Evaluation of Adopted Flow Standards for the Trinity River, Phase 2

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

"PURSUANT TO HOUSE BILL 1 AS APPROVED BY THE 84TH 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. 1600011940

Final Report – November 2017

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Acknowledgements
This work could not have been completed without the hard work, blood, sweat, drive shafts and grit given up by the dedicated field staff who persevere so we can all get to know the Trinity River a little better:

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Texas Water Development Board – Mike Vielleux, Nathan Brock
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1 Background

1.1 Objective

The ultimate goal of this project is to use empirical data, field observations, and modeling results to understand and document instream conditions and/or functions of the Senate Bill 3 (SB3) flow standards. As such, this report and accompanying data deliverable is not intended to recommend flows or provide an exhaustive explanation of each flow possibility, but is designed to serve the following purposes:

1. Summarize field and analysis methods used for this project;
2. Document existing data;
3. Provide a data archive deliverable that the Trinity and San Jacinto Basin and Bay Area Stakeholder Committee (BBASC) can use to answer questions during the upcoming adaptive management phase of SB3;
4. Provide the morphology, hydrology, riparian, sediment, and connectivity backdrop for the incorporation of upcoming biological data collection results;
5. Provide an overview of selected results; and
6. Characterize the system at different flows.

This Phase 2 project is a continuation of work completed in 2015 (Mangham et al. 2015) to evaluate the SB3 environmental flow standards for the Trinity River. Combined, Phase 1 and Phase 2 focus on high flow pulses and address data gaps identified in the SB3 BBASC Work Plan Report (TSJ 2012). Phase 2 includes the following three tasks as identified in the Scope of Work (Appendix 1 – Scope of Work):

1. Acquisition of field data in the vicinity of: river mile 485 (the United States Geological Survey (USGS) gage 08049500, at Grand Prairie, TX), near Belt Line Road bridge; river mile 444, near Malloy Bridge Road in southern Dallas County; river mile 295 (the USGS gage 08065000), near Oakwood, TX; and river mile 75 (the USGS gage 08066500), near Romayor, TX. (Table 1 and Figure 1);
2. Data processing, analysis, modeling and reporting; and
3. Coordination with other instream study efforts.

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 United States Geological Survey (USGS) Gage Number	Measurement Point USGS Gage Name	Representative Site (Basin Number and River Mile)
08049500	West Fork Trinity River near Grand Prairie	080486
08057000	Trinity River at Dallas	080444
08065000	Trinity River at Oakwood	080295
08066500	Trinity River at Romayor	080075

This project deliverable report details field work, modeling results, and analysis relative to the Texas Commission on Environmental Quality's adopted SB3 environmental flow standards for the four measurement locations in the Trinity River basin. The deliverable includes a site-specific field dataset transmitted in the data archive format developed during Phase 1 (Mangham et al. 2015).

The format of this Phase 2 report differs from that of the Phase 1, which focused on reporting of field data measurements and modeling results. Field data collection and modeling efforts continued during Phase 2, but the additional measurements and results are summarized in the appropriate appendices. The main body of this Phase 2 report focuses on combined results and relevance of Phase 1 and Phase 2 findings to the SB3 flow standards.

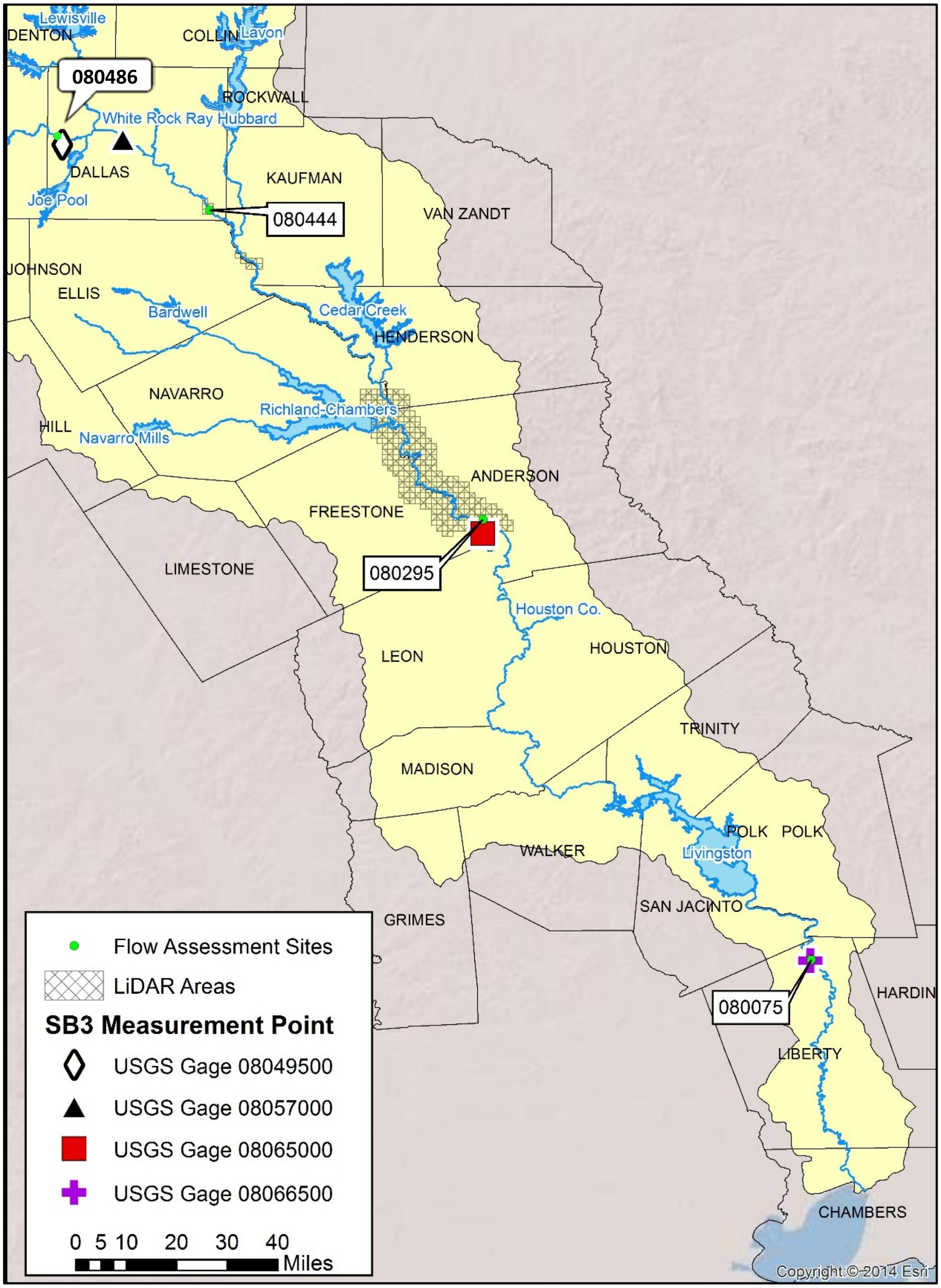

Figure 1. Flow assessment sites and USGS gauge measurement points.

1.2 Review of previous work

Phase 1 tasks included acquisition of a LiDAR dataset, development of a data archive structure, measurement of field data at three river site locations (080444, 080295 and 080075) downstream of SB3 Trinity River measurement points (Dallas, Oakwood and Romayor, respectively), modeling of water surface profiles and inundation mapping, and data analysis relative to SB3 pulse flow levels (Mangham et al. 2015). In addition to reporting on those activities, Phase 1 reported on prior relevant studies funded by other sources and programs.

Since completion of the Phase 1 report, a Texas Water Development Board (TWDB)-funded Texas Instream Flow Program (TIFP) project related to base flows and water quality downstream of Dallas and upstream of Lake Livingston (encompassing the middle two sites from this report - 080444 and 080295) has been completed (RPS and ASI 2015). The results of that work indicate that, with a degree of uncertainty, for base flow levels higher than 450 cubic feet per second (cfs) both the dissolved oxygen (DO) and temperature goals for the TIFP are maintained. For flows above 75 cfs but below 450 cfs, the DO goal is maintained but the temperature goal may be exceeded during hot summertime conditions in some shallow depth river habitats.

1.3 Coordination with other entities (Task 3)

Project staff working on Phase 2 have coordinated with the TIFP Senate Bill 2 (SB2) staff and with staff conducting Senate Bill 3 (SB3) studies in other basins. Environmental Flow Assessment studies are relatively new to Texas, and it is important for researchers to discuss methods, results, and future sampling plans to verify if data can be relevant and comparable across basins, thus maximizing state resources for these important studies. Among many interactions between the project team staff and agency staff, two meetings in particular highlight these coordination efforts:

2016-07-06 – Trinity TIFP SB2 agency work group meeting:
This was an interagency meeting with discussion focused primarily on data collection, specifically, 1) what flow conditions are appropriate for base flow field data collection efforts, and 2) what is the impact of two years of extraordinary high flows on site conditions.

Two field efforts were discussed to assess whether conditions have changed, as compared to the baseline fish sampling event conducted in 2011 and to the sediment mapping that occurred in 2013. The riparian data collection effort being initiated by Tom Hays for the Texas Parks and Wildlife Department (TPWD) was discussed. The TPWD field methods are comparable to those proposed for the Trinity River SB3 project, with these differences: 1) TPWD is using longer transects (up to 100 meters); 2) TPWD is geolocating each tree; and 3) TPWD is recording herbaceous vegetation. Those TPWD riparian field efforts remain in-progress.

2017-06-29 – Brazos, Colorado, Guadalupe, San Antonio SB3 Instream Flow Project integration meeting:
Following two pre-meetings with consultant staff working on the SB3 instream flow projects being conducted in the Brazos, Colorado and Guadalupe-San Antonio basins, Trinity River Phase 2 project staff participated in a meeting to discuss field and analysis methods. The other project is collecting base flows fish data and relating that to antecedent high flow pulses along with oxbow connectivity data and riparian data. Riparian methods initiated in the other project

represent a different site sampling approach that allows for statistical comparison between project sites and between repeat measurements. Trinity River staff presented information being used in Phase 2 for evaluating high flow pulses, including channel changes, riparian sampling, and sediment collections.

1.4 Recent basin flow conditions

River conditions measured during Phase 1 and Phase 2 of this study are the product of historical and current events that shape the river in small and large ways. Following the drought beginning in 2011 and extending through 2014, flow in the Trinity River basin was over 10 times greater in both 2015 and 2016 (Figure 2). Because of the high flow events, some river areas that are in transition, like the 080444 site near where the river recently bypassed the lock, have experienced increased bank migration as a result of the change in river base level. Other river areas, like near the 080075 Romayor site, have experienced bank change as a result of natural river process responses to extended periods of high flow.

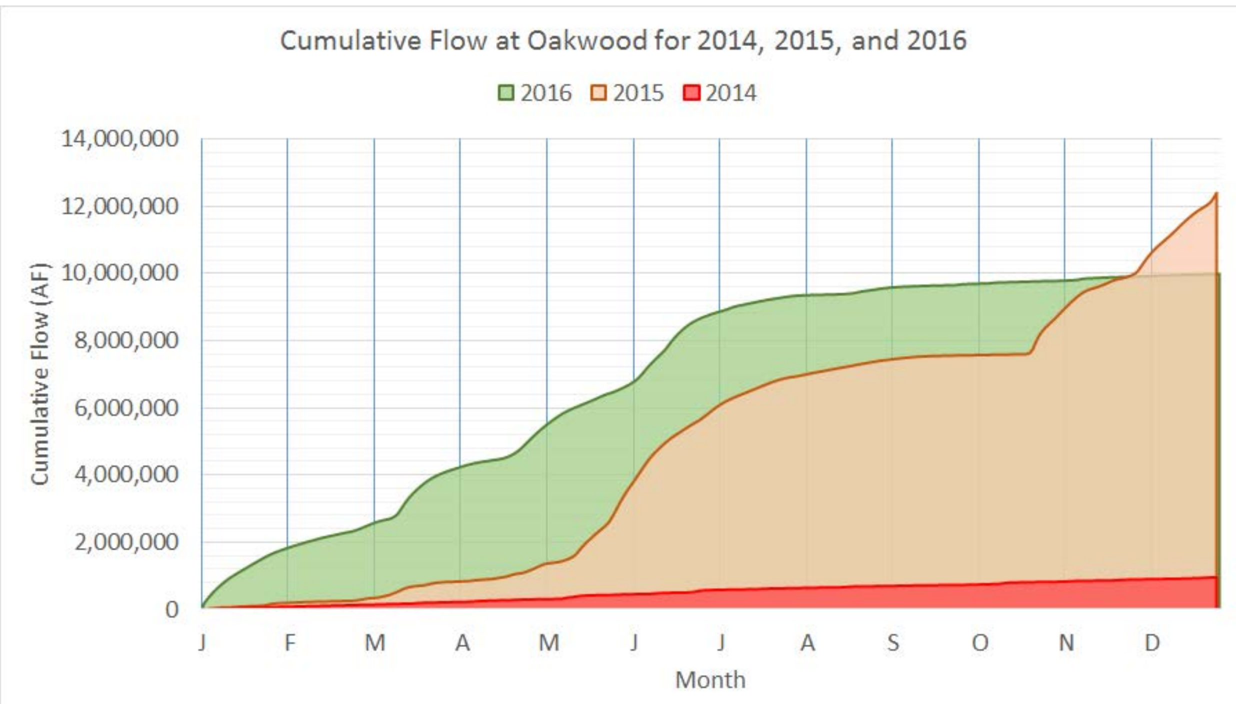

Figure 2. Cumulative flow (acre-feet) 2014-2016 at USGS Oakwood gauge during the study period.

2 Field data collection

Methodology for the field study program and data descriptions were included in the Phase 1 report (Mangham et al. 2015). The same methods were used for all Phase 2 work (Table 2); therefore, to avoid duplication, only modified methods or new methods are reported here. New descriptive sections are reported with a section number consecutive to that contained in the Phase 1 report.

Table 2. Field data collected by site and data type.

Site	Photos	Time-lapse Photographs	Sediment	Flow	Bench-marks	Cross-section Survey	Pressure Transducers	Riparian	Base Flow	High Flow
080075	X	X*	X*	X	X	X*	X	X*		X
080295	X	X*	X	X	X*	X*	X	X*	X	X
080444	X	X	X	X	X	X*	X	X	X	X
080486	X*		X*	X*	X*	X*	X*			

Notes: X = completed in Phase 1 or prior
X* = completed or repeated in Phase 2

2.1 Accuracy goals

Goals for positional accuracy of surveys remain unchanged from Phase 1. The overarching goal is to be able compare repeat measurements and changes through time within an acceptable level of confidence. For example, for cross-section geometry comparisons, the goal is to be able to document lateral and vertical changes at one foot resolution.

2.2 Cross-section field methods

Field methods for on-the-ground and echosounding surveys were contained in Phase 1 report sections 2.2.1 through 2.2.4.

2.2.5 Submerged river bed bathymetry collected with SonarMite

All bathymetry data was obtained using a Seafloor SonarMite BT MILSpec Echosounder (Seafloor Systems, 2017). The transducer utilizes a 200kHz signal at a 6Hz ping rate (2 pings per second) to obtain depth data while attached to a jon boat. Depth accuracy is reported to be 1cm/0.1 percent of depth. The elevation was tracked using a Trimble RTK system, with VRS capability.

2.3 Sediment

Methods for sediment field sampling are consistent with that in Phase 1 report.

2.3.1 Lab grain size analysis

Sediment samples were analyzed at the TWDB laboratory in Austin using standard drying and sieving methods. This yielded two grain size distributions, one distribution for the banks and one for the channel.

A summary of the data and procedures are reported in Appendix 4 – Sediment sample grain size analysis.

2.4 Riparian Survey

Information measured at each site is reported in Appendix 5 – Riparian assessment. Riparian transect methods are summarized in the Phase 1 report.

2.4.1 Tree Cores

As part of the ongoing investigations into the potential relationships between the riparian forest community and the Trinity River flow regime, tree cores were taken from 40 trees at the upstream and middle cross-sections of site 080295 Oakwood. Black willow, green ash and boxelder trees were selected for tree coring. The cores were taken using a 24” Haglof tree borer, from breast height to the approximate center of each sampled tree (Figure 3). Each tree core was aged (Figure 4) and compared to its diameter at breast height (DBH). Based upon tree ring dating and estimated age, each tree was assigned to a two-year age class and the age classes were associated with river flow data.

Figure 3. Coring tree with tag 340.

Figure 4. Example cores (tree tagged 339 top, 337 bottom).

2.5 High Flow – Overbank observation

Because of high flows throughout the basin in 2015, researchers were able to collect data during an overbank event. This data is documented in the Phase 1 report. In addition, flow conditions during the beginning of Phase 2 allowed for validation of water levels and river connectivity with backwater and off-channel areas.

2.5.1 Linear Survey Methods

During Phase 2, opportunity existed to document high flow pulses at the Oakwood 080295 and Romayor 080075 sites. These surveys were conducted as linear surveys within the segment surrounding each site and consisted of documentation of habitat, water surface elevation and connectivity to flood plain areas.

Habitat types and connectivity locations were identified from a boat using a Trimble GeoXH GPS unit, and photos were taken every river mile. Water surface elevation was measured along the profile using a Trimble R8 in FastStatic mode.

With an eye calibrated for the SB3 pulse flows, the reach was surveyed looking for inundated backwater habitat areas and lateral connectivity to flood plains throughout the reach.

Information measured is reported in Appendix 2 – Linear Survey for High Flow Pulse Event.

3 Results

3.1 Inundation and Connectivity

Inundation mapping was completed in HEC-RAS and the results were converted to shapefiles and imported into geographic mapping software. The area of the inundation polygons for each flow rate were calculated and plotted against flow to determine it how much increased inundation area is provided for each flow.

The urban site 080486 is located in Grand Prairie, within the Dallas/Fort Worth (DFW) metropolitan area. The channel is entrenched and is armored with rip rap in many locations. High flow pulses remain well within the banks with very little increase in inundated area as flow increases up to 15,000 cfs, the highest pulse observed during the study (Figure 5).

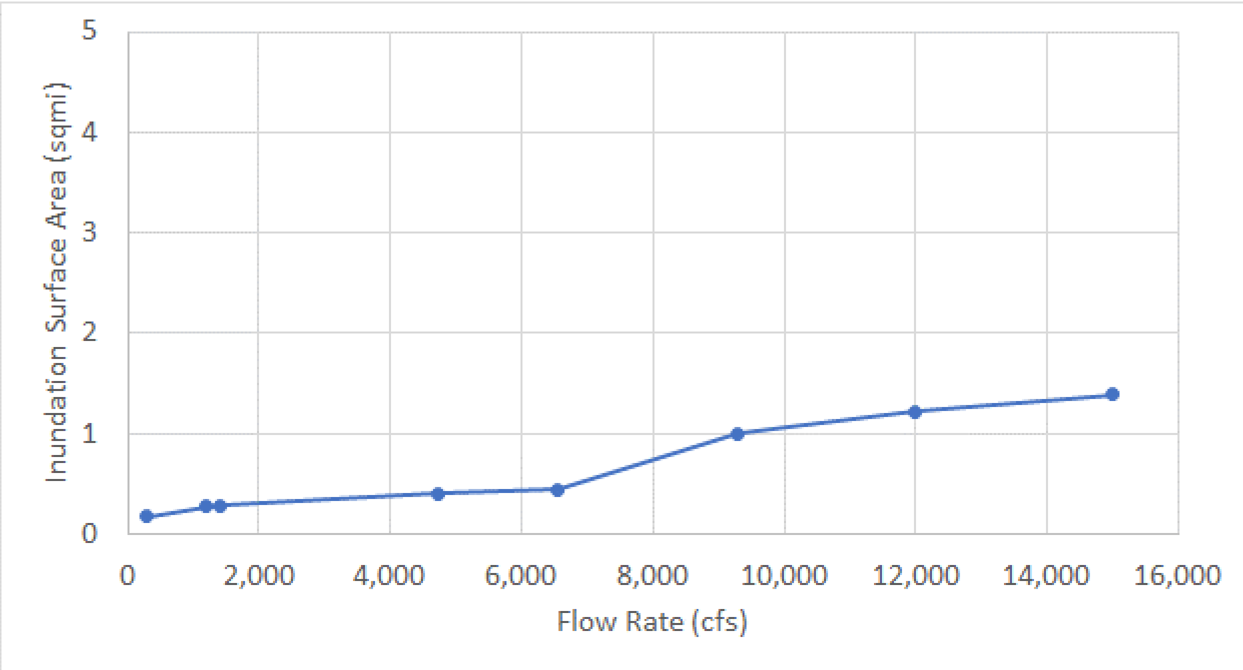

Figure 5. 080486 Grand Prairie - Inundation vs flow rate for pulse flows.

The lock site 080444 is located south of Dallas within a stream segment that is highly modified. Adjacent to the channel are flood control levees and within the channel exist lock and dam structures. Both locks within this reach have recently been flanked (erosion caused water to bypass the century-old structures). Up to 14,000 cfs, the river stays between the main banks of the river and does not overflow into the floodplain toward the levees (Figure 6). The riparian area adjacent to this site is affected since the floodplain is narrow between the levees. Primary connectivity of the river channel to the riparian area within this segment is through over banking flows on the lower half of this segment. Some inundation of backwater and oxbows occurs in the upper half of the reach near Interstate I-20 and the USGS gage Trinity River below Dallas (08057000).

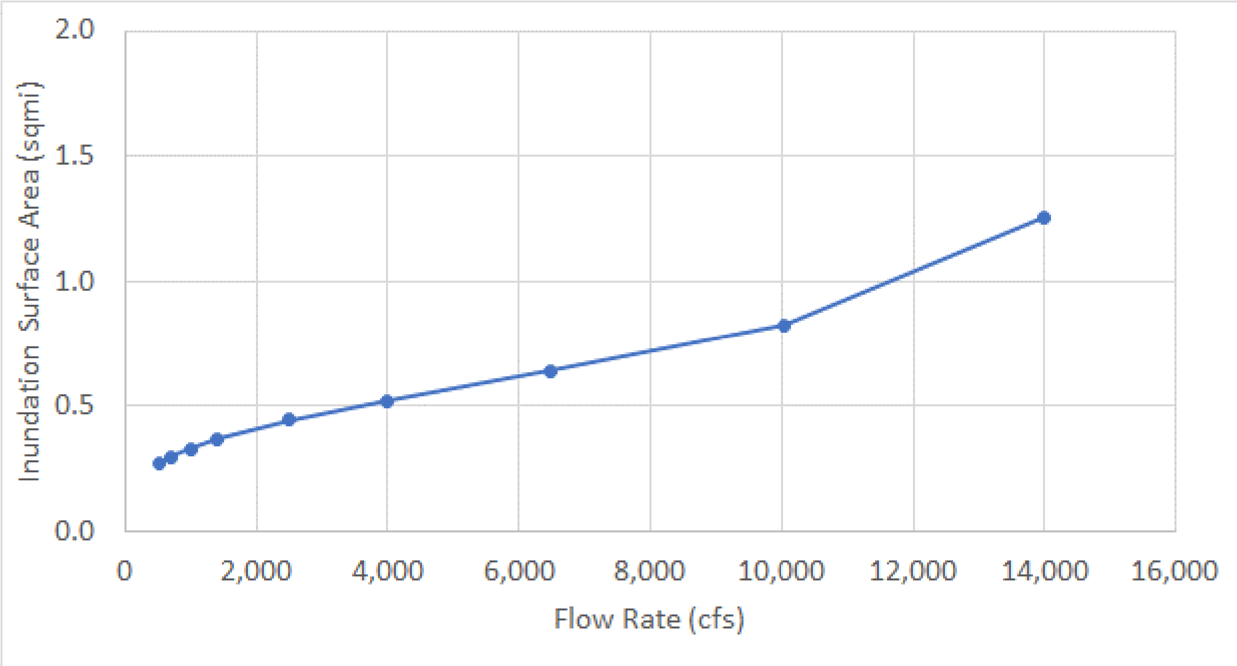

Figure 6. 080444 Dallas lock site - Inundation vs flow rate for pulse flows.

The Oakwood site 080295 is located in more of a natural channel than the two upstream sites. Although the hydrology is highly modified from upstream reservoirs and return flows, there are no levees and it is far downstream of the nearest in-channel lock structure. As such, the floodplain supports a wide riparian area. Pulse flows of approximately 13,000 cfs begin to inundate in-channel and off-channel backwater areas. Flows below 30,000 cfs tend to stay between the banks (Figure 7), flows higher than approximately 30,000 cfs crest the banks, and flows over 50,000 cfs tend to extend to the edges of the valley (Figure 8). Because of a northward meander of the river, the study site experiences reverse flow during extreme overbank events like those exhibited in 2015 where water flows southward between the valley walls and over top the channel. The complex floodplain contributes to a diversity of trees and riparian habitats at this site.

Figure 7. 080295 Oakwood site at 16,500 cfs.

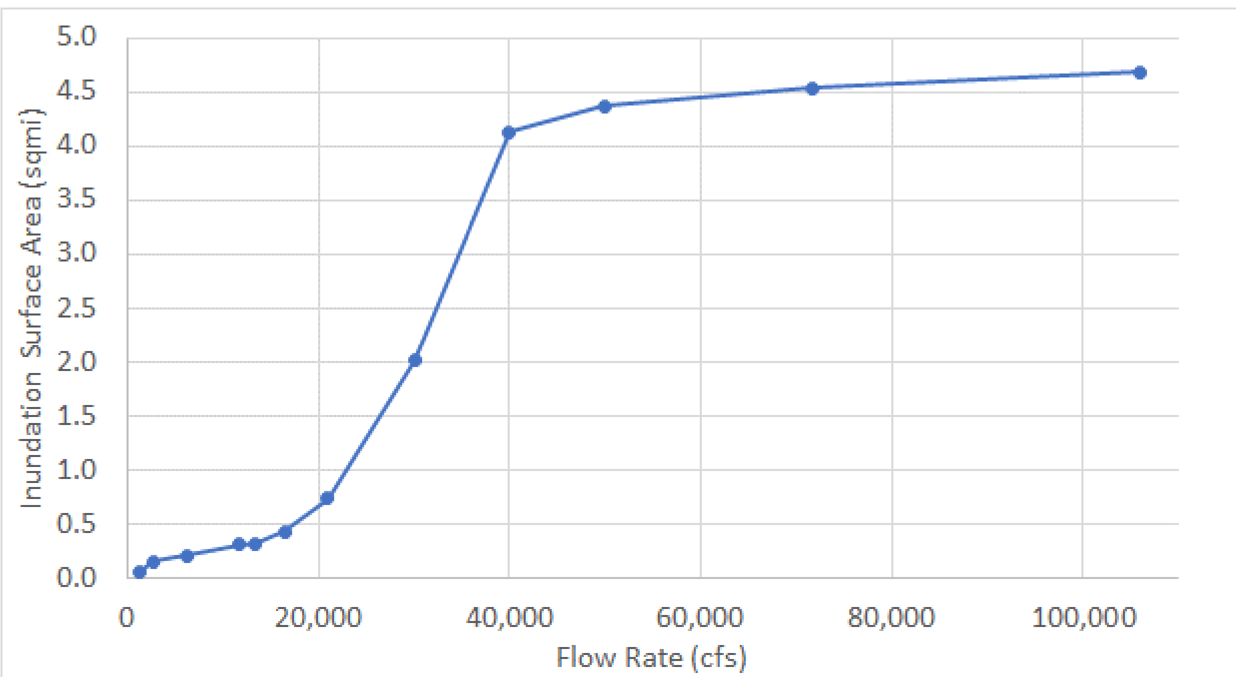

Figure 8. 080295 Oakwood - Inundation vs flow rate for pulse flows and overbanking flows.

The Romayor site 080075 is located between Lake Livingston and Trinity Bay on the Gulf Coastal Plain. This is a generally low lying area where the river's natural levees contribute to the diversity of wetland and riparian habitats. The natural levee tends to hold the river inside the banks for flows below 70,000 cfs. At the same time, the natural levees tend to hamper overland drainage within the floodplain into the river channel, creating low wetlands and low slope drainage networks behind the natural levees that form small tributary creeks that drain to the channel. Mapping of the inundation areas is reflective of water beginning to pool in the overbank areas for flow levels over 40,000 cfs while the channel remains distinct and defined (Figure 9, Figure 10, Figure 11). Pulse flows of approximately 12,000 cfs begin to inundate the in-channel backwater areas and to begin to connect tributaries and off channel backwaters.

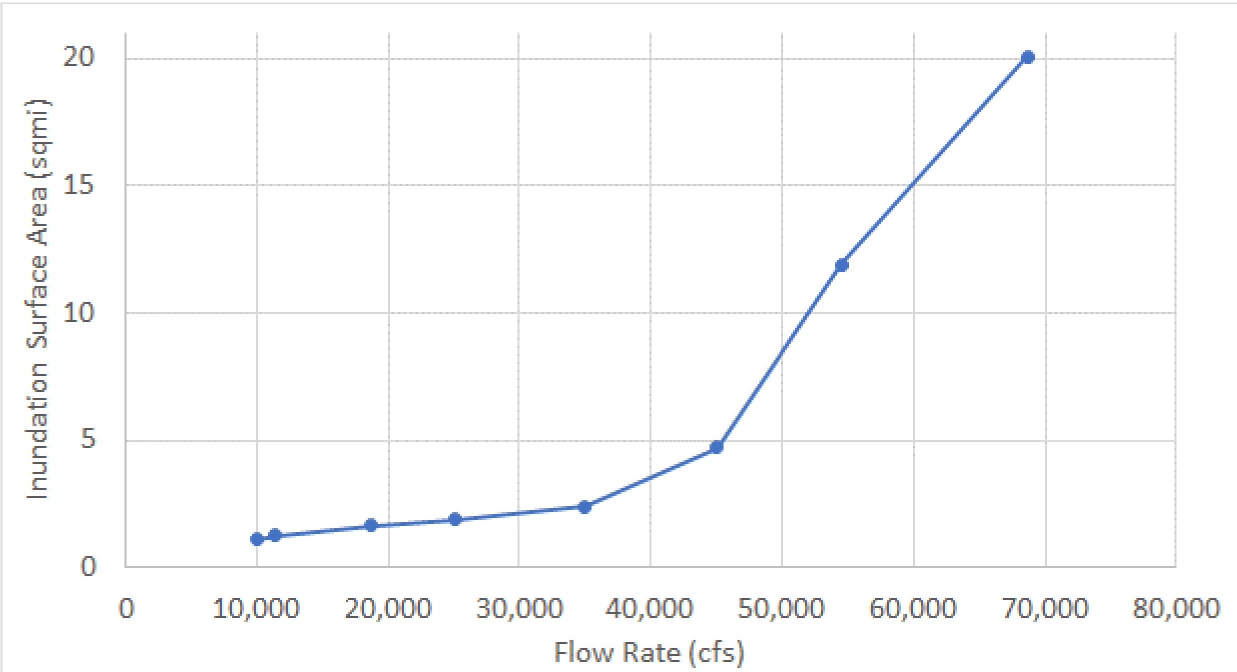

Figure 9. 080075 Romayor - Inundation vs flow rate for pulse flows and overbanking flows.


Figure 10. 080075 Romayor site at 22,500 cfs.

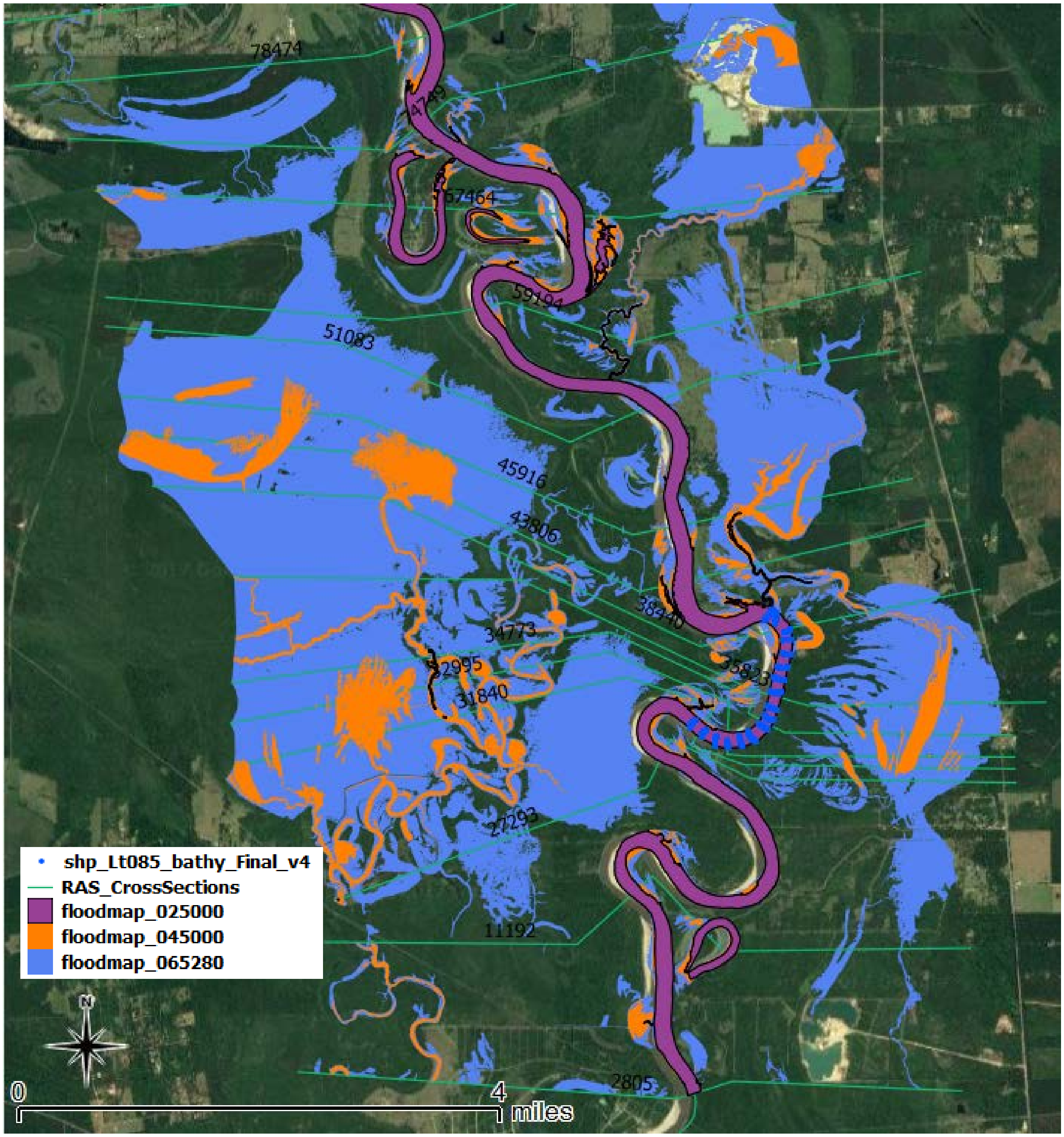

Figure 11. 080075 Romayor - Inundation map for selected pulse flows.

Additional observation information related to connectivity of pulse flows to riparian and backwater areas is included in Appendix 2 – Linear Survey for High Flow Pulse Event for both the 080295 Oakwood site and the 080075 Romayor sites. Additional photos for a range of flow rates are included in Appendix 3 – Cross-section measurements and HEC-RAS Modeling for both the 080295 Oakwood site and the 080075 Romayor sites.

3.2 Physical processes

3.2.1 Cross-section movements

This section compares temporal physical changes to the Trinity River Authority's (TRA) study site cross-sections on the Trinity River at four study sites (Table 3).

Table 3. Cross-section surveys at study sites on the Middle Trinity River.

Study Site Number	Study Site Name	Number of Cross-sections	Surveys Conducted
080486	Grand Prairie	3	2017
080444	Dallas / Lock 3	5	2014, 2015, 2017
080295	Oakwood	3	2012, 2016
080075	Romayor	4	2015, 2016

Three metrics were used to track dynamic temporal changes to cross-sections in each study site:

- **Minimum channel elevation.** The change in minimum channel elevation for each survey.
- **Horizontal shifts in channel cross-section.** The horizontal shift of a cross-section due to erosion or deposition.
- **Cross-sectional area versus flow.** Charts of cross-sectional surface area to flow rates.

Table 4 summarizes comparison metrics for each cross-section with at least two survey measurements. Details and figures are provided in Appendix 3 – Cross-section measurements and HEC-RAS Modeling.

Horizontal and vertical shifts are apparent in both the 080444 lock site and at the 080075 Romayor site. The 080295 Oakwood study site does not exhibit shifts, which may be due to the reverse flow dynamic of this site which limits high water velocities throughout this site.

At the 080444 lock site, the horizontal shifts at cross-section 4 near the lock (the lock is located between cross-section 4 and 5) are the results of a grade control change (lock failure and flanking) and adjustment to the new base water level. For this area, the magnitude of horizontal shifts are not typical of the remainder of the study segment, as exhibited at cross-sections 1 and 2 upstream and cross-section 5 which are farther from the influence of the failed lock structure. Vertical changes, specifically downcutting, are evident at cross-sections 1, 2, and 3; cross-section 4 does not exhibit such change because of the bedrock base.

Small changes are exhibited at the 080295 Oakwood site. While difficult to quantify, this may be the result of small-magnitude but continuous low-flow processes balancing with the recent episodes of high reverse flow overbanking.

Changes at the 080075 Romayor site are representative of that river segment located in the low coastal plain region with predominantly sand sediments. The magnitude of horizontal shift of the banks at the outside of bends is not surprising given widespread installation by pipeline companies of bendway bank stabilization measures discovered during the TRA 2013 longitudinal survey throughout the entire segment. Downward vertical shifts, or degradation of the channel elevation, was apparent at all cross-sections. It is difficult to quantify at this time whether the degradation is widespread and regional, or the result of a local grade control change that occurred downstream of the study site. However, downstream grade controls appear to remain unchanged since water levels did not change as significantly as the bed elevation, when comparing on-site measurements at roughly the same flow rate in 2015 to that measured in 2017. This indicates a localized, rather than regional, change in bed elevation. The elevation changes likely occurred during the episodic high flow events and will be likely to fill back in to the prior elevation over time, if lower flow conditions are not interrupted by another episodic flood event.

These repeat cross-section measurements indicate the magnitude with which dynamic rivers are likely to change under a typical range of flow conditions.

Table 4. Summary of repeat cross-section comparison metric results.

Site Number	Site Name	Cross-section	RAS Xsec Station Number	Xsec Description	Survey Years Comparison	Horizontal Shift[1] (Ft)	Vertical Shift[2] (ft)	Change in Cross-sectional Area[3] (sqft)	SB3 Flow rate used for Xsec Area Changes (cfs)
080486	Grand Prairie	1		Riffle	2017 only				
		2		Run	2017 only				
		3		Run	2017 only				
080444	Lock, Dallas	1	3849.9	Pool	2014 to 2017	6	-2.92		
		2	3478.9	Pool		0	-2.30		
		3	3013.7	Run		26	-1.68		
		4	2157	Riffle		60	-0.55		
		5	92.8	Riffle		0	0.19		
080295	Oakwood	1	295.32	Run	2012 to 2016	0	2.17		
		2	294.79	Run		0	-1.20		
		3	294.62	Riffle/Bend		-9.7	1.02		
080075	Romayor	1	38440	Bend	2015 to 2016	52.73	-1.82	1505.56	4,000
		2	35823	Run		0.53	-1.94	630.19	
		3	34773	Riffle		15.69	-3.68	1472.84	
		4	31840	Run/pool		50.29	-4.64	674.69	

1. Horizontal shift is either measured from a single bank (when the other bank has not moved) or it is the distance between the average channel centerlines. A positive number is a shift in the direction of the left bank, while a negative number is a shift in the direction of the right bank.
2. Difference between the lowest point in the Xsec channel between surveys. A positive number is an increase in elevation from the earliest year to the most recent year.
3. HEC-RAS model results were used to measure differences in area between survey years. A positive number is an increase in cross-sectional area from original year to most recent year. SB3 flow rates for the cross-sectional areas are listed in the column to the right.

3.2.2 Sediment incipient motion calculations – 080486 Grand Prairie

Shear stress calculations were performed using the new HEC-RAS model developed during this phase of the project for the 080486 Grand Prairie site. As was done for the other three sites during Phase 1, the shear stress calculations at this site were used to understand what sediment grain sizes would become transported across a range of flow rates based upon incipient motion. The shear stress needed to move each sediment type (Table 5) was related to shear stress and sediment motion across a range of flows at this site (Table 6).

Table 5. Shear stress causing incipient motion by sediment grain size.

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	

Table 6. 080486 Grand Prairie – HEC-RAS predicted channel shear stress (lb/sf) and associated sediment site in motion.

	Channel shear stress (lb/sf) and transportable grain size					
	XS3 Downstream		XS2 Mid		XS1 Upstream - Riffle	
Flow (cfs)	Shear stress	Grain size	Shear stress	Grain size	Shear stress	Grain size
300	0.010	Coarse sand	0.040	Coarse sand	1.070	Vry crs grvl*
1200	0.040	Coarse sand	0.080	Fine grvl	0.260	Coarse grvl
1420	0.050	Coarse sand	0.090	Fine grvl	0.250	Coarse grvl
2010	0.070	Fine grvl	0.110	Fine grvl	0.240	Med grvl
4740	0.14	Med grvl	0.140	Med grvl	0.240	Med grvl
6560	0.17	Med grvl	0.140	Med grvl	0.240	Med grvl
9300	0.19	Med grvl	0.140	Med grvl	0.230	Med grvl
12000	0.2	Med grvl	0.140	Med grvl	0.210	Med grvl
15000	0.21	Med grvl	0.140	Med grvl	0.220	Med grvl
		Note: * = erosion of compacted clay				

Sand is predicted to be transported across all flow levels modeled even through the lowest-energy pool cross-section 2. This is consistent with a predominance of sand and silt material in the channel bed and banks at this site indicating that this site is not aggrading or filling its pools or riffles at the corresponding flow values (Appendix 4 – Sediment sample grain size analysis).

3.3 Riparian

Riparian transect data was collected during Phase 1 at the 080444 Dallas lock site (Mangham et al 2015). During Phase 2, riparian transect data was collected at 080295 Oakwood and 080075 Romayor sites. Summary information for all three sites is provided below and additional data for Phase 2 activities is provided in Appendix 5 – Riparian assessment.

3.3.1 Riparian - 080444

As previously reported in Mangham, Osting and Flores (2015) riparian woody vegetation found along the riparian cross-sections at long-term monitoring site 080444 consisted of hydrophilic species, Black Willow (*Salix nigra*) and Green Ash (*Fraxinus pennsylvanica*) at lower elevations (i.e. moist soils near normal water surface elevations), and floodplain species, Cedar Elm (*Ulmus crassifolia*), Southern Hackberry (*Celtis laevigata*) and Pecan (*Carya illinoinensis*) at higher elevations with mesic species in between.

During a February 2017 field survey at long-term monitoring site 080444, large quantities of cottonwood (*Populus deltoides*) seedlings were observed at the upstream half of the site. It is unclear if the significant erosion processes or the flow regime documented in 2017 contributed to the recruitment of cottonwood seedlings.

3.3.2 Riparian - 080295

Biological and river geomorphic processes appear to be active at this long-term study site following the 2015 high flow event, including a large bank sluff observed along the left bank of cross-section 2 during the riparian survey. Those active conditions appeared to be ideal for black willow recruitment as a high density of black willow seedlings and saplings were documented during the survey. Several stands of large diameter black willow trees were observed adjacent to the riparian cross-section on both banks of the river.

Tree core sampling at riparian Cross-section 2 revealed the large black willow trees were beginning to rot due to oversaturation of the roots and trunk. Beaver activity cleared numerous large black willow trees on this bank within the time of the two field trips. Once these large trees rot away or are harvested by beavers, the banks will be more vulnerable to erosional processes.

Ongoing river channel changes may be the reason that riparian tree species like cottonwood and sycamore that are typical in other areas are not present at this site. As seen in the riparian vegetation tables, large quantities of black willow, hackberry, and swamp privet seedlings and saplings were observed during the 2017 riparian surveys. However, the high germination rates for these species did not translate into recruitment of mature (tree; >2” DBH, diameter at breast height) individuals.

Tree coring at 080295

Riparian tree recruitment is not exclusively related to one set of abiotic or biotic factors; rather, it is dependent on the overall timing of these processes and interaction. Abiotic processes known to effect recruitment of riparian trees are soil moisture, nutrient availability, soil temperature, sediment deposition, and flooding magnitude and duration (Gucker 2005). Biotic interactions include processes like wildlife browsing and canopy coverage/shading. The relationship between river flow regime and riparian tree recruitment was investigated using tree cores to understand if there are hydrological relationships that predict strong riparian tree recruitment.

Forty tree cores were collected at the site within cross-sections 1 and 2 and the near vicinity (Table 19). Of those, only twenty-seven tree cores were analyzed to determine tree age and associated "estimated date of germination." Sixteen of the cores were of too poor quality to analyze primarily as a result of oversaturated and rotting black willow trees. The overall period of record for estimated tree germination was 1969 to 2003.

Only individual trees having a DBH of greater than 2 inches were sampled during this study. The youngest trees sampled were from the 14-year age class (2-inch DBH) with an estimated germination date of 2003 (Figure 12).

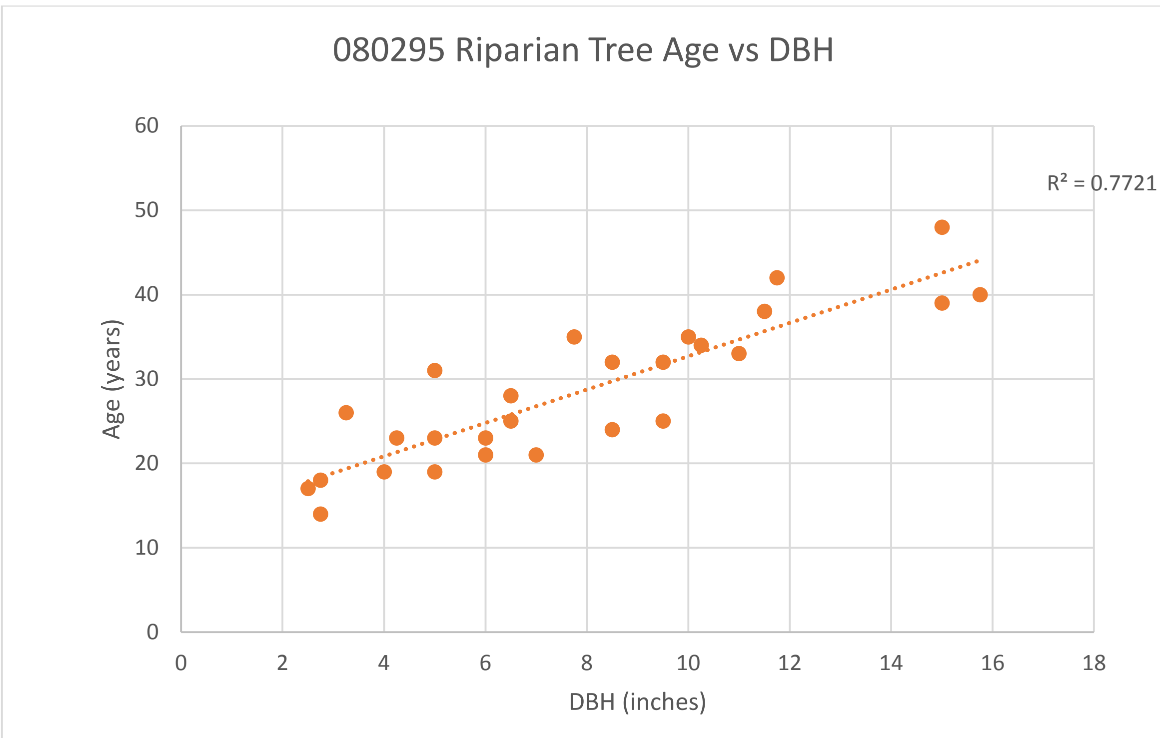

Figure 12. Relationship between estimated tree age and DBH for select 080295 riparian trees

All trees were arranged in order from youngest to oldest and a two-year interval age class was used to categorize raw age data. The two-year interval was used because of a small sample size. The United States Geologic Survey (USGS 2017) 080295 Oakwood gage daily average flows were used to compare riparian recruitment to flow.

The riparian recruitment versus flow analysis utilized data from 1967 to 2003 due to tree age. Consistent recruitment of riparian trees continued throughout the time period although there was some variability in recruitment quantity. Tree recruitment appeared greater during two periods, 1979-1985 and 1993-1999 (Figure 13 and Figure 14). Tree ages for these time periods were 32 to

38 and 18 to 24 respectively. Trinity River flows for these time periods can be seen in Figure 15 through Figure 19). Three lower recruitment periods were identified (1969-1977, 1987-1991, 2001-2003) consisting of 40 to 48, 26 to 30 and 14 to 16-year-old trees, respectively.

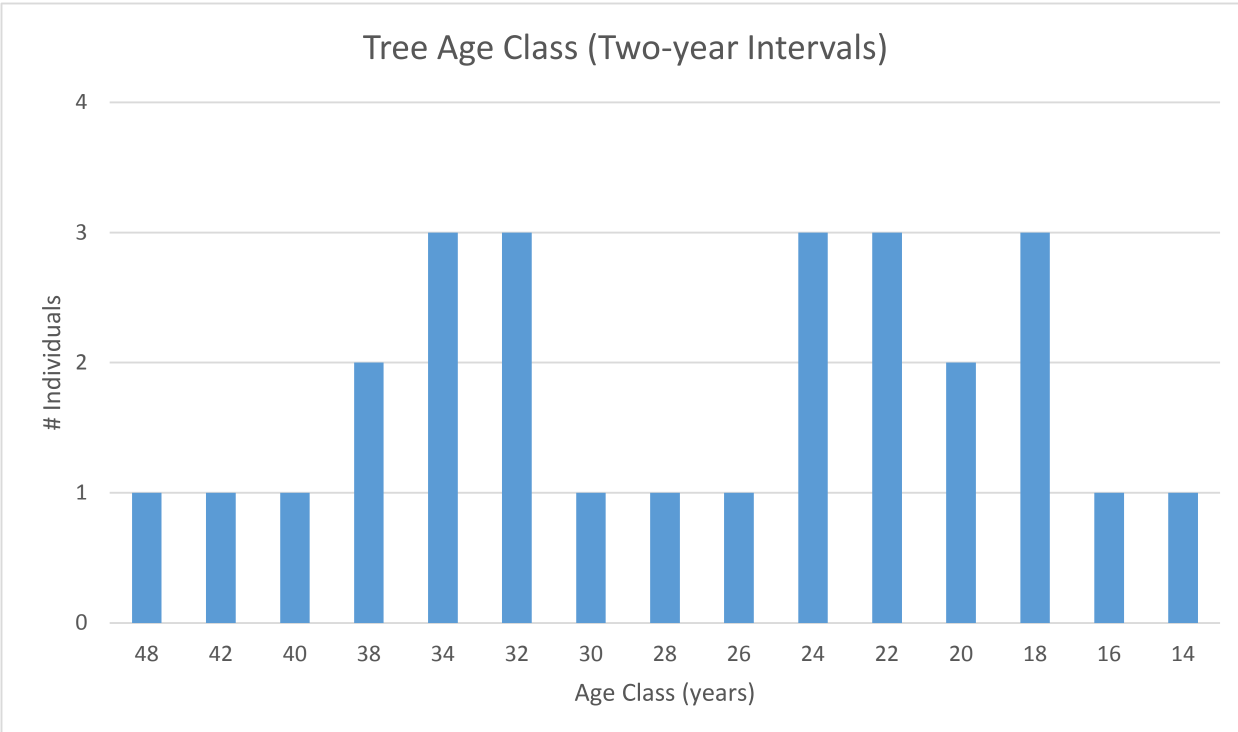

Figure 13. 080295 riparian tree age classes. Example: tree ages 14 – 15 = 14 age class, tree ages 16 – 17 = 16 age class, etc.

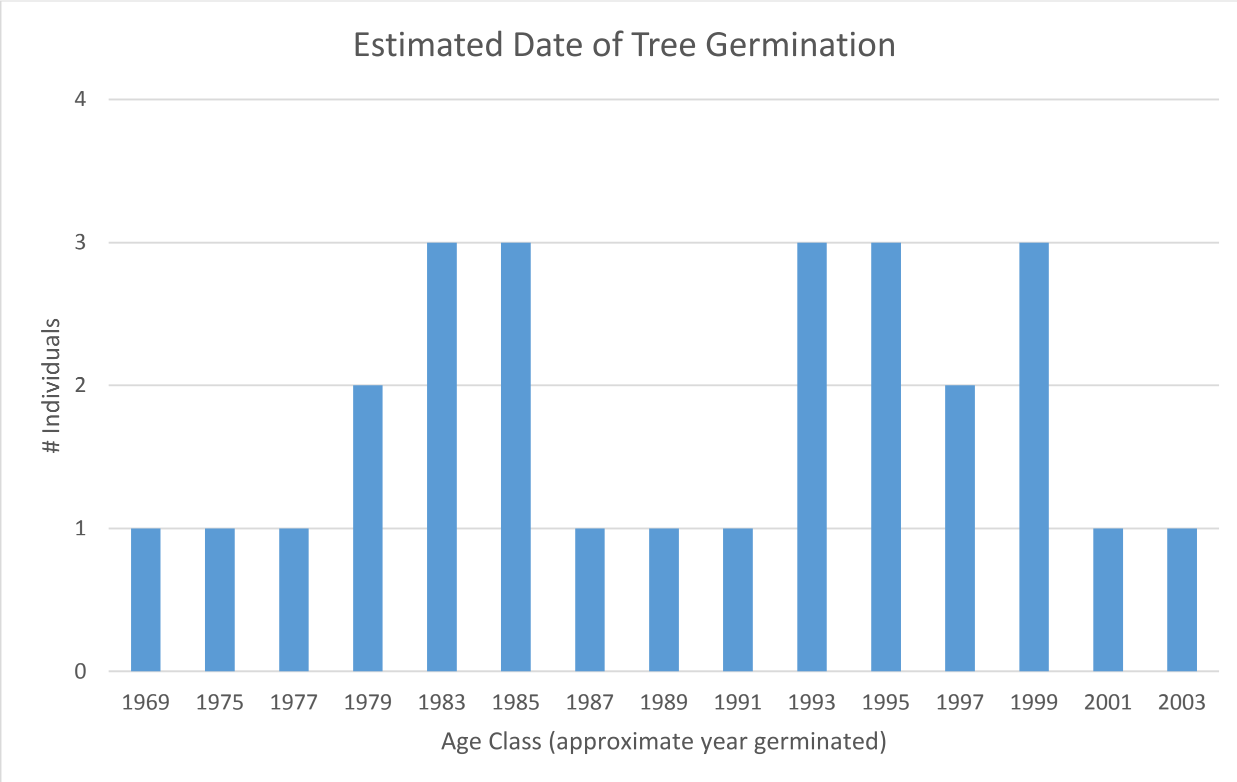

Figure 14. 080295 riparian tree estimated date of germination

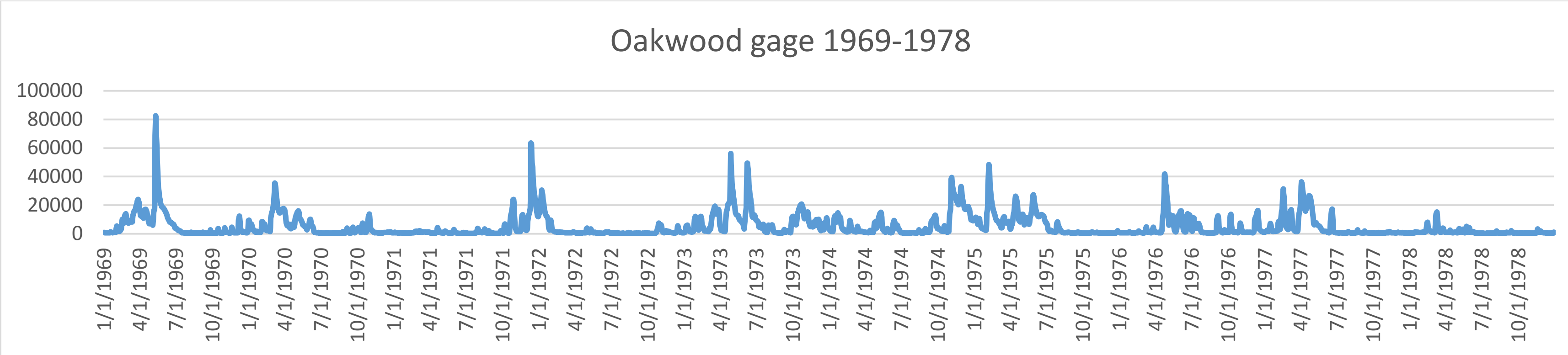

Figure 15. USGS Oakwood gage data for 1969 to 1978

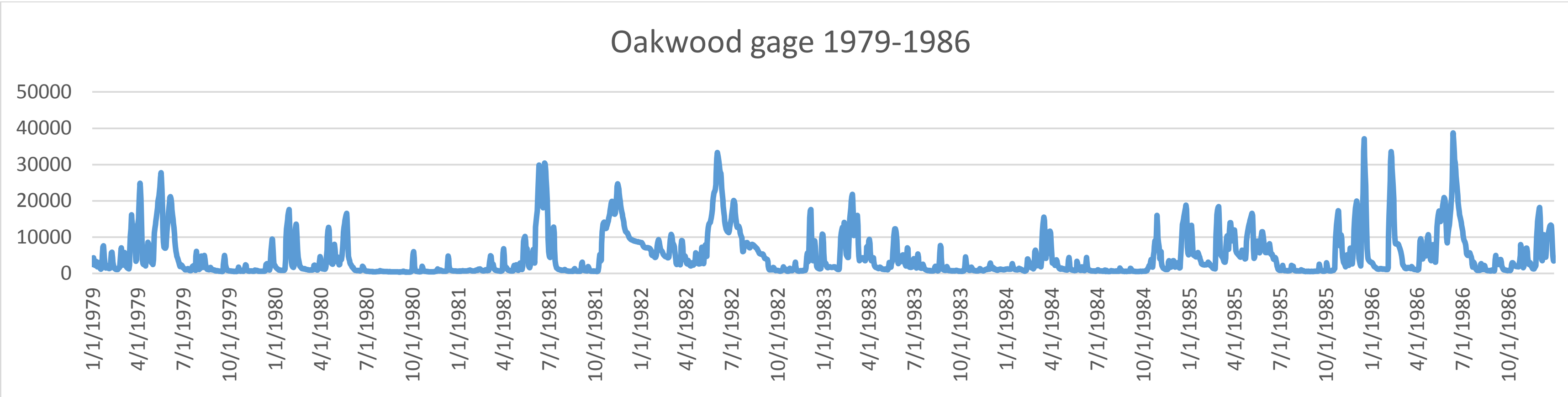

Figure 16. USGS Oakwood gage data for 1979 to 1986

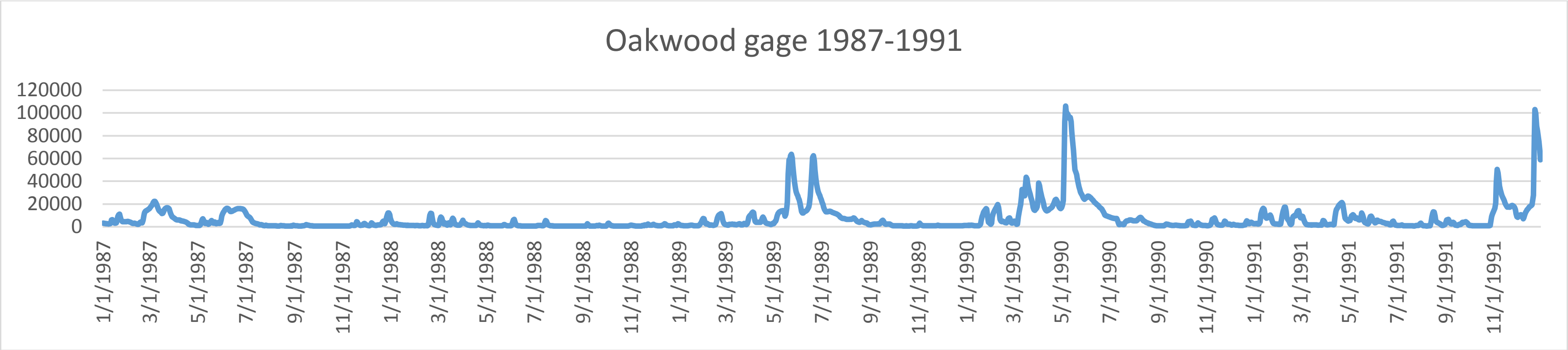

Figure 17. USGS Oakwood gage for 1987 to 1991

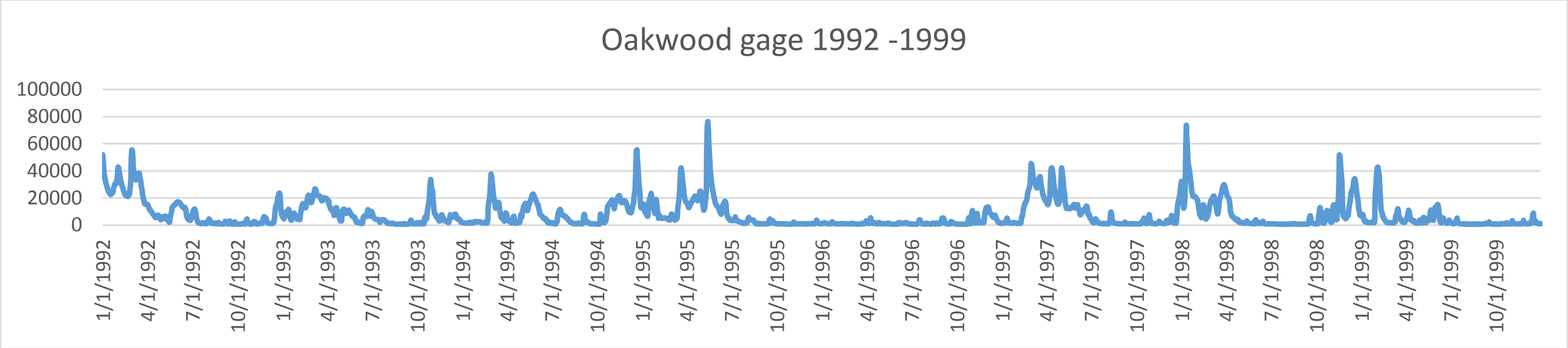

Figure 18. USGS Oakwood gage data for 1992 to 1999

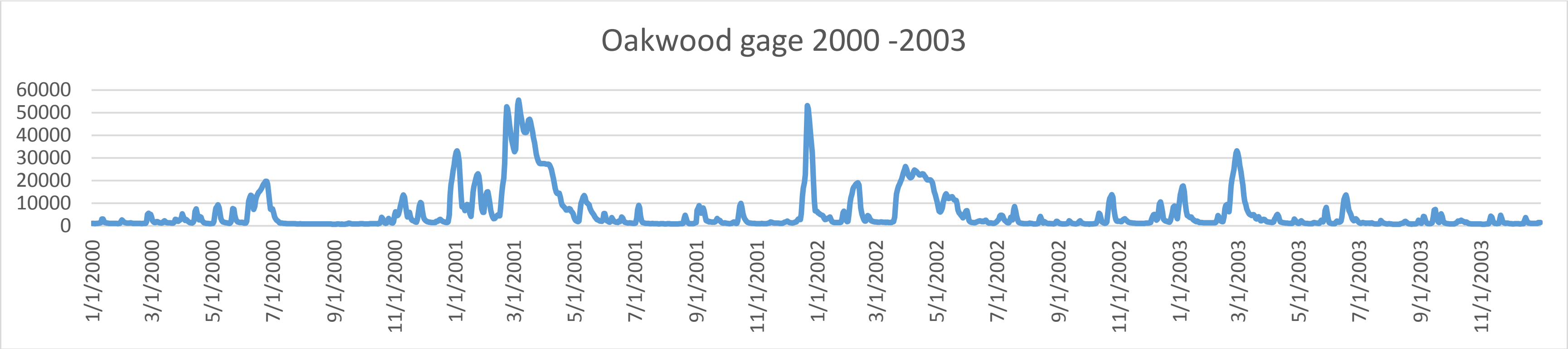

Figure 19. USGS Oakwood gage for 2000 to 2003

During the greater riparian tree recruitment periods, three tree individuals were recruited in most of the age classes compared to one tree in the low riparian tree recruitment periods. Despite a low number of total tree cores collected, the flow trends are consistent among age classes and data analysis suggests differences exist between periods evaluated. Additional tree cores should be collected in future riparian studies to better understand relationships between riparian recruitment and instream flows. Greater riparian tree recruitment occurred under a flow regime in which peak pulses never exceeded 37,100 cubic feet per second (cfs), and only three pulse flows exceeded 30,000 cfs from 1979 to 1985. Two pulses exceeded 70,000 cfs from 1993 to 1999, during May 1995 and January 1998. No 22-year-old trees (1995 germination) were identified during this investigation, but two 19-year-old trees (1998 germination) were, suggesting timing of pulse flows are critical to successful riparian recruitment. Lower riparian recruitment (i.e., one individual per two-year age class) occurred under a flow regime in which peak pulses exceeded 40,000 cfs six times from 1969 to 1977 and included a maximum pulse flow of 82,600 cfs; two peak pulses, 106,000 cfs and 103,000 cfs during the period 1987 to 1991; and one peak pulse of 53,000 cfs from 2001 to 2003. To summarize, tree abundance in age classes having overbank flows greater than 40,000 cfs is lower than abundance during other age classes.

Additional analysis of pulse flow effects at the two riparian cross-sections was performed to evaluate the depth of water based on HEC-RAS modeled results (Mangham, Osting and Flores 2015). At these two cross-sections, flows ranging from 21,000 cfs to 30,000 cfs begin to provide inundation to the riparian forest community (Figure 20 through Figure 25). At 30,000 cfs the model predicts approximately 2 ft. depth of inundation over cross-section 1 left river bank benchmark and approximately 4 ft. depth at cross-section 2 left river bank benchmark.

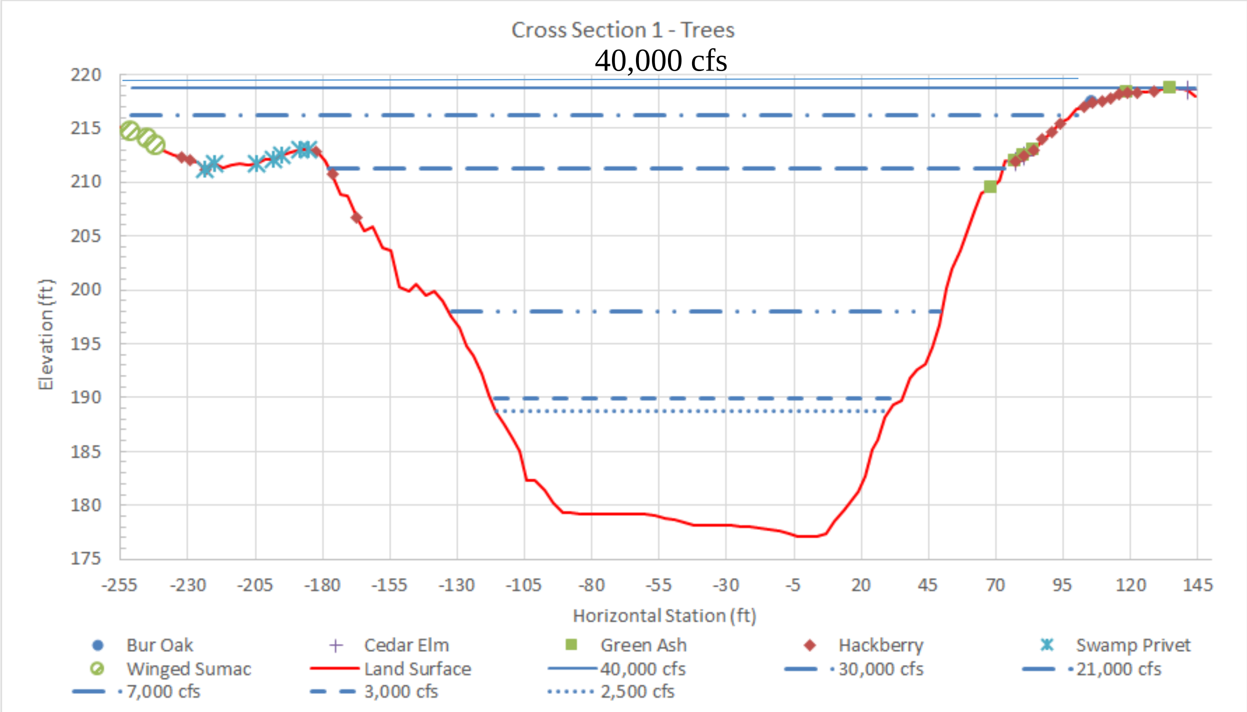

Figure 20. 080295 XS1 – Upstream riparian cross-section trees with flow levels. Note: 7,000 cfs, 3,000 cfs, and 2,500 cfs correspond to the SB3 pulses required for this site.

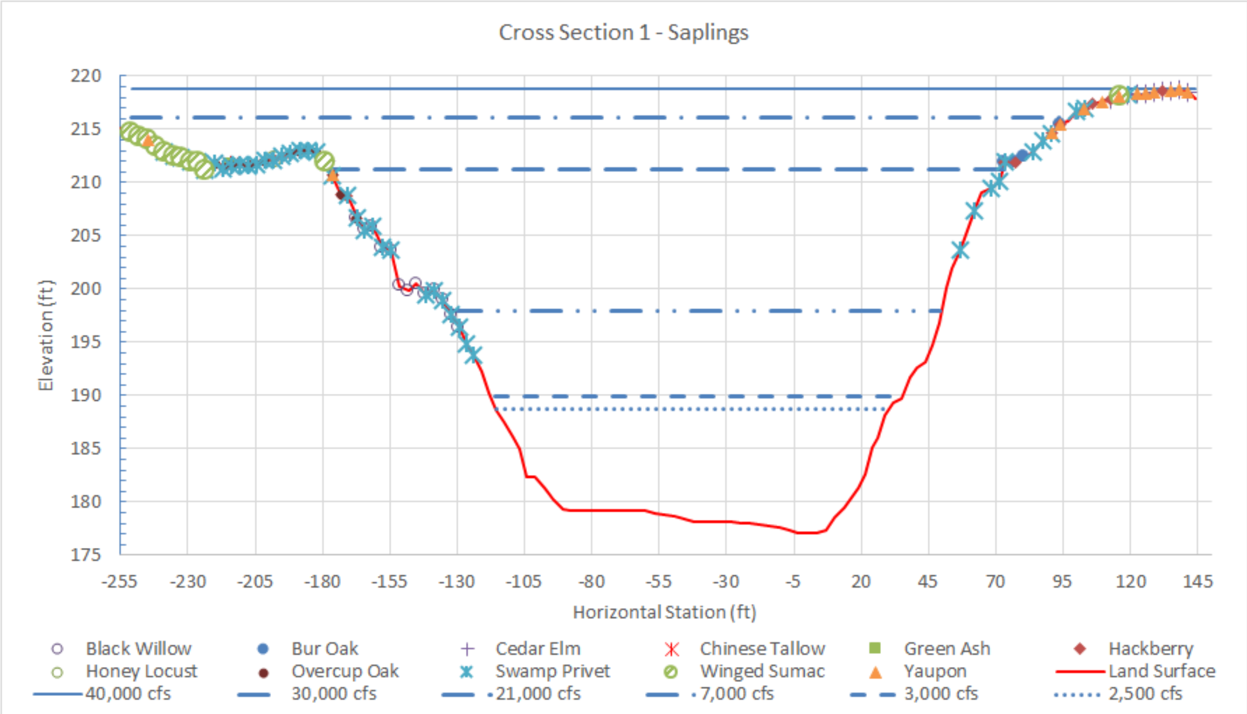

Figure 21. 080295 XS1 – Upstream riparian cross-section saplings

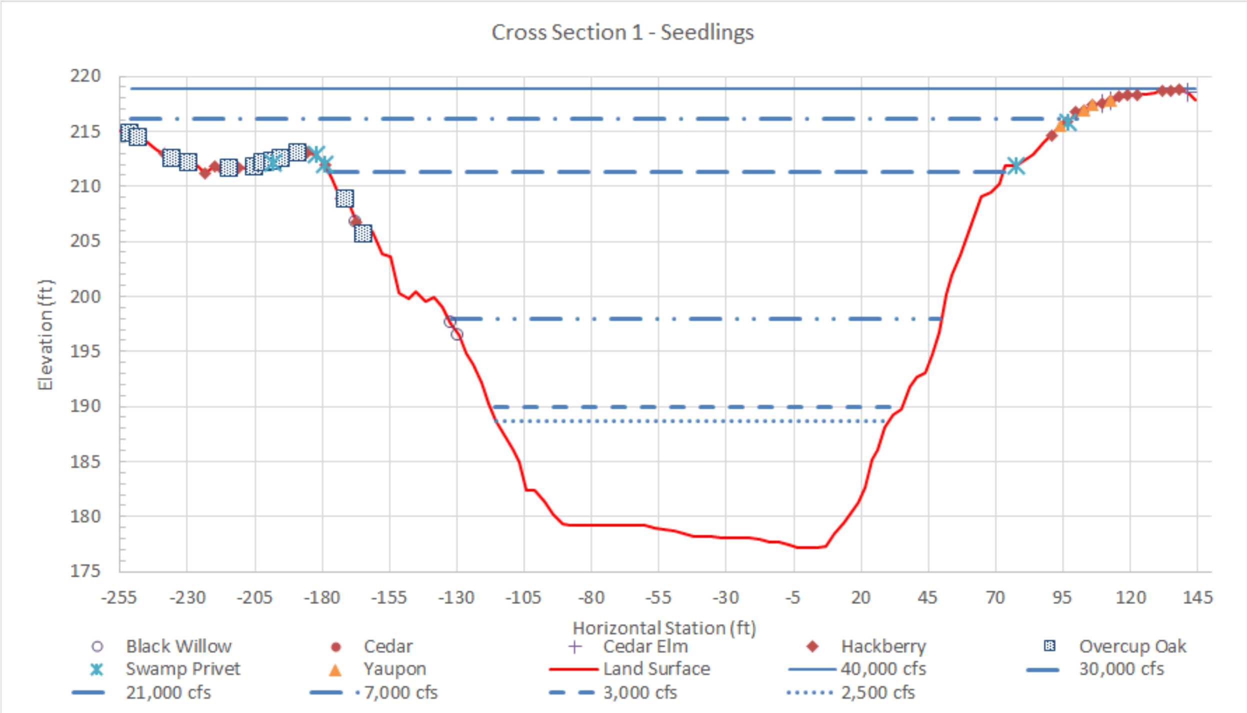

Figure 22. 080295 XS1 – Upstream riparian cross-section seedlings

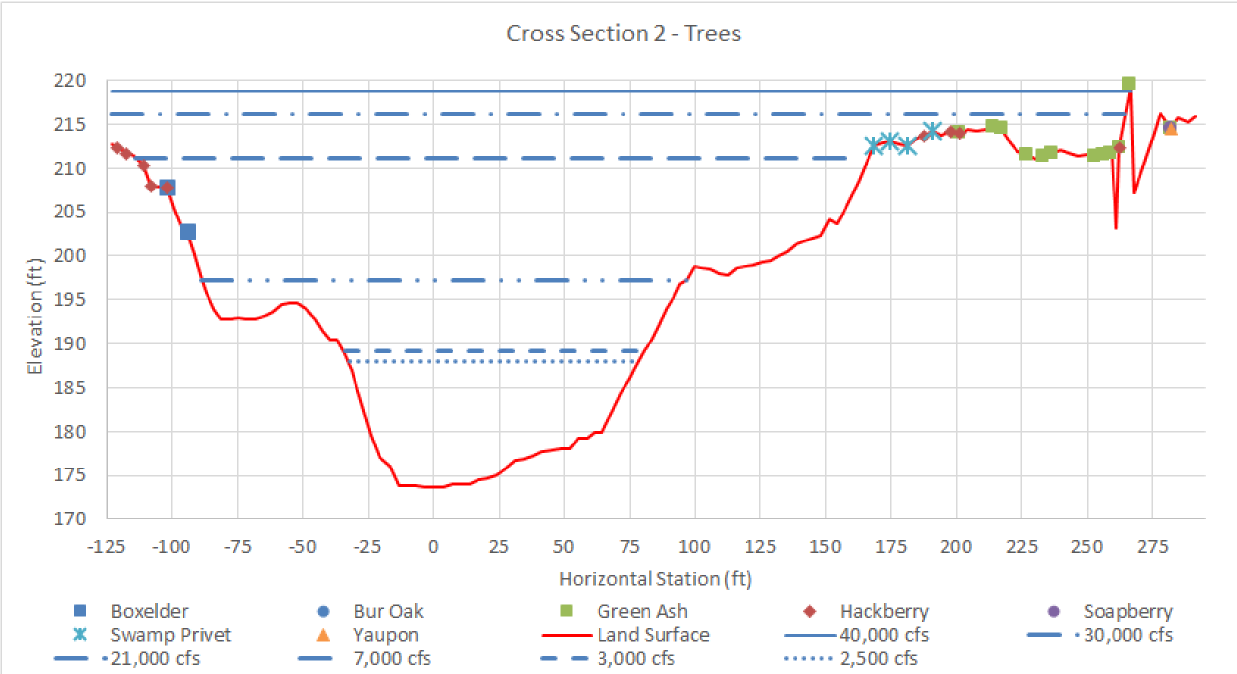

Figure 23. 080295 XS2 – Middle riparian cross-section trees with flow levels. Note: 7,000 cfs, 3,000 cfs, and 2,500 cfs correspond to the SB3 pulses required for this site.

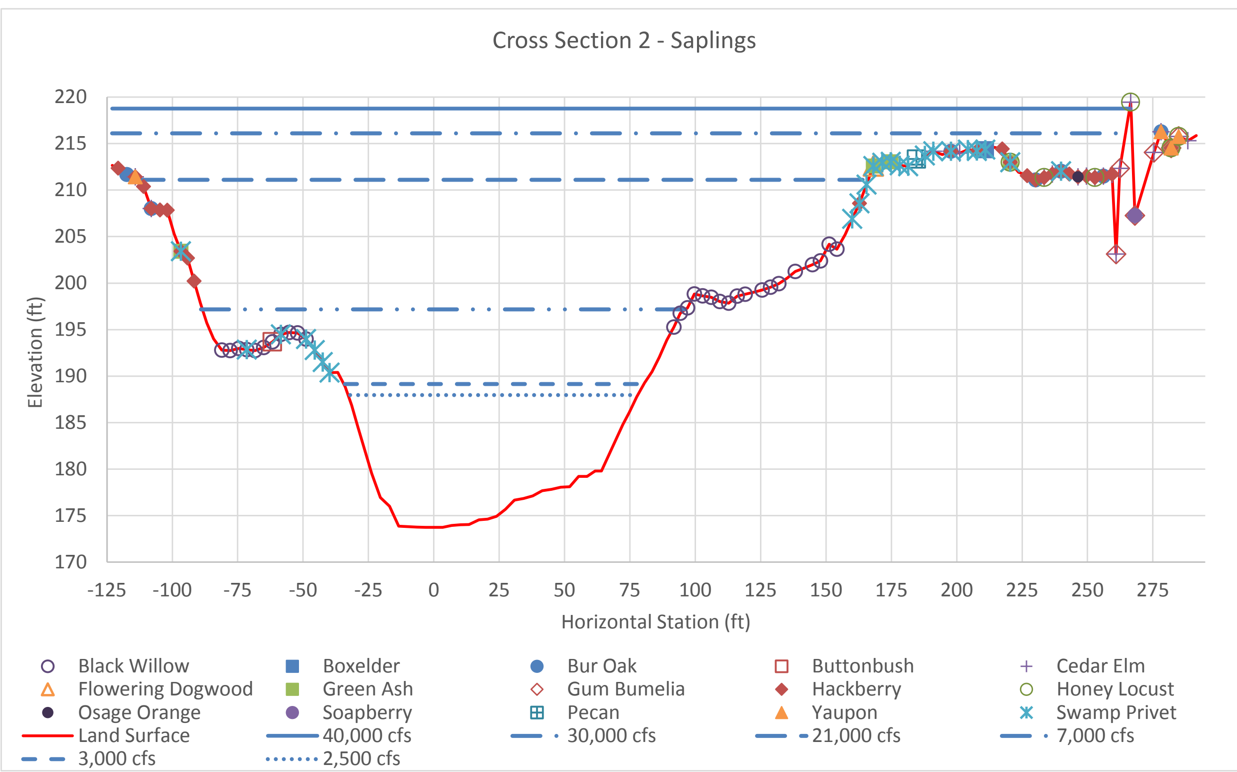

Figure 24. 080295 XS2 – Middle riparian cross-section saplings

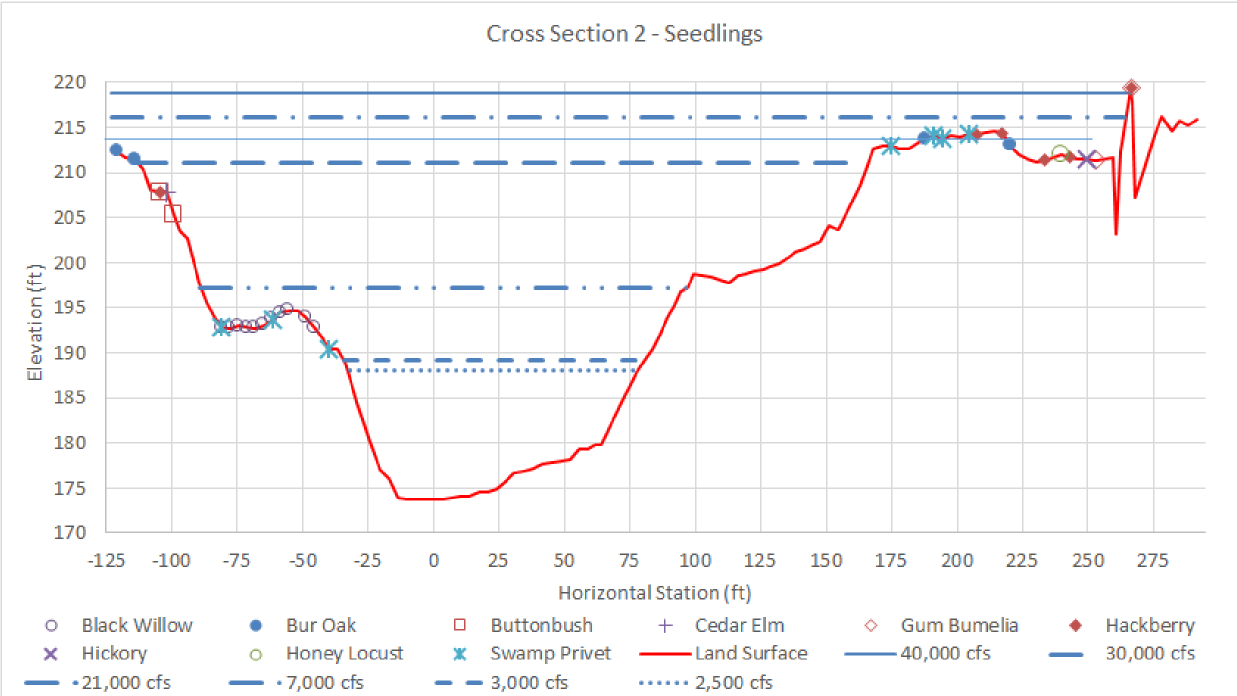

Figure 25. 080295 XS2 – Middle riparian cross-section seedlings

Green ash (*Fraxinus pennsylvanica*) represents most of the individuals sampled during the tree coring effort (23 of 27 individuals). Green ash seedlings can tolerate saturated soil conditions including <1 inch of inundation for up to 60 days with no mortality (Hosner and Boyce 1962); however, seedlings with one foot of inundation had 100 percent mortality (Hosner 1958). Established black willow (*Salix nigra)* trees can survive up to 30 days of complete inundation (Hosner 1958), and well-established boxelder (*Acer negundo*) trees can withstand short periods of inundation (Sutton and Johnson 1974). Additionally, biotic factors such as wildlife browsing (Boerner and Brinkman 1996) can also limit riparian tree recruitment.

Study results reveal a lower recruitment during time periods with large pulse events or spring/summer large pulse events. This indicates that a variable flow regime benefits ongoing recruitment and survival of riparian tree species within this reach. Summer to late season long-duration pulse flows have potential lethal effects on seedlings. While overbanking flows are important for floodplain ecosystems and inherently provide essential nutrients, water, sediments, etc., there can be competing negative short-term impacts of overbanking flows to individual communities within this ecosystem. For example, riparian trees benefit from pulses but extended inundation of seedlings can negatively impact recruitment.

Continued long-term monitoring of the riparian community will allow further investigation into the effects from flow regime variability; specifically the effect of overbank peak pulses in contrast to lower level more frequent pulses. Future studies could also focus on investigating recent riparian tree recruitment because in 2007 there was a peak pulse flow of 70,600 cfs, and from 2015 to 2017 there were five peak pulse flows greater than 60,000 cfs with a 99,200 cfs peak pulse flow in 2015. Based upon information presented above, these periods should represent reduced age-class years because of the high flow and extended inundation periods.

3.3.3 Riparian - 080075

Study site 080075 is the most downstream long-term study site and is unique from other riparian study sites due to the relatively large point bar on the right bank. With a steep bank slope, the left bank is considerably higher in elevation than the right. Riparian vegetation at this site is largely similar to other long-term riparian study sites. Compared to the Oakwood 080295 site, different wetland-type species were identified here, such as swamp white oak (*Quercus bicolor)*, sweetgum (*Liquidamber styraciflua*), honey locust (*Gleditsia triacanthos)* and hickory. Additionally, black willow (*Salix nigra)* specimens were not documented at this site.

This site had recently experienced a large duration overbanking flow event which submerged areas near the river channel including floodplain depressions and back channel areas. These overbanking events provide the necessary hydrology and soil conditions to support wetland-type vegetation in the riparian areas.

These long duration high flow events can also submerge near shoreline riparian vegetation long enough to severely stress or kill riparian vegetation and deposit large amounts of sediment in high activity areas. These depositional events can bury riparian seedlings as well as provide optimal conditions for new seedlings to germinate. The extended duration and magnitude of flooding and depositional processes at this site are likely the reasons for black willow, *Salix nigra*, to be absent from this site.

3.3.4 Riparian - Basin-wide conclusions

In summation, long-term monitoring of riparian cross-sections throughout the Trinity River indicates that riparian areas appear to be consistent in the ecological niches which make up the riparian community. More specifically, at every riparian site there are hydric species, mesic species and upland species found. While individual species may differ between long-term monitoring sites, such as the presence of sweetgum (*Liquidamber styraciflua*), honey locust (*Gleditsia triacanthos)*, etc. at only long-term monitoring site 080075 Romayor, this is more likely due to individual species ranges (i.e. biogeography) rather than a result of river processes and/or management practices.

River flows higher than the SB3 high flow pulse trigger values are needed to begin inundating riparian trees. Lower flow levels, such as the SB3 high flow pulse trigger values, further discussed in Section 4, may also affect establishment of trees in the riparian zone by affecting the water table. No water table data was measured to estimate how varying river flow levels may affect varying water table levels in this study.

3.4 Water Availably and Water Rights

The Trinity River basin is a unique system in Texas as it is the only basin that provides water to both a major population center in the upper basin (DFW area) and a second major metropolitan population in the lower basin (Houston area). Additionally, it is a complex system with over 30 in-basin and out-of-basin water supply reservoirs and several major wastewater dischargers.

The Upper Trinity River Water Quality Compact (Compact), created in 1975, is comprised of the Cities of Dallas and Fort Worth, North Texas Municipal Water District (NTMWD), and the Trinity River Authority. The Compact was created to improve the water quality in the Trinity River and to work together, along with the Texas Commission on Environmental Quality (TCEQ), to allocate the permitted loadings to the group, as opposed to each entity individually. In the early 1970's, treatment plant discharges were considered a waste byproduct. Today, discharged water is of shuch high quality, it has become a major waer supply strategy to meet future water demand needs. According to the Region C Water Planning Group, the state water planning group which covers all or part of sixteen North Central Texas counties, reuse is expected to provide 12% (283,893 af/yr) of water in 2020, increasing to 18% (427,011 af/yr) by 2070 (Freese and Nichols, Inc., et. al, 2015).

As such, Compact entities have applied for and received water rights for those discharges. Each of the four Compact members are required to discharge and let flow downstream a certain portion of that water to satisfy senior water rights in the lower basin and/or provide for instream flows. The relevant existing agreements and permit requirements are summarized below:

1. 30% of discharges from Fort Worth's Village Creek plant (simplified from Tarrant Regional Water District's Amended Certificate of Adjudication #08-5035C, February 8, 2005) are to pass downstream;
2. 30% of discharges from TRA's Central, Ten Mile, and Red Oak Creek plants are to pass downstream to Lake Livingston;
3. 114,000 af/yr of Dallas Central and Southside plants are to remain in the river for instream flows; and
4. 32% of NTMWD's in-basin derived discharges from plants are to pass downstream to address the needs of downstream water rights and the environment.

TCEQ uses the Water Rights Analysis Package (WRAP) program and Water Availability Model (WAM) input files to evaluate and permit water rights and amendments in Texas. The assumptions of the WAM for long-term water rights (Run 3, 1940-1996) permits include 100% usage of existing water rights with 0 return flows, i.e. Run 3 makes water 100% consumptive. In the Trinity basin, these assumptions are inappropriate as increasing population (resulting in higher water consumption) has led directly to higher return flows and increased baseflows (Figure 26).

In order to test the reliability of the SB3 baseflows, WAM Run 3 was modified as follows:

1. The 2001-05 minimum monthly return flow record "Constant Inflow" (CI) records from Run 8 were copied and inserted in to Run 3;
2. All return flows *except for the Compact entities* were removed; and
3. Compact return flows were adapted to match the requirements listed above.

At each control point for seasonal SB3 baseflows, Run 3 Compact Mod showed equal or better reliability than the naturalized flows (Table 7), with the worst reliability being 96.5% in the Fall at the USGS gage 08065000 Trinity River near Oakwood. Additional information, CI card code, and detailed results are included in Appendix 6 – Water Availability Modeling.

This modification, Run 3 Compact Mod, is also a conservative estimation of instream flows at the SB3 control points and represents current and near-future conditions. This model still *likely underestimates actual instream flows* because it assumes the *minimum* monthly discharge and utilizes old discharge data, 2001-2005.

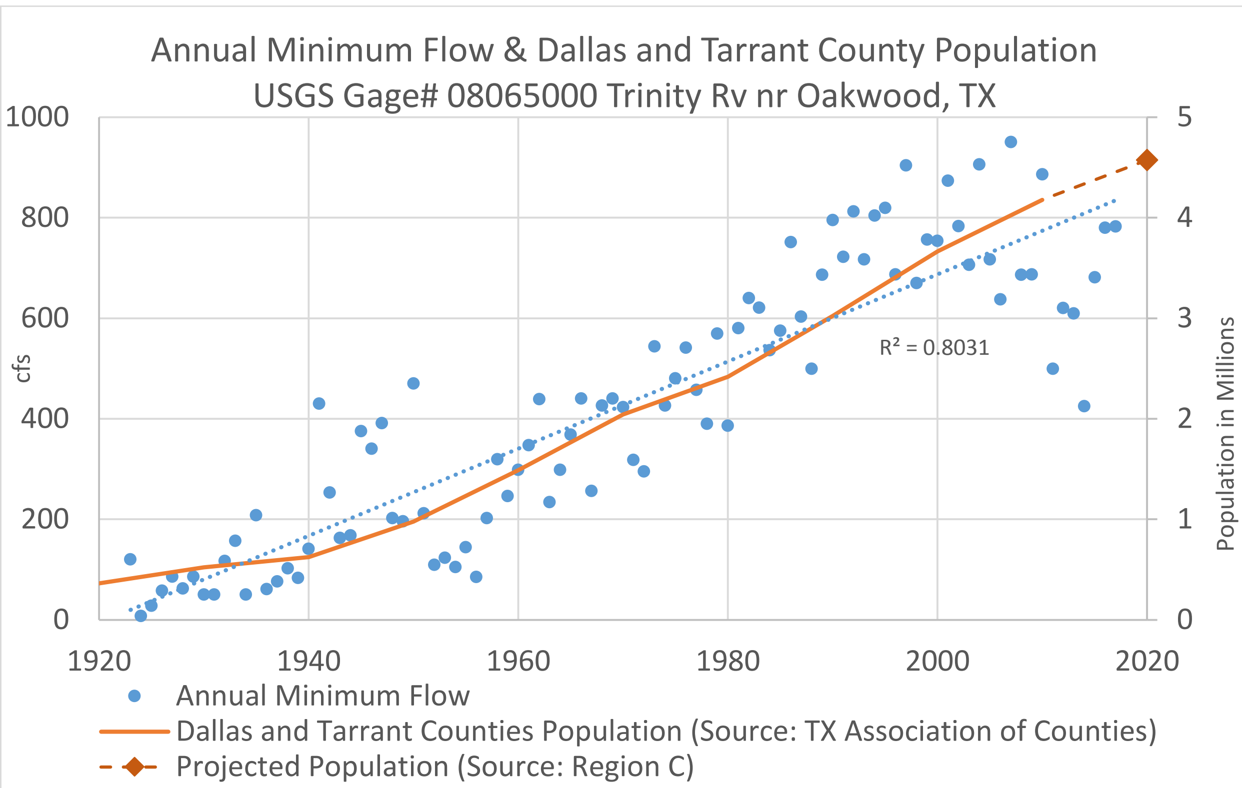

Figure 26. Annual Minimum Flow at USGS Gage # 08065000 Trinity River near Oakwood, TX & Dallas and Tarrant County Populations

Table 7. Comparison of WAM Reliability Results from Run 3, Naturalized Flows, and Run 3 Compact Mod, 1940-1996.

	WAM CP 8WYGP				WAP CP 8TRDA				WAM CP 8TROA			
	USGS Gage 08049500 West Fork Trinity River at Grand Prairie, TX				USGS Gage 08057000 Trinity River at Dallas, TX				USGS Gage 08065000 Trinity River near Oakwood			
SB3 Base Flow (cfs)	45	45	35	35	50	70	40	50	340	450	250	260
Season	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F
Full Auth. NO Return Flows (Run 3)	75.4%	96.5%	80.7%	77.2%	86.0%	96.5%	91.2%	78.9%	94.7%	98.2%	89.5%	77.2%
Naturalized Flows	100.0%	100.0%	94.7%	89.5%	100.0%	100.0%	98.2%	93.0%	100.0%	100.0%	94.7%	91.2%
Run3 Compact Mod	**100.0%**	**100.0%**	**98.2%**	**100.0%**	**100.0%**	**100.0%**	**98.2%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**96.5%**

Downstream of Lake Livingston at the Romayor site, instream baseflows are augmented by upstream releases to meet demands from senior downstream water rights holders, not return flows. According to Region H, the water planning entity encompassing the greater Houston area, demands from the City of Houston are expected to draw 718,832 af/yr from Lake Livingston in 2020, increasing to over one-million af/yr in 2070. The two diversion points for this water, the Coastal Water Authority's Main Canal and the Luce Bayou Interbasin Transfer Project (under construction), are 54.5 and 25 river miles, respectively, downstream of the Romayor SB3 measurement point.

Using the total monthly demands from Lake Livingston from the City of Houston between July 2016 and June 2017 to create the seasonal demand pattern, the Region H future demand projections from Lake Livingston were converted to average daily flows and aggregated by SB3 season. Between 2020 and 2070, all SB3 baseflow targets were projected to be met or exceeded except for a 105 cfs deficit in the spring of 2020 (Table 8). It is important to note that these baseflows *only represent water supply releases from Lake Livingston* and do not include any natural drainage basin inflows, although this region received an average of >50 inches of rain between 1981-2010 according to the Texas Natural Resources Information System (TNRIS, 2017).

In summary, Trinity River baseflows are driven by natural rainfall-runoff events and are also influenced by water demand and supply factors that are different upstream and downstream of Lake Livingston. Based on this analysis, seasonal subsistence flows are achieved 100% of time and baseflow targets are expected to be met or exceeded on average 99% of the time above Lake Livingston and 96% of the time below. This analysis should be considered conservative, as it only looks at *minimum monthly inflows from specific dischargers* upstream and *removes all natural inflow* downstream of Lake Livingston. As water usage increases in the future, SB3 baseflow levels are expected to be achieved more frequently than shown in this report.

Table 8. Comparison of SB3 Romayor Baseflows to Projected Region H Water Demands Downstream of Lake Livingston for the City of Houston. The red highlight indicates the Romayor SB3 baseflow is not met.

	SB3 Baseflow Targets at USGS Gage 08066500 Trinity River at Romayor, TX			
	Winter	**Spring**	**Summer**	**Fall**
Region H Water Demands (yr)	**875**	**1150**	**575**	**230**
2020	953	1045	1159	806
2030	1176	1289	1430	994
2040	1265	1387	1539	1070
2050	1298	1424	1580	1098
2060	1315	1442	1600	1112
2070	1327	1456	1615	1122

4 Discussion

The overall purpose of this study is to understand what is happening at the SB3 flow standard levels in the river channel and floodplain at the locations where the flow standards are applicable.

4.1 SB3 Grand Prairie flow values - 080486

Pulse trigger flows (Table 7) all remain contained within the channel at this site near Grand Prairie. Anthropogenic factors like upstream reservoir releases, urban-area flood control, wastewater return flows and site development, are current factors affecting the study site and the stream segment in general. Floodplain management will likely have more impact on the riparian areas than high flow pulse flow management. Return flows will remain the main factor at base flow levels and will satisfy subsistence and base flows for the foreseeable future (Table 8).

Table 9. SB3 environmental flow standards, West Fork Trinity River near Grand Prairie (USGS 08049500)

United States Geological Survey (USGS) Gage 08049500, West Fork Trinity River near Grand Prairie

Season	Subsistence	Base	Pulse
Winter	19 cfs	45 cfs	Trigger: 300 cfs Volume: 3,500 af Duration: 4 days
Spring	25 cfs	45 cfs	Trigger: 1,200 cfs Volume: 8,000 af Duration: 8 days
Summer	23 cfs	35 cfs	Trigger: 300 cfs Volume: 1,800 af Duration: 3 days
Fall	21 cfs	35 cfs	Trigger: 300 cfs Volume: 1,800 af Duration: 3 days

cfs = cubic feet per second
af = acre-feet

SB3 high flow pulse levels at the site ensure that the dominant bed grain size gets moved through the system (Table 8). The predominant sediments in riffles, gravel, are not moved through pools at any of the pulse flow levels. The SB3 pulses do not connect to riparian or backwater areas. Estimated flow levels that connect backwaters is 5,000 cfs, and overbank flow is 30,000 cfs. In the most recent 10 years, flow events of 5,000 cfs have occurred 15 times for 5 days or longer and events exceeding 30,000 cfs have occurred twice, with one of those events lasting longer than 5 days. Additional pulse flow occurrence information is presented in Section 9.5 All sites - Recent occurrence of selected pulse flows.

Table 10. SB3 flow value assessment - 080486 Grand Prairie

Site 080486 – Grand Prairie Assessment of SB3 Flow Standards				
	Winter	**Spring**	**Summer**	**Fall**
	Subsistence			
	19 cfs	**25 cfs**	**23 cfs**	**21 cfs**
Flow is satisfied by existing or future water rights/return flow agreements*	Y 100%	Y 100%	Y 100%	Y 100%
SB2 WQ goals are met	N/a	N/a	N/a	N/a
	Base Flows			
	45 cfs	**45 cfs**	**35 cfs**	**35 cfs**
Flow is satisfied by existing or future water rights/return flow agreements*	Y 100%	Y 100%	Y 98.2%	Y 100%
SB2 WQ goals are met	N/a	N/a	N/a	N/a
	High Flow Pulses			
Trigger Duration	**300 cfs 4 days**	**1,200 cfs 8 days**	**300 cfs 3 days**	**300 cfs 3 days**
Sediment and Channel Maintenance				
Moves dominant sediment through riffles	Y	Y	Y	Y
Moves dominant sediment through pools	Y	Y	Y	Y
Moves dominant riffle sediments through pools	N	N	N	N
Riparian trees				
Inundates riparian tree species	No data	No data	No data	No data
Inundates 50% of the riparian area	No data	No data	No data	No data
Inundates too long	No data	No data	No data	No data
If no inundation, what flow would begin to inundate riparian area	No data			
Connection to Floodplain				
On-channel backwater habitats	N	N	N	N
Off channel backwater (trib and gullies) (OCBW)	N	N	N	N
If no connection, what flow would begin to connect OCBW	5,000 cfs (15 recent events >= 5 days)**			
What flow HEC-RAS modeled is overbank?	30,000 cfs (1 recent event >=5 days)**			
National Weather Service Flood Triggers	Minor – 16,350 cfs/Moderate – 25,200 cfs			
Notes: * - See Section 3.4 for additional information and methods, period of record, and reliability. ** - For most recent 10 year period 2007-09-01 through 2017-08-31				

4.2 SB3 Dallas flow values - 080444

The SB3 flow standard values for the Trinity River at Dallas measurement locations (Table 9) are applicable to the lock site at river mile 444.

At the lowest pulse flow trigger, 700 cfs, at cross-section 2, which is the lowest energy cross-section in the study site, incipient motion calculations performed in Phase 1 indicate that coarse sand begins to become mobilized. At the highest pulse trigger flow, 4,000 cfs, at cross-section 2, fine gravel is mobilized.

The higher-energy cross-sections 4 and 5 exhibit coarser surface sediments; modeling shows that sufficient shear stress exists to keep the finer sands and gravels moving through downstream, leaving larger sediments like gravels and cobbles. Since the gravels and cobbles exist at these locations, they must be sourced upstream and transported through cross-section 2 at flow levels higher than 10,000 cfs.

Table 11. SB3 flow standards at the measurement point Trinity River at Dallas.

United States Geological Survey (USGS) Gage 08057000, Trinity River at Dallas

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

Return flows at this site will satisfy SB3 subsistence and base flows for the foreseeable future (Table 10). SB3 high flow pulse levels at the site ensure that the dominant bed grain size gets moved through the system (Table 10). The predominant sediments in riffles, coarse gravel and cobbles, are not moved through pools at any of the SB3 pulse flow levels. The SB3 pulses do not connect to riparian or backwater areas. Estimated flow levels that that connect backwaters is 7,000 cfs and that connect to riparian areas is 14,000 cfs. In the most recent 10 years, flow events of 7,000 cfs have occurred 16 times for 5 days or longer and events exceeding 14,000 cfs have occurred five times. Overbank flow values have not been estimated for this study site. Additional pulse flow occurrence information is presented in Section 9.5 All sites - Recent occurrence of selected pulse flows.

Table 12. SB3 flow assessment - 080444 Dallas

Site 080444 – Dallas Assessment of SB3 Flow Standards				
	Winter	**Spring**	**Summer**	**Fall**
	Subsistence			
	26 cfs	**37 cfs**	**22 cfs**	**15 cfs**
Flow is satisfied by existing or future water rights/return flow agreements*	Y 100%	Y 100%	Y 100%	Y 100%
SB2 WQ goals are met	N/a	N/a	N/a	N/a
	Base Flows			
	50 cfs	**70 cfs**	**40 cfs**	**50 cfs**
Flow is satisfied by existing or future water rights/return flow agreements*	Y 100%	Y 100%	Y 98.2%	Y 100%
SB2 WQ goals are met	N/a	DO – Y Temp – Y**	N/a	N/a
	High Flow Pulses			
Trigger **Duration**	**700 cfs** **3 days**	**4,000 cfs** **9 days**	**1,000 cfs** **5 days**	**1,000 cfs** **5 days**
Sediment and Channel Maintenance				
Moves dominant sediment through riffles	Y	Y	Y	Y
Moves dominant sediment through pools	Y	Y	Y	Y
Moves dominant riffle sediments through pools	N	N	N	N
Riparian trees				
Inundates riparian tree species	N	N	N	N
Inundates 50% of the riparian area	N	N	N	N
Inundates too long	N	N	N	N
If no inundation, what flow would begin to inundate riparian area	14,000 cfs (5 recent events >= 5 days)***			
Connection to Floodplain				
On-channel backwater habitats	N	N	N	N
Off channel backwater (trib and gullies) (OCBW)	N	N	N	N
If no connection, what flow would begin to connect OCBW	7,000 cfs (16 recent events >= 5 days)***			
What flow is overbank?	n/a			
National Weather Service Flood Triggers	Not Available			

Notes:
* - See Section 3.4 for additional information and methods, period of record, and reliability.
** - goal may not be met in some backwater locations during portions of an unusually hot summer afternoon
*** - For most recent 10 year period 2007-09-01 through 2017-08-31

4.3 SB3 Oakwood flow values - 080295

The SB3 flow standard values for the Trinity River near Oakwood measurement locations (Table 11) are applicable to the Oakwood site in vicinity of river mile 295.

At the pulse trigger flows, medium to coarse gravels are transported in all cross-sections. At the riffle cross-section, cross-section 3, the highest shear stress is predicted at the 7,000 pulse trigger flow. For flow levels between 2,500 cfs and 7,000 cfs, herbaceous vegetation on the banks is inundated, but no mature trees.

Based upon work conducted under SB2 by the TIFP, base flows between 75 cfs and 450 cfs could exhibit temperatures above the TIFP goals in selected shallow areas during afternoons of the hottest air temperature days of the year (RPS and ASI 2015). DO conditions meet TIFP goals for flows higher than 75 cfs.

Table 13. 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

Return flows at this site will satisfy SB3 subsistence and base flows for the foreseeable future (Table 12). SB3 high flow pulse levels at the site ensure that the dominant bed grain size gets moved through the system (Table 12). The predominant sediments in riffles, small cobbles, are not moved through pools at any of the SB3 pulse flow levels. The SB3 pulses do not connect to riparian or backwater areas. Estimated flow levels that that connect backwaters is 13,000 cfs and that connect to riparian areas is 10,000 cfs. In the most recent 10 years, flow events of 10,000 cfs have occurred 23 times for 5 days or longer and events exceeding 13,000 cfs have occurred 21 times. Overbank flow values are estimated at 30,000 cfs for this study site and have occurred 13 times in the last 10 years. Additional pulse flow occurrence information is presented in Section 9.5 All sites - Recent occurrence of selected pulse flows.

Table 14. SB3 flow value assessment - 080295 Oakwood

Site 080295 – Oakwood - Assessment of SB3 Flow Standards				
	Winter	**Spring**	**Summer**	**Fall**
	Subsistence			
	120 cfs	**160 cfs**	**75 cfs**	**100 cfs**
Flow is satisfied by existing or future water rights/return flow agreements*	Y 100%	Y 100%	Y 100%	Y 100%
SB2 WQ goals are met	DO – Y Temp – Y**	DO – Y Temp – Y**	DO – Y Temp – Y**	DO – Y Temp – Y**
	Base Flows			
	340 cfs	**450 cfs**	**250 cfs**	**260 cfs**
Flow is satisfied by existing or future water rights/return flow agreements*	Y 100%	Y 100%	Y 100%	Y 96.5%
SB2 WQ goals are met	DO – Y Temp – Y**	Y	DO – Y Temp – Y**	DO – Y Temp – Y**
	High Flow Pulses			
Trigger **Duration**	**3,000 cfs** **5 days**	**7,000 cfs** **11 days**	**2,500 cfs** **5 days**	**2,500 cfs** **5 days**
Sediment and Channel Maintenance				
Moves dominant sediment through riffles	Y	Y	Y	Y
Moves dominant sediment through pools	Y	Y	Y	Y
Moves dominant riffle sediments through pools	N	N	N	N
Riparian trees				
Inundates riparian tree species	N	N	N	N
Inundates 50% of the riparian area	N	N	N	N
Inundates too long	N	N	N	N
If no inundation, what flow would begin to inundate riparian area	10,000 cfs (23 recent events >= 5 days)**			
Connection to Floodplain				
On-channel backwater habitats	N	N	N	N
Off channel backwater (trib and gullies) (OCBW)	N	N	N	N
If no connection, what flow would begin to connect OCBW	13,000 cfs (21 recent events >= 5 days)***			
What flow is overbank?	30,000 cfs (13 recent events >= 5 days)***			
National Weather Service Flood Triggers	Minor – 25,300 cfs/Moderate – 33,375 cfs			
Notes: * - Section 3.4 for additional information and methods, period of record, and reliability. ** - goal may not be met in some backwater locations during portions of an unusually hot summer afternoon *** - For most recent 10 year period 2007-09-01 through 2017-08-31				

4.4 SB3 Romayor flow values - 080075

The SB3 flow standard values for the Trinity River at Romayor measurement locations (Table 13) are applicable to the study site in vicinity of river mile 75.

For flow levels higher than 575 cfs, the lowest of base flows, sand is in continuous transport. This is consistent with sediment material found onsite (Appendix 4 – Sediment sample grain size analysis). The lowest energy cross-section 1 does not begin to transport coarser materials (i.e., fine gravel) until flow higher than the 8,000 cfs pulse trigger. Therefore, the 10,000 cfs pulse trigger appears to provide the function of ensuring some gravel transport in this reach.

Table 15. 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

Releases from Lake Livingston to satisfy downstream water rights at this site will satisfy SB3 subsistence and base flows for the foreseeable future (Table 14). SB3 high flow pulse levels at the site ensure that the dominant bed grain size gets moved through the system (Table 14). The predominant sediments in riffles, coarse sand, are moved through pools at all of the SB3 pulse flow levels. The SB3 pulses do not connect to riparian or backwater areas. Estimated flow levels that connect backwaters is 12,000 cfs and that connect to riparian areas is 18,000 cfs. In the most recent 10 years, flow events of 12,000 cfs have occurred 35 times for 5 days or longer and events exceeding 18,000 cfs have occurred 26 times. Overbank flow values are estimated at 70,000 cfs for this study site and have occurred 3 times in the last 10 years. Additional pulse flow occurrence information is presented in Section 9.5 All sites - Recent occurrence of selected pulse flows.

Table 16. SB3 flow assessment - 080075 Romayor.

Site 080075 – Romayor **Assessment of SB3 Flow Standards**				
	Winter	**Spring**	**Summer**	**Fall**
	Subsistence			
	495 cfs	**700 cfs**	**200 cfs**	**230 cfs**
Flow is satisfied by existing or future water rights/return flow agreements*	Y 100%	Y 100%	Y 100%	Y 100%
SB2 WQ goals are met	N/a	N/a	N/a	N/a
	Base Flows			
	875 cfs	**1150 cfs**	**575 cfs**	**625 cfs**
Flow is satisfied by existing or future water rights/return flow agreements*	Y 100%	Yr 2020 –N 2030-70 -Y	Y 100%	Y 100%
SB2 WQ goals are met	No data	No data	No data	No data
	High Flow Pulses			
Trigger **Duration**	**8,000 cfs** **7 days**	**10,000 cfs** **9 days**	**4,000 cfs** **5 days**	**4,000 cfs** **5 days**
Sediment and Channel Maintenance				
Moves dominant sediment through riffles	Y	Y	Y	Y
Moves dominant sediment through pools	Y	Y	Y	Y
Moves dominant riffle sediments through pools	Y	Y	Y	Y
Riparian trees				
Inundates riparian tree species	N	N	N	N
Inundates 50% of the riparian area	N	N	N	N
Inundates too long	N	N	N	N
If no inundation, what flow would begin to inundate riparian area	18,000 cfs (26 recent events >= 5 days)**			
Connection to Floodplain				
On-channel backwater habitats	N	N	N	N
Off channel backwater (trib and gullies) (OCBW)	N	N	N	N
If no connection, what flow would begin to connect OCBW	12,000 cfs (35 recent events >= 5 days)**			
What flow is overbank?	70,000 cfs (3 recent events >= 5 days)**			
National Weather Service Flood Triggers	Minor – 86,650 cfs/Moderate – 93,125 cfs			
Notes: * - See Section 3.4 for additional information and methods, period of record, and reliability. ** - For most recent 10 year period 2007-09-01 through 2017-08-31				

5 Recommendations for Further Work

5.1 Conclusions

The high flow pulse values in the SB3 flow standards primarily provide sediment, water table, and in-channel habitat functions. Inundation of riparian areas by SB3 flow values is limited, with the only inundated riparian habitats being the in-channel willow habitats identified in the vicinity of the Oakwood and Romayor reaches.

Riparian tree surveys indicate a distribution of tree species at varying elevations at each site that is typical for the region and typical for adjacent river basins where similar studies are progressing. Tree coring at the Oakwood site indicates relatively continuous recruitment of ash trees, with some indication that years with overbank flow levels higher than 40,000 cfs result in lower recruitment near the Oakwood site.

Naturally-occurring, pulse, and overbanking flows that are higher-magnitude than the adopted SB3 pulse flows are currently occurring and providing inundation and morphological functions that maintain existing riparian areas and cause lateral and vertical changes to channel cross-sections.

5.2 What is needed?

Characterization of base flows and instream habitat are two items that have not been specifically evaluated as part of the Phase 1 and Phase 2 projects. This is for two reasons. The SB3 flow standard subsistence and base flows are generally lower than flows exhibited at any time of the year in the Trinity River channel as a result of continuous waste water return flows. Additionally, as SB2 studies are completed, more information will be available at base flow levels. Because data at low flows is not available, Phase 1 and Phase 2 data collection efforts focus on higher flow pulses.

Specific study components that would improve understanding of the conditions and processes active at each of the study sites and throughout the Trinity River basin include:

1. Fish habitat distribution surveys to determine if the recent drought and high flow years have changed distribution since initial study in 2011;
2. Fish abundance and habitat surveys;
3. Follow-up channel cross-section monitoring;
4. Targeted bathymetric surveys adjacent to study sites within study segments to further develop and calibrate HEC-RAS models; this will allow further analysis of small pulse inundation and connectivity;
5. Conduct bank stability modeling to develop a tool to predict how different levels of pulse flows affect channel migration, to allow for more refined analysis of pulse flow levels;
6. Collect additional tree cores and refine age class findings;
7. Coordinate with TPWD on the results of their riparian study;
8. Aggregation of SB2 fish and benthic macroinvertebrate data within the context of this study;

9. Pulse flow biological and morphological sampling events; and
10. Research to better understand the quality/functional capacity of backwater habitat in relation to the needs of indicator species.

6 References

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7 Appendix 1 – Scope of Work

Evaluation of Adopted Flow Standards for the Trinity River, Phase II

Background and Overview

The Texas Commission on Environmental Quality adopted flow standards for the Trinity River and Galveston Bay system on April 20, 2011. Measurement points in the Trinity River basin are located on the West Fork Trinity River near Grand Prairie (USGS gage 08049500), Trinity River at Dallas (USGS gage 08057000), Trinity River near Oakwood (USGS gage 08065000), and Trinity River near Romayor (USGS gage 08066500). Work completed in 2015 (Mangham et al. 2015) began the process of evaluating adopted flow standards in relation to geomorphic and ecological conditions in and along the Trinity River. Specifically, field data was collected from three sites representative of conditions near three of the measurement points (surrogate location for Trinity River at Dallas, near Oakwood, and near Romayor). Data collected included repeat measurements of channel shape and transect surveys of riparian trees. This work allowed some evaluation of flow regime components identified in the standards and their physical and ecological impact on the Trinity River. However, data collection efforts were hampered by limited time to complete measurements and historic high flow conditions during much of 2015. Due to high flows, baseline riparian transect measurements were completed at only one site (surrogate location for Trinity River at Dallas). Evaluation of standards at all three sites would benefit from additional measurements over time and under a variety of flow conditions.

This project will continue efforts to evaluate environmental flow standards for the Trinity River. As part of this effort, channel data collection and monitoring will continue at three existing monitoring sites (surrogate location for Trinity River downstream of Dallas, near Oakwood, and downstream of Romayor). In addition, data collection efforts will be extended to a fourth site on the West Fork of the Trinity River near Grand Prairie. Riparian surveys will be completed at all four sites. Data collected as part of this effort will be stored in a format compatible with a data archive structure developed previously (Mangham et al 2015). The proposed project will deliver (1) a site-specific field dataset and (2) 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 the four measurement locations in the Trinity River Basin.

At the same time, other Texas Basin and Bay Area Stakeholder Groups are performing similar studies designed to relate flow standards to instream conditions and responses. It is important to coordinate with other basins to share data collection methodologies, study processes, archive structures, and results to provide a possible basis for future cross-basin data comparisons and analysis.

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 models and incorporating the best survey, bathymetry, and Digital Terrain Model (DTM) data whenever available.

Task 1: Acquisition of field data in the vicinity of: river mile 485 (the USGS gage 08049500, at Grand Prairie, TX), near Belt Line Road bridge river mile 444 near Malloy Bridge Road in southern Dallas County, river mile 295 (the USGS gage 08065000, near Oakwood, TX) and river mile 75 (near the USGS gage 08066500 at Romayor, 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;
- Linear survey of selected portions of each site; and
- 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 2: Data processing, analysis, modeling, and reporting

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 by previous work (Mangham et al 2015). Georeferenced HEC-RAS (a hydraulic modeling format developed by the Army Corps of Engineers) models will be built and calibrated for one site (river mile 485) and refined for three additional sites (river mile 444, 295, and 75 sites). Modeling efforts will include riparian inundation, water surface profiles and grain size transport potential for relevant (SB3 standards) steady-state flow rates.

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

Task 3: Coordinate with other instream study efforts

TRA will coordinate with other instream study efforts and attend workgroups when available. The goal of this task is to determine the best available methodologies regarding sampling methods, data archiving, and analysis techniques for this report.

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, 2017.

References

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8 Appendix 2 – Linear Survey for High Flow Pulse Event

Write this section in the tone of: We saw X at the flow we were there. Based on the understanding of the system, what would have been happening at the SB3 flows?

8.1 Linear Survey 080295

Staff completed a linear on-water survey of 23 miles of TRA segment C3 containing site 080295 over a 2-day span. Conditions were generally high flow conditions (falling from 16,000 cfs on day one to 13,400 cfs on day 2).

The majority of segment C3 was included in the survey; the upper 12 miles was not completed within the scheduled time due to field conditions (lightning). The linear survey was designed to study the riparian area and map areas of connectivity between the river and flood plain at high flows (Figure 26, Figure 27, Figure 28 and Figure 29). In general, two types of connectivity situations were encountered 1) inundated on-channel backwater areas (Figure 30) and 2) inundated off-channel backwater (OCBW) areas (Figure 27 at 296.99 and Figure 31), though some of them had slow, but positive flow moving into the river. Keechi creek was measured to have approximately 450 cfs moving, though limited mixing or color changes were apparent; surface waters appeared to be river backwater.

The segment is characterized by an abundance of on-channel backwater areas (Figure 30), especially downstream on the insides of bends, as can be expected since this zone is a low-velocity deposition zone. These areas showed low velocity within the inundated vegetation and the inundated trees were almost exclusively various age classes of black willow with some swamp privet mixed in. There was little to no giant ragweed or other herbaceous shrubbery exhibited, likely due to extended high flows. Within the 080295 site, an on-channel backwater was identified and an automated game camera was deployed and the riparian transect was located for the follow-up survey.

Additionally, WSE and flow was collected as validation of the water surface profile (HEC-RAS) modeling efforts. Based upon mapping and inspection, the previous modeling appeared to adequately predict islands as is evident by the the mapping efforts (Figure 26 through Figure 29). Among the vegetation, velocities were slow. Flow at the Oakwood gage were between 15,600 and 13,200 cfs (stage difference of 1.2 feet); on-site observed flow (M9) was between 16,400 and 12,300 cfs.

Figure 27. Segment C3 upstream of 080295 1 of 4- Observed inundation and connectivity areas over the RAS 13400cfs inundation map (orange). Note: Numbers represent approximate river mile.

Figure 28. Segment C3 upstream of 080295 2 of 4 - Observed inundation and connectivity areas over the RAS 13400cfs inundation map (orange). Note: Numbers represent approximate river mile.

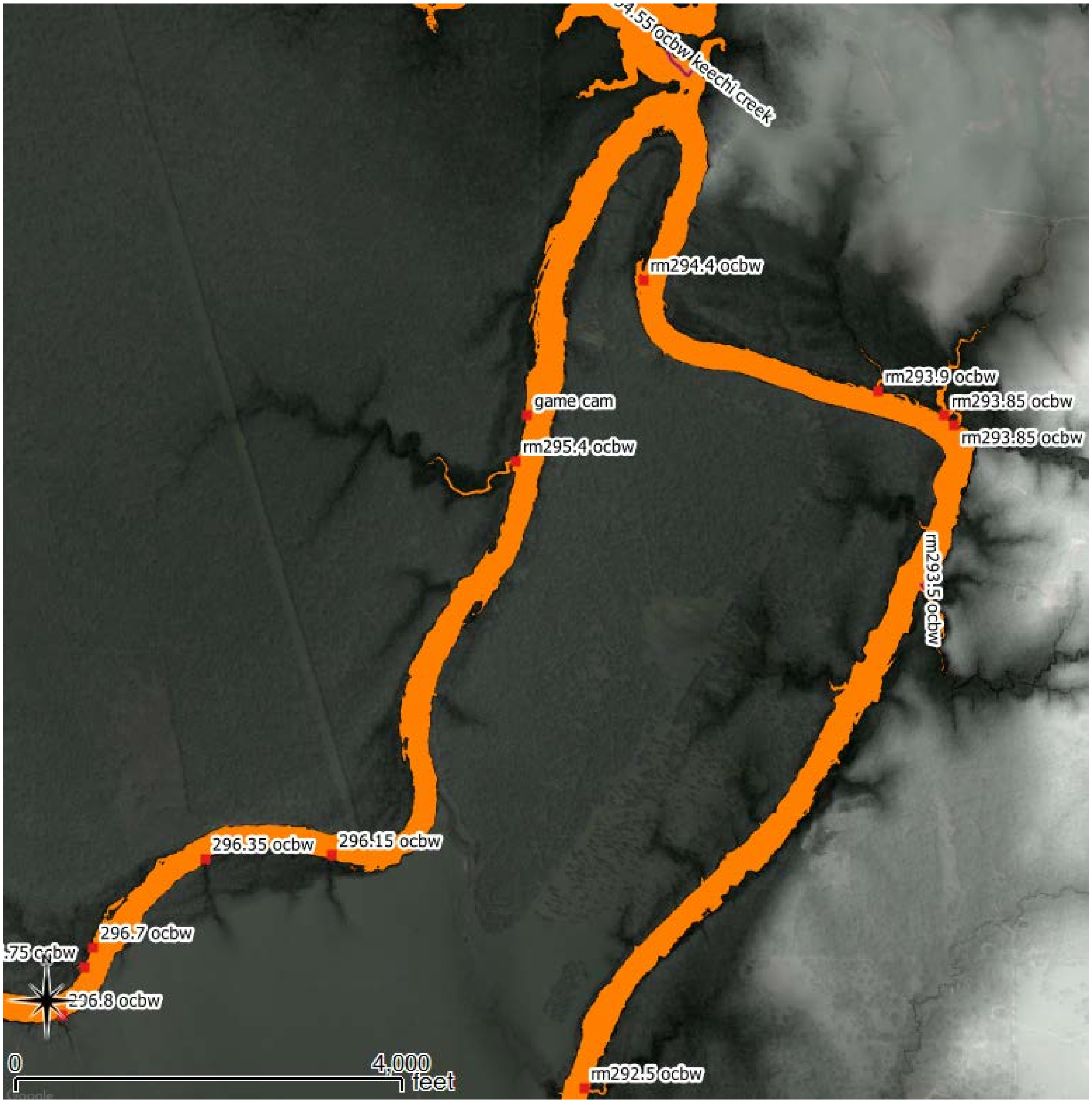

Figure 29. Segment C3 upstream and downstream of 080295 3 of 4 - Observed inundation and connectivity areas over the RAS 13400cfs inundation map (orange). Note: Numbers represent approximate river mile.

Figure 30. Segment C3 downstream of 080295 4 of 4 - Observed inundation and connectivity areas over the RAS 13400 cfs inundation map (orange). Note: Numbers represent approximate river mile.


Figure 31. 080295 - in-channel willow habitat near river mile (RM) 297.


Figure 32. 080295 - Off-channel backwater habitat “296.99 ocbw”.

8.2 Linear Survey - 080075

Staff completed a 34-mile linear survey of the Romayor reach on 2016-07-07. The reach, for which site 080075 study site is considered characteristic, was delineated based on Phillips (2010) zonation and started upstream at RM 96 (upstream of the Romayor USGS gauge) and ended at RM 62 (downstream of SH105). The flow at the upstream end of the reach was measured at 13,783 cfs (average of 5 flow measurements throughout the day) with very little variability of flow between locations over the course of the day. Inundation habitats found at this site (Figure 32, Figure 33 and Figure 34) were characterized as:

- Connected Tributary (Figure 36)
- Disconnected Oxbow (Figure 37)
- ICSH – In-channel sycamore habitat (Figure 38)
- ICWH – In-channel willow habitat (Figure 39)
- Off-channel Backwater (Figure 40)

The reach at this flow is characterized by exposed sand (majority sand with some areas of small gravel) point bars with inundated stands of riparian trees along the channel (ICSH and ICWH) (Figure 35). The trees extend linearly along what would be the channel margins at low flow. The majority of these habitats consisted of willow stands from approximately -2 feet (trunks inundated) to +5 feet (above water level) with a range of DBH sizes from 1” to 10”. In most cases, the stands were made up of the smaller trees (1” to 5”) closer to the water with the larger, more mature trees being sparse and higher up the bank. Most of the inundated willow were alive, but some groupings showed >50% mortality due to long extended periods of high flow.

In contrast to the in-channel willow habitats, few juvenile trees were observed on top of bank where there were mostly mature stands of trees. Various age classes were evident within the channel, though none generally above 10”. One large stand of sycamore trees were inundated, though the majority of sycamore observed were higher on the bank but below the top of bank. Within the inundated tree areas, velocities were very low and represented backwater or very slow run mesohabitat types, though a few of the stands of willows further into the channel were fast run with high velocities further towards the middle of the channel and backwater with slow velocities near the banks. Old, large cypress trees on top of bank in the downstream area of reach were exhibited near a relic oxbow connection. Boxelder and ash were observed on top of bank, but not in the channel.

Tributary confluences were connected and deep with very slow velocities, though the tributaries were still within their banks as far as the boat could make it up.

Oxbow lakes were all disconnected.

Gullies, low spots in the bank were disconnected.

Moving bed was measured during the flow measurement which further indicates that sand and small gravel is mobile at these flows.

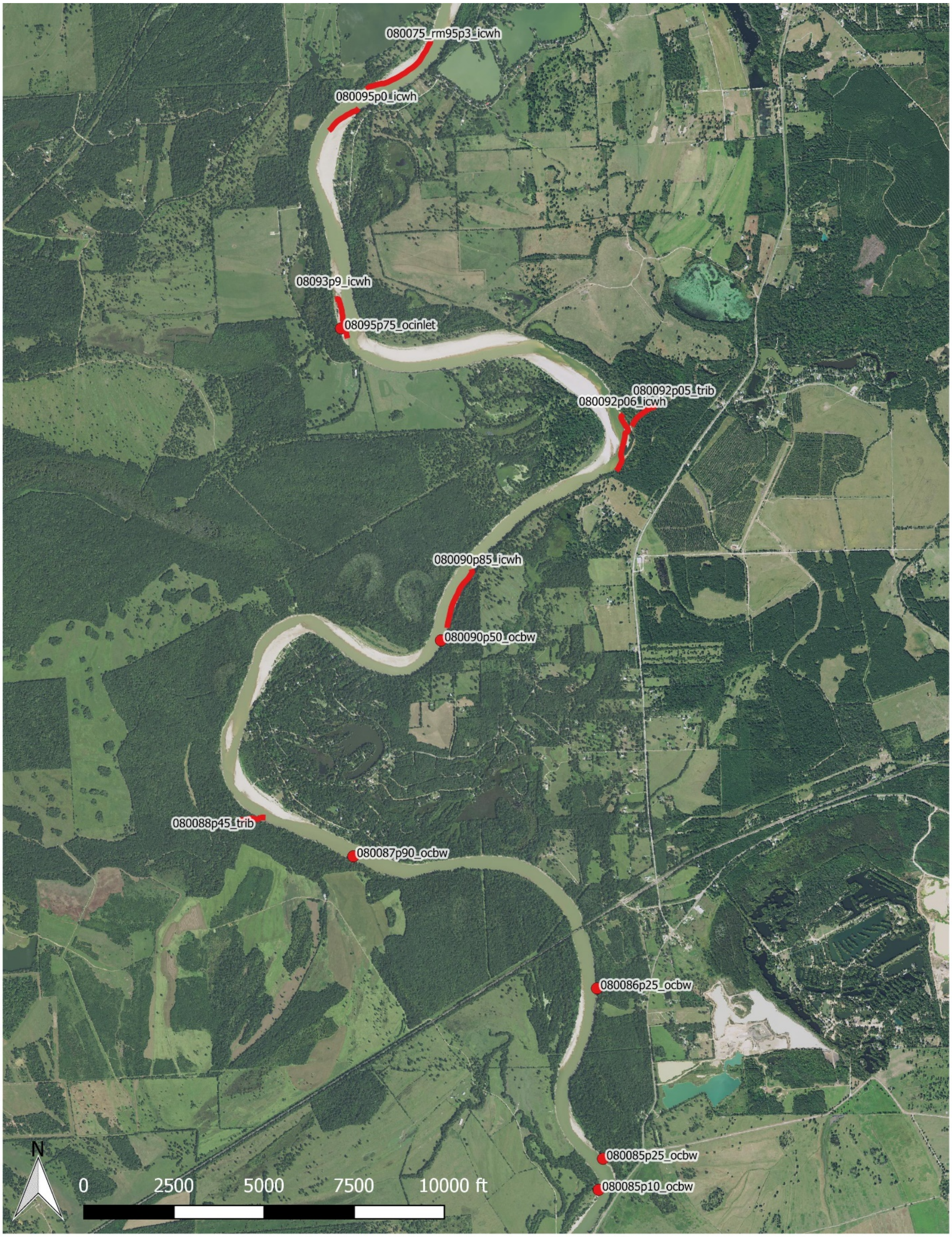

Figure 33. Lower Segment upstream of 080075 1 of 3 - Observed inundation and connectivity areas over the RAS 14,000cfs inundation map (orange).

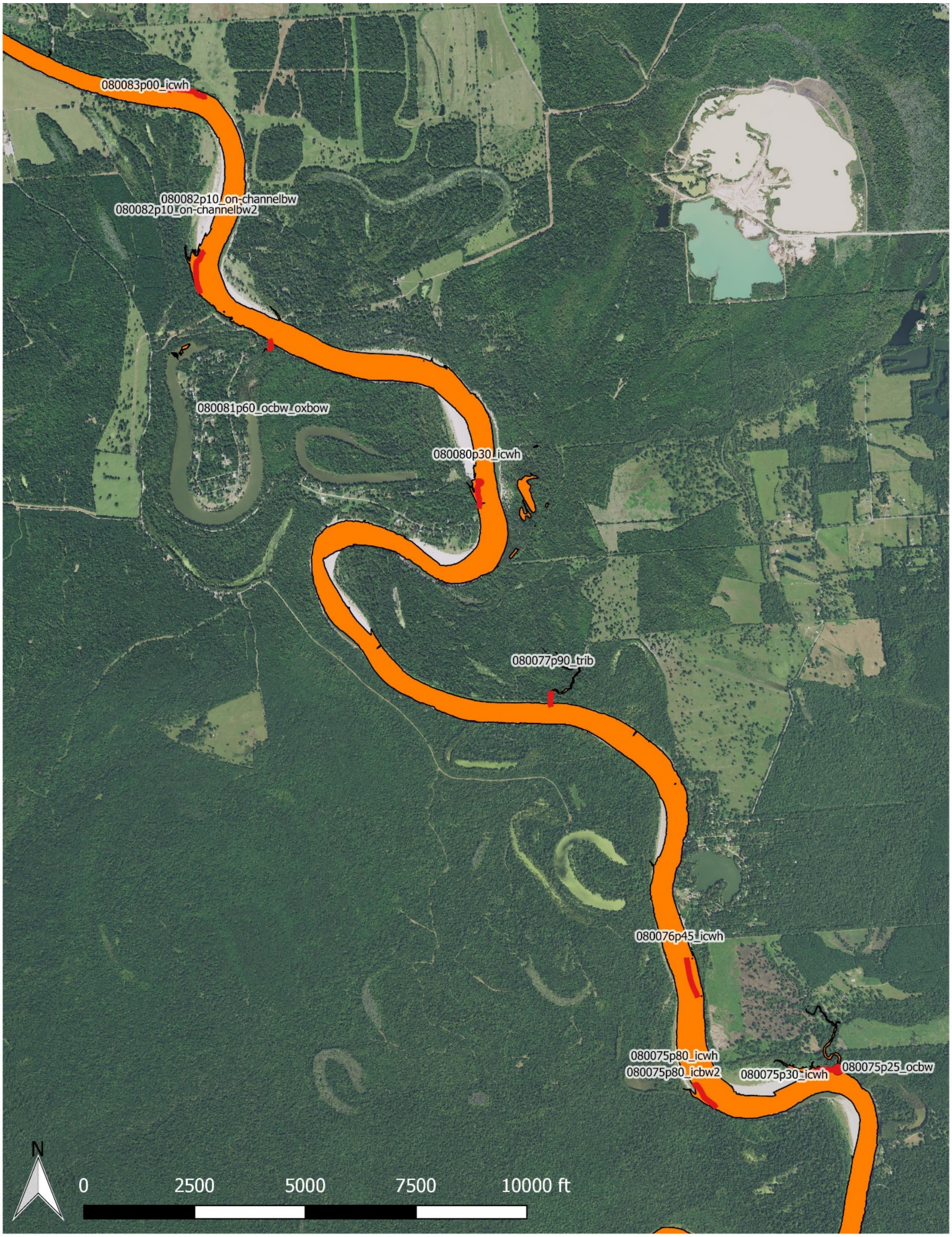

Figure 34. Lower Segment upstream of 080075 2 of 3 - Observed inundation and connectivity areas over the RAS 14,000cfs inundation map (orange).

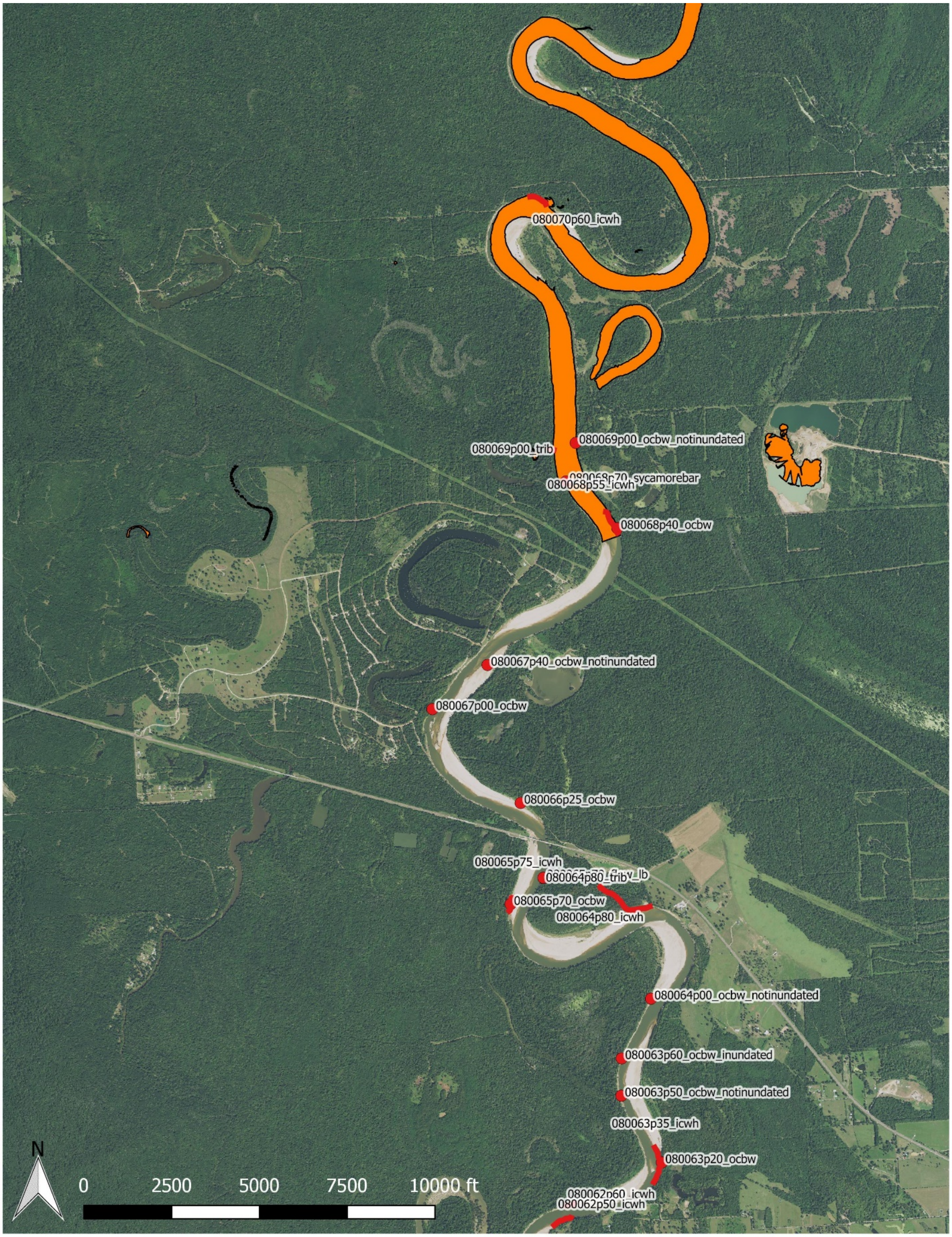

Figure 35. Lower Segment downstream of 080075 3 of 3 - Observed inundation and connectivity areas over the RAS 14,000cfs inundation map (orange).

Figure 36. 080075 – Characteristic view of channel.

Figure 37. 080075 habitat mapping type - Connected tributary


Figure 38. 080075 habitat mapping type – Disconnected oxbow.


Figure 39. 080075 habitat mapping type – In-channel sycamore habitat.

Figure 40. 080075 habitat mapping type – In-channel willow habitat.

Figure 41. 080075 habitat mapping type – Off-channel backwater habitat.

9 Appendix 3 – Cross-section measurements and HEC-RAS Modeling

9.1 080486 – Grand Prairie

9.1.1 080486 – Cross-section changes

Repeat cross-sections have not yet been measured at this site.

9.1.2 080486 – HEC-RAS modeling

Study Area: Lower West Fort Trinity River between (DS) Beltline Rd. (RM 486) and Greenbelt Road US) (RM ~503).

Terrain Data: The terrain data was created from the 2016 Tarrant Regional Water District (TRWD) terrain LiDAR data (which includes the 2011 TRA longitudinal data) with the 2017 site survey data integrated into the terrain.

Cross-section (XS) Source Data: XSs were cut with GeoRAS and XS locations with additional XS site survey data were updated with the actual point data using the Update Elevations tool. The XS cut data is from All data_080486_QA.xlsx spreadsheet that was adjusted form the Feb 2017 site install survey. It is also in the GIS geodatabase associated with this model folder.

XS point data were derived from: All data_080486_QA.xlsx

XSs in HEC-RAS model were QAd and outlier data were removed or adjusted as appropriate.

Bank stations were adjusted in HEC-RAS

Flow profiles were created using the SB3 pulse flows and the 2, 5, and 10-year recurrence intervals as calculated form the Grand Prairie (GP) peak flow gage records.

Boundary conditions were created using the rating curve from the GP gage. The datum of the gage was adjusted down by -0.414 feet to match the site survey VRS elevation data. The adjustment was based on the water surface (WS) slope calculated from the water surface profile (WSP) between XS3 (most downstream) and the turning point 2000 ft upstream (slope -0.000133).
201706201240 - Initial model run:
Initial Model Run 080486_RAS_2017_v3
GP_080486_201706_v2
080486_Flow_v1
20170620 - Ran model with updated flows and geometry. After reopening the project, Geometry V3 and V4 were gone and corrupted. Started back with v5 and re-worked.

20170621 0950- Found error from corrupt .xls file. Repaired and corrected the flow data for 080486_Flow_v1 to reflect the corrected information. Reference: 080486_PT_Combined_v2.xlsx under "calibration flows" tab.

After reviewing the WSP for the 3 PTs, there were too many discrepancies between the 1420 & 1430 cfs profiles indicating there could have been one of the flows where one PT was knocked over and the other was not. See notes regarding how they were found.

Calibration flow on the low end will be 2100 cfs and on the high end, it will be 6560 cfs. The model was calibrated using the 2100 cfs flow. The water surface was too high and the geometry was adjusted down 6.36 feet from cross-section 7025 - top of the reach at Greenbelt Rd. This adjustment was done to make up for the error in the TRWD terrain data that incorporated data from the TRA 2011 longitudinal survey that was created using M9 depths and the slope between the gages. The drop in depth agreed with the change in elevation along the slope between the GP gage and the low water dam invert elevation just US of Handley Ederville Road in Tarrant County.

The model agreed well at the upstream end at 2,100, 4,740 and 6,560 cfs, but the predicted water surface was 3 feet lower at the upstream end at 9,300 cfs, which represents the 2 year return interval (RI) of that gage based on peak flow statistics. At the highest flow modeled (15,000 cfs) the predicted 7.5' below the Observed WS at the Greenbelt USGS gage.

Calibration:

Station	WS 2100 cfs Obs	OWS 2100 cfs Obs	Obs v. Predicted
1038.369995	412.7242737	412.389801	-0.334472656
3315.640015	413.0454407	412.8507996	-0.194641113
4386.190018	413.1838989	413.045105	-0.138793945
90337.85009	448.5483704	448.82	0.271629639

Validation:

Station	WS 6560 cfs Obs	OWS 6560 cfs Obs	Obs. V Pred.
1038.369995	420.2938232	420.0729065	-0.220916748
3315.640015	420.8352661	420.7672119	-0.068054199
4386.190018	420.9626465	421.1940918	0.231445313
90337.85009	454.9345398	456.3699951	1.435455322

As the flow increases there is a bigger delta between the observed and predicted at the US end of the study area. Additional channel detail and survey data are needed to increase the accuracy of the model during future studies.
Final Files:
080486_RAS_2017_v4.prj
080486_RAS_2017_v4.p09
080486_RAS_2017_v4.g09
080486_RAS_2017_v4.f02

Predicted WSE at SB3 Pulse Flows 300 and 1,200 cfs.

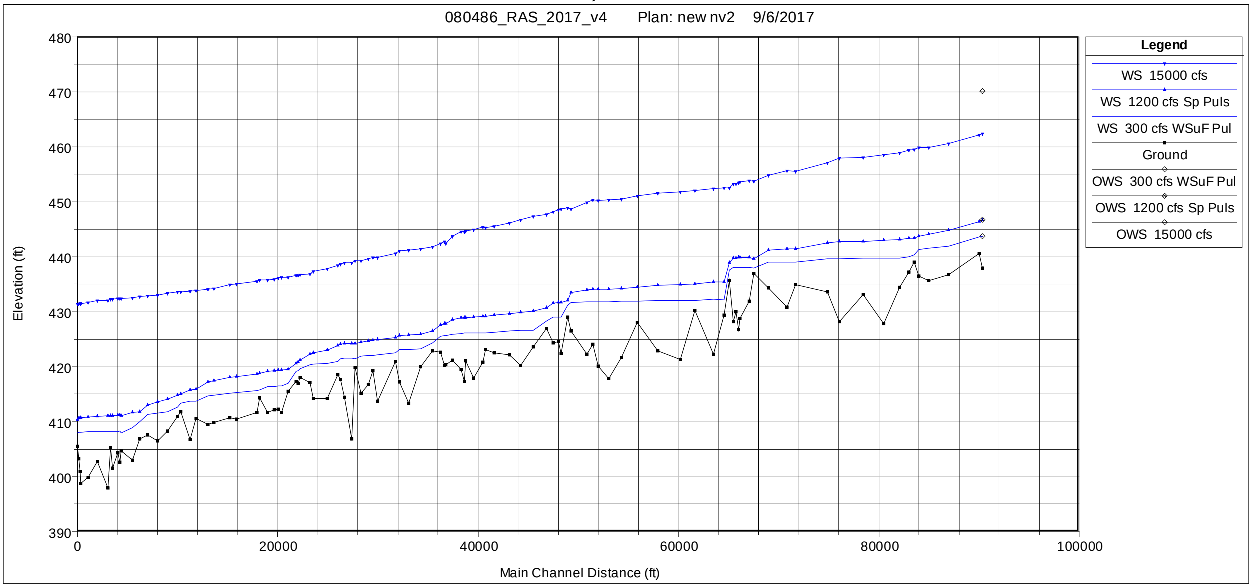

Figure 42. Predicted WSE at SB3 Pulse Flows 300 and 1,200 cfs.

Figure 43. Selected are of the 080486 model showing inundation at various flows.

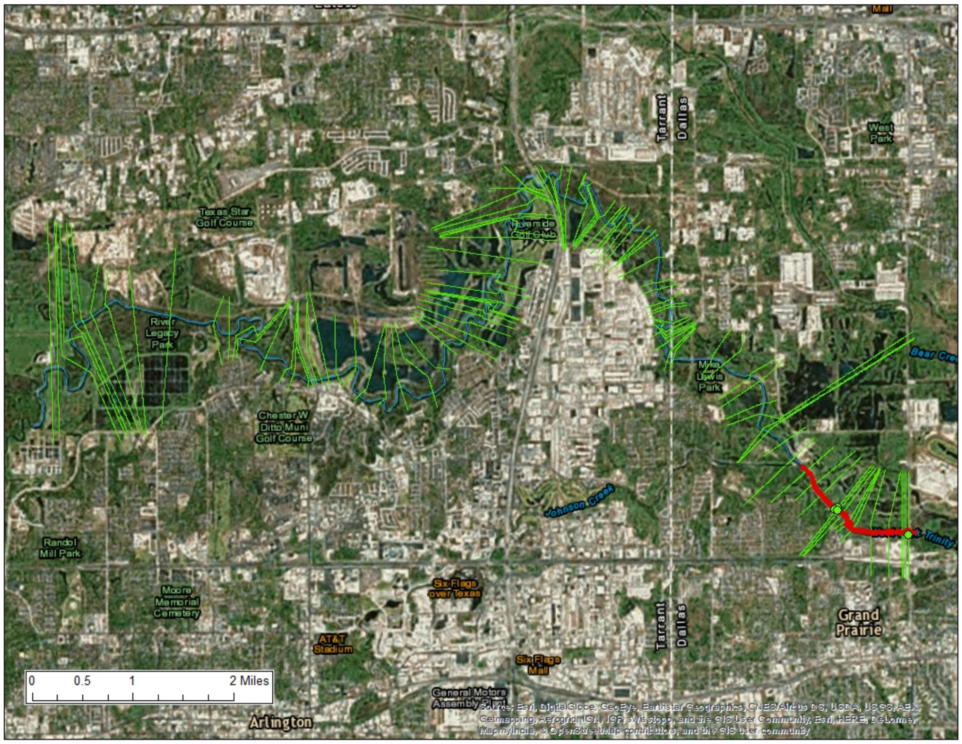

Figure 44. 080486 Model overview map showing cross-section locations. Note: Red points represent area of intensive site survey.

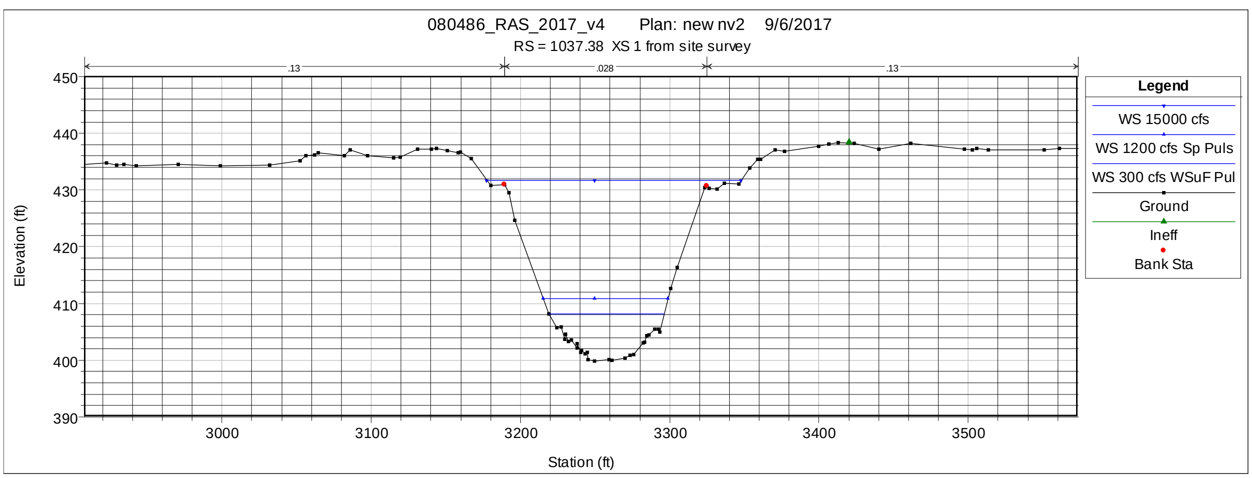

Figure 45. Intensive survey cross-section at station 1037.38 showing the water surface elevation at 300, 1,200, and 15,000 cfs.

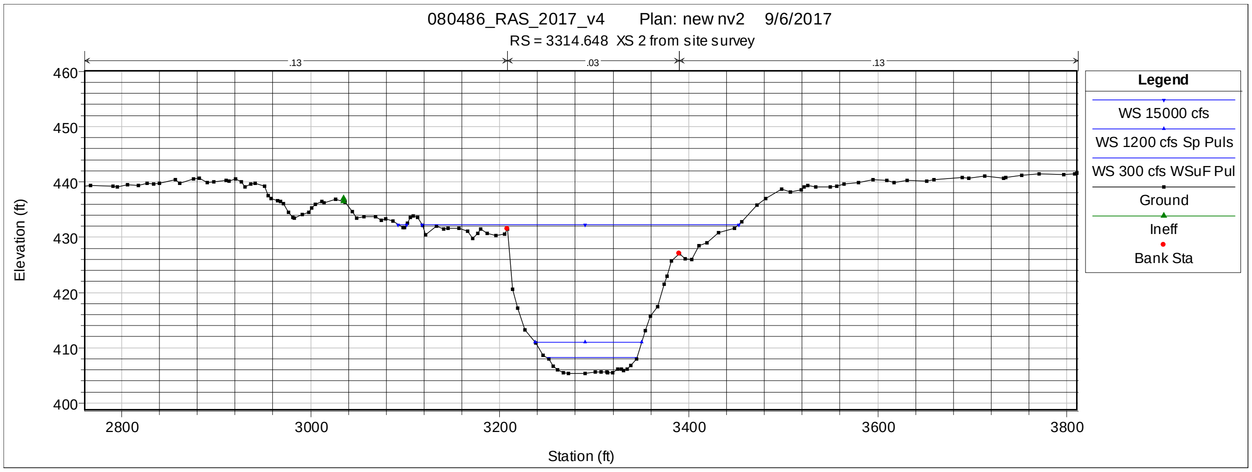

Figure 46. Intensive survey cross-section at station 3314.648 showing the water surface elevation at 300, 1,200, and 15,000 cfs.

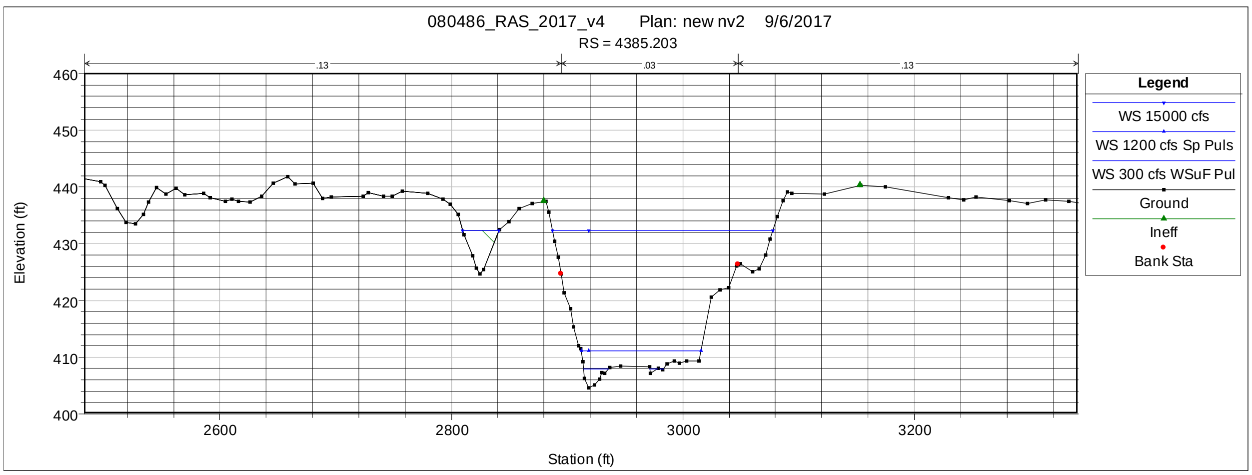

Figure 47. Intensive survey cross-section at station 4385.203 showing the water surface elevation at 300, 1,200, and 15,000 cfs.

9.2 080444 – Lock site downstream of Dallas

9.2.1 080444 – Cross-section changes

Multiple repeat cross-section measurements have been taken at this site. This site is in the midst of transition; the base water level dropped approximately 5 feet as the result of the 2012 failure of a relic lock structure that had impounded the river like a check dam.

Cross-section 4 is the closest cross-section upstream of the failed lock and represents the largest channel change, approximately 75 feet laterally (toward river left, the same side where the dam was flanked).

Below are figures showing changes in five cross-sections from the 2014, 2015 and 2017 surveys.

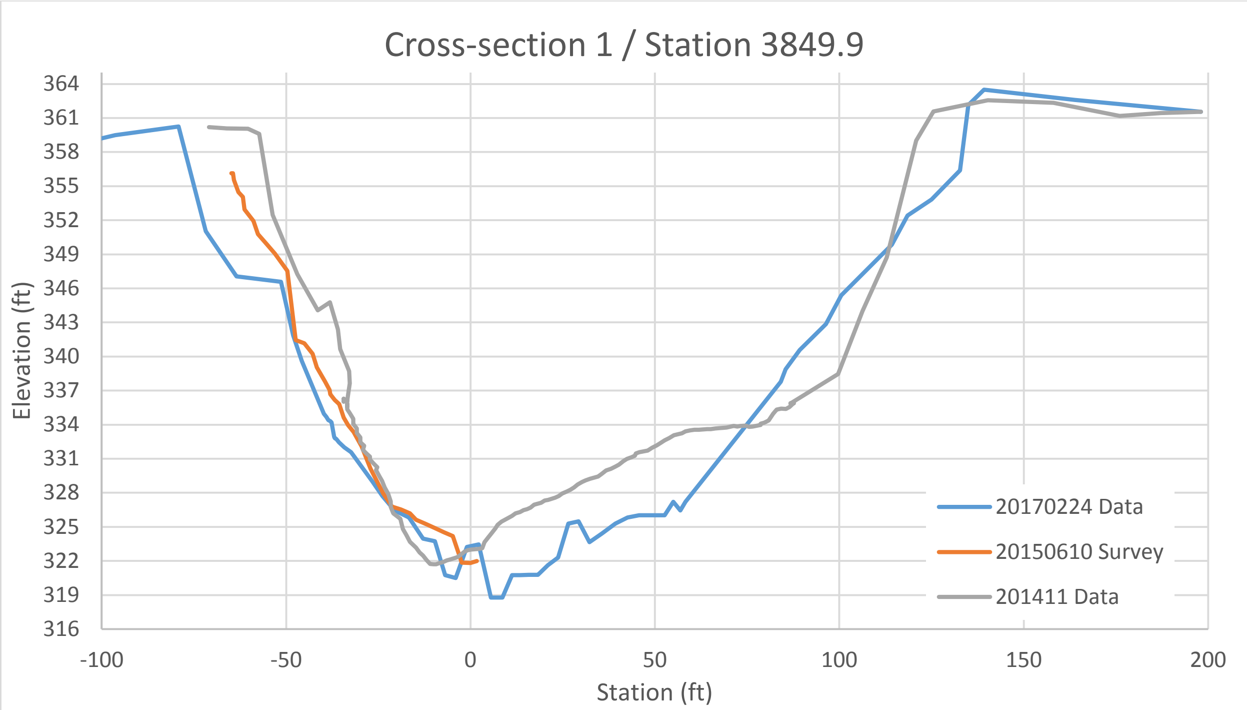

Figure 48. Changes in cross-section at station 3849.9.

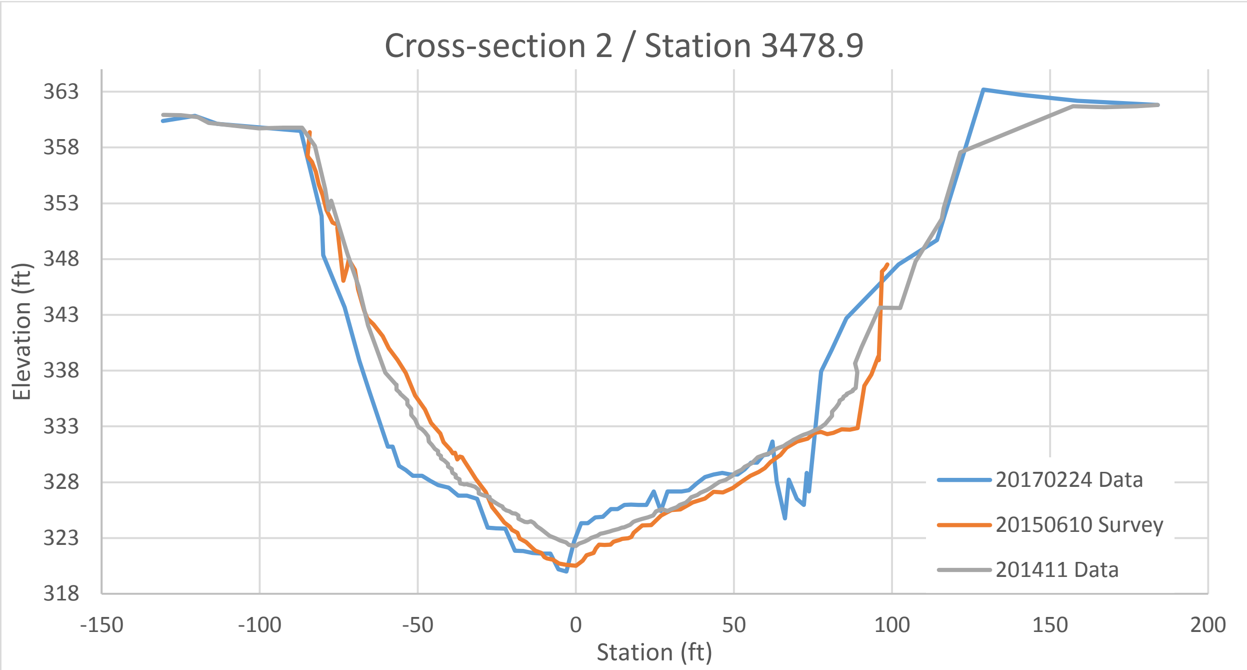

Figure 49. Changes in cross-section at station 3478.9.

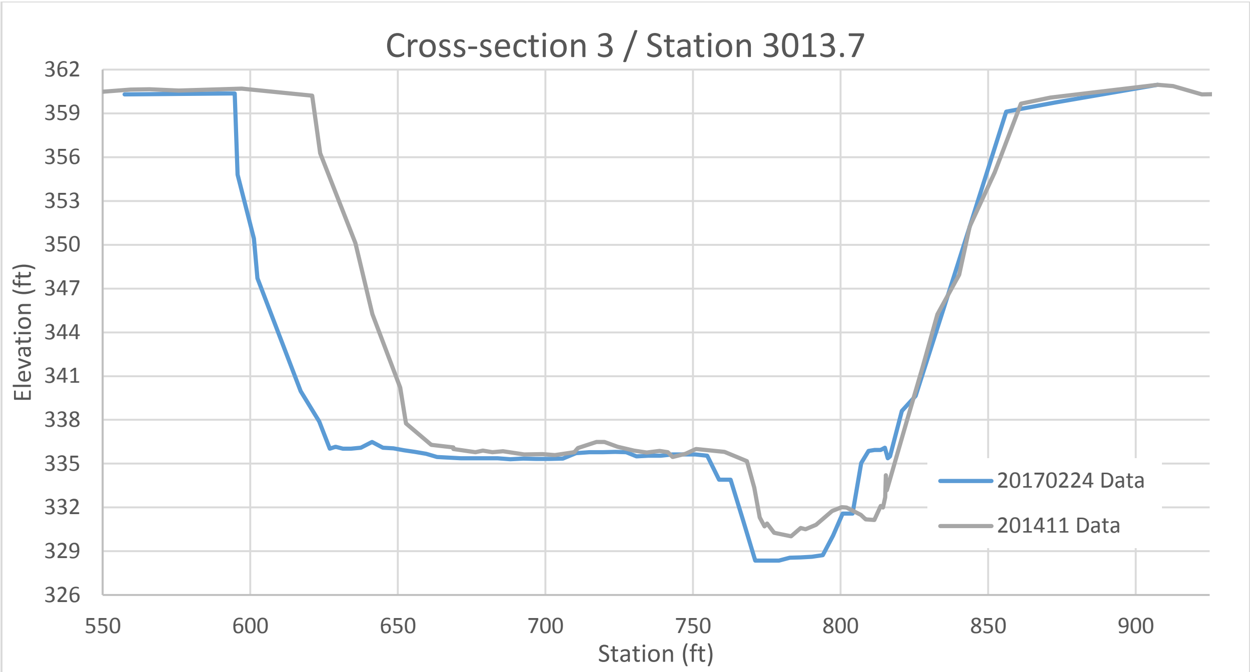

Figure 50. Changes in cross-section at station 3013.7.

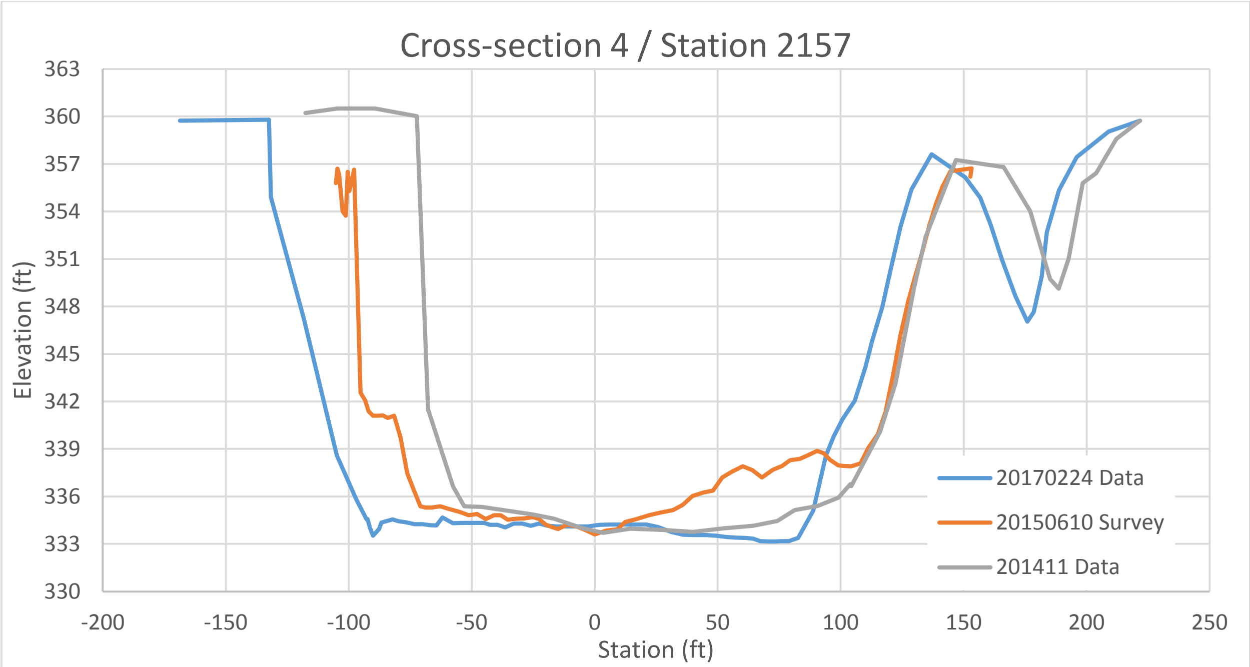

Figure 51. Changes in cross-section at station 2157.

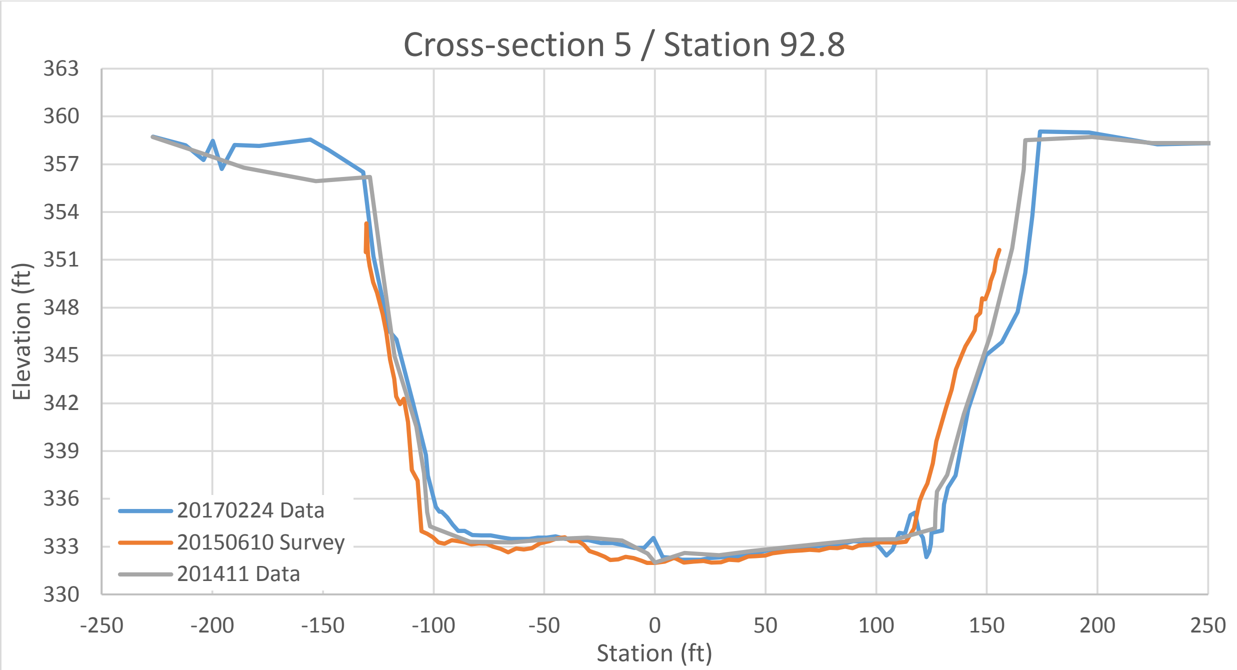

Figure 52. Changes in cross-section at station 92.8.

9.2.2 080444 – HEC-RAS Modeling

This model was created by TRA in August of 2017 and extended the Phase I model for this section upstream to the USGS gage Trinity River below Dallas (08057000).

-Geometry
Georeferenced (4202) geometry data was created in GeoRAS using the 2017 TRWD Terrain Model which incorporates the 2011 longitudinal survey and the new LiDAR.
The old XS lines were re-digitized from the 2015 model were used in the new survey. GeoRAS was used to incorporate the new survey data to the XS lines.
Cross-sections that had erroneous data were adjusted based on the previous survey, knowledge of the system, and field data/notes/photographs.
The topo and bathymetry data were based on AllData_080444_QA.xlsx (2017-06-23).

-Flow Data
3 PTs were deployed and 2 were recovered. The middle XS PT was not found in the field. The PT data from XS1 (DS) and XS5(US) was suspect due to the travel times and distance from the USGS gage TR below Dallas (Loop 12) and the site. Because of this and the fact that the DS XS1 did not change much, the same flow data were used that were developed from 2015 with the exception of replacing the 4000 cfs Q in the rating curve with the measured 3931cfs Q and WSE of 337.32 which represented the conditions during the install and the WSP from that for all flows except: 3931, 700, 1000, 4000, 526, and 6114 where the data was unavailable. For these flows, the flow change was estimated based on the data available:

HEC_RAS Date/Time |TR_Q |Dalls_SS_Daily_AV_CFS| HEC_Ras_Flows

11/25/13 2:15	1060	107	1167
4/13/14 16:45	1350	91	1441
5/26/14 19:45	1810	90	1900
11/23/13 8:00	2410	93	2503
11/5/14 13:30	3460	107	3567
3/16/14 18:00	4320	107	4427
6/24/14 6:00	4460	80	4540
10/14/14 2:15	7150	124	7274
12/22/13 11:15	9880	162	10042
8/18/14 3:00	6350	120	6470

A flow change location was used at the Dallas SS WWTP. Reported Dallas SSWWTP average daily flow was subtracted from the gage data.

-Model Processing
4 Cross-sections were adjusted to remove erroneous data from survey processing and were re-cut from the terrain. Other cross-sections were adjusted to remove the 2015 LiDAR points that no longer represented the field conditions since the historic flooding of 2015 and 2016 which caused extensive erosion.

Manning's n was slightly adjusted down from the 2015 model in the Lock area since the channel is wider and less obstructed as the channel migrates to river left.

-Calibration
Model was calibrated at 3931 cfs and validated with the 10,000 cfs.

Station	**WS 10042**	**OWS 10042**	**CFS Delta 10042**	**WS 3931**	**OWS 3931**	**3931CFS Delta**
793.42	344.54			337.96	337.75	-0.21
1263.28	344.75			338.31	338.36	0.06
1634.05	344.76			338.73	338.50	-0.23
2059.32	345.37			339.75	339.19	-0.57
2915.58	345.78			340.38	340.03	-0.36
3380.12	345.98			340.57	339.87	-0.70
3750.38	345.95	345.87	-0.08	340.56	340.32	-0.24
105912.93	382.55	382.45	-0.10	375.44	374.93	-0.51

The OBS vs. predicted looks reasonable within the site and at the Loop 12 gage location and is reasonable within the range of error for the VRS GPS.

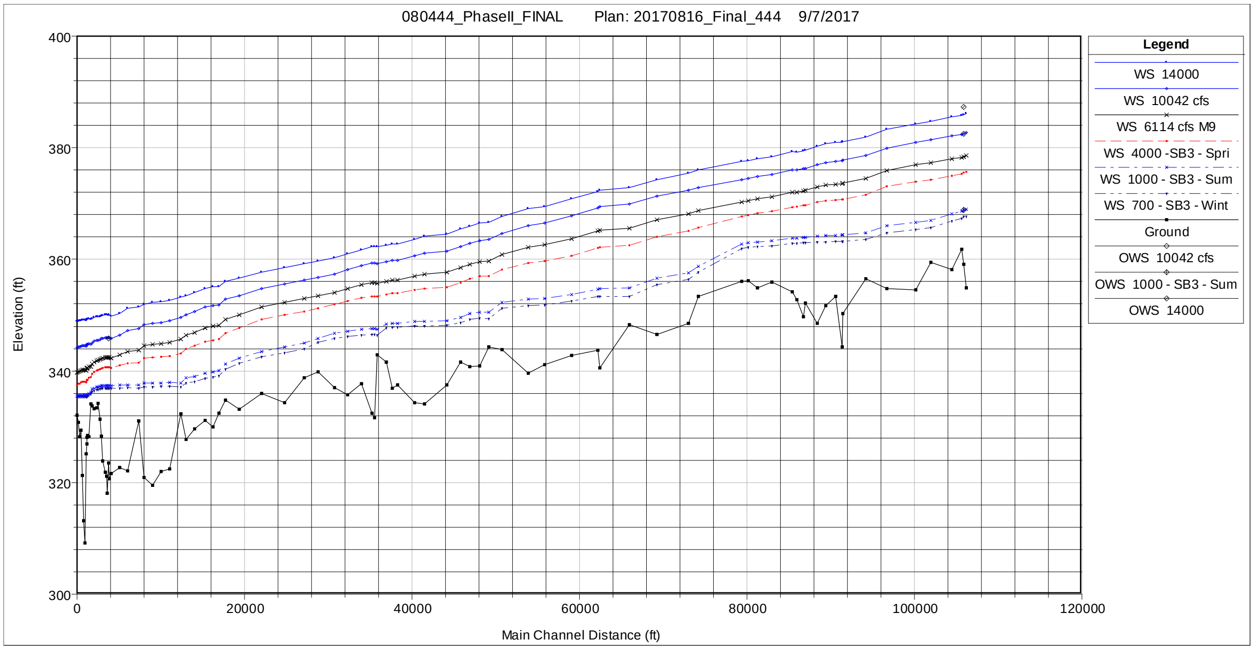

Figure 53. Site 080444 water surface profile for selected flows. Note: SB3 Pulses at this site are 700, 1,000, and 4,000 cfs.

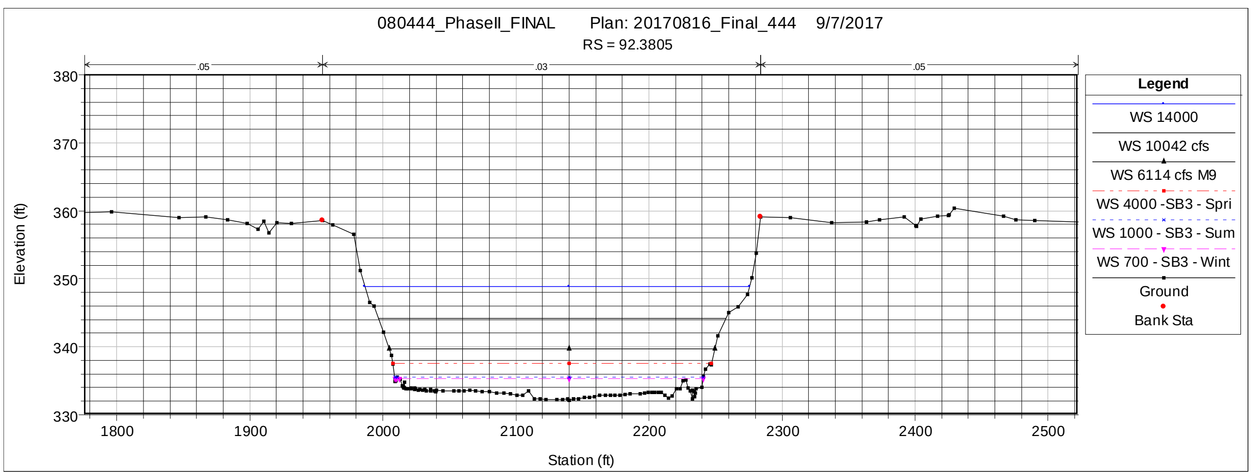

Figure 54. Channel Cross-section for XS5 at site 080444. Note: SB3 Pulses at this site are 700, 1,000, and 4,000 cfs.

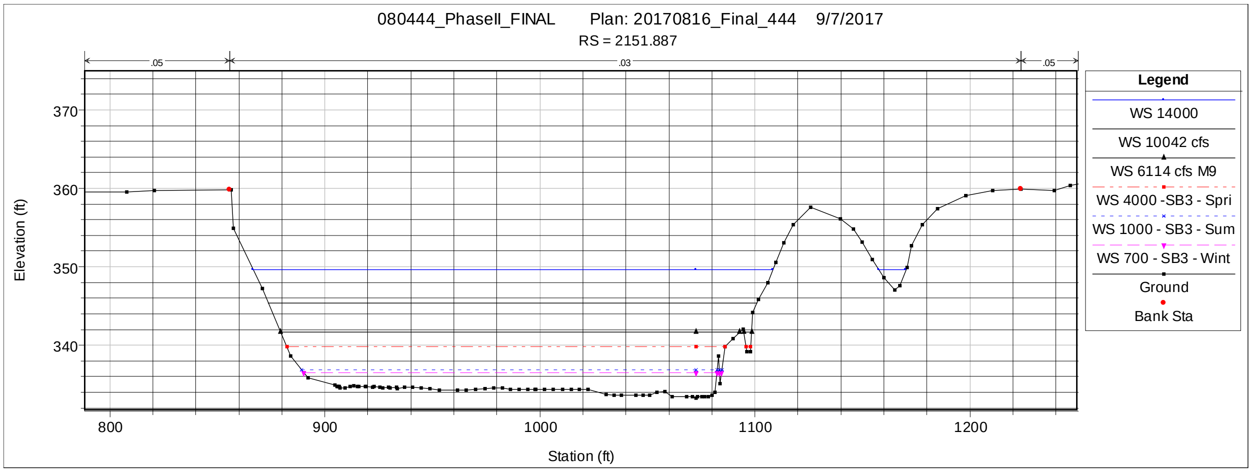

Figure 55. Channel Cross-section for XS4 at site 080444. Note: SB3 Pulses at this site are 700, 1,000, and 4,000 cfs.

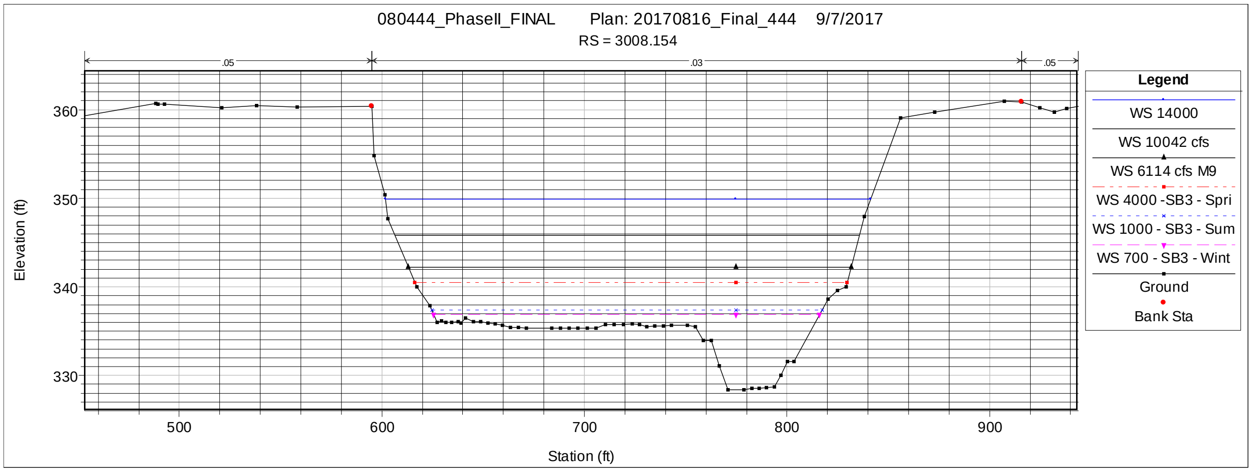

Figure 56. Channel Cross-section for XS3 at site 080444. Note: SB3 Pulses at this site are 700, 1,000, and 4,000 cfs.

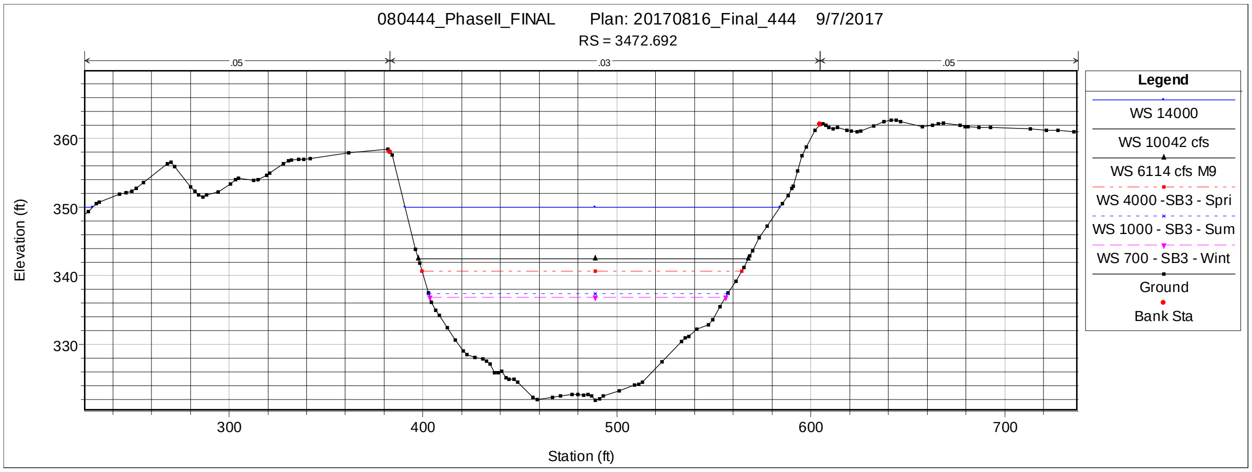

Figure 57. Channel Cross-section for XS2 at site 080444. Note: SB3 Pulses at this site are 700, 1,000, and 4,000 cfs.

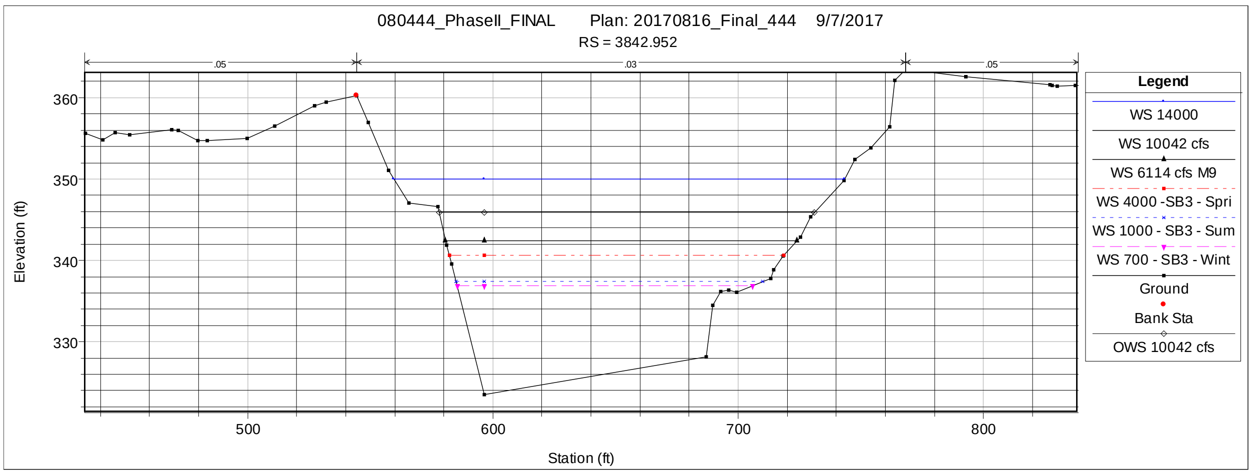

Figure 58. Channel Cross-section for XS1 at site 080444. Note: SB3 Pulses at this site are 700, 1,000, and 4,000 cfs.

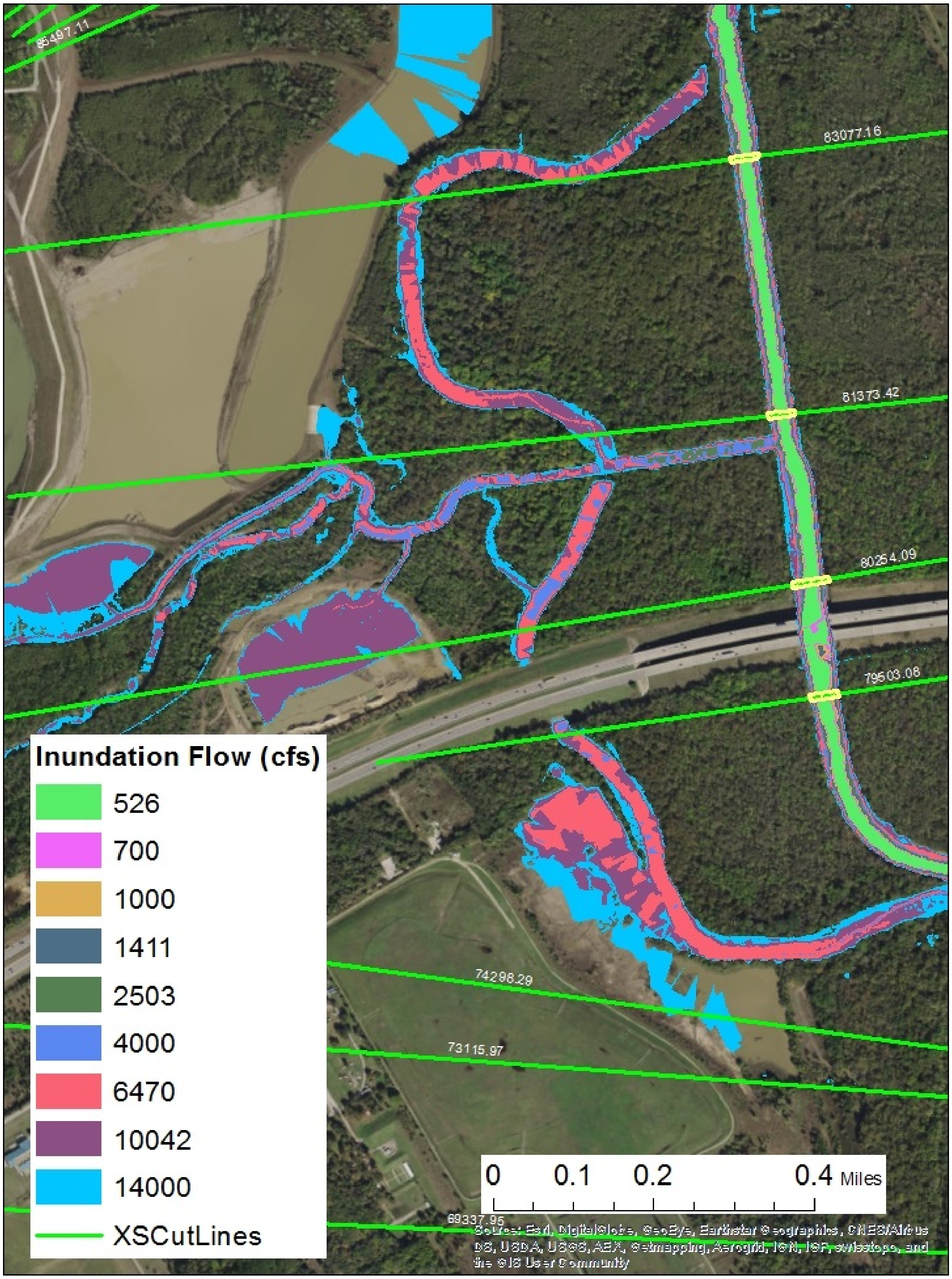

Figure 59. Selected location at site 080444 showing inundation at various flows. Note: SB3 Pulses at this site are 700, 1,000, and 4,000 cfs.

Figure 60. Site 080444 model overview map

9.3 080295 – Oakwood

9.3.1 080295 – Cross-section changes

Below are figures showing changes in three cross-sections from the 2012 and 2016 survey. The large differences between the 2012 and 2016 surveys right overbanks are where USGS NED 10m data was used in 2012 instead of GPS survey data as in 2016.

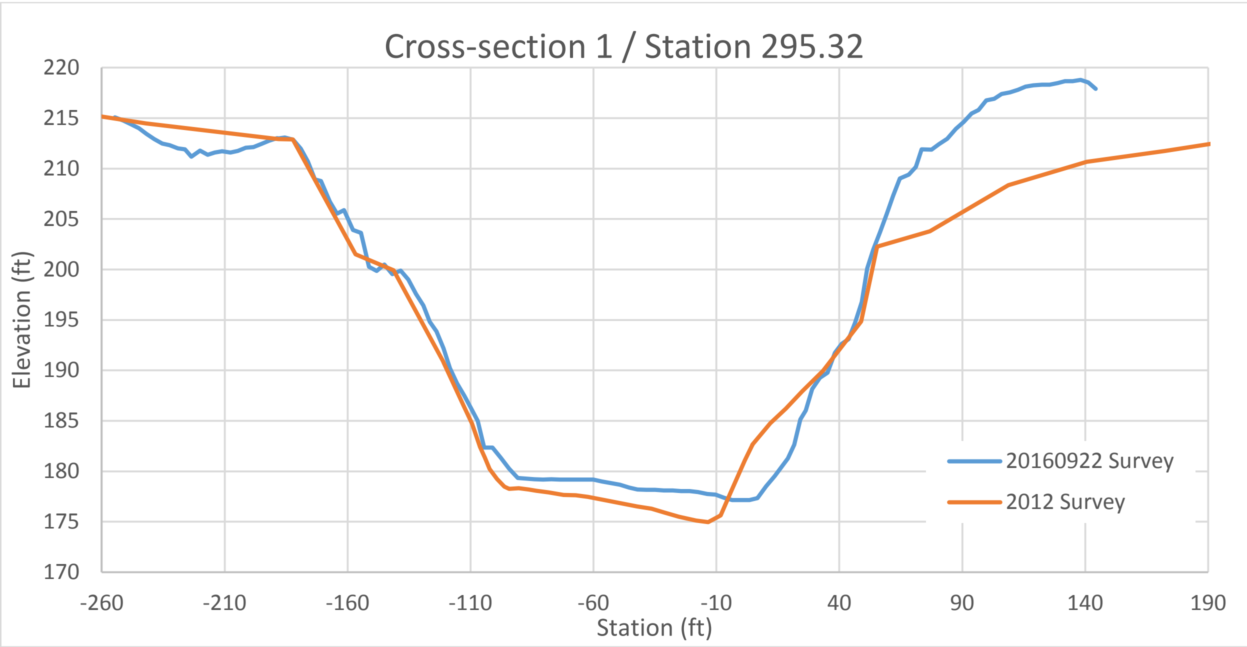

Figure 61. Changes in cross-section at station 295.32.

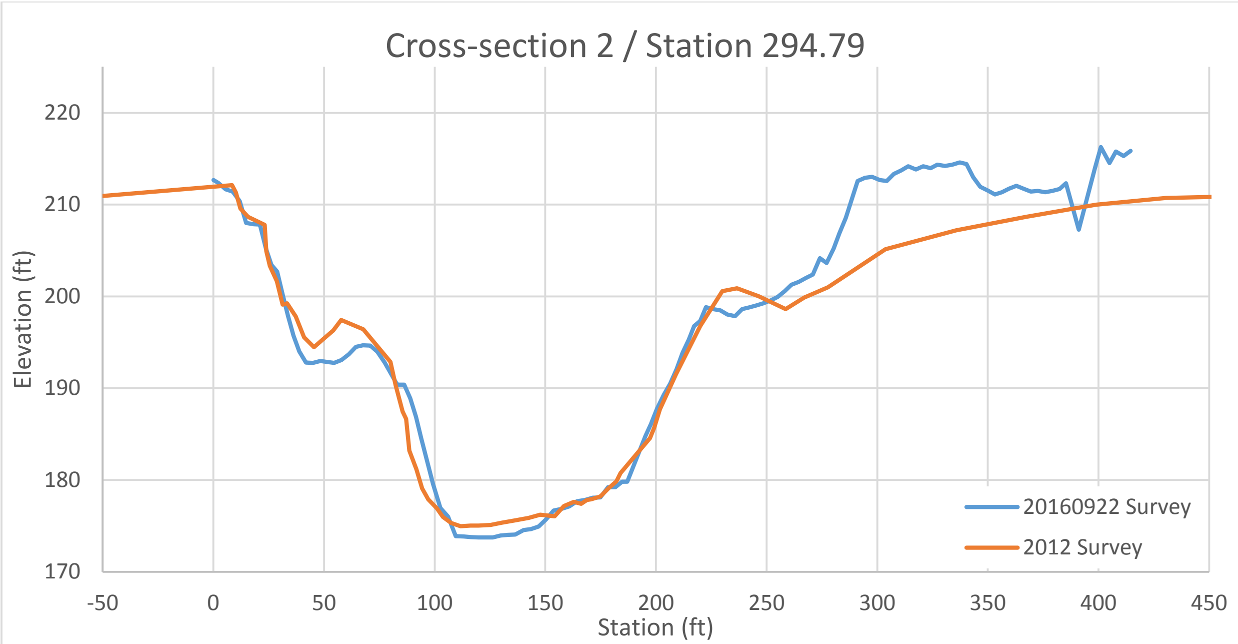

Figure 62. Changes in cross-section at station 294.79.

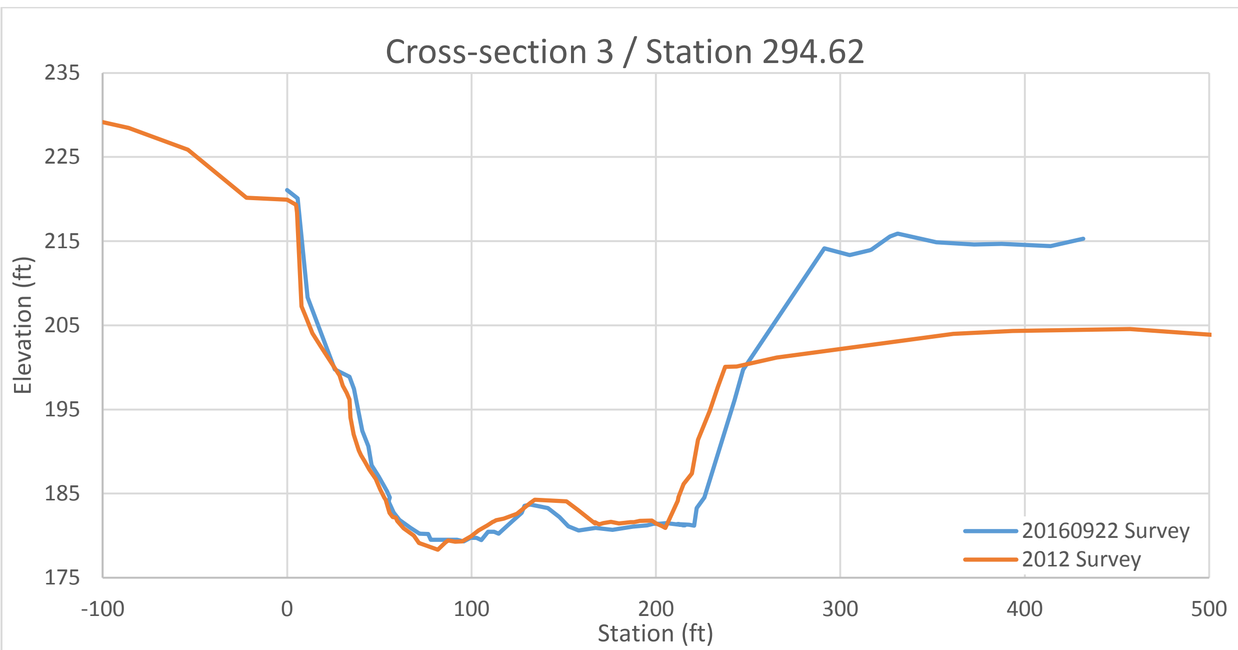

Figure 63. Changes in cross-section at station 294.62.

9.3.2 080295 – HEC-RAS model

The HEC-RAS model for the Oakwood site developed during Phase 1 was updated for Phase 2 in two ways. Updates were conducted within a new geometry file. Within the study site, the model was updated using Phase 2 2016 survey data for the three cross-sections. In addition, the model was extended several miles upstream to the upstream end of the segment C3 (Figure 63). The cross-sections were derived from a TRWD flood model based upon 2008 elevation data.

Inundation mapping of model results was derived from a terrain derived from the 2015 LiDAR mapping efforts.

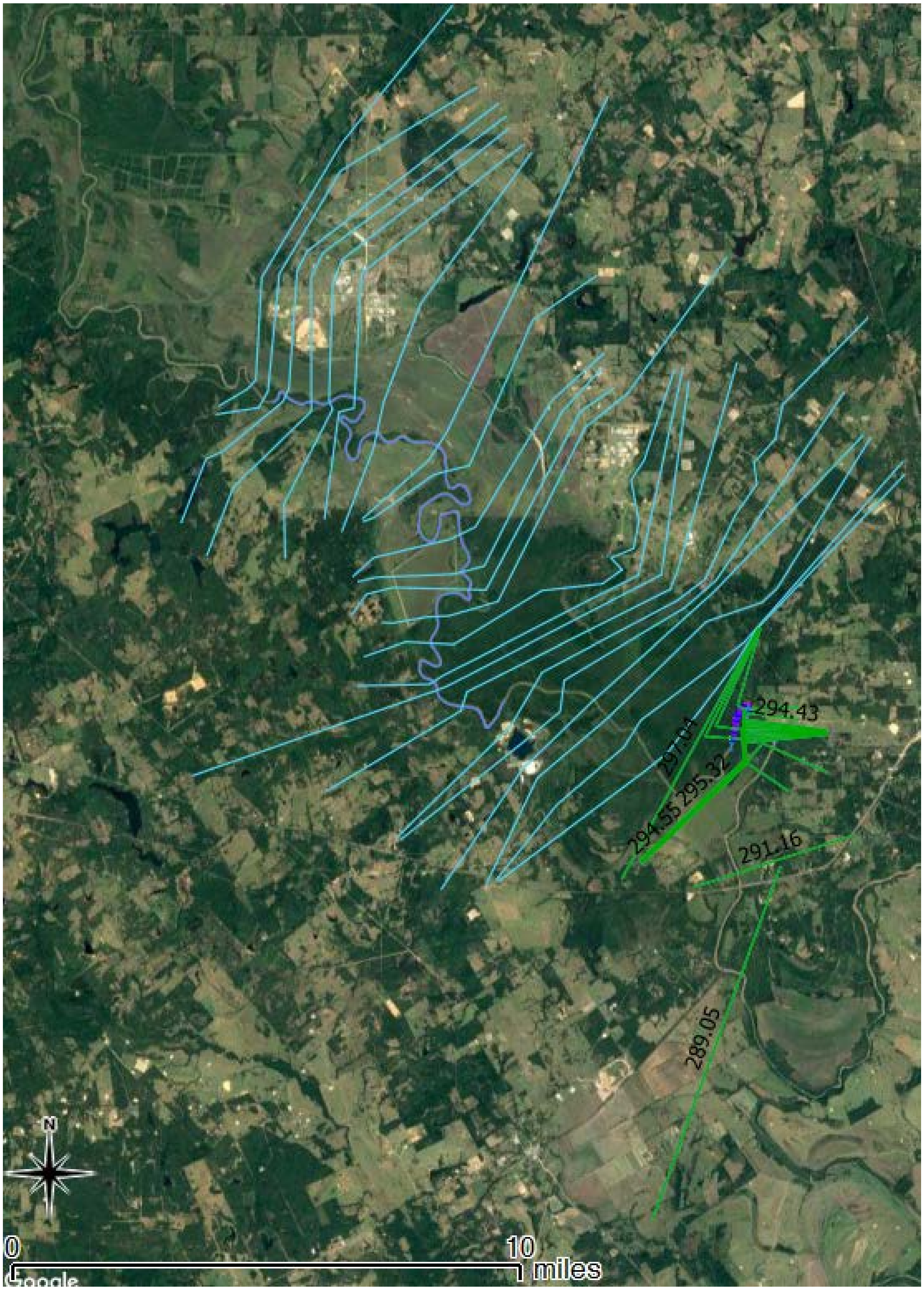

Figure 64. 080295 – Extended HEC-RAS model – Green cross-sections from Phase 1 model; Blue cross-sections added from TRWD; inundation surfaces developed from 2015 LiDAR data.

9.3.3 080295 – Cross-section 2 - Game camera photographs for selected flow rates

Water levels were documented using an autonomous game camera at the Oakwood site at cross-section 2. The camera was set to photograph the study site at regular intervals at set times, allowing the time-stamped photographs to be cross-referenced and assigned to the USGS flow occurring at roughly the same time. Selected photographs are provided in Figure 64 through Figure 72.

Figure 65. 080295 Oakwood - Game camera 761 cfs minimum recorded flow.

Figure 66. 080295 Oakwood - Game camera 2,500 cfs SB3 pulse trigger Fall Summer.

Figure 67. 080295 Oakwood - Game camera 3,000 cfs SB3 pulse trigger Winter.

Figure 68. 080295 Oakwood - Game camera 7,000 cfs SB3 pulse trigger Spring.

Figure 69. 080295 Oakwood - Game camera 10,000 cfs begins to inundate riparian trees.

Figure 70. 080295 Oakwood - Game camera 13,000 cfs begins to inundate off-channel backwaters.

Figure 71. 080295 Oakwood - Game camera 16,100 cfs maximum recorded in 2017.

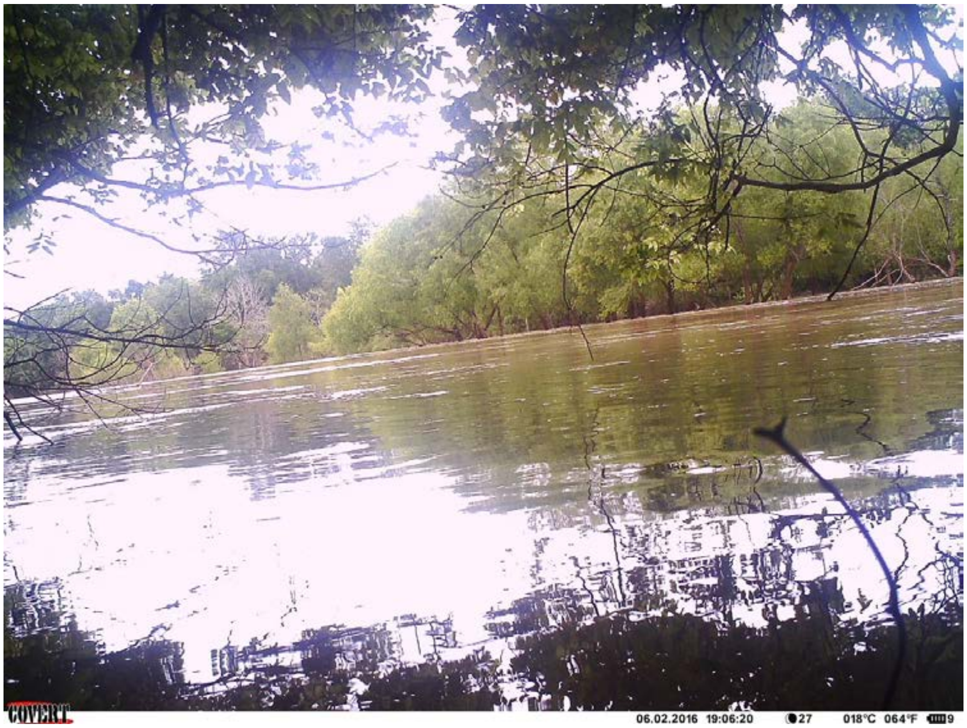

Figure 72. 080295 Oakwood - Game camera 24,000 cfs in June 2016.

Figure 73. 080295 Oakwood - Game camera 25,000 cfs maximum recorded in June 2016.

9.4 080075 – Romayor

9.4.1 080075 – Cross-section changes

At the end of 2016 a survey was conducted at the Trinity River Authority's (TRA) Romayor study site on the Trinity River. A total of four cross-sections (HEC-RAS Stations: 38440, 35823, 34773, 31840) were surveyed within each channel's bench marks using an RTK GPS unit. For portions within the Trinity River and along those cross-sections bathymetric data was collected using an M9 depth sounder. One cross-section (River station 32995) only had limited bathymetric survey data collected. In addition, bathymetric data was collected parallel with the Trinity River through each cross-section. Figure 35 shows the existing HEC-RAS cross-sections, land points surveyed and bathymetric points collected.

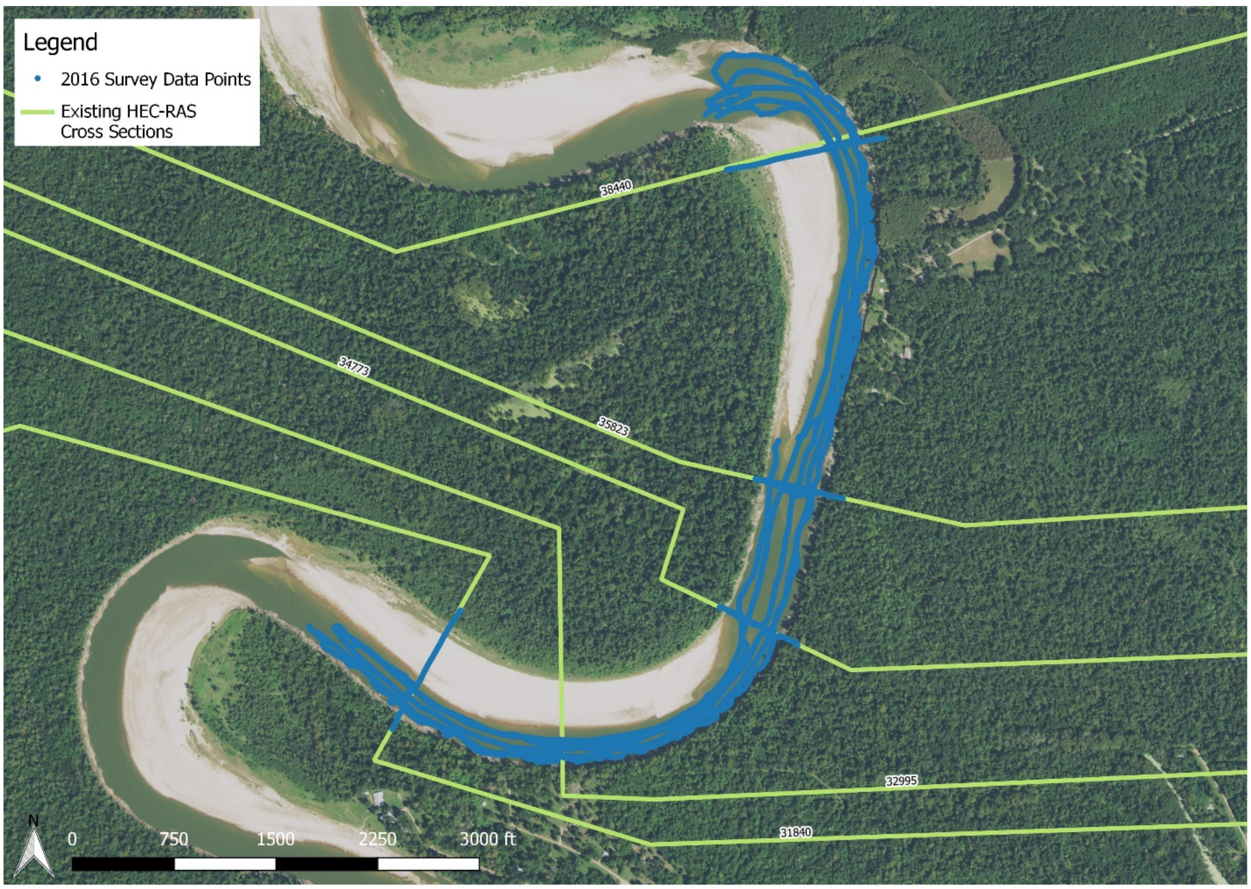

Figure 74. HEC-RAS cross-sections with 2016 land survey and bathymetric survey data.

Existing HEC-RAS cross-section data was updated with processed 2016 data, when available. The cross-sections were only changed if 2016 data was present, otherwise the 2015 data was used. Figure 36 through Figure 40 show the changes in cross-sections from 2015 to 2016.

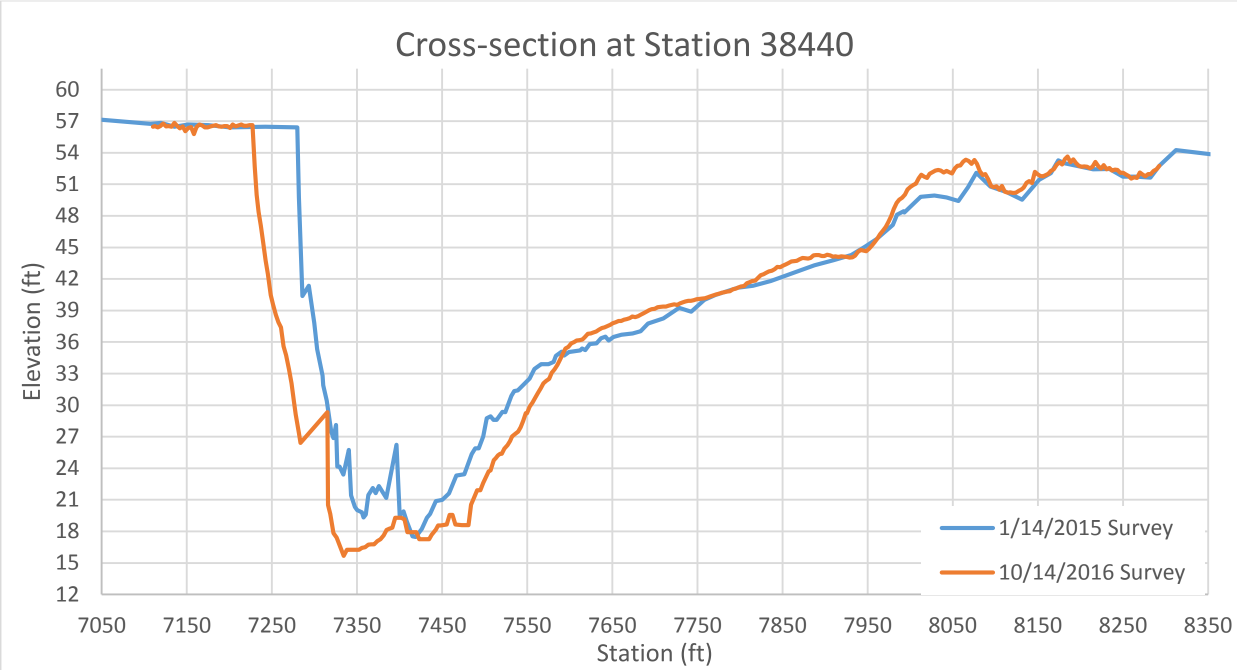

Figure 75. Changes from 2015 to 2016 in cross-section 1 at HEC-RAS station 38440.

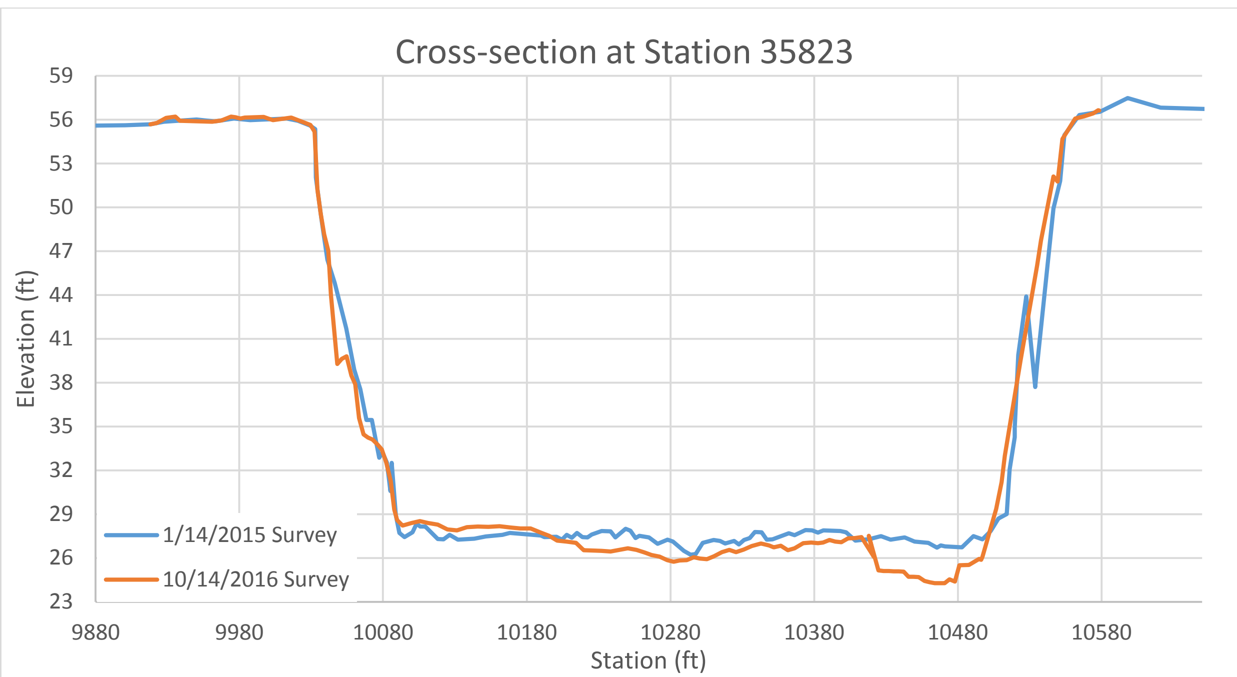

Figure 76. Changes from 2015 to 2016 in cross-section 2 at HEC-RAS station 35823.

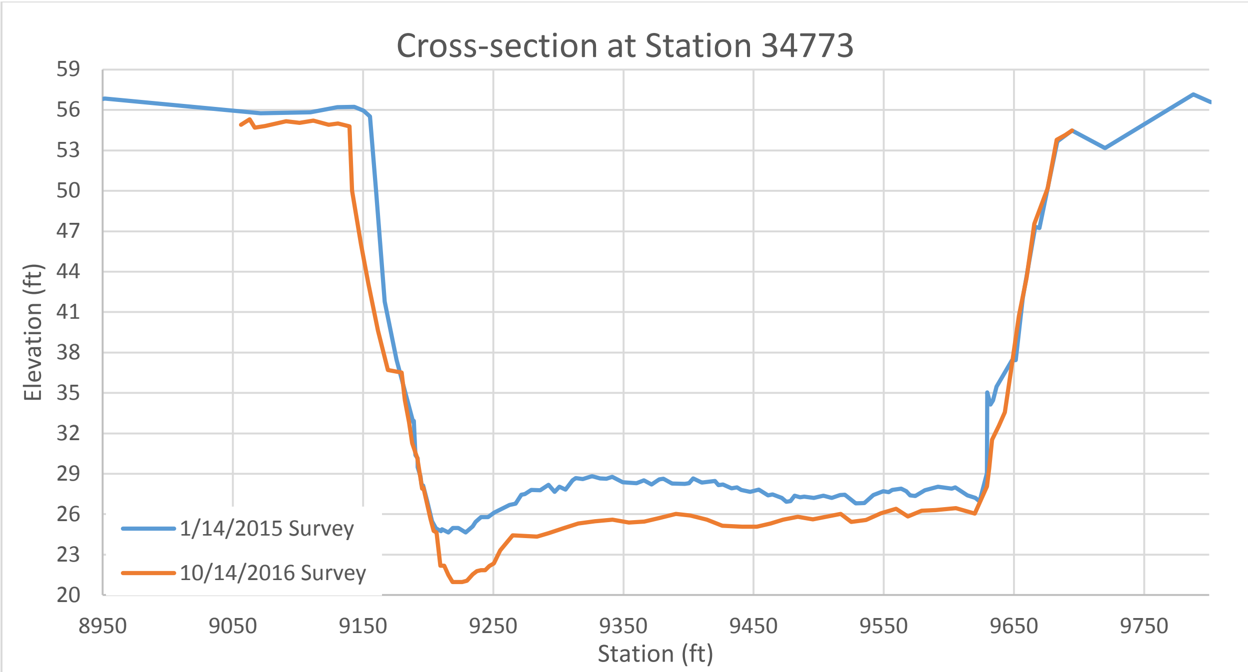

Figure 77. Changes from 2015 to 2016 in cross-section 3 at HEC-RAS station 34773.

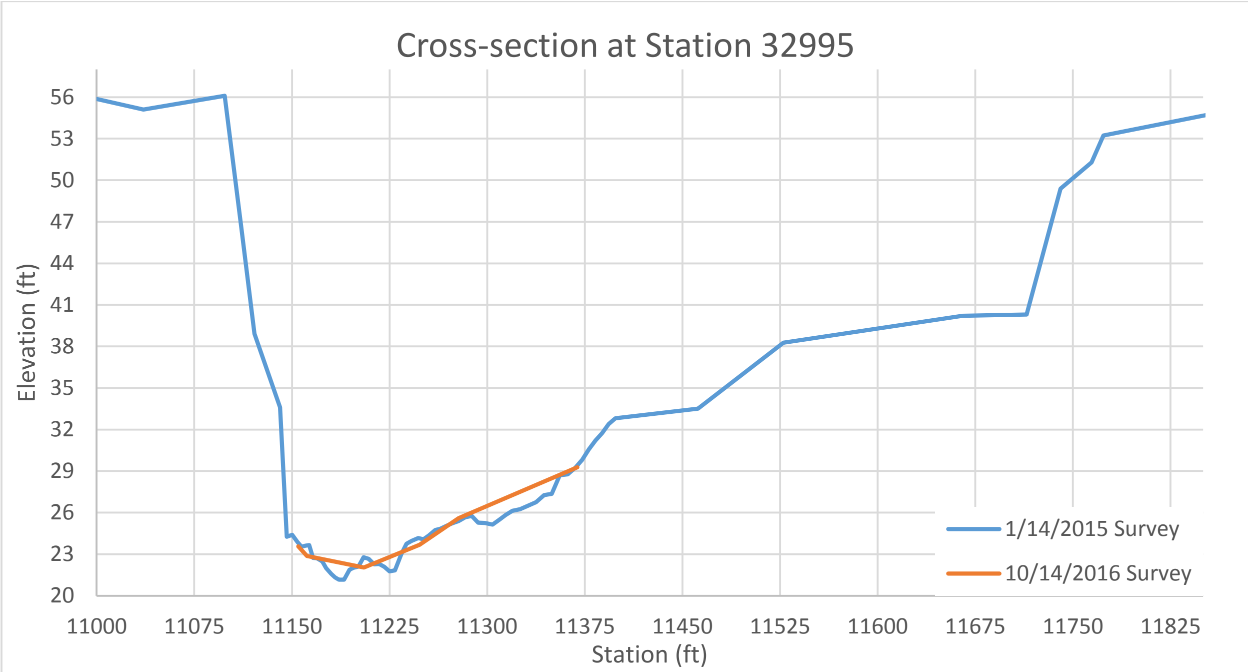

Figure 78. Changes from 2015 to 2016 in cross-section at HEC-RAS station 32995 (only bathymetric survey data).

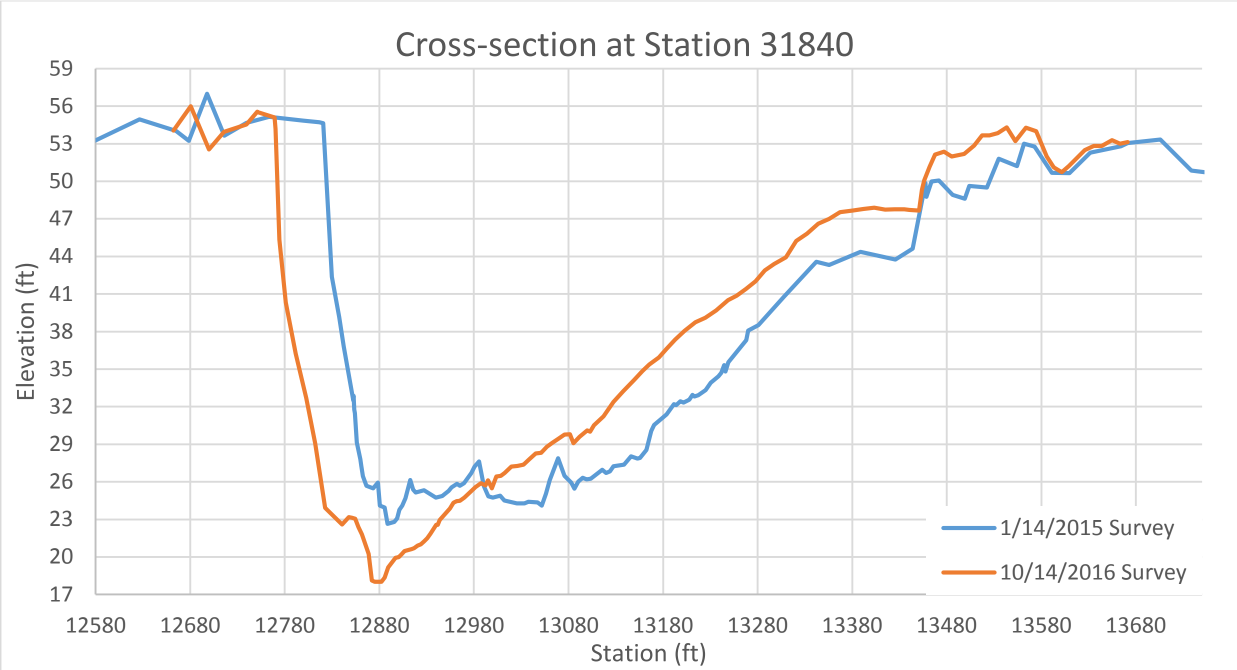

Figure 79. Changes from 2015 to 2016 in cross-section 4 at HEC-RAS station 31840.

The following figures are changes in cross-section (cross-sectional area versus water surface elevation) at the Romayor study site.

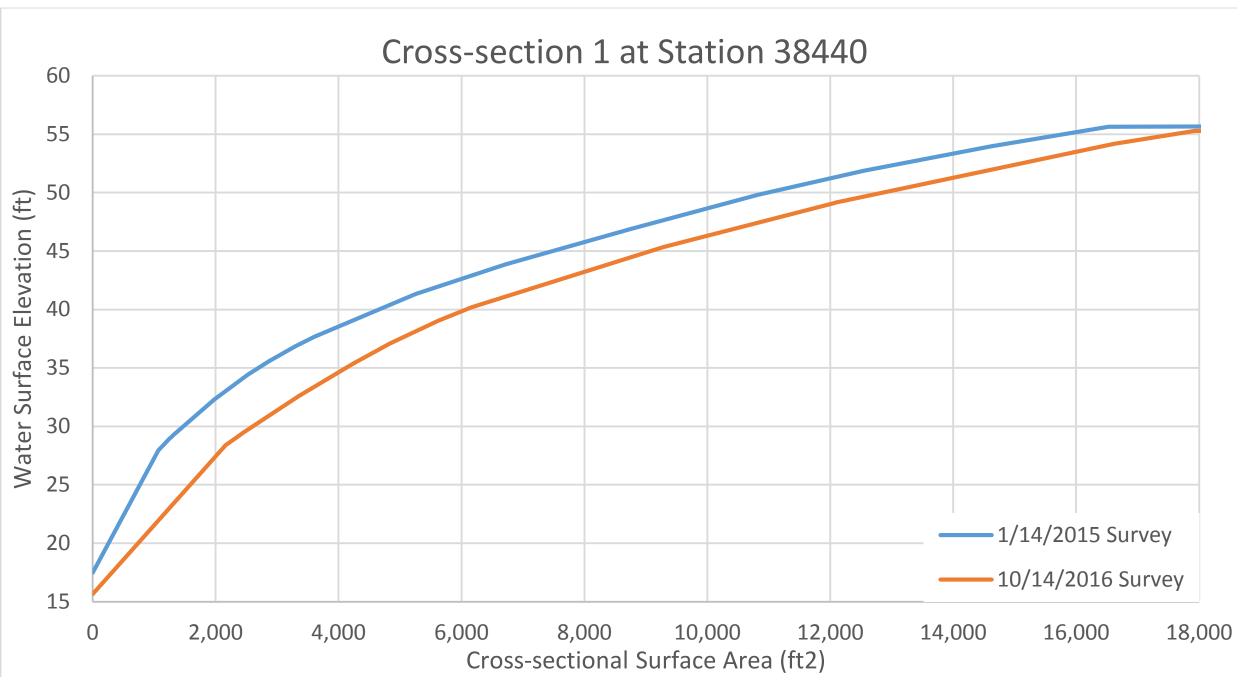

Figure 80. Comparison of cross-sectional area to water surface elevation for Romayor study site river station 38440.

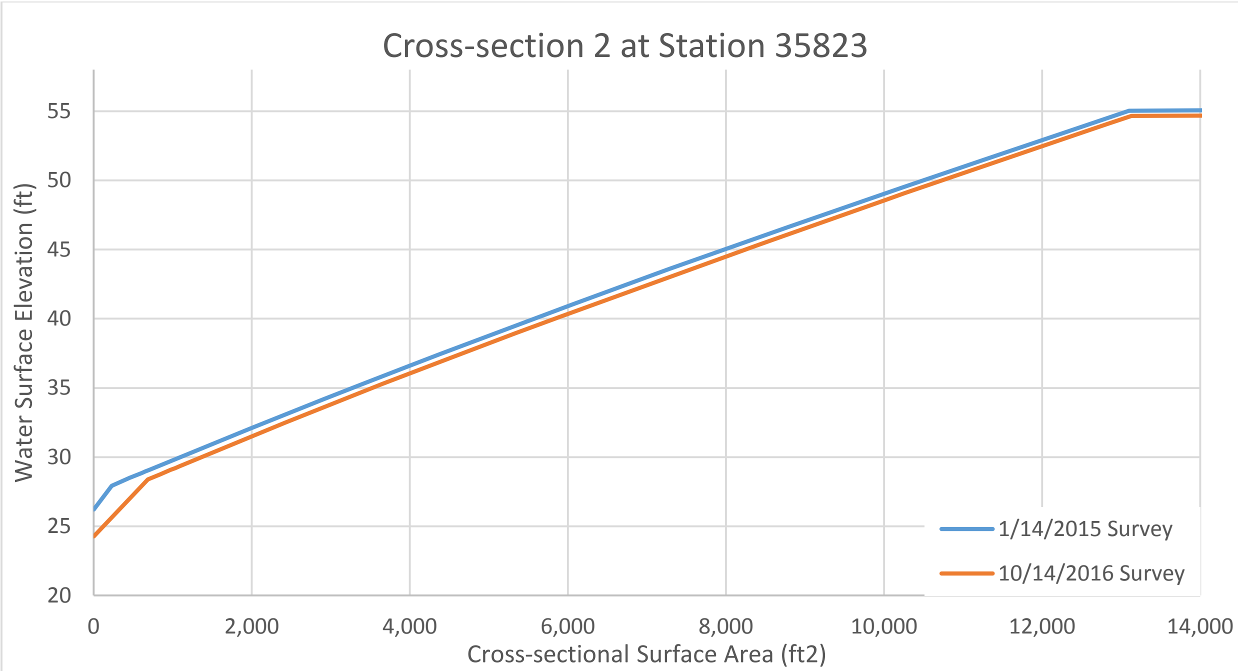

Figure 81. Comparison of cross-sectional area to water surface elevation for Romayor study site river station 35823.

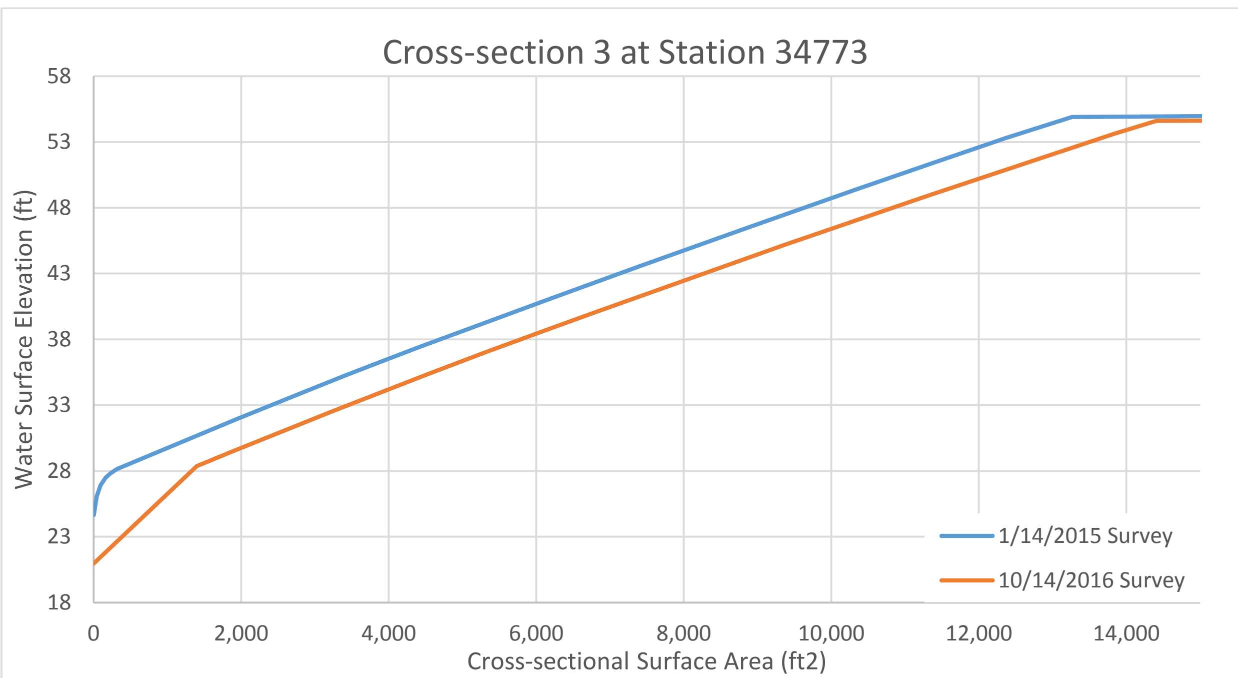

Figure 82. Comparison of cross-sectional area to water surface elevation for Romayor study site river station 34773.

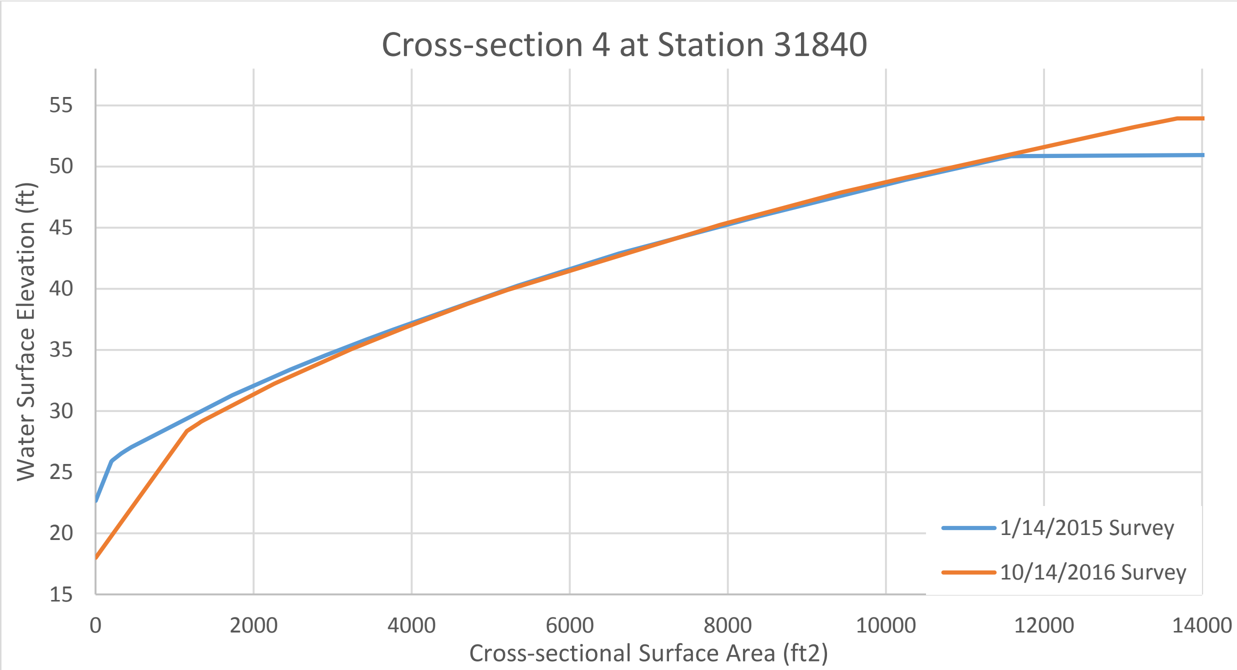

Figure 83. Comparison of cross-sectional area to water surface elevation for Romayor study site river station 31840.

9.4.2 080075 – HEC-RAS Modeling

The Romayor HEC-RAS model was rerun under steady state conditions using updated cross-section data (updated geometry file) and previously modeled flow rates (Table 15).

Table 17. 080075 - Steady flow rates modeled in HEC-RAS.

Flow Rates Modeled (cfs)	
230	11,400
575	18,700
875	25,000
1,000	35,000
1,150	45,000
4,000	54,500
6,380	68,640
8,000	79,000
10,000	127,000

Initial modeled water surface elevations in the study area for the flow rate of 1,150 cfs were an estimated 2 to 4 feet lower than the collected water surface elevation points, which resulted in needing to calibrate the model. The only feasible option to calibrate the model was to input two new cross-sections downstream of the study site to raise water surface elevations in the study site. Texas Natural Resources Information System (TNRIS) aerial imagery was used to identify appropriate locations for new cross-sections. The aerial imagery was taken approximately two weeks before the 2016 survey was conducted and according to the USGS Romayor stream gage over that time period the flows did not vary more than 100 cfs. These new cross-sections, which are shown in Figure 83, were locations with shallow water depths and wide widths. Depths and widths were estimated using aerial imagery, as it was found to be fairly representative of the conditions during the survey. All other cross-section data was interpolated from the upstream and downstream cross-sections using HEC-RAS tools. Channel bottom elevation for the new lower cross-section (station 5779) was referenced from the 2013 longitudinal profile collected on the Trinity River. Channel bottom elevation for the new upper cross-section (station 23451) was adjusted until the model's water surface profile was aligned with the collected water surface elevation points.

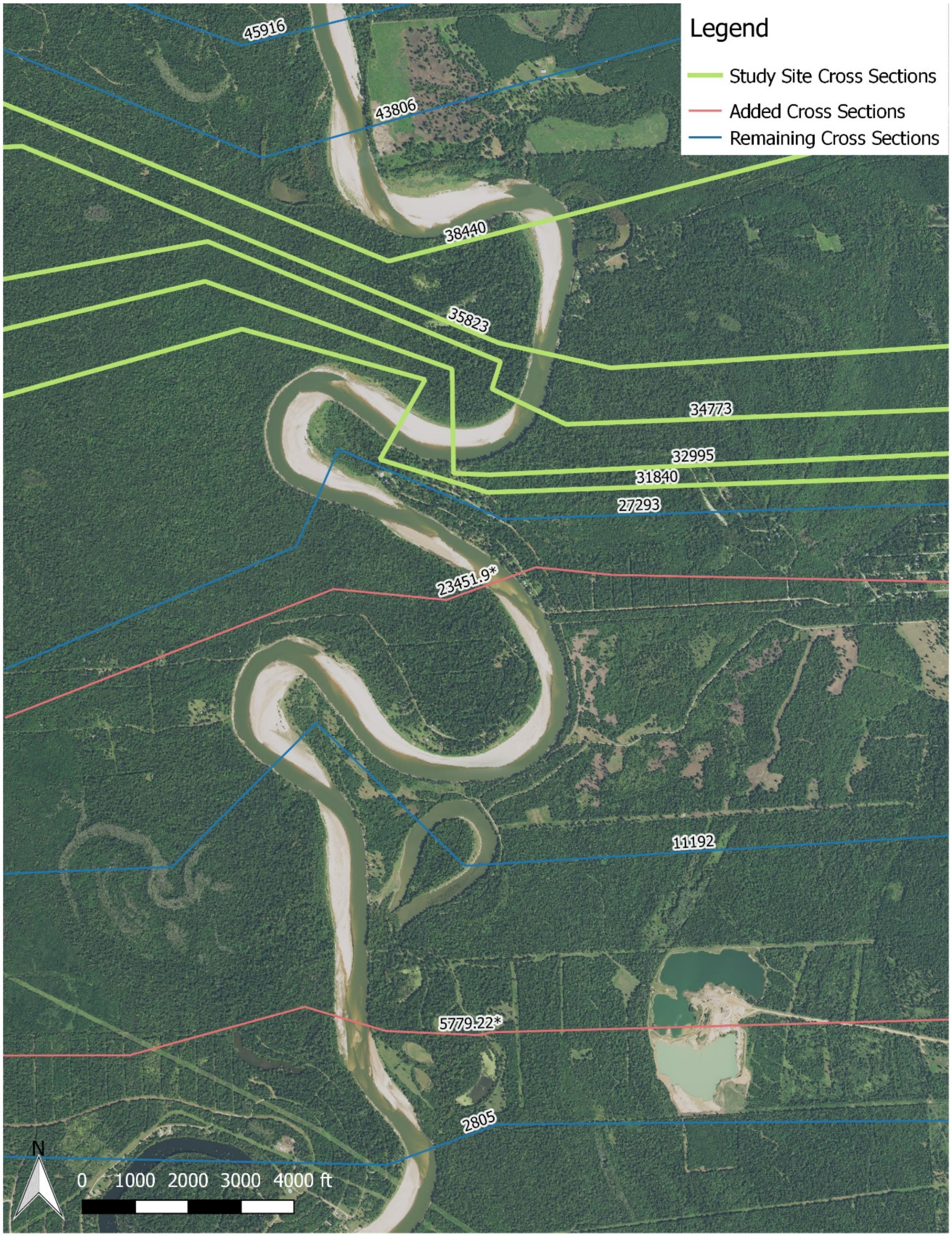

Figure 84. Map of existing and added cross-sections for the Romayor HEC-RAS model.

Figure 84 shows the water surface profile of a number of modeled flow rates throughout the entire modeled reach as well as observed water surface elevations. Figure 85 shows the water surface profile for the 1,150 cfs modeled flow rate, the flow rate the model was calibrated to.

Additionally, Figure 86 through Figure 90 show the same flow rates' water surface elevations for each of the modified cross-sections.

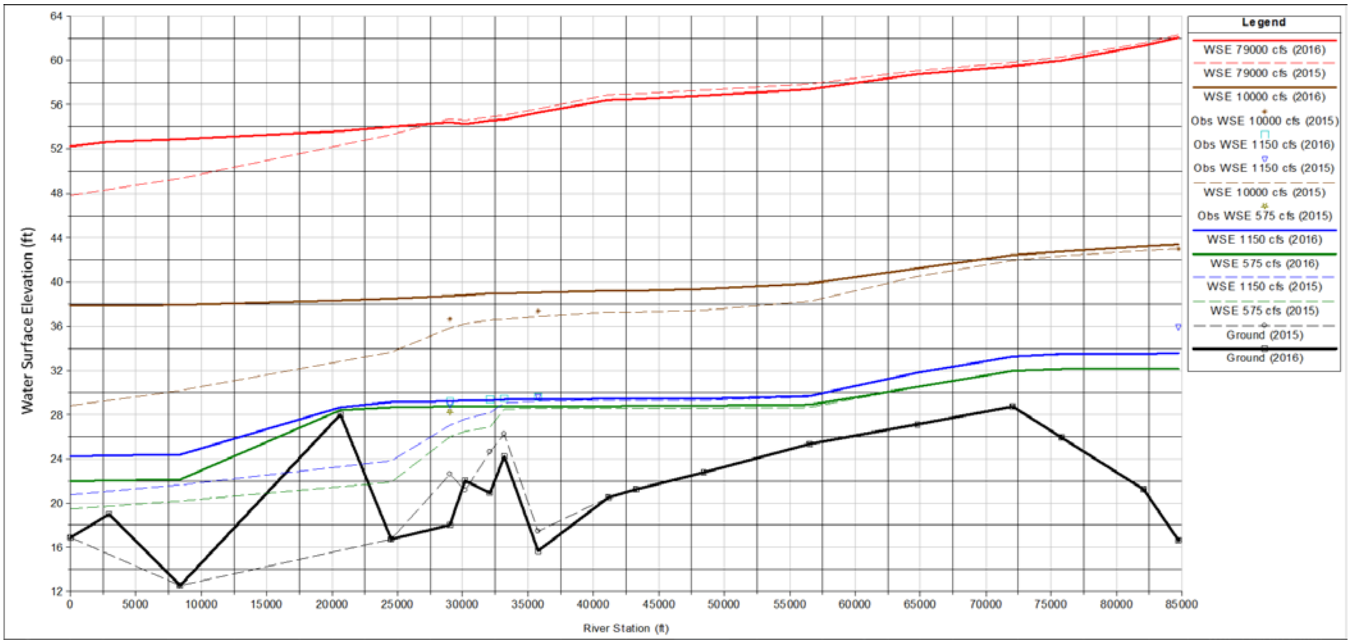

Figure 85. Water surface profile, ground surface, and observed water surface elevations of certain modeled flow rates for 2016 and 2015 HEC-RAS modeled results.

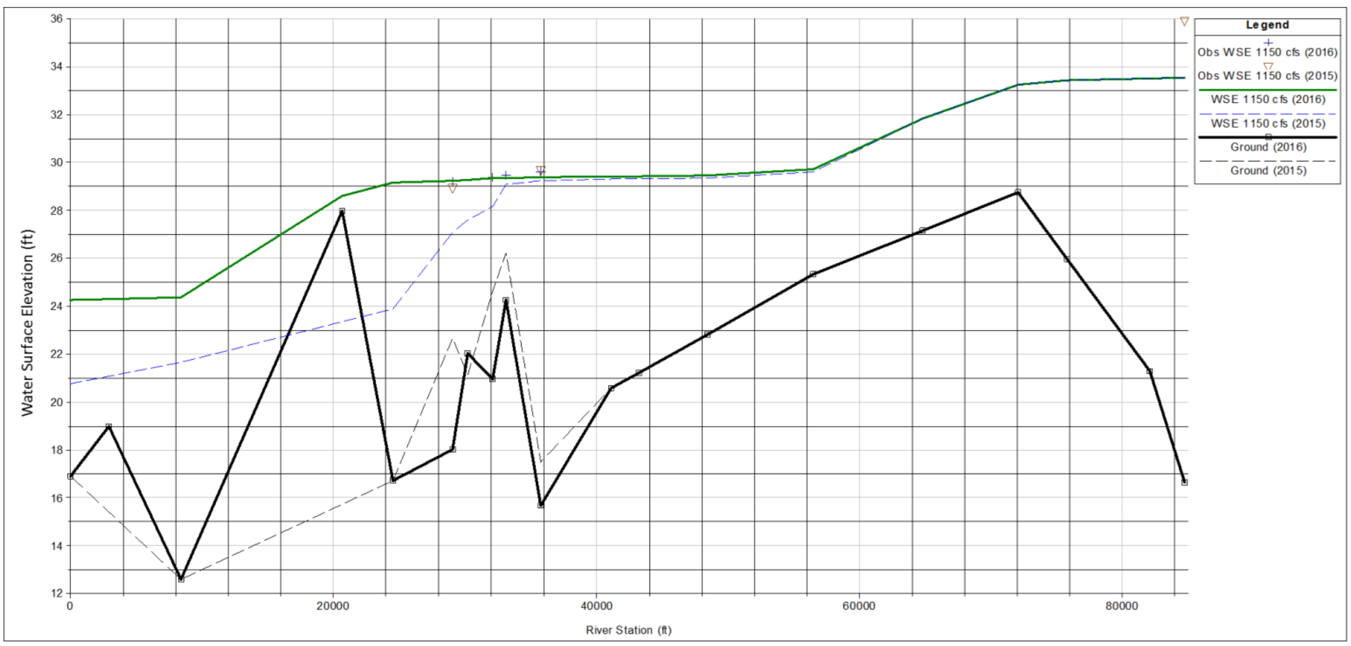

Figure 86. Water surface profile, ground surface and observed water surface elevations of 1,150 cfs modeled flow rate for 2016 and 2015 HEC-RAS modeled results.

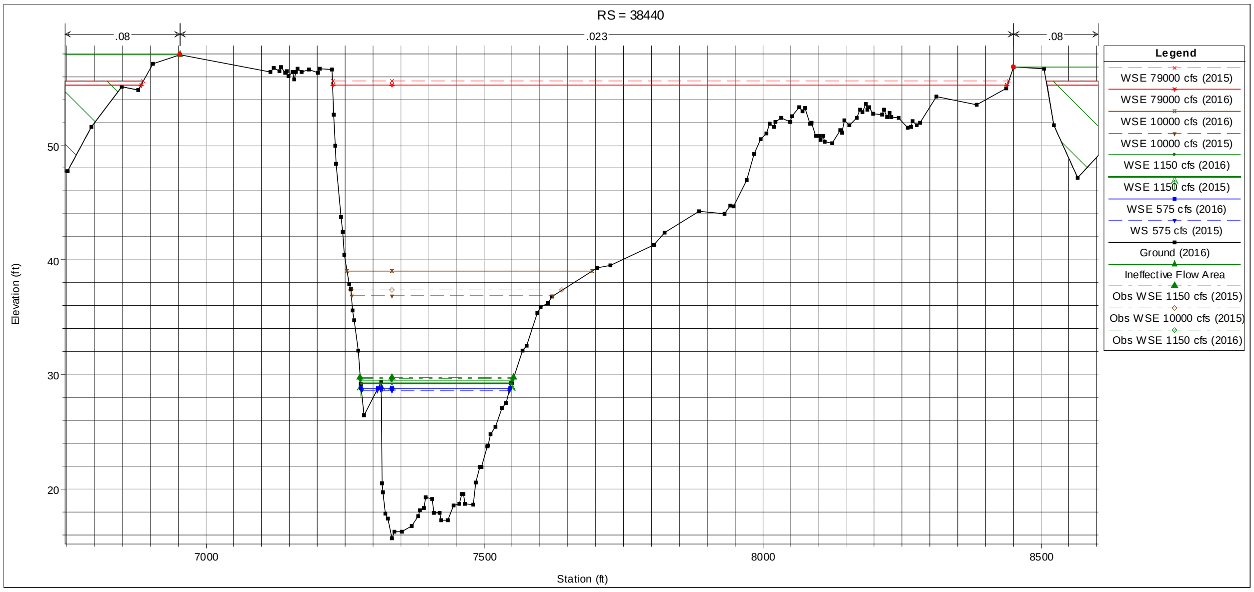

Figure 87. Cross-section 38440 water surface elevations for certain modeled flow rates for 2015 and 2016 survey data.

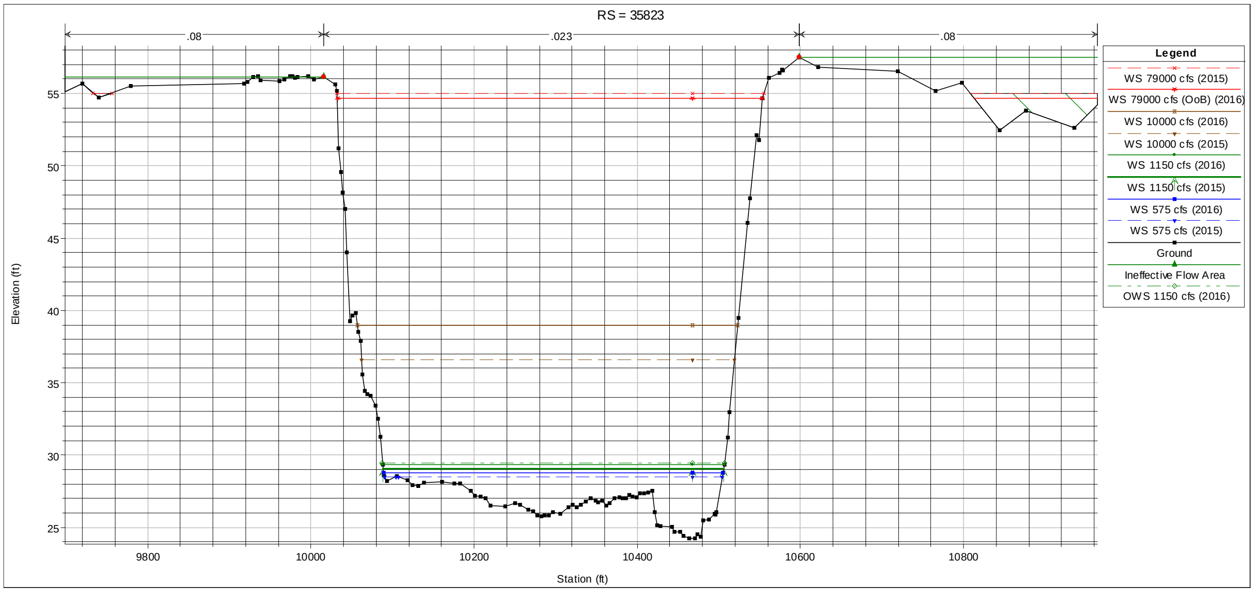

Figure 88. Cross-section 35823 water surface elevations for certain modeled flow rates for 2015 and 2016 survey data.

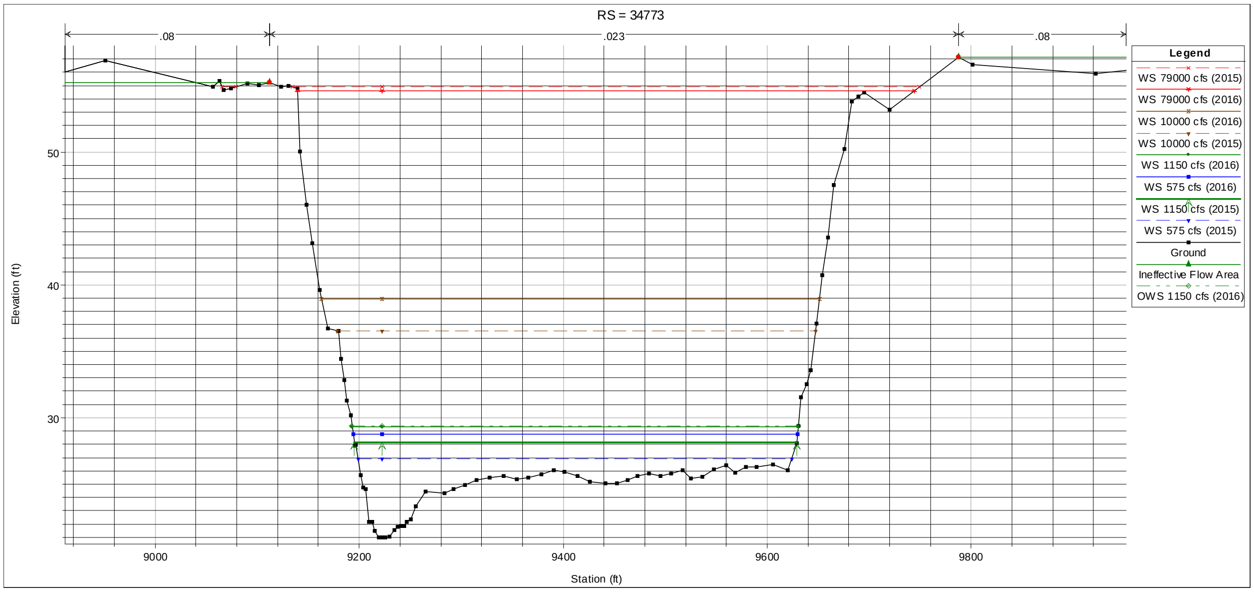

Figure 89. Cross-section 34773 water surface elevations for certain modeled flow rates for 2015 and 2016 survey data.

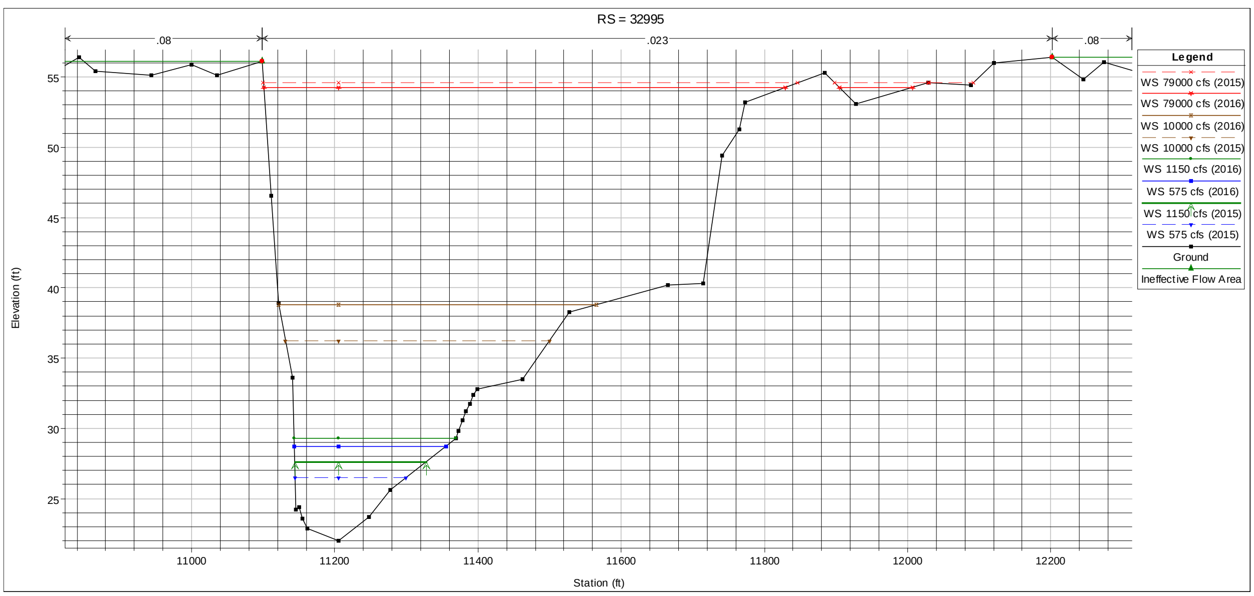

Figure 90. Cross-section 32995 water surface elevations for certain modeled flow rates for 2015 and 2016 survey data.

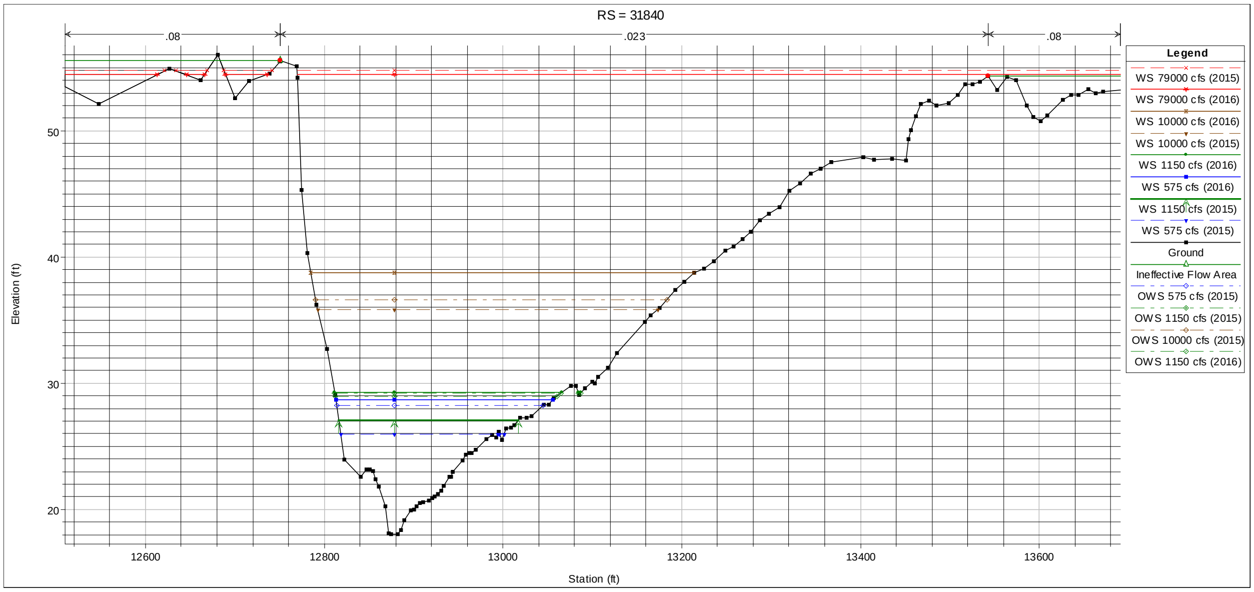

Figure 91. Cross-section 31840 water surface elevations for certain modeled flow rates for 2015 and 2016 survey data.

9.4.3 080075 – Cross-section 1 - Game camera photographs for selected flow rates

Water levels were documented using an autonomous game camera. The camera was set to photograph the study site at regular intervals at set times, allowing the time-stamped photographs to be cross-referenced and assigned to the USGS flow occurring at roughly the same time. Selected photographs are provided in Figure 91 through Figure 97.

Figure 92. 080075 Romayor - Game camera 873 cfs minimum recorded flow.

Figure 93. 080075 Romayor - Game camera 4,000 cfs SB3 pulse trigger Summer and Fall.

Figure 94. 080075 Romayor - Game camera 8,000 cfs SB3 pulse trigger Winter.

Figure 95. 080075 Romayor - Game camera 10,000 cfs SB3 pulse trigger Spring.

Figure 96. 080075 Romayor - Game camera 12,000 cfs off-channel backwaters begin to connect.

Figure 97. 080075 Romayor - Game camera 18,000 cfs riparian trees begin to become inundated.

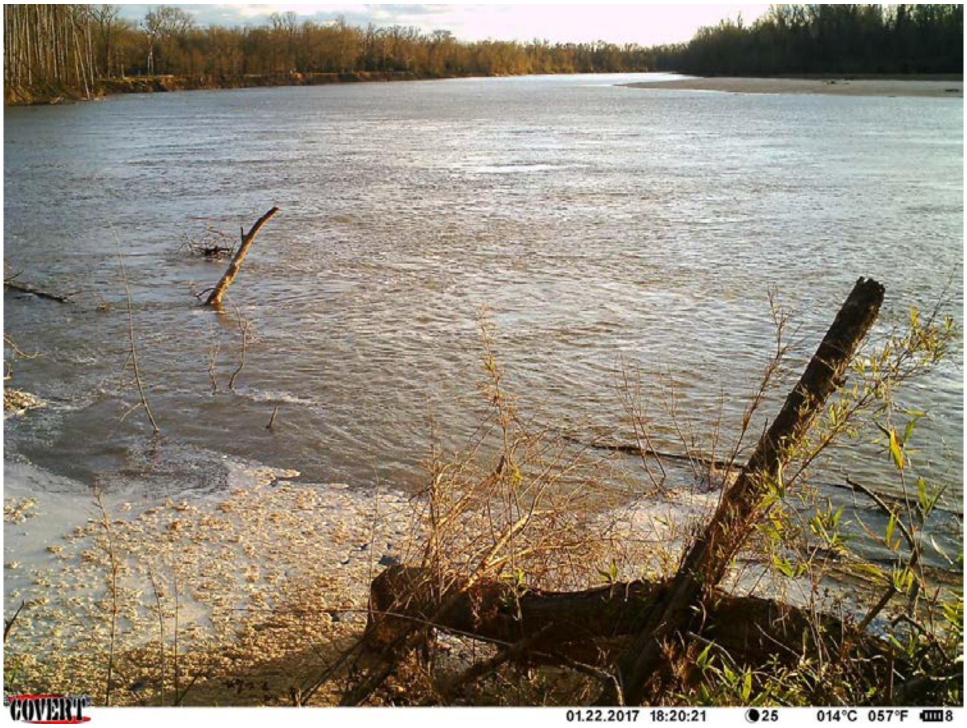

Figure 98. 080075 Romayor - Game camera 22,500 cfs maximum recorded flow.

9.5 All sites - Recent occurrence of selected pulse flows

Each site for this report is represented by the hydrologic record of a corresponding USGS gage. Table 16 below characterizes the previous ten-year period of record, 2007-09-01 to 2017-08-31, for the overbank, backwater, and riparian inundation flow values determined from the HEC-RAS models for each site. It is important to note that these results are not recommended flow pulse values or inundation periods, rather they are intended to characterize each site to better understand how often these flows have occurred in the preceding ten-year period.

Table 18. All sites – Recent occurrence of selected pulse flows.

USGS Gage Record Review, Average Daily Flow 10 Year Period of Record (2007-09-01 to 2017-08-31)					
Flow (cfs)*	**Inundation Type**	**# of Days Above**	**# of Events >= 3 days**	**# of Events >= 5 days**	**# of Events >= 11 days**
TR at Beltline					
30,000	Overbank	13	2	1	0
5,000	Backwater	679	32	15	12
na**	Riparian	-	-	-	-
TR Below Dallas					
na**	Overbank	-	-	-	-
7,000	Backwater	489	32	16	10
14,000	Riparian	108	13	5	3
TR near Oakwood					
30,000	Overbank	186	13	13	9
13,000	Backwater	544	31	21	10
10,000	Riparian	656	33	23	11
Trinity River at Romayor					
70,000	Overbank	14	3	3	0
12,000	Backwater	616	42	35	18
18,000	Riparian	616	33	26	16

* These flow values were determined based on empirical data collected in the field and HEC-RAS model results. These are NOT recommended flows, but are included to help characterize the flow record.

** More data is needed to determine flow value

10 Appendix 4 – Sediment sample grain size analysis

Sediment samples were collected at all cross-sections with consistent stationing per cross-section. The stations were as follows: T1 left bank (out of water), T2 left channel (in channel; submerged), T3 middle channel (in channel; submerged), T4 right channel (in channel; submerged) and T5 right bank (out of water). Bank sediment samples were collected by shovel and stream bed samples were collected by Ekman dredge sampler dropped from the deck of a boat. Samples were prepped and contained on top of clean plastic cases. Care was taken to ensure the integrity of the samples and that fine sediment was not lost. The shovel and dredge used for sampling, as well as the sample preparation area was rinsed prior to each new sample. Samples were stored in new plastic gallon size zipper bags and labeled by location. Grain size analysis was performed in the laboratory for each cross-section with combined station samples. Bank samples are comprised of T1 and T5 combined, and channel samples are comprised of T2, T3, T4 combined. When necessary, stations were subsampled to the proper volume to fit the drying and sifting instruments.

10.1 080486 - Grand Prairie

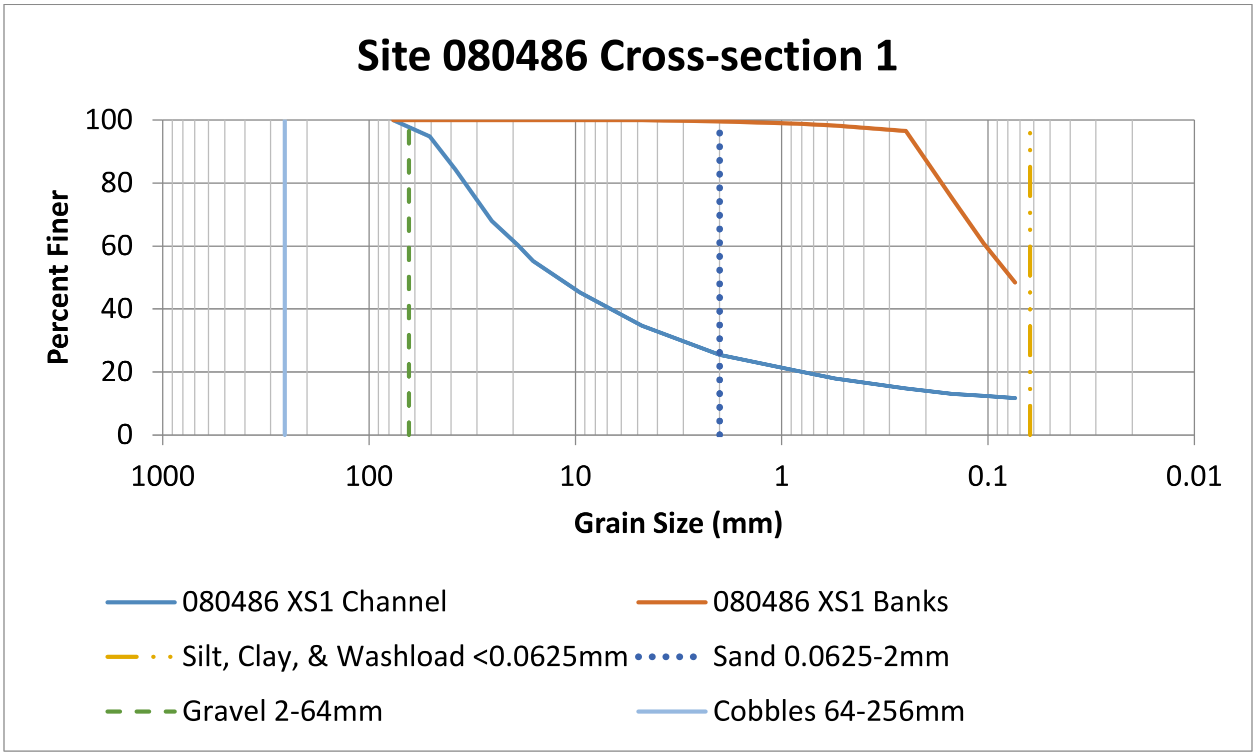

Figure 99. Sediment gradations for site 080486 cross-section 1 composited by channel and banks.

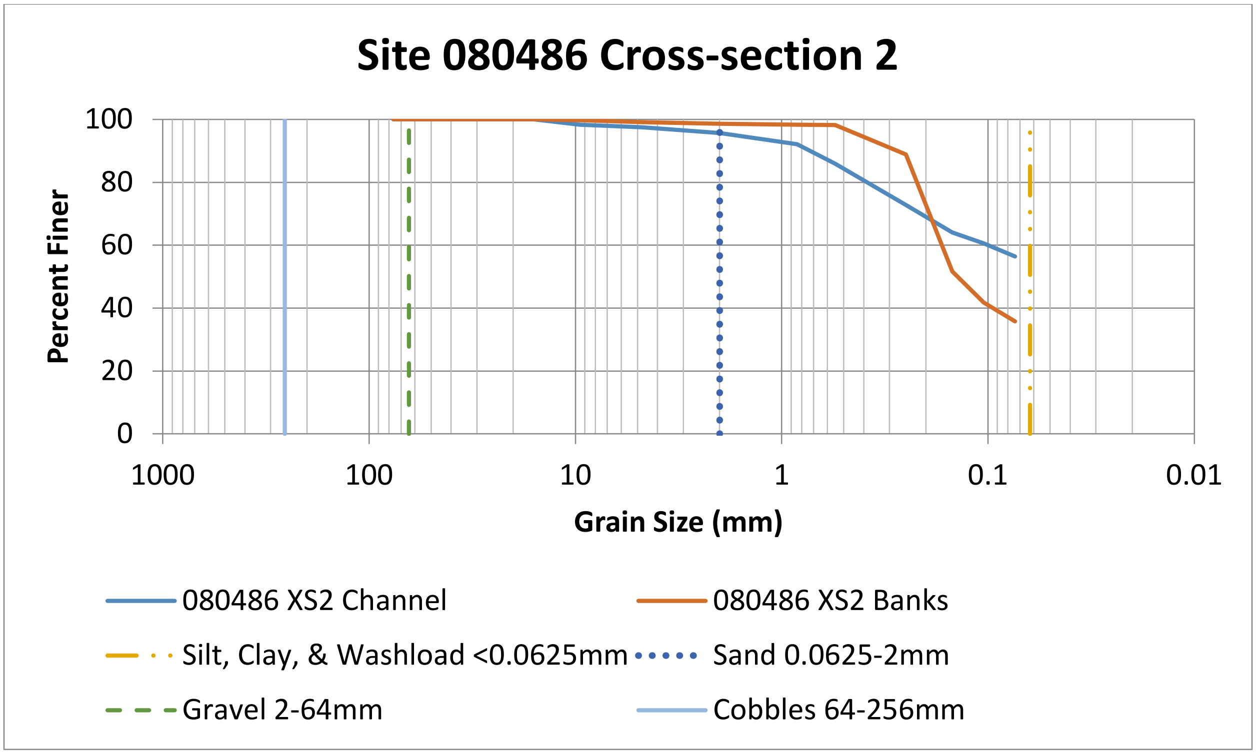

Figure 100. Sediment gradations for site 080486 cross-section 2 composited by channel and banks.

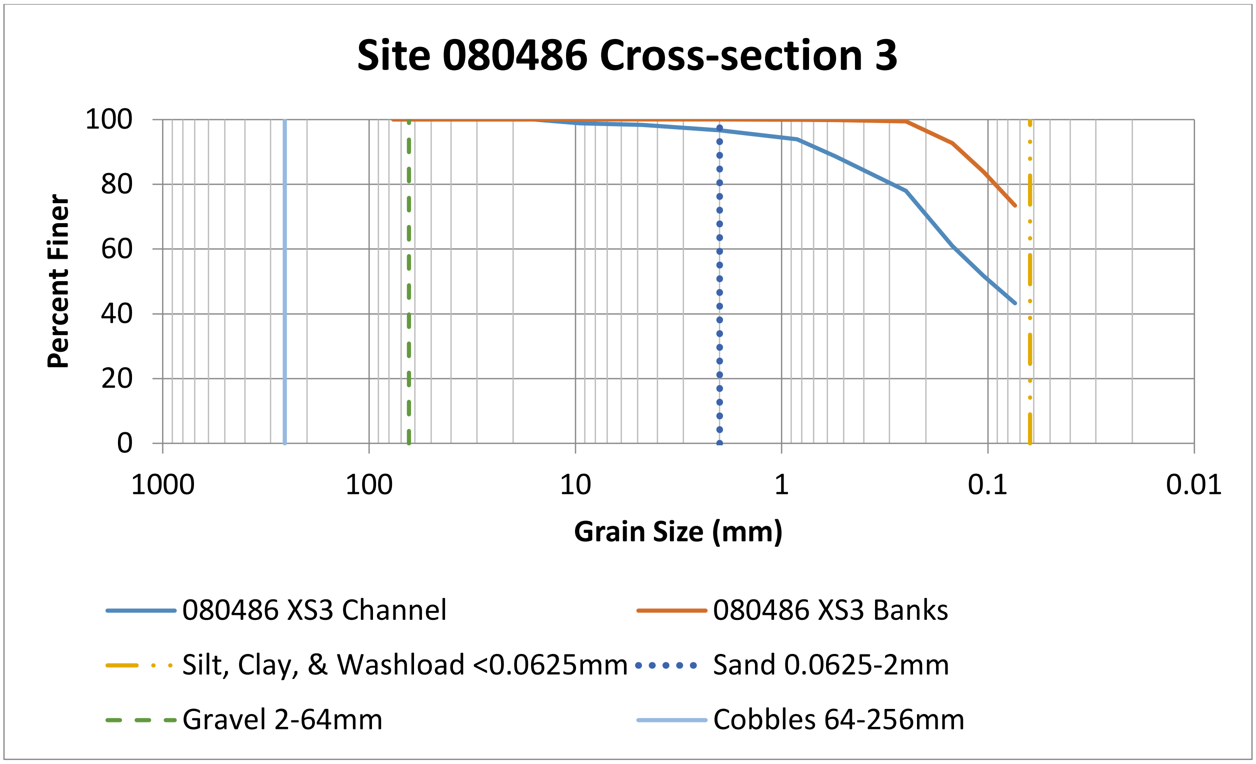

Figure 101. Sediment gradations for site 080486 cross-section 3 composited by channel and banks.

10.2 080444 – Lock d/s of Dallas

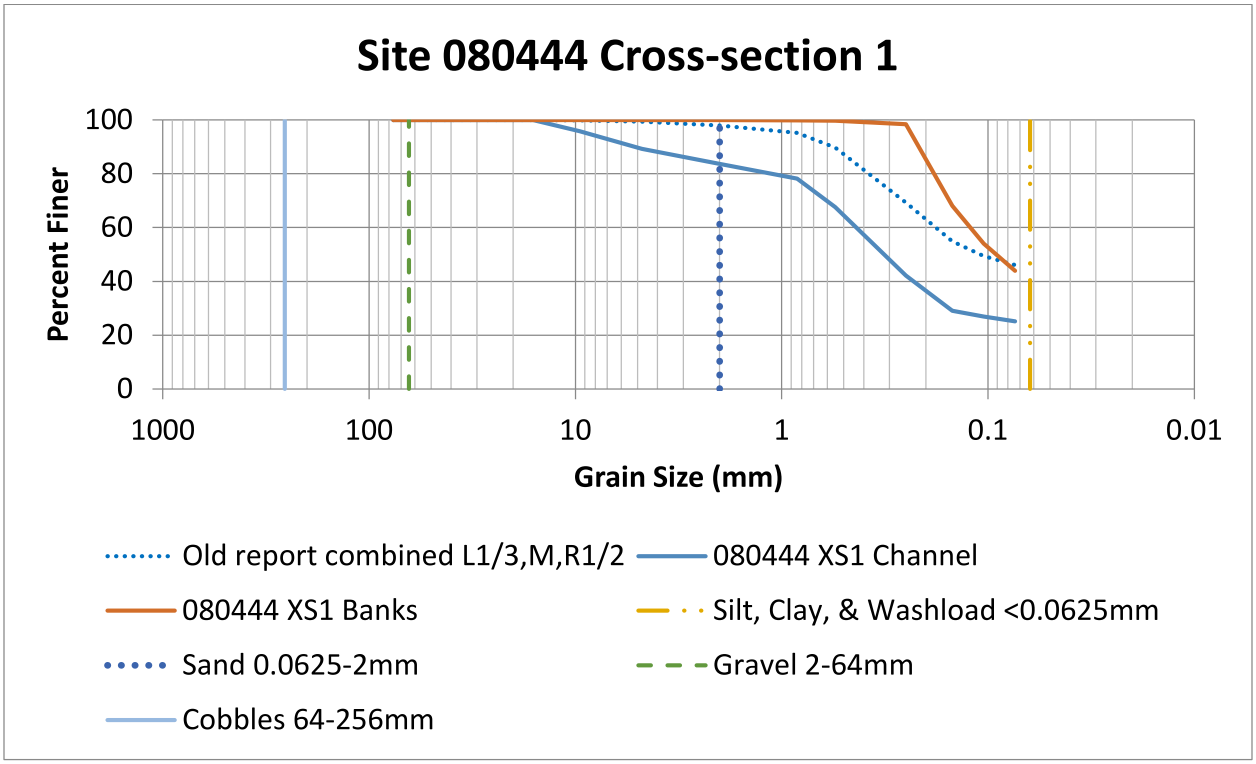

Figure 102. Sediment gradations for site 080444 cross-section 1 composited by channel and banks.

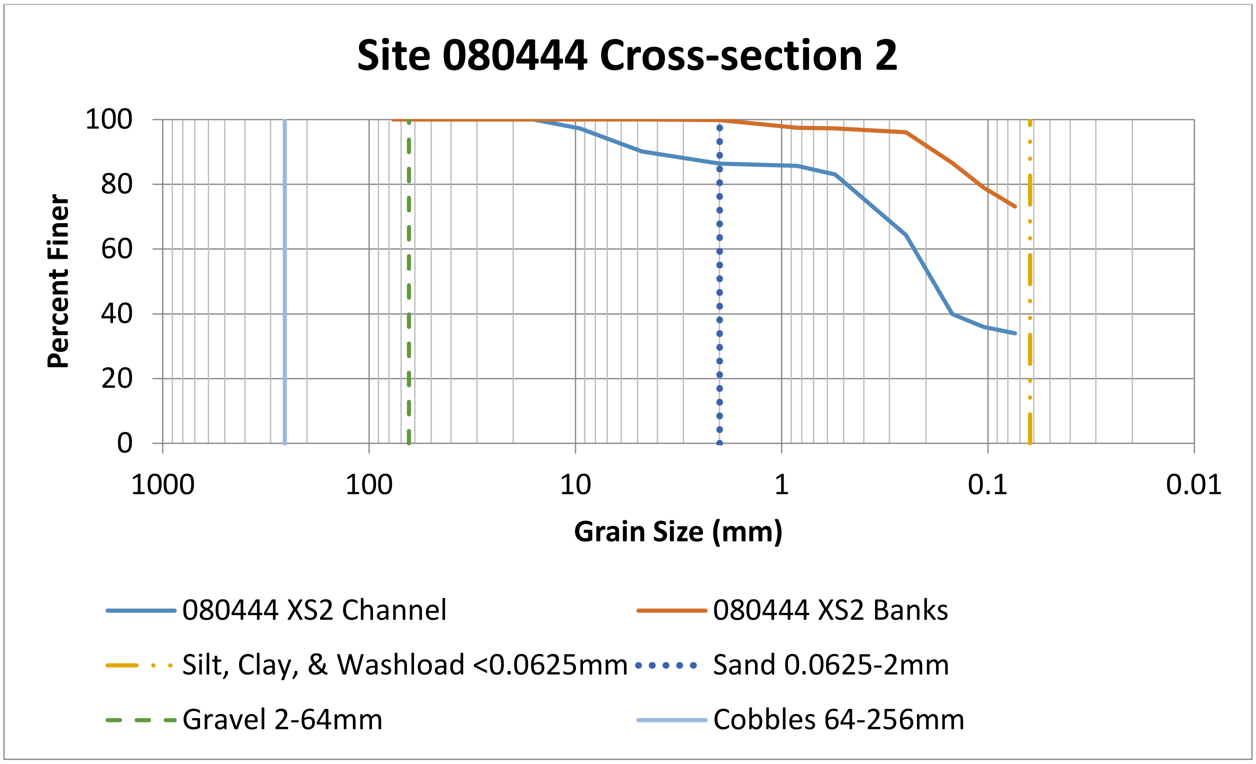

Figure 103. Sediment gradations for site 080444 cross-section 2 composited by channel and banks.

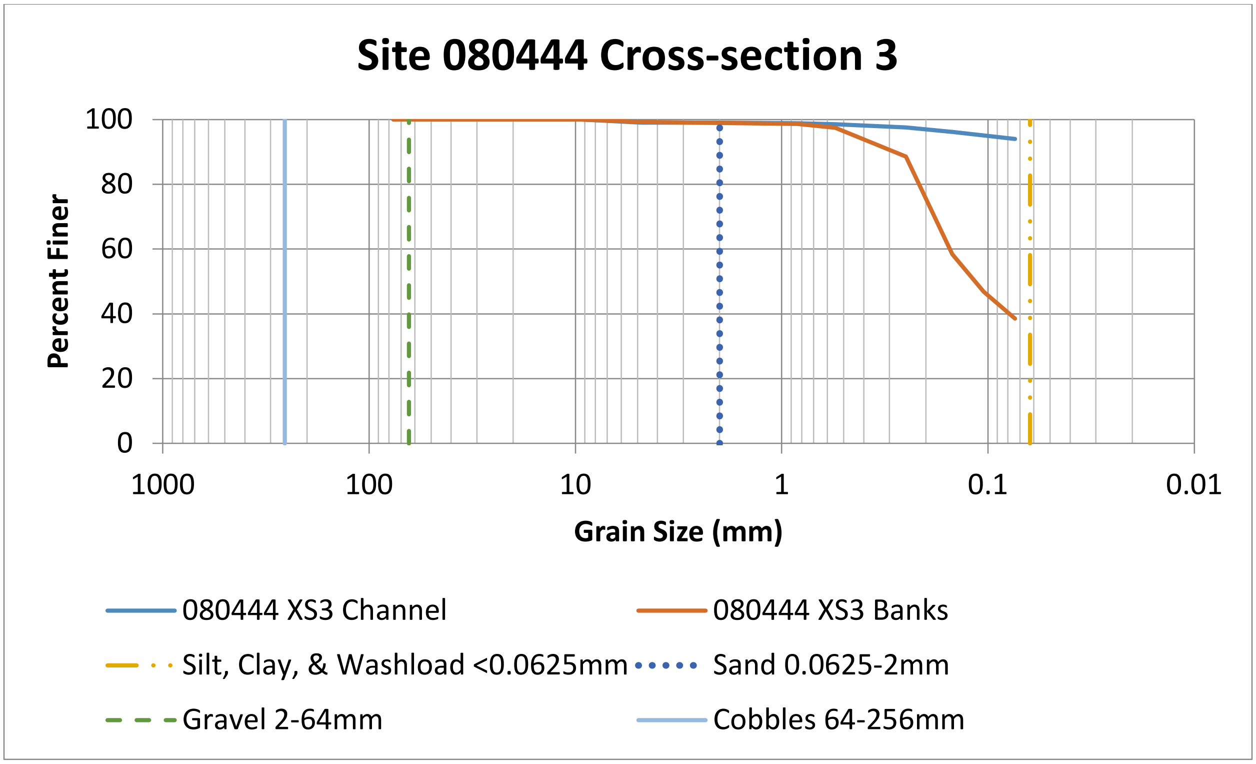

Figure 104. Sediment gradations for site 080444 cross-section 3 composited by channel and banks.

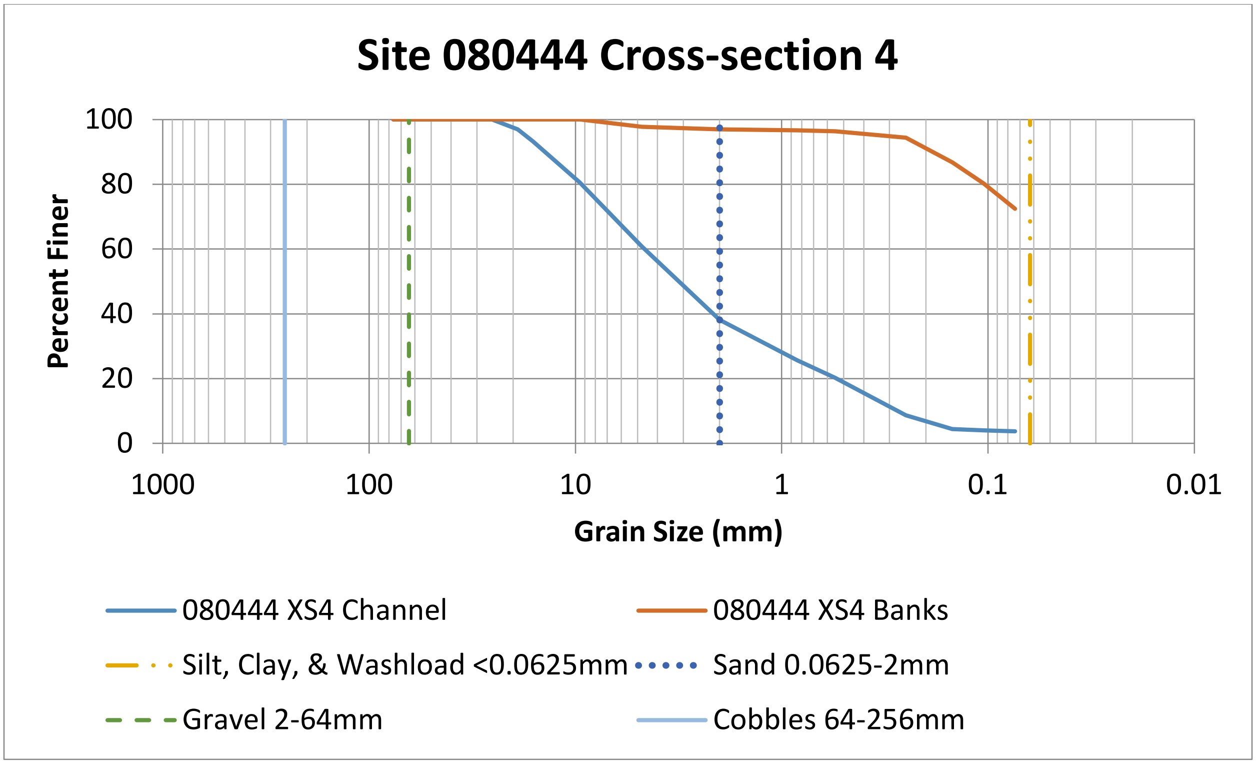

Figure 105. Sediment gradations for site 080444 cross-section 4 composited by channel and banks.

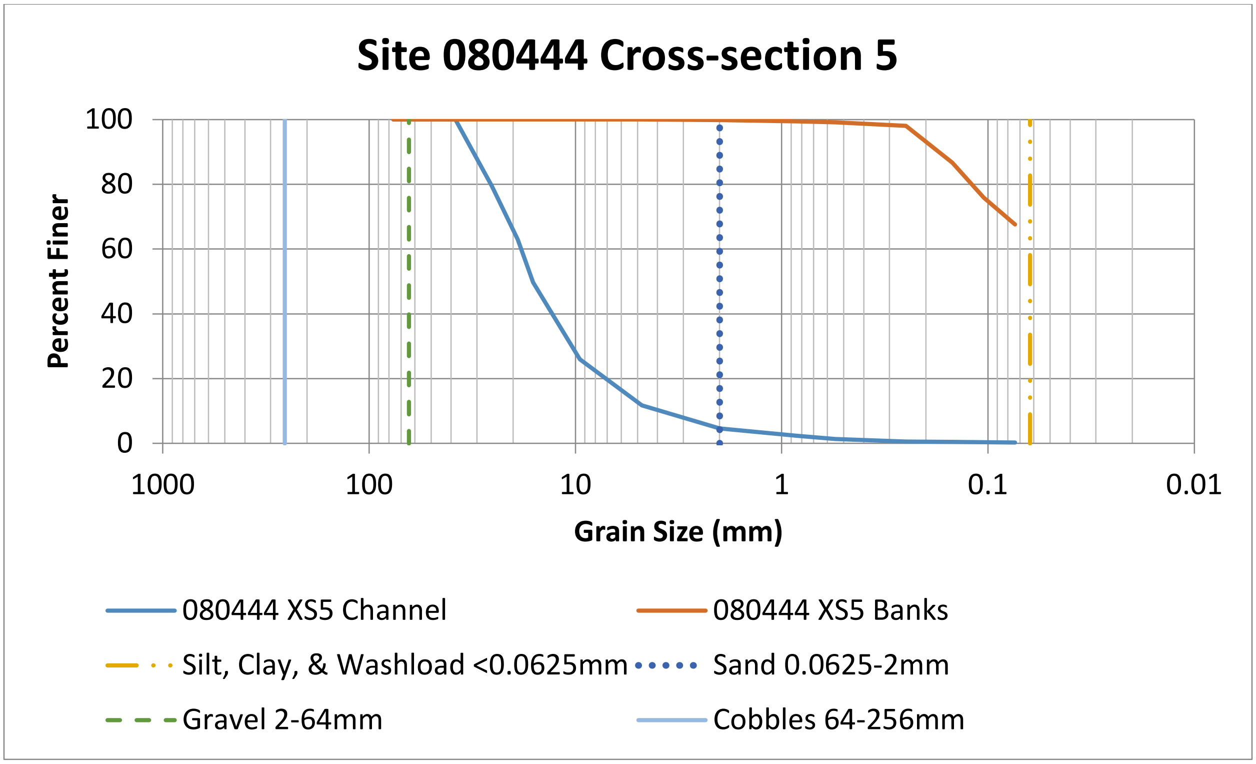

Figure 106. Sediment gradations for site 080444 cross-section 5 composited by channel and banks.

10.3 080295 – Oakwood

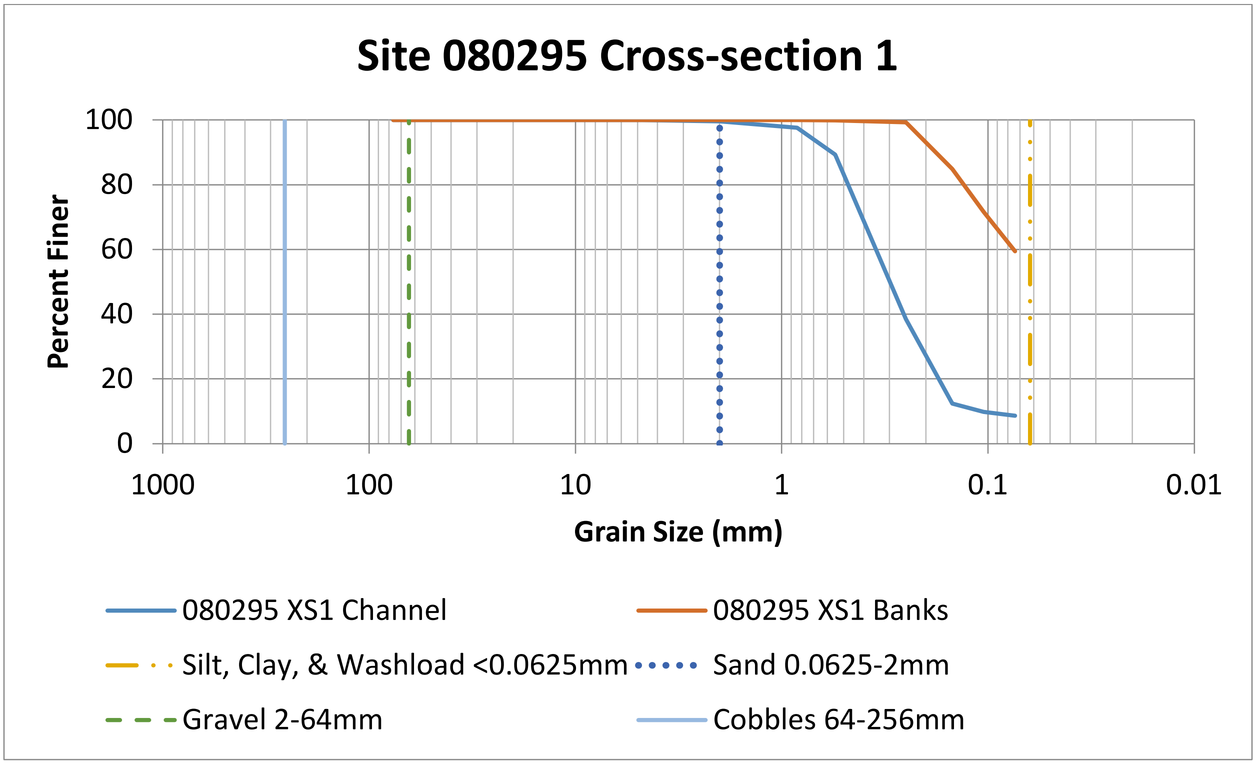

Figure 107. Sediment gradations for site 080295 cross-section 1 composited by channel and banks.

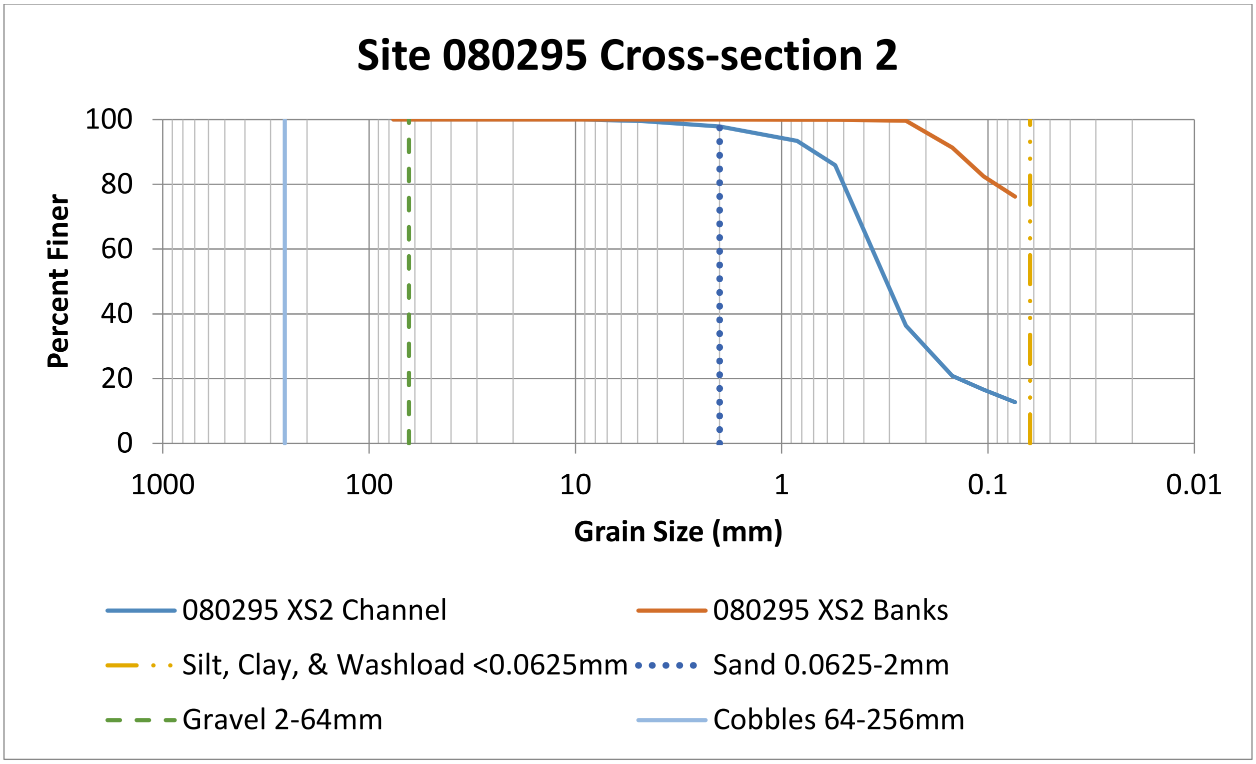

Figure 108. Sediment gradations for site 080295 cross-section 2 composited by channel and banks.

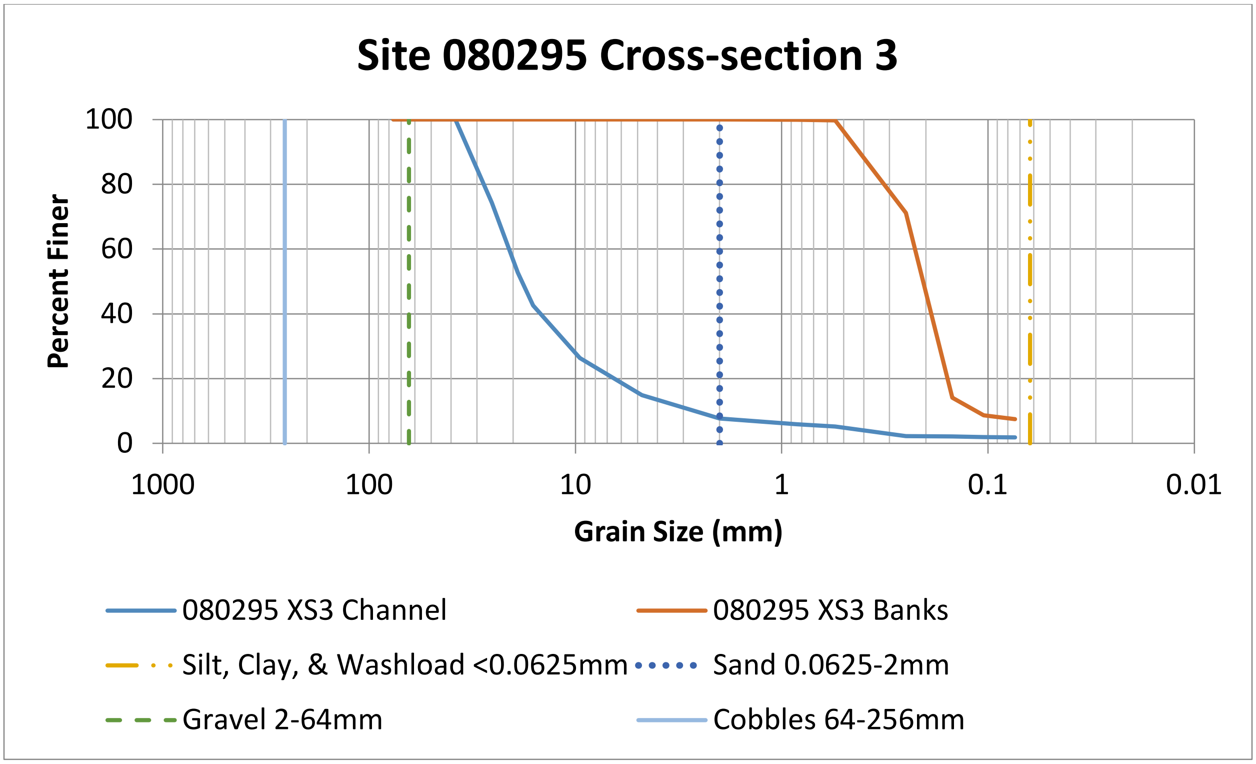

Figure 109. Sediment gradations for site 080295 cross-section 3 composited by channel and banks.

10.4 080075 - Romayor

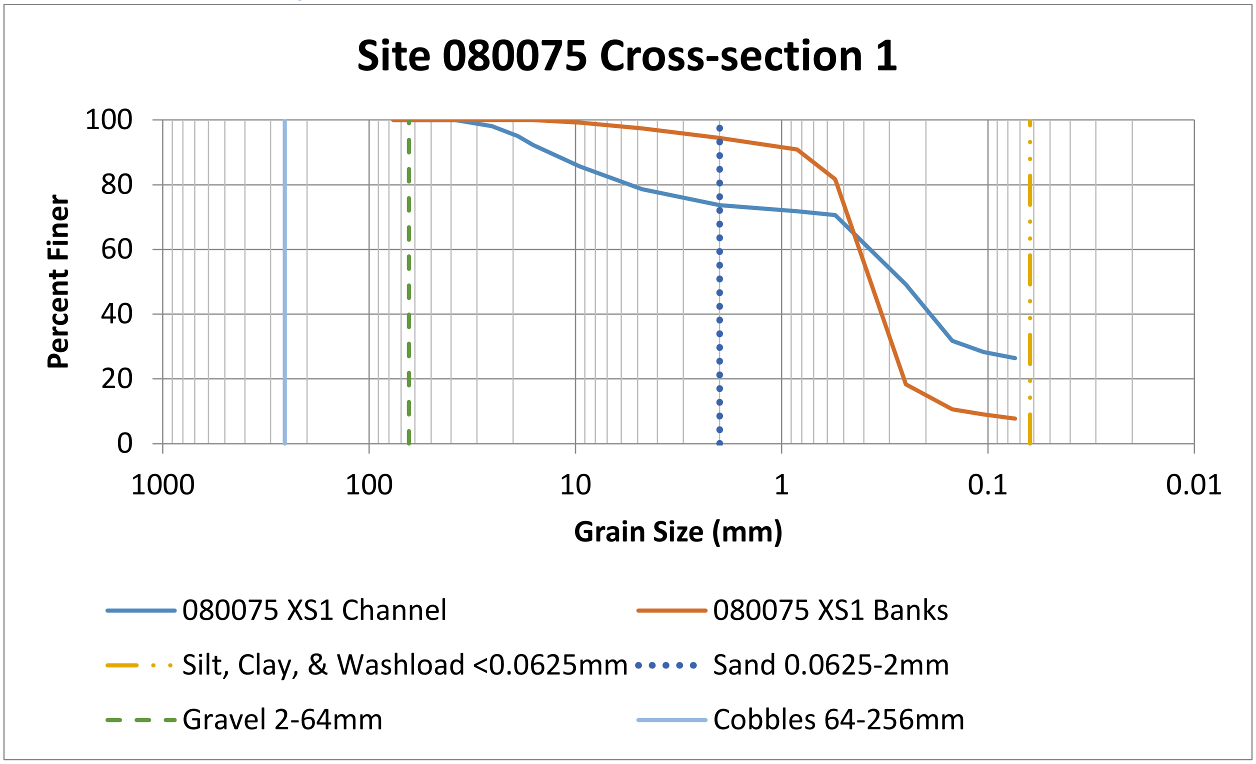

Figure 110. Sediment gradations for site 080075 cross-section 1 composited by channel and banks.

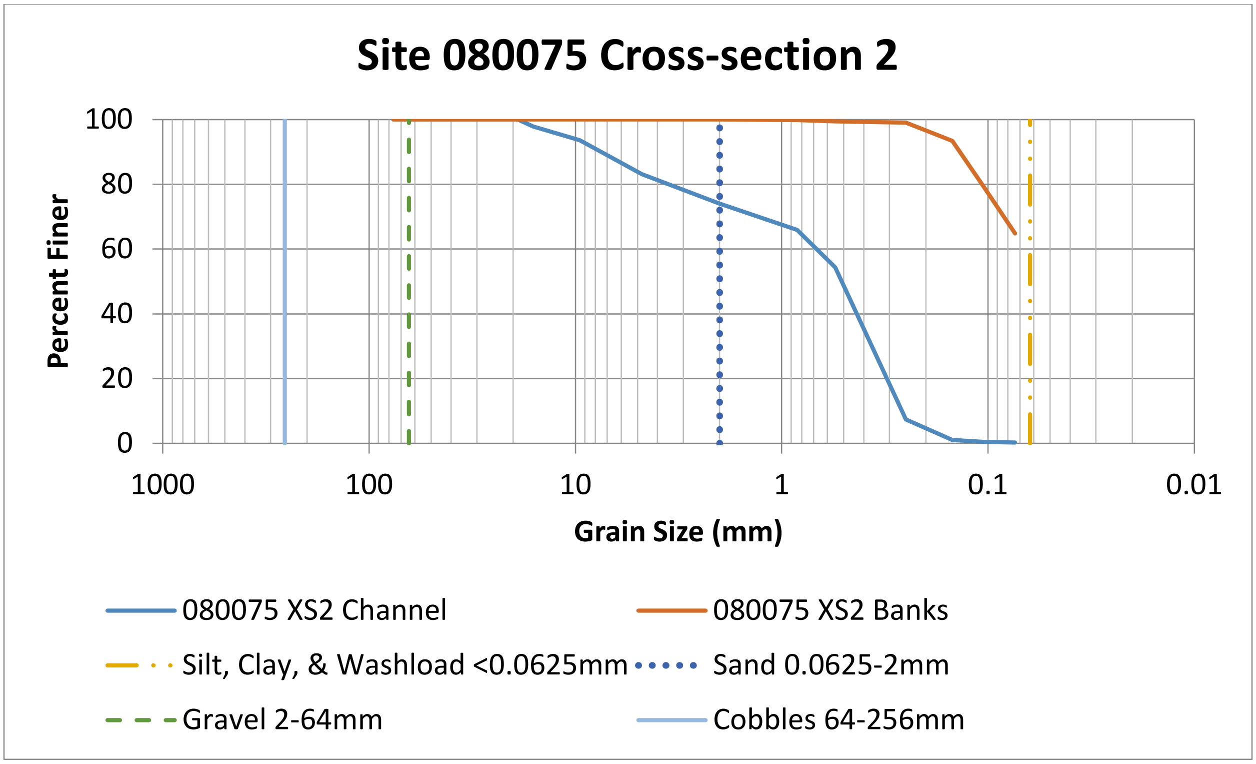

Figure 111. Sediment gradations for site 080075 cross-section 2 composited by channel and banks.

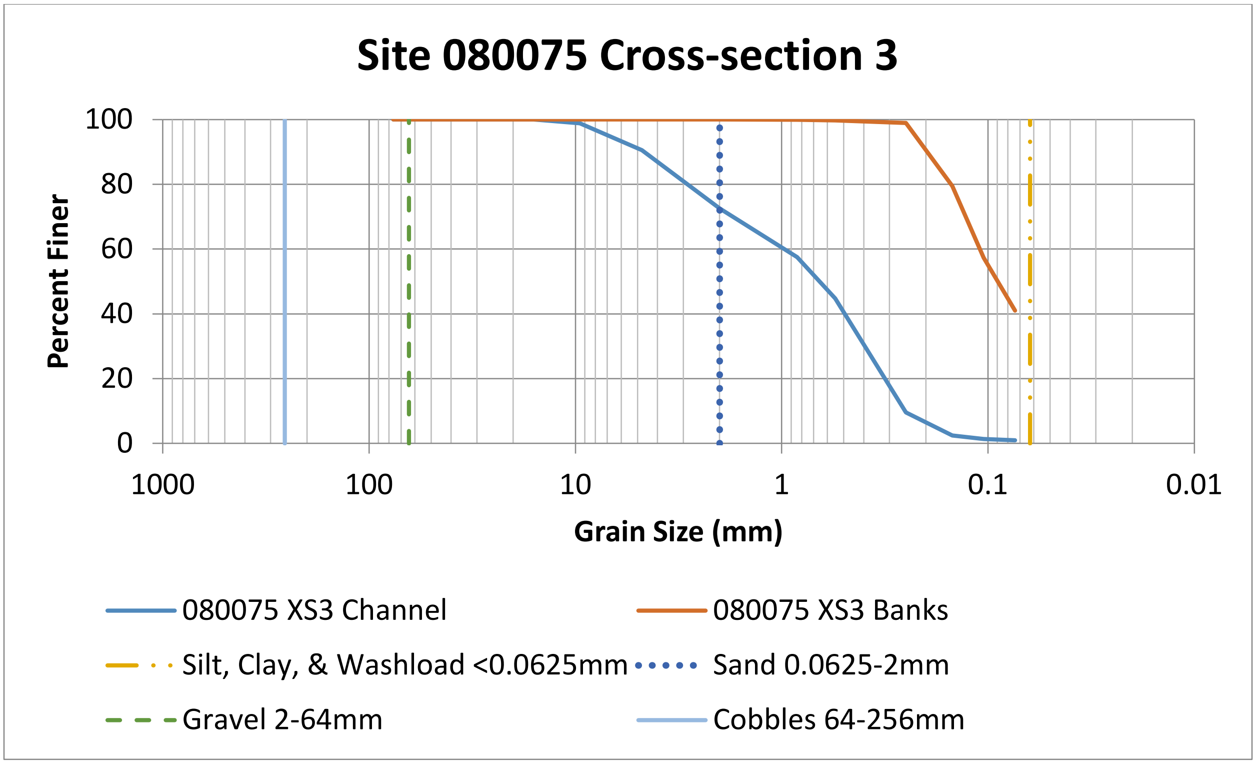

Figure 112. Sediment gradations for site 080075 cross-section 3 composited by channel and banks.

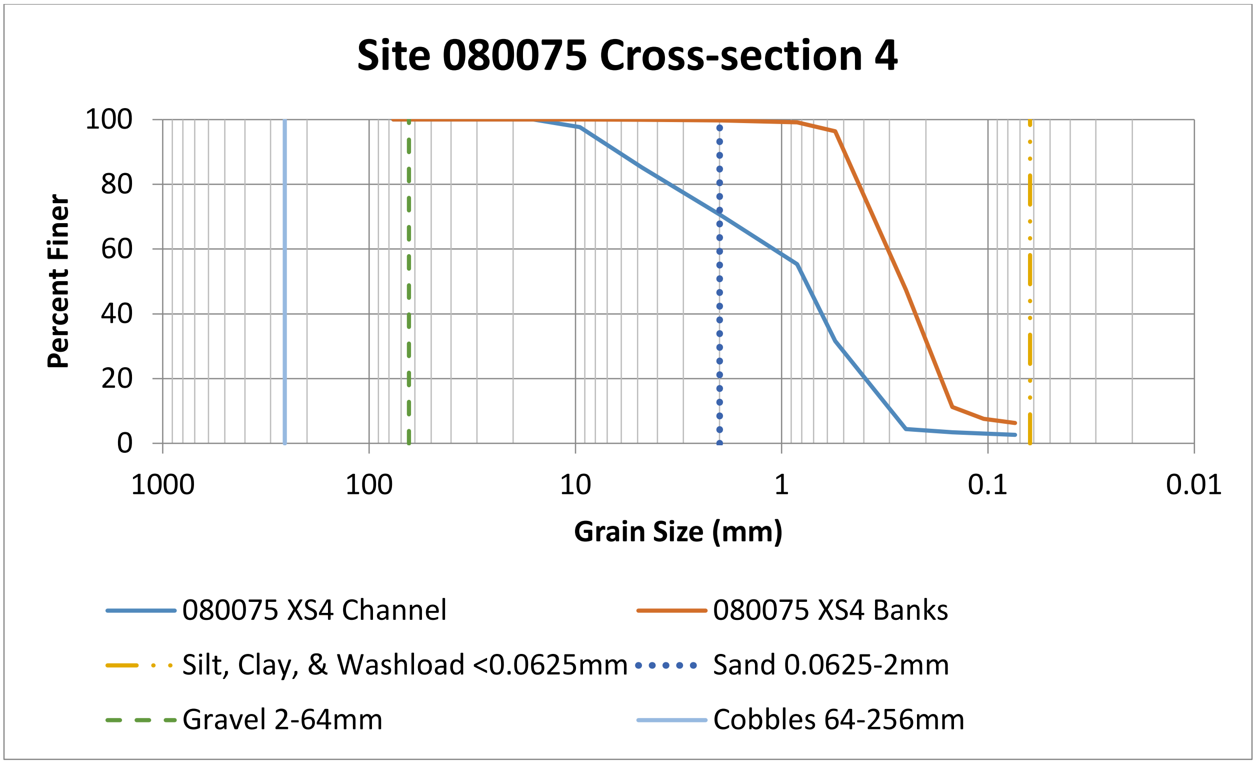

Figure 113. Sediment gradations for site 080075 cross-section 4 composited by channel and banks.

11 Appendix 5 – Riparian assessment

11.1 080295 - Riparian

Riparian woody vegetation was surveyed in September 2016 at site 080295 at Cross-sections 1 and 2 and summarized below. Riparian data included in the following sections is presented in metric units which is customary for this type of scientific information. Additionally, the station 0.0 of each transect is used to identify the water's edge at the time of the riparian survey.

11.1.1 Cross-section 1 – Upstream

Cross-section 1 is located along an almost straight stretch of river. Twelve woody species were identified on Cross-section 1 (Table 7). The most common woody species identified were Black Willow (*Salix nigra*), Swamp Privet (*Forestiera acuminata*) and Hackberry (*Celtis laevigata*). The location of each individual is shown in Figure 55, Figure 56 and Figure 57

Table 19. 080295 - Cross-section 1 woody vegetation counts

	Cross-section 1	
Common Name	**Scientific Name**	**Total Individuals**
Trees		
Bur Oak	*Quercus macrocarpa*	1
Cedar Elm	*Ulmus crassifolia*	4
Green Ash	*Fraxinus pennsylvanica*	6
Hackberry	*Celtis laevigata*	32
Swamp Privet	*Forestiera acuminata*	12
Winged Sumac	*Rhus copallinum*	4
Saplings		
Black Willow	*Salix nigra*	272
Bur Oak	*Quercus macrocarpa*	7
Cedar Elm	*Ulmus crassifolia*	64
Chinese Tallow	*Triadica sebifera*	1
Green Ash	*Fraxinus pennsylvanica*	1
Hackberry	*Celtis laevigata*	114
Honey Locust	*Gleditsia triacanthos*	2
Overcup Oak	*Quercus lyrata*	65
Swamp Privet	*Forestiera acuminata*	216
Winged Sumac	*Rhus copallinum*	46
Yaupon	*Ilex vomitoria*	62
Seedlings		
Black Willow	*Salix nigra*	7
Cedar	*Juniperus sp.*	1
Cedar Elm	*Ulmus crassifolia*	5
Hackberry	*Celtis laevigata*	154
Overcup Oak	*Quercus lyrata*	35

Swamp Privet	*Forestiera acuminata*	17
Yaupon	*Ilex vomitoria*	6

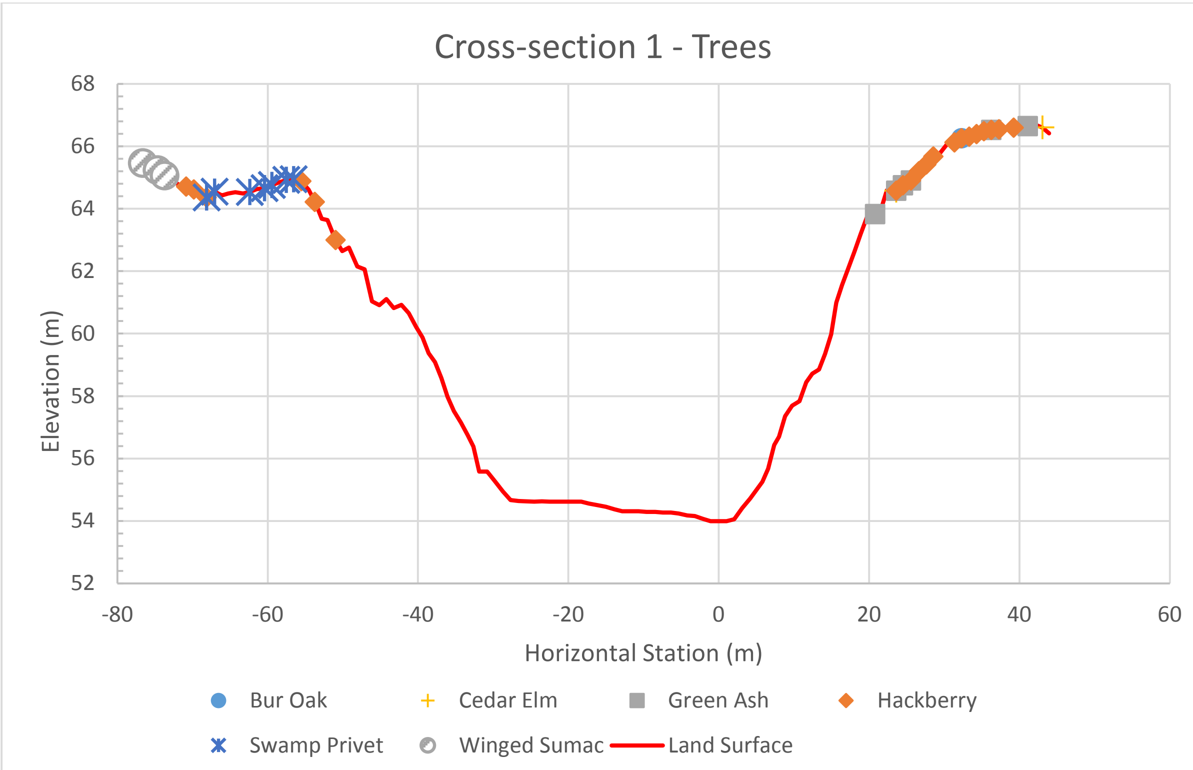

Figure 114. 080295 - Cross-section 1 - Trees - Location along cross-section

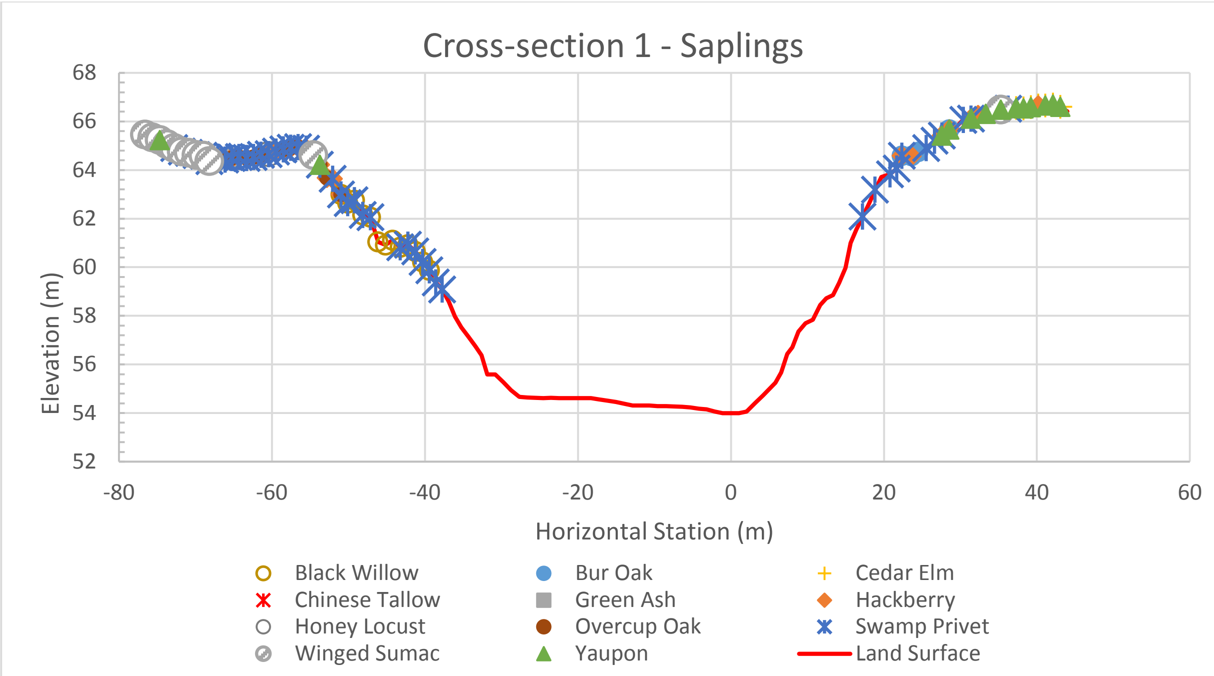

Figure 115. 080295 - Cross-section 1 - Saplings - Location along cross-section

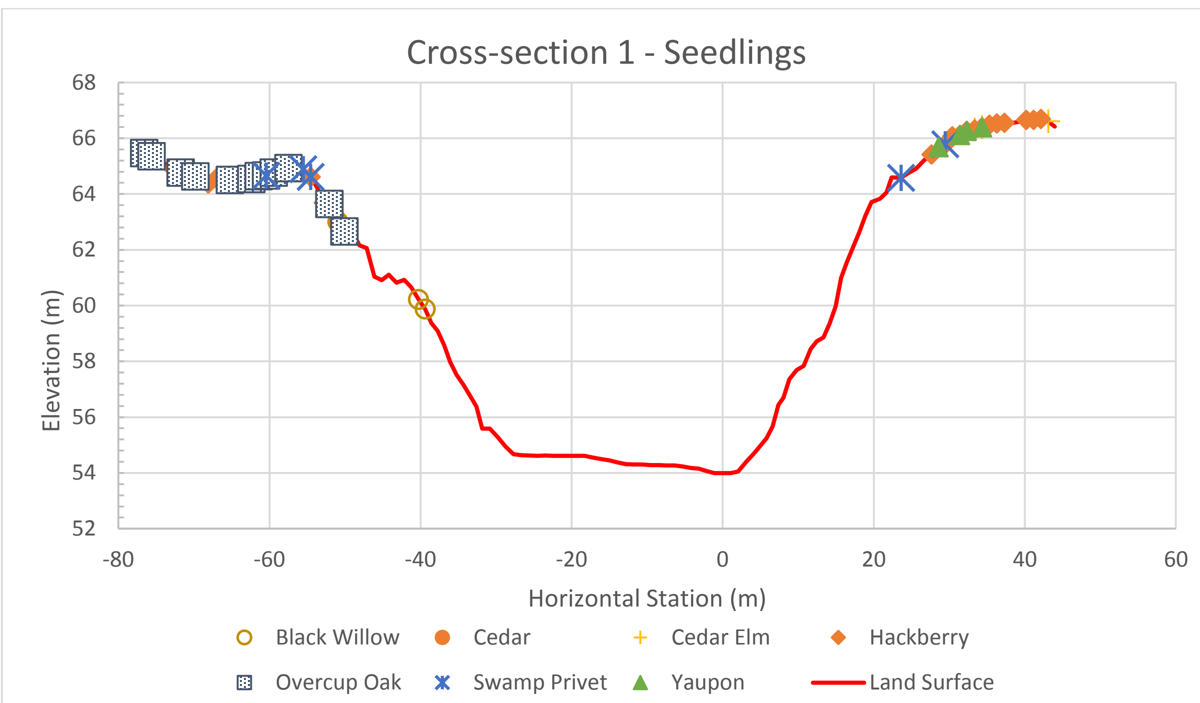

Figure 116. 080295 - Cross-section 1 - Seedlings - Location along cross-section

11.1.2 Cross-section 2 – Middle

Cross-section 2 is located just before a sharp right turn of the river. Sixteen woody species were identified on Cross-section 2 (Table 8). The most common woody species identified were Black Willow (*Salix nigra*), Swamp Privet (*Forestiera acuminata*), and Hackberry (*Celtis laevigata*). The location of each individual is shown in Figure 58, Figure 59 and Figure 60.

Table 20. 080295 - Cross-section 2 woody vegetation counts

Cross-section 2		
Common Name	**Scientific Name**	**Total Individuals**
Trees		
Boxelder	*Acer negundo*	1
Bur Oak	*Quercus macrocarpa*	1
Green Ash	*Fraxinus pennsylvanica*	16
Hackberry	*Celtis laevigata*	17
Soapberry	*Sapindus saponaria*	1
Swamp Privet	*Forestiera acuminata*	3
Yaupon	*Ilex vomitoria*	2
Saplings		
Boxelder	*Acer negundo*	1
Black Willow	*Salix nigra*	740
Bur Oak	*Quercus macrocarpa*	9
Buttonbush	*Cephalanthus occidentalis*	2
Cedar Elm	*Ulmus crassifolia*	217
Flowering Dogwood	*Cornus florida*	2
Green Ash	*Fraxinus pennsylvanica*	11
Gum Bumelia	*Sideroxylon lanuginosum*	7
Hackberry	*Celtis laevigata*	87
Honey Locust	*Gleditsia triacanthos*	7
Osage Orange	*Maclura pomifera*	1
Pecan	*Carya illinoinensis*	1
Soapberry	*Sapindus saponaria*	1
Swamp Privet	*Forestiera acuminata*	148
Yaupon	*Ilex vomitoria*	18
Seedlings		
Black Willow	*Salix nigra*	540
Bur Oak	*Quercus macrocarpa*	6
Buttonbush	*Cephalanthus occidentalis*	2
Cedar Elm	*Ulmus crassifolia*	1
Gum Bumelia	*Sideroxylon lanuginosum*	2
Hackberry	*Celtis laevigata*	8
Hickory	*Carya sp.*	1
Honey Locust	*Gleditsia triacanthos*	1
Swamp Privet	*Forestiera acuminata*	14

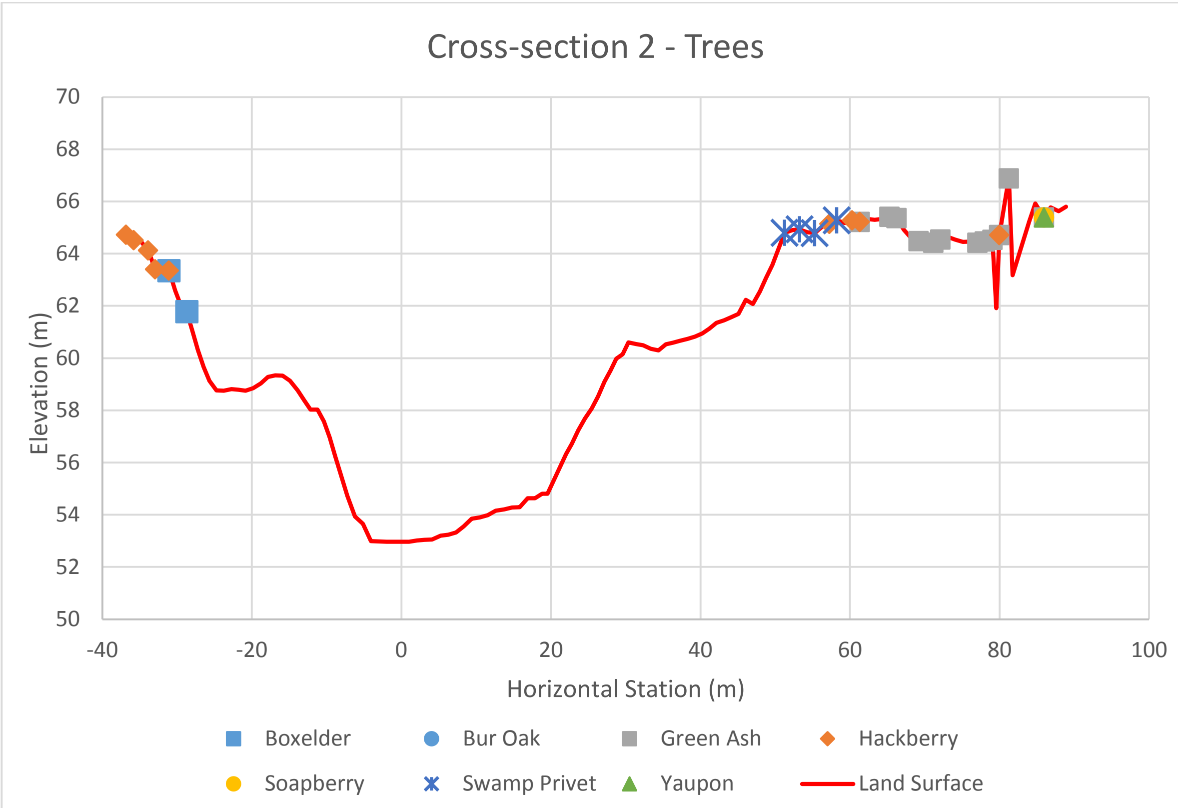

Figure 117. 080295 - Cross-section 2 - Left Bank - Trees - Location along cross-section

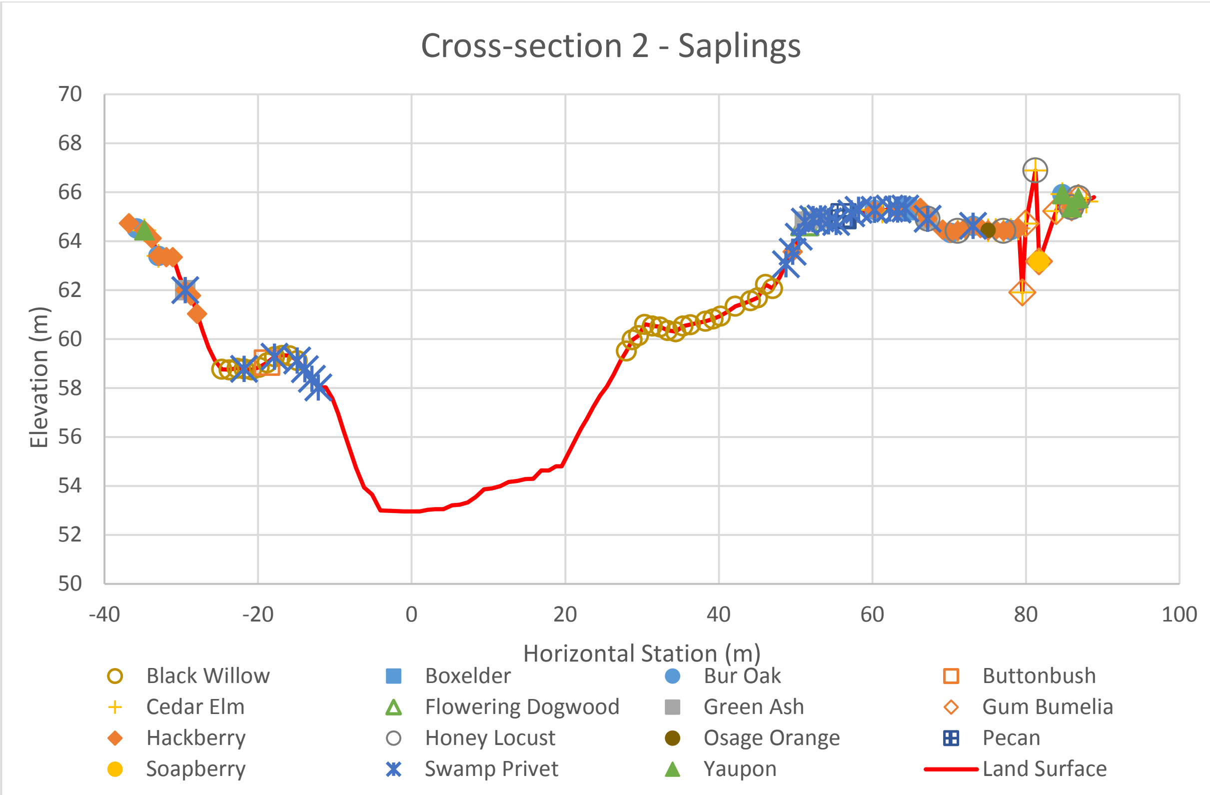

Figure 118. 080295 - Cross-section 2 - Left Bank - Saplings - Location along cross-section

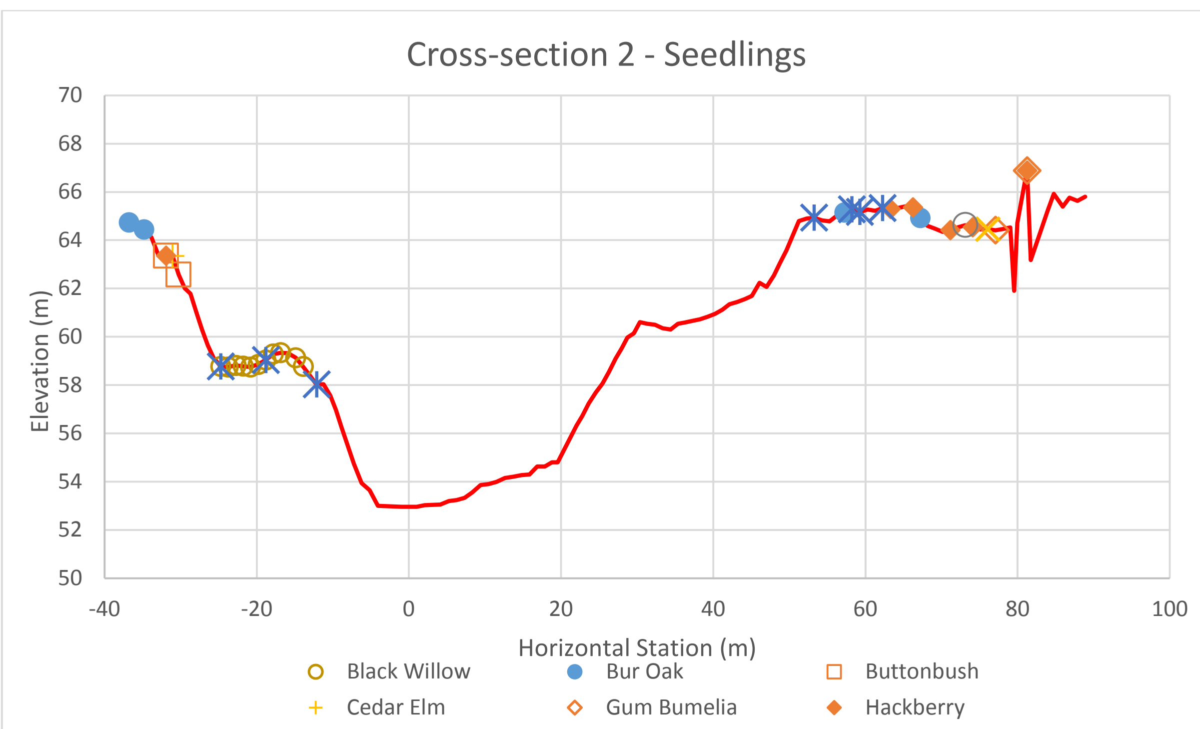

Figure 119. 080295 - Cross-section 2 - Left Bank - Seedlings - Location along cross-section

11.1.3 Tree Coring

Tree coring was conducted at the 080295 Oakwood study site within and adjacent to cross-sections 1 and 2. Tree coring data collection efforts of select riparian trees (boxelder, black willow and green ash) allowed for an age class analysis. Due to limited riparian trees, the tree coring sampling area was increased to include trees within close proximity of the riparian cross-sections. Processing of the trees cores was not possible for thirteen of the forty sampled trees due to tree rot or poor core quality. The oldest and youngest trees aged were 48 years and 14 years respectively (Table 19). For this data set a strong correlation was found between tree age and tree DBH ($R^2 = 0.77$) (Figure 119).

Table 21. Tree core data for 080295.

Type	Tag No.	DBH (in)	Photograph No.	Transect	Age (yrs)	Age Class (yrs)
Green Ash	305	2.75	825	1-RB	14	15
Green Ash	325	2.50	848	2-LB	17	15
Green Ash	304	2.75	824	1-RB	18	20
Box Elder	318	5.00	839	2-LB	19	20
Green Ash	322	4.00	845	2-LB	19	20
Box Elder	320	7.00	841	2-LB	21	20
Green Ash	347	6.00	863	2-RB	21	20
Green Ash	306	4.25	826	1-RB	23	25
Green Ash	321	6.00	844	2-LB	23	25
Green Ash	324	5.00	847	2-LB	23	25
Green Ash	309	8.50	829	1-RB	24	25
Green Ash	323	9.50	846	2-LB	25	25
Box Elder	345	6.50	861	2-RB	25	25
Green Ash	346	3.25	862	2-RB	26	25
Green Ash	344	6.50	860	2-RB	28	30
Green Ash	340	5.00	855-856	2-RB	31	30
Green Ash	308	9.50	828	1-RB	32	30
Green Ash	342	8.50	858	2-RB	32	30
Black Willow	303	11.00	823	1-RB	33	35
Green Ash	337	10.25	852	2-RB	34	35
Green Ash	307	10.00	827	1-RB	35	35
Green Ash	341	7.75	857	2-RB	35	35
Green Ash	310	11.50	830	1-RB	38	40
Green Ash	343	15.00	859	2-RB	39	40

Green Ash	339	15.75	854	2-RB	40	40
Green Ash	311	11.75	831	1-RB	42	40
Green Ash	338	15.00	853	2-RB	48	50

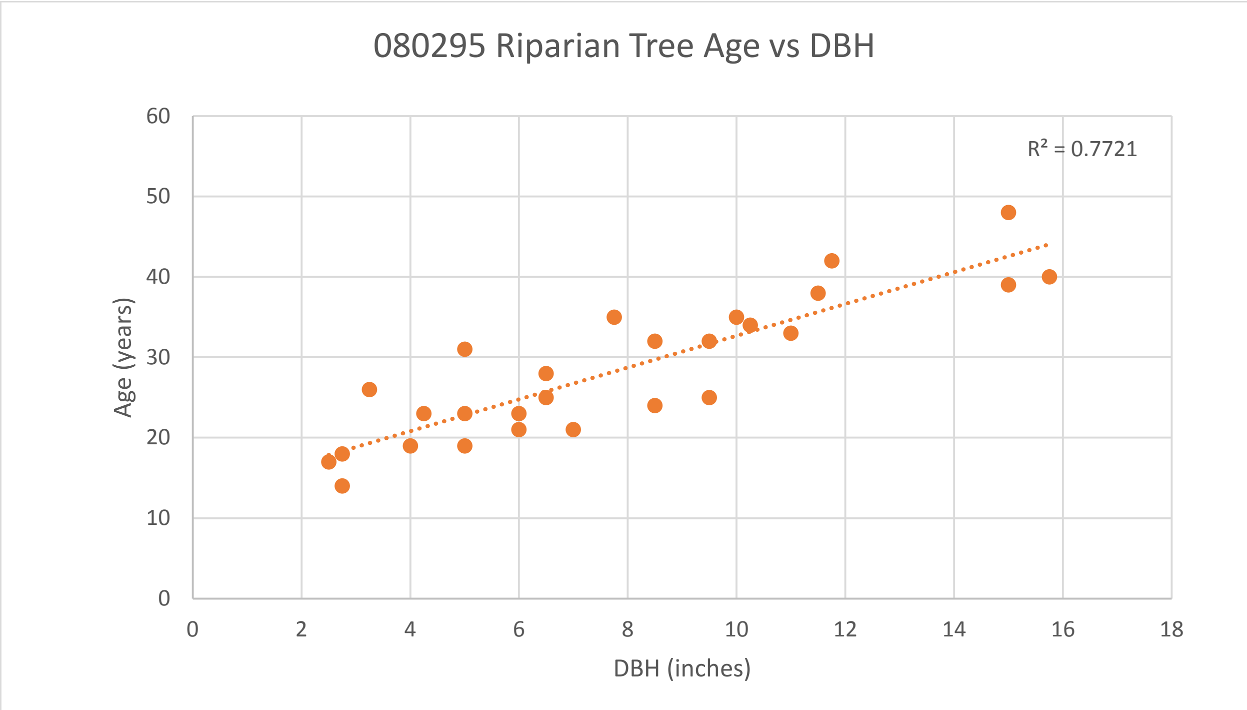

Figure 120. Riparian tree age vs DBH (inches) for 080295.

11.2 080075 – Riparian

Riparian woody vegetation was surveyed in October 2016 at site 080075 at Cross-sections 1 and 2 and summarized below. Riparian data included in the following sections is presented in metric units which is customary for this type of scientific information. Additionally, the station 0.0 of each transect is used to identify the water's edge at the time of the riparian survey.

11.2.1 Cross-section 1 – Upstream

Cross-section 1 is located just after a right curve. A large portion of the cross-section consists of a large sandbar along the right bank.

Twenty-three woody species were identified on Cross-section 1 (Table 20). The most common woody species identified were Yaupon (*Ilex vomitoria*), Swamp Privet (*Forestiera acuminata*), Swamp White Oak (*Quercus bicolor*) and Boxelder (*Acer negundo*). The location of each individual is shown in Figure 120, Figure 121, and Figure 122.

Table 22. 080075 - Cross-section 1 woody vegetation counts

Cross-section 1		
Common Name	**Scientific Name**	**Total Individuals**
Trees		
Boxelder	*Acer negundo*	6
Buttonbush	*Cephalanthus occidentalis*	3
Flowering Dogwood	*Cornus florida*	1
Hackberry	*Celtis leavigata*	2
Honey Locust	*Gleditisa triacanthos*	1
Slippery Elm	*Ulmus rubra*	1
Swamp White Oak	*Quercus bicolor*	11
Sweetgum	*Liquidamber styraciflua*	5
Winged Elm	*Ulmus alata*	1
Saplings		
American Sycamore	*Platanus occidentalis*	1
Boxelder	*Acer negundo*	24
Buttonbush	*Cephalanthus occidentalis*	6
Chinaberry	*Melia azedarach*	1
Chinese Tallow	*Sapium sebiferum*	4
Chinquapin Oak	*Quercus muhlenbergii*	2
Eve's Necklace	*Sophora affinis*	1
Flowering Dogwood	*Cornus florida*	1
Green Ash	*Fraxinus pennsylvanica*	3
Gum Bumelia	*Sideroxylon lanuginosum*	3
Hackberry	*Celtis leavigata*	21
Hickory	*Carya sp.*	1
Honey Locust	*Gleditsia triacanthos*	31
Roughleaf Dogwood	*Cornus drummondii*	8
Slippery Elm	*Ulmus rubra*	6
Southern Wax-Myrtle	*Myrica cerifera*	5
Swamp Hickory	*Carya glabra*	2
Swamp Privet	*Forestiera acuminata*	38
Swamp White Oak	*Quercus bicolor*	24
Sweetgum	*Liquidamber styraciflua*	2
Winged Elm	*Ulmus alata*	4
Yaupon	*Ilex vomitoria*	69
Seedlings		
Boxelder	*Acer negundo*	3
Cedar Elm	*Ulmus crassifolia*	2
Hackberry	*Celtis leavigata*	1
Honey Locust	*Gleditsia triacanthos*	4
Roughleaf Dogwood	*Cornus drummondii*	1
Slippery Elm	*Ulmus rubra*	1
Swamp Privet	*Forestiera acuminata*	52

Swamp White Oak	*Quercus bicolor*	3
Winged Elm	*Ulmus alata*	1
Yaupon	*Ilex vomitoria*	1

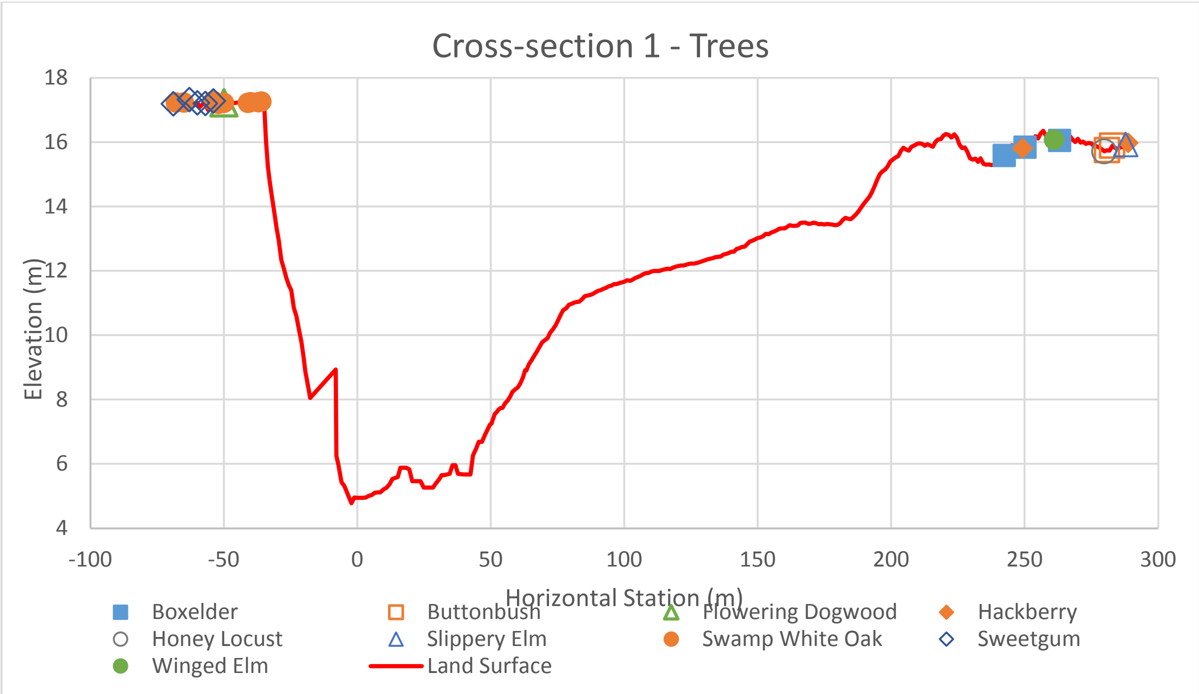

Figure 121. 080075 - Cross-section 1 - Trees - Location along cross-section

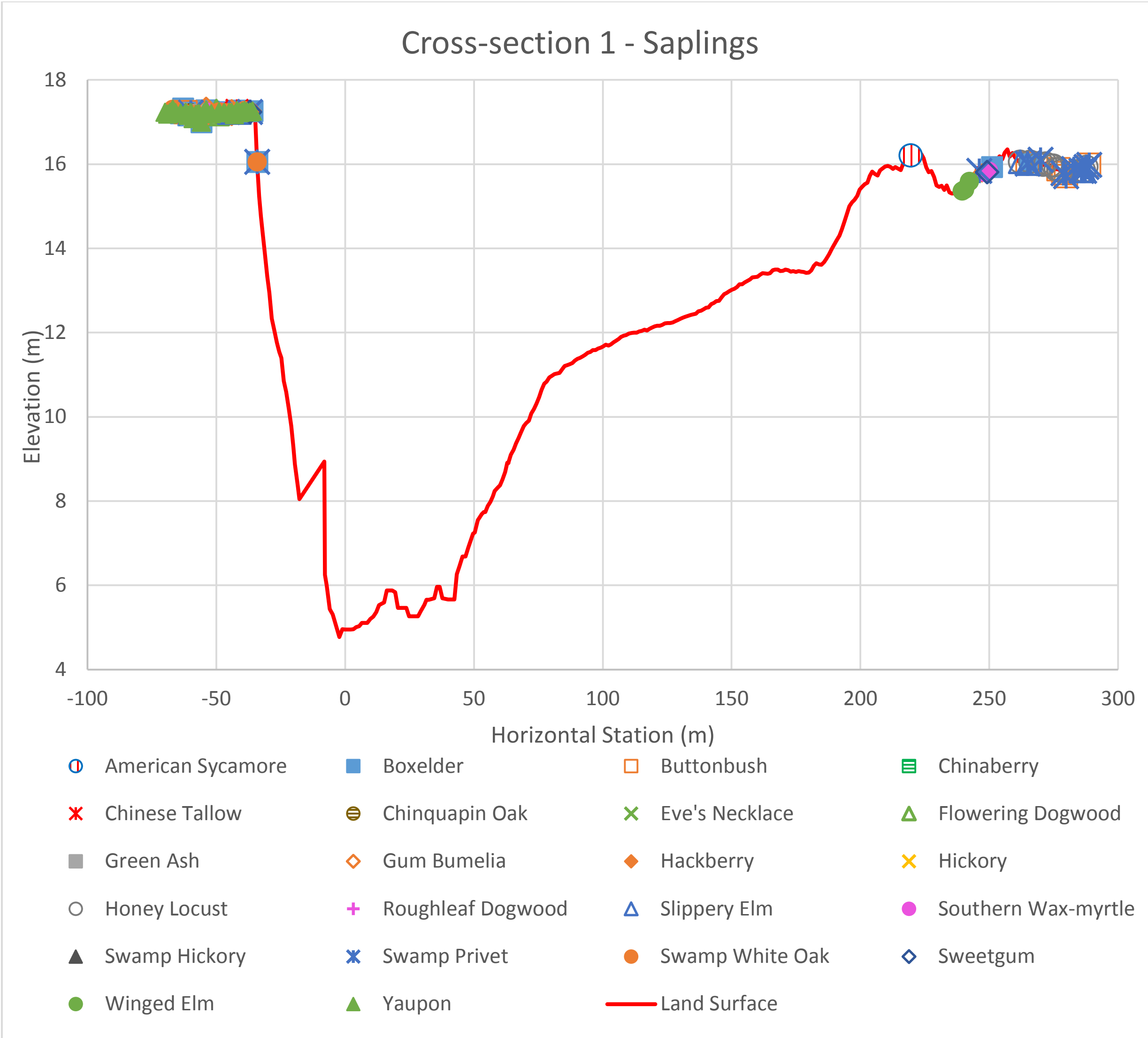

Figure 122. 080075 - Cross-section 1 - Saplings - Location along cross-section

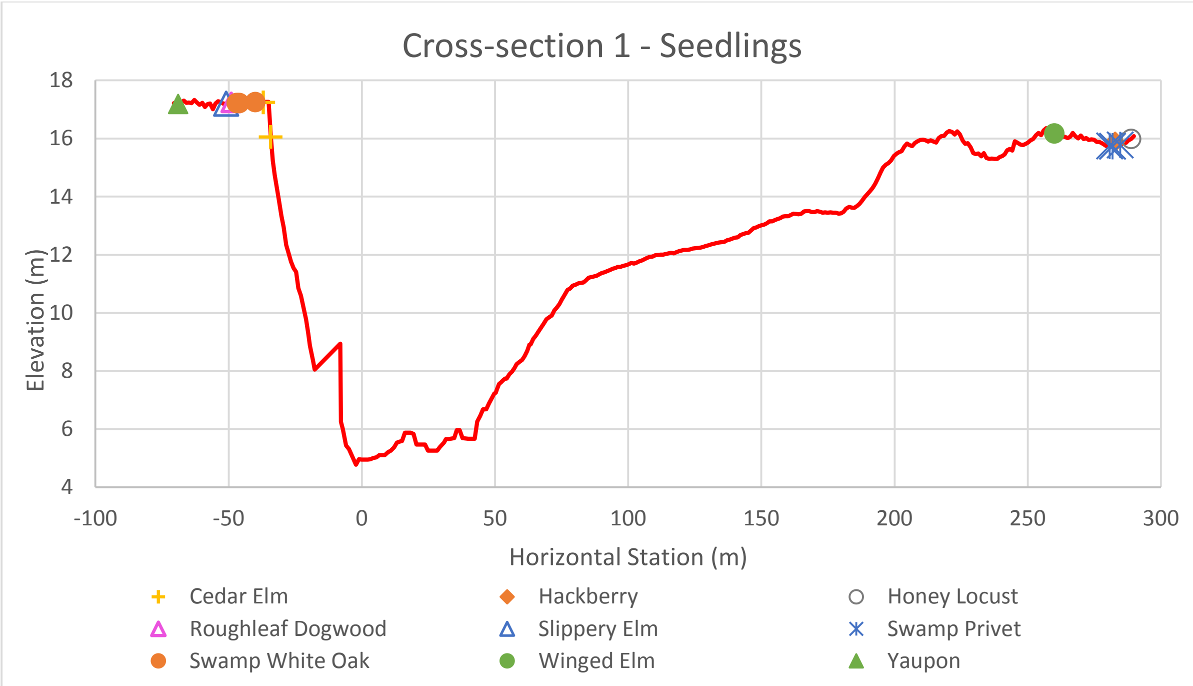

Figure 123. 080075 - Cross-section 1 - Seedlings - Location along cross-section

11.2.2 Cross-section 2 – Middle

Cross-section 2 is located between 2 sharp right bends in the river. Nineteen woody species were identified on Cross-section 2 and summarized below (Table 21). The most common woody riparian species identified were Cedar Elm (*Ulmus crassifolia*), Yaupon (*Ilex vomitoria*), Winged Elm (*Ulmus alata*), Swamp White Oak (*Quercus bicolor*) and Roughleaf Dogwood (*Cornus drummondii*). The location of each individual is shown in Figure 123, Figure 124, and Figure 125.

Table 23. 080075 - Cross-section 2 woody vegetation counts

Cross-section 2		
Common Name	**Scientific Name**	**Total Individuals**
Trees		
American Sycamore	*Platanus occidentalis*	1
Boxelder	*Acer negundo*	2
Cedar Elm	*Ulmus crassifolia*	4
Chinese Tallow	*Sapium sebiferum*	2
Hackberry	*Celtis leavigata*	3
Roughleaf Dogwood	*Cornus drummondii*	6
Slippery Elm	*Ulmus rubra*	2
Swamp Hickory	*Carya glabra*	3
Swamp White Oak	*Quercus bicolor*	2
Sweetgum	*Liquidamber styraciflua*	1
Winged Elm	*Ulmus alata*	5
Yaupon	*Ilex vomitoria*	9
Saplings		
Boxelder	*Acer negundo*	2
Cedar	*Juniperus sp.*	3
Cedar Elm	*Ulmus crassifolia*	115
Chinese Tallow	*Sapium sebiferum*	3
Green Ash	*Fraxinus pennsylvanica*	4
Gum Bumelia	*Sideroxylon lanuginosum*	2
Hackberry	*Celtis leavigata*	5
Loblolly Pine	*Pinus taeda*	2
Musclewood	*Carpinus caroliniana*	8
Osage Orange	*Maclura pomifer*	1
Roughleaf Dogwood	*Cornus drummondii*	76
Slippery Elm	*Ulmus rubra*	4
Swamp Hickory	*Carya glabra*	2
Swamp Privet	*Forestiera acuminata*	1
Swamp White Oak	*Quercus bicolor*	56
Sweetgum	*Liquidamber styraciflua*	2
Winged Elm	*Ulmus alata*	60
Yaupon	*Ilex vomitoria*	245
Seedlings		
Cedar Elm	*Ulmus crassifolia*	1
Chinese Tallow	*Sapium sebiferum*	1
Gum Bumelia	*Sideroxylon lanuginosum*	1
Hackberry	*Celtis leavigata*	5
Slippery Elm	*Ulmus rubra*	2
Swamp White Oak	*Quercus bicolor*	8

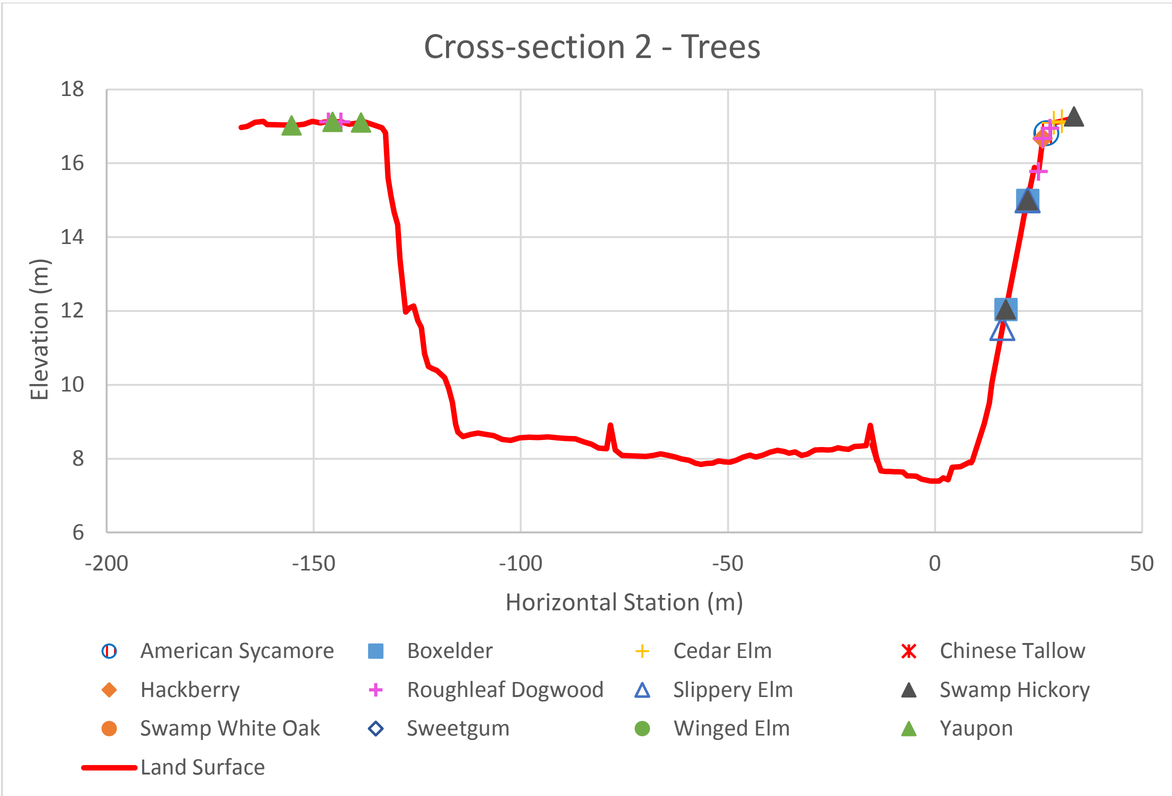

Figure 124. 080075 - Cross-section 2 - Trees - Location along cross-section

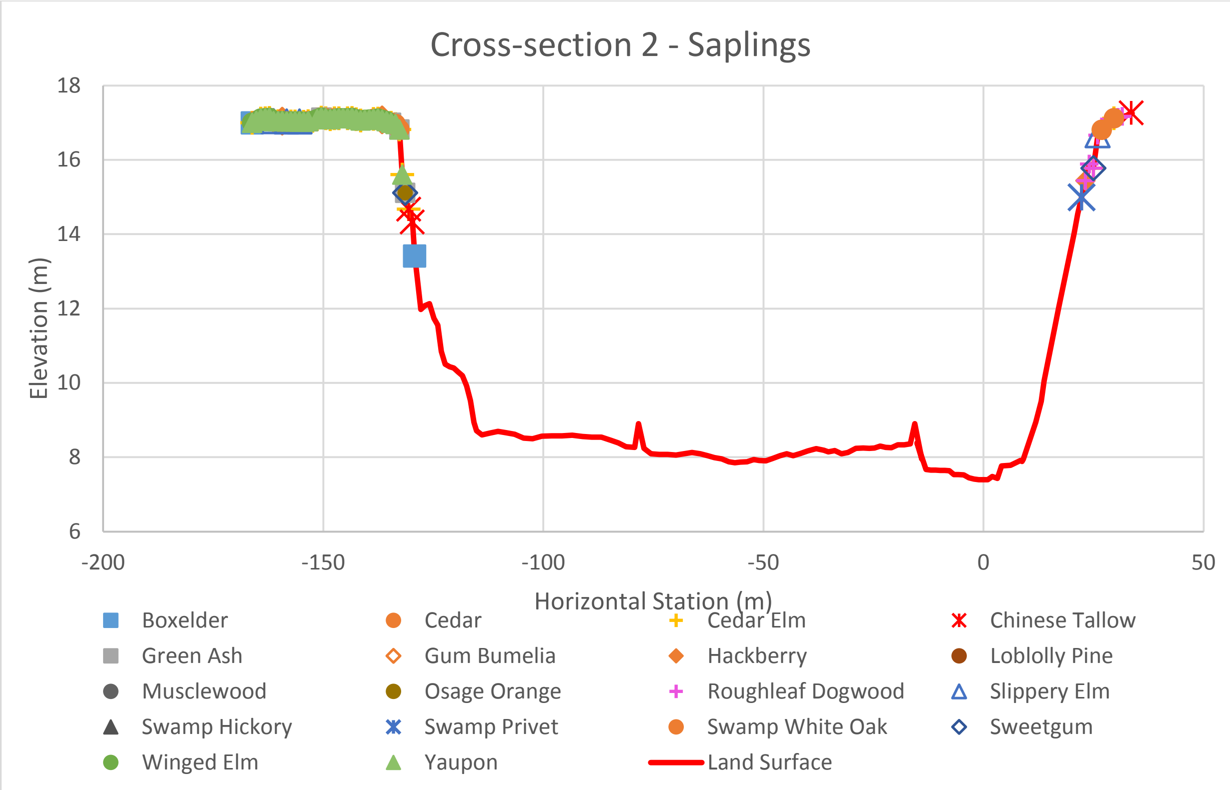

Figure 125. 080075 - Cross-section 2 - Saplings - Location along cross-section

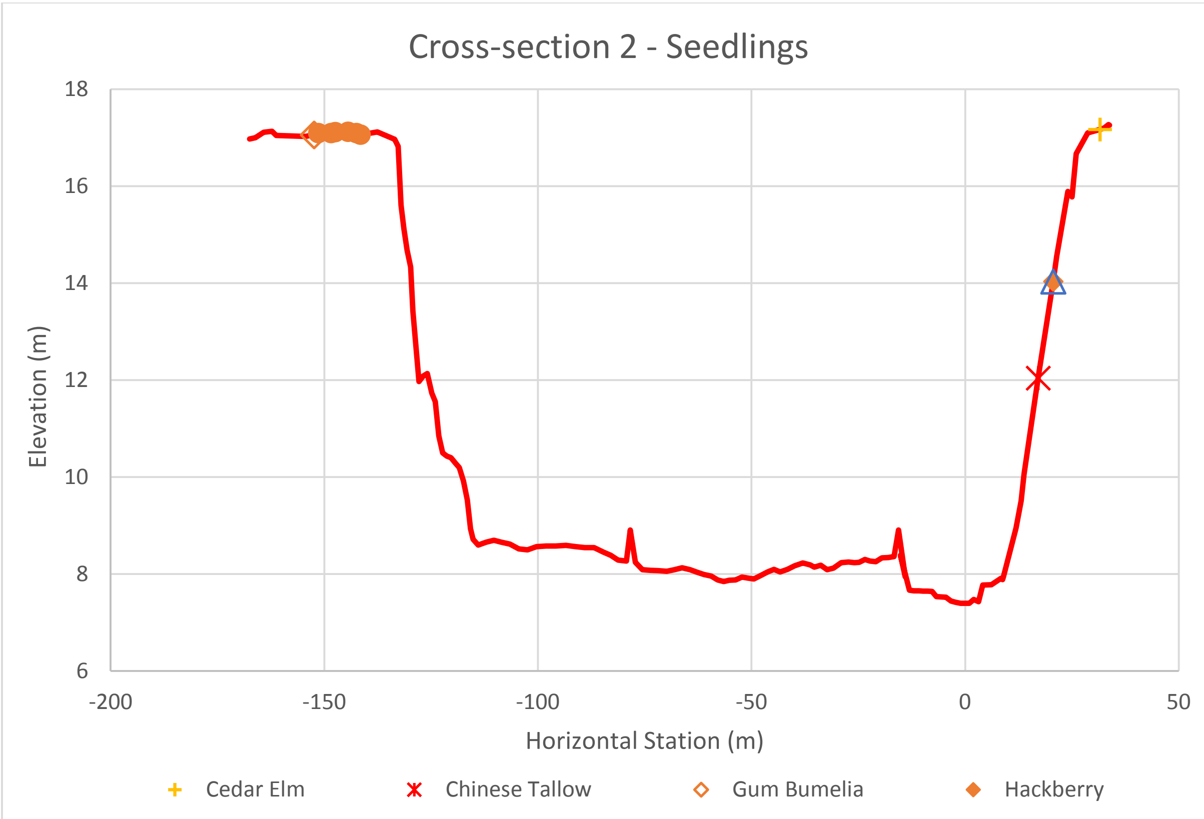

Figure 126. 080075 - Cross-section 2 - Seedlings - Location along cross-section

12 Appendix 6 – Water Availability Modeling

Table 24. Detailed WAM Output for Comparison of Trinity River Run 3 Compact Mod, Naturalized Flows, and Run 3. Red indicates that Target SB3 Seasonal Baseflow Was Not Met.

USGS Gage 08049500 West Fork Trinity River at Grand Prairie, TX

	WAM CP 8WYGP								WAM CP 8TROA			
	*Full Auth NO Return Flows (Run 3)				**Full Auth with ONLY Compact Minimum Return Flows (Run 3 Compact Mod)				Naturalized Flows			
	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base
	45	45	35	35	45	45	35	35	45	45	35	35
1940	399	102	592	192	442	150	631	235	740	442	1668	792
1941	739	1418	2733	681	780	1467	2775	722	1063	1843	3229	1421
1942	40	5122	479	267	81	5170	518	305	134	6065	811	770
1943	31	353	110	31	68	412	153	74	140	1161	400	90
1944	96	361	69	44	131	409	71	88	538	1247	243	287
1945	401	2275	218	35	449	2339	260	75	1137	3547	694	457
1946	511	512	216	289	564	561	195	330	1425	1063	493	868
1947	218	352	191	45	254	398	198	88	564	901	281	203
1948	310	248	64	1	359	298	87	43	852	513	215	31
1949	165	1741	317	90	210	1782	357	131	368	2716	748	612
1950	483	773	938	384	526	843	981	423	837	1879	1506	642
1951	33	48	102	6	75	96	145	47	130	266	688	23
1952	32	99	55	62	72	147	76	70	106	300	86	153
1953	14	137	69	28	55	179	61	76	65	466	130	481
1954	19	30	3	9	60	80	45	50	98	315	31	14
1955	15	77	56	13	55	125	74	54	51	318	320	152
1956	15	57	7	7	54	106	52	48	158	262	65	93
1957	33	3724	902	132	74	3777	944	173	317	7669	1189	669
1958	24	1410	31	97	58	1458	55	138	127	2527	107	153
1959	26	33	82	358	58	81	125	395	131	104	418	1680
1960	246	97	28	6	291	143	70	47	751	329	96	124
1961	127	100	176	40	169	149	218	82	520	393	440	133
1962	41	60	219	323	83	99	236	362	243	285	1024	1361
1963	28	138	12	0	66	185	54	41	68	625	46	0
1964	83	132	73	377	124	180	91	423	201	560	217	1152
1965	446	601	34	69	488	671	77	110	861	1328	155	297
1966	65	1078	193	89	105	1127	236	130	223	2675	463	342
1967	44	112	55	43	85	160	97	84	112	404	380	121
1968	178	848	82	47	201	913	125	88	517	2294	303	107
1969	147	1306	43	168	188	1355	85	209	492	2731	171	410
1970	319	1157	17	118	360	1205	59	158	634	2082	62	353
1971	663	56	83	295	710	104	126	330	1221	181	247	592
1972	151	86	0	119	192	134	42	160	283	697	0	319
1973	139	513	689	257	180	561	731	298	399	1101	1235	742
1974	170	99	138	884	211	147	179	926	337	362	300	2202
1975	681	1048	699	0	723	1097	740	41	1131	1555	1681	0
1976	85	336	83	98	124	376	115	138	249	929	313	468
1977	225	1425	6	2	275	1474	49	43	487	2492	44	8
1978	69	120	45	51	111	165	64	92	137	399	108	86
1979	163	916	345	26	206	983	388	65	342	2364	581	44
1980	102	309	4	150	145	358	22	158	334	526	18	440
1981	71	269	237	2084	115	322	303	2125	170	970	563	5441
1982	248	2673	1183	59	290	2721	1221	100	497	3659	1700	93
1983	90	213	190	80	131	261	233	121	231	589	473	126
1984	184	259	13	121	225	307	55	162	610	475	54	361
1985	119	523	60	103	160	571	103	131	543	1472	287	538
1986	191	386	813	86	233	435	841	127	500	1147	1375	372
1987	344	706	601	30	383	754	644	69	951	1448	1005	66
1988	69	77	77	94	112	126	120	120	211	217	267	139
1989	279	2155	2803	60	322	2217	2845	101	754	4901	4277	168
1990	301	6414	334	99	341	6463	377	140	570	7787	745	243
1991	2693	438	235	1431	2734	486	277	1472	3707	863	640	2402
1992	1834	1122	1019	164	1885	1171	1048	207	2462	1579	1399	328
1993	721	749	159	540	764	795	170	581	1256	1379	502	1355
1994	383	754	92	663	424	802	129	704	713	1360	350	1500
1995	285	1928	212	82	326	1976	241	123	481	2591	674	121
1996	274	145	112	471	315	182	153	513	514	309	200	1506
Mean	278	846	323	212	320	896	357	252	574	1556	627	590
% Years Target Met	75.4%	96.5%	80.7%	77.2%	100.0%	100.0%	98.2%	100.0%	100.0%	100.0%	94.7%	89.5%

USGS Gage 08057000 Trinity River at Dallas, TX

	WAP CP 8TRDA								WAM CP 8TROA			
	*Full Auth NO Return Flows (Run 3)				**Full Auth with ONLY Compact Minimum Return Flows (Run 3 Compact Mod)				Naturalized Flows			
	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base
	50	70	40	50	50	70	40	50	50	70	40	50
1940	594	222	979	249	672	352	1085	344	1940	1601	3734	1518
1941	989	1907	4218	756	1077	2047	4331	848	2439	3980	7225	2364
1942	62	7948	849	336	147	8121	952	430	379	14540	2149	1338
1943	39	638	141	33	108	788	225	118	265	3266	817	176
1944	243	682	81	59	311	818	125	155	1883	3879	474	527
1945	724	4024	412	126	807	4200	520	230	3659	9428	2300	1503
1946	969	1112	630	485	1075	1254	680	575	4490	3638	2099	2351
1947	494	510	516	48	559	640	528	134	1749	2126	1119	287
1948	561	476	163	0	642	633	251	51	2754	1693	678	0
1949	422	2383	595	143	537	2502	697	241	1499	4838	1558	1471
1950	980	1356	844	318	1055	1504	913	392	2975	4377	2906	1843
1951	33	47	133	9	107	172	224	87	258	422	1708	38
1952	47	132	52	64	123	274	132	123	187	926	108	228
1953	27	376	58	18	111	484	77	105	168	1783	70	699
1954	37	118	7	17	128	264	102	107	258	738	154	83
1955	23	66	76	24	99	195	155	117	167	778	606	192
1956	28	111	0	14	106	245	90	87	292	484	45	97
1957	110	7661	1358	143	199	7701	1446	217	655	19481	2517	2058
1958	183	2818	98	64	267	3025	178	150	714	7835	462	203
1959	123	114	123	649	211	226	211	777	601	340	1166	2976
1960	423	119	111	0	536	217	229	67	1948	820	544	85
1961	365	259	267	62	461	397	373	151	1606	1207	808	232
1962	78	245	448	759	172	381	509	816	568	1074	2088	4539
1963	36	282	12	0	109	412	119	79	168	1743	50	0
1964	105	239	80	903	187	391	132	1022	396	1828	259	5580
1965	712	1105	110	150	803	1277	212	264	2433	2948	598	934
1966	105	2268	305	160	181	2429	424	268	1033	8265	1035	598
1967	107	245	57	159	194	396	171	267	258	1423	989	301
1968	352	1463	123	93	421	1632	221	202	1191	6962	865	576
1969	194	2715	6	221	278	2878	36	319	1846	8285	351	651
1970	434	1557	60	262	515	1716	142	361	1842	5756	370	1467
1971	1281	120	151	829	1375	262	256	928	4469	412	508	2448
1972	178	167	7	296	247	294	100	399	578	1065	32	1143
1973	401	1161	1497	893	483	1312	1574	1005	1447	4123	3635	3251
1974	407	300	288	1526	490	427	407	1636	984	1405	941	6964
1975	1433	2118	1166	0	1517	2268	1286	83	3176	4563	3131	0
1976	237	831	214	153	330	954	323	261	564	2406	908	584
1977	416	2002	126	51	510	2126	227	160	1412	5983	344	101
1978	123	289	73	91	210	410	159	190	284	1104	194	151
1979	286	1666	388	30	370	1838	495	112	667	6173	864	59
1980	232	422	47	291	330	542	124	371	765	770	84	1128
1981	112	729	946	3977	203	883	1080	4091	390	3059	2173	14390
1982	808	6924	2391	239	901	7075	2508	343	2415	11208	4348	328
1983	315	474	353	228	383	608	454	317	887	1350	935	594
1984	567	597	100	549	660	739	216	653	1749	1595	230	1088
1985	538	1218	153	417	615	1368	260	517	1984	4715	930	1626
1986	293	823	1319	384	377	968	1420	497	1959	3595	3529	1363
1987	596	1222	891	240	664	1372	1000	350	3496	4143	2354	479
1988	187	237	364	225	259	386	472	323	786	614	641	348
1989	629	3656	4853	194	722	3819	4971	300	3098	10166	9591	408
1990	699	11449	487	168	773	11595	572	247	1827	20114	1626	353
1991	4705	1178	616	2309	4800	1313	736	2418	9705	2689	1396	5345
1992	3182	2064	1836	818	3285	2214	1918	930	6806	3752	2926	1480
1993	1471	1356	416	871	1566	1503	505	975	4723	4313	1711	3391
1994	718	1668	522	2952	800	1818	637	3062	2148	4289	2890	6370
1995	558	5160	431	80	650	5310	532	162	1204	8544	1293	175
1996	332	323	380	1505	416	463	499	1559	981	801	616	5322
Mean	532	1603	578	450	616	1745	671	544	1739	4200	1538	1646
% Years Target Met	86.0%	96.5%	91.2%	78.9%	100.0%	100.0%	98.2%	100.0%	100.0%	100.0%	98.2%	93.0%

USGS Gage 08065000 Trinity River near Oakwood

	WAM CP 8TROA								WAM CP 8TROA			
	*Full Auth NO Return Flows (Run 3)				**Full Auth with ONLY Compact Minimum Return Flows (Run 3 Compact Mod)				Naturalized Flows			
	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base	Base
	340	450	250	260	340	450	250	260	340	450	250	260
1940	3982	2341	3426	1843	4211	2651	3670	2081	6293	5100	7260	4370
1941	5939	8449	11066	1057	6183	8764	11316	1292	8307	11603	15143	2986
1942	966	21435	3962	1523	1196	21791	4184	1765	2068	30205	5996	3866
1943	932	4422	2725	646	1148	4682	2966	776	1831	8754	4308	1465
1944	2242	11961	1969	244	2551	12269	2143	482	6490	17002	2934	876
1945	2108	24923	4867	852	2278	25267	5116	958	7504	30824	8039	3328
1946	5371	6765	5556	3916	5723	6967	5753	4153	10330	9572	7670	7860
1947	2816	4495	854	682	3042	4772	1021	912	6444	7297	2069	1274
1948	1164	5943	558	91	1332	6281	787	281	4451	9398	1398	116
1949	332	4322	2742	513	470	4616	2980	754	3172	9063	4287	2101
1950	5455	5263	1192	844	5722	5585	1379	1005	10494	9878	3907	2608
1951	408	583	977	130	653	881	1229	340	1098	1336	4287	242
1952	575	1108	931	120	802	1326	1155	335	1540	4950	1253	451
1953	747	4109	219	165	981	4281	387	385	1503	10566	313	927
1954	434	671	34	703	673	987	266	936	1196	2259	234	1248
1955	563	1036	254	183	790	1337	475	346	1120	2710	898	365
1956	270	607	54	125	498	911	251	349	921	1915	116	463
1957	734	9084	8088	3826	967	9405	8411	4044	1898	33852	10549	7543
1958	1216	12055	728	428	1447	12328	882	659	2467	18321	1483	1554
1959	2073	4171	2094	1440	2311	4501	2324	1698	4170	6054	3821	4802
1960	7391	931	337	223	7658	1203	588	427	12490	2408	1131	500
1961	8701	2585	1663	303	8987	2923	1902	471	11659	4687	3344	1297
1962	1089	1223	1080	1235	1335	1532	1319	1439	2440	3630	3733	6063
1963	230	1468	193	0	443	1535	392	222	553	4011	341	0
1964	702	514	274	1401	933	833	469	1542	1173	2712	561	7232
1965	2004	4627	872	255	2244	5202	1113	505	5348	10545	1677	1092
1966	516	11402	1059	450	744	11754	1302	699	1878	23271	2061	1072
1967	1389	658	425	1659	1672	980	676	1834	2362	2548	1963	6203
1968	4123	14566	1645	359	4308	14956	1880	606	6407	21338	3098	1083
1969	1496	14214	1149	487	1739	14548	1327	725	5062	21509	1754	1065
1970	1309	7467	698	1089	1540	7809	921	1297	4284	13733	1409	3429
1971	4102	299	794	2081	4500	613	947	2291	10848	917	1468	6052
1972	3302	453	82	656	3534	752	312	871	4674	1562	176	1949
1973	2844	8480	7122	5119	3079	8815	7343	5361	6062	14687	10069	9197
1974	5876	2082	912	7900	6112	2379	1123	8196	7513	4444	2087	15354
1975	6997	9101	3063	34	7236	9425	3321	242	9327	12356	5775	49
1976	1485	4724	3034	1581	1720	5019	3284	1827	2500	9537	4732	2883
1977	3494	8834	1146	101	3734	9154	1384	334	5494	14798	1657	210
1978	629	1472	282	290	864	1727	474	527	1341	3440	503	456
1979	1562	4699	2127	221	1804	5054	2379	436	3585	14831	3812	400
1980	1652	3214	276	269	1898	3505	468	442	3924	4545	466	1112
1981	440	1921	3666	4951	681	2245	3926	5224	1082	5454	9310	16357
1982	2496	8294	5741	653	2742	8621	5992	896	5804	12966	8513	878
1983	1934	3610	1297	401	2182	3919	1528	618	4482	5780	2646	892
1984	1998	2067	248	1432	2257	2354	478	1682	5829	5240	439	3018
1985	5792	5373	578	1964	6038	5705	817	2203	8989	10068	1501	5449
1986	5951	4936	5825	1479	6192	5265	6058	1735	8927	8839	8805	3891
1987	2990	4400	3386	285	3208	4725	3628	536	7711	8553	5544	689
1988	651	1243	393	1422	879	1538	637	1589	2484	2439	936	2089
1989	1542	12096	10947	323	1788	12514	11202	567	5671	21390	16234	595
1990	3359	30860	2724	1034	3573	31193	2951	1248	7092	39886	4668	1591
1991	16995	4486	1471	5985	17240	4807	1717	6241	23466	7838	3573	10957
1992	16025	10739	3479	955	16281	11064	3688	1207	21478	13490	5358	2262
1993	6044	8318	1205	3188	6298	8640	1436	3431	10239	12227	3144	7985
1994	8795	7952	1508	7662	9030	8279	1763	7915	10959	11667	4820	12762
1995	4751	20366	1940	800	4993	20690	2179	958	6106	24560	4029	1023
1996	1434	632	560	1381	1708	941	775	1577	3100	1527	1000	7616
Mean	3165	6387	2202	1385	3406	6699	2428	1605	5713	10774	3830	3389
% Years Target Met	94.7%	98.2%	89.5%	77.2%	100.0%	100.0%	100.0%	96.5%	100.0%	100.0%	94.7%	91.2%

*Most recent TCEQ Published WAM - Trinity River Basin WAM Run 3, Full Authorized Diversions, 100% Reuse, Last Updated 10/7/2014

**Run 3 Compact Mod was adapted from the most recent TCEQ Published WAM - Trinity River Basin WAM Run 3. Parameters: Full Authorized Diversions, Only NTMWD, TRA, FWVC, Dallas SS and Central Modified Reuse CI cards added, Created 20171026. Modification parameters include:

CI Cards from WAM Run 8 (min monthly discharges 2001-05) for the Upper Trinity River Water Quality Compact (Compact-NTMWD, TRA, TRWD, Dallas) were adjusted to reflect current permit and/or Compact agreements as follows:

a) Dallas Central (B37) and Southside (B40) are required by permit to discharge 114,000 af/yr for Lake Livingston & Environmental Flows

b) North Texas Municipal Water District (NTMWD) is required by permit to let flow downstream 32% of their total in-basin derived supplies return flows (Control Points B63, B213, B71, B43, B42,& B76)

According to Region C (2016), 63% of NTMWD raw water supplies are from in-basin reservoirs, so selected NTMWD CI cards were adjusted to 63% for all values and control points (above), then 32% of that value was proportioned out based on the original monthly proportions.

c) TRA Central (B66), Ten Mile Creek (B135), and Red Oak Creek (B262) were adjusted to 30% per agreements with Houston to protect water in Livingston and the Compact

Table 25. Modified CI Card Code for Run 3 Compact Mod.

**Added only Compact Return Flows at minimum required by permit/agreements
** CI records based on the minimum monthly value for each month for the period 2001-2005
**Proportional Split of Dallas SS B40 and Central B37 by % of the 2001-05
**discharges and 114000 af/yr accounting plan requirements
**CI B37 11348 10939 13321 11969 11929 11213
**CI 10071 10595 10540 10967 10401 11177
CI B37 6654 6414 7810 7018 9664 6475
CI 5905 6212 6180 6430 6098 6553
**CI B40 4955 5413 5384 4979 5145 5035
**CI 4907 4431 4057 5231 5413 5012
CI B40 2905 3174 3157 2919 3017 2952
CI 2877 2598 2379 3067 3174 2939
**Reduced B66 TRA CENTRAL to 30pcnt of reuse
**CI B66 11836 11213 12822 11685 12628 11756
**CI 12016 12131 11802 11837 11438 11603
CI B66 3551 3364 3847 3506 3788 3527
CI 3605 3639 3541 3551 3431 3481
**63% of NTMWD Supplies in 2020 are "in basin" and 37% are IBT (2016 Region C Water Plan)
**CI B76 106 295 132 100 119 95
**CI 89 96 89 94 84 104
CI B76 21 59 27 20 24 19
CI 18 19 18 19 17 21
**Reduced B88 FW Village Creek to 30pcnt of reuse
**CI B88 8356 8176 10719 8990 9176 8547
**CI 8299 8518 8041 8528 8096 8204
CI B88 2507 2453 3216 2697 2753 2564
CI 2490 2555 2412 2559 2429 2462
**Reduced TMC to 30 pcnt
**CI B135 1024 1029 1432 1150 1156 1068
**CI 1100 1086 1048 1094 1071 1014
CI B135 307 309 430 345 347 320
CI 330 326 314 328 321 304
**Reduced ROC to 30 pcnt
**CI B262 147 174 222 175 178 134
**CI 147 126 107 187 171 171
CI B262 44 52 67 53 53 40
CI 44 38 32 56 51 51
** B42-TCEQ Current RUN8-Garland Duck CK
**63% of NTMWD Supplies in 2020 are "in basin" and 37% are IBT (2016 Region C Water Plan)

**CI B42 1093 923 1393 1127 1159 881
**CI 704 778 749 919 922 1012
CI B42 220 186 281 227 234 178
CI 142 157 151 185 186 204
**B43-TCEQ Current RUN8-Grarland Rowlett CK
**63% of NTMWD Supplies in 2020 are "in basin" and 37% are IBT (2016 Region C Water Plan)
**CI B43 1387 1459 1552 1427 1495 1333
**CI 1368 1416 1320 1319 1258 1294
CI B43 280 294 313 288 301 269
CI 276 285 266 266 254 261
**B71-TCEQ Current RUN8-Rowlett CK
**63% of NTMWD Supplies in 2020 are "in basin" and 37% are IBT (2016 Region C Water Plan)
**CI B71 1427 1046 1141 968 969 913
**CI 947 870 912 871 901 1058
CI B71 288 211 230 195 195 184
CI 191 175 184 176 182 213
**B63-TCEQ Current RUN8-Squabble CK
**63% of NTMWD Supplies in 2020 are "in basin" and 37% are IBT (2016 Region C Water Plan)
**CI B63 54 77 67 76 66 60
**CI 57 59 61 61 61 51
CI B63 11 16 14 15 13 12
CI 11 12 12 12 12 10
**B213 TCEQ Current RUN8 buffalo CK
**63% of NTMWD Supplies in 2020 are "in basin" and 37% are IBT (2016 Region C Water Plan)
**CI B213 67 85 108 78 85 61
**CI 93 83 88 90 74 60
CI B213 14 17 22 16 17 12
CI 19 17 18 18 15 12

13 TWDB Comments to Draft Report & Trinity River Authority Responses to Comments

Evaluation of Adopted Flow Standards for the Trinity River, Phase 2
Draft-final report to the Texas Water Development Board

Contract number 1600011940

Overall, the report is well written and documents a research effort that achieved the objectives of the Scope of Work.

REQUIRED CHANGES

General Draft Final Report Comments:

1. Please review the report for typos (such as the following) and correct as necessary:
    - **a.** Page 13, 1st paragraph, 1st sentence, "Senate Bill 3 environmental flow standards" should be "SB3 environmental flow standards." **- Changed**
    - b. Page 28, 1st paragraph, 2nd sentence, "across of range of flow" should be "across a range of flow." **- Changed**
    - **c.** Page 29, 3rd paragraph, 2nd sentence, "flow regiment" should be "flow regime." **- Done**
    - d. Page 31, 1st paragraph, 2nd sentence, "consisting of 14 to 16, 26 to 30 and 40 to 48-year-old trees, respectively" should be "consisting of 40 to 48, 26 to 30, and 14 to 16-year-old trees, respectively." **- Done**
    - e. Page 30, 5th paragraph, 3rd sentence, "18 to 24 and 32 to 38 respectively" should be "32 to 38 and 18 to 24 respectively." **- Done**
    - **f.** Page 70, 2nd paragraph, 1st sentence, "where on PT" should be "where one PT." **- Done**
    - **g.** Page 107, 1st paragraph, 1st sentence, "2007-09-01 to 2007-08-31" should be "2007-09-01 to 2017-08-31." **- Done**
    - h. Page 108, 1st paragraph, 1st sentence, "Sediments samples" should be "Sediment samples." **– Done**
    - i. Page 124, 1st paragraph, 5th sentence, "(Table 9)" should be "(Table 19)." **- Done**
    - j. Page 124, 1st paragraph, last sentence, "(Figure 61)" should be "(Figure 119)." **- Done**
    - **k.** Page 125, 3rd paragraph, 1st sentence, "(Table 5)" should be "(Table 20)." **- Done**
    - **l.** Page 125, 3rd paragraph, 2nd sentence, "Figure 49, Figure 50, and Figure 51" should be "Figure 120, Figure 121, and Figure 122." **- Done**
    - m. Page 129, 1st paragraph, 1st sentence, "(Table 6)" should be "(Table 21)." **- Done**
    - n. Page 129, 1st paragraph, last sentence, "Figure 52, Figure 53, and Figure 54" should be "Figure 123, Figure 124, and Figure 125." **– Done**

2. To be consistent with the description of other sites, please add "(the USGS gage 0805700, at Dallas, TX)" to the description of the field data collected at river mile 444 in the second paragraph on page 12. *– Comment to reviewer: Not changed: RM 444 is about 30 miles from that gage as this site is a surrogate for that measurement point. Researchers do not want to imply that it is near the gage.*

3. In order to make titles for figures and tables more readable, please use a larger, non-italic font size with black color. Times New Roman, 12 point (similar to rest of report) is recommended. **- Done**

4. Please provide a description of the "accelerated bank equalization processes" referred to on page 16, 2nd paragraph, 3rd sentence. Reviewers are not familiar with this term. **– Replaced "accelerated bank equalization processes" with "increased bank migration"**

5. Please provide definitions for the abbreviations such as the following prior to their use in the text:
    - **a.** "USGS" on page 12, 2nd paragraph and Table 1, **- Done**
    - b. "cfs" on page 15, paragraph 2, **- Done**
    - c. "PTs" on page 17, Table 2, **- Done**
    - d. "DFW" on page 20, 1st paragraph, 1st sentence, **- Done**
    - e. "RM" on page 60, caption for Figure 30, **- Done**
    - f. "TRWD" on page 69, 3rd paragraph, 1st sentence, **- Done**
    - g. "GP" on page 69, 8th paragraph, 1st sentence, **- Done**
    - h. "WS" on page 69, 9th paragraph, 3ed sentence, **- Done**
    - i. "WSP" on page 69, 9th paragraph, 3rd sentence, **- Done**
    - j. "RI" on page 70, 4th paragraph, 2nd sentence, **- Done**
    - k. "TNRIS" on page 96, 2nd paragraph, 2nd sentence. **– Done**

6. Please provide an entry in Section 6 of the report for the following reference: (Seafloor 2017) on page 17, 4th paragraph, 1st sentence. **– Done**

7. Reference to "(T1 and T5)" on page 17, 6th paragraph, 2nd sentence and "(T2, T3, T4)" on page 18, 1st paragraph, 1st sentence without providing definitions for these abbreviations is confusing. Please remove these abbreviations and refer the reader to the appendix for the details of the compositing procedure. **– Done**

8. Please provide a description of how "inundation surface area", shown in Figures 5 and 6 on pages 20 and 21, was measured. **- Done**

9. Reference to "segment C3" on page 21, 1st paragraph, 1st sentence is confusing. Please provide a description for this term. – Deleted reference to C3, not needed for this report

10. On page 22, 1st paragraph, the 3rd sentence states "The natural levee tends to hold the river inside the banks for flows exceeding 70,000 cfs." Please check and confirm the use of "exceeding" rather than "not exceeding" in this sentence. **– Changed exceeding to "below"**

11. The report states on page 30, 2nd paragraph, 1st sentence that "Forty tree cores were collected at the site." Please clarify the species sampled and the number of samples from each species. - **Add to end of sentence "(see Section 11.1.3, Table 19)".**

12. On page 39, 3rd paragraph, last sentence states "A minimum of 50 quality cores should be collected and analyzed as a future study goal" Given species specific responses to inundation (described in the first paragraph on page 39), please comment as to whether study objectives would be better served by collecting 50 total cores from a set of species (such as black willow, green ash, or box elder, as was apparently done for A minimum of 50 quality cores per species should be collected and analyzed as a future study goal and, if needed, additional cores from adjacent areas should be collected to meet the minimum sample count. **– Deleted**

13. Sections 4.1, 4.2, and 4.3, state that return flows will satisfy SB3 subsistence and base flows for the foreseeable future. Section 4.4 states that releases from Lake Livingston to satisfy downstream water rights will satisfy SB3 subsistence and base flows for the foreseeable future. Please provide justification or a reference for these statements. – **Added section 3.4 which includes a review of the WAM modeling and gage analysis used to address the comment. Updated sections 4.1, 4.2, and 4.3 to reflect results.**

14. To be consistent with the abbreviation used in the text (on page 12), please change the 8th reference on page 51from "Trinity and San Jacinto" to "[TSJ] Trinity and San Jacinto." **– Done**

15. To be consistent with the format of other references, please change the 9th reference on page 51 from "United States Geological Survey (USGS)" to "[USGS] United States Geological Survey." **– Done**

16. On Figures 26-29 on pages 56-59, please provide a description of what the numbers on the figures represent (e.g. water surface elevations, river mileage). **– Added: "Note: Numbers represent approximate river mile."**

17. On page 61, 1st paragraph, 1st sentence, please provide the citation mentioned in the text. **- Done**

18. It appears that lines in Figures 47 to 51, 60-62, 74-78, and 100-112 are being artificially smoothed by the plotting software. Please insure that point-to-point data is being plotted in these figures by turning off any data smoothing options (such as "Smoothed line" in Microsoft Excel). **– Done**

19. On page 118, Section 11.1 title and Table 17 title describe the study site as being study site 080295 (Oakwood). However, the 1st sentence of the 1st paragraph describes the study site as being 080075 (Romayor). Please check and correct as necessary. **– Changed to 080075 to "080295"**

SUGGESTED CHANGES

20. The 1st sentence of the 1st paragraph on page 36 states "During the greater riparian tree recruitment periods, three tree individuals were recruited in most of the age classes compared to one tree in the low riparian tree recruitment periods." Given the uncertainties of making predictions based on such sparse data, please consider providing some statement qualifying conclusions based on this data set and/or recommending collection of additional data in order to validate conclusions. **– Added "Despite a low number of total tree cores collected, the flow trends are consistent among age classes and data analysis suggests differences exist between periods evaluated. Additional tree cores should be collected in future riparian studies to better understand relationships between riparian recruitment and instream flows."**

21. Please consider plotting water surface elevations for flows that provide inundation to the riparian forest community in Figures 20 through 25 on pages 36-39 (mentioned in the text as ranging from 21,000 to 30,000 cfs). **– Done** Also, consider explicitly stating in the text or figure legend that water surface elevations for flows of 2,500 cfs, 3,000 cfs, and 7,000 cfs correspond to pulse flows currently in the standards for this location. **– Added note to captions:** "**Note: *XXXX* cfs, *XXXX* cfs, and *XXXX* cfs**

correspond to the SB3 pulses required for this site." *Comment to reviewer: (XXXX = appropriate SB3 flows for each corresponding site.)*

22. Section 3.3.4 on page 40 provides conclusions about the SB3 high flow pulse trigger values. These values are not introduced until Section 4 of the report. Please consider moving these conclusions to Section 4. **– Did not move due to congruency issues with the Riparian Section 3, but did add the following underlined text: "such as the SB3 high flow pulse trigger values, further discussed in Section 4, may also affect establishment"**

23. The National Weather Service (NWS) provides estimates of overbank flows at USGS gage sites number 08049500,08057000, 08065000, and 08066500. For example, for the Trinity River at Oakwood, USGS gage no. 08065000, NWS provides a value of 25,300 cfs as the flow when minor flooding occurs (see http://water-mo.weather.gov/ahps2/hydrograph.php?wfo=fwd&gage=lolt2&hydro_type=2). Please consider mentioning NWS's estimates of when flooding occurs to compare with and/or validate values provided for "What flow is overbank?" in Tables 8, 10, 12, and 14. **–**

Added bold text below to:

Table 8

National Weather Service Flood Triggers	**Minor – 16,350 cfs/Moderate – 25,200 cfs**

Table 10

National Weather Service Flood Triggers	**Not Available**

Table12

National Weather Service Flood Triggers	**Minor – 25,300 cfs/Moderate – 33,375 cfs**

Table 14

National Weather Service Flood Triggers	**Minor – 86,650 cfs/Moderate – 93,125 cfs**

Comment to reviewer: Gage data from this site is taken from TR below Dallas (not TR at Dallas which is the SB3 measurement point), which does not have a NWS rating.

24. Riparian analysis in this report identified flows that "begin to provide inundation to the riparian forest community." Please consider identifying other flows that may be of benefit to the riparian forest community, such as flow rates that will get within the rooting depth of mature trees, saplings, or seedlings. **- Added "Lower flow levels, such as the SB3 high flow pulse trigger values, may also may also affect establishment of trees in the riparian zone by affecting the water table. No water table data was measured to estimate how varying river flow levels may affect varying water table levels in this study."**