Toronto Lake Water Quality: 2023

The Toronto Lake Dam is located at river mile 271.5 on the Verdigris River about three miles south of the city of Toronto in Woodson County, Kansas (KS) within Hydrologic Unit Code 11070101. Project construction began in November 1954 and the conservation pool first filled in March 1960. Authorized purposes of the lake include flood damage reduction, water supply, water quality, fish and wildlife, and recreation. Toronto Lake is operated in conjunction with Fall River, Elk City, and Pearson-Skubitz Big Hill Lakes to provide maximum flood control benefits to the upper limits of Oologah Lake. The watershed above the Toronto dam site extends northwest ~45 miles up to I-35 and the Flint Hills in KS and encompasses ~716 square miles. Land use/cover (Dewitz 2023) is dominated by grassland and pasture (81.8%) and cropland (6.3%). Basin elevations range from about 856 feet at the dam to 1,665 feet in the headwaters of the North Branch Verdigris River near the Chase/Greenwood County border (Figure 1). The project's designed sediment storage has been filled, and sedimentation now encroaches on conservation pool storage. The most recent bathymetric survey conducted in 2010 (Kansas Biological Survey 2011) indicated an annual conservation pool sedimentation rate of 212 ac-ft/yr since embankment closure, reducing the original conservation pool volume by 39.3%. Descriptive characteristics of Toronto Lake are included in Table 1.

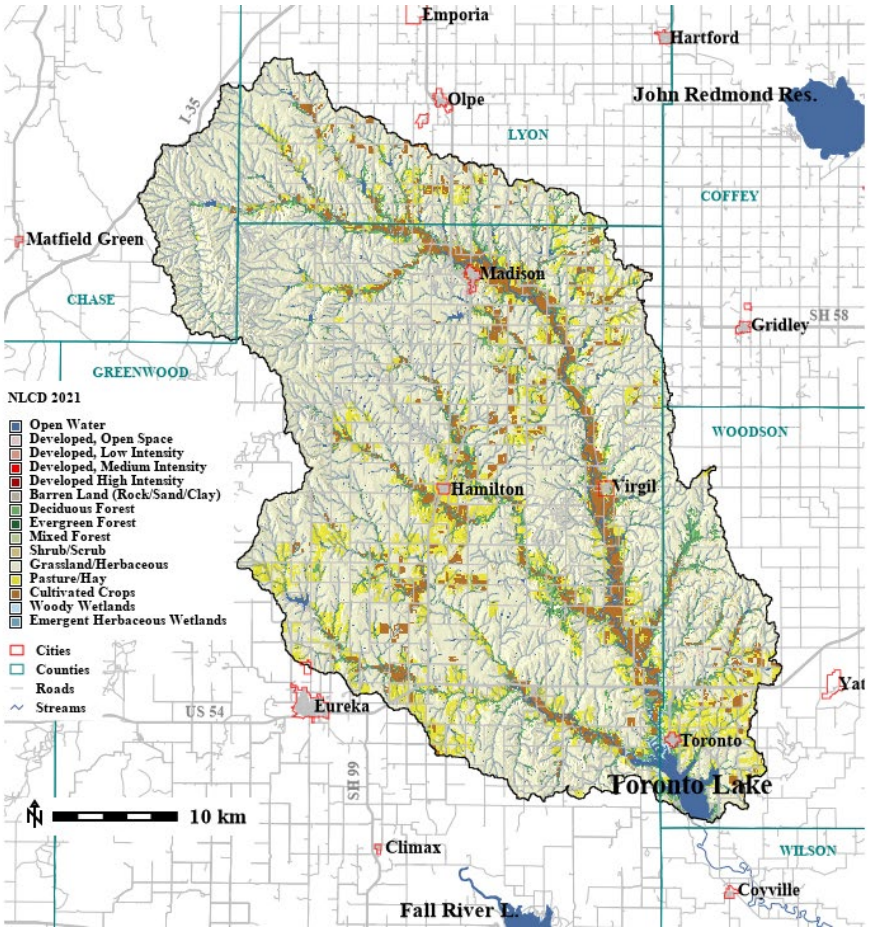

Figure 1. The Toronto Lake (Verdigris River) Watershed above the Toronto Lake Dam.

Table 1. Descriptive Characteristics of Toronto Lake, KS (2023).

Parameter	English Units	Metric Units
Lake Elevation (Conservation Pool)	901.5 ft NGVD	274.78 m
Lake Surface Area (Conservation Pool)	2,210 ac	894.36 ha
Lake Volume (Conservation Pool)	16,530 ac-ft	20,389,455 m^3
Total Drainage Area	716 mi^2	1,854.4 km^2
Mean Depth	7.5 ft	2.3 m
Maximum Depth (Conservation Pool)	26.5 ft	8.1 m
Shoreline Length	25.1 mi	40.3 km
Shoreline Development Index	3.7	3.7
Annual Inflow, Average 1922 – 2022 [Water Years]	336,050 ac-ft	414,511,572 m^3
Annual Inflow, 2023 [Calendar Year]	56,540 ac-ft	69,741,063 m^3
Hydraulic Residence Time, 2023 [Calendar Year]	100.2 d	0.27 yr

Data derived from the Tulsa District's Pertinent Data Book (U.S. ACE - Tulsa District 2004), the FY 2023 Annual Water Control Report (U.S. ACE - SWD RCC 2024), Tulsa District's Water Control page for Toronto Lake (U.S. ACE - Tulsa District 2024), and the 2010 KBS Bathymetric Survey (Kansas Biological Survey 2011).

Use designations (KDHE 2021) for Toronto Lake include expected aquatic life (AL), primary contact recreation (CR), domestic water supply (DS), food procurement (FP), ground water recharge (GR), industrial water supply (IW), irrigation use (IR), and livestock watering (LW). Based on the 2022 Kansas Integrated Water Quality Assessment (KDHE 2022), Toronto Lake is listed as impaired by lead (Pb), epilimnetic dissolved oxygen concentrations less than 5.0 mg/l, and eutrophication, all affecting aquatic life. Additionally, Toronto Lake is listed as impaired by siltation affecting water supply.

Physical and chemical water quality data were collected by USACE approximately monthly at Toronto Lake, KS, April through September 2023 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, shown in Figure 2, included TORKSS0017 (buoy line near outlet works), TORKSS0019 (channel east of Duck Island), and TORKSS0023 (stilling basin below dam). Historically, in-lake water quality samples were also collected from TORKSS0020 (upper lake, near the Verdigris River/Walnut Creek confluence, not shown). During the 2023 (and 2012) study, site (TORKSS0020) was inaccessible by boat due to sedimentation and shallow conditions, and not sampled.

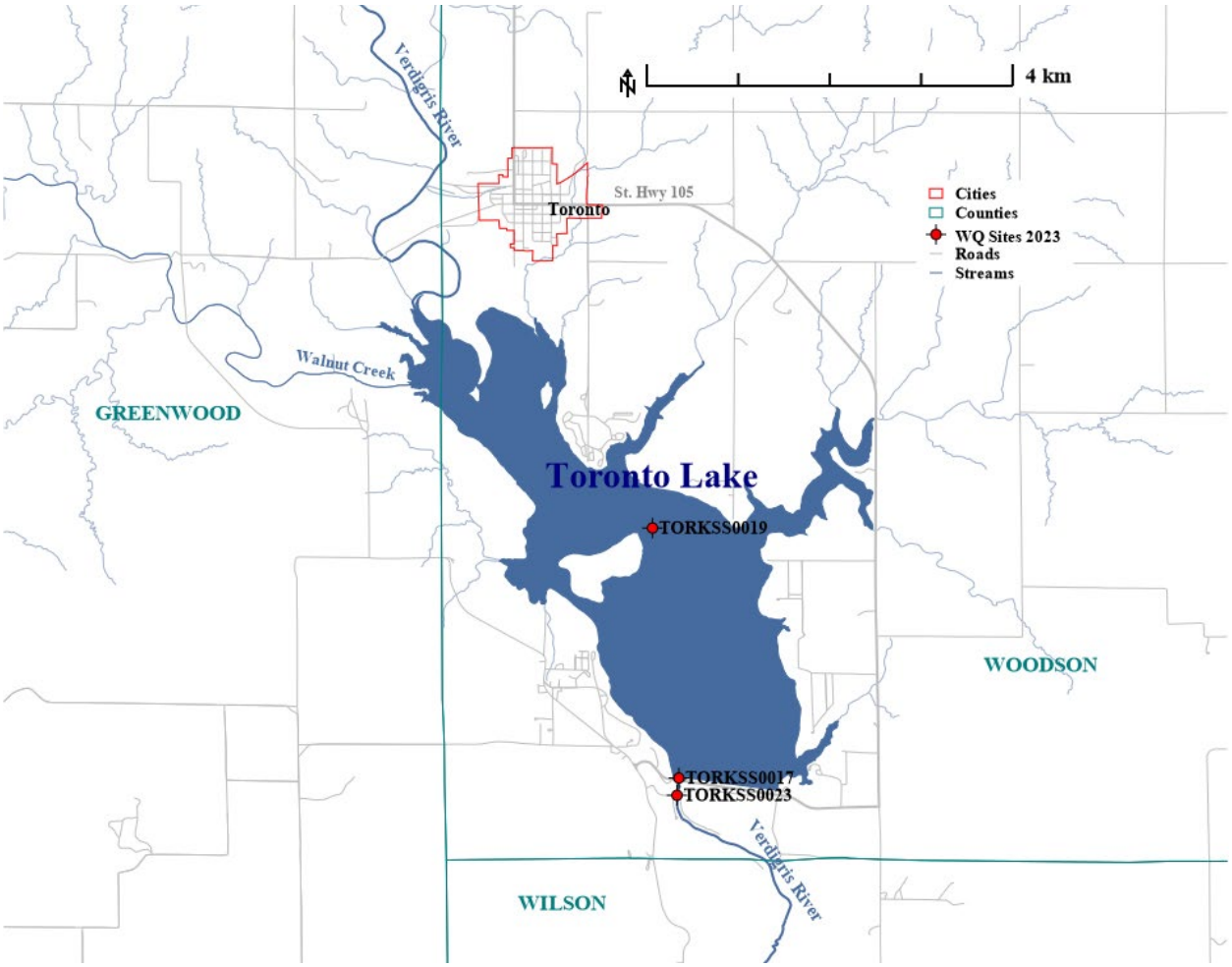

Figure 2. Locations of water quality sampling sites at Toronto Lake, KS, 2023.

Toronto Lake pool elevation was above the conservation pool elevation April through June, but lower than normal precipitation contributed to a consistently diminishing pool elevation drifting below 900-feet in early September 2023. Data from a weather station located in the watershed (Madison, KS) indicated that at the beginning of September 2023, annual cumulative precipitation was 13 inches below the 30-year (1990 – 2020) normal (SCIPP 2024). Low September pool elevation prevented boat launching. September 2023 water quality samples representing site TORKSS0017 were collected from the roadway on the dam structure, and samples representing TORKSS0019 were collected from shore at a nearby boat ramp (Toronto Point). Calendar year 2023 lake elevation, conservation pool elevation, basin precipitation, calculated evaporation rate, and water quality sampling dates are shown in Figure 3.

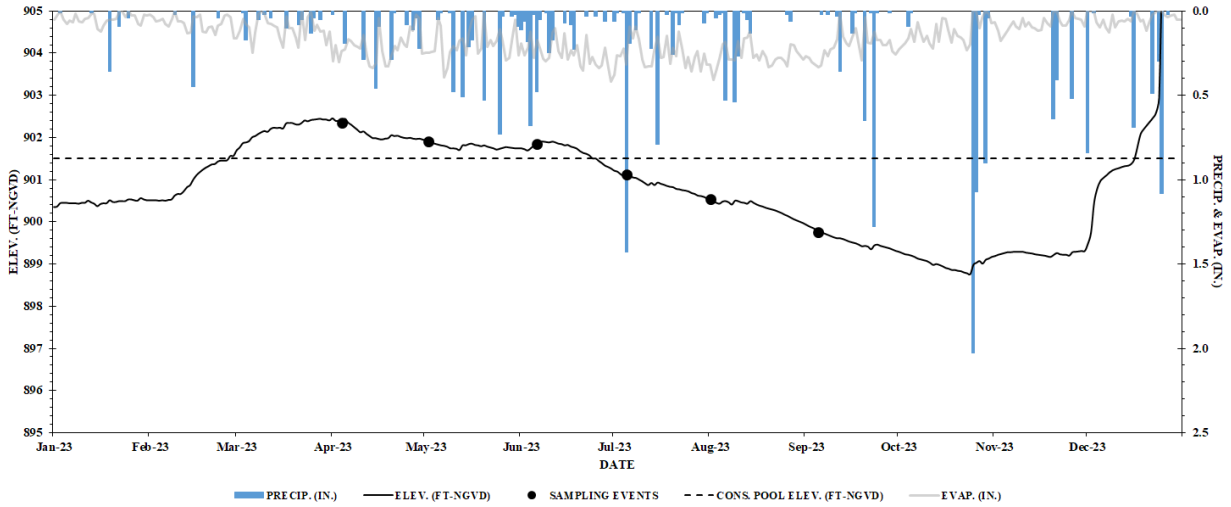

Figure 3. Daily lake elevation (feet, NGVD 29 at 0800 hours), conservation pool elevation (feet), basin precipitation (in.), evaporation rates, and water quality sampling dates at Toronto Lake, KS, 2023.

Water temperatures varied seasonally (ranging from 13.2 to 29.3 ºC), peaking in August, but lake-wide water temperatures, on individual sampling dates, displayed nominal variation. A water temperature profile at TORKSS0017 in June indicated developing thermal stratification. Wind and wave action frequently mix the generally shallow reservoir, and June was the only month with dissolved oxygen concentrations revealing hypoxia at depth at both TORKSS0017 and TORKSS0019. Median dissolved oxygen concentration for Toronto Lake through the study period was 6.78 mg/l. All observations of dissolved oxygen concentrations <3.0 mg/l were noted in June. Lake-wide total organic carbon concentrations were generally high (median 7.2 mg/l).

Specific conductance (median 434.7 µS/cm) was elevated relative to data collected since 2000. Total dissolved solids concentration (median 240 mg/l) was consistent with observed and regional norms. Concentrations of chloride (median 21.6 mg/l) were higher than past observations. Sulfate concentrations (median 23.5 mg/l) were comparable to historic levels. Alkalinity levels (median 167.5 mg/l as $CaCO_3$), higher than past observations, imply a well-buffered system capable of maintaining pH levels. Hardness levels, median concentration of 185 mg/l as $CaCO_3$, with a minimum value of 168 mg/l as $CaCO_3$, indicate 'very hard' water. Observed pH, ranging from 7.67 to 8.49, was within historic and regional norms.

The lake remained consistently turbid through 2023 primarily due to suspended inorganic particles. The maximum recorded Secchi depth was 0.59 meters with a study period median of 0.32 meters. A high percentage (91%) of recorded turbidity measurements were greater than or equal to 25 NTUs (median 41.08 NTU). Total suspended solids concentrations (median 32.5 mg/l) were influenced by re-suspension of bottom sediments through wind and wave action. The euphotic zone, assessed at Toronto Lake site TORKSS0017, was highest in June (2.6 meters) corresponding with the maximum observed Secchi depth. Typical euphotic zone depth through the 2023 study period was <1.5 meters.

Ammonia concentrations ranged from 0.03 to 0.26 mg/l (median 0.11 mg/l). Nitrite plus nitrate concentrations, ranging from <0.025 to 0.13 mg/l, were generally low with 79% of in-lake observations <0.025 mg/l. Total Kjeldahl nitrogen concentrations were moderate to high

(median 0.67 mg/l). Estimated median surface total nitrogen concentration through the study period was 0.69 mg/l. Lakewide median total phosphorus concentration was 0.11 mg/l, and surface median total phosphorus concentration was 0.09 mg/l. Nineteen of twenty-four (79%) in-lake dissolved ortho-phosphate concentration observations (median 0.04 mg/l) were ≥0.01 mg/l. Surface nitrogen to phosphorus (N:P) ratios varied from 1.8 to 12.6 through the study period, with a lake-wide median of 6.9, implying nitrogen availability may seasonally limit algal growth. Certain species of blue-green algae that can fix atmospheric nitrogen may have a competitive advantage during periods characterized by low N:P ratios.

Chlorophyll-*a* concentrations ranged from 6.8 to 62.1 µg/l through the study period and the lakewide median concentration of 17.6 µg/l indicates a productive system. Highest concentrations were observed at in-lake sites in September 2023. Figure 4, below, summarizes relative abundance and biovolume of divisions of phytoplankton observed at Toronto Lake. Relative abundance of Cyanophytes, Bacillariophytes, Chlorophytes, and Cryptophytes remained relatively stable through the sampling period. Relative biovolume indicates seasonal domination by Bacillariophytes with significant warm month representation by Euglenophytes and Pyrrophytes. Figure 5 summarizes zooplankton densities observed in 2023 (note the log scale density axis) at TORKSS0017 and TORKSS0019. Cladocerans, Copepods, and Rotifers were generally well represented across the sampling period.

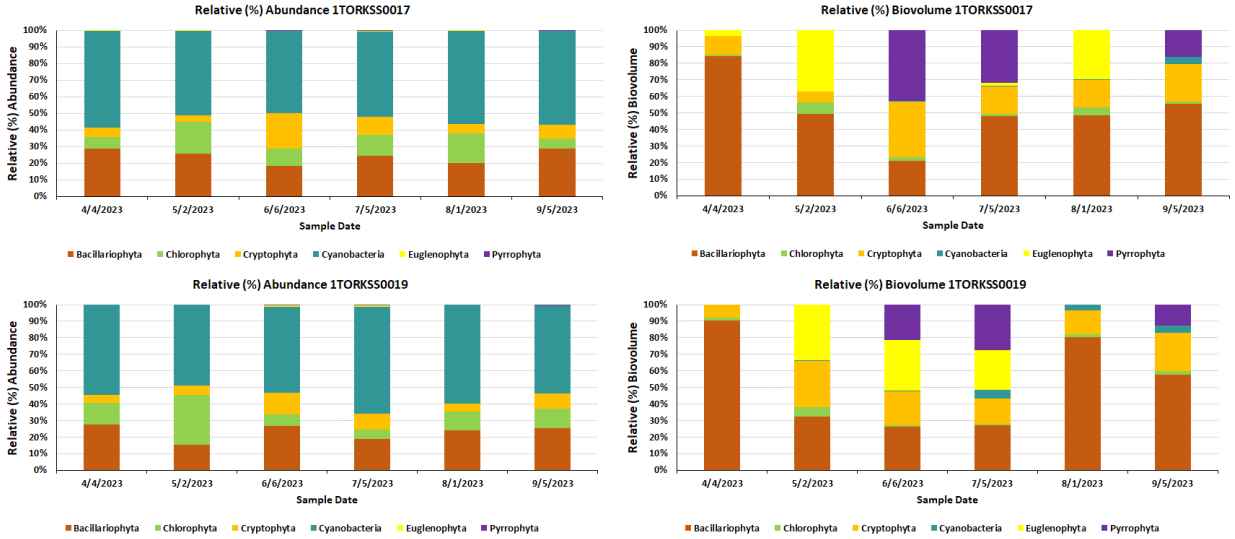

Figure 4. Phytoplankton relative abundance (left) and relative biovolume (right) at TORKSS0017, and TORKSS0019 April through September 2023.

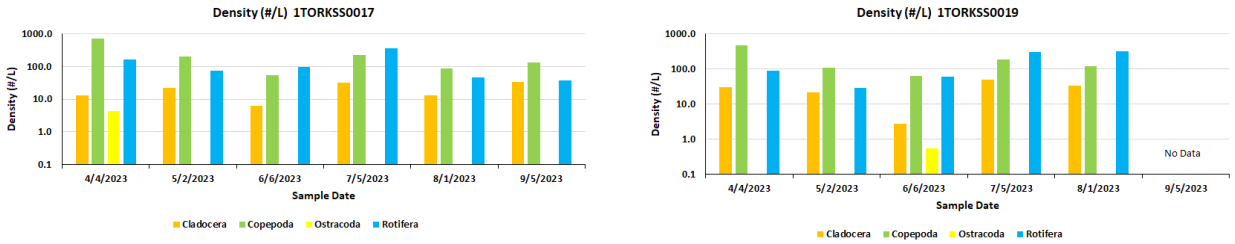

Figure 5. Zooplankton density at TORKSS0017 (left), and TORKSS0019 (right) April through September 2023.

The trophic status of Toronto Lake during the 2023 study period, assessed using Carlson's trophic state index (TSI) based on chlorophyll-*a* concentrations, TSI(CHLa), resulted in an index value of 58.7 indicating a eutrophic lake (Figure 6). The lakewide index value based on Secchi depth, TSI(SD), median 76.0, is elevated due to low water clarity primarily caused by suspended inorganic particles. The lakewide index based on surface total phosphorus concentrations, TSI(TP), median 69.8, indicates abundant phosphorus in the system, although a significant fraction may be bound to suspended sediment and not readily available for algal growth.

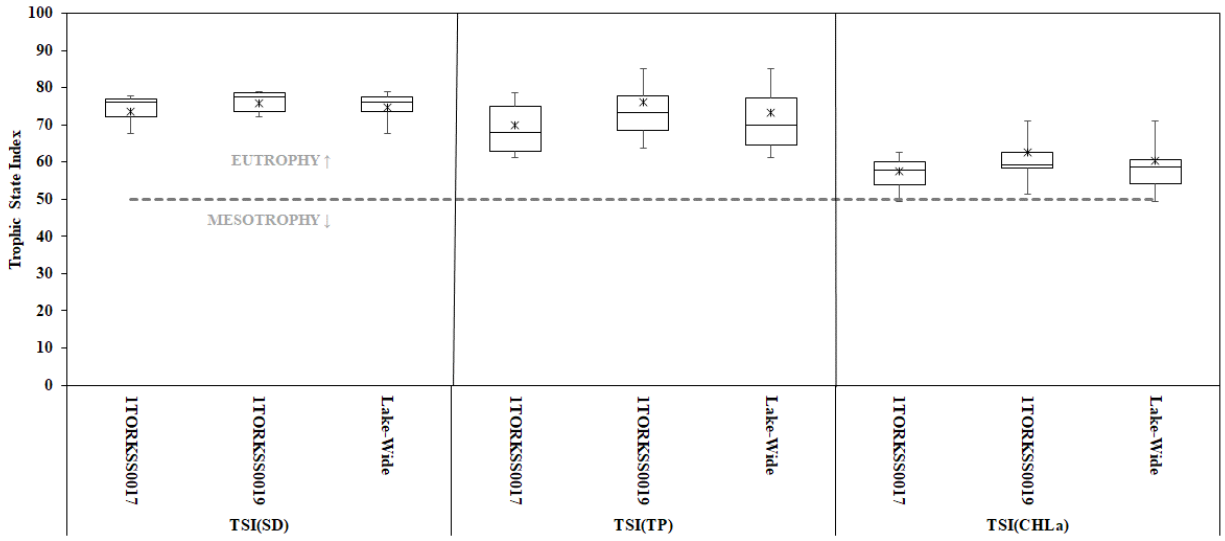

Figure 6. Distributions of Carlson's Trophic Sate Index (TSI), by sampling site and for the lake as a whole, based on observations of Secchi Depth (TSI(SD)), surface total phosphorus concentrations (TSI(TP)), and chlorophyll-a concentrations (TSI(CHLa)) at Toronto Lake, KS, April through September 2023.

Iron (median 0.69 mg/l) and manganese (median 0.21 mg/l) concentrations were relatively high. Approximately 17% of iron concentration observations exceeded the recommended criterion (1.0 mg/l) for protection of freshwater aquatic life. Observed manganese concentrations ranged from 0.09 to 0.87 mg/l with a lakewide median of 0.21 mg/l. All samples revealed detectable concentrations of metal pollutants arsenic, chromium, copper, lead, nickel, and zinc. Detectable mercury concentrations were found in 21% of samples collected with a maximum concentration of 0.39 µg/l found in a surface sample (0.5 meters depth) at TORKSS0017 in September.

Water samples were also collected in the stilling basin below the Toronto Lake dam at site TORKSS0023. Generally, statistical parameter results are comparable to in-lake data collected near the dam (TORKSS0017). Recorded dissolved oxygen concentrations were all ≥7.5 mg/l. A notably high chlorophyll-a concentration, 101.2 µg/l, was observed in June 2023.

USACE conducted water quality studies of Toronto Lake in 1998 and 2012. Each noted reduced water clarity likely limiting lake productivity. Also noted in earlier efforts were relatively high ammonia concentrations, and the trace metals arsenic and mercury occasionally exceeding U.S. EPA criteria for the protection of human health and aquatic life. A comparison of parameter medians between prior studies (1998 and 2012) and 2023 reveals similar results. Notable differences include higher median alkalinity, hardness, conductance, organic carbon, ammonia, and chlorophyll-a levels in 2023.