Eufaula Lake Water Quality: 2017

The Eufaula Lake dam is located on the Canadian River at river mile 27, about 12 miles east of Eufaula, Oklahoma (OK). The reservoir is located in Okmulgee, Haskell, McIntosh, and Pittsburg Counties, OK. Eufaula Lake is a multi-purpose project authorized for flood control, water supply, recreation, fish and wildlife, hydropower, navigation, and sediment control. The project was designed to provide maximum flood protection on the Canadian River and the Arkansas River when operated in conjunction with the Arkansas River Basin System. The irregularly shaped impoundment, with a surface area of nearly 95,000 acres, extends more than 26 miles west-southwest of the dam following the Canadian River channel. Arms of the lake follow tributary channels including the North Canadian River, Gaines Creek, and the Deep Fork. The lake is within Hydrologic Unit Codes 11090204 (Lower Canadian), 11100302 (Lower North Canadian), and 11100303 (Deep Fork). Construction began in February 1956 and the conservation pool was filled in March 1968. The total drainage area above the dam includes 47,522 square miles extending into Texas and New Mexico (Figure 1), and about 9,700 square miles of the total watershed area is considered non-contributing. Land use/cover (Dewitz, 2021) in the lower part of the basin, east of Oklahoma City (8,405 square miles), is dominated by forest (41.4%) and grassland/pasture (41.9%). A bathymetric survey conducted in 2015 (Bowen Engineering & Surveying, Inc., 2016) estimated lake capacity at the conservation pool elevation has diminished about 8% since impoundment due to sedimentation. Descriptive characteristics of Eufaula Lake are included in Table 1.

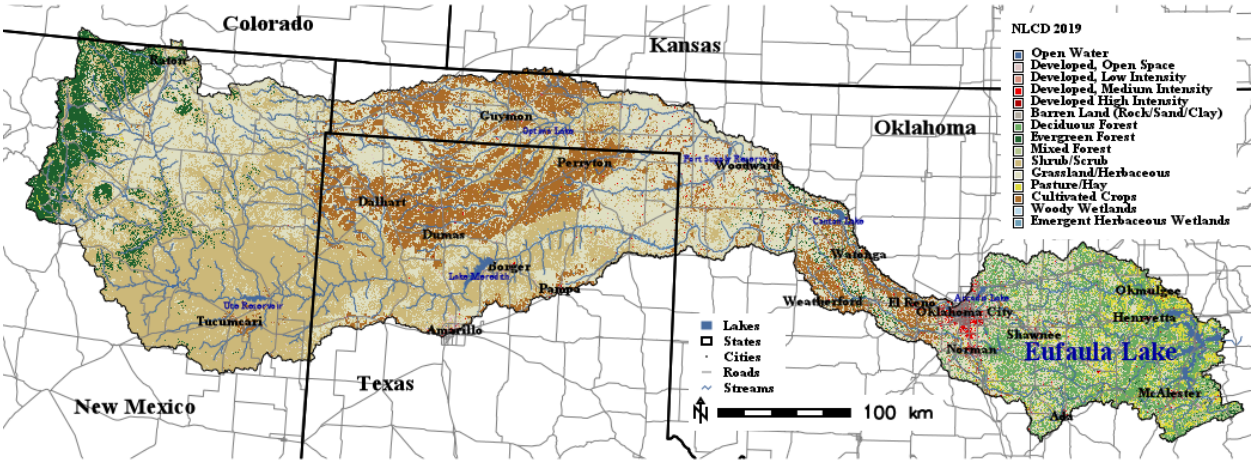

Figure 1. The Eufaula Lake Watershed above the Eufaula Lake Dam.

Table 1. Descriptive Characteristics of Eufaula Lake, OK.

Parameter	English Units	Metric Units
Lake Elevation (Conservation Pool, Power Pool)	585.0 ft NGVD	178.3 m
Lake Surface Area (Conservation Pool)	93,544 ac	37,856 ha
Lake Volume (Conservation Pool)	2,194,857 ac-ft	$2{,}707.3*10^6$ m^3
Drainage Area (lower only)	8,405 mi^2	21,769 km^2
Mean Depth	23.5 ft	7.16 m
Maximum Depth (Conservation Pool)	87 ft	26.5 m
Shoreline Length	988 mi	1,591 km
Shoreline Development Index	22.2	22.2
Annual Inflow, Average 1923 – 2017 [Water Years]	4,444,500 ac-ft	$5{,}482.2*10^6$ m^3
Annual Inflow, 2017 [Calendar Year]	3,176,447.5 ac-ft	$3{,}918.1*10^6$ m^3
Hydraulic Residence Time, 2017 [Calendar Year]	243.5 d	0.67 yr

Data derived from the Tulsa District's Pertinent Data Book (U.S. ACE - Tulsa District, 2021), the FY 2017 Annual Water Control Report (U.S. ACE - SWD RCC, 2018), Tulsa District's Water Control page for Eufaula Lake (U.S. ACE - Tulsa District, 2024), and a 2015 bathymetric survey (Bowen Engineering & Surveying, Inc., 2016).

Designated beneficial uses of the impoundment created by the Eufaula Lake Dam include Public and Private Water Supply, Fish and Wildlife Propagation as a Warm Water Aquatic Community, Agriculture, Primary Body Contact Recreation, and Aesthetics (OAC, 2023). Based on the 2022 Integrated Water Quality Assessment prepared by the Oklahoma Department of Environmental Quality (ODEQ 2022), Eufaula Lake is listed as impaired by mercury affecting Fish Consumption, and by turbidity affecting Fish and Wildlife Propagation as a Warm Water Aquatic Community.

Physical and chemical water quality data were collected in May, June, August, and September 2017 by USACE from eight in-lake sites to define existing limnological conditions, provide a basis for future water quality investigations, and to support operational and environmental missions of the Tulsa District. Sampled sites included EUFOKS0037 (channel at the dam), EUFOKS0038 (mouth of Longtown Creek), EUFOKS0039 (near a gas well, Canadian River Arm), EUFOKS0040 (mouth of Gaines Creek Arm), EUFOKS0173 (mid-Gaines Creek Arm near Crowder), EUFOKS0175 (Hwy 69 bridge, N Canadian Arm), EUFOKS0174 (upper N Canadian Arm near Stidham), and EUFOKS0044 (Deep Fork Arm W of Gentry Creek mouth). Sites were accessed by boat and samples were collected from locations over the deepest portion of the stream channel (thalweg). Sampling locations are identified in Figure 2.

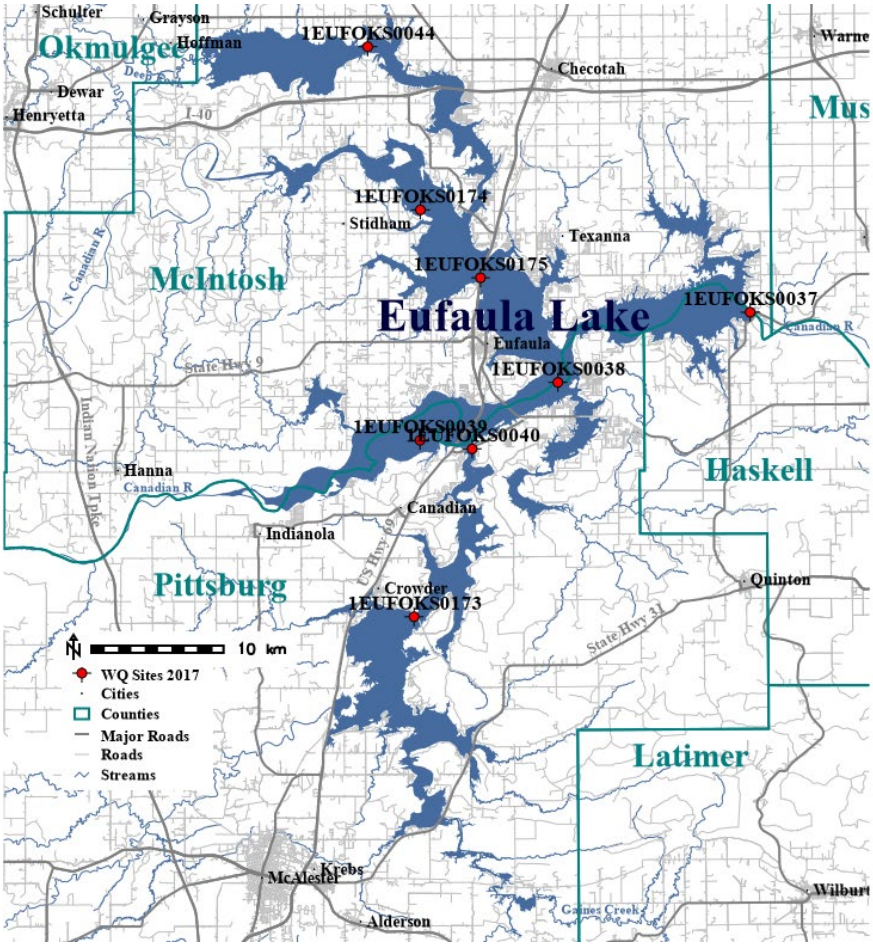

Figure 2. Locations of water quality sampling sites at Eufaula Lake, OK.

Because the drainage basin is so large, climatic characteristics vary significantly from extreme western to extreme eastern portions of the basin. In the lake area, near Eufaula, OK, mean annual temperature is 62.5 °F and average annual precipitation is 45.95 inches. On average, the wettest months are May June, and September. In calendar year 2017, recorded basin precipitation was 42.91 inches.

The Eufaula Lake pool was near the conservation/power pool elevation (585 feet) in May, June, August, and September. Calendar year 2017 lake elevation, conservation pool elevation, basin precipitation, calculated evaporation rate, and water quality sampling events are shown in Figure 3.

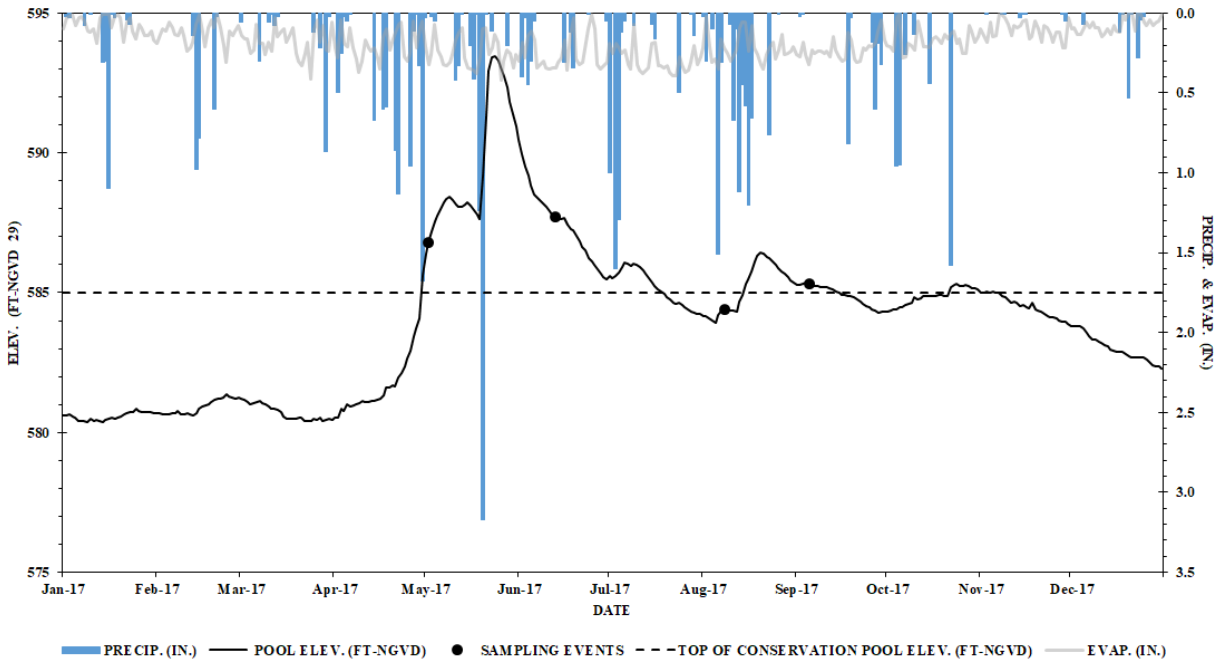

Figure 3. Daily lake elevation (feet, NGVD at 0800 hours), conservation pool elevation (feet), basin precipitation and evaporation (in.), and water quality sampling events at Eufaula Lake, OK, 2017.

Water temperature ranged from 14.32 to 28.67 ºC, peaking in August. All recorded water temperatures ≤16 ºC were observed in May. Thermal stratification was observed beginning in June at EUFOKS0037, EUFOKS0040, EUFOKS0173, and EUFOKS0175. Hypoxia at depth was noted at site EUFOKS0037 through September, and through August at sites EUFOKS0040 and EUFOKS0175. Thermal stratification was moderated and suppressed by frequent rainfall/runoff events generating significant inflows to the lake. The study period lakewide median dissolved oxygen concentration (DO) was 6.47 mg/l, with observations ranging from 0.0 to 9.67 mg/l. Site median DO concentrations were lowest at sites with significant mid-summer hypoxia (EUFOKS0173, 4.72 mg/l; EUFOKS0040, 5.03 mg/l; and EUFOKS0037, 5.77 mg/l). DO concentrations >8.5 mg/l were recorded at all lake sites in May. Lakewide total organic carbon concentrations were high with a study period lakewide median of 8.11 mg/l. Site median total organic carbon concentrations were high throughout the lake ranging from 7.29 to 9.59 mg/l.

Specific conductance (lakewide median 385.0 µS/cm) was moderate to high, consistent with regional geology. Total dissolved solids lakewide median concentration was 265.0 mg/l with site medians ranging from 142.5 (EUFOKS0173) to 415.5 (EUFOKS0039) mg/l. Moderate lakewide chloride and sulfate concentrations (medians 32.1 and 40.2 mg/l, respectively) were observed. Alkalinity levels (lakewide median 92.5 mg/l as $CaCO_3$) imply a system capable of maintaining pH levels. Observed in-lake pH ranged from 5.61 to 8.84. All pH observations ≤6.5 were recorded at EUFOKS0044 in May, and observations of pH ≥8.75 were recorded in June at EUFOKS0037. Hardness levels, median 122.0 mg/l as $CaCO_3$, indicate 'hard' water.

Lakewide median Secchi depth was 0.59 meters with site medians ranging from 0.31 (EUFOKS0174 and EUFOKS0044) to 1.29 (EUFOKS0037) meters. Lakewide median turbidity was 29.0 NTU with 59% of all in-lake observations greater than or equal to 25 NTU. Median lakewide total suspended solids concentration was 8.6 mg/l, with the lowest site median

observed at EUFOKS0037 (2.78 mg/l), and highest site median recorded at EUFOKS0174 (25.5 mg/l). The euphotic zone at EUFOKS0037 (dam site) ranged from 7.9 meters in August to 4.5 meters in June. Gaines Creek Arm (EUFOKS0173) euphotic zones ranged from 2.2 to 3.0 meters and estimates in the N Canadian Arm (EUFOKS0175) ranged from 2.4 to 4.2 meters.

Lakewide ammonia concentrations (median 0.08 mg/l) and nitrite plus nitrate concentrations (median 0.10 mg/l) were moderate. Surface concentrations of nitrite plus nitrate were generally higher (median 0.13 mg/l) than bottom concentrations (median 0.10 mg/l). Total Kjeldahl nitrogen concentrations, lakewide median 0.54 mg/l, increased moving upstream from EUFOKS0037 (median 0.45 mg/l) to the N Canadian Arm (EUFOKS0174, 0.84 mg/l), and the Deep Fork Arm (0.75 mg/l). Estimated lakewide median surface total nitrogen concentration during the 2017 study was 0.63 mg/l ranging from 0.52 (EUFOKS0037) to 0.97 mg/l (EUFOKS0174). Total phosphorus concentrations ranged from 0.02 to 0.26 mg/l with a lakewide median of 0.07 mg/l. Over 85% of all observations of dissolved ortho-phosphate had reportable concentrations and the lakewide median was 0.03 mg/l. Lakewide surface nitrogen to phosphorus ratio (N:P) in 2017 was 10.5. N:P ratios in the Deep Fork and N Canadian Arms were <10 while all other sites were >10 indicating a general tendency toward phosphorus limitation of phytoplankton growth.

Chlorophyll-*a* concentrations ranged from 1.6 to 36.4 µg/l, with a lakewide median of 11.0 µg/l. Highest site median chlorophyll-a concentration was 15.0 µg/l at EUFOKS0174 (upper N Canadian Arm). Figure 4, below, summarizes relative abundance and biovolume of divisions of phytoplankton observed at Eufaula Lake at five sites on three dates in 2017. Abundance was dominated by Cyanophytes (blue green 'algae' that are photosynthetic bacteria) in August and September. Biovolume shows variable seasonal representation of Bacillariophytes (diatoms), Cryptophytes (flagellated algae), Chlorophytes (greens), plus Cyanophytes (blue greens) and others, by site. Figure 5 summarizes zooplankton densities observed in 2017 (note the log scale density axis) at the same five sites. Cladoceran, Copepod, and Rotifer densities were comparable by site across dates. *Quagga* veligers (Bivalvia) were noted in May at EUFOKS0037.

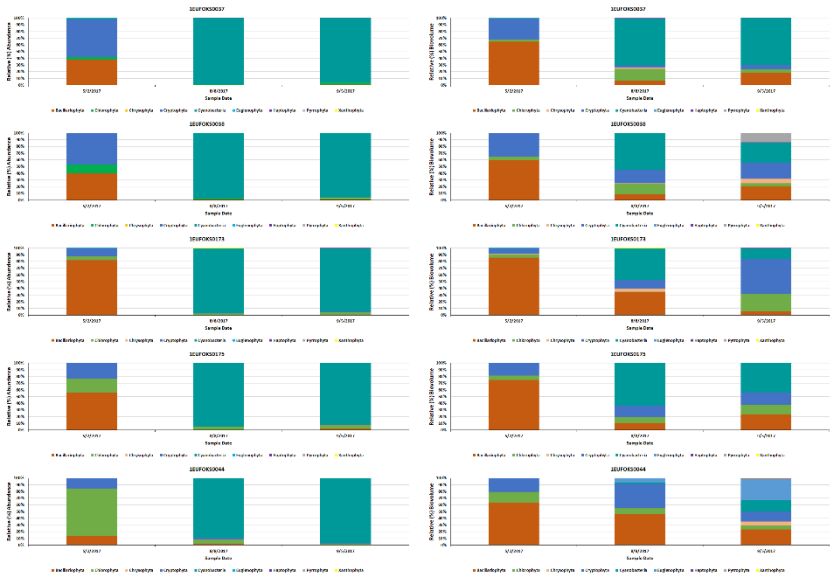

Figure 4. Phytoplankton relative abundance (left) and relative biovolume (right) at EUFOKS0037, EUFOKS0038, EUFOKS0173, EUFOKS0175, and EUFOKS0044 in 2017.

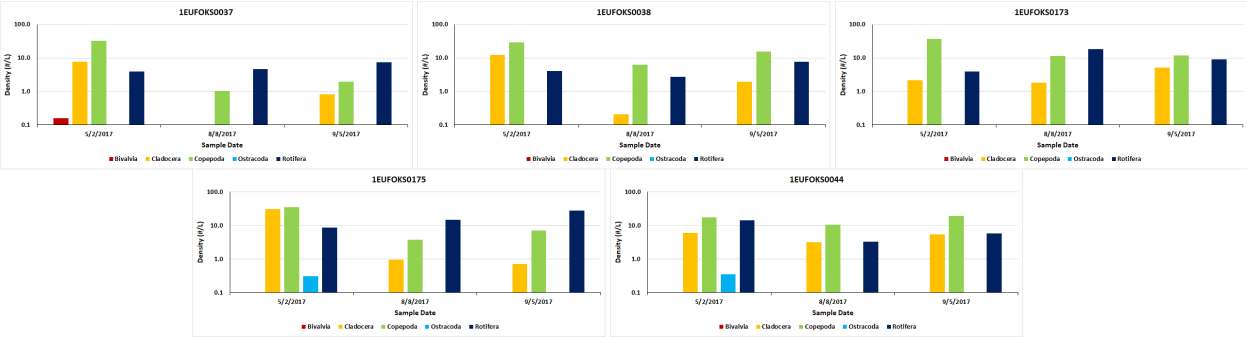

Figure 5. Zooplankton density at EUFOKS0037, EUFOKS0038, EUFOKS0173, EUFOKS0175, and EUFOKS0044 in 2017.

Trophic status of Eufaula Lake was assessed using all three metrics of Carlson's trophic state index (TSI (Carlson, 1977)) at each lake site and the lake as a whole. Median lakewide indexes based on Secchi depth (TSI(SD)) and surface total phosphorus (TSI(TP)), 68 and 64, respectively, indicated eutrophy. The median lakewide TSI value based on chlorophyll-a concentrations (TSI(CHLa)), 54, also suggest eutrophy, although moderated by water clarity (Figure 6).

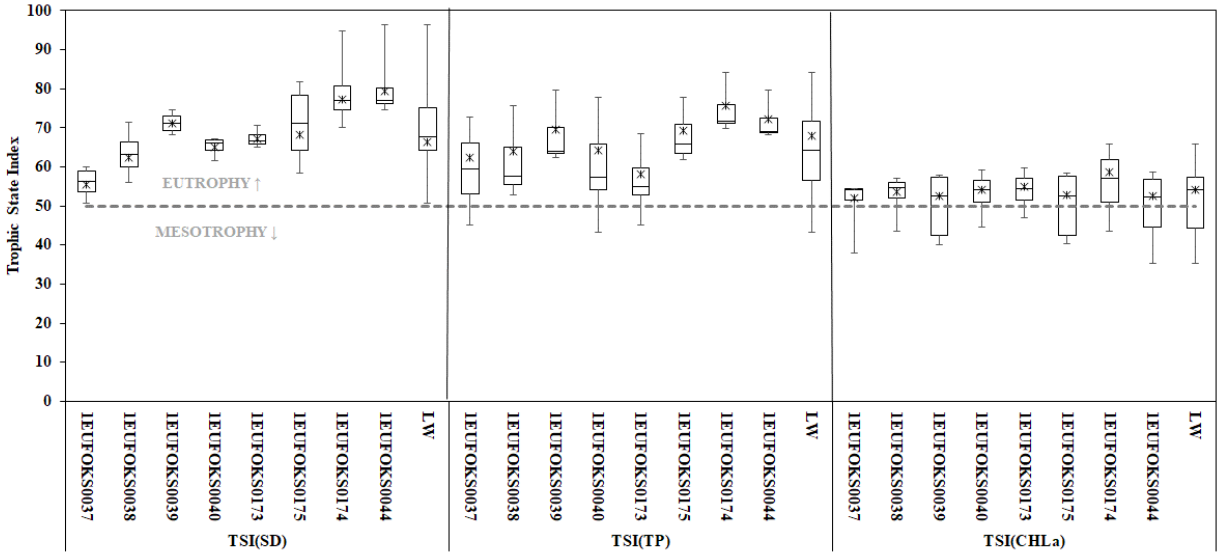

Figure 6. Distributions of Carlson's Trophic State Index (TSI), by sampling site and lakewide (LW), based on Secchi depth (TSI(SD)), surface total phosphorus (TSI(TP)) and chlorophyll-*a* concentrations (TSI(CHLa)) at Eufaula Lake, OK, 2017.

Total iron and manganese concentrations (lakewide medians 0.26 and 0.10 mg/l, respectively) were moderate. Median bottom sample iron and manganese concentrations (0.33 and 0.13 mg/l, respectively) were higher than surface medians. Highest iron concentrations were from surface samples at EUFOKS0044 (median 0.74 mg/l) and EUFOKS0174 (0.50 mg/l). Reportable concentrations of arsenic, chromium, nickel, and zinc were noted in all in-lake samples. Reportable concentrations of copper, lead, and mercury were present in 79, 88, and 4%, respectively, of all samples collected.

USACE previously conducted water quality sampling at Eufaula Lake in 2001. Thermal stratification with hypoxia at depth was noted from June through August at deeper sites. Water clarity ranged from poor to excellent, with poorest clarity in tributary arms of the lake transitioning to moderately clearer waters moving downstream toward the dam. Macronutrients nitrogen and phosphorus were generally abundant. The TSI based on chlorophyll-a suggested a relatively productive lake, bordering between mesotrophy and eutrophy. Analysis of metals revealed abundant quantities of iron and manganese. Priority pollutant metals observed at concentrations above the analytical detection limit included arsenic, cadmium, chromium, lead, and mercury.