

Riparian Productivity along the Middle Trinity River

November 15, 2018

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Texas Conservation Science, Inc.
P. O. Box 150894, Austin, TX 78715-0894

Performed for:
Texas Parks and Wildlife Department
P.O. Box 1685 San Marcos, TX 78667

Texas Parks and Wildlife Department Contract No. 490954
Texas Water Development Board Contract No. 1348311645

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Abstract

This report covers the first task from the scope of work for this project (Task 1 – Riparian productivity along the middle Trinity River). The second task (Task 2 – Refinement of riparian productivity versus flow relationships for Texas rivers) is discussed in a separate report. Activities described in this report are (a) data collection along 16 transects (8 transects at each of two riparian study sites) and subsequent analysis and (b) inundation analysis for a 50-mile section of the middle Trinity River. Data collected along 50 meter (164 feet) transects was associated with snag-live tree, shrub-sapling, and herb-seedling vegetation layers. Inundation analysis was completed using satellite imagery (Landsat Thematic Mapper), US Geological Survey daily gage data, and habitat maps from the Texas Ecological System.

Significant findings from the analysis of riparian transect data include:

- The existing riparian tree community appears to be stable and diverse.
- Tree species that are tolerant of frequent and/or extended durations of inundation (black willow and swamp privet) are thriving relative to other riparian species.
- At the endpoints of transects (higher elevation, farther from the channel) species that are less tolerant of inundation appear to be less sustainable due to high mortality rates.

Significant findings from the inundation analysis include:

- Although some riparian habitats are inundated with flows as low as 1,150 cfs, flows of 10,400 cfs or greater are required to begin inundating larger areas of riparian habitat in the meander belt of the river.
- Flows greater than 21,000 cfs are required to inundate all riparian habitats within the meander belt of the river.
- Flows as great as 59,500 cfs are required to inundate all riparian areas along the 50-mile segment of river.

1. Introduction

Since 2009, Texas Conservation Science, Inc., (TCS) has measured the environmental-flow requirements to sustain riparian habitats, with an emphasis on declining riparian hardwood forests. The Middle Trinity River riparian assessment is a component of the Texas Instream Flow Program (TIFP), which is a cooperative effort of the Texas Parks and Wildlife Department (TPWD), the Texas Water Development Board (TWDB), and the Texas Commission on Environmental Quality (TCEQ). TCS's TIFP efforts have so far implemented eleven long-term riparian study sites mostly on private ranches and farms in the Guadalupe, Brazos, and Trinity River basins. With other funding from the Caddo Lake Institute and the Sustainable Rivers Program (U.S. Army Corps of Engineers [USACE], The Nature Conservancy [TNC]), TCS maintains six additional riparian research sites on Big Cypress Bayou and Little Cypress Bayou (Cypress-Caddo basin), above Caddo Lake in northeast Texas. In this manner, a total of 17 long-term riparian research sites within four Texas river basins utilize comparable methods for quantifying environmental flows for riparian resources.

This report covers task 1 of the scope of work, riparian productivity along the middle Trinity River. Funding for this report was provided by TWDB contract number 1348311645 through TPWD contract number 490954. Task 2, refinement of riparian productivity versus flow relationships for Texas rivers, is included in a separate report (completed December 31, 2018) focused upon riparian productivity in the Trinity, Brazos, and Guadalupe river basins (TWDB contract number 1600011933 through TPWD contract number 492283).

The combination of local and river-reach scales allows the assessment of status and connectivity within middle Trinity River riparian habitats, which is critical for the restoration and conservation of floodplain habitats (King et al. 2009). Similarly, Nilsson and Svedmark (2002) present riparian areas as complex non-equilibrium ecosystems functioning as multi-level floodplain networks extending down to the low-water mark of stream channels. Their literature review identifies three fundamental approaches for understanding riparian systems: (1) flow-regime control of plant productivity and ecological function, (2) riparian-corridor connectivity for material transport, and (3) species-rich linkages of land and water processes. To incorporate

integrative approaches for riparian stewardship, the current research combines quantitative plant ecology, remote sensing, and hydrology. The follow-up report in December 2018 quantifies linkages among riparian productivity and river flow.

1.1 Project Area

The primary project area is located in Anderson County within the Texas Gulf Coastal Plain, which, in terms of both area and population, is the most important region of Texas (Hudson and Heitmuller 2008). The extended riparian assessment covers a 50 river-mile study reach of the middle Trinity River near Palestine, Texas, including the primary project area consisting of two riparian research sites (Sites B and C) on TPWD's Big Lake Bottom Wildlife Management Area (BLBWMA), in Anderson County. Along with historical habitat inundation analyses of floodplain areas within the river reach, the assessment encompasses quantitative forest-plot inventories within the two sites.

The river at BLBWMA is 13-30 m (13-98 ft) wide, between sandy bluffs atop periodic sandstone outcroppings (Kleinsasser and Linam 1990), which support springs and seeps and lead to frequent bank sloughing (Figure 5). Phillips (2010) describes the river geomorphology of Trinity River Zone 10, which includes the BLBWMA riparian study area, as having a partially confined valley with medium to highly variable width of 5-8+ km (3.1-5.0 mi)), extremely low gradient (< 0.0002), moderate to strong meandering (1.5-3.0 sinuosity), and medium connectivity. The well-defined channel traverses a bottom consisting of a mixture of clay, silt, and sand, interspersed with infrequent gravel riffles (Kleinsasser and Linam 1990). The adjacent floodplain consists of deep clay soils of the Kaufman-Trinity Association (Coffee 1970).

Situated between the Pineywoods and the Post Oak Savannah vegetation regions of east Texas (Gould 1962), BLBWMA is one of the largest remnants of bottomland hardwood forest along the middle Trinity River. No longer containing the large parcel that included Big Lake itself, Figures 2 and 6 depict the current configuration of BLBWMA and the surrounding landscape. Compared to the surrounding conversion predominantly to pastureland, BLBWMA is relatively undisturbed, except for selective timber harvests in the late 1930s and early 1940s, and 65 ha converted to cropland in the 1950s (Fleming et al. 2002). Otherwise, serious erosion along

streams and other drainages is a continuing issue, caused by the widening of the Trinity River during water control and agricultural activities, and all-terrain vehicle traffic on BLBWMA (Fleming et al. 2002).

The next section (Section 2) summarizes peer-reviewed research on the ecology, flow requirements, and ecosystem processes within riparian habitats. Subsequent sections address methods, results, discussion, and conclusions. Data are presented as figures and tables in the appendices following Section 7 (Citations).

2. Riparian Habitats

High species diversity is characteristic of undisturbed riparian environments, due to their spatial and structural complexity, along with water and nutrient subsidies provided by a naturally variable flow regime. Such environments are a patchwork of swamp and riparian forests, shrub and herbaceous wetlands, and lentic and lotic aquatic habitats. Nearest the Trinity River, the active meander belt is dominated by early successional plant species, such as black willow, box elder, and cottonwood, which establish on recent deposits of alluvial sediments. On the floodplain immediately inland from the meander belt, sediment deposition during overbank floods raises the elevation of the near-channel floodplain and natural levees, which support sugarberry, cedar elm, bur oak, and other hardwoods. Within the floodplain farther from the channel, reduced sedimentation results in lower elevations that support backwater swamps, dominated by overcup oak, water hickory, etc.

Floodplain habitats exhibit fine-grained environmental gradients due to spatiotemporally variable flows and geomorphic disturbance during large floods. Floodplain habitats with different surface elevations are distinguished in terms of dominant species, due to dissimilar species tolerances to elevation-dependent regimes of inundation and soil saturation. In this manner, an elevation change of a few centimeters can lead to a change in dominant tree species. Therefore, the Trinity River riparian assessment relies largely on empirical methods (quantitative plot inventories, remote sensing, etc.) to accurately measure habitat inundation and productivity within the spatial complexity of riparian landscapes.

Interconnection of these riparian habitat patches via overbank flow is essential for sustaining productivity and related ecosystem functions (Thoms et al. 2005, Junk et al. 1989). In fact, river flow impacts riparian tree growth much more than climate. When researching connections between tree growth and inundation, Smith et al. (2013) showed that river flow and related soil moisture variables controlled forest productivity, not climate. Within Cache River riparian forests in Arkansas, intensive hydrologic studies revealed that river discharge accounted for more than 90 percent of the annual riparian water budget (Walton et al. 1996). These and other studies reveal that groundwater, precipitation, and evapotranspiration are insignificant contributions to riparian-forest water budgets, compared to river flow.

In addition to competitive outcomes among more and less flood-tolerant species, riparian plant communities vary according to geomorphology and soils. Consequently, the variable flow regime, in combination with the geomorphologic patchwork of microtopography and soil types, produces high species diversity in riparian habitats (Junk et al. 1989, McKnight et al. 1981). Unlike upland forests that typically have one or two dominant tree species, undisturbed riparian forests usually have a least twice as many tree species as nearby upland forests (Gosselink et al. 1981).

2.1 Riparian Forest-Flow Connectivity

Riparian plant and animal communities are determined by the intersection of available species and the local hydroperiod, as defined by frequency, timing, duration, and depth of inundation (Bedinger 1981, King and Allen 1996). In east Texas, the hydroperiod variable most important to riparian species composition is flood duration (Dewey et al. 2006). The competitive sorting of species during annual tree recruitment is mostly determined by the spring hydroperiod, due to its strong effect on germination and seedling establishment; however, the annual hydroperiod is more consequential for the long-term survival of riparian species (Townsend 2001).

Riparian forests depend on annual or nearly annual flooding. In the midwestern United States, undisturbed river and stream hydroperiods equal or exceed bank-full two out of three years

(Leopold et al. 1964, Mitsch and Rust 1984). Relatively unregulated rivers in the Mississippi/Red River region flood about once per year for about 40 days on the average (Gosselink et al. 1981). During their comprehensive study of the Ogeechee River in Georgia, Benke et al. (2000) found more than 50 percent of the natural floodplain to be inundated for a minimum of 30 days annually. On average, floods in larger floodplains have reduced flood frequency, but increased duration and seasonal predictability (Junk et al. 1989).

High flows and floods provide valuable ecosystem and societal functions, such as removing nutrients and organic matter, recharging alluvial aquifers, increasing biological and agricultural productivity, sequestering carbon, providing recreation, reducing storm damage, and filtering and redistributing sediment load (Hunter et al. 2008, Opperman et al. 2009). Increasingly important environmental and economic benefits peak with annual flooding, including biological productivity, wildlife use, organic matter export, and improved water quality (Gosselink et al. 1981, Hunter et al. 2008, Opperman et al. 2009).

The sustainability of riparian forests depends upon overbank flows. For many riparian plant species, seed germination and seedling establishment must follow floods severe enough to remove existing vegetation and create new seedbeds from bare soil (Rood et al. 2005). Floods also distribute seeds and vegetative propagules to reestablish plants across the floodplain (Bendix and Hupp 2000). The timing of seed dispersal and germination varies by tree species, so that the spatial and temporal variation of forest-reviving floods creates riparian forests as patchworks of different ages and species compositions (Hughes and Rood 2003).

To sustain or restore forest regeneration, environmental flows should: (1) schedule inundation to match the phenology (seed dispersal and germination) of target tree species, (2) vary the inter-annual timing of floods to increase plant diversity, (3) slow the rate of flood-water recession to promote seed germination and seedling viability, and (4) promote new scour and sedimentation sites to create regeneration sites (Hughes and Rood 2003, Rood et al. 2005). The stream-stage elevation should not decline faster than the average rate of seedling root growth, which Hughes and Rood (2003) measured as less than 2.54 cm (1.0 in) per day for cottonwood in western North America.

In addition to regenerating riparian species, overbank flows need to be frequent and long enough to exclude upland species. Townsend (2001) found that prolonged inundation, when possible during wet years, best maintains riparian species composition, largely due to increased mortality of upland species. To control upland tree species, Gosselink et al. (1981) found that the total duration of intermittent flooding should exceed that of continuous flooding. To be most effective, both in terms of maintaining riparian tree species and discouraging invasive upland species, the duration of early spring floods following leaf emergence should be 2-4 weeks (Gosselink et al. 1981).

Long-term reductions in peak river flows, due to drought and reservoir operation, reduce competition by native species unsuited to the drier conditions, so that both native and exotic habitat generalist weeds benefit (Catford et al. 2011). By means of population modeling and network theory, Tonkin et al. (2018) determined that the most adverse consequence of flow regime change on riparian plant communities is flood reduction. Communities connected by a natural flood regime maintain high biological diversity, and are both more resilient to species loss and more resistant to encroachment by generalist species and exotic weeds.

Drought affects the species composition and spatial distribution of recruitment through extensive seedling mortality at middle and high elevations in the floodplain, in combination with increased establishment at low elevations (Cooper et al. 2003). Exacerbated by climate change, the drier conditions promote invasion of riparian habitats by both native upland and exotic species. In this manner, riparian habitats are becoming more terrestrial, with the increasing dominance by introduced species dependent on minimal flooding (Catford et al. 2011).

In Figure 1, the five major riparian forest-flow guilds and other wetland types within the middle Trinity River assessment area are schematically summarized according to surface elevation, morphology, dominant species, and hydroperiod variables. In this way, flood duration and frequency targets are provided, as necessary to identify and maintain the primary riparian habitats within the area.

2.2 Riparian Productivity

Merging overbank flows with high species diversity maximizes primary and secondary production in riparian forests (Bayley 1995). With primary production exceeding 1000 g/m²/y (Conner et al. 1990), riparian forests with naturally variable hydroperiods are ranked among the most productive wetland ecosystems. In their literature review, Conner et al. (1990) correlated riparian forest productivity peaks with annual floods in winter and early spring.

When measured in two-year timeframes, Anderson and Mitsch (2008) showed that annual tree productivity and flood duration exhibit a statistically significant, positive relationship. However, they found that this relationship is not statistically important for single-year measurements. Prior growing conditions are important, since most tree growth occurs early in spring, and, therefore, depends upon stored energy from the previous growing season. Current-year flooding also influences growth.

Local and downstream water quality is impacted by the health of riparian forests. One of the most important benefits of riparian forests to society is increased water quality. Naturally variable river flows increase the capacity of riparian forests to remove nitrogen (N) and phosphorus (P) from floodwaters (Ardon et al. 2010). Broad, well-connected floodplains, like those adjacent to the BLBWMA study sites, prolong flood retention so that large nutrient pulses during storms are absorbed, reducing downstream pollutant loads.

Successive aerobic and anaerobic soil environments are created in riparian habitats during flood cycles. Nitrification is an aerobic, dry-cycle process during which oxidizing microbes convert ammonia to nitrate. During the next wet period, anaerobic soil conditions boost denitrifying bacteria, which transform the newly available nitrate to N gases such as nitrous oxide. The overall result is lower N concentrations in the river.

Similar to seedling establishment, the rate of drawdown following a flood is likely more important to watershed productivity than how rapidly water levels increase (Bayley 1995). In addition to the rates of rise and fall, the timing of overbank flows relative to rising temperatures

influences in-channel productivity. Since most floods in the southeastern United States occur in winter or spring, water temperatures are more conducive to high biotic productivity during drawdown, rather than during rising water levels.

The timing of overbank flows relative to rising temperatures also influences biological functions (Bayley 1995). When the post-flood infusion of carbon and nutrients from riparian habitats coincides with warming spring temperatures, the productivity of in-stream and other downstream habitats, including estuaries, is magnified. Significantly more organic matter and detritus are exported by retreating winter and spring floods in east Texas, compared to summer floods (Gosselink et al. 1981, Junk et al. 1989). The productivity and diversity of aquatic macrophytes are also greater after spring floods, compared to after summer floods (Robertson et al. 2001).

For fish and other biota, the primary function of the main river channel is not production, but is access to adjacent floodplain resources, especially during overbank flows. Such access is critical, since almost all biomass within riverine systems is produced within floodplains, not river channels (Junk et al. 1989). For instance, even for smaller streams, 67-95 percent of invertebrate production takes place in the floodplain, not the stream channel (Smock et al. 1992). Consequently, many researchers find that bird, mammal, and fish populations decline in riparian ecosystems, when flood frequency decreases (Gosselink et al. 1981).

When the area of accessible floodplain expands, fish production increases (Junk et al. 1989). For instance, fish spawning is often coordinated with rising floodwater, with spring spawners targeting the seasonal coincidence of rising floodwaters and warmer temperature. Similar to the effect on tree recruitment, good fish recruitment depends on the gradual retreat of flood waters during the warm growing season (Junk et al. 1989). A slow drop in water levels also allows invertebrate prey populations, which increase due to coincidental nutrient runoff, to reach higher densities. Bayley (1995) documented that the earlier and briefer overbank events in recent decades, largely due to anthropogenic floodplain disturbance, disrupts the evolutionarily synchronized timing of fish spawning and invertebrate prey availability.

3. Methods

Figure 2 depicts the general project vicinity, and the boundaries for both the BLBWMA study area and the 80.47 X 6.44 km (50 X 4 mi) inundation study reach area. A brief photographic overview of the study area is presented in Figures 3-5, including a black willow streamside stand, a bottomland hardwood stand, and ongoing geomorphic disturbance (bank sloughing) within the river channel. The images are discussed in Section 4. Figure 6 is the location map for the two study sites for quantitative plant inventories within BLBWMA, while Figures 7-8 are more detailed maps of the two study sites (B & C) and their vegetation-transect locations. Each study site contains a total of eight 50-m (164 ft) transects.

3.1 Forest Inventory

3.1.1 Field Methods

The following vegetation measurements are taken along the 50-m (164 ft) transects. Transect coordinates are provided in Table 3. The tape measure is extended 50 m (164 ft) into the riparian forest from the Mean High Water Mark (MHW) in the direction determined to be perpendicular to the river channel. In the field, the MHW is delineated as the lowest streamside extent of permanent woody vegetation. The tape is kept tight, straight, and level.

Tree Layer: Macroplot Method:

Snags and live trees: The tree layer consists of all live and dead (snags) woody species with a Diameter at Breast Height (DBH) greater or equal to 5.0 cm. For multi-stemmed woody species, trees are defined as having a least one stem ≥ 5.0 cm DBH, in order to be included in this layer. A snag is defined as a standing dead tree with an angle equal to or greater than 45° to the horizontal. Dead trees with an angle less than 45° are downed woody debris, which are not included in this method and therefore not recorded.

Several measurements are recorded for all snags and live trees ≥ 5.0 cm DBH throughout each 50 m X 10 m (164 ft X 32.8 ft) macroplot. The species name, DBH, and position of each tree is recorded along the central 50-m transect, as well as the perpendicular distance from the transect position to the tree. Also recorded is whether the tree is left or right of the center transect, when facing the 50-m (164-ft) endpoint of the transect. These data allow one to relocate each tree, and if necessary construct a tree map for each macroplot. The data also allow the basal area, frequency, and density of tree species to be calculated on a per hectare basis, as described in Section 3.1.2.

In the USA, DBH is defined as the average stem diameter, outside bark, at 1.37 m (4.5 ft) above the ground on the uphill side of the tree, disregarding any bark-litter mound at the base of tree. For consistent measurement, the steel diameter tape must be level and pulled taut, while avoiding bumps, stubs, and other outer bark and bole irregularities. For multi-stemmed woody species, trees are defined as having a least one stem ≥ 5.0 cm DBH, in order to be included in this layer. More than one DBH may be recorded for each multi-stemmed tree. Only stems ≥ 5.0 cm DBH are recorded.

The following procedure for measuring DBH of irregular trees is modified according to Avery and Burkhart (2001). When swellings, deformities, or branches occur at 1.37 m (4.5 ft) above ground, DBH is measured above the irregularity where normal stem form ceases to be affected. If trunk forks immediately above DBH height, DBH is taken immediately below swelling caused by fork. For forks below true DBH, each stem is normally measured at DBH above fork. The exception is when normal DBH height is too close to fork so that it is influenced by swelling associated with the fork, in which case the DBH is measured immediately above such swelling. For swell-butted stems, DBH is measured above swell if swell is at normal DBH height. When you encounter a trunk that forks below DBH, DBH is measured for each of the forks of the stem.

The vigor class is recorded as % dead canopy volume. Modified from the Braun-Blanquet cover-abundance scale (Mueller-Dombois and Ellenberg, 1974), the six vigor class codes are based on % dead-crown volume relative to potential crown volume (including any broken top). As defined below, the lower the vigor class the fuller and healthier the live tree crown:

Code	% Dead Canopy Volume	Code	% Dead Canopy Volume
6	> 95	3	26-50
5	76-95	2	5-25
4	51-75	1	< 5

For snags, the decay class is recorded in order to estimate the time of tree death. The following decay-class codes emphasize branching characteristics over all other characteristics:

- 1 = all fine branches present;** normally pointed top, all bark remaining, sound sapwood, hard heartwood;
- 2 = no fine branches,** normally few large branches, usually broken top with main bole unbroken;
- 3 = all or most coarse branch stubs present,** but not branches, usually broken top with main bole unbroken;
- 4 = few branch stubs,** usually broken top with main bole unbroken;
- 5 = no branch stubs,** usually broken top with main bole unbroken;
- 6 = broken main bole,** no branch stubs;
- 7 = decomposed,** emphasize no branch stubs, broken main bole;
- 8 = fallen,** no branch stubs, broken main bole;
- 9 = stump.**

To determine individual-tree competitive status, the crown class for live trees is also recorded on the field sheets, as follows:

- S: Suppressed (crown completely over topped with none exposed to direct sunlight).
- I: Intermediate (less than half of the top of the crown exposed to direct sunlight).
- C: Co-dominant (more than half of the crown top exposed to direct sunlight, but none of the sides of the crown).
- D: Dominant (the top and much of the sides of the crown fully exposed to direct sunlight).

Forest Canopy Cover: Spherical Densiometer Method: The instrument is held level, 30.5 cm - 45.7 cm (12 in – 18 in) in front of the body and at elbow height, so that operator's head is just outside of grid area. The operator assumes four equally spaced dots in each square of the densiometer grid, and systematically measures canopy cover based on the number of dots that intercept the overhead canopy. In this manner, with the operator sequentially facing North, East, South, and West, four sets of readings of the densiometer grid are recorded at the 15-m (49.2-ft) and 35-m (114.8 –ft) points along the transect. The average value is calculated for the four sets of canopy hits at each point, then multiplied by 1.04 to estimate percent of forest canopy cover at each point.

Shrub-Sapling Layer: Line-Intercept Method:

The shrub layer is defined as live woody species 0.1-4.9 cm DBH including tree and shrub species. For multi-stemmed woody species, the DBH of all stems must be < 5.0 cm to be included in this layer.

A tape is used to measure 50 m (164 ft) into the riparian forest from the MHW. The bearing of forest transects is perpendicular to the river channel. The tape is kept tight, straight, and level to the ground surface. The total intercept length for each species is determined within each 5-m increment. Intercept length is that portion of the transect length intercepted by the plant, as measured by a vertical projection of its circumscribed canopy that overlaps the line. For each species, total intercept length to the nearest cm is recorded. Total canopy cover for all species may exceed 100%, due to multi-layers shrub canopies.

Herb-Seedling Layer: Point-Transect Method

The herb layer is defined as all herbs of any height plus woody seedlings 0.01-1.37 m tall, and is quantified using the point intercept method. Along the central 50-m transect in each 50 m X 10 m macroplot, interception is measured at 51 points (0-50 m), recording the number of all contacts between plants (leaves, stems, etc.) and the tip of a narrow (2-mm diameter) pin passed into the vegetation. The pin must be kept vertical and on point. A plumb bob is used to establish

a ground reference point at each point, using a polished aluminum nail head as a target to direct the pin. The pin is kept vertical as it descends and/or ascends through the vegetation, using a pin level and point densiometer. The point densiometer is especially useful when extending the point vertically to intercept tall herbs such as giant ragweed.

At each point the uppermost hit is tallied separately from further hits along the vertical projection until the ground is hit. Multiple vertical contacts with vegetation, including with the same species and/or individual plant, at a given point are recorded. In addition to canopy cover of leaves and stems, ground cover is recorded at each point according to the categories listed in the table below. As described in Section 3.1.2, the summed number of hits is used to estimate plant cover, leaf area, and ground cover.

BM	Bare mineral soil
BR	Bare rock
FF	Forest floor (organic litter layer)
MB	Moss on bare mineral soil
MR	Moss on rocks
MW	Moss on dead decaying fallen wood
NV	Other notable non-vegetation feature (identify)
VW	Other vegetated wetland (sedges, etc.)
RT	Root tip-ups
S	Snag
SWD	Semi-wet depressions (sparsely vegetated)
TB	Living tree or shrub bole
WD	Wet depressions (non-vegetated, gray/gley litter)
WD-C	Woody debris, coarse (> 20 cm dia.)
WD-F	Woody debris, fine (0.5 < 10 cm dia.)
WD-M	Woody debris, medium (10 < 20 cm dia.)

3.1.2 Data Analysis

All field data were analyzed in Microsoft Excel using standard ecological calculations. This information was then summarized to determine the most important species for each vegetation layer, transect, and site. Percent cover, frequency, and density were calculated where applicable, and then used to attain percent relative values for each species in comparison to the other species present within each transect and site. These percent relative values were ultimately used to find

the percent relative importance of each herbaceous, shrub, and tree species within each transect and site.

Tree Layer:

Tree field data were summarized in Microsoft Excel for each 50-m transect. DBH measurements, taken in the field for each individual tree located in the 50 m X 10 m transect, were used in calculating basal area in square meters per hectare (m^2/ha). These calculations were performed separately for snags and live trees. Frequency of distribution was also determined for individual species present on each transect. This was done by evaluating distance from the 0-m pin and plotting presence or absence in each 5-m segment of the 50-m transect, resulting in possible frequencies of 0-100% with 10% intervals. Frequency was also calculated in the same manner for all snags. Next, density was calculated for each transect. This was done by dividing the total number trees for a given species, by the area ($500 m^2$) of the plot, then converting the density to the number of trees per species per hectare. This was done for both snags and live trees.

Percent relative values for basal area, frequency, and density were then calculated for each species within each transect, in the same manner as described above for the shrub layer. Percent relative importance was then calculated for each species by averaging its three percent relative values.

Forest Canopy Cover:

Field calculations for the spherical densiometer method are described above. Average percent canopy cover values for each transect and site were subsequently tabulated.

Shrub Layer:

Data were collected from the shrub layer using the line-intercept method. Within each 5-m increment, percent cover was calculated by dividing the total intercept length of each species by 500 cm. Percent frequency was calculated for each species based on how many of the 5-m segments contained that species, out of the ten total segments. Total percent cover and frequency

values for each species were determined for each transect. Averages were then calculated for each species across all eight transects. Percent relative cover and percent relative frequency were then calculated for each species within each transect. These values are determined by dividing the percent cover or frequency of that species by the total percent cover/frequency of all species in that transect. Percent relative importance was then calculated by averaging percent relative cover and percent relative frequency.

Herb Layer:

The point-intercept method was used to collect cover data for herbs and woody seedlings, in order to calculate percent cover and percent frequency for each species. Percent cover was calculated based on the total number of hits tallied for each species, divided by the total number of intercept points per transect (51). Percent frequency for a species or ground-cover attribute is determined by dividing the number of points where it occurs by the total number of points (51).

The total cover of vegetation or ground attributes for a given transect is determined by adding the cover percentages for all plant species or ground attributes, respectively. Total cover values for a site are determined by similarly adding transect totals and dividing by the total number of transects. These transect and site totals for percent cover may exceed 100 percent if multiple hits (overlapping canopies) are recorded at each point.

Percent relative cover by species or ground-cover attribute, is calculated by dividing the percent cover for each species or ground-cover attribute by the total cover for all species or ground-cover attributes, respectively. Similarly, percent relative frequency for a species or an attribute is provided by dividing the percent frequency for a given transect by the transect total for all species or attributes. For the herb layer, percent relative importance for each species or attribute is the sum of its percent relative cover and percent relative frequency divided by two.

3.2 Inundation Analysis

The methodology directly measures habitat inundation. Transitions among riparian habitats and from wetland to non-wetland floodplain communities can occur with an elevation change of only a few centimeters (Alldredge and Moore 2012). Therefore, the following empirical approach may more accurately delineate wetted surfaces within the geomorphic complexity of riparian areas. In this manner, quantifying the wetted surface created by a given river stage provides a direct estimate of the affected elevations and habitat areas within riparian areas.

3.2.1 Flow Event Selection

Historical U.S. Geological Survey (USGS) daily stream flow records (1982-present) were analyzed to select flow-event dates for wetted-surface classification of Landsat data. Table 2 lists information for the Oakwood USGS stream gage (# 8065000), including the period of record and distances to the two BLBWMA riparian study sites.

To avoid imagery obscured by canopy cover, only flow events during the leaf-off period between mid-December and mid-March were considered for wetted-surface analysis. To avoid error due to previous inundation lingering on the floodplain, none of the selected event days experienced higher flows during the preceding three days. In this manner, the selected days were limited to periods of rising or stable flow. No dates were selected during a period of declining flows. Primarily due to issues with gaps within Landsat scenes and cloud cover, less than 0.5 percent of examined dates had usable Landsat data.

3.2.2 Wetted-Surface Classification

Environment for Visualizing Images (ENVI) and Environmental Systems Research Institute (ESRI) ArcGIS software were used to map wetted-surface based on each suitable Landsat TM scene. All classifications follow the same step-wise methodology, as described below.

Wetted-Surface Mapping:

1. Download the acquired Landsat TM scenes for specified dates. Load the band 5 image in TIFF format.
2. Mask the study reaches. The mask is created from a 51X5-mile buffer of the study reaches and saved as a shapefile via ESRI ArcGIS.
3. The Landsat TM images covering the study reaches are classified into two thematic classes using the ENVI color slicing process. The minimum threshold is two. The original maximum threshold is 27. The maximum threshold varies from 27 to 67. Increase the maximum threshold until the wetted-surface class is clearly separated from non-wetted-surface class. Convert the two-class thematic image into shapefile format via ESRI ArcGIS.
4. Two thematic classes are then assigned to either wetted-surface class or non-wetted-surface class by visual interpretation using the raw image in bands 4, 3, and 2.
5. The resulting two-class image is re-coded using the ESRI ArcGIS Raster Editor tool. The ESRI ArcGIS Eliminate tool is then run on the two-class image. The ESRI ArcGIS Eliminate tool is used to remove all groups of pixels less than one hectare in area, those areas smaller than one hectare are assigned the value of nearby larger class.

Quality Control:

1. Create a set of random points within the thematic classified area and assign the two-class code to each individual point via visual interpretation for referencing.
2. ESRI ArcGIS Spatial Selection is run on the random points using the wetted-surface and non-wetted-surface polygons separately. Assign the class information to the set of random points above.

The accuracy estimate is the ratio between the number of “error” wetted-surface (non-wetted-surface) points and the actual wetted-surface (non-wetted-surface) points.

3.3 Geographical Information System

ArcGIS ArcMap 10 was used to calculate inundation acreages for each TPWD Texas Ecological System (TES) type (Elliott 2009, Elliott et al. 2014) within the specified study reaches by overlaying final wetted-surface shape files based on suitable Landsat TM scenes. TES types are also called habitat types in this study.

The first step was to acquire suitable TPWD Texas Ecological System (TES) shapefiles for each study site (<https://tpwd.texas.gov/gis/data/downloads>), prepare study-reach shapefiles, and acquire previously prepared wetted-surface shapefiles for specified dates.

To compensate for channel meander, study-reach area shapefiles were created for each site, including gaps created for meanders moving more than 50 m laterally over the approximately three-decade long study period (Figure 2). To ensure channel position accuracy throughout the project, TWDB river channel (<http://www.twdb.texas.gov/mapping/gisdata.asp>) position is updated and adhered to the position indicated by TES “open water” data. Next, for meander channel position comparison, first and last Landsat Thematic Mapper (TM) shapefiles showing inundation were overlaid. Next, meanders were located where both a clear channel is outlined and there is a recognizable shift in location of banks between the two dates. Meanders were numbered for identification and future comparison to evaluate importance. Additionally, 1982 National High Altitude Photography (NHAP), 1988 National Aerial Photography Program (NAPP), 1996 Texas Orthoimagery Program (TOP), and 2014 National Agriculture Imagery Program (NAIP) color infrared imagery was referenced to compare meanders throughout the study period and further verify movement.

Using the ArcGIS Measure tool, first and last Landsat TM inundation shapefiles were overlaid and distances between well-defined banks of each meander were measured. For each meander that moved 50 m or more, the following steps were used: using the Split tool in ArcMap in

conjunction with the TWDB river shapefile, the length attribute (set to miles) was measured for selected meanders, then the Buffer tool was used to create polygon shapefiles to identify channel positions for future reference. Using a study-reach shapefile of 50x4 miles as a template, the Line Construction tool was used to create parallel lines to exclude selected meanders from the study area. These lines were perpendicular to the channel when possible, as well as parallel to the first line placed. Due to the exclusion of selected channel meanders, the decrease in study reach length was tabulated and added to any channel segment in the area affected by the exclusion of a selected meander, in order to maintain the total 50-mile length of the study reach.

The gap-modified study-reach shapefile was then created, using the Split tool on each half upstream (US) and downstream (DS) of the center point of the selected meander. The Split tool was set to 25 miles plus new increased length. US and DS lines were then combined after which the Buffer tool was used with distance set to 2 miles and “dissolve all” option selected to create new study reach polygon. Next, additional buffers were created with distances set to 0.5 and 1 mile to measure inundation distance incrementally from channel. Cut Polygons tool was used on the new study reach polygons with lines from the previous meander-based line construction step as templates. Resulting gaps were deleted from the study reach polygon. Any rounded ends were removed from study reach polygons by using similar method, as in previous steps. After the above meander-gap analysis, channel meander (1982-present) was found to be very minimal in the Middle Trinity River study reach and easily corrected by excluding two short gaps in the Landsat data.

In order to measure area of inundation, first TES data were clipped into the study-reach area polygon created in the previous step. When multiple TES data sets were required for the study area, the Merge tool was used to combine into one after clipping. To tabulate acreages, an attribute field in the TES attribute table named “area” was created and set to calculate area in hectares.

Using shapefiles created from incremental buffers of 0-0.5 mi, 0.5-1 mi and 1-2 mi (0-0.8 km, 0.8-1.6 mi, and 1.6-3.2 mi) extending from the river centerline located within the study reach, the Clip tool was used to apply TES data to each incremental sub-reach.

The Intersect tool was used to choose a Landsat wetted-surface shapefile and the incremental TES shapefiles as inputs, in order to determine which habitat types were located in the same position as the wetted-surface data for that increment.

For each incremental intersect, ArcMap's Summary Statistics tool was used to summarize area data. Using Summary Statistics, the newly formed intersects' Statistics field was set to the previously created area attribute and the Case field set to Common Name. Summary results were opened and acreages transferred from ArcMap into an Excel spreadsheet. The Summary Statistics tool was also utilized when tabulating total habitat areas for study sites by using the previously clipped TES data as input with no wetted-surface intersect.

4. Results

4.1 Riparian Forest Inventory

Table 1 provides an annotated list of 91 representative plant species identified during quantitative surveys within the two study sites. The list includes scientific and common names, wetland indicator status, family, environmental information, growth form, and relative abundance for each of the study sites. Eighty-two (90.1%) of the listed species, which include the most common species within the forest macroplots, are wetland indicators. Though only common names are used in the narrative sections, all plant inventory tables list both scientific and common names for cross-referencing.

4.1.1 Tree Layer

Habitat Overview

Riparian forests include forested wetlands (swamps) at lower elevations and riparian forests (seasonally and temporarily flooded forests) at higher elevations (Figure 1). Within the study areas, black willow lower swamps occur primarily within the meander belt at low surface

elevations near the edge of the river (Figure 3). These discontinuous forest stands are inundated during large portions of the growing season every year, and may be only intermittently exposed adjacent to the river channel. At Palestine near BLBWMA, the growing season is March 24 – November 12 (freeze-free period), according to the Texas State Climatologist (2010).

Slightly higher elevations within the riparian corridor support upper swamps (Figure 1), which are intermittently or semi-permanently flooded (more than two months during the growing season). In the study area, these swamps usually occupy the frequently flooded area between the first and second levees. Upper swamps also occur in low-elevation swales and backwater areas often at some distance from the river channel. Following overbank flow events, these backwater swamps, lying within the active floodplain farthest from the river and often adjacent to transitional upland slopes, may be inundated longer than all but the streamside lower swamps. Upper swamps are typically inundated every year for two or more months during the growing season. In addition to black willow and box elder, the mix of dominant species may include overcup oak, swamp privet, water hickory, green ash, and cottonwood, depending on local hydroperiod.

Riparian forests include seasonally flooded and temporarily flooded forests (Figure 1). The probability of seasonally flooded riparian forests being flooded in a given year is 51-100 percent (Huffman and Forsythe 1981). When the natural hydrologic regime is relatively intact, these forests flood a total of 1-2 months (12.5-25 percent) during the growing season. Species composition of seasonally flooded forest is diverse, and within study sites is often dominated by various combinations of cedar elm, green ash, sugarberry, box elder, slippery elm, roughleaf dogwood, American elm, and other species.

With an annual flood probability of 11-50 percent, temporarily flooded forests at higher floodplain elevations experience a total growing-season flood duration of 5-30 days or 2-12.5 percent (Figure 1; Huffman and Forsythe 1981). Tree species diversity in temporarily flooded forests is relatively high, and in BLBWMA includes sugarberry, cedar elm, bur oak, Osage orange, deciduous holly, cottonwood, and honey locust.

Data Summaries

Inventory data for the tree layer at the two sites are summarized in Tables 4.1-4.2, while more detailed transect data for the tree layer are presented in Tables 5.1-5.2. For each live and dead tree species measured in the 50 m X 10 m (164 ft X 32.8 ft) macroplots, these tables list species data for basal area (m²/ha), frequency per 5-m increments, and density (trees/ha), along with percent relative values for basal area, frequency, density, and overall importance. In the two sites, swamp privet, black willow, green ash, sugarberry, and cedar elm are the most important riparian tree species within 50 m (164.04 ft) of the MHWM. The top three most important tree species in order of importance at each site are:

Site B: black willow, swamp privet, sugarberry

Site C: swamp privet, black willow, green ash

All of these dominant tree species are wetland indicators, as are almost all trees found within the BLBWMA. These species depend upon overbank flows and/or high water tables.

Table 6 tallies the percentage of snags versus live trees based on basal area within each study site, in order to examine the viability of riparian tree species under the current flow regime. Site B and site C have four and one species, respectively, with a high mortality rate. Based on live-tree importance values and percentage of snags, the least sustainable tree species at site B is sugarberry, a dominant species adapted to drier upper elevations in bottomlands. At site C, green ash, also a dominant species but adapted to wetter soils at lower elevations without extended inundation, has the highest mortality rate. These mortality results indicate that tree species composition may be adapting to recent decreases in the occurrence of inundation at higher elevations, and increases in flood duration at lower elevations, within riparian forests at the BLBWMA riparian sites. This interpretation is supported by the most dominant tree species with the lowest mortality rates at the two sites (swamp privet, black willow) having the highest flood tolerance and occupying the lowest elevations near the main river channel. The possible implications of this mortality pattern are discussed in Section 5.1, in terms of changes in the high-pulse flow regime.

Percent forest-canopy cover is recorded as transect and site averages in Table 7. Though individual transects vary widely (53.5-99.5%) in canopy cover, site averages are very similar (80.3-83.4%), which may be due to similar disturbance regimes.

4.1.2 Shrub-Sapling Layer

Tables 8.1-8.2 summarize site B and site C data, respectively, for canopy cover, frequency, and relative importance for species within the shrub-sapling layer. In both sites, by far the most dominant species is swamp privet, with green ash a distant second in importance. Site averages for total shrub-sapling canopy cover are similar (22.2% and 26.3%), although for individual transects it is extremely variable. Total shrub-sapling cover for different transects ranges from 0.8-92.3% in site B, and 7.3-45.1% in site C (Tables 9.1-9.2).

4.1.3 Herb-Seedling Layer and Ground Cover

The forest layer with the highest species diversity is the herb-seedling layer. Tables 10.1-10.2 organize herb-seedling data as site summaries, while Tables 11.1-11.2 do so by transect. Important herb species include Cherokee sedge, bushy American aster, American buckwheat vine, Virginia wild rye, and marshelder. The most important species among woody seedlings are box elder, black willow, cedar elm, swamp privet, and sugarberry.

Table 12 summarizes the ground-cover transect data. The most prevalent ground cover is forest floor consisting of woody organic litter derived from decomposed leaf and twig material. Forest floor has overall relative importance values of 84.8% (site B) and 76.7% (site C). Bare mineral soil is the other common forest-floor type, with relative importance values of 12.5% (site B) and 18.9% (site C).

4.2 Habitat Inundation

Habitat inundation was determined for sixteen event dates (1983-2015) for the Trinity River assessment reach (Table 13-14), for Mean Daily Discharge (MDD) values of 1,150--59,500 cfs (32.6-1,684.9 m³/s).

Within the 80.5-km (50-mi) river study reach (Figure 2), inundation was measured 3.2 km (2.0 mi) from the river channel centerline, for a total width of 6.4 km (4.0 mi). In this manner, the area and percent of inundation were measured for all habitats across 36,577.5 ha (141.2 sq. mi.) within the study area. During the wetted-surface classifications, habitat inundation connected to (a) the main river channel and (b) total floodplain inundation were separately quantified. Though the wetted-surface Landsat classifications covered the inundation study area, channel-connected inundation did not occur farther than 0.8 km (0.5 mi) from the river centerline for any flow event.

Summary habitat-inundation results are presented as tables (Tables 13-14), graphs (Figures 9-10), and maps (Figures 11-17), with both summary and detailed habitat-inundation data also available in the companion spreadsheets. With an emphasis on bottomland habitats, but also including upland and disturbed habitats, Tables 13 and 14 present summary data for channel-connected and all inundation, respectively, within the study reach.

Figures 9-10 (channel-connected and all habitat inundation, respectively) are summary graphs of habitat inundation (ha) versus mean daily river discharge (cfs), for herbaceous wetlands, bottomland forests, and total bottomland habitats.

To aid visualization, maps of channel-connected and all inundation, respectively, include Figures 12 and 15 (1,530 cfs MDD), 13 and 16 (21,000 cfs MDD), and 14 and 17 (36,800 cfs MDD). The full array of floodplain, upland, and disturbed habitats are depicted. The habitat-type legend for the inundation maps is Figure 11.

Despite the examination of Landsat imagery for hundreds of flow-event dates identified in the USGS stream-gage data, no usable Landsat imagery was available for events above 36,800 cfs MDD, within the leaf-off period (December 15-March 1) from 01/01/82 through 03/01/16. The paucity of usable Landsat data during flood events is a frequent issue due to storm-related cloud cover, and is exacerbated by the long-malfunctioning Landsat 7 satellite. Since the satellite's Scan Line Corrector failed in May 2003, coverage gaps further limit usable Landsat data.

In order to include larger floods in the wetted-surface classification, two flow events outside the leaf-off period were selected: 46,800 cfs MDD (03/16/01) and 59,500 cfs MDD (12/04/15). During these two events, inundated area is accurately measured within non-forested habitats such as herbaceous wetlands. However, the detection of inundation within bottomland forests is less than is actually the case, due to interfering canopy cover during the two leaf-on overbank events. Due to the increased occurrence of bottomland forest in areas that experience channel-connected inundation, these leaf-on overbank events are excluded from summaries of channel-connected habitat inundation (Table 13, Figure 9).

The two leaf-on overbank events are included in the all-habitat inundation summaries (Table 14, Figure 10), in order to illustrate the phase shift in increased all-habitat inundation at the higher discharge rates. However, it is important to note that the sharp rise in inundated area above 36,800 cfs MDD is actually significantly greater than measured, due to unmeasured bottomland-forest flooding caused by canopy cover. This deficiency is clearly visible in Table 14 and Figure 10.

Despite the above limitation, channel-connected inundation expands until MDD exceeds 21,000 cfs, which may correspond to the filling of the incised meander belt. The total inundation rate accelerates at approximately this same discharge value (21,000-23,600 cfs MDD). Above these discharge values, the suddenly rapid increase in the rate of flooding provides further evidence for the initiation of overbank flows out of the meander belt, and a phase shift as the water surface quickly extends across the wider floodplain. The stage of accelerated inundation continues at least until 59,500 cfs MDD, the highest discharge rate for which the wetted surface could be classified.

5. Discussion

5.1 Riparian Forest

Table 1 provides information concerning plant species inventoried within the BLBWMA macroplots, which is useful in interpreting overall forest health. However, the 91 listed species are limited in number, due to fieldwork during single season (fall) and a focus on quantitative methods within only 16 macroplots. A more extensive survey, in terms of both area and seasons, would list additional species. For example, a multi-year inventory of vegetation surrounding the two study sites in BLBWM identified 459 species, 298 genera, and 99 families, including 23 (5%) non-native species (Fleming et al. 2002). This diversity of plant species may be explained by an earlier inventory along the length of the Trinity River basin (Nixon et al. 1990), which applied the Shannon-Weiner Diversity Index to 53 sampled plant communities. With this systematic approach, Nixon et al. (1990) confirmed their hypothesis that decreased water stress increased plant diversity in the moist middle Trinity River basin, compared to both the drier upper basin and the wetter lower basin.

Nixon and Willett (1974) inventoried trees and shrubs within five bottomland hardwood sites near BLBWMA. The sites were located near Big Lake 2-5 km (1.2-3.1 mi) north of BLBWMA. The overall dominant species recorded by Nixon and Willett (1974) was cedar elm, with overcup oak and green ash also important dominants. Other dominants included hawthorn, sugarberry, swamp privet, and water locust. Like other prior plant inventories in the Trinity River basin, Nixon and Willett (1974) highlighted plant communities on the floodplain terrace and its drainageways above the active meander belt, where species and structural composition of riparian forests is much more in flux.

Based on dominant species, topographic position, and soil water content, Fleming et al. (2002) delineated eight forest alliances (National vegetation classification system-Oklahoma-Texas subset 1997) on BLBWMA. The most common alliances are Overcup Oak (Water Hickory) Seasonally Flooded, Sugarberry-Cedar Elm Temporarily Flooded, and Bur Oak-Shumard Oak.

Relatively common on bluffs and high terraces near the river, the latter alliance is only known to exist on BLBWMA in Texas (Fleming et al. 2002). Near the inland 50-m endpoints, the 50-m transects intersect the latter two associations on the upper terrace starting at the 4-8 m tall bluffs above the meander belt.

With its focus on the riparian forest extending inland 50 m from the river bank (MHWB), the current inventory is largely concerned with a relatively minor forest association on BLBWMA, Cottonwood Temporarily Flooded (National Vegetation Classification Standard -OK-TX 1997), which is restricted to the meander belt adjacent to the Trinity River. In BLBWMA, the overwhelmingly dominant tree species in the meander belt is black willow, with other onsite tree and shrub species characteristic of this association being swamp privet, cottonwood, box elder, honey locust, and sugarberry.

In both sites, strong dominance in the meander belt by flood-dependent black willow and swamp privet confirms a naturally variable hydroperiod with frequent high flows. The bottomland hardwood forest near the 50-m (164 ft) transect endpoints is dominated by a mixture of swamp privet with other species, such as sugarberry, green ash, and cedar elm, which are adapted to hydroperiods with less frequent and shorter duration inundation. However, all of these species are wetland indicators and the mixing of these species of varying flood tolerances reinforces the variability of the flow regime. Sugarberry and green ash were the least sustainable species in the macroplots (Table 6), which likely indicates that inundation may be on the increase, since these species are adversely impacted by long flood durations.

The importance of mature black willow and box elder across the three forest layers is also indicative of frequent floods. These species flower in spring, and prefer full sun and moist soils usually near rivers and other water bodies. Both species produce large seed crops every year, which are wind- and water-dispersed. Since both are phreatophytes that reproduce sexually, maintaining high soil moisture during the first two growing seasons (seedling stage) is most critical. Once past the seedling stage, the two species are fast growing and short-lived.

Due to past flow events frequently meeting the placement criteria for black willow in the two BLBWMA study sites, mature black willow is the dominant species on accreting alluvial sediments throughout the meander belt starting at the MHW. Black willow seeds ripen April to July and are very short-lived, in contrast with box elder. For this reason, the dispersal of black willow seeds depends on the timing of certain river stages (USDA-NRCS 2016). Short-lived black willow seeds need the river stage at time of seed fall to precisely place them at low elevations near the water table in soils with moderate sand content, but above the scour of oncoming high-flow events (Pezeshkia et al. 2007). Therefore, the river stage at seed fall should be at or up to a few feet above MHW for the successful establishment of black willow.

Box elder seeds ripen in autumn and disperse from autumn to spring, remaining viable over winter until the spring when they germinate both in shade or full sun; however, shaded seedlings must attain full sun within about two years through canopy gap formation or they die (USDA-NRCS 2016).

Black willow and box elder were well represented among tree saplings and seedlings within the meander belt. High reproduction rates were also measured for swamp privet, green ash, cedar elm, and soapberry, with reproduction by the latter three species bolstered by high rates in the floodplain terrace above the meander belt. Reproduction of a variety of wetland tree species is more evidence of a variable flow regime.

Examining population traits of a single plant species or a single forest community allows examination of the long term effect of a flow pattern (Merritt et al. 2010). At the scales of forest stands and river reaches used in this study, metrics more sensitive to long-term hydrologic change include species composition, canopy cover, the ratio of relative importance values for live trees versus snags, and the percentage of wetland indicator species among dominant plant species. As discussed above, these metrics point to a relatively stable riparian forest at BLBWMA supported by variable flows.

Nonetheless, tree mortality at BLBWMA indicates the flow regime is currently altered by upstream reservoir operation. The results in Section 4.1.1 that described high mortality among

sugarberry at high elevations, coupled with increased mortality at low elevations of green ash, which is intolerant to extended inundation, resembles the downstream impacts of reservoirs on the Brazos River riparian forests (TIPP 2018). The reservoirs alter the high-pulse hydroperiod on the Brazos River, so that the pre-impact regime of higher pulse flows with shorter durations was converted to regulated flows consisting of lower pulse flows of longer duration. In this manner, the increased mortality of high-elevation sugarberry at BLBWMA is probably due to its reduced inundation by lower pulse flows. And the increased mortality of low-elevation green ash measured in this study is likely caused by the longer duration by lower pulse flows, again due to upstream reservoir operation.

Though soil and hydrology are also important and sometimes overriding indicators, wetlands are indicated for areas where wetland indicator plant species are dominant, which means more than 50% of species in the Obligate Wetland (OBL), Facultative Wetland (FACW), or Facultative Wetland (FAC) category (USACE 1987, Lichvar et al. 2014). Over 90% of plant species tallied in BLBWMA study sites are wetland indicators (Table 1), indicating wetlands are generally sustained by existing hydrological conditions.

5.2 Riparian Connectivity

Habitat inundation results indicate that flood events within the 50-mi (80.5-km) study reach connect with significant portions of the floodplain. Channel-connected inundation gradually increases above 1,530 cfs MDD, punctuated by a sharper increase above 10,400 cfs MDD. The meander belt apparently fills at 21,000-22,100 cfs MDD (Figure 9), initiating overbank flooding of the larger floodplain (Figure 10). The inundation of riparian and other floodplain habitats continues to expand at least until 59,500 cfs MDD, despite the previously discussed technical issues artificially decreasing bottomland forest inundation values above 36,800 cfs MDD.

At the nearby Oakwood site, Mangham et al. (2017) similarly found that a discharge rate of 13,000 cfs MDD initiated inundation of in- and off-channel areas within the meander belt, with overbank flows beginning at 21,000-30,000 cfs and flows over 50,000 cfs submerging the entire floodplain.

The benefits of high and overbank flows to floodplain sustainability extend beyond the surface inundation mapped by this project, since such flows also connect vertically to maintain groundwater and saturated soils. Raising the water table during floods recharges floodplain wetlands (King et al. 2009). On the other hand, reduced flooding, due to reductions in high and overbank flows, decreases soil moisture and shifts the water balance of riparian wetlands from functioning as discharge sources to recharge sinks.

The amount of inundated habitat generally increases as streamflow increases; however, the area of inundation may not always be directly related to daily mean river discharge. This is largely due to obstructions within side channels that slow the ingress and egress of floodwaters, such as temporary side-channel blockage by woody debris and deposited sediment during river-channel or tributary flood events. Another important local factor is tributary inflow during local rain events, which may back up in a variable manner depending on the stage elevation within the main river channel. Other impediments to the connection of floodwaters with backwater habitats include natural levees.

This study focuses on the connection of high and overbank flows to riparian habitats, in order to examine how the frequency and duration of environmental flows help sustain riparian services, even as water availability is generally reduced. The maintenance of a natural flow regime is essential to restoring riparian forest functions (Alldredge and Moore 2012; Merritt et al. 2010). Due to the large coordinated effort required to modify the flow regime of major rivers, floodplain restoration has mostly been implemented through smaller local projects, where disturbed vegetation and hydrology have been reestablished (King et al. 2009).

Within individual sites, flow reestablishment is not overly difficult. Research by Hunter et al. (2008) demonstrated that simply placing flashboard risers in drainage ditches recreated a hydroperiod and associated wetland functions similar to natural riparian forests. They quantified and contrasted biogeochemical functions in natural wetlands, restored wetlands with relatively natural hydrology, and restored wetlands without re-established hydrology. The first two treatments maintained critical riparian functions, but the third treatment without hydrological

connections did not. In this manner, Hunter et al. (2008) verified that both channel-connected hydrology and surface runoff are necessary to reestablish riparian functions, such as nutrient cycling and sediment reduction.

Riparian restoration at the current study's reach scale requires significantly more effort than at the local scale, including collaborations with multiple agencies and stakeholders, baseline vegetation and hydrology data, development and implementation of environmental-flow regimes, and long-term monitoring of aquatic and riparian habitats.

6. Conclusion

Study results document the status of riparian habitats within the BLBWMA study sites, and quantify the discharge rates needed to inundate riparian and floodplain habitats within the study reach. At the nearby Oakwood site, Mangham et al. (2017) reported a high diversity of tree species and habitats supported by a varied floodplain geomorphology. They also described the hydrology to be highly altered, due to upstream reservoir operation. Flow variability, possibly augmented by return flows, is sufficient to create new alluvial surfaces through deposition of mobilized sediment, with contributions by bank sloughing. These newly scoured and filled surfaces sustain flood-tolerant pioneer species, like black willow and box elder, which increases floodplain biodiversity (Shankman 1993).

Significant findings from this report's analysis of riparian transect data include:

- The existing riparian tree community appears to be stable and diverse.
- Tree species that are tolerant of frequent and/or extended durations of inundation (black willow and swamp privet) are thriving relative to other riparian species.
- At the endpoints of transects (higher elevation, farther from the channel) species that are less tolerant of inundation appear to be less sustainable due to high mortality rates.

Wetted-surface remote sensing also indicates the existing overbank flood regime connects a variety of habitats within the broad floodplain. Dominance by black willow, green ash, and box

elder within the BLBWMA study sites affirms that existing flow connectivity supports healthy riparian forests (Duke 2011).

Significant findings from the current inundation analysis include:

- Although some riparian habitats are inundated with flows as low as 1,150 cfs, flows of 10,400 cfs or greater are required to begin inundating larger areas of riparian habitat in the meander belt of the river.
- Flows greater than 21,000 cfs are required to inundate all riparian habitats within the meander belt of the river.
- Flows as great as 59,500 cfs are required to inundate all riparian areas along the 50-mile segment of river.

These habitat-inundation results firmly support the conclusion by Mangham et al. (2017) that the Texas State Senate Bill 3 (SB3) standards, including the spring pulse of 7,000 cfs MDD for 11 days, do not inundate and sustain Trinity River riparian habitats within the middle Trinity River riparian assessment area.

6.1 Recommendations

An important result of the study is the expansion of long-term forest monitoring necessary to relate vegetation dynamics and hydrology. Recommendations for future research and implementation include the following:

(1) As recommended in prior environmental-flow studies, including TIFP (2018), long-term monitoring is essential for effective implementation and adaptive management of instream flow recommendations. Monitoring should include selected riparian tree species, which are most indicative of floodplain integrity and responsive to active floodplain processes. Knowing the long-term status of black willow and box elder, which dominate riverside locations with increased inundation, allows one to determine the width of the most frequently flooded zone. Due to their dominance in sustainable riparian forests and their widespread decline in riparian forests across Texas, cottonwood and green ash should also be specifically monitored.

Sugarberry should also be monitored, since it appears to be increasing in importance due to drier conditions and increased disturbance.

(2) Increased focus on vegetation-flow response guilds should be the focus of future research, so that riparian assessments and associated restoration techniques may become broadly applicable (Merritt et al. 2010). A shift in the species composition of guilds indicates an environmental variable, such as hydrology or geomorphic flood damage, has been altered. The black willow-box elder guild is an example of a response guild sensitive to both hydrological and geomorphic change, within the study reach.

(3) Empirical and quantitative performance standards should be established to confirm successful stewardship and restoration of riparian habitats and related ecosystem functions. These standards should apply to designated river reaches and to local restoration efforts that may become increasingly needed in the future.

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Appendix A: Tables

Table 1. Representative Plant Species List: Middle Trinity River Riparian Study Sites

Common Name ¹	Scientific Name ¹	Family	Wetland Indicator Status ²	Growth Form ³	Native or Exotic?	Primary Habitat ⁴
slender threeseed mercury	<i>Acalypha gracilens</i>	EUPHORBIACEAE	FAC	AH	N	B
box elder	<i>Acer negundo</i>	ACERACEAE	FAC	T	N	B
valley redstem	<i>Ammannia coccinea</i>	LYTHRACEAE	OBL	AH	N	M
peppervine	<i>Ampelopsis arborea</i>	VITACEAE	FAC	WV	N	B
Alabama supplejack	<i>Berchemia scandens</i>	RHAMNACEAE	FAC	WV	N	B
smallspike false nettle	<i>Boehmeria cylindrica</i>	URTICACEAE	FACW	PH	N	B
American buckwheat vine	<i>Brunnichia ovata</i>	POLYGONACEAE	FACW	PV	N	M
American beautyberry	<i>Callicarpa americana</i>	VERBENACEAE	FACU	S	N	B
trumpet creeper	<i>Campsis radicans</i>	BIGNONIACEAE	FAC	WV	N	B
balloon vine	<i>Cardiospermum halicacabum</i>	SAPINDACEAE	FAC	PV	E	M
Cherokee sedge	<i>Carex cherokeensis</i>	CYPERACEAE	FACW	PH	N	B
water hickory	<i>Carya aquatica</i>	JUGLANDACEAE	OBL	T	N	B
sugarberry	<i>Celtis laevigata</i>	ULMACEAE	FACW	T	N	B
buttonbush	<i>Cephalanthus occidentalis</i>	RUBIACEAE	OBL	S	N	B
inland sea oats	<i>Chasmanthium latifolium</i>	POACEAE	FAC	PH	N	B
sessile-flowered chasmanthium	<i>Chasmanthium sessiliflorum</i>	POACEAE	FAC	PH	N	B
blue mistflower	<i>Conoclinium coelestinum</i>	ASTERACEAE	FAC	PH	N	M
roughleaf dogwood	<i>Cornus drummondii</i>	CORNACEAE	FAC	T	N	B
hawthorn	<i>Crataegus</i> sp.	ROSACEAE	NA	T	N	B
Bermudagrass	<i>Cynodon dactylon</i>	POACEAE	FACU	PH	E	M
redroot flatsedge	<i>Cyperus erythrorhizos</i>	CYPERACEAE	OBL	PH	N	M

¹ Sources (scientific & common names): Ladybird Johnson Wildflower Center 2018 (primary) & USDA, NRCS 2018 (secondary)

² Wetland indicator status codes (Lichvar et al. 2016): OBL- Obligate Wetland, FACW- Facultative Wetland, FAC- Facultative, FACU- Facultative Upland, UPL- Obligate Upland, NA- Not Available

³ Growth Form Codes (singly or in combination): T- tree, S- shrub, H- herb, W- woody, A- annual, P- perennial, V- vine

⁴ Habitat Codes: B - Bottomland, M - Meander Belt

Table 1. Representative Plant Species List: Middle Trinity River Riparian Study Sites (continued)

Common Name ¹	Scientific Name ¹	Family	Wetland Indicator Status ²	Growth Form ³	Native or Exotic?	Primary Habitat ⁴
manyspike flatsedge	<i>Cyperus polystachyos</i>	CYPERACEAE	FACW	PH	N	M
nutgrass	<i>Cyperus rotundus</i>	CYPERACEAE	FAC	PH	E	M
bundleflower	<i>Desmanthus illinoensis</i>	FABACEAE	FAC	S	N	B
branched dicliptera	<i>Dicliptera brachiata</i>	ACANTHACEAE	FACW	PH	N	B
common persimmon	<i>Diospyros virginiana</i>	EBENACEAE	FAC	T	N	B
Virginia wild rye	<i>Elymus virginicus</i>	POACEAE	FAC	PH	N	B
wahoo	<i>Euonymus atropurpureus</i>	CELASTRACEAE	FAC	S	N	B
white boneset	<i>Eupatorium serotinum</i>	ASTERACEAE	FAC	PH	N	M
swamp privet	<i>Forestiera acuminata</i>	OLEACEAE	OBL	T	N	M
green ash	<i>Fraxinus pennsylvanica</i>	OLEACEAE	FACW	T	N	B
white avens	<i>Geum canadense</i>	ROSACEAE	FAC	PH	N	B
honey locust	<i>Gleditsia triacanthos</i>	FABACEAE	FAC	T	N	B
Indian heliotrope	<i>Heliotropium indicum</i>	BORAGINACEAE	FAC	AH	E	M
flower-of-an-hour	<i>Hibiscus trionum</i>	MALVACEAE	UPL	H	E	B
common St. Johnswort	<i>Hypericum perforatum</i>	CLUSIACEAE	FACU	PH	E	B
deciduous holly	<i>Ilex decidua</i>	AQUIFOLIACEAE	FACW	S	N	B
American holly	<i>Ilex opaca</i> var. <i>opaca</i>	AQUIFOLIACEAE	FAC	T	N	B
yaupon	<i>Ilex vomitoria</i>	AQUIFOLIACEAE	FAC	S	N	B
marshelder	<i>Iva annua</i>	ASTERACEAE	FAC	AH	N	B
eastern red cedar	<i>Juniperus virginiana</i>	CUPRESSACEAE	FACU	T	N	B

¹ Sources (scientific & common names): Ladybird Johnson Wildflower Center 2018 (primary) & USDA, NRCS 2018 (secondary)

² Wetland indicator status codes (Lichvar et al. 2016): OBL- Obligate Wetland, FACW- Facultative Wetland, FAC- Facultative,

FACU- Facultative Upland, UPL- Obligate Upland, NA- Not Available

³ Growth Form Codes (singly or in combination): T- tree, S- shrub, H- herb, W- woody, A- annual, P- perennial, V- vine

⁴ Habitat Codes: B - Bottomland, M - Meander Belt

Table 1. Representative Plant Species List: Middle Trinity River Riparian Study Sites (continued)

Common Name ¹	Scientific Name ¹	Family	Wetland Indicator Status ²	Growth Form ³	Native or Exotic?	Primary Habitat ⁴
weedy dwarfandelion	<i>Krigia cespitosa</i>	ASTERACEAE	UPL	AH	N	B
rice cutgrass	<i>Leersia oryzoides</i>	POACEAE	OBL	PH	N	M
narrowleaf palseed	<i>Leucospora multifidi</i>	SCROPHULARIACEAE	OBL	AH	N	M
water-pinnose	<i>Ludwigia peploides</i> subsp. <i>glabrescens</i>	ONAGRACEAE	OBL	PH	N	M
taperleaf water horehound	<i>Lycopus rubellus</i>	LAMIACEAE	OBL	PH	N	M
Osage orange	<i>Madura pomifera</i>	MORACEAE	FACU	T	N	B
red mulberry	<i>Morus rubra</i>	MORACEAE	UPL	T	N	B
slender yellow wood sorrel	<i>Oxalis dillenii</i>	OXALIDACEAE	FACU	PH	N	B
yellow wood sorrel	<i>Oxalis stricta</i>	OXALIDACEAE	UPL	PH	N	B
violet wood sorrel	<i>Oxalis violacea</i>	OXALIDACEAE	UPL	PH	N	B
panic grass	<i>Panicum</i> sp.	POACEAE	NA	PH	N	M
Virginia creeper	<i>Parthenocissus quinquefolia</i>	VITACEAE	FACU	WV	N	B
hairyseed paspalum	<i>Paspalum pubiflorum</i>	POACEAE	FACW	PH	N	M
yellow passionflower	<i>Passiflora lutea</i>	PASSIFLORACEAE	UPL	PHV	N	B
swamp smartweed	<i>Polygonum hydropiperoides</i>	POLYGONACEAE	OBL	PH	N	M
curlytop knotweed	<i>Polygonum lapathifolia</i>	POLYGONACEAE	FACW	AH	N	M
pink smartweed	<i>Polygonum pensylvanica</i>	POLYGONACEAE	FACW	AH	N	M
lanceleaf frogfruit	<i>Phyla lanceolata</i>	VERBENACEAE	OBL	PH	N	M
water elm	<i>Planera aquatica</i>	ULMACEAE	OBL	T	N	B
American sycamore	<i>Platanus occidentalis</i>	PLATANACEAE	FACW	T	N	B
resurrection fern	<i>Pleopeltis polypodioides</i> ssp. <i>michauxiana</i>	POLYPODIACEAE	FAC	PF	N	B
cottonwood	<i>Populus deltoides</i> subsp. <i>deltoides</i>	SALICACEAE	FAC	T	N	M

¹ Sources (scientific & common names): Ladybird Johnson Wildflower Center 2018 (primary) & USDA, NRCS 2018 (secondary)

² Wetland indicator status codes (Lichvar et al. 2016): OBL- Obligate Wetland, FACW- Facultative Wetland, FAC- Facultative, FACU- Facultative Upland, UPL- Obligate Upland, NA- Not Available

³ Growth Form Codes (singly or in combination): T- tree, S- shrub, H- herb, W- woody, A- annual, P- perennial, V- vine

⁴ Habitat Codes: B - Bottomland, M - Meander Belt

Table 1. Representative Plant Species List: Middle Trinity River Riparian Study Sites (continued)

Common Name ¹	Scientific Name ¹	Family	Wetland Indicator Status ²	Growth Form ³	Native or Exotic?	Primary Habitat ⁴
overcup oak	<i>Quercus lyrata</i>	FAGACEAE	OBL	T	N	B
bur oak	<i>Quercus macrocarpa</i> var. <i>macrocarpa</i>	FAGACEAE	FACU	T	N	B
sand post oak	<i>Quercus margarettiae</i>	FAGACEAE	UPL	T	N	B
post oak	<i>Quercus stellata</i>	FAGACEAE	UPL	T	N	B
sessile-flowered yellow cress	<i>Rorippa sessiliflora</i>	BRASSICACEAE	OBL	AH	N	M
southern dewberry	<i>Rubus trivialis</i>	ROSACEAE	FACU	S	N	B
curly dock	<i>Rumex crispus</i>	POLYGONACEAE	FAC	PH	E	B
dwarf palmetto	<i>Sabal minor</i>	ARECACEAE	FACW	S	N	B
black willow	<i>Salix nigra</i>	SALICACEAE	OBL	T	N	M
soapberry	<i>Sapindus saponaria</i> var. <i>drummondii</i>	SAPINDACEAE	FACU	T	N	B
sassafras	<i>Sassafras albidum</i>	LAURACEAE	FACU	T	N	B
woolly buckthorn	<i>Sideroxylon lanuginosum</i>	SAPOTACEAE	FACU	T	N	B
saw greenbrier	<i>Smilax bona-nox</i>	SMLACACEAE	FAC	WV	N	B
Carolina horsenettle	<i>Solanum carolinense</i>	SOLANACEAE	FACU	PH	N	B
black nightshade	<i>Solanum pycnanthum</i>	SOLANACEAE	FACU	AH	N	M
coralberry	<i>Symphoricarpos orbiculatus</i>	CAPRIFOLIACEAE	FACU	S	N	B
bushy aster	<i>Symphoricarpos dumosum</i> var. <i>dumosum</i>	ASTERACEAE	FAC	PH	N	B
Texas aster	<i>Symphoricarpos eulae</i>	ASTERACEAE	FAC	PH	N	B
late purple aster	<i>Symphoricarpos patens</i>	ASTERACEAE	UPL	PH	N	M
sweetleaf	<i>Symplocos tinctoria</i>	SYMPLOCACEAE	FAC	T	N	B

¹ Sources (scientific & common names): Ladybird Johnson Wildflower Center 2018 (primary) & USDA, NRCS 2018 (secondary)

² Wetland indicator status codes (Lichvar et al. 2016): OBL- Obligate Wetland, FACW- Facultative Wetland, FAC- Facultative,

FACU- Facultative Upland, UPL- Obligate Upland, NA- Not Available

³ Growth Form Codes (singly or in combination): T- tree, S- shrub, H- herb, W- woody, A- annual, P- perennial, V- vine

⁴ Habitat Codes: B - Bottomland, M - Meander Belt

Table 1. Representative Plant Species List: Middle Trinity River Riparian Study Sites (concluded)

Common Name ¹	Scientific Name ¹	Family	Wetland Indicator Status ²	Growth Form ³	Native or Exotic?	Primary Habitat ⁴
Canada germander	<i>Teucrium canadense</i>	LAMIACEAE	FACW	PH	N	M
Spanish moss	<i>Tillandsia usneoides</i>	BROMELIACEAE	FAC	PH	N	B M
poison ivy	<i>Toxicodendron radicans</i>	ANACARDIACEAE	FAC	WV	N	B M
cedar elm	<i>Ulmus crassifolia</i>	ULMACEAE	FAC	T	N	B
neckweed	<i>Veronica peregrina</i>	SCROPHULARIACEAE	FAC	AH	N	M
violet	<i>Viola sp.</i>	VIOLACEAE	NA	H	N	B
red grape	<i>Vitis palmata</i>	VITACEAE	FACW	WV	N	M
rough cocklebur	<i>Xanthium strumarium</i>	ASTERACEAE	FAC	AH	N	M

¹ Sources (scientific & common names): Ladybird Johnson Wildflower Center 2018 (primary) & USDA, NRCS 2018 (secondary)

² Wetland indicator status codes (Lichvar et al. 2016): OBL- Obligate Wetland, FACW- Facultative Wetland, FAC- Facultative,

FACU- Facultative Upland, UPL- Obligate Upland, NA- Not Available

³ Growth Form Codes (singly or in combination): T-tree, S-shrub, H-herb, W-woody, A-annual, P-perennial, V-vine

⁴ Habitat Codes: B - Bottomland, M - Meander Belt

Table 2. USGS Stream Gage Information Used to Select Flow Events at Middle Trinity River Riparian Study Sites:
 Periods of Record and Stream Distances to Study Sites

USGS Stream Gages: Middle Trinity River Study Sites						
USGS Gage_ID	Name	Available Data	County	Study Area	Stream Distance: gage to study sites (river miles) *	Notes
8065000	Trinity Rv nr Oakwood, TX	10/01/23-pres	Anderson	Middle Trinity River Riparian Assessment	Site B: 6.00 mi US, Site C: 9.75 mi US	USGS gage at river mile 291.0, Site B: river mile 297.00, Site C: river mile 300.75

*US: upstream, DS: downstream

Table 3. Transect Coordinates, Middle Trinity River Riparian Study Sites

Site	Transect	Position	Latitude	Longitude
B	5	0	31.698115	-95.852178
B	5	50	31.698559	-95.852256
B	7A	0	31.692271	-95.858111
B	7A	50	31.692394	-95.858622
B	9A	0	31.690583	-95.858741
B	9A	50	31.690809	-95.859190
B	11A	0	31.697705	-95.849218
B	11A	50	31.698145	-95.849087
B	12	0	31.69458	-95.857034
B	12	50	31.694313	-95.856611
B	13A	0	31.696318	-95.855663
B	13A	50	31.696241	-95.855477
B	14A	0	31.698013	-95.850586
B	14A	50	31.698452	-95.850514
B	15	0	31.697209	-95.854567
B	15	50	31.697553	-95.854903

Site	Transect	Position	Latitude	Longitude
C	2	0	31.67452	-95.810788
C	2	50	31.67489	-95.810488
C	4A	0	31.673592	-95.810213
C	4A	50	31.673738	-95.809922
C	6	0	31.677416	-95.813291
C	6	50	31.677636	-95.812836
C	8	0	31.672612	-95.803981
C	8	50	31.672841	-95.804412
C	9	0	31.679098	-95.814541
C	9	50	31.679335	-95.814108
C	11	0	31.676143	-95.812433
C	11	50	31.676359	-95.811973
C	14A	0	31.675101	-95.811586
C	14A	50	31.675404	-95.811198
C	15	0	31.671823	-95.804503
C	15	50	31.672076	-95.804936

Table 4.1 Tree-Layer Site Summary
Study Site B, Middle Trinity River Riparian Productivity Assessment

Common Name	Scientific Name	Basal Area		Frequency 5m increments ¹	Density trees/ha	% Relative Values ²			
		m ² /ha	m ² /ha			Basal Area	Frequency	Density	Importance ³
LIVE:									
black willow	<i>Salix nigra</i>	13.91		23.75%	130.00	55.01%	23.42%	30.20%	36.21%
swamp privet	<i>Forestiera acuminata</i>	1.51		23.75%	227.50	8.13%	23.21%	26.07%	19.14%
sugarberry	<i>Celtis laevigata</i>	2.63		17.50%	82.50	16.63%	18.77%	17.65%	17.68%
green ash	<i>Fraxinus pennsylvanica</i>	2.29		11.25%	42.50	11.89%	10.57%	8.41%	10.29%
cedar elm	<i>Ulmus crassifolia</i>	1.43		10.00%	32.50	4.79%	8.57%	6.08%	6.48%
box elder	<i>Acer negundo</i>	0.22		5.00%	20.00	0.90%	5.56%	4.97%	3.81%
soapberry	<i>Sapindus saponaria</i>	0.09		3.75%	22.50	0.27%	2.50%	3.52%	2.09%
woolly buckthorn	<i>Sideroxylon lanuginosum</i>	0.50		3.75%	7.50	1.64%	3.23%	1.28%	2.05%
hawthorn	<i>Crataegus sp.</i>	0.02		1.25%	2.50	0.10%	1.56%	0.50%	0.72%
honey locust	<i>Gleditsia triacanthos</i>	0.19		1.25%	2.50	0.57%	0.89%	0.46%	0.64%
water hickory	<i>Carya aquatica</i>	0.01		1.25%	2.50	0.04%	0.89%	0.46%	0.46%
Eve's necklace	<i>Styphnolobium affine</i>	0.01		1.25%	2.50	0.04%	0.83%	0.39%	0.42%
LIVE TOTAL		22.81		103.75%	575.00	100.00%	100.00%	100.00%	100.00%
SNAG:									
swamp privet	<i>Forestiera acuminata</i>	0.02		2.50%	5.00	40.00%	40.00%	40.00%	40.00%
soapberry	<i>Sapindus saponaria</i>	0.03		2.50%	5.00	20.25%	23.33%	23.33%	22.30%
cedar elm	<i>Ulmus crassifolia</i>	0.30		1.25%	2.50	20.00%	20.00%	20.00%	20.00%
green ash	<i>Fraxinus pennsylvanica</i>	0.71		1.25%	2.50	14.06%	3.33%	3.33%	6.91%
box elder	<i>Acer negundo</i>	0.07		2.50%	5.00	1.29%	6.67%	6.67%	4.87%
black willow	<i>Salix nigra</i>	0.20		1.25%	2.50	3.97%	3.33%	3.33%	3.55%
sugarberry	<i>Celtis laevigata</i>	0.02		1.25%	2.50	0.43%	3.33%	3.33%	2.37%
SNAG TOTAL		1.34		12.50%	25.00	100.00%	100.00%	100.00%	100.00%

¹ Frequency based on presence/absence in 5m segments of 50m transects

² % Relative Value = (Species Total/All-Species Total)*100

³ Importance = Average of % Relative Values for Basal Area, Frequency, and Density

Table 4.2 Tree-Layer Site Summary
Study Site C, Middle Trinity River Riparian Productivity Assessment

Common Name	Scientific Name	Basal Area		Frequency 5m increments ¹	Density trees/ha	% Relative Values ²			
		m ² /ha	m ² /ha			Basal Area	Frequency	Density	Importance ³
LIVE:									
swamp privet	<i>Forestiera acuminata</i>	1.53		35.00%	312.50	8.92%	30.93%	49.71%	29.85%
black willow	<i>Salix nigra</i>	9.81		25.00%	95.00	47.59%	23.79%	17.95%	29.78%
green ash	<i>Fraxinus pennsylvanica</i>	5.14		16.25%	77.50	19.08%	11.69%	9.70%	13.49%
sugarberry	<i>Celtis laevigata</i>	2.32		17.50%	65.00	9.70%	14.75%	10.78%	11.74%
cedar elm	<i>Ulmus crassifolia</i>	1.27		7.50%	22.50	9.72%	9.54%	6.37%	8.54%
box elder	<i>Acer negundo</i>	1.30		7.50%	27.50	4.39%	5.24%	4.07%	4.57%
soapberry	<i>Sapindus saponaria</i>	0.02		1.25%	2.50	0.08%	1.39%	0.45%	0.64%
red mulberry	<i>Morus rubra</i>	0.04		1.25%	2.50	0.11%	0.89%	0.42%	0.47%
Eve's necklace	<i>Styphnolobium affine</i>	0.03		1.25%	2.50	0.22%	0.89%	0.28%	0.46%
honey locust	<i>Gleditsia triacanthos</i>	0.03		1.25%	2.50	0.19%	0.89%	0.28%	0.45%
	LIVE TOTAL	21.47		113.75%	610.00	100.00%	100.00%	100.00%	100.00%
SNAG:									
green ash	<i>Fraxinus pennsylvanica</i>	0.74		2.50%	5.00	30.17%	26.67%	26.67%	27.83%
box elder	<i>Acer negundo</i>	0.08		2.50%	5.00	28.23%	26.67%	26.67%	27.19%
soapberry	<i>Sapindus saponaria</i>	0.02		1.25%	5.00	20.00%	20.00%	20.00%	20.00%
black willow	<i>Salix nigra</i>	0.07		1.25%	2.50	17.95%	10.00%	10.00%	12.65%
swamp privet	<i>Forestiera acuminata</i>	0.02		2.50%	5.00	3.65%	16.67%	16.67%	12.33%
	SNAG TOTAL	0.92		10.00%	22.50	100.00%	100.00%	100.00%	100.00%

¹ Frequency based on presence/absence in 5m segments of 50m transects

² % Relative Value = (Species Total/All-Species Total)*100

³ Importance = Average of % Relative Values for Basal Area, Frequency, and Density

Table 5.1 Tree-Layer Transect Summary
Study Site B, Middle Trinity River Riparian Productivity Assessment

Common Name	Scientific Name	5		7A		9A		11A		12		13A		14A		15		Site Averages		% Relative Importance										
		BA	Freq	Den	BA	Freq	Den	BA	Freq	Den	BA	Freq	Den	BA	Freq	Den	BA	Freq	Den											
LIVE:																														
black willow	<i>Salix nigra</i>	17.7	20.0%	220.0	0.0	0.0%	0.0	12.1	20.0%	160.0	26.2	50.0%	200.0	18.6	30.0%	180.0	5.1	10.0%	20.0	22.4	50.0%	200.0	9.2	10.0%	60.0	13.91	23.75%	130.00	36.21%	
swamp privet	<i>Forestiera acuminata</i>	0.0	0.0%	0.0	1.0	40.0%	280.0	1.2	20.0%	80.0	0.0	10.0%	20.0	0.6	20.0%	100.0	9.3	100.0%	1340.0	0.0	0.0%	0.0	0.0	0.0%	0.0	1.51	23.75%	227.50	19.14%	
sugarberry	<i>Celtis laevigata</i>	3.0	30.0%	60.0	2.5	30.0%	80.0	2.5	20.0%	40.0	1.4	10.0%	60.0	0.0	0.0%	0.0	0.0	0.0%	0.0	1.5	10.0%	60.0	10.0	40.0%	360.0	2.63	17.50%	82.50	17.68%	
green ash	<i>Fraxinus pennsylvanica</i>	0.0	0.0%	0.0	1.7	20.0%	120.0	0.0	10.0%	20.0	3.6	40.0%	160.0	1.8	10.0%	20.0	11.2	10.0%	20.0	0.0	0.0%	0.0	0.0	0.0%	0.0	2.29	11.25%	42.50	10.29%	
cedar elm	<i>Ulmus crassifolia</i>	8.1	40.0%	120.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.3	10.0%	60.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	10.0%	20.0	0.5	10.0%	40.0	1.43	10.00%	32.50	6.48%	
box elder	<i>Acer negundo</i>	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	1.0	20.0%	40.0	0.0	0.0%	0.0	0.22	5.00%	20.00	3.81%	
soapberry	<i>Sapindus saponaria</i>	0.7	30.0%	180.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.09	3.75%	22.50	2.09%	
woolly buckthorn	<i>Sideroxylon lanuginosum</i>	3.4	20.0%	40.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.6	10.0%	20.0	0.50	3.75%	7.50	2.05%	
hawthorn	<i>Crataegus</i> sp.	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.2	10.0%	20.0	0.02	1.25%	2.50	0.72%	
honey locust	<i>Gleditsia triacanthos</i>	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	1.5	10.0%	20.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.19	1.25%	2.50	0.64%	
water hickory	<i>Carya aquatica</i>	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.1	10.0%	20.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.01	1.25%	2.50	0.46%	
laurel	<i>Sophora</i> sp.	0.1	10.0%	20.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.01	1.25%	2.50	0.42%	
TOTALS		32.9	150.0%	640.0	5.2	90.0%	480.0	15.9	70.0%	300.0	33.2	140.0%	340.0	24.4	90.0%	440.0	25.5	120.0%	1380.0	24.9	90.0%	320.0	20.4	80.0%	500.0	22.81	103.75%	575.00	100.00%	
SNAG:																														
swamp privet	<i>Forestiera acuminata</i>	0.0	0.0%	0.0	0.0	0.0%	0.0	0.1	10.0%	20.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.02	2.50%	5.00	40.00%	
soapberry	<i>Sapindus saponaria</i>	0.1	10.0%	20.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.1	10.0%	20.0	0.0	0.0%	0.0	0.03	2.50%	5.00	22.30%	
cedar elm	<i>Ulmus crassifolia</i>	0.0	0.0%	0.0	2.4	10.0%	20.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.30	1.25%	2.50	20.00%	
green ash	<i>Fraxinus pennsylvanica</i>	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	5.7	10.0%	20.0	0.0	0.0%	0.0	0.71	1.25%	2.50	6.91%	
box elder	<i>Acer negundo</i>	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.5	20.0%	40.0	0.0	0.0%	0.0	0.07	2.50%	5.00	4.87%	
black willow	<i>Salix nigra</i>	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	1.6	10.0%	20.0	0.0	0.0%	0.0	0.20	1.25%	2.50	3.55%	
sugarberry	<i>Celtis laevigata</i>	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.2	10.0%	20.0	0.0	0.0%	0.0	0.02	1.25%	2.50	2.37%	
TOTALS		0.1	10.0%	20.0	2.4	10.0%	20.0	0.1	10.0%	20.0	0.0	0.0%	0.0	0.1	10.0%	20.0	0.1	10.0%	20.0	8.1	60.0%	120.0	0.0	0.0%	0.0	1.34	12.50%	25.00	100.00%	

BA = Basal Area (m²/ha)

Freq = Frequency = % of 5m increments with species presence

Den = Density = # trees/ha

Table 5.2 Tree-Layer Transect Summary
Study Site C, Middle Trinity River Riparian Productivity Assessment

Common Name	2A		4A		6		8		9		11		14A		15		Site Averages		% Relative Importance										
	BA	Frq	Den	Frq	BA	Frq	Den	Frq	BA	Frq	Den	Frq	BA	Frq	Den	BA	Frq	Den											
LIVE:																													
swamp privet	0.0	0.0%	0.0	0.0	50.0%	620.0	0.0	400%	220.0	0.0	120.0	0.0	40.0%	260.0	0.0	40.0%	360.0	0.0	40.0%	200.0	0.0	40.0%	200.0	0.0	32.50%	292.50	29.85%		
black willow	0.0	0.0%	0.0	0.0	10.0%	20.0	0.0	20.0%	120.0	0.0	30.0%	120.0	0.0	30.0%	160.0	0.0	30.0%	120.0	0.0	20.0%	40.0	0.0	20.0%	40.0	0.03	23.75%	92.50	29.78%	
green ash	0.0	0.0%	0.0	1.5	40.0%	240.0	0.5	200%	60.0	5.9	0.0%	0.0	0.0	0.0%	0.0	0.0	10.0%	60.0	6.6	30.0%	140.0	0.0	30.0%	140.0	2.32	16.25%	77.50	13.49%	
sugarberry	0.0	0.0%	0.0	0.0	30.0%	80.0	0.0	10.0%	20.0	0.0	30.0%	80.0	0.0	20.0%	40.0	0.1	0.0%	0.0	0.0	50.0%	300.0	0.02	17.50%	65.00	0.02	17.50%	22.50	8.54%	
cedar elm	8.0	30.0%	120.0	0.0	0.0%	0.0	0.0	0.0%	0.0	1.3	10.0%	20.0	0.6	10.0%	0.0	0.0	0.0%	0.0	0.2	10.0%	20.0	0.0	10.0%	20.0	1.27	7.50%	22.50	8.54%	
box elder	3.1	10.0%	20.0	1.1	20.0%	60.0	18.5	40.0%	160.0	13.5	0.0%	0.0	8.1	0.0%	0.0	13.1	0.0%	0.0	15.8	0.0%	0.0	5.4	0.0%	0.0	9.81	8.75%	30.00	4.57%	
sourberry	0.9	20.0%	160.0	2.3	0.0%	0.0	1.0	0.0%	0.0	0.5	0.0%	0.0	3.6	0.0%	0.0	1.1	0.0%	0.0	2.1	10.0%	20.0	0.7	0.0%	0.0	1.53	3.75%	22.50	0.64%	
red mulberry	0.0	0.0%	0.0	12.0	0.0%	0.0	2.5	10.0%	20.0	0.0	0.0%	0.0	0.8	0.0%	0.0	0.0	0.0%	0.0	1.4	0.0%	0.0	24.4	0.0%	0.0	5.14	1.25%	2.50	0.47%	
river's necklce	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.03	1.25%	2.50	0.46%	
honey locust	0.0	0.0%	0.0	1.1	0.0%	0.0	9.3	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	1.30	1.25%	2.50	0.45%	
TOTALS	12.1	60.0%	300.0	18.0	100.0%	400.0	31.8	100.0%	380.0	21.2	70.0%	220.0	13.5	100.0%	340.0	18.1	60.0%	200.0	19.5	50.0%	200.0	37.4	110.0%	500.0	21.44	81.25%	317.50	100.00%	
SNAG:																													
green ash	0.0	0.0%	0.0	0.0	10.0%	20.0	0.0	0.0%	0.0	0.0	10.0%	20.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.00	2.50%	5.00	0.00	27.83%
box elder	0.0	0.0%	0.0	0.0	10.0%	20.0	0.0	10.0%	20.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.00	2.50%	5.00	0.00	27.19%
sourberry	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.00	1.25%	5.00	20.00%	
black willow	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.00	1.25%	2.50	12.65%	
swamp privet	0.0	0.0%	0.0	0.0	10.0%	20.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	10.0%	20.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.00	2.50%	5.00	12.33%	
cedar elm	0.0	0.0%	0.0	0.4	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.74	0.00%	0.00	0.00%	
red mulberry	0.0	0.0%	0.0	0.3	0.0%	0.0	0.3	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.08	0.00%	0.00	0.00%	
river's necklce	0.0	0.0%	0.0	0.1	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.1	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.07	0.00%	0.00	0.00%	
sugarberry	0.0	0.0%	0.0	0.1	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.1	0.0%	0.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.02	0.00%	0.00	0.00%	
TOTALS	0.0	0.0%	0.0	0.7	20.0%	40.0	0.3	10.0%	20.0	5.5	0.0%	0.0	0.0	20.0%	40.0	0.2	10.0%	40.0	0.0	0.0%	0.0	0.0	0.0%	0.0	0.84	7.50%	17.50	100.00%	

BA = Basal Area (m²/ha)

Frq = Frequency = % of 5m increments with species presence

Den = Density = # trees/ha

Table 6. Percent Snag versus Live-Tree Basal Area
 Sites B and C, Middle Trinity River Riparian Productivity Assessment

SITE B:

Common Name	Scientific Name	Snag BA m ² /ha	Live BA m ² /ha	% Snag/Live
sugarberry	<i>Celtis laevigata</i>	0.71	2.29	31.04%
soapberry	<i>Sapindus saponaria</i>	0.03	0.09	29.78%
cedar elm	<i>Ulmus crassifolia</i>	0.07	0.22	29.51%
black willow	<i>Salix nigra</i>	0.30	1.43	21.16%
swamp privet	<i>Forestiera acuminata</i>	0.20	13.91	1.45%
green ash	<i>Fraxinus pennsylvanica</i>	0.02	1.51	1.00%
box elder	<i>Acer negundo</i>	0.02	2.63	0.83%
All species		1.34	22.08	6.08%

SITE C:

Common Name	Scientific Name	Snag BA m ² /ha	Live BA m ² /ha	% Snag/Live
green ash	<i>Fraxinus pennsylvanica</i>	0.74	5.14	14.40%
box elder	<i>Acer negundo</i>	0.08	1.30	5.84%
swamp privet	<i>Forestiera acuminata</i>	0.02	1.53	0.99%
soapberry	<i>Sapindus saponaria</i>	0.02	2.32	0.86%
black willow	<i>Salix nigra</i>	0.07	9.81	0.68%
All species		0.92	20.09	4.57%

BA = Basal Area

Table 7. Forest Canopy Cover Data, Sites B and C
 Middle Trinity River Riparian Assessment

Site B		Site C	
Transect:	Average % Canopy	Transect:	Average % Canopy
5	83.88	2	82.71
7A	53.46	4A	70.10
9A	64.12	6	94.80
11A	84.66	8	82.45
12	99.09	9	79.59
13A	97.40	11	89.21
14A	78.42	14A	68.93
15	81.54	15	99.48
Site Average:	80.32	Site Average:	83.41
Two-Site Average:		81.87	

Table 8.1 Summary of Shrub-Sapling Site Data, Site B, Middle Trinity River Riparian Assessment

Common Name	Scientific Name	Cover	Frequency ¹	% Relative Values		
				Cover ²	Frequency ²	Importance ³
swamp privet	<i>Forestiera acuminata</i>	23.09%	40.00%	58.47%	58.93%	58.70%
green ash	<i>Fraxinus pennsylvanica</i>	0.29%	2.50%	16.38%	16.67%	16.52%
soapberry	<i>Sapindus saponaria</i> var. <i>drummondii</i>	1.55%	2.50%	12.50%	12.50%	12.50%
yaupon	<i>Ilex vomitoria</i>	0.50%	2.50%	9.62%	8.33%	8.97%
black willow	<i>Salix nigra</i>	0.83%	2.50%	3.03%	3.57%	3.30%
Totals:		26.25%	50.00%	100.00%	100.00%	100.00%

¹ Frequency based on presence/absence in 5m segments of 50m transects

² % Relative Value = (Species Total/All-Species Total)*100

³ Importance = Average of % Relative Values for cover and Frequency

Table 8.2 Summary of Shrub-Sapling Site Data, Site C, Middle Trinity River Riparian Assessment

Common Name	Scientific Name	Cover	Frequency ¹	% Relative Values		
				Cover ²	Frequency ²	Importance ³
swamp privet	<i>Forestiera acuminata</i>	17.73%	46.25%	84.04%	81.52%	82.78%
green ash	<i>Fraxinus pennsylvanica</i>	0.66%	2.50%	5.64%	5.00%	5.32%
black willow	<i>Salix nigra</i>	1.90%	3.75%	4.21%	3.41%	3.81%
box elder	<i>Acer negundo</i>	0.75%	3.75%	2.81%	4.17%	3.49%
deciduous holly	<i>Ilex decidua</i>	0.93%	3.75%	2.05%	3.41%	2.73%
soapberry	<i>Sapindus saponaria</i> var. <i>drummondii</i>	0.28%	1.25%	1.25%	2.50%	1.88%
Totals:		22.24%	61.25%	100.00%	100.00%	100.00%

¹ Frequency based on presence/absence in 5m segments of 50m transects

² % Relative Value = (Species Total/All-Species Total)*100

³ Importance = Average of % Relative Values for cover and Frequency

Table 9.1 Summary of Shrub-Sapling Transect Data, Site B, Middle Trinity River Riparian Assessment

Common Name	Scientific Name	5		7A		9A		11A		12		13A		14A		15		Site Averages		% Relative Importance	
		Cov	Frq	Cov	Frq	Cov	Frq	Cov	Frq	Cov	Frq	Cov	Frq	Cov	Frq	Cov	Frq	Cov	Frq		
swamp privet	<i>Forestiera acuminata</i>	0.0%	0.0%	15.8%	70.0%	20.6%	50.0%	3.0%	20.0%	53.0%	80.0%	92.3%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	23.09%	40.00%	58.70%
green ash	<i>Fraxinus pennsylvanica</i>	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.26%	10.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.82%	10.0%	1.2%	10.0%	0.29%	3.75%	16.52%
soapberry	<i>Sapindus saponaria</i> var. <i>drummondii</i>	12.4%	20.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.55%	2.50%	12.50%
yaupon	<i>Ilex vomitoria</i>	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.0%	20.0%	0.50%	2.50%	8.97%
black willow	<i>Salix nigra</i>	0.0%	0.0%	0.0%	0.0%	6.6%	20.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.83%	2.50%	3.30%
Totals:		12.4%	20.0%	15.8%	70.0%	27.2%	70.0%	3.3%	30.0%	53.0%	80.0%	92.3%	100.0%	0.82%	10.0%	5.2%	30.0%	26.25%	51.25%	100.00%	

Definitions: Cov = % canopy cover along 50m transect, Frq = frequency = Percentage of 5m increments with species present along 50m transect
 Relative Importance = Average of % Relative Values for Cover and Frequency, where % Relative Value = (Species Total/All-Species Total)* 100

Table 9.2 Summary of Shrub-Sapling Transect Data, Site C, Middle Trinity River Riparian Assessment

Common Name	Scientific Name	2		4A		6		8		9		11		14A		15		Site Averages		% Relative Importance
		Cov	Frq	Cov	Frq	Cov	Frq	Cov	Frq	Cov	Frq	Cov	Frq	Cov	Frq	Cov	Frq	Cov	Frq	
swamp privet	<i>Forestiera acuminata</i>	22.5%	50.0%	40.9%	90.0%	7.3%	30.0%	20.7%	60.0%	6.2%	40.0%	19.6%	40.0%	19.8%	40.0%	4.8%	20.0%	17.73%	46.25%	82.78%
green ash	<i>Fraxinus pennsylvanica</i>	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.00%	0.0%	3.8%	10.0%	1.5%	10.0%	0.00%	0.0%	0.0%	0.0%	0.66%	2.50%	5.32%
black willow	<i>Salix nigra</i>	15.2%	30.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.90%	3.75%	3.81%
box elder	<i>Acer negundo</i>	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.0%	30.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.75%	3.75%	3.49%
deciduous holly	<i>Ilex decidua</i>	7.4%	30.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.93%	3.75%	2.73%
soapberry	<i>Sapindus saponaria</i> var. <i>drummondii</i>	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.2%	10.0%	0.0%	0.28%	1.25%	1.88%
Totals:		45.1%	110.0%	40.9%	90.0%	7.3%	30.0%	26.7%	90.0%	10.0%	50.0%	21.1%	50.0%	22.0%	50.0%	4.8%	20.0%	22.24%	61.25%	100.00%

Definitions: Cov = % canopy cover along 50m transect, Frq = frequency = Percentage of 5m increments with species present along 50m transect
 Relative Importance = Average of % Relative Values for Cover and Frequency, where % Relative Value = (Species Total/All-Species Total)* 100

Table 10.1 Summary of Herb-Seedling Site Data, Site B, Middle Trinity River Riparian Assessment

Common Name	Scientific Name	Field Data		Percent Relative Values ³		
		Cover ¹	Frequency ²	Cover	Frequency	Importance ⁴
Virginia wild rye	<i>Elymus virginicus</i>	44.61%	13.48%	23.37%	22.10%	22.74%
Cherokee sedge	<i>Carex cherokeensis</i>	75.49%	12.99%	22.14%	15.46%	18.80%
American buckwheat vine	<i>Brunnichia ovata</i>	10.54%	5.15%	9.11%	10.09%	9.60%
bushy American aster	<i>Symphyotricum dumosum</i>	12.75%	4.41%	7.12%	7.07%	7.09%
redroot flatsedge	<i>Cyperus erythrorhizos</i>	10.78%	3.43%	7.43%	6.26%	6.85%
sedge	<i>Carex</i> sp.	3.92%	2.21%	3.85%	4.71%	4.28%
white boneset	<i>Eupatorium serotinum</i>	9.07%	2.94%	3.86%	4.57%	4.22%
cedar elm	<i>Ulmus crassifolia</i>	5.15%	2.21%	2.62%	4.04%	3.33%
black willow	<i>Salix nigra</i>	3.19%	1.47%	2.91%	2.92%	2.92%
rough cocklebur	<i>Xanthium strumarium</i>	6.37%	1.96%	3.22%	2.56%	2.89%
marshelder	<i>Iva frutescens</i>	3.19%	1.47%	2.35%	2.66%	2.51%
swamp privet	<i>Forestiera acuminata</i>	2.94%	1.47%	1.70%	2.28%	1.99%
southern dewberry	<i>Rubus trivialis</i>	4.41%	2.21%	1.51%	2.45%	1.98%
lanceleaf frogfruit	<i>Phyla lanceolata</i>	1.23%	0.74%	1.34%	1.95%	1.65%
peppervine	<i>Ampelopsis arborea</i>	1.23%	0.74%	1.34%	1.75%	1.55%
saw greenbrier	<i>Smilax bona-nox</i>	1.23%	1.23%	0.75%	2.26%	1.51%
hairyseed paspalum	<i>Paspalum pubiflorum</i>	3.43%	0.98%	0.98%	1.19%	1.09%
unidentified dicot seedling	NA	0.74%	0.74%	0.60%	1.46%	1.03%
box elder	<i>Acer negundo</i>	0.98%	0.49%	0.91%	1.10%	1.00%
unidentified grass seedling	NA	0.98%	0.25%	1.00%	0.69%	0.85%
panic grass	<i>Panicum</i> sp.	0.74%	0.25%	0.78%	0.60%	0.69%
valley redstem	<i>Ammannia coccinea</i>	0.49%	0.49%	0.25%	0.64%	0.44%
knotweed	<i>Persicaria</i> sp.	0.25%	0.25%	0.26%	0.60%	0.43%
inland sea oats	<i>Chasmanthium latifolium</i>	1.96%	0.25%	0.42%	0.27%	0.34%
poison ivy	<i>Toxicodendron radicans</i>	0.49%	0.25%	0.17%	0.33%	0.25%
TOTALS		206.13%	62.01%	100.00%	100.00%	100.00%

¹ Cover based on number of hits at 51 points on each of eight random 50m transects per site

² Frequency based on presence/absence at 51 points on each of eight random 50m transects per site

³ Percent Relative Value = (Species Total/All-Species Total)*100

⁴ Importance = Average of % Relative Values for Cover and Frequency

Table 10.2 Summary of Herb-Seedling Site Data, Site C, Middle Trinity River Riparian Assessment

Common Name	Scientific Name	Field Data			% Relative Values ³		
		Cover	Frequency ²	Cover	Frequency	Importance ⁴	
bushy American aster	<i>Symphoricarpos dumosus</i>	27.21%	9.31%	19.84%	16.89%	18.36%	
Cherokee sedge	<i>Carex cherokeensis</i>	13.48%	5.39%	15.56%	9.78%	12.67%	
marshelder	<i>Iva frutescens</i>	9.07%	5.39%	11.42%	9.78%	10.60%	
American buckwheat vine	<i>Brunnichia ovata</i>	11.03%	4.66%	9.22%	8.44%	8.83%	
box elder	<i>Acer negundo</i>	8.33%	4.41%	9.63%	8.00%	8.81%	
redroot flatsedge	<i>Cyperus erythrorhizos</i>	5.64%	3.43%	4.43%	6.22%	5.32%	
rough cockleburr	<i>Xanthium strumarium</i>	2.94%	1.96%	6.07%	3.56%	4.81%	
white boneset	<i>Eupatorium serotinum</i>	7.84%	2.70%	4.62%	4.89%	4.75%	
lanceleaf frogfruit	<i>Phyla lanceolata</i>	3.68%	2.21%	3.16%	4.00%	3.58%	
saw greenbrier	<i>Smilax bona-nox</i>	3.68%	2.21%	2.74%	4.00%	3.37%	
black willow	<i>Salix nigra</i>	3.19%	1.72%	1.96%	3.11%	2.53%	
Virginia wild rye	<i>Elymus virginicus</i>	3.43%	1.72%	1.72%	3.11%	2.42%	
American aster	<i>Symphoricarpos</i> sp.	2.45%	1.47%	1.45%	2.67%	2.06%	
swamp privet	<i>Forestiera acuminata</i>	1.96%	1.23%	1.20%	2.22%	1.71%	
cedar elm	<i>Ulmus crassifolia</i>	1.72%	0.98%	1.19%	1.78%	1.48%	
poison ivy	<i>Toxicodendron radicans</i>	0.98%	0.98%	0.70%	1.78%	1.24%	
sedge	<i>Carex</i> sp.	1.96%	0.74%	0.88%	1.33%	1.11%	
sugarberry	<i>Celtis laevigata</i>	1.47%	0.74%	0.79%	1.33%	1.06%	
blue mistflower	<i>Conoclinium coelestinum</i>	0.98%	0.49%	0.64%	0.89%	0.77%	
black nightshade	<i>Solanum ptycanthum</i>	0.74%	0.49%	0.54%	0.89%	0.71%	
red grape	<i>Vitis palmata</i>	0.74%	0.49%	0.47%	0.89%	0.68%	
peppervine	<i>Ampelopsis arborea</i>	0.98%	0.49%	0.44%	0.89%	0.66%	
deciduous holly	<i>Ilex decidua</i>	0.74%	0.49%	0.44%	0.89%	0.66%	
southern dewberry	<i>Rubus trivialis</i>	0.49%	0.49%	0.34%	0.89%	0.62%	
inland sea oats	<i>Chasmanthium latifolium</i>	0.49%	0.49%	0.29%	0.89%	0.59%	
unknown dicot seedlings	NA	0.49%	0.49%	0.28%	0.89%	0.58%	
TOTALS		115.69%	55.15%	100.00%	100.00%	100.00%	

¹ Cover based on number of hits at 51 points on each of eight random 50m transects per site

² Frequency based on presence/absence at 51 points on each of eight random 50m transects per site

³ Percent Relative Value = (Species Total/All-Species Total)*100

⁴ Importance = Average of % Relative Values for Cover and Frequency

Table 11.1 Summary of Herb-Seedling Transect Data, Site B, Middle Trinity River Riparian Assessment

Common Name	Scientific Name	5		7A		9A		11A		12		13A		14A		15		Site Averages		% Relative Importance
		Cov	Freq	Cov	Freq	Cov	Freq	Cov	Freq	Cov	Freq	Cov	Freq	Cov	Freq	Cov	Freq	Cov	Freq	
Cherokee sedge	<i>Carex cherokeensis</i>	284.3%	41.2%	143.1%	19.6%	23.5%	5.9%	0.0%	0.0%	0.0%	0.0%	7.8%	3.9%	0.0%	0.0%	145.1%	33.3%	75.49%	12.99%	33.00%
Virginia wild rye	<i>Elymus virginicus</i>	94.1%	23.5%	66.7%	17.6%	33.3%	13.7%	13.7%	3.9%	37.3%	11.8%	64.7%	23.5%	5.0%	2.0%	41.2%	11.8%	44.61%	13.48%	21.66%
bushy American aster	<i>Symphoricarpos dumosus</i>	5.9%	3.9%	0.0%	0.0%	2.0%	2.0%	7.8%	3.9%	0.0%	0.0%	33.3%	11.8%	0.0%	0.0%	52.9%	13.7%	12.75%	4.41%	6.40%
American buckwheat vine	<i>Branthia ovata</i>	2.0%	2.0%	3.9%	3.9%	29.4%	13.7%	19.6%	11.8%	0.0%	0.0%	0.0%	0.0%	29.4%	9.8%	0.0%	0.0%	10.54%	5.15%	5.85%
redroot flatsedge	<i>Cyperus erythrorhizos</i>	0.0%	0.0%	23.5%	9.8%	29.4%	7.8%	9.8%	2.0%	21.6%	5.9%	0.0%	0.0%	2.0%	2.0%	0.0%	0.0%	10.78%	3.43%	5.30%
white bonaset	<i>Eupatorium serotinum</i>	54.9%	15.7%	0.0%	0.0%	0.0%	0.0%	2.0%	2.0%	0.0%	0.0%	0.0%	0.0%	15.7%	5.9%	0.0%	0.0%	6.37%	1.96%	4.48%
rough cocklebur	<i>Xanthoxylum strumarium</i>	0.0%	0.0%	0.0%	0.0%	51.0%	15.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.07%	1.96%	3.11%
cedar elm	<i>Ulmus crassifolia</i>	0.0%	0.0%	23.5%	7.8%	9.8%	3.9%	0.0%	0.0%	7.8%	5.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.15%	2.21%	2.74%
southern dewberry	<i>Rubus trivialis</i>	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	35.3%	17.6%	4.41%	2.21%	2.47%
sedge	<i>Carex</i> sp.	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	13.7%	5.9%	0.0%	0.0%	9.8%	3.9%	3.9%	3.9%	3.9%	3.9%	3.92%	2.21%	2.29%
marshelder	<i>Iva frutescens</i>	0.0%	0.0%	2.0%	2.0%	0.0%	0.0%	0.0%	0.0%	3.9%	2.0%	3.9%	2.0%	7.8%	2.0%	7.8%	3.9%	3.19%	1.47%	1.74%
black willow	<i>Salix nigra</i>	0.0%	0.0%	2.0%	2.0%	3.9%	2.0%	2.0%	2.0%	13.7%	2.0%	0.0%	0.0%	3.9%	2.0%	0.0%	0.0%	3.19%	1.47%	1.74%
hairyseed paspalum	<i>Paspalum pubiflorum</i>	11.8%	3.9%	15.7%	3.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.43%	0.98%	1.65%
swamp privet	<i>Forestiera acuminata</i>	0.0%	0.0%	7.8%	3.9%	11.8%	5.9%	3.9%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.94%	1.47%	1.65%
saw greenbrier	<i>Smilax bona-nox</i>	0.0%	0.0%	2.0%	2.0%	0.0%	0.0%	0.0%	0.0%	3.9%	3.9%	0.0%	0.0%	0.0%	0.0%	3.9%	3.9%	1.23%	1.23%	0.91%
inland sea oats	<i>Chasmodon latifolium</i>	15.7%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.96%	0.25%	0.82%
peppervine	<i>Ampelopsis arborea</i>	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.9%	2.0%	0.0%	0.0%	2.0%	2.0%	3.9%	2.0%	0.0%	0.0%	1.23%	0.74%	0.73%
lanceleaf frogfruit	<i>Phyla lanceolata</i>	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	2.0%	2.0%	0.0%	0.0%	5.9%	2.0%	0.0%	0.0%	1.23%	0.74%	0.73%
box elder	<i>Acer negundo</i>	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.9%	2.0%	3.9%	2.0%	0.0%	0.0%	0.98%	0.49%	0.55%
unknown dicot seedling	NA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.9%	3.9%	2.0%	2.0%	0.74%	0.74%	0.55%
unknown grass seedling	NA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.8%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.98%	0.25%	0.46%
valley redstem	<i>Ammannia coccinea</i>	0.0%	0.0%	0.0%	0.0%	3.9%	3.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.49%	0.49%	0.37%
panic grass	<i>Panicum</i> sp.	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.9%	2.0%	0.0%	0.0%	0.74%	0.25%	0.37%
poison ivy	<i>Toxicodendron radicans</i>	0.0%	0.0%	3.9%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.49%	0.25%	0.27%
knottweed	<i>Persicaria</i> sp.	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	2.0%	0.0%	0.0%	0.25%	0.25%	0.18%
TOTALS		468.6%	92.2%	294.1%	74.5%	198.0%	76.5%	78.4%	37.3%	98.0%	35.3%	125.5%	49.0%	94.1%	41.2%	292.2%	90.2%	206.13%	62.01%	100.00%

Cov: Cover based on number of hits at 51 points on each of eight random 50m transects per site

Freq: Frequency based on presence/absence at 51 points on each of eight random 50m transects per site

% Relative Importance: Average of % Relative Values for Cover and Frequency, with % Relative Value = (Species Total/All-Species Total)*100

Table 11.2 Summary of Herb-Seedling Transect Data, Site C, Middle Trinity River Riparian Assessment

Common Name	Scientific Name	2		4A		6		8		9		11		14A		15		Site Averages		% Relative Importance
		Cov	Freq	Cov	Freq	Cov	Freq	Cov	Freq	Cov	Freq	Cov	Freq	Cov	Freq	Cov	Freq	Cov	Freq	
bushy American aster	<i>Symphycaricium dianthosum</i>	19.6%	7.8%	58.8%	15.7%	3.9%	2.0%	47.1%	17.6%	0.0%	0.0%	76.5%	27.5%	0.0%	0.0%	11.8%	3.9%	27.21%	9.31%	21.38%
Cherokee sedge	<i>Carex cherokeensis</i>	62.7%	17.6%	3.9%	2.0%	2.0%	2.0%	0.0%	0.0%	5.9%	5.9%	7.8%	3.9%	2.0%	2.0%	23.5%	9.8%	13.48%	5.39%	11.05%
American buckwheat vine	<i>Brunnichia ovata</i>	2.0%	2.0%	3.9%	2.0%	0.0%	0.0%	5.9%	3.9%	0.0%	0.0%	27.5%	9.8%	25.5%	11.8%	23.5%	7.8%	11.03%	4.66%	9.18%
marshelder	<i>Iva frutescens</i>	5.9%	5.9%	0.0%	0.0%	2.0%	2.0%	15.7%	11.8%	2.0%	2.0%	2.0%	2.0%	41.2%	17.6%	3.9%	2.0%	9.07%	5.39%	8.46%
box elder	<i>Acer negundo</i>	0.0%	0.0%	3.9%	3.9%	9.8%	7.8%	51.0%	21.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	2.0%	8.33%	4.41%	7.46%
white bonset	<i>Eupatorium serotinum</i>	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	27.5%	11.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	35.3%	9.8%	7.84%	2.70%	6.17%
redroot flsedge	<i>Cyperus erythrorhizos</i>	2.0%	2.0%	33.3%	15.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.9%	3.9%	5.9%	5.9%	0.0%	0.0%	5.64%	3.43%	5.31%
lanceleaf frogfruit	<i>Phylla lanceolata</i>	2.0%	2.0%	5.9%	2.0%	2.0%	2.0%	15.7%	7.8%	0.0%	0.0%	3.9%	3.9%	0.0%	0.0%	0.0%	0.0%	3.68%	2.21%	3.44%
saw greenbrier	<i>Smilax bota-tox</i>	0.0%	0.0%	3.9%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	13.7%	9.8%	2.0%	2.0%	9.8%	3.9%	3.68%	2.21%	3.44%
Virginia wild rye	<i>Elymus virginicus</i>	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	21.6%	9.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.9%	3.9%	3.43%	1.72%	3.01%
black willow	<i>Salix nigra</i>	21.6%	11.8%	3.9%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.19%	1.72%	2.87%
rough cocklebur	<i>Xanthium strumarium</i>	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	3.9%	3.9%	3.9%	0.0%	0.0%	3.9%	2.0%	13.7%	5.9%	2.94%	1.96%	2.87%
American aster	<i>Symphycaricium</i> sp.	19.6%	11.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.45%	1.47%	2.30%
swamp privet	<i>Forsytia acuminata</i>	13.7%	7.8%	2.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.96%	1.23%	1.87%
sedge	<i>Carex</i> sp.	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	15.7%	5.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.96%	0.74%	1.58%
cedar elm	<i>Ulmus crassifolia</i>	2.0%	2.0%	3.9%	2.0%	0.0%	0.0%	3.9%	2.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	2.0%	2.0%	1.72%	0.98%	1.58%
sugarberry	<i>Celtis laevigata</i>	0.0%	0.0%	2.0%	2.0%	0.0%	0.0%	7.8%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	2.0%	1.47%	0.74%	1.29%
poison ivy	<i>Toxicodendron radicans</i>	0.0%	0.0%	3.9%	3.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.9%	3.9%	0.98%	0.98%	1.15%
peppervine	<i>Ampelopsis arborea</i>	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.8%	3.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.98%	0.49%	0.86%
blue mistflower	<i>Conoclinium coelestinum</i>	3.9%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.9%	2.0%	0.0%	0.0%	0.0%	0.0%	0.98%	0.49%	0.86%
deciduous holly	<i>Ilex decidua</i>	5.9%	3.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.74%	0.49%	0.72%
black nightshade	<i>Solanum pycnanthum</i>	0.0%	0.0%	5.9%	3.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.74%	0.49%	0.72%
red grape	<i>Vitis palmata</i>	3.9%	2.0%	2.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.74%	0.49%	0.72%
inland sea oats	<i>Chasmanthium latifolium</i>	3.9%	3.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.49%	0.49%	0.57%
southern dewberry	<i>Rubus trivialis</i>	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.9%	3.9%	0.49%	0.49%	0.57%
unknown dicot seedlings	NA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	2.0%	0.49%	0.49%	0.57%
TOTALS		168.6%	82.4%	137.3%	60.8%	19.6%	15.7%	223.5%	103.9%	11.8%	11.8%	139.2%	62.7%	82.4%	41.2%	143.1%	62.7%	115.69%	55.15%	100.00%

Cov: Cover based on number of hits at 51 points on each of eight random 50m transects per site

Freq: Frequency based on presence/absence at 51 points on each of eight random 50m transects per site

% Relative Importance: Average of % Relative Values for Cover and Frequency, with % Relative Value = (Species Total/All-Species Total)* 100

Table 12. Ground-Cover Transect Data, Sites B and C, Middle Trinity River Riparian Assessment

Site B Transects	5	7A	9A	11A	12	13A	14A	15	Means
Forest floor (organic litter layer)	84.31%	78.43%	82.35%	92.16%	94.12%	90.20%	70.59%	86.27%	84.80%
Bare mineral soil	15.69%	17.65%	17.65%	7.84%	0.00%	0.00%	27.45%	13.73%	12.50%
Woody debris, fine (0.5<10 cm dia.)	0.00%	3.92%	0.00%	0.00%	0.00%	3.92%	1.96%	0.00%	1.23%
Woody debris, coarse (>20 cm dia.)	0.00%	0.00%	0.00%	0.00%	1.96%	3.92%	0.00%	0.00%	0.74%
Woody debris, medium (10<20 cm dia.)	0.00%	0.00%	0.00%	0.00%	1.96%	0.00%	0.00%	0.00%	0.25%
Living tree or shrub bole	0.00%	0.00%	0.00%	0.00%	1.96%	0.00%	0.00%	0.00%	0.25%
Moss on bare mineral soil	0.00%	0.00%	0.00%	0.00%	0.00%	1.96%	0.00%	0.00%	0.25%
Totals	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Site C Transects	2	4A	6	8	9	11	14A	15	Means
Forest floor (organic litter layer)	70.59%	66.67%	72.55%	84.31%	47.06%	96.08%	80.39%	96.08%	76.72%
Bare mineral soil	25.49%	31.37%	21.57%	7.84%	43.14%	3.92%	13.73%	3.92%	18.87%
Woody debris, fine (0.5<10 cm dia.)	0.00%	0.00%	5.88%	0.00%	7.84%	0.00%	3.92%	0.00%	2.21%
Woody debris, coarse (>20 cm dia.)	0.00%	1.96%	0.00%	3.92%	1.96%	0.00%	0.00%	0.00%	0.98%
Woody debris, medium (10<20 cm dia.)	3.92%	0.00%	0.00%	1.96%	0.00%	0.00%	0.00%	0.00%	0.74%
Living tree or shrub bole	0.00%	0.00%	0.00%	1.96%	0.00%	0.00%	1.96%	0.00%	0.49%
Moss on bare mineral soil	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Totals	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Table 13. Channel-Connected Habitat Inundation Summary, Middle Trinity River Study Reach

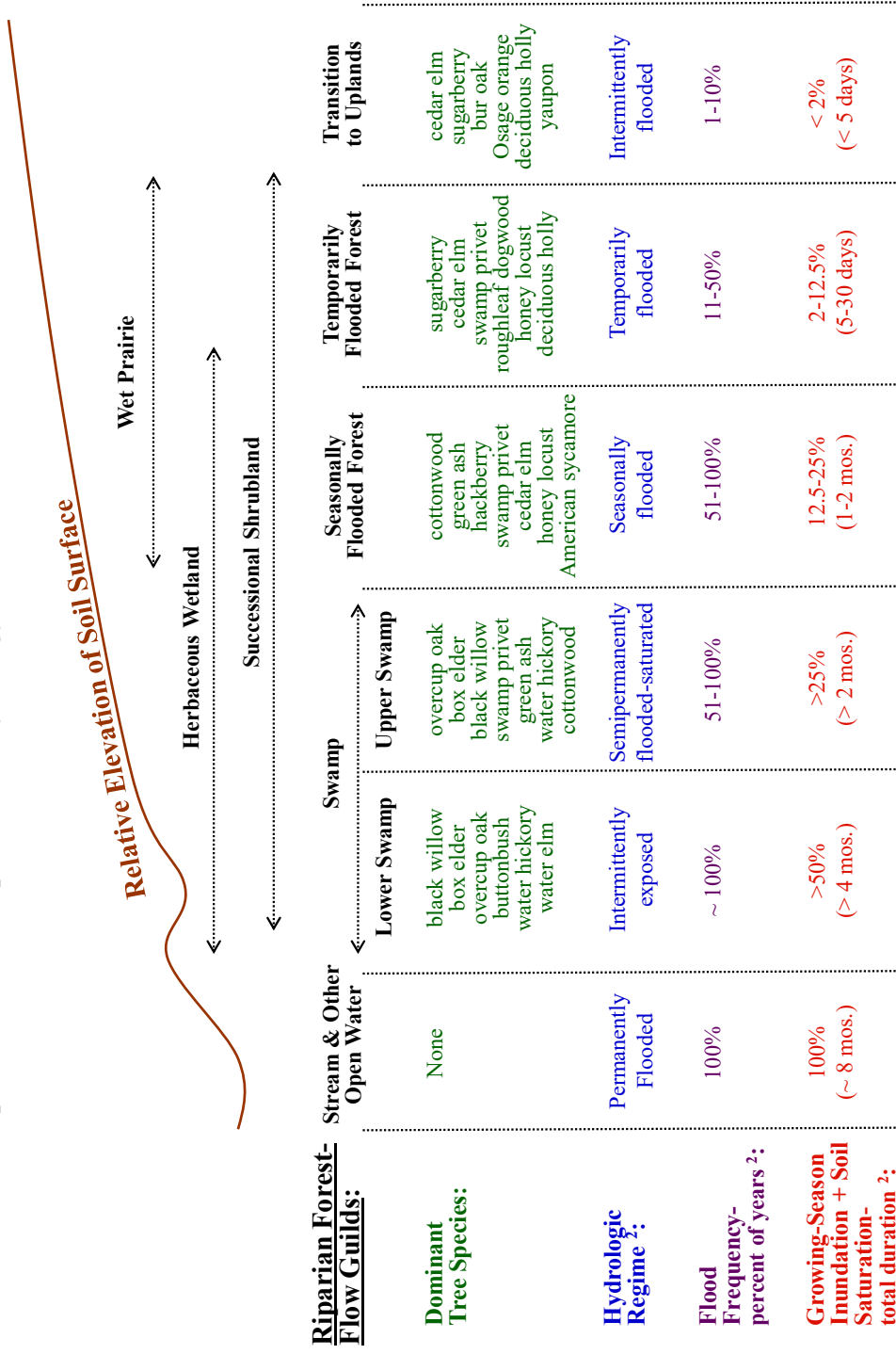
Middle Trinity River Riparian Study Reach: 0-0.5 mi from River Centerline*		01/01/09	02/19/15	03/02/96	01/08/94	01/14/02	02/03/83
Channel-Connected Habitat Inundation versus River Flow		1,390 CFS		1,460 CFS		1,530 CFS	
Central Texas/Pineywoods/Post Oak Savanna Habitat Types**		0-.5mi	%	0-.5mi	%	0-.5mi	%
BOTTOMLAND HABITATS:		8,084.28	0.9%	65.65	1.8%	58.47	2.7%
Bottomland Forest Subtotals		4,619.79	69.91	35.67	0.8%	55.35	2.1%
Bottomland Shrubland Subtotals		415.49	1.14	0.85	0.2%	0.96	0.2%
Herbaceous Wetland Subtotals		3,049.00	3.87	1.25	0.0%	2.17	0.1%
UPLAND HABITATS:		1,918.21	0.4%	4.80	0.3%	7.24	0.5%
Upland Forest/Woodland Subtotals		1,357.79	8.25	3.68	0.3%	7.24	0.5%
Upland Grassland Subtotals		560.42	0.04	0.00	0.0%	0.00	0.0%
DISTURBED & INVASIVE HABITATS:		1,092.04	0.31	0.09	0.0%	0.20	0.0%
OPEN WATER:		473.22	180.11	38.1%	168.21	35.5%	159.14
CHANNEL-CONNECTED INUNDATION GRAND TOTALS:		11,567.76	2.3%	238.80	2.1%	225.06	1.9%
Middle Trinity River Riparian Study Reach: 0-0.5 mi from River Centerline*		01/21/93	01/01/03	01/27/95	01/19/01	02/17/97	
Channel-Connected Habitat Inundation versus River Flow		10,400 CFS		13,300 CFS		14,800 CFS	
Central Texas/Pineywoods/Post Oak Savanna Habitat Types**		0-.5mi	%	0-.5mi	%	0-.5mi	%
BOTTOMLAND HABITATS:		8,084.28	4.4%	178.38	4.8%	239.60	6.5%
Bottomland Forest Subtotals		4,619.79	151.52	3.6%	265.46	5.7%	221.52
Bottomland Shrubland Subtotals		415.49	3.79	0.9%	4.99	1.2%	5.30
Herbaceous Wetland Subtotals		3,049.00	6.46	0.2%	9.57	0.3%	12.78
UPLAND HABITATS:		1,918.21	17.49	0.9%	16.62	0.9%	18.39
Upland Forest/Woodland Subtotals		1,357.79	17.45	1.3%	16.49	1.2%	18.21
Upland Grassland Subtotals		560.42	0.04	0.0%	0.13	0.0%	0.17
DISTURBED & INVASIVE HABITATS:		1,092.04	0.66	0.1%	0.52	0.0%	0.69
OPEN WATER:		473.22	283.02	59.8%	294.21	62.2%	332.19
CHANNEL-CONNECTED INUNDATION GRAND TOTALS:		11,567.76	4.0%	489.74	4.2%	643.24	5.6%
Middle Trinity River Riparian Study Reach: 0-0.5 mi from River Centerline*		02/25/94	02/22/93	01/19/92	01/03/01	12/21/01	
Channel-Connected Habitat Inundation versus River Flow		22,100 CFS		23,600 CFS		33,200 CFS	
Central Texas/Pineywoods/Post Oak Savanna Habitat Types**		0-.5mi	%	0-.5mi	%	0-.5mi	%
BOTTOMLAND HABITATS:		8,084.28	389.23	10.4%	353.49	9.5%	407.90
Bottomland Forest Subtotals		4,619.79	362.42	7.8%	405.61	8.8%	375.08
Bottomland Shrubland Subtotals		415.49	8.05	1.9%	7.88	1.9%	7.72
Herbaceous Wetland Subtotals		3,049.00	18.76	0.6%	13.69	0.4%	25.10
UPLAND HABITATS:		1,918.21	23.96	1.2%	31.07	1.6%	30.94
Upland Forest/Woodland Subtotals		1,357.79	23.75	1.7%	22.16	1.6%	30.60
Upland Grassland Subtotals		560.42	0.21	0.0%	0.16	0.0%	0.34
DISTURBED & INVASIVE HABITATS:		1,092.04	2.10	0.2%	2.48	0.2%	5.55
OPEN WATER:		473.22	332.37	70.2%	320.66	67.8%	347.84
CHANNEL-CONNECTED INUNDATION GRAND TOTALS:		11,567.76	7.47.66	6.5%	698.97	6.0%	820.64

* No inundation occurred > 0.5 mi from river centerline

** Habitat Types by Ecoregions, Texas Ecological Systems Data: <https://tpwd.texas.gov/gis> (Elliott, L.F., et al. 2014)

Appendix B: Figures

Figure 1. Riparian Forest Habitats in Middle Trinity River Study Area: Landscape Context, Tree Species, and Hydrology



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¹ Diamond, D. 2009. FIA Bottomland Summary: East Texas. Unpub. document, Missouri Resource Assessment Partnership, School of Natural Resources, U. Mo. - Columbia.

² Huffman, T., and S.W. Forsyth. 1981. Bottomland hardwood forest communities and their relation to anaerobic soil communities. in: Clark, J.R., and J. Benforado. Wetlands of Bottomland Hardwood Forests, Elsevier Scientific Pub. Co., New York, N.Y., pp. 187-196.

Figure 2. Vicinity Map: Middle Trinity River Riparian Assessment
 Big Lake Bottom Wildlife Management Area and 50x4 Mile Study Reach

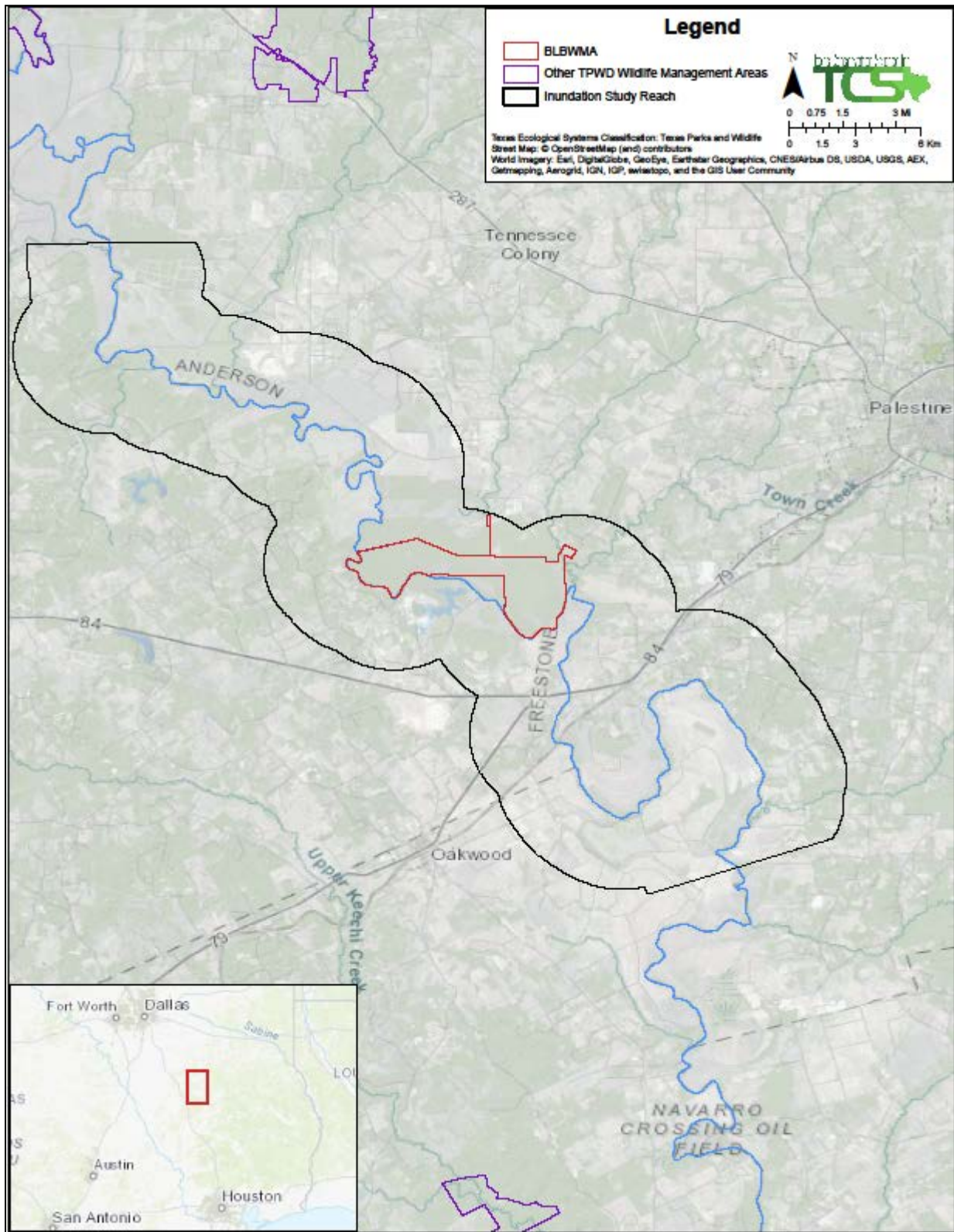


Figure 3. Black Willow Riparian Forest, Site C, 08/11/17



Figure 4. Bottomland Hardwood Forest, Site B, 05/14/18



Figure 5. Riverbank Sloughing, Site C, 07/14/18



Figure 6. Location Map: Study Sites B and C

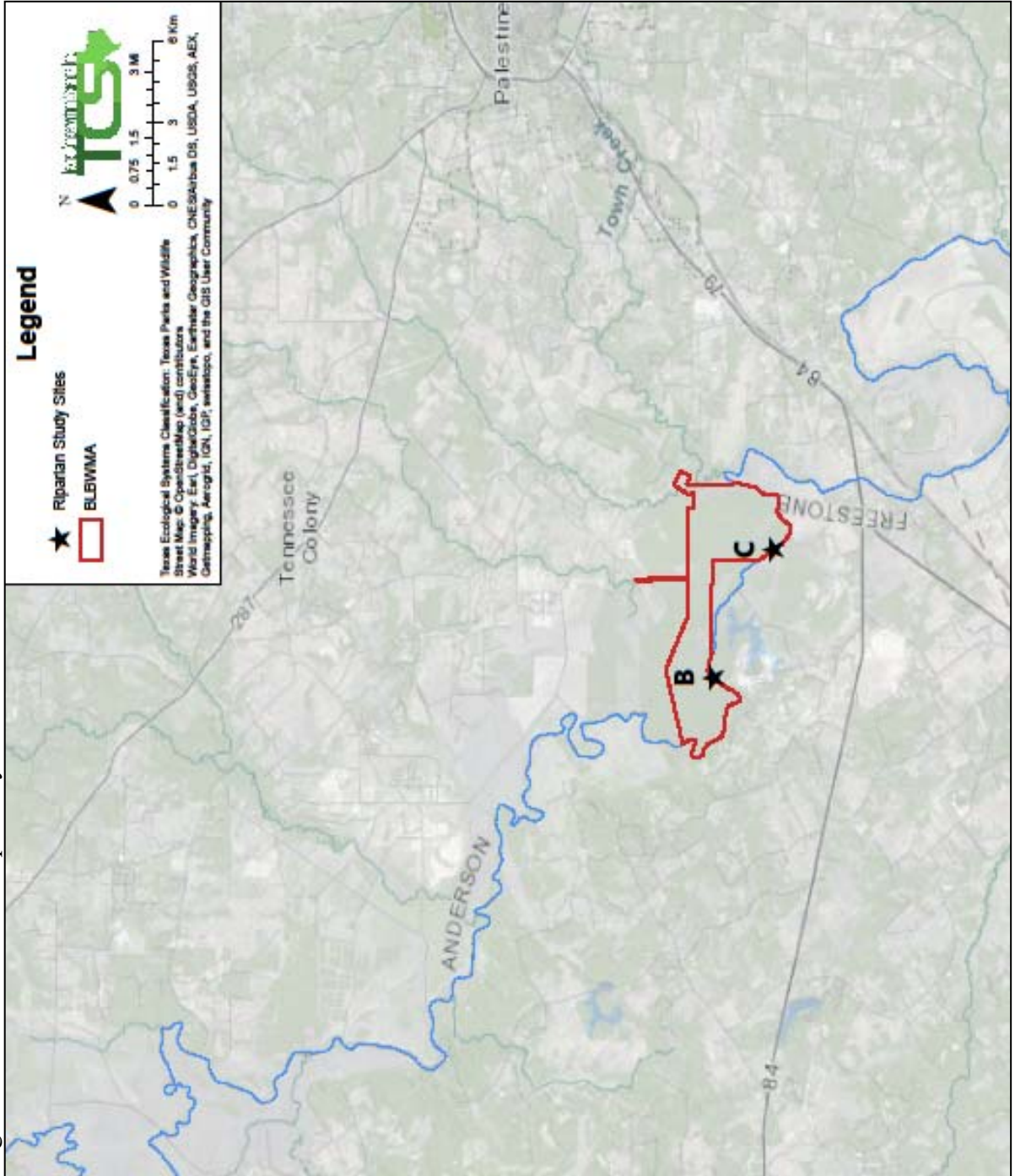


Figure 7. Site B: Transect Locations

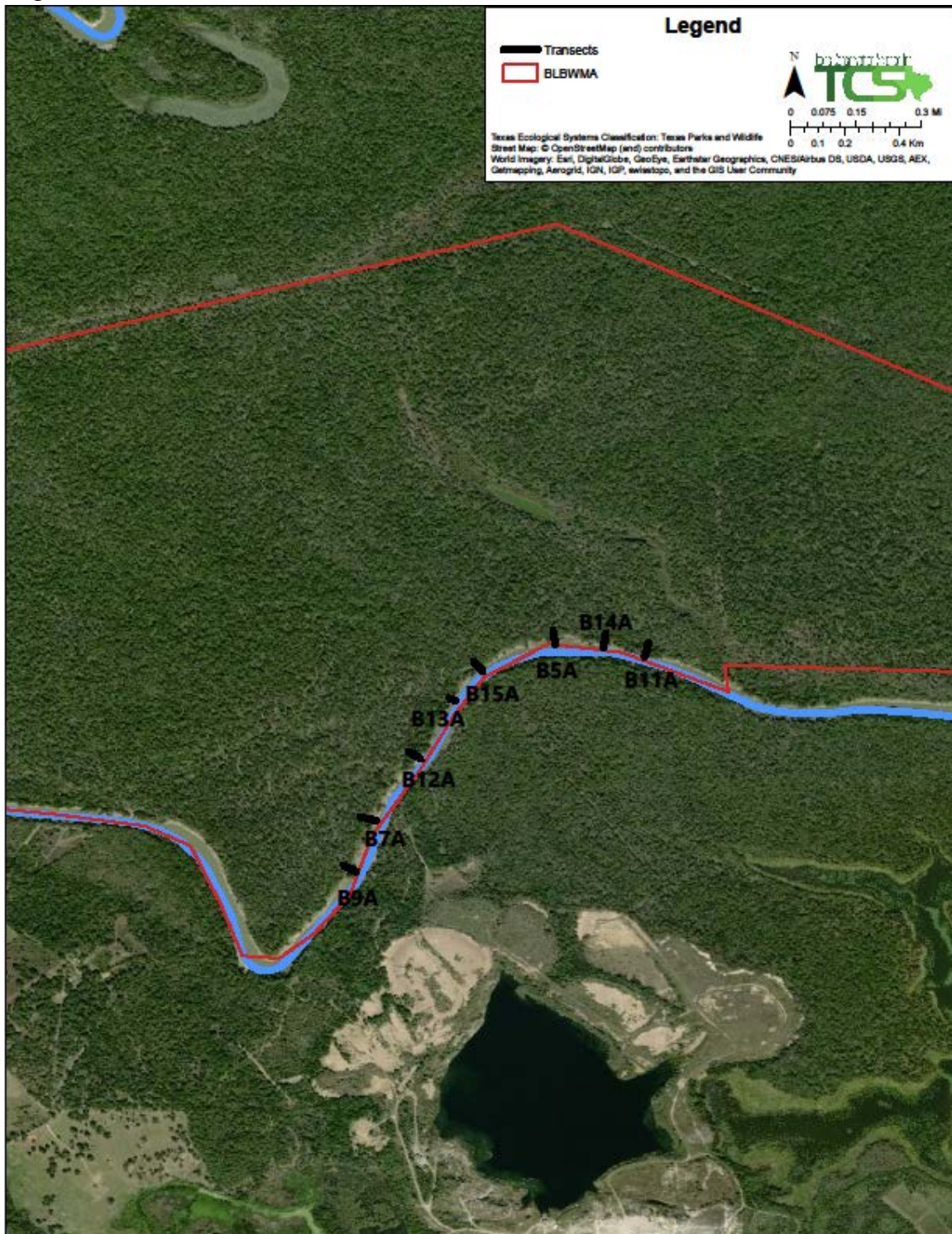


Figure 8. Site C: Transect Locations

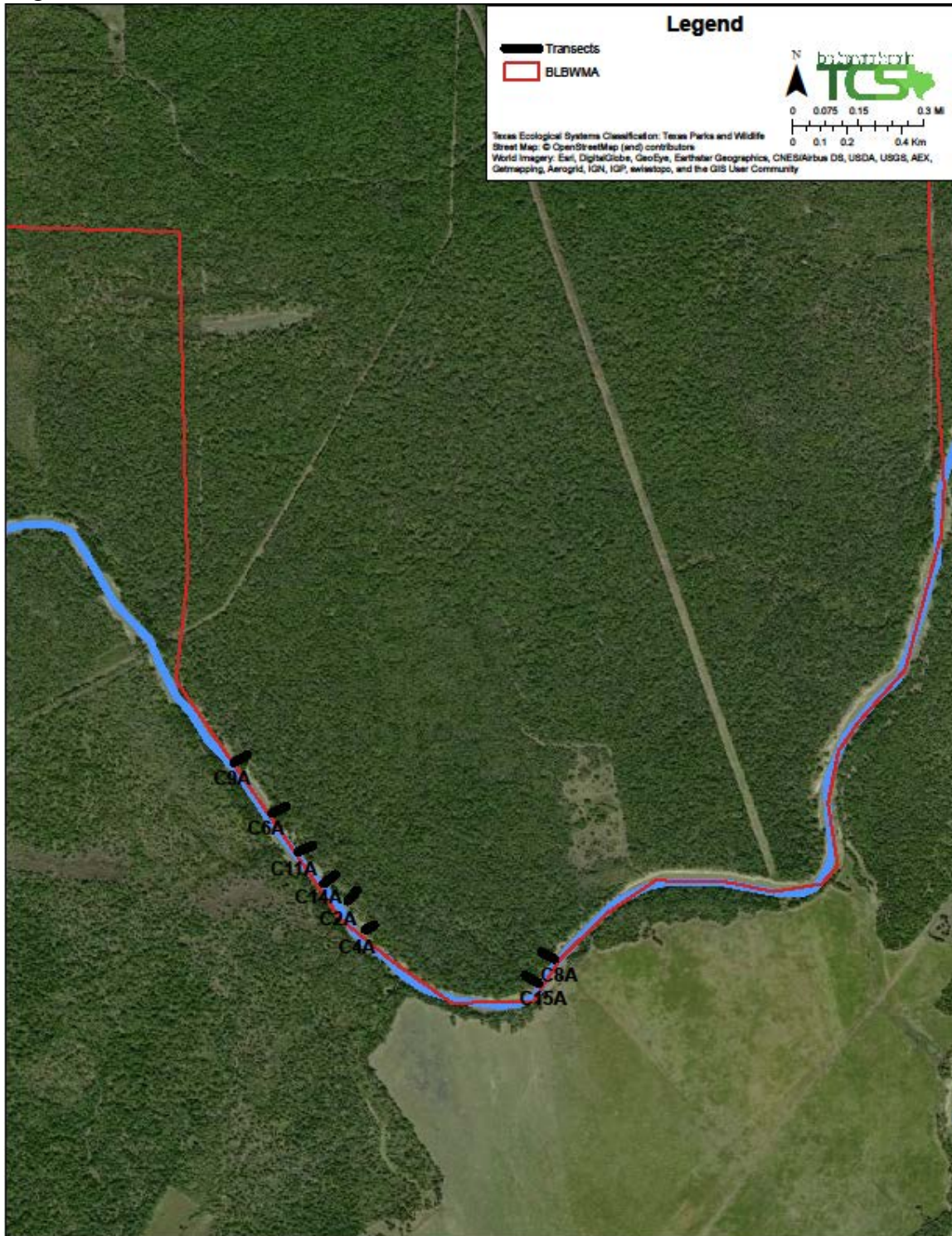


Figure 9. Channel-Connected Inundation Graphs: 1,150-36,800 cfs
Middle Trinity River Riparian Assessment

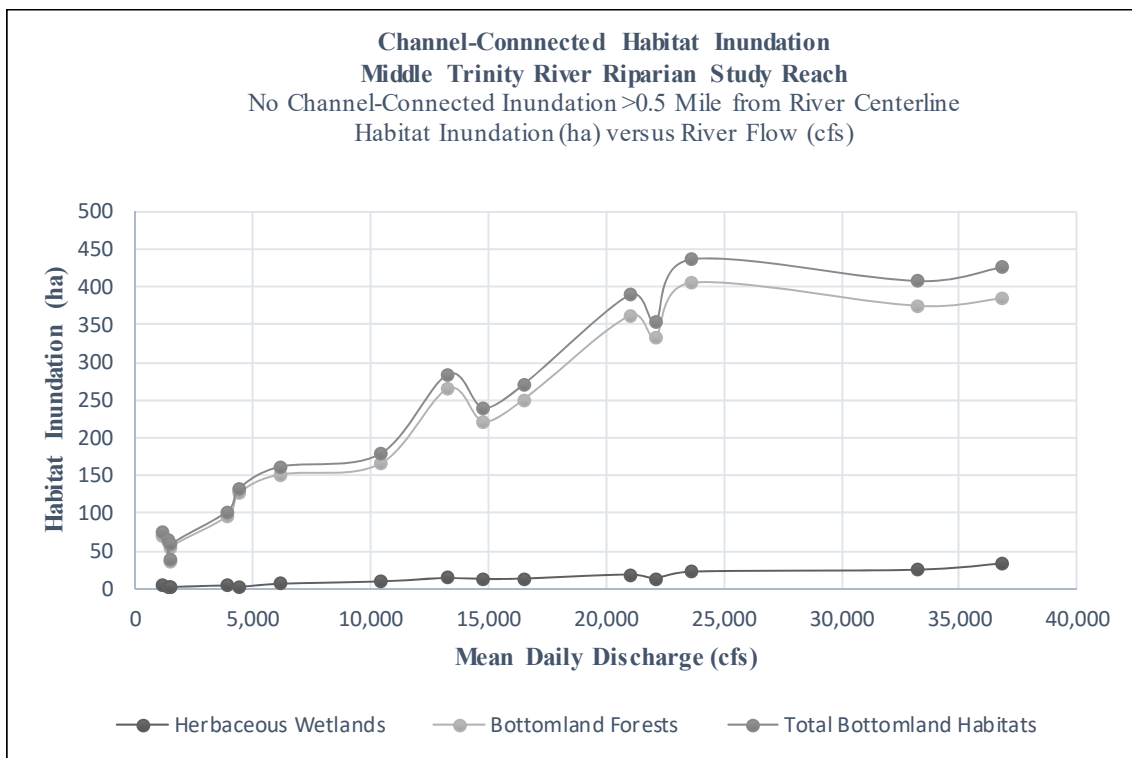
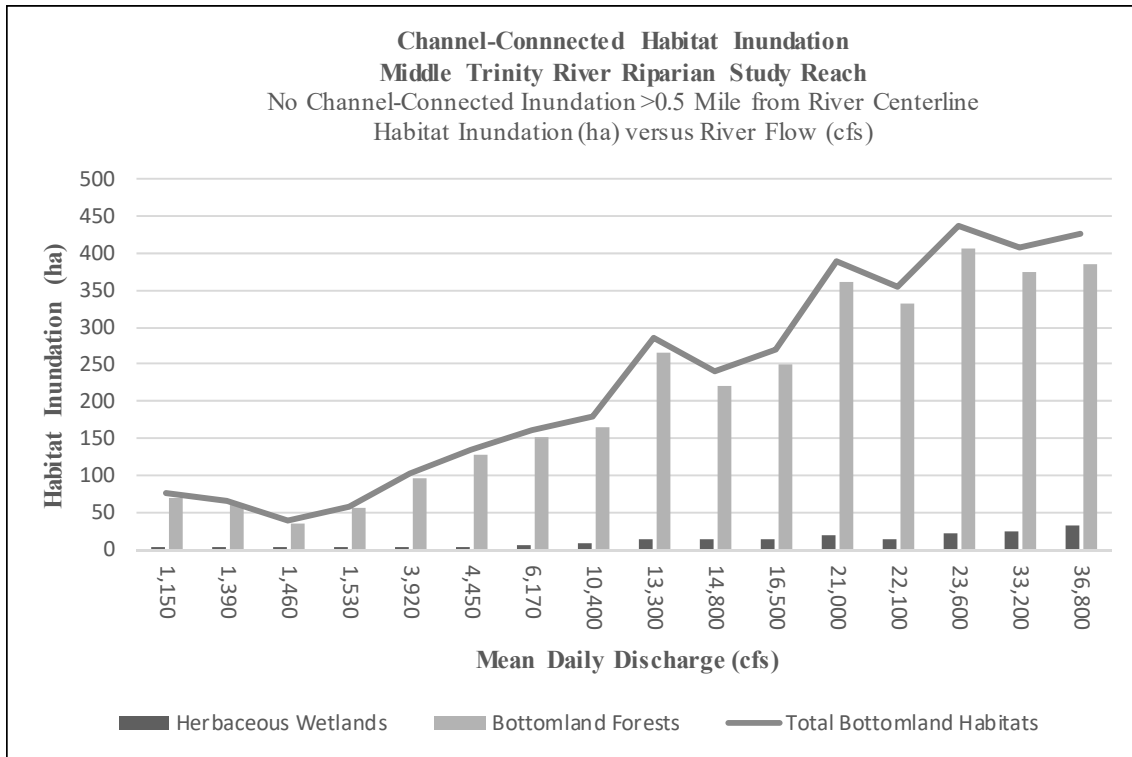


Figure 10. All-Habitat Inundation Graphs: 1,150-59,500 cfs
Middle Trinity River Riparian Study Reach

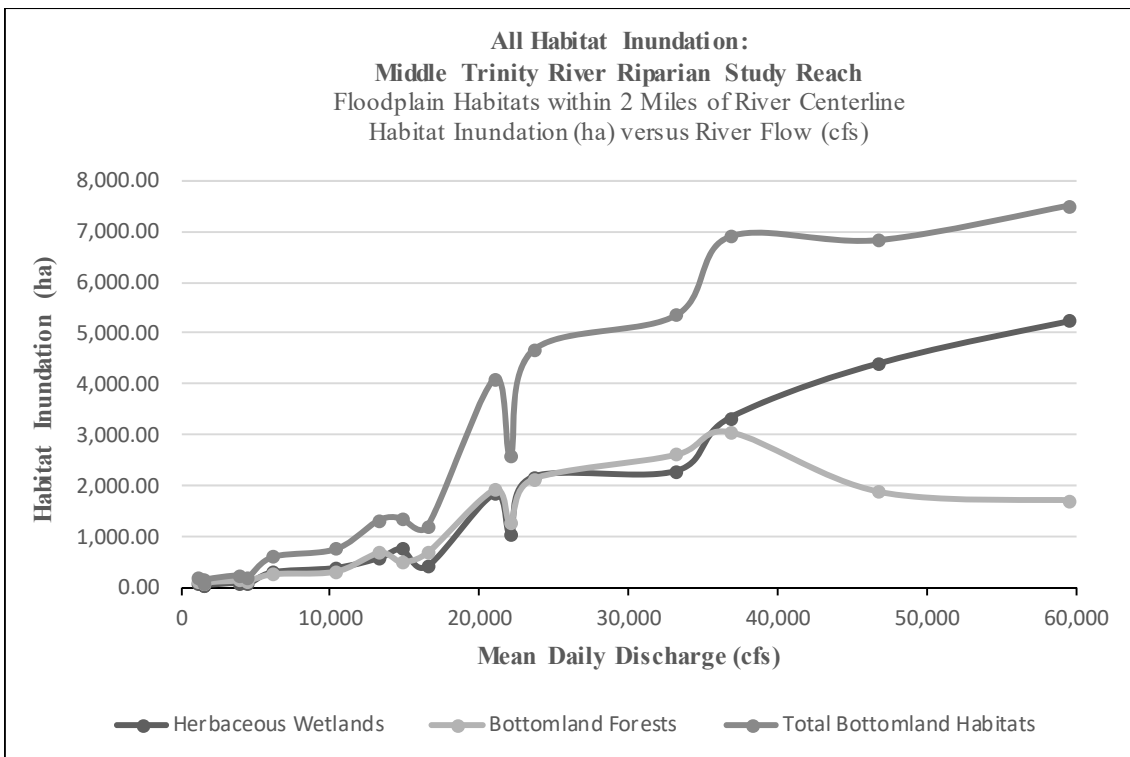
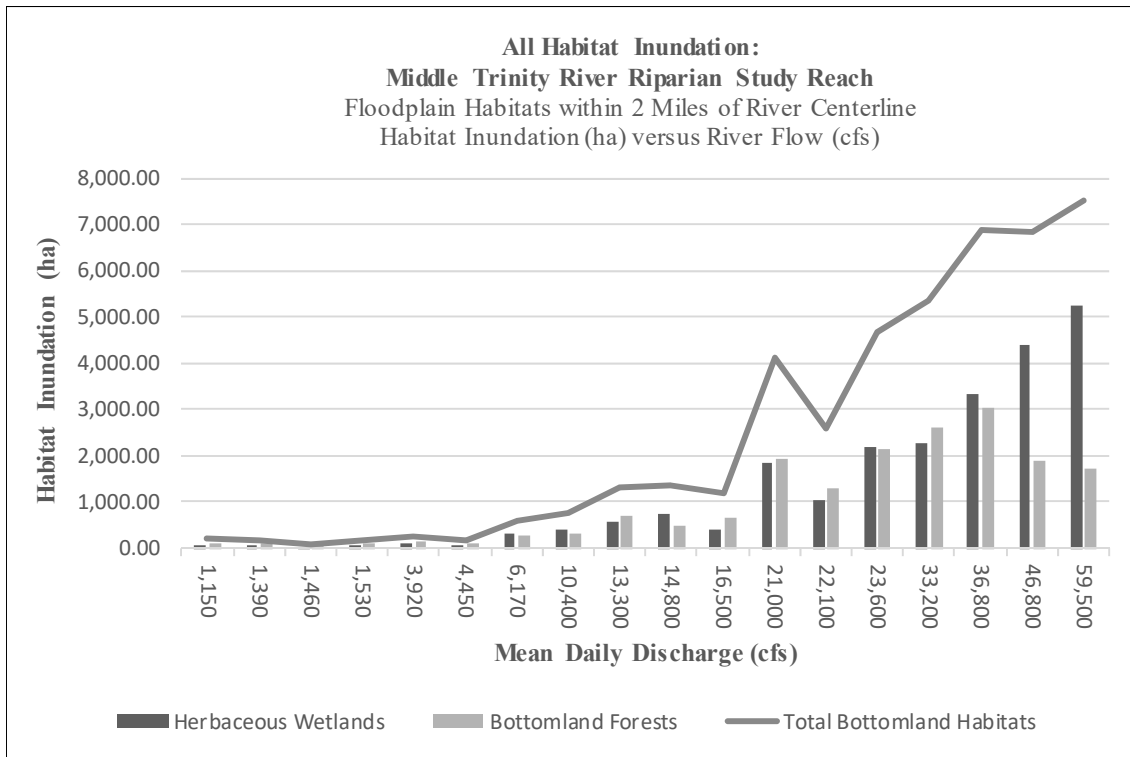


Figure 11. Inundation Maps: Legend for Habitat Types
 Blackland Prairie, Central Texas, Pineywoods, and Post Oak Savanna Habitat Types
 Middle Trinity River Riparian Assessment

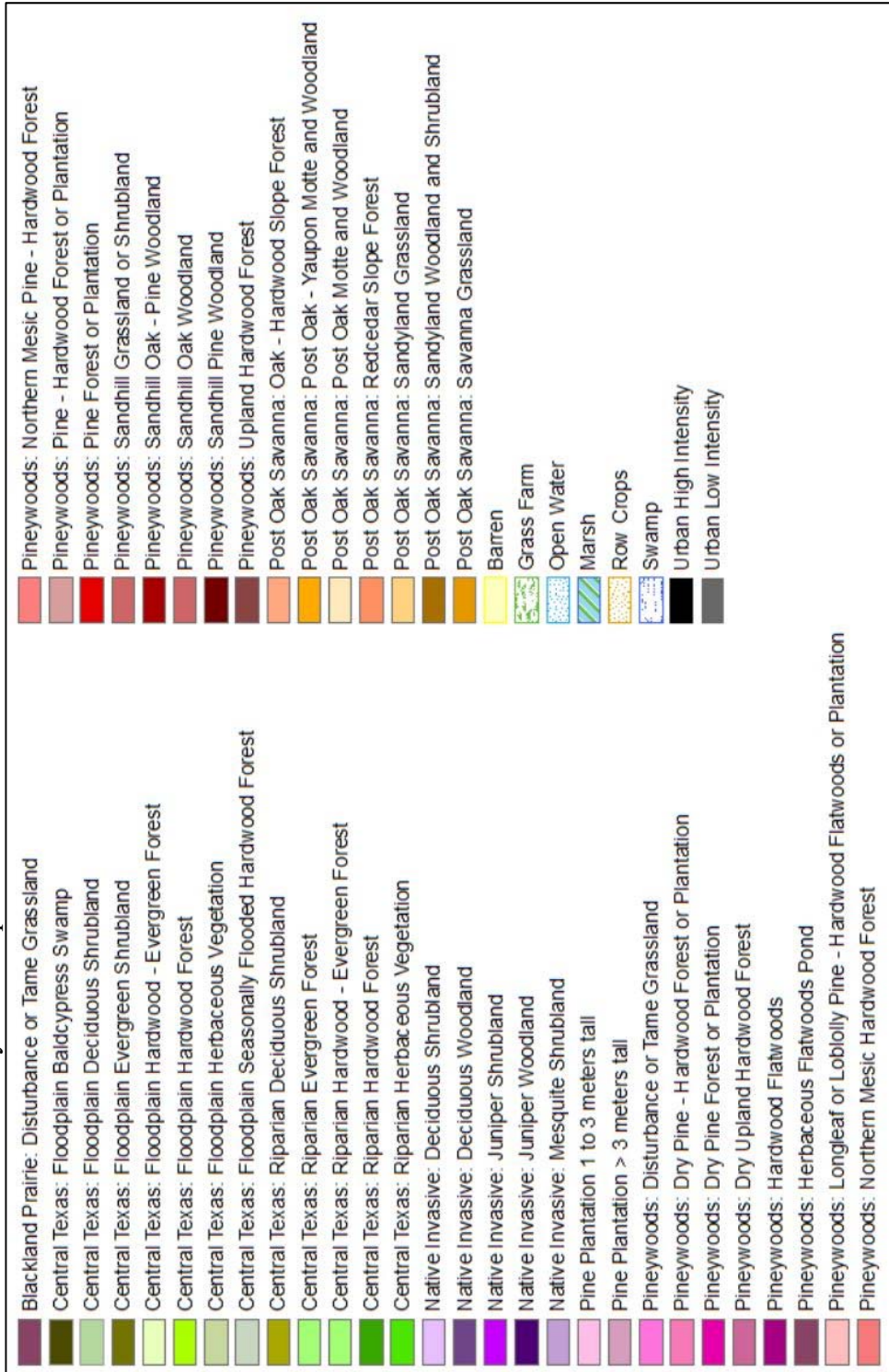


Figure 12. Channel-Connected Habitat Inundation Map
Daily mean discharge: 1,530 cfs, 01/08/94
Middle Trinity River Riparian Study Reach
No Connected Inundation Detected > 0.5 mi from River Centerline
(See Figure 11 for habitat legend)

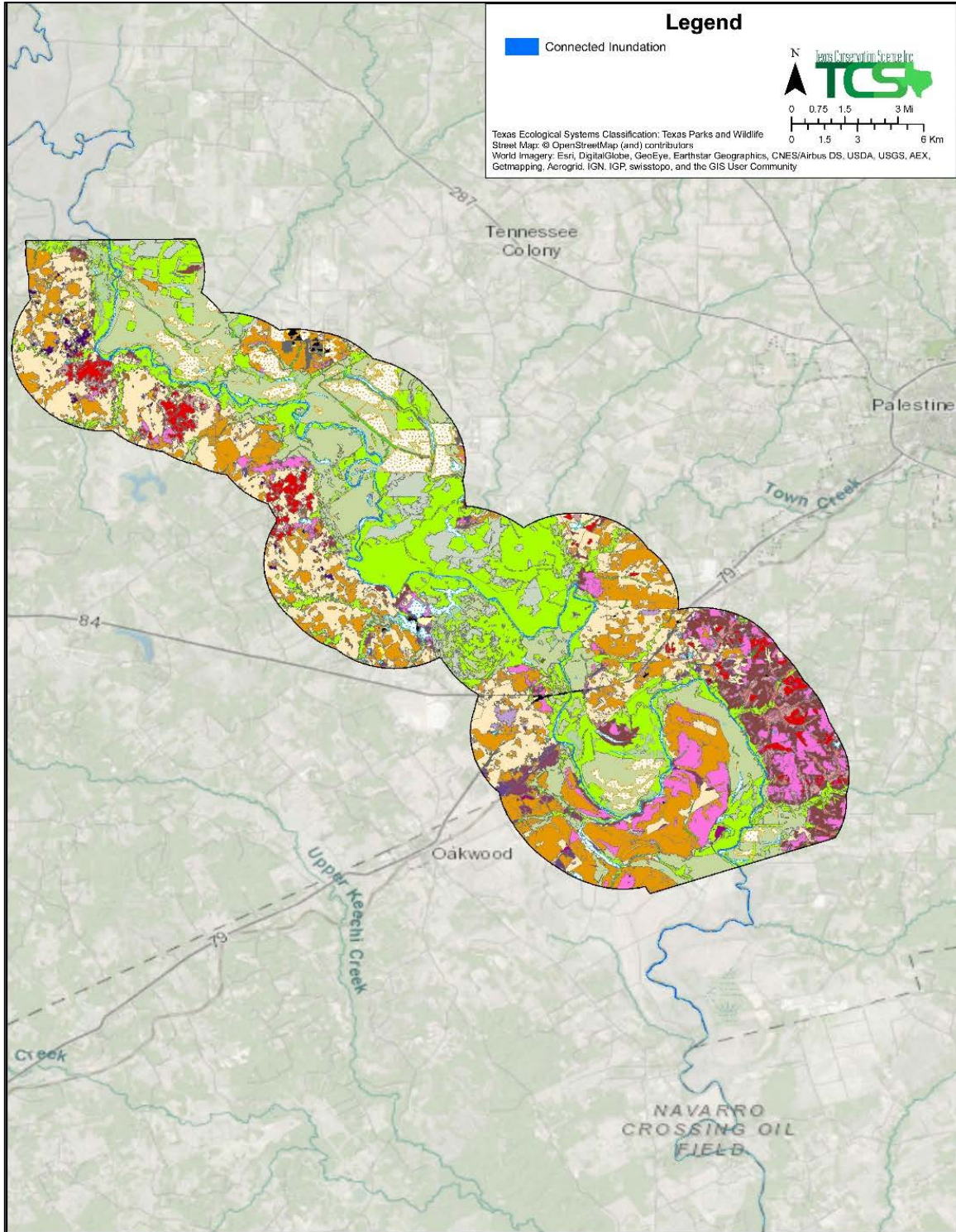


Figure 13. Channel-Connected Habitat Inundation Map
Daily mean discharge: 21,000 cfs, 02/25/94
Middle Trinity River Riparian Study Reach
No Connected Inundation Detected > 0.5 mi from River Centerline
(See Figure 11 for habitat legend)

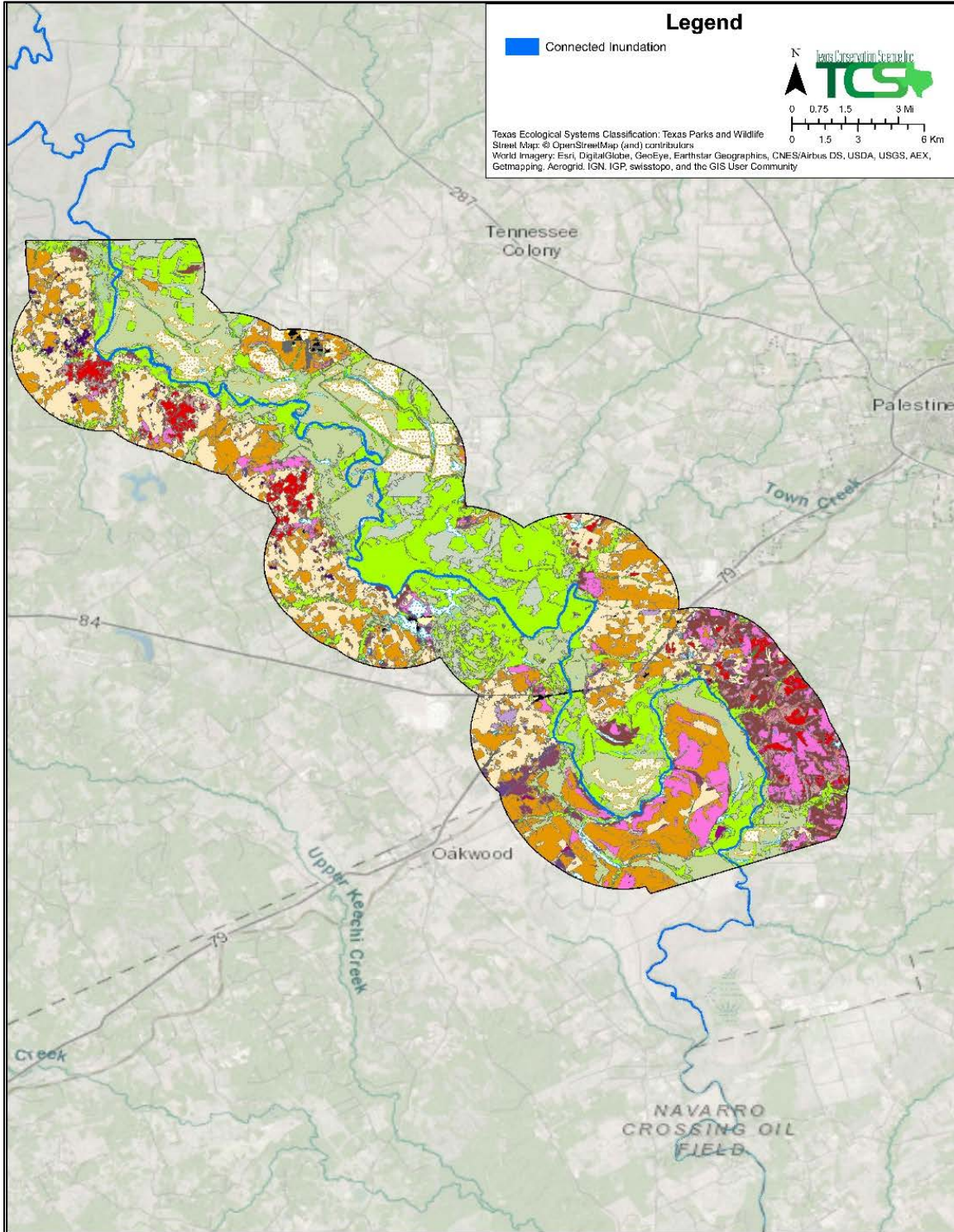


Figure 14. Channel-Connected Habitat Inundation Map
 Daily mean discharge: 36,800 cfs, 12/21/01
 Middle Trinity River Riparian Study Reach
 No Connected Inundation Detected > 0.5 mi from River Centerline
 (See Figure 11 for habitat legend)

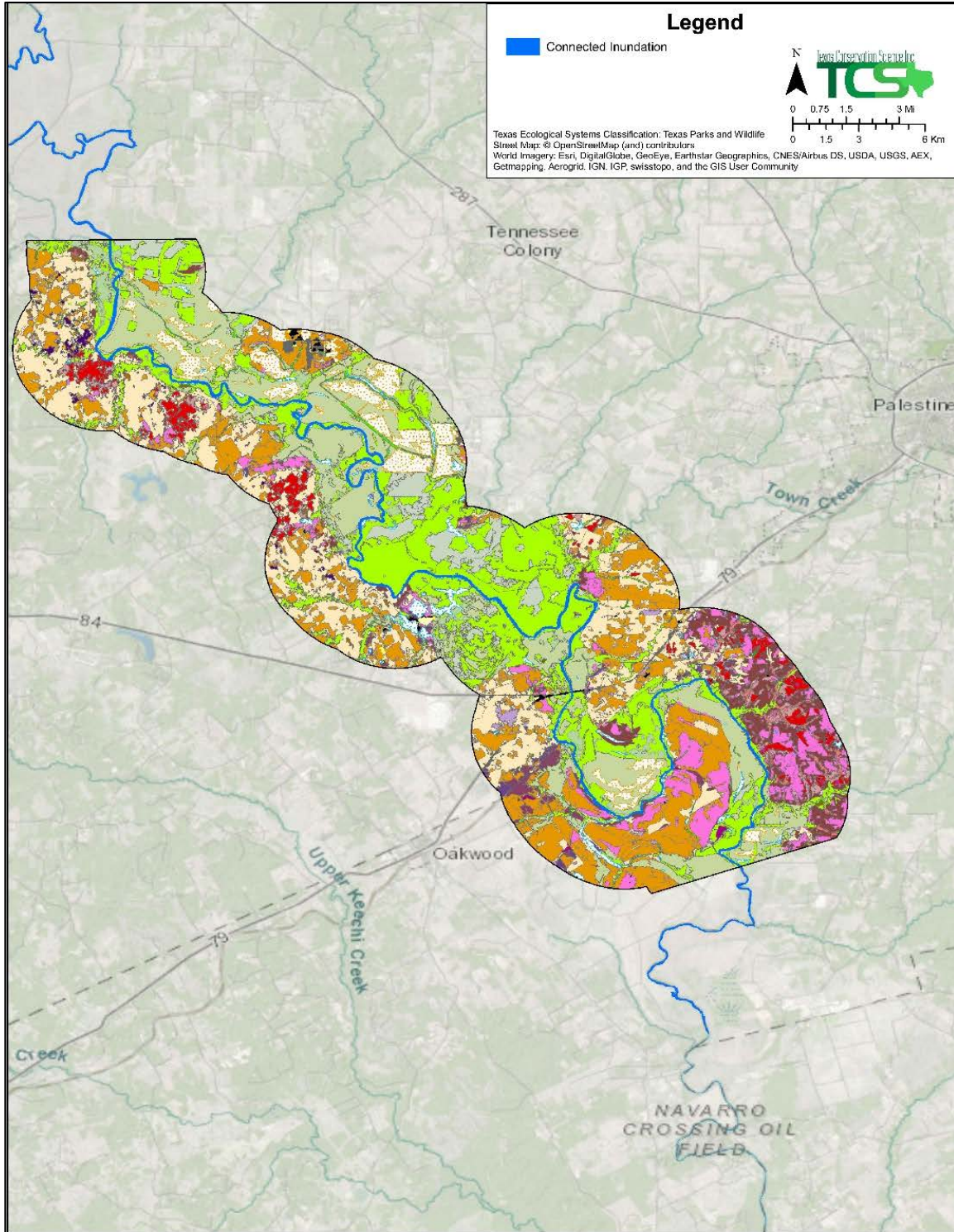


Figure 15. All-Habitat Inundation Map
 Daily mean discharge: 1,530 cfs, 01/08/94
 Middle Trinity River Riparian Study Reach
 Within 2.0 mi from River Centerline
 (See Figure 11 for habitat legend)

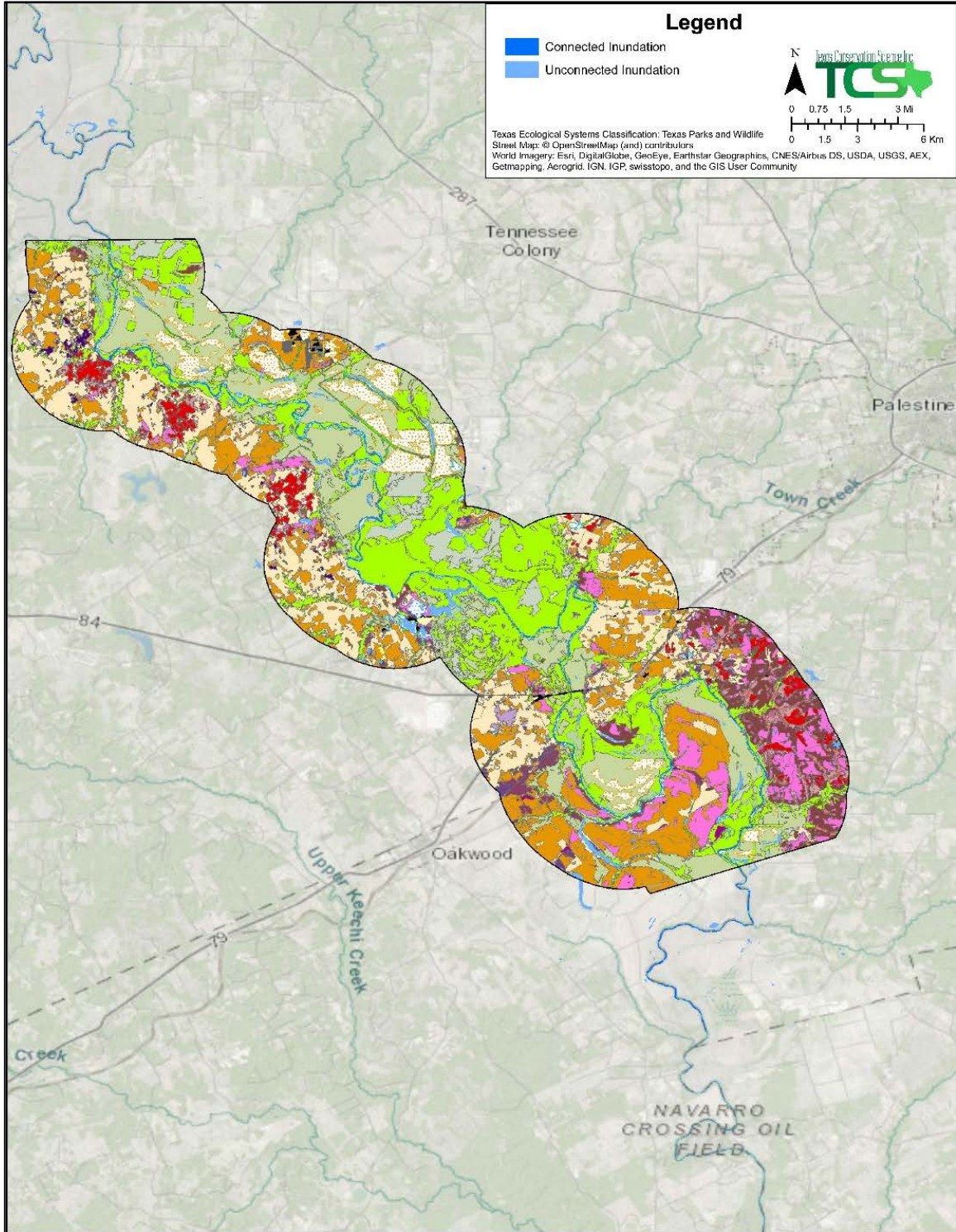


Figure 16. All-Habitat Inundation Map
 Daily mean discharge: 21,000 cfs, 02/25/94
 Middle Trinity River Riparian Study Reach
 Within 2.0 mi from River Centerline
 (See Figure 11 for habitat legend)

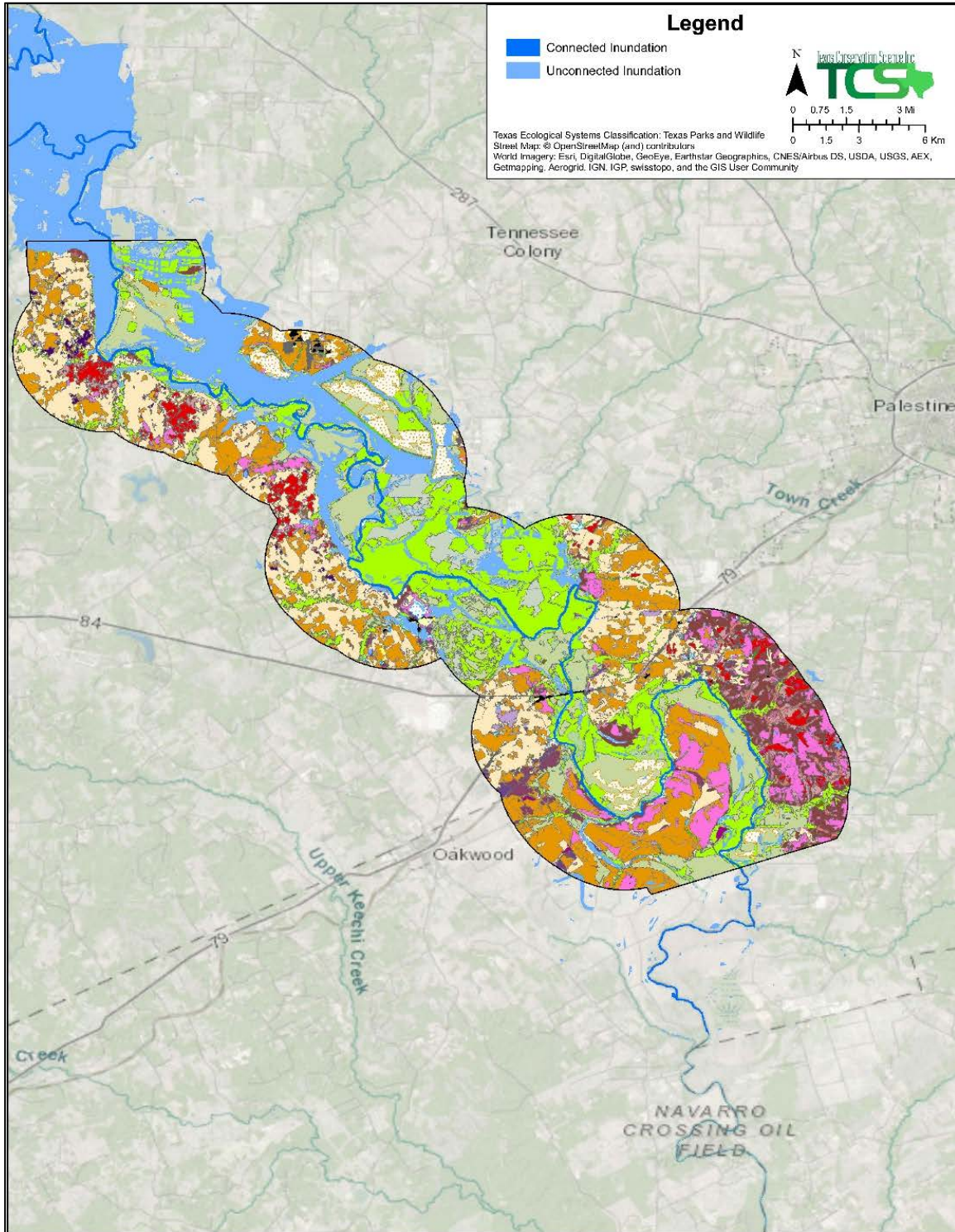
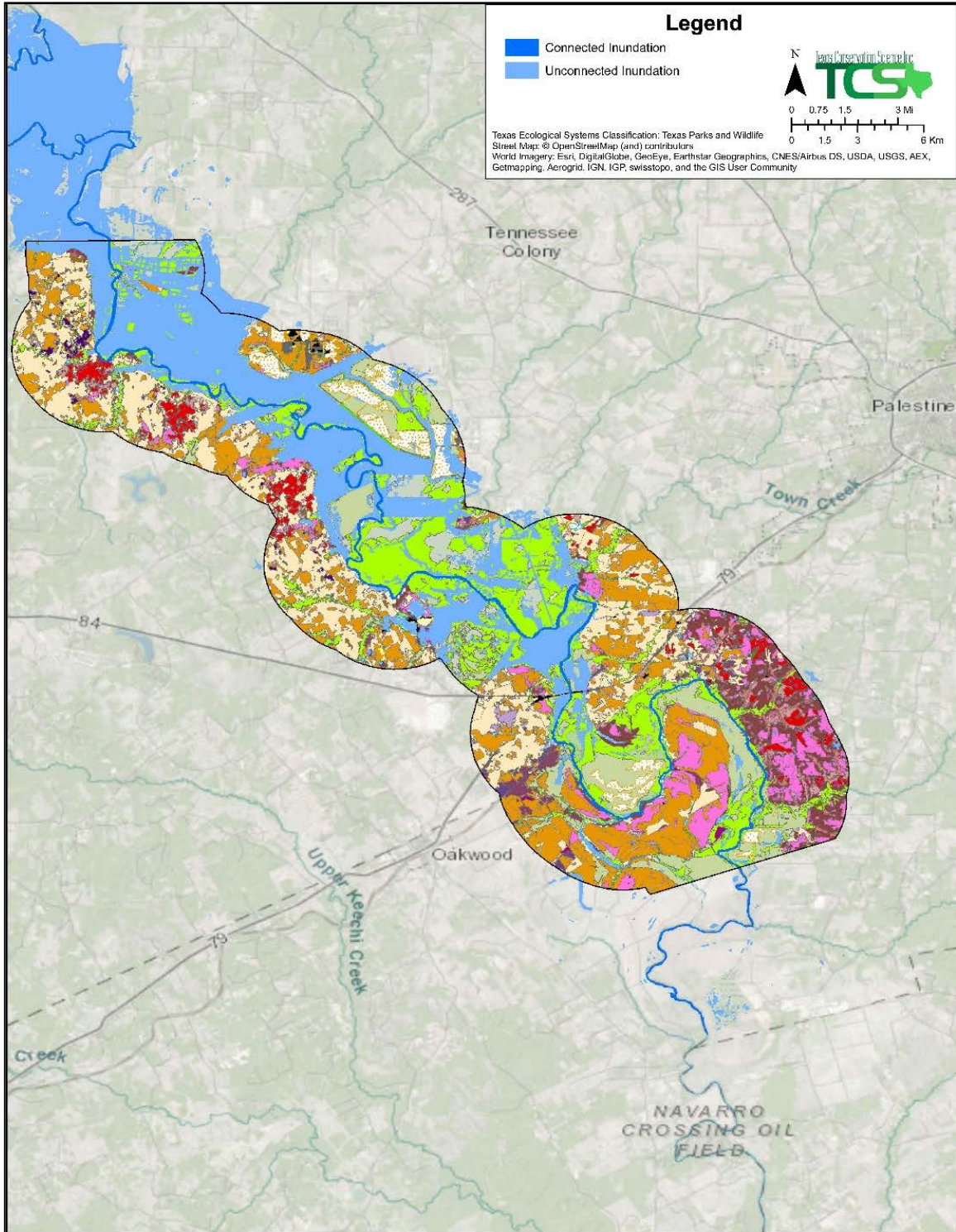


Figure 17. All-Habitat Inundation Map
 Daily mean discharge: 36,800 cfs, 12/21/01
 Middle Trinity River Riparian Study Reach
 Within 2.0 mi from River Centerline
 (See Figure 11 for habitat legend)



Appendix C: TWDB Comments on Draft Report

Attachment 1
Texas Parks and Wildlife Department
Riparian productivity along the middle Trinity River
Contract No. 1348311645
TWDB Comments on Draft Report

General Draft Final Report Comments:

As described in the report, this report covers the first task from the scope of work for this project (Task 1 – Riparian productivity along the middle Trinity River). The second task (Task 2 – Refinement of riparian productivity versus flow relationships for Texas rivers) will be discussed in a separate report. Activities described in this report are (a) data collection along 16 transects (8 transects at each of two riparian study sites) and subsequent analysis and (b) inundation analysis for a 51-mile section of the middle Trinity River. Data collected along 50 meter (164 feet) transects was associated with snag-live tree, shrub-sapling, and herb-seedling vegetation layers. Inundation analysis was completed using satellite imagery (Landsat Thematic Mapper), US Geological Survey daily gage data, and habitat maps from the Texas Ecological System. Overall, the report is well written and data collection and analysis methods are described adequately.

Significant findings from the analysis of riparian transect data include:

- The existing riparian tree community appears to be stable and diverse.
- Tree species that are tolerant of frequent and/or extended durations of inundation (black willow and swamp privet) are thriving relative to other riparian species.
- At the endpoints of transects (higher elevation, farther from the channel) species that are less tolerant of inundation appear to be less sustainable due to high mortality rates.

Significant findings from the inundation analysis include:

- Although some riparian habitats are inundated with flows as low as 1,150 cfs, flows of 10,400 cfs or greater are required to begin inundating larger areas of riparian habitat in the meander belt of the river.
- Flows greater than 21,000 cfs are required to inundate all riparian habitats within the meander belt of the river.
- Flows as great as 59,500 cfs are required to inundate all riparian areas along the 51-mile segment of river.

REQUIRED CHANGES TO REPORT

1. Please check the report for typos such as the following and correct as necessary:
 - a. Page 13, 4th paragraph, 1st sentence, “, Several measurements” should be “Several measurements.”
 - b. Page 16, 3rd paragraph, last sentence, “Total canopy caver” should be “Total canopy cover.”
 - c. Page 21, last paragraph, 1st sentence, “Elliott al. 2014” should be “Elliot et al. 2014.”
2. Please insure that all acronyms are defined before they are used in the text. For example, ENVI, ESRI, and TM on page 20 and NAHP, NAPP, TOP, and NAIP on page 22.
3. On page 23, the last two sentences of the first paragraph are difficult to understand. Specifically the meaning of the phrases “while constraining parallel” and “corrected by excluding merging two short gaps” is unclear. Please check these sentences for clarity and rewrite as necessary.

4. On page 26, 2nd paragraph, the 2nd sentence states “Each site has only one tree species with a high mortality rate.” However, for Site B, Table 6 on page A-13 lists four species (sugarberry, soapberry, cedar elm, and black willow) with percentages of snag to live tree basal area of between 21 and 31 percent. Please correct the statement on page 26 (or the data in Table 6) or provide further explanation of why the percentages of snag to live tree basal area for soapberry, cedar elm, and black willow at Site B do not represent “high mortality.”

SUGGESTED CHANGES TO REPORT

5. Please consider using a larger font for the Table of Contents and List of Tables and Figures on pages 2 and 3.
6. To improve the ease of reading the report, please consider embedding tables and figures within the body of the report rather than appended to the end of the report.
7. To make results understandable to the widest audience, please consider using both imperial and metric units throughout the document. For example, on page 27, 4th paragraph, lengths are provided in units of kilometers and miles and areas are provide in units of hectares and square miles. Unfortunately, in other areas of the report, data is provided in only imperial or metric units (not both). For example, on page 6, 2nd paragraph, length is provided in miles (but not kilometers) while in the 3rd paragraph on the same page, widths are provided in units of meters and kilometers (but not feet and miles).
8. Please consider providing a citation for the following statement (last sentence on page 6, continuing to page 7): “serious erosion along streams and other drainages is a continuing issue, caused by the widening of the Trinity River during water control and agricultural activities, and all-terrain vehicle traffic on BLBWMA.”
9. On page 17, 1st paragraph, 1st sentence, please consider listing all methods used to keep the pin vertical as it descends and/or ascends through the vegetation, rather than resorting to the use of the abbreviated expression “etc.”
10. For clarity, please consider listing the portion of the year implied by the phrase “the growing season” on page 24, 2nd paragraph, last sentence. A parenthetical reference to a specific period (such as “March through October”) would be sufficient.
11. On page 26, 2nd paragraph, 5th sentence states “These mortality results indicate that tree species composition may be adapting to recent increases in flood duration.” At present, there don’t seem to be any citable references to describe changes in flood duration at this site on the Trinity River, but TIFP 2018 (included in the citations for the report) found evidence that the operation of large reservoirs in the Brazos basin changed high pulse flows from having higher peaks with shorter durations before reservoir construction to smaller peaks with longer durations in recent years (Figure 16, page 33 of TIFP 2018). Such changes would cause riparian areas with higher elevations (typically farther from the main channel) to be inundated less frequently, while riparian areas with lower elevations (typically closer to the main channel) would be inundated for longer portions of the year. Please consider explaining if the mortality results shown in this study are consistent with similar changes in high pulse hydrology.

Appendix D: TCS Response to TWDB Comments on Draft Report

Appendix D
Texas Parks and Wildlife Department
Riparian productivity along the middle Trinity River
TWDB Contract No. 1348311645
TCS Response to TWDB Comments on Draft Report

TCS completed all required changes and most of the suggested changes. The only suggested edits that were not fully addressed were numbers 6-7, for reasons described below.

TWDB General Draft Final Report Comments:

Some of the TWDB general comments were modified and partially included in both Abstract and Section 6 (Conclusion) of final report.

REQUIRED CHANGES TO REPORT

1. The three listed typos and all other typos were corrected throughout the entire report.
2. All acronyms in the final report were defined prior to their use in the text, including those listed on page 22 of the draft report.
3. On page 23, the last two sentences were rewritten as requested, along with the entire paragraph as follows:

The gap-modified study-reach shapefile was then created, using the Split tool on each half upstream (US) and downstream (DS) of the center point of the selected meander. The Split tool was set to 25 miles plus new increased length. US and DS lines were then combined after which the Buffer tool was used with distance set to 2 miles and “dissolve all” option selected to create new study reach polygon. Next, additional buffers were created with distances set to 0.5 and 1 mile to measure inundation distance incrementally from channel. Cut Polygons tool was used on the new study reach polygons with lines from the previous meander-based line construction step as templates. Resulting gaps were deleted from the study reach polygon. Any rounded ends were removed from study reach polygons by using similar method, as in previous steps. After the above meander-gap analysis, channel meander (1982-present) was found to be very minimal in the Middle Trinity River study reach and easily corrected by excluding two short gaps in the Landsat data.

4. The subject paragraph was rewritten as follows:

Table 6 tallies the percentage of snags versus live trees based on basal area within each study site, in order to examine the viability of riparian tree species under the current flow regime. Site B and site C have four and one species, respectively, with a high mortality rate. Based on live-tree importance values and percentage of snags, the least sustainable tree species at site B is sugarberry, a dominant species adapted to drier upper elevations in bottomlands. At site C, green ash, also a dominant species but adapted to wetter soils at lower elevations without extended inundation, has the highest mortality rate. These mortality results indicate that tree

species composition may be adapting to recent decreases in the occurrence of inundation at higher elevations, and increases in flood duration at lower elevations, within riparian forests at the BLBWMA riparian sites. This interpretation is supported by the most dominant tree species with the lowest mortality rates at the two sites (swamp privet, black willow) having the highest flood tolerance and occupying the lowest elevations near the main river channel. The possible implications of this mortality pattern are discussed in Section 5.1, in terms of changes in the high-pulse flow regime.

SUGGESTED CHANGES TO REPORT

5. As requested, a larger font was used for the Table of Contents and List of Tables and Figures on pages 2 and 3.
6. TCS decided not to insert tables and figures throughout the text, and to keep them together at the end of the report, since their large number may impede readability if dispersed throughout the report. A separate PDF file of only Appendices A and B (tables and figures) was instead provided, in case that is helpful for cross-referencing while reading the report.
7. In response, the number of measurements with both metric and imperial values was greatly increased. Since adding both sets of values throughout the report may again impede readability, in some cases both sets of values were only used at the initial use of a type of measurement (i.e., cfs). Imperial values for many of the smaller-scale (i.e., cm) vegetation measurements were also not included.

Instead of using dual sets of values, TCS suggests that all measurements be only metric, like is standard in scientific papers. However, the need to reach out to stakeholders and the general public is well understood. Please advise if more imperial values should be added beyond those added in response to the suggestion, or if additional changes are desired.

8. The requested citation (Fleming 2002) was inserted.
9. As suggested, all primary methods to keep the pin vertical were added to the paragraph, as follows:

The herb layer is defined as all herbs of any height plus woody seedlings 0.01-1.37 m tall, and is quantified using the point intercept method. Along the central 50-m transect in each 50 m X 10 m macroplot, interception is measured at 51 points (0-50 m), recording the number of all contacts between plants (leaves, stems, etc.) and the tip of a narrow (2-mm diameter) pin passed into the vegetation. The pin must be kept vertical and on point. A plumb bob is used to establish a ground reference point at each point, using a polished aluminum nail head as a target to direct the pin. The pin is kept vertical as it descends and/or ascends through the vegetation, using a pin level and point densiometer. The point densiometer is especially useful when extending the point vertically to intercept tall herbs such as giant ragweed.

10. As requested, the last two sentences of the subject paragraph were revised as follows:

These discontinuous forest stands are inundated during large portions of the growing season every year, and may be only intermittently exposed adjacent to the river channel. At Palestine

near BLBWMA, the growing season is March 24 – November 12 (freeze-free period), according to the Texas State Climatologist (2010).

11. As suggested, the identified paragraph was revised as follows, with a more extended response provided in Section 5.1:

Table 6 tallies the percentage of snags versus live trees based on basal area within each study site, in order to examine the viability of riparian tree species under the current flow regime. Site B and site C have four and one species, respectively, with a high mortality rate. Based on live-tree importance values and percentage of snags, the least sustainable tree species at site B is sugarberry, a dominant species adapted to drier upper elevations in bottomlands. At site C, green ash, also a dominant species but adapted to wetter soils at lower elevations without extended inundation, has the highest mortality rate. These mortality results indicate that tree species composition may be adapting to recent decreases in the occurrence of inundation at higher elevations, and increases in flood duration at lower elevations, within riparian forests at the BLBWMA riparian sites. This interpretation is supported by the most dominant tree species with the lowest mortality rates at the two sites (swamp privet, black willow) having the highest flood tolerance and occupying the lowest elevations near the main river channel. The possible implications of this mortality pattern are discussed in Section 5.1, in terms of changes in the high-pulse flow regime.

Additional response in second to last paragraph in Section 5.1:

Nonetheless, tree mortality at BLBWMA indicates the flow regime is currently altered by upstream reservoir operation. The results in Section 4.1.1 that described high mortality among sugarberry at high elevations, coupled with increased mortality at low elevations of green ash, which is intolerant to extended inundation, resembles the downstream impacts of reservoirs on the Brazos River riparian forests (TIPP 2018). The reservoirs alter the high-pulse hydroperiod on the Brazos River, so that the pre-impact regime of higher pulse flows with shorter durations was converted to regulated flows consisting of lower pulse flows of longer duration. In this manner, the increased mortality of high-elevation sugarberry at BLBWMA is probably due to its reduced inundation by lower pulse flows. And the increased mortality of low-elevation green ash measured in this study is likely caused by the longer duration by lower pulse flows, again due to upstream reservoir operation.