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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
May 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

May 2010

May 19, 2010

STATE OF TEXAS
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FREESE AND NICHOLS

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EXECUTIVE SUMMARY

This report presents the findings and recommendations of the instream flow study on Bois d'Arc Creek in support of permitting activities for the proposed Lower Bois d'Arc Creek Reservoir. The purpose of the study was to characterize the baseline stream conditions of Bois d'Arc Creek within the proposed reservoir site and downstream, develop predictions of conditions within the reservoir pool, and develop a proposed instream flow regime to maintain a sound ecological environment downstream of the proposed dam.

In accordance with the Texas Instream Flow Program, this study evaluated the four technical components that characterize stream conditions: hydrology and hydraulics, fluvial geomorphology, water quality, and aquatic biology. These components were evaluated in the context of the existing and future stream system, and collectively were used to define a sound ecological environment for Bois d'Arc Creek. To achieve a sound ecological environment, the instream flow regime must:

- Provide sufficient stream power to move sediment in the channel while not creating excessive stream bed and bank erosion;
- Support a spectrum of mesohabitats – pools, runs, riffles and structures;
- Provide hydraulic connectivity to support biological communities;
- Maintain existing water quality standards of the stream for High Aquatic Life use;
- Provide seasonally varying flows to support fish reproduction; and
- Maintain or improve existing fish and macroinvertebrate communities and biodiversity as measured by scientific standards.

With the assistance of an Inter-Agency Team (representatives of state and federal agencies), the scope of work for this study was refined and field data were collected over a five-month period from March 2009 through July 2009. In addition to these field data, literature reviews, data from previous studies (including studies for this project and other independent studies), and available resource data were used to define the stream baseline conditions and evaluate the proposed instream flow regime.

Bois d'Arc Creek is a highly channelized stream system. This has been identified and documented in previous studies as well as in this instream flow study. 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, lack of habitat diversity in channelized sections, and minimal lateral migration of the stream.

The frequent large flow pulses that occur in response to rain events in the watershed are contributing to continuing erosion, including channel downcutting and bank mass failures. This

results in negative impacts to aquatic habitats by mass wasting and high current velocities that scour established habitats. This study found that large flows are not necessary to move sediment along the creek bed. The sediment transport analyses determined that flows less than 1 cfs can transport fine sediments and that gravel transport begins at 25 cfs.

While the Texas Commission on Environmental Quality (TCEQ) classifies Bois d'Arc Creek as perennial, this instream flow study documented extended periods with little to no flows. During these dry times, the aquatic species must migrate from runs and riffle areas and seek refuge in deeper pools. There were 42 species of fish collected and identified as part of this study. Most of these species are generalist species, with red shiner accounting for 50 percent of the relative abundance and longear sunfish accounting for 13.7 percent. Generalist species are more adapted for survival than obligate stream species in the widely varying hydraulic conditions documented in Bois d'Arc Creek, with flows ranging from 0 to greater than 10,000 cfs. The quality of the existing fish communities, as measured by the fish Index of Biological Integrity (IBI), was found to be generally in the High Aquatic Life Use category. Aquatic habitats are dominated by pools (70 to 80% of the weighted useable area) and runs (14 to 28% WUA). Habitat modeling found that flows as low as 2 to 3 cfs provide connectivity between the mesohabitats in the modeled reaches. When evaluating the relationship of habitats with the identified species, there are no statistically significant species-habitat associations. These findings are consistent with the stream hydraulics and the types of species identified in the creek.

Of the fish species identified, most reproduce from spring to early summer. The reproductive cues appear to be largely temperature dependent. The conditions of Bois d'Arc Creek tend to favor the generalist species. The little to no flow conditions observed during the summer months are unfavorable spawning conditions for fluvial specialists.

A total of 2,621 macroinvertebrates, consisting of 103 identified genus and 46 families, were collected as part of this study. The macroinvertebrates were used to define the tropic structure of Bois d'Arc Creek and assess the aquatic life use. Using the Rapid Bioassessment Protocol, the analyses found the overall biological integrity of the macroinvertebrate community at the instream flow sampling sites to be at the higher end of the intermediate range. This is consistent with previous studies on Bois d'Arc Creek and the nearby North Sulphur River.

Water quality data collected during this study and from others (USGS, TCEQ, Red River Authority) is consistent with the High Aquatic Use classification of the stream. Measured dissolved oxygen concentrations generally ranged between 5.4 and 10.7 mg/L at all sites but the U.S. 82 site. The low dissolved oxygen concentrations at this site during limited sampling by the Red River Authority were attributed to warm temperatures and very low current velocity due to a log jam located upstream. Water quality does not appear to be a limiting factor for aquatic life in Bois d'Arc Creek. The observed data indicate that there are sufficient dissolved oxygen concentrations in the creek provided there is any flow in the stream. However, even during

extreme drought conditions, there apparently is adequate dissolved oxygen in pools to sustain aquatic life.

Hydrologic and geomorphic analyses indicate that the Bois d'Arc Creek is currently in disequilibrium. Downcutting and streambank erosion have increased, and lateral migration of the stream (i.e., meander creation) has slowed. Channelization has increased the "flashy" nature of flows in the watershed, with rapid rise and fall in flow in response to rainfall events. This likely has reduced base flows in the watershed as well. Instream habitats continually vary, as high flows scour gravel bars and dislodge large woody debris or low flows reduce connectivity along the stream. The frequency of extreme flow events, both high and low, has resulted in an environment that favors generalist species. Although water quality in the watershed is generally good, Bois d'Arc Creek is not able to support a large variety of aquatic life because the relatively few habitat features in the watershed are frequently washed away by high flow events. The apparent lack of reliable subsistence or baseflow hydrology from year to year may also be a limiting factor for fish and other aquatic species. With no changes in the watershed, Bois d'Arc Creek is expected to continue to downcut and erode, enlarging the existing channel. This will further reduce longitudinal connectivity at low flows and continue to constrain aquatic species to specific habitats that contain water (i.e., pools).

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 modeling studies, this occurs 9 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.

Flows greater than 50 cfs would not be released from the reservoir to minimize erosional processes, channel downcutting and habitat destruction. There still would be naturally occurring larger flow events associated with runoff from the watershed downstream of the dam, spills from the Lower Bois d'Arc Creek Reservoir, and spills from existing downstream reservoirs (Coffee Mill and Crockett Lake). This reduction in the number and volume of large erosive flow events would also allow vegetation to become established along the stream banks and help restore the downstream riparian corridor.

The proposed flow regime is expected to allow the establishment of and preservation of relatively long-lived habitats while less frequently occurring larger events would perform the maintenance that is needed from time to time for habitat sustainability.

With the dam in place and the proposed environmental flow releases, there would be

- Higher median flows during low flow periods;
- Fewer erosive high flow events;
- Improved water quality during typically low flow summer months;
- Sustainable aquatic habitats;
- Increased stability of stream banks; and
- Increased potential for aquatic diversity and migration with higher median low flows.

1 INTRODUCTION

The North Texas Municipal Water District (NTMWD) is projected to need an additional 318,000 acre-feet per year of water in the next 50 years to meet the water supply needs of its growing customer base (FNI, 2008). The NTMWD is actively pursuing conservation, water purchases and the development of new water supplies to help meet its growing demands. One of the new supply sources is the proposed Lower Bois d'Arc Creek Reservoir project. This project is located approximately 15 miles northeast of the City of Bonham in Fannin County and would provide about 126,200 acre-feet per year of additional supply (Figure 1.1).

The NTMWD is currently seeking the necessary permits for the Lower Bois d'Arc Creek Reservoir project. An application for a State of Texas water right was submitted to the Texas Commission on Environmental Quality (TCEQ) on December 29, 2006, and declared administratively complete on June 26, 2007. The application for a Section 404 permit was submitted to the Tulsa District of the U.S. Army Corps of Engineers (USACE) on June 3, 2008, and supplemented with an *Environmental Report* on July 1, 2008.

This instream flow study report was prepared in support of these permitting activities and requests for additional information from the permitting agencies. It includes:

- an assessment of the current instream flow conditions in Bois d'Arc Creek,
- a discussion of expected conditions in the reservoir pool after the reservoir is built,
- an evaluation of the instream flow needs for a sound ecological environment downstream of the dam,
- an assessment of downstream conditions with the proposed dam and recommended operation,
- a reservoir operation plan with recommended instream flow releases, and
- a proposed monitoring and adaptive management plan.

1.1 Purpose of the Instream Flow Study

The primary purpose of this instream flow study is to characterize baseline stream conditions within the proposed reservoir site and downstream, develop predictions of conditions in the reservoir pool, and develop a proposed instream flow regime to maintain a sound ecological environment downstream of the dam. The instream flow regime considers the four technical components described in the *Texas Instream Flow Studies: Technical Overview* (Texas Water Development Board (TWDB), 2008): fluvial geomorphology, hydrology and hydraulics, water quality and biology. The report is intended to provide information on instream flows sought in a TCEQ Request for Information dated February 22, 2007 (the "RFI").

Legend

- Tributary Sites
- Instream Flow Study Sites
- Caddo National Grasslands
- Urban Areas
- Proposed Lower Bois d'Arc Creek Reservoir
- Texas Counties

Red River
Kemp
FM 273
78
FM 1753
Ravenna
FM 2645
Savoy
82
Bonham
Ector
121
FM 1752
FM 898
FM 271
56
Bois d'Arc Creek
Sandy Creek
FM 1396
CR 2645
US 82
Bullard Creek
Dodd City
FM 2077
Windom
FM 1743
Farm Road 1743
Honey Grove Creek
Honey Grove
FM 79
FM 197
USFS
FM 409
FM 2029
F-M 2216
Farm Road 2952
FM 100
FANNIN
LAMAR
FM 38
Farm Road 137
34
F-M 924

Proposed Lower
Bois d'Arc Creek Reservoir

0 1 2 3 Miles

N
W E
S

Figure 1.1

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

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

Instream Study Sites

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1.2 Participants in Instream Flow Study

The TIFP is a relatively new approach to assessing instream flow needs. The State developed guidelines for assessing instream flows in 2008. To date, most, if not all, of the instream flow studies conducted with this approach have been on large river systems in Texas.

To facilitate the development of the scope of work and conduct the field studies for this study, an Inter-Agency Team was formed including representatives from the United States Fish and Wildlife Service (USFWS), United States Army Corps of Engineers (USACE), United States Environmental Protection Agency (USEPA), United States Forest Service (USFS), Texas Parks and Wildlife Department (TPWD), TCEQ, Red River Authority (RRA), NTMWD and Freese and Nichols (FNI). A list of the participants and associated role or expertise is shown in Table 1.1.

FNI conducted two scoping meetings in advance of the field data collection. At each meeting, input was solicited from the Inter-Agency Team and adjustments to the scope of work were made in response to comments received. An aerial video of the Bois d'Arc Creek, from upstream of the reservoir site to the Red River, was shown to all Inter-Agency Team members to orient the team members on the issues specific to the watershed and the stream.

All team members were invited to participate in the field data collection. Representatives from TPWD, TCEQ, USACE and NTMWD accompanied FNI in data collection from March through July 2009.

A follow-up meeting was held with the Inter-Agency Team on September 1, 2009 to present the findings of the field data collection to date. At that time, there was a request to collect an additional sampling event during the 2009-2010 fall/winter time period. The NTMWD and FNI agreed to the additional sampling. However, due to an extremely wet winter, high flow conditions made it impossible to conduct this sampling safely during this period. Because of on-going El Niño conditions, the high flows in Bois d'Arc Creek were projected to continue through the spring and possibly into the summer months. In March 2010, FNI and NTMWD concluded that the available field data and analyses, combined with literature reviews, provide sufficient information to characterize baseline stream conditions and develop an environmental flow recommendation that would support a sound ecological environment as defined herein for Bois d'Arc Creek. Subsequent to this decision, the agreed upon one additional sampling episode was conducted in May 2010. The data collected from this sampling event will be analyzed and summarized in a supplemental report to this study.

Table 1.1 Inter-Agency Team

Name	Agency	Position/ Role
Doyle Mosier	TPWD	Inland Fisheries Division
David Bradsby	TPWD	Aquatic Biologist
Clint Robertson	TPWD	Aquatic Biologist
John Botros	TPWD	Aquatic Biologist
Chris Loft	TCEQ	Resource Protection, Office of Water
Dakus Geeslin	TCEQ	Instream Uses, Water rights
Louis Kindler	TCEQ	Instream Uses, Water rights
Peter Schaefer	TCEQ	Aquatic Biologist, 401 Certification
Mark Fisher	TCEQ	Aquatic Ecologist, 401 Certification
Andy Commer	USACE	Regulatory, Permits
Mark Wentzel	TWDB	Hydrologist, Modeling
Nolan Raphelt	TWDB	Geomorphologist
Henry Wied	RRA	Operations
Jim Crooks	USFS	District Ranger Caddo/LBJ National Grasslands
Dave Peterson	USFS	Fisheries Biologist
Jeanene Peckham	USEPA	Water Quality Protection
Sid Puder	USFWS	Biologist
Kathy Alexander	TCEQ	Hydrologist, Water Rights
Robert McCarthy	NTMWD	Project Manager
Mike Rickman	NTMWD	Assistant General Manager
Steve Watters	FNI	Hydrologist
Stephanie Capello	FNI	Geomorphologist
Patrick Garnett	FNI	Wildlife Biologist
Randall Howard	FNI	Aquatic Biologist
Jon Albright	FNI	Hydrologist
Simone Kiel	FNI	Project Manager
Jessica Strickland	FNI	Fisheries Biologist

1.3 Definition of a Sound Ecological Environment for Bois d'Arc Creek

Creating and maintaining a sound ecological environment is the ultimate goal of the instream flow assessment and instream flow regime development process, as prescribed by the Texas Legislature and the Texas Instream Flow Program (TIFP). The Bois d'Arc Creek watershed has been greatly altered since the early 1920s to reduce flooding in order to facilitate agricultural development, making the existing ecological environment of Bois d'Arc Creek different from original pre-settlement conditions. Based on the current conditions and history of Bois d'Arc Creek, the objectives of the TIFP, and input from the Inter-Agency Team, NTMWD proposes the

following attributes to represent a sound ecological environment for Bois d'Arc Creek downstream of the proposed Lower Bois d'Arc Creek Reservoir:

1. Geomorphology:
    a. Stream power that provides for reworking of sediment (depositional features) but not stream bed and bank erosion (downcutting and widening).
    b. Spectrum of mesohabitats – pools, runs, structures (snags, large woody debris, brush piles, other), and "riffle-like" shallows.
2. Hydrology and Hydraulics:
    a. Seasonally varying flows.
    b. Flow regime to support targeted geomorphic processes identified above, meet water quality goals, and maintain or improve existing biological communities.
    c. Hydraulic connectivity to support biological communities.
3. Water Quality:
    a. Maintain existing water quality standards as established in 30 TAC 307, including:
        i. High aquatic life use
        ii. Contact recreation – fully supporting
4. Biology:
    a. Maintain or improve existing fish and macroinvertebrate communities and biodiversity as measured by Index of Biological Integrity (IBI) and Rapid Bioassessment (RBA) metrics.
        i. Fish IBI= High
        ii. Macroinvertebrate RBA = Intermediate

1.4 Report Organization

The main body of this report is intended to provide an overview of the four technical components of the study (hydrology and hydraulics, fluvial geomorphology, biology and water quality) and information on the integration of these components that resulted in the proposed environmental flow releases. Detailed information on the four components of the study may be found in Appendices B through E.

2 BACKGROUND

The NTMWD proposes to build the Lower Bois d'Arc Creek Reservoir project on Bois d'Arc Creek and Honey Grove Creek in the Red River Basin in Fannin County, Texas (Figure 2.1). The proposed dam will cross Bois d'Arc Creek and Honey Grove Creek about 20 miles upstream of the confluence of Bois d'Arc Creek and the Red River.

BACKGROUND

Bois d'Arc Creek watershed is an altered stream system from extensive channelization.

There are periods of little or no flow in the creek.

Stream habitat is heavily influenced by geology and geomorphic processes.

Instream flow study follows TIFP technical components:

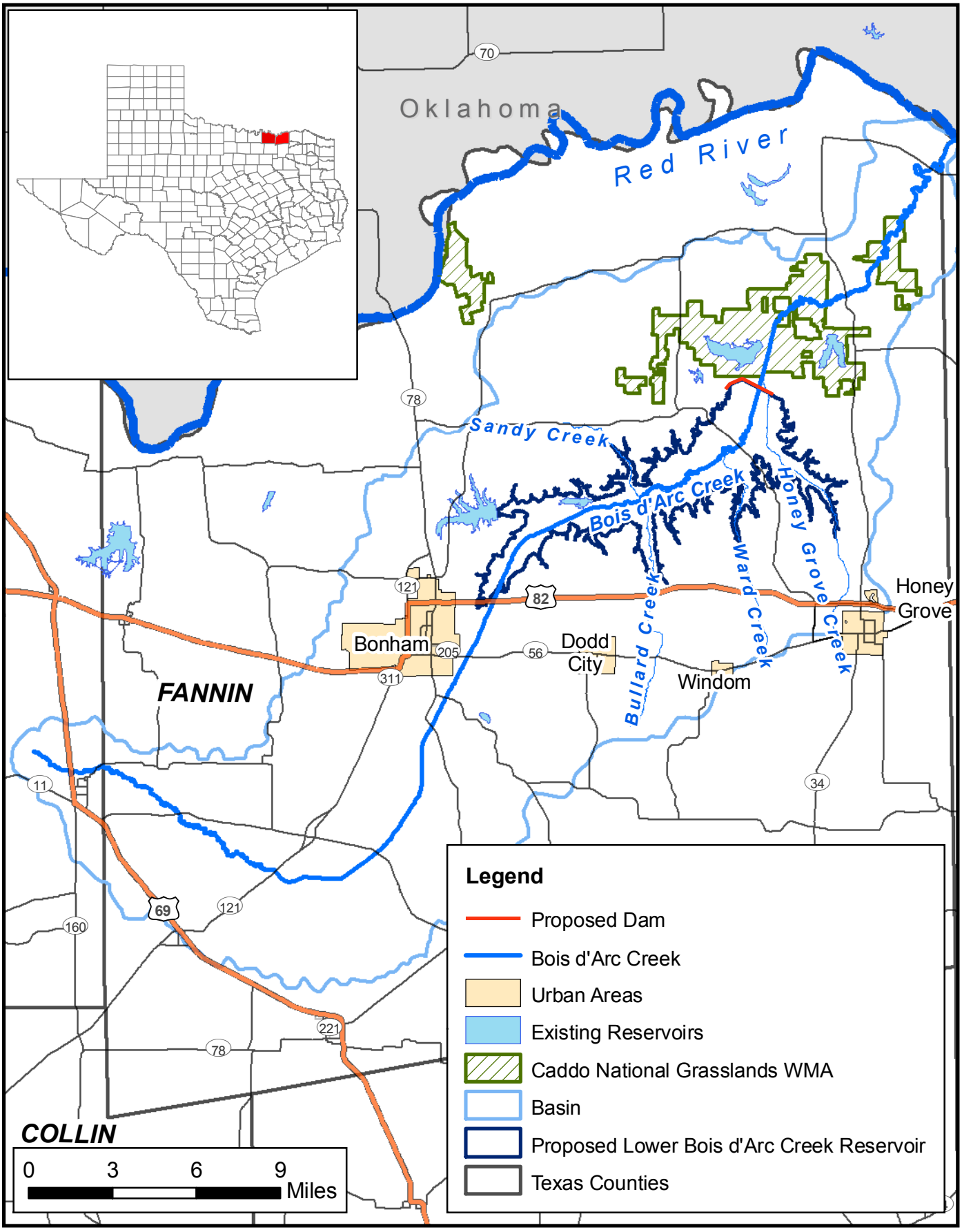
- **Hydrology**
- **Geomorphology**
- **Water Quality**
- **Biology**

Previous site-specific environmental studies and reports prepared in support of this project include:

- *Rapid Geomorphic Assessment in the Lower Bois d'Arc Creek Reservoir Site* (FNI, 2009)
- *Environmental Report,* Application for a 404 Permit for Lower Bois d'Arc Creek Reservoir, Volume II (FNI, 2008)
    - Habitat Evaluation Procedure Report for Lower Bois d'Arc Creek Reservoir
    - Archeological Potential of the Proposed Lower Bois d'Arc Creek Reservoir Project
    - Probable Maximum Flood Analysis (FNI, 2007)
- *Jurisdictional Determination Report and Application for a Section 404 Permit for Lower Bois d'Arc Creek Reservoir,* Volume I (FNI, 2008)

Streams in the project area are characterized by extensive channelization, especially along the main channel of Bois d'Arc Creek. Approximately 62 percent of the length of Bois d'Arc Creek within the project site has been channelized, as have portions of a number of tributaries. Much of the channelization was performed to reduce flooding along the creeks. These characteristics continue in the watershed downstream of the proposed dam, with long sections of straightened stream channels followed by sections of meandering channel. The hydrology of the watershed is characterized by the rapid rise and fall of stream flow in response to rain events, which is in part due to the extensive channelization in the watershed. During dry times there may be little or no flow in the creeks. The previous fluvial geomorphologic analyses indicate that the prior channelization and lack of bank stability have reduced habitat and other functions of the streams within the project area.

Additional background information is presented in Appendices B through E.



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

Bois d'Arc Creek Watershed Location Map

FN JOB NO	NTD06128
FILE	Basins.mxd
DATE	February 2010
SCALE	1:300,000
DESIGNED	BME
DRAFTED	BME

2.1
FIGURE

2.1 Environmental Setting

The Bois d' Arc Creek basin is located in northeastern Texas in Fannin and Grayson counties (Figure 2.1). Bois d'Arc Creek originates at the eastern border of Grayson County near Whitewright, Texas and flows in a northeasterly direction across Fannin County to its confluence with the Red River at river mile 612. The watershed has a length of about 58 miles, a maximum width of about 18 miles, and a drainage area of approximately 425 square miles.

2.1.1 Water Quality and Biology

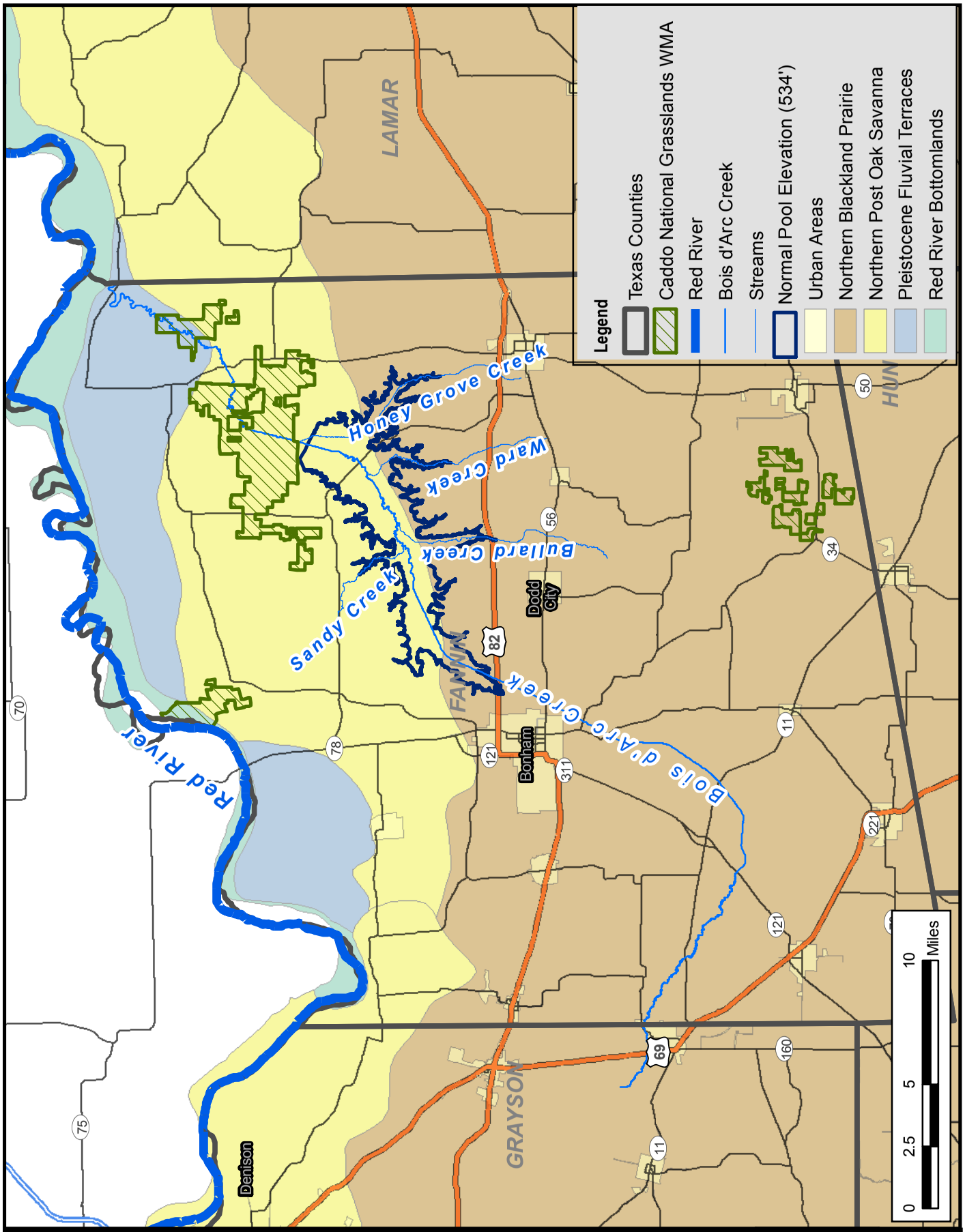
According to the TCEQ's 2008 Water Quality Inventory, Bois d'Arc Creek (Segment 0202A – unclassified water body) has perennial flow and a high aquatic life use designation from its confluence with the Red River up to its confluence with Sandy Creek within the proposed reservoir site. From the Sandy Creek confluence upstream to the confluence with Pace Creek (upstream of the reservoir site), the TCEQ categorizes the flow as perennial with an intermediate aquatic life use designation (30 TAC § 307.10(4)). Hydrologic data collected within the Bois d'Arc Creek watershed, including the recently installed gage at F.M. 1396, show extended periods of little or no flow in Bois d'Arc Creek. These data indicate that Bois d'Arc Creek might more appropriately be classified as having intermittent flow rather than perennial flow. Zero flow conditions were observed during an October 2008 site visit conducted by the U.S. Army Corps of Engineers accompanied by representatives of the USFWS, TPWD, and FNI to verify FNI's waters of U.S. determination. These zero flow conditions were also observed and documented in a video of the creek during a flyover on December 19, 2008 and recorded by the USGS gage at F.M. 1396.

Although no use assessment was conducted for the 2008 Water Quality Inventory, the TCEQ concluded that the water quality was fully supporting aquatic life and overall uses based on prior assessments.

Surveys conducted by TPWD in 1982 and by the RRA in 1998 indicate that the majority of the fish assemblage in Bois d'Arc Creek is comprised of generalist species – those able to survive in both riverine and lacustrine habitats. These results corroborate the data collected in the current study. The RRA's results yielded a calculated index of biological integrity (IDB) score of 35, indicative of low intermediate biological integrity.

2.1.2 Physiography

The Bois d'Arc Creek watershed is a smoothly dissected undulating upland plain located in four distinct ecoregions as mapped and described by Griffith et al. 2004 (Figure 2.2). In addition, there are extensive high flats, or river terraces, in the northern portion of the watershed along the Red River. The southern portion of the watershed is in the Northern



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Proposed Lower Bois d'Arc Creek Reservoir

Eco-Regions for Fannin County

FN JOB NO	NTD06128
FILE	Figure2.2.mxd
DATE	April 2010
SCALE	1:335,000
DESIGNED	BME
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2.2 FIGURE

Blackland Prairies of the Texas Blackland Prairies Ecoregion, which is dominated by a diverse assortment of grasses and forbs. The central portion of the watershed lies within the Northern Post Oak Savannah in the East Central Texas Plains Ecoregion. In both of these ecoregions the forested or wooded areas tend to be restricted to bottomlands along major rivers and streams. The most northern portion of the watershed is within the Pleistocene Fluvial Terraces of the South Central Plains Ecoregion and eventually converges with the Red River in the Red River Bottomlands of the South Central Plains Ecoregion.

Each ecoregion has unique characteristics of soils, climate, flora and fauna. With the Bois d'Arc Creek watershed crossing four ecoregions, the behavior of the stream system changes as it moves from the upper end of the watershed to the Red River. These changes tend to coincide with changes in geologic structure.

2.1.3 Geology and Soils

The stream channel patterns and characteristics of the Bois d'Arc Creek system are influenced by geologic structure and lithology occurring in Fannin County (Figure 2.3). The creeks and streams in the watershed, including Bois d'Arc Creek, generally flow in channels cut through alluvium deposited by larger streams during the Pleistocene and Holocene Epochs in the Quaternary Period (USDA 2001). Alluvial deposits along Bois d'Arc Creek reflect the Cretaceous bedrock and reworked Pleistocene deposits found in the watershed (Lokke and Brent 1966). The bedrock consists primarily of sandstone, clay, marl, chalk, and limestone (Adkins 1932; Barnes 1967). Pleistocene terraces lie across much of the northern portion of the watershed. The terraces are underlain by clastic sediments deposited by the Red River. The sediments were derived from sources extending to the Texas panhandle and northeastern New Mexico (Fyre and Leonard 1963). Holocene alluvium along Bois d'Arc Creek and its tributaries consist of sediments derived from local bedrock and reworked Pleistocene deposits (Lokke and Brent 1966). Much of the underlying geology in the Bois d'Arc Creek watershed is poorly consolidated and is easily weathered and eroded.

The Preston Anticline, the major geologic structure in the county, is a broad arch that trends northwest-southeast and plunges southeastward. It enters the county in the northwest and continues through the western part of the county (Bullard 1931). Bedrock, stream channels, and soil types are deflected southeastward in broad curves as they pass over the axis of the anticline (TDWR 1982; USDA 2001). The anticline is responsible for the change in direction of Bois d'Arc Creek from flowing in a southeast direction at the headwaters to a northeast direction in the rest of the watershed.

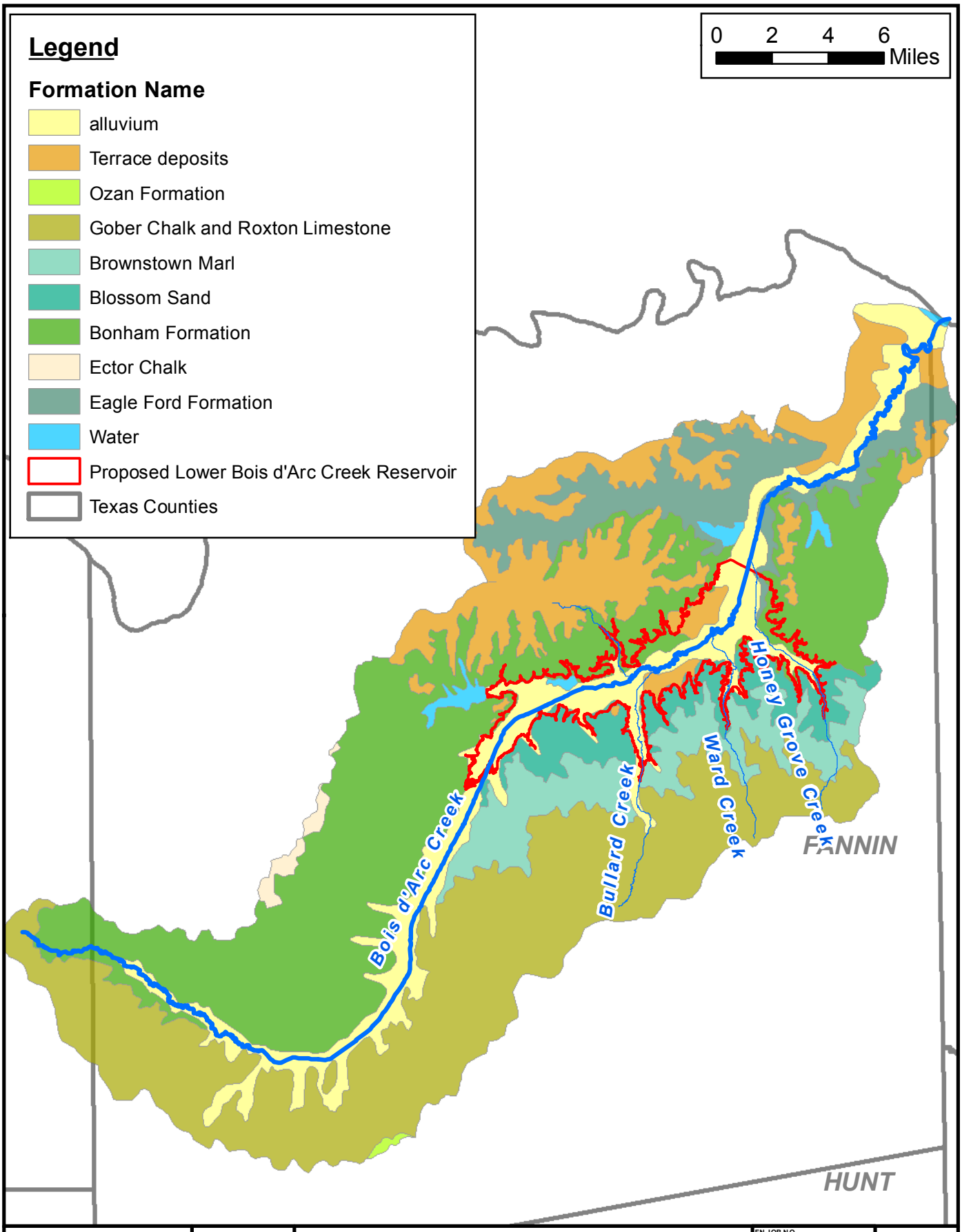
There is a close correspondence between surface geology and soils (Barnes, 1967). The soils were formed in Cretaceous bedrock residuum, Pleistocene fluvial sediment, and Holocene alluvium (Figure 2.4). Pleistocene terraces lie across much of the northern

portion of the watershed. The terraces consist of very strongly acidic to neutral, very deep, loamy soils. The soils have a moderate to high available water capacity and moderate to very slow permeability. All of the soils have a deep rooting depth and low shrink swell potential in the surface soils, but higher potential in the subsoils. The soils may have a water table that ranges between 2 to 3.5 feet during December through May, but some soils show no water table within 6 feet of the surface.

The mainstem of Bois d'Arc Creek from upstream of Bonham and downstream to about three miles above the confluence with the Red River traverses the Tinn and Frioton soil series. These soils are moderately alkaline, very deep, well drained loamy soils on floodplains. The soils have a high available water capacity, slow permeability, a very deep root zone, no water table within a depth of 6 feet, and a high shrink swell potential.

Soils found within the proposed Lower Bois d'Arc Creek Reservoir range from clay-based soils to loam-based soils. According to the General Soil Map of Fannin County Texas, there are three soil associations underlying the proposed reservoir. These soil associations are the Normangee-Wilson-Bonham Association, the Whakana-Porum-Freestone Association, and the Ellis-Crocket Association (USDA, 2001). These soil associations consist of loamy and clayey, moderately acidic to neutral soils. These soils have a high available water capacity, slow to very slow permeability, and a very deep rooting depth. The soils have a moderate to high shrink swell potential, which is influenced by soil moisture. The water table depth varies between soil types, where some are at a depth between 2.5 to 3.5 feet; others may show no water table within a depth of 6 feet.

The south side of Bois d'Arc Creek and the remaining drainages in the headwaters of the watershed consist of slightly acidic to moderately alkaline loamy and clayey soils. They are moderately to very deep and have the potential for shrinking and swelling with changes in moisture and a shallow or moderate depth to bedrock. The soils vary between low to high for available water capacity. All the soils have a deep rooting depth and show no water table within a depth of 6 feet.



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Proposed Lower Bois d'Arc Creek Reservoir

Geology of the Bois d'Arc Creek Watershed

FN JOB NO	NTD06128
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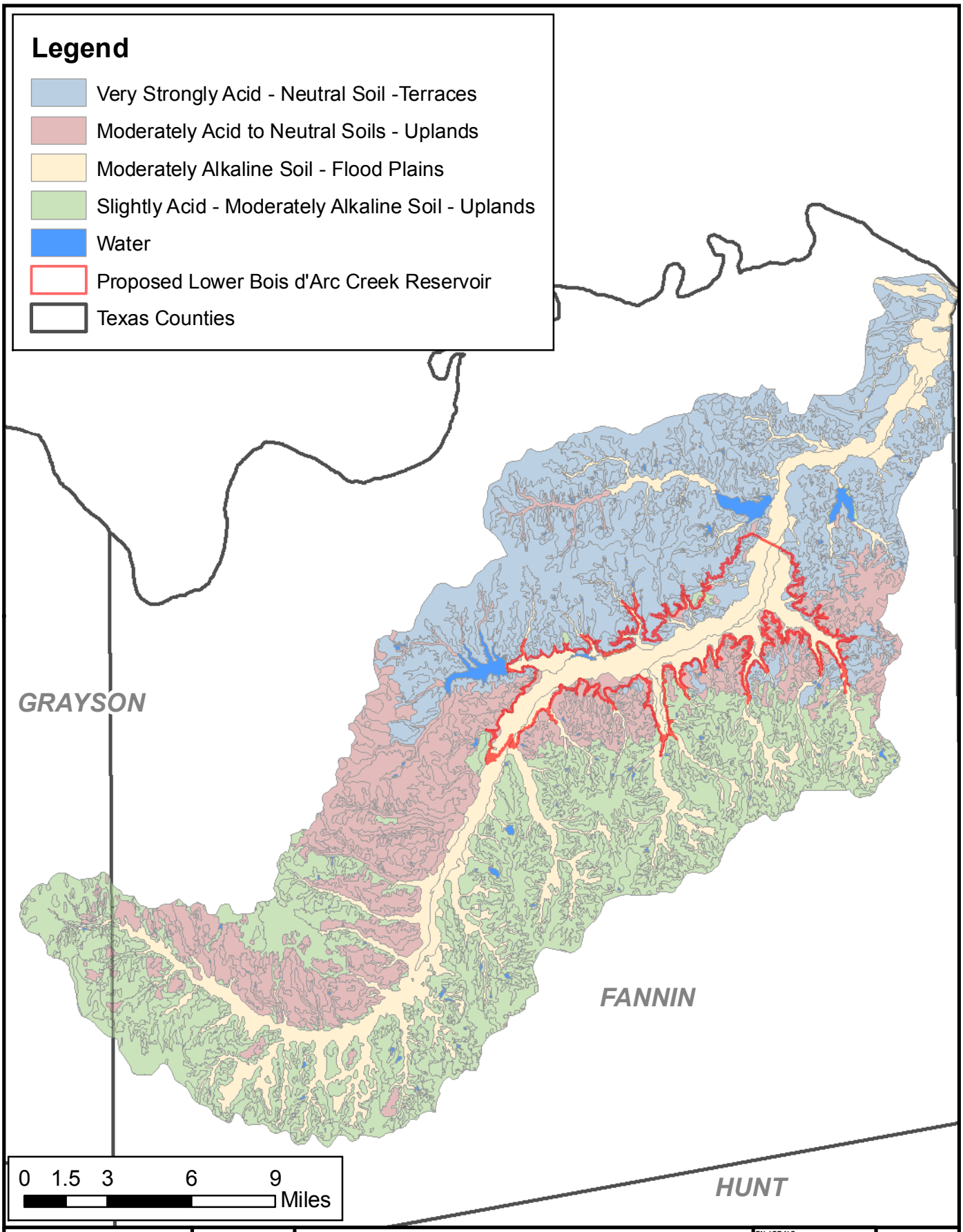
2.3
FIGURE



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Soils of the Bois d'Arc Creek Watershed

FN JOB NO	NTD06128
FILE	Soils.mxd
DATE	March 2010
SCALE	1:300,000
DESIGNED	SVC
DRAFTED	SVC

2.4
FIGURE

2.1.4 Climate

The climate in the Bois d'Arc Creek watershed is warm-temperate, humid, and continental. The average annual temperature is 64 degrees Fahrenheit, and the mean annual precipitation is 44 inches (Figure 2.5). The watershed lies well within the more southerly paths of the high and low pressure systems that periodically sweep across the United States, and weather changes are pronounced. The summers are long, with hot days and warm nights; the winters are short, mild, and characterized by brief cold spells, alternating with short periods of warm sunny days (Templin et al. 1946). During the two hottest months, July and August, the average daily maximum temperature is approximately 93 degrees Fahrenheit (°F) and the average daily minimum is 71°F. During the two coldest months, December and January, the average daily maximum is approximately 52°F and the average daily minimum is 32°F. Although freezing weather is not unusual, it is of short duration. The ground is never frozen to a depth greater than six inches or for periods longer than two weeks (Templin et al. 1946). The growing season is from mid-March to mid-November, approximately 247 days.

2.1.5 Land Use

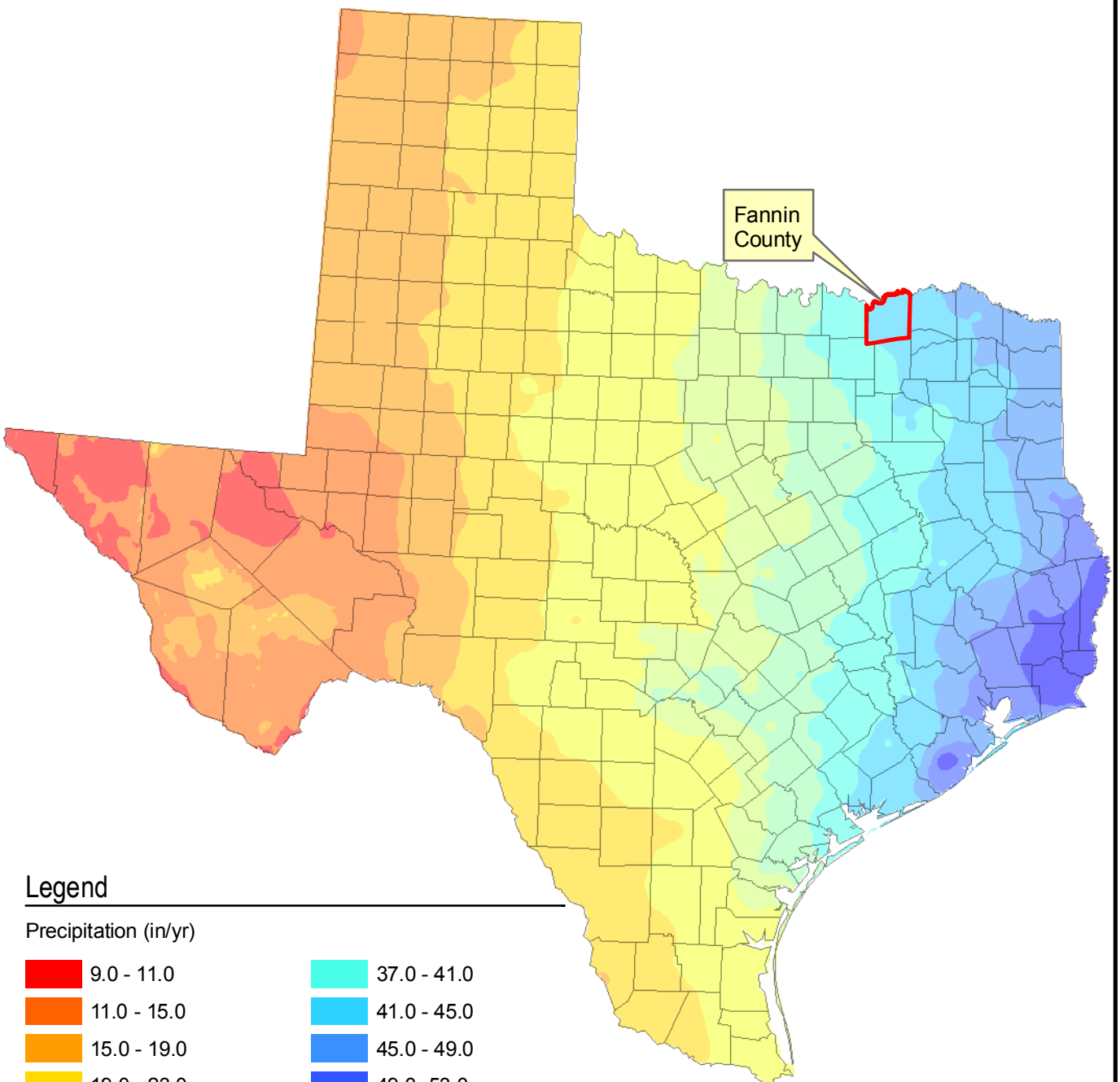
Approximately 97 percent of the Bois d'Arc Creek watershed is within Fannin County, Texas. With the exception of the City of Bonham and several small lakes, much of the watershed is rural or agricultural land.

The major land uses in Fannin County are cropland and improved pasture. In the Bois d'Arc Creek watershed, the Caddo National Grasslands comprise a significant portion of the watershed downstream of the project area. Only a portion of the designated Grasslands proclamation area is currently owned and maintained by the USFS. Much of the privately owned property in the proclamation area is undeveloped or used for timber production, livestock, crops, or hunting.

2.1.6 Channelization

Channelization is a general term covering various forms of channel modification for the purposes of flood control, drainage improvement, maintenance of navigation and erosion prevention. Flood control is of particular importance and typically involves straightening, resectioning, and levee construction, the principal aim being to speed water transport, confine floodwaters within the channel and reduce or eliminate overbank flow (Brookes 1988).

Based on historical maps and satellite photographs of the watershed, there is evidence that landowners in the Bois d'Arc Creek watershed modified the terrain by digging drainage channels through their property, bypassing and sometimes completely abandoning the natural drainage system (Figure 2.6). This drainage modification, a type



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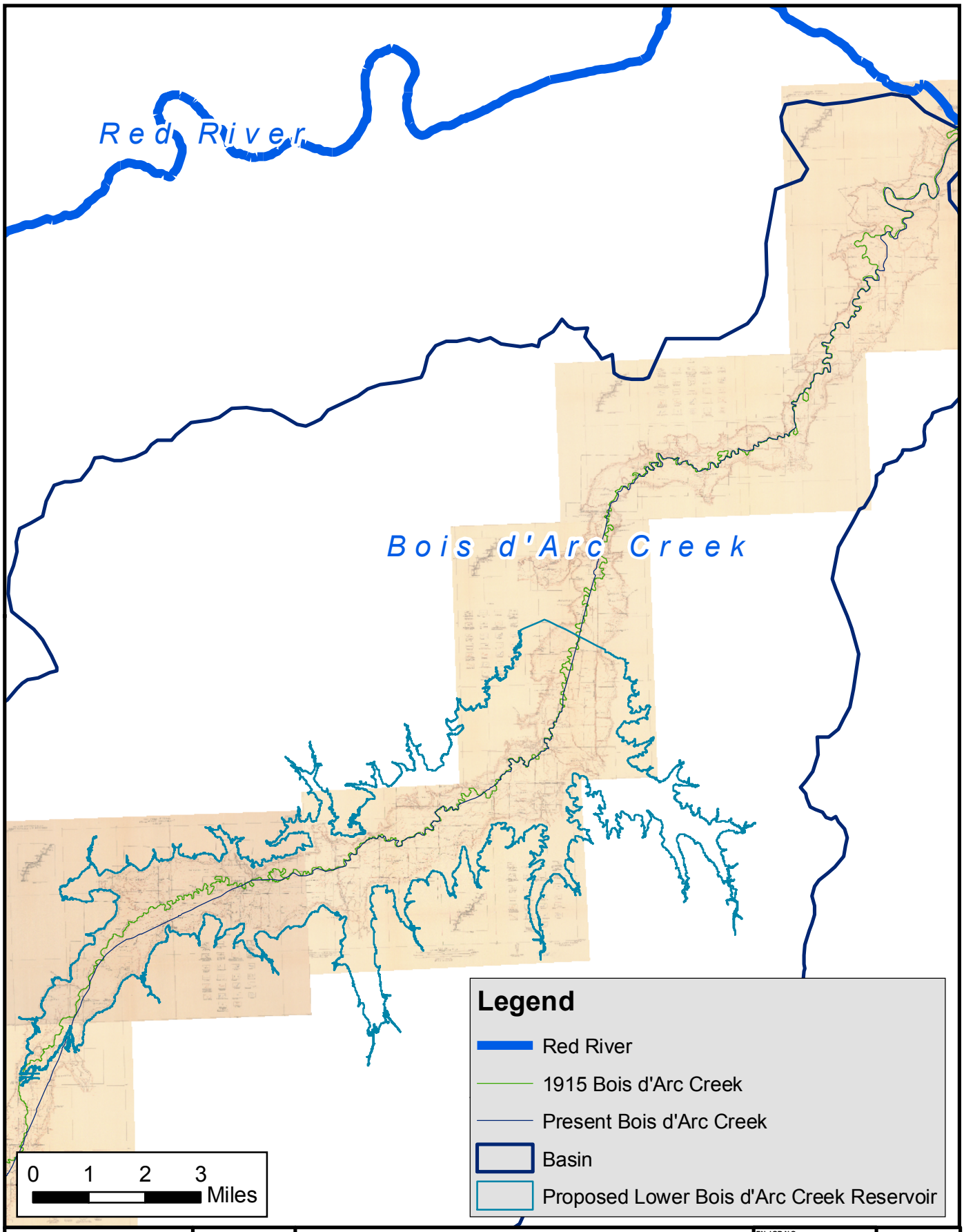
Mean Annual Precipitation

FN JOB NO	NTD06128
FILE	Texas_Precipitation.mxd
DATE	January 15, 2010
SCALE	1:6,889,100
DESIGNED	BME
DRAFTED	BME

2.5
FIGURE



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Bois d'Arc Creek
Historical (1915) Channel Alignment

FN JOB NO	NTD06128
FILE	Historic.mxd
DATE	March 2010
SCALE	1:150,000
DESIGNED	SVC
DRAFTED	SVC

2.6
FIGURE

of channelization, started around 1920 and continued well into the 1970s in the Bois d'Arc Creek watershed. Comparison of the historical 1915 watershed map to the current stream configuration indicates that Bois d'Arc Creek has lost over 20 stream miles from the effects of channelization. While the channelization achieved a more rapid conveyance of stream flow and bed materials, the ecological attributes of the stream were fundamentally compromised. As shown in comparisons of the channelized sections of the creek to unchannelized sections, channelization appears to have caused a loss in the complexity of instream geomorphic structures and reduced the diversity of habitats. The narrowing and shortening of the stream by straightening and realignment increased the erosive potential of the flow in Bois d'Arc Creek, which resulted in incision and channel enlargement. Progressively larger flood flows have become concentrated in the channel zone as a result of downcutting into the underlying bed material.

The impacts of channelization on stream configuration, hydrology and habitats are dramatic in the nearby North Sulphur River in southwest Fannin County. In less than 90 years, the channel in the upper reaches of the North Sulpur River increased from 48 feet wide by 6 feet deep to over 300 feet wide by 40 feet deep (Mussetter Engineering, 2006). While the impacts of channelization have not been as severe in the Bois d'Arc Creek watershed, the watershed is experiencing similar consequences. Channel widening and downcutting are occurring and will most likely continue under present conditions. The likelihood of continued erosion was evaluated through an assessment of stream equilibrium as part of the current study. This is discussed in Section 4 and 5.

2.2 Technical Components of an Instream Flow Study

Instream flow refers simply to the water flowing in a stream channel (Annear et al. 2002). The goal of this instream flow study is to identify an appropriate flow regime that will support a sound ecological environment in the stream channel of Bois d'Arc Creek downstream of the proposed Lower Bois d'Arc Creek Reservoir, as defined in the introduction to this report.

Instream flow programs involve technical components for identifying appropriate flow regimes. The Texas Instream Flow Program (TIFP) addresses the riverine components of hydrology, biology, geomorphology, and water quality (TWDB 2008). In the current study, each of these technical elements requires data collection and analyses specific to the technical component; however these analyses were integrated to address the connectivity, structure, and function of the stream system. The TIFP is a method to assess instream flow needs for river basins at a relatively large scale. For small scale systems, such as Bois d'Arc Creek, all of the complexities of the TIFP may not apply or be necessary to arrive at a recommended flow regime. The following subsections provide overviews of the major elements of the Bois d'Arc Creek instream flow study.

2.2.1 Hydrology and Hydraulics

Hydrology is the component that is most easily measured and plays a major role in biological, geomorphic and water quality functions. The TIFP identifies a flow regime that consists of a set of four flow components: subsistence flows, base flows, high flow pulses, and overbank flows. However, not all of these flows necessarily occur in every river or even in every reach of a river (NRC 2005), nor are all of these flows always required to achieve a sound ecological environment.

Subsistence flow is the minimum streamflow needed to maintain tolerable water quality conditions and to provide minimal habitat for the survival of aquatic organisms. Subsistence flows are expected to occur infrequently, most likely during extreme drought conditions. Base flow is the "normal" flow condition occurring between storm events. Base flows sustain habitat and maintain soil moisture and suitable water quality. High flow pulses are short-duration, high flows within the stream channel resulting from a storm event. High flow pulses flush fine sediment deposits, restore water quality following extended low flows, and offer longitudinal connectivity for organism migration. Overbank flows are high flow events that overtop the riverbanks. These flows provide lateral connectivity of a stream to the active floodplain and serve to maintain riparian habitat.

Hydraulics refers to the motion and action of water and other liquids. For this application, hydraulics is the distribution of water velocities across the width and depth resulting from the channel morphology and discharge through the channel. Hydraulic conditions are important for describing instream habitat since aquatic organisms prefer habitats with particular combinations of velocities and depths (TWDB 2008).

2.2.2 Fluvial Geomorphology and Physical Processes

Fluvial geomorphology is the study of the interactions between stream channel forms and processes at various ranges of space and time scales. These include the physical processes that form and maintain stream channels, floodplains, and habitat, flush fine sediment and transport sediment loads (TWDB 2008). Rivers and streams are continuously changing ecosystems that interact with the surrounding climatic and hydrological factors, biotic factors, and terrestrial and geological factors. As a result, geomorphic processes vary between and within basins and sub-basins (Brierley and Fryirs 2005).

The form of a stream channel results from interactions among discharge, sediment supply, sediment size, channel width, depth, velocity, slope, and roughness of channel materials (Lane 1955; Leopold et al. 1964; Knighton 1998). The magnitude, frequency, timing, and duration of flows are major factors in the geomorphic structure of a channel. Sediment transport and deposition also influence the morphology of a stream. Stream

channels react to changes in sediment dynamics and will degrade or aggrade along the longitudinal gradient in response to the sediment load.

Many researchers have recognized and emphasized the importance of geomorphic features, and the processes that form them, when considering the affects of instream flows on riverine ecology (Brierley and Fryirs 2005; Benda et al. 2004a; Torgersen et al. 2008; Phillips 2007). The type and quality of aquatic and riparian habitats are directly related to specific landforms and geomorphic processes (Hupp and Osterkamp 1996; Scott et al. 1996; Robertson and Augspurger 1999; Johnson et al. 2001; Gumbricht et al. 2004; Moret et al. 2006). Human modification, such as channelization and bank fortification influence the channel form and the resulting habitat.

2.2.3 Water Quality

Water quality is important to growth, survival, and reproduction of aquatic organisms (TWDB 2008), and it determines whether or not desired uses of a water body can be maintained. Water quality characteristics directly reflect the influence of the watershed geology, soils, land use, and climate. The primary water quality parameters that indicate the ability of a stream to support aquatic life include dissolved oxygen (DO) and temperature. Consistently depressed DO concentrations will favor a biological community typically less diverse than a system with higher DO levels.

Streams that are subject to temperature extremes will exhibit limited biological diversity as well, either directly due to species temperature intolerance, or indirectly by limiting the capacity of the stream to maintain adequate DO or by encouraging other adverse water chemistry condition. Factors that influence temperature include flow, channel width and depth, riparian shading, thermal inputs, turbulence, and current velocity (Armour 1991; TWDB 2008).

Other water quality constituents, such as turbidity, suspended solids, pH, dissolved solids, nutrients and other inorganic and organic compounds, can also affect the ability of a stream to support a sound ecological environment. The degree of influence of these constituents is often related to human activities, or the lack thereof, within a watershed. The greater the population density, or the more intensive the agriculture activities in rural watersheds, the more likely that particular water quality constituents will become unbalanced in a receiving stream due to point or nonpoint source contributions and thus impair or degrade desired water uses. While these other constituents can have an important role in maintenance of a sound ecological stream environment, they typically are assessed as secondary parameters to the primary constituents of DO and temperature in instream flow studies unless previously identified as constituents of concern.

2.2.4 Biology

The biological component of the instream flow studies reflects the integration of the hydrology/hydraulics, geomorphology and water quality aspects of the stream. These three components (hydrology/hydraulics, geomorphology, and water quality) directly impact aquatic habitats, biological migration, reproduction and overall aquatic life viability. Understanding these relationships provides a mechanism to create and maintain a sound ecological environment.

To characterize the baseline conditions of the stream, the biological component of instream flow studies includes developing relationships among aquatic communities, life histories, and habitats (TIFP 2008). This element considers the physical processes that create and maintain the habitat, water quality, and hydrology (Bovee et al. 1998; Annear et al. 2002; TWDB 2008). Flow regimes affect the quality and quantity of available habitat (Bunn and Arthington 2002). Habitat conditions are generally characterized in terms of water velocity, depth, substrate composition, and instream cover and are a key component of any instream flow prescription. Flow regimes also manipulate the geomorphic structure of a channel and affect water quality conditions in streams, in turn influencing the biological processes.

3 OVERVIEW OF METHODS

3.1 Instream Flow Study Plan Development

The instream flow study was developed with input from the Inter-Agency Team (Table 1.1), incorporating the key instream flow study components as identified in the TIFP: hydrology and hydraulics, water quality, fluvial geomorphology and biology. For each study component baseline conditions of the Bois d'Arc Creek study area were described using existing data supplemented by field data collected by the Inter-Agency Team. The future conditions of each study component were predicted using computer modeling or other appropriate techniques described in this report with the assumption that the proposed reservoir is in place and operating at full water supply demand. The baseline and predicted future conditions were used to evaluate the following:

- Effects of the proposed reservoir on Bois d'Arc Creek within the reservoir pool and the reach between the dam and FM 409
- Ability of the proposed flow regime to support a sound ecological environment between the proposed dam site and the FM 409

A series of inter-agency coordination meetings were held to describe the proposed instream flow study, seek input from regulatory agencies, and solicit participation in field studies. The following summarizes the relevant decisions made by the group with regard to sampling and data analysis protocols:

- The biological sampling effort would be conducted following the protocols of the TCEQ Surface Water Quality Monitoring (SWQM) guidelines.
- The protocols used for assessing biological quality would be the Index of Biotic Integrity (IBI) and benthic macroinvertebrate Rapid Bioassessment (RBA). This would be used for both the baseline biology and predicted future biology.
- During sampling, fish species would be identified and information collected to determine the mesohabitats from which they are caught. Additionally, information on flow and substrate would be recorded.
- Sampling efforts would not be restricted to the "critical period" and would be allowed flexibility based on field/sampling conditions.
- Fish species collected during sampling efforts may be grouped using a guild approach for data analysis. In addition, data would be collected on flow sensitive species and species of concern if discovered during sampling efforts.
- In addition to fish and macroinvertebrates, mussels would be collected (or identified in the field) at sampling sites when present for additional data.
- Sampling sites would be located in the vicinity of the proposed reservoir and downstream of the proposed dam. Locations would be finalized pending access. In addition to these sampling sites, up to four additional biological sampling sites along Honey Grove Creek,

Sandy Creek, Bullard Creek, and Pig Branch may be sampled opportunistically to characterize the biota. Sampling sites may be modified, if needed, to adapt to field conditions and land access.

- Field sampling and data collection would not be conducted during "high flow" events due to safety issues. Data collection for "high flows" could be completed two weeks after these events. Hydrology and water quality data were collected continuously at the USGS gage at FM 1396 and FM 409, including high flow events.
- It was agreed that the classification of hydrologic conditions (i.e., low/medium/high flows) for biological data collection and analyses should be different from flows used for the hydrology analyses. For biological purposes, it was suggested that only median flows and below be considered as the flow range for biological sampling.
- Stream geomorphology would be characterized only at the study reaches. FNI would extrapolate stream geomorphology for the downstream corridor with the use of aerial photography and the helicopter flyover. FNI staff would field check geomorphology at the additional cross-sections surveyed at intermediate locations between the study reaches for the HEC-RAS model (visual observation only).
- The following sections briefly describe the methods used for data collection. More detailed information on methods is presented with the study results in later chapters and in Appendices B through E.

3.2 Instream Flow Study Data Collection and Methods

The primary sampling sites for the instream flow study were located on the mainstem of Bois d'Arc Creek above and below the proposed reservoir at U.S. 82, CR 2645, FM 1396, FM 409,and USFS property located downstream of FM 100 (Figure 3.1). In addition to these primary sites, two representative tributary sites (i.e., Bullard and Honey Grove Creeks) were sampled for biota. Representatives from the Inter-Agency Team (TCEQ, TPWD, and TWDB) assisted with the site and reach selection. The reach length was determined by using 40 times the average stream width (USEPA 2000; TCEQ 2007). Two of the four sites (FM 1396 and FM 409) were selected to measure detailed transects (Figure 3.2 and Figure 3.3). The Inter-Agency Team also collaborated in the placement of the transect locations.

Legend

- Tributary Sites
- Instream Flow Study Sites
- Caddo National Grasslands
- Urban Areas
- Proposed Lower Bois d'Arc Creek Reservoir
- Texas Counties

Red River
Kemp
FM 273
78
FM 79
FM 197
Red River
USFS
FM 409
FM 2029
F-M 2216
Farm Road 2952
Sandy Creek
Proposed Lower
Bois d'Arc Creek Reservoir
FM 1396
Ravenna
FM 1753
FM 100
FM 898
CR 2645
FM 1396
Honey
Grove
Creek
FANNIN
LAMAR
FM 38
FM 2645
US 82
Bullard
Creek
Honey Grove Creek
Savoy
Bonham
82
82
82
Honey
Grove
56
Ector
Dodd
City
Bois d'Arc Creek
Bullard Creek
Windom
56
Farm Road 137
FM 1752
121
78
FM 271
F-M 2077
FM 1743
Farm Road 1743
34
F-M 924
FM 898
0 1 2 3 Miles

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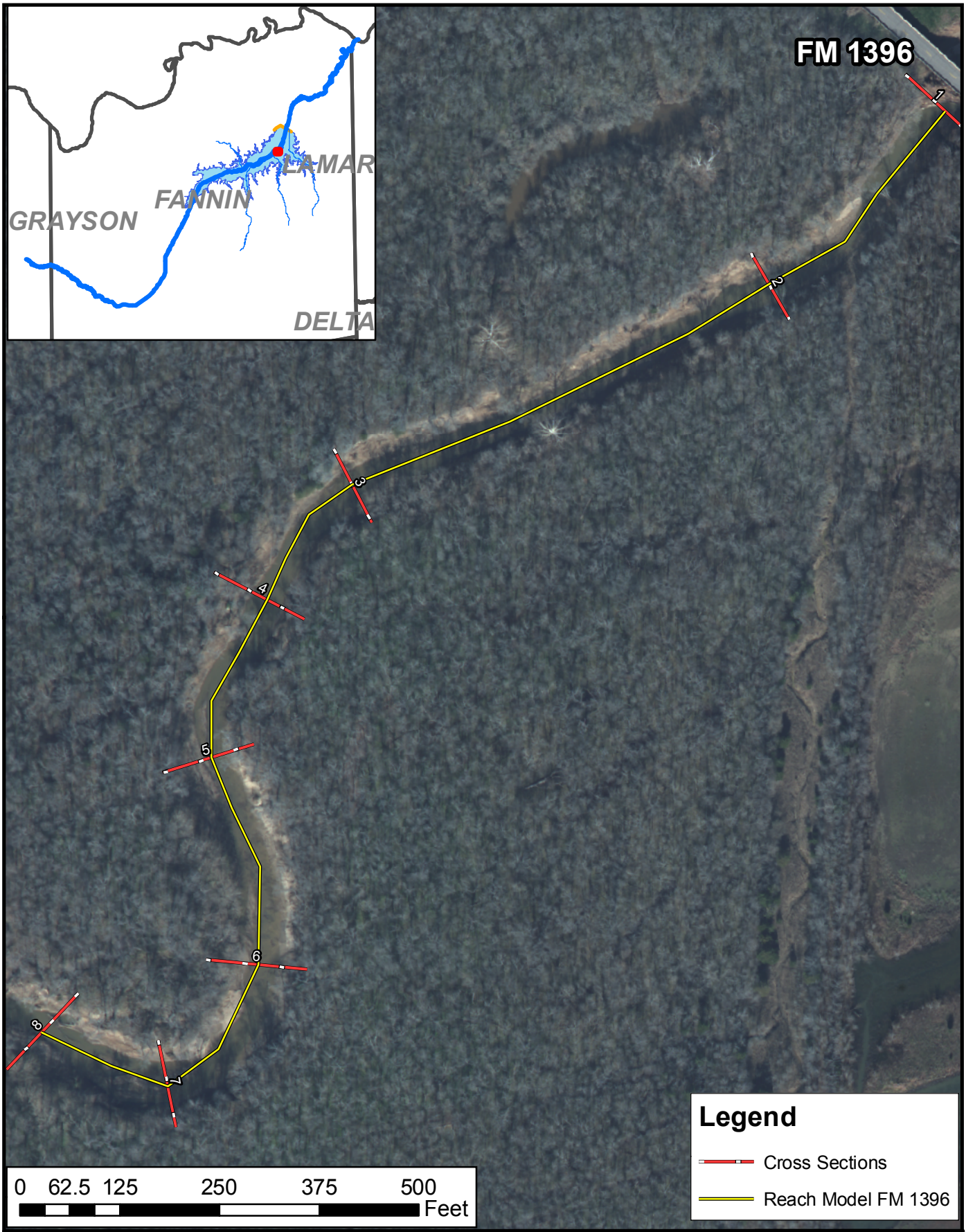
Instream Study Sites

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

Figure 3.1



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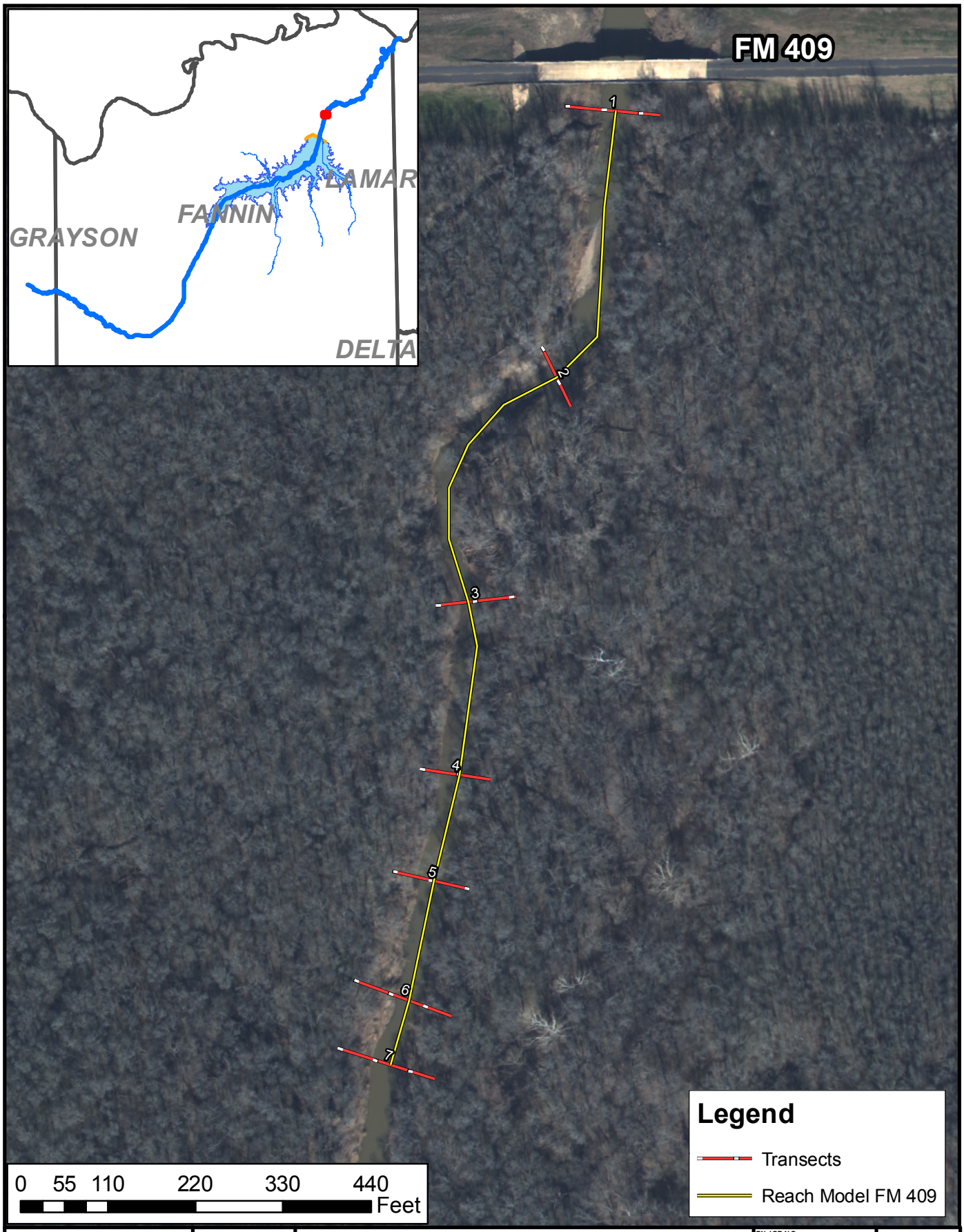
Transects at Bois d'Arc Creek
Study Reach near FM 1396

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

3.2
FIGURE



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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

3.3
FIGURE

The sampling events were conducted in March 2009, June 2009 and July 2009. All biological collections were made at a minimum of 14 days after storm pulse events to allow for species recolonization (per Inter-Agency Team recommendations). Each instream flow technical component had specific field methods (Table 3.1) which were utilized at the instream flow study sites (Table 3.2).

Table 3.1 Field Methods Utilized for the Bois d'Arc Creek Instream Flow Study

Technical Component	Field Methods
Hydrology/ Hydraulics	(1) Measure transects (2) High flow measurements: Discharge (3) Low flow measurements: Discharge Velocity (at habitat) Depth (at habitat)
Geomorphology	(4) Geomorphic mapping (habitat) (5) Bulk sediment sample: Surface sample Subsurface sample (6) Erosion pins
Water Quality	(7) Measure and record water quality parameters – DO, temperature, pH, conductivity, turbidity
Biology	(8) Macroinvertebrate sampling: Kicknet Live pick and preserve on site (9) Fish sampling: Backpack electrofishers Seine

Table 3.2 Field Methods Utilized at Each Instream Flow Study Site

Site	Field Method[1]
US 82	3,4,7,8,9
CR 2645	3,4,7,8,9
FM 1396	1,2,3,4,5,6,7,8,9
FM 409	1,2,3,4,5,6,7,8,9
USFS	3,7,8,9
Bullard Creek	3,7,8,9
Honey Grove Creek	3,7,8,9

[1]Refer to Table 3.1 for Field Method Identification

3.1.1 Hydrology and Hydraulics

The hydrology and hydraulic component of the proposed Lower Bois d'Arc Creek Reservoir Instream Flow Study consisted of four major activities:

- Evaluating historical and current flow data for Bois d'Arc Creek using USGS stream gage data;
- Surveying transects within the instream flow study reaches and making flow and water surface elevation measurements at the transects;
- Developing a hydraulic model to determine rating curves that relate water depth to flow rates using the Hydrologic Engineering Center's River Analysis System (HEC-RAS); and
- Developing a long-term hydrologic model to evaluate the historical streamflow response in the watershed.

The hydrology and hydraulic data and analyses generated from these activities were used to describe the current and future flow conditions in the Bois d'Arc Creek watershed and in the analyses of the other technical components of this study. The hydraulic model was used as data input with the habitat analyses for the biological evaluations. It was also used in support of the geomorphic analyses. The long-term hydrologic model evaluated long-term frequencies and provided data to assess on-going and future processes.

3.1.2 Fluvial Geomorphology

The geomorphic component of the Lower Bois d'Arc Creek Reservoir Instream Flow Study included:

- Conducting a geomorphic characterization of the stream system of the Bois d'Arc Creek watershed using the River Styles Framework®;
- Analyzing channel stability by comparing the lateral movement of Bois d'Arc Creek on historical maps and aerial photos and making field measurements of stream bank erosion using erosion pins; and
- Evaluating sediment transport potential within Bois d'Arc Creek by collecting and analyzing bulk sediment samples and modeling sediment transport capacity using the Stable Channel Analytical Model, Windows version (SAMWin) hydraulic design software package.

The fluvial geomorphic component of the study provided information on the stream equilibrium and fluvial processes that influence aquatic habitats and water quality. The geomorphic characterization that included mapping of aquatic habitats, sediment transport and channel stability analyses provide an assessment of the baseline stream conditions and an understanding of the processes for future conditions. These data were used in conjunction with other data components (hydrology, biology and water quality) to establish a proposed flow regime for a sound ecological environment.

3.1.3 Water Quality

The water quality component of the Bois d'Arc Creek Instream Flow Study included:

- Defining the baseline water quality of Bois d'Arc Creek by reviewing existing data collected by TCEQ and the USGS;
- Collecting dissolved oxygen, pH, temperature, and specific conductance at the study sites to identify instantaneous water quality conditions; and
- Predicting future temperature and dissolved oxygen conditions in the proposed Lower Bois d'Arc Creek Reservoir based on data from existing North Texas reservoirs and below the reservoir using the Qual-TX model.

3.1.4 Biology

Biological assessment in the study included:

- Reviewing previous biological studies that included data collected in the Bois d'Arc Creek watershed or in nearby watersheds;
- Collecting fish samples using TCEQ's 2007 Surface Water Quality Monitoring Procedures (TCEQ 2007);
- Collecting macroinvertibrates using TCEQ 2007 SWQM Rapid Bioassement Protocol (RBP);
- Characterizing habitat based on substrate composition, current velocity, and water depth;
- Categorizing fish data by relative abundance by:
    - Sampling site, flow, season, and mesohabitat, and

    - Trophic structure and reproductive guild composition to identify potentially predominant life history strategy; and
- Calculating the regionalized Index of Biotic Integrity (IBI) (TPWD 2002) and Rapid Biassessment (RBA) index for each biological sample where suitable data were collected.

The biological component of instream flow studies is the barometer for identifying and describing a sound ecological environment. The flow regime, water quality, physical habitat, and the other numerous physical and chemical constraints can affect the many types of organisms that live in streams such as macrophytes, bacteria, algae, protozoans, invertebrates, and vertebrates including amphibians, reptiles, and fish.

In this study, three groups of organisms were selected to study, sample and describe selected population and community attributes. These were benthic macroinvertebrates, mussels, and fish. Macroinvertebrates were sampled to provide data to calculate a Rapid Bioassessment (RBA) index of water quality, while mussels were observed to document presence of living species in the stream. Fish sampling included community measures (calculation of Index of Biotic Integrity scores) and mesohabitat sampling. Measurements of substrate characteristics, current velocity, water depth, and water quality were made at mesohabitat sites to provide data to correlate fish presence and abundance with hydrologic, geomorphic, and water quality variables. Habitat modeling using River2D software was used to calculate useable areas of habitats at varying flows.

3.2 Data Sources

3.2.1 Geomorphic Data

The general environmental framework of the Bois d'Arc Creek basin (geology, soils, land use and land cover) is well established. The Land Resources Map of Texas (Kier et al. 1977) and Land Use and Land Cover (LULC) for Fannin County, Texas were available, along with complete geologic mapping at 1:250,000 scale (Geologic Atlas of Texas), and full soil map coverage from the Soil Survey Geographic (SSURGO) Database.

Geologic framework and constraints were derived from 1:250,000 scale geologic maps from the Texas Bureau of Economic Geology (Geologic Atlas of Texas) from the Sherman and Texarkana sheets. The Tectonic Map of Texas (Ewing, et al. 1991) as well as a map of the structural framework of the East Texas Basin (Jackson 1982) was used to identify potential tectonic influences. Many articles, reports and bulletins published by universities and various government agencies (as cited in this report) were used to describe the geology of the Bois d'Arc Creek basin.

Soils data from the U.S. Department of Agriculture (USDA) Natural Resources Conservation Services (NRCS) were obtained for the Bois d'Arc Creek basin from the online Soil Survey Geographic (SSURGO) Database. Published surveys for Fannin and Grayson Counties were

also consulted. While the soil maps are useful in establishing the general environmental framework, their primary purpose in this study was to aid in distinguishing modern Holocene flood plains from Pleistocene alluvial terraces that occupy the river valleys and to recognize the range of soil parameters within the basin.

3.2.2 Hydrologic and Hydraulic Data

Discharge and river stage data from the U.S. Geological Survey (USGS) were used to establish hydrologic regimes. Discharge and velocity measurements were also collected in the field with the use of the SonTek ® River Surveyor M9 and Flow Tracker Handheld-ADV® (Acoustic Doppler Velocimeter). The River Surveyor was used during times of higher flows (>100 cfs) when the stream was not wadable. Discharge and velocity measurements were obtained at various locations within study reaches. The FlowTracker Handheld-ADV® was used when the stream was wadable and the velocity less than 2.5 ft/sec.

Long-term hydrologic data were developed from historical USGS gage stream flow records and evaporation data obtained from the Texas Water Development Board. Since there are limited historical stream gage data in the Bois d'Arc Creek watershed, data were also obtained from the USGS gage at the North Sulphur River near Cooper, TX (USGS 07343000). This gage is located in an adjacent watershed with similar characteristics to Bois d'Arc Creek. Historical flows from the North Sulfur River were compared to the flows recorded in Bois d'Arc Creek to confirm applicability for this study.

3.2.3 Mapping Data

Digital map and aerial photographic data were obtained primarily from the Texas Natural Resources Information Systems (TNRIS) Geographic Information Systems (GIS). U.S. Geological Survey 1:24,000 topographic maps were obtained in Digital Raster Graphics (DRG) form. The topographic maps used in the study were originally surveyed in the 1964–1984 time frame and have not been revised. Digital Elevation Model (DEM) data at 30 m resolution were obtained for the entire Bois d'Arc Creek basin. The topographic maps and DEMs were used to evaluate the elevation of the terrain and location and shape of landscape units. General visualization of the geomorphic features were discerned from 1-meter resolution digital orthophoto quarter quads (DOQQ) obtained from TNRIS. A map of the Bois d'Arc Creek system dating from circa 1915 was used along with aerial photographs from 1950, 1969, 1970, 1976, 1996, 2007 to evaluate changes in stream patterns, land use practices, and riparian vegetation. Changes that impacted or influenced the channel pattern and profile were evaluated and documented. The morphometric and spatial distribution parameters of the Bois d'Arc Creek basin were evaluated in the GIS environment, using ArcInfo 9.3.

3.2.4 Water Quality Data

Water quality data in Bois d'Arc Creek were collected by the TCEQ, RRA, NTMWD and USGS. Most of the stream data is from 1997 to the present. There are currently four water

quality sampling stations in Bois d'Arc Creek: 1) at FM 100, downstream of the proposed reservoir site, 2) at FM 409, downsteam of the proposed reservoir site, 3) at FM 78, just upstream of the proposed reservoir site, and 4) at FM 1396 within the proposed reservoir site. The two sites at FM 100 and FM 78 are sampled by the RRA and TCEQ as part of the Clean Rivers Program. Data from the TCEQ sampling sites extend from October 1997 to July 2007, and include a variety of parameters. Two USGS, real-time data gages are located on the mainstem of Bois d'Arc Creek: 1) at FM 1396 near Honey Grove (water quality data beginning in September 2006), and 2) at FM 409 (June 2009) also near Honey Grove. The gages are separated by approximately five stream miles. In addition to collecting gage height and discharge measurements, the gages also collect water temperature, specific conductance, pH, and dissolved oxygen.

USGS water quality profile data from multiple North Texas Lakes were examined to estimate water temperature and dissolved oxygen concentrations at different depths within the proposed reservoir. Jim Chapman Lake (also known as Cooper Lake), located northwest of Sulphur Springs, TX, is located in close proximity to the proposed Lower Bois d'Arc Creek Reservoir and has similar size, depth, and geology. For the months of April, October, November, and December, Jim Chapman Lake USGS data were not available. Consequently, USGS data from other lakes in North Texas, including Lake Texoma, Lake Whitney, Lewisville Lake, and Benbrook Lake were used to estimate water temperature and dissolved oxygen concentrations for these months.

In addition to the existing and current collection of water quality data, dissolved oxygen, pH, temperature, specific conductance, and turbidity were measured and recorded during each biological sampling event. The water quality parameters were measured using a calibrated Horiba U-22 Multiparameter Sonde. Instantaneous field measurements were taken at each site specific habitat location also including profiles in deeper areas as the water column is often stratified due to the temperature and salinity. The water quality measurements taken during the biological sampling events were compared to the existing data as well as the gage data.

3.2.5 Biological Data

The biological data included the review and incorporation of data from previous studies in the watershed as well as data collected as part of this instream flow study. There is little baseline data on the fish or macroinvertebrates of Bois d'Arc Creek. Data sources include fish and macroinvertebrates collected by the Red River Authority (RRA, 1999), and a species list for Bois d'Arc Creek from the Texas Natural History Collection(TNHC) Ichthyology archives; however, the TNHC list did not identify collection location, date, or numerical species accounts. Other existing data sources included personal sightings and recordings and broader studies in the Red River basin in Texas and Oklahoma.

Biological sampling conducted as part of this study included three groups of organisms: benthic macroinvertebrates, mussels, and fish. Collections were made at each of the five study reaches on Bois d'Arc Creek and two tributaries as described in Table 3.2.