfs represent transport of the most common grain size exhibited in the substrates on site – coarse sand. The SB3 pulse flow levels will maintain that transport. As flow levels and energy increase, sediment carrying capacity of the channel increases and, to the limited degree that coarser sediment exists in the region, it can be transported.

Sand transport is predicted at flow levels modeled higher than 575 cfs, but may begin depositing in some point bar/cut bank areas for lower flows.

Instream aquatic habitat

Sand is continually being transported at the flow levels currently exhibited. Different, coarser, edge habitats may have existed under lower base flow levels considering higher shear stress exhibited that would be exhibited at lower flow levels.

5.8 080075 - Site Next Steps

The following tasks would augment this analysis:

1. Complete a riparian tree, sapling, seedling transect count consistent with the effort at site 080075.
2. Analyze riparian areas using the TESCP by developing the flow to riparian area relationships using the updated HEC-RAS inundation maps based upon 2011 LiDAR.
3. Measure cross-sections during a base flow condition, after the pulse event has subsided.
4. Collect and analyze sediment at this site.
5. Install water table monitoring wells to better understand the sub-surface connectivity of riparian species to river water levels.

6 Data Archive Structure

Field intensive environmental studies generate large amounts of data from a variety of instruments and collection methodologies across multiple entities. Organizing the data into manageable and usable information is a difficult and time consuming task and there is not one clear, easily identifiable solution. Structured data management practices require significant time and resource inputs that may not be consistent and available throughout a projects life cycle and finding the right balance is key. For some projects, data will be collected, analyzed, and modeled, but for others, it may be not be processed until years later. It is important that these data be organized, maintained, rapidly accessible, and easily transmitted across entities and digital platforms.

For this project, data were collected across five separate entities, seven data types, numerous instrumentation types, with different data processing requirements. Additionally, some data is merged during the processing phase. For example, cross-section data can be a combination of topographic survey, GPS, and echosounder bathymetry.

After several iterations, the architecture that organized field data by *data type* worked the most efficiently. Generally, data move from *Bulk Raw Data,* where it is either stored indefinitely or until it is ready to be parsed, out into a specific site folder. Once in the *Site* folder, data is quality assured and housed by data type. Data are stored here permanently, or migrated to the *Working/Data Processing* Folder if further processing or combination is required. Data used for analysis or modeling is moved into the *Model/Analysis Type by Site* folder. The data processing may stop anywhere along this path and be stored until needed.

The most important aspect of the process is to ensure that each entity contributing data understands the structure and naming convention, and that a data project manager is assigned. The architecture is described and shown in detail in Figure 110 and Table 23. The final data used for analysis for this project and relevant data from these sites from previous projects has been migrated into this archive format and are included in Appendix 2. Electronic Data Archive Structure and Final Data.

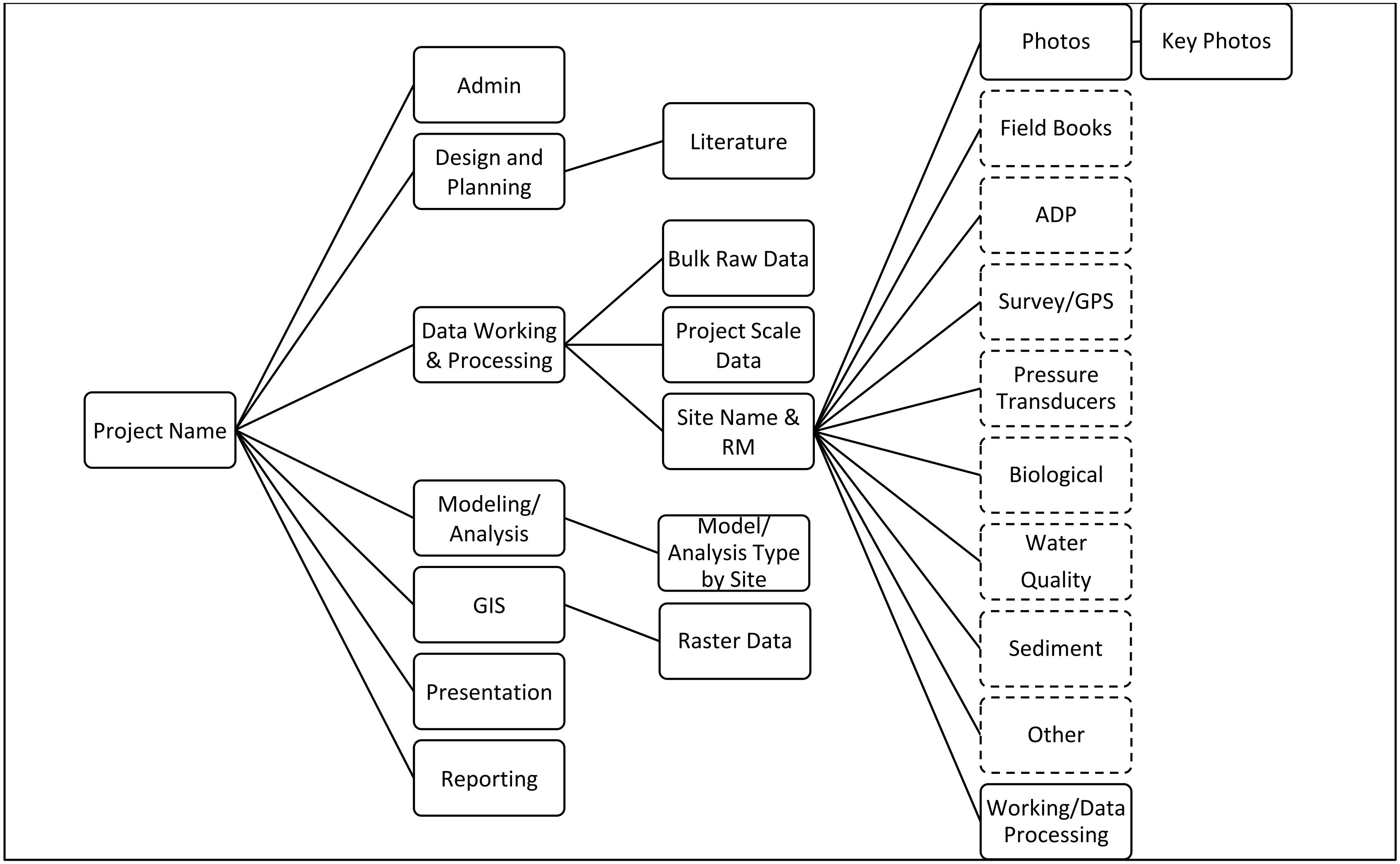


Figure 110. Flowchart describing the data storage structure for projects and field studies. Files stored within boxes shown drawn with dotted lines should be named as follows: [Site Number (Basin ID and River Mile)]_[Deployment or Collection Date (YYYYMMDD)]_[Data Type]_[description if needed (version, raw, final)].[file extension] with no spaces. Examples: *080444_20150101_PT_v3.xlsx, 080075_20140601_Survey_processed.job, 080295_20151101_M9_raw.csv*.

Table 23. Table describing the Data Archive Structure. The Utility abbreviations are described as follows: An-Analysis, Ar-Archive, M-Modeling, P-Processing, PM-Project Management, QA-Quality Assurance, TS-Temporary Storage, S-Storage, Ref-Reference, and Rep-Reporting.

Level	Title	Description	Utility
I	Project Name	Name of the project.	PM
II	Admin	Documents pertaining to the contracting, budgeting, invoicing, and/or other administrative needs of the project. This section should include an email archive, if required.	S
II	Design and Planning	Documents and files needed to plan and implement the project. Examples: meeting notes, planning maps, discussion points, landowner contact information	S, Ref
II	Data Working & Processing	Data housing and processing location.	Ar, P, TS
II	Modeling/Analysis	Data modeling and analysis.	An, Ar, M
II	GIS	GIS directory for project scale GIS data. May include project specific subfolders as required for site-scale basemaps.	An, Ar, M
II	Presentation	Presentations for internal and external audiences.	S, Rep
II	Reporting	Reporting notes, concepts, and documents.	Rep
III	Literature	Project specific literature.	Ref, S
III	Bulk Raw Data	This is strictly bulk data storage for all parties. This provides a single repository for all raw field data across entities.	Ar, S
III	Project Scale Data	Data that pertains to the entire project, not just one specific site. Examples: statewide rainfall data, basin-wide biological data, and reach specific data that covers more than one site.	S
III	Site Name and RM	Site specific data. This folder is where data QA, combination, and processing takes place. The naming convention incorporates the basin name and river mile, if appropriate. Example 080444 (Trinity basin “080” and river mile nearest center of the site “444”. Subfolders may include some intermediate GIS files; completed GIS files are transferred to Level II GIS folder.	Ar, P, S
III	Model/Analysis Type by Site	This folder will include final, processed data that is formatted for specific modeling or analysis purposes. This folder may include subfolders by site and/or model type, if applicable. Examples: HEC-RAS files, final cross-sections, water surface profiles, hydrologic analysis spreadsheets, model-specific GIS outputs and SWAT modeling results.	An, Ar, M
III	Raster Data	Raster and aerial images. Examples: land use, land cover, LiDAR, and digital terrain models	An, Ar, M, P, Rep
IV	Field Books	Scanned field books and field sheets.	Ar, Ref
IV	Photos	All photographs. Photographs should be tagged in the image metadata with the site name, date, and other relevant information as appropriate. Whenever possible, photographs will include latitude and longitude.	An, AR
IV	ADP	Acoustic Doppler Profiler data, point velocity or similar. Examples: electronic flow, velocity, depth data.	A, P, QA

IV	Survey	Topographic survey data. Examples: surveyor's level, robotic total stations, laser range data, GPS, and RTK base correction files.	A, P, QA
IV	Pressure Transducer	Pressure transducer and barometric pressure data, or other water level information.	A, P, QA
IV	Biological	Biological field data. Examples: fish, benthic macroinvertebrates, and riparian vegetation identification	A, P, QA
IV	Water Quality	Field collected water quality data. Examples: water quality sondes, long-term sonde deployments, and laboratory analysis.	A, P, QA
IV	Sediment	Field collected sediment data. Examples: gradations, particle size descriptions, diameter measurements, and Wolman pebble counts.	A, P, QA
IV	Other	Other site or project specific data not identified in other folders. If appropriate, this folder can be renamed to the data type.	A, P, QA
IV	Working/Data Processing	This is the working folder for each site and includes the intermediate files created during processing. Examples: working directory for combining pressure transducer and survey data into cross-sections, and creating elevations from pressure transducer and water surface profiles data.	A, P, QA
V	Key Photos	Specific photographs of interest or photographs specifically identified for use in analysis or reporting	An, Ar, Rep

7 Conclusions

The work summarized in this report represents intensive data measurement efforts at three sites in the Trinity River basin at locations representative of Senate Bill 3 (SB3) measurement points. The work relates primarily to high flow pulses, with focus on riparian areas, sediment substrates, and cross-sectional changes. This limited one-year data collection effort benefits from additional work conducted by TRA since 2011 that laid a groundwork for choosing site locations, employing well-developed field methods, and extracting baseline information from a growing database of river data.

This work in 2015 was impacted by significant over-bank flood events that hampered efforts to measure riparian vegetation on two sites. The high water levels also hampered repeat cross-section surveys desired during low-flow conditions. However, the over-bank event afforded a rare opportunity to conduct measurements *during* high flow events including cross-section and flow data measurements in overbank areas, up to 2 miles wide, that have not previously been measured.

At site 080444 nearest to the Trinity River at Dallas measurement point, high flows are constricted between levees. Transect surveys of riparian trees indicate a healthy diversity of typical riparian and upland tree species. The existence of a relic lock and dam structure that was flanked (breached to river left) by natural erosion processes in 2012 indicates this will be an area of morphologic change. Monitoring of cross-sections and riparian species trends in this area will be fruitful to understand how change in base flow elevation will affect the riparian area as well as the stream morphology and in-channel habitats. Already, the left bank one half mile upstream of the relic dam is exhibiting significant mass failure as higher velocity low-flow waters act upon the toe of the slope that for over 100 years had been inundated within the dam’s backwater.

At site 080295 nearest to the Trinity River near Oakwood measurement point, the direction of overbank flood waters passing down-valley are transverse to the channel, and even reverse the channels typical low flow direction, in some sections near the study site. Mass failures were observed at this site after an extended period of high flows that peaked at approximately 80,000 cfs. This site is coincident with a Senate Bill 2 TIFP baseflow instream flow study site.

At site 080075 nearest to the Trinity River near Romayor measurement point, riparian areas are more easily inundated by local runoff and drainage in this low coastal plain than by the river channel. The natural levees on the river channel represent a localized high point in the river valley that holds the river within the channel except near low points on the bank from old meander scars or oxbow cutoffs.

Future work should continue to characterize the riparian vegetation at these study sites and at other locations along the channel and through the basin. Additional data will continue to illuminate spatial differences in the sediment conditions and riparian communities, and how those differences relate to flow regime values.

Recommended additional work:

- Riparian cross-sections should be completed at each site since high flows prevented data collection during this project.
- SB3 flow standards profiles at study sites should be projected upstream and downstream of the sites and linear survey field work should be completed to determine if the flow standards would inundate tributary confluences or other low lying junctions, especially at near known oxbow lakes.

- Game-cams can be installed to capture water level during pulse flow events to estimate riparian inundation; installation would be beneficial within a mile of SB3 measurement point USGS stations and/or near tributary confluences, low lying junctions or oxbow lakes.
- Repeat channel monitoring should be completed at these sites to determine the effects of the 2015 flood events on the morphology of the channel.
- Biological data should be collected and compared with the 2012 Supplemental Biological Data Collection effort to determine the effects of extended high flow scouring events on fish, benthic macroinvertebrates, and native mussels.
- Additional LiDAR should be collected, especially in locations where the existing LiDAR is out dated or inaccurate.
- Another channel monitoring site should be installed to represent the most upstream SB3 measurement point at USGS gage 08049500 - West Fork Trinity River at Grand Prairie.
- Develop a historical timeline for each of the Trinity River study segments identified in the TRA Long-term Study, identifying flood control, navigation, and other pertinent characteristics.
- The historical USACE cross-section data from 1899 and 1939 should be location-referenced to facilitate comparison to modern-day survey data.
- Measure pre-failure baseline conditions upstream at Lock #2 in anticipation for a future dam failure.
- The Data Archive Structure should be adopted by other entities working on instream flow studies in order to assist in sharing data across platforms.

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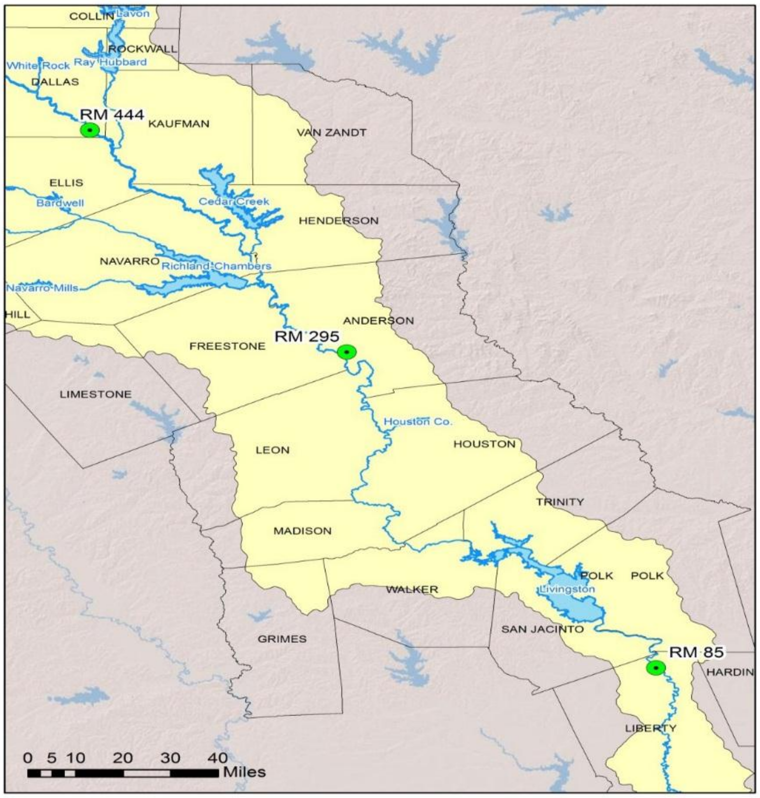
9 Appendix 1. LiDAR Acquisition and Flow Assessment for the Middle Trinity River Scope

Scope of Work

LiDAR Acquisition and Flow Assessment for the Middle Trinity River

The Texas Commission on Environmental Quality adopted flow standards for the Trinity River and Galveston Bay system on April 20, 2011. To date, limited work has been completed to link adopted Senate Bill 3 environmental flow standards to instream physical and ecological characteristics. For example, few studies have been conducted to relate how each Senate Bill 3 study site location represents a characteristic river reach or how the adopted standards relate to the geomorphology, biology, and hydrology of the Trinity River. This project will collect site-specific field data and will analyze river characteristics at three Senate Bill 3 measurement sites in the Trinity River basin to determine system responses to the adopted standards. River study sites will be in the vicinity of the Dallas (river mile 444, USGS stream gage #08057000), Oakwood (river mile 295, USGS stream gage #08065000), and Romayor (river mile 85, USGS stream gage #08066500) Senate Bill 3 study locations.



The proposed project will deliver (1) a Light Detection and Ranging (LiDAR) topographic dataset, (2) a site-specific field dataset and (3) a final report detailing field work, modeling results, and analysis relative to the Texas Commission on Environmental Quality's adopted Senate Bill 3 environmental flow standards for these river locations. Senate Bill 3 funds will cover site-specific field study, analysis and reporting to relate physical stream characteristics to the adopted Senate Bill 3 environmental flow standards. The total cost of the project is $212,000. The Trinity River Authority (Authority) has committed $64,000, and Tarrant Regional Water District has committed $26,000 towards the base LiDAR topographic dataset. The Authority has committed an additional $10,000 of in-kind services to support Senate Bill 3 field efforts. The amount of funding committed to the project by this contract is $112,000.

LiDAR

LiDAR derived Digital Terrain Model (DTM) data has been shown to be the recommended approach for large river basin management because accurate and precise river geometry data are important in order to properly identify aquatic habitat types (Marchamalo, Bejarano, Garcia de Jalon, & Marin, 2007) (Hauer, Mandlburger, & Habersack, 2008). The majority of LiDAR in Texas is collected for flood mapping in populated areas; therefore, there is a large data gap in the middle Trinity River basin. LiDAR acquisition benefits greatly from economies of scale - the larger the study area, the lower the unit price.

Authority staff identified an existing Texas Natural Resource Information System (TNRIS) supported LiDAR project near the middle Trinity River subbasin and pooled resources with Tarrant Regional Water District in order to save an estimated $200,000 compared to completing a standalone LiDAR project. The LiDAR study area consists of a six-mile buffer (3 miles on each side) of the mainstem Trinity River between SH 79/US 84 near Oakwood to approximately ten river miles upstream of US 287 in southern Henderson and Navarro Counties, plus two additional small river reaches upstream in Kaufman and Dallas Counties. The project deliverable is expected before January 1, 2015 and includes a quality assured and publically available 1m DEM for the entire study area generated from fully-accepted point cloud and hydro breakline data and metadata. This data will be archived by TNRIS and publically available through their standard delivery options to meet the modeling needs of Senate Bill 3 and other efforts.

Flow Assessment

The Authority completed initial hydraulic, riparian inundation and sediment modeling at one site on the Middle Trinity River upstream of the USGS gage near Oakwood near river mile 295 in 2013. Results suggested that a better understanding of the system can be gained from refining the model with LiDAR data (currently being collected) at this location and completing similar studies at other SB3 measurement points.

Task 1: Data archive structure

The Authority has a large amount of electronic field survey, bathymetric, flow, sediment and habitat data throughout the Trinity River system. Additionally, Task 2 of this project will generate a significant amount of additional data. In order to ensure that the hard-earned field data is best utilized for this project and available for future projects, this task will develop a process for storage and retrieval of final quality-checked data and metadata that can be hosted online and easily disseminated to external researchers and field crews. Once the format and data Quality Assurance process is complete, existing data will be migrated into the framework and final project data will be hosted at the Authority.

Task 2: Acquisition of field data in the vicinity of: river mile 444 near Malloy Bridge Road in southern Dallas County, river mile 295 (the USGS gage 08065000, near Oakwood, TX) and river mile 85 (near the USGS gage 08066500 at Romayer, TX)

Field data will be collected in order to understand the biology, geomorphology, and hydrology of each study site. Additionally, whenever possible, hardened benchmarks will be installed at each site to facilitate future studies and confirmation of modeling efforts associated with this project, if needed. Data will be collected in accordance with standard industry practices and will include, but is not limited to:

- Bathymetric survey (cross-section and longitudinal);
- Field survey (cross-section and water surface profile);
- Flow (Acoustic Doppler and wading rod, as required);
- Photographic (automated camera and standard photographs);
- Field observation;
- Riparian cross-section;
- GPS
- Sediment

A minimum of one multi-day field event and one single day follow-up/maintenance field event will be completed at each study site.

Task 3: Data processing and modeling

Field data will be converted to digital format (if needed), processed and quality assured according to standard industry practices. Once final, all data will be formatted to meet the standards determined in Task 1. Georeferenced HEC-RAS (a hydraulic modeling format developed by the Army Corps of Engineers) models will be built and calibrated for two sites (river mile 444 and river mile 85) and refined for the river mile 295 site. Modeling efforts will include riparian inundation, water surface profiles and grain size transport potential for relevant (SB3 standards) steady-state flow rates.

Task 4: Data analysis and reporting

The report will include an analysis of the data compiled by site along with relevant photographs, descriptions and summary statistics. Final data will be included on a DVD with the report. HEC-RAS results for each site will include, but are not limited to, the appropriate SB3 required flows. Assessment of historical US Army Corps of Engineers data will be completed and, if appropriate, included in the analysis of current data.

Schedule

Due to the nature of flow dependent field studies, fieldwork will be completed as soon as possible when instream conditions are right. The general work flow will consist of an existing data review, field data collection, data processing and quality assurance, final data formatting, archiving, model preparation, model calibration, model refinement, analysis and reporting. Quarterly progress reports will be submitted to the TWDB. The final data and report will be completed and delivered to the TWDB no later than August 31, 2015.

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10 Appendix 2. Electronic Data Archive Structure and Final Data

See Associated Electronic Deliverable

11 Appendix 3. Texas Water Development Board Executive Administrator’s Draft Report Comments

Attachment I

LiDAR Acquisition and Flow Assessment for the Middle Trinity River

Tim Osting, Webster Mangham, and David Flores

TWDB Contract No. 1400011696

TPWD Comments to Draft Report

REQUIRED CHANGES

General Draft Final Report Comments:

The report appears to fulfill contract requirements to address the study goals and objectives as described in the study scope of work (SOW). The SOW prepared for this study identified four major work elements to be contained in the final report. These tasks were identified, as follows:

- Task 1: Data archive structure
- Task 2: Acquisition of field data
- Task 3: Data processing and modeling
- Task 4: Data analysis and reporting

Information is presented regarding all four work elements above. Although some study work elements were unable to be completed due to significant flooding throughout the Middle Trinity River in the spring and summer of 2015, valuable cross-section and flow data was collected during a major overbanking event. Such parameters have not previously been measured.

The report could generally be improved with the inclusion of additional scientific citations where ecological inferences are made.

The SOW calls for an assessment of historical US Army Corps of Engineers data but all data mentioned in the report appears to have been collected in 2013 or more recently. It is unclear whether an assessment of historical USACE data was completed.

Please edit the document for typos and miss-spellings. For example, Texas Parks and Wildlife Department is incorrectly abbreviated as "TWPD" on two occasions. The section number 3.1 is used for different portions of the text on pages 29 and 48.

Please provide definitions for several abbreviations used in the document. For example: PT, WS, and WSP used in Table 4 and other locations in the document and WS and OWS in Figure 25 and other locations in the document. Perhaps a glossary would be useful for this purpose.

Specific Draft Final Report Comments:

- Please add the following statement to the cover page of the final report: *"PURSUANT TO SENATE BILL 1 AS APPROVED BY THE 83RD TEXAS LEGISLATURE, THIS STUDY REPORT WAS FUNDED FOR THE PURPOSE OF STUDYING ENVIRONMENTAL FLOW NEEDS FOR TEXAS RIVERS AND ESTUARIES AS PART OF THE ADAPTIVE MANAGEMENT PHASE OF THE SENATE BILL 3 PROCESS FOR ENVIRONMENTAL FLOWS ESTABLISHED BY THE 80TH TEXAS*

LEGISLATURE. THE VIEWS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE AUTHOR(S) AND DO NOT NECESSARILY REFLECT THE VIEWS OF THE TEXAS WATER DEVELOPMENT BOARD."

- Section 2.2, page 22, 1st sentence: Please clarify whether the "As this study" refers to the study documented in this report, TRA's long-term study, or some other effort.
- Section 2.4.1, page 24, 1st paragraph: Please include a brief description of sampling methods.
- Section 3.2.2, page 61, 2nd sentence: Please amend the sentence to read, "…species identified on *right* bank were…" rather than "*left* bank."
- Section 5.1, page 100, 1st sentence: Please amend the sentence to read, "8 miles upstream of SH105 (Figure *94*)…" rather than "Figure *95*."

Figures and Tables Comments:

- Figure 3, page 16: Please change drought categories from "Mild, Med, and Severe" to "Moderate, Severe, Extreme, and Exceptional" to match US Drought Monitor categories or explain how your designations compare to theirs.
- Figure 18, page 33: Please change y-axis label to "Elevation (*ft*)" rather than "(*cfs*)."
- Figure 23, page 38: Please provide the meaning of the varying symbols and abbreviations.

SUGGESTED CHANGES

Specific Draft Final Report Comments:

- Section 3.2.1, page 48, 2nd paragraph: Please consider providing a brief description of why riparian tree, sapling, and seedling data are important factors in instream flow studies. A citation to the scientific literature would also be helpful.
- Section 3.2.2, page 57, last sentence: Please consider adding a citation to the scientific literature to strengthen the point regarding effectiveness of riparian vegetation recruitment.
- Section 3.2.4, page 68, 2nd paragraph: Please consider adding a citation to the scientific literature to strengthen inferences regarding riparian recruitment and nutritional benefits. Any information related to what would be an adequate (*substantial*) frequency or amount of inundation to the riparian community would be informative. If such information is not available or outside of the scope of the effort, consider identifying the utility of such information in the text.
- Section 4.2.1, page 73: Please consider adding a reference to Figures 65-67 in this section.
- Section 6, page 123, 1st paragraph, last sentence: Please consider revising to state: "It is important that *these* data be organized, *maintained*, rapidly accessible, and…"
- Section 6, page 124: Please consider adding additional text describing the importance of the development of an appropriate data archive structure and further explanation of the data archive structure adopted by this project.

Figures and Tables Comments:

- In the tables showing relationships between flow, sediment grain size, and sheer stress (e.g. Table 6, Table 14, Table 15), please consider further explaining what the different colors symbolize. If the colored boxes on the tables represent the flow ranges at which the different grain sizes mobilize, please clearly describe them as such.
- Figure 24, page 39: Please consider explain in the caption what the blue and pink squares symbolize and their significance or remove them from the figure.
- Figure 25 – 29, pages 41-45: Please consider using different colored lines to allow the reader to more readily differentiate between the various flow levels.
- Figures 32-34, 38-40, 44-46, 50-52: Please consider removing pie charts for tree communities from the report as they add little beyond what is already conveyed in Tables 7-10.