2018 Yates and Thurlow Reservoirs Report

Rivers and Reservoirs Monitoring Program

Alabama Department of Environmental Management

Field Operations Division
Rivers and Reservoirs Unit
June 2022

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2018

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LIST OF ACRONYMS

A&I	Agriculture and Industry water supply use classification
ADEM	Alabama Department of Environmental Management
AGPT	Algal Growth Potential Test
APCo	Alabama Power Company
CHL *a*	Chlorophyll *a*
DO	Dissolved Oxygen
F&W	Fish and Wildlife
MAX	Maximum
MDL	Method Detection Limit
MIN	Minimum
MSC	Mean Standing Crop
NTU	Nephelometric Turbidity Units
OAW	Outstanding Alabama Waters
ONRW	Outstanding National Resource Water
PWS	Public Water Supply
QAPP	Quality Assurance Project Plan
RRMP	Rivers and Reservoirs Monitoring Program
S	Swimming and Other Whole Body Water-Contact Sports
SD	Standard Deviation
SOP	Standard Operating Procedures
TEMP	Temperature
TN	Total Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSI	Trophic State Index
TSS	Total Suspended Solids
USACE	United States Army Corp of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

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INTRODUCTION

Established in 1928 with the completion of Yates Dam, Yates Reservoir contains approximately 1,980 acres of surface water. It is the third reservoir on the Tallapoosa River system in Alabama, located downstream of Martin Reservoir. Thurlow Reservoir, completed in 1930, is located immediately downstream of Yates Reservoir and contains approximately 585 acres of surface water. The 2015 and 2018 Yates and Thurlow Reservoirs monitoring information is presented together in this report due to the each reservoir's small size and close proximity to each other.

The Alabama Department of Environmental Management (ADEM) monitored Yates and Thurlow Reservoirs as part of the 2015 and 2018 assessments of the Tallapoosa River basins under the Rivers and Reservoirs Monitoring Program (RRMP). ADEM began monitoring lake water quality statewide in 1985, followed by a second statewide survey in 1989. In 1990, the Reservoir Water Quality Monitoring Program (now known as RRMP) was initiated by the Field Operations Division of the ADEM. The current objectives of this program are to provide data that can be used to assess current water quality conditions, to identify trends in water quality conditions, and to develop Total Maximum Daily Loads (TMDLs) and water quality criteria. Descriptions of all RRMP monitoring activities are available in ADEM's 2017 Monitoring Strategy (ADEM 2017).

In 1998, the Sougahatchee embayment of Yates Reservoir was placed on Alabama's Clean Water Act (CWA) §303(d) list of impaired waters for not meeting its Public Water Supply (PWS)/Swimming (S)/Fish & Wildlife (F&W) water use classifications. The reservoir was listed for impairments caused by nutrients and organic enrichment/dissolved oxygen (OE/DO). USEPA approved delisting the Sougahatchee embayment for these contaminants in the 2010 §303(d) listings after a TMDL developed to address these pollutants was approved in 2008 (ADEM 2008). The Alabama Department of Public Health (ADPH) issued consumption advisories for Thurlow Reservoir in 2011 and for the Sougahatchee embayment of Yates Reservoir in 2014 due to mercury found in fish tissue. As a result, Thurlow Reservoir was placed on Alabama's 2012 Clean Water Act (CWA) §303(d) list of impaired waters for mercury contamination caused by atmospheric deposition. The Sougahatchee embayment was listed on the 2016 Clean Water Act

(CWA) §303(d) list. Additionally, the Channahatchee embayment of Yates Reservoir was listed on the 2012 Clean Water Act (CWA) §303(d) list for organic enrichment (BOD) resulting from nonpoint source runoff. A TMDL has not yet been approved for this embayment.

In 2002, the ADEM implemented specific water quality criteria for nutrient monitoring at the lower Yates and Thurlow locations (Table 1). These criteria represent maximum growing season mean (April-October) chlorophyll *a* (chl *a)* concentrations that are protective of the reservoirs' Public Water Supply, Swimming and Fish & Wildlife (PWS/S/F&W) use classifications.

The purpose of this report is to summarize data collected at four stations in Yates Reservoir and one station in Thurlow Reservior during the 2015 and 2018 growing seasons and to evaluate trends in mean lake trophic status and nutrient concentrations using ADEM's historical dataset. Monthly and/or mean concentrations of nutrients [total nitrogen (TN); total phosphorus (TP)], algal biomass/productivity [chl *a*; algal growth potential testing (AGPT)], sediment [total suspended solids (TSS)], and trophic state [Carlson's trophic state index (TSI)] were compared to ADEM's existing data and established criteria.

METHODS

Sampling stations were selected using historical data and previous assessments (Figure 1). Specific location information can be found in Table 1. Yates and Thurlow Reservoirs were both sampled in the dam forebay. Yates Reservoir was also sampled in the Martin Dam tailrace and in two tributary embayment stations—Channahatchee and Sougahatchee Creeks. Because Sougahatchee Creek has such a large watershed that contains a rapidly developing urban/suburban area, monthly graphs were prepared and included in the report along with those of mainstem sampling locations.

Water quality sampling was conducted at monthly intervals throughout the growing season, April-October. All samples were collected, preserved, stored, and transported according to procedures in the ADEM Field Operations Division Standard Operating Procedures (ADEM 2018a), Surface Water Quality Assurance Project Plan (ADEM 2018b), and Quality Management Plan (ADEM 2018c).

Mean growing season TN, TP, chl *a*, and TSS were calculated to evaluate water quality conditions at each site. Monthly concentrations of these parameters were graphed with the closest available discharge data and ADEM's previously collected data to help interpret the 2015 and 2018 results.

Figure 1. Yates and Thurlow Reservoirs with 2015 and 2018 sampling locations. A description of each sampling location is provided in Table 1.

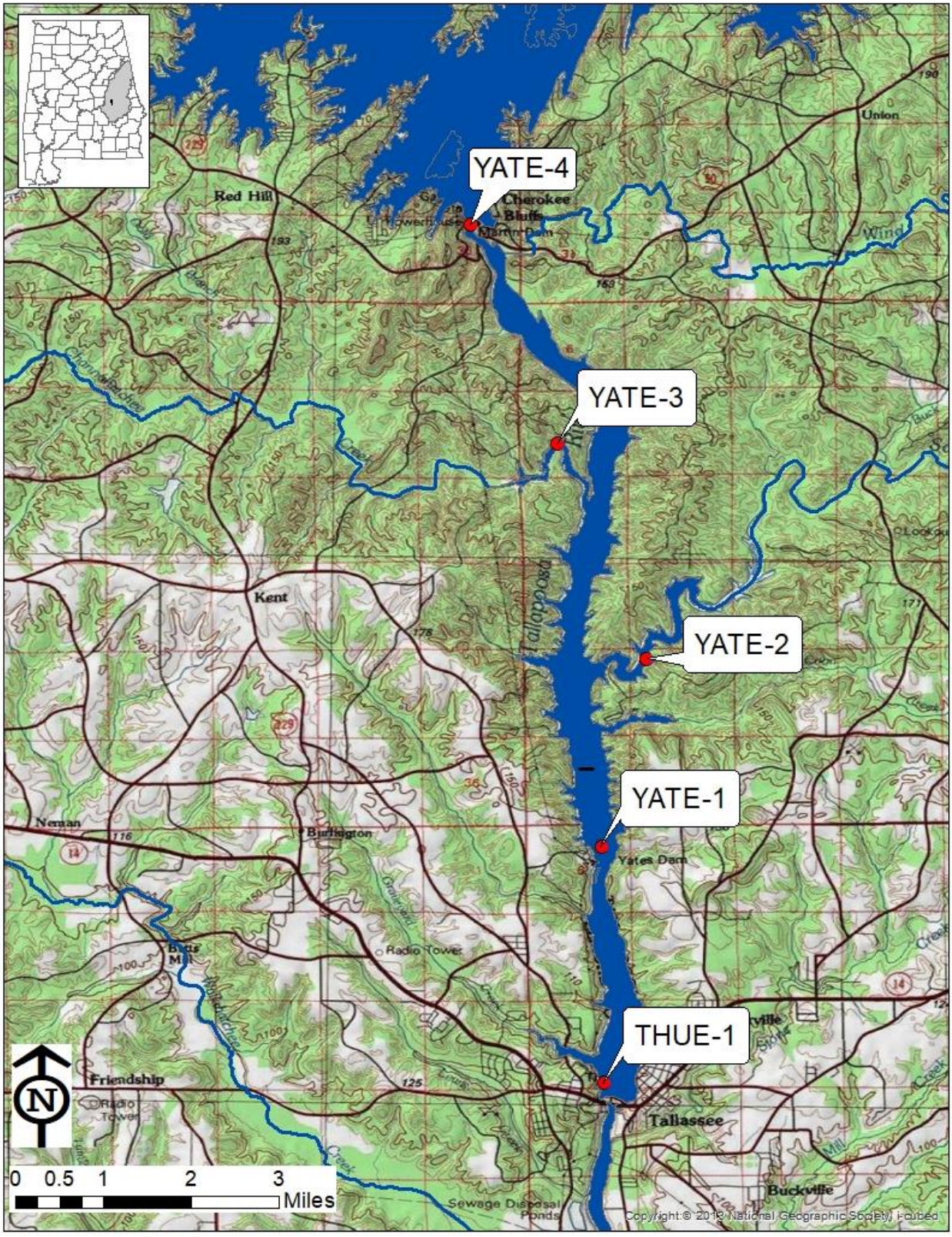


Table 1. Descriptions of the 2015 and 2018 monitoring stations on Yates and Thurlow Reservoirs.

Thurlow and Yates Reservoirs								
HUC	**County**	**Station Number**	**Report Designation**	**Waterbody Name**	**Station Description**	**Chl *a* Criteria**	**Latitude**	**Longitude**
031501100406	Elmore	THUE-1*	Lower Thurlow	Tallapoosa R	Deepest point, main river channel, dam forebay .	5 μg/L	32.5376	-85.8893
031501100406	Tallapoosa	YATE-1*	Lower Yates	Tallapoosa R	Deepest point, main river channel, dam forebay.	5 μg/L	32.5766	-85.8896
031501100104	Tallapoosa	YATE-2	Sougahatchee Ck	Sougahatchee Cr	Deepest point, main creek channel, Sougahatchee Creek embayment. Approx. 1.6 miles upstream from the Tallapoosa River confluence.		32.6131	-85.8765
031501100402	Elmore	YATE-3	Channahatchee Ck	Channahatchee Cr	Deepest point, main creek channel, Channahatchee Creek embayment, approx. 0.5 miles upstream of lake confluence.		32.6432	-85.8969
031501100406	Tallapoosa	YATE-4	Upper Yates	Tallapoosa R	Deepest point, main river channel, Martin Dam tailrace		32.67943	-85.91125

*Growing season mean chl *a* criteria implemented at this station in 2002.

RESULTS

Growing season mean graphs for TN, TP, chl *a*, and TSS are provided in this section (Figures 2 & 3). Monthly graphs for TN, TP, chl *a*, TSS, DO, and TSI are also provided (Figures 4-9 & 14-15). Mean monthly discharge included as an indicator of flow and retention time in the months sampled. AGPT results appear in Table 2. Depth profile graphs of DO, temperature, and conductivity appear in Figures 10-13. Summary statistics of all data collected during 2015 and 2018 are presented in Appendix Table 1 and Appendix Table 2, respectively. The table contains the minimum, maximum, median, mean, and standard deviation of each parameter analyzed.

Stations with the highest concentrations of nutrients, chlorophyll *a*, and TSS are noted in the paragraphs to follow. Though stations with lowest concentrations may not be mentioned, review of the graphs that follow will indicate these stations that may be potential candidates for reference waterbodies and watersheds.

In both 2015 and 2018, the highest mean growing season TN value was calculated for the Sougahatchee Ck station (Figure 2). All stations on Yates and Thurlow Reservoirs saw a slight decrease in mean TN from 2015 to 2018. Mean values in Sougahatchee Ck have decreased since 2010, whereas the other stations have remained relatively stable. In 2015, monthly TN concentrations reached historical highs at the upper Yates station in August, September, and October, at the lower Yates station in April, and at the lower Thurlow station in October (Figure 4). In 2018, monthly TN concentrations were at or below historic means for most months, the exceptions being April at the upper Yates station, which was a historical high, and April at the lower Yates station.

In both 2015 and 2018, the highest mean growing season TP value was calculated for the Sougahatchee Ck station, though mean concentrations at Channahatchee Ck were only slightly less (Figure 2). The mean TP values calculated in 2018 at Sougahatchee Ck, the lower Yates station, and the lower Thurlow station were the lowest concentrations measured since monitoring began in 1997. In general, all stations appear to show a decreasing trend in mean values. All monthly TP concentrations measured during both years were at or below historic means, except

at the lower Yates station in October 2018 and at the lower Thurlow station in April 2015 (Figure 5).

In 2015, the highest mean growing season chl *a* value was calculated for the Channahatchee Ck station. In 2018, the highest mean growing season chl *a* value was calculated for the Sougahatchee Ck station (Figure 3). While mean concentrations at Sougahatchee Ck and the lower Yates station have generally decreased since 2008, concentrations at the lower Thurlow station have increased since 2000. Mean chl *a* at Channahatchee Ck has been variable over the years, and values at the upper Yates station were much lower than the other stations sampled, except in 2018. Specific water quality criteria for nutrient management were established at the lower Yates station and the lower Thurlow station in 2002. The seasonal mean chl *a* concentration measured at the lower Yates station was below the criteria limit in both 2015 and 2018. However, in 2018, the mean chl *a* concentration in Thurlow Reservoir exceeded the criteria limit for the first time. Most monthly chl *a* concentrations in Yates Reservoir were at or below historic means throughout the growing season in 2015 and 2018 (Figure 6). Thurlow Reservoir had the highest monthly value observed during either growing season during September 2018, which was a historic high. Historic highs were also measured in the lower Thurlow station in August 2015 and the upper Yates station in September 2018.

In 2015, the highest mean growing season TSS value was calculated for the Channahatchee Ck station (Figure 3). In 2018, the highest mean growing season TSS value was calculated for the Sougahatchee Ck station. Mean TSS concentrations have been much lower in the mainstem stations than in the embayment station in all years sampled. In 2018, upper Yates, lower Yates, and lower Thurlow had the lowest mean TSS values calculated since monitoring began at those stations. Monthly TSS concentrations in 2015 were at or below historic mean values in all months at all stations, except Sougahatchee Ck in April (Figure 7). In 2018, the highest monthly TSS concentration was measured in October at Sougahatchee Ck.

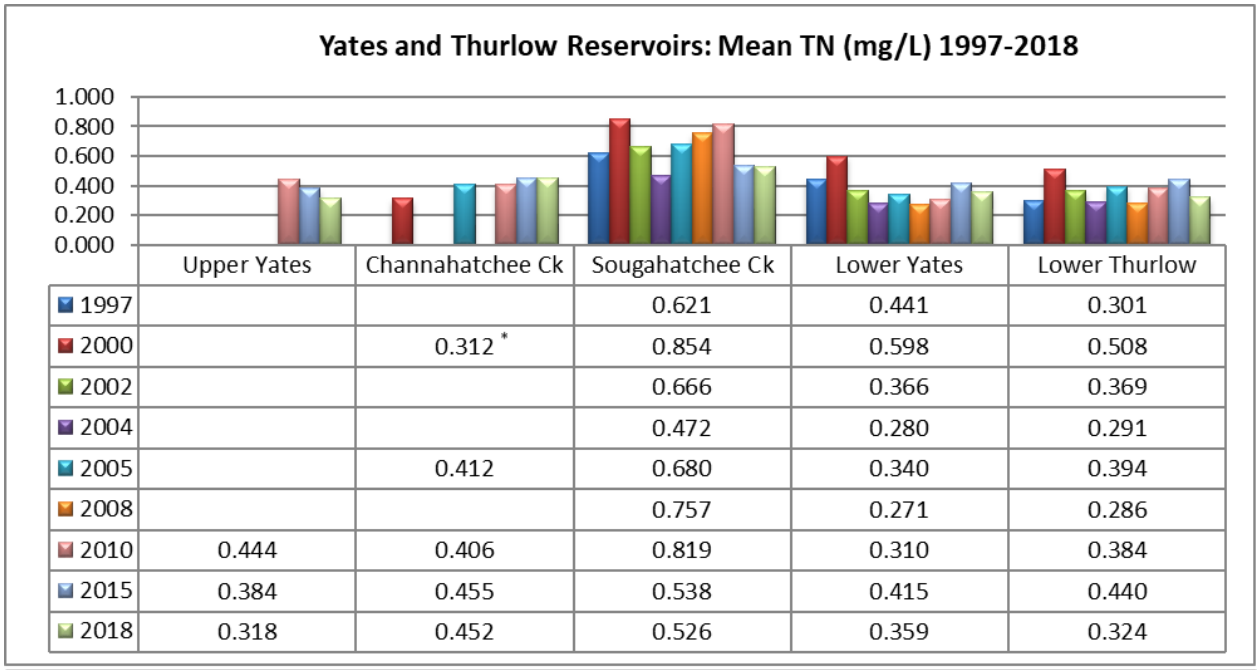
AGPT results collected in 2015 for the upper and lower Yates stations indicated they were phosphorus-limited (Table 2). Channahatchee Ck and Sougahatchee Ck were co-limiting in 2015. Raschke and Schultz (1987) defined a mean standing crop (MSC) value of 5.0 mg/L as protective of reservoir and lake systems. All MSC values in Yates Reservoir were <5.0 mg/L,

except at Sougahatchee Ck, which was 5.82 mg/L, slightly above the 5.0 mg/L target, but still the lowest MSC value measured at that station. No AGPT samples were collected at Yates Reservoir in 2018 or at Thurlow Reservoir in 2015 or 2018.

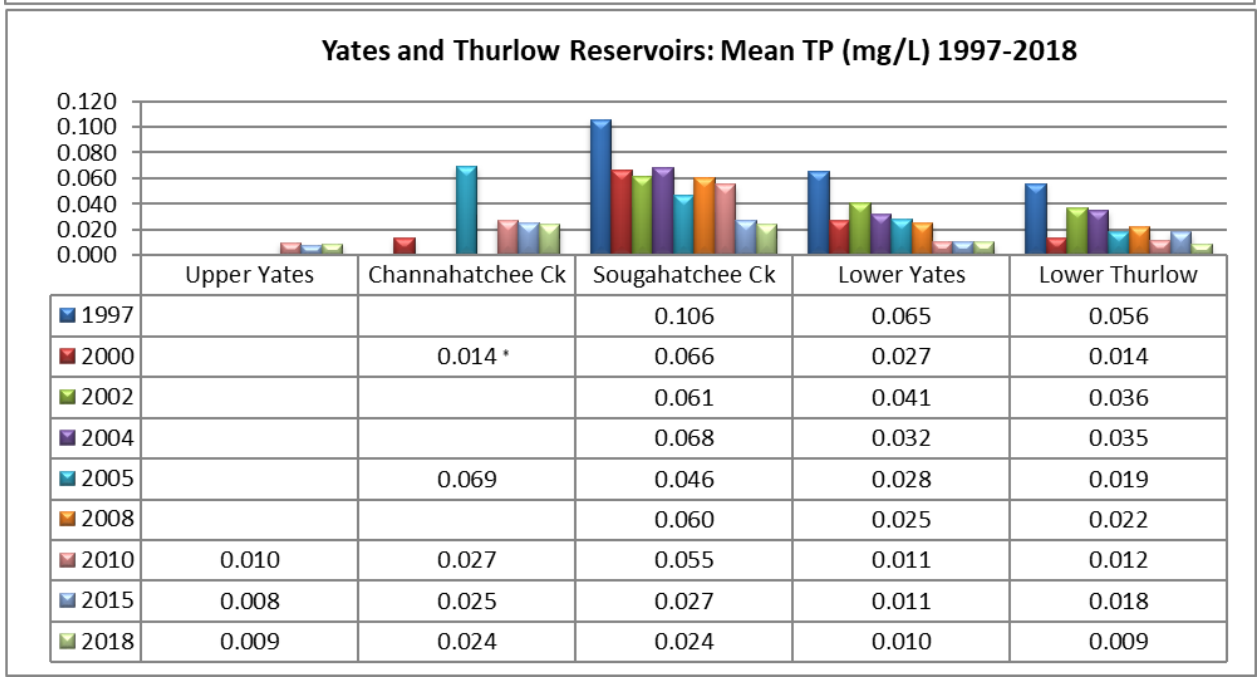
In 2015, dissolved oxygen (DO) concentrations were below the minimum criteria limit of 5.0 mg/L at 5.0 ft (1.5 m) (ADEM Admin. Code R. 335-6-10-.09) at Sougahatchee Ck in June, July, and September and at Channahatchee Ck in June and July (Figure 8). All mainstem stations had DO values above criteria throughout the growing season in 2015. In 2018, DO concentrations were below the minimum criteria limit at Sougahatchee Ck in July and September and at Channahatchee Ck in July, August, and September (Figure 9). All mainstem DO concentrations were at or above criteria throughout the growing season in 2018. In 2015, both Yates and Thurlow Reservoirs were thermally stratified May-September (Figures 10 & 11). In 2018, the lower Yates station was thermally stratified May-September, and the lower Thurlow station was thermally stratified June-September (Figures 12 & 13).

Monthly TSI values were calculated using monthly chl *a* values and Carlson's Trophic State Index (Carlson 1977). The upper Yates station was oligotrophic all months sampled in 2015, while the lower Yates station was oligotrophic all months except July and September, which were mesotrophic (Figure 14). Channahatchee Ck reached eutrophic conditions July-September, Sougahatchee Ck was eutrophic in July, September, and October, and the lower Thurlow station was eutrophic in August and September. In 2018, the upper Yates station was oligotrophic all months except August, which was eutrophic (Figure 15). The lower Yates station was oligotrophic in May, June, and October but was mesotrophic all other months. Eutrophic conditions were observed in Channahatchee Ck in July and September and in Sougahatchee Ck in September and October. The lower Thurlow station reached eutrophic conditions in September, but varied between oligotrophic and mesotrophic all other months sampled.

Figure 2. Mean growing season total nitrogen and total phosphurous of all stations in Yates and Thurlow Reservoirs, April-October 1997-2018**.** Bar graphs consist of multiple stations, illustrated from upstream to downstream as the graph is read from left to right.



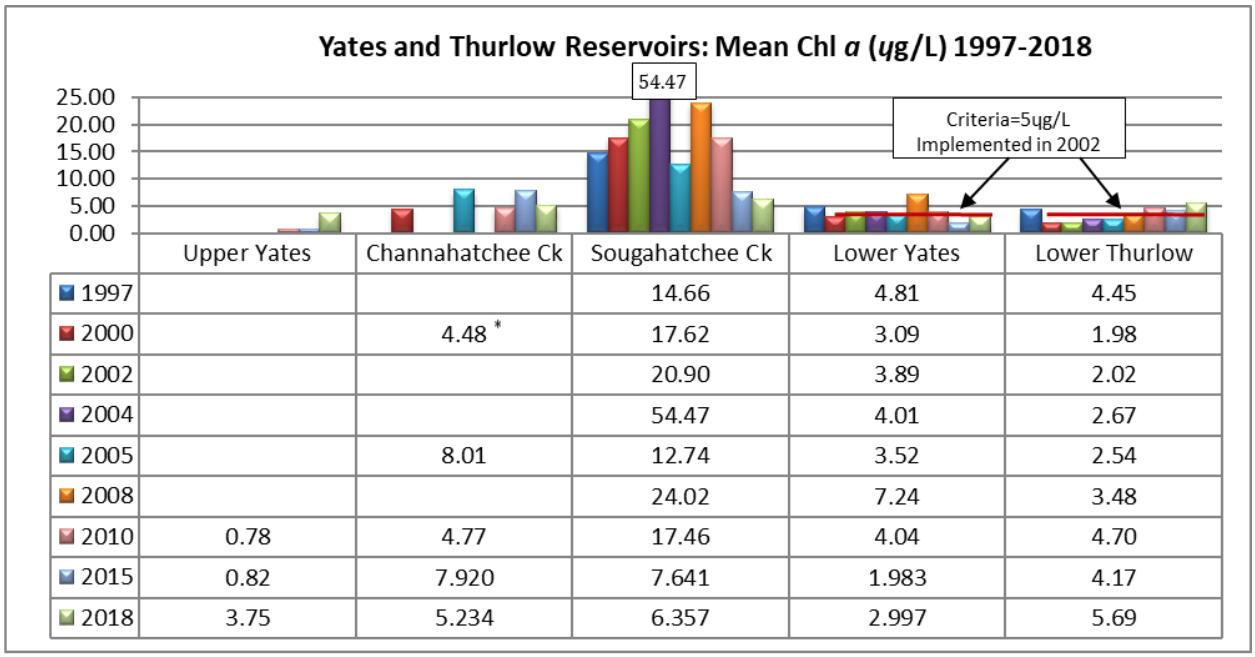
	Upper Yates	Channahatchee Ck	Sougahatchee Ck	Lower Yates	Lower Thurlow
1997			0.621	0.441	0.301
2000		0.312 *	0.854	0.598	0.508
2002			0.666	0.366	0.369
2004			0.472	0.280	0.291
2005		0.412	0.680	0.340	0.394
2008			0.757	0.271	0.286
2010	0.444	0.406	0.819	0.310	0.384
2015	0.384	0.455	0.538	0.415	0.440
2018	0.318	0.452	0.526	0.359	0.324



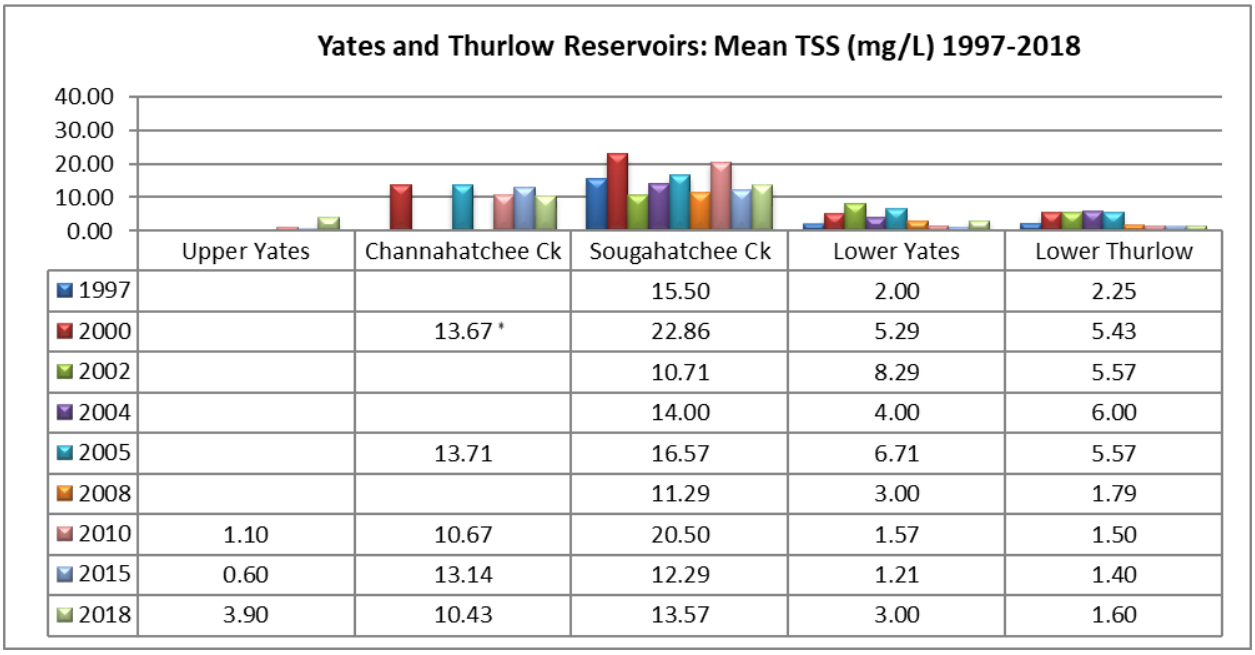
	Upper Yates	Channahatchee Ck	Sougahatchee Ck	Lower Yates	Lower Thurlow
1997			0.106	0.065	0.056
2000		0.014 *	0.066	0.027	0.014
2002			0.061	0.041	0.036
2004			0.068	0.032	0.035
2005		0.069	0.046	0.028	0.019
2008			0.060	0.025	0.022
2010	0.010	0.027	0.055	0.011	0.012
2015	0.008	0.025	0.027	0.011	0.018
2018	0.009	0.024	0.024	0.010	0.009

*Mean of April/June/August only.

Figure 3. Mean growing season chlorophyll *a* and total suspended solids in all stations in Yates and Thurlow Reservoirs, April-October 1997-2018. Bar graphs consist of multiple stations, illustrated from upstream to downstream as the graph is read from left to right.



	Upper Yates	Channahatchee Ck	Sougahatchee Ck	Lower Yates	Lower Thurlow
1997			14.66	4.81	4.45
2000		4.48 *	17.62	3.09	1.98
2002			20.90	3.89	2.02
2004			54.47	4.01	2.67
2005		8.01	12.74	3.52	2.54
2008			24.02	7.24	3.48
2010	0.78	4.77	17.46	4.04	4.70
2015	0.82	7.920	7.641	1.983	4.17
2018	3.75	5.234	6.357	2.997	5.69



	Upper Yates	Channahatchee Ck	Sougahatchee Ck	Lower Yates	Lower Thurlow
1997			15.50	2.00	2.25
2000		13.67 *	22.86	5.29	5.43
2002			10.71	8.29	5.57
2004			14.00	4.00	6.00
2005		13.71	16.57	6.71	5.57
2008			11.29	3.00	1.79
2010	1.10	10.67	20.50	1.57	1.50
2015	0.60	13.14	12.29	1.21	1.40
2018	3.90	10.43	13.57	3.00	1.60

*Mean of April/June/August only.

Figure 4. Monthly TN concentrations measured in Yates and Thurlow Reservoirs, April-October 2015 and 2018 vs. average monthly discharge. Monthly discharge acquired from Alabama Power at Yates Reservoir Dam. Each bar graph depicts monthly changes in each station. The historic mean (1994-2018) and min/max ranges are also displayed for comparison. The "n" value equals the number of datapoints included in the monthly historic calculations.

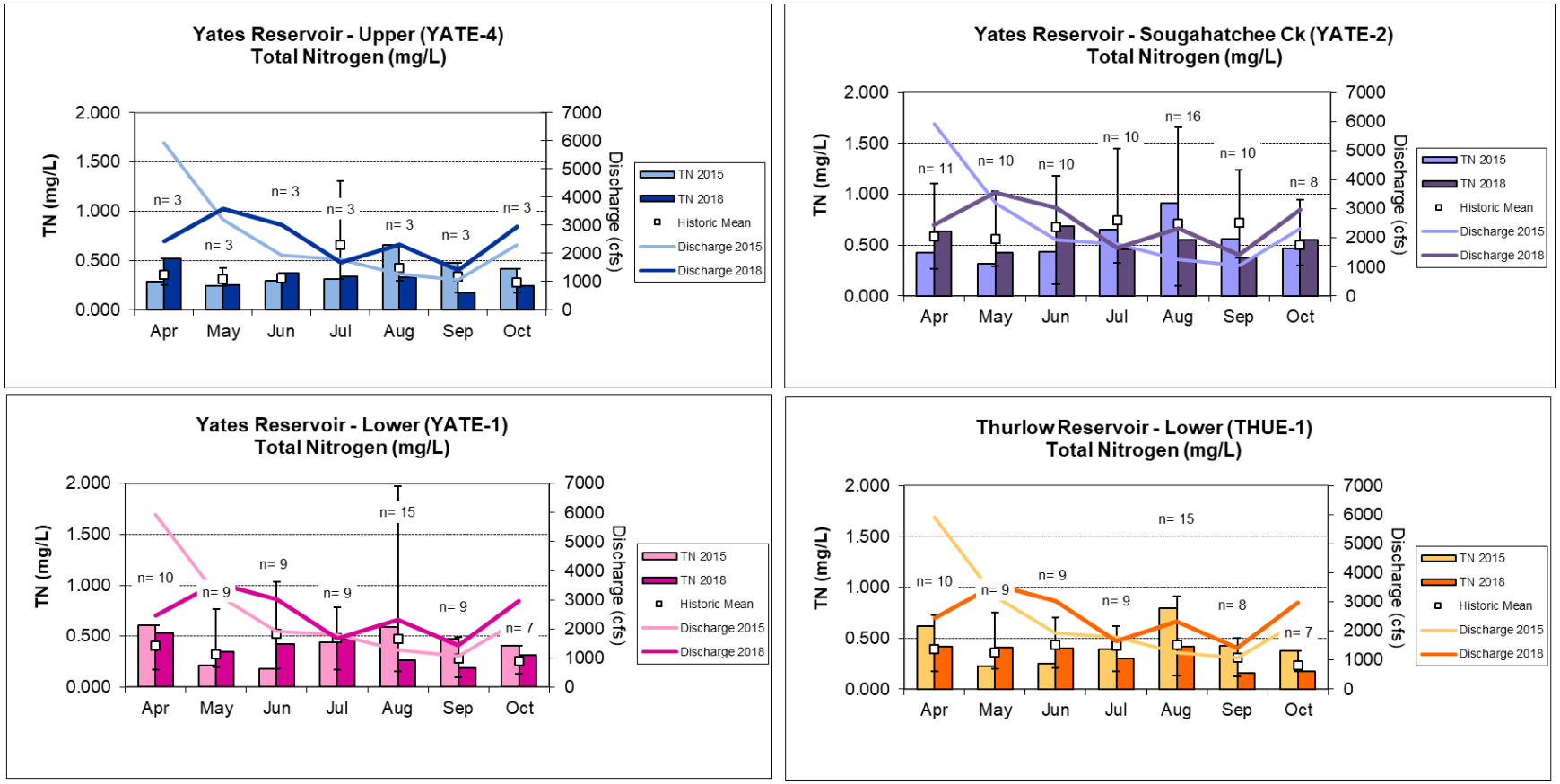


Figure 5. Monthly TP concentrations measured in Yates and Thurlow Reservoirs, April-October 2015 and 2018 vs. average monthly discharge. Monthly discharge acquired from Alabama Power at Yates Reservoir Dam. Each bar graph depicts monthly changes in each station. The historic mean (1994-2018) and min/max ranges are also displayed for comparison. The "n" value equals the number of datapoints included in the monthly historic calculations.

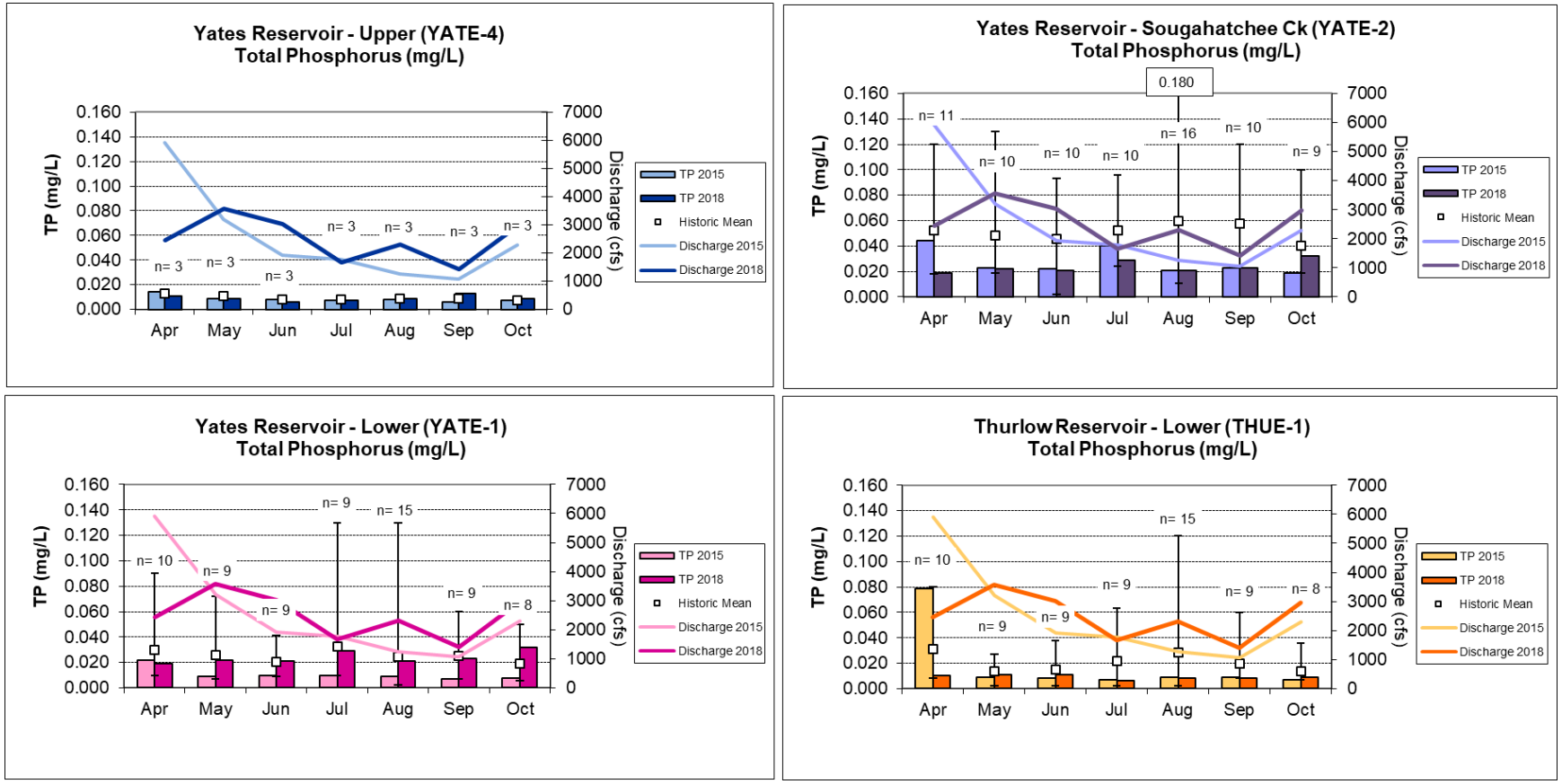


Figure 6. Monthly chl *a* concentrations measured in Yates and Thurlow Reservoirs, April-October 2015 and 2018 vs. average monthly discharge. Monthly discharge acquired from Alabama Power at Yates Reservoir Dam. Each bar graph depicts monthly changes in each station. The historic mean (1994-2018) and min/max ranges are also displayed for comparison. The "n" value equals the number of datapoints included in the monthly historic calculations.

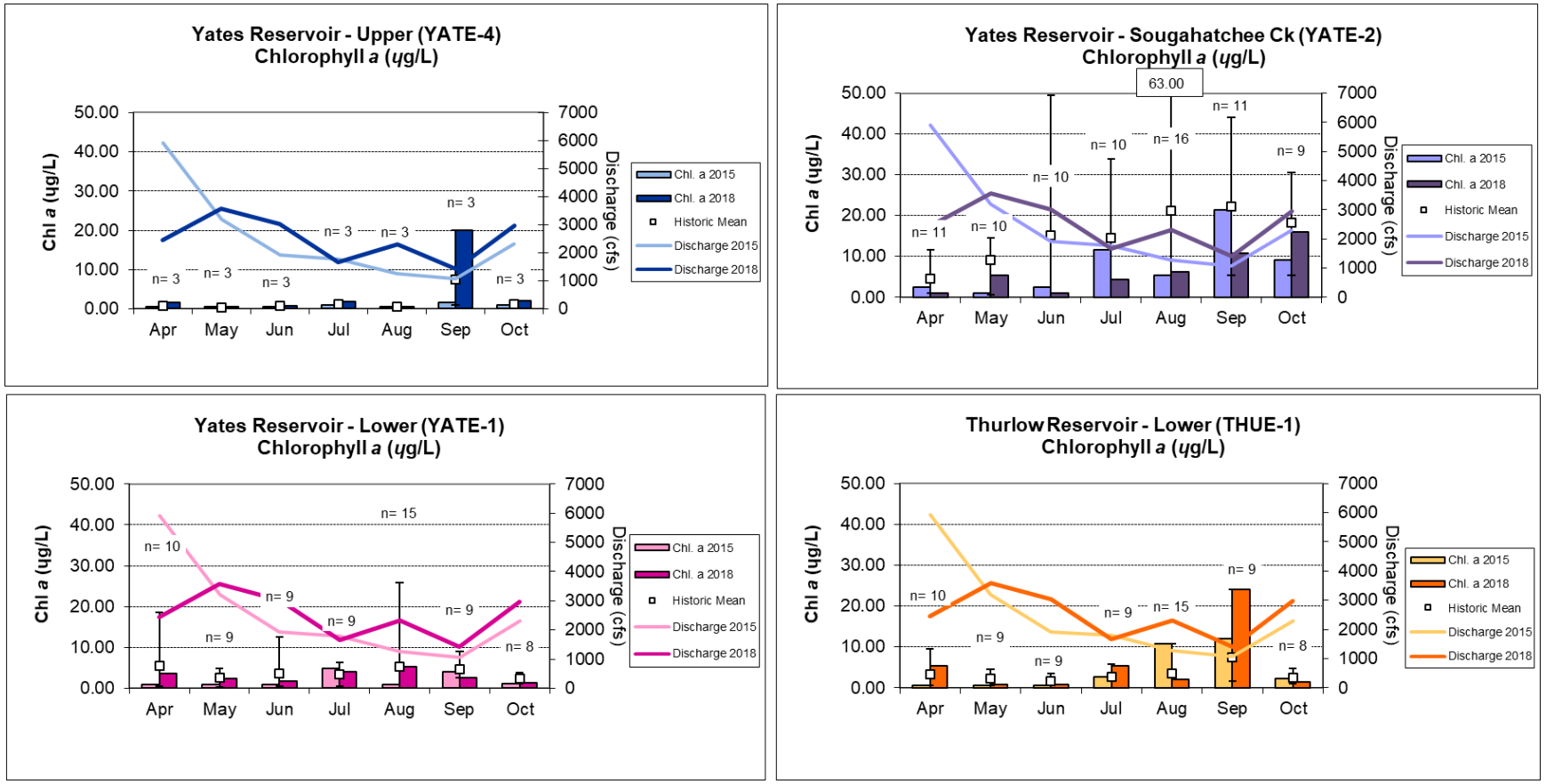


Figure 7. Monthly TSS concentrations measured in Yates and Thurlow Reservoirs, April-October 2015 and 2018 vs. average monthly discharge. Monthly discharge acquired from Alabama Power at Yates Reservoir Dam. Each bar graph depicts monthly changes in each station. The historic mean (1994-2018) and min/max ranges are also displayed for comparison. The "n" value equals the number of datapoints included in the monthly historic calculations.

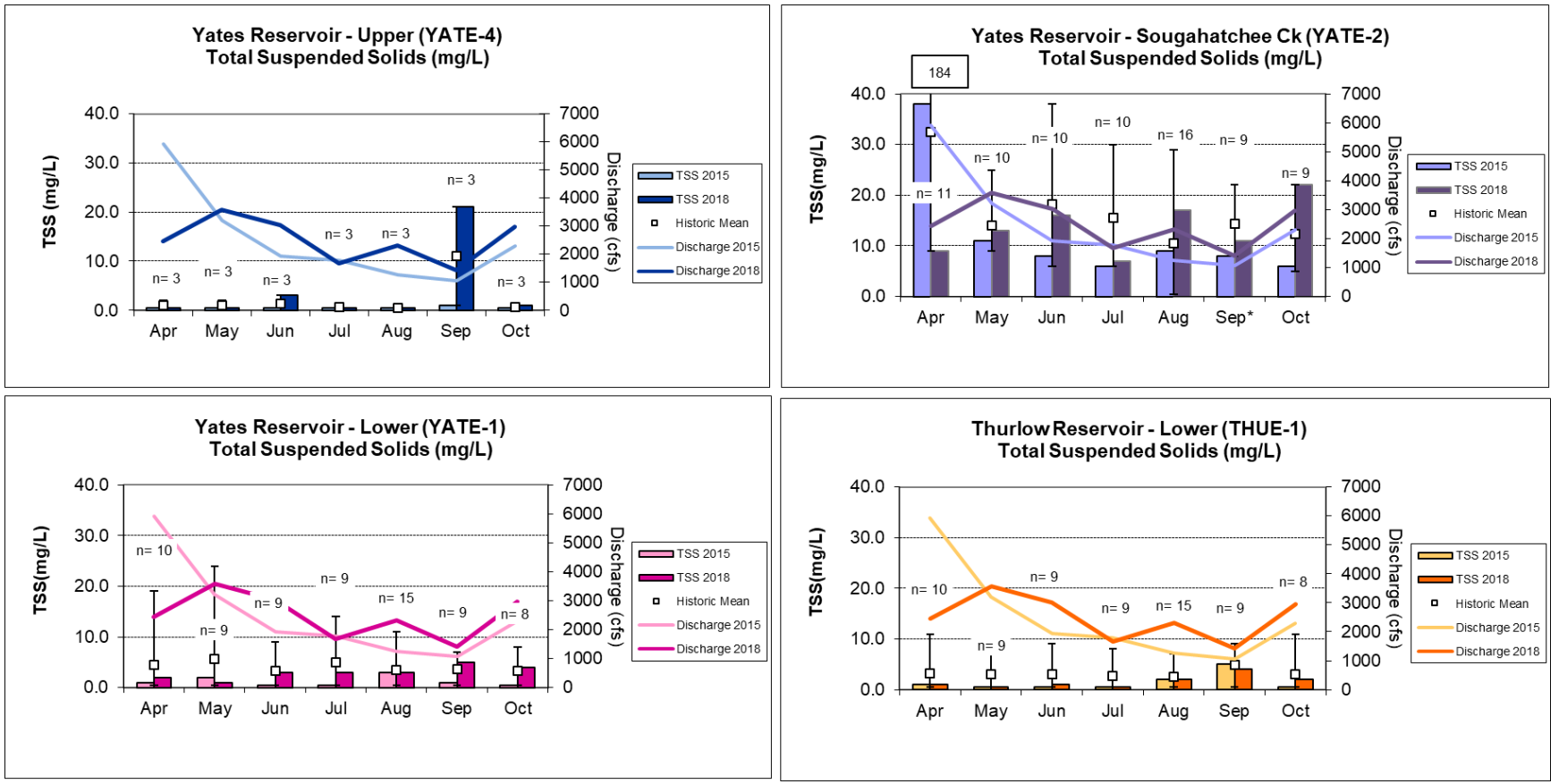


Table 2. Algal growth potential test results, Yates and Thurlow Reservoirs, (expressed as mean Maximum Standing Crop [MSC] dry weights of *Selenastrum capricornutum* in mg/L) and limiting nutrient status. MSC values below 5 mg/L are considered to be protective in reservoirs and lakes (Raschke and Schultz 1987).

Station	Upper Yates (YATE-4)		Channahatchee Ck (YATE-3)		Sougahatchee Ck (YATE-2)		Lower Yates (YATE-1)	
	Control mean MSC	Limiting Nutrient	Control mean MSC	Limiting Nutrient	Control mean MSC	Limiting Nutrient	Control mean MSC	Limiting Nutrient
1997	---	---	---	---	36.92	NITROGEN	1.29	PHOSPHORUS
2000	---	---	---	---	7.14	NITROGEN	2.52	PHOSPHORUS
2005	---	---	---	---	---	---	3.35	PHOSPHORUS
2010	---	---	3.22	PHOSPHORUS	9.32	PHOSPHORUS	---	---
2015	2.09	PHOSPHORUS	3.26	CO-LIMITING	5.82	CO-LIMITING	3.47	PHOSPHORUS
2018	---	---	---	---	---	---	---	---

Station	Lower Thurlow (THUE-1)	
	Control mean MSC	Limiting Nutrient
1997	1.39	PHOSPHORUS
2000	2.53	PHOSPHORUS
2005	4.6	PHOSPHORUS
2010	1.52	PHOSPHORUS
2015	---	---
2018	---	---

Figure 8. Monthly DO concentrations at 1.5 m (5 ft) for Yates and Thurlow Reservoirs stations collected April-October 2015. ADEM Water Quality Criteria pertaining to reservoir waters require a DO concentration of 5.0 mg/L at this depth (ADEM 2017).

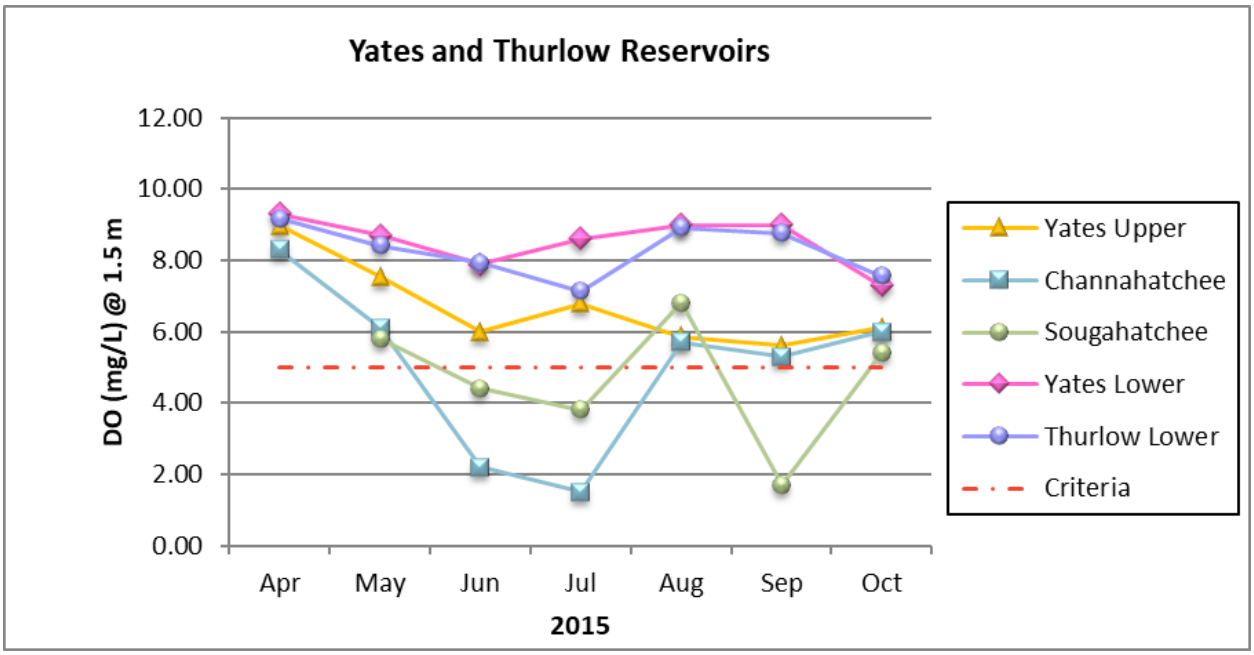


Figure 9. Monthly DO concentrations at 1.5 m (5 ft) for Yates and Thurlow Reservoirs stations collected April-October 2018. ADEM Water Quality Criteria pertaining to reservoir waters require a DO concentration of 5.0 mg/L at this depth (ADEM 2017).

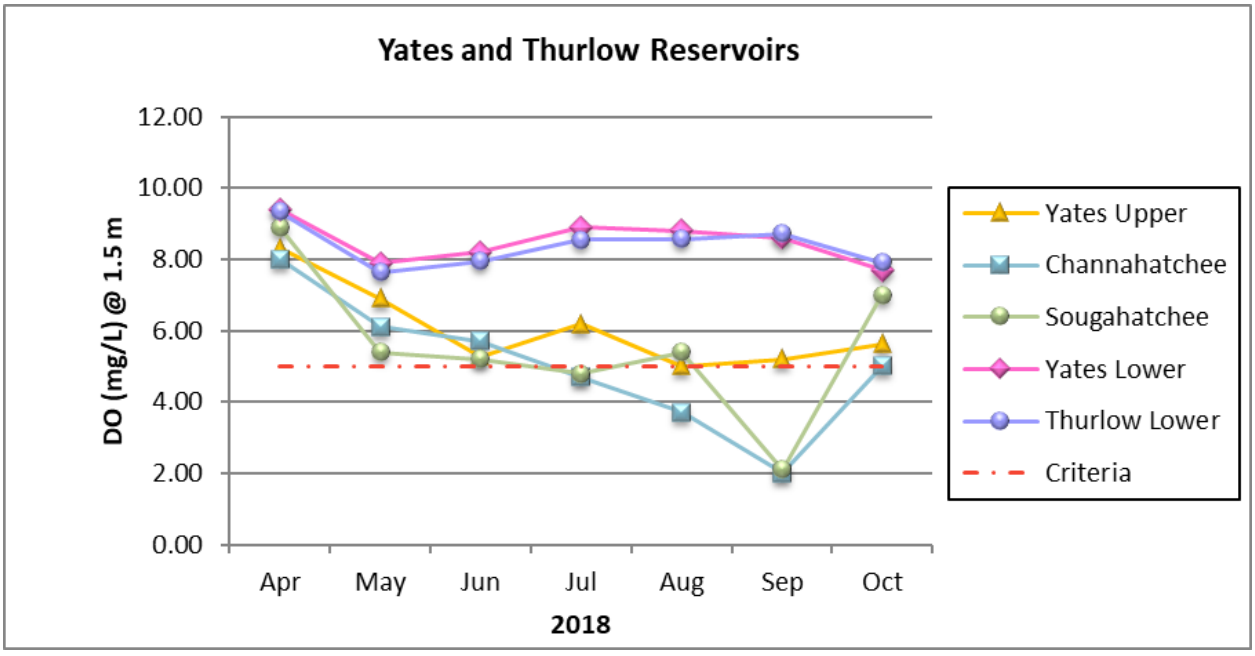


Figure 10. Monthly depth profiles of dissolved oxygen, temperature, and conductivity in the lower Yates Reservoir station, April-October 2015.

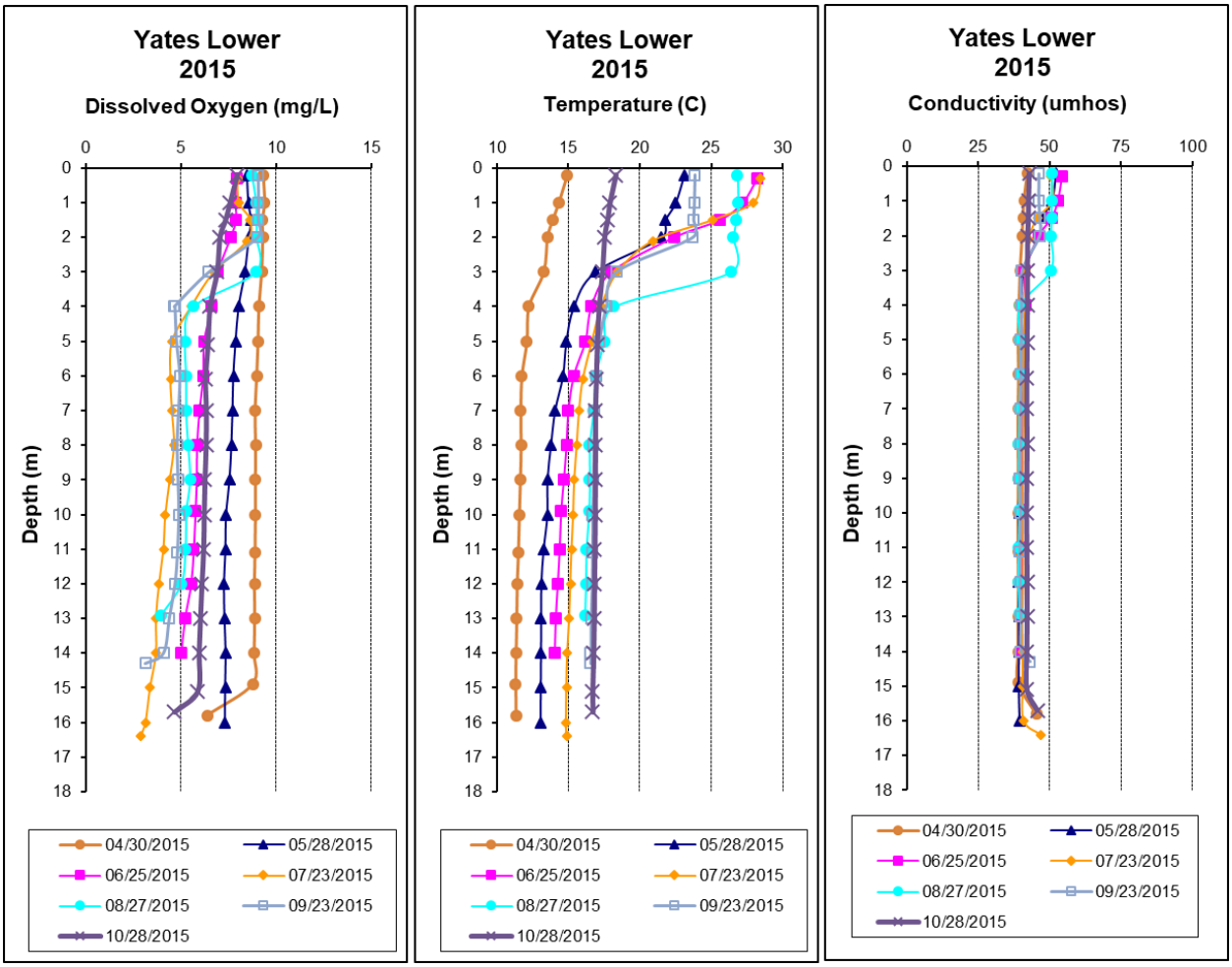


Figure 11. Monthly depth profiles of dissolved oxygen, temperature, and conductivity in the lower Thurlow Reservoir station, April-October 2015.

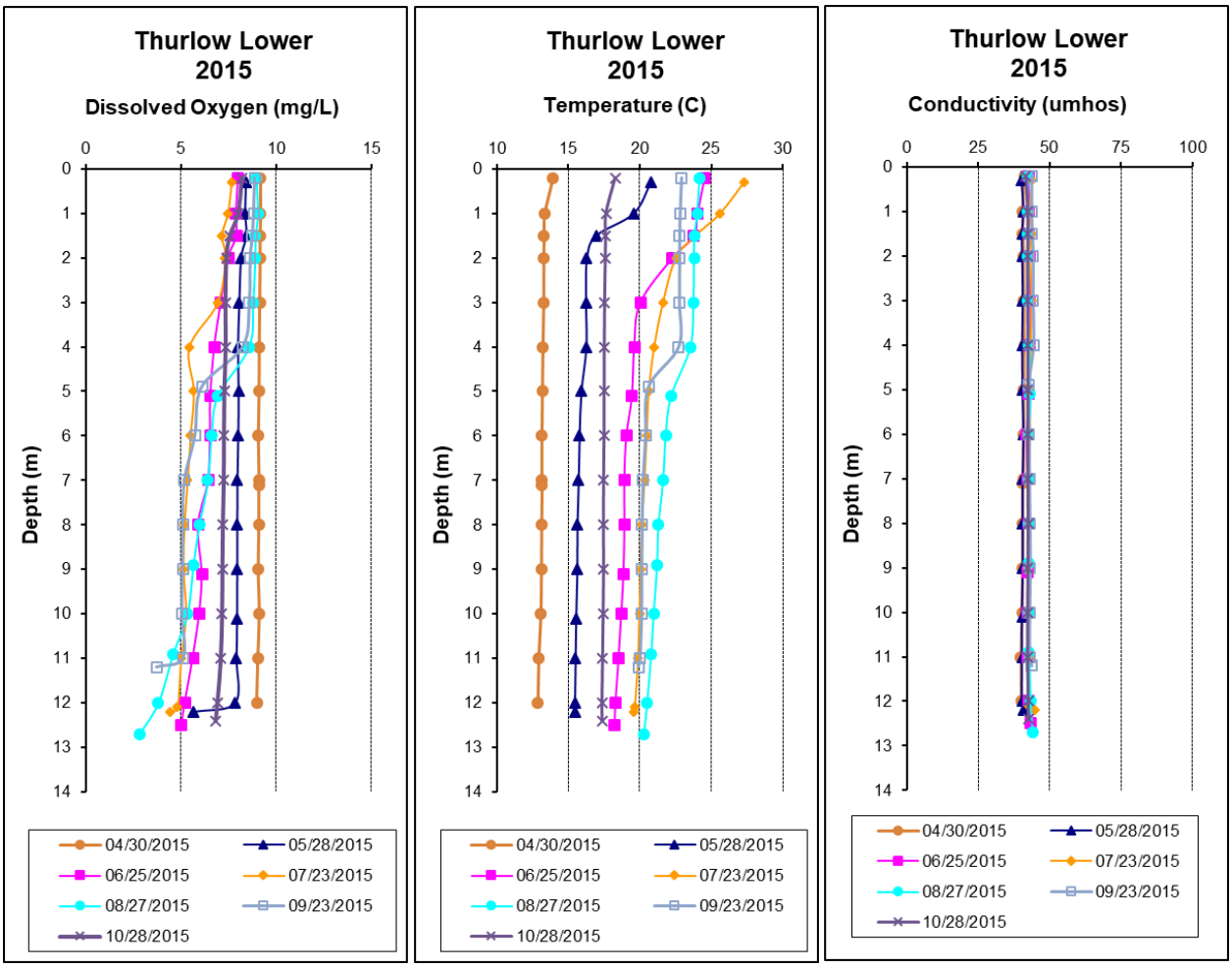


Figure 12. Monthly depth profiles of dissolved oxygen, temperature, and conductivity in the lower Yates Reservoir station, April-October 2018.

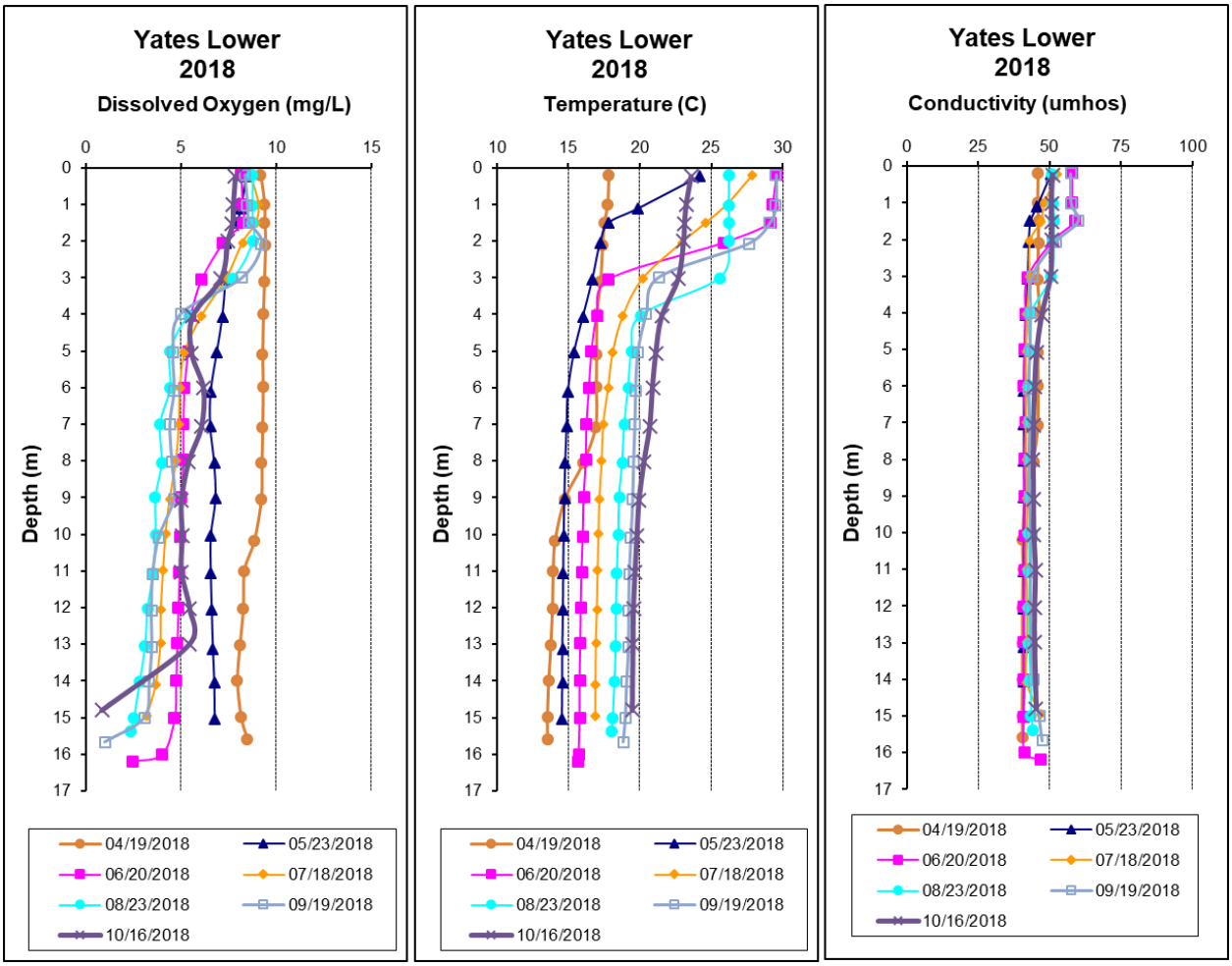


Figure 13. Monthly depth profiles of dissolved oxygen, temperature, and conductivity in the lower Thurlow Reservoir station, April-October 2018.

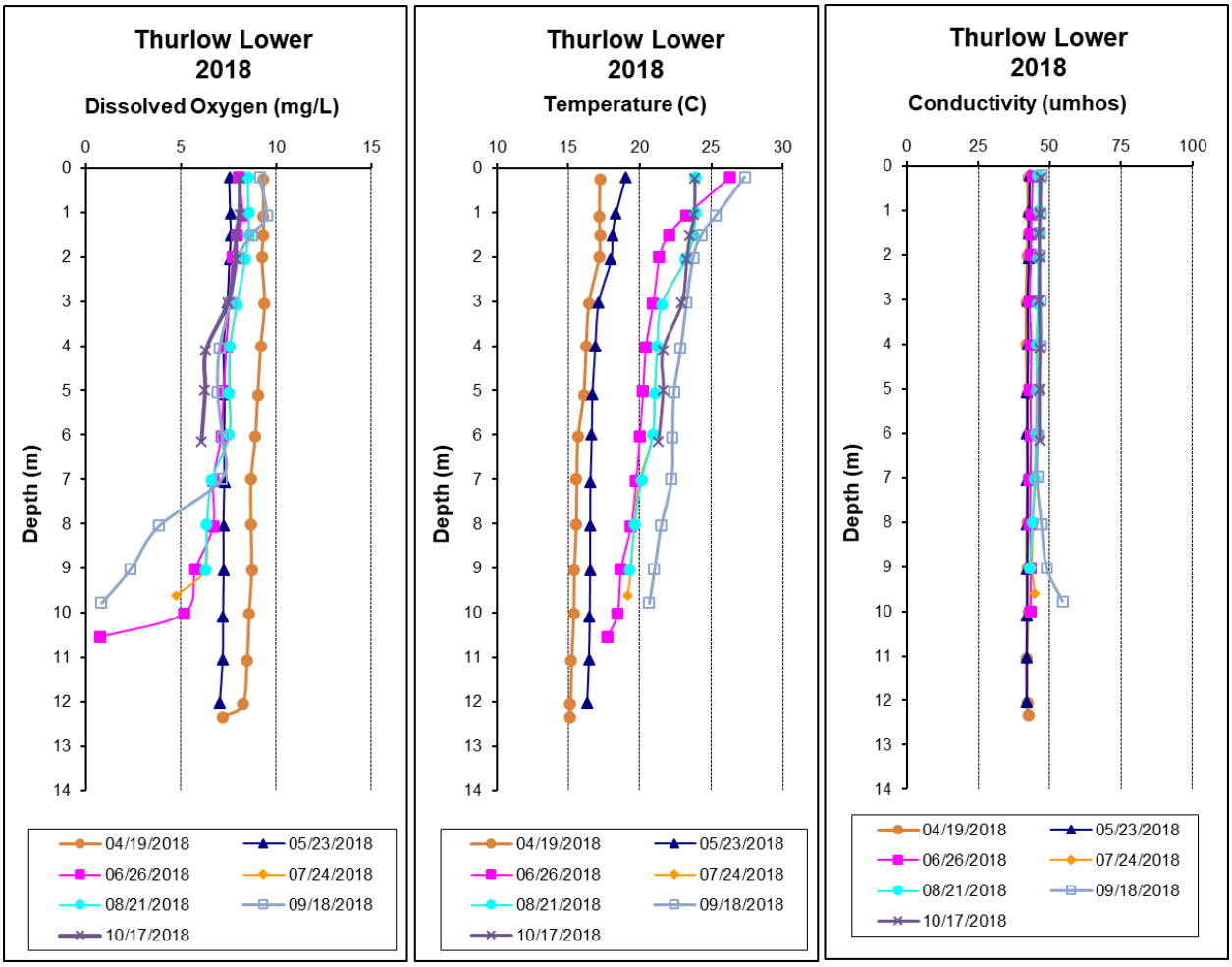


Figure 14. Monthly TSI values calculated for mainstem and tributary Yates and Thurlow Reservoir stations in 2015 using chl *a* concentrations and Carlson's Trophic State Index calculation. Monthly discharge acquired from Alabama Power at Yates Dam.

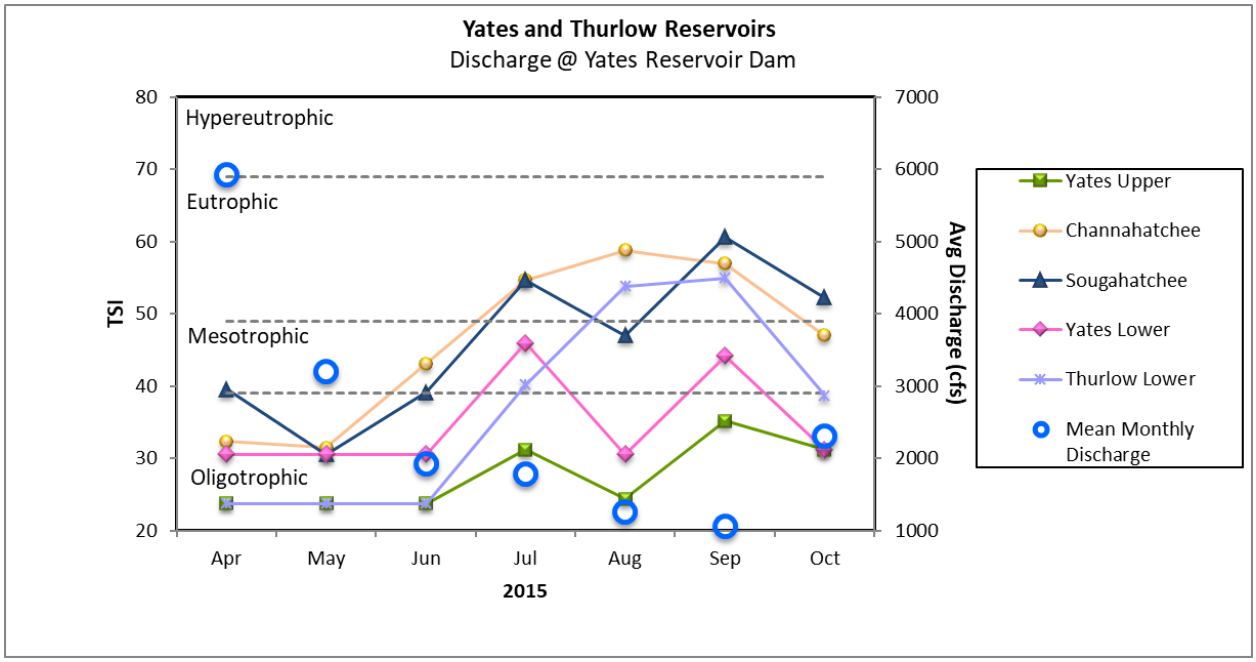
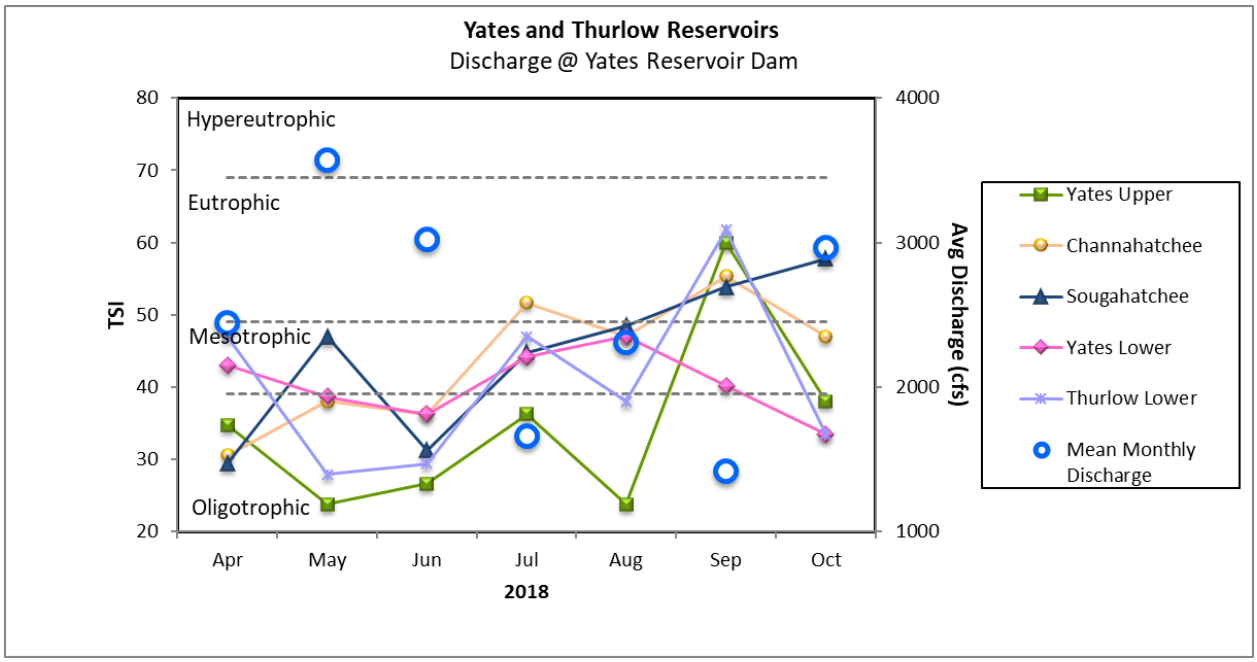


Figure 15. Monthly TSI values calculated for mainstem and tributary Yates and Thurlow Reservoir stations in 2018 using chl *a* concentrations and Carlson's Trophic State Index calculation. Monthly discharge acquired from Alabama Power at Yates Dam.



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APPENDIX

Appendix Table 1. Summary of water quality data collected April-October, 2015. Minimum (Min) and maximum (Max) values calculated using minimum detection limits (MDL) when results were less than this value. Median (Med), average (Avg), and standard deviations (SD) values were calculated by multiplying the MDL by 0.5 when results were less than this value.

Station	Parameter	N		Min	Max	Med	Avg	SD
THUE-1	**Physical**							
	Turbidity (NTU)	8		2.1	5.7	2.8	3.2	1.2
	Total Dissolved Solids (mg/L)	7		8.0	38.0	33.0	29.0	10.5
	Total Suspended Solids (mg/L)	7	<	1.0	5.0	0.5	1.4	1.7
	Hardness (mg/L)	4		11.7	14.3	12.4	12.7	1.1
	Alkalinity (mg/L)	7		12.3	15.0	13.7	13.6	1.0
	Photic Zone (m)	7		4.84	6.83	5.53	5.63	0.68
	Secchi (m)	7		1.38	2.61	2.07	2.05	0.45
	Bottom Depth (m)	8		10.1	12.7	12.2	11.9	0.9
	Chemical							
	Ammonia Nitrogen (mg/L)[J]	7	<	0.010	0.133	0.005	0.038	0.054
	Nitrate+Nitrite Nitrogen (mg/L)	7		0.040	0.208	0.151	0.135	0.066
	Total Kjeldahl Nitrogen (mg/L)[J]	7	<	0.064	0.738	0.250	0.305	0.238
	Total Nitrogen (mg/L)[J]	7	<	0.672	2.379	0.394	0.440	0.202
	Dis Reactive Phosphorus (mg/L)[J]	7	<	0.002	0.063	0.003	0.012	0.023
	Total Phosphorus (mg/L)[J]	7		0.007	0.079	0.009	0.018	0.027
	CBOD-5 (mg/L)	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		2.3	2.5	2.4	2.4	0.1
	Biological							
	Chlorophyll a (mg/m³)	7	<	1.00	12.00	2.29	4.17	5.00
	E. coli (MPN/DL)	3		2	118	2	41	67
YATE-1	**Physical**							
	Turbidity (NTU)	7		2.8	6.6	4.3	4.5	1.2
	Total Dissolved Solids (mg/L)	7		9.0	57.0	37.0	36.0	16.0
	Total Suspended Solids (mg/L)	7	<	1.0	3.0	1.0	1.2	1.0
	Hardness (mg/L)	4		11.4	15.5	13.4	13.4	1.7
	Alkalinity (mg/L)	7		12.3	15.6	13.8	13.9	0.1
	Photic Zone (m)	7		4.95	7.69	5.59	5.84	0.90
	Secchi (m)	6		1.25	2.15	1.81	1.78	0.32
	Bottom Depth (m)	7		12.9	16.4	15.7	15.0	1.3
	Chemical							
	Ammonia Nitrogen (mg/L)[J]	7	<	0.010	0.078	0.024	0.030	0.028
	Nitrate+Nitrite Nitrogen (mg/L)	7		0.079	0.195	0.145	0.143	0.038
	Total Kjeldahl Nitrogen (mg/L)	7	<	0.064	0.511	0.290	0.272	0.182
	Total Nitrogen (mg/L)	7	<	0.531	1.821	0.441	0.415	0.168
	Dis Reactive Phosphorus (mg/L)[J]	7	<	0.003	0.012	0.003	0.004	0.004
	Total Phosphorus (mg/L)[J]	7		0.007	0.022	0.009	0.011	0.005
	CBOD-5 (mg/L)	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		2.3	2.6	2.4	2.4	0.1
	Biological							
	Chlorophyll a (mg/m³)	7	<	0.89	4.81	0.89	1.75	1.84
	E. coli (MPN/DL)	3		2	83	10	32	45

Station	Parameter	N		Min	Max	Med	Avg	SD
YATE-2	**Physical**							
	Turbidity (NTU)	8		11.3	44.7	17.0	21.0	11.1
	Total Dissolved Solids (mg/L)[J]	7		31.0	66.0	61.0	55.0	13.0
	Total Suspended Solids (mg/L)	7		6.0	38.0	8.0	12.3	11.5
	Hardness (mg/L)	4		19.2	27.6	23.4	23.4	3.8
	Alkalinity (mg/L)	7		24.8	35.9	28.2	29.5	4.3
	Photic Zone (m)	7		0.70	1.59	1.53	1.38	0.32
	Secchi (m)	6		0.51	0.71	0.52	0.56	0.08
	Bottom Depth (m)	8		0.7	6.8	4.2	3.9	2.2
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.010	0.165	0.051	0.062	0.057
	Nitrate+Nitrite Nitrogen (mg/L)	7		0.029	0.170	0.050	0.076	0.057
	Total Kjeldahl Nitrogen (mg/L)	7		0.171	0.883	0.404	0.462	0.236
	Total Nitrogen (mg/L)	7		0.945	2.736	0.466	0.538	0.196
	Dis Reactive Phosphorus (mg/L)[J]	7	<	0.004	0.012	0.004	0.005	0.003
	Total Phosphorus (mg/L)	7		0.019	0.044	0.023	0.027	0.010
	CBOD-5 (mg/L)	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		3.1	4.6	4.1	4.0	0.5
	Biological							
	Chlorophyll a (mg/m³)	7	<	1.00	21.40	5.34	7.57	7.28
	E. coli (MPN/DL)	3		8	105	62	58	49
YATE-3	**Physical**							
	Turbidity (NTU)	8		12.6	24.2	20.2	19.7	3.9
	Total Dissolved Solids (mg/L)	7		21.0	62.0	44.0	43.6	14.4
	Total Suspended Solids (mg/L)	7		1.0	25.0	12.0	13.1	7.3
	Hardness (mg/L)	4		9.8	13.1	12.7	12.1	1.5
	Alkalinity (mg/L)	7		13.5	21.3	15.5	16.7	3.1
	Photic Zone (m)	7		1.04	1.62	1.39	1.37	0.20
	Secchi (m)	6		0.43	0.73	0.56	0.56	0.10
	Bottom Depth (m)	8		0.4	4.6	4.1	3.7	1.4
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.010	0.181	0.048	0.075	0.070
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7		0.006	0.057	0.027	0.031	0.020
	Total Kjeldahl Nitrogen (mg/L)	7	<	0.064	0.693	0.528	0.424	0.227
	Total Nitrogen (mg/L)[J]	7	<	0.264	2.097	0.553	0.455	0.209
	Dis Reactive Phosphorus (mg/L)[J]	7	<	0.003	0.010	0.003	0.004	0.003
	Total Phosphorus (mg/L)	7		0.016	0.034	0.026	0.025	0.007
	CBOD-5 (mg/L)	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		2.4	2.6	2.4	2.4	0.1
	Biological							
	Chlorophyll a (mg/m³)	7		1.10	17.80	5.34	7.92	6.77
	E. coli (MPN/DL)	3		32	79	54	55	24

Station	Parameter	N		Min	Max	Med	Avg	SD
YATE-4	**Physical**							
	Turbidity (NTU)	7		1.8	6.5	4.2	3.9	1.7
	Total Dissolved Solids (mg/L)[J]	7		19.0	56.0	32.0	35.3	11.6
	Total Suspended Solids (mg/L)	7	<	1.0	1.0	0.5	0.6	0.2
	Hardness (mg/L)	4		11.1	12.5	12.3	12.0	0.6
	Alkalinity (mg/L)	7		11.8	14.3	12.5	12.7	0.8
	Photic Zone (m)	7		5.31	7.56	6.59	6.47	0.94
	Secchi (m)	6		1.98	3.78	2.75	2.85	0.70
	Bottom Depth (m)	7		6.1	12.5	8.1	8.5	2.3
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.010	0.107	0.005	0.035	0.041
	Nitrate+Nitrite Nitrogen (mg/L)	7		0.111	0.222	0.211	0.196	0.039
	Total Kjeldahl Nitrogen (mg/L)[J]	7	<	0.064	0.437	0.101	0.188	0.152
	Total Nitrogen (mg/L)[J]	7	<	0.729	1.977	0.313	0.384	0.146
	Dis Reactive Phosphorus (mg/L)[J]	7	<	0.002	0.008	0.003	0.004	0.002
	Total Phosphorus (mg/L)[J]	7		0.006	0.014	0.008	0.008	0.003
	CBOD-5 (mg/L)	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		2.3	2.4	2.3	2.3	0.0
	Biological							
	Chlorophyll a (mg/m³)	7	<	0.53	1.60	0.53	0.82	0.43
	E. coli (MPN/DL)	3		1	15	4	7	7

J=one or more of the values provided are estimated; < = Actual value is less than the detection limit.

Appendix Table 2. Summary of water quality data collected April-October, 2018. Minimum (Min) and maximum (Max) values calculated using minimum detection limits (MDL) when results were less than this value. Median (Med), average (Avg), and standard deviations (SD) values were calculated by multiplying the MDL by 0.5 when results were less than this value.

Station	Parameter	N		Min	Max	Med	Avg	SD
THUE-1	**Physical**							
	Turbidity (NTU)	7		3.0	4.4	3.7	3.7	0.5
	Total Dissolved Solids (mg/L)[J]	7		7.0	40.0	33.0	27.3	12.5
	Total Suspended Solids (mg/L)[J]	7	<	1.0	4.0	1.0	1.6	1.2
	Hardness (mg/L)	4		13.9	17.0	14.6	15.0	1.4
	Alkalinity (mg/L)	7		13.4	15.4	13.8	14.1	0.7
	Photic Zone (m)	7		4.37	6.02	5.01	5.20	0.69
	Secchi (m)	7		1.25	2.56	1.98	1.91	0.48
	Bottom Depth (m)	7		6.2	12.3	9.8	9.9	2.1
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.007	0.023	0.004	0.007	0.007
	Nitrate+Nitrite Nitrogen (mg/L)	7		0.058	0.194	0.157	0.140	0.054
	Total Kjeldahl Nitrogen (mg/L)[J]	7	<	0.097	0.258	0.203	0.184	0.068
	Total Nitrogen (mg/L)[J]	7	<	0.465	1.245	0.397	0.324	0.116
	Dis Reactive Phosphorus (mg/L)[J]	7	<	0.004	0.007	0.004	0.004	0.002
	Total Phosphorus (mg/L)[J]	7		0.006	0.011	0.009	0.009	0.002
	CBOD-5 (mg/L)	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		2.6	2.9	2.7	2.7	0.1
	Biological							
	Chlorophyll a (mg/m³)	7		0.76	24.00	2.14	5.69	8.31
	E. coli (MPN/DL)[J]	4	<	1	5	4	4	2
YATE-1	**Physical**							
	Turbidity (NTU)	7		3.2	11.0	5.4	5.9	2.7
	Total Dissolved Solids (mg/L)	7		20.0	46.0	40.0	37.4	9.7
	Total Suspended Solids (mg/L)[J]	7		1.0	5.0	3.0	3.0	1.3
	Hardness (mg/L)	4		14.1	18.1	16.9	16.5	1.7
	Alkalinity (mg/L)	7		14.3	20.0	16.3	16.3	1.8
	Photic Zone (m)	7		3.22	5.73	5.02	4.63	0.88
	Secchi (m)	7		1.00	2.05	1.50	1.55	0.39
	Bottom Depth (m)	7		14.8	16.2	15.4	15.4	0.5
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.007	0.045	0.004	0.010	0.016
	Nitrate+Nitrite Nitrogen (mg/L)	7		0.041	0.183	0.107	0.111	0.051
	Total Kjeldahl Nitrogen (mg/L)[J]	7		0.144	0.374	0.234	0.249	0.093
	Total Nitrogen (mg/L)[J]	7		0.555	1.584	0.345	0.359	0.120
	Dis Reactive Phosphorus (mg/L)[J]	7	<	0.004	0.006	0.002	0.003	0.002
	Total Phosphorus (mg/L)[J]	7		0.009	0.011	0.010	0.010	0.001
	CBOD-5 (mg/L)	7	<	2.0	2.2	1.0	1.2	0.4
	Chlorides (mg/L)	7		2.6	3.1	2.8	2.8	0.2
	Biological							
	Chlorophyll a (mg/m³)	7		1.34	5.34	2.67	3.00	1.39
	E. coli (MPN/DL)[J]	4	<	1	6	3	2	3

Station	Parameter	N		Min	Max	Med	Avg	SD
YATE-2	**Physical**							
	Turbidity (NTU)	7		15.7	43.3	23.7	27.6	10.8
	Total Dissolved Solids (mg/L)	7		51.0	67.0	58.0	58.0	5.6
	Total Suspended Solids (mg/L)	7		7.0	22.0	13.0	13.6	5.2
	Hardness (mg/L)	4		24.2	28.0	27.1	26.6	1.8
	Alkalinity (mg/L)	7		24.1	33.8	29.3	29.3	3.3
	Photic Zone (m)	7		1.20	2.29	1.55	1.69	0.41
	Secchi (m)	7		0.38	0.58	0.50	0.48	0.08
	Bottom Depth (m)	7		2.0	3.0	2.5	2.6	0.4
	Chemical							
	Ammonia Nitrogen (mg/L)[J]	7	<	0.007	0.056	0.004	0.013	0.019
	Nitrate+Nitrite Nitrogen (mg/L)	7		0.043	0.244	0.191	0.181	0.065
	Total Kjeldahl Nitrogen (mg/L)	7		0.228	0.495	0.335	0.345	0.104
	Total Nitrogen (mg/L)	7		1.134	2.058	0.550	0.526	0.112
	Dis Reactive Phosphorus (mg/L)[J]	7		0.004	0.007	0.005	0.005	0.001
	Total Phosphorus (mg/L)	7		0.019	0.032	0.022	0.024	0.005
	CBOD-5 (mg/L)	7	<	2.0	2.1	1.0	1.3	0.5
	Chlorides (mg/L)	7		3.3	4.8	3.7	3.9	0.6
	Biological							
	Chlorophyll a (mg/m³)	7		0.89	16.00	5.34	6.36	5.40
	E. coli (MPN/DL)	4		6	65	26	31	25
YATE-3	**Physical**							
	Turbidity (NTU)	7		12.7	27.5	20.4	20.0	6.0
	Total Dissolved Solids (mg/L)	7	<	1.0	64.0	52.0	42.1	21.4
	Total Suspended Solids (mg/L)[J]	7		8.0	14.0	10.0	10.4	2.2
	Hardness (mg/L)	4		13.3	14.8	13.8	13.9	0.6
	Alkalinity (mg/L)	7		16.3	21.3	17.2	17.7	1.7
	Photic Zone (m)	7		1.30	1.87	1.58	1.58	0.18
	Secchi (m)	7		0.42	0.79	0.60	0.61	0.14
	Bottom Depth (m)	7		1.6	3.0	2.0	2.1	0.5
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.007	0.100	0.042	0.048	0.031
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7		0.010	0.080	0.034	0.042	0.024
	Total Kjeldahl Nitrogen (mg/L)	7		0.312	0.456	0.420	0.410	0.046
	Total Nitrogen (mg/L)[J]	7		0.966	1.557	0.450	0.452	0.066
	Dis Reactive Phosphorus (mg/L)[J]	7		0.004	0.006	0.005	0.005	0.001
	Total Phosphorus (mg/L)	7		0.019	0.027	0.024	0.024	0.003
	CBOD-5 (mg/L)	7	<	2.0	2.4	1.0	1.2	0.5
	Chlorides (mg/L)	7		2.4	3.0	2.5	2.6	0.2
	Biological							
	Chlorophyll a (mg/m³)	7		0.89	12.50	5.34	5.22	4.17
	E. coli (MPN/DL)	4		11	308	27	93	143

Station	Parameter	N		Min	Max	Med	Avg	SD
YATE-4	**Physical**							
	Turbidity (NTU)	7		2.6	13.3	6.1	6.5	3.7
	Total Dissolved Solids (mg/L)[J]	7		4.0	41.0	31.0	28.7	13.2
	Total Suspended Solids (mg/L)	7	<	1.0	21.0	0.5	3.9	7.6
	Hardness (mg/L)	4		12.8	14.5	13.6	13.6	0.8
	Alkalinity (mg/L)	7		12.7	15.2	12.9	13.2	0.9
	Photic Zone (m)	7		4.75	7.98	6.90	6.87	1.10
	Secchi (m)	7		2.20	4.10	2.90	3.03	0.72
	Bottom Depth (m)	7		10.0	13.1	11.6	11.6	1.0
	Chemical							
	Ammonia Nitrogen (mg/L)[J]	7	<	0.007	0.016	0.004	0.005	0.003
	Nitrate+Nitrite Nitrogen (mg/L)	7		0.069	0.233	0.194	0.177	0.056
	Total Kjeldahl Nitrogen (mg/L)[J]	7	<	0.077	0.324	0.135	0.140	0.097
	Total Nitrogen (mg/L)[J]	7	<	0.526	1.554	0.328	0.318	0.110
	Dis Reactive Phosphorus (mg/L)[J]	7	<	0.004	0.004	0.002	0.002	0.001
	Total Phosphorus (mg/L)[J]	7		0.006	0.013	0.009	0.009	0.002
	CBOD-5 (mg/L)	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		2.4	2.7	2.6	2.5	0.1
	Biological							
	Chlorophyll a (mg/m³)	7	<	0.10	20.00	1.53	3.74	7.22
	E. coli (MPN/DL)	4		2	15	6	7	6

J=one or more of the values provided are estimated; < = Actual value is less than the detection limit.