APPENDIX M: INSTREAM FLOW STUDY AND SUPPLEMENTAL DATA CONDUCTED FOR THE PROPOSED LOWER BOIS D’ARC CREEK RESERVOIR

M-1: INSTREAM FLOW STUDY FOR THE PROPOSED LOWER BOIS D’ARC CREEK RESERVOIR

M-2: INSTREAM FLOW STUDY SUPPLEMENTAL DATA FOR THE PROPOSED LOWER BOIS D’ARC CREEK RESERVOIR

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Proposed Lower Bois d'Arc Creek Reservoir

Fannin County, Texas

Instream Flow Study Supplemental Data

September 2010

prepared for:
North Texas Municipal Water District

prepared by:
Freese and Nichols, Inc.

THE Lower Bois d'Arc Creek RESERVOIR
NORTH TEXAS MUNICIPAL WATER DISTRICT

Proposed Lower Bois d'Arc Creek Reservoir

Fannin County, Texas

INSTREAM FLOW STUDY

Supplemental Data

September 2010

9-15-10

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EXECUTIVE SUMMARY

This report presents the results and interpretation of data collected after the May 2010 submission of the Proposed Lower Bois d'Arc Creek Reservoir Instream Flow Study (FNI, May 2010). The purpose of this report is to: (1) document supplemental geomorphic and biological data, and (2) present comparisons made with the baseline biological data used to describe Bois d'Arc Creek, and (3) relate results to the proposed instream flow regime presented in the 2010 Instream Flow Study.

Information presented in this report includes fluvial geomorphic and biological data collected after the submission of the 2010 Instream Flow Study report. The geomorphic data were used to monitor change in stream channel morphology of Bois d'Arc Creek. Supplemental biological data were used for comparative analyses as well as trial testing of the proposed mitigation monitoring metrics of benthic macroinvertebrate (Rapid Bioassessment Protocol [RBA] and fish Index of Biotic Integrity [IBI]). These analyses were conducted to augment the biological characterization of Bois d'Arc Creek, and to test the sensitivity of IBI and RBA metrics as long-term monitoring tools. Finally, modeled flow duration curves with and without the reservoir in place were related to the proposed subsistence, base, and pulse environmental flow regime amount (3,10, and 50 cfs, respectively) and schedule. Deliberate releases for overbanking flows are not included in the proposed flow regime. Supplemental information regarding overbanking flows is presented in Appendix C.

Results from the fluvial geomorphological investigation showed that the study reaches in Bois d'Arc Creek are currently increasing in cross-sectional area under the current unregulated flow regime. The primary erosional process driving these increases is mass failure of bank material. In most cases mass failure was induced by scouring and removal of lower bank material leading to over-steepening of banks and subsequent bank collapse. Erosion pins were used to quantify bank loss resulting from fluvial erosion. Higher amounts of fluvial erosion were measured on the sparsely vegetated, exposed banks at the FM 1396 site than the FM 409 site.

Results from the supplemental biological data supported the original biological characterization presented in the May 2010 Instream Flow Study report. Comparative analysis of fish community composition, trophic and reproductive community structure, and mesohabitat association illustrated similar patterns as the data collected the previous year, which identified Bois d'Arc Creek as a system dominated by generalist species with weak specific habitat associations. Additionally, the new RBA and IBI scores fell within the same Aquatic Life Use (ALU) range as previously quantified (i.e., intermediate and high, respectively). Finally, analysis of modeled hydrological data re-affirmed that as stream discharge increases in Bois d'Arc Creek habitat diversity rapidly decreases.

Further analysis of the modeled with and without the dam flow duration curves indicated that there would be an increase in duration of aquatic habitat under the proposed flow regime.

Comparisons of the pre-dam and post-dam spring (fish spawning) flow duration curves indicate that there will be an increase in the duration of the discharge (10 cfs) that provides optimal habitat diversity and supports fish reproduction (26% or 24 days), and an increase in the duration of maximum riffle habitat (18% or 16 days). Additionally, summer ("critical period") comparisons indicated an increase in duration of stream connectivity by 55% or 66 days.

The findings of the fluvial geomorphic component of this study support the proposed instream flow regime. Decreases in the magnitude and frequency of higher flow pulse events (> 100 cfs), and increases in the duration of low flow events would allow vegetation to become established on the banks. This should reduce the lower banks' susceptibility to erosion and increase overall bank stability.

The additional biological data collected did not introduce any new information that would require revising the 2010 Instream Flow Study proposed flow regime. The supplemental biological data complemented the original data, also indicating that additional sampling events would not supply different information than has already been attained.

The evaluation of modeled flow duration curves, at the proposed release conditions, identified that the flow release schedule would maintain or improve the duration of available aquatic habitat in Bois d'Arc Creek. Overbanking flows were not evaluated because study results indicate that reservoir releases should not exceed 50 cfs in order to minimize erosional processes, channel downcutting, and habitat destruction. In addition, TCEQ indicated during a March 2009 interagency Instream flow planning meeting that overbanking flows would not be required by the water right permit, if granted.

Based on the information developed by this study, the 2010 Instream Flow Study proposed flow regime[1] is valid and would provide a sound ecological environment for Bois d'Arc Creek downstream of the proposed reservoir.

The existing condition of Bois d'Arc Creek is not sound ecologically. The creek is a highly channelized stream system. The altered nature of the stream system is important because the channelization plays a significant role in the current behavior and existing processes occurring in the stream system. The straightened and channelized sections of Bois d'Arc Creek contribute to the flashy nature of the creek, substantial erosion of the stream bed and banks, lack of habitat diversity in channelized sections, and minimal lateral migration of the stream.

The frequent high erosive flows that occur in response to rain events in the watershed are currently degrading the channel, contributing to continuing erosion, including channel downcutting/widening and bank mass failures. This results in negative impacts to aquatic habitats by mass wasting and high current velocities that scour established habitats resulting in a

[1] 2010 Instream Flow Study, FNI, Section 5.2, Page 101

constant state of flux. The channel also experiences a recurrence of zero flow on an almost annual basis. This limits habitat and species diversity.

To provide a sound ecological environment in Bois d'Arc Creek, it is necessary to reduce the frequent highly erosive flows and provide sufficient flows to maintain water quality, provide connectivity between habitats, and foster aquatic species reproduction and habitat maintenance. Consistent with the Texas Instream Flow Program, it is proposed that the following instream flow regime as measured at the USGS gage located at FM 409 would provide a sound ecological environment for Bois d'Arc Creek downstream of the proposed reservoir:

- **Subsistence flow: 1 cfs** . This would provide flow to maintain water quality during extreme drought. Water would be released through the dam when the Lower Bois d'Arc Creek Reservoir is less than 40 percent full. Based on reservoir operation modeling studies, this would occur nine percent of the time.

- **Base Flow (July to March)**: **3 cfs**. This flow would provide connectivity of mesohabitats and is capable of moving sediment through the channel. Releases of 3 cfs are proposed to occur from July through March.

- **Base Flow (April to June): 10 cfs**. These higher base flows are proposed during the primary spawning months of the dominant fish species to encourage and support reproductive activities.

- **Pulse Flow: 50 cfs.** It is proposed that two deliberate pulse flows would be released annually if such flows do not occur naturally. One pulse flow of 50 cfs would be released on June 1 if one did not occur in the previous April or May. Another pulse release would occur on October 1 if one did not occur in the previous September. These pulse releases would provide the necessary stream power to move larger sediment particles (gravel) and maintain habitats. However, these flows would remain below the volume and duration that are expected to cause stream channel and habitat degradation.

1 INTRODUCTION

The North Texas Municipal Water District submitted an application for a State of Texas water right for the Lower Bois d'Arc Creek Reservoir project in December 2006. An application for a Section 404 permit was submitted to the Tulsa District of the U.S. Army Corps of Engineers (USACE) in June 2008. In support of the permitting activities associated with this project, an Instream Flow Study was conducted based on protocols established by the Texas Instream Flow Program. In May 2010 the Instream Flow Study Report was submitted to the Texas Commission on Environmental Quality (TCEQ), Tulsa District USACE and cooperating agencies.

During the development of this study, an Inter-Agency Team consisting of representatives of state and federal agencies provided input on the Instream Flow Study methodologies and sampling locations. During a meeting in September 2009 the Inter-Agency team requested additional biological sampling of Bois d'Arc Creek to capture a longer time period. Due to an unusually wet autumn and winter, this event could not be conducted until May 2010. This supplemental report presents the findings of this additional sampling event and geormorphic data subsequent to the 2010 Instream Flow Study Report.

Additional stream geomorphic and biological data were collected approximately one year after the data presented in the submitted 2010 Instream Flow Study report. The geomorphic data includes recently quantified stream bank erosion and sediment transport measurements, which were used to evaluate stream geomorphic changes over time. Biological data (benthic macroinvertebrates and fish) were collected during the May 2010 supplemental sampling event, and these data were analyzed comparatively against previously described aquatic communities, habitat associations, and aquatic life use (ALU) designations found in Bois d'Arc Creek.

The subsequent sections describe the study components, methods, comparative analyses, results, and interpretation of data not included in the previously submitted 2010 Instream Flow Study report. Detailed information such as geomorphic field datasheets, raw biological data, and supplemental tables or figures is presented in Appendices A and B.

2 SAMPLE COMPONENTS AND METHODS

2.1 Fluvial Geomorphology

The additional geomorphic data provides a baseline inventory (pre-project) of existing channel bed and bank conditions at two reaches of Bois d'Arc Creek, including measurements of erosional changes between 2009 and 2010. Comparison of baseline conditions with post-project measurements would allow assessments of channel processes. This report presents monitoring data and describes changes to channel bed and banks observed during the baseline measurement period.

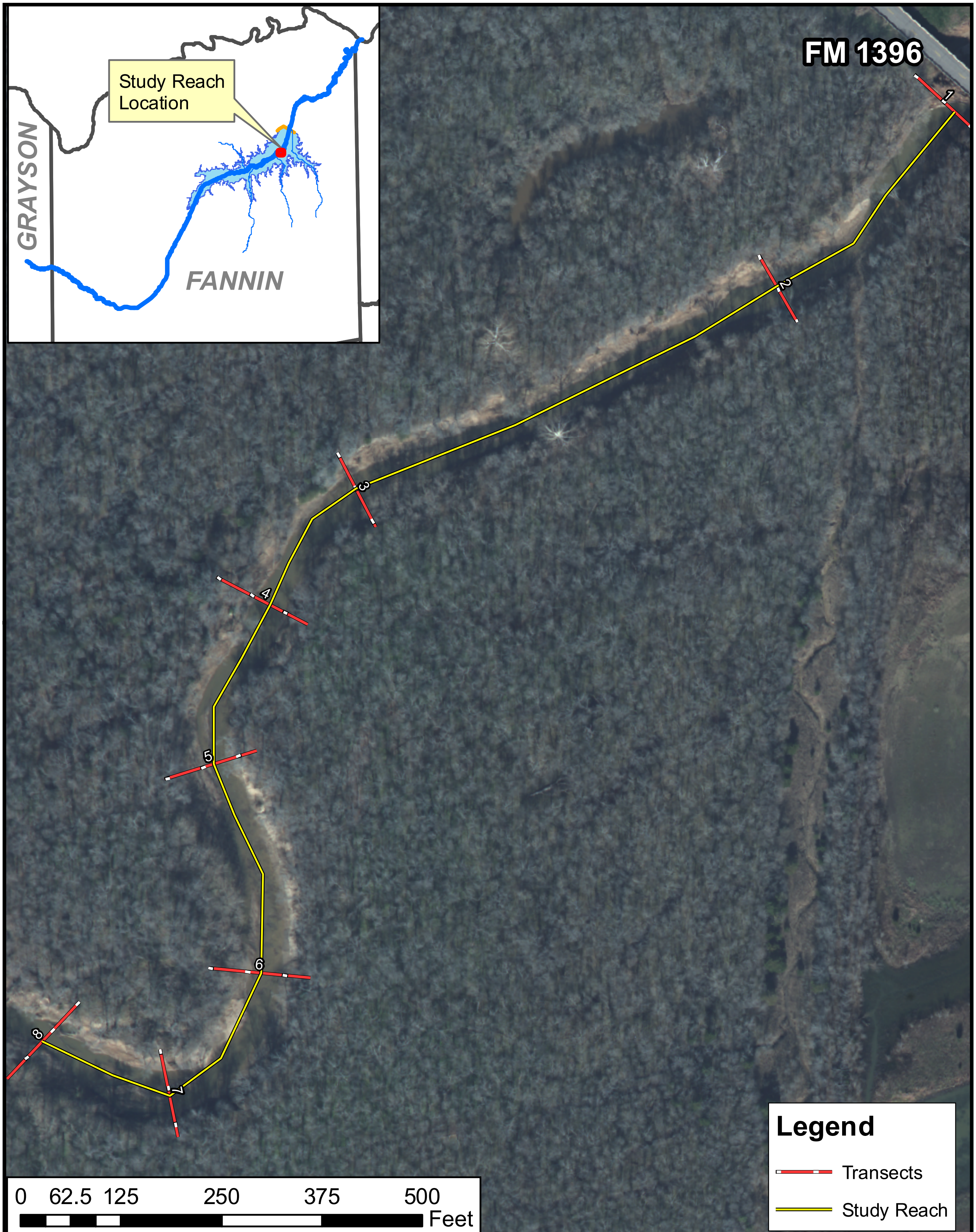
2.1.1 Methods

Eight and seven permanent transect sites were established within the Instream Flow Study reaches FM 1396 and FM 409, respectively (Figure 2.1 and 2.2). The Inter-Agency Instream Flow Team collaborated and concurred on the placement of the transect locations which were spaced to provide good representation across geomorphic units (pools, runs, bars, etc.) within each reach. At each transect a primary control point was established on the left bank and surveyed to determine the absolute elevation. A line-of-sight was established at right angles to the channel, and two 2-foot long steel bars (quarter-inch diameter) were driven in the line-of-sight (each adjacent to the top of the channel bank of either side of the stream). Transects were measured with the use of surveying equipment (sighting level, tripod, and stadia rod). Transects were measured in March to April 2009 and July 2010, allowing approximately a one year period for monitoring change.

Cross-sectional area was calculated with WinXSPRO version 3 (Hardy et al. 2005) which computes area based on the surveyed bank dimensions. The cross-sectional area of a stream is determined by multiplying channel depth by channel width along a transverse section of stream. Calculated cross-sectional area for each year was compared to determine an amount of change in the channel morphology.

Repeated transect measurements were used to identify channel changes of about 1-foot or more, and erosion pins were used to monitor bank changes directly with a detection limit of about 0.01-foot. Erosion pin monitoring is an established method of assessing bank erosion in which a permanent marker is installed and measurements of the amount of pin exposed are made over time (Curran 2000).

Fluvial erosion at FM 1396 and FM 409 was monitored using erosion pins (Wolman 1959; Haigh 1977; Hooke 1980; Throne and Tovey 1981; Lawler 1993; Couper and Maddock 2001; Couper et al. 2002; Zaimes et al. 2005; and Capello 2008). Erosion pins are steel rods 2 feet long and ¼ inch in diameter that are inserted perpendicular into the bank wall (Wolman 1959). Pins were hammered into the stream bank with minimal disturbance to surrounding soil and were



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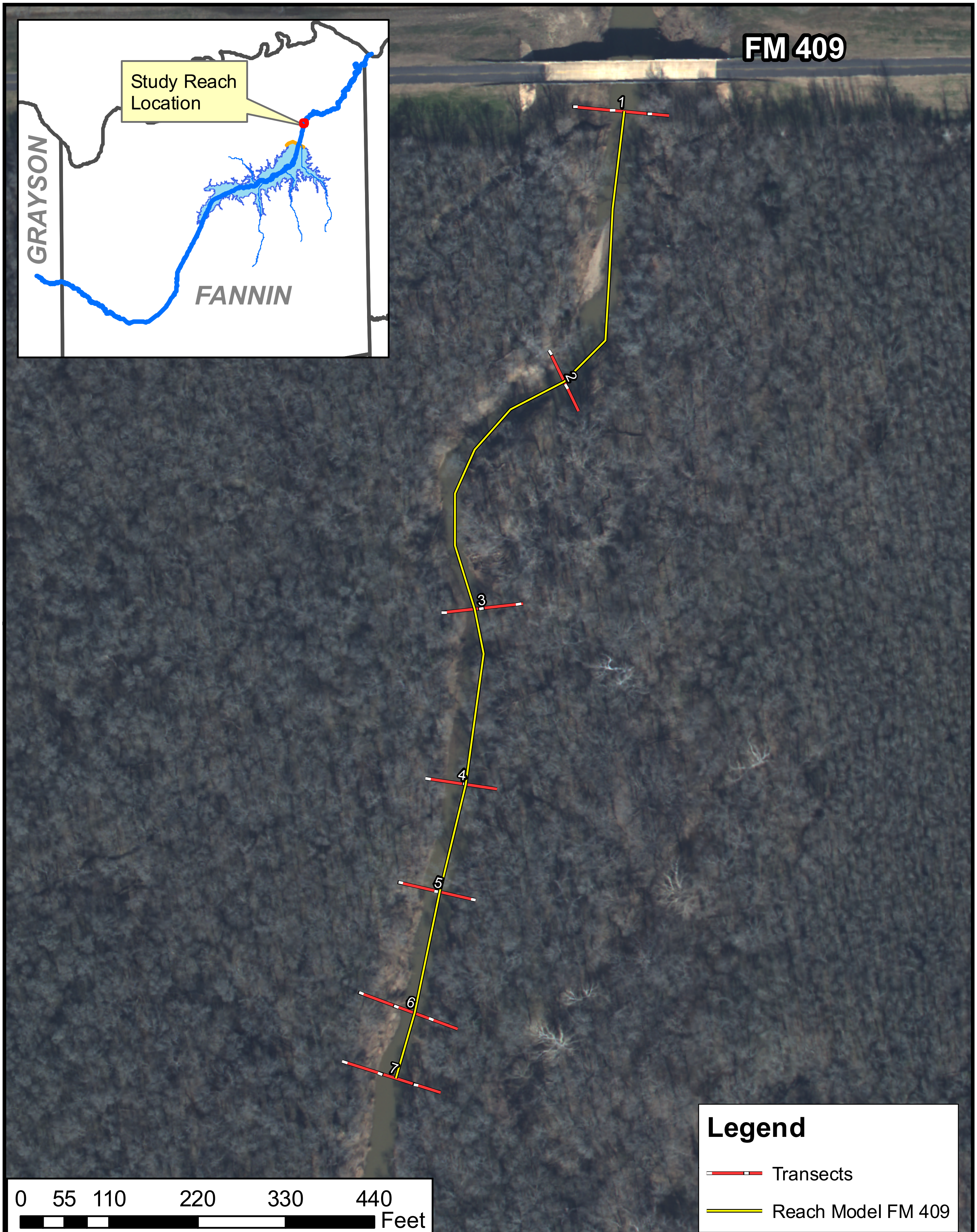
Transects at Bois d'Arc Creek Study Reach near FM 1396

FN JOB NO	NTD06128
FILE	Historic.mxd
DATE	March 2010
SCALE	1:2,000
DESIGNED	SVC
DRAFTED	SVC

FIGURE 2.1



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Transects at Bois d'Arc Creek Study Reach near FM 409

FN JOB NO	NTD06128
FILE	Historic.mxd
DATE	March 2010
SCALE	1:2,000
DESIGNED	SVC
DRAFTED	SVC

2.2
FIGURE

left with 2 inches exposed to aid in re-locating the pins (Couper and Maddock, 2001). Only one severely eroding stream bank was chosen per site to assess the maximum potential erosion loss rates for the erosion pin grids. These types of sites supply the majority of the sediment into stream channels (Zaimes et al. 2005). A severely eroding bank is characterized by being bare with slumps and with vegetative overhangs and/or exposed tree roots (USDA 1998; Capello 2008).

Ten pins were placed at each site. One row of five pins, spaced three feet apart, was placed at the active channel (lower bank) height, and a second row was placed at twice the active channel (upper bank) height (Zaimes et al. 2005; Capello 2008; Coffman, 2009 [FNI May 2010, Appendix C]). Over the monitoring period, the exposed erosion pins were measured with digital Vernier calipers to determine bank erosion loss. The pins were hammered back into the bank with a 2-inch exposure after each measurement. Five erosion measurements were obtained from each site between flow events when the channel was safely accessible during March 2009 to May 2010.

Erosion pins were installed at Transect 7 at FM 1396. Erosion pins were placed on the right bank on the outside of a meander. The monitored bank was bare of vegetation with a relatively steep side slope of 2:1. The erosion pins were placed at bank heights of 6 and 12 feet. The erosion pins were installed at Transect 3 at FM 409. At this location the pins were also placed on the right bank in a straight reach. The bank supported sparse surficial vegetation, but contained numerous deep roots from trees in the forested riparian corridor that also shaded the bank. The slope of the bank was 2.5:1. The erosion pins at FM 409 were placed at bank heights of 4 and 8 feet.

Soil samples were collected on the stream bank wall at the same locations as the erosion pins. Soil bulk density samples were collected with an aluminum core tube. The bulk density was measured after the soil samples were weighed after drying for 1 day at 105°C (Blake and Hartge, 1986).

2.2 Biology

The supplemental biological samples were collected to evaluate the relative influence of additional sampling on the previously reported biological results (i.e., species assemblage composition, community structure, species-habitat associations, and RBA/IBI metric scores). These data were also compared to baseline data to determine if there were differences in biological results across sample events. An in-depth analysis of individual IBI scores was also conducted to identify the primary components creating differences among ALU designations. Additionally, modeled (River 2D) stream depths and current velocities were re-examined to evaluate available aquatic habitat at the proposed reservoir release flows.

2.2.1 Methods

On May 12, 2010, a supplemental biological sample was conducted at sampling reaches FM 409 and USFS (Figure 2.3). Biological sampling was conducted in accordance with the TCEQ's 2007 Surface Water Quality Monitoring Procedures. Detailed biological field sampling, habitat association analysis, and IBI/RBA calculation methods can be found in the 2010 Instream Flow Study Report[2].

Biological data were analyzed using three groups of data input, and will be referred to as follows for the remainder of the report:

- All data collected for 2010 Instream Flow Study report [Pre-Supplemental data]
- May 2010 collection [Supplemental data]
- Combined data [Post-Supplemental data]

This method of analysis was used to determine if and how the supplemental data differed or altered previously reported results. It should be noted that, at the USFS sampling reach, several areas were too deep for effective biological sampling (approximate stream discharge: 15.4 cfs). Therefore, the sample effort at USFS may not be considered equivalent to sampling reach FM 409.

Benthic macroinvertebrate RBA and fish IBI were calculated with the FM 409 data to compare ALU designations to previously reported scores, and to analyze the primary factors creating differences among individual IBI scores. To gain a better understanding of the calculated IBI scores at FM 409, IBI metric components were compared across sample events.

Multivariate techniques (canonical correspondence analysis, CCA) were explored to re-evaluate potential species-habitat associations with the newly incorporated data, and to identify differences among sample events. This was achieved with the same technique used to identify species-habitat associations for the 2010 Instream Flow Study (sample observations enveloped in ordination space by parameter of interest). The pre-supplemental samples were differentiated from the supplemental samples to determine if sample events differed in measured habitat variables or species assemblage.

A Bray-Curtis Similarity Coefficient was calculated to evaluate differences across sample events. The Bray-Curtis is a metric of community composition similarity, and is often used to determine site or sample similarity based on species abundances. The coefficient reflects differences between two samples incorporating both differing community composition and/or total species abundance.

[2] Section 3.1.4, Page 28 - 29; Appendix D, Page D-3:D-8

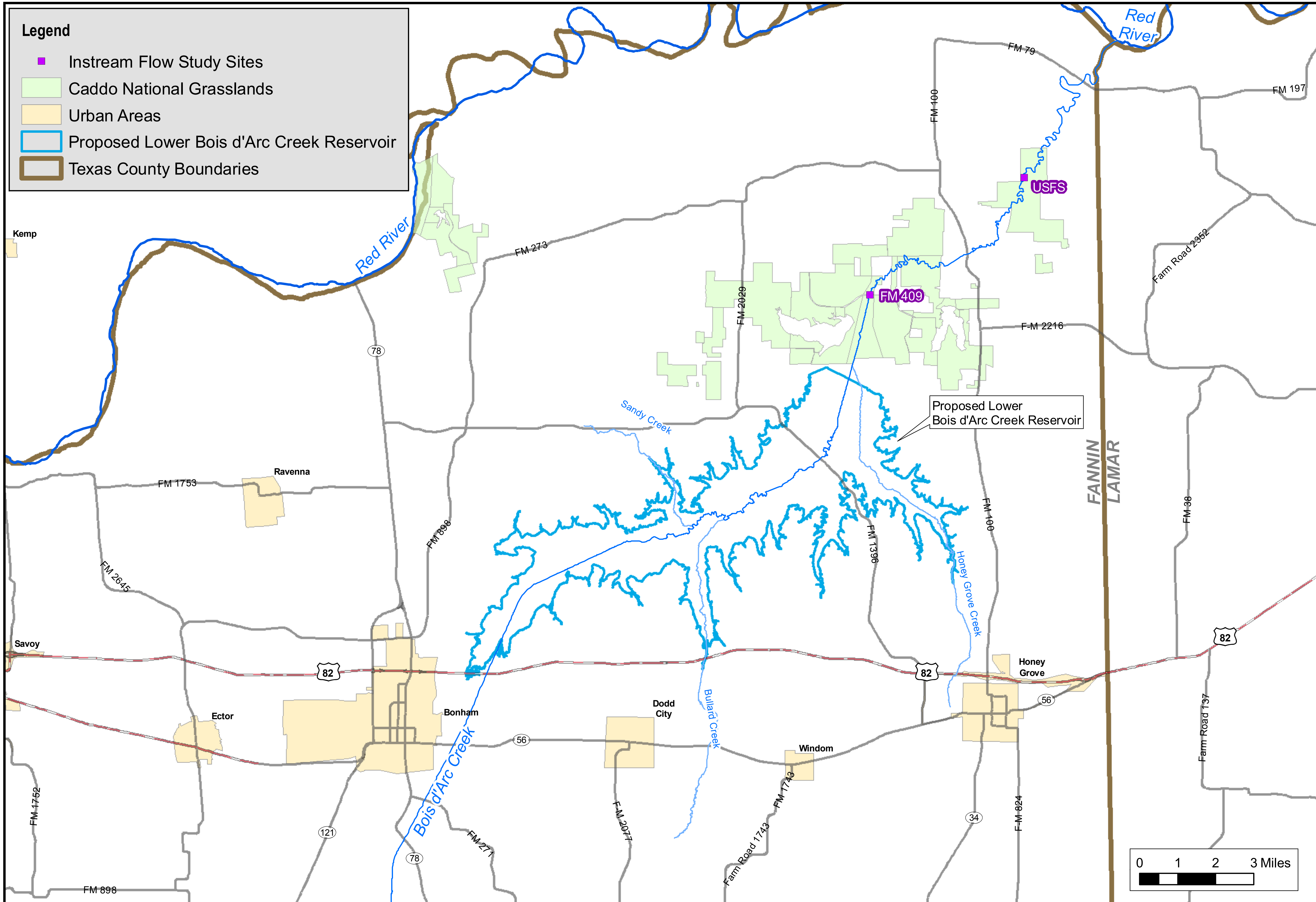

Figure 2.3

North Texas Municipal Water District
Proposed Lower Bois d'Arc Creek Reservoir

Instream Study Sites
May 2010 Supplemental Biological Sample

FN JOB NO	NTD06128
FILE	Figure3.1.mxd
DATE	August 2010
SCALE	1:149,333
DESIGNED	BME
DRAFTED	BME

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Fish species diversity (Shannon-Wiener Index [*H*]) and evenness (Evenness Index [*J*]) were calculated by sample event to further analyze potential changes to community structure over time (mathematical formulas are presented in Appendix B) (Gotelli and Ellison 2004). The *H* Index is a measure of species diversity that takes into account the number of species present as well as the relative abundance of those species. Index values generally range from 1.5 to 3.5 (rarely exceed 4.5) with higher scores representing higher species diversity. This could also be viewed as the probability that two individuals selected from a sample will be different species. Evenness (*J*) measures the relative abundance of each species as it is represented in an area; therefore, species evenness is greatest when all species are equally abundant (scale: 0 - 1). An analysis of variance (ANOVA) followed by a Tukey's Multiple Comparison Procedure was used to compare indices across sample events (June 2009, July 2009, and May 2010) (Gotelli and Ellison 2004).

To further examine available fish habitat at proposed reservoir releases, stream depths and current velocities (CV) were evaluated at the FM 409 study reach. Output from HEC-RAS software was used to model water depths and River 2D model output was used to model river current velocities at field measured Transect 3. Transect 3 is located approximately mid reach, has a relatively homogenous stream bed, and was most often categorized as run-type habitat during biological sampling (one of the dominant habitat-types of Bois d'Arc Creek). The proposed reservoir release flows of 3, 10, and 50 cfs, along with an additional high discharge (500 cfs), were used in the analyses. Methods for HEC-RAS modeling[3] and River 2D modeling[4] are presented in the Instream Flow Study 2010 Report.

[3] Section 3.1.1, Page 27; Appendix B, Page C-6: B-15
[4] Appendix D, Page D-46: D-47

3 SAMPLE RESULTS AND DISCUSSION

3.1 Fluvial Geomorphology

3.1.1 Cross-sectional Change at Channel Transects

Fifteen transects (Figures 2.1 and 2.2) were established and surveyed as a repeatable measure of channel morphology from which to detect changes over time. Differences between the initial survey in 2009 and a repeat survey in 2010 provide a measure of the vertical and horizontal changes to the stream channel. Although not necessarily indicative of long-term change, these initial measurements provide information about the types and locations of erosional processes in Bois d'Arc Creek. The cross-sectional results are presented graphically in Figures 3.1 and 3.2. The cross-sectional area for each transect was calculated after both measurement periods and compared, and these results are shown in Table 3.1.

Repeated measurements of a large number of points at the same transects were used to determine the amount of vertical and horizontal change (erosion or deposition) at each transect. Results show that all 15 transects are increasing in cross-sectional area.

The Instream Flow Study reach of FM 1396 extends approximately 1,950 feet upstream from the FM 1396 bridge (Figure 2.1). The stream banks and riparian corridor of the study reach are sparsely vegetated and have a narrow forested riparian buffer. During the baseline period, the banks are subject to increased rates of drying by direct sunlight and exhibit lack of stability provided by roots. From April 2009 to July 2010, the cross-sectional area of the channel at the FM 1396 transects increased between 5 and 183 square feet (Table 3.1). Five of the transects were located in straight sections and three were located on meander bends within the reach. Six of the eight transects experienced between 0.5 to 4 feet of channel bed downcutting and/or scour. All transects show channel widening or bank retreat caused by fluvial erosion or mass wasting. Mass wasting was observed in the form of rotational failures, planar failures, or slumps. The stream banks were near vertical with sparse vegetation. The sparsely vegetated banks and bank material antecedent moisture conditions contributed to the channel loss at this study reach. Long-term subaerial processes (e.g., wet and dry cycles, soil desiccation, frost heave) most likely weakened the stream bank material by reducing soil strength prior to fluvial erosion (Thorne 1982). This weathered bank material was removed as flowing water moves across the stream bank.

The Instream Flow Study reach of FM 409 extended approximately 1,400 feet upstream from the FM 409 bridge (Figure 2.2). This study reach was located within the USFS National Grasslands where the riparian corridor has been protected from vegetation removal (logging and cattle grazing). Stream banks were shaded by the more dense vegetation and the banks had less steep side slopes than the FM 1396 reach. During the baseline period, the stream channel cross-sectional area at FM 409 transect increased between 25 and 245 square feet (Table 3.1), with

Transect 2 having the greatest increase of change (245 square feet). Transect 2 was influenced by complex flow, located at the downstream end of a meander and at point where additional flow is conveyed through a bypass chute at greater velocities during high flow events. These flows converge in the vicinity of Transect 2, and scoured the banks of the channel. Fluvial entrainment (removal) of material from the bank toe during high flow pulse events has induced mass failure in the upper banks in the form of slumps, rotational failures and slow moving creep failures. The failed material was either completely removed from the bank by flowing water or displaced to the lower bank as the material slid down the bank along the plain of failure. The deposited material at the bank toe may have become vegetated and temporarily stabilized the upper banks, until it was removed by a high flow pulse and the toe was left unprotected for the process to begin again. Table 3.2 describes the processes observed in the field and interpretations of the measured transect results for each study reach.

Table 3.1 Cross-Sectional Areas of Measured Transects in Study Reaches FM 1396 and FM 409

	Reach FM 1396			Reach FM 409		
	April 2009 cross-section area (ft^2)	July 2010 cross-section area (ft^2)	Change in cross-sectional area (ft^2)	April 2009 cross-section area (ft^2)	July 2010 cross-section area (ft^2)	Change in cross-sectional area (ft^2)
Transect 1	1317.84	1501.47	183.63	873.27	961.58	88.31
Transect 2	1120.08	1130.50	10.42	937.68	1181.95	244.27
Transect 3	1301.34	1341.88	40.54	1020.02	1126.30	106.28
Transect 4	1211.09	1378.79	167.7	887.84	923.89	36.05
Transect 5	1324.57	1417.59	93.02	1011.12	1143.86	132.74
Transect 6	1312.82	1487.71	174.89	1362.91	1387.80	24.89
Transect 7	1362.78	1478.77	115.99	1128.86	1246.07	117.21
Transect 8	1173.55	1178.52	4.97			

Figure 3.1 Transect Measurements for Instream Flow Study FM 1396 Reach

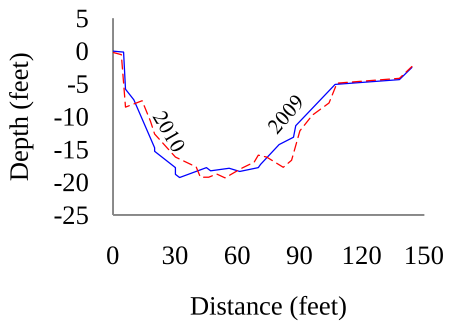
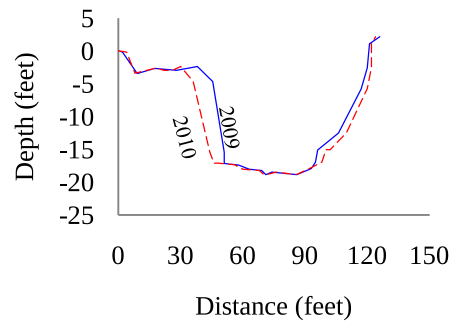
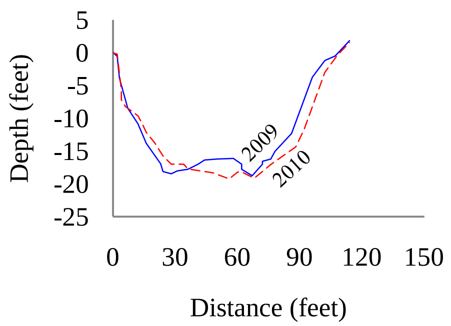
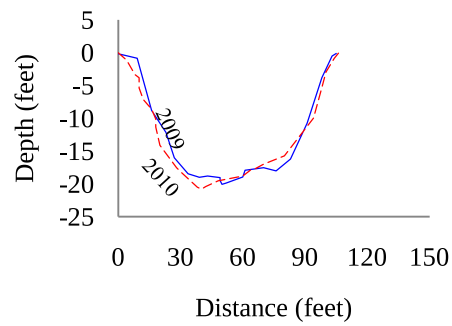
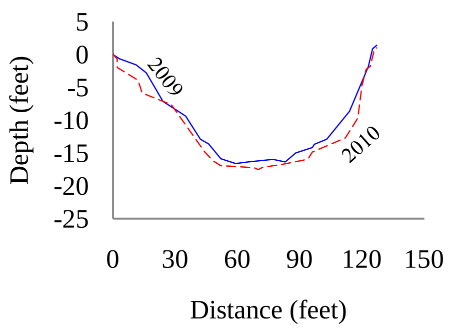
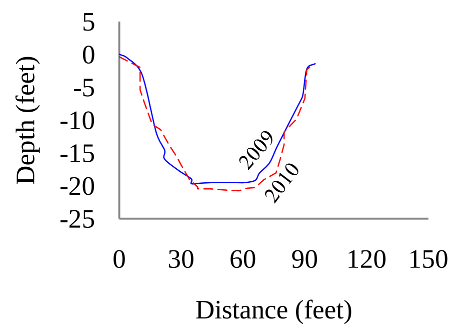
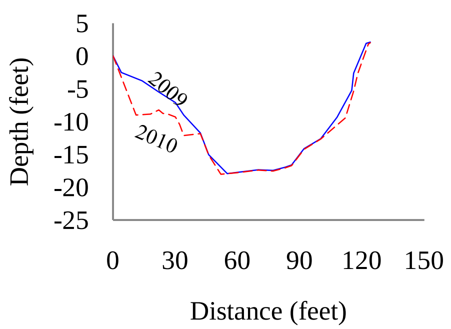
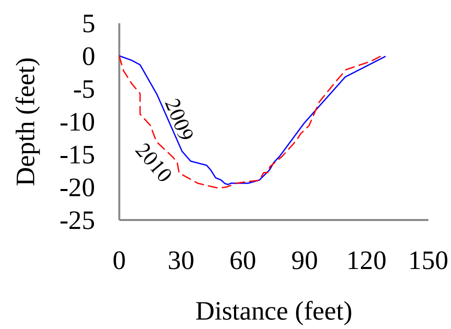
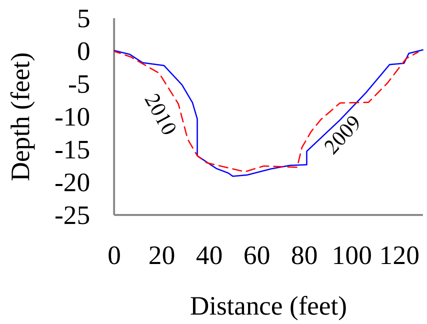
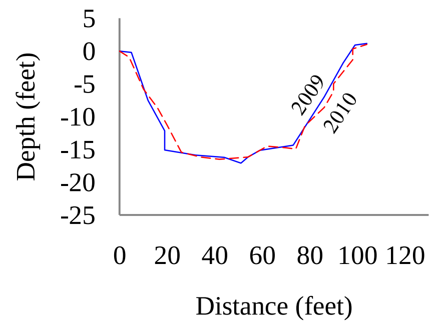
Transect 8	Transect 4
	
Transect 7	**Transect 3**
	
Transect 6	**Transect 2**
	
Transect 5	**Transect 1**
	

Figure 3.2 Transect Measurements for Instream Flow Study FM 409 Reach

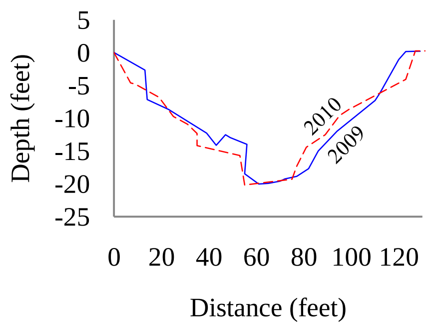
Transect 7



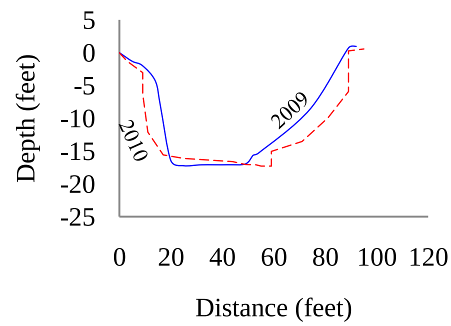
Transect 3



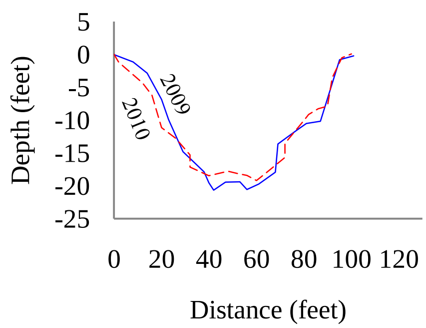
Transect 6



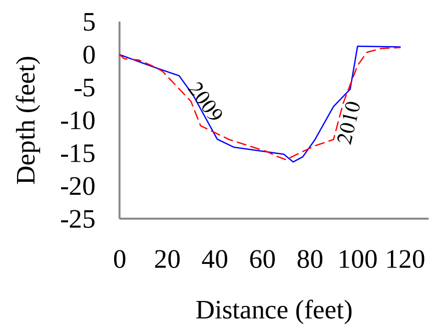
Transect 2



Transect 5



Transect 1



Transect 4

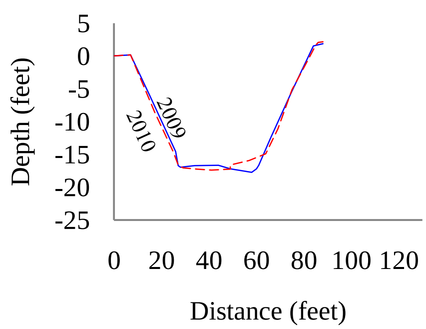


Table 3.2 Channel Processes Observed at Measured Transects in Study Reaches FM 1396 and FM 409 from April 2009 to July 2010

Reach	Transect	Left Bank	Channel Bed	Right Bank
FM 1396	8	• 1-foot upper bank loss due to mass failure	• Thalweg shift to the right	• Slump • Material deposited at toe
	7	• 2 feet aggradation at bank toe on inside of meander bend	• 4 feet vertical scour	• 6 feet erosion on outside of meander bend
	6	• Upper bank slump	• 0.5 to 1.5 feet downcutting	• 6 feet lower bank erosion
	5	• Rotational failure • 10 feet of material loss	• Less than 1-foot scour	• 1 to 3 feet erosion
	4	• Slab failure • 10 feet of material loss	• Generally stable	• 6 feet erosion
	3	• Slump on outside of meander bend • 1 to 5 feet of material loss	• Thalweg shift 15 feet left • 1-foot downcutting	• 3 feet aggradation at bank toe on inside of meander bend
	2	• 0.5 to 3 feet of material loss in upper bank • Deposition on lower bank	• 2 feet downcutting	• 1 to 2 feet erosion upper bank • 3 to 5 feet scour
	1	• 10 to 15 feet scour upstream of bridge	• Thalweg shift left • 1-foot downcutting	• Upper bank deposition • 1 to 3 feet erosion lower bank
FM 409	7	• Rotational failure • All failed material removed	• 1-foot aggradation	• Rotational failure • Failed material deposited at toe
	6	• Slumps and creep failures	• Generally stable • Scour at left bank toe	• Rotational failure • Failed material deposited at toe

Table 3.2 Channel Processes Observed at Measured Transects in Study Reaches FM 1396 and FM 409 from April 2009 to July 2010 (Continued)

Reach	Transect	Left Bank	Channel Bed	Right Bank
FM 409	5	• Slumping and rotational failure • Failed material deposited at toe	• 1 to 2 feet aggradation	• Slumping and rotational failure • Failed material deposited at toe
	4	• Fluvial erosion	• Thalweg slight shift to left	• Fluvial erosion
	3	• Slumps and creep failures • Failed material deposited at toe	• Generally stable • Some aggradation and degradation	• Slumps and creep failures • Failed material deposited at toe
	2	• 10 feet scour	• 2 feet aggradation	• 10 feet scour
	1	• 1 to 3 feet erosion	• Thalweg shift 3 feet left	• 8 feet scour

The channel processes observed in both study reaches were responsible for removing material from the channel and increasing the cross-sectional area. The sediment loss was calculated using the average bulk density of the soil material at each site (Table 3.3), multiplied by the average increase in cross-sectional area (Table 3.1) multiplied by the length of the reach. FM 1396 had a calculated sediment loss of 8,542 tons, and FM 409 had a calculated sediment loss of 6,732 tons. These values represent the sediment loss experienced during the time period of April 2009 to July 2010 for the length of the two study reaches.

Table 3.3 Bulk Density Values for Bank Material in the Study Reaches

Instream Flow Study Reach	Lower Bank Bulk Density (lbs/ft^3)	Upper Bank Bulk Density (lbs/ft^3)	Average Bulk Density (lbs/ft^3)
FM 1396	86.70	90.50	88.60
FM 409	88.68	91.10	89.89

3.1.2 Bank Erosion at Study Reaches

Measured erosion values at the five pins on the lower and upper banks were averaged for each monitoring event to produce a mean loss due to erosion (Table 3.4). The FM 1396 site experienced 29.12 total inches of loss in the lower bank and 35.02 inches of loss in the upper bank. The FM 409 site experienced only 5.21 and 6.09 inches in the lower and upper banks, respectively. The results indicate that fluvial erosion rates at the FM 1396 site were approximately 82 percent higher in the upper and lower banks than at the FM 409 site. This reflects the stabilizing effect of the more substantial forested riparian buffer along the FM 409 reach.

Table 3.4 Erosion Pin Measurements in Inches for the Study Reaches

	Date Measured	FM 1396	FM 409
Lower Bank	04/22/09	0.24	0.08
	05/21/09	4.33	1.95
	06/24/09	0.64	0.18
	08/05/09	3.10	0.20
	05/13/10	20.81	2.80
Total Lower Bank Erosion (inches)		**29.12**	**5.21**
Upper Bank	04/22/09	0.10	0.89
	05/21/09	11.20	2.00
	06/24/09	0.08	0.09
	08/05/09	2.37	0.10
	05/13/10	21.27	3.01
Total Upper Bank Erosion (inches)		**35.02**	**6.09**

3.2 Biology

The subsequent sections present the data collected on May 2010 (supplemental sampling) from the FM 409 and USFS sampling reaches. Data comparisons, statistical analyses, and further analyses of fish habitat in relation to river hydrology are also described in detail.

3.2.1 Habitat

Supplemental sampling was conducted at a discharge of approximately 15 cfs. At the FM 409 reach, three forms of mesohabitat were available for sampling: runs, pools, and structures (snags, large woody debris, brush piles, other). At the USFS reach, only deep run-pool habitat was available for sampling. Run-type habitat was the dominant mesohabitat form, which is consistent with previous visual observations and the habitat modeling results presented in the Instream Flow Study Report. Table 3.5 summarizes measured water features in each sampled mesohabitat. Habitat measurements fell within the range of previously reported habitat data[5] except for the following:

- Water Temperature: Below range (all habitats)
- Current Velocity: Above range (run and structure habitat)
- Depth: Above range (run habitat)

[5] 2010 Instream Flow Study, FNI, Table 4.5, Section 4.3.1, Page 64.

Table 3.5 Means, Standard Deviations, and Ranges for Selected Water Features by Mesohabitat at FM 409

	Run (n = 8)				Pool (n = 1)	Structure (n = 1)
	Mean	[St Dev]	Min	Max	Measure	Measure
Current Velocity (ft/s)	0.9	[0.60]	0.2	2.0	0.3	1.6
Depth (ft)	1.7	[0.62]	0.8	2.5	1.7	1.1
Temperature (°C)	23.1	[0.52]	22.6	23.9	22.7	22.9
Dissolved O_2 (mg/L)	8.1	[1.08]	7.2	10.2	7.3	8.2
pH	7.9	[0.28]	7.3	8.1	7.8	8.0
Sp. Cond (uS/cm)	606	[33.81]	572	680	602	579

* No riffle habitat was present for sampling

3.2.2 Benthic Macroinvertebrates

A total of 379 insects and crustaceans consisting of 30 genus and 21 families were collected and identified from FM 409 and USFS in May 2010 (Table B-1, Appendix B). Ten new genera and four new families were identified from the supplemental collection.

The relative abundance of functional feeding groups was calculated to evaluate and compare trophic structure across the three datasets (Figure 3.3). Analysis of calculated trophic structure identified that the number of shredder species (those that consume course particulate organic matter such as leaves) declined at FM 409, though this only slightly shifted the post-supplemental trophic structure. The opposite pattern occurred at the USFS stream reach, where more shredders were collected increasing the final trophic distribution 5.1%. Both FM 409 and USFS sample reaches had a decreased abundance of scraper species (those that consume submerged attached materials such as algae) in the supplemental sample collected (17% and 13%, respectively). The decrease in scrapers is largely attributed to a decrease in Ephemeroptera (mayfly) species. Considering measured DO levels were high (Table 3.5) and within the previously measured range, the decrease is likely associated with the timing of the sampling event in the life cycle of these species. It could also be associated with reduced resource availability as several genera of this taxa are classified as intolerant of reduced water quality (e.g. DO, temperature, flow).

3.2.2.1 Benthic Macroinvertebrate RBA

The calculated RBA score for the supplemental sampling event at FM 409 was 26, providing an ALU designation of intermediate (Figure 3.4). The supplemental sample score is consistent with previous results at this study reach, though on the lower end (range: 26 – 31). The new sample score only slightly lowered the overall mean for the FM 409 study reach (mean: pre-supplemental: 28.75, post-supplemental: 28.20).

Figure 3.3 Benthic Macroinvertebrate Trophic Structure at FM 409 and USFS: Pre and Post-Supplemental Sampling Event Distribution Comparison

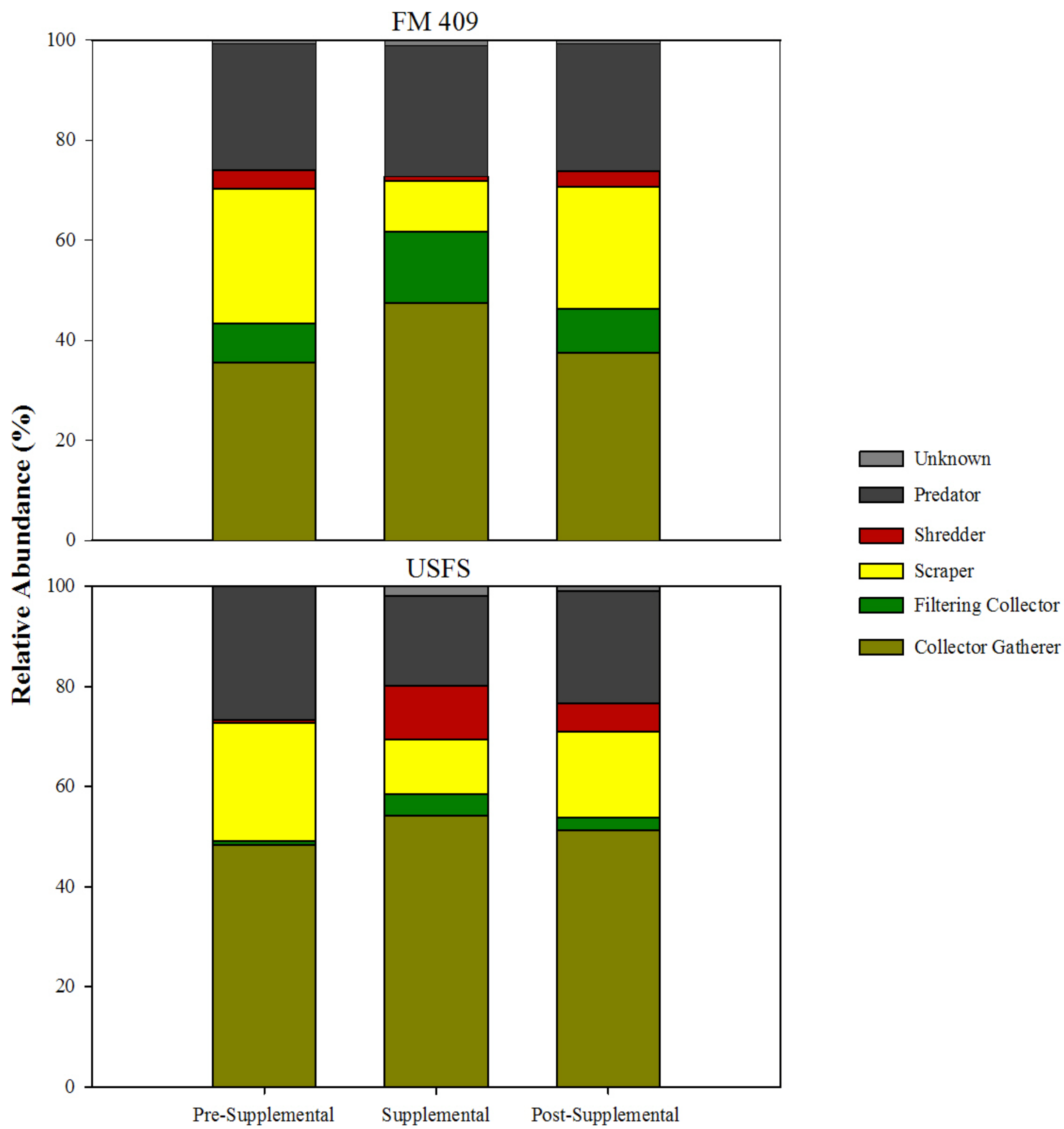
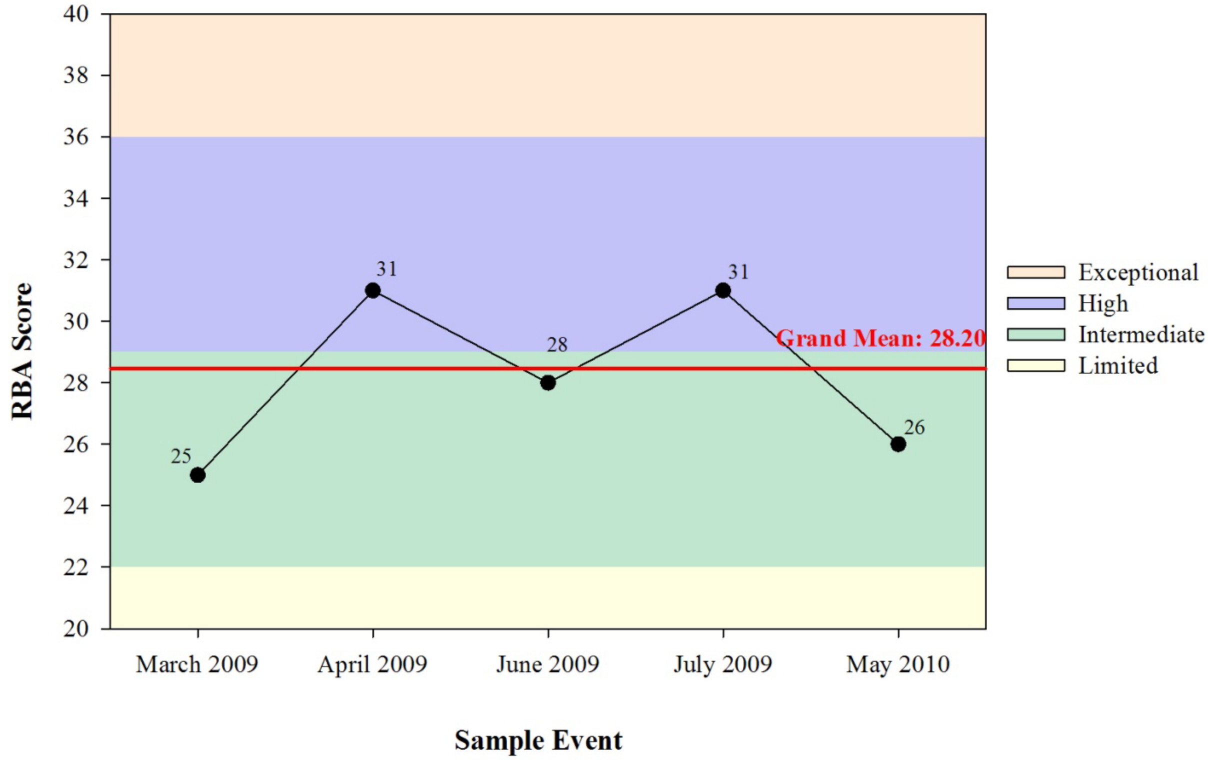


Figure 3.4 Rapid Bioassessment Results at FM 409 by Sampling Event

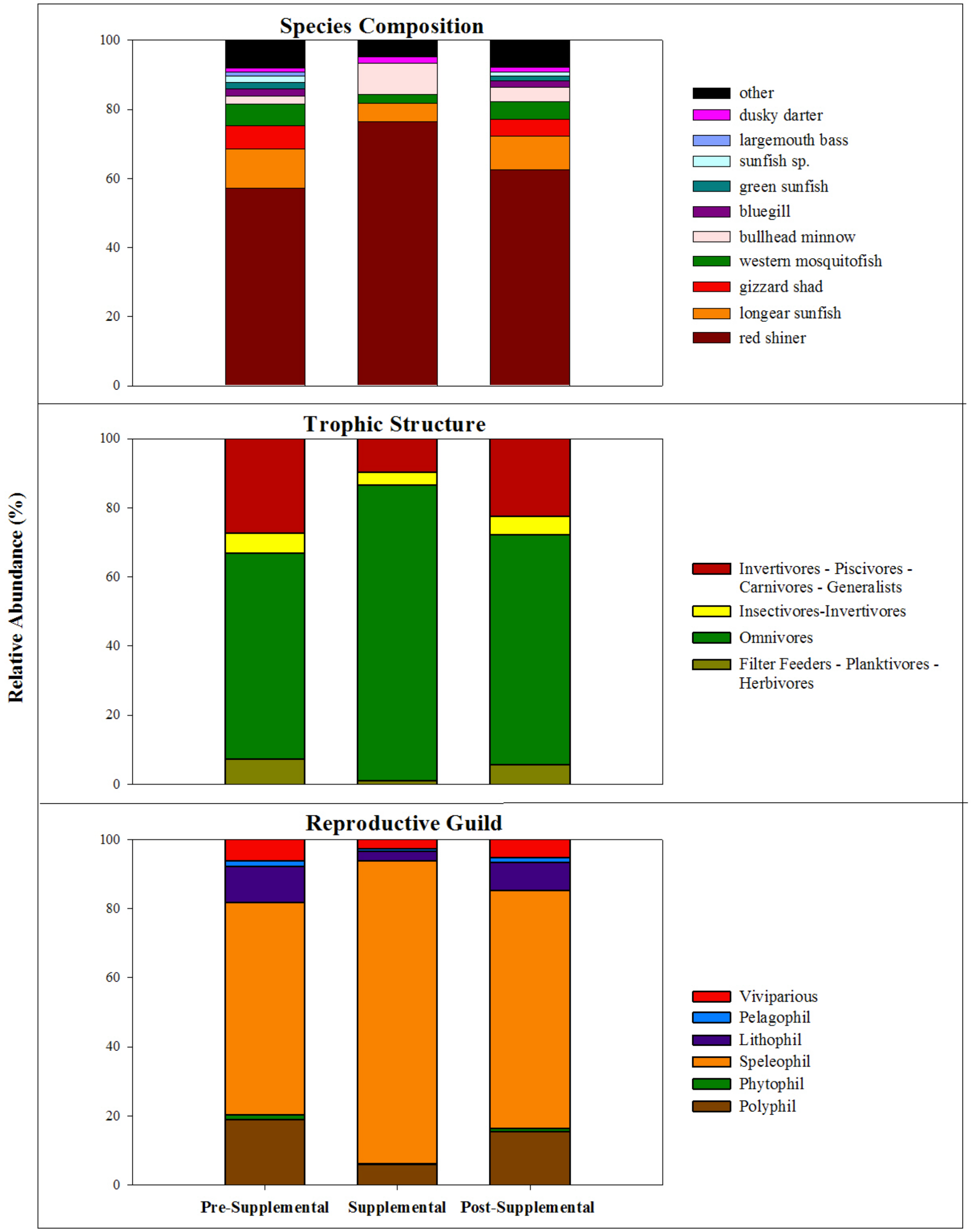


3.2.3 Fish

A total of 868 fish, consisting of 19 species and 9 families, were collected from the FM 409 and USFS study reaches in May 2010 (Table B-2, Appendix B). Supplemental sample species composition was consistent with what was previously found in Bois d'Arc Creek with the exception of three new species (*Pimephales promelas* [fathead minnow], *Menidia beryllina* [inland silverside], and *Moxostoma poecilurum* [blacktail redhorse]).

Similar to the pre-supplemental data, the two most dominant species from the May 2010 collection were *Cyprinella lutrensis* (red shiner) and *Lepomis megalotus* (longear sunfish), comprising approximately 78% of the total relative abundance (Figure 3.5). Trophic structure and reproductive guild composition was generally consistent with previous results, with the large percentage of omnivores and speleophilic spawners (crevice spawners) driven by the prevalence of red shiner. Species relative abundance across mesohabitat, flow, and season was recalculated for the FM 409 study reach with the supplemental data incorporated into the appropriate mesohabitat, flow regime (i.e., high) and season (i.e., spring) (Figures B1:B3, Appendix B). Pre- and post-supplemental sample comparisons by mesohabitat illustrated similar distributions across all sampled habitat types. The only notable differences were greater red shiner abundance in general and higher taxa diversity in structural-type habitat. Distributions across flow and season only slightly shifted, and here again these shifts were associated with the prevalence of red shiner in the supplemental collection.

Figure 3.5 Fish Species, Trophic Structure, and Reproductive Guild Composition: Supplemental Sample Data Comparison



3.2.3.1 Species-Habitat Associations

To reevaluate potential species-habitat associations the supplemental data was added to the CCA dataset for analysis. The addition of new data slightly increased the percentage of variance explained by the model-included environmental variables (i.e., water depth, CV, substrate type, and specific conductivity) from 27.7% to 33.8% (Monte Carlo Permutation $P = 0.04$), though it did not increase the ability to detect species-habitat associations. The pre-supplemental CCA did not find species-habitat associations, but reaffirmed that Bois d'Arc Creek is a system dominated by generalist species that can tolerate a wide range of environmental conditions[6]. Additionally, the pre-supplemental CCA did not illustrate species groups or "guilds" when the sample scores were delineated by the sample's identified habitat type (e.g., run, riffle, pool, or structure)[7]. This lack of separation in species by habitat type was also apparent in the post-supplemental ordination diagram (Figure B-4, Appendix B).

The pre-supplemental CCA did identify some associations with individual species and environmental variables. *Moxostoma erythrurum* (golden redhorse), *Percina macrolepida* (bigscale logperch), *Dorosoma petenense* (threadfin shad), and *Dorosoma cepedianum* (gizzard shad) were all associated with swifter CV and gravel substrate, and these associations were also apparent in the post-supplemental CCA.

3.2.3.2 Fish Index of Biotic Integrity

The calculated IBI score for the supplemental sampling event at FM 409 was 41, indicating an ALU designation of high (Figure 3.6). Though the supplemental sample score was in the same ALU range as previous sample scores, it received the lowest score of all samples calculated at this study reach (45 and 48; March and July 2009 samples, respectively). The new sample score lowered the mean for the FM 409 study reach approximately two units (mean: pre-supplemental: 46.5, post-supplemental: 44.67).

The metric components from FM 409 IBI scores were compared across sample event (Table 3.6). There were five factors that created differences in the final calculated IBI scores, including:

- Number of native cyprinid species
- Number of sunfish species
- Percent of individuals as tolerant species
- Number of piscivores
- Number of individuals in the sample

These components appear to have the strongest influence on final IBI scores because they had larger differences across samples, whereas the other metrics were generally consistent across

[6] 2010 Instream Flow Study, FNI, Section 4.3.4, Page 73; Appendix D, Pages D-42:D45
[7] 2010 Instream Flow Study, FNI, Appendix D, Figure D-8, Page D-45

samples. For example, the supplemental collection received the lowest possible values in percent composition as tolerant species, number of piscivores, and number of individuals in the sample. Additionally, these component scores were the lowest received by any sample event. This procedure helped to identify how the supplemental sample differed biologically from previous samples, and why it had the lowest overall IBI score.

It can be concluded that the IBI metrics are sensitive to detecting differences in community composition and species abundance in general, thus making them effective monitoring tools.

Figure 3.6 Fish Index of Biotic Integrity at FM 409 by Sampling Event

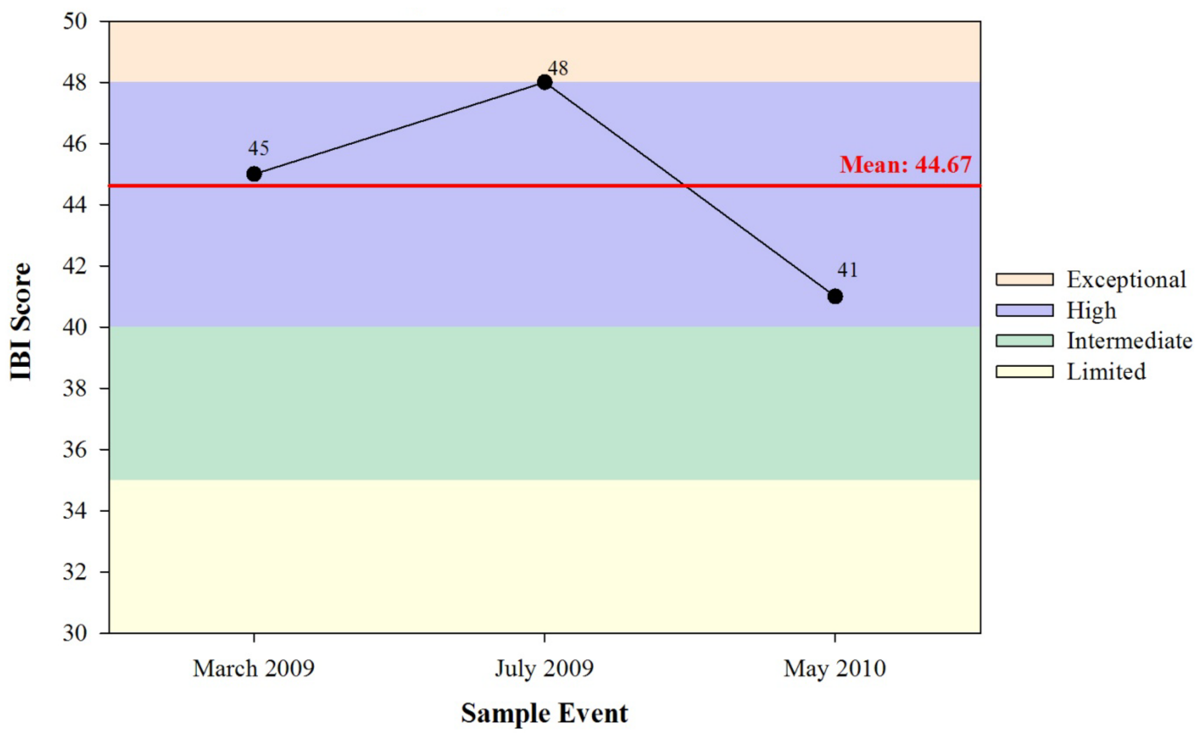


Table 3.6 Fish IBI Metric Component Breakdown by Sampling Event at FM 409

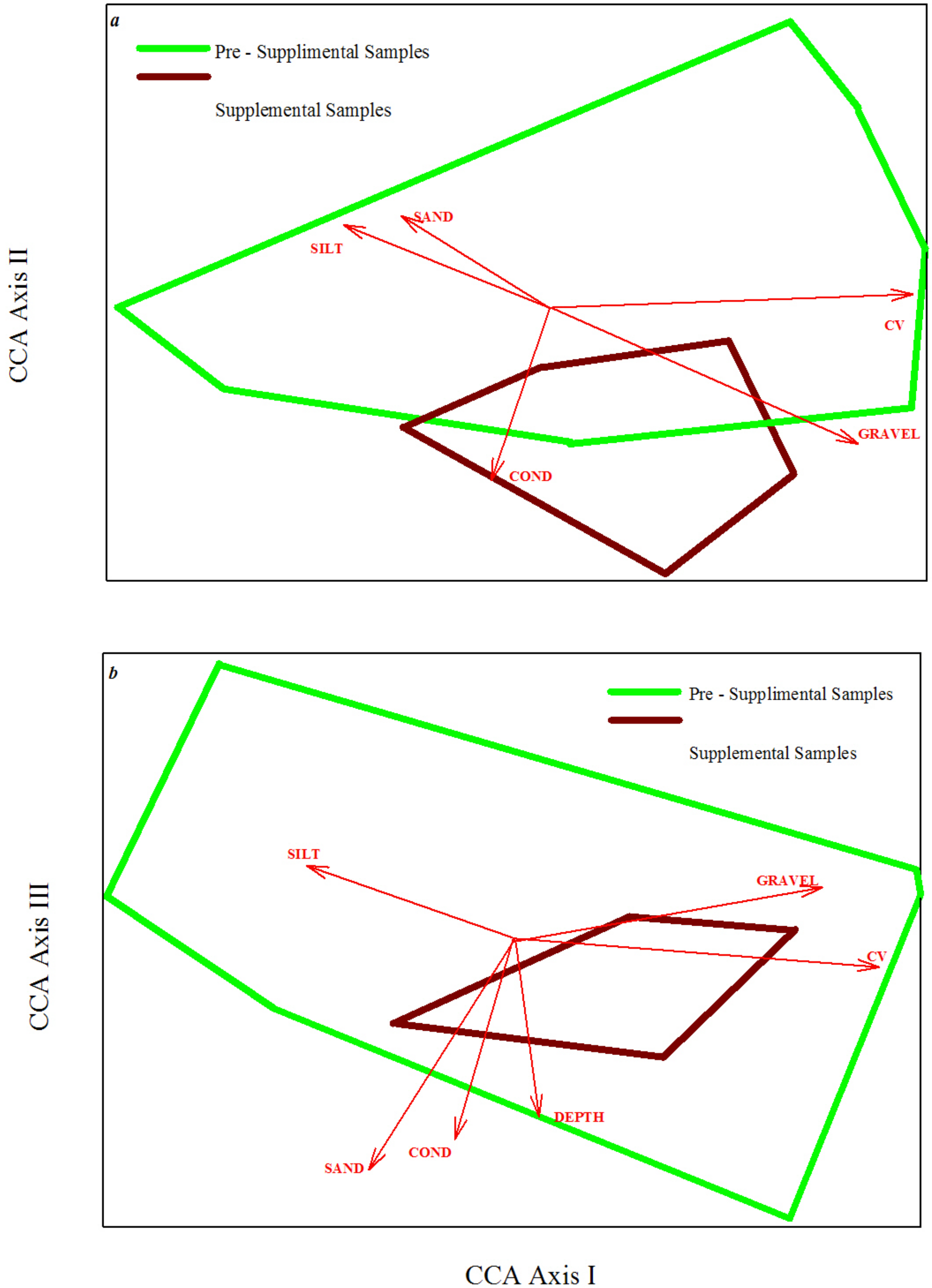
Collection	March 2009		July 2009		May 2010	
METRIC	**Raw**	**Final**	**Raw**	**Final**	**Raw**	**Final**
Total Number of Fish Species	14	5	21	5	15	5
Number of Native Cyprinid Species	2	**3**	5	5	4	5
Number of Benthic Invertivore Species	2	5	3	5	5	5
Number of Sunfish Species	4	5	6	5	2	**3**
% of Individuals as Tolerant Species	75.7	1	49.9	**3**	78.8	1
% of Individuals as Omnivores	0.0	5	2.0	5	1.6	5
% of Individuals as Invertivores	91.8	5	89.8	5	97.6	5
% of Individuals as Piscivores	4.7	3	7.6	3	0.8	**1**
Number of Individuals in Sample:		3		2		**1**
Number of Individuals/seine haul	38.7	**3**	20.0	1	21.8	1
Number of Individuals/min electrofishing	3.4	3	3.6	3	2.2	1
% of Individuals as Non-native Species	0.0	5	0.0	5	0.0	5
% of Individuals With Disease/Anomaly	0.0	5	0.0	5	0.0	5
FINAL IBI SCORE:		**45**		**48**		**41**

*Individual metric scores illustrating differences across sample event are identified in bold.

3.2.3.3 Supplemental Sample Comparative Analysis

Results from the CCA sample event delineation did not identify a clear separation between pre-supplemental samples and supplemental samples. There was slight sample separation along CCA Axis II (Figure 3.7), where supplemental samples had larger negative scores. Environmental measures negatively associated with CCA Axis II were specific conductivity and gravel substrate, indicating a higher prevalence of these habitat features during the supplemental sample event. Fish species associations were those of newly collected species or individuals that had only been collected in one other sample (blacktail redhorse, fathead minnow, *Percina phoxocephala* (slenderhead darter), and *Lepisosteus oculatus* (spotted gar)).

Figure 3.7 Multivariate Ordination Diagram Illustrating Sample Event Separation



The Bray-Curtis Similarity Coefficient did not reveal an apparent pattern in sample similarities, and in most cases the supplemental sampling event was more similar to the previous year's samples than within year comparisons (Table 3.7). On average, samples were approximately 50% similar with scores ranging from 28 to 79. After reviewing the data, it appears that differences in sample similarity are largely driven by the abundance of red shiner in the sample and the presence of one or two rare species (e.g., spotted gar and slenderhead darter). Additional sample events will likely reflect a similar pattern, providing little insight into seasonal or inter-annual community composition.

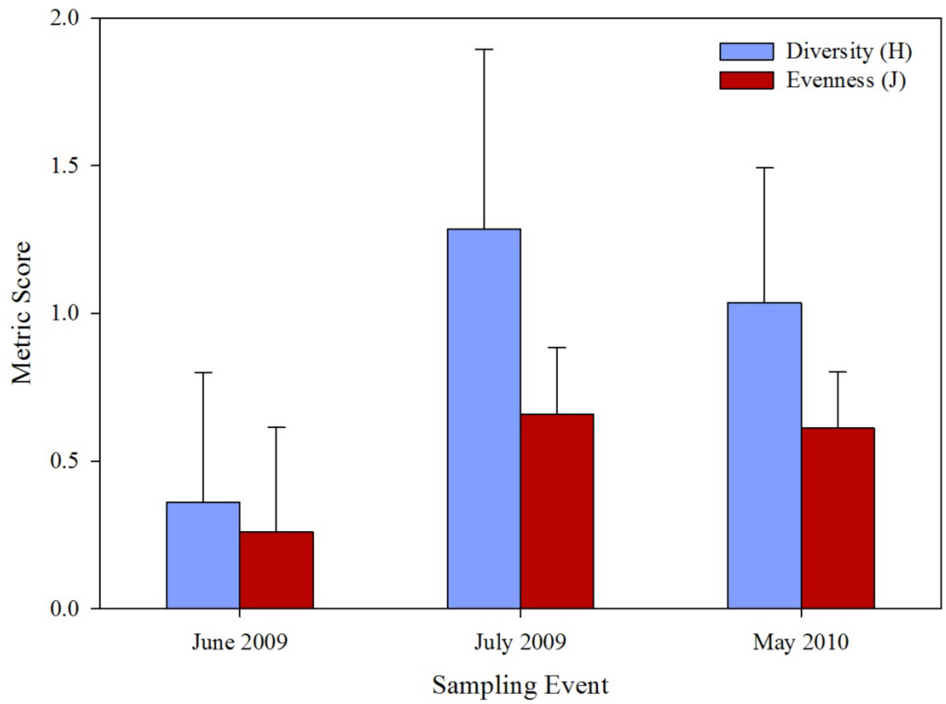
Table 3.7 Bray-Curtis Similarity Coefficient Matrix for FM 409 Sampling Events

Sample Event			
	March 2009	June 2009	July 2009
Jun-09	28		
Jul-09	53	37	
May-10	**79**	**33**	**59**

*Supplemental sample comparisons identified in bold

Species diversity (*H*) and evenness (*J*) were calculated for each collection made in Bois d'Arc Creek in 2009, and the 2010 supplemental sample. The average *H* and *J* values were 0.96 and 0.53, respectively. Species diversity and evenness were very low despite the relatively high species richness of Bois d'Arc Creek (45 total taxa). This is explained by most collections being dominated by a few species with one or two additional rare species, and several collections only had red shiner. When indices were compared across sample events (Figure 3.8), only the June 2009 sample was significantly different in *H* ($F = 8.15$, $P = 0.006$) and *J* ($F = 6.47$, $P = 0.005$); however, this is likely due to sampling bias as no electroshocking was conducted on that sampling event. The July 2009 sample had the highest average *H* (1.28) and *J* (0.66), despite being the collection with lowest stream discharge (FM 409: 2.1 cfs). No references of comparable indices in neighboring watersheds were available. However, in four tributaries of the Red River in western Louisiana, the species diversity was much higher than Bois d'Arc Creek (range: 1.93 - 2.15) though species evenness was comparable (range: 0.53 – 0.63) (Williams et al. 2005).

Figure 3.8 Average Species Diversity and Evenness by Sampling Event



* Error bars illustrate one standard deviation.

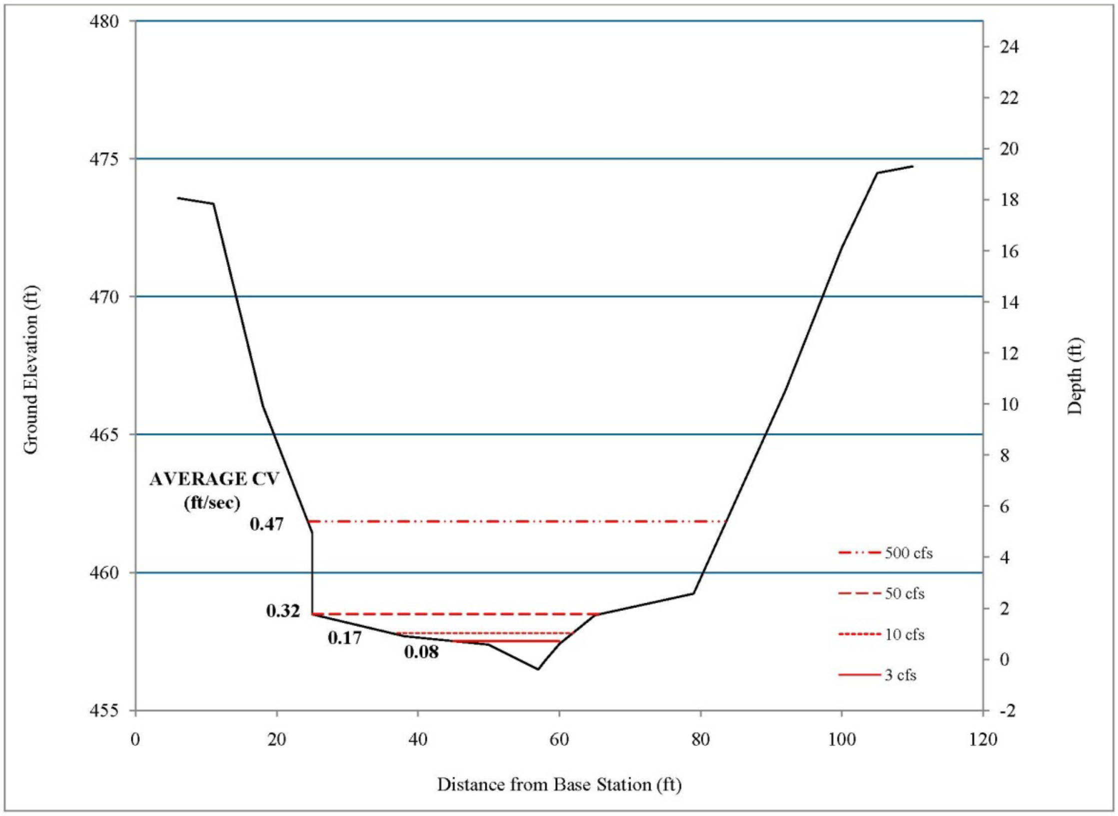
3.2.3.4 Fish Habitat and Hydrology

Figure 3.9 illustrates modeled water surface elevations with stream depths and the average current velocities (in the wetted perimeter) across FM 409 Transect 3 (River 2D model current velocity output points at every 0.5 meter). Based on the Habitat Suitability Criteria presented in the 2010 Instream Flow Study Report[8] all habitat types (runs, riffles, pools, and structures) would be supported by the illustrated discharges under current velocity criteria; however, depth suitability declined for several habitat types at this location. Above 50 cfs run and riffle habitat were no longer suitable (depths > 2 feet), leaving only pool or structural-type habitat. At water depths greater than four feet (approximately >400 cfs) there was a loss of all structural-type habitats. This figure illustrates how the incised banks and stream bank instability (attributed to channelization and in part to high erosive flows) of Bois d'Arc Creek have altered the conditions under which aquatic habitats are made available as flow varies. The steep banks of Bois d'Arc Creek block access to the adjacent floodplain creating a deep "chute" through which water passes. This creates a deep run-pool dominated system, and under these conditions water depths, and in some cases current velocities, are too great for most fluvial specialist species. This also reduces aquatic habitat for invertebrate species that utilize structural material that extends from

[8] Appendix D, Page D51:D52

the water's surface. Therefore, regulated low flows are expected to increase the duration of suitable habitat for the aquatic communities of Bois d'Arc Creek.

Figure 3.9 River Modeled Water Depths and Current Velocities at Transect 3 FM 409



4 PROPOSED INSTREAM FLOW REGIME AND STUDY RESULTS

The Bois d'Arc Creek proposed flow regime includes four recommendations that were developed in accordance with the flow classifications of the Texas Instream Flow Program (TWDB, 2008). A summary of the proposed environmental flow regime schedule is presented in Table 4.1, with a detailed account of schedule development and condition criteria available in the 2010 Instream Flow Study Report[9].

Table 4.1 Proposed Environmental Flow Releases for the Bois d'Arc Creek Reservoir

Flow Component	Release Amount [1] (cfs)	Condition	Duration
Subsistence	1	Drought	Based on Conditions
$Base_a$	3	Normal – Wet	July – February
$Base_b$	10	Normal – Wet	April – June
High Flow Pulse	50	Normal – Wet	1 in spring 1 in summer
Overbank Flows	NA [2]	NA	NA

(1) Subsistence flow would be released through the dam when the reservoir is less than 40 percent full. Pulse flow would be released seasonally if such flows do not occur naturally.

(2) No overbanking flows are scheduled in the proposed flow regime.

The flow release schedule was developed based on the four primary components identified to support a sound ecological environment (i.e., hydrology and hydraulics, fluvial geomorphology, biology, and water quality). The subsequent sections discuss how the two components discussed in this supplemental study (fluvial geomorphology and biology) correspond with the recommended flow regime. Appendix C provides further discussion on overbanking flows in the Bois d'Arc Creek watershed.

4.1 Fluvial Geomorphology

Bois d'Arc Creek is a highly channelized stream system. The altered nature of the stream system is important because the channelization plays a significant role in the current behavior and processes occurring in the stream system. The straightened and channelized sections of Bois d'Arc Creek contribute to the flashy nature of the creek, substantial erosion of the stream bed and banks, and lack of habitat diversity in channelized sections.

The major erosional process observed in the Bois d'Arc Creek study reaches is mass wasting (bank failure). This occurs when the weight of the bank is greater than the shear strength of the soil. It often results from increases in bank height or bank angle due to fluvial erosion (Wynn

9 Section 5.2, Page 101:103

and Mostaghimi 2006). Mass wasting depends on the bank geometry, soil properties, and the type and density of bank vegetation (Throne, 1990).

Mass failures often occur following high flow pulse events (Thorne and Tovey 1981; Simon et al. 2000; Couper et al. 2002). Rainfall and rising stream stage increase the moisture content and weight of the bank soils. As a result, apparent soil cohesion in the channel banks is decreased through saturation and the reduction of matric suction (Thorne, 1982). Positive pore pressures may develop after periods of prolonged rainfall, resulting in a decrease in frictional soil strength. Additionally, the bank height or angle may be increased as high flows scour the channel bed or bank toe. Such processes, combined with rapid loss of confining pressure of the water on the stream banks as the stream stage recedes, have triggered mass failures in the study reaches of Bois d'Arc Creek.

The placement of the proposed dam combined with the proposed instream flow regime for Bois d'Arc Creek will decrease the magnitude and frequency of high flow pulses downstream of the dam. This will effectively reduce stream power, thereby reducing the erosive nature of the high flow events. Currently, banks experiencing mass failures accumulate excess sediment at the bank toe. The decrease in magnitude and frequency of high flow pulses and reduction in stream power should allow this material to remain in place and stabilize the upper banks instead of being transported downstream during high flow events. The reduction in overbanking, erosive flow events would also allow for vegetation to become more permanently established along the banks. Increase in vegetation cover following the proposed impoundment of Bois d'Arc Creek would provide multiple benefits. The riparian forest buffer would increase stream bank stability because of the deeper and denser rooting habits of trees than those of crops and grasses (Zaimes et al. 2006). Plants that become established on the banks slopes would serve the same function, with their roots reinforcing the bank material, making it more resistant to erosive forces. Additionally, plant matter on the bank faces deflects flowing water away from the banks effectively reducing shear stress exerted on the banks by flowing water.

The proposed instream flow regime also includes a continuous low flow release throughout the year. The vegetation cover along Bois d'Arc Creek downstream of the proposed reservoir is expected to increase as a result of the increased duration of flow throughout the summer months due to the reservoir releases, when the channel currently experiences no-flow conditions. This should allow for vegetation to become more permanently established on the lower banks downstream of the dam, further increasing the banks' resistance to erosion.

4.2 Biology

Several criteria were identified as defining factors of a sound ecological environment in the context of the present and future conditions of Bois d'Arc Creek. Of these factors, maintaining **habitat** and **species diversity**, supporting fish species **reproduction**, and providing **connectivity** between aquatic habitats were the focal point of the biological component of the 2010 Instream

Flow Study. The following paragraphs describe how the factors were addressed, thus how the proposed flow regime supports a sound ecological environment.

The 3 cfs base flow recommendation primarily addresses hydrologic **connectivity,** while also maintaining **species diversity**. Based on River 2D modeling results, 3 cfs would maintain stream connectivity and would be released through the TCEQ (2008) established "critical period" of low stream flows (July to September). Additionally, at 3 cfs, modeled average stream depth was approximately one foot with maximum depths and current velocities of 2.68 feet and 0.61 feet/second, respectively. Based on Aaland (1993) stream classifications, this would create mostly medium-sized pool habitat, characterized as providing the most fish age-class and species diversity.

The 10 cfs spring base flow recommendation would support fish **reproduction**[10], while maintaining **habitat diversity.** River 2D modeling results indicated that 10 cfs would create current velocities (modeled maximum: 4.48 feet/second) that would distribute eggs for pelagic spawners (broadcast spawners), thus supporting the reproductive success of fluvial specialist species (riverine obligate fishes). Additionally, modeling results suggested that 10 cfs would provide optimal habitat diversity based on the nearest point of maximum weighted usable area versus discharge curves for all habitat types.

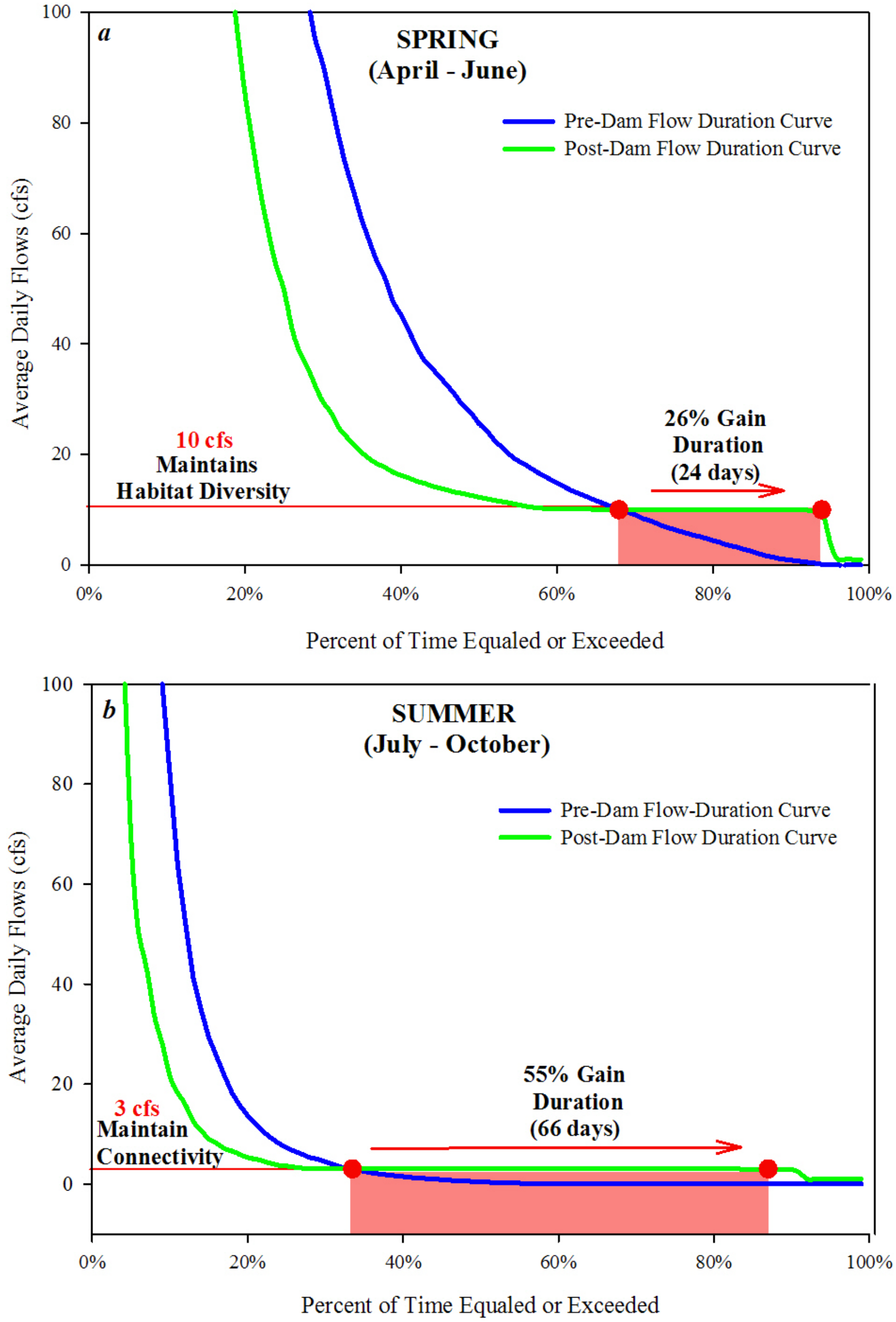
The predicted influence of the proposed flow regime on the biological environment was evaluated using the Riverware modeled without reservoir (i.e., pre-dam) and with reservoir (i.e., post-dam) flow duration curves. Flow duration curves for spring (i.e., spawning) and summer ("critical period") seasons were plotted against the set base flow release amounts for that season (10 and 3 cfs, respectively) (Figure 4.1).

Comparison of the pre-dam and post-dam flow duration curves indicated that, with the dam in place, there is a 26% increase (24 days) in duration at which flows are at least 10 cfs during the key spring spawning months of April – June (Figure 4.1*a*). The reservoir releases would potentially increase the number of days where stream discharge is sufficient for spawning as compared to the pre-dam duration curve, which exhibits exponential decay. Above 10 cfs, the post-dam duration curve indicates lower average daily discharges for a greater percentage of time than the pre-dam curve. Due to the incised channel morphology, this would increase riffle habitat. Based on the modeled weighted usable area curve below 100 cfs[11], maximum riffle habitat is achieved at 30 cfs. Therefore, through reduced average daily flows, an 18% increase (16 days) in maximum riffle habitat is achieved. This also supports fish reproduction, as fluvial specialist species are typically pelagic spawners with a preference for riffle habitats.

[10] Duration of April to June based on spawning time for the dominant and fluvial specialist species of Bois d'Arc Creek
[11] Below 100 cfs was evaluated as there is a site-specific anomaly in which a side channel becomes inundated

Comparison of the pre-dam and post-dam flow duration curves for summer months (July – October) indicated that the proposed flow regime would provide an increase in duration of stream connectivity during this critical season. The post-dam duration curve illustrates a 55% gain in duration (66 days) at which stream connectivity is achieved by the proposed 3 cfs base flow. (Figure 4.1*b*) The pre-dam duration curve indicates flows would be below 3 cfs approximately 70% of the time, with 30% of that time at 1 cfs and 40% at zero flow. Therefore, the proposed flow regime not only maintains but also improves the ecological environment of Bois d'Arc Creek by providing reliable stream flow to support and sustain aquatic species and their habitats.

Figure 4.1 Pre- and Post-Dam Flow Duration Curves During the Spring and Summer Seasons with Proposed Base Flow Reservoir Releases



5 CONCLUSIONS

The data collected and analyzed as part of this supplemental study support the instream flow regime proposed in the May 2010 *Instream Flow Study Report*. The additional biological data collected did not introduce any information that would change the conclusions in the May 2010 report, but rather complemented the original data set, which identified Bois d'Arc Creek as a system dominated by generalist species with weak specific habitat associations. Based on current data and analyses, it is expected that further sampling would not provide significantly different biological information than has already been collected.

The fluvial geomorphic component of this study confirmed the observed erosion and mass wasting of the existing channel under current high flow events. The altered channel configuration, which was designed to rapidly move flood waters, contributes to the highly erosive flows observed in Bois d'Arc Creek. The proposed flow regime would decrease the magnitude and frequency of higher flows, and increase the duration of low flows. This would allow vegetation to become established on the banks, increasing overall bank stability and reducing erosion, thus enhancing the ecological system.

5.1 Fluvial Geomorphology

The purpose of supplemental data collection was to strengthen the baseline inventory of existing channel bed and bank conditions at two reaches of Bois d'Arc Creek and to provide an inventory of erosional changes between 2009 and 2010. This baseline monitoring study defined existing conditions so that future comparisons can be made. This study found that the study reaches in Bois d'Arc Creek are currently increasing in cross-sectional area under the current flow regime. The primary erosional process driving these increases is mass failure of bank material. In most cases mass failure was induced by scouring and removal of lower bank material leading to over-steepening of banks and subsequent bank collapse. Erosion pins were used to quantify bank loss resulting from fluvial erosion. Higher amounts of fluvial erosion occurred on the sparsely vegetated, exposed banks at the FM 1396 site than the FM 409 site.

The findings of the fluvial geomorphic portion of this study support the proposed instream flow regime. Decreases in the magnitude and frequency of high flow pulse events, and increases in the duration of low flow events are expected to allow vegetation to become established on the channel banks. This should reduce the lower banks' susceptibility to erosion and increase overall bank stability.

As stated in the Monitoring and Adaptive Management Plan included in the 2010 Instream Flow Study, the baseline study reach located upstream of FM 409 will be used for monitoring the effectiveness of the prescribed flow regime. Stream bank erosion will be quantified by measuring changes in channel cross-sectional area annually and changes in bank erosion pin exposure during the required biological monitoring period at the FM 409 study reach. Pre- and post-dam closure measurements will be made to compare channel cross-section changes before and after construction. Increased erosion, if indicated by channel cross-section or erosion pin measurements after implementation of the required instream flow releases, will be assessed in light of other monitoring data (e.g., biological or water quality) and in consultation with the USACE and other state and federal agencies to determine if the permitted instream flow regime should be adjusted.

5.2 Biology

Comparing the May 2010 supplemental biological sample to data presented in the 2010 Instream Flow Study report yielded the conclusion that the additional biological data did not produce better descriptions of patterns in community structure, seasonality, or habitat associations within Bois d'Arc Creek. Results from the supplemental biological data collected indicated that the biological environment of Bois d'Arc Creek is as characterized in the original Instream Flow Study report, which described Bois d'Arc Creek as a disturbed system (extensively channelized, severely eroded and incised) dominated by generalist species with weak specific habitat associations. Because Bois d'Arc Creek is dominated by short-lived small-bodied species (mostly Cyprinids), patterns in inter-annual and spatial variability are driven by differences in environmental factors, which are difficult to quantify, especially in "flashy" watersheds (Poff and Allan 1995).

The IBI and RBA scores fell within the same range as previously quantified, confirming that the ALU of Bois d'Arc Creek is adequately categorized. Additionally, the fish IBI metric was sensitive to changes in the Bois d'Arc Creek biological environment, thus supporting its use as an effective long-term monitoring tool.

Further analysis of modeled hydrological data indicated that the habitat diversity within Bois d'Arc Creek rapidly decreases as stream discharge increases. This is a result of unsuitable stream depths under higher flow conditions. Due to the deeply incised stream channel and steep banks water rises rapidly in response to minor changes in stream discharge. Evaluation of pre- and post-dam flow duration curves based on the proposed reservoir release flows yielded the conclusion that the proposed flow regime would promote aquatic habitat and species diversity, stream connectivity, and fish reproduction. Thus, the proposed flow regime is expected to support a sound ecological environment in Bois d'Arc Creek downstream of the proposed reservoir.

APPENDIX A

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REFERENCES

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APPENDIX B

BIOLOGICAL DATA AND INFORMATION

Formulas

Shannon's Diversity Index: $H' = - \Sigma p_i \ln p_i$

$p_{i=}$ proportion of the i^{th} species

ln=natural logarithm

Evenness Index: $J = E_H = H/H_{max}$,

Table B.1 Benthic Macroinvertebrates Collected in FM 409 and USFS Stream Reaches in May 2010

Taxonomy				Site	
Class	**Order**	**Family**	**Genus**	**FM 409**	**USFS**
Oligochaeta				2	1
Insecta	Coleoptera	Dryopidae	**Postelichus**		**1**
			Coptotomus	1	
			Laccophilus		1
		Elmidae	**Dubiraphia**		**2**
			Ordobrevia		3
			Stenelmis	5	
		Gyrinidae	Dineutus	2	6
			Gyretes	1	
		Haliplidae	Peltodytes	2	13
		Hydrophilidae	Berosus		3
			Hydrochus		1
	Collemobla	Poduridae	**Podura**	**1**	
	Diptera	Chironomidae		34	19
	Ephemeroptera	Baetidae	**Acerpenna**		**17**
			Baetis	2	13
			Centroptilum		1
			Paracloeodus		1
			Procloeon	18	4
				2	
		Caenidae	Brachycercus		3
			Cercobrachys		2
		Heptageniidae	Leucrocuta	12	
			Stenonema		1
		Isonychiidae	Isonychia	1	
		Leptohyphidae	Tricorythodes	46	57

Table B.1 Benthic Macroinvertebrates Collected in FM 409 and USFS Stream Reaches in May 2010 (Continued)

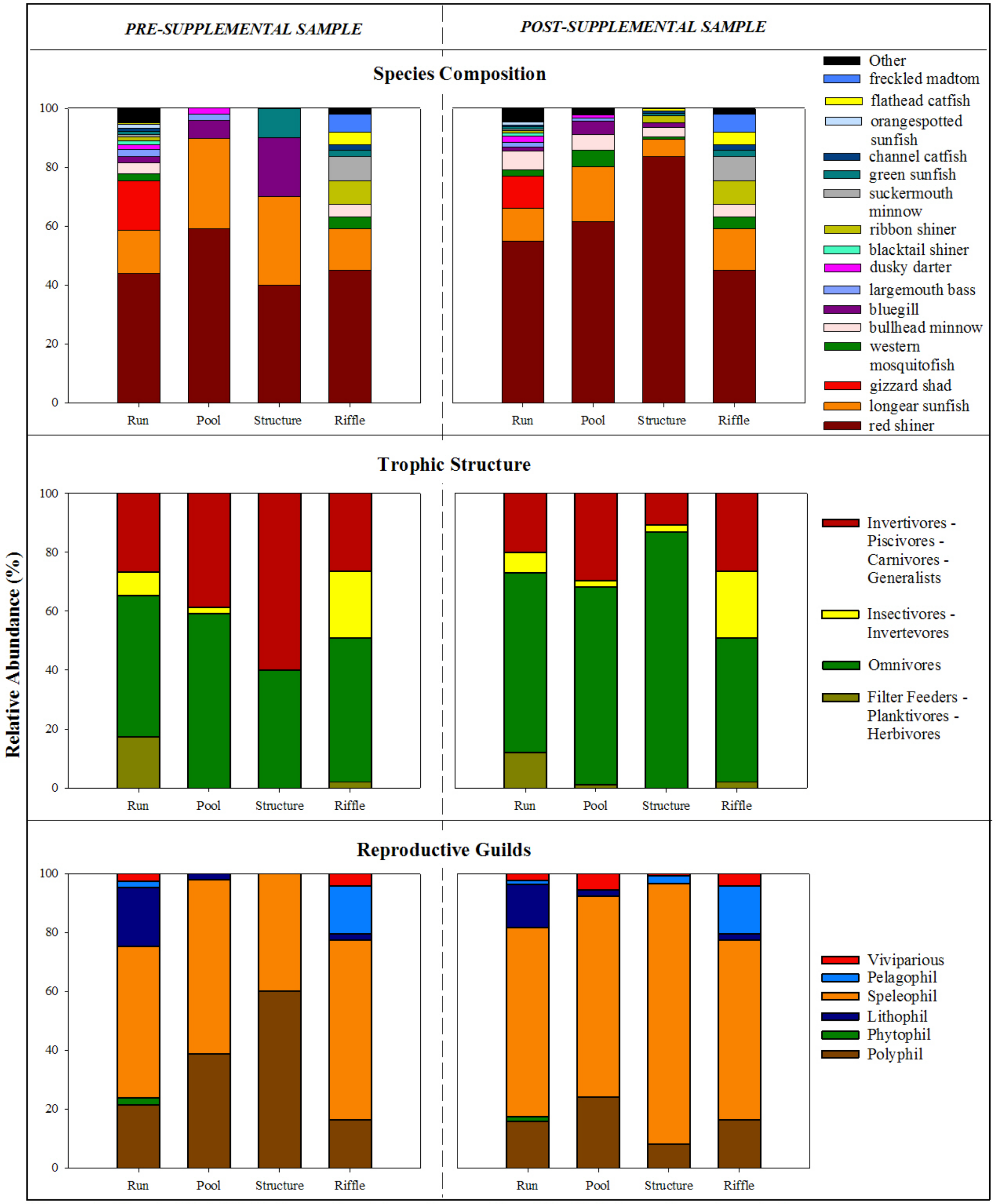
Taxonomy				**Site**	
Class	**Order**	**Family**	**Genus**	**FM 409**	**USFS**
Insecta	Hemiptera	Corixidae	Dasycorixa	5	4
			Trichocorixa	10	2
					2
		Gerridae	**Rheumatobates**		**1**
		Hydrometridae	**Hydrometra**	**1**	
		Nepidae	Ranatra	1	
		Pleidae	**Neoplea**		**2**
		Veliidae	**Microvelia**		**3**
	Megaloptera	Corydalidae	**Chauliodes**	**1**	
	Odonata	Coenagrionidae	Argia		1
			Enallagma		2
		Gomphidae	Ophiogomphus	9	
			Progomphus	1	
		Macromiidae	Macromia	4	
			Didymops	2	
	Plecoptera	Perlidae	**Perlesta**	**2**	
	Trichoptera	Hydropsychidae	Cheumatopsyche	10	2
			Leptonema	4	
Malacostraca	Amphipoda	Hyalellidae	Hyalella	1	28
	Decapoda	Cambaridae		1	
Gastropoda	Basommatophora	Physidae	Physa		2
			Total	***181***	***198***

*New genus identified in bold

Table B.2 Fish Species Collected in FM 409 and USFS Stream Reaches in May 2010

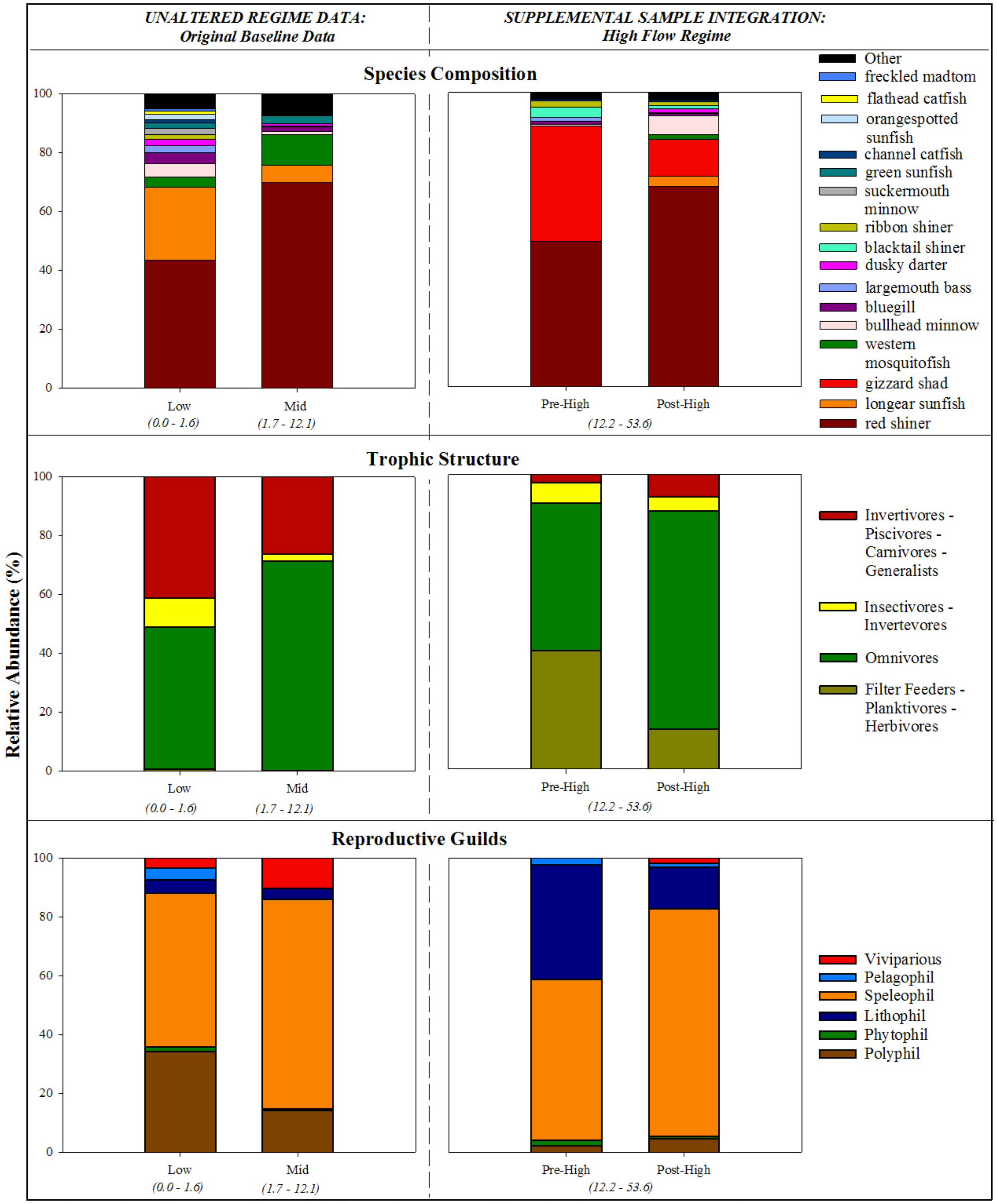
Family	Species	FM 409	USFS	Relative Abundance
Lepisosteidae	*Lepisosteus osseus*	1		0.20%
Cyprinidae	*Cyprinella lutrensis*	288	48	68.43%
	Lythrurus fumeus	3		0.61%
	Pimephales promelas	4	1	1.02%
	Pimephales vigilax	34	21	11.20%
Catostomidae	***Moxostoma poecilurum***	1		0.20%
Ictaluridae	*Ictalurus punctatus*	2		0.41%
	Noturus nocturnus	1		0.20%
	Pylodictis olivaris	2		0.41%
Atherinopsidae	***Menidia beryllina***		1	0.20%
Fundulidae	*Fundulus notatus*		1	0.20%
Poeciliidae	*Gambusia affinis*	10	3	2.65%
Centrarchidae	*Lepomis humilis*		11	2.24%
	Lepomis macrochirus	2	1	0.61%
	Lepomis megalotis	20	26	9.37%
	Micropterus salmoides		1	0.20%
Percidae	*Percina caprodes*	1		0.20%
	Percina phoxocephala	1		0.20%
	Percina sciera	7		1.43%
Total Number Collected		**337**	**114**	***Grand Total: 491***
Taxa		**15**	**10**	***Total Taxa: 19***

Figure B.1 Mesohabitat Composition with Supplemental Sample Integration: Species Distribution, Trophic Structure, and Reproductive Guild Comparison.



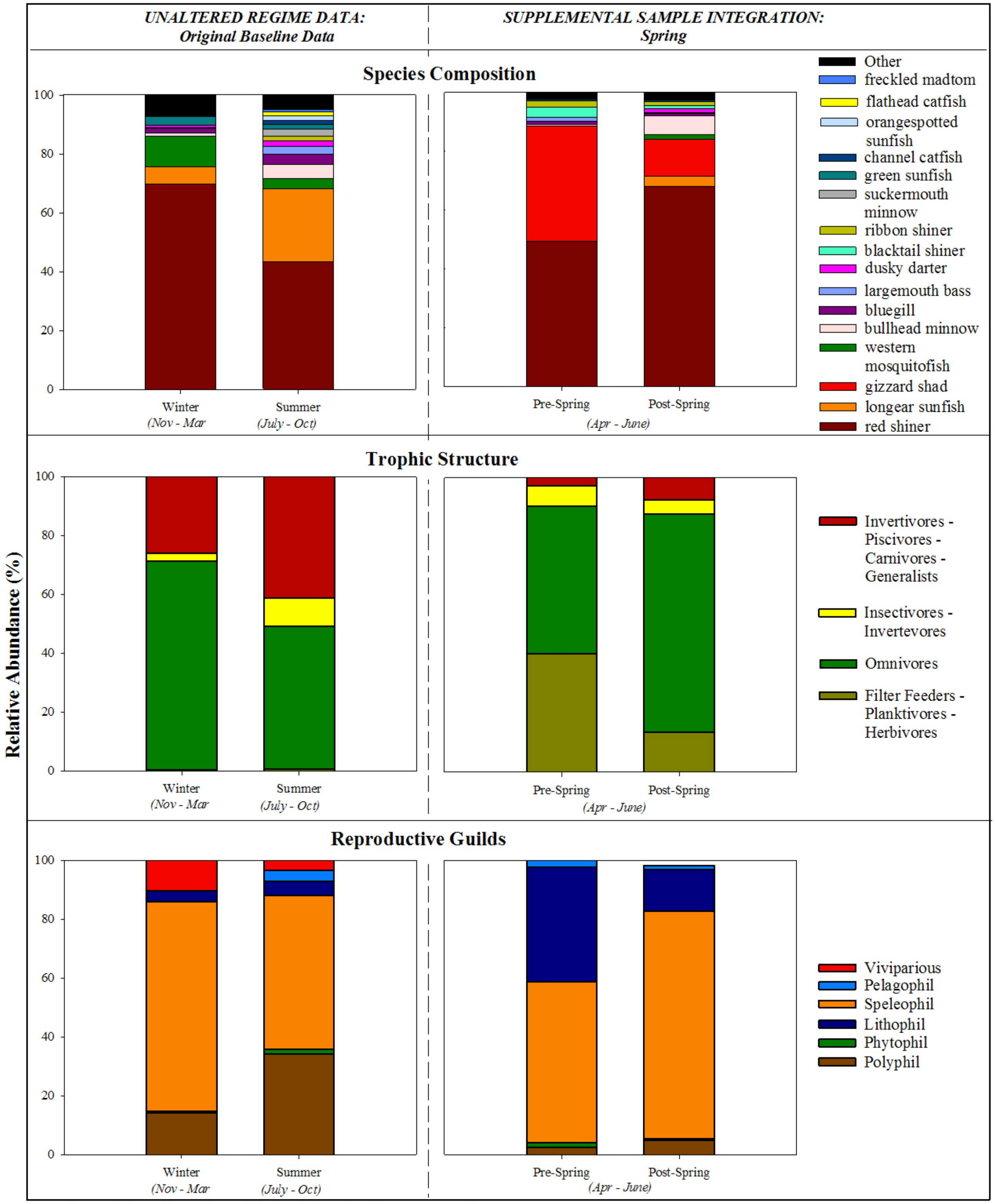
*No samples taken in riffle habitat during supplimental sampling event (i.e., riffle distributions will remain constant)

Figure B.2 Flow Regime Composition with Supplemental Sample Integration: Species Distribution, Trophic Structure, and Reproductive Guild Comparison.



* Supplemental sample conducted during high flow regime stream conditions (i.e., flows greater than 12.1 cfs)

Figure B.3 Flow Regime Composition with Supplemental Sample Integration: Species Distribution, Trophic Structure, and Reproductive Guild Comparison.



* Supplemental sample conducted during the spring (i.e., May 2010)

Figure B.4 Multivariate CCA Results Illustrating Habitat Features, Fish Species, and Mesohabitat Delineation

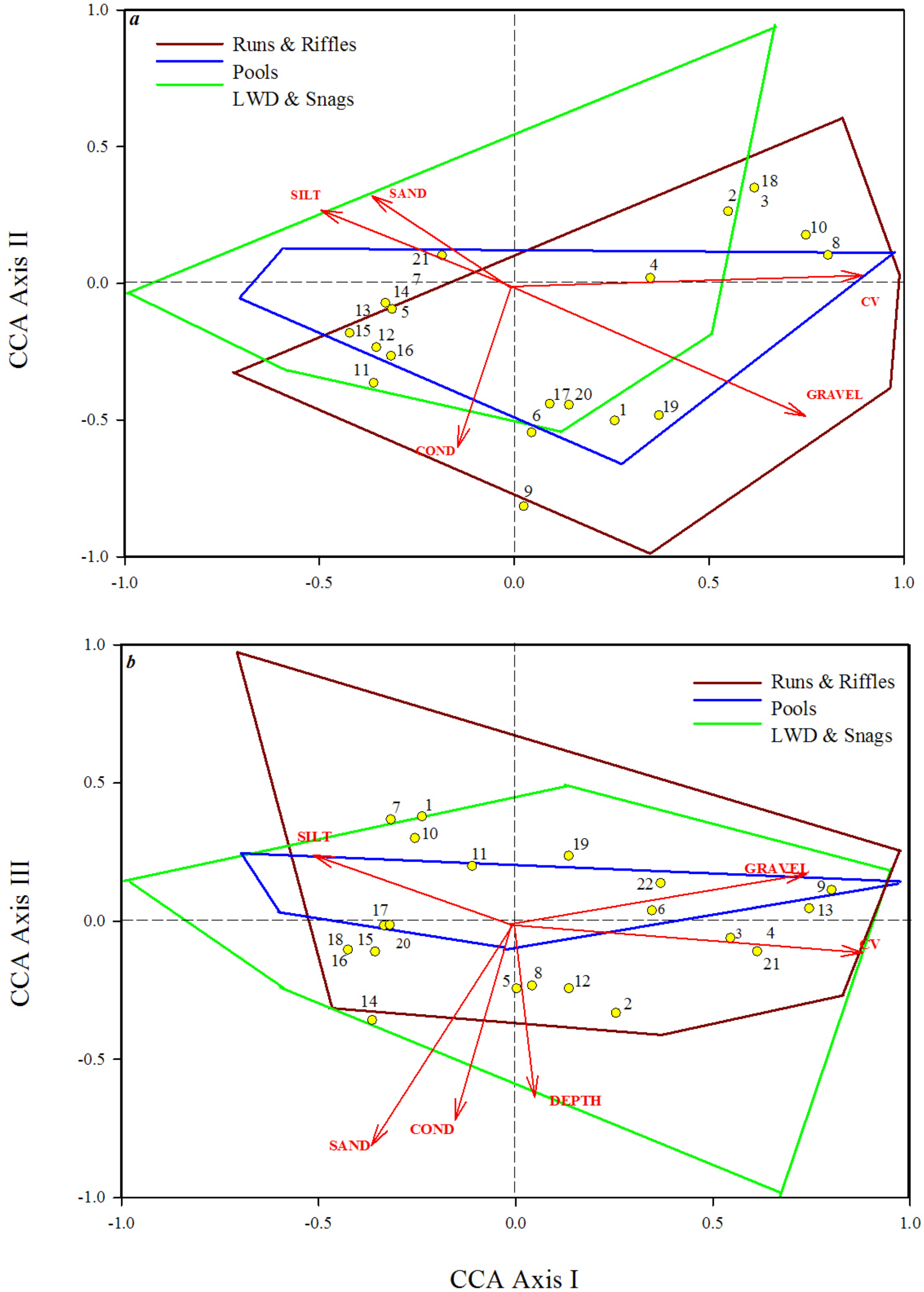


Table B.3 Multivariate CCA Figure Species Identification

Species	***Numbered Point*** *Figure B-4a*	*FigureB-4b*
Lepisosteus oculatus	1	1
Lepisosteus osseus	-	2
Dorosoma cepedianum	2	3
Dorosoma petenense	3	4
Cyprinella hybrid	-	5
Lythrurus fumeus	4	6
Notropis stramineus	5	7
Pimephales promelas	6	8
Ictiobus bubalus	7	-
Moxostoma erythrurum	8	9
Moxostoma poecilurum	9	-
Ameiurus melas	-	10
Ameiurus natalis	-	11
Ictalurus punctatus	-	-
Noturus nocturnus	-	12
Labidesthes sicculus	10	13
Menidia beryllina	11	14
Lepomis humilis	12	15
Lepomis microlophus	13	16
Micropterus punctulatus	14	17
Pomoxis annularis	15	18
Pomoxis nigromaculatus	-	19
Etheostoma gracile	16	20
Percina caprodes	17	-
Percina macrolepida	18	21
Percina phoxocephala	19	22
Percina sciera	20	-
Aplodinotus grunniens	21	-

* To exclude species without strong associations with environmental parameters, only fish whose species score was greater than one standard deviation from the mean score are listed.

APPENDIX C

DOWNSTREAM CORRIDOR IMPACTS

C-1 INTRODUCTION

The flow regime of Bois d'Arc Creek has evolved over time. More than 100 years ago, the channel was a meandering stream that moved flood waters slowly through the basin to the Red River. Today, the creek responds to rain events by moving flood waters quickly through the channel, which is observed in the rapid rise and fall of flood waters. This response results in continued downcutting of the channel and potential future disconnect between the channel and riparian corridor. The proposed flow regime for Bois d'Arc Creek is expected to reduce the downcutting and may contribute to aggradation of the stream, which would better serve the downstream riparian corridor. This flow regime is based on three components defined for the Texas Instream Flow Program (TIFP), and is expected to be sufficient to protect the instream flow needs of the channel and the associated riparian corridor.

Overbanking flows are the fourth category of environmental flow criteria established by the TIFP. The proposed flow regime for Bois d'Arc Creek excludes deliberate releases from the reservoir to produce overbanking flows. This recommendation was supported by the results of the hydrological, biological, and fluvial geomorphological components of the 2010 *Instream Flow Study*, as high flows were shown to be erosive and destructive to existing instream habitats. It is also consistent with the Texas Commission on Environmental Quality's (TCEQ) position to not require overbank releases in water rights permits, as indicated by agency staff during meetings for the Bois d'Arc Creek instream flow study. Deliberate overbanking or flooding flows create liability issues relating to potential property damage and/or loss of life.

A sound ecological environment, as defined for the Bois d'Arc Creek *Instream Flow Study* (FNI, 2010), requires environmental flow releases that provide sufficient stream power to move sediment in the channel to promote habitat diversity without creating excessive stream bed and bank erosion. The recommended pulse release amount to meet this criterion is 50 cfs. This flow, while sufficient to meet this goal, will not generate overbank flows by itself. The anticipated change in the number and frequency of overbank flows may result in potential impacts to the instream and floodplain environments downstream of the proposed dam. Potential impacts and established mitigation for instream impacts associated with the proposed Lower Bois d'Arc Creek Reservoir project were addressed in the 2010 *Instream Flow Study* report and supported with this Supplemental Report. The primary purpose of this Appendix is to address potential impacts to the floodplain of Bois d'Arc Creek downstream of the proposed dam, specifically those effects that pertain to expected modification of overbanking flows.

C-2 POTENTIAL IMPACTS OF LOWER BOIS D'ARC CREEK RESERVOIR ON DOWNSTREAM FLOODPLAIN

In a comprehensive report on Dams and Development (WCD, 2000), the World Commission on Dams documented potential environmental impacts of dams (Petts, 1984). These potential impacts can be considered within a hierarchical framework of interconnected effects, with differing levels of impacts.

Considerations of potential impacts to the downstream floodplain environments include abiotic variables relating to hydrology, water quality, and sediment loading. The proposed project ecosystem and reservoir purpose (i.e., whether water is extracted, diverted, or released) dictate the extent of change to downstream floodplain hydrology and sedimentation processes (WCD, 2000). Significant changes associated with the abiotic variables can result in altered floodplain morphology and riparian vegetation. These are dependent on the extent of impacts created by dam operations, local conditions, and the characteristics of the stream prior to dam (Acreman, 2000). Potential changes to the biological environment are the result of the integrated effects of these impacts. Complex interactions may take place over many years before a new "ecological equilibrium" is achieved (McCartney et al., 2000).

The proposed flow regime for Lower Bois d'Arc Creek Reservoir may result in changes to the downstream corridor. However, based on local conditions, these changes are not expected to have a negative impact, and may help contribute to maintaining a sound ecological environment in the area.

C-2.1 Potential Effects on Hydrology and Sedimentation

Several integrated factors determine how the modified flow regime and reduced sediment loading will impact the downstream floodplain. Overbanking flows can play a role in floodplain inundation duration and frequency, sediment deposition, and soil fertility (McCartney, 2000). Reducing overbanking flows may also influence longer-term processes of groundwater/aquifer recharge and connectivity. However, other factors such as current channel conditions, climatic conditions (e.g., precipitation), topography, soils, land cover, and dam design and operation will affect the level of impacts.

C-2.1.1 Hydrology

The current channel conditions of Bois d'Arc Creek are generally considered "poor" and in a state of disequilibrium and stream instability (FNI, 2010). Bois d'Arc Creek watershed is a highly channelized stream system (62%), with stream bank heights ranging between 20 to 30 feet. Stream channelization began in the 1920s; therefore, current stream conditions to a degree reflect over 90 years of altered stream-floodplain connectivity.

With the dam in place, hydrologic modeling results indicate that there will be fewer overbanking events along the downstream corridor of Bois d'Arc Creek; however, several other factors will continue to contribute to floodplain inundation. These include spills from the reservoir, effects associated with overbanking events associated with local tributaries, regional climatic conditions and existing riparian vegetation. Regionally, inundation is supplemented by high average annual rainfall and existing soils types (i.e. Tinn clay) with the slow permeability and low runoff potential (USDA, 2001). Behind the Gulf Coastal Plains and the Pacific Northwest, East Texas receives among the highest average rainfall in the conterminous U.S. (about 42-44 inches/year). Additionally, 42 percent of the downstream floodplain (modeled post-dam) is part of the Caddo National Grasslands. The relatively undisturbed vegetative state of these areas potentially promotes water retention and encourages soil infiltration (Acreman, 2000).

Hydrological effects of dams become less significant with distance downstream because the area of uncontrolled catchment of the watershed increases. The frequency of tributary confluence and their hydrological contribution play a large role in determining the length of stream affected by an impoundment (Acreman, 2000). Below the proposed Bois d'Arc Creek reservoir, there are numerous contributing tributaries (Figure C-2). These tributaries provide additional stream flow to Bois d'Arc Creek as well as the potential to provide overbanking flows to the adjacent floodplain.

Altered drainage systems, such as Bois d'Arc Creek, create reduced groundwater-surface water interaction and modify infiltration processes resulting in decreased groundwater recharge (Winter et al., 1998). The floodplain soils are documented to have a deep groundwater table (greater than six feet) (USDA, 2001). Groundwater-stream channel interaction may actually increase as a result of the proposed environmental flow regime, as it maintains steady base flows throughout the year. This can promote lateral connectivity between the active channel and the near surface groundwater table (Winter et al., 1998).

C-2.1.2 Sedimentation

The majority of impacts associated with reduced sediment loading occur within the active channel, though overbanking flows do contribute fluvial sediment deposits and associated soil nutrients to the adjacent floodplain (Ligon et al., 1995).

Over the course of the modeled historical hydrological record, overbanking events in Bois d'Arc Creek occur on average three times per year. With continued channel incision and degradation, the frequency of overbanking flows could decrease, limiting sediment and nutrient deposition as compared to pre-channelized stream conditions. The 2010 *Instream Flow Study* proposed environmental flow regime incorporates pulse flow events (50 cfs) to maintain or improve channel characteristics by minimizing erosional processes and promoting the establishment of stream bank vegetation. With the proposed flow regime, the channel is expected to aggrade over time, increasing potential connectivity with the adjacent floodplain. (See discussion on Yegua Creek in Section C-2.2.1.)

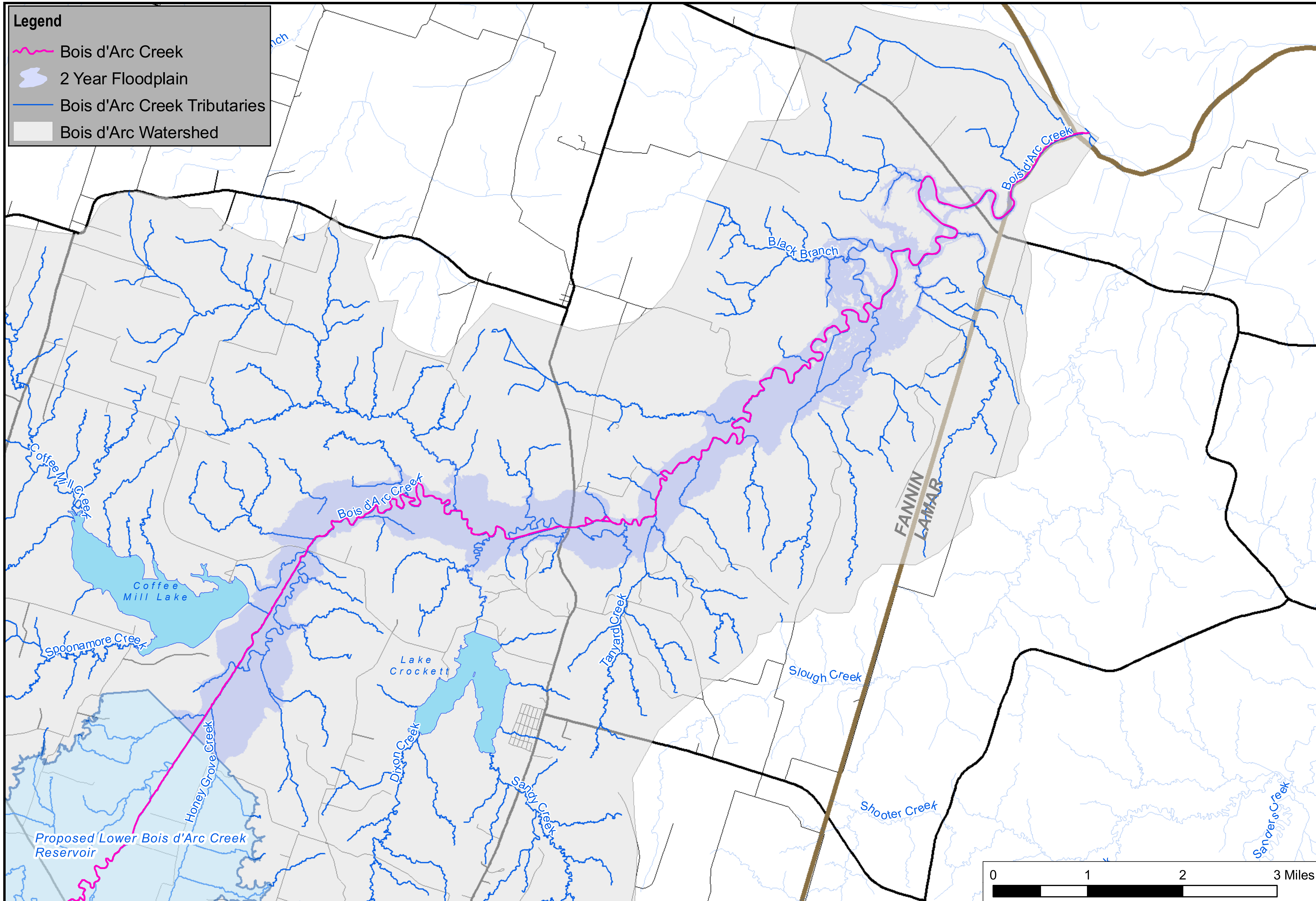


Figure C-2

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DATE	August 2010
SCALE	1:60,000
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DRAFTED	BME

North Texas Municipal Water District
Proposed Lower Bois d'Arc Creek Reservoir

Contributing Downstream Tributaries

Freese and Nichols
4055 International Plaza Suite 200
Fort Worth, Texas 76109-4895
817-735-7300

C-2.2 Potential Effects on Floodplain Morphology and Riparian Vegetation

C-2.2.1 Floodplain Morphology

Downstream of the proposed dam, the floodplain morphology of Bois d'Arc Creek has been affected by the historical upstream channelization practices. In general, the banks of Bois d'Arc Creek downstream of the proposed dam are actively eroding, resulting in channel widening (approximately 0.5 feet/year), incision, and bank steepening. Currently, all stream migration is confined within the incised channel; therefore, the proposed stable low flow reservoir releases are expected to promote floodplain retention through stream bank stabilization and channel aggradation.

Stream aggradation has been documented at other streams downstream of existing reservoir sites. In Yegua Creek, downstream of Somerville Dam, Somerville, TX, the channel capacity decreased following dam closure due to reduced flood flow frequency. Since construction of the dam, there has been an 85 percent reduction in flood peaks. Aggradation has caused the channel depth to decrease approximately 60 percent. Channel banks have remained stable as a result of increased vegetation density caused by increased low flows during the typically dry summer months. Decreased channel capacity allows for increased sediment delivery to the floodplain by flows that have been traditionally contained in a larger channel (Chin et al., 2002).

C-2.2.2 Riparian Vegetation

The inclusion of overbanking flows in the TIFP is often cited to maintain the ecological health of the downstream riparian corridor. Concerns with reduced overbanking include potentially decreased soil fertility and reduced "seedbed" area for riparian vegetation. However, impacts on riparian vegetation are site specific and depend, to a large extent, on dam operations and current site conditions (e.g., existing vegetative species, active channel width, land use, topography) (Acreman, 2000; Chang and Crowley, 1997; Williams and Wolman, 1984). In some instances, particularly in altered systems, regulated stream flows promote stream bank stabilization, vegetation growth, and species diversity.

For example, the riparian corridor below the Sam Rayburn Reservoir promotes greater species diversity than a relatively undisturbed corridor along the Neches River. For this assessment, streamflow and vegetation characteristics were compared between the study areas: 1) immediately below Sam Rayburn Dam in the Angelina River floodplain and 2) a relatively undisturbed area along the Neches River approximately 12 miles to the west. After impoundment, the monthly stream flows were higher in the summer months, duration of high flows was lower, and spring peak flows and flood conditions were reduced due to reservoir operation and management. Vegetation comparisons, including woody and herbaceous species in all strata of the forest stands at each site, indicated that the site immediately below Sam Rayburn Dam had greater species diversity, richness and evenness. The study concluded that the reduced flooding and moderation of stream flow variation created a more suitable habitat for plant growth and development. The dam created a more diverse and stable ecosystem in the downstream area (Chang and Crowley, 1997). Similar results could be expected to occur downstream of the Lower Bois d'Arc Creek Reservoir dam where the regulated flow regime would encourage channel bank stability and vegetative growth.

To assess the potential impacts from reduced overbanking events to the riparian vegetation along the downstream corridor, vegetative species were identified using the Habitat Evaluation Procedures (HEP) protocol and indicator species defined for the HEP survey of the proposed reservoir pool (FNI, 2007). A total of eight HEP points were collected in August 2009 as part of the downstream study. Both the species composition data from the 2007 HEP reservoir surveys and the downstream riparian corridor (2009) were used to establish a representative vegetative community assemblage for Bois d'Arc Creek. Each species' wetland indicator status (USDA-NRCS, Region 6) and anaerobic soil tolerance (USDA-NRCS 2010) were used as surrogates for flood tolerance. Table C-1 defines wetland indicator status with comments on occurrence, and Tables C-2 and C-3 identify HEP documented species by vegetative strata (i.e., trees, shrubs, and herbaceous) with wetland indicator status and anaerobic soil tolerance.

As described in Table C-1 wetland plant species except for obligates (OBL) can, to various degrees, grow in non-wetland conditions. Facultative species may occur equally in wetland or non-wetland conditions. The anaerobic tolerance of a species is also an indicator of a species' ability to grow in hydric soils, which can produce anaerobic (no free oxygen) conditions during periods of inundation. Non-wetland species actually have none to low tolerance of anaerobic soils conditions.

In the Bois d'Arc Creek downstream riparian corridor, the riparian woodland community is currently most similar to the forest cover type described as Sugarberry-American Elm-Green Ash (Society of Foresters; Allen et al., 2001). These woodlands are typically found at transitional elevations between poorly drained flats (e.g., overcup oak-water hickory stands) and well-drained ridges (e.g., sweetgum-willow oak stands). In total, one-third of the tree species are classified as facultative upland or upland species, suggesting a community prone to temporary rather than semi-permanent flooding. Every vegetative strata was dominated by facultative species (equally likely to occur in wetlands or uplands), and would be considered drought-tolerant.

Table C-1 Wetland Indicator Categories with Comments on Occurrence (USDA-NRCS, 2010)

Wetland Type	Indicator Code	Comment
Obligate Wetland	OBL	Occurs almost always (estimated probability 99%) under natural conditions in wetlands.
Facultative Wetland	FACW	Usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.
Facultative	FAC	Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
Facultative Upland	FACU	Usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%).
Obligate Upland	UPL	Occurs in wetlands in another region, but occurs almost always (estimated probability 99%) under natural conditions in non-wetlands in the project region. If a species does not occur in wetlands in any region, it is not on the National List of Plant Species that Occur in Wetlands..

Table C-2 Plant Species of the Bois d'Arc Creek Riparian Woodlands and Bottomland Hardwood Forest with Wetland Indicator Status and Anaerobic Soil Tolerance -2007 HEP Study at the Proposed Lower Bois d'Arc Creek Reservoir Site

Wetland Indicator Status	*TREES*			*SHRUBS*			*HERBACEOUS*		
	Observed Species	**Anaerobic Tolerance**	***% of Total***	**Observed Species**	**Anaerobic Tolerance**	***% of Total***	**Observed Species**	**Anaerobic Tolerance**	***% of Total***
OBL				Button Bush	High		Duckweed	High	
			0	Water Hickory	Medium	***10***	Sedge Species	Medium - High	***20***
FACW	Box-Elder	Medium		Box-Elder	Medium		Cherokee Sedge	--	
	Green Ash	Medium		Deciduous Holly	Medium		Frog Fruit	--	
	Black Willow	High		Green Ash	Medium				
				False Willow	High				
			33	Black Willow	High	***25***			***20***
FAC	Cedar Elm	None		Yaupon	None		Poison Ivy	--	
	Honey Locust	None		Cedar Elm	None		Virginia Wildrye	--	
	Sugarberry	Medium		Cottonwood	High		Virginia Creeper	Medium	
				Honey Locust	None		Ragweed	None	
				Poison Ivy	--		Inland Sea Oats	Medium	
				Ragweed	--		Trumpet Vine	None	
				Sugarberry	Medium				
			33	False Willow	--	***40***			***60***
FACU	Red Mulberry	Medium		Eastern Red Cedar	Low				
	Winged Elm	Low		Western Soapberry	None				
				Red Mulberry	Medium				
				Winged Elm	Low				
			22	Coral Berry	None	***25***			***0***
UPL	Bois d'Arc	None	***11***			***0***			***0***

Table C-3 Plant Species of the Bois d'Arc Creek Riparian Woodlands and Bottomland Hardwood Forest with Wetland Indicator Status and Anaerobic Soil Tolerance -Data Points Downstream of Proposed dam Site

	TREES		***SHRUBS***	
Wetland Indicator Status	**Observed Species**	**Anaerobic Tolerance**	**Observed Species**	**Anaerobic Tolerance**
OBL	Water Locust	Low		
FACW	Green Ash	Medium	Box-Elder	Medium
			Deciduous Holly	Medium
			Green Ash	Medium
FAC	Bur Oak	None	Cedar Elm	None
	Cedar Elm	None	Honey Locust	None
	Sugarberry	Medium	Northern Catalpa	None
			Roughleaf-Dogwood	
			Sugarberry	Medium
			Yaupon	None
FACU	Eastern Red Cedar	Low	Eastern Red Cedar	Low
			Western Soapberry	None
UPL	Bois d'Arc	None	Bois d'Arc	None

Several facultative upland species were found in adjacent upland areas (Table C-4) that were not found in the riparian woodlands and bottomland hardwood forests of Bois d'Arc Creek. Over time, if the downstream riparian corridor experiences a decline in facultative wetland species (e.g., green ash, box-elder, deciduous holly) there is potential to gain hardmast producing species (e.g., southern red oak, post oak, black cherry) from the adjacent uplands. An increase in these species will help to mediate faunal impacts and increase available habitat types.

Table C-4 Plant Species of the Lower Bois d'Arc Creek Upland Deciduous Forest with Wetland Indicator Status and Anaerobic Tolerance

Wetland Indicator Status	*TREES*			*SHRUBS*			*HERBACEOUS*		
	Observed Species	**Anaerobic Tolerance**	***% of Total***	**Observed Species**	**Anaerobic Tolerance**	***% of Total***	**Observed Species**	**Anaerobic Tolerance**	***% of Total***
OBL			***0***			***0***			***0***
FACW							Beggars Ticks	Medium	
			0	Green Ash	Medium	***6***	Cherokee Sedge	--	***10***
FAC	Cedar Elm	None		Common Persimmon	None		Alabama-Supplejack	--	
	Common Persimmon	None		Hawthorn	Medium - High		Blackberry		
	Honey Locust	None		Honey-Locust	None		Canada Wildrye	--	
	Sugarberry	Medium		Roughleaf-Dogwood	Low		Common Greenbriar	Low	
	Water Oak	Medium		Sugarberry	Medium		Dewberry	None	
							Grape Vine	--	
							Poison Ivy	--	
							Spike Uniola	--	
							Tick Seed	Medium	
							Tick Trefoil	Medium	
							Trumpet Creeper	None	
							Virginia Creeper	None	
							Virginia Wildrye	Medium	
			50			***31***		--	***65***
FACU	Black Cherry	None		American-Beautyberry	None		Carolina Snailseed	--	
	Eastern Red Cedar	Low		Black Cherry	None		Frostweed	--	
	Post Oak	Low		Coral Berry	None		Prickly Pear	--	
	Southern Red Oak	None		Eastern Red Cedar	Low		Yellow-Woodsorrel	--	
				Gum Bumelia	--				
				Post Oak	Low				
				Rusty Blackhaw	None				
				Winged Elm	Low				
			40	Yaupon Holly	None	***56***			***20***
UPL	Bois d'Arc	None	***10***	Eastern Redbud	None	***6***	Threeseed-Mercury	--	***5***

C-2.3 *Potential Effects on Downstream Fauna*

The integrated effects of impacts can lead to changes to the biological environment. These include potential impacts to species close to the top of the food chain (e.g., fish, birds, and mammals), and can be the result of direct habitat loss, reduced resource availability, or reduced habitat quality. In some cases, there have been noted increases in habitat availability and quality associated with the shift in riparian vegetation.

Wildlife species observed and habitat quality data collected during HEP surveys were used to characterize the current habitat conditions along Bois d'Arc Creek and to evaluate future conditions. In the HEP procedure, a set of evaluation species were selected by state and federal resource agency representatives and current habitat conditions were evaluated in light of the optimum habitat characteristics for these species (FNI, 2008). Habitat quality is expressed in terms of a Habitat Suitability Index (HSI), and ranges from 0.0 to 1.0 (i.e., unsuitable to suitable). This metric was used as a surrogate to estimate current habitat quality in accordance with HEP protocols.

Bois d'Arc Creek riparian woodland and bottomland hardwood evaluation species were the Barred Owl, Downy Woodpecker, Wood Duck, Fox Squirrel, and Raccoon (Table C-5). The 2007 HEP study indicated that the quality of riparian woodland and bottomland hardwood wildlife habitat was fairly poor, with HSI values ranging from 0.03 to 0.52 (Table C-6). The HEP study of the downstream sites conducted in 2009 indicated that these areas might also have poor quality habitat for all species except the downy woodpecker. The measured habitat characteristics used to assess habitat availability were compared to potential impacts associated with reduced overbanking flows. Table C-7 identifies these habitat characteristics and the associated predicted change represented as +/0/- (i.e., positive, neutral, or negative, respectively).

Based on the predicted changes to the downstream riparian corridor, habitat quality and availability are expected to increase. Improvements to wildlife habitat quality would result from the continued maturation of the forest within the current floodplain, and a potential shift in vegetative composition. Primary effects of a shift in vegetation might include: (1) increased hardmast producers, (2) decreased shrubs and herbaceous species (e.g., green ash), and (3) increased heterogeneity in canopy cover. In protected areas, such as the corridor through the Caddo National Grasslands, such a vegetative shift would expect to be minimal due to the existing closed canopy that limits seedbed areas. Areas where a vegetative shift would have the greatest potential impact are areas that could be disturbed by logging, fire, insects or disease. The combination of forest maturation and potential vegetative shift would increase resource availability, while providing habitat for nesting, foraging, and refugia. The proposed steady base flow releases will also provide permanent water for wildlife species.

Table C-5 Wildlife Species of the Bois d'Arc Creek Riparian Woodland and Bottomland Hardwood

Observed Species	Evaluation Species
Birds	
American Crow	Barred Owl
Barred Owl	Downy Woodpecker
Carolina Chickadee	Wood Duck
Carolina Wren	
Downy Woodpecker	
Hummingbird	
Indigo Bunting	
Mourning Dove	
Northern Cardinal	
Northern Parula	
Red-eyed Vireo	
Tufted Titmouse	
White-eyed Vireo	
Wood Duck	
Yellow-billed Cuckoo	
Mammals	
Beaver (chew marks)	Fox Squirrel
	Raccoon
Hog (tracks)	
Raccoon (tracks)	

Table C-6 Baseline habitat Suitability Index (HSI) Values of the Bois d'Arc Creek Riparian Woodland and Bottomland Hardwood

Evaluation Species	HSI Values	
	Reservoir	*Downstream*
Barred Owl	0.14	0.14
Downy Woodpecker	0.34	0.71
Fox Squirrel	0.03	0.1
Raccoon	0.52	0.26
Wood Duck	0.22	0.0

Table C-7 Predicted Changes in Quality of Habitat Variables Measured in the Downstream Portion of the Lower Bois d'Arc Creek Riparian Woodland / Bottomland Hardwood After Dam Construction

Evaluation Species	Habitat Characteristic	Potential Impact	Predicted Change
Barred Owl	Number of large trees	Growth with Age	+
	Average diameter of overstory trees	Growth with Age	+
	Canopy cover of overstory trees	Growth with Age	+
Downy Woodpecker	Basal area	Growth with Age	+
	Number of large snags	Reduced flooding	-
Fox Squirrel	Canopy closure of large trees that produce hard mast	Growth with Age	+
	Distance to available grain	Agricultural Production Not Expected	0
	Average diameter of overstory trees (inches)	Growth with Age	+
	Percent tree canopy closure	Growth with Age	+
	Percent shrub crown cover	Increased shrub/herbaceous mortality	+
Raccoon	Distance to water	Permanent base flows	+
	Water regime (Permanent, Semi-permanent, or Ephemeral)	Permanent base flows	+
	Overstory forest size class	Growth with Age	+
	Number of refuge sites	Increased Tree Mortality with Age	+
Wood Duck	Number of potentially suitable tree cavities	Increased Tree Mortality with Age	+
	Number of nest boxes (management tool)	-	+
	Percent of water surface covered by potential brood cover	Reduced inundation duration	-
	Percent of water surface covered by potential winter cover	Reduced inundation duration	-

C-3 CONCLUSIONS

Potential impacts to the downstream floodplain of Bois d'Arc Creek would likely be limited by several factors: (1) the existing community is not dependent upon overbank flow for reproduction and overall success. Many of the species along Bois d'Arc Creek riparian corridor are equally likely to occur in uplands; (2) the local site conditions (e.g., rainfall, soil type, and land cover) supplement floodplain inundation; (3) the proposed release of steady base flows should increase channel-groundwater connectivity and promote growth of streambank vegetation; (4) the reduction in highly erosive flows would allow the stream to aggrade over time increasing the potential for floodplain connectivity; and (5) contributing downstream hydrology provide instream flow and supplement floodplain connectivity. Certain aspects of the riparian corridor may even be improved as a result of the dam, including increased streambank stabilization, vegetation growth, and gain of hardmast producing woody species.