Waurika Lake Water Quality: 2022

The Waurika Lake dam is located in Jefferson County, Oklahoma (OK) at river mile 27.0 on Beaver Creek, a tributary of the Red River, approximately 6.0 miles northwest of Waurika, OK. The impoundment extends northwest of the dam following the Beaver Creek channel for ~9 miles through the southwest corner of Stephens County into Cotton County, OK. The lake, within Hydrologic Unit Code 11130208 (Northern Beaver), is a multiple-purpose project for flood control, irrigation, water supply, water quality, recreation, and fish and wildlife. Construction began in July 1971 and the project was placed into operation in August 1977. The conservation pool filled to elevation 951.4 feet in May 1982. Waurika Lake is a unit of the multiple purpose system which regulates flood control, generation of hydropower, navigation, and other beneficial water uses on the Red River and its tributaries. The total drainage area above the dam is ~563 square miles. The full watershed is shown in Figure 1. Beaver Creek rises in the foothills of the Wichita Mountains and flows in a southerly direction and meets left bank tributary Little Beaver Creek at the lake. Land use/cover (Dewitz, 2023) in the basin is dominated by grassland/pasture (~68%), cropland (~15%), and forest (8%). Based on a 2010 bathymetric survey (OWRB, 2011), at the conservation pool elevation of 951.4 feet (NGVD 29), lake capacity has diminished by ~5% due to sedimentation since impoundment. Descriptive characteristics of Waurika Lake are included in Table 1.

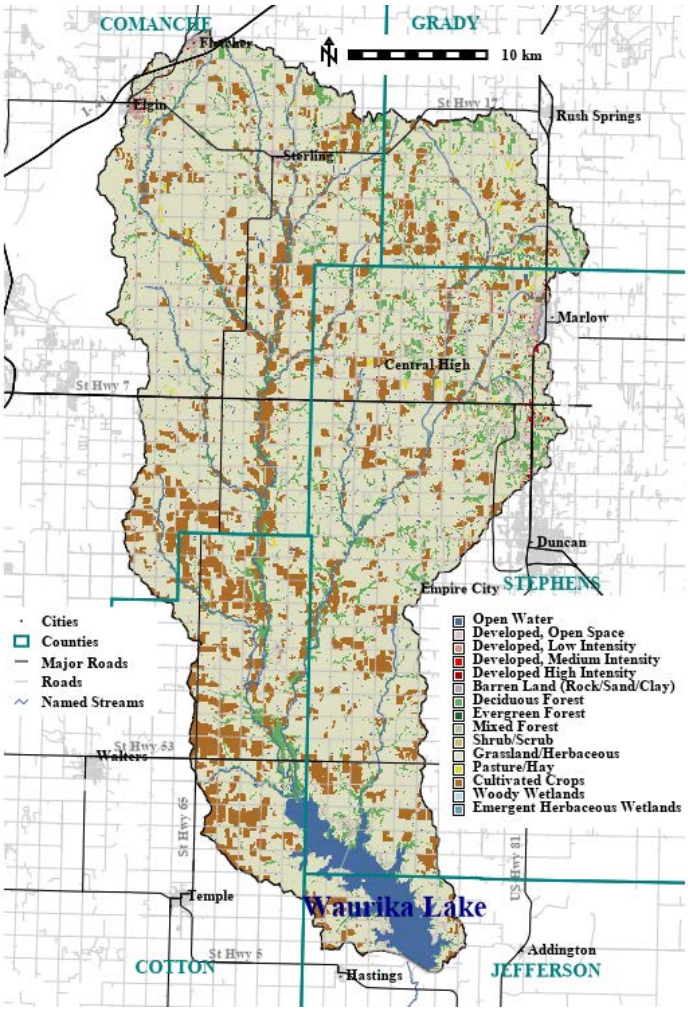

Figure 1. The Waurika Lake (Beaver Creek) Watershed above the Waurika Lake Dam.

Table 1. Descriptive Characteristics of Waurika Lake, OK.

Parameter	English Units	Metric Units
Lake Elevation (Conservation Pool)	951.4 ft. NGVD	289.99 m
Lake Surface Area (Conservation Pool)	10,114 ac	4,093 ha
Lake Volume (Conservation Pool)	187,460 ac-ft	$231.23*10^6$ m^3
Total Drainage Area (contributing)	563 mi^2	1,458 km^2
Mean Depth	18.5 ft.	5.64 m
Maximum Depth (Conservation Pool)	52 ft.	15.8 m
Shoreline Length	80.1 mi	128.9 km
Shoreline Development Index	5.7	5.7
Annual Inflow, Average 1926 – 2022 [Water Years]	111,570 ac-ft	$137.62*10^6$ m^3
Annual Inflow, 2022 [Calendar Year]	59,169 ac-ft	$72.98*10^6$ m^3
Hydraulic Residence Time, 2022 [Calendar Year]	1,078 d	2.95 yr

Data derived from the Tulsa District's Pertinent Data Book (U.S. ACE - Tulsa District, 2004), the FY 2022 Annual Water Control Report (U.S. ACE - SWD RCC, 2023), Tulsa District's Water Control page for Waurika Lake (U.S. ACE - Tulsa District, 2024), and the 2010 bathymetric survey (OWRB, 2011).

Designated beneficial uses of the impoundment created by the Waurika Lake Dam include Public and Private Water Supply, Fish and Wildlife Propagation as a Warm Water Aquatic Community, Agriculture, Primary Body Contact Recreation, Aesthetics, and the lake and watershed are designated as Sensitive Public and Private Water Supply (OAC, 2023). Based on the 2022 Integrated Water Quality Assessment prepared by the Oklahoma Department of Environmental Quality (ODEQ, 2022), Waurika Lake is listed as impaired by high algal densities affecting Public and Private Water Supply, elevated turbidity affecting Fish and Wildlife Propagation as a Warm Water Aquatic Community, and by mercury concentrations affecting Fish and Shellfish Consumption. A Total Maximum Daily Load (TMDL) document addressing nutrients promoting high algal densities (chlorophyll-a) was completed in 2013.

Physical and chemical water quality data were collected monthly by USACE from three in-lake sites and the tailwater beginning 12 April and ending 13 September 2022 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 WAROKS0169 (channel at the dam), WAROKS0102 (mid-lake, channel), WAROKS0170 (upper lake, channel at N2740 Road bridge), and WAROKS0168 (tailwater below dam). Sites WAROKS0169, WAROKS0102 were accessed by boat from locations over the deepest portion of the stream channel (thalweg). WAROKS0102 was accessed from the bridge. Vertical profiles of water temperature, dissolved oxygen, pH, and conductivity were not recorded in April. Sampling locations are identified in Figure 2.

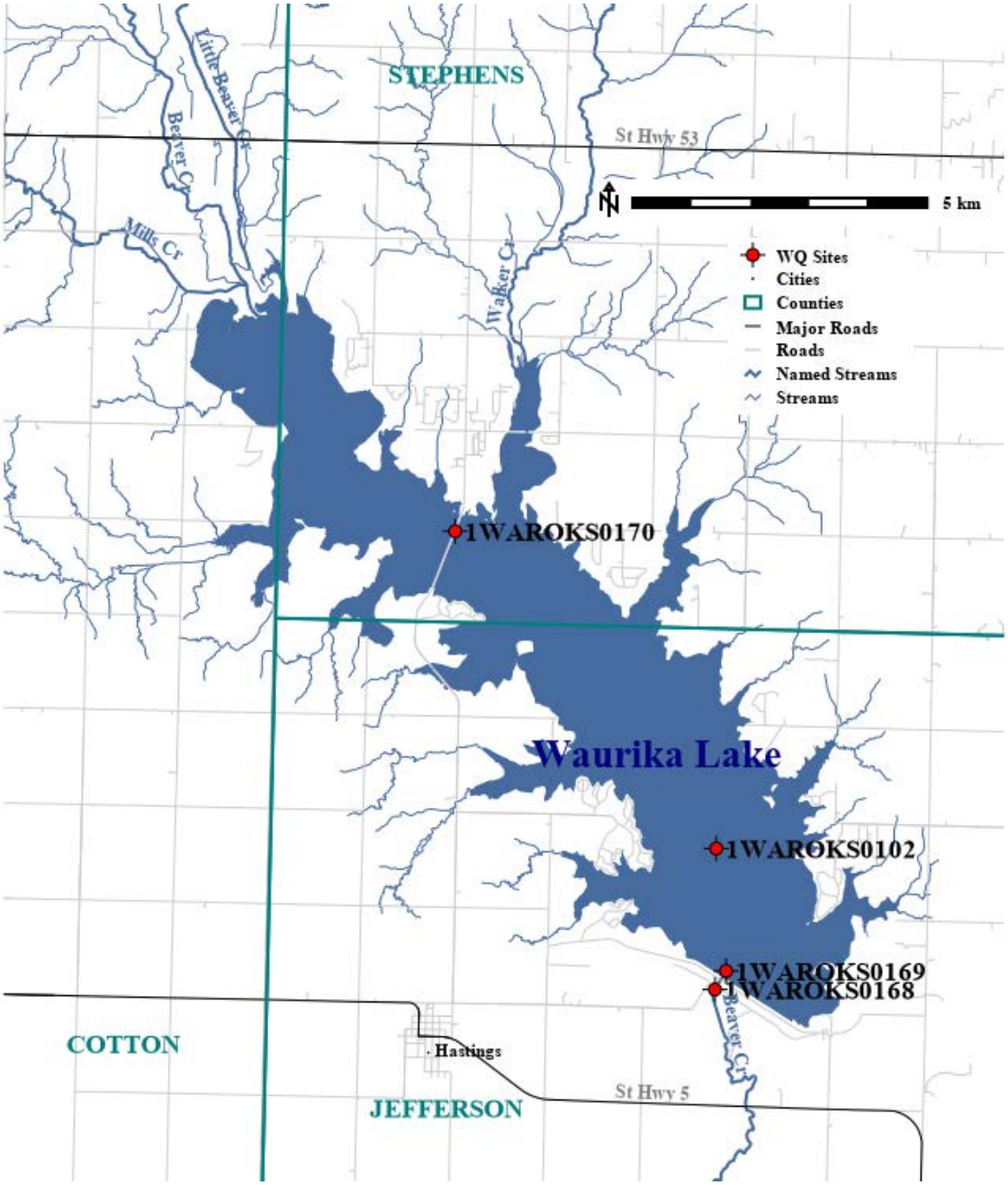

Figure 2. Locations of water quality sampling sites at Waurika Lake, OK, 2022.

The Waurika Lake pool was below the conservation pool elevation April through June, peaking at 951.35 feet in June. Calendar year 2022 lake elevation, conservation pool elevation, basin precipitation, calculated evaporation rate, and water quality sampling events are shown in Figure 3.

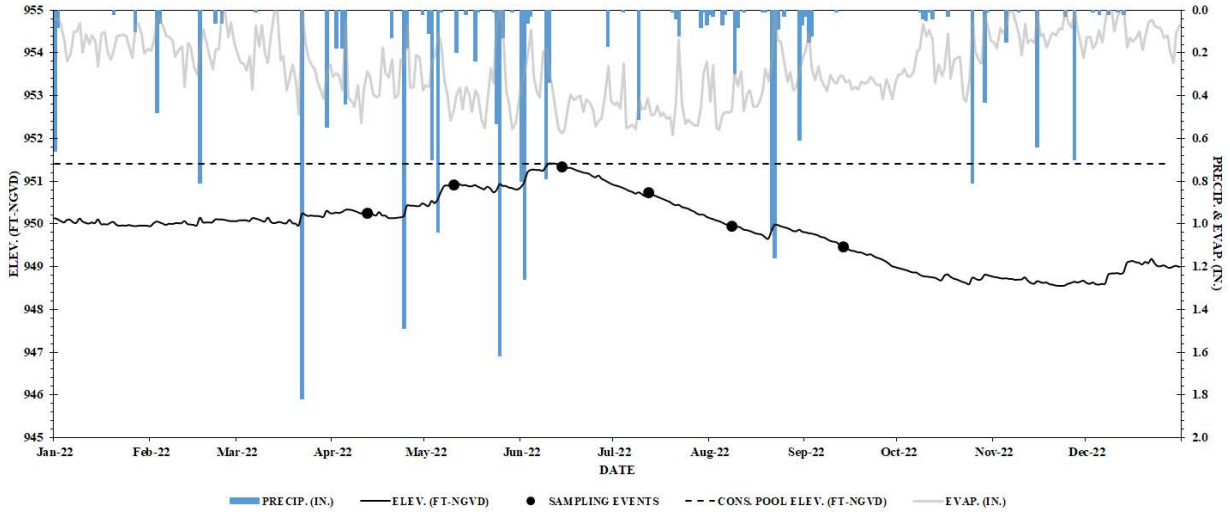

Figure 3. Daily lake elevation (feet, NGVD at 0800 hours), conservation pool elevation (feet), basin precipitation and evaporation (in.), and water quality sampling events at Waurika Lake, OK, 2022.

Water temperatures varied seasonally (ranging from 19.09 to 30.66 ºC) peaking in July. July surface water temperatures recorded at WAROKS0169, WAROKS0102, and WAROKS0170 were >29.75 ºC. Water temperature observations <20 ºC were recorded May 2022 at WAROKS0169 at depth (11- to 13-meters). Thermal stratification was noted beginning in June at WAROKS0169 (7-meters depth); evident at WAROKS0169 (2-meters), WAROKS0102 (3-meters), and WAROKS0170 (3-meters) in July; and continuing at WAROKS0169 and WAROKS0102 through August (6-meters depth each). The study period lakewide median dissolved oxygen concentration (DO) was 6.06 mg/l. Median DO was lower at WAROKS0169 and WAROKS0102 (4.66 and 6.06 mg/l, respectively) than at WAROKS0170 (6.84 mg/l). Observed in-lake DO ranged from 0.57 to 11.82 mg/l. DO concentrations ≤2 mg/l were observed at WAROKS0169 July and August (below 9 meters depth), and at WAROKS0102 in July and August at depths 8- and 9-metersbelow the surface. Highest DO concentrations (>10 mg/l) were observed in July at WAROKS0169 (surface to 1-meters depth), WAROKS0102 (surface to 2-meters depth), and WAROKS0170 (surface to 0.5-meter depth). Lakewide total organic carbon concentrations were high with a study period median of 7.46 mg/l. Observed site median total organic carbon concentration was highest at WAROKS0170 (8.11 mg/l).

Specific conductance (lake wide median 651.0 µS/cm) was moderately high, consistent with regional geology, ranging from 349.0 to 686.0 µS/cm. Total dissolved solids median concentration was 425.0 mg/l with in-lake site medians ranging from 419.5 (WAROKS0170) to 429.0 (WAROKS0169) mg/l. Lakewide chloride and sulfate concentrations (medians 33.25 and 124.0 mg/l, respectively) were moderate to high. Alkalinity levels (median 168.5 mg/l as $CaCO_3$) suggest a system capable of maintaining pH levels. Hardness levels, lakewide median 222.5 mg/l as $CaCO_3$, indicate 'hard' water. Observed in-lake pH (7.02 to 8.89) tended toward alkaline with a median of 8.09. Highest pH was recorded at WAROKS0170 in June, July, and August corresponding with higher chlorophyll-a concentrations. Recorded pH <7.5 was noted at WAROKS0169, at depth, in August 2022.

Median lakewide Secchi depth was 0.73 meters. Through the sampling period, median Secchi depth was lowest at WAROKS0102 (0.62 m) and highest at WAROKS0169 (0.81 m). Lakewide median turbidity was 28.5 NTUs, and 64% of in-lake observations were greater than or equal to

25 NTUs. Median lakewide total suspended solids concentration was 9.25 mg/l, with the highest site median concentration at WAROKS0170 (12.5 mg/l). Lakewide, total suspended solids concentrations were comparable in bottom samples (median 9.5 mg/l) and surface samples (median 9.0 mg/l). The euphotic zone at Waurika Lake site WAROKS0169 ranged from 2.6 to 3.8 meters with greatest depth in June.

Lakewide ammonia concentrations (median 0.05 mg/l) and nitrite plus nitrate concentrations (median 0.20 mg/l) were moderate to high. Ammonia concentrations >0.10 mg/l were found in 26% of samples collected with 89% of those observations at WAROKS0169. Nitrite plus nitrate concentrations were highest at WAROKS0169 and WAROKS0102, surface and bottom, in May (≥0.20 mg/l). Total Kjeldahl nitrogen concentrations (lakewide median 0.70 mg/l) were comparable at all in-lake sites. Estimated lakewide median surface total nitrogen concentration during the 2022 study was 0.77 mg/l. Total phosphorus concentrations lakewide ranged between 0.02 and 0.82 mg/l (median 0.16 mg/l). Detectable concentrations of dissolved ortho-phosphate, lakewide median 0.05 mg/l, were present in 65% of samples collected. Nitrogen to phosphorus ratios (N:P) in 2022 were <10 (median 5.6) indicating a tendency toward limited nitrogen availability and the potential for phytoplankton dominance by cyanophytes.

Chlorophyll-*a* concentrations (in-lake) ranged from 4.6 to 43.1 µg/l, with a median concentration of 19.5 µg/l. Median site chlorophyll-a concentrations were highest at WAROKS0170 (28.0 µg/l) and WAROKS0102 (20.0 µg/l). Lakewide, chlorophyll-a concentrations averaged <10 µg/l in April and May, 14.6 µg/l in June, and ≥30 µg/l July through September. Figure 4, below, summarizes relative abundance and biovolume of divisions of phytoplankton sampled at select Waurika Lake sites. Cyanophyte (blue green 'algae' that are photosynthetic bacteria) abundance dominated the latter half of the sampled period (WAROKS0169, July to September), while biovolume shows a varying seasonal representation of an array of phytoplankton divisions influenced by site-specific water quality. Figure 5 summarizes zooplankton densities observed in 2022 (note the log scale density axis) at WAROKS0169 and WAROKS0170. Cladocerans, Copepods, and Rotifers were generally well represented across the sampling period, while notable Bivalve densities (exclusively Dreissena, or zebra mussel, veligers) were found at each site.

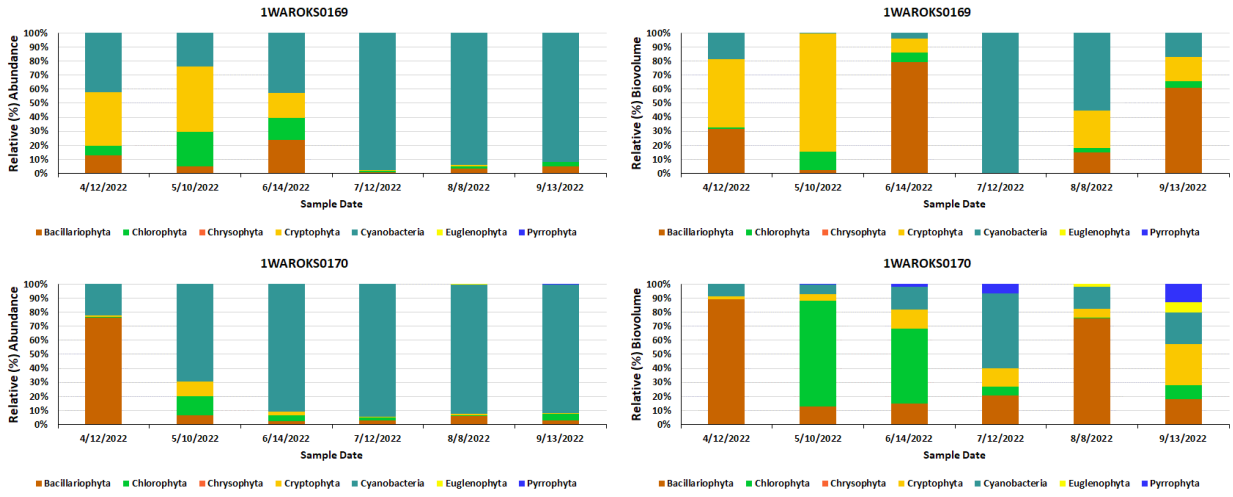

Figure 4. Phytoplankton relative abundance (left) and relative biovolume (right) at WAROKS0169 and WAROKS0170 April through September 2022.

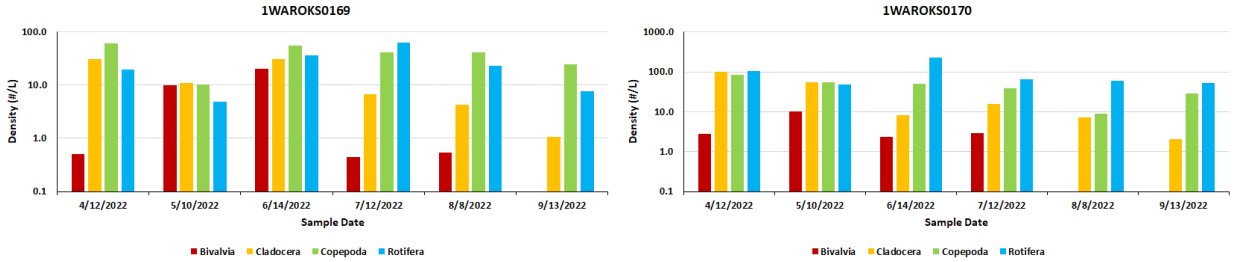

Figure 5. Zooplankton density at WAROKS0169 and WAROKS0170 April through September 2022.

Trophic status of Waurika 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. The median lakewide index based on Secchi depth (TSI(SD)), 63.9 reflects the generally turbid conditions encountered and includes no observations from WAROKS0170. The median index based on surface total phosphorus (TSI(TP)), 76.0 reflects abundant phosphorus. The median chlorophyll-a index (TSI(CHLa)), 59.7, indicates eutrophy at Waurika Lake (Figure 6).

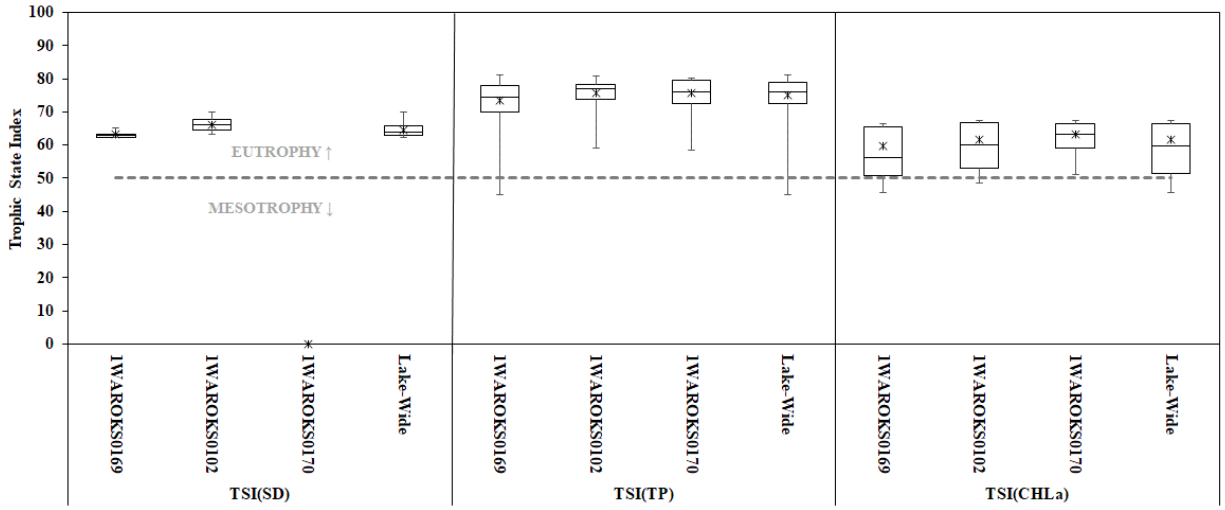

Figure 6. Distributions of Carlson's Trophic Sate Index (TSI), by sampling site and lakewide, based on observations of Secchi Depth (TSI(SD)), surface total phosphorus concentrations (TSI(TP)), and chlorophyll-*a* concentrations (TSI(CHLa)) at Waurika Lake, OK, April through September 2022.

Total iron (median 0.12 mg/l) and manganese (median 0.05 mg/l) concentrations were moderate. Reportable low concentrations of arsenic were found in all in-lake samples collected, with a median concentration of 0.0038 mg/l. Reportable concentrations of copper, nickel, and zinc were noted in all in-lake samples. Reportable chromium and lead concentrations were found in 85% and 62%, respectively, of all samples. No detectable mercury concentrations were noted. Results of water quality parameters from the tailwater (WAROKS0168) were comparable to samples collected at WAROKS0169 with notably higher median total phosphorus and dissolved ortho-phosphate concentrations. Median chlorophyll-a concentration at WAROKS0168 was 42.7 µg/l.

USACE previously conducted water quality sampling at Waurika Lake, OK in 1995 and 2011. The 1995 effort noted elevated nutrient levels (ammonia, nitrite plus nitrate, and total phosphorus), limited water clarity, and concerning mercury concentrations. A study of mercury

concentrations in fish was performed in October 1995, and 20 of 26 carnivorous fish samples revealed measurable concentrations. A regional drought in 2011 led to decreasing pool elevations and a long hydraulic residence time (>5 years). The 2011 effort found consistent low concentrations of arsenic, nickel, and zinc; and occasional detectable levels of chromium, copper, and mercury. Both prior efforts classified Waurika Lake as eutrophic.