Fort Parker Lake and Fairfield Lake
Water Quality Project

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Executive Summary

Fort Parker Lake and Fairfield Lake have exhibited low dissolved oxygen levels that may harm aquatic life. Fort Parker Lake, also known as Springfield Lake, lies within Fort Parker State Park and Fairfield Lake borders Fairfield Lake State Park. In 2005 the Texas Parks and Wildlife Department (TPWD) Water Quality Program began collecting water quality data at three locations at Fort Parker Lake, and in 2006 began a similar project on Fairfield Lake. Objectives for both projects included collecting enough data for the Texas Commission on Environmental Quality (TCEQ) to complete a regulatory water quality assessment of both reservoirs, to identify the cause of fish kills at Fairfield Lake and to improve our understanding of dissolved oxygen dynamics in small reservoirs.

Diel physicochemical data from Fort Parker Lake showed dissolved oxygen and pH swings indicative of algal photosynthesis and respiration. All three sites had values below the dissolved oxygen criterion supporting high aquatic life use. Of the 31 diel measurements collected, 19% of the mean values and 29% of the minimum values were below the criteria. In 2004 TCEQ placed Fort Parker Lake on the water quality concerns list for dissolved oxygen and nutrients. In the 2008 assessment, TCEQ continued the concerns listing for low dissolved oxygen and nutrient enrichment based on data from the site near the dam.

In 2006 and 2007 there were no fish kills at Fairfield Lake and diel physicochemical data showed no exceedances. Investigation of a major fish kill in 2009 showed that algal respiration combined with cloudy days caused extended periods of low dissolved oxygen. These data suggest that similar patterns are responsible for autumn fish kills observed in 2004, 2005 and 2008. The TCEQ will assess Fairfield Lake will in 2010.

Both reservoirs are hypereutrophic. Nutrient loads need to be reduced for the reservoirs to maintain water quality that is protective of aquatic life.

Introduction

Maintaining water quality on agency lands is part of the TPWD mission. TPWD manages state parks and wildlife management areas to conserve biodiversity and cultural heritage and to provide recreational opportunities. Many of these areas include water bodies protected by the federal Clean Water Act and the Texas Surface Water Quality Standards to ensure waters of the state are fishable and swimmable (TCEQ 2000). The TCEQ is the state agency with primary responsibility for protecting, monitoring and assessing water quality. Where water bodies lie within TPWD-managed areas, there is an opportunity for our agency to collect data and to make informed management decisions to maintain or improve water quality for the needs of aquatic life and recreation.

Fort Parker Lake, also known as Springfield Lake, lies within Fort Parker State Park in Limestone County. Fairfield Lake borders Fairfield Lake State Park, and is the cooling reservoir for the Luminant (formerly TXU) Big Brown power plant in Freestone County. Both lakes have exhibited low dissolved oxygen levels that may harm aquatic life. TCEQ monitors Fort Parker Lake as part of its routine monitoring program. However, Fairfield Lake was not monitored prior to 2005. In 2004 Fort Parker Lake (TCEQ Segment 1253A) was reported to have an aquatic life use concern due to a limited amount of data which indicated the presence of low dissolved oxygen levels (TCEQ 2004). In 2004 Fairfield Lake (Segment 0804J) began having fish kills related to low dissolved oxygen. Neither reservoir has site-specific water quality criteria. Both reservoirs are presumed to have a high aquatic life use and corresponding dissolved oxygen criteria of 5.0 mg/L mean and 3.0 mg/L minimum (TCEQ 2000).

In 2005 the TPWD Water Quality Program began collecting water quality data at three locations at Fort Parker Lake representing the upper, middle, and lower portions of the reservoir. In 2006 a similar project began on Fairfield Lake at one location near the dam. Objectives for both projects included collecting enough data for TCEQ to complete a regulatory water quality assessment of both reservoirs, to identify the cause of fish kills at Fairfield Lake and to improve our understanding of dissolved oxygen dynamics in small reservoirs.

Project Area

Fort Parker Lake is a small impoundment on the Navasota River in the Brazos River Basin below Lake Mexia in Limestone County. The 293 ha (725 acre) reservoir was created in 1939 and is entirely within Fort Parker State Park. The reservoir is used for swimming, boating and fishing. The fishery is managed by TPWD and includes channel catfish *Ictalurus punctatus*, blue catfish *Ictalurus furcatus*, white bass *Morone chrysops*, largemouth bass *Micropterus salmoides* and white crappie *Pomoxis annularis*. The reservoir is shallow with mean depth of 1.2 m (TPWD 2007). The deepest water is found in the flooded river channel upstream of the main body (Figure 1). The upper and middle portions of the reservoir are very shallow. In 2005, this area of the reservoir had over 202 ha (500 acre) affected by American Lotus (TPWD 2007) and was often covered with floating leaves in the summer and fall (Figure 2). In the spring this area was mostly free of floating vegetation (Figure 3). During the project there was an annual infestation of insects that consumed the lotus (Figure 4), which recovered in the late summer before its growth cycle was complete. The lower portion of Fort Parker Lake near the dam is narrow and shallow. Project monitoring sites are located at TCEQ surface water quality monitoring (SWQM) stations representing the upper (station 17039), middle (station 18799) and lower portions (station 16247) of the reservoir. The report refers to these sites as "river channel," "mid-reservoir" and "near dam."

Figure 1. Ft. Parker Lake river channel site (Oct 2006).

Figure 2. Ft. Parker Lake mid-reservoir site (Oct 2006).


Figure 3. Ft. Parker Lake mid-reservoir site (May 2006).


Figure 4. Ft. Parker Lake mid-reservoir site (Jul 2006).

Figure 5. Ft. Parker Lake near dam site (Jun 2006).

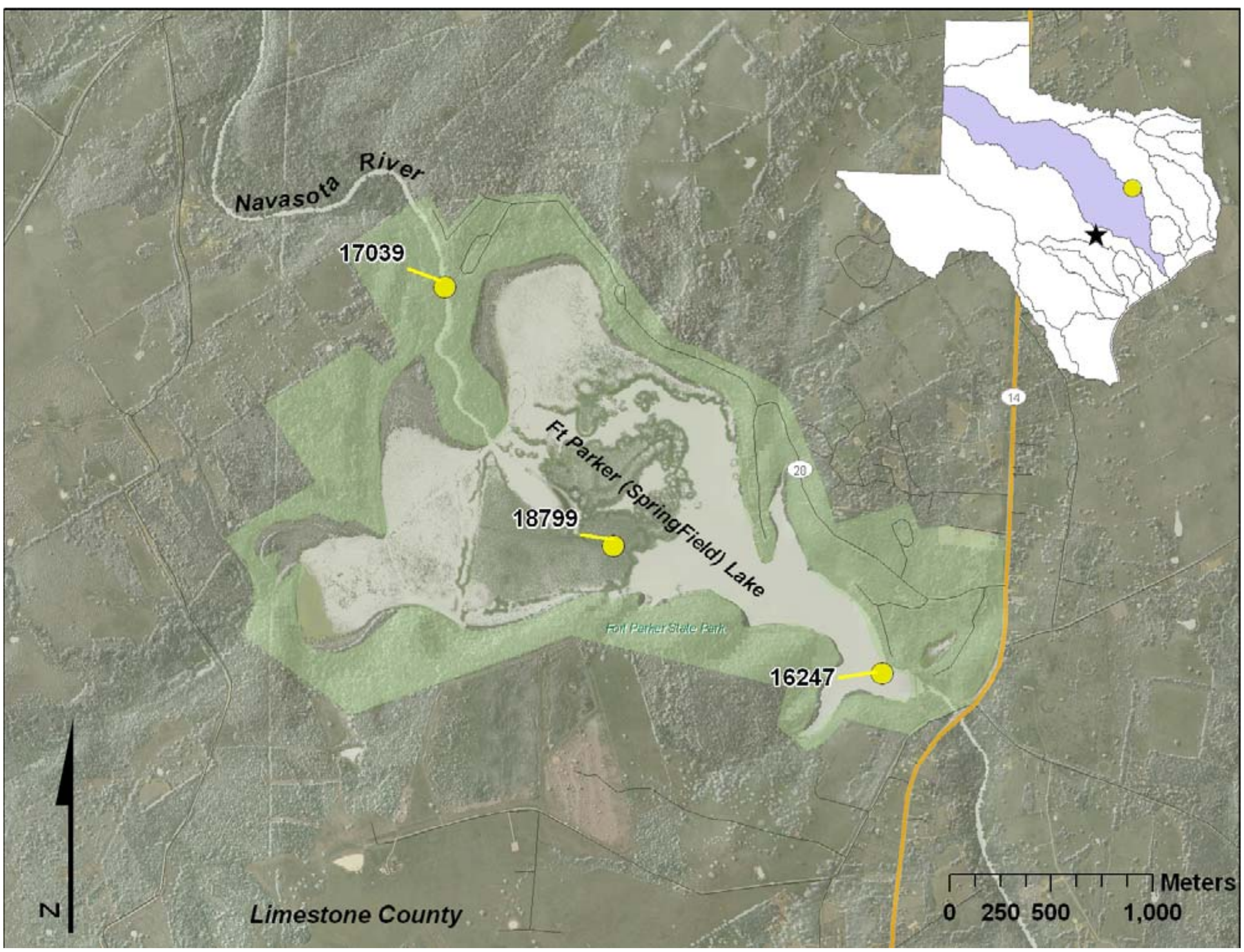

Figure 6. Fort Parker Lake showing TCEQ monitoring stations.

Fairfield Lake was constructed by Luminant in 1969 to provide cooling water for two 575 megawatt lignite-fired electric generation units at the Big Brown power plant in Freestone County. The 823 ha (2,034 acre) reservoir impounds Big Brown Creek and Little Brown Creek, tributaries of the Trinity River above Lake Livingston. Although it is an off-channel reservoir, it receives make-up water from the Trinity River in a cove near the south end of the dam. In the summer, this is the predominant source of water to the reservoir. TPWD leases property bordering the upper watershed and the southeast side of the reservoir for Fairfield Lake State Park. The state park provides access to the reservoir for swimming, boating and fishing. The fishery is managed by TPWD and includes red drum *Sciaenops ocellatus*, largemouth bass, channel catfish, blue catfish, flathead catfish *Pylodictis olivaris,* bluegill *Lepomis macrochirus,* and redear sunfish *Lepomis microlophus*. Red drum have been stocked in the reservoir since 1984 and have become a popular sport fish. The current state freshwater red drum record (36.83 lbs, 44 inches) was set on Fairfield Lake in 2001 (TPWD 2005). Fairfield Lake is relatively deep with a maximum depth of 15 m and a mean depth of 5 m (TPWD 2005). The project monitoring site is located in the middle of the reservoir near the dam at TCEQ SWQM station 17951 (Figure 8).

Figure 7. Fairfield Lake site (Apr 2007).

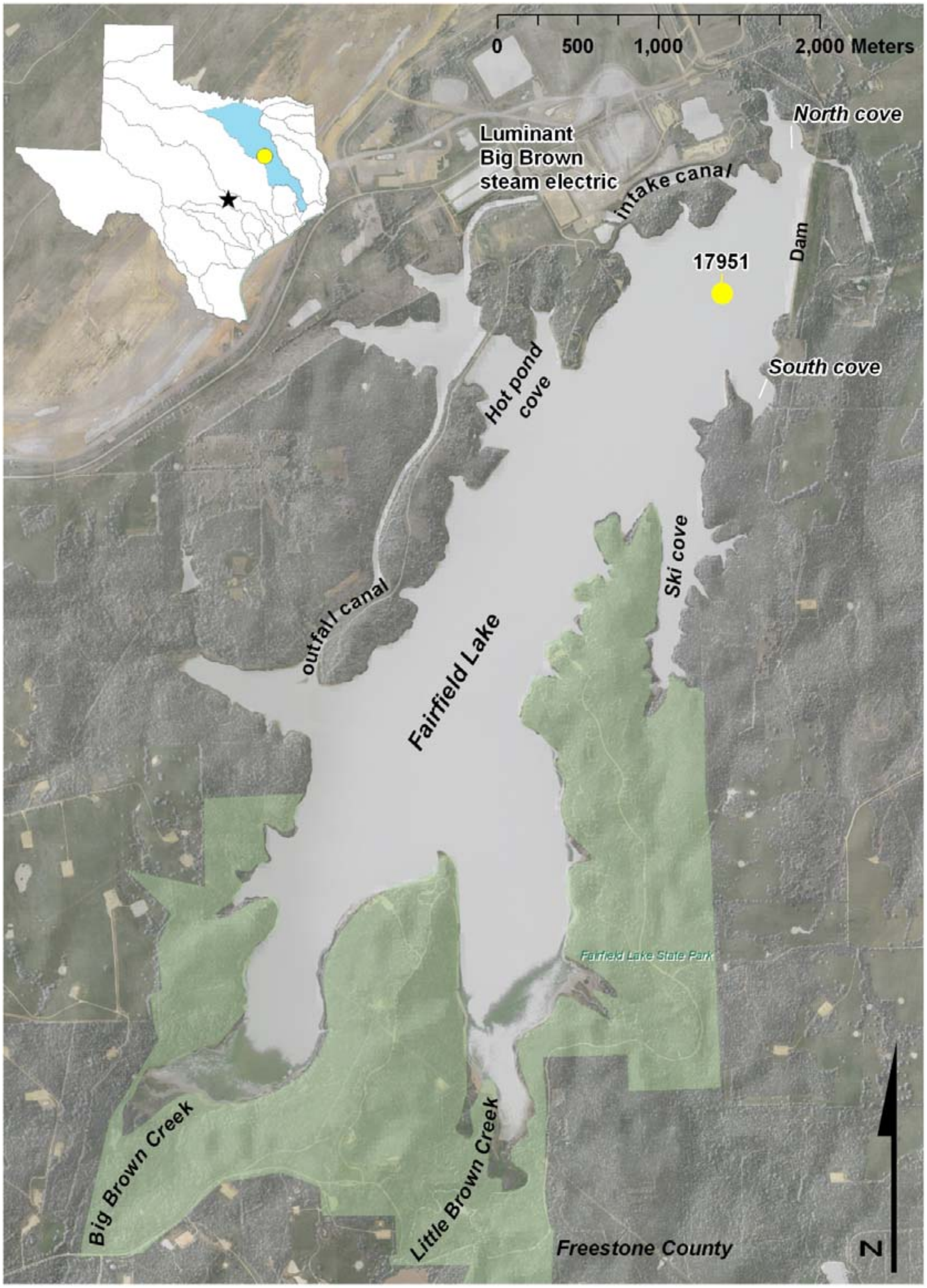

Figure 8. Fairfield Lake showing TCEQ monitoring station.

Background

Dissolved oxygen criteria are the primary regulatory means of protecting aquatic life. In addition to numeric dissolved oxygen criteria, there is a narrative criterion that prohibits excessive growth of aquatic vegetation. In the absence of numeric nutrient criteria, TCEQ uses screening levels, observations of excessive plant growth and fish kill data to assess water bodies (TCEQ 2008a). TCEQ has established screening levels for select nutrients and chlorophyll-*a* and uses the Carlson Trophic State Index (TSI) to assess nutrient enrichment in reservoirs. Fish kill data is available through the TPWD Pollution Response Inventory and Species Mortality (PRISM) database (TPWD 2009a).

Water Chemistry

Water chemistry data reported in the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) from January 1999 to August 2009 were compared with screening levels (TCEQ 2009, Table 1). Data indicate that both reservoirs have elevated nutrient and chlorophyll-*a* levels that are contributing to eutrophication. Chlorophyll-*a* was significantly elevated at the Fort Parker Lake near dam site but not in the river channel. Twelve of 13 chlorophyll-*a* measurements at Fairfield Lake exceeded the screening level, with a maximum value of 127 µg/L.

Table 1. Water chemistry data for nutrient parameters (Jan 1999 – Aug 2009, TCEQ 2009).

		Nitrogen [a] (mg/L)		Phosphorus [a] (mg/L)		Chlorophyll-*a* [a]
Location		Ammonia	Nitrate	Orthophosphorus	Total	(µg/L)
Screening level (TCEQ 2008a)		0.11	0.37	0.05	0.2	26.7
Ft. Parker Lake - River channel	N	21	21	19	21	21
	Min	0.03	0.03	0.03	0.08	5.0
	Max	0.22	0.54	0.17	0.25	36.8
	Mean	0.07	0.15	0.05	0.15	14.7
Percent of samples that exceed screening level		24%	14%	21%	10%	14%
Ft. Parker Lake - Near dam	N	41	42	41	42	42
	Min	0.03	0.03	0.02	0.07	5.0
	Max	0.39	0.63	0.17	0.32	91.4
	Mean	0.08	0.08	0.05	0.18	36.7
Percent of samples that exceed screening level		22%	2%	29%	26%	57%
Fairfield Lake	N	15	15	15	15	13
	Min	0.02	0.02	0.02	0.03	23.1
	Max	0.05	0.27	0.22	0.34	127.0
	Mean	0.05	0.04	0.05	0.13	61.0
Percent of samples that exceed screening level		0%	0%	33%	13%	92%

a Measurements reported as non-detect were included as one-half the detection limit.

Trophic State

The Carlson's Trophic State Index for chlorophyll-*a* places both reservoirs in the hypereutrophic class. TCEQ uses chlorophyll-*a* data to rank the reservoirs as it is the best indicator for algal biomass in most reservoirs. The chlorophyll-*a* TSI value for Fort Parker Lake was 63.8, ranking it 93 out of 102 reservoirs assessed, which places the reservoir in the hypereutrophic class

(TCEQ 2008b). Fairfield Lake was not included in the 2008 trophic classification of reservoirs, as data was absent prior to November 2005. The TSI can be calculated using a procedure similar to that employed by TCEQ and the mean chlorophyll-*a* value (Table 1).

TSI (Chlorophyll-*a*) = (9.81 * ln (Chlorophyll-*a*)) + 30.6

The TSI value is 70.9, placing it well within the hypereutrophic class. While TCEQ typically uses ten years of data in calculating a TSI score, using just these 13 chlorophyll-*a* measurements collected over four years ranks Fairfield Lake 101 of 103 reservoirs. For perspective, the TSI range and number of reservoirs for each class of the 102 reservoirs that TCEQ assessed are oligotrophic (0 to 35), 0 reservoirs; mesotrophic (>35 to 45), 13 reservoirs; eutrophic (>45 to 55), 48 reservoirs; and hypereutrophic (>55), 41 reservoirs.

Fish Kills

In October 2003, TPWD began receiving reports of fish dying in the lower end of Fairfield Lake (Table 2). The fish kills were large and included many important game species such as red drum, largemouth bass, channel catfish, and flathead catfish. Threadfin shad *Dorosoma petenense*, gizzard shad *Dorosoma cepedianum*, redear sunfish and bluegill were found in abundance in the larger fish kills in September 2004, September 2005, October 2008 and September 2009 (TPWD 2009a). Some of the fish kills were isolated in coves while others were in open water and along the shoreline (Figure 9). The location for a majority of the kills included the cove north of the dam.

Water quality measured during the fish kill investigations indicated that low dissolved oxygen was the cause, and algal respiration was likely the source contributing to the decline in oxygen (Table 2). TPWD staff investigated the 2004 and 2005 fish kills, but were not able to collect data while the kills were occurring (Table 3). In 2006 TPWD staff began regular data collection with hope of observing a fish kill in progress. Fish kills were not reported during 2006 and 2007, but recurred in 2008 and 2009 after the original scope of work for this project was completed. In response to the recurring fish kills, the project was expanded to collect additional data.

Fort Parker Lake has not experienced many fish kills. The last fish kill reported at Fort Parker Lake occurred in July 1996 when the reservoir was being dredged (TPWD 2009a).

Table 2. Fairfield Lake fish kill investigations from the TPWD PRISM database (2000-2009). Values based on criteria established by the American Fisheries Society (AFS 1992).

Date	Cause and source of fish kill	Estimated total killed	Total value
26 Oct 2003	Temperature - cold front suspected	4,300	$840.97
24 Sep 2004	Low dissolved oxygen and algal respiration suspected	114,050	$25,142.97
24 Sep 2005	Low dissolved oxygen confirmed and algal respiration suspected	128,143	$72,122.01
7 Oct 2005	Low dissolved oxygen confirmed and algal respiration suspected	3,251	$8,496.98
3 Sep 2008	Low dissolved oxygen and algal respiration suspected	7,347	$1,138,435.45
17 Oct 2008	Low dissolved oxygen confirmed and algal respiration suspected	114,223	$41,443.04
13 Sep 2009	Low dissolved oxygen confirmed and algal respiration confirmed	914,189	$451,247.30
	Total	1,285,503	$1,737,728.72

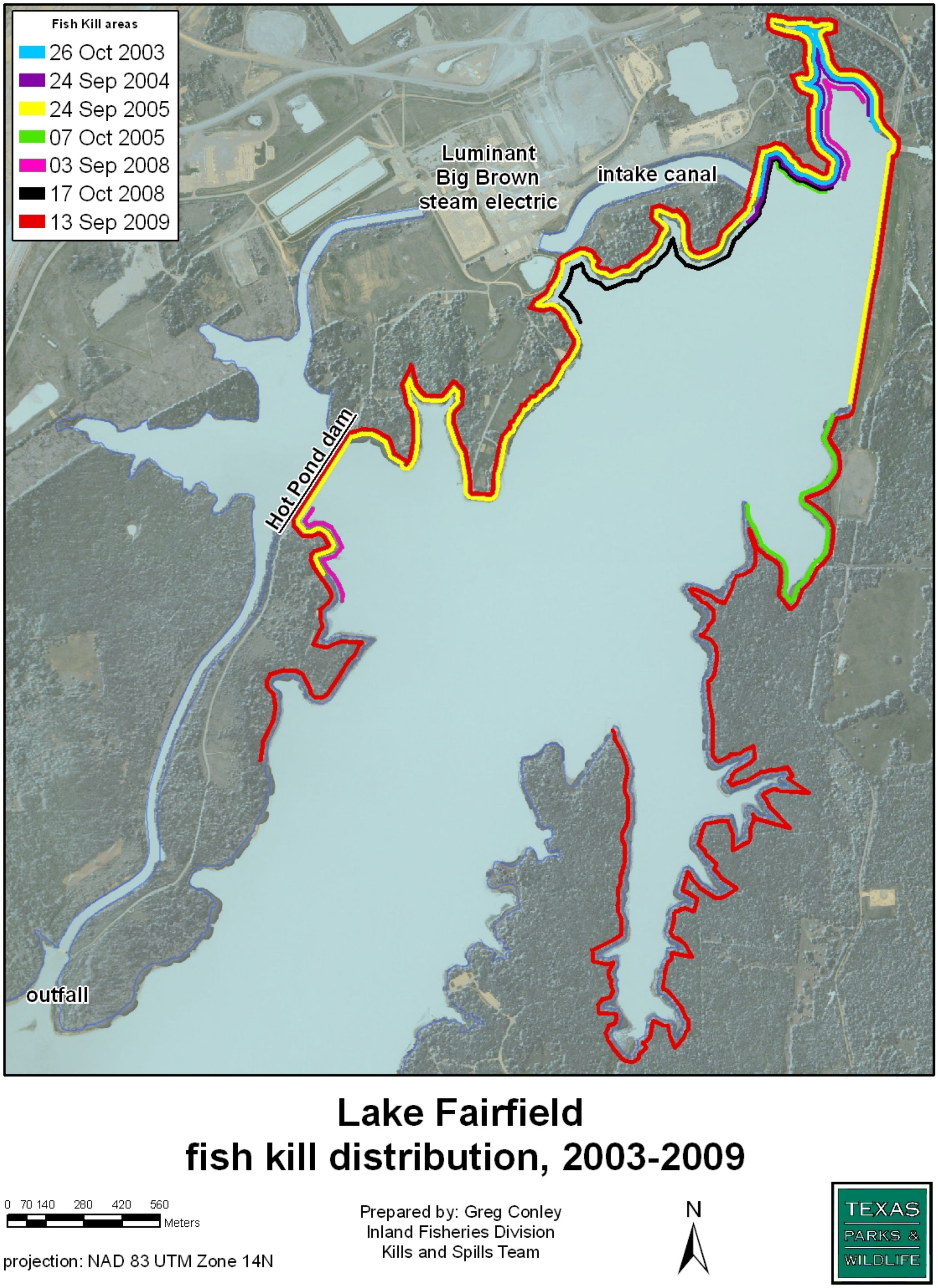

Figure 9. Fairfield Lake fish kill distribution.

Table 3. Fairfield Lake instantaneous physicochemical measurements (2004 - 2005).

Location	Date	Time	Depth (m)	Temp (ºC)	pH	DO (mg/L)
Middle of dam, near fish kill area	26 Sep 2004	1120	0.3	29.8	8.3	4.3
			1.0	29.8	8.3	3.9
			2.0	29.7	8.2	3.0
			5.0	29.4	8.1	2.8
			7.5	29.4	8.0	2.0
			10.0	28.3	7.3	0.2
			13.7	23.6	6.7	0.2
		1530	0.3	30.0	8.4	5.4
			1.0	30.0	8.3	3.0
			2.0	29.9	8.2	3.0
			5.0	29.6	8.1	2.5
			10.0	27.9	7.1	0.2
		1709	0.3	29.8	8.3	4.3
Mid-reservoir, outside fish kill area		1140	0.3	30.9	8.3	5.1
			1.0	30.8	8.3	4.6
			2.0	30.6	8.2	3.5
			5.0	29.8	7.9	1.1
			7.5	29.4	7.7	0.1
			9.7	28.9	7.3	0.1
		1702	0.3	31.3	8.5	7.3
West shoreline upstream of fish kill area		1655	0.3	31.6	8.7	9.1
Near Luminant intake, in fish kill area		1655	0.3	30.7	8.6	8.1
Ski cove, outside fish kill area	26 Sep 2005	1545	0.3	32.7	10.4	13.5
			1.0	33.9	10.1	8.3
Mid-channel near dam and fish kill area		1730	0.3	32.1	10.1	9.8
			2.5	32.0	10.0	8.3
			5.0	31.6	9.9	6.5
			7.5	30.3	9.2	1.2
			10.0	27.9	8.7	0.2
			11.5	26.3	8.4	0.2
			13.0	22.7	8.2	0.3
West shoreline, in fish kill area	27 Sep 2005	1030	0.3	30.9	9.9	6.1
			2.0	30.8	9.9	2.7
			3.0	30.8	9.8	2.5
			5.5	29.6	9.3	0.2
			7.0	29.3	9.1	0.3
			8.5	28.9	9.0	0.2
			10.5	28.7	8.9	0.3
			11.5	23.6	8.2	0.4
Mid-channel near dam, in fish kill area		1510	0.3	31.8	10.1	8.2
			1.0	31.2	10.0	6.5
			2.0	30.6	9.6	2.8
			3.0	30.1	9.2	0.3
			5.0	29.8	9.2	0.2
			7.0	29.6	9.2	0.1
			9.0	29.4	9.1	0.1
			11.3	27.1	8.5	0.1
			13.4	22.7	8.2	0.2
Near Luminant intake, in fish kill area		1529	0.3	31.4	10.1	7.5
			1.0	31.1	10.0	6.9
			2.1	30.3	9.4	1.4
			3.0	29.9	9.3	0.1
Cove south of dam, in fish kill area	11 Oct 2005	1430	0.3	28.1	9.1	15.0

Location	Date	Time	Depth (m)	Temp (ºC)	pH	DO (mg/L)
			1.0	27.4	8.8	9.7
			2.0	27.1	8.5	6.4
			3.0	27.0	8.5	6.0
			4.0	27.0	8.5	6.2
Mid-channel near dam, near fish kill area		1545	0.3	28.9	9.1	13.3
			1.0	27.7	8.9	11.6
			2.5	27.1	8.6	7.0
			5.0	26.9	8.5	5.3
			7.5	26.9	8.3	3.7
			10.0	26.9	8.3	3.3
			12.5	25.8	7.3	0.3
			13.5	23.3	6.8	0.2
Mid-reservoir, outside fish kill area		1622	0.3	30.4	8.9	12.2
			1.0	28.4	8.6	7.1
			2.5	27.5	8.4	4.5
			5.0	27.2	8.4	4.2
			7.5	27.0	8.0	0.4

Methods

A YSI 600 XLM multi-parameter datasonde was used to measure instantaneous and diel physicochemical parameters. Instantaneous and diel data were recorded for dissolved oxygen, temperature, pH and specific conductance at each site a minimum of 10 times. Data recording, instrument calibration, and post-calibration procedures adhered to the TPWD Water Quality Program, Quality Assurance Project Plan (QAPP) (TPWD 2009b). The procedures can be found in TCEQ SWQM Procedures Manual (TCEQ 2003).

Instantaneous physicochemical and Secchi disk measurements were made at the time the datasonde was deployed for diel measurements. A surface measurement was recorded at 0.3 m followed by 1 m depth measurements until the bottom was reached. At times, measurements were not collected at each meter at Fairfield Lake as it was greater than 13 m deep. An attempt was made to locate the depth where hypoxia, defined as dissolved oxygen values less than 2 mg/L, began in the water column.

Datasondes were deployed in the mixed surface layer for at least 24 hours and recorded data every 30 minutes. The mixed surface layer is defined as that portion of the water column from the surface to the depth at which water temperature decreases more than 0.5 degrees Celsius (TCEQ 2003). An anchor, chain and buoy system was used to deploy each datasonde.

If a fish kill occurred at Fairfield Lake, plans were in place to conduct additional instantaneous and diel measurements to characterize the water quality. Fish kills were not reported in 2006 and 2007. In response to the fish kills in September and October 2008 and September 2009, additional instantaneous measurements were collected under the 2008 and 2009 TPWD Water Quality Program QAPPs (TPWD 2009b). In September 2009, datasondes were also deployed in two of the primary fish kill areas, one in the mouth of the cove north of the dam and one in the mouth of the cove south of the dam, approximately 30 hours after the start of the fish kill. Diel measurements were recorded in the mixed surface layer at 30 minute increments for approximately 14 days.

To help interpret how fluctuations in the amount of sunlight which reaches the earth's surface affects dissolved oxygen, solar radiation data from a nearby weather station was examined (NOAA).

Results

Instantaneous physicochemical parameters were measured at Fort Parker Lake and Fairfield Lake (Table 4 - Table 7). Measurements suggest that algal growth affects dissolved oxygen, pH and water transparency.

In the middle of the day, instantaneous dissolved oxygen concentrations at both Fort Parker Lake and Fairfield Lake were greater than 10 mg/L in May, June and August 2006 and March 2007 at Fort Parker and in March and August 2007 at Fairfield Lake. These supersaturated values typically occur when algal blooms are present. In addition, depth profiles showed that measurements consistently declined with increasing depth at each site in both reservoirs. Hypoxia occurred at different depths in the two reservoirs. These low levels occurred in Fort Parker Lake at two to three meters from the bottom at the river channel site and just above the bottom at the mid-reservoir site and near the dam. Hypoxia was present in the water column at Fairfield Lake during all but one site visit (March 2007). The depth at which hypoxia occurred ranged from just above the bottom to its highest value at 10 m above the bottom (5 m below the water surface) in June 2006 and August 2007. The lowest observed surface dissolved oxygen level in either reservoir was 1.0 mg/L at Fort Parker Lake mid-reservoir in July 2005.

At each site in both reservoirs, pH declined with increasing depth, with measurements ranging from 6.3 to 8.5 at Fort Parker Lake and 6.6 to 9.3 at Fairfield Lake. Elevated pH was also observed at the surface at both reservoirs. Surface pH at Fairfield Lake never fell below 8.4 and exceeded the general criterion, 9.0, in August and October 2006 (TCEQ 2000). Elevated pH may be a result of algal photosynthesis (Horne 1994).

Water transparency levels measure the effects of algal blooms and suspended sediment. All except one of 19 Secchi measurements were less than one meter. The highest Secchi measurement in either reservoir was 1.0 m in Fairfield Lake in March 2007. Algal growth and suspended sediment are likely reducing the water transparency at Fort Parker Lake, and algal growth appeared to be the primary influence on transparency at Fairfield Lake. Fort Parker Lake Secchi measurements were greatest in the river channel where the reservoir is deeper and confined in a sheltered narrow channel, which reduces the suspension of sediment from wind disturbances. Secchi measurements were lower at the shallower and more open near dam site, where the reservoir is more susceptible to disturbances from wind. While the mid-reservoir site is also susceptible to wind disturbance, it is also heavily populated with American lotus, which lessens disturbances from wind. Water transparencies were clear to bottom at the mid-reservoir site in August and October 2006, probably due to an abundance of American lotus and low water depths. The Fairfield Lake site is greater than 12 m deep. Field observations noted green to dark green water at each visit, indicating the primary reason for low Secchi measurements is algal growth and not suspended sediments.

Table 4. Ft. Parker Lake river channel instantaneous physicochemical measurements (2005-2007).

Date	Time	Secchi depth (m)	Depth (m)	Temp (ºC)	pH	DO (mg/L)	Specific cond. (µS/cm)
25 May 2005	1330	0.6	0.3	28.0	8.5	12.1	392
			1.0	27.5	8.3	9.4	411
			2.0	24.6	7.4	2.2	493
			3.0	19.4	7.0	0.7	461
			4.0	17.4	7.0	0.6	425
29 Jun 2005	1122	0.7	0.3	29.8	8.0	7.4	350
			1.0	29.5	7.8	6.1	351
			2.0	29.2	7.6	3.6	351
			3.0	28.4	7.3	1.3	356
			4.0	25.1	6.8	1.4	414
26 Jul 2005	1100	0.8	0.3	29.9	7.7	7.0	380
			1.0	29.9	7.7	6.5	380
			2.0	29.5	7.4	4.3	375
			3.0	29.2	7.2	3.2	375
25 Aug 2005	1200	0.5	0.3	31.6	7.9	8.3	391
			1.0	30.9	7.7	6.8	392
			2.0	30.3	7.4	5.1	392
			3.0	29.0	7.1	4.1	398
			4.0	26.8	6.7	3.9	411
27 Sep 2005	1145	0.9	0.3	27.9	7.4	4.2	399
			1.0	27.5	7.3	2.7	399
			2.0	27.4	7.2	1.8	397
			3.0	26.8	7.2	1.3	389
			3.7	26.3	7.1	1.4	385
3 May 2006	1340	0.4	0.3	25.8	8.0	8.6	248
			1.0	24.3	7.4	5.8	262
			2.0	23.0	7.0	3.3	327
			3.0	21.5	6.7	0.4	294
			4.0	21.0	6.6	0.3	226
7 Jun 2006	1345	0.6	0.3	28.8	8.3	10.3	252
			1.0	27.8	7.8	6.8	254
			2.0	27.3	7.1	2.6	250
			3.0	26.8	6.9	0.9	246
			4.0	25.4	6.7	0.7	248
11 Jul 2006	1310	0.6	0.3	29.1	7.4	6.0	
			1.0	28.4	7.3	5.3	
			2.0	28.0	7.1	3.0	
			3.0	27.3	6.8	0.4	
			4.0	26.4	6.6	0.5	
			5.0	25.2	6.5	0.4	
16 Aug 2006	1345	0.6	0.3	31.1	7.6	7.8	385
			1.0	30.0	7.1	4.1	386
			2.0	29.9	7.0	2.7	386
			3.0	29.6	6.8	1.0	393
			4.0	27.2	6.3	1.1	394
9 Oct 2006	1445	0.6	0.3	24.6	7.5		352
			1.0	23.8	7.3		352
			2.0	23.7	7.2		353

Date	Time	Secchi depth (m)	Depth (m)	Temp (ºC)	pH	DO (mg/L)	Specific cond. (µS/cm)
			3.0	23.6	7.2		354
			3.5	23.6	7.1		354

Table 5. Ft. Parker Lake mid-reservoir instantaneous physicochemical measurements (2005-2007).

Date	Time	Secchi depth (m)	Depth (m)	Temp (ºC)	pH	DO (mg/L)	Specific cond. (µS/cm)
25 May 2005	1400	0.3	0.3	28.3	7.9	11.1	335
			0.5	28.0	7.7	8.2	339
29 Jun 2005	1056	0.9	0.3	29.6	7	1.0	395
			1.0	29.1	6.9	0.7	397
26 Jul 2005	1030	0.5	0.3	29.8	7.3	4.4	387
			1.0	29.5	7.3	3.9	387
27 Sep 2005	1112	0.3	0.3	27.3	7.6	4.7	378
			0.8	27.2	7.4	3.4	377
3 May 2006	1315	0.3	0.3	26.4	8.1	8.6	241
			0.9	26.1	8	7.9	241
7 Jun 2006	1320	0.3	0.3	28.7	7.5	6.7	271
			1.0	28.0	7.2	3.8	271
11 Jul 2006	1240	0.5	0.3	29.0	6.9	2.9	
			0.7	28.4	6.9	1.4	
16 Aug 2006	1421	0.5	0.3	30.8	7.3	6.6	433
9 Oct 2006	1515	0.4	0.3	21.4	7.1		380
21 Mar 2007	1500	0.3	0.3	20.6	7.9	10.9	173
			1.0	20.5	7.8	9.4	173
12 Sep 2007	1135	0.3	0.3	26.7	7.7	7.2	206
			1.0	26.2	7.5	5.6	208

Table 6. Ft. Parker Lake near dam instantaneous physicochemical measurements (2005-2007).

Date	Time	Secchi depth (m)	Depth (m)	Temp (ºC)	pH	DO (mg/L)	Specific cond. (µS/cm)
25 May 2005	1115	0.4	0.3	29.1	8.1	7.4	356
			1.0	27.7	7.7	4.4	362
			2.0	27.5	7.6	3.9	362
29 Jun 2005	1029	0.5	0.3	30.6	7.5	5.8	396
			1.0	30.1	7.3	3.8	393
			2.0	29.8	7.2	2.8	394
26 Jul 2005	1015	0.5	0.3	30.3	7.6	6.7	381
			1.0	30.0	7.4	5.2	381
			2.0	30.0	7.4	5.0	381
25 Aug 2005	1122	0.4	0.3	31.9	8.1	8.8	377
			1.0	31.3	7.9	7.6	378
			2.0	31.0	7.5	5.9	380
27 Sep 2005	1034	0.4	0.3	28.6	8.3	9.1	374
			1.0	28.2	7.9	6.5	377
			2.0	27.7	7.5	2.6	380
3 May 2006	1245	0.3	0.3	25.3	8.0	8.8	237
			1.0	23.9	7.3	5.2	238
			2.0	23.4	7.1	3.2	240
7 Jun 2006	1255	0.4	0.3	29.9	8.1	10.0	268
			1.0	28.9	7.6	7.0	270
			2.0	27.7	7.1	2.4	270
11 Jul 2006	1215	0.4	0.3	29.4	7.5	4.9	
			1.0	29.0	7.5	3.7	
			1.7	28.7	7.3	1.8	
16 Aug 2006	1320	0.6	0.3	31.6	8.3	12.1	334
			1.0	30.1	7.7	5.9	341
			1.5	29.5	7.0	1.2	343
9 Oct 2006	1526	0.3	0.3	24.2	7.8		331
			1.0	23.3	7.5		333
			1.6	23.2	7.4		337
21 Mar 2007	1440	0.4	0.3	19.8	7.6	9.4	169
			1.0	19.6	7.6	8.6	169
			2.0	18.8	7.5	7.2	170
15 Aug 2007	1057	0.6	0.3	32.2	8.0	8.2	165
			1.0	31.7	7.6	6.2	165
			2.0	30.1	6.8	0.5	178

Table 7. Fairfield Lake instantaneous physicochemical measurements (2006-2007).

Date	Time	Secchi depth (m)	Depth (m)	Temp (ºC)	pH	DO (mg/L)	Specific cond. (µS/cm)
3 May 2006	1015	0.8	0.3	27.7	8.7	9.0	951
			1.0	27.7	8.7	9.0	950
			5.0	27.6	8.6	8.3	950
			7.0	26.1	8.3	5.7	936
			8.0	25.4	7.9	2.9	953
			9.0	24.9	7.7	1.0	953
			10.0	22.8	7.5	0.2	967
			13.0	19.3	7.2	0.2	973
7 Jun 2006	1030	0.7	0.3	31.8	8.9	9.9	966
			1.0	31.8	8.9	9.7	966
			2.0	31.7	8.9	8.8	967
			4.0	31.6	8.8	8.3	967
			4.5	31.6	8.7	7.5	967
			5.0	29.9	8.0	0.7	977
			7.0	28.8	7.8	0.2	979
			9.0	27.2	7.6	0.9	973
			11.0	23.6	7.3	1.0	979
			13.0	20.9	7.0	1.3	998
11 Jul 2006	0950	0.7	0.3	32.6	9.0	7.7	963
			1.0	32.6	9.0	7.6	964
			2.0	32.5	9.0	7.7	963
			3.0	32.5	9.0	7.6	963
			4.0	32.5	9.0	7.6	963
			5.0	32.5	9.0	7.5	961
			6.0	32.5	9.0	7.5	958
			7.5	32.2	8.9	6.7	933
			8.0	29.4	7.6	0.2	974
			11.0	24.0	7.2	0.2	999
			13.0	22.0	7.0	0.1	1030
16 Aug 2006	0930	0.6	0.3	33.7	9.2	8.4	1041
			1.0	33.7	9.2	8.3	1041
			2.0	33.7	9.1	8.2	1042
			3.0	33.7	9.1	8.2	1041
			4.0	33.7	9.1	8.2	1041
			5.0	33.7	9.1	8.0	1041
			5.5	33.3	8.8	3.6	1042
			6.0	32.7	8.7	0.4	1046
			8.0	31.4	7.7	0.3	1054
			10.0	26.0	6.8	0.9	1083
			12.0	23.2	6.6	0.6	1134
9 Oct 2006	1130	0.6	0.3	29.0	9.3		1046
			1.0	28.6	9.2		1047
			2.0	28.6	9.2		1047
			3.0	28.5	9.1		1048
			4.0	28.5	9.0		1048
			5.0	28.5	9.0		1048
			6.0	28.4	9.1		1048
			7.0	28.4	9.1		1053

Date	Time	Secchi depth (m)	Depth (m)	Temp (ºC)	pH	DO (mg/L)	Specific cond. (µS/cm)
			9.0	28.0	8.6		1058
			10.0	27.7	8.4		1050
			12.0	27.0	7.5		1080
21 Mar 2007	1120	1.0	0.3	23.3	8.6	12.0	985
			1.0	23.3	8.6	11.0	986
			2.0	23.3	8.6	10.5	991
			4.0	23.2	8.6	9.9	991
			6.0	22.2	8.5	8.4	992
			7.0	21.0	7.9	5.8	995
			8.0	19.6	7.6	2.9	1013
			10.0	17.9	7.6	3.1	1039
			12.0	17.4	7.6	3.1	1042
			14.0	17.1	7.3	3.1	1046
18 Apr 2007	1013	0.9	0.3	22.3	8.6	8.8	1003
			1.0	22.3	8.6	8.8	1003
			3.0	22.3	8.6	8.7	1003
			5.0	22.1	8.6	8.5	1003
			7.0	21.6	8.4	7.2	1004
			9.0	20.7	8.0	4.6	1004
			10.0	20.5	7.9	3.7	1005
			11.0	20.4	7.8	2.1	1006
			12.0	19.9	7.7	0.4	1014
			14.0	18.2	7.3	0.2	1048
30 May 2007	1320	0.5	0.3	27.1	8.6	9.1	916
			1.0	27.1	8.6	9.1	916
			2.0	27.1	8.6	9.1	916
			3.0	27.1	8.6	9.0	916
			4.0	27.0	8.6	8.9	916
			5.0	26.9	8.5	8.2	917
			6.0	26.4	8.0	3.5	919
			7.0	23.2	7.5	1.5	940
			9.0	22.0	7.3	0.2	979
			11.0	21.2	7.2	0.1	1001
			13.0	20.1	7.1	0.1	1015
11 Jul 2007	1154	0.9	0.3	31.9	8.7	8.0	886
			1.0	31.9	8.7	8.0	886
			2.0	31.8	8.7	7.7	886
			4.0	31.7	8.6	7.1	887
			6.0	31.6	8.6	6.6	887
			7.0	30.2	7.8	0.9	882
			8.0	28.4	7.9	0.1	908
			12.0	22.0	7.3	0.0	1002
			15.0	20.6	7.2	0.0	1038
15 Aug 2007	1300	0.7	0.3	36.7	8.8	10.7	881
			1.0	35.8	8.8	10.3	880
			2.0	35.4	8.8	9.2	879
			3.0	34.9	8.7	7.5	880
			4.0	34.4	8.5	5.7	880

Date	Time	Secchi depth (m)	Depth (m)	Temp (ºC)	pH	DO (mg/L)	Specific cond. (µS/cm)
			5.0	33.1	7.9	0.8	875
			6.0	32.1	7.7	0.2	873
			10.0	25.4	7.1	0.2	944
			14.0	21.1	6.9	0.0	1036
17 Sep 2007	1100	0.7	0.3	31.4	8.7	10.0	904
			1.0	31.4	8.8	9.8	904
			2.0	31.4	8.8	9.1	905
			3.0	31.4	8.8	8.9	905
			4.0	31.4	8.8	8.6	905
			5.0	31.3	8.7	8.2	905
			6.0	30.7	8.3	3.9	907
			7.0	30.6	8.2	3.5	907
			8.0	29.8	7.7	0.8	914
			10.0	25.4	7.1	0.7	957
			13.0	21.9	6.7	0.8	1032

Diel measurements of temperature, pH, dissolved oxygen and specific conductance were collected at Fort Parker Lake and Fairfield Lake (Table 8 and Table 9). Both exhibited diel dissolved oxygen and pH swings typical of algal photosynthesis and respiration. Dissolved oxygen, and to some extent pH, increased as daylight progressed, peaking in the late afternoon then decreasing during the evening hours and into the early morning (Figure 10). At times, diel swings in dissolved oxygen were large. Values ranged from below the minimum criterion (3.0 mg/L) to supersaturation within the same 24-hour period in August 2006 at Fort Parker Lake river channel and in June and August 2006 at Fort Parker Lake mid-reservoir. The largest of these dissolved oxygen swings was a 10.2 mg/L range between the minimum and maximum at mid-reservoir in August 2006. Fairfield Lake diel dissolved oxygen measurements never fell below the mean criterion (5.0 mg/L), and in August 2006 and September 2007 values remained above 9.0 mg/L for 24 hours. The largest swing in dissolved oxygen was in June 2006, with a range of 5.9 mg/L to 14.4 mg/L in a 24-hour period.

At Fort Parker Lake, in addition to large dissolved oxygen swings, at times the reservoir did not maintain concentrations protective of high aquatic life use. The river channel site had a mean dissolved oxygen value below the mean criterion in September 2005 and a minimum value below the minimum criterion in August 2006. The near dam site fell below the mean and minimum dissolved oxygen criteria in August 2006 and the minimum criterion in July 2006. The mid-reservoir site dissolved oxygen minimum and mean values fell below the criteria frequently with mean values below 3.0 mg/L in June 2005 and October 2006. Frequent low dissolved oxygen levels at the mid-reservoir site can be attributed to the warm, shallow water and the abundance of decaying biomass from American lotus.

Diel measurements are consistent with instantaneous data in suggesting that algal photosynthesis affected dissolved oxygen and pH levels.

Table 8. Ft. Parker Lake diel measurements (2005-2007).

			Temperature (ºC)			pH		Dissolved oxygen (mg/L)			Specific conductance (µS/cm)		
Location	Deployment date	Depth (m)	Min	Max	Mean	Min	Max	Min	Max	Mean	Min	Max	Mean
River channel	25 May 2005	0.8	27.6	29.2	28.4	8.3	8.8	9.0	13.8	11.4			
	29 Jun 2005	1.1	29.5	30.2	29.9	7.7	8.2	5.3	8.1	6.6	347	353	351
	26 Jul 2005	1.0	29.6	30.4	29.9	7.6	8.1	5.5	8.2	6.7	376	380	378
	25 Aug 2005	1.1	31.0	31.6	31.3	7.6	8.0	6.3	8.6	7.5	390	394	392
	27 Sep 2005	0.7	27.6	28.5	28.1	7.4	7.7	3.5	7.2	4.8	397	402	399
	3 May 2006	0.6	25.1	26.2	25.5	7.5	8.5	4.5	10.0	6.8	248	256	251
	7 Jun 2006	0.5	27.9	29.5	28.7	7.6	8.7	6.2	11.6	8.5	249	254	252
	11 Jul 2006	0.6	28.3	29.6	28.9	7.5	8.1	3.8	8.0	5.9			
	16 Aug 2006	0.7	30.1	31.5	30.8	7.5	8.5	1.9	11.3	6.1			
	9 Oct 2006	0.7	23.7	24.3	24.0	7.5	7.7	6.2	7.4	6.8	350	359	353
Mid-reservoir	25 May 2005	0.4	27.1	31.1	28.8	7.5	8.6	3.2	13.8	7.6	329	343	338
	29 Jun 2005	0.6	29.4	30.0	29.6	7.0	7.1	1.0	2.1	1.8	376	396	385
	26 Jul 2005	0.5	29.3	31.1	30.2	7.4	7.5	2.8	4.4	3.5	387	389	389
	27 Sep 2005	0.6	27.3	29.0	28.4	7.2	7.6	1.1	5.2	3.1	407	470	420
	3 May 2006	0.3	25.3	27.4	26.3	7.7	8.6	5.6	10.4	7.9			
	7 Jun 2006	0.4	28.8	31.3	29.8	7.2	8.5	1.7	10.6	6.2	267	275	272
	11 Jul 2006	0.3	28.1	30.3	29.2	7.0	7.2	10.0	13.4	11.3	302	304	303
	16 Aug 2006	0.3	29.8	33.6	31.4	7.3	8.3	2.0	12.2	6.4	426	434	431
	9 Oct 2006	0.6	21.7	22.6	22.3	7.1	7.3	0.6	3.4	1.8	388	407	395
	21 Mar 2007	0.6	19.8	21.2	20.4	7.5	8.0	6.5	8.8	7.7	171	175	173
	11 Sep 2007	0.8	26.0	28.6	27.3	7.4	7.8	5.8	7.9	6.8	206	211	208
Near dam	26 May 2005	0.6	27.3	28.8	27.9	7.6	8.8	4.5	12.9	7.6	351	358	355
	29 Jun 2005	0.6	30.1	31.3	30.7	7.4	7.8	3.3	6.8	5.0	357	359	358
	26 Jul 2005	0.7	29.8	31.0	30.4	7.3	7.9	4.7	7.5	5.7	409	436	424
	25 Aug 2005	0.5	31.3	32.8	31.9	7.8	8.4	4.3	8.5	6.0	376	380	378
	27 Sep 2005	0.5	28.6	31.2	29.8	7.7	8.8	3.8	13.9	9.3	368	380	374
	3 May 2006	0.3	24.2	25.9	24.7	7.6	8.6	6.3	10.9	7.5	241	246	245
	7 Jun 2006	0.6	28.8	32.4	29.8	7.7	8.9						
	11 Jul 2006	0.5	28.8	30.6	29.5	7.4	8.1	2.8	8.4	5.0	291	298	293
	16 Aug 2006	0.5	29.7	30.9	30.2	7.7	8.3	2.2	7.8	4.7	337	341	339
	9 Oct 2006	0.3	23.7	25.3	24.3	7.8	8.6				332	338	335
	21 Mar 2007	0.4	19.4	20.2	19.7	7.2	7.3	6.4	7.8	6.8	169	172	171
	15 Aug 2007	0.5	31.3	32.5	31.9	7.3	8.1	4.3	8.0	5.7	169	172	171

Table 9. Fairfield Lake diel measurements (2006-2007).

		Temperature (ºC)			pH		Dissolved oxygen (mg/L)			Specific conductance (µS/cm)		
Deployment date	Depth (m)	Min	Max	Mean	Min	Max	Min	Max	Mean	Min	Max	Mean
3 May 2006	1.6	27.7	28.5	28.1	8.6	8.8	8.4	10.9	9.5	981	985	982
7 Jun 2006	1.2	30.6	32.6	31.4	8.5	8.9	5.9	14.4	9.3	973	985	980
11 Jul 2006	1.0	32.2	32.9	32.5	8.7	8.8	7.0	9.6	8.0	984	990	987
16 Aug 2006	1.2	33.7	35.8	34.9	8.6	9.2	9.1	13.5	11.3	1030	1036	1033
21 Mar 2007	0.9	23.3	24.1	23.6	8.5	8.6	8.3	9.5	8.9	989	992	991
18 Apr 2007	1.1	21.6	22.2	21.9	8.4	8.6	7.1	9.7	8.4	968	981	970
30 May 2007	1.2	26.3	27.3	26.6	8.4	8.7	6.1	9.5	7.8	905	910	906
11 Jul 2007	0.9	31.9	33.2	32.5	8.6	8.7	8.0	10.3	9.1	883	887	885
15 Aug 2007	0.4	35.3	36.8	35.8	8.7	8.9	7.7	11.3	9.3	875	880	878
17 Sep 2007	1.2	31.5	33.4	32.2	8.8	9.0	9.1	13.8	10.9	912	915	915

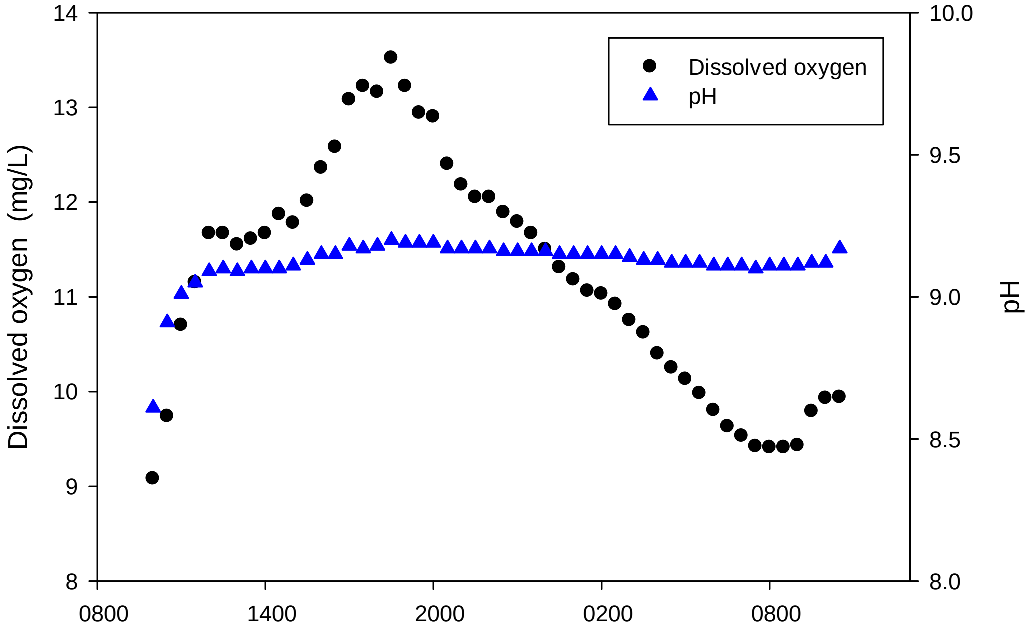

Figure 10. Fairfield Lake diel dissolved oxygen and pH measurements (16-17 Aug 2006).

Fairfield Lake Water Quality Data Collected 2008-2009

In the period, 2006 to 2007, in which the instantaneous and diel physicochemical parameters were collected, no fish kills were reported at Fairfield Lake. However, in September and October 2008 and September 2009 fish kills returned. Water quality data were collected in response to those events.

For the September 3, 2008, and October 17, 2008, fish kills, instantaneous values of low dissolved oxygen were measured (Table 10). Soon after the start of both fish kills in 2008, measurements were below the minimum criterion in the mixed surface layer. The instantaneous dissolved oxygen measurements collected soon after the September 13, 2009, fish kill were also low and showed levels below the minimum criterion (Table 11).

Instantaneous measurements collected in daylight hours may show influences from algal photosynthesis, which can make interpretation difficult when seeking to confirm the cause of a fish kill. Typically, measurements are not collected in the dark when algal respiration and other oxygen demands are often at their greatest. In hypereutrophic reservoirs such as Fairfield Lake, dissolved oxygen generally changes dramatically between the early morning hours and daylight, when instantaneous measurements are usually made. Diel measurements taken with datasondes provide a more complete picture of how dissolved oxygen concentrations may impact fish.

Datasondes were deployed in two areas soon after the start of the September 13, 2009, fish kill. Data showed a clear diel pattern of dissolved oxygen from algal photosynthesis and respiration in both areas (Table 12). Nearly identical periods of supersaturation as well as periods of low dissolved oxygen were observed. The longest period of supersaturation in both coves was

September 19-21, 2009, when even in the early morning hours, dissolved oxygen levels remained high. This supersaturated period was sandwiched between two periods of low dissolved oxygen, during which values fell well below the minimum criterion (Figure 11).

In addition to algal processes, periods of cloudy and sunny weather have a significant influence on dissolved oxygen. Solar radiation data from a nearby weather station was examined to help interpret how fluctuations in the amount of sunlight which reaches the earth's surface affects dissolved oxygen (NOAA 2009, Figure 11). Dissolved oxygen measurements tracked the solar radiation data. Periods of cloudy weather (less solar radiation) limited algal photosynthesis, which in turn reduced the amount of dissolved oxygen measured. The inverse was observed during periods of sunny weather (more solar radiation). When the cloudy weather cleared, dissolved oxygen rebounded due to an increase in algal photosynthesis. The diel dissolved oxygen pattern observed at Fairfield Lake is an extreme example of how a combination of hypereutrophic conditions and changes in weather can impact aquatic life.

The diel data from September 2009 confirms that low dissolved oxygen was the cause of the September 13, 2009 fish kill and algal respiration was the primary oxygen demand. The data also gives us confidence that historical fish kills in September and October can be attributed to low dissolved oxygen. The cause of the October 26, 2003 fish kill, originally attributed to a cold front, may need to be reevaluated. Historical solar radiation and temperature data can be used to determine whether similar conditions were present in 2003 as in September 2009.

Table 10. Fairfield Lake instantaneous physicochemical measurements (Sep and Oct 2008).

Location	Date	Time	Depth (m)	Temp (ºC)	pH	DO (mg/L)
Near Luminant outfall, outside fish kill area	4 Sep 2008	1600	0.3	39.2	8.9	7.2
			0.4	39.3	8.8	7.2
Mid-reservoir, outside fish kill area		1630	0.3	31.6	8.9	6.1
			1.0	31.6	8.9	5.9
			2.0	31.6	8.9	5.6
			3.0	31.5	8.8	5.1
			4.0	31.5	8.8	4.6
			5.0	31.3	8.7	1.4
			7.0	31.1	8.7	0.2
			8.0	30.8	8.6	0.2
			9.0	30.6	8.6	0.1
Hot pond cove, in fish kill area		1649	0.3	31.1	8.8	3.8
			1.0	31.1	8.8	3.4
			2.0	31.0	8.8	2.6
			3.0	30.9	8.7	1.5
			4.0	30.9	8.7	1.2
			5.0	30.8	8.8	1.0
			6.0	30.7	8.7	0.7
			7.0	30.6	8.7	1.7
Cove north of dam, in fish kill area		1746	0.3	31.2	9.2	11.3
			1.0	30.8	9.0	6.2
			2.0	30.6	8.9	3.7
			3.0	30.6	8.9	3.8
			4.0	30.6	8.9	3.7
			5.0	30.5	8.9	4.3
Mid-channel near dam, outside fish kill area		1829	0.3	31.3	9.1	9.5
			1.0	31.2	9.1	9.0
			2.0	31.0	8.9	6.5
			3.0	30.9	8.9	5.6
			4.0	30.9	8.9	4.4
			5.0	30.8	8.8	3.3
			6.0	30.8	8.8	3.1
			7.0	30.8	8.8	3.0
			8.0	30.8	8.8	3.0
			9.0	30.7	8.8	3.0
			10.0	30.7	8.8	2.9
			11.0	30.7	8.8	3.0
			12.0	30.5	7.0	0.3
			13.0	27.1	6.9	0.4
Small cove west of the intake canal, in fish kill area	17 Oct 2008	1530	0.3	27.2	8.8	2.9
			2.1	26.8	8.6	0.9
			3.5	26.8	8.6	1.1
West shoreline upstream of fish kill area		1600	0.2	27.8	8.9	7.0
Second small cove west of intake canal, in fish kill area	18 Oct 2008	0930	0.3	26.3	8.9	5.2
			3.0	26.3	8.9	5.5

Table 11. Fairfield Lake instantaneous physicochemical measurements (Sep 2009).

Location	Date	Time	Depth (m)	Temp (ºC)	pH	DO (mg/L)
Ski cove near mouth, in fish kill area	13 Sep 2009	1415	0.3	32.0	9.1	5.7
			1.0	32.0	9.1	5.4
			2.0	31.8	9.1	3.1
			3.0	31.7	9.1	2.5
			4.0	31.7	9.1	2.7
			5.0	31.4	9.1	2.7
			5.8	30.9	9.1	2.1
Ski cove near back of cove, in fish kill area		1420	0.3	31.7	9.2	8.2
			2.0	30.9	9.2	8.6
Cove north of dam, in fish kill area		1440	0.3	31.2	9.1	5.8
			1.0	31.3	9.0	5.3
			2.0	31.2	9.0	4.7
			3.0	30.1	8.8	1.8
Cove south of dam, in fish kill area		1510	0.3	31.7	9.0	4.6
			1.0	31.7	9.0	4.2
			2.0	31.7	9.0	3.9
			3.0	31.5	9.0	3.3
			4.0	31.4	8.9	2.7
			5.0	30.9	8.9	4.7
Cove south of dam, in fish kill area	14 Sep 2009	1245	0.3	31.6	8.9	3.2
			1.0	31.4	8.9	2.6
			2.0	31.3	8.9	1.7
			3.0	31.0	8.9	0.3
			4.0	30.9	8.9	1.3
			5.0	30.5	8.8	3.3
Mid-channel near dam, in fish kill area		1251	0.3	32.4	9.1	6.3
			1.0	31.7	9.0	4.7
			2.0	31.4	8.9	2.6
			3.0	31.1	8.9	0.6
			4.0	31.0	8.9	0.1
			5.0	31.0	8.9	0.1
			6.0	31.0	8.9	0.1
			7.0	31.0	8.9	0.1
			8.0	31.0	8.9	0.1
			9.0	30.9	8.9	0.1
Cove north of dam, in fish kill area		1308	0.3	31.8	9.1	5.8
			1.0	31.4	9.1	5.2
			2.0	31.0	8.9	0.8
			3.0	30.9	8.9	0.8
			4.0	30.8	8.9	0.7
			5.0	30.8	8.9	0.8
Cove south of dam, in fish kill area	15 Sep 2009	1215	0.3	30.4	8.8	2.4
			1.0	30.4	8.9	2.6
			2.0	30.4	8.9	2.4
			3.0	30.3	8.9	2.9
			4.0	30.2	8.9	3.3
			5.0	29.0	8.9	3.9
Cove north of dam, in fish kill area		1230	0.3	30.3	8.9	3.6

Location	Date	Time	Depth (m)	Temp (ºC)	pH	DO (mg/L)
			1.0	30.4	8.9	2.2
			2.0	30.4	9.0	1.8
			3.0	30.3	9.0	1.6
			4.0	30.3	9.0	1.5
			5.0	30.2	9.0	1.0
			6.0	29.8	8.7	0.3
Near Luminant intake, in fish kill area		1323	0.3	30.6	8.8	1.3
			1.0	30.6	8.8	1.0
			2.0	30.6	8.8	1.0
			3.0	30.6	8.9	0.9
			4.0	30.6	8.9	0.6
			5.0	30.6	8.9	0.5
			6.0	30.5	8.8	0.3
			7.0	30.4	8.6	0.3
Upper end of lake mid-channel, outside fish kill area		1441	0.3	33.2	9.0	5.8
			1.0	33.2	9.0	5.6
			2.0	33.1	9.0	5.4
			2.5	32.9	9.0	5.3
Hot pond cove, in fish kill area		1500	0.3	30.3	8.9	3.1
			1.0	30.4	9.0	2.7
			2.0	30.4	9.0	2.7
			3.0	30.4	9.0	2.2
			4.0	30.3	9.0	2.1
			5.0	30.3	9.0	2.0
			6.0	30.3	9.0	2.1
			7.0	30.2	9.0	1.9
Ski cove near back of cove, in fish kill area		1530	0.3	30.0	9.0	7.1
			1.0	30.0	9.1	6.8
			2.0	29.8	9.1	6.6
			2.5	29.6	9.2	6.8
Ski cove near mouth of cove, in fish kill area		1535	0.3	31.0	8.8	3.8
			1.0	31.1	8.9	3.6
			2.0	31.0	8.9	3.6
			3.0	31.1	9.0	3.3
			4.0	31.0	9.0	3.3
			5.0	30.9	9.0	3.4
			6.0	30.8	9.0	3.7
			7.0	30.2	9.1	4.1
Cove south of dam, in fish kill area	17 Sep 2009	1435	0.3	30.0	8.9	4.6
			1.0	30.0	8.9	4.4
			2.0	29.9	8.9	4.3
			3.0	29.8	8.9	3.7
			4.0	29.5	8.9	4.4
			5.0	28.4	8.8	4.0
Cove north of dam, in fish kill area		1445	0.3	30.0	9.0	6.9
			1.0	29.9	9.0	5.7
			2.0	29.8	8.9	4.8

Location	Date	Time	Depth (m)	Temp (ºC)	pH	DO (mg/L)
			3.0	29.7	8.8	2.8
			4.0	29.6	8.9	3.3
			5.0	29.5	8.9	3.5
			6.0	29.1	8.8	2.7
Cove south of dam, in fish kill area	23 Sep 2009	0919	0.3	28.9	8.8	4.0
			1.0	28.9	8.8	3.8
			2.0	28.9	8.8	3.7
			3.0	28.8	8.8	4.2
			4.0	28.4	8.7	4.5
			5.0	27.8	8.7	4.8
Mid-channel near dam, in fish kill area		1020	0.3	29.1	8.7	3.4
			1.0	29.1	8.7	3.5
			2.0	29.1	8.7	3.4
			3.0	29.1	8.7	3.3
			4.0	29.1	8.7	3.5
			5.0	29.1	8.7	3.6
			6.0	29.1	8.8	3.7
			7.0	29.1	8.7	3.7
			8.0	29.1	8.7	3.7
			9.0	29.0	8.7	3.9
			10.0	29.0	8.8	4.1
			12.0	28.5	8.6	
			13.0	27.7	6.7	0.9
Cove north of dam, in fish kill area		1033	0.3	28.6	8.8	5.1
			1.0	28.7	8.8	5.1
			2.0	28.7	8.8	5.0
			3.0	28.6	8.8	4.9
			4.0	28.6	8.8	4.9
			5.0	28.5	8.8	4.8
			6.0	28.2	8.7	2.3
Cove south of dam, in fish kill area	28 Sep 2009	1305	0.3	30.6	9.2	14.4
			1.0	30.4	9.1	13.8
			2.0	30.2	9.1	12.6
			3.0	30.1	9.0	11.6
			4.0	30.1	9.0	10.9
			5.0	29.9	9.0	9.8
Cove north of dam, in fish kill area		1530	0.3	30.5	9.2	15.1
			1.0	30.4	9.2	12.9
			2.0	29.9	9.0	9.4
			3.0	29.9	9.0	9.8
			4.0	29.9	9.0	9.8
			5.0	29.8	9.0	7.8

Table 12. Fairfield Lake fish kill investigation diel measurements (Sep 2009).

			Temperature (ºC)			pH		Dissolved oxygen (mg/L)			Specific conductance (µS/cm)		
Location	Deployment date	Depth (m)	Min	Max	Mean	Min	Max	Min	Max	Mean	Min	Max	Mean
South cove	14 Sep 2009	0.9	30.4	32.0	31.1	8.7	9.0	2.0	6.2	4.4	1204	1216	1210
	15 Sep 2009	0.9	30.2	30.6	30.4	8.7	8.8	0.8	3.1	2.1	1208	1221	1216
	16 Sep 2009	0.9	29.6	30.7	30.1	8.6	8.7	1.6	4.0	2.8	1208	1220	1215
	17 Sep 2009	0.6	29.3	30.1	29.6	8.7	8.9	1.2	5.6	2.9	1195	1216	1202
	18 Sep 2009	0.6	29.2	30.1	29.4	8.8	9.0	2.0	8.9	3.8	1200	1208	1205
	19 Sep 2009	0.6	30.1	31.8	30.7	8.9	9.1	8.1	17.1	11.9	1200	1206	1203
	20 Sep 2009	0.6	31.4	33.2	32.1	9.0	9.3	11.5	25.8	16.9	1197	1206	1202
	21 Sep 2009	0.6	30.6	31.8	31.2	9.0	9.2	7.2	18.5	12.1	1200	1206	1203
	22 Sep 2009	0.7	28.9	30.7	29.6	8.8	9.0	2.9	10.2	6.9	1183	1220	1197
	23 Sep 2009	0.6	28.1	28.9	28.4			1.8	4.5	2.7	1205	1218	1214
	24 Sep 2009	0.6	27.4	28.3	27.8			0.7	4.4	1.8	1200	1207	1204
	25 Sep 2009	0.6	28.3	30.0	29.1			5.1	10.6	8.1	1196	1221	1208
	26 Sep 2009	0.6	30.1	32.6	31.0			10.1	18.6	14.0	1205	1216	1212
	27 Sep 2009	0.5	29.8	31.1	30.4			7.5	15.4	11.2	1208	1219	1213
North cove	14 Sep 2009	0.9	30.4	32.5	31.2	8.8	9.1	0.3	8.8	3.2			
	15 Sep 2009	1.0	29.9	30.5	30.2	8.9	9.0	0.6	3.2	1.9			
	17 Sep 2009	0.8	29.0	29.9	29.4	8.8	9.0	4.5	7.0	5.4	1158	1190	1180
	18 Sep 2009	0.8	28.7	29.9	29.1	8.7	9.0	4.4	8.4	5.4	1183	1188	1185
	19 Sep 2009	0.8	29.5	32.9	30.2	8.9	9.2	6.4	17.1	9.1	1185	1192	1189
	20 Sep 2009	0.8	31.5	33.4	32.3	9.1	9.3	11.9	19.5	14.8	1169	1189	1181
	21 Sep 2009	0.8	30.4	32.1	31.2	9.1	9.3	8.7	15.4	11.5	1158	1181	1171
	22 Sep 2009	0.8	28.5	30.4	29.3	8.8	9.1	4.2	9.5	6.2	1158	1178	1167
	23 Sep 2009	0.5	27.8	28.5	28.1	8.6	8.9	2.3	5.7	3.7	1174	1179	1177
	24 Sep 2009	0.5	27.1	29.3	27.7	8.5	8.8	1.1	6.8	2.9	1167	1175	1173
	25 Sep 2009	0.5	27.7	31.3	28.8	8.6	9.2	2.5	17.0	8.7	1165	1185	1177
	26 Sep 2009	0.4	30.2	32.5	31.0	9.1	9.3	11.9	20.3	15.2	1173	1184	1182

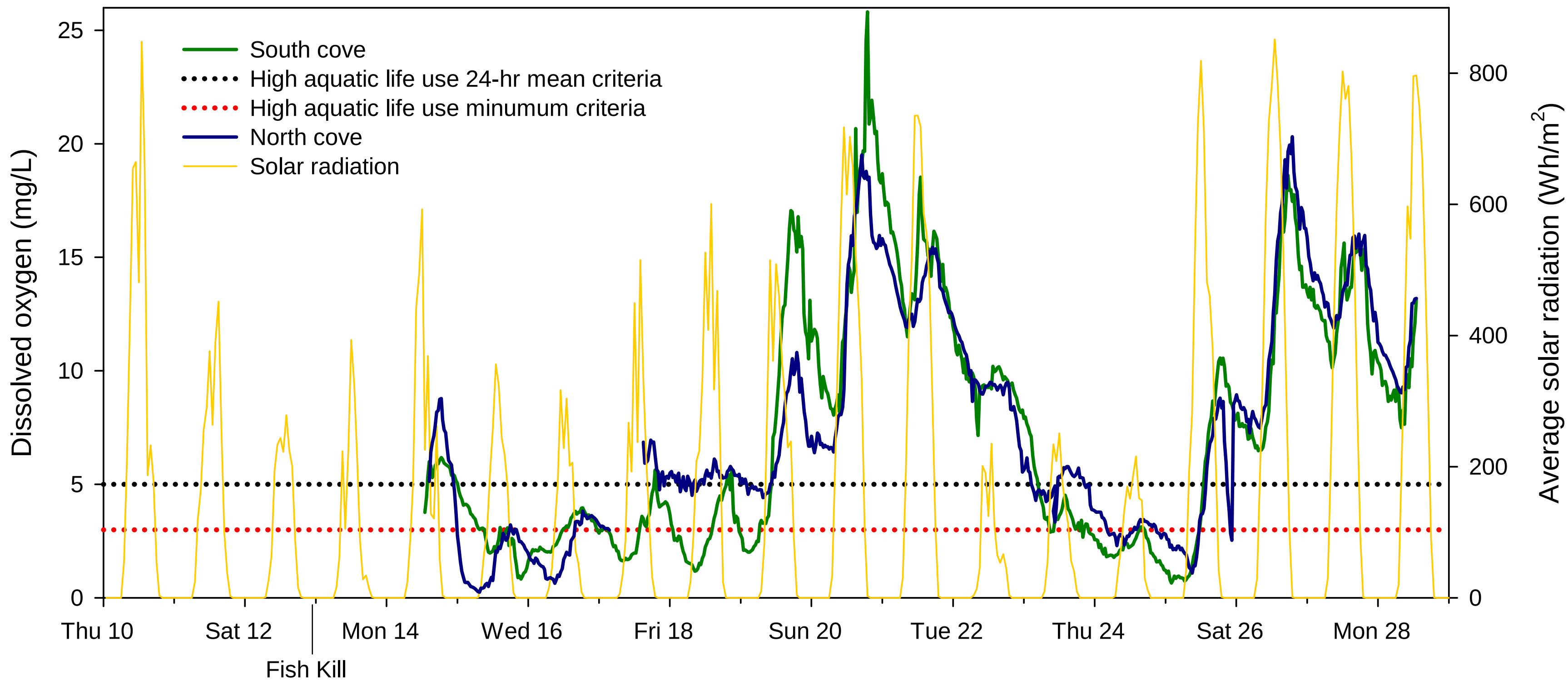

Figure 11. Fairfield Lake diel dissolved oxygen and average hourly solar radiation data (Sep 2009). Solar radiation data from NOAA NCDC weather station in Palestine, Texas.

Discussion

Data from this project was submitted to TCEQ, and was adequate to fulfill the objective of completing an assessment in 2008. Even though enough data was provided to assess both Fairfield Lake and Fort Parker Lake, TCEQ assessed only Fort Parker Lake. The 2008 assessment addressed only classified water bodies and unclassified water bodies with water quality impairments or concerns. Fairfield Lake was not included in the 2008 assessment since it is not a classified segment, and no data was available for assessment prior to 2005. It is expected that the reservoir will be assessed in 2010.

TCEQ evaluated Fort Parker Lake because it was on the 2004 concerns list. In 2008, data from this project indicated that Fort Parker Lake continued near nonattainment of the high aquatic life use dissolved oxygen criteria. In addition, TCEQ monitoring data demonstrated ongoing nutrient enrichment as evidenced by chlorophyll-*a* values exceeding the screening level (TCEQ 2008c).

In keeping with TCEQ practice of assessing reservoirs based on near-dam sites, the mid-reservoir site and river channel sites were not assessed. Overall the river channel site had the best dissolved oxygen levels and the mid-reservoir site had the lowest. If data from the mid-reservoir site had been used in the assessment, the reservoir would not support high aquatic life use. However, it is not appropriate to use these data. The mid-reservoir site is shallow and is affected by American lotus. When American lotus is present much of the reservoir resembles a wetland or a backwater cove (Figure 2).

This project determined the cause of the Fairfield Lake fish kills. Diel data measured at Fairfield Lake in 2009 confirmed that low dissolved oxygen was the cause of the September 13, 2009 fish kill. The data also supports suspicions that low dissolved oxygen was the cause of the historical fish kills in September and October.

The 2006 and 2007 Fairfield Lake diel data showed that scheduled trips at one location near the dam may not adequately describe conditions that cause fish kills. Historical fish kills occurred throughout the lower end of the reservoir in response to nutrient loads and weather patterns. The project design, based on scheduled monitoring, would not have been flexible enough to determine the cause, had any fish kills been reported in 2006 and 2007. Furthermore instantaneous measurements conducted during daylight hours in sunny weather are unlikely to capture episodic low dissolved oxygen events. Instead, targeted monitoring in response to observed kills was successful in elucidating the cause. The water quality data and the five years of fish kill data suggest that future collections would need to include extended periods of diel data collection in September and October when shortening daylight hours are decreasing. This would increase the likelihood of documenting low dissolved oxygen values during a fish kill, as well as levels prior to a kill.

The last objective of the project was to improve the understanding of dissolved oxygen dynamics in small reservoirs. Both reservoirs experienced extreme diel swings. The magnitude of these swings can be attributed to a number of factors, including watershed size, water temperature, water depth, available nutrients, aquatic vegetation, weather and season. This project did not evaluate every factor. The diel data from this project identified algal photosynthesis and respiration as the primary influence on dissolved oxygen levels. In addition, solar radiation data helped explain how prolonged cloudy weather suppressed algal photosynthetic oxygen production at Fairfield Lake. The solar radiation data may also be able to explain how the seasonal decrease in daylight hours from summer to fall affects algal photosynthesis. Finally, at Fort Parker Lake, stagnant and shallow water conditions related to drought conditions likely affected dissolved oxygen levels.

Water chemistry data from both reservoirs indicated nutrient enrichment. The sources of nutrients at Fort Parker Lake are unknown. There are no active permitted outfalls upstream of or in the reservoir. An examination of the watershed would be necessary to identify nonpoint sources of nutrients. Fairfield Lake, on the other hand, has a direct source of nutrient-rich water from the Trinity River. Due to its operation as a cooling reservoir and its small watershed, Fairfield Lake rarely releases water. Luminant pumps in raw Trinity River water to make-up for evaporative losses. The water from the nutrient-rich river is the primary source of freshwater to Fairfield Lake in the warm months when energy production is at its greatest. This portion of the Trinity River is on the 2008 concerns list for nutrient enrichment for nitrate and orthophosphorus values exceeding screening levels (TCEQ 2008c).

Both reservoirs are hypereutrophic. Nutrient loads need to be reduced for the reservoirs to maintain water quality that is protective of aquatic life. The rate of eutrophication is increasing at Fort Parker Lake, where TSI chlorophyll-*a* values have increased from 59.2 in 2004 to 62.6 in 2006 to 63.8 in 2008. Although historical water quality data is unavailable at Fairfield Lake, it is likely that the rate of eutrophication is increasing there as well.

As a first step in reducing nutrient loads, an investigation of inputs into each watershed would be valuable. Watershed protection plans could be helpful in pulling together stakeholders interested in protecting the water quality and developing management strategies for reducing nutrient loads.

At Fairfield Lake, it would also be helpful to reduce nutrient input from the Trinity River make-up water. In other areas of the Trinity River Basin water managers are pumping raw river water through a series of constructed wetlands to remove nutrients prior to discharging into a reservoir. This practice also has the potential to create wildlife habitat.

Water quality monitoring data collected by TCEQ has been important in evaluating Fort Parker Lake and Fairfield Lake. Continued efforts by TCEQ and their partners to collect water quality data at each reservoir will be essential in ensuring that water quality concerns are addressed.

Conclusion

Fort Parker Lake and Fairfield Lake have exhibited low dissolved oxygen levels that may harm aquatic life. Fort Parker Lake lies within Fort Parker State Park and Fairfield Lake borders Fairfield Lake State Park. In 2005 the TPWD Water Quality Program began collecting water quality data at three locations at Fort Parker Lake, and in 2006 began a similar project on Fairfield Lake. Objectives for both projects included collecting enough data for TCEQ to complete an assessment of both reservoirs, identifying the cause of fish kills at Fairfield Lake and improving our understanding of dissolved oxygen dynamics in small reservoirs.

Diel data from Fort Parker Lake showed dissolved oxygen and pH swings typical of algal photosynthesis and respiration. All three sites had values below the high aquatic life use criteria. Of the 31 diel measurements collected, 19% of the mean values and 29% of the minimum values were below the criteria. In the 2008 assessment, TCEQ continued the concerns listing for dissolved oxygen and nutrient enrichment based on data from the near dam site.

In 2006 and 2007 there were no reported fish kills at Fairfield Lake during the study period, and diel data showed no exceedances. Investigation of a major fish kill in 2009 showed that algal respiration combined with cloudy days caused extended periods of low dissolved oxygen. These data suggest that similar patterns are responsible for autumn fish kills observed in 2004, 2005 and 2008. Fairfield Lake is scheduled to be assessed in 2010.

Both reservoirs are hypereutrophic. Nutrient loads need to be reduced for the reservoirs to maintain water quality that is protective of aquatic life.

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