ATTACHMENT B

TRINITY RIVER AND LAKE LIVINGSTON BIOLOGICAL CHARACTERIZATION FOR THE PROPOSED LAKE LIVINGSTON HYDROELECTRIC PROJECT – POLK, SAN JACINTO, TRINITY, AND WALKER COUNTIES, TEXAS

Trinity River and Lake Livingston
Biological Characterization for the Proposed
Lake Livingston Hydroelectric Project
Polk, San Jacinto, Trinity,
and Walker Counties, Texas

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TRINITY RIVER AND LAKE LIVINGSTON BIOLOGICAL CHARACTERIZATION FOR THE PROPOSED LAKE LIVINGSTON HYDROELECTRIC PROJECT POLK, SAN JACINTO, TRINITY, AND WALKER COUNTIES, TEXAS

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Acronyms and Abbreviations

°C	Celsius
°F	Fahrenheit
ADCP	Acoustic Doppler Current Profiler
cfs	cubic feet per second
CPUE	catch-per-unit-effort
DO	dissolved oxygen
EA	Environmental Assessment
ETEC	East Texas Electric Cooperative
FERC	Federal Energy Regulatory Commission
ft	feet
ft^2	square foot
ISS	inorganic suspended solids
LDOM	labile dissolved organic matter
LPOM	labile particulate organic matter
mg/L	milligrams per liter
mm	millimeters
NN	net night
RDOM	refractory dissolved organic matter
RPOM	refractory particulate organic matter
SH	State Highway
TCEQ	Texas Commission on Environmental Quality
TDSHS	Texas Department of State Health Services
TOC	total organic carbon
TPWD	Texas Parks and Wildlife Department
TRA	Trinity River Authority
TSS	total suspended solids
US	U.S. Highway
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VSS	volatile suspended solids
Wr	weight ratio
WSC	wind sheltering coefficient

1.0 INTRODUCTION

This report presents the results of the study that was described in the “Trinity River and Lake Livingston Biological Characterization Study Plan, Lake Livingston Hydroelectric Project” (Study Plan) that was submitted to the Federal Energy Regulatory Commission (FERC), Texas Parks and Wildlife Department (TPWD), Texas Commission on Environmental Quality (TCEQ), and the U.S. Fish and Wildlife Service (USFWS) by the East Texas Electric Cooperative (ETEC). The purpose of the study was to characterize the aquatic community in the vicinity of the proposed Lake Livingston Dam Hydroelectric Project (Project) and address specific concerns identified by the agencies regarding possible project impacts. This report supplements the project Environmental Assessment (EA). Discussions regarding possible project impacts will be provided in the EA.

The ETEC proposes to construct the hydroelectric generating station adjacent to the dam on the east shore of Lake Livingston. The facility would use the existing flow from the reservoir to generate electricity. Presently, discharge from the reservoir is through tainter gates on the dam, which release water from 30 feet (ft) below the surface. There are 12 tainter gates and each gate is 40 ft wide.

Water is presently discharged from the reservoir at a depth of approximately 30 ft through one or more of the 12 gates on the dam. Releases of 1,000 cubic ft per second (cfs) or less are discharged through gate 6, which is near the center of the tainter gates. As flow increases above 1,000 cfs, adjacent gates are opened approximately 1 ft at a time. When flow reaches 12,000 cfs, all 12 gates are open approximately 1 ft at a depth of 30 ft. When flows exceed 12,000 cfs, gate 6 and adjacent gates are opened an additional foot until the desired flow is achieved. Lake Livingston is operated as a water supply reservoir, with a normal operating pool of approximately 131 ft mean sea level. Therefore dam releases approximate flow into the reservoir. With the exception of local runoff, all of the flow in the river below Lake Livingston Dam in the study reach results from reservoir discharges.

A tailwater control weir dam (weir) was constructed across the river channel, approximately 400 ft downstream of the tainter gates (Figure 1-1) to prevent further erosion and scouring in the spillway channel below the dam that had occurred during flood flows. The weir reestablished the evaluation of the downstream tailwater that had been diminished by scouring and erosion of the river channel below the stilling basin. It raised the tailwater elevation in order to get the hydraulic jump back into the spillway area. The weir is approximately 9 ft tall, 760 ft wide, and made of sheet pile with rip-rap armoring on the downstream side. The weir slows water movement through the stilling basin into the river below the weir. There is a rectangular notch in the center of the weir that is 10 ft wide and 6 ft deep. With the exception of water flowing through the notch, water flow appears to be relatively uniform across the entire width of the weir. Under low flow conditions, a relatively large proportion of the reservoir release flows through the notch in the weir. As reservoir releases increase, a greater proportion of the flow is widely distributed over the width of the weir.

The project will use up to 5,500 cfs. When reservoir releases need to exceed 5,500 cfs, the flows exceeding this amount will be released through the existing gates at the dam. When reservoir releases are less than 5,500 cfs, the majority of the reservoir releases will pass through the hydropower project and a small portion will be released through the existing tainter gates. The release of water used for electric generation will come from depths ranging from the surface to approximately 15 ft below the surface. Discharge would flow through a headrace, bar screens, penstock, turbines, and then to the east shore of the Trinity River immediately downstream of the weir.

Water Quality Segment 0803, Lake Livingston, and Segment 0802, Trinity River below Lake Livingston, have high aquatic life use designations, daily average dissolved oxygen (DO) criteria of 5.0 milligrams per liter (mg/L), and maximum temperature criteria of 93 degrees Fahrenheit (°F) (33.9 degrees Celsius [°C]) (TCEQ, 2008a). The 2008 Texas Water Quality Inventory indicates there are no impairments of the designated high aquatic life use, DO, or temperature criteria in these waterbodies (TCEQ, 2008b).

During summer months, Lake Livingston may vertically stratify at times with reduced DO and lower temperatures near the bottom. During the remainder of the year, the reservoir is usually vertically mixed. Surface waters proposed for use by the hydroelectric facility typically have higher DO and temperatures compared to bottom waters, particularly during the late summer.

Lake Livingston was constructed for downstream water supply. Boating, swimming, and fishing are important secondary uses of the reservoir. The Trinity River downstream of Lake Livingston supports a valuable recreational fishery and limited commercial fishing is allowed in the river. Lake Livingston and the Trinity River downstream of Lake Livingston are critical to the TPWD's striped bass (*Morone saxatilis*) stocking program. Striped bass are stocked as juveniles in the reservoir and eventually pass downstream through the tainter gates. Many of these fish reside in the river immediately downstream of the dam. The TPWD obtains adult striped bass downstream of the dam for brood fish. Brood fish are collected during the spring and transported to hatcheries for spawning. Offspring of these fish are stocked in various waterbodies throughout the state.

In addition to the passage of striped bass through the tainter gates, other important species are discharged downstream as well. Although previously not studied, passage of forage fish through the tainter gates is believed to be important for supporting striped bass and other predators that congregate downstream of the dam. Most fish are believed to survive passage through the tainter gates. Depending on flow and other variables, fish may disperse downstream of the dam into the river. However, numerous large fish are believed to remain between the weir and Lake Livingston Dam.

A number of meetings were held with natural resource agencies, which included the TPWD, TCEQ, USFWS, and U.S. Army Corps of Engineers (USACE) to obtain recommendations on study design and identify concerns about possible effects of the project on the aquatic communities. A preliminary sampling plan was developed and disseminated among the agencies for review. The agencies provided comments and also identified specific issues of concern.

1. Temperate change (TCEQ and USFWS)
2. Dissolved oxygen change (TPWD, TCEQ, USACE, and USFWS)
3. Striped bass broodfish collection below Lake Livingston Dam (TPWD and USACE)
4. Habitat impacts on fish (particularly American eel) and other aquatic species (USFWS)
5. Impacts on paddlefish (TCEQ Region 10 and USFWS Trinity River National Wildlife Refuge)
6. Endangered and threatened species (TPWD, USACE, and USFWS)
7. Water quality – siltation and blockage of nutrients by Lake Livingston Dam (USFWS Trinity River National Wildlife Refuge)

A final study was developed to incorporate agency comments and was later modified to include additional studies to address specific concerns (see Appendix). Limited modifications were made as necessary to adapt to field conditions. Changes in objectives and methods that deviated from those described in the Study Plan are presented in this report. In addition, the need to document the distribution of the American eel (*Anguilla rostrata*) was identified when the study was nearing completion. The methods for this study were not included in the Study Plan, but are included in this report.

The following sections present a summary of results. In addition, due to the broad scope of the study and extensive data sets, the raw data (Microsoft Access format) are available electronically. Discussion of the results with respect to the specific issues of concern will be provided in a supplemental report, and the alternatives for resolving potential adverse impacts of the project will be provided in the EA.

Figure 1-1

Lake Livingston Dam and Weir
Livingston Dam Hydroelectric Project

2.0 BASELINE SAMPLING RESULTS

This section presents an overview of the Trinity River and Lake Livingston sample locations and the results of the baseline survey as described in the Study Plan. Where the sampling approaches differed from the Study Plan, the modifications are described in this document.

Eleven miles of the Trinity River, from Lake Livingston Dam downstream to U.S. Highway 59 (US 59), was included in the study and was divided into five sampling reaches (Figure 2-1). The sample reaches generally correspond to the different habitats along this reach of the river. The sampling methods common among the reaches were boat electrofishing, gill netting, and seining (Table 2-1).

2.1 TRINITY RIVER STUDY REACHES

Reach 1: With the exception of samples taken from the stilling basin for gut-content analysis, all biological sampling was downstream of the weir. The river in this 2,500-ft-long reach is relatively shallow with boulder, cobble, gravel, and sand substrates. Velocity is relatively high in the main river channel and water level and flows are highly influenced by releases from the reservoir (Figure 2-2). This reach also included the man-made channel that drains the outlet works (draw-down tube). There is little available habitat in the channel when the flow is low. Substrate in this area consists of sand and silt.

A YSI 600XLM continuous-recording multiparameter water quality instrument (meter) equipped with optical dissolved oxygen probes was stationed upstream of the weir from May 1, 2008, to October 20, 2008. Backpack electrofishing was employed immediately downstream of the weir when flows were low. In addition, American eel (eel) traps were set in this reach along the rip-rap of the weir and among the boulders at the drawn-down tube during the last sample event.

Reach 2: The riverbed along this reach has no sinuosity and is deeply incised with clay and sand banks. The velocity was low and the substrates consist of silt, sand, and gravel. Available cover was sparse and consisted of submerged trees and brush (Figure 2-3).

Reach 3: This reach of river has moderate sinuosity and velocities. The substrate consisted of sand and clay. Sand bars and submerged trees and brush are common along this reach (Figure 2-4).

Reach 4: This reach is dominated by rock/boulder outcrops, particularly along the west shore and in the river channel. Submerged trees and brush are common and boulder/cobble/gravel riffles were present (Figure 2-5). Eel traps were placed among the rock/boulder habitats during the last sample event.

Reach 5: This reach consisted of deeply incised banks with sand and silt substrates with scattered rock/boulder outcrops. There is low channel sinuosity and in-stream cover is sparse, but consisted of submerged trees and brush (Figure 2-6). Long King Creek drains into the left bank of the river at the lower end of Reach 5, approximately 100 m upstream of US 59. Eel traps were placed in Long King Creek near the confluence of the river during the last sample event.

2.2 LAKE LIVINGSTON SAMPLE STATIONS

Four locations were sampled in Lake Livingston in the vicinity of the dam and the proposed project (Figure 2-1).

L1: This station was along the dam, east of the tainter gates and included the rip-rap armoring of the dam. Sampling depths ranged from 0 to 5 ft. Electrofishing was conducted for a distance of 300 ft along the rip-rap.

L2: This station was in open water, approximately 500 ft upstream of the tainter gates on the dam. The depths in this area range from 20 to 52 ft. The reservoir bottom is bottom relatively flat and the substrate consists of silt with no physical cover. This station was sampled with gill nets and paired-frame trawls. Three continuous recording water quality meters were deployed in a vertical profile at this station from March 20–October 20, 2008. The meters were positioned at depths of 4, 29, and 50 ft from the surface.

L3: This station was in open water approximately 0.6 mile upstream from the tainter gates on the dam. The depths in this area ranged from 32 to 67 ft. The bottom is relatively flat and the substrate consists of silt with no physical cover. This station was sampled with paired-frame trawls.

L4: This station was in open water and approximately 100 ft from the proposed headrace. The depth ranged from approximately 5 to 30 ft. The reservoir bottom has a gentle slope and the substrate consists of clay and silt. There was no physical cover in the vicinity of the station. This station was sampled with gill nets and a paired-frame trawl. One continuous-recording water quality meter was deployed at this location at a depth of approximately 5 ft from the surface from March 20–October 20, 2008.

2.3 SAMPLE PERIODS

Sample events were conducted during each of the four different seasons and included the critical and index periods defined by the TCEQ. When biological assessments are made in freshwater streams with two samples collected in a year, the TCEQ recommends collection of one sample within the index period (March 15 through October 15) and a second sample within the critical period (July 1 through September 30) (TCEQ, 2007).

The first sample event was during the fall from December 3 to December 6, 2007. Water temperatures ranged from 10.5°C to 16.6°C and air temperatures dropped below 0°C during the early morning. Flow from Lake Livingston was 4,000 cfs when sampling began and lowered to 1,000 cfs by the end of the sample event. Reservoir release peaked at 8,000 cfs on November 25, 2007, due to localized heavy rainfall. Otherwise, flows had been relatively stable and low for the 30 days preceding the sample event.

Winter sampling was conducted from February 25–28, 2008. Water temperatures ranged from 12.2°C to 14.2°C. Flow from the reservoir was 3,000 cfs at the beginning of the sampling event and was reduced to

2,000 cfs by the end of the sampling event. This sample event was preceded approximately 2 weeks earlier by high-flow that peaked at 33,900 cfs on February 17, 2008.

DIDSON high definition sonar data of fish moving from Lake Livingston to the Trinity River were collected from March 25 through March 27, 2008, to ensure fish passage data were collected during high flows in addition to the quarterly sampling with DIDSON in February, April, and August. No other data were collected during the March sample event.

The spring sampling was conducted from April 28–May 1, 2008. This sample was within the TCEQ's index period. Water temperatures ranged from 20.0°C to 24.0°C and flow from the reservoir was 14,000 cfs. Prior to the sample event, flow increased to 10,000 cfs on March 8 and continued to rise to 30,900 cfs on April 1 and remained at that level until April 9.

The summer sample event was from August 18–22, 2008. This sample was within the TCEQ's critical period. Water temperatures ranged from 26.9°C to 29.5°C. The reservoir release was constant at 1,000 cfs during sampling and ranged from 1,000–1,250 cfs for the 30 days preceding the sample event.

2.4 FISH SURVEY RESULTS

Fifty-five species of fish were collected from Lake Livingston and the Trinity River downstream of Lake Livingston (Table 2-2). In addition, four taxa of crustacea were collected with fish sampling gear including blue crab (*Callinectes sapidus*), crayfish (Cambaridae), prawn (*Macrobrachium ohione*), and grass shrimp (*Palaemonetes*).

Twenty-six species of fish were collected in Lake Livingston. Two species, tadpole madtom (*Noturus gyrinus*) and redear sunfish (*Lepomis microlophus*), were collected only in the reservoir. Thirteen fish species were collected from the reservoir and each of the Trinity River reaches. These included the sport fish, striped bass, white bass (*M. chrysops*), blue catfish (*Ictalurus furcatus*), channel catfish (*I. punctatus*), and largemouth bass (*Micropterus salmoides*).

2.4.1 Trinity River

Tables 2-3 through 2-6 summarize fish-sampling from the Trinity River. The minimum, maximum, and mean lengths by species are provided in Table 2-7. Threadfin shad (*Dorosoma petenense*) and red shiner (*Cyprinella lutrensis*) were among the most common species collected from the river. Forty-five fish species, the highest taxa richness among the sample reaches, were collected from Reach 1 (Table 2-2). Bowfin (*Amia calva*), logperch (*Percina caprodes*), and an unidentified darter species were collected in Reach 1 and not any other sample station. This richness might have been due to the shallow depths and abundant rock habitats downstream of the weir, which improved sampling efficiency when compared to the deeper water in the downstream reaches. In addition, the weir and Lake Livingston Dam present barriers to upstream movement; therefore, many species tend to congregate in that area.

Three nongame, exotic species were collected downstream of the dam. These were common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), and goldfish (*Carassius auratus*). Several estuarine species were collected in the river. These included skipjack herring (*Alosa chrysochloris*), striped mullet (*Mugil cephalus*), hogchoker (*Trinectes maculatus*), and blue crab.

2.4.1.1 Trinity River Electrofishing

Forty-three species were collected by boat electrofishing with the greatest number of taxa during each sample event usually collected from Reach 1 and Reach 2 (see Table 2-3). The February 2008 sample event was an exception when the fewest species electrofished were collected in Reach 1. Threadfin shad was the most abundant species and was collected in higher numbers by boat electrofishing than any other species. The average catch-per-unit-effort (CPUE) was 2,017/hour (hr) with the highest CPUE, 13,896/hr, during the April sample event. With the exception of the August sample event, more threadfin shad were observed than were represented in samples because of the difficulty in netting all fish when large numbers are stunned at the same time. In some instances, only a small number of threadfin shad, relative to those electrofished, were collected. During the August sample event, the abundance of threadfin shad decreased substantially from the previous events, which was likely related to the prolonged reduced flow from the reservoir and excessive predation by striped bass and other predators.

The boat electrofishing CPUEs for striped bass, smallmouth buffalo (*Ictiobus bubalus*), blue catfish, and gar (*Lepisosteus* spp.) were greatly underestimated for Reach 1. Exceptionally high densities of fish congregate immediately downstream of the weir and are vulnerable to electrofishing. Collection of large numbers of large fish was very difficult because the high number of fish stunned at the same time combined with the swift current that swept stunned fish out of reach of the netters. Additionally, netting of large numbers of large fish would have resulted in unnecessary mortality. Therefore, only limited electrofishing was performed near the weir.

With respect to season, the highest electrofishing CPUE was in April at 6,150/hr and the lowest was in February at 234/hr. However, the high CPUE in April was skewed by the large number of threadfin shad. Excluding threadfin shad, the average CPUE among the reaches for April was 340/hr.

2.4.1.2 Trinity River Gill Netting

Twenty-five species were collected with gill nets from the Trinity River (see Table 2-4). Blue catfish and smallmouth buffalo were the most commonly collected species. The highest numbers and diversity of fish were collected in Reach 1, followed by Reach 2 except during the August sample event when the greatest taxa richness in gill nets was observed in Reach 4. The CPUE (number/net night [NN]) for Reach 1 varied from 47 to 186. The gill net CPUE for Reach 1 did not adequately reflect the density of fish downstream of the weir because the net would quickly fill with fish (primarily smallmouth buffalo) and would twist in the currents, reducing collection efficiency. The lowest CPUE was from Reach 5, which ranged from 7 to 16/NN. With respect to season, the highest mean number of fish collected in gill nets was in December at 60/NN and the lowest was in August at 25/NN.

2.4.1.3 Trinity River Seining

Thirty-nine fish species were collected by seining (see Table 2-5). The highest concentrations of fish collected by seining were from Reach 5 during each sample event and the highest numbers of species were collected in Reach 5 during three of the four sample events. Red shiner, inland silverside (*Menidia beryllina*), bullhead minnow (*Pimephales vigilax*), and threadfin shad were the most common species collected by seining. Ribbon shiner (*Lythrurus fumeus*), blackstripe topminnow (*Fundulus notatus*), redspotted sunfish (*Lepomis miniatus*), and hogchoker were collected only in Reach 5, but were not collected frequently or in high numbers. With respect to season, the highest numbers of fish were collected during the April sample event.

2.4.1.4 Trinity River Backpack Electrofishing

The cobble/gravel riffles downstream of the weir and the rip-rap armor on the downstream side of the weir were sampled with a backpack electrofisher during the December 2007, February 2008, and August 2008 sample events (see Table 2-6). Flows were too high during the April sample event to safely wade in the river in Reach 1 and backpack electrofishing was not conducted. Twelve fish species were collected by backpack electrofishing with inland silverside and red shiner collected in the highest numbers. However, prawn were exceptionally abundant during each sample event along the rip-rap armoring of the weir. The lowest numbers and fewest species were collected with the backpack electrofisher during the August sample event. At this time, there was an apparent scarcity of smaller fish in Reach 1, particularly immediately downstream of the weir. As previously discussed, this was likely the result of the lower flows from the reservoir and intensive predation by striped bass and blue catfish. It is important to note that numerous striped bass and smallmouth buffalo could have been collected with the backpack electrofisher, especially during the August sample event, when the flows were the lowest during the study. Large numbers of fish were crowded in shallow water downstream of the weir; however, an effort was not made to collect those fish.

2.4.2 Lake Livingston Fish Community

Tables 2-8 through 2-11 summarize results of fish sampling in Lake Livingston. Table 2-12 summarizes the total length data for fish collected from the reservoir. Since the reservoir is routinely monitored by the TPWD, the sampling focused on characterizing fish communities in the vicinity of the tainter gates (existing discharge location) and the area near the proposed headrace and rather than characterizing the fish community for the entire reservoir. Sample methods were designed to collect data that would help understand how downstream movement might be altered by the design and operation of the facility and whether management actions might be needed ensure the downstream movement of certain species. Additional supporting studies were conducted and are described in later sections.

2.4.2.1 Lake Livingston Dam Electrofishing

Boat electrofishing was conducted along the rip-rap armor of the east end of the dam (L1) to characterize the shoreline fish community adjacent to the proposed headrace. A total of 18 species were collected in the four sample events (see Table 2-8). Boat electrofishing methods in this area were quantitative with a 300-ft reach of shoreline sampled. The reach was sampled in both directions multiple times until few or no more fish were collected. The width of the sampling zone was estimated to extend from the shoreline into the reservoir a distance of 15 ft. Results are expressed as number of fish per square foot (ft^2). This electrofishing method differs from TPWD methods which usually involve electrofishing for a fixed time period.

Inland silverside was the most numerous species collected. During the August sample event, small (Age-0) inland silverside were exceptionally abundant and only a few of the fish were collected. It was estimated that approximately 10,000 inland silverside were observed, but not collected. Longear sunfish (*L. megalotis*) and bluegill (*L. macrochirus*) were the next most abundant species. Recreationally important species common to the reservoir, such as largemouth bass, white bass, channel catfish, crappie, and blue catfish were generally uncommon in samples along the dam. The majority of individuals collected were believed to be residents of the rip-rap armor. Some of the larger species probably use the dam intermittently for feeding.

2.4.2.2 Lake Livingston Gill Netting

Gill net sets in the reservoir were designed to help compare the spatial and temporal differences in numbers and species of fish between the existing discharge location through the tainter gates and the proposed discharge location through the facility headrace. It is important to note that gill nets are used for collecting larger individuals and are not effective for collecting small (e.g., <3 inches in length) fish. Fifteen species of fish were collected with gill nets (see Table 2-9). Gizzard shad (*Dorosoma cepedianum*), common carp, white bass, smallmouth buffalo, and blue catfish were the most common species collected. Blue catfish was the only species collected in every sample.

With respect to the difference between L4 and L2, the CPUE and number of species was higher during each sample event at L4 than at either depth at L2 (see Table 2-9). Considering all species collected and all sample events, the proportion of fish at L4 was over three times higher than the surface sample and five times higher than the 30-ft sample at L2. This difference was probably due to habitat differences since L4 includes littoral and open-water habitats and is in the transition area where the natural shoreline converges with the rip-rap of the dam. Conversely, L2 was in open water, relatively far from the shore and any other type of structure or fish cover.

With respect to depth at L2, the mean CPUE was over two times higher for all species at the surface than at 30 ft. The exceptions to this were smallmouth buffalo and common carp, which had higher CPUEs at 30 ft. CPUE and species varied seasonally among sample events, although the differences in species composition were marginal. The highest CPUE for all stations was during the April sample event and the lowest was during the August sample event.

Striped bass were common in gill nets during the February and April sample events, but were not present during the August sample event and only one was collected during the December sample event. Although sample sizes were small, striped bass were more common at L4 and at L2 at the surface than at L2 at a depth of 30 ft. Blue catfish were also much more common at L4 and L2 near the surface than at L2 at a depth of 30 ft. Blue catfish appeared to be common throughout the year near the dam.

2.4.2.3 Lake Livingston Paired-Frame Trawls

Paired-frame trawls (trawl) were used to sample smaller fish at selected depths in the water column. Trawling is the preferred method for quantifying threadfin shad and smaller gizzard shad (Boxrucker, 1995; Michaletz et al., 1995), but are also effective for sampling other species generally <10 inches long that are susceptible to collection by the trawls and that occur in open water. L3 was located in the main body of the reservoir and was used as a reference station.

Samples were collected at different depths to compare vertical differences in fish densities. The depth of the samples reported was for the mid-depth (center) of the trawl. Due to the relatively shallow depths at L4, two trawls were made during each sample event, one near the surface and one at a depth near the bottom, which ranged from 10 to 21 ft depending on the exact starting location during each sample event. For L2 and L3, three depths were sampled. The goal was to sample near the surface, 30 ft (depth of the existing reservoir release), and 15 ft (midpoint between the surface and 30 ft). While the surface trawl was consistent among the sample events, there was considerable variability among the depths of the other trawls, which confounded attempts to quantify the differences between catch at different depths below the surface.

Seven species were collected in trawls over the course of the study (see Table 2-10). Threadfin shad were the most numerous fish collected and were in each sample. One point of interest was the presence of juvenile (Age-0) blue catfish in the December trawls. These individuals ranged in length from approximately 3 to 5 inches. Blue catfish are generally associated with littoral habitats; however, these results indicate a substantial number of these fish may be feeding in the water column on plankton during the winter. As a result, these fish are probably susceptible to entrainment in reservoir releases during winter, resulting in their passage downstream during this period.

Considering all stations, depths, and sample events, the mean threadfin shad density was 190/acre-ft. The highest density of threadfin shad was during the August sample event at 473/acre-ft, which was over four times higher than the other sample events (see Table 2-11). This difference was expected since shad densities are generally highest in the late summer and fall, following spring and summer spawning. As observed in this study, shad densities are generally lowest in the spring, before spawning begins.

With respect to location, surface densities were consistently higher at L4 compared to the surface at L2. Figure 2-7 illustrates threadfin shad densities by sample event, station, and depth. Three of the four sample events included trawls close to the depth of water release from the reservoir at L2. In December and April, the densities of threadfin shad were lower at L2 near the depth of discharge than at the surface or mid-depth at the same station. However, in August, the density was higher at L2 at this depth than in the surface and mid-depth samples.

Threadfin shad length-frequency indicates that a single cohort (Age-0) with a peak length frequency at 80 millimeters (mm) was present during the December 2007 sample event (Figure 2-8). Threadfin shad lengths did not increase appreciably through the April sample event, suggesting that growth was slow during the winter. In addition, it appeared that spawning had not occurred or that if spawning had occurred, that the newly spawned cohort had not recruited to a size susceptible to trawl collection at this time. The length-frequency distribution for August represents the 2008 cohort, in which the mode of length-frequency was 55 mm. The data also show a significant reduction in Age-1 (2007 cohort) threadfin shad, which indicates that most threadfin shad survive (or possibly reside in the reservoir) for <1 year. The length of the remaining Age-1 individuals in August exceeded 78 mm.

2.4.3 Important Fish Species

"Important species" for purposes of this report include (a) commercially or recreationally valuable; (b) threatened or endangered; (c) critical to the survival of a species satisfying criteria (a) or (b); (d) critical to the structure and function of the ecological system, or (e) biological indicators. There are several species that meet the first definition, but have varying degrees of recreational or commercial value. Among these, striped bass may be the most important since the Lake Livingston/Trinity River (downstream of Lake Livingston) population is the main source of brood fish for the TPWD striped bass stocking program. In addition, striped bass appear to be the most sought-after recreational species in the study area. As indicated in the study results, striped bass are abundant during all seasons downstream of the dam.

Blue catfish are also an important recreational species in addition to being sought by a limited number of commercial anglers. Other species, including channel catfish, white bass (*M. chrysops*), crappie (*Pomoxis* spp.), and spotted bass (*M. punctulatus*) are sought by anglers downstream of the dam, but appear to be less abundant than striped bass or blue catfish.

Results of this study indicate threadfin shad are important forage for predatory species, particularly striped bass and blue catfish (see Section 3.1). As described in Section 3.2, it appears that relatively high numbers of threadfin shad move downstream from the reservoir which is probably one reason predatory species congregate in high densities in Reach 1.

There are no federally listed threatened or endangered species in the Trinity River. However, paddlefish (*Polyodon spathula*), which is a state-listed threatened species, were reintroduced to Lake Livingston through a stocking program in the 1990s. While the stocking program apparently failed to establish a reproducing population, some of the stocked paddlefish remain in the Trinity River basin (TPWD, 2008).

Some of the paddlefish moved downstream (through the tainter gates) and are in the lower Trinity River. A total of three paddlefish were collected in Reach 1 and 2 during three of the sample events. In addition, at least two additional paddlefish were observed, but not collected while electrofishing in Reach 1. Anecdotal reports by anglers suggest paddlefish are periodically seen downstream of the dam.

American eel do not meet the definition of important species in Texas. All American eel are considered part of one, panmictic, population extending from northern Venezuela along the Gulf of Mexico and Atlantic coasts to northern Canada. Their life history involves migration of adults from the entire range to the Sargasso Sea where they reproduce and young eels are delivered to estuaries by ocean currents. Commercial harvest of eels shows a decline in numbers over the past two decades but there does not appear to be significant changes in recruitment of juvenile eels. Recent declines in commercial harvest, combined with the understanding that all eels belong to the same population, have raised the question of whether the American eel should be a protected species. After a thorough review of all available scientific and commercial harvest information, the USFWS concluded it was not necessary to list American eel as a threatened or endangered species (USFWS, 2007).

2.5 BENTHIC MACROINVERTEBRATE COMMUNITY SURVEYS

Kick-net samples for benthic macroinvertebrates were collected from gravel-cobble riffles during the December 2007, February 2008, and August 2008 sample events (Table 2-13). Samples were not collected during the April 2008 sample event because flows exceeded 14,000 cfs and all gravel-cobble riffles were submerged by 3 to 10 ft of water. Reach 1 was sampled for benthic macroinvertebrates each time, Reach 2 was sampled in December 2007 and February 2008 and Reach 4 was sampled in August 2008. Twenty-two taxa of benthic macroinvertebrates were collected. Samples with the highest diversity and numbers of individuals were collected during August when the flow was approximately 1,000 cfs. The lowest numbers and taxonomic diversity were from samples collected in February. High flows prior to this sample event probably scoured the substrate and reduced benthic diversity and abundance in the February sample.

Live and recently deceased freshwater mussels were collected during the February, April, and August 2008 sampling events. Most mussels were observed during the February and August 2008 sample events when flows were relatively low. The fragile papershell (*Leptodea fragilis*) and the southern mapleleaf (*Quadrula apiculata*) were common in reaches 2, 3, and 4. The exotic Asiatic clam (*Corbicula fluminea*) was common in Reach 1 below the stilling basin. A recent dead specimen of the western pimpleback (*Q. mortoni*) was observed in Reach 2 during the August 2008 sample event. No federally or state-listed threatened or endangered species of mussels were observed.

2.6 WATER QUALITY AND HABITAT

Table 2-14 summarizes water quality data collected with YSI multiparameter water quality meters when biological samples were collected. When water quality criteria for Lake Livingston and the Trinity River are compared to the values measured during sample collection, it appears temperatures were less than the standard of 33.9°C (as a maximum), pH values were always between 6 and 9 standard units, and the instantaneous DO concentration always exceeded 4 mg/L.

Table 2-1. Sample Effort by Location and Sample Event, Lake Livingston and the Trinity River

		Gill Net (net nights)	Boat Electrofish (sec)	Backpack Electrofish (sec)	Shad Trawl (ac-ft)	Seine (number)	DIDSON (hrs)	Gut Content (Fish)	Benthics (Kick-net samples)
December 2007	Reservoir	3	387	-	6.60	-	44.00	-	-
	Reach 1	2	1,066	1,276	-	3	-	-	1
	Reach 2	2	1,760	-	-	5	-	-	1
	Reach 3	1	900	-	-	4	-	-	-
	Reach 4	1	780	-	-	-	-	-	-
	Reach 5	-	-	-	-	6	-	-	-
February 2008	Reservoir	3	391	-	7.52	-	36.25	38	-
	Reach 1	1	416	1,800*	-	6	-	-	1
	Reach 2	1	917	-	-	5	-	-	1
	Reach 3	1	890	-	-	6	-	-	-
	Reach 4	1	900	-	-	6	-	-	-
	Reach 5	1	936	-	-	6	-	-	-
April 2008	Reservoir	3	383	-	6.59	-	60.00	28	-
	Reach 1	1	1,965	-	-	7	-	-	-
	Reach 2	1	926	-	-	6	-	-	-
	Reach 3	1	900	-	-	7	-	-	-
	Reach 4	1	1,092	-	-	6	-	-	-
	Reach 5	1	947	-	-	6	-	-	-
August 2008	Reservoir	3	917	-	7.06	-	57.00	32	-
	Reach 1	1	962	1,800*	-	6	-	-	1
	Reach 2	1	1,034	-	-	6	-	-	-
	Reach 3	1	900	-	-	6	-	-	-
	Reach 4	1	988	-	-	6	-	-	1
	Reach 5	1	1,074	-	-	6	-	-	-

*Estimated

Table 2-2. Fish Species Collected from Lake Livingston and the Trinity River Downstream of Lake Livingston, December 3, 2007, to August 22, 2008

Common Name	Species	Reservoir	River Reach 1	River Reach 2	River Reach 3	River Reach 4	River Reach 5
Paddlefish	*Polyodon spathula*		X	X			
Spotted gar	*Lepisosteus oculatus*	X	X		X	X	X
Longnose gar	*L. osseus*		X	X	X	X	X
Alligator gar	*L. spatula*	X	X	X		X	
Bowfin	*Amia calva*		X				
American eel	*Anguilla rostrata*		X	X		X	
Skipjack herring	*Alosa chrysochloris*		X	X		X	
Gizzard shad	*Dorosoma cepedianum*	X	X	X	X	X	X
Threadfin shad	*D. petenense*	X	X	X	X	X	X
Threadfin x gizzard shad	*D. petenense x D. cepedianum**	X	X				
Goldfish	*Carassius auratus*				X		
Grass carp	*Ctenopharyngodon idella*				X	X	
Red shiner	*Cyprinella lutrensis*		X	X	X	X	X
Blacktail shiner	*C. venusta*		X	X	X	X	X
Common carp	*Cyprinus carpio*	X	X	X	X	X	X
Ribbon shiner	*Lythrurus fumeus*						X
Golden shiner	*Notemigonus chrysoleucas*		X	X	X		
Sabine shiner	*Notropis sabinae*		X	X	X	X	X
Silverband shiner	*N. shumardi*		X	X	X	X	X
Sand shiner	*N. stramineus*		X		X		
Mimic shiner	*N. volucellus*		X	X	X	X	X
Shiner spp.*	Cyprinidae		X		X		
Bullhead minnow	*Pimephales vigilax*		X	X	X	X	X
River carpsucker	*Carpiodes carpio*		X	X			X
Smallmouth buffalo	*Ictiobus bubalus*	X	X	X	X	X	X
Black buffalo	*I. niger*		X				
Blacktail redhorse	*Moxostoma poecilurum*		X	X	X		
Yellow bullhead	*Ameiurus melas*	X				X	
Blue catfish	*Ictalurus furcatus*	X	X	X	X	X	X
Channel catfish	*I. punctatus*	X	X	X	X	X	X
Tadpole madtom	*Noturus gyrinus*	X					
Flathead catfish	*Pylodictis olivaris*	X	X	X		X	X
Sheepshead minnow	*Cyprinodon variegatus*				X		
Blackstripe topminnow	*Fundulus notatus*						X
Western mosquitofish	*Gambusia affinis*		X	X	X	X	X
Inland silverside	*Menidia beryllina*	X	X	X	X	X	X
White bass	*Morone chrysops*	X	X	X	X	X	X
Yellow bass	*M. mississippiensis*	X	X	X	X	X	
Striped bass	*Morone saxatilis*	X	X	X	X	X	X
White x striped bass	*M. chrysops x M. saxatilis*	X	X			X	
Warmouth	*Lepomis gulosus*	X		X			X
Orangespotted sunfish	*L. humilis*	X	X	X	X	X	X
Redspotted sunfish	*L. miniatus*			X		X	X
Bluegill	*L. macrochirus*	X	X	X	X	X	X
Longear sunfish	*L. megalotis*	X	X	X	X	X	X
Redear sunfish	*L. microlophus*	X					
Spotted bass	*Micropterus punctulatus*		X	X	X	X	X
Largemouth bass	*M. salmoides*	X	X	X	X	X	X
White crappie	*Pomoxis annularis*	X	X	X	X		
Black crappie	*P. nigromaculatus*	X	X	X	X		X
Logperch	*Percina caprodes*		X				
Dusky darter	*P. sciera*		X	X		X	
Unidentified darter	Percidae		X				
Freshwater drum	*Aplodinotus grunniens*	X	X	X	X	X	X
Striped mullet	*Mugil cephalus*		X	X	X	X	X
Hogchoker	*Trinectes maculatus*						X
Total number of species		26	45	38	35	35	33

* Not included in total

Table 2-3. Species and CPUE (fish/hr) of Fish Collected by Boat Electrofishing for each Reach and Sample Event, Trinity River

	December 2007				February 2008					April 2008					August 2008					Mean
	R1	R2	R3	R4	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	fish/hr
Paddlefish										2										2
Spotted gar	3		4				12	12	8				7	23						10
Longnose gar														4		3				4
Alligator gar										2	8									5
Bowfin										2										2
American eel																3		15		9
Skipjack herring										5			7							6
Gizzard shad	14	12							4	251	23	4	49	34	11	10	36	15	47	39
Threadfin shad	236	248	60	14	138	79		116	196	13,896	2,772	7,532	4,398	452	41			77		2,017
Grass carp				5								4								4
Red shiner		2			9	4					4			8	7				3	5
Blacktail shiner		4	24	5					15				13	38	109	49		40	57	35
Common carp			4			20				18	4		3		4		20			10
Silverband shiner	20	14													49	10				23
Mimic shiner								4			8				52					21
Shiner spp.	20																			20
Bullhead minnow	44	29				12						4			4	7			20	17
Smallmouth buffalo	20	2	60		87		24	16	27	24	4	4	16	11	*	*	*	4	*	23
Blacktail redhorse															4	3	4			4
Yellow bullhead																		4		4
Blue catfish	17	4	20	18	9	20	4			7			185		30	73	76		3	36
Channel catfish	51		4	14			4		4	9	19		10	4	30	38	20	7	7	16
Flathead catfish											4		10	4				7		6
Inland silverside	71	51	12		43			4	4	11	31	16	10	4		3				22
White bass	7	6	12			8		4		4	4	12			7		4			7
Yellow bass	165		8							5	4				4					37
Striped bass	78			14	*	8	8	36		5					56		36	77		35
Hybrid bass								8		4										6
Warmouth		2																		2
Orangespotted sunfish	24										4		3		4					9
Redspotted sunfish																3		4		4
Bluegill	95	39	4	5		4		4	8	4	4	8		11	41	24	28	26	7	19
Longear sunfish	135	20	24	208		31		4	23	9	12	8			30	66	48	102	57	52
Spotted bass	3	10	16	37	9	8	12	16	12			8	3		19	10	8	22	27	14
Largemouth bass	3		4	5		4	8	4	12		4		10	8	11	3		18	10	7
White crappie		2				4				4										3
Black crappie									4	2	12	4			4	3	8			5
Logperch	7																			7
Dusky darter															11	10		11		11
Freshwater drum	81			9			4			31						7	8	7	3	19
Striped mullet	51		4	9		4	8	28	15	471	47	24	36	27	56	21	24		37	54
Blue crab				5								4								4
Prawn				18																18
Total taxa	21	15	15	14	6	13	9	13	13	21	18	13	15	13	22	19	13	16	12	
Total fish per hour	1,145	446	260	365	294	204	85	256	331	14,766	2,966	7,632	4,760	627	584	352	320	434	278	
Sample period mean				554					234					6,150					394	

* Observed but not netted

Table 2-4. Species and CPUE (Number/Net Night) of Fish Collected with Gill Nets for each Reach and Sample Event, Trinity River

	December 2007				February 2008					April 2008					August 2008				
	R1	R2	R3	R4	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5
Paddlefish		0.5													1				
Spotted gar			1																
Longnose gar		1.5	3							2		1						1	2
Alligator gar						2				7								1	
Skipjack herring	0.5	0.5																	
Gizzard shad	3.5	0.5			7	4		1	6	1								5	1
Threadfin shad	4.5																		
Threadfin shad x Gizzard shad	2.5																		
Common carp	0.5	1.5				4				5								3	
River carpsucker	0.5	0.5																	1
Smallmouth buffalo	14	22.5	17	3	7	6	1	2	1	14		2			8		3	5	1
Black buffalo	0.5																		
Blue catfish	21.5	13.5	7	4	10	4	2	7		64		1			30	6	18	11	11
Channel catfish	33	15								31			2		1	2		2	
Flathead catfish								1											
White bass	3	3.5			5					1								1	
Yellow bass	12.5	5	2		44					18								1	
Striped bass	32	2.5			42	6	1	4		21				2	1				
Bluegill										2									
Longear sunfish			1							1									
Spotted bass		1				1									1				
Largemouth bass					1			1				1							
White crappie										14									
Freshwater drum	2	1.5	1		1					5			1		2	1			
Blue crab		0.5		1									1		3			1	
Total Species	14	15	7	3	8	7	3	6	2	14	0	4	3	1	8	3	2	10	5
Total Fish/NN	130.5	70	32	8	117	27	4	16	7	186	0	5	4	2	47	9	21	31	16
Sample Period Mean				60.1					34.2					39.4					24.8

Table 2-5. Species and CPUE (Number/Acre) of Fish Collected by Seining for each Reach and Sample Event, Trinity River

	December 2007				February 2008					April 2008					August 2008					Total
	R1	R2	R3	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	number/acre
Spotted gar															10					0.7
Longnose gar												6								0.7
Gizzard shad				248							141	23			77	8	123		52	40.6
Threadfin shad	29	1,168	76		2,008	115	8	139	345	336	538	5,520		1,007	125		7		35	950.6
Goldfish												12								1.4
Red shiner		799	83	1,133	162	115	201	139	230	230	256	3,730	790	6,955	58	98	6,534	644	15,336	1,904.0
Blacktail shiner	29	18	14	528	11				345		179			275	154	837	486	2,013	4,092	362.2
Common carp										9	13								35	2.7
Ribbon shiner				62					77											4.1
Golden shiner										9	26	46				8				8.1
Sabine shiner							39	55		9	13	110		366			493		717	95.5
Silverband shiner		90	7	16						1,140	1,960	3,777	226		58				455	663.6
Sand shiner							31			9										3.4
Mimic shiner		27		1,397	270	1,268	116	776	4,793	442	26	1,709		275					542	459.1
Unidentified shiner							8													0.7
Bullhead minnow	58	862	7	559	173		23	55	767	150	128	220	564	824	96		181		4,284	362.2
Smallmouth buffalo				16											39					3.4
Blue catfish								28			13									1.4
Channel catfish															58				52	6.1
Sheepshead minnow												6								0.7
Blackstripe topminnow																			17	0.7
Western mosquitofish				636			548		2,531		26	35	790	9,792	473	16	268	1,208	787	313.5
Inland silverside	1,016	907	5,089	652	1,846		301	83	77	3,483	295	736	677	2,471	1,669	131	747	765	385	1,380.6
White bass												6			10				87	4.7
Striped bass															10					0.7
Warmouth									77		13								35	3.4
Orangespotted sunfish		45					15		38		13	180			125					35.9
Redspotted sunfish									38											0.7
Bluegill		18		16		115			115		154	81			68					27.1
Longear sunfish		9	7	16	11		15		38		38	6	226		10	41		242	157	23.0
Spotted bass																16	7	81	122	8.1
Largemouth bass	29									124	551	324	226	641	10			40	17	85.3
White crappie										9		12								2.0
Black crappie									38		128	87								17.6
Dusky darter																8				0.7
Unidentified darter															10					0.7
Freshwater drum						115									29			40	87	6.8
Striped mullet									38			12			10		7			3.4
Hogchoker																			17	0.7
Total taxa	5	12	7	13	8	5	13	8	17	12	20	22	8	10	20	9	10	8	21	
Total fish/sample area in acres	1,162	4,051	5,283	5,292	4,491	1,729	1,604	1,358	9,816	5,949	4,574	16,648	3,724	23,427	3,098	1,166	8,854	5,032	27,402	

Table 2-6. Species and Total Number of Individuals Collected by Backpack Electrofishing from Reach 1, Trinity River*

	December 2007	February 2008	August 2008
American eel	2	3	2
Bullhead minnow	1	5	
Red shiner		8	
Silverband shiner	2		
Mimic shiner		4	
Channel catfish		1	
Flathead catfish	1		
Inland silverside	3	17	
Yellow bass	2		
Longear sunfish	9		4
Dusky darter	3		
Striped mullet	1		
Prawn	1	24	**
Blue crab	1		1
Total	**26**	**62**	**7**

*** High flow precluded backpack electrofishing during the April 2008 sample event.**

**** Collected, but not enumerated**

Table 2-7. Lengths of Fish Collected (all Gear Types), Trinity River

Species	Minimum length (mm)	Maximum length (mm)	Average length (mm)	Number measured
Paddlefish	1,016	1,778	1,381	3
Spotted gar	395	900	642	20
Longnose gar	30	1,321	953	15
Alligator gar	528	751	645	13
Bowfin	522	522	522	1
American eel	200	367	267	12
Skipjack herring	216	380	270	7
Gizzard shad	40	582	184	204
Threadfin shad	11	559	74	679
Threadfin shad x gizzard shad	175	188	184	5
Goldfish	26	36	31	2
Grass carp	490	630	560	2
Red shiner	13	68	37	516
Blacktail shiner	16	116	49	407
Common carp	201	662	358	40
Ribbon shiner	28	53	36	6
Golden shiner	56	86	70	12
Sabine shiner	18	82	36	119
Silverband shiner	24	92	50	344
Sand shiner	38	46	41	5
Mimic shiner	17	71	38	346
Shiner spp.	61	73	65	6
Unidentified shiner	43	43	43	1
Bullhead minnow	18	73	42	298
River carpsucker	289	320	301	3
Smallmouth buffalo	170	790	482	189
Black buffalo	496	496	496	1
Blacktail redhorse	101	112	108	3
Yellow bullhead	80	80	80	1
Blue catfish	42	714	359	352
Channel catfish	86	500	279	207
Flathead catfish	102	855	273	9
Sheepshead minnow	35	35	35	1
Blackstripe topminnow	29	29	29	1
Western mosquitofish	14	46	24	249
Inland silverside	15	100	60	724
White bass	52	417	260	47
Yellow bass	73	342	184	152
Striped bass	117	790	471	234
Hybrid temperate bass	487	521	505	4
Warmouth	19	81	50	6
Orangespotted sunfish	11	66	42	62
Redspotted sunfish	76	138	97	3
Bluegill	19	156	83	137
Longear sunfish	21	869	97	234
Spotted bass	54	421	210	74
Largemouth bass	13	494	77	146
White crappie	13	360	215	21
Black crappie	21	213	109	36
Logperch	90	90	90	2
Dusky darter	55	97	74	13
Freshwater drum	117	571	290	62
Striped mullet	35	435	227	162
Hogchoker	120	120	120	1
Blue crab (carapace width)	104	187	144	10
Total number measured				**6,209**

Table 2-8. Species and Total Number of Fish Collected by Boat Electrofishing, Station L1, Lake Livingston Dam

Species	December 2007	February 2008	April 2008	August 2008
Threadfin shad		55	56	16
Gizzard shad		37	9	
Common carp	9		19	12
Smallmouth buffalo		18	9	4
Yellow bullhead	19		9	4
Channel catfish	9	9	66	51
Flathead catfish				31
Tadpole madtom				4
Inland silverside	1,172	1,482	56	39*
Yellow bass				4
Warmouth	9		9	
Orangespotted sunfish				8
Bluegill	84	18	28	63
Longear sunfish	744	147	150	137
Redear sunfish				4
Largemouth bass	19	18	28	35
Black crappie	9			
Freshwater drum	19		9	20
Total species	**10**	**8**	**12**	**15**
Total fish/hr	**2,103**	**1,786**	**451**	**393**

*Inland silverside were exceptionally numerous and appeared to be small, Age 0 fish.

Table 2-9. Species and CPUE (No./NN) of Fish Collected with Gill Nets from Reservoir Stations, Lake Livingstor

	December 2007			February 2008			April 2008			August 2008			Proportional Difference			
	L4	L2 (Surface)	L2 (30-ft)	L4	L2 (Surface)	L2 (30-ft)	L4	L2 (Surface)	L2 (30-ft)	L4	L2 (Surface)	L2 (30-ft)	Mean	L4:L2 (Surface)	L4: L2 (30-ft)	L2(Surface): L2 (30-ft)
Spotted gar				1	1								0.17	1.0	1.0	2.0
Alligator gar				1									0.08	1.0	1.0	1.0
Gizzard shad	6	1		2	8	4	24	15	2	12	3	2	6.58	1.6	5.5	3.4
Threadfin shad								1					0.08	0.0	0.5	2.0
Common carp				5			23	10	11	1		1	4.25	2.9	2.4	0.8
Smallmouth buffalo	9		4	10	1	4	23	4	4	5			5.33	9.4	3.9	0.4
Blue catfish	23	8	2	3	6	2	16	3	3	3	9	2	6.67	1.7	5.0	2.9
Channel catfish	3						11			3			1.42	17.0	17.0	1.0
White bass	12	16	1	4	15	3	5	16	3	12	13		8.33	0.6	4.7	8.6
Yellow bass		2	1				6	1		2	1		1.08	2.0	8.0	4.0
Striped bass	1			5	4	1	3	2	1				1.42	1.5	4.5	3.0
White x Striped bass				5					2				0.58	5.0	2.5	0.0
White crappie	7	1	1	4			3	2		6	1		2.08	5.0	20.0	4.0
Black crappie	1				1								0.17	1.0	1.0	2.0
Freshwater drum						2							0.17	1.0	0.0	1.0
Total Species	8	5	5	10	7	6	9	9	7	8	5	3	6.83	1.3	1.7	1.2
Total Fish/NN	62	28	9	40	36	16	114	54	26	44	27	5	45	3.4	5.0	2.4

Table 2-10. Species and CPUE (No./acre-ft) of Fish Collected by Paired-frame Trawling by Station and Location, Lake Livingston

	Location	Depth of Trawl (ft)	Gizzard shad	Threadfin shad	Blue catfish	Channel catfish	Inland silverside	White bass	Yellow bass
December 2007	L4	5		127	4		32		
		10		88			22		
	L2	5		55	1		13		
		16		115	6		4		
		30		54	2		5		
	L3	5		77	2		5		
		15		183	30		2		1
		20		154	25		2		
February 2008	L4	5		26			19		
		13	1	148			1	1	
	L2	5		35			8		
		16		108			1		
		17	1	190					
	L3	5		26			5		
		14	1	143			3		
		17	7	190	2				
April 2008	L4	5		150					3
		21		43		4		1	
	L2	5		94					
		22		29			1		
		31		17					
	L3	5		91					
		16		94		7			
		36		50		3			
August 2008	L4	5	5	108					
		14		166		1			
	L2	5		72					
		15		92		3			
		34	1	160		1	1		
	L3	5		1,844		1			1
		22	1	842					
		27	1	837		2			

Table 2-11. Threadfin Shad Densities (No./acre-ft) by Station, Season, and Depth, Lake Livingston

December-07							
Sample Depth	**5**	**10**	**15**	**16**	**20**	**30**	**Mean**
L4	127	88					108
L2	55			115		54	75
L3	77		183		154		138
Mean							**107**
February-08							
Sample Depth	**5**	**13**	**14**	**16**	**17**		
L4	26	148					87
L2	35			108	190		111
L3	26		143		190		120
Mean							**106**
April-08							
Sample Depth	**5**	**16**	**21**	**22**	**31**	**36**	
L4	150		43				97
L2	94			29	17		47
L3	91	94				50	78
Mean							**74**
August-08							
Sample Depth	**5**	**14**	**15**	**22**	**27**	**34**	
L4	108	166					137
L2	72		92			160	108
L3	1,844			842	837		1,174
Mean							**473**
Study Mean							**190**

Table 2-12. Total Lengths of Fish Collected (all Gear Types), Lake Livingston

Species	Minimum Length (mm)	Maximum Length (mm)	Average Length (mm)	Number Measured
Spotted gar	640	710	675	2
Alligator gar	652	652	652	1
Gizzard shad	61	305	176	101
Threadfin shad	26	126	75	1,436
Common carp	213	3,221	413	57
Smallmouth buffalo	175	661	410	68
Yellow bullhead	107	228	155	4
Blue catfish	61	547	227	143
Channel catfish	81	450	210	56
Tadpole madtom	55	55	55	1
Flathead catfish	165	630	278	8
Inland silverside	40	103	76	169
White bass	136	443	258	102
Yellow bass	72	218	172	17
Yellow bass hybrid	281	281	281	1
Striped bass	195	533	388	17
Hybrid bass	455	624	505	7
Warmouth	100	178	139	2
Orangespotted sunfish	73	76	75	2
Bluegill	53	155	124	30
Longear sunfish	62	145	107	92
Redear sunfish	146	146	146	1
Largemouth bass	117	440	240	16
White crappie	159	332	237	25
Black crappie	127	215	179	3
Freshwater drum	123	431	177	10
Total measured				**2,371**

Table 2-13. Total Number of Benthic Macroinvertebrates per Sample Collected from the Trinity River Downstream of Lake Livingston Dam

	December 5, 2007		February 26, 2008		August 22, 2008			
Taxa	Reach 1	Reach 2	Reach 1	Reach 2	Reach 1	Reach 4	Pollution Tolerance[1]	Functional Feeding Group[1]
Phylum Annelida, Oligochaeta (worms)		3	2		1		8	Collector gatherer
Phylum Annelida, Euhirudinea (leeches)					1		8	Predator
Phylum Nematoda (nematodes)				3			5	Predator
Class Gastropoda (snails)								
Helisoma anceps					4		7	Scraper
Physella sp					25		9	Scraper
Class Bivalvia (clams)								
Family Corbiculidae								
Corbicula fluminea	1	1			3	1	6	Filtering collector
Family Sphaeriidae			1			3		
Eupera cubensis					8	17		Scraper
Class Crustacea (crustaceans)								
Order Decapoda								
Macrobrachium ohione (freshwater prawn)	2	1			3		4	Collector gatherer
Order Amphipoda (amphipods)								
Hyallela		1					8	Collector gatherer, shredder
Gammarus		9			1		3	Collector gatherer, shredder
Order Odonata		1						
Family Coenagrionidae (damselflies)								
Argia sp	1		1			1	6	Predator
Order Trichoptera (caddisflies)								
Family Hydroptilidae?						1	3	Collector gatherer, scraper
Family Hydropsychidae								
Cheumatopsyche sp					5	7	6	Filtering collector
Family Polycentropodidae								
Cyrnellus sp?					1			
Neureclipsis sp?						1	4	Filtering collector, shredder, predator
Order Diptera (flies)								
Family Chironomidae (midge flies)	10	9			15	2	6	Predator, collector gatherer, filtering collector
Family Dolichopodidae	1							
Unidentified pupa				1	1	1		

Table 2-13. Total Number of Benthic Macroinvertebrates per Sample Collected from the Trinity River Downstream of Lake Livingston Dam

Taxa	December 5, 2007		February 26, 2008		August 22, 2008		Pollution	
	Reach 1	Reach 2	Reach 1	Reach 2	Reach 1	Reach 4	Tolerance[1]	Functional Feeding Group[1]
Order Ephemeroptera (mayflies)								
Family Baetidae								
Baetis						19	4	Scraper, collector gatherer
Family Heptageniidae								
Stenonema						1	4	Scraper, collector gatherer
Family Tricorythidae								
Tricorythodes					4	11	5	Collector-gatherer
Total	15	25	4	4	72	65		
Taxa Richness	5	6	3	2	13	12		
Number of Ephemeroptera, Plecoptera and Tricoptera taxa	0	0	0	0	3	6		
Hilsenhoff's Biotic Index	5.3	4.9	5.5	3.8	6.1	3.2		
Percent of individuals that are Chironomidae	67	36	0	0	21	3		
Percent dominant taxon	67	36	50	75	35	29		
Percent Dominant Functional Feeding Group	33	68	50	75	51	57		
Percent predators	73	36	25	75	22	5		
Ratio of intolerant:tolerant taxa	0.1	0.4	0.0	100.0	0.1	0.8		
Percent of total Trichoptera as Hydropsychidae					17	22		
Number of non-insect taxa	2	5	2	1	8	3		
Percent Collector gatherers	33	68	50	0	13	37		
Percent of total number as Elmidae	0	0	0	0	0	0		
Aquatic Life Use Score[2]	17	16	16	17	23	26		

[1] From TCEQ 2008

[2] These values are not adequate for Aquatic Life Use assessment because the counts of individuals in each sample were less than 100.

Table 2-14. Basic Water Quality Parameters Measured Duirng Biological Sampling Events, Lake Livingston and the Trinity River

	Temperature (˚C)			Conductivity (mS/cm)			Dissolved oxygen (mg/l)			pH (standard units)			Secchi disk transparency (m)		
Reach	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Dec-07															
L1	14.4	14.4	14.4	0.362	0.362	0.362	9.9	10.0	9.9	8.3	8.3	8.3	0.90	0.90	0.90
L2	14.5	15.2	14.6	0.361	0.362	0.362	10.0	10.7	10.2	8.2	8.4	8.3	1.00	1.00	1.00
R1	14.8	15.4	15.0	0.362	0.367	0.364	11.1	17.2	14.9	8.3	8.4	8.4	-	-	-
R2	14.6	15.6	15.1	0.361	0.366	0.362	10.8	17.4	13.0	8.3	8.5	8.4	-	-	-
R3	10.5	16.1	13.8	0.204	0.385	0.329	10.9	11.5	11.1	7.9	8.4	8.2	1.00	1.10	1.05
Feb-08															
R1	13.2	14.1	13.8	0.381	0.399	0.388	7.8	9.9	9.2	8.6	8.8	8.7	-	-	-
R2	13.1	13.9	13.6	0.375	0.385	0.381	8.3	10.4	9.7	8.6	8.8	8.7	-	-	-
R3	12.2	13.4	12.6	0.389	0.599	0.431	6.8	10.0	9.3	7.5	8.7	8.3	-	-	-
R4	13.6	14.2	13.7	0.381	0.393	0.391	10.6	11.2	10.9	8.7	8.8	8.8	-	-	-
R5	12.8	13.9	13.1	0.380	0.399	0.390	10.4	11.3	10.9	8.5	8.8	8.7	-	-	-
Apr-08															
L2	21.1	21.9	21.6	0.366	0.371	0.369	9.3	11.3	10.4	8.0	8.4	8.2	-	-	-
R1	21.5	24.0	22.6	0.243	0.386	0.367	9.5	15.6	11.5	7.6	8.7	8.3	0.40	0.40	0.40
R2	21.4	23.2	21.8	0.366	0.379	0.370	10.0	13.3	11.6	7.8	8.5	8.3	0.43	0.43	0.43
R3	20.0	22.2	21.5	0.366			9.6	13.8	12.0	8.1	8.4	8.3	0.50	0.70	0.60
R4	20.3	21.9	20.7	0.367			9.3	13.8	10.1	7.9	8.2	8.2	0.51	0.64	0.56
R5	20.4	22.1	20.8	0.366			9.7	13.3	10.5	7.7	8.3	8.2	0.36	0.64	0.52
Aug-08															
L2	28.7	28.9	28.8	0.378	0.379	0.379	4.4	7.4	5.8	7.7	7.9	7.7	1.00	1.00	1.00
R1	24.6	29.4	28.6	0.361	0.460	0.389	6.1	9.8	8.4	7.8	8.8	8.1	0.37	0.91	0.73
R2	28.7	29.1	29.0	0.365	0.377	0.370	7.4	9.1	7.7	8.0	8.5	8.3	0.94	0.94	0.94
R3	28.4	29.5	28.8	0.364	0.383	0.370	6.6	10.6	7.6	8.0	8.5	8.3	0.88	0.88	0.88
R4	28.6	29.5	28.8	0.374	0.379	0.378	8.9	10.5	9.7	7.8	8.3	8.0	0.90	0.90	0.90
R5	26.9	29.4	28.3	0.212	0.379	0.346	8.4	10.5	9.5	7.8	8.1	8.1	0.70	0.70	0.70

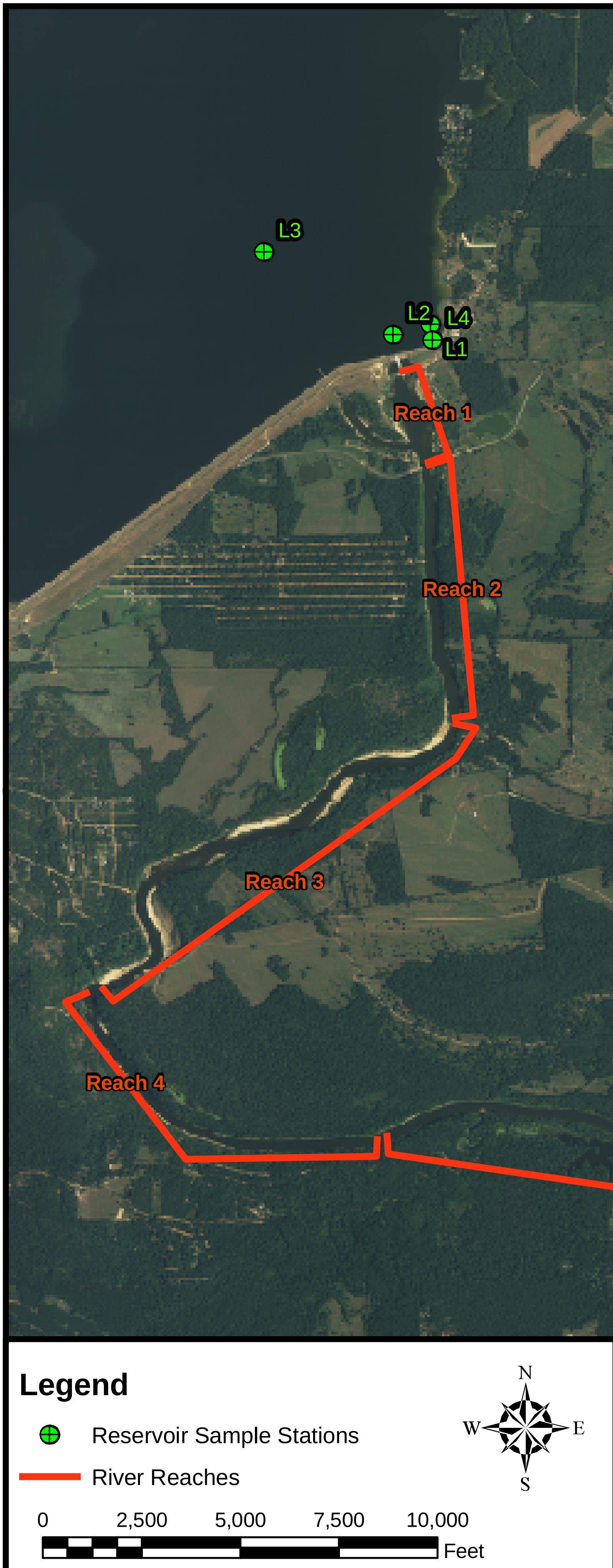

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Figure 2-1

Reservoir and River Sample Locations
Livingston Dam Hydroelectric Project

Figure 2-2. Reach 1 and Weir

Figure 2-3. Reach 2

Figure 2-4. Reach 3

Figure 2-5. Reach 4

Figure 2-6. Reach 5

Figure 2-7. Threadfin Shad Densities Compared Between Stations and Depths, Lake Livingston

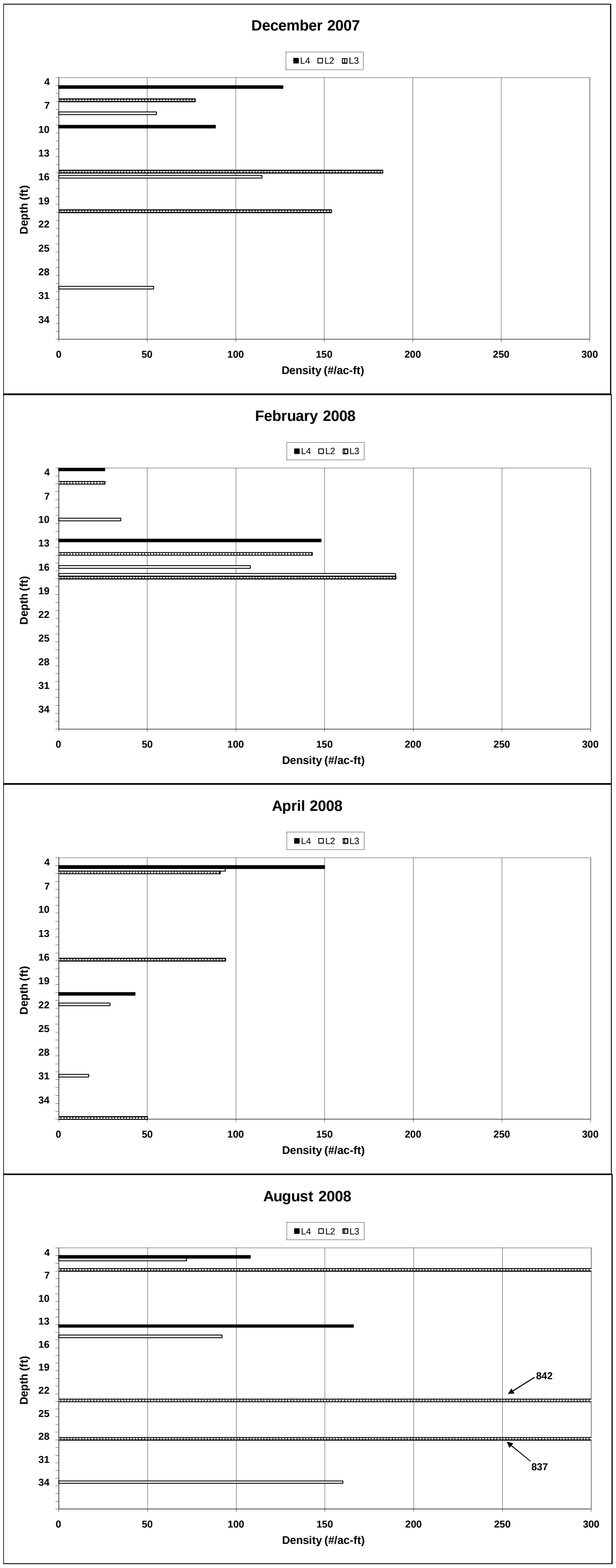
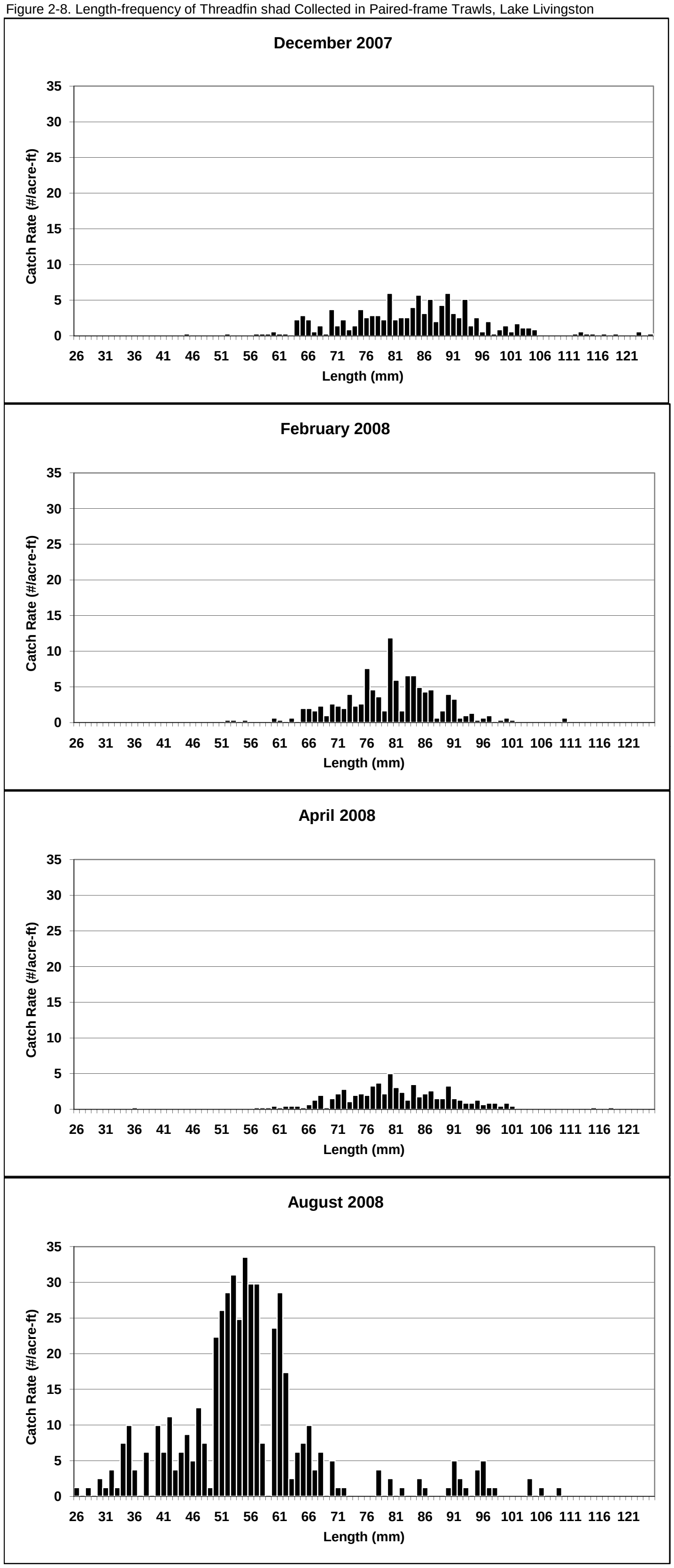


Figure 2-8. Length-frequency of Threadfin shad Collected in Paired-frame Trawls, Lake Livingston



3.0 SUPPLEMENTAL STUDIES

Additional studies were conducted to help understand potential effects of the hydropower project on the fishery in the Trinity River downstream of Lake Livingston Dam. In particular, these studies were designed to:

1. Characterize downstream passage of fish through the dam;
2. Collect temporally and spatially intensive water quality data to support modeled and empirical evaluations of temperature and dissolved oxygen immediately downstream of the dam; and
3. Characterize the American eel population downstream and upstream of Lake Livingston Dam.

3.1 STOMACH CONTENTS OF STRIPED BASS AND BLUE CATFISH DOWNSTREAM OF LAKE LIVINGSTON DAM

An exceptionally large biomass of predatory species resides immediately downstream of Lake Livingston Dam. This reach of river is particularly important to striped bass, presumably because of the thermal refuge provided by the reservoir releases during the summer. The energy demand of these predators is high and the transfer of forage fish from the reservoir to the river is presumed to be very important. This study was conducted to characterize the species composition and sizes of prey that are important to striped bass and blue catfish in the reach immediately downstream of the dam.

Stomach contents of 66 striped bass, 25 blue catfish, and 4 striped (x) white bass were identified and measured (Table 3-1). Ten of 25 striped bass (40%) and 7 of 11 (64%) blue catfish collected during the February sample event had empty stomachs The most common forage species by number was threadfin shad (13) followed by inland silverside (4), and American eel (3). Eleven of the fish with identifiable stomach contents had eaten shad. Some of the prey could not be identified because of degradation resulting from digestive processes. The average number of prey per stomach was 1.3 during the February sample event.

During the April sample event, 6 of 14 striped bass (43%) and 8 of 9 (89%) blue catfish had empty stomachs (Table 3-1). All four striped (x) white bass contained prey. One blue catfish contained 19 threadfin shad. The average number of prey per stomach was 2.0 during the April sample event.

During the August sample event, 20 of 27 (74%) striped bass had empty stomachs. The prey were small minnows and prawn. Similarly, four of the five blue catfish (collected from upstream of the weir) did not contain prey. The one prey item observed in the blue catfish was a smaller blue catfish.

Results of the stomach analysis indicate that threadfin shad are the principal forage species of striped bass and blue catfish downstream of the dam. However, the biomass of shad and other prey species appeared to be too low to support the predatory species under the low-flow conditions observed during August in this study. Weight ratio (Wr), which is a measure of body condition, was calculated for striped bass

(Table 3-2). The mean Wr for February and April were 102 and 100, respectively, which indicates that the weights of the fish were normal for their lengths. However, the average Wr during August was 76, which indicated striped bass body condition had declined substantially since the spring.

Threadfin shad abundance and biomass is highest in the reservoir during summer and fall (see subsection 2.4.1.1). However, the low flows that persisted through the summer and that were observed during this study, reduced the transfer of total forage from the reservoir to the river. Similarly, the abundance of forage was also the lowest in this reach of river during the August sample (see Table 2-3). The problem of low forage availability appeared to be compounded since this reach of river provides thermal refuge for striped bass during the summer. As a consequence, there does not appear to be enough forage under the conditions observed in this study to adequately support the high biomass of striped bass in the river.

Another point of interest was the presence of American eel in the stomachs of striped bass. As described later in this report, American eel were collected in relatively low numbers in the river; however, the individuals that were collected were collected from boulder/cobble/gravel habitats. In particular, the area in which they appeared to be most common was in Reach 1, along the rip-rap of the weir. This habitat overlaps with the area used by high densities of striped bass and other predators. As a consequence of the overlapping habitats, it appears that striped bass predation might adversely affect American eel in this reach.

3.2 ACOUSTIC MONITORING OF FISH PASSING THROUGH LAKE LIVINGSTON DAM

Acoustic imagery of fish discharged through tainter gate Number 7 of the dam with reservoir releases was collected for 197.25 hour over 13 days, from February 26 through August 21, 2008 (Table 3-3) using a DIDSON high-definition sonar developed by Sound Metric, Inc. The DIDSON was suspended at a depth of approximately 20 ft from a pole adjacent to the concrete pillar on the east side of Gate 7. The lens of the DIDSON was aimed slightly downward towards Gate 7. The portion of the gate imaged included about 20 ft of the west half of Gate 7, from the middle of the gate to the concrete pillar on the west side of Gate 7 where it lifts off the concrete dam.

The estimated water velocity at the point that the water exits the reservoir, between the tainter gate and the concrete floor of the dam, is estimated at 25 ft/s. Velocity estimated at a location 3 ft from the tainter gate on the reservoir side is approximately 4 ft/s. Most fish that moved within 3 ft of the tainter-gate opening were unable to swim upstream against the current and were swept from the reservoir into the river. Larger fish (>8 inches in length) appeared better able to swim against the current than did smaller fish (<8 inches total length).

All fish that moved from the reservoir through the imaged portion of the gate were counted. Counting intervals were 15 minutes. Fish counts were placed in one of four different total length categories: 2–4 inches, 4–8 inches, 8–14 inches, and greater than 14 inches.

3.2.1 Number of Fish Passing Through Lake Livingston Dam

The total volume of water that passed through this tainter gate when DIDSON data were collected was 24,000 acre-ft (ac-ft). A total of 60,433 fish were counted, which was an average density of 2.5 fish/ac-ft. The highest concentration that passed through the dam was 89.9 fish/ac-ft, which was measured during the August sample event when the reservoir discharge was lowest (Figure 3-1). The lowest concentration of fish, which was consistently <7 fish/ac-ft, was measured during the March sample event. Total reservoir discharge was 35,700 ac-ft/day during the March sample event, which was the highest discharge measured during the sample events. When combining the rate of fish passing through the dam with total reservoir discharge, the highest number of fish passage through the dam was 13,900, which occurred in one 15-minute period during the April sample event when discharge was 27,800 ac-ft/day (Figure 3-2).

The total number of fish that may have moved from Lake Livingston to the Trinity River with reservoir releases during the study period from December 3, 2007, through August 22, 2008, was estimated. The estimate is based on the median of the estimated rates of fish movement (fish/ac-ft) for all 15-minute intervals during a sample event. These median values were multiplied by the total reservoir release for selected dates, which encompassed each sample period. The median values were applied as follows:

- February sample event medians applied to total reservoir releases from December 3, 2007, through March 11, 2008
- March sample event medians applied to total reservoir releases from March 12 through April 11, 2008
- April sample event medians applied to total reservoir releases from June 26 through August 22, 2008
- August sample event medians applied to total reservoir releases from June 26 through August 22, 2008

The total estimated number of fish, 8.03 million fish, was then determined by summing the totals for each date range. Figure 3-3 illustrates the estimated total number of fish in two size ranges, <8 inch and greater than 8 inch for each of the date ranges utilized. Of those fish, 7.8 million, or 98% of the total were estimated to be 8 inch or less in total length. For comparison, if the same calculations had been made using the means of the estimated rates of fish movement, the total number of fish passed would have been approximately 16 million fish moving through the dam over the same period.

3.2.2 Identification of Fish Passing Through Lake Livingston Dam

In most cases, fish counted with the DIDSON could not be identified to species. Information including lengths of fish counted, observed schooling behavior, and collection of species with other gear in the reservoir in front of the dam and in the river immediately downstream of the dam was used to speculate about the species composition of fish recorded by the DIDSON. During each sample event, large numbers of small organisms, less than 2 inches long were observed flowing out of the reservoir beginning at dusk and continuing until sunrise. These organisms were not counted, but may have been threadfin shad. Although these organisms were not counted, their abundance was significantly higher than the abundance of fish counted with the DIDSON.

The majority of fish counted with the DIDSON during the February, March, and April sample events were believed to be gizzard shad and temperate bass, mainly white and yellow bass (*M. mississippiensis*). This conclusion is based on the numerical dominance of these species in gill net samples in the reservoir and in the river immediately downstream of the dam during these sample events. A secondary factor influencing this conclusion was that most counted fish were between 4 and 8 inches in length during these sample events. Few schools of fish were observed moving from the reservoir into the river during these sample events. The few schools that were observed during these events consisted of small fish, less than 4 inches long, which were believed to be threadfin shad. Based on the reservoir sampling, the only species of this size that occur in appreciable numbers near the dam was threadfin shad. Second, these fish demonstrated strong schooling behavior during the daylight period, which is characteristic of threadfin shad. While some juvenile gizzard shad were present, the overwhelming majority of shad in the reservoir samples were threadfin shad. Finally, as described in subsection 2.4.2.3, two threadfin shad cohorts were observed through the length-frequency analysis of the August trawl sample.

The majority of fish counted with the DIDSON during the August sample event were believed to be schooling threadfin shad moving from the reservoir into the river during daylight hours. Most fish were 3 to 4 inches in length. Schools of larger fish, believed to be gizzard shad 6 to 8 inches long, were abundant in the DIDSON data. These schools were observed swimming back and forth in front of the gate where some individuals on the downstream edge of the schools were washed through the dam. Larger fish were observed that displayed different behavior, particularly schooling in loosely aggregated schools and pursuing smaller fish. Since the larger fish were in the water column and appeared to chase smaller fish, many were believed to be temperate bass, including yellow, white, and striped bass.

3.2.3 Diurnal Variation in Fish Passage through Lake Livingston Dam

A diurnal pattern of fish movement through the dam was observed during the February, March, and April sample events (Figure 3-5). The concentration of fish moving through the gate appeared to increase at dusk and reached peak concentrations between midnight and 5:30 AM. The pattern was reflective of the behavior of fish that associate in schools. During daylight periods, schooling fish, such as threadfin shad, use visual cues to maintain their close aggregation. The visual cues are lost at night and fish generally disaggregate from schools and, more or less, distribute randomly in the water column. When the fish were disaggregated, they appeared to be more susceptible to the high velocity associated with the discharge through the tainter gates. Therefore, most fish passed through the dam as individuals and were not in schools during the night. Conversely, during daylight periods, the fish were in schools and larger fish appeared more capable of evading the high velocity through the tainter gate. As a result, fewer fish passed through the tainter gates during the day during the February, March, and April sample events.

A different pattern was observed during the August sample event when most fish moved through the dam during the day (Figure 3-6). The higher numbers of fish moving through the dam during the day were a result of schools of small fish, which were less than 4 inches in length. This suggests that the smaller fish (Age-0 threadfin shad) were more susceptible to the high velocity. In contrast, the passage of schools was not commonly observed during the other sample events, possibly because the threadfin shad were larger and more capable of negotiating the high velocity. Although the diurnal pattern during August differed from the diurnal pattern during the previous sample events, the rate of fish passage during the day in August was comparable to the rate of fish passage during the day during the earlier samples periods (<2,000 fish/15 minutes).

One point of interest is that the density of threadfin shad passing through the dam appeared to be, at times, higher than the apparent density of fish observed in the trawl samples. One explanation for the passage of fish during the night might be behavior, or the tendency of fish to move to areas of flow to migrate downstream. However, this did not appear to be supported during the day, when the fish clearly avoided the high velocity near the tainter gate.

3.2.4 Striped Bass Movement through Lake Livingston Dam

Of 233 striped bass collected in the Trinity River downstream of Lake Livingston Dam (all sample methods combined), all but two were greater than 13 inches long. One specimen was approximately 4.7 inches and another was 8.5 inches long. Although relatively few striped bass were collected in reservoir gill nets, 7 of the 17 collected were less than 13 inches long. All but one of the striped bass collected in the reservoir were collected during the February and April sample events. No striped bass were collected in the reservoir during the August sample event. The mean length of striped bass collected in the reservoir was 15.3 inches compared to 18.5 in the Trinity River downstream of the dam. The TPWD (2004) stated the mean length of Age-1 striped bass in Lake Livingston was 9.3 inches and of Age-2 striped bass was 18.0 inches.

DIDSON data showed that as many as 457,000 fish longer than 8 inches may have moved from the reservoir into the river during the period from December 3, 2007, through August 22, 2008. Ninety-four percent of all fish longer than 8 inches counted with the DIDSON were counted during the February, March, and April sample events. Observations of DIDSON data suggest many of the larger specimens observed in front of the dam and which moved through the dam had physical profiles, relatively long and narrow, comparable to the physical profiles for striped bass. When considered together, this information indicates striped bass probably pass through the dam during winter and spring high flows as Age-1 or Age-2 fish. It is not possible to precisely estimate the number of striped bass that moved from the reservoir into the river; however, it is believed that a substantial portion of those 457,000 fish longer than 8 inches were probably striped bass.

3.3 WATER QUALITY IN LAKE LIVINGSTON AND THE TRINITY RIVER DOWNSTREAM OF LAKE LIVINGSTON DAM

Temperature and DO were intensively monitored at three locations from spring through summer 2008 using meters equipped with optical dissolved oxygen probes. The locations were in the reservoir near the existing tainter gates, the proposed facility headrace, and in the river between the dam and the weir. The meters collected data every 30 minutes.

The data documented water quality during this period and provided valuable information for updating the water quality model, which was calibrated with historic data. TRA staff from the Lake Livingston facility operated the meters including retrieving, deploying, calibrating, and downloading data. Data were retrieved, downloaded, and meters recalibrated approximately every 2 weeks through September 2008. Three meters were deployed in the reservoir approximately 500 ft in front of the dam at depths, which correspond to typical depths of the epilimnion (4 ft), metalimnion (29 ft), and hypolimnion (50 ft) in Lake Livingston. The depth of 29 ft also measured water quality at the depth at which water is discharged from the reservoir. The meter that was near the proposed headrace was placed at a depth of 5 ft. The meter that was downstream of the dam was placed adjacent to the shore and was near the surface. Table 3-4 provides a summary of water quality parameters over the period from May 1 through September 11, 2008, for each location.

3.3.1 Temperature

The difference between the water temperature in the reservoir in the vicinity of the proposed headrace and the water temperature between the dam and the weir are shown on Figure 3-7. This comparison provides some insight into the relative difference that might occur with the change in the location of the discharge from the dam to the proposed headrace. Since the area between the weir and the dam is small and shallow, the detention time is relatively short, which ensures the temperature at this location is comparable to the temperature near the tainter gates (in the reservoir) at 30 ft. The summary data provided in Table 3-4 show little difference between temperature at the 29-ft-deep station near the tainter gate and immediately downstream of the dam.

As provided in Table 3-4, the mean temperature at the proposed headrace was 0.6ºC higher than the temperature downstream of the dam. The maximum temperature at the proposed headrace was 2.1°C higher than the maximum temperature downstream of the dam. As shown on Figure 3-7, the greatest difference in temperature between the two locations occurred in June and July. This issue is discussed in more detail in Section 3.4.

3.3.2 Dissolved Oxygen

There were wide variations in DO at and between each of the locations monitored. These fluctuations are discussed in more detail in Section 3.4. Fluctuations in reservoir DO are normal due to a number of physical and biological processes. However, low DO in reservoir surface waters has not been commonly reported other than during periods of fall overturn. This phenomenon was observed on multiple dates at each of the surface stations. Lowest DO was usually during the early morning, when concentrations fell below 1 mg/L on some dates at the surface stations.

DO was generally stable downstream of the dam due to physical reaeration as the water is discharged from the reservoir. The lowest observed DO in the stilling basin was 5.7 mg/L. Although the reservoir release is periodically hypoxic, passage of water through the dam appears to aerate the water to near saturation.

Figure 3-8 illustrates the DO that was observed in the vicinity of the proposed headrace and downstream of the dam. The daily mean DO differences between the two stations are shown on Figure 3-9. Since the DO in the river is relatively stable, the difference between the two locations results from the fluctuations in surface DO in the reservoir. Figure 3-10 illustrates the DO concentrations at each of the monitoring locations and depths in the reservoir.

3.3.3 Conductivity and pH

Conductivity and pH remained within acceptable levels during the critical sampling period (see Table 3-4). Conductivity varied at all locations within the narrow range from 0.334 to 0.446 mS/cm from May through September 11, 2008. Values for pH ranged from 7.1 to 9.1 during the same period with highest concentrations, 9.1, measured at the surface locations in Lake Livingston. Higher pH concentrations at these locations probably reflected higher phytoplankton productivity at these two sites.

3.4 MODELING TEMPERATURE AND DISSOLVED OXYGEN IN LAKE LIVINGSTON, THE STILLING BASIN, AND THE PROPOSED TAILRACE AREA

Water quality modeling was conducted to help predict how water quality in Lake Livingston, the stilling basin, and the proposed tailrace area would be affected by different hydroelectric and reservoir release scenarios. Modeling was conducted in two phases. The first phase calibrated the model using historical reservoir and river water quality and bathymetric data. At the end of data collection in September 2008, model calibration was reviewed, and the more detailed intensively collected data were incorporated into the model. The revised, updated model was used to develop the most accurate predictions possible.

CE-QUAL-W2 is a widely used two-dimensional (longitudinal/vertical) hydrodynamic and water quality model available from the USACE. It modeled temperature and DO in the reservoir and the river. The model was calibrated with historical data from the TRA and other organizations. Modeling focused on the main body of the reservoir in front of Lake Livingston Dam, the stilling basin between the dam and the weir dam, and the proposed tailrace area downstream of the weir dam.

A report describing model scenarios and outputs will estimate the:

- Minimum release rate needed from Lake Livingston Dam to support the existing stilling basin DO and temperature regimes and maintain water quality standards in the river;
- Impact of low epilimnetic DO levels like those recently observed in the reservoir on DO levels in the Trinity River if the water were passed through the hydroelectric facility;
- River temperatures resulting from facility operations at various flows and seasons; and
- Effects on reservoir stratification near Lake Livingston Dam associated with the change in discharge location.

The report describing model results will help evaluate potential mitigation alternatives for supplemental aeration of the water passing through the hydroelectric facility or for evaluating mechanical aeration of the stilling basin. It will also address other water quality issues identified by the agencies as the process unfolds. Model construction, calibration with available data, and validation for the main body of Lake Livingston in front of Lake Livingston Dam and including the area of the proposed hydroelectric facility, the stilling basin, and the river will be summarized.

The water quality study recently completed will be used to test the model and update the model calibration. The second phase of the modeling effort will use the new information to review and revise as necessary the model calibration. Simulations may be run for different hydropower operation alternatives and a final report with full model documentation would be prepared.

3.4.1 Model Calibration

The following presents the calibration of a water quality model for Lake Livingston, the stilling basin, and approximately 10 miles of the Trinity River below Lake Livingston Dam. The calibration period is January 1, 2000, through December 31, 2006. Data development, model segmentation, and comparison between model results and field measurements are described.

The model is CE-QUAL-W2 Version 3.5, which is a two-dimensional, longitudinal/vertical, hydrodynamic and water quality model. The model has undergone continuous development since 1975 and has been applied to rivers, lakes, reservoirs, and estuaries. The current model release enhancements were developed under research contracts between the USACE and Portland State University. The model and further information about the model can be obtained from the following web site http://www.ce.pdx.edu/w2/.

3.4.2 Data Development

3.4.2.1 Inflows and Outflows

The components of flows out of and into Lake Livingston consist of the following:

- Flows out of the reservoir:
  - Spillway flow

- Evaporation from the reservoir
- Seepage
- Miscellaneous withdrawals

- Flows into the reservoir
  - Trinity River inflow and inflows from the local watershed
  - Precipitation on the reservoir

The U.S. Geological Survey (USGS) operates the following flow gages in the vicinity of Lake Livingston:

- 08065350 Trinity River near Crockett, Texas
- 08066250 Trinity River near Goodrich, Texas
- 08065800 Bedias Creek near Madisonville, Texas
- 08066170 Kickapoo Creek near Onalaska, Texas
- 08066200 Long King Creek at Livingston, Texas

The locations of these gages are shown on Figure 3-11. An attempt was made to model the reservoir with inflows and reservoir releases estimated from USGS gage flows, adjusted for the ungaged areas surrounding the reservoir based on ratios of drainage areas, and accounting for evaporation and precipitation. However, the results were not satisfactory and a different approach described below was used.

The reservoir is operated to maintain a pool elevation of 131 ft with relatively small water level fluctuations. The main driving force of the hydrodynamics of the reservoir is the Trinity River flow through the reservoir. For the purpose of the calibration, the recorded reservoir releases by the TRA were used as both inflow and outflow, without explicitly accounting for the other inflow/outflow components. This outflow from the dam was carried through the river section of the model. A stage-discharge relationship was developed with the data at Gage 08066250 (Trinity River near Goodrich), and applied at the downstream end of the river model.

It is noted that Long King Creek joins the Trinity River approximately 1,200 ft upstream of Gage 08066250. The drainage area at Gage 08066250 is 16,844 square miles. The drainage area at the dam (Gage 08066190) is 16,583 square miles. The difference is approximately 1.5%. Therefore, most of the time, the flow at the downstream end of the river model should be similar to the flow from the reservoir. Moreover, there is a lack of water quality data to characterize the inflow of Long King Creek. This tributary is not included in the model because of the uncertainty in the input data. However, it must be recognized that at times the contribution of Long King Creek flows can affect conditions at Goodrich.

3.4.3 Inflow Loads

The reservoir receives loads of solids, organic matter, and nutrients from the upstream watershed. The loads were calculated from the quantities and concentrations of the inflows. Figure 3-12 provides plots of concentration versus daily average flow at Trinity River near Crockett (Monitoring Station 13690) for the period 1990–2006. This is the first stream monitoring station on the Trinity River immediately upstream of the reservoir. Inorganic suspended solids (ISS) are the differences between total suspended solids (TSS) and volatile suspended solids (VSS). The pattern of ISS is unexpected, with a maximum concentration at approximately 10,000 cfs. The TSS and VSS data show a similar pattern. While this is a curious phenomenon, it is outside the scope of this study to investigate the cause. The total organic carbon (TOC) plot shows data at the Trinity River at US 79 (Monitoring Station 10919), the next upstream station, since there are no TOC data at Station 13690. When concentrations of variables were below detectable levels, the data were entered at one half of the laboratory detection level. These stations are also shown on Figure 3-11.

There are significant ($p < 0.05$) relationships between concentration and daily average flow for ISS, nitrate plus nitrite nitrogen (NO_{23}-N), and orthophosphate phosphorus (PO_4-P). There is a marginally significant flow-concentration relationship with the ammonia nitrogen (NH_3-N) data. However, the value of R^2 was very low, indicating that a regression relation would be of little use in load estimation. For the other parameters, there are no statistically significant relationships. The regression equations and R^2 values are shown on the figures for ISS, nitrite+nitrate-N, and PO_4-P, and the average concentrations are shown for the other parameters. The model requires input of labile dissolved organic matter (LDOM), refractory dissolved organic matter (RDOM), labile particulate organic matter (LPOM), and refractory particulate organic matter (RPOM). According to Liscum and East (2000), these are estimated as LDOM = 0.3 x TOC/0.45, RDOM = 0.7 x TOC/0.45, POM = 0.3 x TOC/0.45. The POM is assumed to be 50% labile and 50% refractory.

The regression equations were used to estimate inflow concentrations for ISS, nitrite+nitrate-N, and PO_4-P based on the river flows. For the other parameters, a constant average concentration was used. The concentrations are the input required by the model. Internally, the concentration is multiplied by the flow to yield load.

3.4.4 Meteorology

Meteorological data required by the model include air temperature, dew point temperature, wind speed, wind direction, and cloud cover. Hourly meteorological data at the Huntsville Municipal Airport (WBAN: 53903) were obtained from the online store of the National Climatic Data Center and used in the model.

3.4.5 Model Parameters

Hydraulic parameters include dispersion coefficients for momentum, temperature, and the Chezy coefficient for calculating boundary friction. Default values were mostly used and the model gave satisfactory results. The vertical diffusion coefficients for momentum and temperature were computed by the model.

The model allows the effects of wind to be adjusted using the wind sheltering coefficient (WSC). The WSC is used to account for the difference in wind at the modeled water body and the weather station where wind measurements are made. The value is usually less than or equal to one. In this case, the orientation of the reservoir aligns in the direction of the prevailing wind and it was found that a value of 1.3 produced the best agreement between observed and simulated data.

Model coefficients for water quality simulation were initially set at default values and adjusted during the calibration process.

3.4.6 Model Segmentation

The model consists of three waterbodies – Lake Livingston, the Livingston spillway stilling basin, and approximately 10 miles of the Trinity River below the dam. Each waterbody is divided into longitudinal segments and each segment is further divided into layers 1 meter (3.28 ft) thick.

Figure 3-13 shows the segmentation of Lake Livingston. Typically the model geometry data are prepared from bathymetry data. However complete bathymetry data are not available for Lake Livingston. The reservoir geometry was based on surveyed cross sections in the 1991 Sedimentation Survey by Bureau of Reclamation (Ferrari, 1992). Essentially the reservoir bathymetry between the surveyed cross sections is inferred from interpolation between the cross sections. The geometry data calculated from the surveyed cross sections were adjusted such that the area capacity curves from the model approximated those from the Sedimentation Survey. In the model, the reservoir is represented by 16 longitudinal segments. The Trinity River inflow is at Segment 2 and the gate outflow is at Segment 13.

The geometry of the Lake Livingston stilling basin was based on drawings provided by TRA. In the model the stilling basin was represented by two longitudinal segments as shown on Figure 3-14. It is noted that the model length of each segment has to be increased to 328 ft (100 m) instead of about 200 ft to avoid stability problems. Since the stilling basin has a small volume with a short retention time, the greater length would not have a significant effect on the model results for the calibration period. For scenario runs with very low flows, the model will be run with flow and it is expected that the model can be run with the actual length with no stability issues.

The geometry of the river was based on a survey performed jointly by USGS and TRA's survey contractor. USGS used their Acoustic Doppler Current Profiler (ADCP) in the survey. They measured the distances from the start of a transect and the corresponding water depths to define the portion of the channel under water at the time of data collection. In the same survey effort a land surveyor ran levels from the edge of water up to the high bank to complete the cross section. The survey was done during the period July 11 through July 23, 2001, when the spillway discharge was at a constant 2,050 cfs. Although the ADCP measurements were not taken at exactly the same time as the land measurements, the water level in the river should be approximately constant during the survey due to the constant flow. Therefore, the water edge could be used as the reference point to relate the two sets of data. The river portion of the model was divided into 25 longitudinal segments as shown on Figure 3-15.

3.4.7 Model Results

Calibration was performed for the period from January 2000 to December 2006. The calibration data are provided by TRA (Paul C. Rizzo Associates, Inc., 2007) and include both surface measurements of various constituents and vertical profiles of temperature and DO. The monitoring stations are shown on Figure 3-11.

Figure 3-16 shows the observed and modeled water surface elevations. The observed water surface elevations in the 5-year period from 2000 to 2004 averaged 131.2 ft and the fluctuations were within ± 2 ft. The model assumption of a constant level reservoir is substantiated by the data. In September 2005, Hurricane Rita caused waves from the north to remove riprap on the dam. To avoid damage to the earthen dam structure, the water level was lowered by 4 ft and repair work was done to the riprap. The water level returned to normal in October 2006. As discussed in Section 3.4.2.1, the recorded reservoir releases by TRA were used as both inflow and outflow and this drop in water level was not modeled. Further refinement in the inflow values could be made to improve the agreement between modeled and observed water surface elevations, but is not expected to change the results of temperature, DO and other constituents significantly.

The only water level data available for the river are the results of the July 2001 survey. Figure 3-16 shows that there is reasonable agreement between the observed and modeled water surface elevations in the river portion of the model.

Figure 3-17 shows the surface water temperature from the model in comparison to the measured data over the course of the 2000–2006 calibration period near the dam (Station 10899). Model temperatures at noon are used for this comparison. The model appears to track the data well.

Figure 3-18 compares the model and measured vertical temperature profiles near the dam (Station 14003) over the course of 5 years from 2000 to 2004. This comparison tests how well the model represents the vertical transfer of heat to the deeper parts of the reservoir. As can be seen, the results are not always perfect, but are close most of the time. Moreover, some discrepancies are expected due to factors such as local variations in meteorological conditions, localized effects of various inflows or outflows, and the fact that the model results are averages over the entire segment and the observations are made at a particular point.

The surface DO results at Station 10899 are shown on Figure 3-17. The model does not reproduce the supersaturation indicated by the data. The supersaturation is due to photosynthesis. On the other hand, there does not seem to be a clear correlation between DO and the chlorophyll *a*. Nevertheless, for the purpose of this study, it is not important for the model to reproduce the supersaturation and it is conservative in the sense that the supersaturation will not be counted on to maintain the DO level downstream. The DO profiles at Station 14003 near the dam are shown on Figure 3-19. On some dates, the model results are zero at the deeper part of the reservoir as expected for a stratified reservoir, but the observations are not. It is also noted that the DO profile data do not show supersaturation at the surface. The differences between the measured DO and modeled DO may result from a wide variety of complex physical, chemical, and biological factors that affect DO.

Figure 3-17 shows the results of nutrients and chlorophyll *a* simulation at the surface at Station 10899 near the dam. These constituents were included in the model because the nutrient/algae dynamics affects DO. In general there is fairly good agreement between model results and data. The reservoir appears to have an abundant supply of phosphorus. This is expected since in non-runoff periods treated effluent is a significant component of the inflow to Lake Livingston. At times the reservoir appears to be nitrogen limited. The TKN model results are consistently higher than the observations. The reason may be an overestimate of the organic matter input, which is derived from inflow estimates that may be based on very limited data. Experience with the model suggests these differences do not have a major effect on results.

There are limited water quality data at Station 16998, approximately 0.5 mile downstream of the dam. The model results are shown on Figure 3-20. For surface water temperatures, the model appears to track the data well. In the summer, the surface DO model results are generally lower than those near the dam shown on Figure 3-17 since lower DO water below the surface is released. The data at Station 16998 show higher DO levels. The reason is likely to be the reaeration that takes place as a result of the spillway and the turbulence in the stilling basin. Modeling of this process can be refined with the new DO data from the stilling basin. For the other parameters, the level of agreement between the data and the model results is similar to that at the reservoir station.

The next downstream monitoring station is 10897 at the USGS gage. There are some data at this station for comparison with model results on Figure 3-21. It should be recognized that the water quality condition may be somewhat affected by the Long King Creek inflow. As discussed previously, this tributary was not modeled due to the uncertainty in input data. In any case, there seems to be reasonable agreement between the model results and the limited data.

3.4.8 Water Quality Modeling Conclusions

The model is calibrated to data from January 2000 to December 2006. The results appear to be in good agreement with measurements. The model will be refined with data collected in 2008 and applied to evaluate various release scenarios.

3.5 COLLECTION OF AMERICAN EELS IN THE TRINITY RIVER DOWNSTREAM OF LAKE LIVINGSTON DAM

During the baseline study of the Trinity River downstream of the dam, eel were collected during the three of the four sample trips. Juvenile eels were collected in the stomach contents of 2 striped bass and 1 blue catfish during the February sample event (see Section 3.1). There were a few DIDSON images collected during the course of the study that illustrated the movement of an animal like an eel or snake; however, it was not possible to verify which.

In response to a request made by the USFWS, additional sampling was conducted during the course of the last sample event in August 2008 for the purpose of better characterizing eel presence downstream of the dam. The additional effort included the deployment of 15 eel traps (traps) for 1 week and intensive boat and backpack electrofishing, particularly in areas of suitable habitat.

3.5.1 American Eel Trap Sampling

Each trap, similar in design to minnow bait traps, was approximately 32 inches long and 10 inches in diameter with an extended funnel on one end. The traps were constructed of ½-inch square mesh, vinyl-coated hardware cloth. Traps were baited initially with sardines. Reaches 1, 4, and 5 were each fished with five traps. In Reach 1, four traps were fished among the rip-rap boulders of the weir and one trap was placed among boulders at the drawn-down tube. In Reach 4, the traps were fished around boulders and brush piles. In Reach 5, the traps were placed around boulders and brush piles at the mouth of Long King Creek. The traps were checked periodically throughout the week and some were baited again with live and dead fish. Traps were deployed on August 18 and retrieved on August 22, 2008.

There were no eels collected in any of the traps. The traps placed at the weir were quickly inhabited by prawn. A limited number of the traps collected longear sunfish and blue catfish.

3.5.2 Boat and Backpack Electrofishing for American Eel

During the August sample event, additional electrofishing was conducted among habitats that were thought suitable for eels. The Trinity River flow was low and remained approximately 1,000 cfs over the course of the sample event. Due to the low flows, water clarity was good (Secchi depth >1 m), which facilitated observation of stunned organisms. Backpack electrofishing was conducted along the rip-rap boulders on the downstream side of the weir.

Results of the eel sampling downstream of the dam are provided in Table 3-5. A total of six eels were observed by backpack electrofishing along the weir and two were collected and retained. One eel was collected with the boat electrofisher from gravel/riffle habitat on the upper end of Reach 2. Additional eels were collected by boat electrofishing in Reach 4. The eels were collected from boulder and cobble substrates. All eel collected were in relatively shallow water with high velocities. The mean length of eels collected was 269 mm.

3.6 AMERICAN EEL IN THE UPPER TRINITY RIVER BASIN

The purpose of this study was to determine whether eels are present upstream of the Lake Livingston Dam and if present their relative abundance. Additionally the relative ages of any eels collected would be identified to evaluate whether or not eels have been able to migrate upstream past Lake Livingston Dam. There have been no prior studies that have focused on eels in Texas or the Trinity River. This field study focused on preferred habitats or locations that eels would likely occur in the upper Trinity River watershed.

3.6.1 Upper Trinity River Basin Sampling

Available fisheries data were reviewed to identify whether eels have been documented upstream of Lake Livingston. In addition, natural resource professionals from academic institutions and agencies were asked if they collected or were aware of any accounts of eels from this part of the basin.

One study of interest was a fish collection effort by the Texas Department of State Health Services (TDSHS) during summer 2008 that included 11 sample locations on the Trinity River from Fort Worth to FM 85 (south of Dallas). While their goal did not include sampling eels, they conducted an exhaustive sampling effort using a boat electrofisher and gill nets in various habitats. The biologists who conducted this study are very familiar with eels and they did not observe any eels over the course of their sampling (Mike Tennant, TDSHS, personal communication).

Additionally, the TPWD conducted an intensive sampling effort in the summer of 1995 at 15 sites in the Trinity River watershed upstream of Lake Livingston using boat-mounted electrofishing, gill nets, and seines. This intensive sampling effort failed to catch any eels (TPWD, 1996)

Eleven locations in the upper Trinity River basin were sampled from September 30 through October 2, 2008. The sample stations are shown on Figure 3-22. The sampling was conducted when stream flows were low, allowing access to the various habitats preferred by eels and also enhancing view of the bottom where shocked eels may remain after being stunned. The majority of sample stations were immediately downstream of dams. Where available, the sampling focused on areas of flowing water with suitable physical habitats such as boulder, cobble, and gravel substrates and/or coarse woody debris. Where accessible by boat, sampling was conducted by boat electrofishing. For stations inaccessible by boat, sampling was conducted with a backpack electrofisher. While the primary study goal was to collect eels, a record was compiled of all fish species collected or observed.

Temperature, conductivity, pH, and dissolved oxygen were recorded with water quality meters at the time of sampling. Flows were estimated from nearby USGS gauging stations (USGS, 2008). The following sections provide a description of each sample station and the sampling method employed.

3.6.2 Benbrook Reservoir Stilling Basin

Benbrook Reservoir impounds the Clear Fork Trinity River, southwest of Fort Worth in Tarrant County. The reservoir discharges to a stilling basin which consists of a deep pool. The study reach was from the shallow margins of the stilling basin pool to approximately 300 ft downstream. Immediately downstream of the pool, the channel narrows to an excavated channel that is approximately 10 ft wide and 150 ft long (Figure 3-23), which discharges to a large pool. The pool discharges to a series of riffles and runs, which were at the downstream end of the sample reach (Figure 3-24). The substrates included limestone bedrock along the narrow channel, fine and course sediments in the pools, and cobble and gravel in the riffles. In addition, boulders lined the stilling basin pool. Pondweed (*Potamogeton* spp.) and filamentous algae covered most of the excavated channel. The reservoir maintains a minimum flow release of approximately 9 cubic ft per second (cfs). With the exception of the middle reach of the stilling basin pool, the study reach was wadeable and was sampled using a backpack electrofisher.

3.6.3 Lake Worth Stilling Basin

Lake Worth is an impoundment on the West Fork Trinity River and is located on the northwest side of Fort Worth in Tarrant County. There is no stilling basin downstream of the dam. Dam discharge flows over an extensive area of flat limestone bedrock (Figure 3-25). A minimum flow release of approximately 12 cfs is maintained through a 10-inch discharge siphon. The study reach was from the discharge siphon to approximately 0.25 mile downstream. From the discharge siphon, part of the water sheet-flows across the bedrock and over a 15-ft-high waterfall that is approximately 800 ft downstream of the dam (Figure 3-26). A large pool is at the base of the waterfall. The remainder of the water flows through a poorly defined secondary channel that consists of a series of riffles and pools, which joins the pool downstream of the waterfall.

Pondweed, hydrilla (*Hydrilla verticillata*), and filamentous algae are common immediately downstream of the dam. Scattered gravel and cobble overlay parts of the limestone bedrock. Boulders, cobble, and gravel are common in the secondary channel. Fish sampling was conducted using a backpack electrofisher.

3.6.4 West Fork Trinity River Upstream of Beach Street

The West Fork Trinity River, downstream of the confluence with the Clear Fork Trinity River, flows through downtown Fort Worth and is impounded by a series of small channel dams. The channel dams along this reach of river consist of rolled concrete and are approximately 10 ft tall (Figure 3-26). The downstream side of the dams is sloped at approximately a 45 degree angle and the rolled concrete forms a series of steps. The river cascades over the top of the dams. This sample station was a 2-mile-long reach of the West Fork Trinity River between two channel dams, from the downstream dam approximately 500 ft downstream of the Beach Street Bridge upstream to the dam at the East 4th Street bridge. Sampling with boat electrofishing was focused from the dam at the East 4th Street bridge downstream for approximately 250 ft. River flow at the time of sampling was approximately 11 cfs. The study reach consisted of the area immediately downstream of the dam to approximately 250 ft downstream. Part of the river bank included rip-rap armoring. Fractured concrete boulders and cobble was the only available habitat along the dam.

3.6.5 West Fork Trinity River Downstream of Beach Street

This sample station was downstream of the Beach Street Bridge for a distance of approximately 500 ft and immediately downstream of a channel dam similar to the channel dam described above and had similar flow. However, the substrate at this station included submerged tires, woody debris, abundant boulders, and cobble. Fish sampling was conducted using a backpack electrofisher.

3.6.6 Lake Grapevine Stilling Basin

Lake Grapevine is an impoundment of Denton Creek, northwest of Dallas in Tarrant County. Constant discharge is maintained from the reservoir. Flow at the time of sampling was approximately 118 cfs. The stilling basin consists of a narrow, deep pool that discharges to a narrow, excavated channel. The study reach was from the downstream end of the stilling basin to approximately 200 ft downstream. The streambed consists primarily of hard clay overlain with abundant boulders, cobble, and gravel (Figure 3-27). Pondweed was present, but sparse in the sample reach. Sampling was conducted by backpack electrofishing.

3.6.7 Lake Lewisville Stilling Basin

Lake Lewisville is a reservoir on the Elm Fork Trinity River, northwest of Dallas in Denton County. Discharge from the dam at the time of sampling was approximately 312 cfs. The majority of the flow was through the hydroelectric station. The stilling basin is relatively shallow and is armored on both sides by concrete walls (Figure 3-28). The stream channel is largely natural immediately downstream of the stilling basin, consisting of a series of riffles and runs. The substrate included abundant boulders, cobble, and gravel. The study reach consisted of the area immediately downstream of the dam to approximately 200 ft downstream. Sampling was conducted by boat electrofishing.

3.6.8 East Fork Trinity River Downstream of Lake Lavon

Lake Lavon is an impoundment on the East Fork Trinity River, northeast of Dallas in Collin County. The reservoir discharges to a large stilling basin, which is broad and deep. There was no boat access to the stilling basin and it was too deep for backpack electrofishing. A small channel dam is located on the river approximately 1 mile downstream of the stilling basin. Sampling was conducted by boat electrofishing immediately downstream of the channel dam to approximately 300 ft downstream (Figure 3-29). Boulders and cobble are abundant immediately downstream of the dam. In addition, coarse woody debris and emergent aquatic plants were common in the study reach. The river channel is deeply incised with depths up to 10 ft. There was no discharge from Lake Lavon nor was there flow in the river.

3.6.9 Lake Ray Hubbard Stilling Basin

Lake Ray Hubbard is the downstream-most reservoir on the East Fork Trinity River, downstream of Lake Lavon in Collin County. Sampling was conducted in the stilling basin, which is broad, and the substrate is dominated by clay and silt. However, boulders were scattered along the shallow margins of the stilling basin (Figure 3-30). There was no flow from the reservoir at the time of sampling. Sampling was conducted by boat electrofishing.

3.6.10 Trinity River Downstream of State Highway 287

This station included the reach of river from State Highway (SH) 287 downstream to the confluence of Richland-Chambers Creek. Sampling was conducted by boat electrofishing. Sampling was conducted among various habitats along approximately 2 miles of river. Habitats sampled included riffles with boulders, cobble, and gravel; shallow and deep woody debris; and undercut banks. Sampling was also conducted at the mouth of Richland-Chambers Creek. Flow in the river was 850 cfs at the time of sampling. Flow in Richland-Chambers Creek was negligible. The river channel along this reach is generally incised with steep, mud banks and deep water.

3.6.11 Cedar Creek Reservoir Discharge Channel

Cedar Creek Reservoir impounds Cedar Creek in Henderson County. The reservoir discharges into an excavated, man-made channel that flows into the Trinity River. The excavated channel is wide and shallow near the reservoir. The channel substrate consists of relatively fine sediments, but also contains boulders and cobble near the spillway (Figure 3-31). There was no flow at the time of sampling. Sampling in the shallow areas immediately downstream of the spillway was conducted by backpack electrofishing. Boat electrofishing was conducted in the deeper reaches of the channel to a distance of up to 0.5 mile downstream of the spillway.

3.6.12 Richland-Chambers Reservoir Stilling Basin

Richland-Chambers Reservoir is an impoundment of Richland and Chambers creeks in Freestone and Navarro counties. The reservoir discharges to a large, deep stilling basin, which narrows to an excavated channel (Figure 3-32). There was no flow from the reservoir at the time of sampling. The substrate in the stilling basin consists primarily of sand and soft sediments. However, gabion armoring and boulders are along the shore of the stilling basin immediately downstream of the dam. Coarse woody debris is common along the channel downstream of the stilling basin. The study reach included the shoreline along the stilling basin and the shore of the channel downstream of the stilling basin.

3.6.13 Results of Sampling for Eels in the Upper Trinity River Watershed

There were no eels collected or observed during this study. Of the 11 stations, five (Benbrook, Lewisville, Worth, and Grapevine reservoir tailraces and the Trinity River at SH 287) were considered to have suitable eel habitat that consisted of flowing water and abundant boulder, cobble, and gravel substrates. In addition, numerous snags and log piles were sampled along the Trinity River station at SH 287. In addition, three of these stations had abundant aquatic vegetation. The West Fork Trinity River stations in the vicinity of Beach Street also appeared have acceptable habitat but in fairly limited amounts. The remaining stations each had rock substrates, but lacked moving water.

Water quality and flow by station is provided in Table 3-6. One point of interest is the slightly depressed dissolved oxygen at the Grapevine and Cedar Creek reservoir stilling basins and the West Fork Trinity River upstream of Beach Street. Discharge from Grapevine Reservoir is from the hypolimnion, which indicates that dissolved oxygen might be periodically limiting water quality conditions for aquatic life immediately downstream of the dam. The depressed dissolved oxygen in the Cedar Creek Reservoir was probably the result of the static water conditions. Staff from the Tarrant Regional Water District mentioned that periodic fish kills occur at this location due to low dissolved oxygen. The depressed dissolved oxygen in the West Fork Trinity River may have resulted from algal respiration and water and sediment oxygen demand.

A list of the fish species collected is provided in Table 3-7. In general, the species composition reflected the altered hydrology and the influence of the reservoir fish communities upstream.

The field survey provided the opportunity to visit with the reservoir controlling authorities about their knowledge of eels at their locations. None of the staff knew of any accounts of eels from their locations. In the case of the lakes Lavon and Ray Hubbard, the stilling basins were recently drained and the controlling authorities were required to relocate the fish downstream. In both cases, no eels were observed.

Results of this study, available fisheries data, and accounts by area natural resource professionals provide a strong indication that few eels may exist in the upper Trinity River basin. The two collections of eels in Lake Lavon since 2000 suggest that a limited number of eels might be present in the reservoir. However, the relatively large size of the eels, greater than 760 mm, indicates those individuals might have been present in the upper basin prior to construction of Lake Livingston Dam. Since eels are present in the lower basin, it appears that Lake Livingston Dam is an effective barrier to upstream eel migration.

Table 3-1. Stomach Contents of Striped Bass and Blue Catfish Collected from the Trinity River Downstream of Lake Livingston Dam

Species Sampled	No. of Prey	Prey Species	Prey Length (mm)
February 2008 - Upstream of Weir			
Blue catfish	0	Empty	-
Blue catfish	3	Unidentifiable	17
		Unidentifiable	35
		Unidentifiable	18
Blue catfish	1	Shad	-
Blue catfish	0	Empty	-
Blue catfish	0	Empty	-
Blue catfish	0	Empty	-
Blue catfish	0	Empty	-
Blue catfish	1	Catfish	-
Blue catfish	0	Empty	-
Blue catfish	0	Empty	-
Blue catfish	4	American eel	130
		Temperate bass	170
		Temperate bass	270
		Blue catfish	95
Channel catfish	2	Lady bugs	-
		Unidentifiable	-
Striped bass	0	Empty	-
Striped bass	0	Empty	-
Striped bass	0	Empty	-
Striped bass	2	Inland silverside	40
		Threadfin shad	60
Striped bass	3	Channel catfish	69
		Threadfin shad	36
		Threadfin shad	51
Striped bass	0	Empty	-
Striped bass	1	Temperate bass	-
Striped bass	0	Empty	-
Striped bass	1	Unidentifiable	30
Striped bass	1	Unidentifiable	33
Striped bass	4	Inland silverside	48
		Threadfin shad	52
		Threadfin shad	38
		Threadfin shad	55
Striped bass	6	Sunfish	95
		Threadfin shad	52
		Threadfin shad	64
		Unidentifiable	31
		Unidentifiable	62
		Unidentifiable	42
Striped bass	6	American eel	85
		Inland silverside	36
		Inland silverside	48
		Threadfin shad	46
		Threadfin shad	58
		Threadfin shad	50
Striped bass	1	Unidentifiable	37
Striped bass	2	Channel catfish	85
		Threadfin shad	74
White bass	2	Unidentifiable	44
		Unidentifiable	43
White bass	1	Threadfin shad	96
February 2008 - Downstream of Weir			
Striped bass	1	Gizzard shad	200
Striped bass	3	Shad	55
		Shad	65
		Shad	120
Striped bass	0	Empty	-
Striped bass	1	American eel	120
Striped bass	0	Empty	-
Striped bass	4	Gizzard shad	220
		Yellow bass	185
		Yellow bass	95
		Yellow bass	110
Striped bass	0	Empty	-
Striped bass	0	Empty	-
Striped bass	0	Empty	-

Species Sampled	No. of Prey	Prey Species	Prey Length (mm)
April 2008 - Downstream of Weir			
Blue catfish	0	Empty	-
Blue catfish	0	Empty	-
Blue catfish	0	Empty	-
Blue catfish	0	Empty	-
Blue catfish	0	Empty	-
Blue catfish	0	Empty	-
Blue catfish	19	Threadfin shad	85
		Threadfin shad	93
		Threadfin shad	65
		Threadfin shad	80
		Threadfin shad	78
		Threadfin shad	85
		Threadfin shad	65
		Threadfin shad	78
		Threadfin shad	95
		Threadfin shad	65
		Threadfin shad	90
		Threadfin shad	76
		Threadfin shad	85
		Threadfin shad	93
		Threadfin shad	155
		Threadfin shad	68
		Threadfin shad	64
		Threadfin shad	93
		Threadfin shad	65
Blue catfish	0	Empty	-
Blue catfish	0	Empty	-
Channel catfisl	0	Empty	-
White x striped bass	5	Gizzard shad	176
		Gizzard shad	165
		Unidentifiable	50
		Unidentifiable	105
		Unidentifiable	50
White x striped bass	1	Gizzard shad	183
White x striped bass	10	Threadfin shad	75
		Threadfin shad	95
		Threadfin shad	70
		Threadfin shad	80
		Threadfin shad	70
		Threadfin shad	80
		Threadfin shad	65
		Unidentifiable	-
		Unidentifiable	-
		Unidentifiable	-
White x striped bass	2	Gizzard shad	140
		Threadfin shad	75
Striped bass	2	Gizzard shad	197
		Gizzard shad	198
Striped bass	1	Unidentifiable	-
Striped bass	0	Empty	-
Striped bass	4	Threadfin shad	70
		Threadfin shad	98
		Threadfin shad	105
		Threadfin shad	95

Species Sampled	No. of Prey	Prey Species	Prey Length (mm)
April 2008 (continued) - Downstream of Weir			
Striped bass	1	Threadfin shad	68
Striped bass	6	Threadfin shad	75
		Threadfin shad	65
		Threadfin shad	95
		Threadfin shad	70
		Threadfin shad	80
		Threadfin shad	70
Striped bass	6	Gizzard shad	130
		Gizzard shad	130
		Gizzard shad	170
		Gizzard shad	195
		Gizzard shad	200
		Gizzard shad	200
Striped bass	5	Threadfin shad	85
		Threadfin shad	90
		Threadfin shad	87
		Threadfin shad	98
		Threadfin shad	55
Striped bass	1	Threadfin shad	72
Striped bass	0	Empty	-
Striped bass	0	Empty	-
Striped bass	0	Empty	-
Striped bass	0	Empty	-
Striped bass	0	Empty	-
August 2008 - Upstream of Weir			
Blue catfish	0	Empty	-
Blue catfish	0	Empty	-
Blue catfish	0	Empty	-
Blue catfish	0	Empty	-
Blue catfish	1	Blue catfish	120
August 2008 - Downstream of Weir			
Striped bass	0	Empty	-
Striped bass	0	Empty	-
Striped bass	0	Empty	-
Striped bass	0	Empty	-
Striped bass	0	Empty	-
Striped bass	2	Bluegill	54
		Sand shiner	52
Striped bass	1	Gizzard shad	170
Striped bass	3	Blacktail shiner	53
		Blacktail shiner	70
		Silverband shiner	76
Striped bass	1	Prawn	-
Striped bass	1	Rock	-
Striped bass	0	Empty	-
Striped bass	0	Empty	-
Striped bass	3	Blacktail shiner	61
		Blacktail shiner	62
		Larger bones	-
Striped bass	1	Blacktail shiner	62
Striped bass	0	Empty	-
Striped bass	2	Blacktail shiner	58
		Blacktail shiner	66
Striped bass	0	Empty	-
Striped bass	0	Empty	-
Striped bass	1	Digested shad	-
Striped bass	0	Empty	-
Striped bass	0	Empty	-
Striped bass	0	Empty	-
Striped bass	0	Empty	-
Striped bass	1	Buffalo scale	-
Striped bass	0	Empty	-
Striped bass	0	Empty	-
Striped bass	0	Empty	-

Table 3-2. Weight Ratio (Wr) of Striped Bass Collected for Stomach Content Analysis, Trinity River

Length (mm)	Measured Weight (g)	Standard Weight (g)*	Wr
February-08			
425	1,092	954	114
485	1,098	1,419	77
495	1,880	1,509	125
501	1,802	1,565	115
506	1,446	1,612	90
510	1,822	1,651	110
511	1,866	1,660	112
520	1,368	1,750	78
520	1,400	1,750	80
528	1,740	1,832	95
540	1,720	1,960	88
545	2,102	2,015	104
547	1,880	2,038	92
561	1,782	2,199	81
568	2,426	2,282	106
578	2,160	2,405	90
581	2,768	2,443	113
586	3,048	2,507	122
595	2,502	2,624	95
621	3,504	2,984	117
626	3,380	3,057	111
720	4,981	4,656	107
750	6,803	5,264	129
760	4,888	5,478	89
Mean Wr			**102**

Length (mm)	Measured Weight (g)	Standard Weight (g)*	Wr
April-08			
421	400	927	43
431	998	995	100
437	1,014	1,037	98
441	1,176	1,066	110
454	1,092	1,164	94
471	1,416	1,299	109
490	1,488	1,464	102
503	1,598	1,583	101
515	1,122	1,700	66
527	1,948	1,822	107
658	4,060	3,551	114
674	4,264	3,818	112
676	4,872	3,852	126
773	6,804	5,764	118
Mean Wr			**100**

Length (mm)	Measured Weight (g)	Standard Weight (g)*	Wr
August-08			
336	370	471	79
395	636	766	83
440	712	1,059	67
452	950	1,148	83
452	780	1,148	68
468	914	1,275	72
471	910	1,299	70
472	980	1,308	75
474	1,088	1,325	82
480	1,162	1,376	84
485	1,126	1,419	79
487	920	1,437	64
491	980	1,473	67
497	1,144	1,527	75
512	1,294	1,670	77
519	1,394	1,740	80
520	1,332	1,750	76
521	1,434	1,760	81
525	1,326	1,801	74
528	1,570	1,832	86
626	2,208	3,057	72
630	3,310	3,116	106
652	2,480	3,455	72
680	2,888	3,921	74
716	3,500	4,579	76
742	3,686	5,097	72
860	5,000	7,944	63
Mean Wr			**76**

Table 3-3. DIDSON Monitoring, Lake Livingston

Sample Date	Sample Time (hr)	Total Number of Fish Counted
2/26/2008	3.25	894
2/27/2008	22.75	4,483
2/28/2008	18.00	1,574
3/25/2008	2.75	633
3/26/2008	22.25	4,074
3/27/2008	11.25	3,394
4/28/2008	3.25	347
4/29/2008	23.25	2,469
4/30/2008	21.50	5,018
5/1/2008	12.00	14,760
8/19/2008	15.00	9,793
8/20/2008	24.00	10,319
8/21/2008	18.00	2,675
Total	**197.25**	**60,433**

Table 3-4. Water Quality from May 1 - September 11, 2008 Measured with Continuous-recording Water Quality Meters, Lake Livingston and the Trinity River Downstream of Lake Livingston Dam

	Temperature (°C)			Dissolved oxygen (mg/l)			Conductivity (mS/cm)			pH (su)			
Station	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**	**Number of measurements**
Proposed headrace	27.8	32.6	21.5	7.3	15.0	0.4	0.392	0.428	0.352	8.363	9.1	7.4	6,155
Near dam, surface	27.9	32.7	21.6	7.8	17.1	0.8	0.389	0.422	0.352	8.398	9.1	7.4	6,112
Near dam, 29 ft	26.9	30.1	21.3	3.3	9.2	0.1	0.419	0.443	0.377	7.763	8.7	7.3	6,153
Near dam, 50 ft	25.2	29.5	21.2	1.5	8.2	0.0	0.393	0.438	0.350	7.473	8.7	7.1	6,096
River, in stilling basin	27.2	30.5	21.7	7.6	9.6	5.7	0.395	0.446	0.334	7.960	8.7	7.5	6,142

Table 3-5. American Eels Collected by Electrofishing, December 2007 through August 2008, Trinity River

Trip	Reach	Length (mm)	Weight (g)
December 2007	1	260	-
December 2007	1	210	-
February 2008	1	260	-
February 2008	1	241	-
February 2008	1	200	-
August 2008	1*	200	-
August 2008	1	203	12
August 2008	1	300	35
August 2008	2	282	-
August 2008	4	321	-
August 2008	4	309	-
August 2008	4	350	-
August 2008	4	367	-

* Four other eels were observed between the boulders downstream of the weir but could not be collected

Table 3-6. Water Quality Parameters and Flow Observed in the Upper Trinity River Basin, September 29 through October 2, 2008

Station	Sample Date	Time	Temperature (˚C)	Conductivity (μmho/cm)	pH (s.u.)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (%)	Flow (cfs)
Benbrook Reservoir tailrace	9/29/2008	2:42 PM	27.0	303	8.4	7.2	90.6	9
Lake Worth tailrace	9/29/2008	4:42 PM	28.4	338	7.9	6.1	78.9	12
Lake Lewisville tailrace	9/30/2008	12:42 PM	25.1	330	6.7	6.2	74.7	312
West Fork Trinity River downstream of Beach Street	10/1/2008	8:09 AM	23.6	366	7.7	4.4	51.6	11
Lake Lavon tailrace	10/1/2008	1:55 PM	24.6	451	7.4	6.6	79.5	0
Lake Ray Hubbard tailrace	9/30/2008	3:49 PM	26.8	371	8.5	9.8	122.8	0
Grapevine Reservoir tailrace	9/30/2008	10:14 AM	25.2	361	7.5	4.9	59.3	118
Trinity River at SH 287	10/1/2008	5:33 PM	25.2	750	8.1	7.8	95.4	850
Cedar Creek Reservoir tailrace	10/2/2008	9:04 AM	22.0	585	8.0	3.8	43.5	0
Richland-Chambers Reservoir tailrace	10/2/2008	12:43 PM	26.0	648	7.4	6.2	75.9	0

Table 3-7. Fish Collected from the Upper Trinity River Basin, September 29 through October 2, 2008

Common name	Scientific name	Benbrook Reservoir tailrace	Lake Worth tailrace	Lake Lewisville tailrace	West Fork Trinity River upstream of Beach Street	West Fork Trinity River downstream of Beach Street	Lake Lavon tailrace	Lake Ray Hubbard Reservoir tailrace	Grapevine Reservoir tailrace	Trinity River at SH 287	Cedar Creek Reservoir tailrace	Richland-Chambers Reservoir tailrace
Gars	**Lepisosteidae**											
Spotted gar	*Lepisosteus oculatus*							X		X	X	X
Longnose gar	*L. osseus*							X		X	X	
Alligator gar	*L. spatula*											X
Shad	**Clupeidae**											
Threadfin shad	*Dorosoma petenense*			X	X		X	X		X	X	
Gizzard shad	*D. cepedianum*			X	X		X	X			X	X
Minnows & Carps	**Cyprinidae**											
Common carp	*Cyprinus carpio*	X					X		X		X	
Central stoneroller	*Campostoma anomalum*	X										
Golden shiner	*Notemigonus chrysoleucas*	X										
Blacktail shiner	*Cyprinella venusta*	X	X	X								
Red shiner	*C. lutrensis*					?				X		
Bullhead minnow	*Pimephales vigilax*		X	X	X	X				X		X
Suckers	**Catostomidae**											
Smallmouth buffalo	*Ictiobus bubalus*			X	X			X			X	X
Bullhead Catfishes	**Ictaluridae**											
Channel catfish	*Ictalurus punctatus*			X				X	X	X	X	
Blue catfish	*I. furcatus*									X	X	X
Yellow bullhead	*Ameirus natalis*	X				X						
Flathead catfish	*Pylodictis olivaris*	X			X		X	X	X	X		
Freckled madtom	*Noturus nocturnus*			X		X				X		
Tadpole madtom	*N. gyrinus*	X										
Killifishes	**Cyprinodontidae**											
Blackstripe topminnow	*Fundulus notatus*	X										
Livebearers	**Poeciliidae**											
Western mosquitofish	*Gambusia affinis*	X	X			X	X		X			
Silversides	**Atherinidae**											
Inland silverside	*Menidia beryllina*				X							
Temperate Basses	**Moronidae**											
White bass	*Morone chrysops*							X				
Striped (x) White bass	*M. saxatilis (x) M. chrysops*			X								
Sunfishes	**Centrarchidae**											
Largemouth bass	*Micropterus salmoides*	X		X	X	X	X	X			X	X
Spotted bass	*M. punctulatus*				X							
Warmouth	*Lepomis gulosus*					X	X					X
Redbreast sunfish	*L. auritus*	X										
Green sunfish	*L. cyanellus*	X	X	X	X	X		X	X		X	
Redear sunfish	*L. microlophus*	X			X		X					
Bluegill	*L. macrochirus*		X	X	X	X	X	X	X	X	X	X
Longear sunfish	*L. megalotis*	X	X	X	X	X	X	X	X	X		X
White crappie	*Pomoxis annularis*	X		X							X	
Black crappie	*P. nigromaculatus*			X								
Perches	**Percidae**											
Dusky darter	*Percina sciera*					X		X		X		
Bigscale logperch	*P. macrolepida*			X	X	X	X			X		X
Drums	**Sciaenidae**											
Freshwater drum	*Aplodinotus grunniens*	X		X			X					X

Figure 3-1. Rate of Fish Movement From Lake Livingston to Trinity River in Reservoir Releases. Note the scale is different for the April and August sample events.

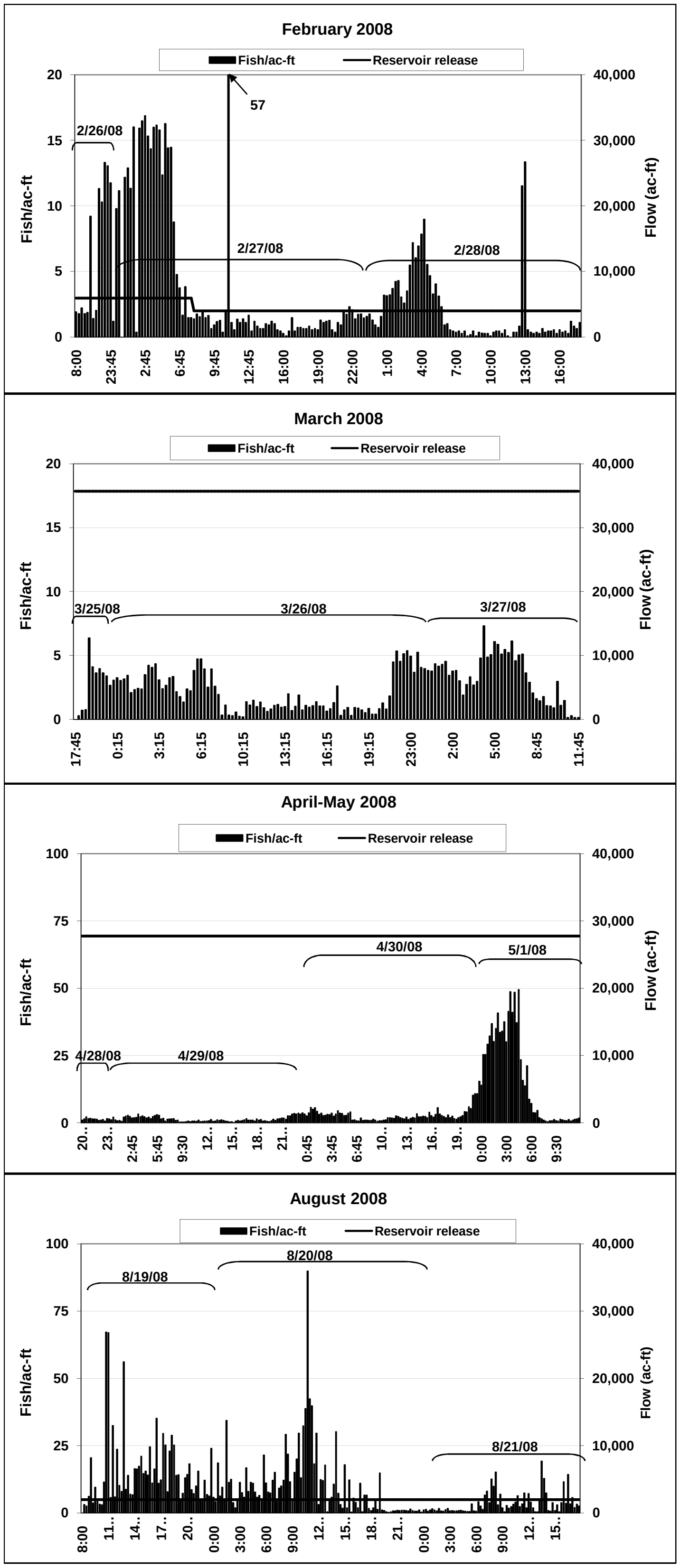


Figure 3-2. Total Fish Movement From Lake Livingston to Trinity River in Reservoir Releases. Note the scale is different for the April sample event.

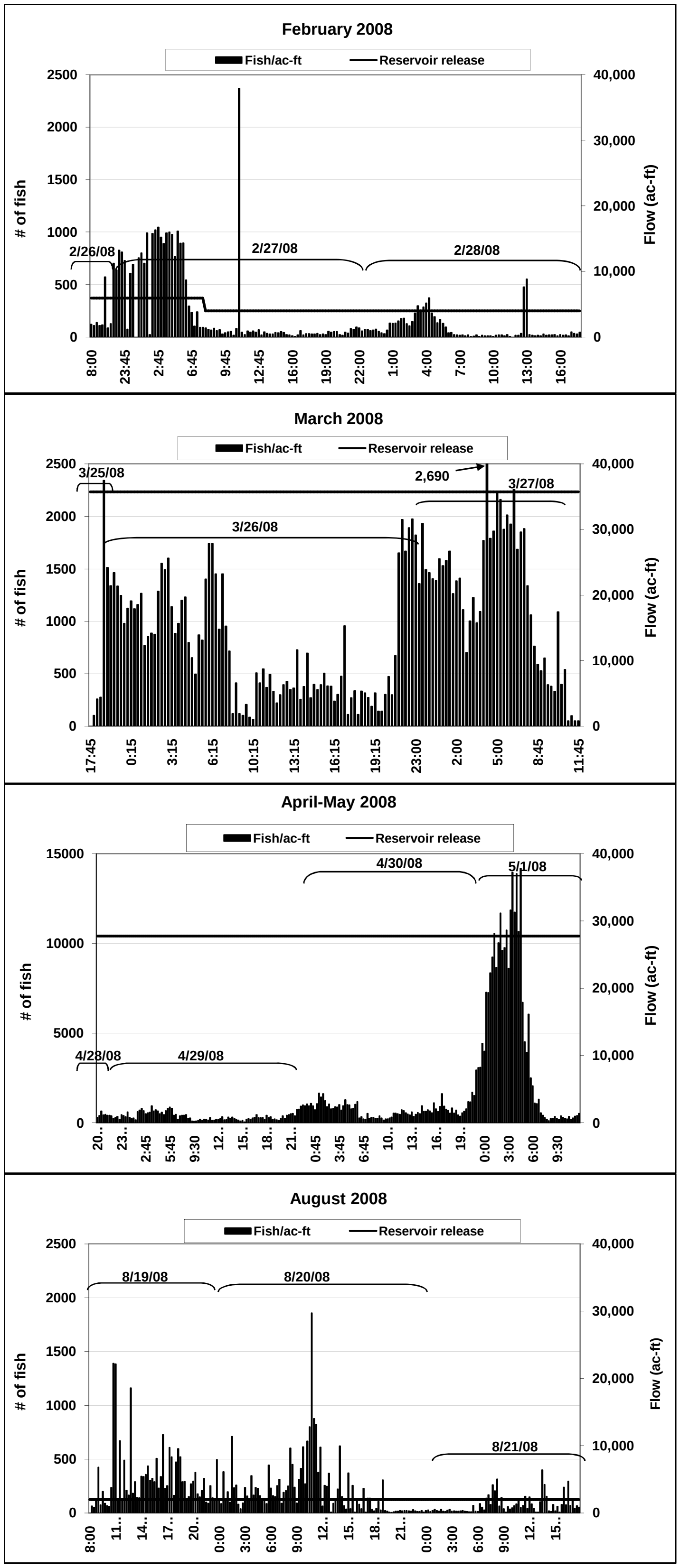


Figure 3-3. Estimated Total Fish Released from Lake Livingston Dam from December 3, 2007 through August 22, 2008.

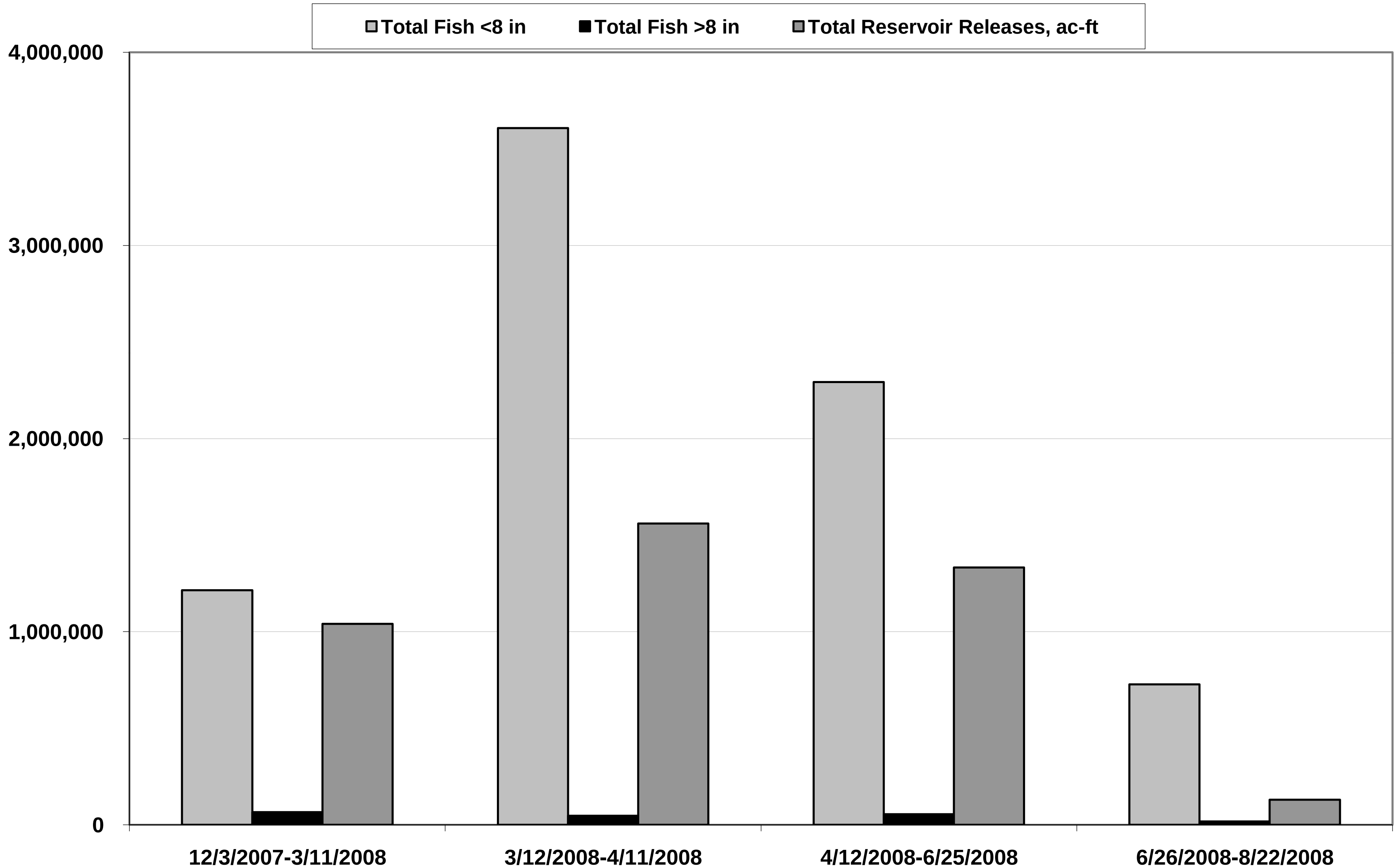


Figure 3-4. Daily Average Reservoir Release from Lake Livingston Dam, December 1, 2007 through August 22, 2008

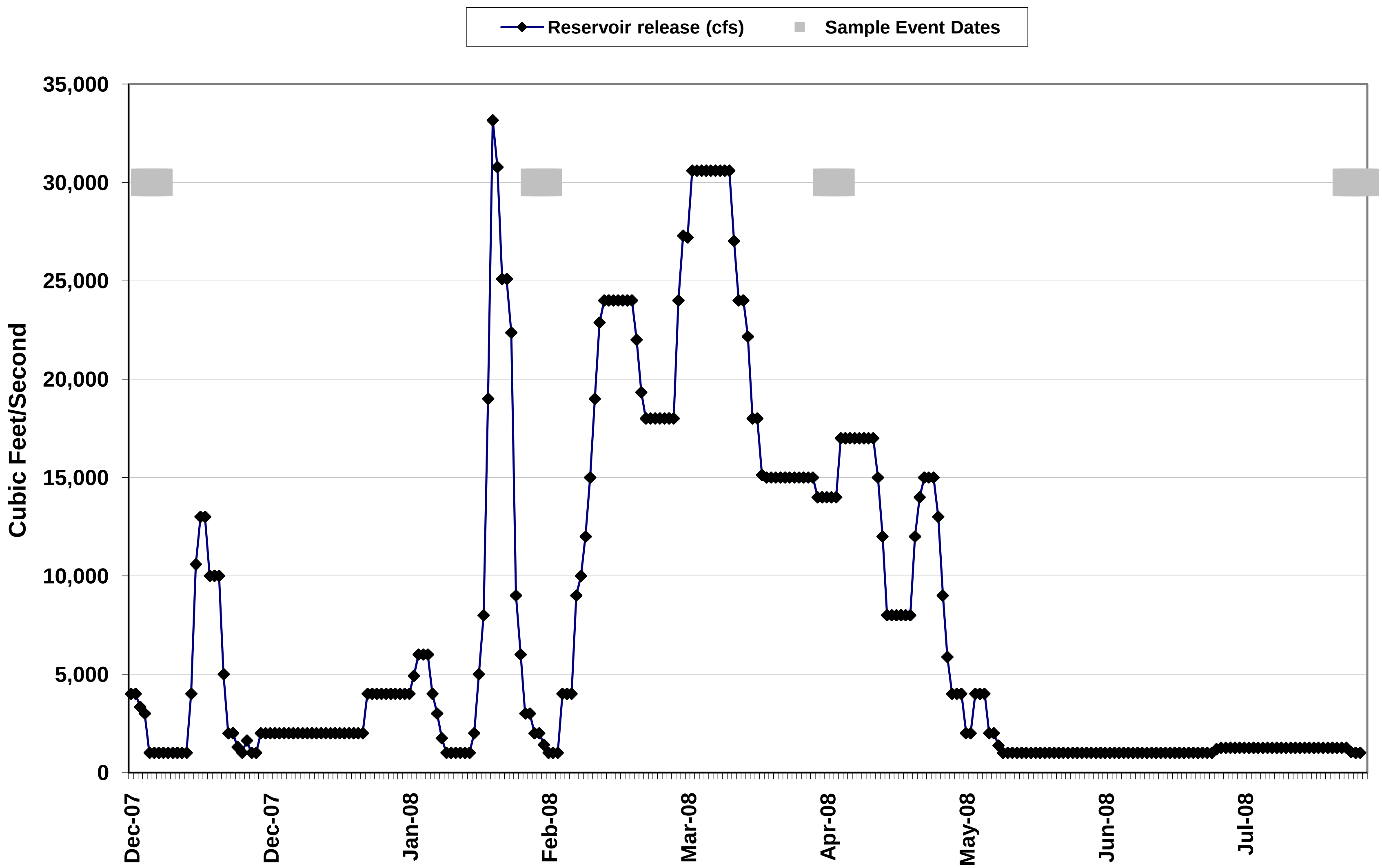


Figure 3-5. Comparsion of Total Fish per 15 Minutes to Time of Day Passing through Lake Livingston Dam, February through April Sample Events

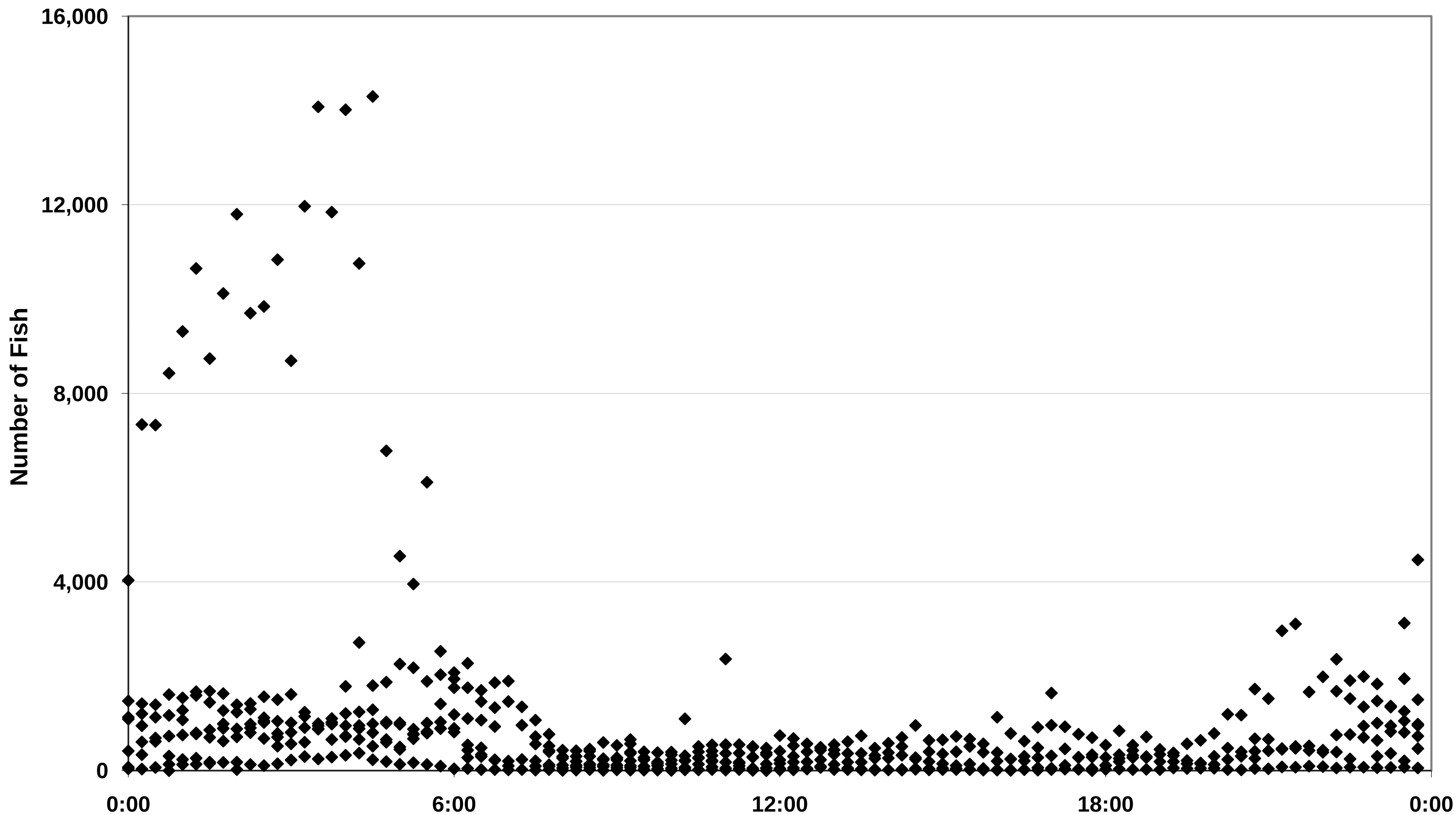


Figure 3-6. Diurnal Variation in Fish Passing Through Lake Livingston Dam, August Sample Event

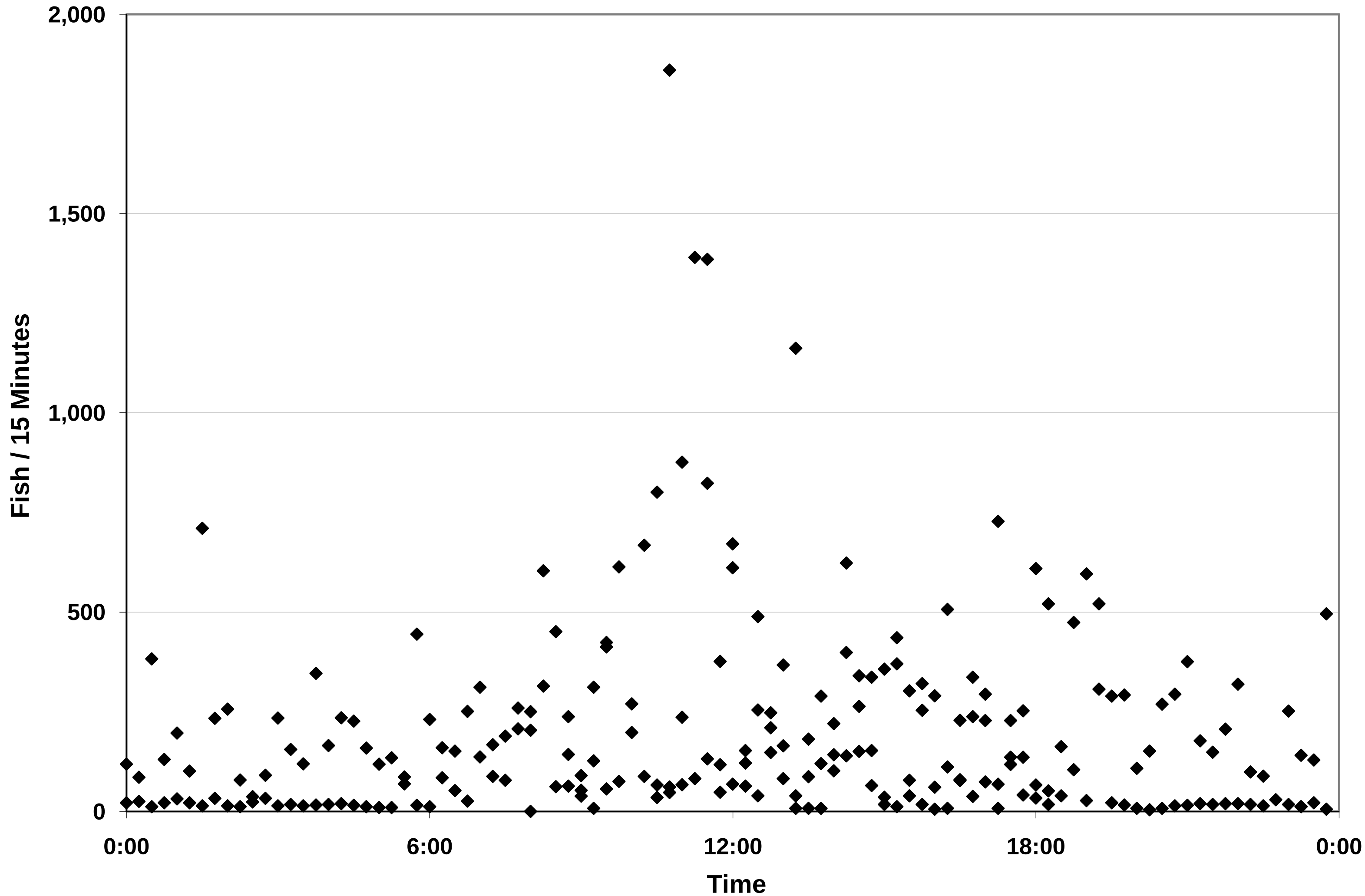


Figure 3-7. Measured Differences in Water Temperature Between the Proposed Headrace (Lake Livingston) and the Trinity River Upstream of the Weir, May 1 through September 11, 2008

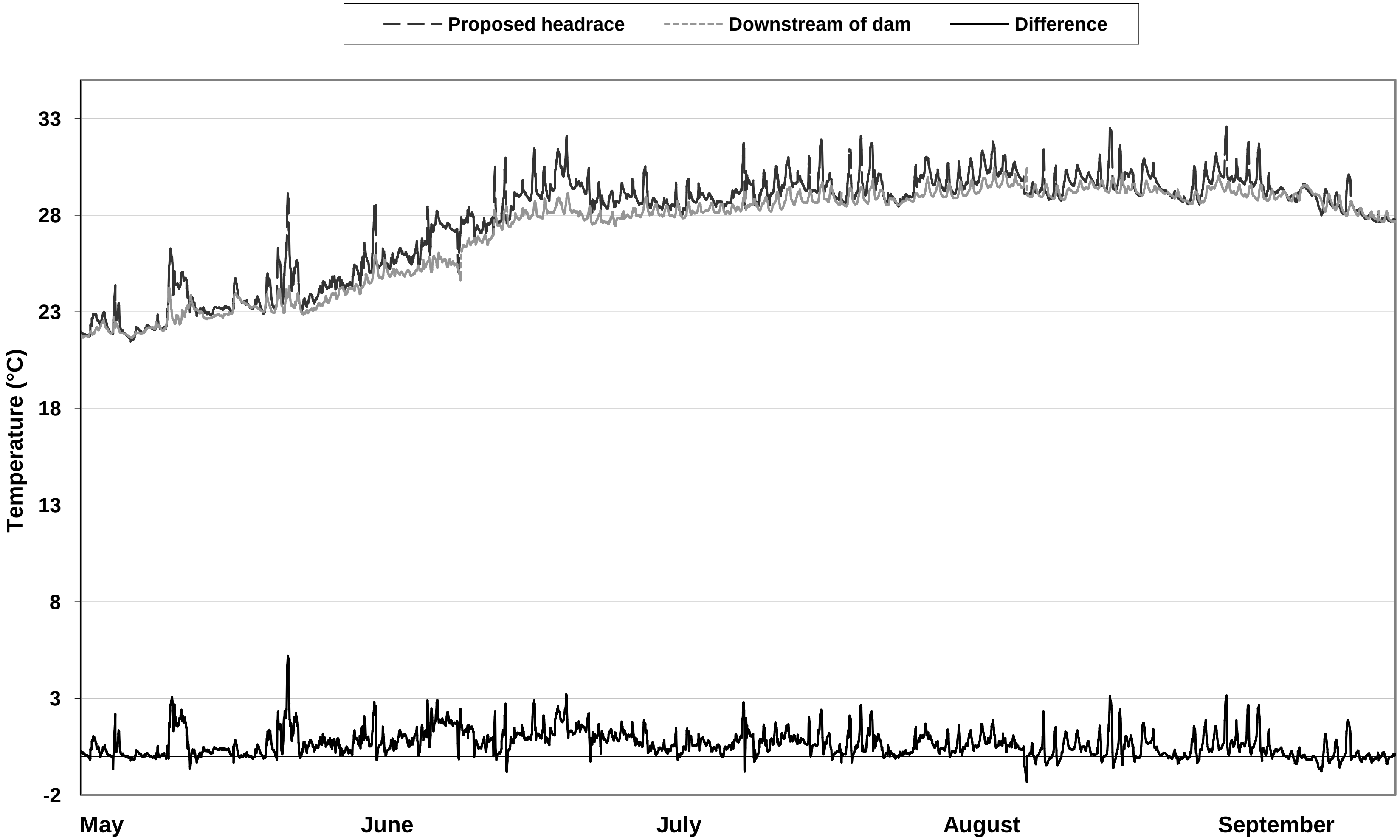


Figure 3-8. Comparison of Dissolved Oxygen Concentrations Every 30 Minutes at the Proposed Intake Site to the Stilling Basin, May 1, 2008 to September 6, 2008, Lake Livingston

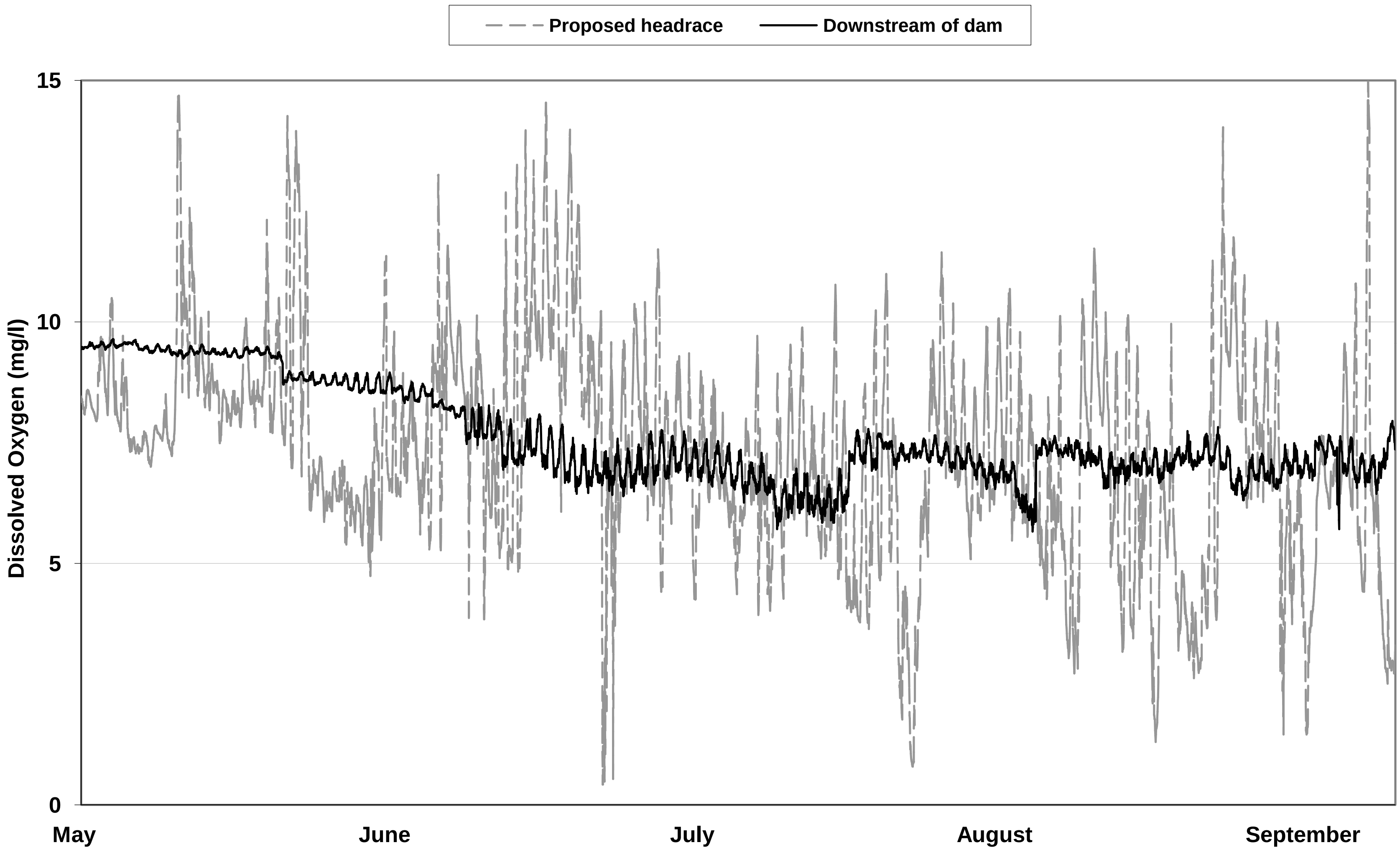


Figure 3-9. Comparison of Daily Average Dissolved Oxygen Concentrations at the Proposed Intake Site to the Stilling Basin, May 1, 2008 to September 6, 2008, Lake Livingston

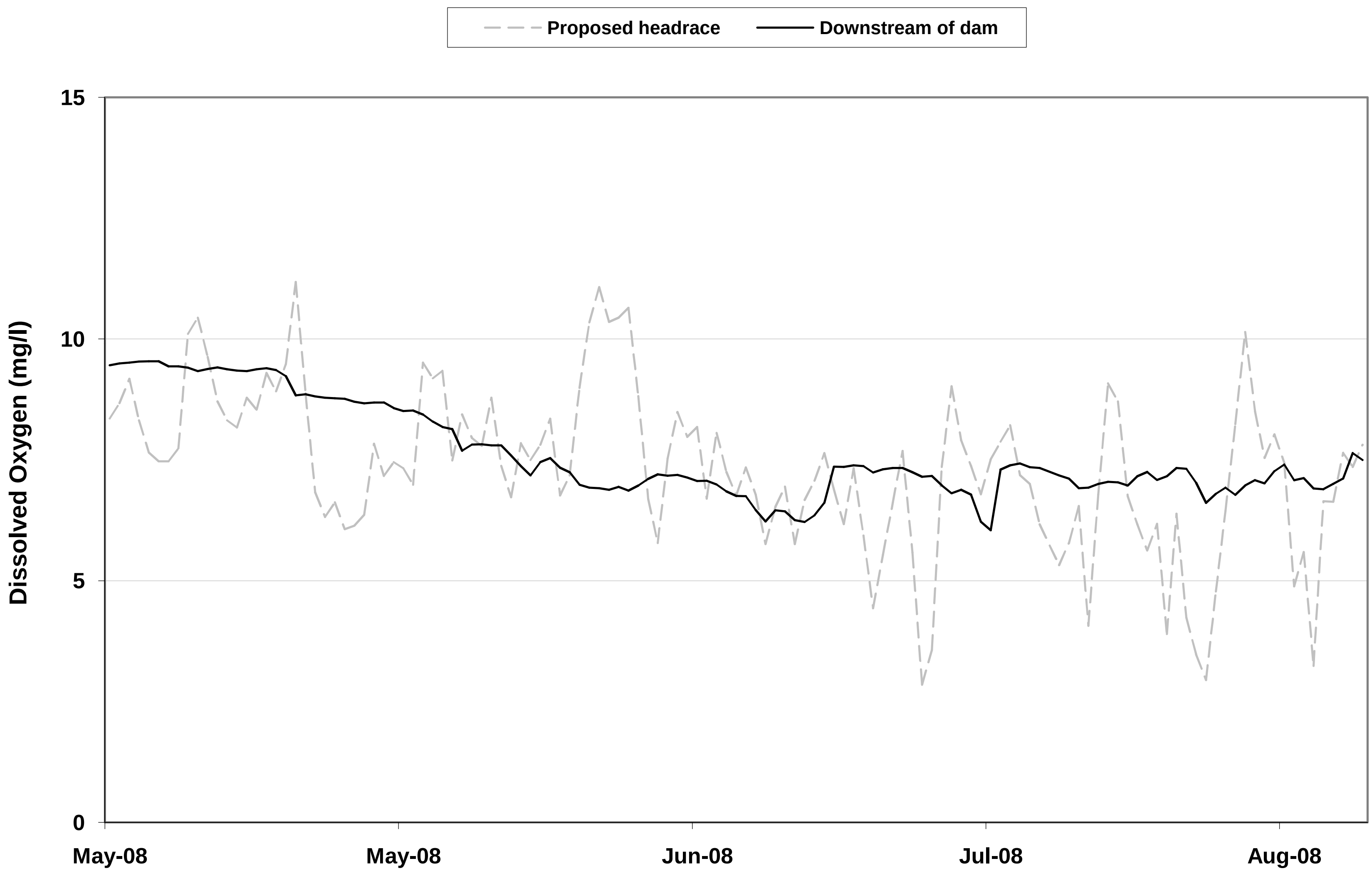
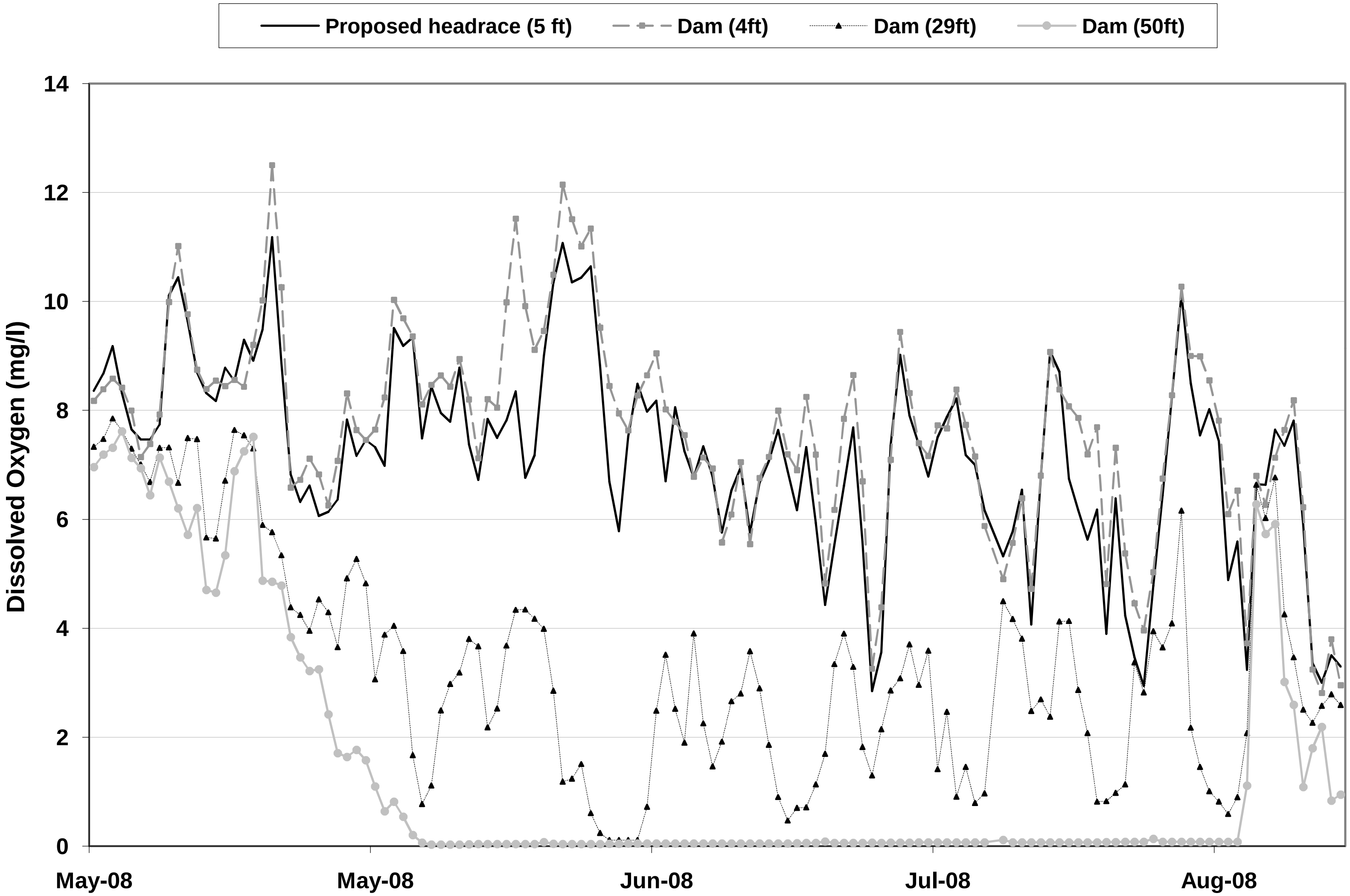
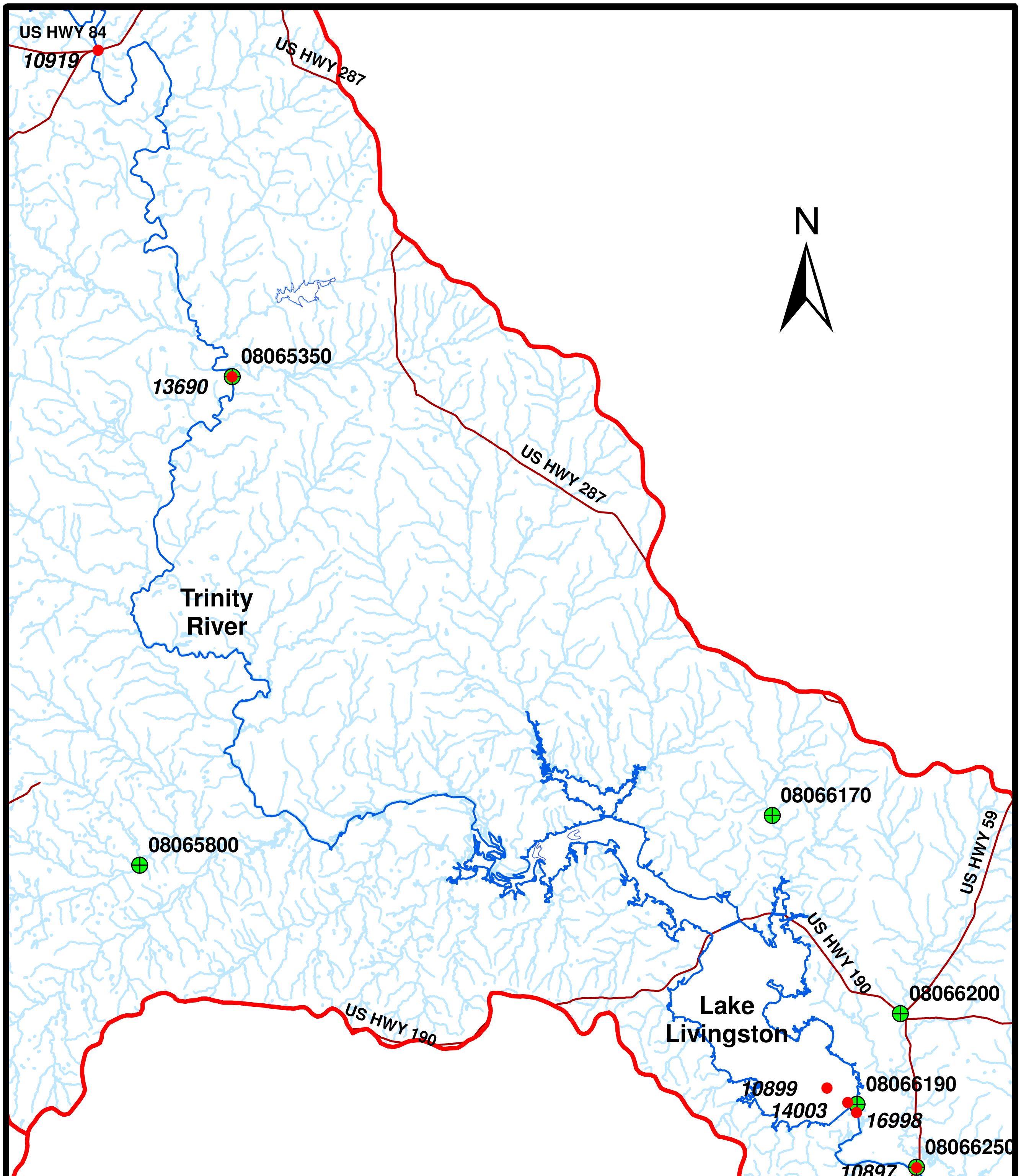


Figure 3-10. Lake Livingston Daily Average Dissolved Oxygen Concentrations at the Proposed Headrace and at the Various Depths Near the Tainter Gates, May 1, 2008 to September 11, 2008





Legend

- Monitoring Station
- USGS Gage
- US Hwys
- Trinity River Basin Boundary

0 2.5 5 10 Miles

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Figure 3-11
Locations of USGS Gages and Monitoring Stations

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Job No.: 044198800	Scale: 1"=50,000'
Prepared by: K.L.Lee	Date: October 2008
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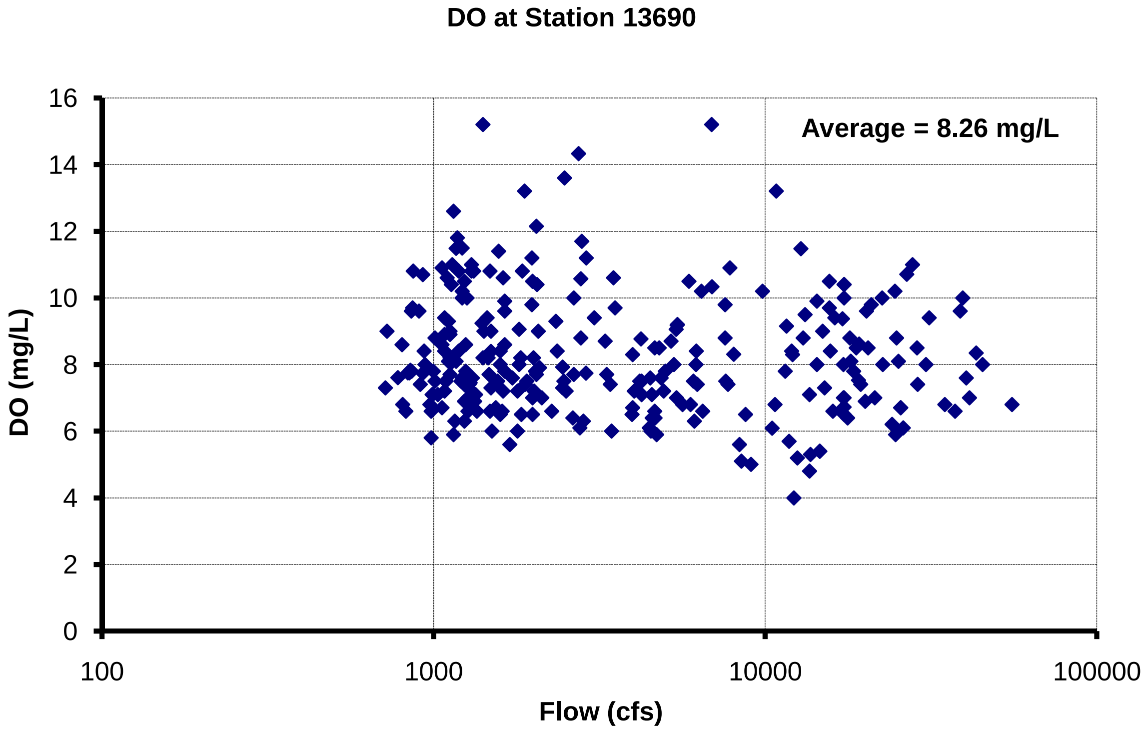
Figure 3-12
Specific Water Quality Parameters in Relation to Flow in the Trinity River at Crockett and at State Highway 79



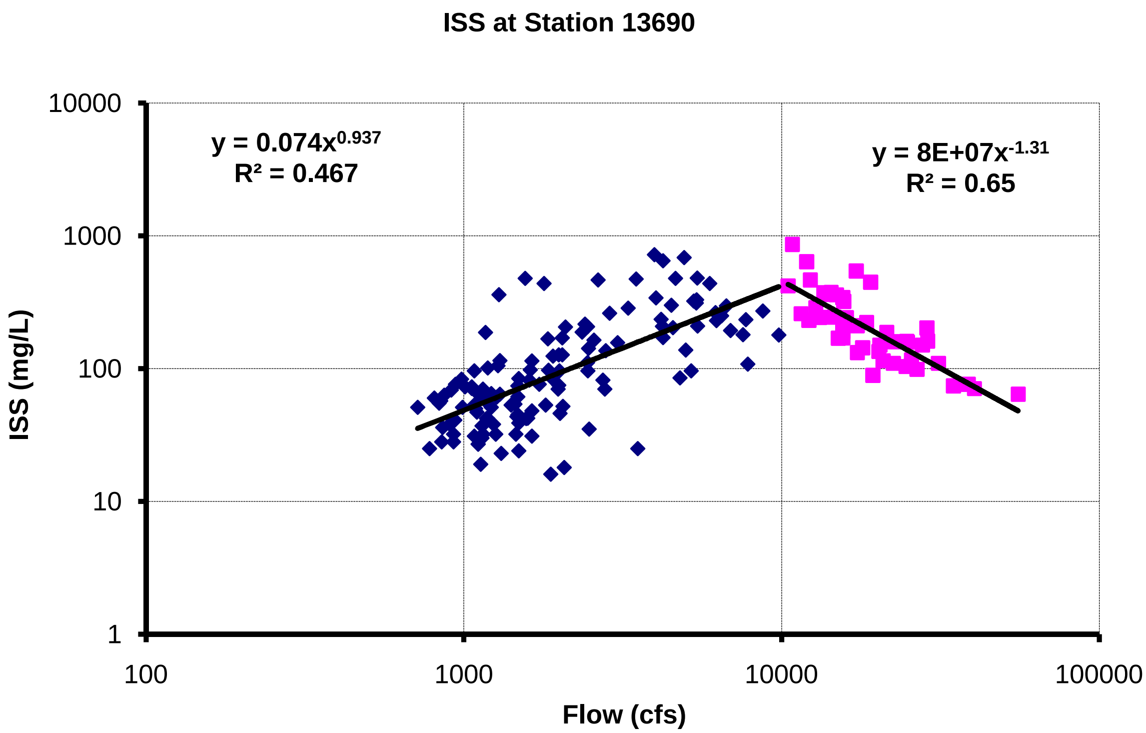
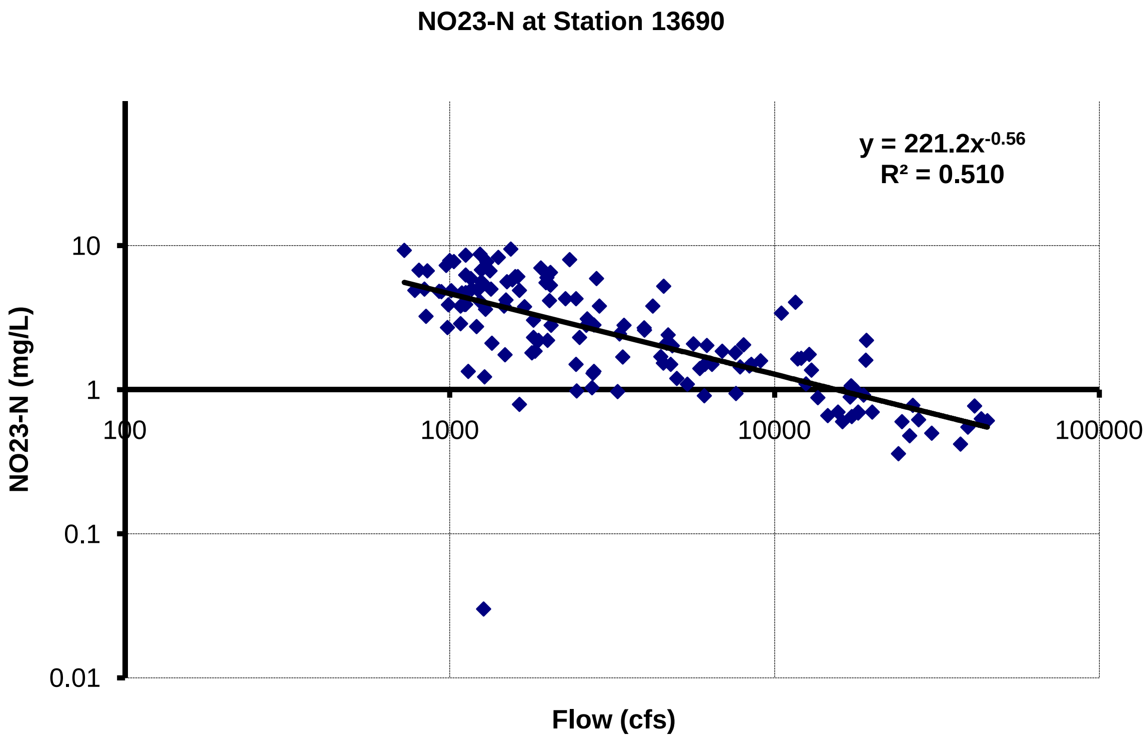
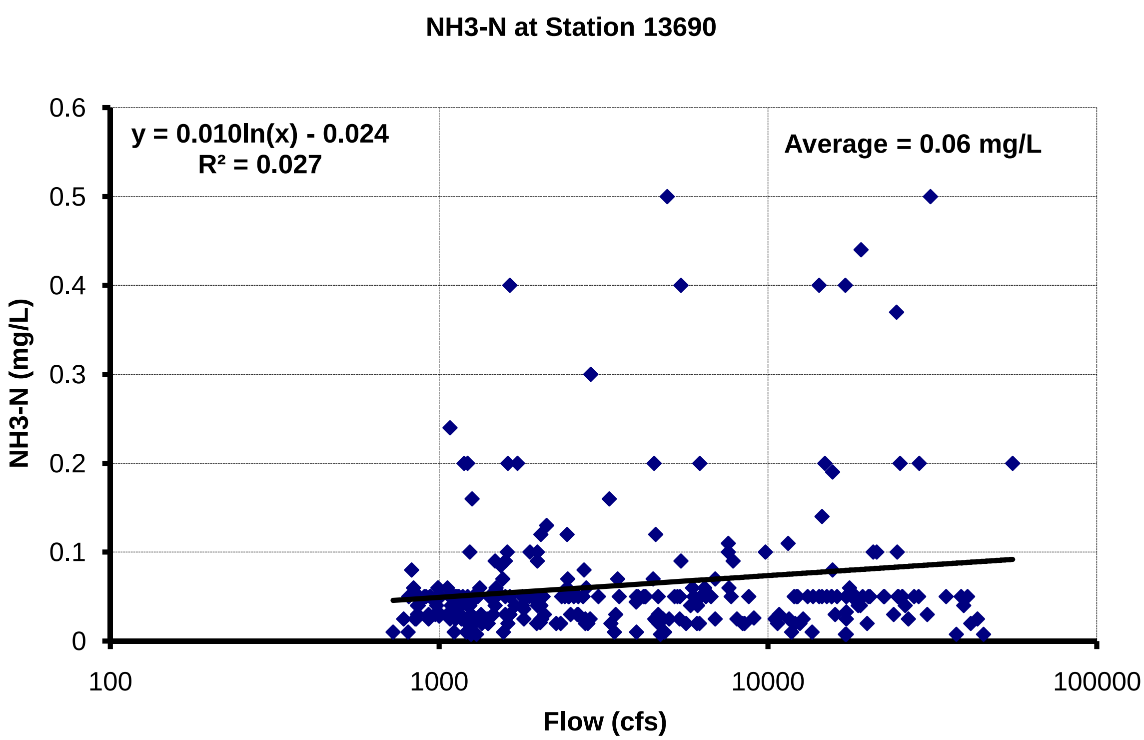


Figure 3-12 (Continued)
Water Quality Data of Trinity River Inflow





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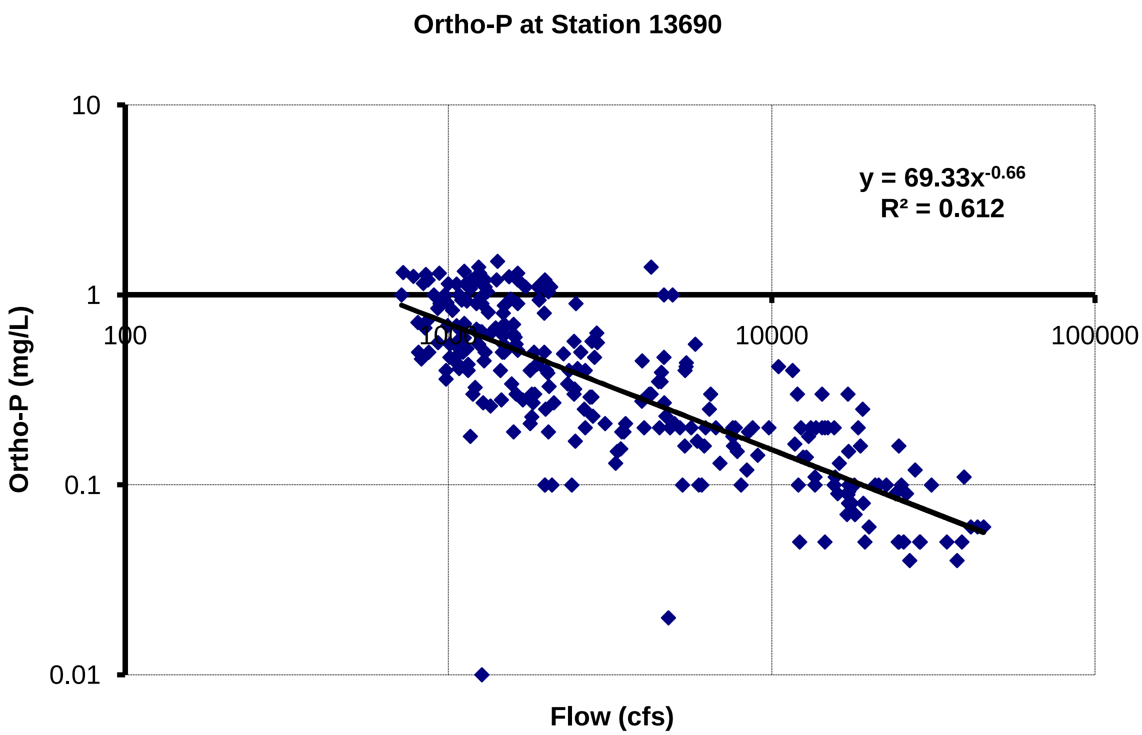
Water Quality Data of Trinity River Inflow



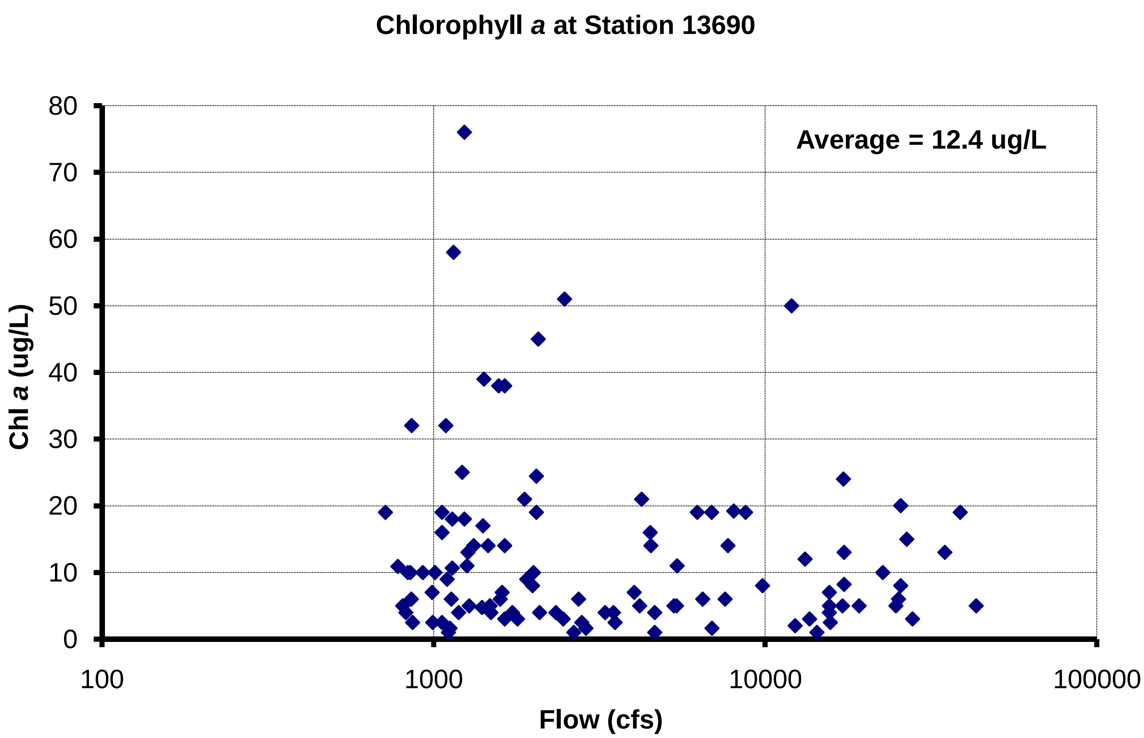
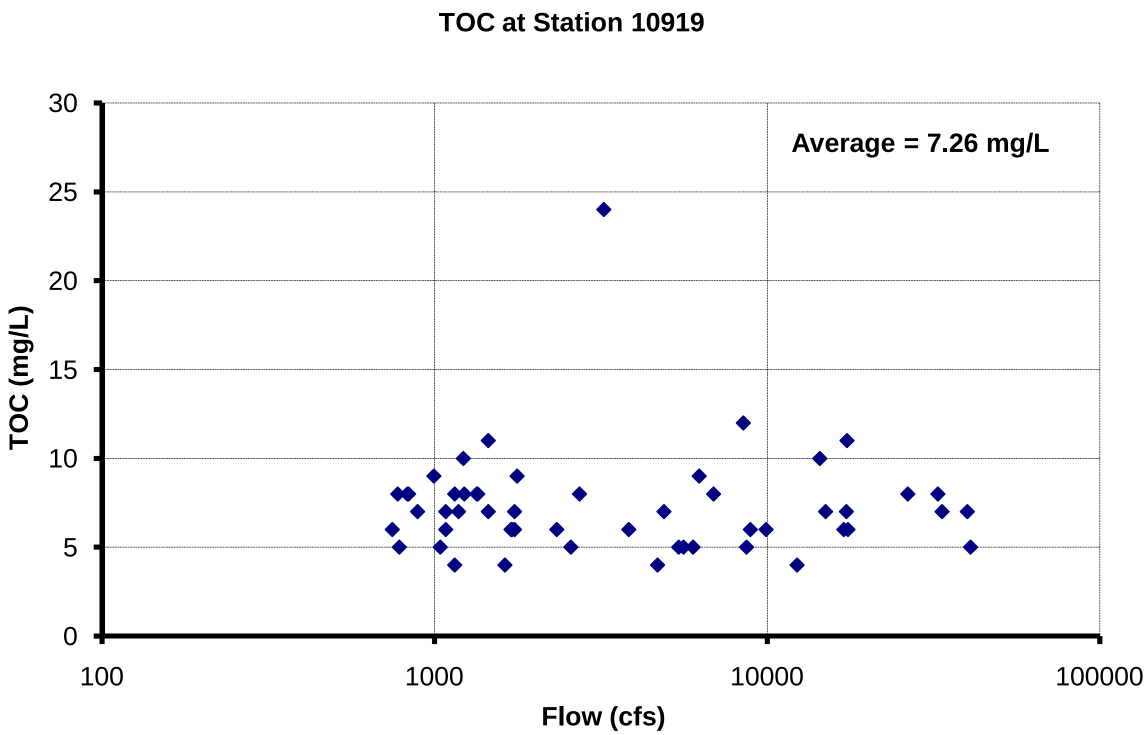


Figure 3-12 (Continued)
Water Quality Data of Trinity River Inflow



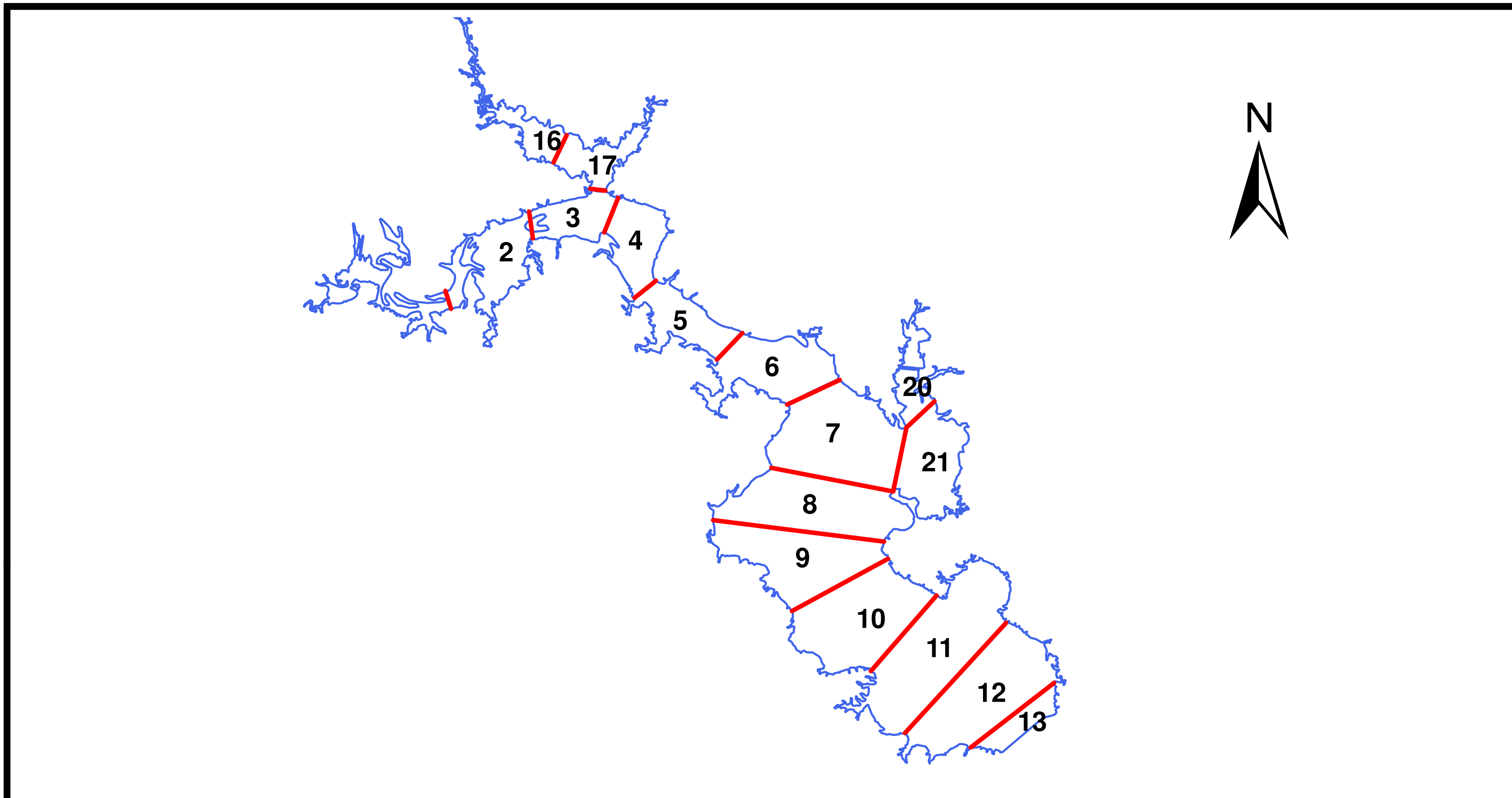


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Figure 3-13
Model Segmentation of Lake Livingston

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Job No.: 044198800	Scale: 1"=30,000'
Prepared by: K.L.Lee	Date: October 2008
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Figure 3-14
Model Segmentation of
Livingston Spillway Stilling Basin

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Prepared by: K.L.Lee	Date: October 2008
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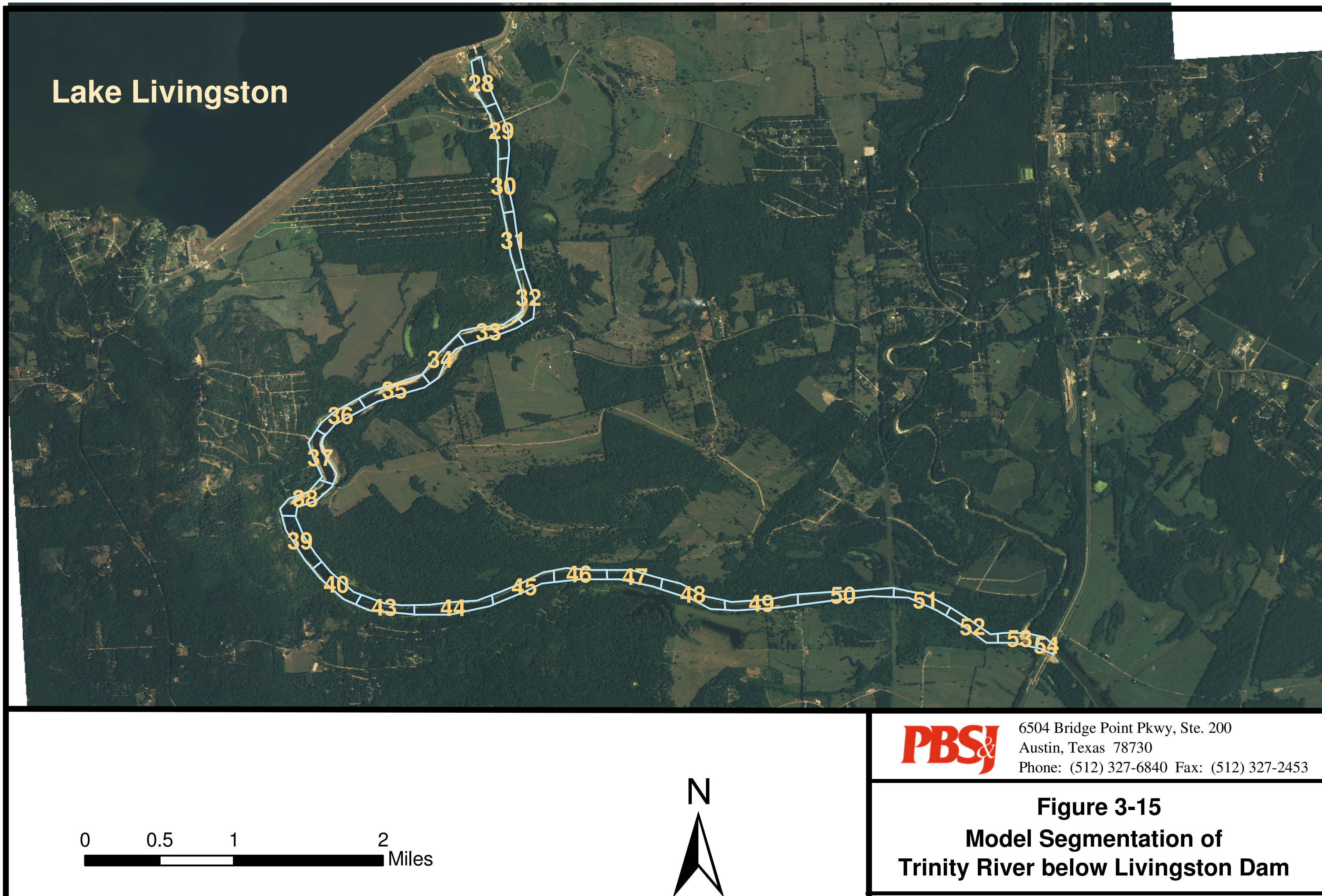

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Figure 3-15
Model Segmentation of
Trinity River below Livingston Dam

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Prepared by: K.L.Lee	Date: October 2008
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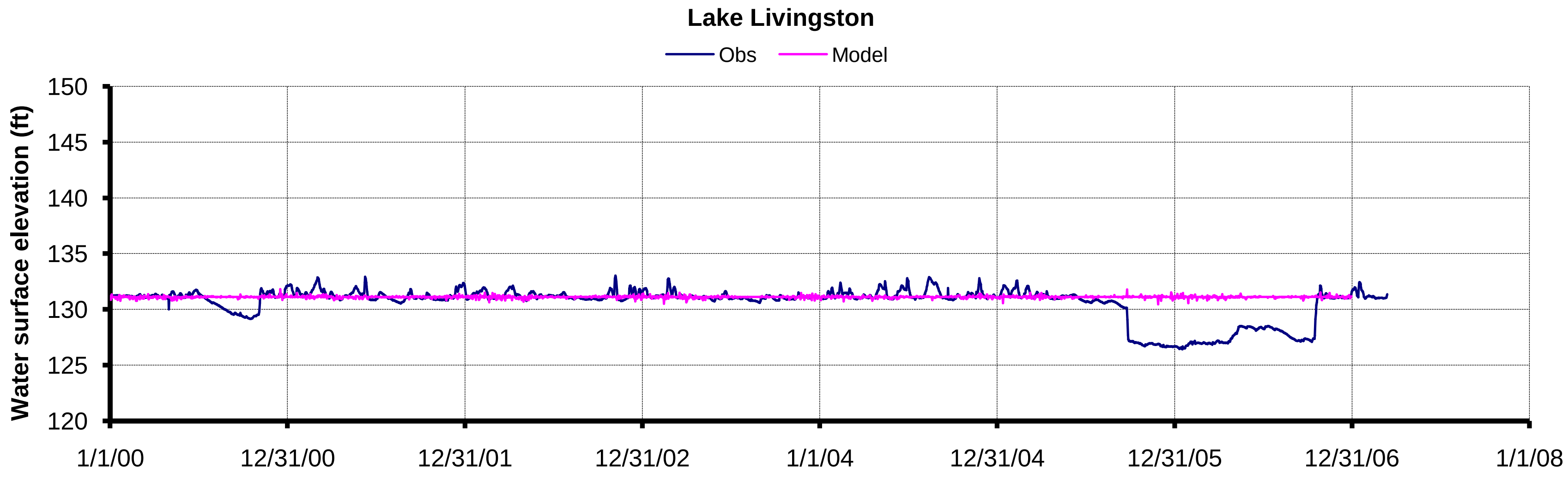
Figure 3-16
Comparison of Observed and Modeled Water Surface Elevations



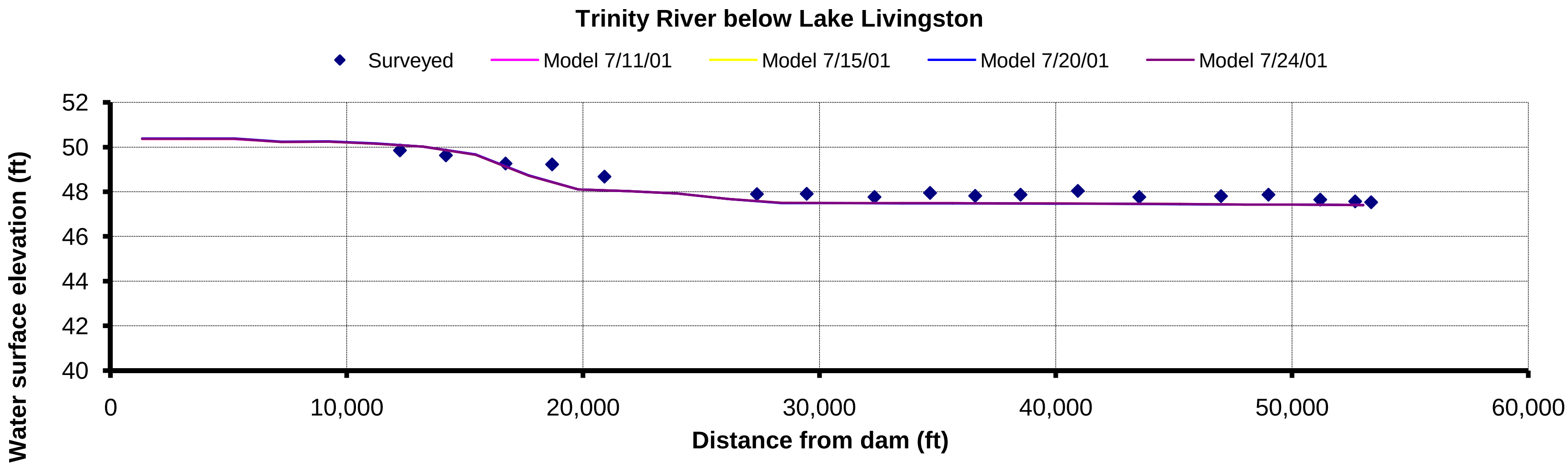
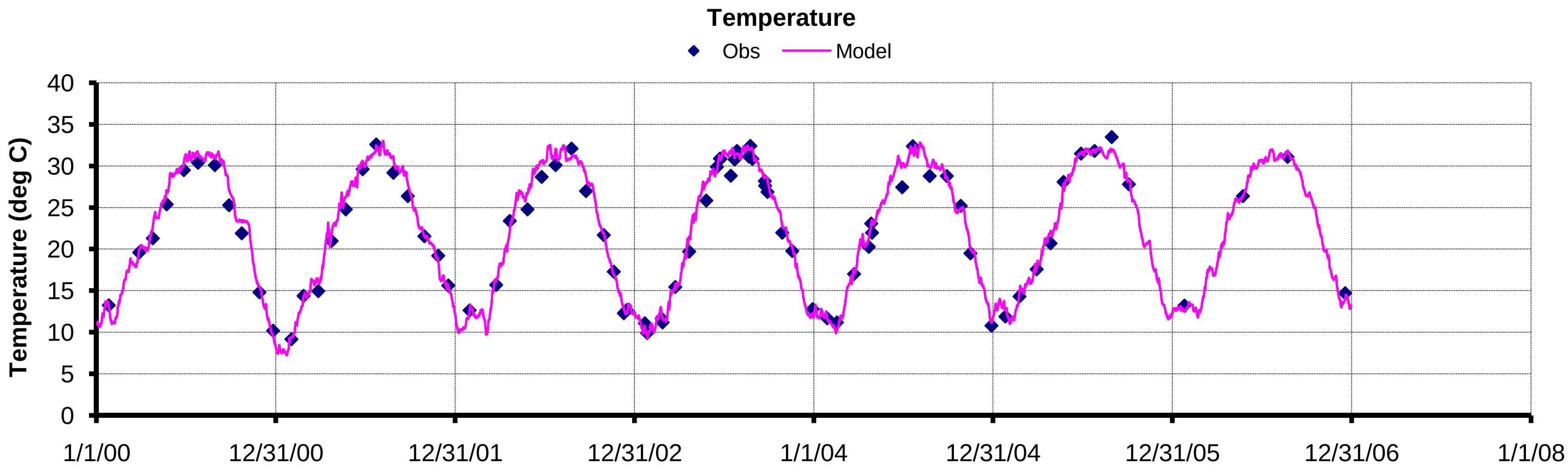


Figure 3-17
Comparison of Observed Data and Model Results in Lake Livingston Near Dam



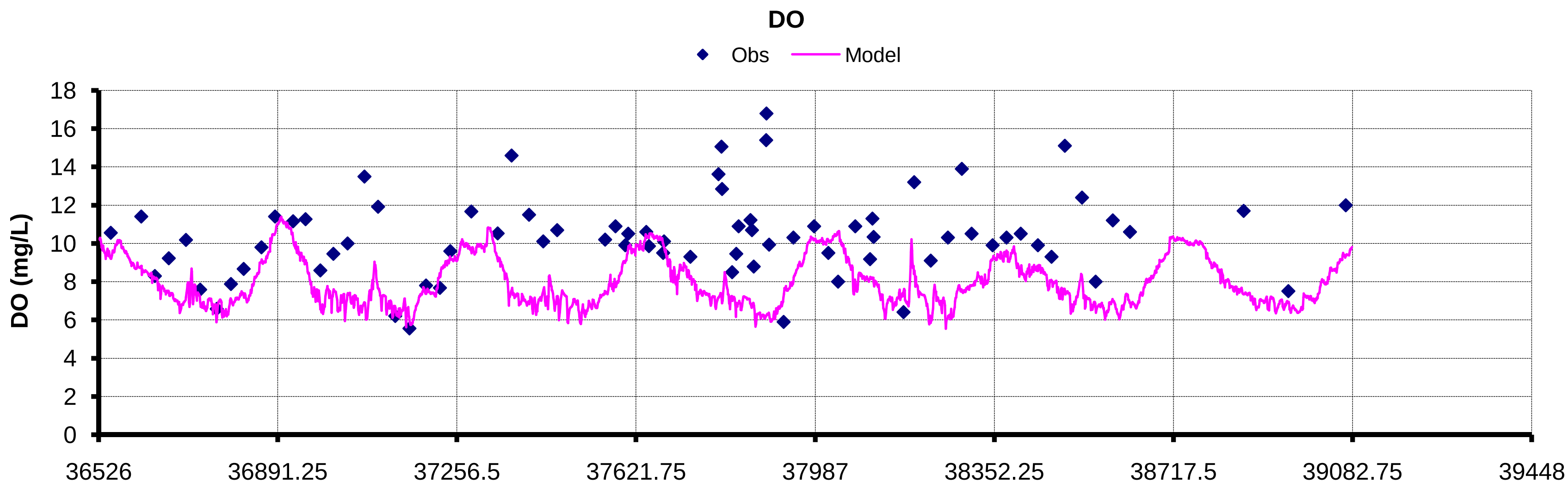
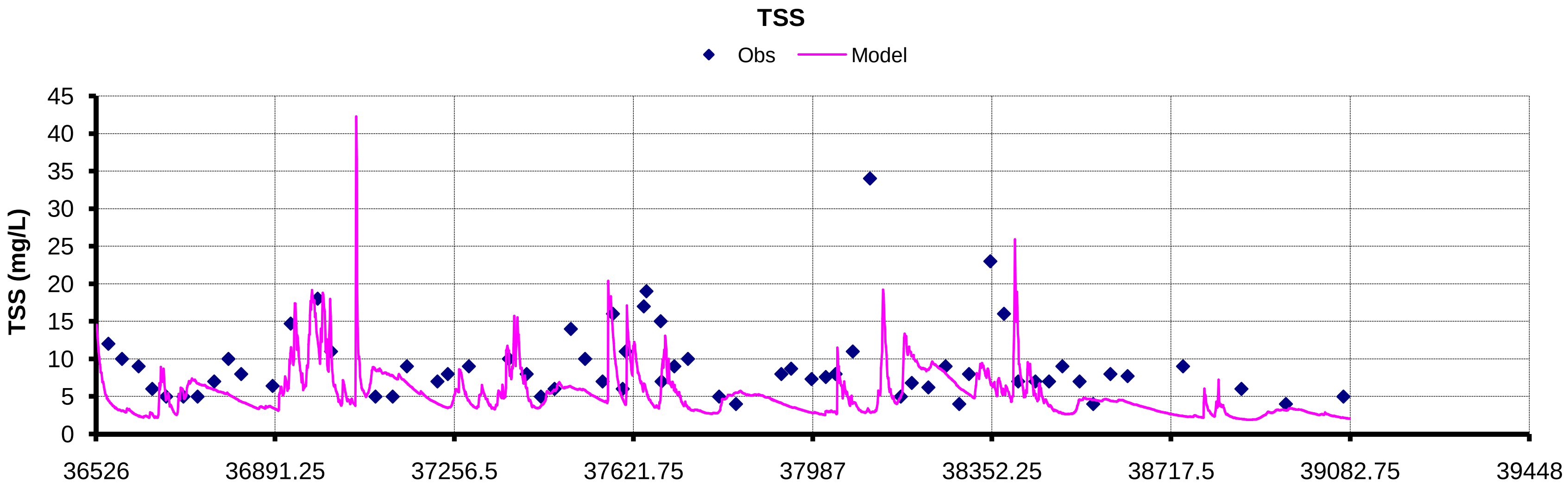


Figure 3-17 (Continued)
Comparison of Observed Data and Model Results in Lake Livingston Near Dam



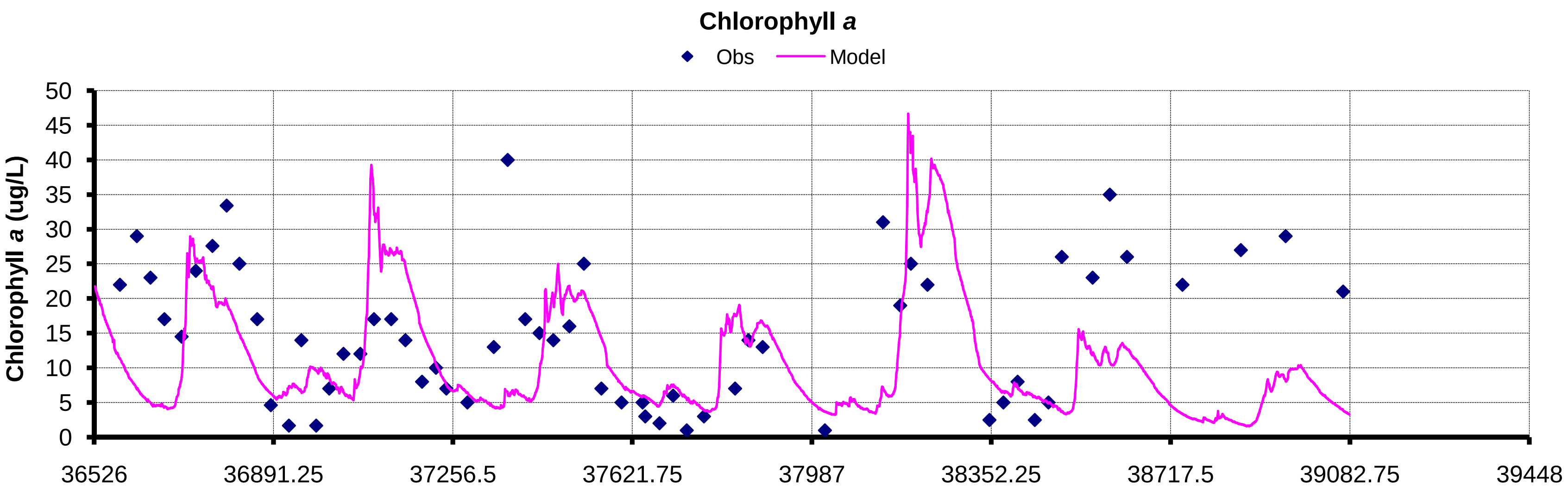
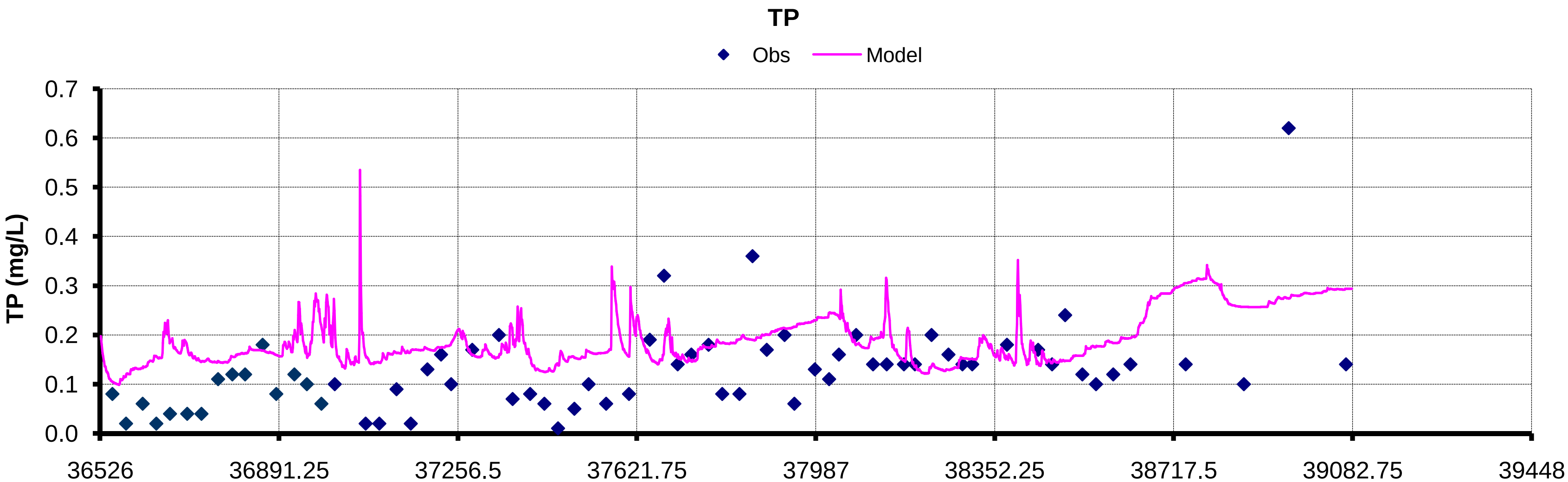


Figure 3-17 (Continued)
Comparison of Observed Data and Model Results in Lake Livingston Near Dam



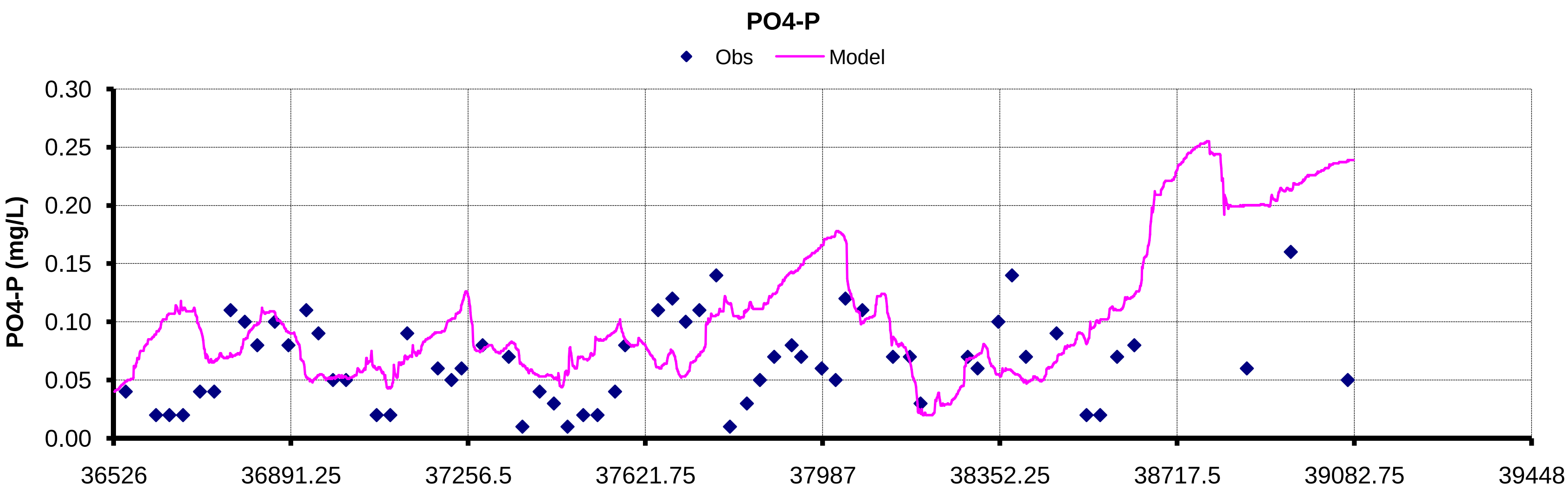
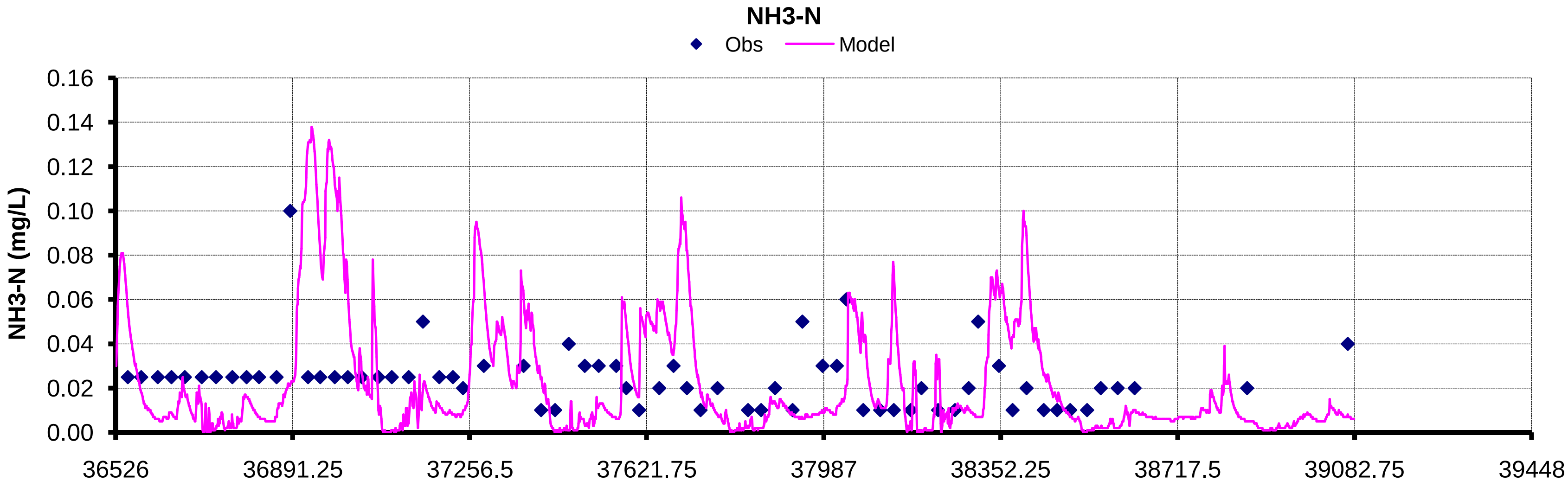


Figure 3-17 (Continued)
Comparison of Observed Data and Model Results in Lake Livingston Near Dam



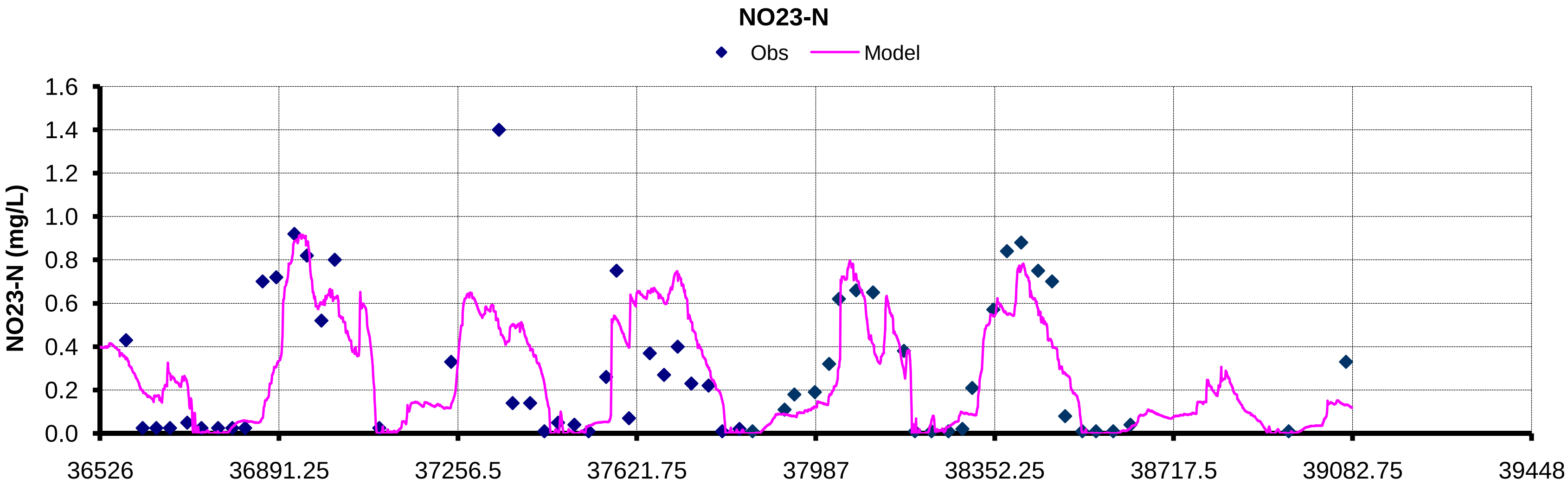


Figure 3-17 (Continued)
Comparison of Observed Data and Model Results in Lake Livingston Near Dam

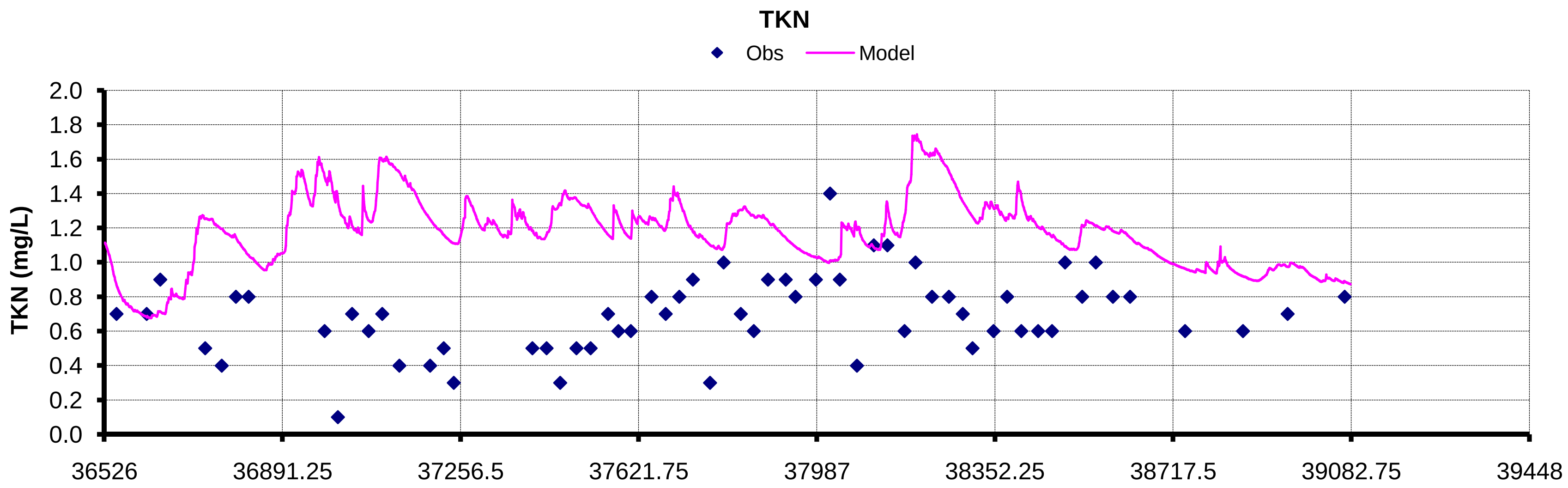
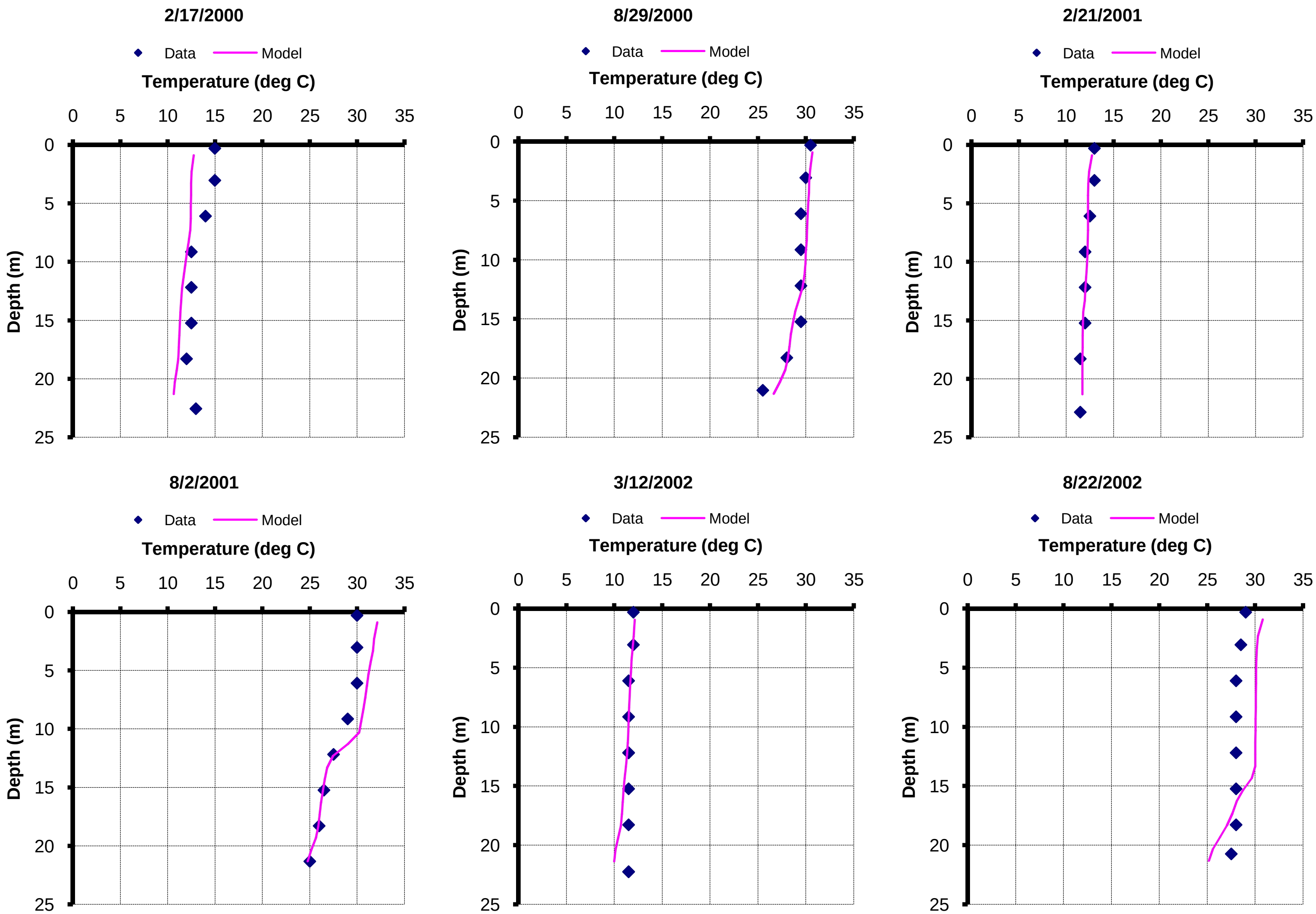


Figure 3-18
Comparison of Observed and Modeled Temperature Profiles in Lake Livingston Near Dam



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Comparison of Observed and Modeled Temperature Profiles in Lake Livingston Near Dam

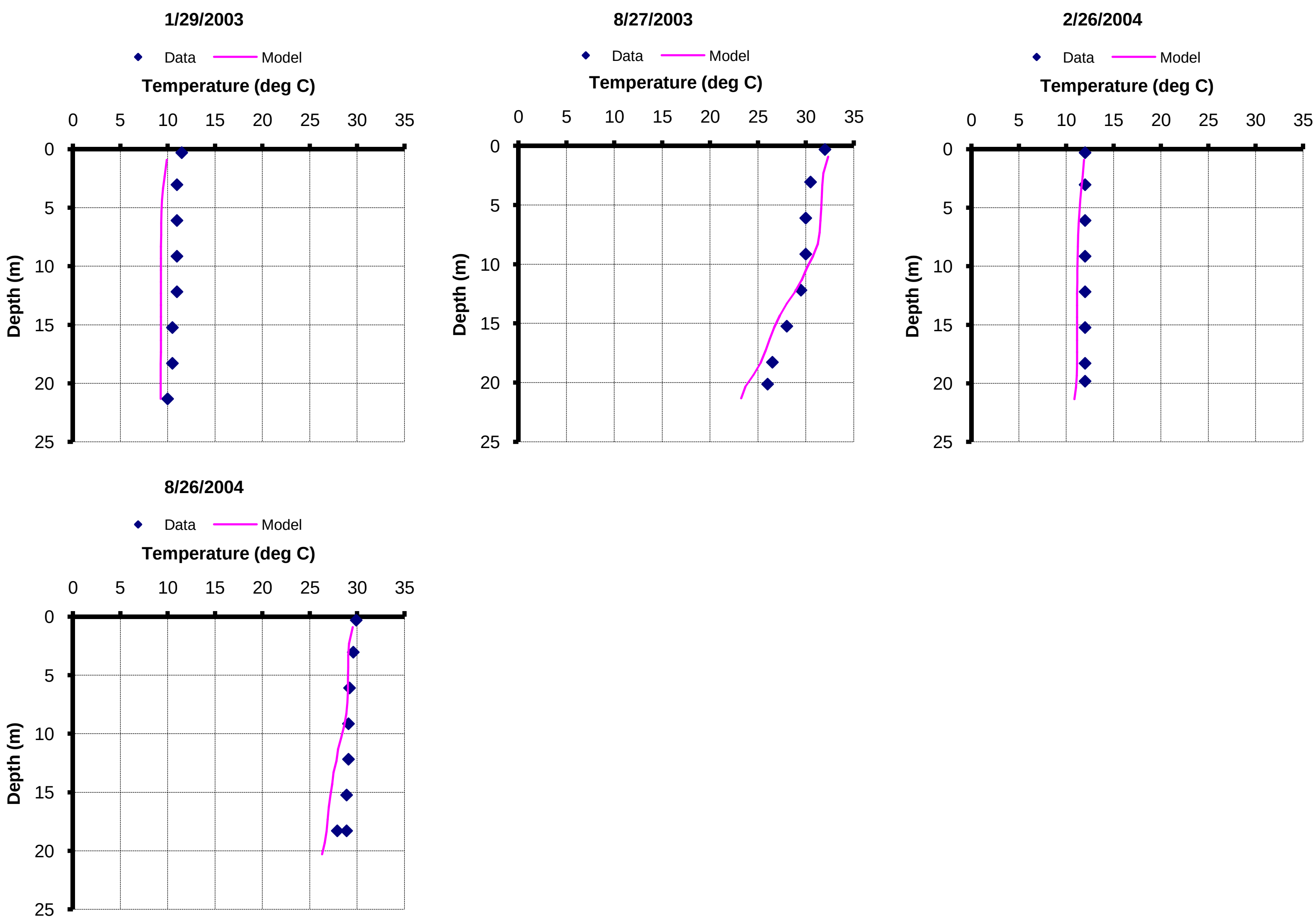
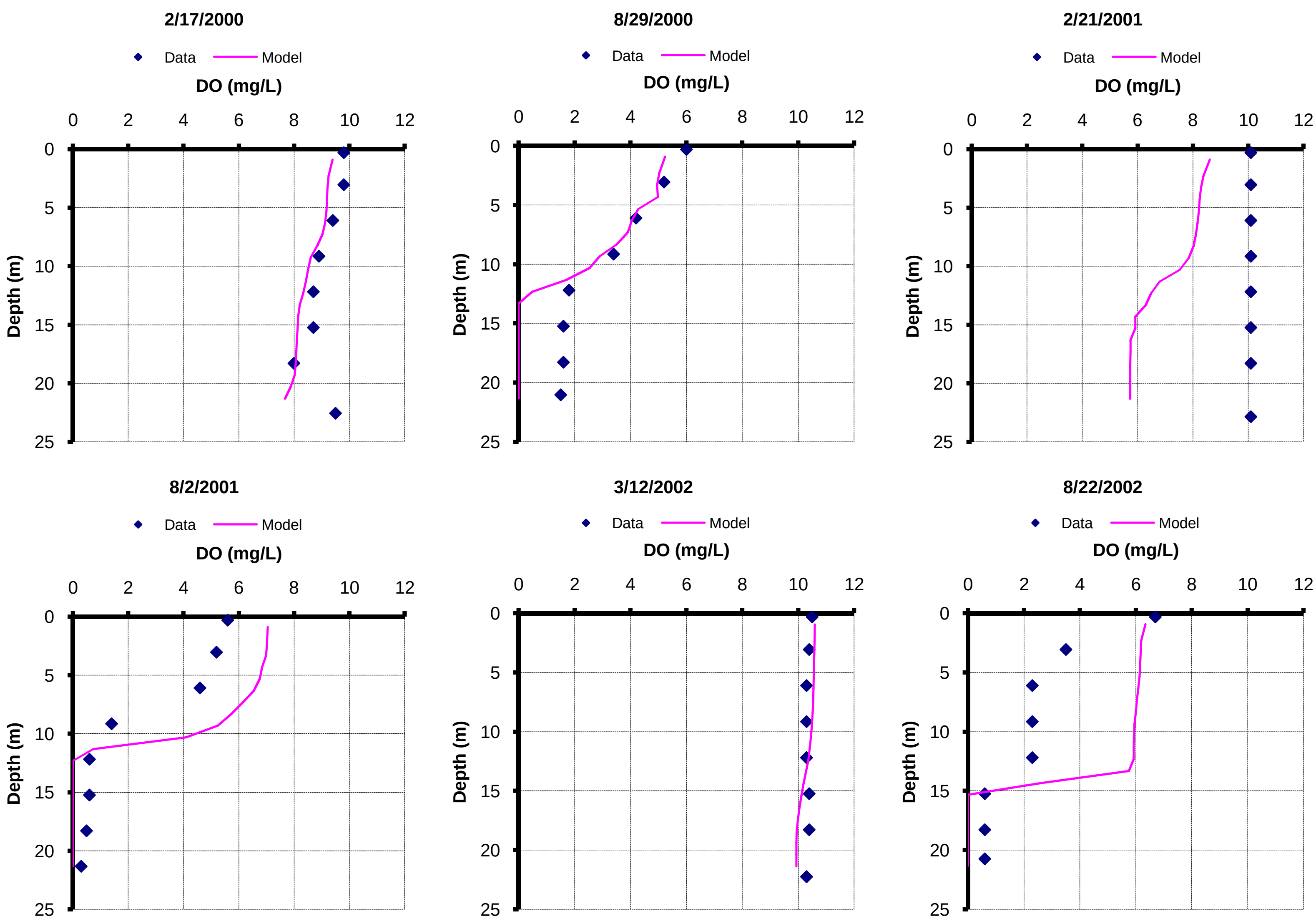


Figure 3-19
Comparison of Observed and Modeled DO Profiles in Lake Livingston Near Dam



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Comparison of Observed and Modeled DO Profiles in Lake Livingston Near Dam

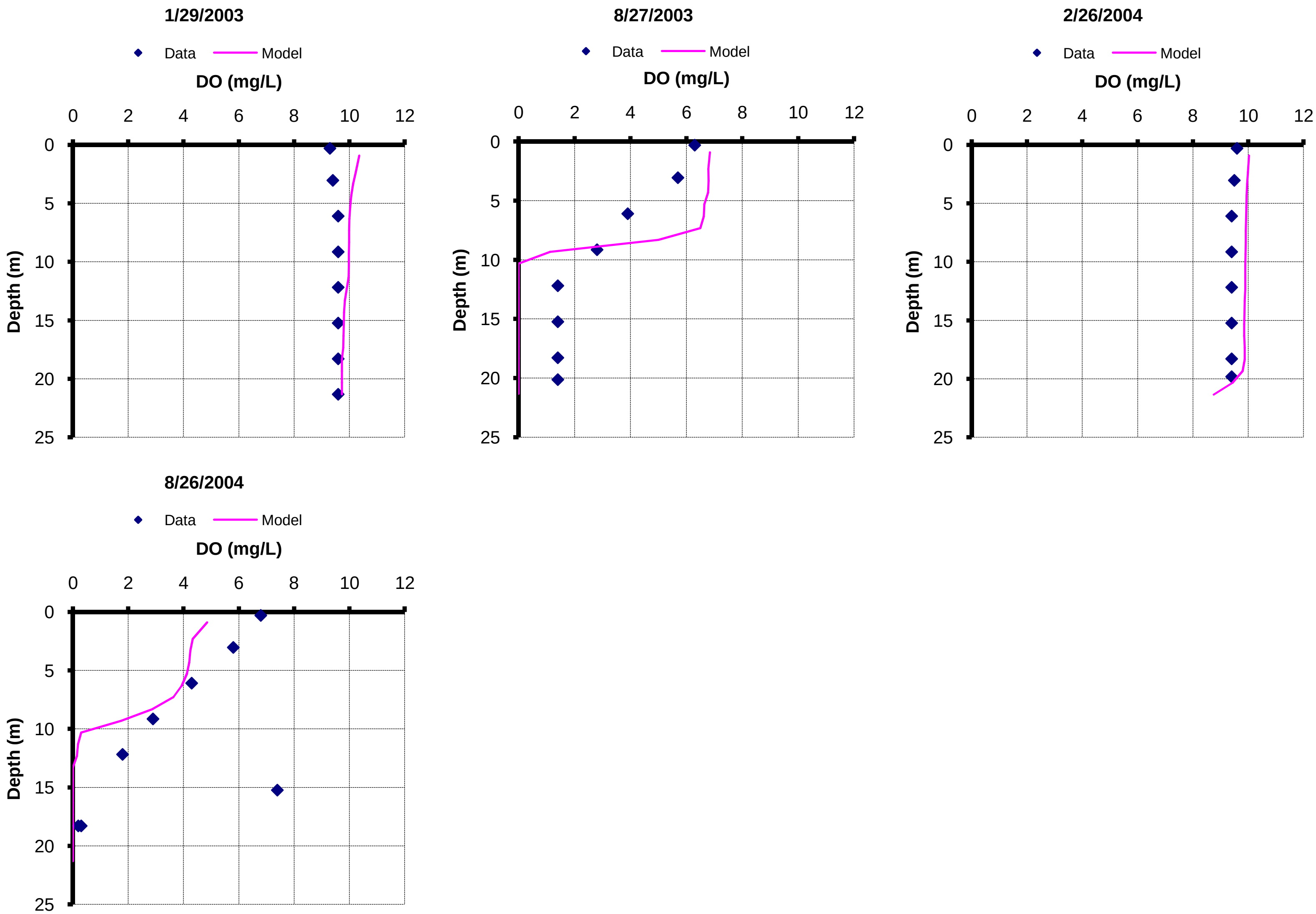
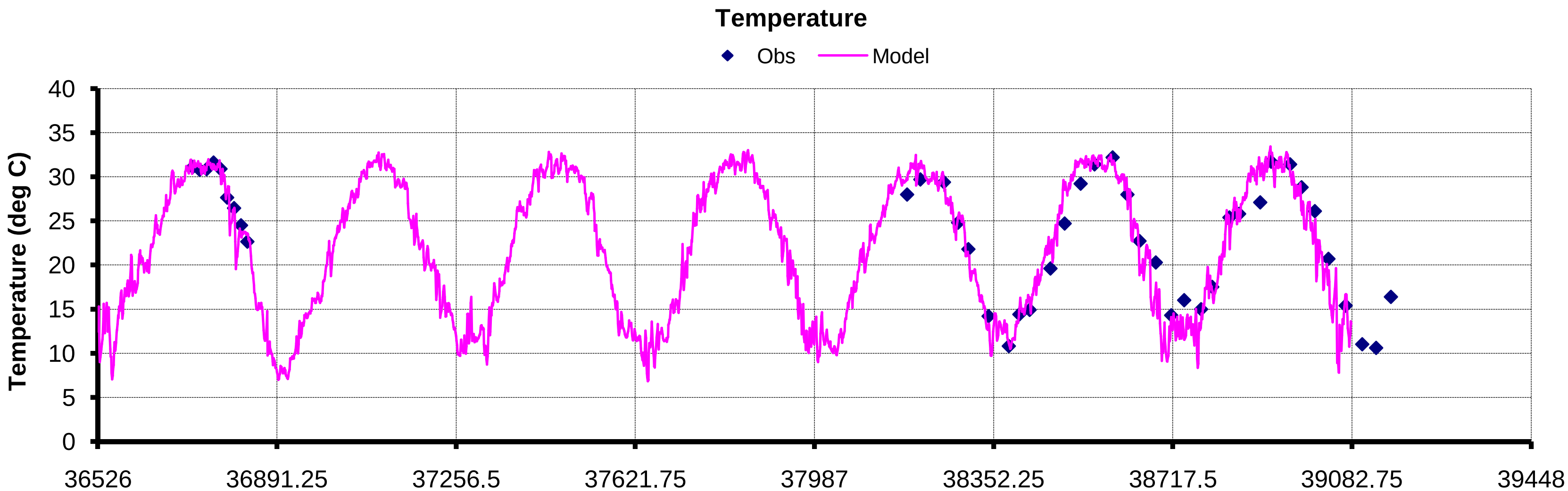
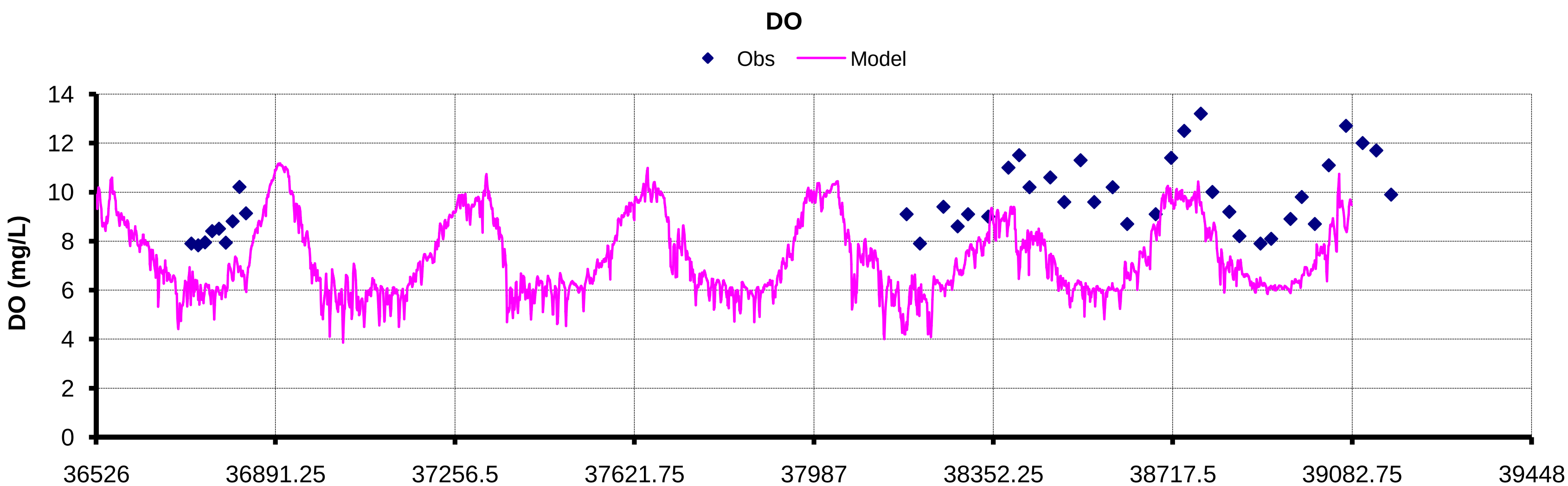


Figure 3-20
Comparison of Observed Data and Model Results in Trinity River at FM3278





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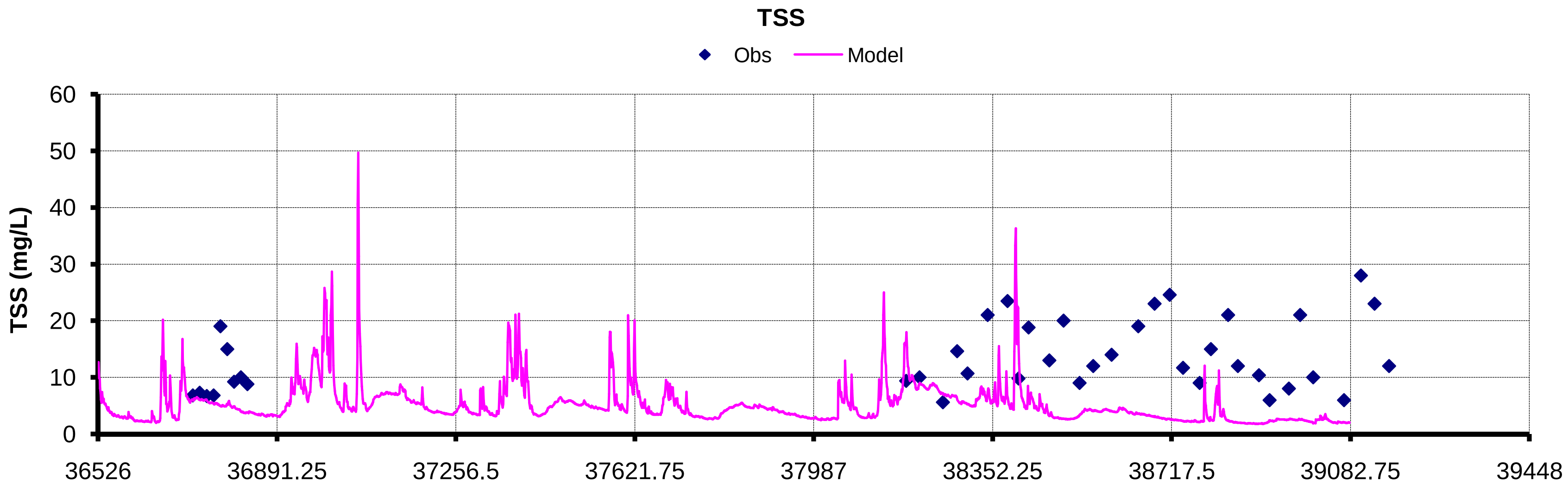
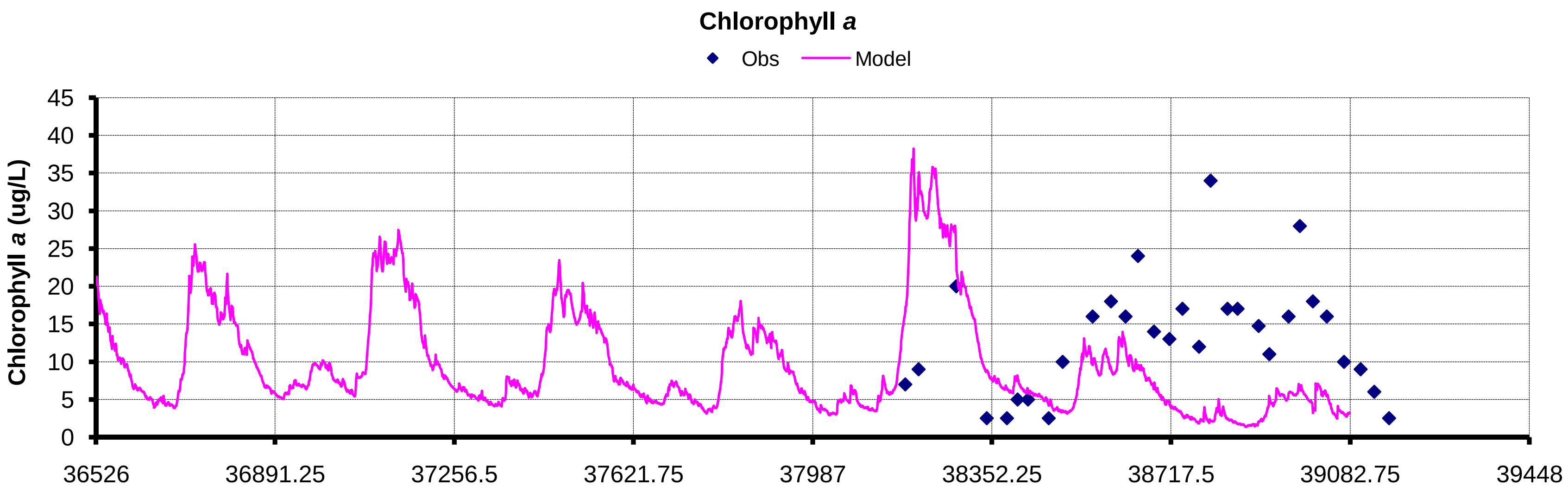
Comparison of Observed Data and Model Results in Trinity River at FM3278





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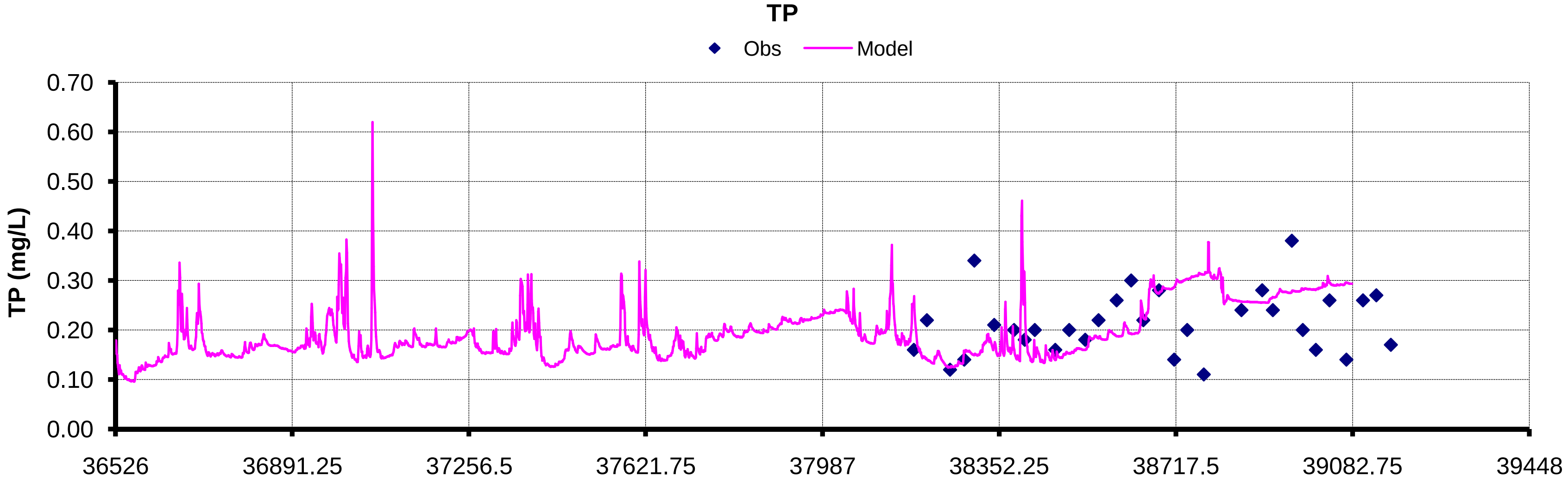
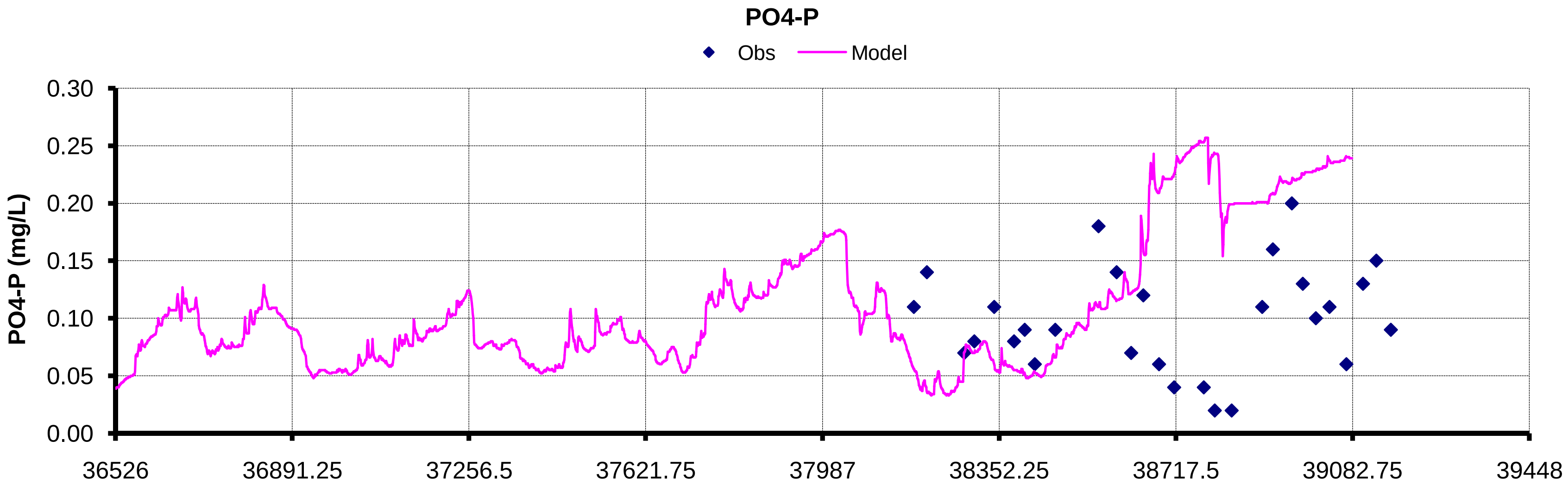
Comparison of Observed Data and Model Results in Trinity River at FM3278





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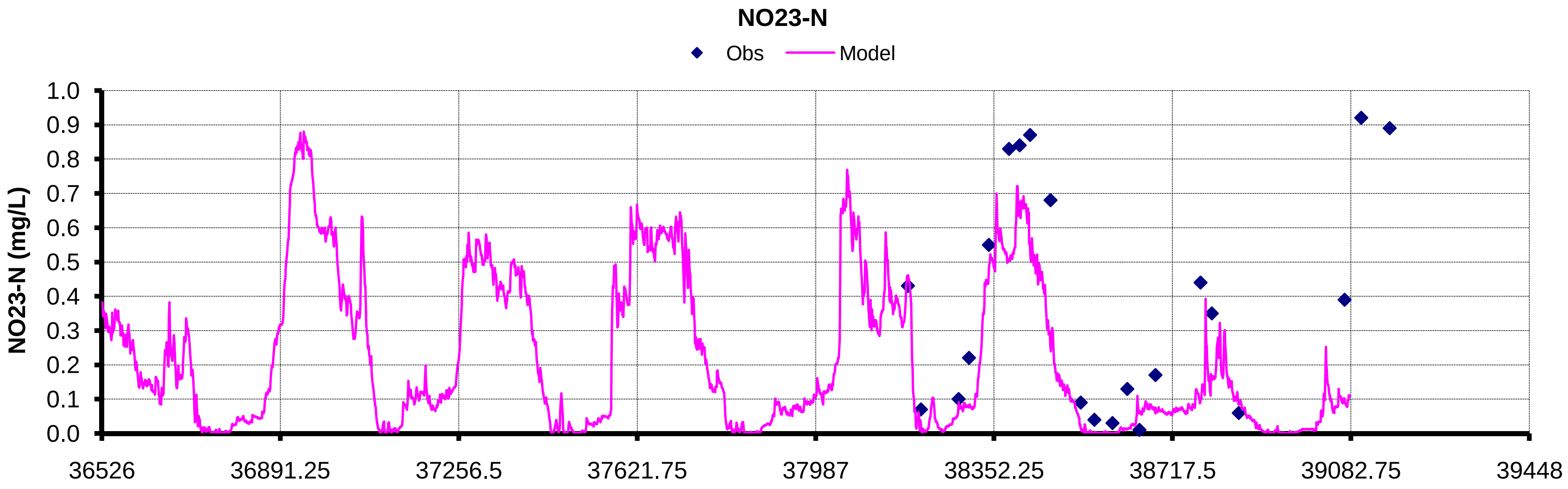
Comparison of Observed Data and Model Results in Trinity River at FM3278



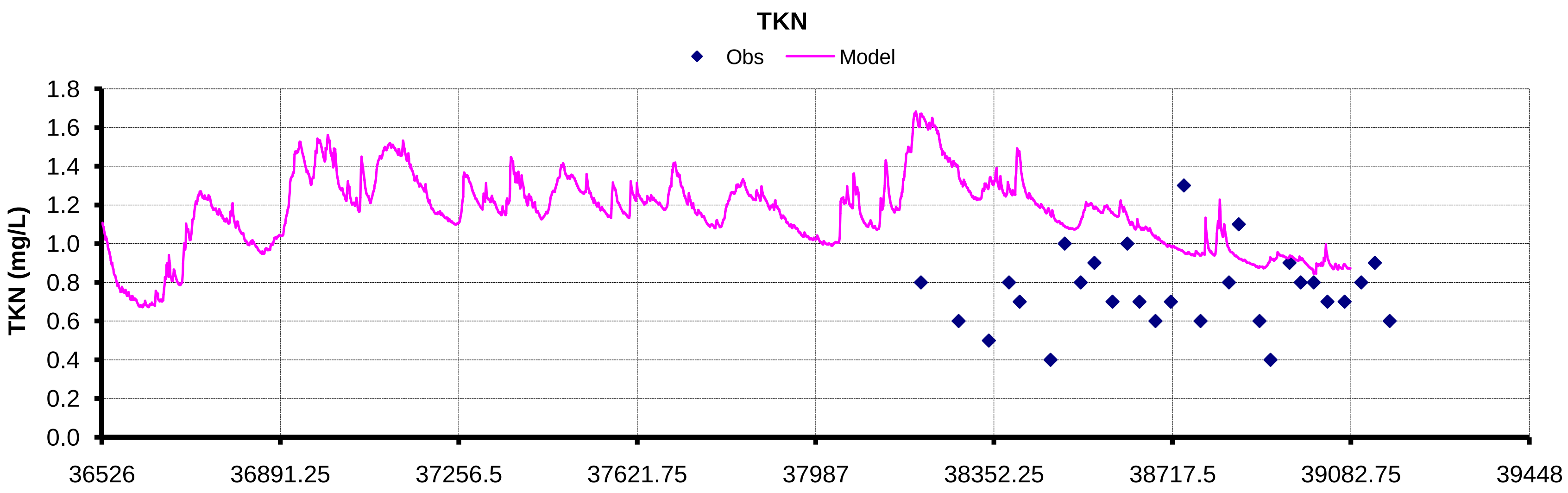
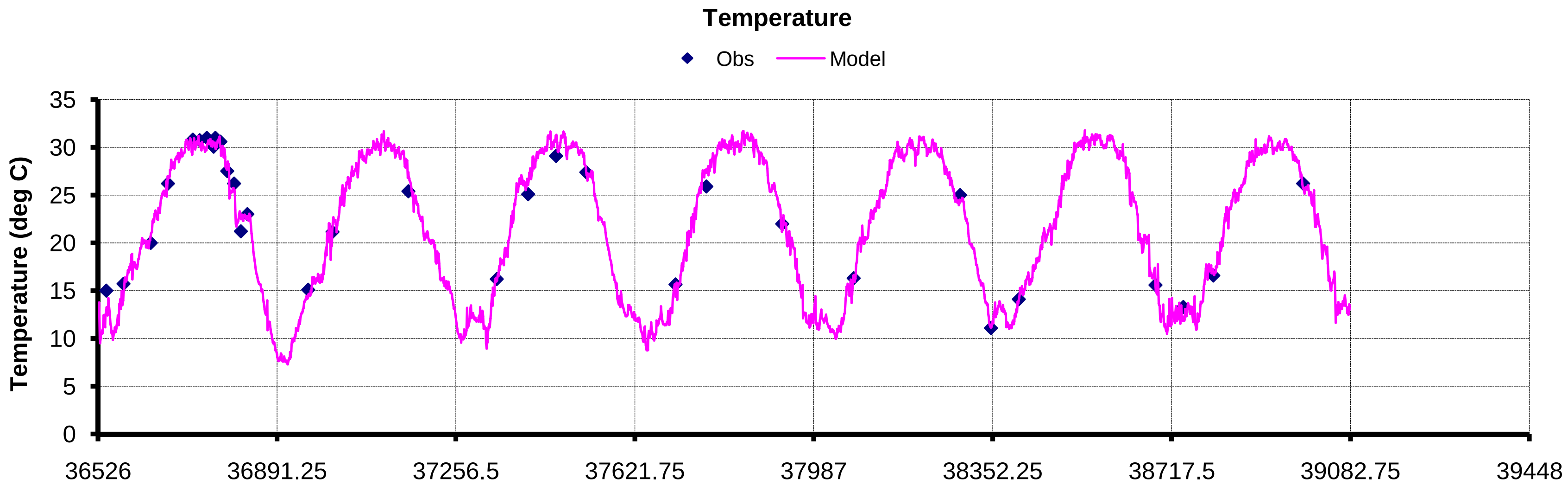
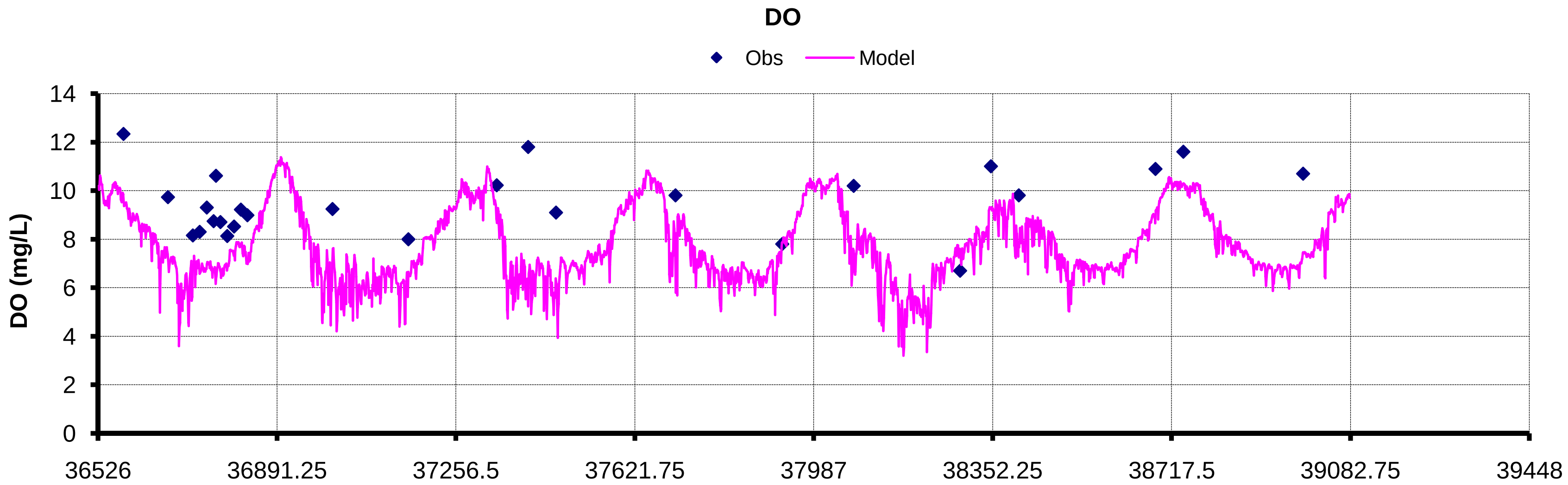


Figure 3-21
Comparison of Observed Data and Model Results in Trinity River at US59





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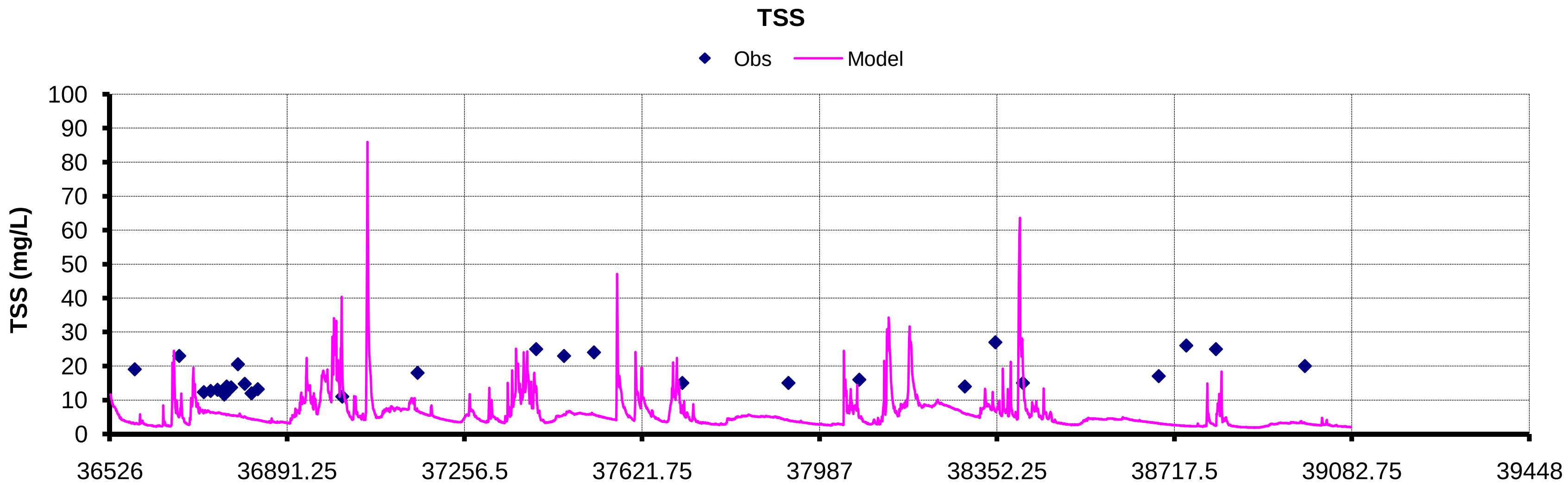
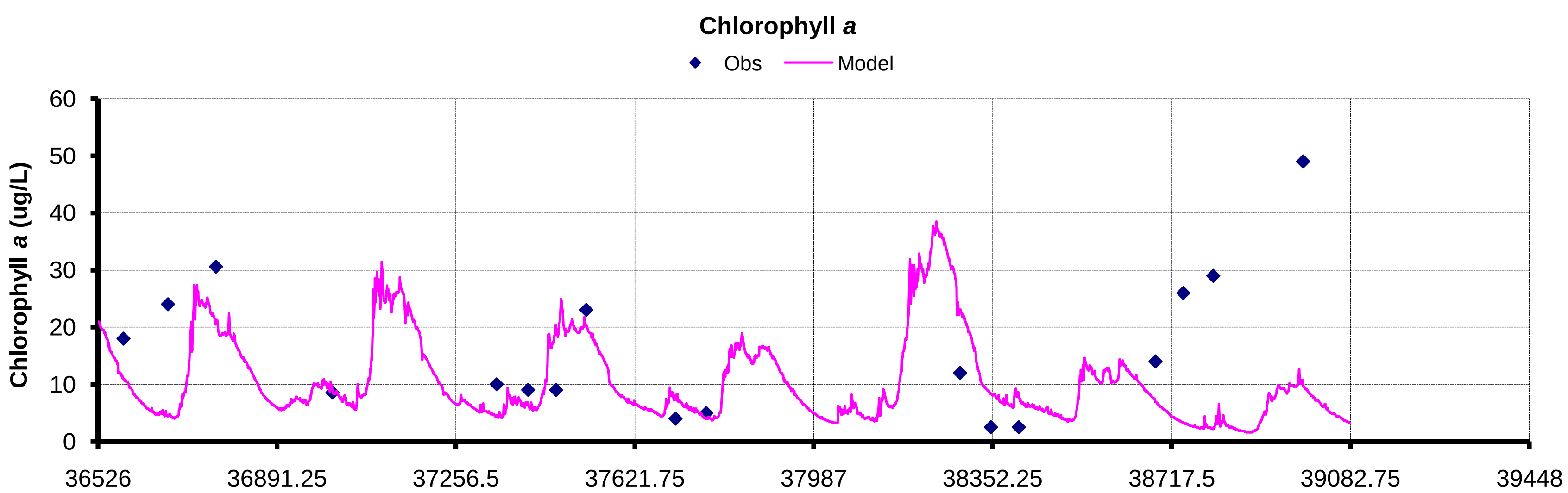
Comparison of Observed Data and Model Results in Trinity River at US59





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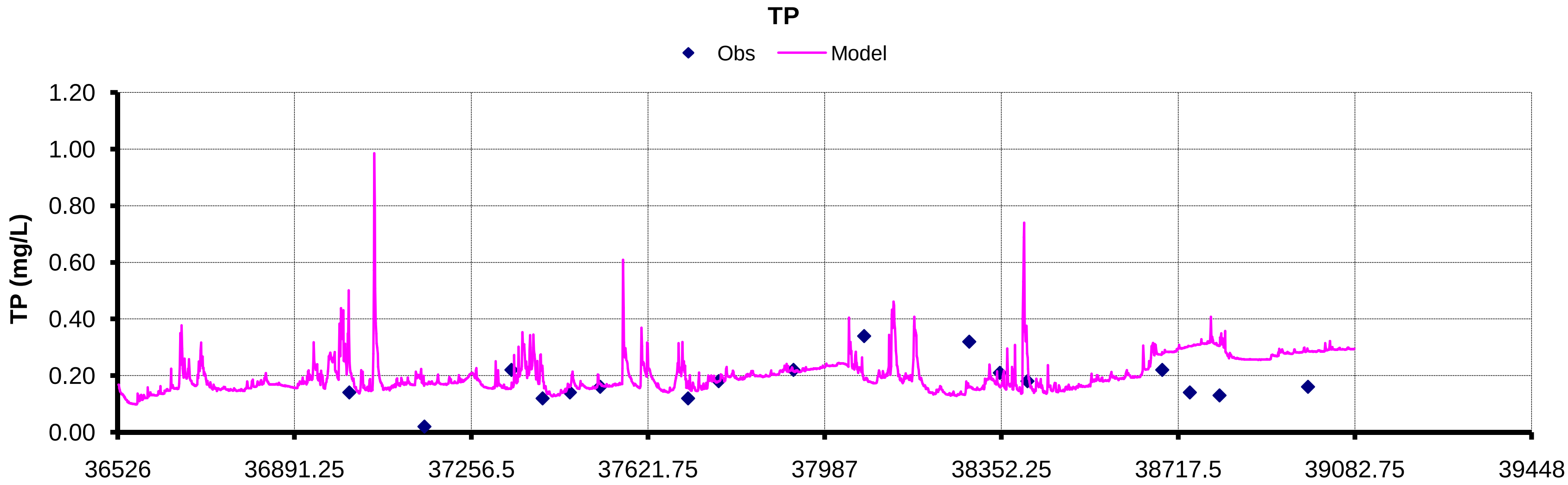

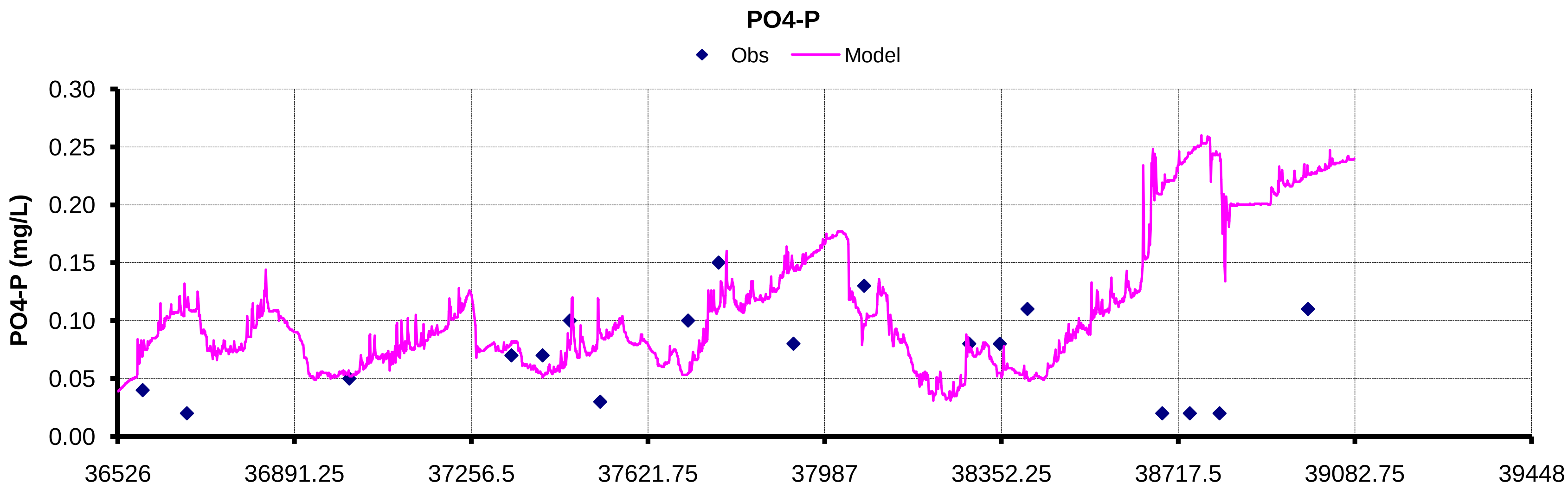

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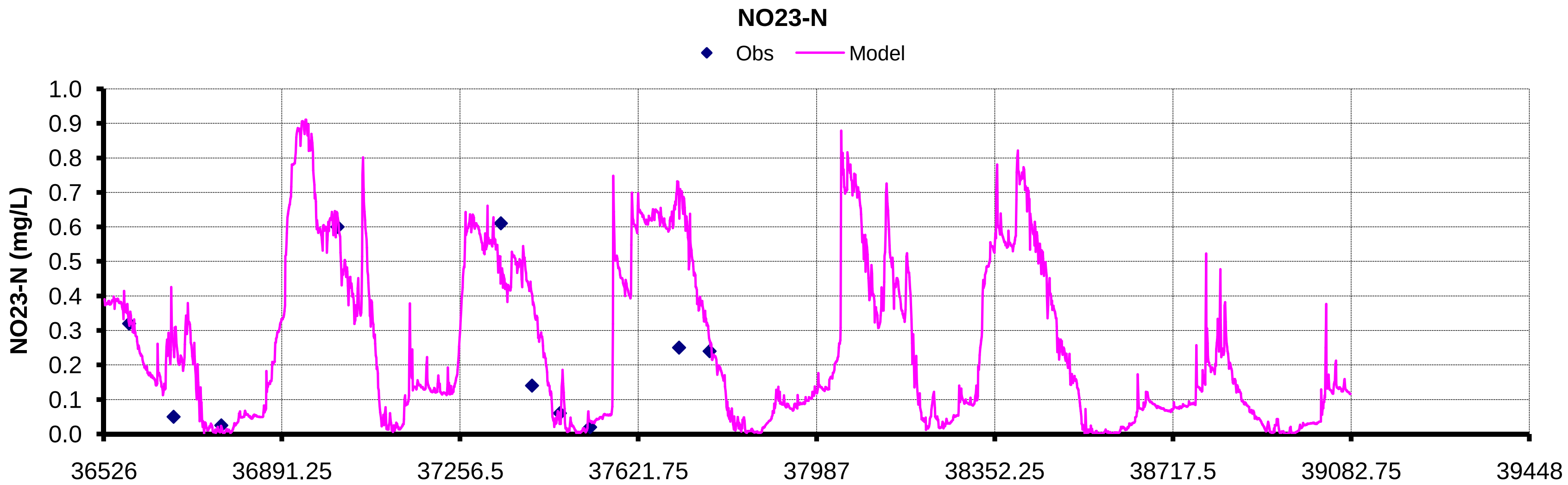

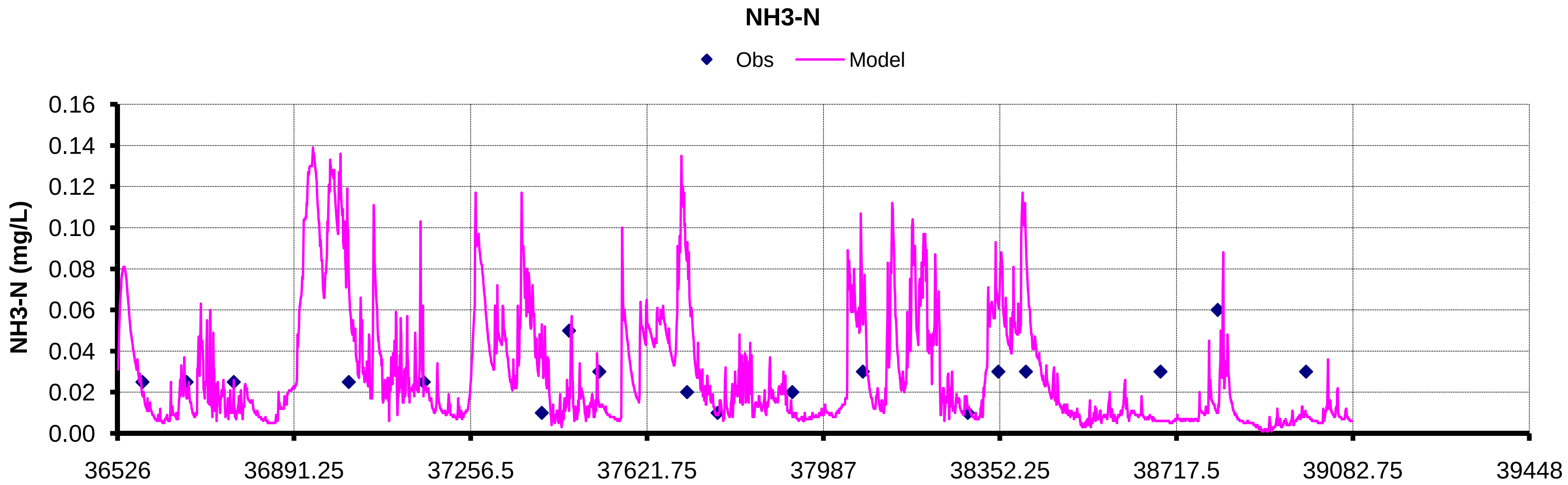

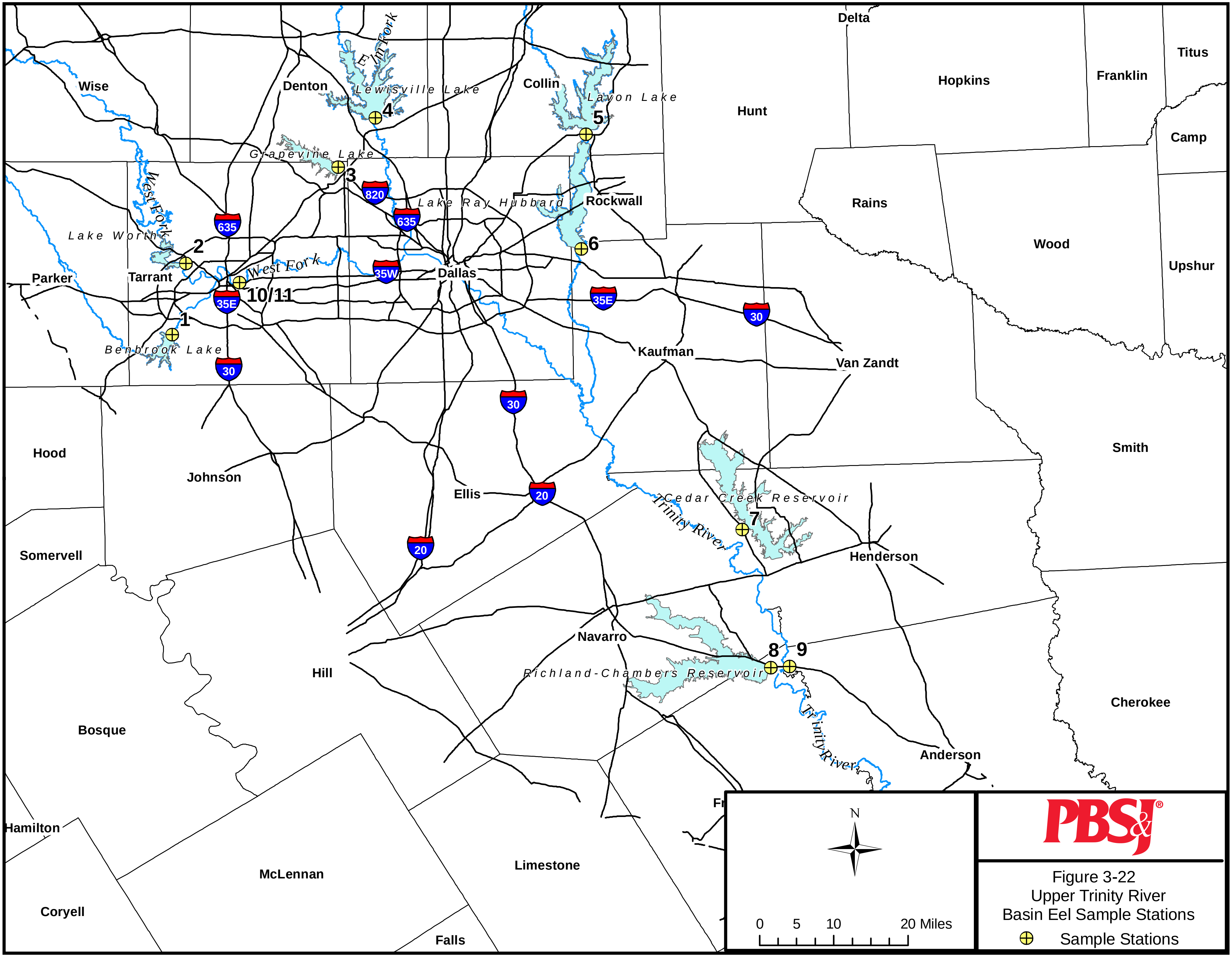

Figure 3-22
Upper Trinity River
Basin Eel Sample Stations

Figure 3-23. Benbrook Reservoir Stilling Basin Channel

Figure 3-24. Benbrook Reservoir Stilling Basin Downstream

Figure 3-25. Lake Worth Dam and Stilling Basin

Figure 3-26. Lake Worth Waterfall

Figure 3-27. West Fork Trinity River at Beach Street

Figure 3-28. Stream Below Lake Grapevine Stilling Basin

Figure 3-29. Lake Lewisville Stilling Basin

Figure 3-30. Channel Dam Downstream of Lake Lavon

Figure 3-31. Lake Ray Hubbard Stilling Basin

Figure 3-32. Cedar Creek Reservoir Dam

Figure 3-33. Richland-Chambers Reservoir Stilling Basin

4.0 LITERATURE CITED

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Appendix

Trinity River and Lake Livingston Biological Characterization Study Plan Lake Livingston Hydroelectric Project

Trinity River and Lake Livingston
Biological Characterization Study Plan
Lake Livingston Hydroelectric Project
Polk and San Jacinto Counties, Texas

Document No. 070277
PBS&J Job No. 441988

TRINITY RIVER AND LAKE LIVINGSTON BIOLOGICAL CHARACTERIZATION STUDY PLAN LAKE LIVINGSTON HYDROELECTRIC PROJECT POLK AND SAN JACINTO COUNTIES, TEXAS

Prepared for:

East Texas Electric Cooperative, Inc.
P.O. Box 631623
Nacogdoches Texas 75963-1623

Prepared by:

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6504 Bridge Point Parkway
Suite 200
Austin, Texas 78730

June 2008

Printed on recycled paper

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Acronyms and Abbreviations

°F	degrees Fahrenheit
DO	dissolved oxygen
ETEC	East Texas Electric Cooperative
ft	feet/foot
m	meter(s)
mg/L	milligrams per liter
TCEQ	Texas Commission on Environmental Quality
TPWD	Texas Parks and Wildlife Department
TRA	Trinity River Authority
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

TRINITY RIVER AND LAKE LIVINGSTON
BIOLOGICAL CHARACTERIZATION STUDY PLAN
LAKE LIVINGSTON HYDROELECTRIC PROJECT

1.0 INTRODUCTION

East Texas Electric Cooperative (ETEC) contracted the services of the Project Team to sample the biological community, field water quality, and aquatic habitat of the Trinity River downstream of Lake Livingston and of Lake Livingston in the vicinity of the proposed hydroelectric project intake. The Project Team will conduct quarterly sampling for a year, analyze samples, quality assure and manage data, and provide a report summarizing the results. Fish will be collected at all locations and benthic macroinvertebrates will be collected downstream of Lake Livingston Dam.

Study design will focus on species composition, abundance, and particularly any species of concern known to occur in the area. Recreational fishing is important in the area immediately downstream of Lake Livingston Dam and sampling will document the relative abundance of sport fish and forage species. The team will also collect and analyze data to enhance understanding of temperature and dissolved oxygen conditions upstream and downstream of the dam and describe movement of fish from the reservoir to the stilling basin and river downstream of the stilling basin.

Physical, chemical, and biological sampling will follow Texas Commission on Environmental Quality's (TCEQ) *Surface Water Quality Monitoring Procedures* (2007). This document describes methods to be used.

This plan is presented to the agencies for review and to develop consensus on the sampling and analyzes required for this project. ETEC will consider comments received and respond as appropriate in a final draft of the study plan prior to commencing additional field studies.

2.0 BACKGROUND

ETEC proposes to construct a hydroelectric facility on Lake Livingston. Surface water from Lake Livingston will be diverted through the hydroelectric facility and discharged into the Trinity River immediately downstream of Lake Livingston Dam. Water Quality Segment 0803, Lake Livingston, and Segment 0802, Trinity River below Lake Livingston, have high aquatic life use designations, daily average dissolved oxygen criteria of 5.0 milligrams per liter (mg/L), and maximum temperature criteria of 93 degrees Fahrenheit (°F). The 2006 Texas Water Quality Inventory indicates there are no impairments of the designated high aquatic life use, dissolved oxygen or temperature criteria in these waterbodies.

Water is presently released from a reservoir depth of approximately 30 feet (ft) through gates on Lake Livingston Dam. During summer months, Lake Livingston stratifies with low dissolved oxygen conditions developing from a depth of about 30 ft to the bottom. Passage of fish through the gates during the summer depends largely on the depth of stratification and whether fish are present. During the remainder of the year, the reservoir is usually vertically mixed and fish can be distributed though the water column. These conditions influence fish passage through the Lake Livingston Dam with water released from the reservoir. The condition of the fish that pass through the Lake Livingston Dam under existing conditions is not known, but there is no information suggesting high mortality rates associated with fish passage. Surface waters proposed for use by the hydroelectric facility are rarely low in oxygen and therefore are expected to have normal fish communities most of the year. Once constructed, most water leaving Lake Livingston under normal flow conditions will pass through the hydroelectric facility instead of the present discharge structure.

This study describes sampling and analysis proposed to characterize the:

- Fish community of Lake Livingston in the vicinity of the proposed water intake;
- Aquatic community and physical/chemical conditions of the Trinity River downstream of Lake Livingston Dam;
- Detailed dissolved oxygen and temperature conditions in the reservoir at the present water release site, the proposed hydroelectric site and in the stilling basin; and
- Fish movement from the present water release site in the reservoir into the stilling basin.

Dissolved oxygen and temperature modeling, which can be used to predict effects of proposed hydroelectric facility operations on oxygen and temperature regimes in the reservoir, in the stilling basin, and the Trinity River downstream, will also be conducted. The information from this study will help ETEC identify if steps need to be taken to avoid negative impacts to water quality or the fish community in Lake Livingston or the Trinity River downstream from the reservoir.

Preliminary meetings were held in May and June 2007 with the TCEQ headquarters and Region 10 staff, Texas Parks and Wildlife Department (TPWD), the U.S. Army Corps of Engineers (USACE) and the U.S. Fish and Wildlife Service (USFWS). Agency staff participating in the meetings identified the possible aquatic ecosystem concerns:

1. Temperature change (TCEQ and USFWS)
2. Dissolved oxygen change (TPWD, TCEQ, USACE, USFWS)
3. Striped bass broodfish collection below Lake Livingston Dam (TPWD, USACE)
4. Habitat impacts on fish (particularly American eel) and other aquatic species (USFWS)
5. Impacts on paddlefish (TCEQ Region 10, USFWS Trinity River National Wildlife Refuge)
6. Endangered and threatened species (TPWD, USACE, USFWS)
7. Water quality – siltation and blockage of nutrients by Lake Livingston Dam (USFWS Trinity River National Wildlife Refuge)

Additional meetings were held with the TCEQ and the TPWD staff in November 2008 to discuss agency concerns about study design and potential project effects. This study is intended to address agency concerns to the extent possible. Data obtained in this study, combined with additional water quality sampling being performed for the project by the Trinity River Authority's water quality department, will be used in dissolved oxygen and temperature modeling and in comparison with data obtained after commencement of project operations to evaluate the project's impacts on dissolved oxygen and temperature.

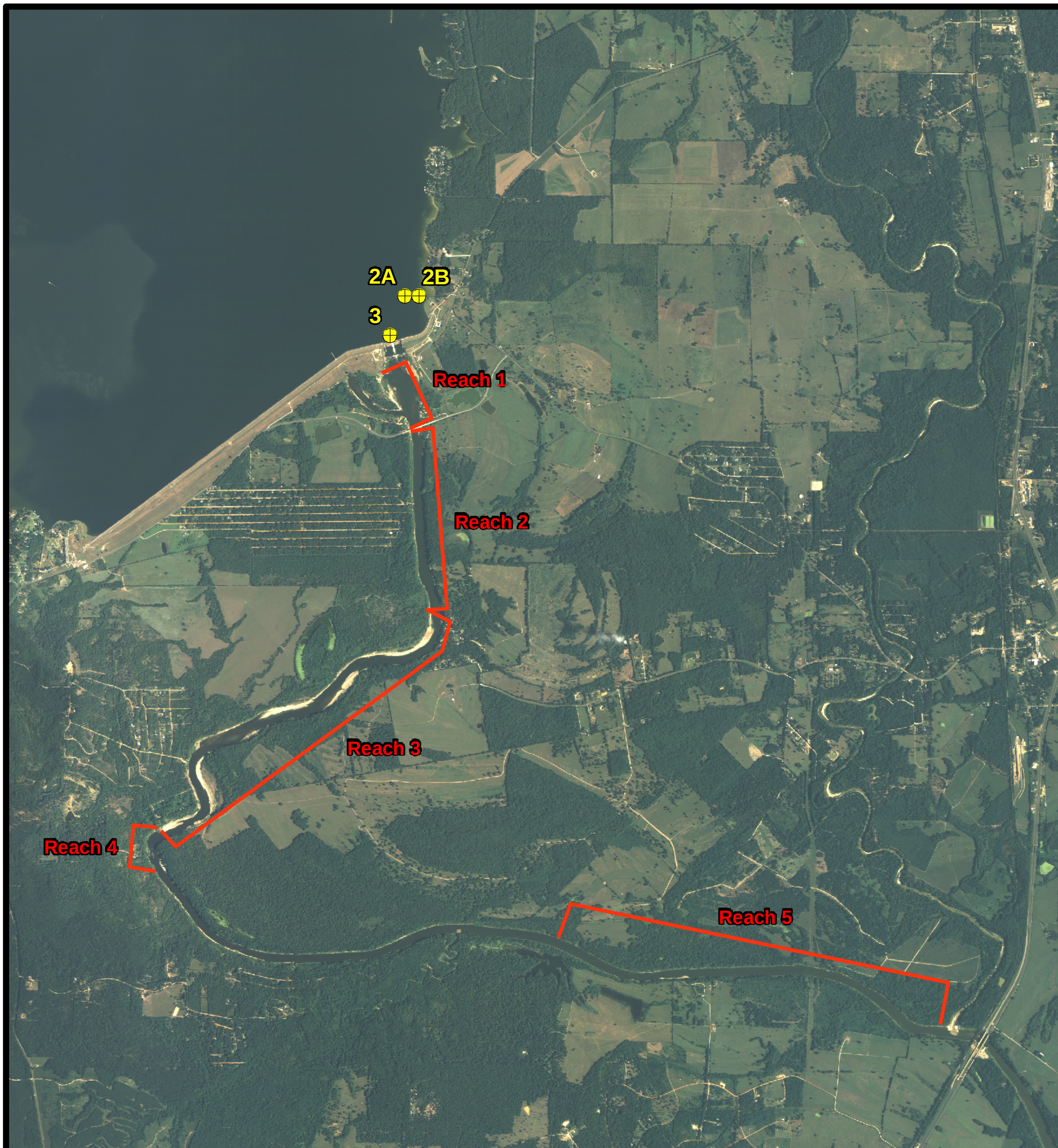
3.0 BASELINE SURVEY

3.1 SAMPLING LOCATIONS

Five sample reaches will be located within the Trinity River study area, which is downstream of Lake Livingston Dam to near U.S. Highway 59 (US 59). The sample reach boundaries reflect the variety of habitats downstream of Lake Livingston Dam. Sampling will focus on characterizing the fish communities of different habitats in the study area. Sampling in the reach upstream of US 59 minimizes interference of factors other than the discharge from Lake Livingston in the evaluation of the aquatic community. One station will be in the area immediately downstream of Lake Livingston Dam if access is possible. The remaining locations will be in habitats that represent the surrounding river reach. Figure 1 illustrates reaches of the river chosen to locate sampling stations. The U.S. Geological Survey (USGS) real-time gauging station, Trinity River at Goodrich (08066250), is located on the river at US 59. The Trinity River study reaches are:

Reach 1 (0.4 mile long):	Relatively shallow, high velocity, boulder and cobble substrate, and highly influenced by Lake Livingston Dam;
Reach 2 (1.2 miles long):	Deeply incised banks with sand, low velocity, mud and gravel substrate, no channel sinuosity, and sparse in-stream cover;
Reach 3 (2.1 miles long):	Relatively sinuous channel, sand and clay substrate, moderate velocity, sand bars common;
Reach 4 (0.3 mile long):	Rock/boulder outcrop relatively high velocity; and
Reach 5 (2.4 miles long):	Deeply incised banks with sand and mud substrate, poor channel sinuosity, little in-stream cover, and low velocity.

Three sampling stations will be located in Lake Livingston. Two stations will be adjacent to the proposed hydroelectric intake to characterize the fish community in the vicinity of the proposed facility (2a–open water near the proposed water withdrawal, and 2b–along the rip-rap armoring on the dam near the



Legend

⊕ Proposed Reservoir Sample Stations

River Reaches where stations are proposed

0 2,500 5,000 10,000 Feet

N W E S

PBSJ
6504 Bridge Point Pkwy, Ste. 200
Austin, Texas 78730
Phone: (512) 329-8342 Fax: (512) 327-2453

Figure 1

Proposed Reservoir and River Sample Locations
Livingston Dam Hydroelectric Project

Prepared for: East Texas Electric Cooperative	
Job No.: 044198800	Scale: 1inch equals 5,000 feet
Prepared by: A. Christiansen	Date: 02/20/2008
File: N:/Clients/E_F/East_TX_Electric_COOP/044198800/Figures/base_map_vr5.mxd	

proposed water withdrawal). A third station, in front of the existing gates on Lake Livingston Dam, will characterize the fish community where water releases are presently made.

3.2 SAMPLE PERIODS

Samples will be scheduled to capture data during different seasons and the critical and index periods defined by the TCEQ. The fall sample was collected December 3 to December 6, 2007. The winter sample was collected February 25–28, 2008. The spring sample was collected April 28–May 1, 2008. This sample was within the TCEQ's index period, but before the critical period. The summer sample will be collected between July 21 and September 5, 2008. This sample will be within the TCEQ's index and critical periods. When biological assessments are made in freshwater streams with two samples collected in a year, the TCEQ recommends collection of one sample within the index period (March 15 through October 15) and the second sample within the critical period (July 1 through September 30).

3.3 TRINITY RIVER FISH COMMUNITY SURVEY

Fish in the Trinity River will be collected by boat electrofishing, backpack electrofishing, seining, and gill netting. Sample gear will be used which are appropriate for the habitats at each location. Specific information about each sample technique is included in Table 1. When replicate samples are collected, for example individual gill net sets or seine hauls, the data from each replicate will be maintained separately. During data analysis, data from replicates may be combined to facilitate certain analyses.

Table 1. Fish Community Sampling Gear and Methods for the Trinity River and Lake Livingston Biological Characterization Study, November 2007 through September 2008

Sample gear	Mesh size	Sample Time/Size/ Number	Distance/Area/Volume	Units of Measure
Boat-mounted electrofisher with dual anode boom; conducted in river and reservoir	Dip net mesh = ¼ inch	15 minutes minimum; effective sample width = 4 meters (m)	Distance boat moved while electroshocking multiplied by width of boom equals sample area	# of fish by species collected per unit time and unit area
Backpack electrofisher with single anode pole ring; conducted in river only	Dip net mesh = ⅛ inch	15 minutes minimum; effective sample width = 2 m	Distance sampled while electroshocking multiplied by effective sample width equals approximate area sampled	# of fish by species collected per unit time and area
Seine; conducted in river only	⅛ inch for minnow seine or ¼ inch for bag seine	6 seine hauls over a measured distance	Total distance seined multiplied by effective seine width (x 0.8 correction) equals sample area	# of fish by species collected per unit area
Gill nets: conducted in river and reservoir	125-ft experimental net with 25-ft panels with stretch mesh sizes of 2, 3, 4, 5, and 6 inches	One or two nets fished parallel with river current; nets fished overnight	Length of time nets were fished	# of fish by species collected per unit time
Paired-frame trawl; conducted in reservoir only	Two 3.3-ft^2 trawls with 12-ft net with ¼-inch mesh; towed in tandem by boat	Trawls conducted at selected depths	Each trawl conducted for 5 minutes; nets equipped with flow meters to estimate sample volume	# fish by species collected per unit volume

Boat electrofishing for a minimum of 15 minutes at each station will be the primary tool for identifying species diversity during each sample trip. Distance traveled while electrofishing will be recorded with an on-board GPS unit. However, if the water is relatively clear and fish appear to avoid the electrofishing gear, night-time electrofishing may be required. Electrofishing at night will not be conducted when conditions are not safe. In those cases electrofishing will be conducted during the day.

Small species or juveniles of large species will be seined. The specific habitat features of each station will determine the type(s) of seines to be used. Typical mesh size will be ⅛ inch, but bag seines with mesh sizes up to ¼ inch may be used. Where seining is feasible, a minimum of 6 seine hauls will be conducted at each station during each sample trip.

Experimental panel monofilament gill nets that are 125 ft long will be used to collect larger fish. Since gill nets are a passive capture technique that may cause fish mortality, use of this method will be suspended if paddle fish are found in the area. One to two gill nets will be fished overnight at each station during each sample trip.

3.4 RESERVOIR FISH SURVEY

The Project Team will survey the fish community in Lake Livingston in the vicinity of the project and the existing spillway/gates to characterize the age, spatial and temporal distributions of species including threadfin (*Dorosoma petenense*) and gizzard shad (*D. cepedianum*) that may pass through the proposed facility. The study design will include a comparison between the fish community present where water is presently released from the reservoir and the fish community near the surface in the vicinity of the project.

Gill netting, boat electrofishing, and paired-frame trawling will be conducted in the reservoir. Two stations will be selected in the vicinity of Lake Livingston Dam and the proposed project. One station will be located near the proposed hydroelectric facility and the second near the existing gates in the dam.

Up to three 125-ft experimental panel monofilament gill nets will be fished at each station. Net placement will depend on the station and water depth.

Boat electrofishing will be conducted along the shoreline of Lake Livingston Dam in the vicinity of the proposed facility. Electrofishing will not be conducted at open-water stations.

Paired-frame trawling involves towing two trawl nets in tandem. The nets consist of 3.3-ft^2 frames with 10-ft-long nets constructed of ¼-inch Delta mesh. A meter is stationed in the mouth of each net to estimate the volume of water sampled. This sample method obtains quantitative estimates of shad densities and other, small (e.g., <6 inches) pelagic species. Trawls will be pulled at predetermined depths to estimate fish densities.

3.5 FISH SAMPLE ANALYSIS

Collected fish will be identified, counted and measured in the field and returned live to the sampling location whenever possible. If a sample contains large numbers of small fish, the sample will be preserved in the field and processed in the laboratory. All fish will be sorted and identified to species. Up to 25 individuals of each species from each station during each sample trip will be measured to total length and fish ≥3 inches (76 millimeters) will be weighed to the nearest gram. Fish <3 inches in length will be measured and a bulk weight obtained by species and station. A voucher collection consisting of two specimens of each species will be maintained for a minimum of 5 years. Taxonomy of the fish will be verified by Dr. Bobby Whiteside, retired director of the Texas State University Aquatic Station and co-author of *The Fishes of Texas*). If a paddlefish or any other species of concern is collected, handling will be minimized and digital photos will be collected.

3.6 BENTHIC MACROINVERTEBRATE COMMUNITY SURVEYS

Benthic macroinvertebrates will be collected at two stations in the Trinity River (Table 2). Kick-sampling for 5 minutes with a D-frame benthic macroinvertebrate net will be done where habitats conducive to kick-sampling exist. Large woody debris, cobble, and other debris if present will be collected and organisms removed. Samples will be preserved in the field with 10% formalin and processed later in the laboratory.

Table 2. Benthic Macroinvertebrate Sampling Gear and Methods for the Trinity River and Lake Livingston Biological Characterization Study, November 2007 through September 2008

Sample gear	Sample Time/Size/Number	Distance or Area	Units of Measure
Kicknet	5 minutes with 500-µm mesh dip net	Not quantified per unit area	List of taxa collected, their relative abundance, and the TCEQ benthic macroinvertebrate metrics
Debris sampling	Will sample each type of debris, logs, emergent or overhanging plants, trash, present at station	Not quantified per unit area	List of taxa collected, their relative abundance
Mussel observations	Survey 50 m of shoreline and probe river bottom at 10 locations at each station	Not quantified per unit area	List of taxa collected, whether recently dead shells (less than 3 months), old dead shells (more than a year) or alive. Numbers of shells or live mussels collected. Estimate of whether densities are high, medium or low and whether the geographic distribution is great, moderate or small.

A qualitative assessment of the mussel community will be made at both stations on each sample trip by searching the shoreline for shells of mussels that recently died. Shallow water will also be sampled by hand for the presence of mussels. Additionally, during fish community sampling and habitat assessment, signs of live or recently dead mussels will be recorded. Empty shells will be collected and sent to the TPWD experts for identification. If live mussels are encountered, they will be tentatively identified, measured, photographed and returned live to the sample location. The absence of mussels will be recorded.

3.7 BENTHIC MACROINVERTEBRATE SAMPLE ANALYSIS

Sample processing and analysis will follow the TCEQ's *Methods for Collecting and Analyzing Biological Assemblage and Habitat Data* (2007). Organisms will be identified to the lowest taxonomic level practical or as required by the above protocol (usually to genus).

A voucher collection consisting of two specimens of each species will be maintained for a minimum of 5 years.

3.8 WATER QUALITY AND HABITAT

Water temperature, dissolved oxygen, pH, and conductivity will be measured at each station during each sample trip using a Hydrolab Minisonde™ or YSI 600XL™. Water clarity will be measured with a Secchi disc at each sample station during each sample trip.

The Trinity River Authority will measure dissolved oxygen, temperature, pH, and conductivity monthly at five locations: two in Lake Livingston, one at the current discharge from the reservoir, and one about 75 ft from the shore at the proposed project site; and three below the Lake Livingston Dam: in the stilling basin, 500 ft downstream of the stilling basin and close to both banks, and 1,000 ft downstream of the stilling basin near both banks. Measurements will be made from the surface and at 5-ft depth intervals to 50 ft in the reservoir and to 10 ft in the river. Reservoir discharge and preceding 24 hours of rainfall will also be recorded.

Habitat will be evaluated at each Trinity River station at least once. Habitat measurements will be performed at 5 to 11 transects at each station. The survey reach for habitat assessment at each station will be between 500 and 1,000 m. The exception to this will be the stilling basin which will only be surveyed if accessible by boat.

Since available habitat varies with flow, changes in habitat occurring between sample events will be related to in-stream flow. The habitat evaluation will follow the TCEQ's *Methods for Collecting and Analyzing Biological Assemblage and Habitat Data* (2007). Observations of water, substrate, and shoreline condition will be recorded at each sample location on each visit.

Discharge during each sample event will be obtained from the USGS gauging station on the Trinity River at Goodrich (USGS 08066250). Habitat availability will be related to flow and gage height. In addition, velocities along transects will be measured with a digital flow meter.

3.9 DATA MANAGEMENT

Data will be recorded in the field on water-resistant field sheets designed to ensure collection of all required data. After each sample event, all data will be reviewed on field sheets, entered into a Microsoft Access™ database, and maintained by the Project Team.

4.0 SUPPLEMENTAL STUDIES

Additional data collection and analysis will help understand potential project impacts to the fishery in the Trinity River downstream of Lake Livingston Dam. These efforts are intended to help understand movement of game fish like striped bass as well as forage fish from the reservoir into the stilling basin and the river downstream. Intensive collection of dissolved oxygen and temperature data over time and depth will support water quality modeling and indicate when conditions may be stressful to fish. Water quality modeling in turn will help describe dissolved oxygen and temperature regimes in the reservoir, stilling basin and river downstream of the stilling basin under proposed hydroelectric facility operation.

4.1 STRIPED BASS AND FORAGE FISH MOVEMENT FROM THE RESERVOIR TO THE TRINITY RIVER

4.1.1 Stomach Analysis of Fish Downstream of Lake Livingston Dam

Stomach contents of striped bass and blue catfish in the stilling basin and/or the area immediately below the weir dam will be sampled. These data combined with fish community data collected during baseline fisheries sampling will help understand movement of forage fish from the reservoir and their utilization by predators downstream of Lake Livingston Dam. Fish will be collected with boat electrofishing or hook and line during the quarterly baseline sample events.

Stomach contents of predatory striped bass and blue catfish will be collected by pumping/flushing the stomachs of live fish. Stomach pumping may not be applicable in all cases. Fish would only be euthanized if necessary for sample collection. Data collected will include number, species, and size of identifiable aquatic organisms in the stomachs of up to 25 striped bass and up to 25 blue catfish per sample event. The number of fish sampled will depend on availability of fish and approval by the TPWD. The length and weight will be recorded for each fish sampled. Data will be used to describe relationships between stomach contents (species, sizes, and numbers), season, flow and water quality conditions; and the relative importance of prey from the reservoir to predatory fish in the river.

4.1.2 Acoustic Monitoring of Fish Moving From the Reservoir into the Stilling Basin

Fish moving from the reservoir into the stilling basin with existing releases from Lake Livingston under a variety of water quality and flow conditions will be monitored using acoustic imaging technology

(DIDSON) over a 72–96 hour period during the three remaining quarterly baseline sample events. An additional 72–96 hour monitoring event will be conducted if necessary to ensure data are collected under a broad range (e.g., high flow) of water quality and flow conditions.

Data will be collected from the reservoir side of the Lake Livingston Dam gates at the depth of water release from the reservoir. Each gate is 40 ft wide and fish movement across the width of an individual gate will be monitored.

Data collected will include the number of fish leaving the reservoir, their estimated sizes and biomass, and when possible the species of fish leaving the reservoir with flow through the dam's gates. Temperature, dissolved oxygen, pH, conductivity and turbidity of water at discharge point from reservoir will be recorded during the acoustic monitoring.

4.2 WATER QUALITY IN LAKE LIVINGSTON AND THE TRINITY RIVER DOWNSTREAM OF LAKE LIVINGSTON DAM

Additional monitoring of temperature and dissolved oxygen in the reservoir near the existing gate releases, near the proposed headrace of the project, and in the stilling basin or proposed tailrace from the spring through fall 2008 will be conducted. The proposed tailrace is where the discharge from the proposed hydroelectric facility would enter the river. This monitoring will complement, but does not replace, the existing Trinity River Authority (TRA) monitoring program. This information will describe short-term changes in dissolved oxygen and temperature at critical locations in the reservoir, stilling basin and river which may be biologically important to the fish community. The data will also provide valuable information to calibrate the water quality model which in turn will be used to evaluate the possible effects of different alternatives for the proposed facility's operations.

Water quality meters will be used to monitor dissolved oxygen (DO) levels along with temperature, pH, and conductivity in the reservoir in front of the dam, at the proposed headrace location, and at the proposed discharge location. Meters will log data at least hourly and will be retrieved, downloaded, and recalibrated approximately every 2 weeks through November 2008.

Three meters will be deployed in the reservoir in front of the dam at depths which correspond to typical depths of the epilimnion, metalimnion, and hypolimnion in Lake Livingston. One meter will be placed in the epilimnion near the proposed headrace of the project. One meter will be placed in a secure location in the stilling basin or at the proposed tailrace location.

4.3 MODELING TEMPERATURE AND DISSOLVED OXYGEN IN LAKE LIVINGSTON, THE STILLING BASIN, AND THE PROPOSED TAILRACE AREA

Water quality modeling will be conducted to help predict how water quality in Lake Livingston, the stilling basin, and the proposed tailrace area may be affected by different hydroelectric and reservoir release scenarios.

Modeling will be conducted in two phases. The first phase will calibrate the model using historical reservoir and river water quality and bathymetric data as well as proposed design and operation of the hydroelectric facility. At the end of data collection in November 2008, model calibration will be reviewed, and new, more detailed data incorporated into the model. The revised, updated model will be used to develop the most accurate predictions possible.

CE-QUAL-W2 is a widely used two-dimensional (longitudinal/vertical) hydrodynamic and water quality model available from the USACE. It will model temperature and dissolved oxygen in the reservoir and the river. The model will be calibrated with historical data from the TRA and other organizations. It is assumed bathymetric data are available for the reservoir.

The initial modeling effort will provide preliminary predictions on expected changes in dissolved oxygen and temperature. These preliminary results will guide ongoing data collection and possible hydroelectric facility design and operational options. Modeling will focus on the main body of the reservoir in front of Lake Livingston Dam, the stilling basin between the dam and the weir dam, and the proposed tailrace area downstream of the weir dam.

A report describing model scenarios and outputs will estimate the:

- Minimum release rate needed from Lake Livingston Dam to support the existing stilling basin dissolved oxygen and temperature regimes and maintain water quality standards in the river;
- Impact of low epilimnetic DO levels like those recently observed in the reservoir on DO levels in the Trinity River, if the water were passed through the hydroelectric facility;
- River temperatures resulting from facility operations at various flows and seasons; and
- Effects on reservoir stratification near Lake Livingston Dam associated with the change in discharge location.

The report describing model results will help evaluate potential mitigative alternatives for supplemental aeration of the water passing through the hydroelectric facility or for evaluating mechanical aeration of the stilling basin. It will also address other water quality issues identified by the agencies as the process unfolds. Model construction, calibration with available data, and validation for the main body of Lake Livingston in front of Lake Livingston Dam and including the area of the proposed hydroelectric facility, the stilling basin, and the river will be summarized.

After a year of detailed data collection there will be more detailed information to test the model and update the model calibration. While not expected, there also may be changes in the proposed design and operation of the hydroelectric facility, which could potentially affect temperature and dissolved oxygen regimes in the reservoir, stilling basin, and the proposed tailrace area. The second phase of the modeling effort will use the new information to review and revise as necessary the model calibration. Simulations may be rerun for all alternatives and a final report with full model documentation would be prepared.

4.4 EVALUATION OF AMERICAN EELS

The USFWS, Clear Lake, Texas, requested information regarding American eels (*Anguilla rostrata*) in relationship to the proposed project.

The USFWS specifically requested three points be evaluated:

- Current impact the dam has as a barrier to upstream movement of eels;
- Different eel ladders;
- Devices that would exclude eels from turbines; and
- Conduct focused sampling to detect the presence of eels below the dam.

4.4.1 Lake Livingston Dam and Upstream Movement of Eels

A comprehensive review of relevant scientific literature, historical records, museum collections, university research, agency databases, and anecdotal information which may contain information about where and when eels were encountered and some estimate of when they may have entered the Trinity River watershed upstream and downstream of Lake Livingston Dam will be conducted. This information will document the collection or occurrence of American eels in the Trinity River watershed. Scientific literature would be reviewed to obtain information about the effects of barriers like dams on the distribution and populations of American eels in other watersheds particularly in the western Gulf of Mexico.

4.4.2 Review of Eel Ladders/Passage

Eel ladders have been constructed in certain waterbodies to facilitate movement of juvenile eels past barriers to upstream migration. Information on the characteristics and effectiveness of different eel ladder designs would be gathered and evaluated for applicability in the Trinity River and at Lake Livingston dam.

4.4.3 Eel Deterrent Technology

Information about the survival of eels migrating downstream through hydropower turbines and available information on deterrents and exclusion devices to keep eels out of hydropower turbines would be gathered. Effectiveness of these approaches to reducing eel mortality would be evaluated in the context of the proposed hydropower facility at Lake Livingston.

4.4.4 Eel Sampling

Although eels have been captured using the baseline fish community sampling procedures described earlier, sampling designed specifically to capture eels will be conducted during the last sampling trip.

- Eel traps will be set at different locations downstream from Lake Livingston dam and upstream of the US 59 Highway bridge at Goodrich. The eel traps will be set on the first sampling day (probably a Monday) and checked daily until the end of the sampling trip (probably Tuesday, Wednesday, Thursday, and Friday).
- Although electrofishing in all available habitat types has been conducted during each sample trip, additional intensive electrofishing will be conducted for about 4 hours under the low flow conditions expected during the last sample event in August. This effort will be focused in the Trinity River and its tributaries in the study reach (e.g., Long King Creek). Habitats preferred by eels like undercut banks, brush piles, and rock piles will be targeted for this effort.

5.0 REPORTING

A report will be prepared which will be a supplement to the project environmental assessment report. The report will describe the aquatic communities and dissolved oxygen and temperature in the vicinity of the proposed project in Lake Livingston and in the Trinity River downstream of Lake Livingston Dam. The report will address comments received by regulatory agencies about the biological communities in the reservoir and the river. All data will be appended. Results will include species lists, description of spatial and temporal distributions, relative abundance, density estimates for the quantifiable sample methods, mean and range of lengths and weights, habitat observations, mapping of specific habitat features, and water quality. Water quality modeling procedures and results will be described.

Potential effects of the proposed project will be described with focus on species of concern and important recreational species. Fish passage and changes in water quality may be affected by the project. The report will include a literature review addressing fish passage through hydroelectric turbines. Analysis of water quality measurements will be conducted to describe reservoir and river water quality changes with season, depth, and downstream movement of the water.