Tenkiller Ferry Lake Water Quality: 2017

The Tenkiller Ferry Lake dam is located on the Illinois River at river mile 12.8 in Sequoyah County, about seven miles northeast of Gore and about twenty-two miles southeast of Muskogee, Oklahoma. The reservoir extends northeast from the dam almost twenty-five miles following the Illinois River channel into Cherokee County, OK. Tenkiller Ferry Lake is a multi-purpose project authorized for flood control, water supply, hydropower, navigation, fish and wildlife, and recreation. The project was designed to provide maximum flood protection on the Illinois River and the Arkansas River when operated in conjunction with the Arkansas River Basin System. The lake and watershed are within Hydrologic Unit Code 11110103 (Illinois River). Construction began in June 1947, final storage began in July 1952, and the conservation pool was filled in May 1955. The conservation pool was raised from 630.0 to 632.0-feet NGVD in September 1972. The drainage area above the dam is ~1,610 square miles extending into the Boston Mountains in Washington County, Arkansas (Figure 1). Land use/cover (Dewitz, 2021) is dominated by forest (44.6%) and pasture/grassland (40.0%). 'Developed' land uses account for >12% of the total watershed area (red areas in Figure 1). A bathymetric survey conducted in 2015 (Bowen Engineering & Surveying. Inc., 2015) suggested lake capacity at the conservation pool elevation has not diminished appreciably since impoundment due to sedimentation. Deposition of sediment has occurred in the upper Illinois River reach of the reservoir. Descriptive characteristics of Tenkiller Ferry Lake are included in Table 1.

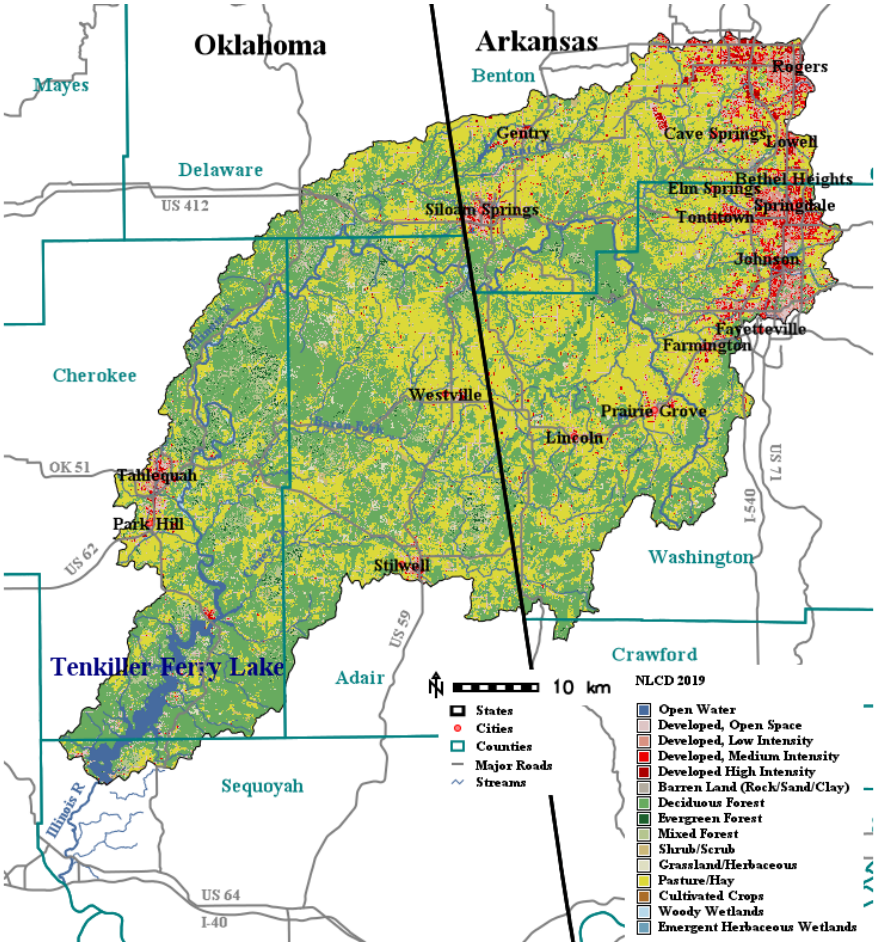

Figure 1. The Tenkiller Ferry Lake (Illinois River) Watershed above the Tenkiller Ferry Lake Dam.

Table 1. Descriptive Characteristics of Tenkiller Ferry Lake, OK.

Parameter	English Units	Metric Units
Lake Elevation (Conservation Pool = Power Pool)	632.0 ft NGVD	192.63 m
Lake Surface Area (Conservation Pool)	12,988 ac	5,256 ha
Lake Volume (Conservation Pool)	668,191 ac-ft	$824.2*10^6$ m^3
Drainage Area	1,610 mi^2	4,169.9 km^2
Mean Depth	51.4 ft	15.7 m
Maximum Depth (Conservation Pool)	145 ft	44.2 m
Shoreline Length	147 mi	236.6 km
Shoreline Development Index	9.3	9.3
Annual Inflow, Average 1923 – 2017 [Water Years]	1,165,100 ac-ft	$1,437.1*10^6$ m^3
Annual Inflow, 2017 [Calendar Year]	1,311,174 ac-ft	$1,617.3*10^6$ m^3
Hydraulic Residence Time, 2017 [Calendar Year]	187.3 d	0.51 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 Tenkiller Ferry Lake (U.S. ACE - Tulsa District, 2024), and a 2015 bathymetric survey (Bowen Engineering & Surveying. Inc., 2015).

Designated beneficial uses of the impoundment created by the Tenkiller Ferry Lake Dam include Public and Private Water Supply, Fish and Wildlife Propagation as a Cold Water Aquatic Community, Agriculture, Primary Body Contact Recreation, and Aesthetics. The reservoir and watershed are designated as High Quality Waters and as a Nutrient-Limited Watershed (OAC, 2023). Based on the 2022 Integrated Water Quality Assessment prepared by the Oklahoma Department of Environmental Quality (ODEQ 2022), the lower portion of Tenkiller Ferry Lake (Waterbody ID: OK121700020020_00) is listed as impaired by low dissolved oxygen affecting Fish and Wildlife Propagation as a Warm Water Aquatic Community, by phosphorus concentrations affecting Aesthetics, and by mercury affecting Fish Consumption. The upper portion of the reservoir (Waterbody ID: OK121700020220_00) is listed as impaired by algal concentrations affecting Public and Private Water Supply, mercury affecting Fish Consumption, and phosphorus concentrations affecting Aesthetics.

Physical and chemical water quality data were collected twice in June, and in August and September 2017 by USACE from five in-lake sites and one in the tailwater 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 1TENOKN0164 (channel at the dam), 1TENOKN0249 (mouth of Snake Creek Cove), 1TENOKN0171 (mouth of Carlile Cove), 1TENOKN0250 (N of Cherokee State Park), 1TENOKN0177 (downstream of Horseshoe Bend PUA), and 1TENOKN0251 (tailwater). In-lake 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.

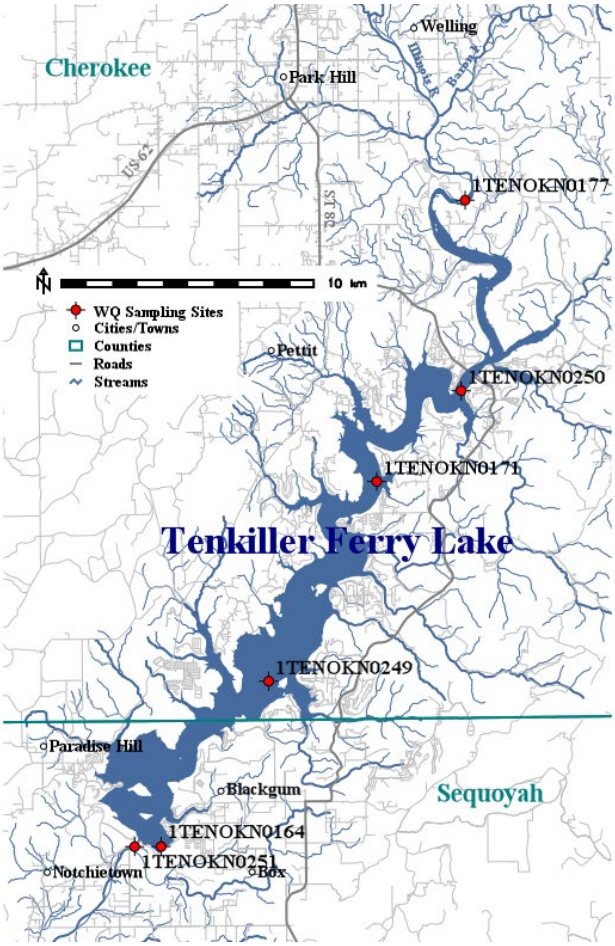

Figure 2. Locations of water quality sampling sites at Tenkiller Ferry Lake, OK.

Mean annual temperature in nearby Tahlequah, OK is 60.0 °F and average annual precipitation is 50.23 inches. On average, wettest months are May, June, and September. In calendar year 2017, recorded basin precipitation was 51.31 inches.

The Tenkiller Ferry Lake elevation was in the flood pool from late April into July with peak elevation over 662 feet in early May. Access to boat ramps for sampling was unavailable in April and May. Calendar year 2017 lake elevation, conservation pool elevation, basin precipitation, calculated evaporation rate, and water quality sampling events are shown in Figure 3.

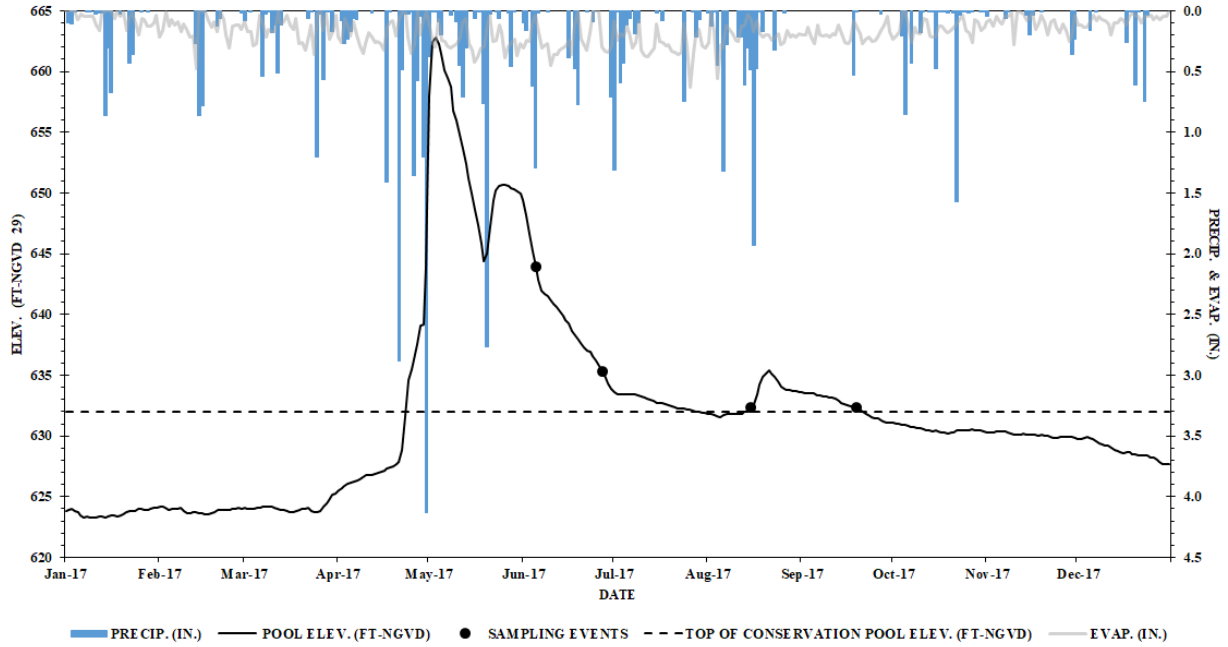

Figure 3. Daily lake elevation (feet, NGVD at 0800 hours), conservation pool elevation (feet), basin precipitation and evaporation (in.), and water quality sampling events at Tenkiller Ferry Lake, OK, 2017.

Water temperature ranged from 15.16 to 28.71 ºC, peaking in August. Surface water temperatures at 1TENOKN0164, 1TENOKN0249, and 1TENOKN0171 were ~28.5 ºC in August. All water temperatures ≤16 ºC were recorded in June at 1TENOKN0164 at depths beginning 32 meters below the surface. Thermal stratification was evident in June at 1TENOKN0164, 1TENOKN0249, 1TENOKN0171, and 1TENOKN0250. In later June, dissolved oxygen (DO) concentration was <2 mg/l seven meters below the surface at 1TENOKN0164 and 1TENOKN0171, and eight meters below the surface at 1TENOKN0249. In August, anoxia (DO <1 mg/l) began eleven meters below the surface at 1TENOKN0164, nine meters at 1TENOKN0249 and 1TENOKN0171, and just 5 meters at 1TENOKN0250. Lower lake sites (1TENOKN0164 and 1TENOKN0249) remained anoxic at depth in September.

The study period lakewide median DO concentration was 3.84 mg/l, with observations ranging from 0.0 to 13.24 mg/l. Site median DO concentrations were lowest at sites with significant mid-summer anoxia (1TENOKN0164, 2.17 mg/l; 1TENOKN0249, 3.63 mg/l; and 1TENOKN0171, 3.81 mg/l). Observed DO concentrations >11.0 mg/l were recorded on both sampling dates in June, near the surface, at sites 1TENOKN0164, 1TENOKN0249, 1TENOKN0171, and 1TENOKN0250. Vertical DO, water temperature, and pH profiles measured at 1TENOKN0164 are shown in Figure 4.

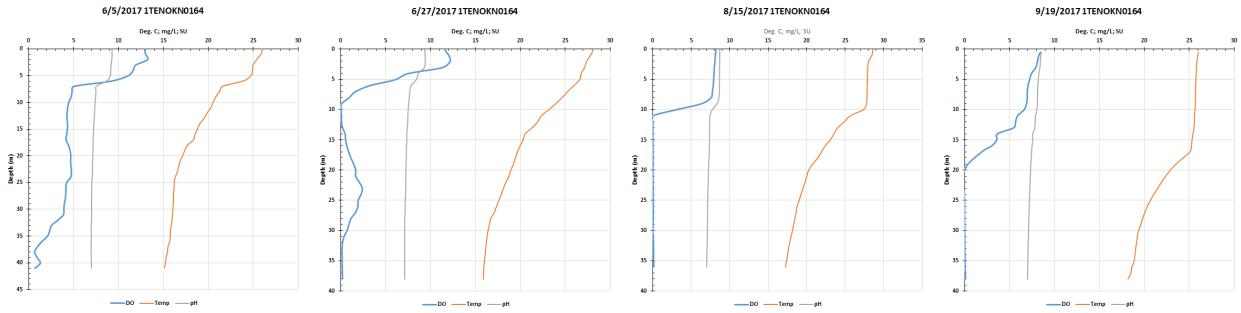

Figure 4. Vertical profiles of DO concentration, water temperature, and pH at 1TENOKN0164 in June (two dates), August, and September 2017.

Lakewide, total organic carbon concentrations were moderate with a study period lakewide median of 4.0 mg/l. Site median total organic carbon concentrations were moderate throughout the lake ranging from 2.40 (1TENOKN0177) to 4.56 (1TENOKN0164) mg/l.

Specific conductance (lakewide median 191.0 µS/cm) was moderate to low, consistent with regional geology. Total dissolved solids lakewide median concentration was 139.0 mg/l with site medians ranging from 127.5 (1TENOKN0164) to 141.5 (1TENOKN0250) mg/l. Low lakewide chloride and sulfate concentrations (medians 6.04 and 8.89 mg/l, respectively) were observed. Alkalinity levels (lakewide median 77.5 mg/l as $CaCO_3$) imply a system capable of maintaining pH levels. Observed in-lake pH ranged from 6.82 to 9.40. All pH observations less than 7 were recorded at depth at 1TENOKN0164, 1TENOKN0249, and 1TENOKN0171 in early June. Observations of pH ≥9.0 were recorded at those same sites (1TENOKN0164, 1TENOKN0249, and 1TENOKN0171) in June near the surface. Hardness levels, median 77.3 mg/l as $CaCO_3$, indicate 'moderately hard' water.

Lakewide median Secchi depth was 1.25 meters with site medians ranging from 0.75 (1TENOKN0177) to 1.98 (1TENOKN0164) meters. Lakewide median turbidity was 12.9 NTU with 28% of all in-lake observations greater than or equal to 25 NTU. Median lakewide total suspended solids concentration was 5.6 mg/l, with the median of surface observations (4.6 mg/l) significantly lower than the median of bottom observations (13.6 mg/l). The euphotic zone at 1TENOKN0164 (dam site) ranged from 4.7 meters in June to 11.0 meters in September. Horseshoe Bend (1TENOKN0177) euphotic zones ranged from 3.7 to 3.8 meters.

Lakewide ammonia concentrations (median 0.06 mg/l) and nitrite plus nitrate concentrations (median 0.29 mg/l) were moderate to high. Surface concentrations of nitrite plus nitrate were generally lower (median 0.16 mg/l) than bottom concentrations (median 0.79 mg/l). Total Kjeldahl nitrogen concentrations, lakewide median 0.44 mg/l, were comparable at all in-lake sites with the lowest site median concentration at 1TENOKN0177 (0.19 mg/l). Estimated lakewide median surface total nitrogen concentration during the 2017 study was 0.67 mg/l with site medians ranging from 0.51 (1TENOKN0164) to 1.48 mg/l (1TENOKN0177). Total phosphorus concentrations ranged from 0.01 to 0.25 mg/l with a lakewide median of 0.06 mg/l. All total phosphorus concentrations >0.1 mg/l were from bottom samples at 1TENOKN0164, 1TENOKN0249, and 1TENOKN0171. Forty percent (40%) of all observations of dissolved ortho-phosphate had reportable concentrations and the lakewide median was 0.04 mg/l. Lakewide surface nitrogen to phosphorus ratio (N:P) in 2017 was 50.8. The lowest site median N:P ratio was 28.7 at 1TENOKN0177. N:P ratios >10 indicate a general tendency toward phosphorus limitation of phytoplankton growth.

Chlorophyll-*a* concentrations ranged from 2.5 to 32.9 µg/l, with a lakewide median of 11.2 µg/l. Highest site median chlorophyll-a concentration was 19.4 µg/l at 1TENOKN0250 (upper lake, N of Cherokee State Park). Figure 5, below, summarizes relative abundance and biovolume of divisions of phytoplankton observed at Tenkiller Ferry Lake at three sites on three dates in 2017. Abundance was dominated by Cyanophytes (blue green 'algae' that are photosynthetic bacteria). Biovolume shows variable seasonal representation of Bacillariophytes (diatoms), Cryptophytes (flagellated algae), Chlorophytes (greens), plus Cyanophytes (blue greens) and others, by site. Figure 6 summarizes zooplankton densities observed in 2017 (note the log scale density axis) at the same three sites. Cladoceran, Copepod, and Rotifer densities were comparable by site across dates.

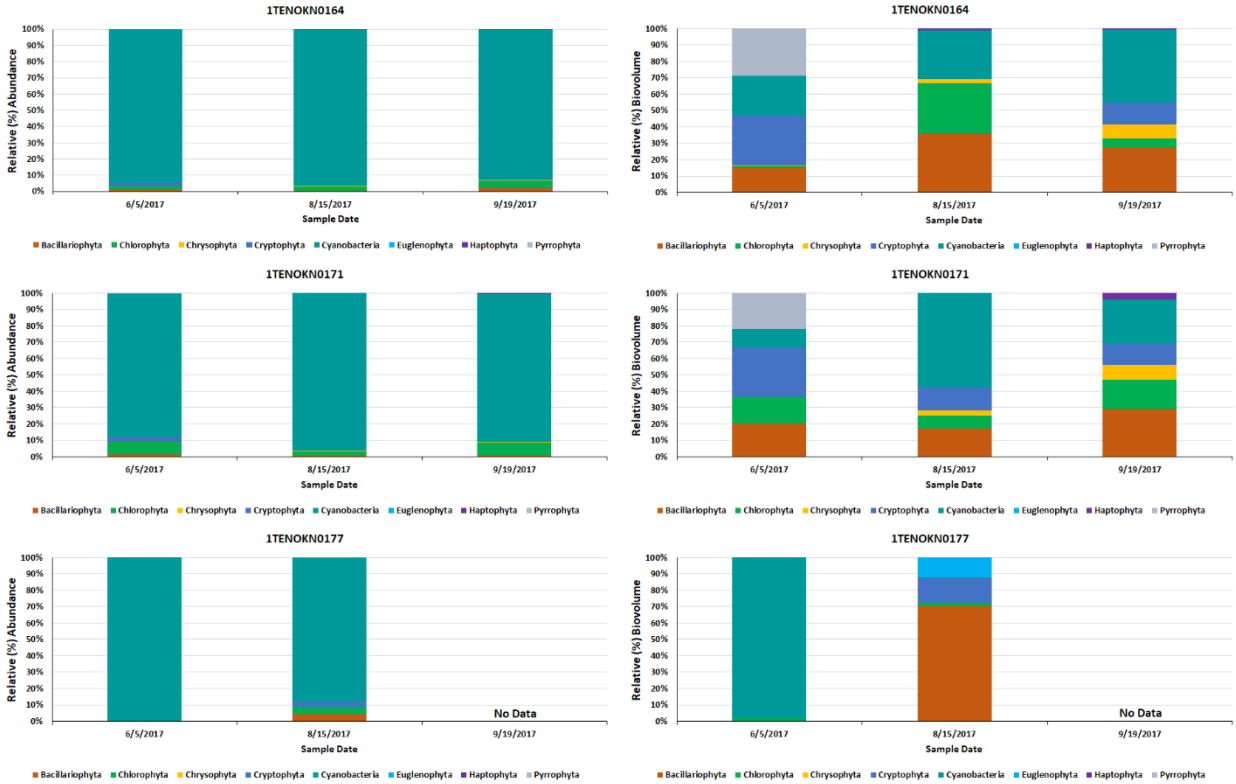

Figure 5. Phytoplankton relative abundance (left) and relative biovolume (right) at 1TENOKN0164, 1TENOKN0171, and 1TENOKN01177 in 2017.

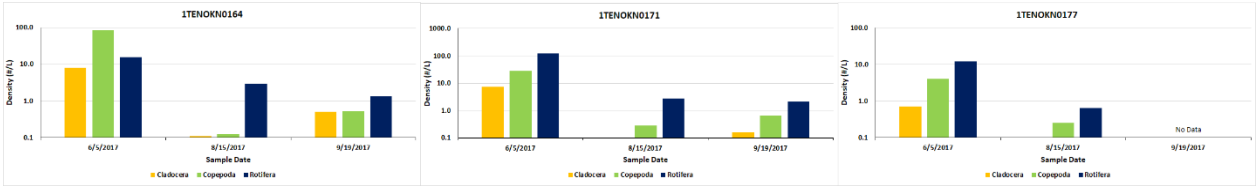

Figure 6. Zooplankton density at 1TENOKN0164, 1TENOKN0171, and 1TENOKN01177 in 2017.

Trophic status of Tenkiller Ferry 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 chlorophyll-a concentrations (TSI(CHLa)), 56.8 and 54.2, respectively, indicated eutrophy. The median lakewide TSI value based on surface total phosphorus concentrations (TSI(TP)), 47.4, suggests a moderately lower level of potential algal productivity (Figure 7).

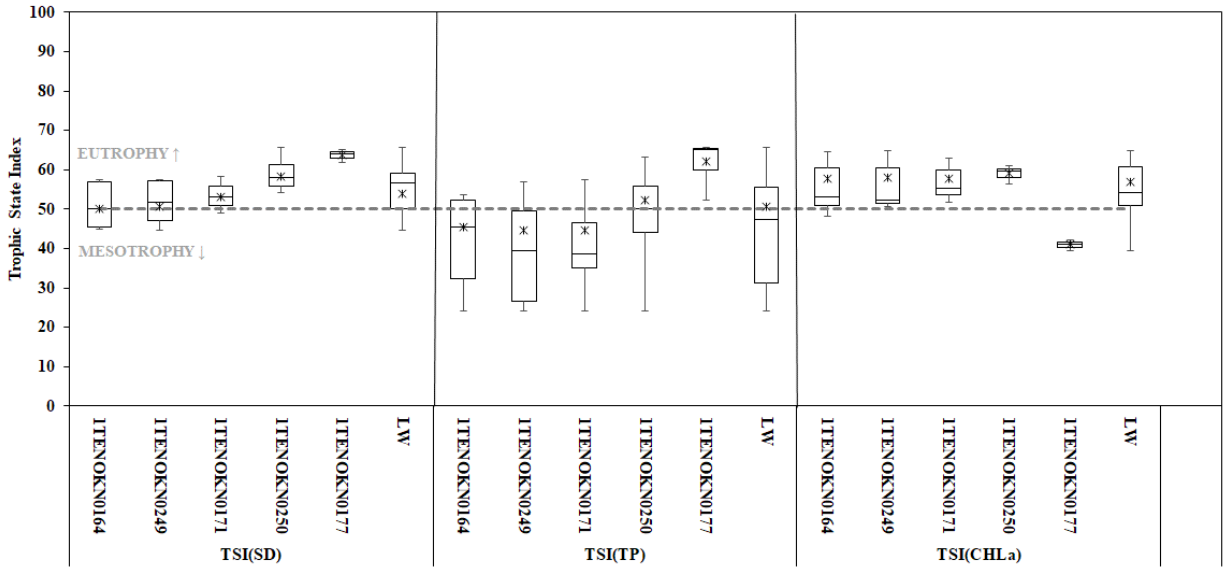

Figure 7. Distributions of Carlson's Trophic State Index (TSI), by sampling site and lakewide (LW), based on Secchi depth (TSI(SD)), surface total phosphorus (TSI(TP)) and chlorophyll-*a* concentrations (TSI(CHLa)) at Tenkiller Ferry Lake, OK, 2017.

Total iron and manganese concentrations (lakewide medians 0.11 and 0.05 mg/l, respectively) were moderate. Median bottom sample iron and manganese concentrations (0.33 and 0.28 mg/l, respectively) were higher than surface medians. Highest iron concentrations were from bottom samples at depth at 1TENOKN0171 (1.76 mg/l) and 1TENOKN0164 (1.37 mg/l) in August and September, respectively. Reportable concentrations of arsenic, copper, and nickel were noted in all in-lake samples. Reportable concentrations of chromium, lead, mercury, and zinc were present in 60, 46, 14, and 94%, respectively, of all samples collected.

Water quality data collected from 1TENOKN0251 (tailwater) was generally comparable to data collected at 1TENOKN0164 (dam site, bottom samples). Notable differences included higher median concentrations of ammonia, iron, manganese, phosphorus, and total Kjeldahl nitrogen in the tailwater samples.

USACE previously conducted water quality sampling at Tenkiller Ferry Lake in 1985-1986. USACE participated in a 1992-1993 USEPA sponsored feasibility study (OWRB; USACE; OSU, 1996), and collected water quality data from 2001-2005. In all efforts thermal stratification with hypoxia at depth was noted beginning in May at deeper sites. Water clarity ranged from excellent to moderate moving upstream from the dam. Macronutrients nitrogen and phosphorus were generally abundant, and annual loading of these nutrients has increased significantly since 1974. The TSI based on chlorophyll-a suggested a relatively productive lake, bordering between mesotrophy and eutrophy for the lake as a whole.