Oologah Lake Water Quality: 2018

The Oologah Lake dam is located at river mile 90.2 on the Verdigris River, about twenty-two miles northeast of Tulsa and two miles southeast of Oologah in Rogers County, Oklahoma (OK). The impoundment extends eighteen miles north-northeast upstream of the dam into Nowata County, OK. Oologah Lake, within Hydrologic Unit Code (HUC) 11070103 (Middle Verdigris) is a multipurpose project for flood control, water supply, recreation, navigation, and fish and wildlife. The project was designed to provide maximum flood protection on the Lower Verdigris and Arkansas Rivers when operated in conjunction with the Arkansas River Basin System. Construction began in July 1950, paused for a period, resumed in December 1955, and the conservation pool was filled in July 1972. Oologah Lake is a component of the multi-purpose Arkansas River Basin flood control and navigation system. The total drainage area above the dam is 4,339 square miles with 23% in Oklahoma and 77% in Kansas. Within the watershed above the Oologah dam are four USACE projects (Toronto Lake on the Verdigris River; Fall River Lake on the Fall River; Elk City Lake on the Elk River; and Pearson-Skubitz Big Hill Lake on Big Hill Creek) reducing the uncontrolled drainage area above the dam to 2,353 square miles. The full watershed is shown in Figure 1. Land use/cover (Dewitz, 2021) in the basin is dominated by grassland/pasture (~65.5%), forest (14.5%), and cropland (~12.6%). Based on a 2020 bathymetric survey (Seaworks Group, LLC, 2020), at the conservation pool elevation of 638.0 feet (NGVD 29), lake capacity has diminished about 18% since impoundment due to sedimentation. Descriptive characteristics of Oologah Lake are included in Table 1.

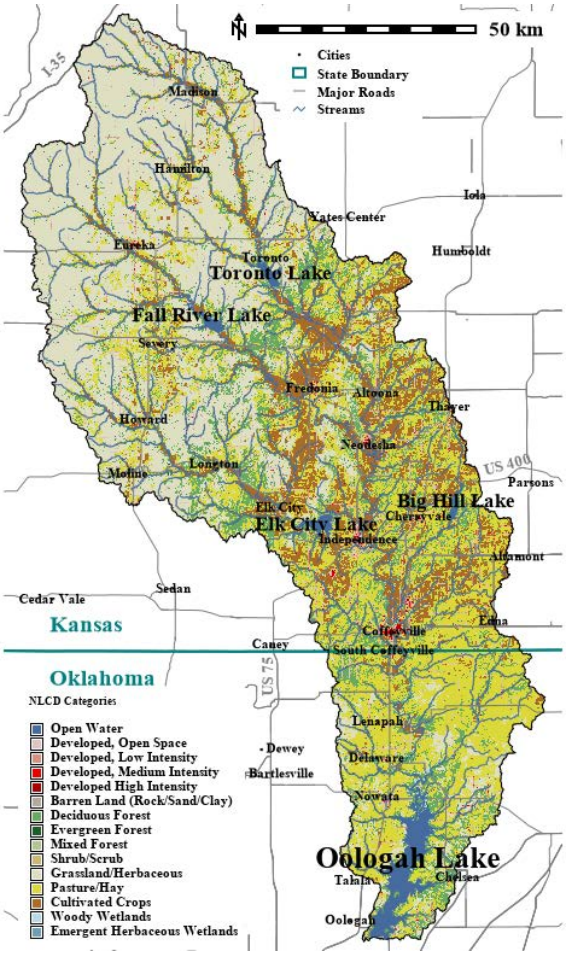

Figure 1. The Oologah Lake (Verdigris River) Watershed above the Oologah Lake Dam.

Table 1. Descriptive Characteristics of Oologah Lake, OK.

Parameter	English Units	Metric Units
Lake Elevation (Conservation Pool)	638.0 ft. NGVD	194.46 m
Lake Surface Area (Conservation Pool)	27,960 ac	6,540 ha
Lake Volume (Conservation Pool)	458,496 ac-ft	$565.55*10^6$ m^3
Total Drainage Area (contributing)	4,339 mi^2	57,886 km^2
Mean Depth	16.4 ft.	5.0 m
Maximum Depth (Conservation Pool)	69 ft.	21.0 m
Shoreline Length	216.9 mi	349.1 km
Shoreline Development Index	9.0	9.0
Annual Inflow, Average 1923 – 2018 [Water Years]	2,106,300 ac-ft	$2,598.1*10^6$ m^3
Annual Inflow, 2018 [Calendar Year]	1,590,745 ac-ft	$1,962.2*10^6$ m^3
Hydraulic Residence Time, 2018 [Calendar Year]	112.13 d	0.31 yr

Data derived from the Tulsa District's Pertinent Data Book (U.S. ACE - Tulsa District, 2004), the FY 2018 Annual Water Control Report (U.S. ACE - SWD RCC, 2019), Tulsa District's Water Control page for Oologah Lake (U.S. ACE - Tulsa District, 2023), and the 2020 bathymetric survey (Seaworks Group, LLC, 2020).

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

Physical and chemical water quality data were collected monthly by USACE from three in-lake sites and the tailwater beginning 4 April and ending 4 September 2018 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 OOLOKN0120 (channel at the dam), OOLOKN0241 (mid-lake ~1 km south-southwest of Winganon Bridge), OOLOKN0127 (upper lake near mouth of Double Creek Cove), and OOLOKN0244 (tailwater below dam). Sites OOLOKN0120, OOLOKN0241, and OOLOKN0127 were accessed by boat from locations over the deepest portion of the stream channel (thalweg). Oologah Lake receives relatively high sediment and nutrient loads during rainfall/runoff events. Significant constituent settling and transition occurs between upper and lower lake areas. An important morphological feature of the lake is a significant change in water depth at mid-lake. A county road, bisecting the lake (Winganon Bridge), restricts down-lake movement of water through a relatively narrow lake opening. Sedimentation above this point has contributed to an expansive area of relatively shallow water from the bridge to the upper end of the lake. Sampling locations are identified in Figure 2.

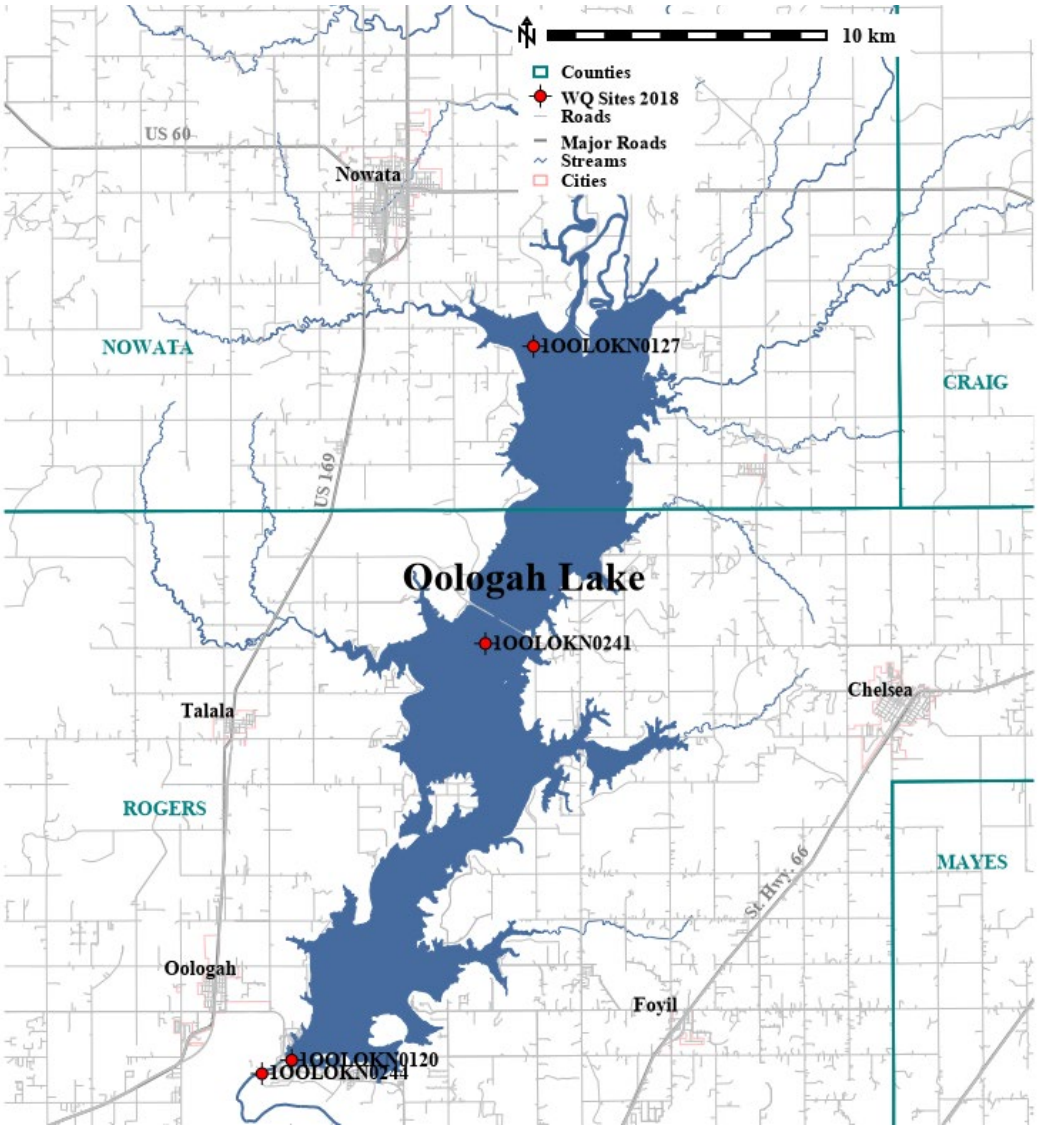

Figure 2. Locations of water quality sampling sites at Oologah Lake, OK, 2018.

The Oologah Lake pool was near the conservation pool elevation April through September 2018. Calendar year 2018 lake elevation, conservation pool elevation, basin precipitation, calculated evaporation rate, and water quality sampling events are shown in Figure 3.

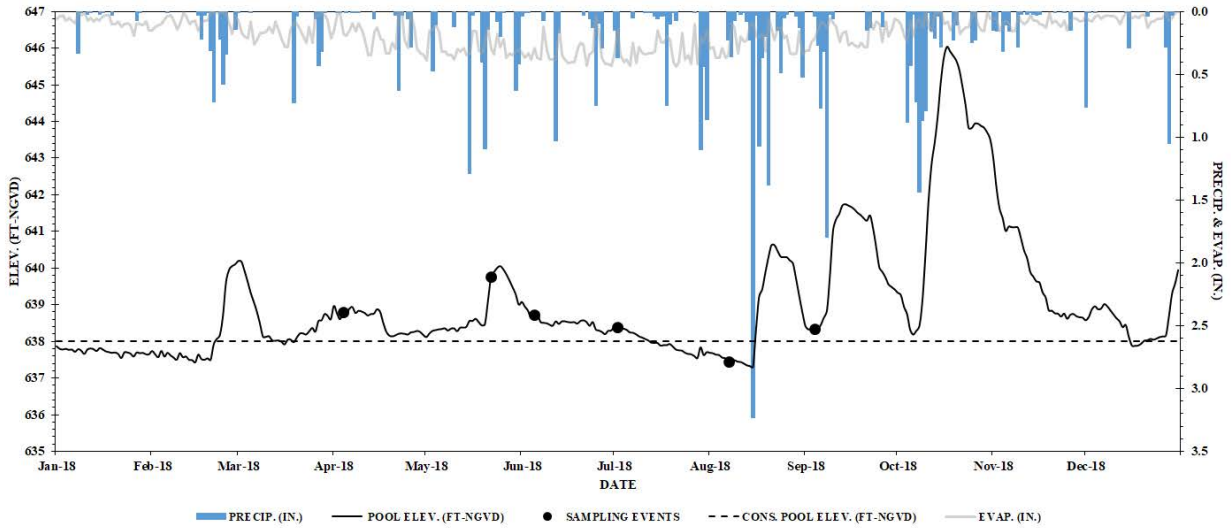

Figure 3. Daily lake elevation (feet, NGVD at 0800 hours), conservation pool elevation (feet), basin precipitation and evaporation (in.), and water quality sampling events at Oologah Lake, OK, 2018.

Water temperatures varied seasonally (ranging from 9.80 to 28.46 ºC) peaking in July. Near surface observations at all in-lake sites were >28 ºC in July. All water temperature observations <10 ºC occurred in April 2018 at OOLOKN0127 (surface to 3.5-meters depth). Weak thermal stratification was noted beginning in May 2018 at both OOLOKN0120 and OOLOKN0241 but was absent by August. The study period lakewide median dissolved oxygen concentration (DO) was 6.62 mg/l. Median DO was moderately higher at the mid-lake site (OOLOKN0241, 7.04 mg/l) and lowest at OOLOKN0120 (6.46 mg/l). Observed in-lake DO ranged from 0.21 to 9.79 mg/l. Lowest DO concentrations (<2 mg/l) were observed at depths beginning 11-meters and below at OOLOKN0120, and 9-meters and below at OOLOKN0241 in June. Highest DO concentrations (>9 mg/l) were observed at OOLOKN0120 in May from the surface to 3-meters depth, and at OOLOKN0127 in April 2018. Total organic carbon concentrations were moderately high with a lakewide study period median of 6.36 mg/l. Observed median total organic carbon concentrations were higher at OOLOKN0241 (6.48 mg/l, mid-lake) and OOLOKN0127 (10.04 mg/l, upper lake).

Specific conductance, ranging from 243.0 to 472.0 µS/cm (lakewide median 370.5 µS/cm), was moderate, consistent with regional geology. Median site conductance increased from upper lake (OOLOKN0127, 336.0 µS/cm) down toward the dam (OOLOKN0120, 377.0 µS/cm). Total dissolved solids median concentration was 244.0 mg/l with site medians ranging from 231.5 (OOLOKN0127) to 257.5 (OOLOKN0120) mg/l. Lakewide chloride and sulfate concentrations (medians 13.3 and 40.0 mg/l, respectively) were low to moderate. Alkalinity levels (lakewide median 125.0 mg/l as $CaCO_3$) imply a system capable of maintaining pH levels. Hardness levels, lakewide median 162.5 mg/l as $CaCO_3$, indicate 'hard' water. Observed in-lake pH (7.37 to 8.65) ranged within regional norms. Highest pH was recorded from the surface to 4-meters depth at OOLOKN0120 in May, and near the surface at OOLOKN0241 and OOLOKN0127 in July. Lowest pH was recorded in June at OOLOKN0120 (11-meters depth and below) and OOLOKN0241 (9-meters depth and below).

Median lakewide Secchi depth was 0.60 meters. Through the sampling period, median Secchi depth was lowest in the upper lake (OOLOKN0127, 0.25 m) and highest at the dam site (OOLOKN0120, 1.17 m). Lakewide median turbidity was 18.1 NTUs, and 38.6% of all in-lake

observations were greater than or equal to 25 NTUs. Median site turbidity was much lower at the dam site (OOLOKN0120, 13.7 NTUs) relative to the upper lake (OOLOKN0127, 68.25 NTUs), where the minimum value recorded was 31.3 NTUs. Median lakewide total suspended solids concentration was 10.5 mg/l, with median OOLOKN0127 concentration (41.0 mg/l) much higher than the OOLOKN0120 median (5.1 mg/l). The euphotic zone at Oologah Lake site OOLOKN0120 ranged from 3.1 to 7.6 meters with largest depths occurring in June. An approximation of euphotic zone depth in the upper lake, based on Secchi depth, ranged from 0.5 to 1.0 meters.

Lakewide ammonia concentrations (median 0.05 mg/l) and nitrite plus nitrate concentrations (median 0.09 mg/l) were low. Highest site median ammonia concentrations were found in surface samples at OOLOKN0127 (0.07 mg/l), and highest site median nitrite plus nitrate concentration was also found at OOLOKN0127 (0.27 mg/l). Total Kjeldahl nitrogen concentrations (lakewide median 0.50 mg/l) were highest in the upper lake (OOLOKN0127, median 0.76 mg/l) and lowest near the dam (OOLOKN0120, median 0.43 mg/l). Estimated lakewide median surface total nitrogen concentration during the 2018 study was 0.59 mg/l ranging from a site median of 0.46 mg/l at OOLOKN0120 to 0.88 mg/l at OOLOKN0127. Total phosphorus concentrations lakewide ranged between 0.02 and 0.22 mg/l (median 0.10 mg/l). Detectable concentrations of dissolved ortho-phosphate, lakewide median 0.03 mg/l, were present in 79% of samples collected. Nitrogen to phosphorus ratios (N:P) in 2018 were <10 (median 7.0) indicating a tendency toward limited nitrogen availability and the potential for phytoplankton dominance by cyanophytes.

Chlorophyll-*a* concentrations (in-lake) ranged from 3.2 to 36.9 µg/l, with a median concentration of 13.4 µg/l. Median chlorophyll-a concentrations were highest at the upper lake site (OOLOKN0127, 22.7 µg/l). Figure 4, below, summarizes relative abundance and biovolume of divisions of phytoplankton sampled at Oologah Lake sites. Bacillariophyte (diatoms), Cryptophyte (flagellated unicellular algae), and Cyanophyte (blue green ‘algae’ that are photosynthetic bacteria) abundance seasonally dominate the sampled period, varying by lake site. Relative biovolume graphics show consistent representation of Bacillariophytes varying by site and season. Figure 5 summarizes zooplankton densities observed in 2018 (note the log scale density axis) at OOLOKN0120, OOLOKN0241, and OOLOKN0127. Cladocerans, Copepods, and Rotifers were generally well represented across the sampled period, while notable Bivalve densities (exclusively *Dreissena*, or zebra mussel, veligers) occurred in warmer months.

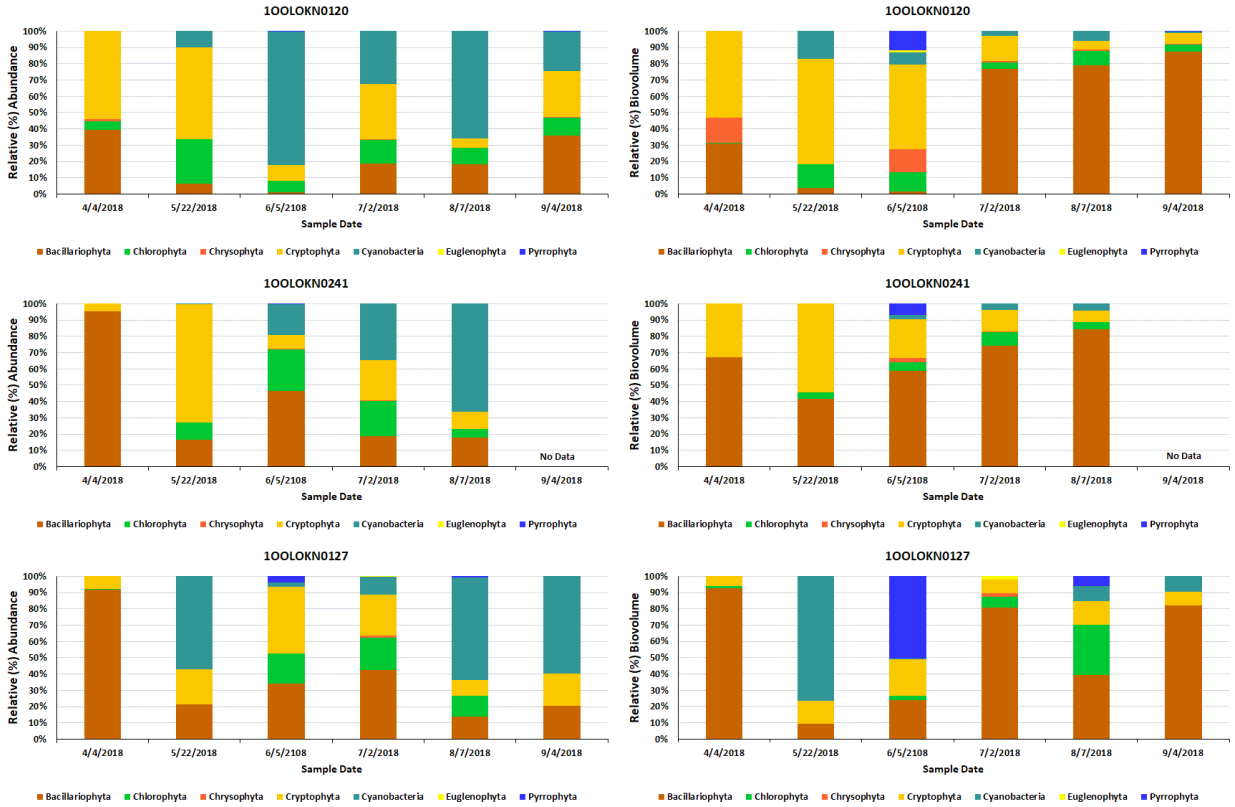

Figure 4. Phytoplankton relative abundance (left) and relative biovolume (right) at OOLOKN0120, OOLOKN0241, and OOLOKN0127 April through September 2018.

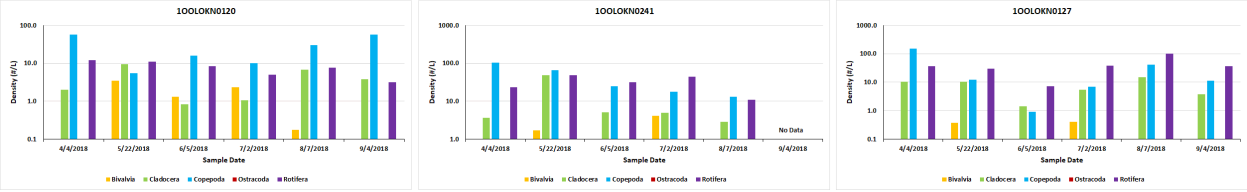

Figure 5. Zooplankton density at OOLOKN0120, OOLOKN0241, and OOLOKN0127 April through September 2018.

Trophic status of Oologah Lake was assessed using all three metrics of Carlson's trophic state index (TSI) at each in-lake site and the lake as a whole. Median lakewide indexes based on Secchi depth (TSI(SD)) and surface total phosphorus concentrations (TSI(TP)) were >65.0. The median lakewide index developed from chlorophyll-*a* concentrations (TSI(CHLa)), 56.0, indicated a moderately eutrophic waterbody (Figure 6).

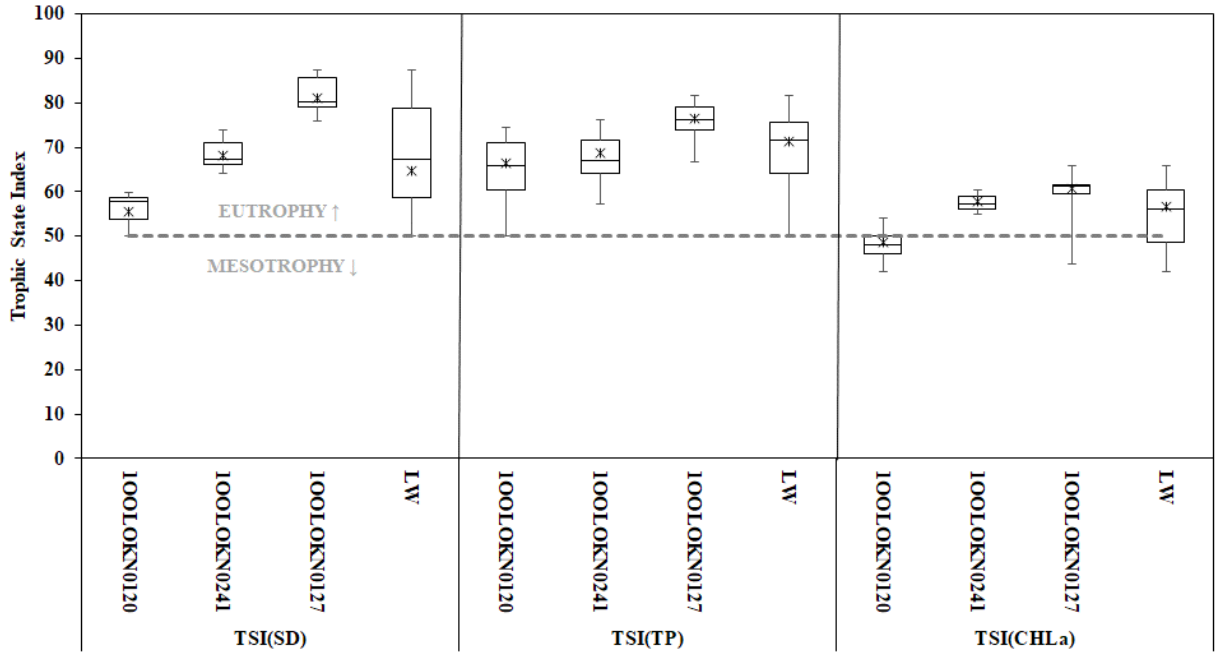

Figure 6. Distributions of Carlson's Trophic Sate Index (TSI), by sampling site and lakewide (LW), based on observations of Secchi Depth (TSI(SD)), surface total phosphorus concentrations (TSI(TP)), and chlorophyll-*a* concentrations (TSI(CHLa)) at Oologah Lake, OK, April through September 2018.

Total iron (median 0.26 mg/l) and manganese (median 0.08 mg/l) concentrations were moderate. Reportable concentrations of arsenic were found in all in-lake samples collected, with a median concentration of 0.0025 mg/l. Reportable concentrations of copper, nickel, and zinc were noted in all in-lake samples. Reportable concentrations of chromium and lead were present in 86 and 79%, respectively, of all samples collected. Detectable mercury concentrations were noted in 18% of samples collected. Statistical summaries of water quality parameters from the tailwater (OOLOKN0244) were comparable to data collected at depth at OOLOKN0120.

USACE previously conducted water quality sampling at Oologah Lake, OK in 1978, 1990, and 2000 – 2009 (U.S. ACE - Tulsa District, 2012). Observations to date at Oologah Lake have revealed neither a strong nor prolonged period of thermal stratification and/or hypolimnetic hypoxia. Wind mixing and a relatively short hydraulic residence time likely limit these conditions. Zebra mussels (*Dreissena polymorpha*) are believed to have infested the lake beginning in the 2002. Nutrients, both nitrogen and phosphorus, were present in concentrations sufficiently high to support a highly productive system. Water clarity is consistently low in the upper lake improving moving downstream toward the dam. Given the turbid nature of Oologah Lake and the high affinity of phosphorus to sorb to soil particles, trophic classification using chlorophyll-a is suggested. Iron and manganese concentrations were high in 1990 shifting to more moderate concentrations (2000 – 2009).