5 FUTURE CONDITIONS WITH RESERVOIR

This chapter is an overview of expected conditions once the reservoir has been built. This evaluation includes an assessment of future habitat conditions within the reservoir pool and downstream of the dam. Environmental release criteria are included to mitigate the impacts of the reservoir and help support a sound ecological environment below the dam.

5.1 Potential Impacts of Reservoirs on Streams

Reservoirs that impound streams can have varying impacts to the aquatic communities, especially fish, within the drainage or watershed. This section includes a summary of literature regarding the potential impacts of dams and ways that those impacts can be mitigated. Such impacts can vary pending existing stream conditions and watershed factors. It is not always true that reservoirs have diversity in aquatic species, especially fish, than the stream that was impounded. Several studies have documented cases where reservoirs have not impacted or have increased species diversity, while in other cases reservoirs have decreased diversity.

5.1.1 Potential Impacts within the Reservoir Pool

5.1.1.1 Impacts on Fish

RESERVOIR POOL

- **Expect similar aquatic species found in this study to thrive in lake environment**
- **Expect similar water quality conditions to existing North Texas lakes.**
    - **Some stratification during hot summer months**
- **May decrease sediment loading due to reduced hydraulic gradient and current velocities**

Impoundments interrupt the continuity of river ecosystems. One of the expected effects of this interruption is a change in the fish assemblage in the reservoir (Vannote et al. 1980; Poff et al. 1997). The change from lotic (river) to lentic (lake) habitat will shift the present species composition toward more pool-associated species, largely composed of sunfish (Centrarchids), temperate bass (Moronidae), catfish (Ictalurids), and suckers (Catostomids) (Aaland 1993). However, the magnitude of the change is dependent upon impoundment size, position of the impoundment along the stream (i.e., near headwaters or near the mouth of the stream), stream size, and current species composition (Marmulla 2001). Fish assemblages that are found only in rivers will be lost, but the newly created lentic habitat can compensate for some of these losses. In some cases reservoirs can increase productivity in terms of fish yield or recreational capacity, particularly in inland streams that do not support popular game fish. The compensatory potential for the newly created lentic habitat is higher in lower order upland streams with more shallow average depths (Marmulla 2001). The average North American reservoir produces a biomass of 24 kg/ha/yr (Jenkins 1982; Marmulla 2001). Additionally, shallow shoreline reservoir habitats can maintain healthy populations of native riverine fishes (Fernando and Holcik 1991).

Taylor et al. (2001) conducted a study to document the effects of an impoundment on a small creek in southern Illinois. Historical collections documented 48 fish species and one hybrid in the creek's drainage. After impoundment a total of 74 species and two hybrids were collected. The 50 percent increase in species richness Taylor et al. (2001) found was attributed to introductions (intentional and unintentional) of non-native species; range expansions from other regions; and creation of habitat favorable to certain species. Six species (*Carpiodes carpio, Notropis atherinoides, Pimephales promelas, Percopsis omiscomaycus*, *Microptus punctulatus, and Percina maculata*), previously documented in the drainage were not collected post-impoundment. They cited studies that showed that reservoirs resulted in:

- Little change in overall fish species richness (Rogner and Brinton, 1982);
- Substantial reductions in richness (Ely et al. 1981; Kapasa and Cowx, 1991); and
- Large shifts in dominant species within assemblages (Erman, 1973; Martinez et al., 1994).

Reservoir Fish Communities in Texas

Hubbs (2002) reported that 86 species of fish have been documented from Caddo Lake located in northeast Texas on the Louisiana border. He noted that the lake is "unique for Texas as a relatively undisturbed and biologically diverse ecosystem." It should be pointed out that Caddo Lake is actually a reservoir created and maintained by a dam on Cypress Creek.

Hubbs et al. (1991) reported that 247 species of fish are known to inhabit freshwaters of Texas. However, 78 of these species are marine or estuarine that may also be found in freshwater. The remaining 169 species would be considered restricted to freshwater habitats.

Dolman (1990) classified 132 large reservoirs in Texas based on fish species associations. He reported that 104 fish species were collected from 132 reservoirs, nearly 62 percent of freshwater fish species in the state. The following 20 species were found to be generally abundant in Texas reservoirs:

Aplodinotus grunniens
Dorosoma cepedianum
Dorosoma petenense
Gambusia affinis
Ictalurus melas
Ictalurus punctatus
Lepomis auritus
Lepomis microlophus
Lepomis cyanellus
Lepomis gulosus
Lepomis humilis
Lepomis macrochirus
Lepomis megalotis
Menidia beryllina
Micropterus salmoides
Notemigonus crysoleucas
Percina caprodes
Pimephales vigilax
Pomoxis annularis
Tilapia aurea

Expected Fish Communities in Lower Bois d'Arc Creek Reservoir

Lower Bois d'Arc Creek Reservoir would probably fall into the Dolman (1990) "Group 3: Longear sunfish" category. This group of 27 reservoirs located in central to northeast Texas was characterized by combinations of longear sunfish, bullhead minnow, freshwater drum, logperch, and orange spotted sunfish as the domanant species.

Other common fish expected in the proposed Lower Bois d'Arc Creek Reservoir would include gizzard shad, threadfish shad, bluegill, redear sunfish, channel catfish, white bass, largemouth bass and others.

Mussel Species

Detrimental impacts to mussel species resulting from construction of the proposed Lower Bois d'Arc Creek Reservoir project are not expected to occur. According to available literature, it appears that all species identified during site visits can and do adapt to life in a lake environment.

5.1.1.2 Expected Water Quality in the Reservoir

Reservoirs alter the water quality of a stream system by increasing the surface area, depth and volume of water at the site, thereby changing the physical, chemical and biological processes of the aquatic ecosystem. For example, in a reservoir, current velocities decrease, sediment particles fall from suspension, and water that may have exhibited low transparency as a flowing stream might become relatively clear. The retention of water in a reservoir, as compared to the transient nature of stream water at any given site, influences the types of physical and chemical processes that will occur in a reservoir.

By virtue of their depth and lack of movement compared to a flowing stream, reservoirs in North Texas and elsewhere often stratify during the late spring through fall as surface water warms at a faster rate than the deeper water. As the summer progresses and the surface water becomes markedly warmer and relatively lighter than the deeper water, a strong temperature gradient known as a thermocline may develop and become a barrier separating the surface water from the deeper water. The layers above and below the thermocline are known as the epilimnion and the hypolimnion, respectively. The epilimnion tends to be well aerated due to processes such as wind mixing and oxygen generated by phytoplankton, but the hypolimnion can become anoxic due to the lack of mixing with epilimnetic waters and consumption of dissolved oxygen by organisms residing below the thermocline. The anoxic condition in the hypolimnion results in the release of sulfides and other reduced compounds and is generally undesirable for gamefish and other aquatic species that require adequate dissolved oxygen concentrations to survive. This stratified condition typically begins to break down in the fall as epilimnetic waters cool in response to reduced solar heating and atmospheric cooling. As the epilimnetic and hypolimnetic water temperatures begin to equalize, wind movement across the surface can effectively mix the entire water body, restoring dissolved oxygen throughout the water column.

In order to estimate the magnitude and timing of stratification in the proposed reservoir, records of temperature and dissolved oxygen with depth in several North Texas reservoirs were examined. These lakes were selected based on proximity to the proposed Lower Bois d'Arc Creek Reservoir site, geographic latitude with respect to the proposed site, and availability of depth related dissolved oxygen and temperature data. No single reservoir site had complete monthly coverage, so the selected sites were identified to provide an estimate of dissolved oxygen and temperature with depth over an entire year. The selected sites included Jim Chapman Lake (also known as Cooper Lake; USGS 331938095374701), Lake Texoma (USGS 334910096342700), Lake Whitney (USGS 315203097222601), Lewisville Lake (USGS 330419096575401), and Benbrook Lake (USGS 323858097265601). The locations of these reservoirs relative to the proposed Lower Bois d'Arc Creek Reservoir site are depicted in Figure 5.1.

Jim Chapman Lake, located northwest of Sulphur Springs, TX, is in close proximity to the proposed Lower Bois d'Arc Creek Reservoir and has similar size, depth, and geology. Accordingly, Jim Chapman Lake data, where available, were used to estimate dissolved oxygen concentrations and temperature in the proposed Lower Bois d'Arc Creek Reservoir Table 5.1. For the months of April, October, November, and December, Jim Chapman Lake USGS data were not available. Consequently, USGS data from the other lakes were used to characterize these months, as noted in Table 5.1.

Based on data from these reservoirs, there is little to no thermocline evidenced in the wetter cooler months (October to April). As temperatures begin to increase in the month of May, existing North Texas lakes begin to exhibit temperature differences with depth along with decreased dissolved oxygen concentration with depth. Similar conditions would be expected in the Lower Bois d'Arc Creek Reservoir. Low dissolved oxygen levels may occur in the proposed reservoir in deeper water during the very hot summer months. By September, dissolved oxygen levels would begin to increase such that by October the levels would exceed the High Aquatic Life criertion of 5.5 mg/L throughout the reservoir pool.

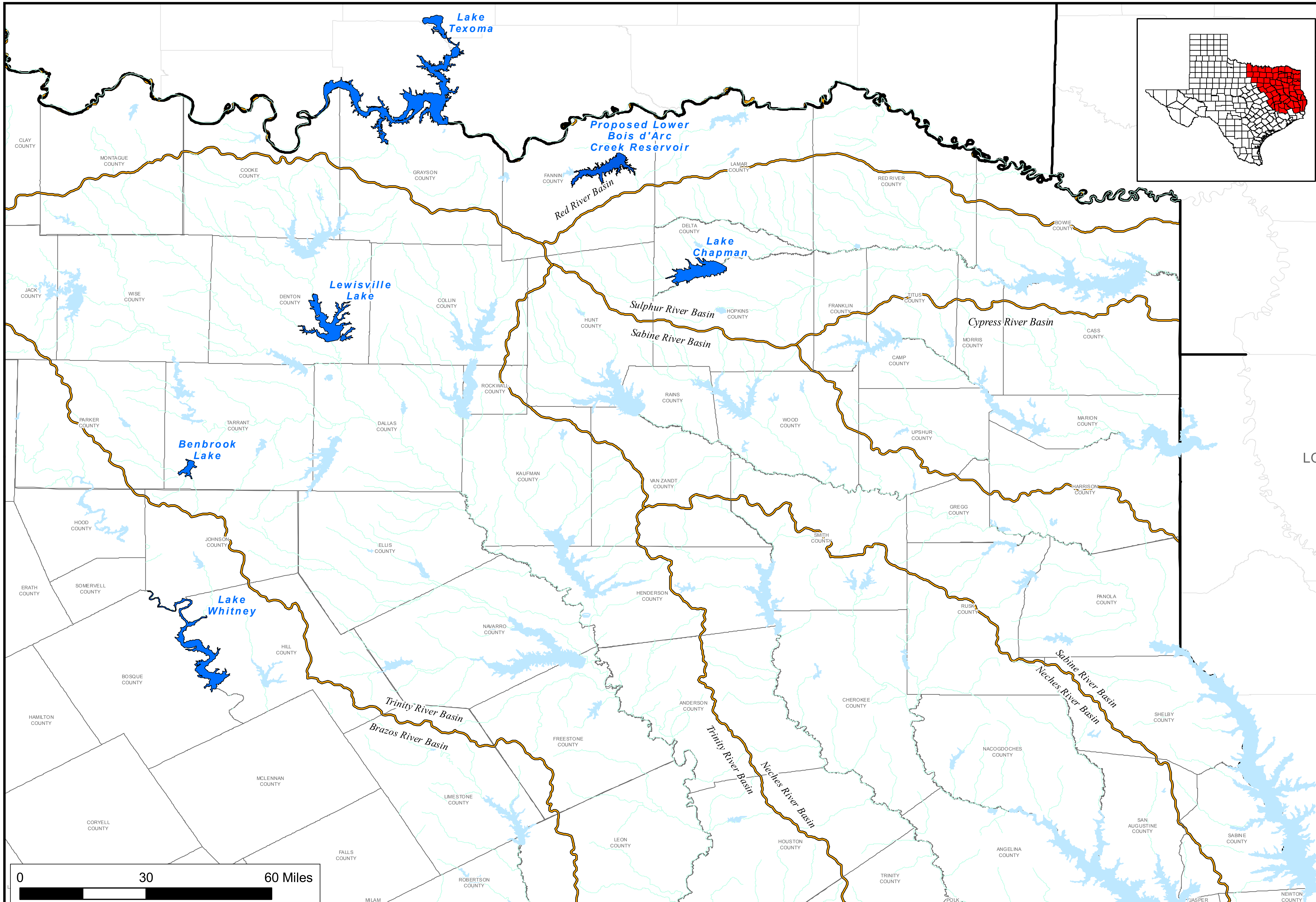

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Figure 5.1

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

Proposed Lower Bois d'Arc Creek Reservoir and Other North Texas Reservoirs

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Table 5.1 USGS Water Quality Data (Temperature and Dissolved Oxygen Concentrations) for Selected North Texas Lakes

		Depth (ft)	Mean Temperature	Mean Dissolved Oxygen
Lake Chapman	January	1	7.3	10.1
		10	7.3	10.0
		20	7.3	10.0
		30	7.3	9.9
		37 - 43	7.3	9.6
Lake Chapman	February	1	11.3	10.5
		10	11.0	10.4
		20	11.0	10.3
		30	11.0	10.4
		37 - 43	11.0	10.5
Lake Chapman	March	1	12.3	9.8
		10	11.8	9.1
		20	11.8	9.0
		30	11.8	8.8
		37 - 43	11.6	8.7
Lake Texoma	April	1	15.3	8.1
		10	15.3	8.2
		20	15.2	8.2
		30	15.2	8.3
		37 - 43	15.3	8.3
Lake Chapman	May	1	24.1	8.2
		10	22.7	7.3
		20	22.0	5.7
		30	21.3	4.6
		37 - 43	20.9	2.6
Lake Chapman	June	1	27.8	7.8
		10	27.7	7.7
		20	27.2	7.0
		30	25.8	3.7
		37 - 43	23.2	0.3
Lake Chapman	July	1	30.0	5.0
		10	29.5	2.6
		20	28.5	0.3
		30	26.0	0.4
		37 – 43	24.0	0.8

Table 5-1 USGS Water Quality Data (Temperature and Dissolved Oxygen Concentrations) for Selected North Texas Lakes (Continued)

		Depth (ft)	Mean Temperature	Mean Dissolved Oxygen
Lake Chapman	August	1	30.2	7.0
		10	29.6	6.0
		20	29.0	4.6
		30	28.4	1.4
		37 - 43	27.5	0.1
Lake Chapman	September	1	27.3	6.5
		10	26.8	4.9
		20	26.5	3.5
		30	26.0	3.2
		37 - 43	25.3	2.4
Lake Whitney	October	1	19	7.1
		10	19	7
		20	19	7
		30	19	7
		37 - 43	19	7
Lake Lewisville	November	1	15.8	7.8
		10	15.8	7.7
		20	15.8	7.8
		30	15.8	7.8
		37 - 43	15.8	7.8
Benbrook Lake	December	1	11	8.4
		10	11	8.3
		20	11	8.3
		30	11	8.2
		37 - 43	11	8.2

5.1.1.3 Geomorphology and Sediment Transport

All reservoirs created by dams on stream channels are subject to sediment inflow and deposition. When a stream is stilled behind a dam, most of the sediment contained in the water will sink to the bottom of the reservoir, making it a very efficient sediment trap. Every reservoir loses water storage to sedimentation, although the rate at which this happens varies greatly. The rate of reservoir sedimentation depends mainly on the size of a reservoir relative to the amount of sediment flowing into it. Large reservoirs in the US lose storage capacity at an average rate of around 0.2 percent per year (McCully 1996).

Sediment accumulation in a reservoir is usually distributed below the top of the conservation pool or normal water surface. Once sediment inflow enters the reservoir it is distributed by depth and by longitudinal profile distance. Studies show that sediment deposition is not necessarily confined to the lower storage increments of the reservoir (US Department of Interior, Bureau of Reclamation 2006; Strand and Pemberton 1982; US Department of Agriculture 1978). Delta deposits are another issue regarding reservoir sediment deposition. This causes the distribution of sediment longitudinally in the extreme upstream portion of the deposition profile. Predicting delta development within a reservoir is very complex because of variables, including operation of the reservoir, sources of sediment, and hydraulics.

The potential sources of sediment to the proposed Lower Bois d'Arc Creek Reservoir include incised channel erosion (bed and banks) and watershed erosion (sheet, rill, ephemeral gully). With the reservoir in place, channel bed and bank sediment yields should decrease as the hydraulic gradients along the tributaries and upper Bois d'Arc Creek decreases. A considerable portion of the incised and highly degraded sections of Bois d'Arc Creek and tributaries is expected to be inundated by the conservation pool, thereby reducing the amount of sediment inflow and deposition that is currently being contributed from these segments. Sediment yields from the watershed will be dependent on the land use and land cover within the remaining watershed, in the areas surrounding and upstream of the proposed reservoir.

5.1.2 Potential Downstream Effects

The flow regime downstream of a reservoir can be substantially different than before the reservoir was built. These changes can be mitigated by establishing release criteria from the reservoir.

5.1.2.1 Impacts on Fish

The change in flow regime downstream from the proposed reservoir could negatively impact fish species with narrower habitat requirements (Freeman 2005). Species sensitive to reservoir operations are those that use temperature or flow for reproductive cues, substrate-specific spawners, and those that depend on higher flows for egg dispersal (i.e., pelagic spawners) (Freeman 2005). Additional impacts may include nutrient limitation (as impoundments can retain nutrients), water temperature regulation, and loss of stream connectivity. Biological interactions may be secondarily affected as decreased instream habitat diversity and changes to water quality may increase competition, predation, and alter community structure (Mosier and Ray 1992). In warmwater systems, cold-water releases from the bottom of a reservoir can impact fisheries below dams (Pasch et al. 1980), as reproduction and growth of some warmwater species are dependent on temperature.

In a study of impacts of reservoirs and water withdrawals, Freeman (2005) analyzed data from 27 sites and found that out of 45 fluvial specialist fish species, about one to five species were "lost" at sites downstream from reservoirs compared to sites with direct stream withdrawals.

Kinsolving and Bain (1993) found that there was "spatial recovery gradient" for fish assemblages downstream of a hydroelectric dam in Alabama. They observed a longitudinal gradient of increasing abundance and richness of fluvial specialists downstream of the dam, but no spatial gradient was observed for macrohabitat generalists. If their longitudinal gradient hypothesis is correct, then at some point downstream there would be a recovery of fluvial specialists.

Given that most fish species collected from Bois d'Arc Creek during the instream flow study are mesohabitat generalists, with the possible exception of a few cyprinids and percids, then it is likely that there would be little impact to the downstream fish community and biodiversity as long as there is water flowing in the creek. It could be speculated that providing a perennial flow, especially during common spawning months, could increase fluvial specialist populations or the number of species. It could also provide better habitat for generalist species.

The proposed flow regime for Bois d'Arc Creek downstream of the proposed dam would provide a sound ecological environment that would support the existing and future aquatic ecosystem environment, barring unforeseen actions by others. The flow regime proposed would maintain flowing water in the creek channel, provide for stream sediment transport processes, maintain existing aquatic habitat and communities, and protect water quality.

5.1.2.2 Riparian Vegetation

Vegetation cover in and along channels downstream of dams has been shown to remain the same or increase following the placement of a dam. In the case of the Canadian River downstream from Sanford Dam (Lake Meredith) in Texas, virtually no releases of any magnitude have been made since the dam closure in 1964, and there has been a major increase in vegetation cover (Williams and Wolman 1984). Due to the scarcity of major tributaries introducing flow that would uproot vegetation, the effect is still very pronounced 120 kilometers downstream from the dam. It should be noted that the annual precipitation at Lake Meredith is less than one-half of the Bois d'Arc Creek site. The reduction in overbanking events can allow stream bank vegetation to become more permanently established. Chin et al. (2002) found that channel vegetation cover along Yegua Creek downstream of the Somerville Dam increased as a result of increased duration of low flow throughout the summer months due to reservoir releases when the channel historically experienced no flow conditions prior to dam construction.

For the Lower Bois d'Arc Creek Reservoir, stream bank vegetation is expected to follow the same trend and increase after the dam is built. The reduction in large erosive flow events would allow vegetation to become readily established along the banks. Increases in vegetation cover would provide multiple functions following the proposed impoundment of ther Bois d'Arc Creek. In incised channels, riparian forest buffers can help increase stream bank stability because of the deeper and denser rooting habits of trees than those of crops or grasses (Lee et al. 2000; Zaimes et al. 2006). Plants that become established on the bank slopes would serve the same function, with their roots reinforcing the bank material, making it more resistant to erosive forces. Additionally, plant matter on bank faces deflects flowing water away from the banks, effectively reducing shear stress exerted on the banks by flowing water.

5.1.2.3 Fluvial Geomorphology

Impoundments can alter downstream flows by possibly reducing base flows as well as disrupting magnitude and frequency of high flow events. This can affect stream geomorphology in reference to aquatic habitat, including filling interstitial spacing in gravel substrates, stabilizing and narrowing channels, and reducing the formation of point bars, oxbows, and secondary channels (Poff et al. 1997).

Channel incision commonly occurs in the area directly downstream of a dam (Wolman 1967; Williams and Wolman 1984; Annandal et al. 1995; Collier et al. 2000). River channels immediately downstream of reservoirs typically experience a decrease in sediment inflows, contributing to the channel incision. The distance downstream that a channel is affected by a dam is typically dependent on the magnitude and duration of uncontrolled spills and releases and the contribution of flow by downstream tributaries (Park 1977; Petts 1979).

The placement of a dam on Bois d Arc Creek would effectively cut off the sediment supply from the upstream channel to the lower reaches. The lack of sediment load will increase the tendency of the channel downstream of the reservoir to erode and incise during high flow events. With the dam in place, there would be fewer highly erosive flow events. Release criteria should be prescribed that will maintain the existing geomorphic features and remove accumulated fine sediments from those features while reducing the potential for additional erosion or downcutting below the reservoir.

5.1.2.4 Water Quality Below the Proposed Reservoir Without an Instream Flow Regime

The quality in Bois d'Arc Creek downstream of the proposed dam without a proposed instream flow regime would be dictated by seepage from the dam, runoff from the watershed downstream from the dam, and baseflow in the channel. As noted from the review of existing water quality data, dissolved oxygen concentrations in the stream are dependent upon temperature and flow. The lower the flow, especially during warm weather, the more depressed dissolved oxygen will be in the creek. Thus, the stream reach closest to the dam would be more likely to suffer from suppressed concentrations, but the effect would be expected to diminish downstream from the dam as baseflow sources and drainage area increase.

5.2 Development of Environmental Flow Criteria

Site-specific environmental flow criteria for the proposed Lower Bois d'Arc Creek Reservoir have been identified to support a Sound Ecological Environment, as defined in Chapter 1 of this report. This section briefly describes how the four components of the study (hydrology and hydraulics, fluvial geomorphology, biology and water quality) were integrated in developing these flow criteria. More detailed information may be found in the Appendices that discuss each of these components.

RECOMMENDED ENVIRONMENTAL FLOW RELEASES

Subsistence flow of 1 cfs.
- **To maintain minimal water quality levels during extreme drought.**

Base flows of 3 cfs and 10 cfs
- **To maintain connectivity of habitats, soil moisture, and provide suitable water quality.**

Pulse releases of 50 cfs, supplement naturally occurring pulse events.
- **To move sediments for habitat maintenance**

5.2.1 Flow Components

The Texas Instream Flow Program (TIFP) divides flows into four components or classifications (TCEQ, 2008):

- *Subsistence flow* – minimum streamflow during extreme drought conditions. During times of subsistence flow one would expect elevated temperatures, increased concentrations of dissolved material in water, and sediment deposition. For Bois d'Arc Creek, a subsistence flow criteria should be designed to maintain minimal water quality levels to limit impacts on aquatic organisms.
- *Base flow* – "normal" flow conditions found between storm events. For Bois d'Arc Creek, base flow criteria should be designed to maintain connectivity between a variety of habitats to support the natural community, maintain soil moisture, and provide suitable water quality.
- *High flow pulses* – short-duration, high flows within the stream channel resulting from a storm event. For Bois d'Arc Creek, high flow pulse criteria should be designed to maintain channel characteristics, move sediments to maintain habitats and restore water quality after periods of low-flow.
- *Overbank flows* – high-flow events that cause flow beyond the riverbanks. Currently overbanking flows are relatively frequent on the Bois d'Arc Creek watershed and follow and precede channel-degrading bank-full flows. Overbank

flow criteria were not developed for Bois d'Arc Creek in order to minimize potential bed and bank erosion and to limit property damage.

Based on the instream flow needs analysis, the following environmental flow releases are proposed for the Lower Bois d'Arc Creek Reservoir:

- During normal and wet conditions, release of a base flow of 10 cfs during the months of April, May and June and 3 cfs during the rest of the year as measured at the FM 409 USGS gage.
- During normal and wet conditions, ensuring that a pulse flow event of at least 50 cfs occurs at FM 409 during the spring season (April through June) and at the end of the summer (September to October).
- Release of a subsistence flow of 1 cfs during extreme, prolonged drought. Pulse releases are not required or proposed during subsistence periods. Extreme drought can be identified using reservoir storage. At this time it is proposed that subsistence flows be released when the reservoir content is less than 40 percent of the conservation storage. If it is found that subsistence conditions occur more than 10 percent of the time, then the storage trigger may be adjusted.

Consistent with the Inter-Agency Team discussions, the proposed criteria do not include deliberate overbanking flows. The hydrologic regime of Bois d'Arc Creek has been so dramatically altered by channelization and straightening with the resulting channel down-cutting and increased erosion, that artificial high pulse flow releases would be counterproductive to maintaining a Sound Ecological Environment. There are also liability issues connected with making deliberate flood releases. For these reasons, the TCEQ has stated that the State of Texas will not issue water rights permits with deliberate overbank release requirements.

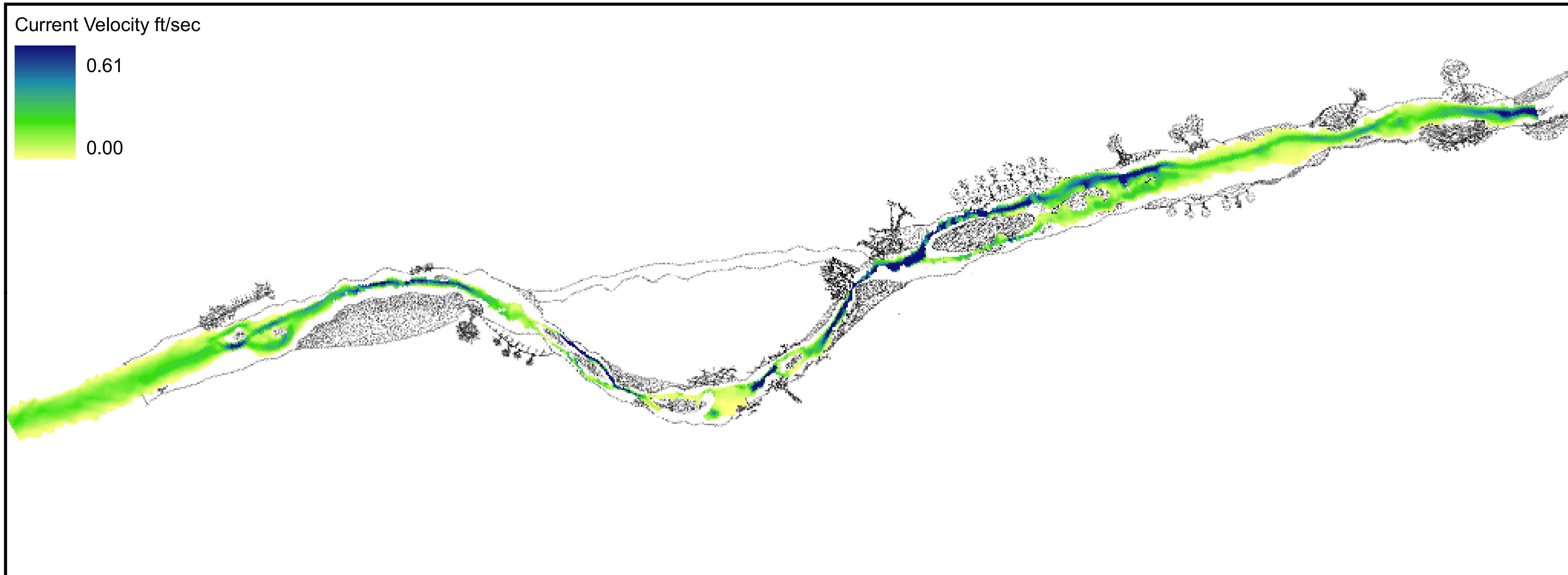
The proposed flow regime is substantially different from the current flow regime. Specifically, pulse flow events will be substantially different in magnitude. The reach below the reservoir will become a perennial stream during all but extended droughts, whereas now it is an intermittent stream with extended periods of little to no flow. A flow regime that mimics current conditions would only exacerbate the on-going erosion and frequent habitat destruction currently observed in the watershed and, thus, would not be supportive of a Sound Ecological Environment. The proposed flow regime is expected to stabilize the stream downstream of the reservoir so it can reach equilibrium, thereby providing support for a Sound Ecological Environment.

5.2.2 Base and Subsistence Flows

The recommended base flow of 3 cfs is based on River2D modeling at the FM 409 study reach. This modeling determined that flows between 2 and 3 cfs would achieve longitudinal stream connectivity, with modeled pool habitats connected by run-riffle habitats (Figure 5.2). This connectivity is important for maintaining fish passage, aquatic habitat, and suitable water quality (i.e., dissolved oxygen and temperature). At a 3 cfs discharge, physical attributes include a maximum water depth of 2.68 ft and current velocity of 0.61 ft/sec. The base flow of 3 cfs has the potential to transport approximately 0.9 tons/day of very fine sand, silt, and clay. A base flow of 10 cfs is recommended for April, May and June. Figure 5.3 shows the modeled flow depth and current velocity at this flow.

The additional base flow at this time of year would provide expanded habitat during the spawning period of the dominant species in Bois d'Arc Creek (Figure 5.4). It would also provide additional depth for fish passage during spawning season and maintenance of dissolved oxygen levels. The 10 cfs base flow release has the potential to transport 5.3 tons/day of sand, silt, and clay.

Subsistence flow recommendations are proposed based on maintaining water quality requirements – mainly temperature and dissolved oxygen, and maintaining soil moisture in the creek channel. A flow of 1 cfs does not maintain full lateral connectivity. However, this flow should be sufficient to maintain some key habitats and pool refugia. (i.e., prevent dewatering) The subsistence flow of 1 cfs has the potential to transport approximately 0.26 tons/day of silt and clay.



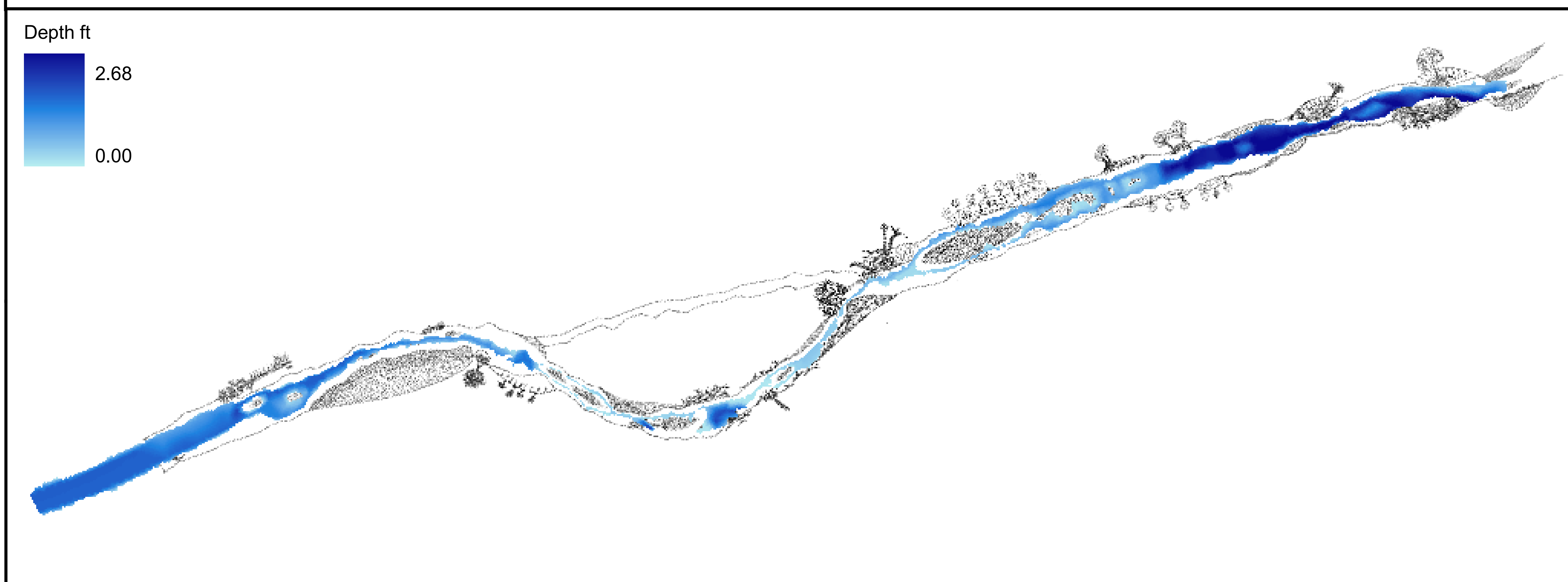


Figure 5.2

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

F.M. 409 Current Velocity and Depth 3 CFS

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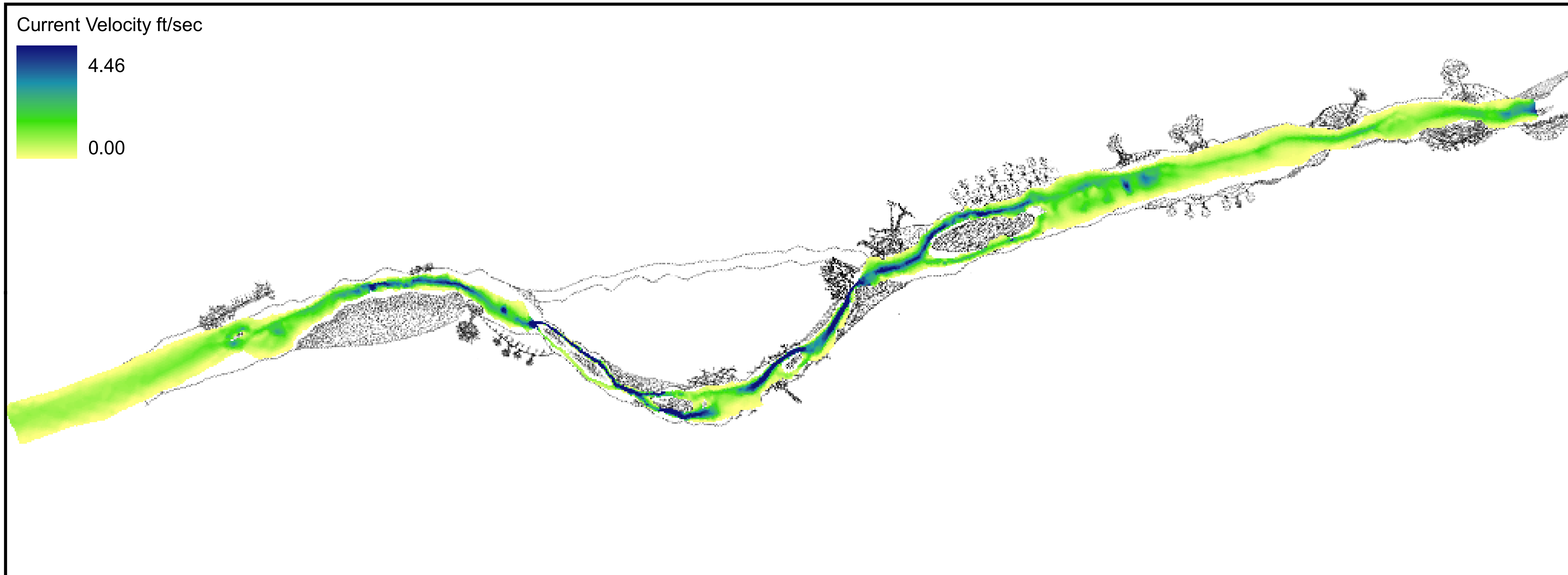

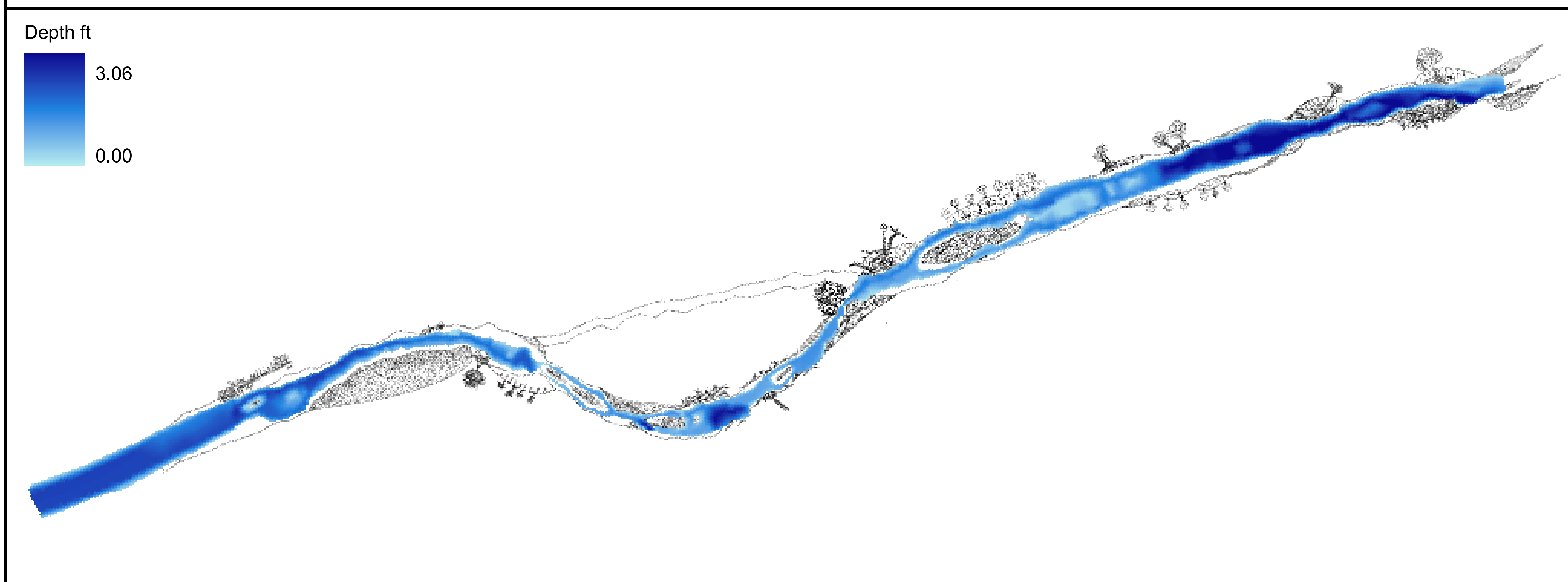

North Texas Municipal Water District

Proposed Lower Bois d'Arc Creek Reservoir

F.M. 409 Current Velocity and Depth
10 CFS

Figure 5.3

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DRAFTED	MJA

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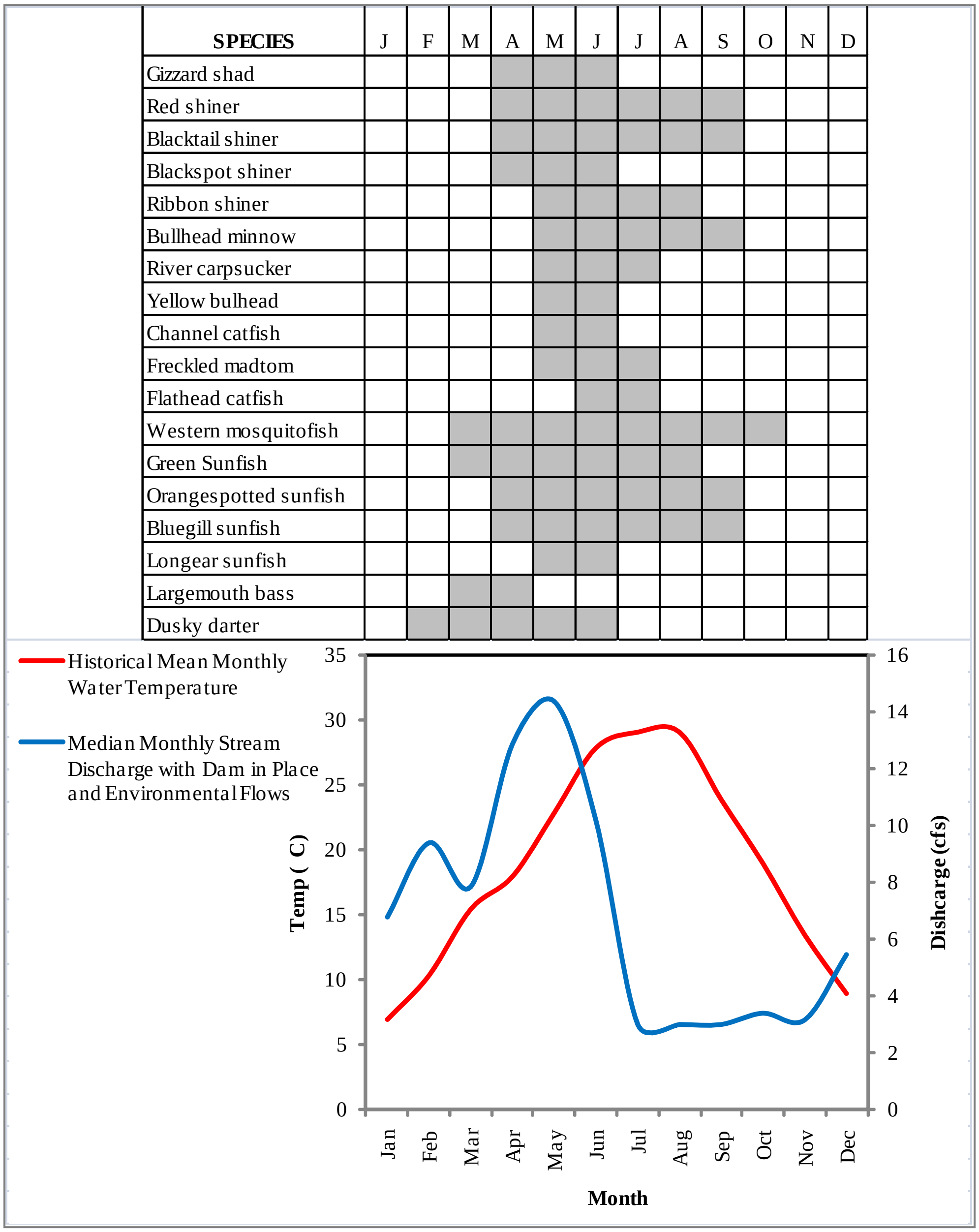
Figure 5.4 Reproductive Timing of Dominant Species at Bois d'Arc Creek with Mean Monthly Temperature vs. Median Monthly Stream Discharge



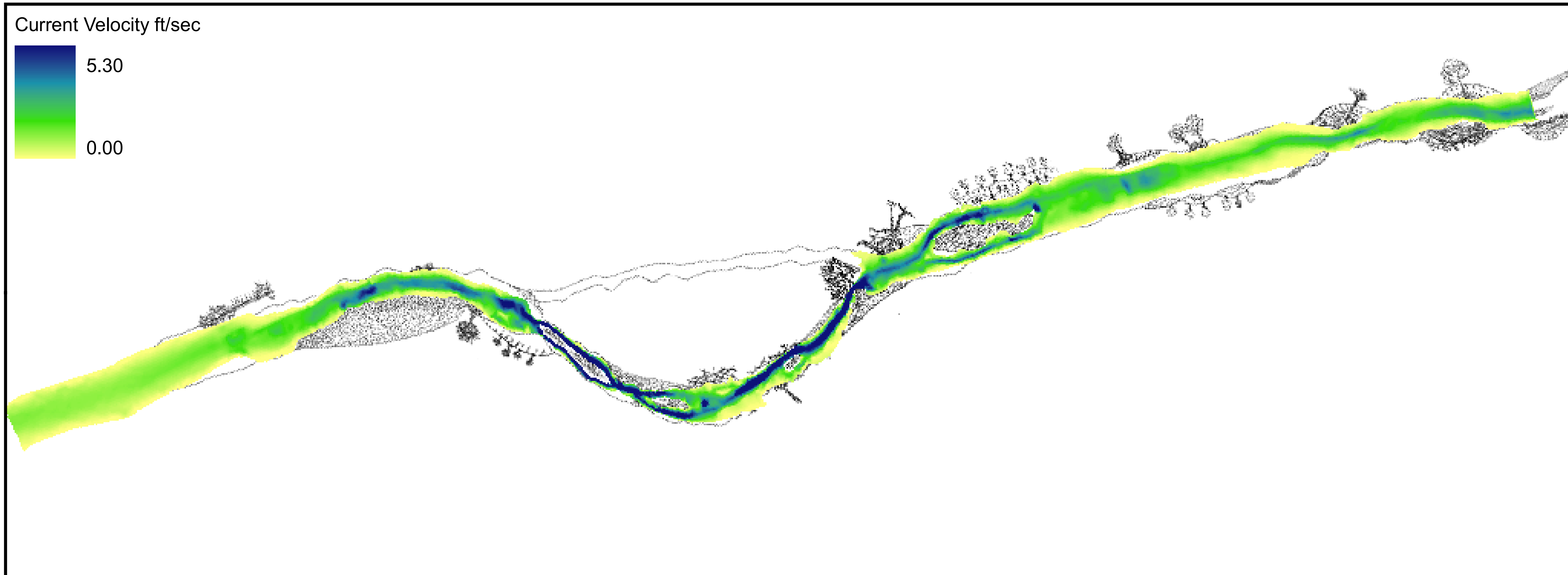
5.2.3 Pulse Flows

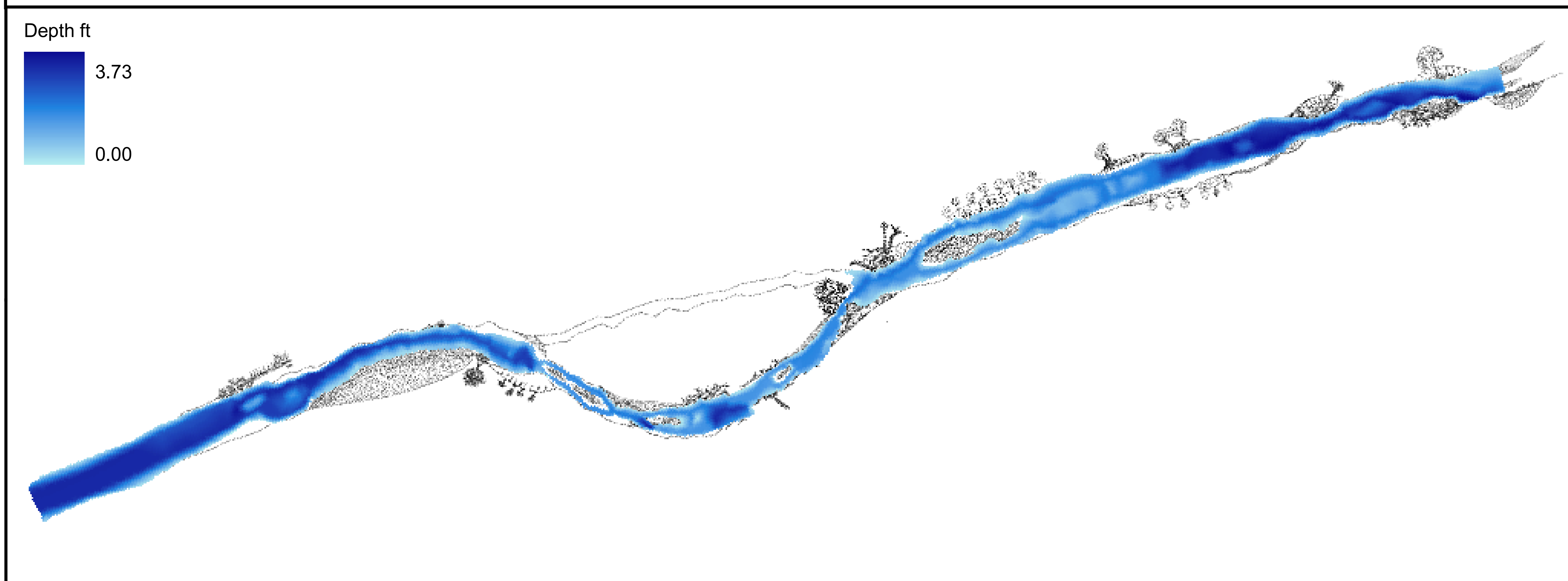
Pulse flows improve water quality, maintain and improve riffle habitat, remove surficial fine sediment deposits, restore and enhance pool habitat, and maintain active channel width and topographic diversity (Kondolf and Wilcock 1996). Figure 5.5 shows the modeled flow depth and current velocity at 50 cfs. Sediment transport analyses and field observations indicate that pulse a flow of 50 cfs is sufficient to move the bed material and flush accumulated fine sediment while maintaining the integrity of gravel beds.

Pulse flow releases are proposed during two seasons each year, if needed due to the absence of natural pulse flow events.

The April to June pulse event is designed to coincide with the spawning season of dominant fish species in Bois d'Arc Creek. The September to October pulse event is designed primarily to flush out the stream, improving water quality and removing sediment. It may also serve as a spawning cue for late-season spawners, such as red shiner, blacktail shiner, bullhead minnow, western mosquito fish, orange spotted sunfish and bluegill.

Currently in the Bois d'Arc Creek watershed the frequent occurrence of very high pulse flows impacts the development of aquatic habitat. Currently these habitats are replaced to a limited extent by sediment and large woody debris from upstream. With the reservoir in place the supply of sediment and large woody debris in the reach below the dam will be limited, exacerbating the potential negative impacts of high flows on habitat. Although the magnitude of pulse events will be reduced, events higher than 50 cfs can and will occur with the reservoir in place. Runoff from the watershed below the reservoir will produce pulse events, and spills from the reservoir will provide flows with sufficient energy to re-work habitats and remove large woody debris. The proposed flow regime is expected to allow the establishment of and preservation of relatively long-lived habitats, while less frequently occurring larger events will perform the "house cleaning" that is needed from time-to-time in every habitat. In other words, the new flow regime should help support a Sound Ecological Environment.



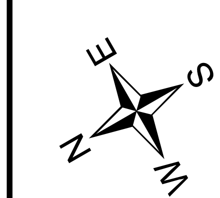


North Texas Municipal Water District
Proposed Lower Bois d'Arc Creek Reservoir

F.M. 409 Current Velocity and Depth 50 CFS

Figure 5.5

FN JOB NO	NTD06128
FILE	5.5_Depth_CV_50.mxd
DATE	April 2010
SCALE	1:1,200
DESIGNED	MJA
DRAFTED	MJA



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5.3 Expected Downstream Conditions with Proposed Flow Regime

5.3.1 Hydrologic Modeling

The proposed release criteria were programmed into a modified version of the RiverWare model that includes Lower Bois d'Arc Creek Reservoir. Figure 5.6 shows the model layout. (The FM 1396 gage would be inundated by the reservoir and was not included in the model.) Appendix B contains more detailed output from the modeling.

The release of base flows and subsistence flows are not dependent on inflow into the reservoir – stored water will be used for releases when inflows are less than the proposed criteria. Releases for base flows and subsistence flows would be measured at the reservoir outlet structure. The measurement point for pulse flow criteria would be at USGS gage at FM 409, which is approximately 2.35 river miles downstream of the proposed reservoir.

HYDROLOGIC MODELING

Hydrologic modeling shows higher median flows during low flow periods.

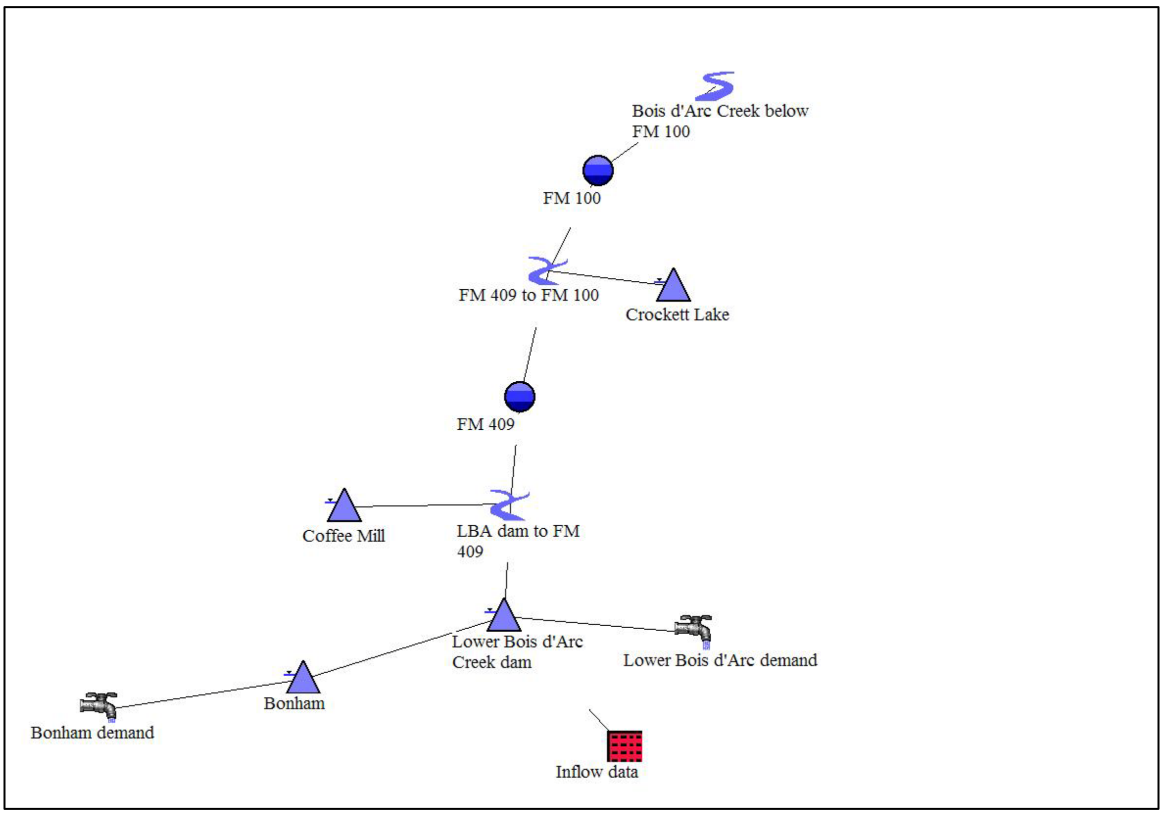
Frequency of pulse events will be reduced. However, modeling shows that watershed below reservoir will continue to produce pulse events.

Reduction in frequency of highly erosive high-flow events will reduce current erosion and downcutting.

New flow regime will help stabilize currently unstable channel.

Release policies will maintain water quality below reservoir.

Figure 5.6 RiverWare Model with Lower Bois d'Arc Creek Reservoir



For modeling purposes, if a flow event of at least 50 cfs has not occurred at the FM 409 gage in the months of April or May, a release is made from the reservoir on June 1. On the first day of the event the flow is set to 50 cfs. On subsequent days the flow is gradually reduced by 75 percent over the next five days until the base flow criteria of 10 cfs is reached, making the pulse a 6-day event. (The 75 percent reduction criterion is based on inspection of historical pulses of similar sizes measured at FM 1396.)

Similarly, if an event with a flow of at least 50 cfs has not occurred at FM 409 during the month of September, a pulse is released on October 1. The first day of the pulse is 50 cfs and declines by 75 percent over the next nine days until the base flow criteria of 3 cfs has been reached, resulting in a 10-day event. Table 5.2 shows the flow for each day of the event. In the model subsistence flows occur when the storage in the reservoir is less than 40 percent of conservation storage (147,043 acre-feet).

Table 5.2 Pulse Release Schedule

	Day	Release (cfs)	
October Pulse	1	50.0	June Pulse
	2	37.5	
	3	28.1	
	4	21.1	
	5	15.8	
	6	11.9	
	7	8.9	
	8	6.7	
	9	5.0	
	10	3.8	

Table 5.3 compares statistics for the modeled flows at the FM 409 gage before the dam is built to flows after the dam is built with the proposed release criteria.

Table 5.4 compares the statistics on environmental flow components at FM 409 before and after construction of the dam. Before construction of the dam, periods of little or no flow occur frequently. After construction of the dam and using the proposed release policy, subsistence flows only occur during extreme drought, and never fall below 1 cfs. With the proposed release policy, the median of base flows is slightly higher in the spring and summer months (April through October) when compared to conditions before the dam is built. During the rest of the year the median is lower with the proposed release policy when compared to the period before the dam was constructed. Peak flows for proposed pulses are substantially less than pre-dam conditions. However, this should be beneficial because the lower flows will be less erosive than current flows.

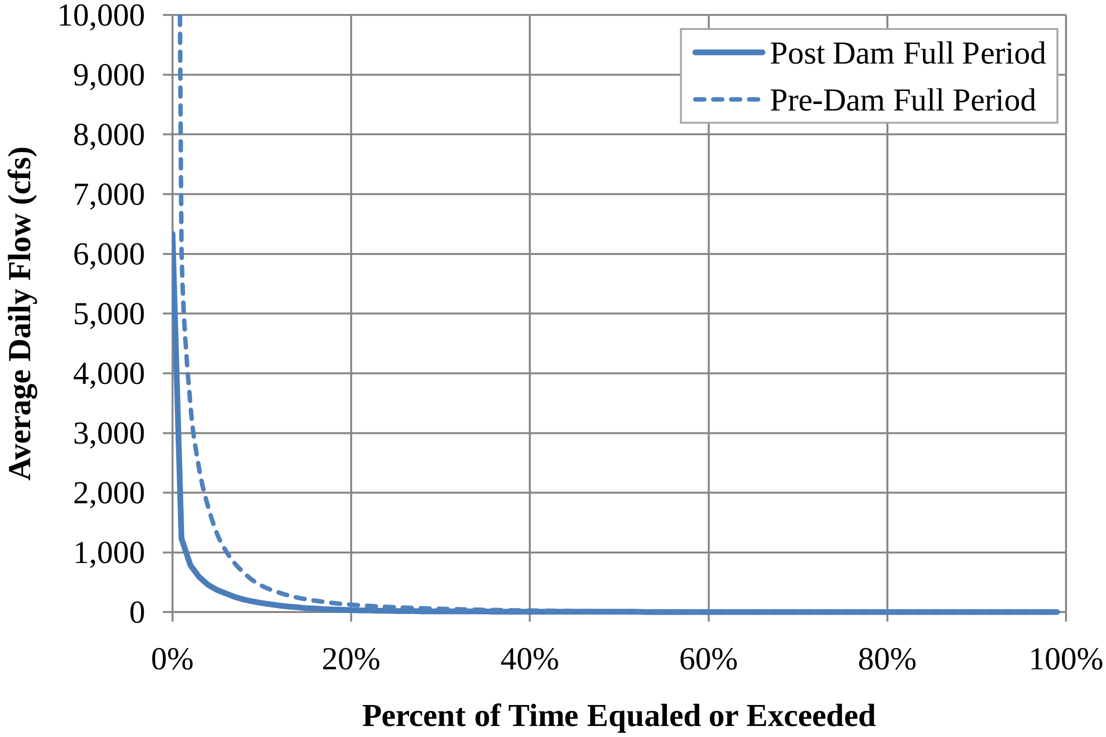
Figure 5.7Figure 5.7 compares the flow-duration curves before and after the dam is built for the full period of data. Note that with the dam, low flows (flows less than the 35th percentile) are higher than the period before the dam. Before the dam, there is no flow about 20 percent of the time, while with the dam the subsistence flow of 1 cfs occurs about 5 percent of the time. There are no periods with zero flow with the proposed release criteria. Flows higher than 3 cfs occur less frequently with the dam in place. Extreme flood events are much lower with the dam, being reduced from 40,000 cfs or more to a maximum of around 6,400 cfs. This implies that flows will be within the current banks most of the time after the dam is built. Currently flows overtop the banks about 1 percent of the time.

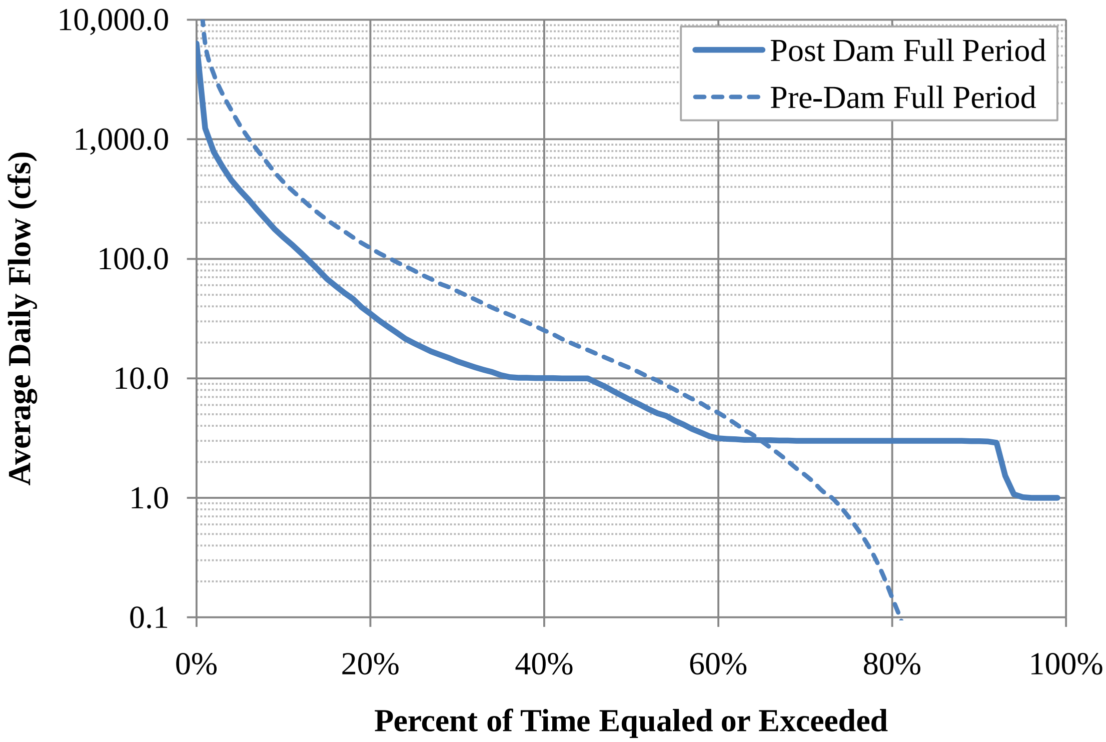
Table 5.3 Comparison of Modeled Flow Statistics at FM 409 - Pre-Dam and Post-Dam with Proposed Releases

Statistic	Pre-Dam				Post Dam with Proposed Operation			
	Full Period	April-June	July-October	November-March	Full Period	April-June	July-October	November-March
Average	313	462	140	364	73	125	22	82
Minimum	0.0	0.0	0.0	0.0	0.5	0.5	0.7	0.7
15%	0.0	2.5	0.0	1.4	3.0	10	3.0	3.0
30%	1.6	9.1	0.0	8.0	3.0	10	3.0	3.1
Median	12	26	0.4	31	6.5	12	3.0	6.2
70%	54	91	4.4	95	14	30	3.1	20
85%	213	357	29	336	67.9	156	9.0	113
Maximum	48,345	48,345	40,047	37,379	6,421	6,421	3,601	4,422

Table 5.4 compares the statistics on environmental flow components at FM 409 before and after construction of the dam. Before construction of the dam, periods of little or no flow occur frequently. After construction of the dam and using the proposed release policy, subsistence flows only occur during extreme drought, and never fall below 1 cfs. With the proposed release policy, the median of base flows is slightly higher in the spring and summer months (April through October) when compared to conditions before the dam is built. During the rest of the year the median is lower with the proposed release policy when compared to the period before the dam was constructed. Peak flows for proposed pulses are substantially less than pre-dam conditions. However, this should be beneficial because the lower flows will be less erosive than current flows.

Figure 5.7 Comparison of Flow Duration at FM 409 Before and After Dam





Even though the release criteria only require two pulses (one in the spring and one at the end of the summer), the average number of pulses per year downstream of the reservoir is not substantially less than before the dam is constructed. After the dam is constructed, pulse flows at FM 409 will originate from four sources:

- Spills from Lower Bois d'Arc Creek Reservoir
- Deliberate releases from Lower Bois d'Arc Creek Reservoir
- Direct runoff into the reach between the dam and FM 409
- Spills from Coffee Mill Lake

Figure 5.8 is the simulated storage trace for Lower Bois d'Arc Creek Reservoir. Lower Bois d'Arc Creek Reservoir is expected to go for long periods of time without spilling, so a significant number of pulse events must come from the other two sources. Coffee Mill Lake is one of two small recreation lakes located on the major tributaries below the proposed dam (Figure 5.6). The other is Lake Crockett. Spills from Coffee Mill Lake enter Bois d'Arc Creek above FM 409, and spills from Lake Crockett enter Bois d'Arc Creek between FM 409 and FM 100. Neither lake is used for water supply. Figure 5.9 is the storage trace for Coffee Mill Lake, and Figure 5.10 is the storage trace for Lake Crockett. Table 5.5 shows the average, minimum and maximum number of days per year that Lower Bois d'Arc Creek Reservoir, Coffee Mill Lake and Lake Crockett spill in the simulation. It also includes the number of days per year that the spills exceed 50 cfs pulse flow. Lakes Coffee Mill and Crockett spill at least once in every year of the simulation. It is these spills, plus the intervening flow below the reservoir, that create the pulse events shown in the simulation.

The frequency of overbanking flows with the dam would substantially less than before the dam based on the flow simulation. Prior to construction of the dam, there are 130 events that exceed the overbank threshold of 6,000 cfs in the 51-year period in the model, or about 3 events per year. With the dam in place, only 2 events with flows greater than 6,000 cfs occur during the same 51-year simulation period, an average of 0.04 per year or about once every 25 years.

Table 5.4 Comparison of Modeled Environmental Flow Components at FM 409 – Pre-Dam and Post-Dam with Proposed Releases

	Pre-Dam				Post Dam with Proposed Release			
Median Flow	**Full Period**	**Nov-Mar**	**Apr-Jun**	**Jul-Oct**	**Full Period**	**Nov-Mar**	**Apr-Jun**	**Jul-Oct**
Subsistence (cfs)	0.00	0.01	0.11	0.00	1.00	1.00	1.00	1.00
Base (cfs)	8.2	15	8.2	2.2	3.1	3.1	10	3.0
Pulse Flows	**Full Period**	**Nov-Mar**	**Apr-Jun**	**Jul-Oct**	**Full Period**	**Nov-Mar**	**Apr-Jun**	**Jul-Oct**
Avg No Per Year	19.6	8.9	5.7	4.9	15.8	7.5	5.1	3.2
Median Peak Flow (cfs)	223	329	299	88	96	122	111	50
Avg Duration (days)	7	7	7	6	7	7	7	7
Flood Flows	**Full Period**	**Nov-Mar**	**Apr-Jun**	**Jul-Oct**	**Full Period**	**Nov-Mar**	**Apr-Jun**	**Jul-Oct**
Avg No Per Year	2.55	1.16	0.98	0.41	0.04	0.00	0.04	0.00
Median Peak Flow (cfs)	11,496	10,927	12,184	11,404	6,379	-	6,379	-
Avg Duration (days)	14	13	13	15	23	-	23	-

Figure 5.8 Simulated Lower Bois d'Arc Creek Reservoir Storage

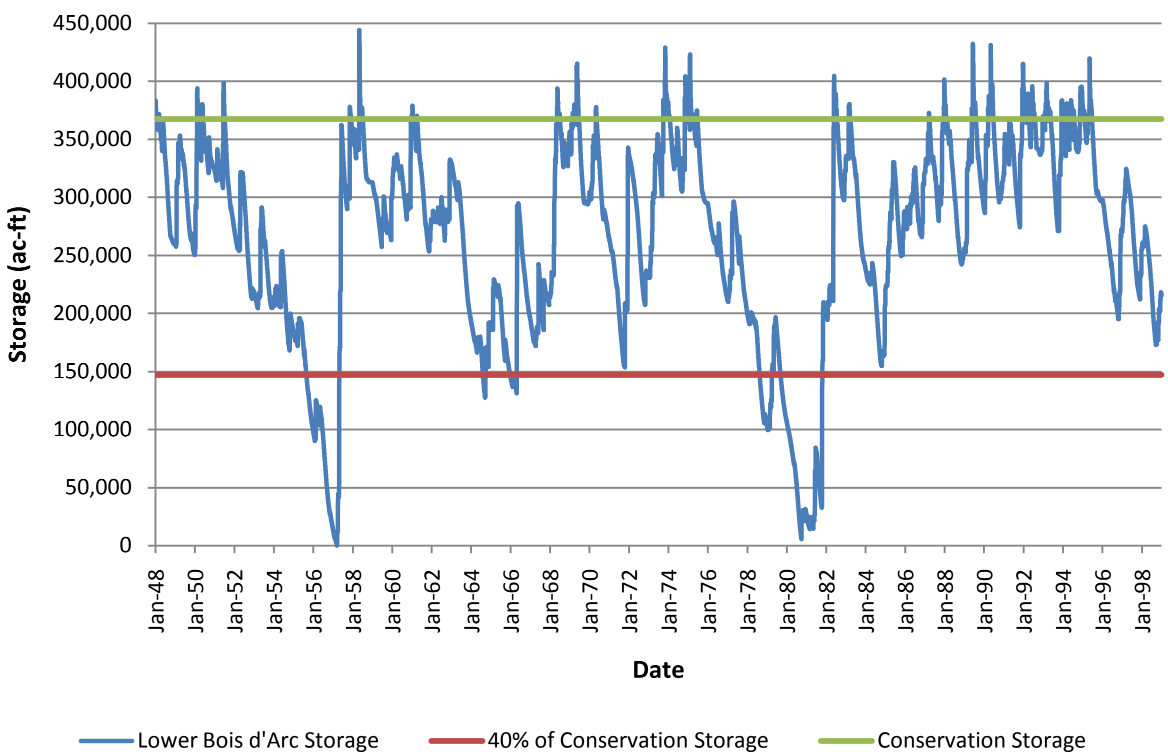


Figure 5.9 Simulated Coffee Mill Lake Storage

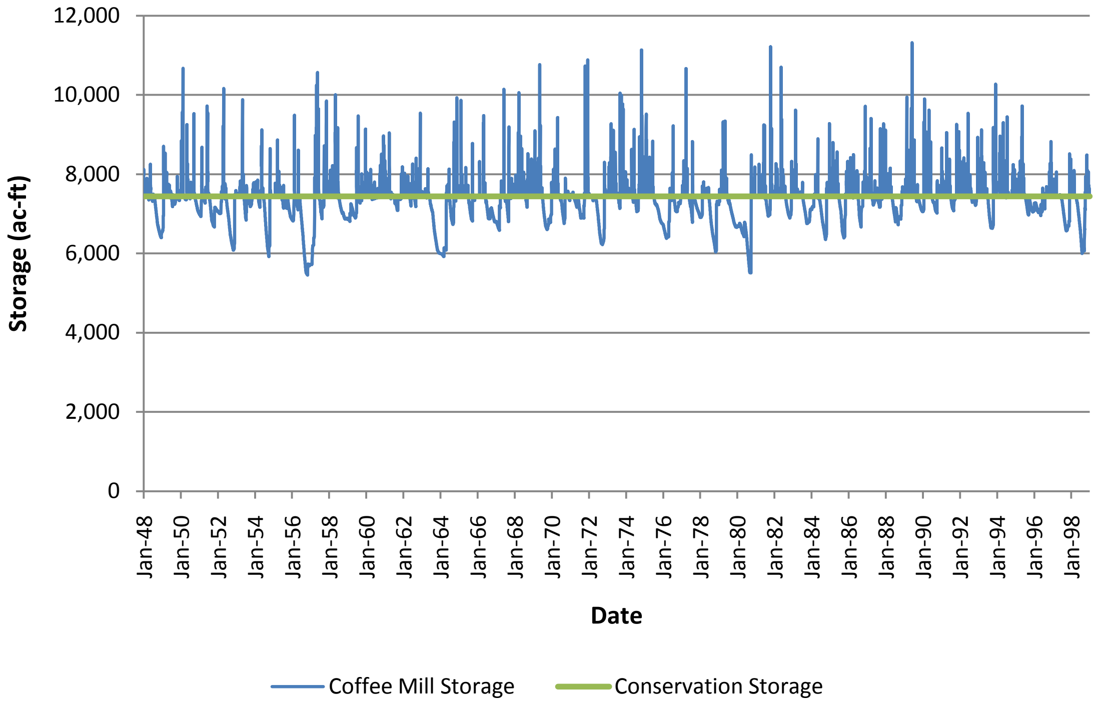


Figure 5.10 Simulated Lake Crockett Storage

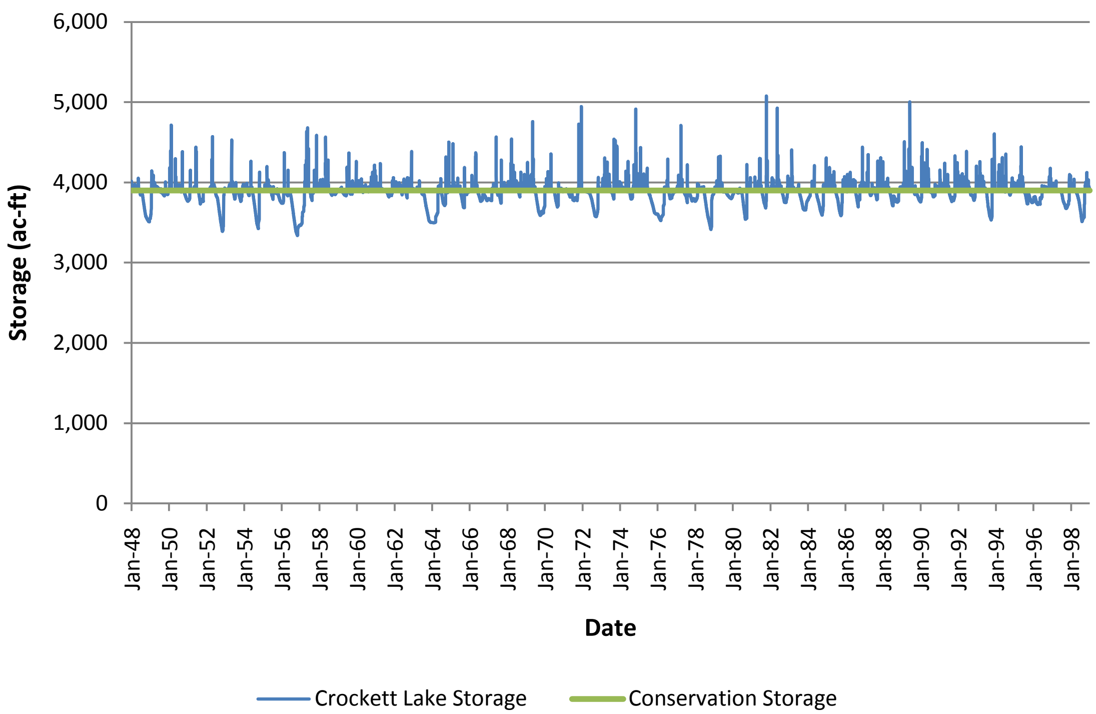


Table 5.5 Number of Reservoir Spill Days per Year in Simulation

Statistic	Lower Bois d'Arc Creek Reservoir		Coffee Mill Lake		Lake Crockett	
	Number of Spill Days	Number of Spills Days > 50 cfs	Number of Spill Days	Number of Spills Days > 50 cfs	Number of Spill Days	Number of Spills Days > 50 cfs
Average	29	26	173	42	181	16
Min	0	0	27	8	30	1
Max	152	137	332	94	300	39

Table 5.6 shows how the number of pulse and overbank events increase with distance downstream from FM 409 to the lower reaches of Bois d'Arc Creek with the proposed release policy. There are 130 more pulses in the lower reach than at FM 409 during the 51-year simulation period, and six more overbank events.

The modeling does not include backwater effects from high flows in the Red River. If high flows are present in the Red River at the same time as high flow events in Bois d'Arc Creek, the frequency of overbank events in the lower portion of Bois d'Arc Creek would be expected to increase.

Table 5.6 Comparison of Pulse and Overbank Events with Proposed Bypass During 1948 to 1998 Simulation Period

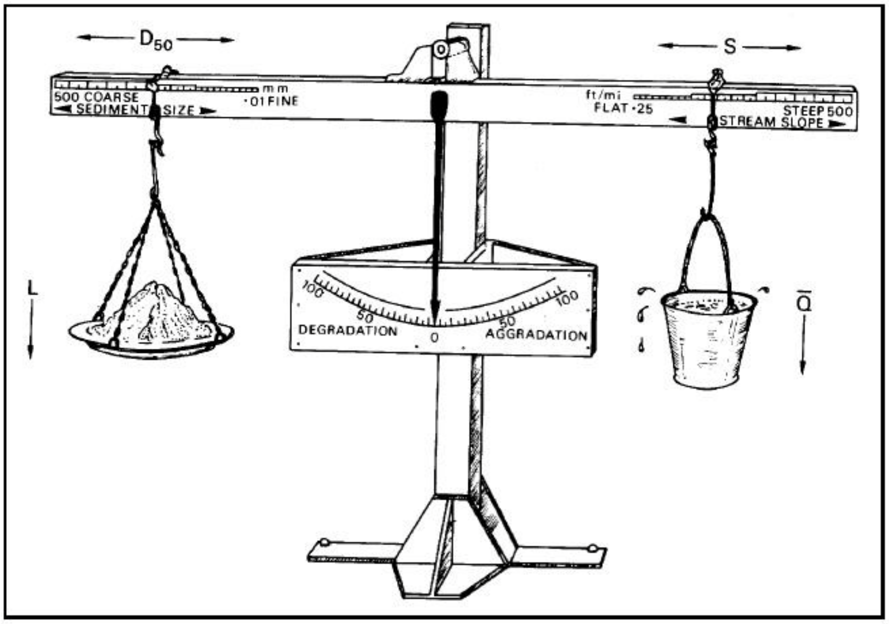
Location	Type of Event	Full Period	Nov-Mar	Apr-Jun	Jul-Oct
FM 409	Pulse	806	381	261	164
FM 100	Pulse	879	416	264	199
Lower Reach	Pulse	936	439	289	208
FM 409	Overbank	2	0	2	0
FM 100	Overbank	3	0	2	1
Lower Reach	Overbank	8	3	3	2

5.3.2 Fluvial Geomorphology

5.3.2.1 Stream Equilibrium and Channel Evolution

There is an important balance between the supply of bedload at the upstream end of a channel reach and the stream power available to transport it. This is known as the Lane's sediment balance. This balance is illustrated schematically by the scale shown in Figure 5.11.

Figure 5.11 Lane's Balance



Source: Chester C. Watson et al. 1999.

The left hand side of the scales represents the volume and size of sediment supplied to a channel reach over a given period of time. Balanced against this is the stream power available to transport it. This is determined by both the volume of water that enters the reach and by the slope over which it flows. The scale is in balance if the stream power is exactly sufficient to transport the sediment load, and therefore there is no net erosion or deposition along the reach. This does not mean that there is no erosion or deposition whatsoever within the reach, since these processes do occur at a localized scale in response to local variations in hydraulic condition. Instead it means that, on balance, neither erosion nor deposition will dominate. Over time, un-impacted streams tend toward an equilibrium condition between the water discharge and the sediment discharge.

An imbalance will occur if there is an increase in the volume of sediment load in relation to the available stream power. If the stream power is insufficient to transport all of the sediment in the reach, then the balance tips towards aggradation, with net deposition occurring along the reach. Aggradation occurs when sediment supply is increased by upstream channel erosion, mass movement, or human activities. Deposition in the channel may lead to the channel bed becoming elevated above the surface of the floodplain, and reduced channel capacity increases flooding and promotes channel migration (Charlton 2008).

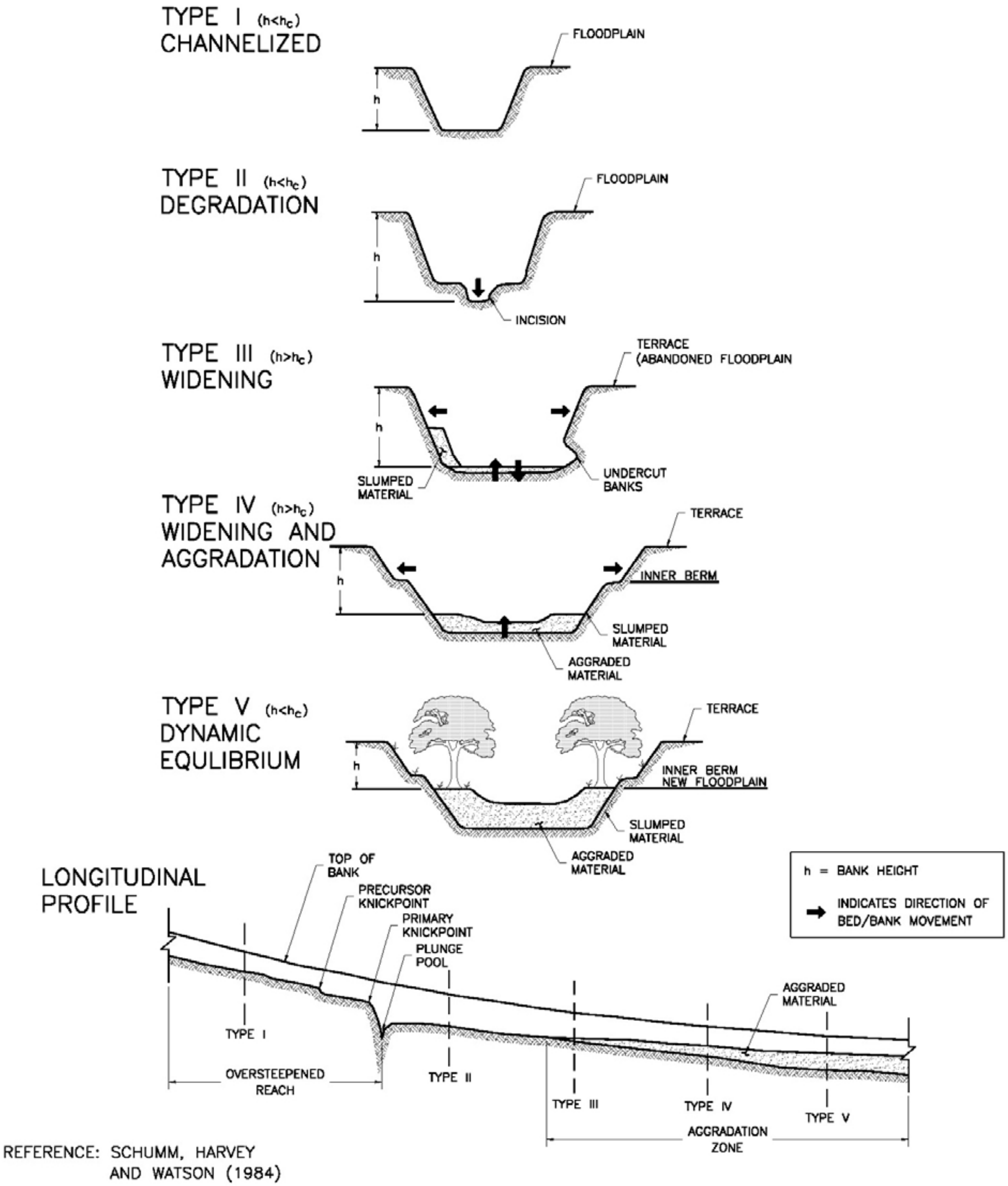
A different situation occurs when the stream power exceeds what is needed to transport the sediment load through the reach. This is the predominant factor that affects artificially straightened channels such as Bois d'Arc Creek. By straightening the channel, the reach is artificially shortened and the gradient is steepened as flow follows a shorter path. This in turn increases flow velocity and transport capacity. The excess energy has to be expended somehow, so it is used to entrain sediment from the bed and erode the banks. In this case degradation predominates. This degradation may promote bank collapse as the channel incises and thereby results in widening of the channel.

Linder (1976) stated, "Once disturbed, a stream channel begins an automatic and relentless process that culminates in its reaching a new state of equilibrium with nature. Reaching a new state of equilibrium may take decades, or even hundreds or thousands of years depending on local conditions and the level of disturbance. The new equilibrium may or may not have the characteristics similar to the stream's original state."

A change in the flow regime below the proposed dam would affect the relationship between stream power and sediment as described in Lane's balance. The reduction in high flow magnitude and frequency as a result of the proposed dam would effectively reduce stream power, therefore reducing the sediment transport capacity of the stream system. Chin et al. (2002) showed that a reduction of stream power in Yegua Creek downstream of Somerville Dam has caused a 61 percent decrease in channel depth from estimated pre-dam conditions as a result of reduced stream power. Similar changes in channel dimension have been observed on the Platte River in Nebraska (Williams 1978), Rio Grande River in Texas (International Boundary Condition 1959), Canadian River in Texas (Williams and Wolman 1984), and Sandstone Creek in Oklahoma (Bergman and Sullivan 1963). These changes in channel dimensions result from aggradation of sediment when carrying capacity is reduced, and from the establishment of vegetation on channel banks that is no longer removed by high magnitude flows. This situation represents an improvement over current conditions downstream of the proposed reservoir site, which are characterized by on-going erosion and downcutting in the reach.

Present and future conditions on Bois d'Arc Creek can be described by the channel evolution model shown as Figure 5.12. This model identifies the stages of channel form beginning with the channelized section, which disrupts the dynamic equilibrium, through major stages of disequilibrium and channel evolution back to a state of dynamic equilibrium. As shown, the channel incises then widens as a result of bank failure and mass wasting. As the channel becomes over-widened it will begin to aggrade (accumulate sediment) because the stream power will be insufficient to carry the existing sediment load. Eventually a new channel will form within the over-widened section with sufficient stream power to carry the total sediment supply and a new dynamic equilibrium will become established.

Figure 5.12 Incised Channel Evolution Model.



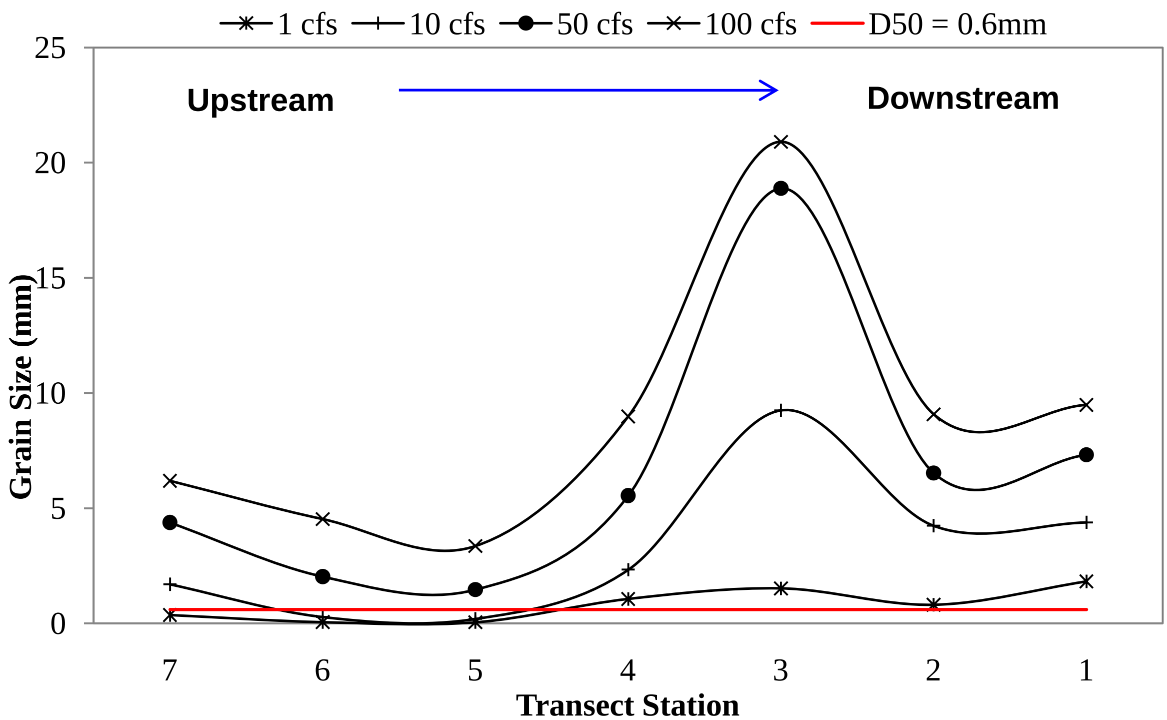
Currently, Bois d'Arc Creek exhibits conditions similar to Types II through IV as shown on Figure 5.12. The stream system has not begun to approach equilibrium, and may not do so for many years. By reducing stream power, the proposed flow regime is expected to speed up the processes by which the channel below the dam achieves equilibrium. With the upstream sediment supply to the lower reaches cut off by the reservoir, it is important that existing bedforms (e.g., gravel bars) be maintained. Replenishment of these bedforms will be dependant entirely on the Bois d'Arc Creek banks as well as tributaries and gullies downstream of the dam. Excessive high flow pulse releases from the proposed reservoir could exceed the capacity of these sources to contribute gravel for maintenance of these bedforms. The magnitude and frequency of proposed pulse flows is expected to balance the need to re-work and cleanse these channel features but not displace them at a rate exceeding the contribution of the bed materials that form them.

5.3.2.2 Predicted Geomorphological Conditions Downstream of Reservoir

Figure 5.13 shows the sediment transport capacity for flows of 1, 10, 50 and 100 cfs in the FM 409 study reach in Bois d' Arc Creek based on the results of the SAMWin hydraulic design model. The red line in the figure signifies the median grain size (D_{50}) of the subsurface sediment at the FM 409 study reach. According to the TIFP guidelines (2008), this grain size is generally thought to be the controlling influence on physical processes. The figure illustrates that a pulse flow of 50 cfs is approximately the minimum flow capable of transporting materials larger than the D_{50} through the entire study reach. Flows greater than 50 cfs would have increasingly greater capacity to transport larger sediment which would result in an increased potential to degrade the stream channel and habitat.

It is anticipated that sediment would be introduced to the channel from bank erosion downstream of the proposed dam to replace sediment lost from the system during the pulse flow releases. Additional sediment would be supplied from tributaries and ephemeral gullies, as well as overland flow, during precipitation driven flow events downstream of the proposed dam. However, it should be noted that the two main tributaries below the proposed dam are also impounded by Coffee Mill Lake dam and Crockett Lake dam, minimizing sediment contributions from these tributaries. The proposed pulse flow regime is expected to provide sufficient flows to benefit and maintain habitat and not cause erosion and channel degradation.

Figure 5.13 Results of the Incipient Motion Analysis Through the FM 409 Study Reach Using Four Different Flows



5.3.3 Water Quality with Proposed Instream Flow Regime

5.3.3.1 Qual-TX Water Quality Model

The proposed flow regime was evaluated using the Qual-TX water quality model to predict the effects of releases of water under varying conditions of flow and temperature. The TCEQ's waste load evaluation model (i.e., the Qual-TX input file developed to evaluate effluent limitations for POTWs in the Bois d'Arc Creek watershed) was modified by truncating the upper model reaches at the proposed dam site. The resulting model has 57 computational elements that begin at the confluence of Honey Grove Creek and Bois d'Arc Creek, 29 kilometers upstream from the mouth of Bois d'Arc Creek. The hydraulic coefficients, oxygen demand rates, and other model coefficients set by TCEQ were not modified.

The model was used to evaluate the impacts of the proposed flow regime on dissolved oxygen downstream of the dam. The applicable criteria for evaluation included 5.0 mg/L dissolved oxygen during all months of the year except the spring spawning season, April through June, which require 5.5 mg/L of dissolved oxygen to meet the high aquatic life use designation assigned by the TCEQ.

The water to be released from the dam was modeled by adjusting the headwater data cards in the model to reflect the proposed flows. The quality of the flows was adjusted for temperature and dissolved oxygen based on the expected stratification characteristics of the proposed reservoir as indicated by existing temperature and dissolved oxygen profile data from Lake Chapman and other North Texas reservoirs. The proposed reservoir would be designed with a multiple level intake structure to allow water to be selectively withdrawn from a depth that would not be likely to result in dissolved oxygen problems downstream.

It was assumed for modeling purposes that no aeration would result from the released water moving through the dam. However, a stilling basin or other energy dissipation system is proposed for the dam. Chanson (1995) demonstrated that, in addition to dissipating the kinetic energy of the water, significant gas exchange occurs in these types of systems. For this reason it can be assumed there would be higher initial dissolved oxygen concentrations in the released water than the Qual-TX model results indicate.

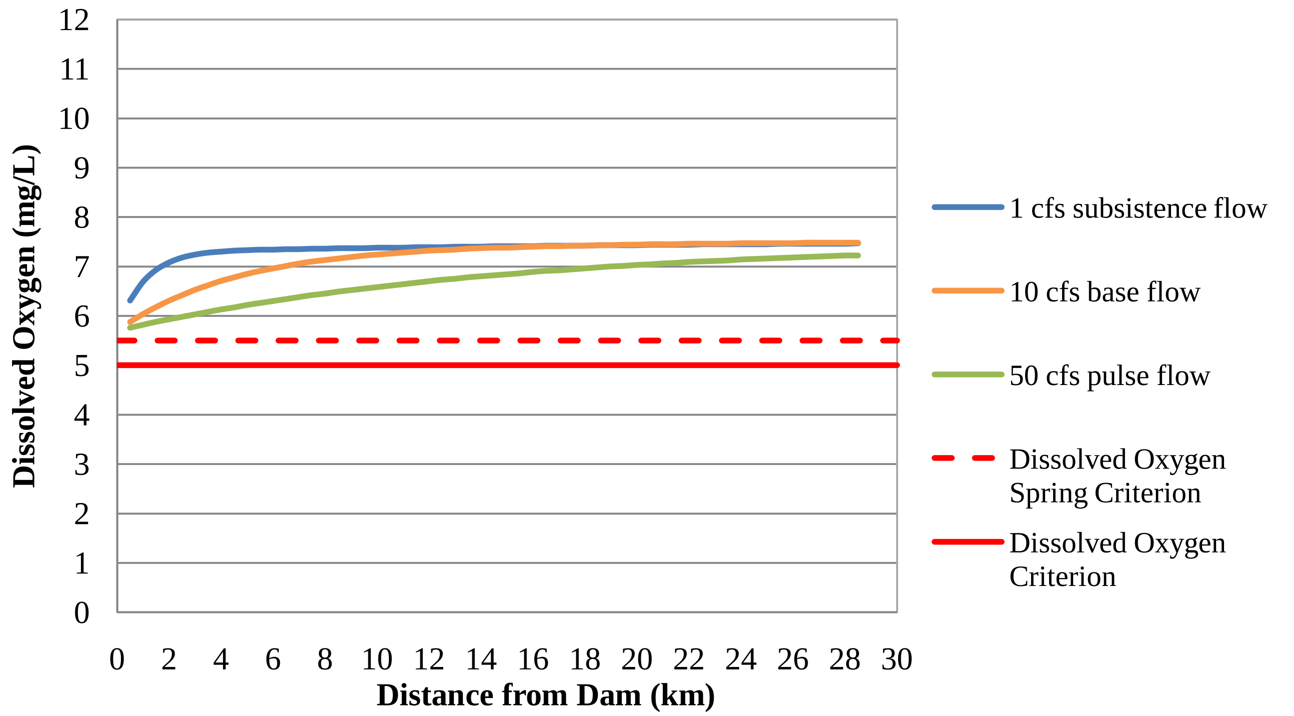
5.3.3.2 Water Quality Modeling Results for the Proposed Flow Regime

The proposed instream flow releases, including subsistence flow (1 cfs), base flows (3 cfs and 10 cfs), and pulse flow (50 cfs), were modeled based on the expected highest mean temperatures and lowest dissolved oxygen concentrations that were observed in the profile data from North Texas reservoirs.

For the April through June season, the proposed subsistence flow of 1 cfs, 10 cfs baseflow, and 50 cfs pulse flow were evaluated with Qual-TX. The initial input values for dissolved oxygen and water temperature for each of these proposed flows were 5.7 mg/L and 27.2°C, respectively. The Qual-TX model results show the minimum downstream dissolved oxygen concentration to be 5.82 mg/L as a result of releasing water from a reservoir depth between 1- and 20-feet (Figure 5.14). This meets the 5.5 mg/L criterion for the spring spawning period. Spring criteria are applied to protect fish spawning periods during that portion of the first half of the year when water temperatures are 17.2 to 22.8 °C.

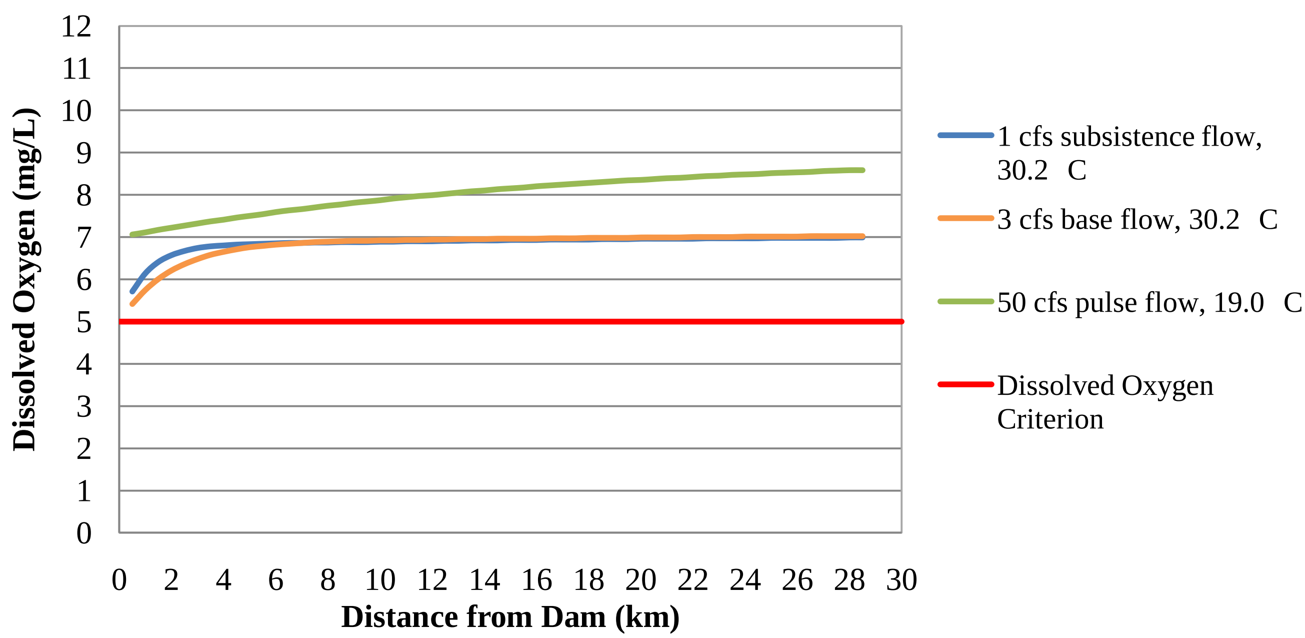
For the July through October season, the proposed 1 cfs subsistence flow and 3 cfs base flow were modeled. The initial input values for dissolved oxygen and water temperature for these flows were 5.0 mg/L and 30.2°C, respectively. In addition, the 50 cfs pulse flow event proposed for the month of October was modeled using a dissolved oxygen value of 7.0 mg/L and the water temperature value of 19°C as the initial input values (based on October lake profile statistics). The Qual-TX model results show the minimum downstream dissolved oxygen concentration to be 5.75 mg/L as a result of releasing water from a reservoir depth of 1-foot (Figure 5.15). This meets the 5 mg/L criterion for non-spawning periods. These results indicate that the proposed flow regime would

Figure 5.14 Predicted Dissolved Oxygen Concentrations in Bois d'Arc Creek Downstream of the Proposed Reservoir for April through June



Proposed Flow Releases at 27.2°C and 5.7mg/L Dissolved Oxygen

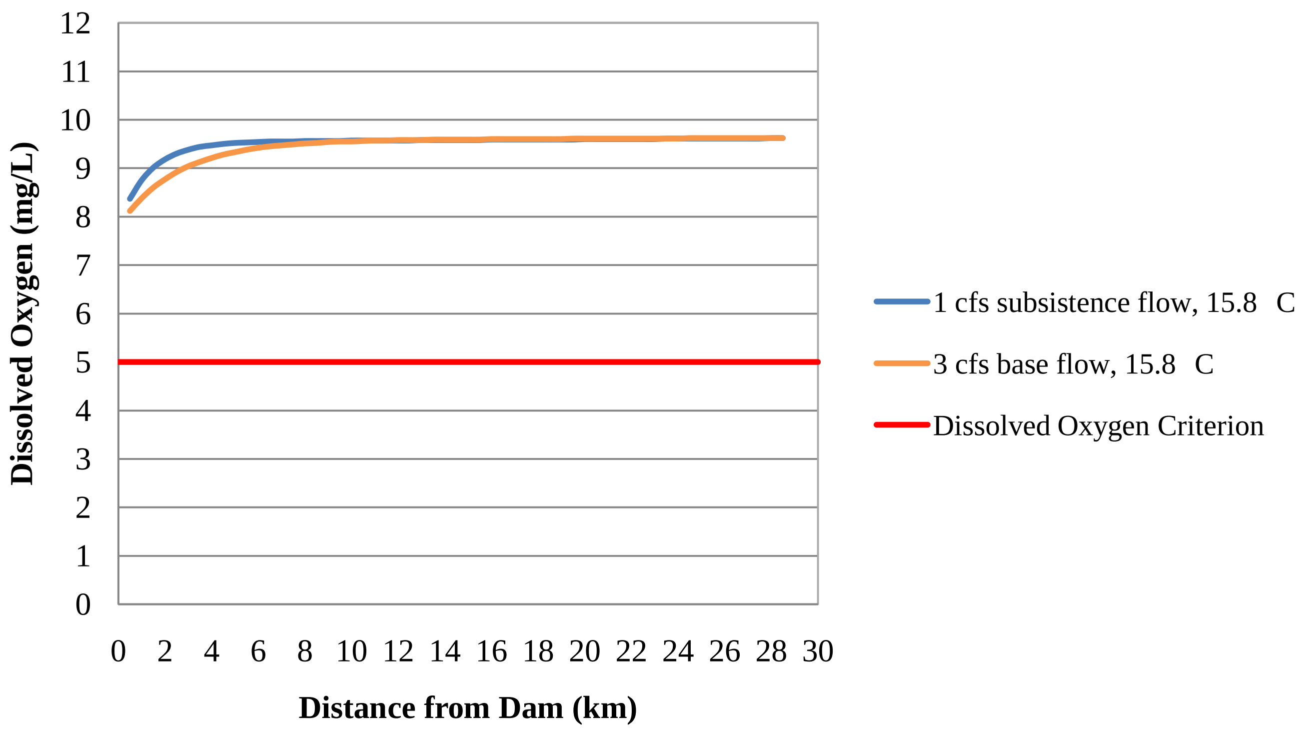
Figure 5.15 Predicted Dissolved Oxygen Concentrations in Bois d'Arc Creek Downstream of the Proposed Reservoir for July through October Proposed Flows



Subsistence and Base Flow Releases at 30.2°C and 5.0 mg/L Dissolved Oxygen, and October Pulse at 19°C and 7.0 mg/L Dissolved Oxygen provide dissolved oxygen levels necessary to support a sound ecological environment during the critical (i.e., warmest) months of the year, July and August.

For the November through March season, the proposed 1 cfs subsistence flow and 3 cfs baseflow were modeled. The initial input values for dissolved oxygen and water temperature for these proposed flows were 7.8 mg/L and 15.8 °C, respectively. The Qual-TX model results show the minimum downstream dissolved oxygen concentration to be 8.38 mg/L as a result of releasing water from reservoir depths ranging between 1- and 40-feet (Figure 5.16). This meets the 5 mg/L criterion for non-spawning periods.

Figure 5.16 Predicted Dissolved Oxygen Concentrations in Bois d'Arc Creek Downstream of the Proposed Reservoir for November through March Proposed Flows



Releases at 15.8°C and 7.8 mg/L Dissolved Oxygen

5.4 Impact on Reservoir Yield

Table 5.7 compares the firm yield of Lower Bois d'Arc Creek Reservoir with the proposed release criteria to other environmental flow criteria. The Consensus Criteria were used in the original application for the reservoir. Note that the yields using the monthly WAM model are about 1,500 acre-feet per year higher than the yield using the daily RiverWare model. Since the monthly total of the flows are identical in these two models, the primary difference is the use of the daily time step. The yield with the proposed release criteria is about 1,500 acre-feet per year less than the yield with the Consensus Criteria using the RiverWare model.

Table 5.7 Impact of Environmental Flows on Reservoir Yield

Model	Environmental Flow Criteria	Firm Yield (ac-ft/yr)
Red River WAM (FNI hydrology)	Consensus	126,280
RiverWare	None	125,907
RiverWare	Consensus	124,757
RiverWare	Proposed	123,309

6 MONITORING AND ADAPTIVE MANAGEMENT

The proposed conceptual monitoring program (described below) is based on the indicators used to quantify the baseline (current conditions) biological, chemical, physical, and hydrologic characteristics of the monitoring reach. The baseline study reach located upstream of FM 409 will be used for monitoring the effectiveness of the prescribed flow regime.

6.1 Monitoring

Detailed pre- and post-construction monitoring plans will be developed to measure representative stream system attributes that will quantify the success of environmental flow releases in supporting a "sound ecological environment," as defined previously in this report. Attributes that would be measured include: water quality, geomorphology, hydrology, and biology. Changes in the values of monitored parameters after construction of the dam will be assessed in consultation with the USACE (the lead permitting agency) and other resource agencies to determine if adjustments to the permitted instream flow regime are warranted to maintain a sound ecological environment.

6.1.1 Water Quality

Water quality will be recorded from the USGS gaging station located at the FM 409 bridge and quarterly at selected stations as part of the Red River Authority's Clean Rivers Program. Dissolved oxygen levels will continue to be monitored at the USGS gage at FM 409 to verify that the operation of the reservoir has not caused dissolved oxygen levels to drop below criteria (5.5 mg/L spring, 5.0 mg/L in the remainder of the year). In addition, water temperature, pH, and specific conductance will be measured continuously at the USGS gaging station as supplemental indicators of water quality and to allow detection of trends over time.

6.1.2 Geomorphology

Stream bank erosion rates will be quantified by measuring changes in cross-section area annually and changes in bank erosion pin exposure during the required biological monitoring period. This will be accomplished by establishing a permanent cross section in the FM 409 study reach Upstream of the bridge. Pre- and post-dam closure measurements will be made to compare channel cross-section changes before and after construction.

The composition of the stream bed and banks also will be used as an indicator of changes in stream character, channel form, hydraulics, erosion rates and sediment supply. This will be accomplished by making pebble counts and sediment grain size measurements at the stream cross-section established in the study reach at FM 409.

A photographic record will be established at the FM 409 monitoring cross-section by taking an upstream and downstream photograph on the annual sampling date. Photographs would be used to subjectively evaluate channel aggradation or degradation, bank erosion, and other visual stream characteristics in the monitoring reach.

Increased erosion rates, 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 resource agencies to determine if the permitted instream flow regime should be adjusted.

6.1.3 Hydrology:

Stream flow will be recorded from the USGS gaging station located at the FM 409 bridge. Compliance with the 50 cfs pulse flow criteria will be measured at this point. Base and subsistence flow criteria will be measured at the outlet works at the dam.

Observations will be made during field visits to document actual flow conditions at representative prescribed flows of 1, 3, 10, and 50 cfs. This will include instantaneous flow measurements using portable flow metering equipment and photographic documentation.

6.1.4 Biology

Aquatic integrity metrics were used to establish the baseline condition of Bois d'Arc Creek and the adjacent riparian zone, and they will be used as monitoring tools to assess impacts of the proposed Lower Bois d'Arc Creek Reservoir downstream of the proposed dam. Biological attributes will follow the protocols established during the instream flow study for the following:

- Fish community (IBI)
- Macroinvertebrate community (RBA)

Biological monitoring will be performed bi-annually for five years (i.e., in years 1, 3, and 5) following closure of the dam and then at 5-year intervals for 10 years (i.e., years 10 and 15). Monitoring will be conducted in the FM 409 instream flow study reach established by the current study. If the metrics show no statistically significant deviation from the baseline metrics, then monitoring will end.

6.2 Adaptive Management

If measured attributes and variables indicate that a sound ecological environment is not being maintained, then an interagency team of hydrologists, biologists, water quality experts, and geomorphologists will be convened to identify the cause of the problems and recommend solutions to the problems. This team would consist of the Tulsa District

USACE, other appropriate federal and state resource agency personnel, and representatives of NTMWD. Potential solutions would be suggested and after receiving appropriate approvals, the recommended actions would be implemented.

As part of the adaptive management process, the Reservoir Operation Plan would be subject to revision as demands and sources available to the NTMWD change. The Reservoir Operation Plan would have the goals of maintaining sufficient supply in the Lower Bois d'Arc Creek Reservoir to meet local demands and supply a constant release of 1cfs during a repeat of drought-of-record conditions. These goals would be evaluated using reservoir operation models similar to the RiverWare Model developed for this study.