Woodruff Reservoir Report 2018 & 2020

Rivers and Reservoirs Monitoring Program

Alabama Department of Environmental Management

Field Operations Division
Rivers and Reservoirs Unit
June 2023

Rivers and Reservoirs Monitoring Program

2018 & 2020

Woodruff Reservoir

Alabama River Basin

Alabama Department of Environmental Management
Field Operations Division
Rivers and Reservoirs Unit

June 2023

Table of Contents

LIST OF ACRONYMS

A&I	Agriculture and Industry
ADEM	Alabama Department of Environmental Management
AGPT	Algal growth Potential Test
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
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
COE	United States Army Corp of Engineers

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Woodruff Reservoir was created with the construction of Robert F. Henry Lock and Dam in the early 1970s by the United States Army Corps of Engineers (COE). The reservoir covers approximately 12,500 acres and stretches from just north of Montgomery to Benton, Alabama. Woodruff serves a key role in hydroelectricity generation and also provides a number of recreational opportunities such as camping, hiking, fishing, and hunting.

The Alabama Department of Environmental Management (ADEM) monitored Woodruff Reservoir as part of the 2018 and 2020 assessments of the Alabama River basin 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).

The purpose of this report is to summarize data collected at seven stations in Woodruff Reservoir during the 2018 and 2020 growing seasons and to evaluate trends in mean lake trophic status and nutrient concentrations using ADEM's historic dataset. Monthly and 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 historical data.

METHODS

Sampling sites were determined using historical data and previous assessments (Figure 1). Specific station location information is listed in Table 1. Woodruff Reservoir was sampled in the dam forebay, mid reservoir, and upper reservoir in 2018 and 2020. Four tributary embayments representing a range of watershed conditions and land use patterns were also monitored. These include Catoma Creek, Pintlala Creek, Swift Creek, and Cypress Creek.

In 2018, water quality sampling was conducted at monthly intervals, April-October. The 2020 sampling schedule was modified to accommodate Departmental precautions related to COVID-19 that occurred early in the sampling season. As a result, no water quality samples were collected in April, and two samples were collected in October to account for the missed sampling event. These modifications are noted in related graphs. All samples were collected, preserved, stored, and transported according to procedures in the ADEM Field Operations Division Standard Operating Procedures (ADEM 2020), Surface Water Quality Assurance Project Plan (ADEM 2018a), and Quality Management Plan (ADEM 2018b).

Growing season mean TN, TP, chl *a*, and TSS were calculated to evaluate water quality conditions at each site. For mainstem stations, monthly concentrations of these parameters were graphed with the closest available COE flow data and ADEM's previously collected data to help interpret the 2018 and 2020 results.

Figure 1. Woodruff Reservoir with 2018 & 2020 sampling locations. A description of each sampling location is provided in Table 1.

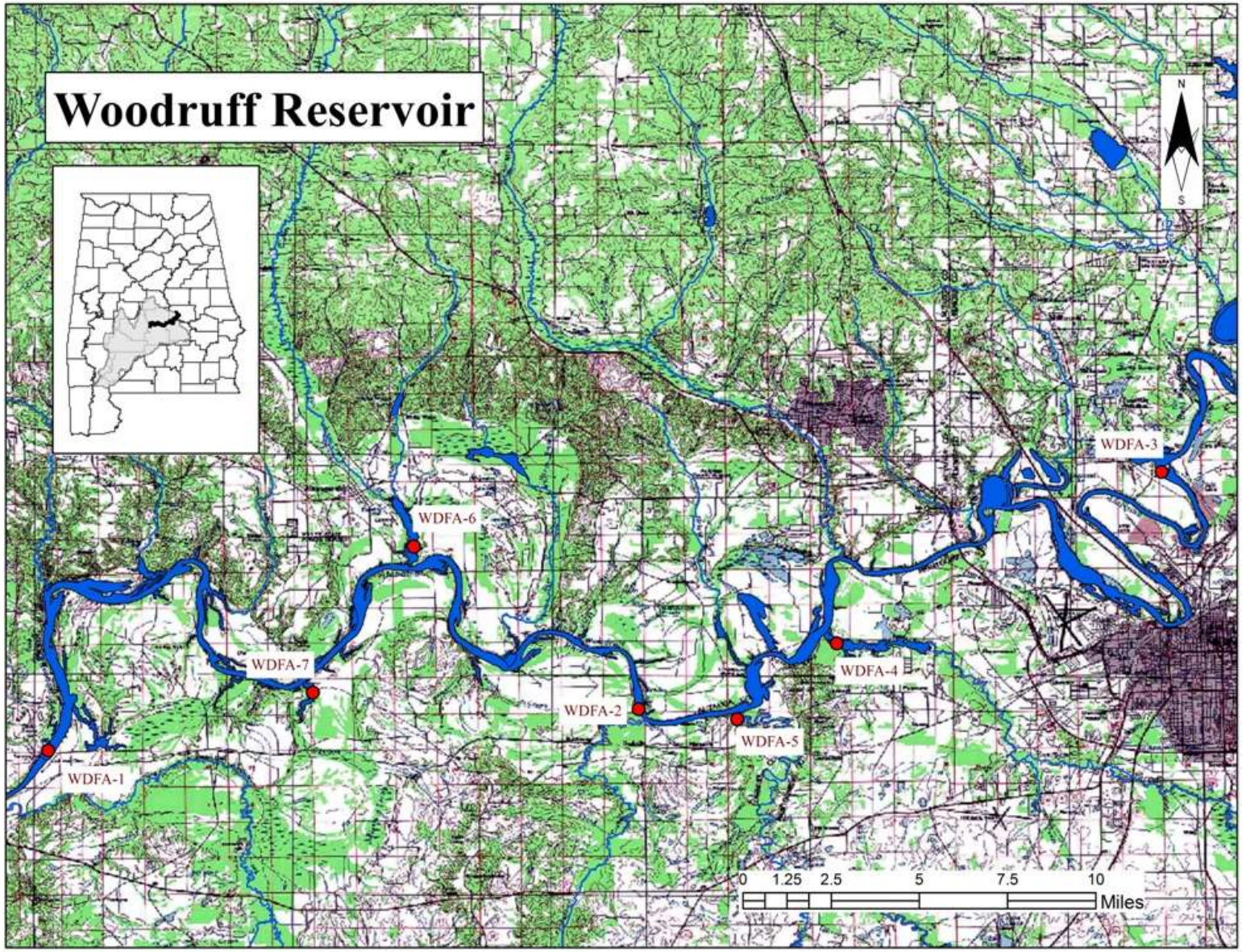


Table 1. Descriptions of the 2018 and 2020 monitoring stations in Woodruff Reservoir.

HUC	County	Station Number	Report Designation	Waterbody Name	Station Description	Latitude	Longitude
Woodruff Reservoir							
031502018706	Autauga	WDFA-1	Lower	Alabama R	Deepest point, main river channel, dam forebay.	32.3273	-86.7820
031502018503	Lowndes	WDFA-2	Mid	Alabama R	Deepest point, main river channel, immediately downstream of Tallawassee Creek confluence.	32.3443	-86.5397
031502018106	Montgomery	WDFA-3	Upper	Alabama R	Deepest point, main river channel, immediately downstream of Jackson Lake.	32.4414	-86.3251
031502018309	Montgomery	WDFA-4	Catoma Cr	Catoma Cr	Deepest point, main creek channel, Catoma Creek embayment, approximately 0.5 miles upstream of lake confluence.	32.3711	-86.4584
031502018407	Montgomery	WDFA-5	Pintlala Cr	Pintlala Cr	Deepest point, main creek channel, Pintlala Creek embayment, approximately 0.5 miles upstream of lake confluence.	32.3402	-86.4992
031502018603	Autauga	WDFA-6	Swift Cr	Swift Cr	Deepest point, main creek channel, Swift Creek embayment, approximately 0.5 miles upstream of lake confluence.	32.4111	-86.6321
031502018702	Lowndes	WDFA-7	Cypress Cr	Cypress Cr	Deepest point, main creek channel, Cypress Creek embayment, approximately 0.5 miles upstream of lake confluence.	32.3521	-86.6796

RESULTS

Growing season mean graphs for TN, TP, chl *a*, and TSS are provided in this section (Figures 2 and 3). Monthly graphs for TN, TP, chl *a*, TSS, DO, and TSI are also provided (Figures 4-9 and Figures 14-15). Mean monthly discharge is included in monthly graphs for TN, TP, chl *a*, TSS, and TSI as an indicator of flow and retention time in the months sampled. Depth profile graphs of temperature, DO, and conductivity appear in Figures 10-13. Summary statistics of all data collected during 2018 are presented in Appendix Table 1; summary statistics of all data collected during 2020 are presented in Appendix Table 2. The tables contain 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 always be mentioned, review of the graphs that follow will indicate these stations that may be potential candidates for reference waterbodies and watersheds.

In 2018 and 2020, the highest mean growing season TN values were observed at the Catoma Creek and Pintlala Creek stations (Figure 2). Mean TN values generally decreased at each station each year. The highest monthly TN concentrations occurred at the mid mainstem station in June and October 2018, and again in September 2020, which was a historical monthly high value (Figure 4). Monthly TN concentrations were equal to or above historical means at the lower and mid mainstem stations in 2018 in most months sampled. At the upper station, TN values were lowest in July 2018 and August 2020.

In 2018 and 2020, the highest growing season mean TP value was observed at the Catoma Creek station (Figure 2). Mean TP concentrations increased at every station from 2018 to 2020. The highest monthly TP concentration was observed in September 2020 at the lower station (Figure 5). In 2018, monthly TP concentrations observed were at or below historical means at all stations throughout the growing season. Mean monthly TP concentrations for both years were generally lowest at the upper station. However, a historical monthly high TP concentration was observed at the upper station in May 2020.

In both 2018 and 2020, the highest growing season mean chl *a* values were calculated at the Catoma Creek station (Figure 3). During both years mean chl *a* concentrations increased substantially at the Catoma Creek and Cypress Creek stations, with the 2020 values being the highest recorded at both stations since sampling began in 2000. In 2018, the highest monthly chl *a* concentration was observed at the mid station in June (Figure 6). In 2020, the highest monthly chl *a* value observed was at the mid station in September. In both years, concentrations were below historic means at the upper mainstem station in all months except April 2018.

The highest growing season mean TSS values were calculated at Catoma Creek in 2018 and 2020 (Figure 3). In 2018, historic high monthly TSS concentrations were observed at the lower station in June and September (Figure 7). In 2020, historic high monthly TSS concentrations were observed at the upper station in June and late October and at the lower station in June. Monthly TSS concentrations were similar to the historic mean at the mid station much of the 2020 growing season.

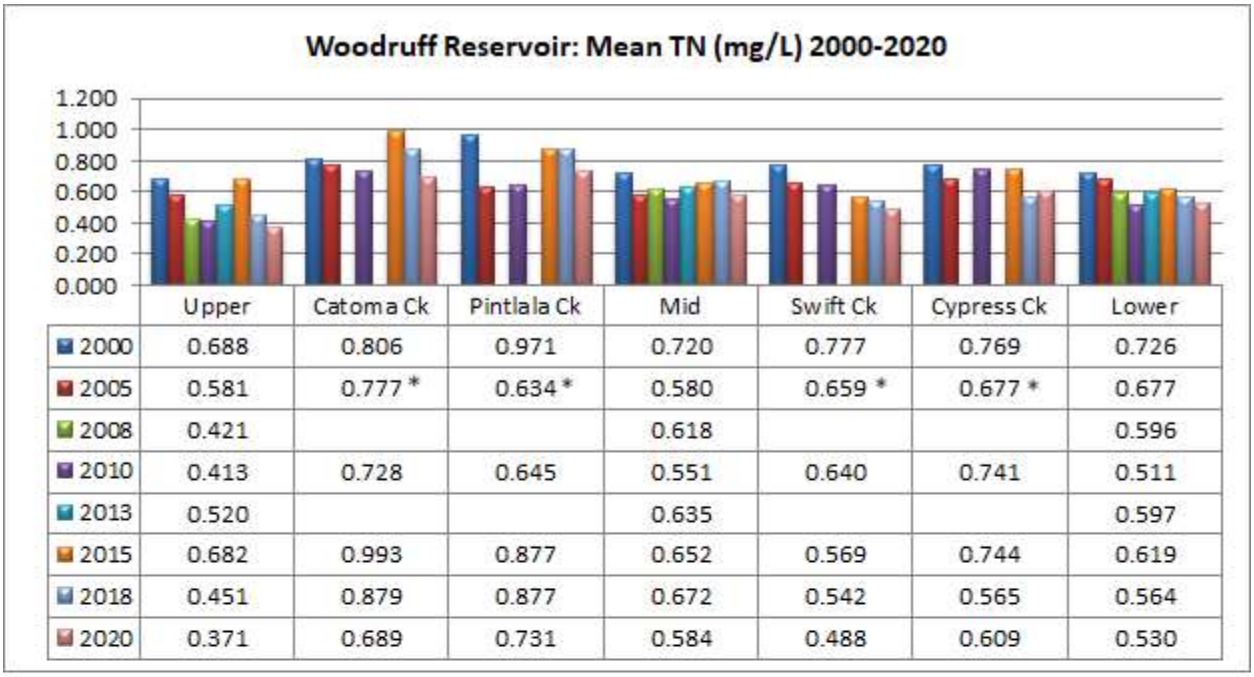
AGPT results for Woodruff Reservoir have varied among nitrogen-limited, phosphorus-limited, and co-limiting throughout the mainstem of the reservoir in years monitored (Table 2). In 2018, the lower station was nitrogen-limited, and the mid and upper stations were co-limiting. Raschke and Schultz (1987) found that maximum standing crop (MSC) values below 5.0 mg/L are considered to be protective of reservoir and lake systems. While some historic AGPT samples collected were less than 5.0 mg/L MSC, all samples collected in 2018 were above 5.0 mg/L MSC. However, all samples collected in the reservoir have been below 20.0 mg/L MSC, the value that Raschke and Schultz (1987) defined as protective of flowing stream and river systems. No AGPT samples were collected at Woodruff Reservoir in 2020.

In 2018, all mainstem stations on Woodruff Reservoir were above ADEM's DO criteria limit of 5.0 mg/L at 5.0 ft (1.5 m) in all months sampled during the growing season (Figure 8). The DO concentration in Pintlala Creek was below the criteria limit in May 2018. While DO concentrations in Catoma Creek and Pintlala Creek were less than 5.0 mg/L at criteria depth in May 2020, all other stations sampled in 2020 were above criteria in all months sampled (Figure 9). Based on monthly DO profiles from 2018, the water column at the lower station was slightly stratified in late June and August, and the mid station showed slight stratification late June-August

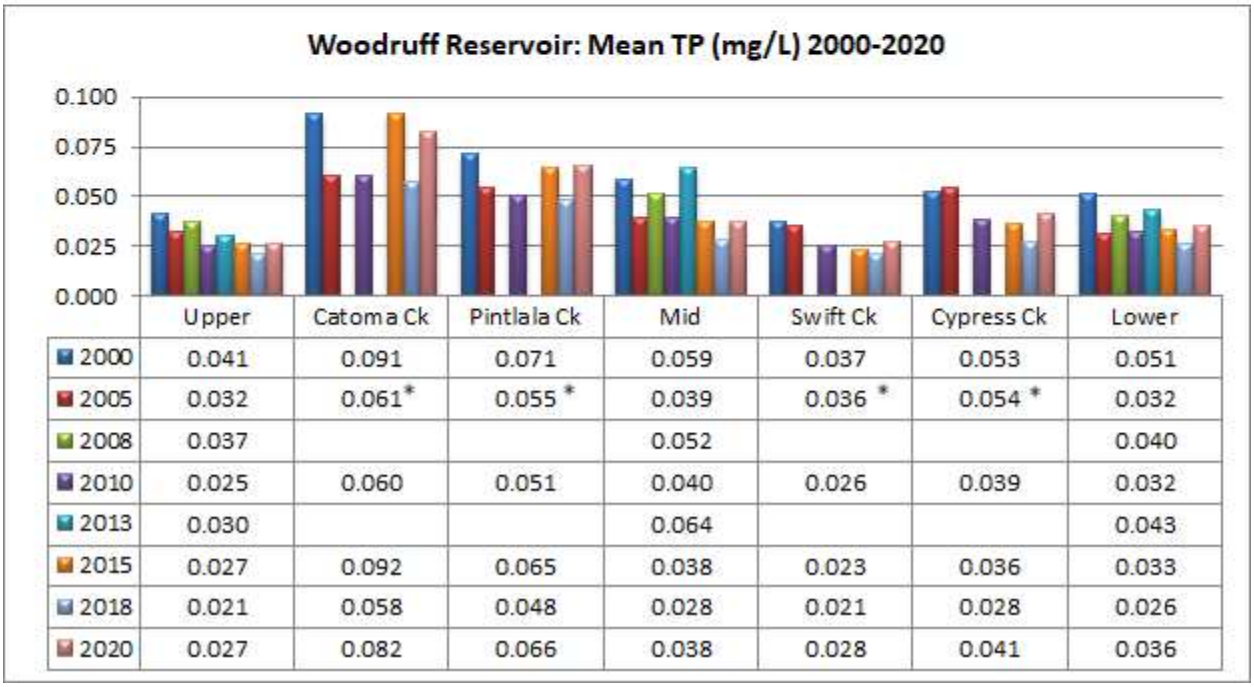
(Figure 10-11). In 2020, the lower station was slightly stratified in July, but the mid station appeared well-mixed throughout the growing season (Figures 12-13). The highest water temperatures were observed July through September of each year.

TSI values were calculated using monthly chl *a* concentrations and Carlson's Trophic State Index. TSI values for the upper mainstem were mesotrophic most of the 2018 growing season, while the middle and lower mainstem stations were eutrophic in most months sampled (Figure 14). Eutrophic conditions were observed in the tributaries during most sampling events. The highest TSI value was calculated in August at Cypress Creek, which reached upper eutrophic conditions. In 2020, the lower mainstem station remained eutrophic the entire growing season (Figure 15). TSI values in the tributaries were higher in 2020 compared to 2018. Catoma Creek reached hypereutrophic conditions in July and September, and Cypress Creek was hypereutrophic in July.

Figure 2. Growing season mean TN and TP concentrations measured in Woodruff Reservoir, April-October, 2000-2020. Bar graphs consist of mainstem and embayment stations, illustrated from upstream to downstream as the graph is read from left to right.



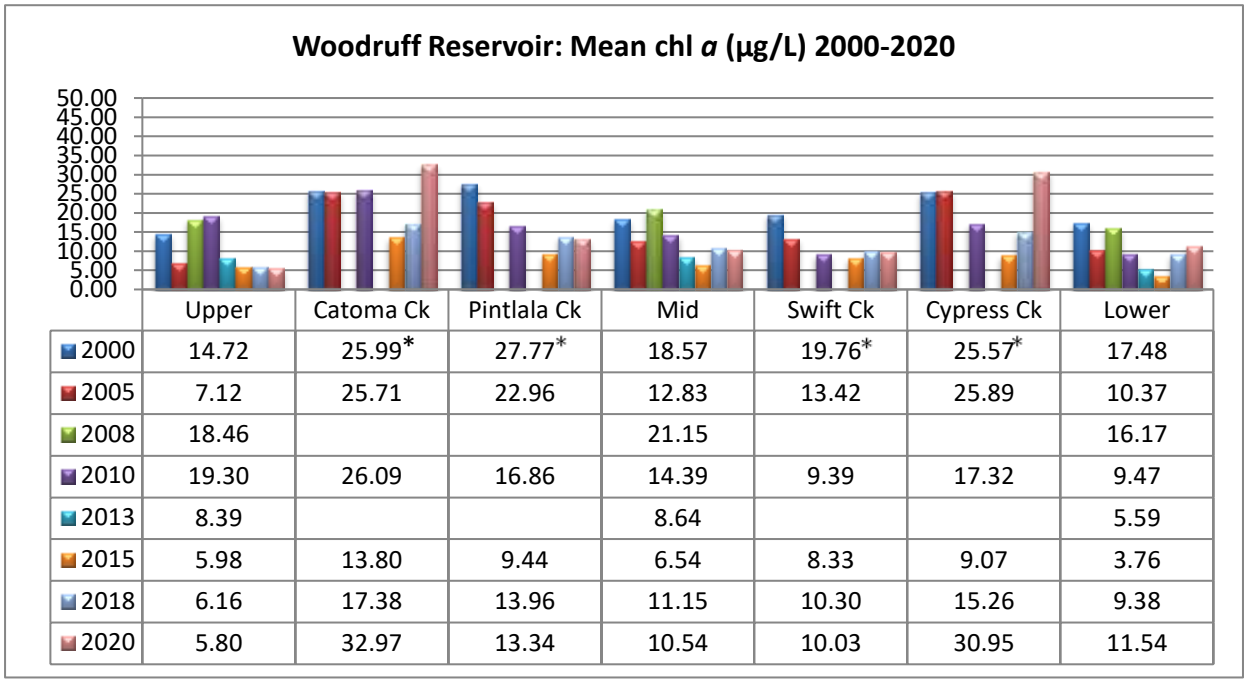
	Upper	Catoma Ck	Pintlala Ck	Mid	Swift Ck	Cypress Ck	Lower
2000	0.688	0.806	0.971	0.720	0.777	0.769	0.726
2005	0.581	0.777 *	0.634 *	0.580	0.659 *	0.677 *	0.677
2008	0.421			0.618			0.596
2010	0.413	0.728	0.645	0.551	0.640	0.741	0.511
2013	0.520			0.635			0.597
2015	0.682	0.993	0.877	0.652	0.569	0.744	0.619
2018	0.451	0.879	0.877	0.672	0.542	0.565	0.564
2020	0.371	0.689	0.731	0.584	0.488	0.609	0.530



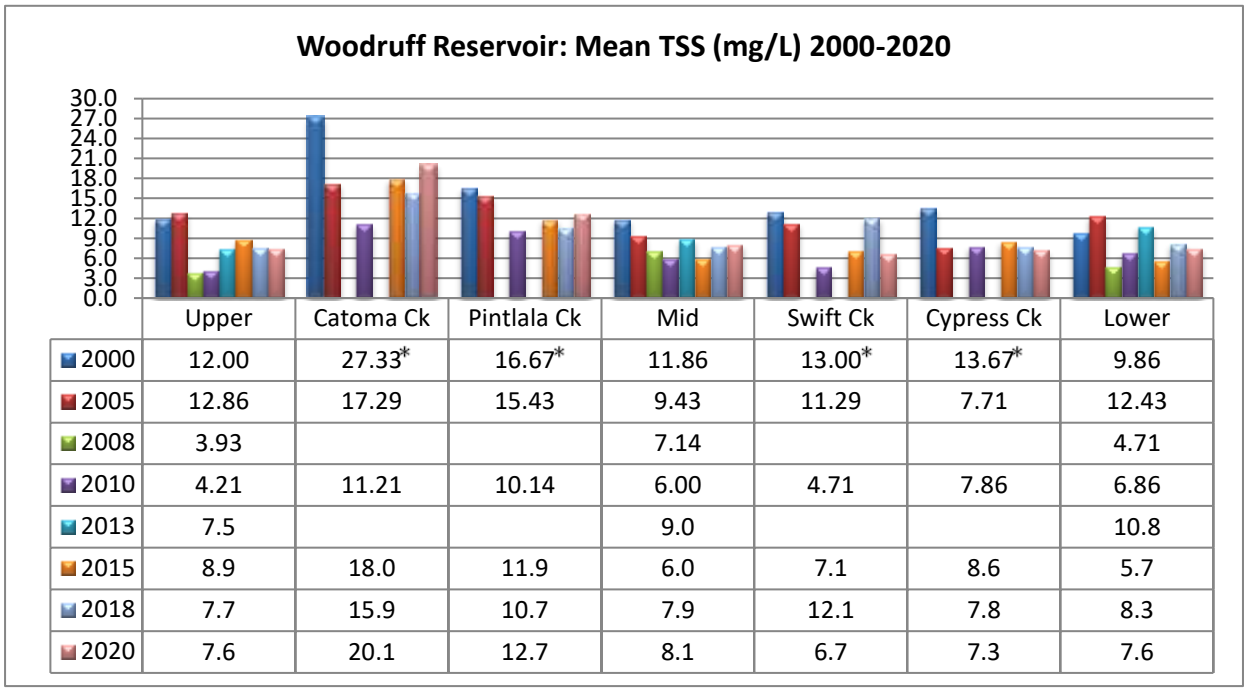
	Upper	Catoma Ck	Pintlala Ck	Mid	Swift Ck	Cypress Ck	Lower
2000	0.041	0.091	0.071	0.059	0.037	0.053	0.051
2005	0.032	0.061*	0.055 *	0.039	0.036 *	0.054 *	0.032
2008	0.037			0.052			0.040
2010	0.025	0.060	0.051	0.040	0.026	0.039	0.032
2013	0.030			0.064			0.043
2015	0.027	0.092	0.065	0.038	0.023	0.036	0.033
2018	0.021	0.058	0.048	0.028	0.021	0.028	0.026
2020	0.027	0.082	0.066	0.038	0.028	0.041	0.036

*Mean of April/June/August only.

Figure 3. Growing season mean chl *a* and TSS concentrations measured in Woodruff Reservoir, April-October, 2000-2020. Bar graphs consist of mainstem and embayment stations, illustrated from upstream to downstream as the graph is read from left to right.



	Upper	Catoma Ck	Pintlala Ck	Mid	Swift Ck	Cypress Ck	Lower
2000	14.72	25.99*	27.77*	18.57	19.76*	25.57*	17.48
2005	7.12	25.71	22.96	12.83	13.42	25.89	10.37
2008	18.46			21.15			16.17
2010	19.30	26.09	16.86	14.39	9.39	17.32	9.47
2013	8.39			8.64			5.59
2015	5.98	13.80	9.44	6.54	8.33	9.07	3.76
2018	6.16	17.38	13.96	11.15	10.30	15.26	9.38
2020	5.80	32.97	13.34	10.54	10.03	30.95	11.54



	Upper	Catoma Ck	Pintlala Ck	Mid	Swift Ck	Cypress Ck	Lower
2000	12.00	27.33*	16.67*	11.86	13.00*	13.67*	9.86
2005	12.86	17.29	15.43	9.43	11.29	7.71	12.43
2008	3.93			7.14			4.71
2010	4.21	11.21	10.14	6.00	4.71	7.86	6.86
2013	7.5			9.0			10.8
2015	8.9	18.0	11.9	6.0	7.1	8.6	5.7
2018	7.7	15.9	10.7	7.9	12.1	7.8	8.3
2020	7.6	20.1	12.7	8.1	6.7	7.3	7.6

*Mean of April/June/August only.

Figure 4. Monthly TN concentrations of the mainstem stations in Woodruff Reservoir, April-October 2018 and 2020. Each bar graph depicts monthly changes in each station. The historic mean and min/max range are also displayed for comparison. The "n" value equals the number of data points included in the monthly historic calculations. TN was plotted vs. the closest discharge (COE Alabama River at Robert F. Henry L&D near Benton, AL).

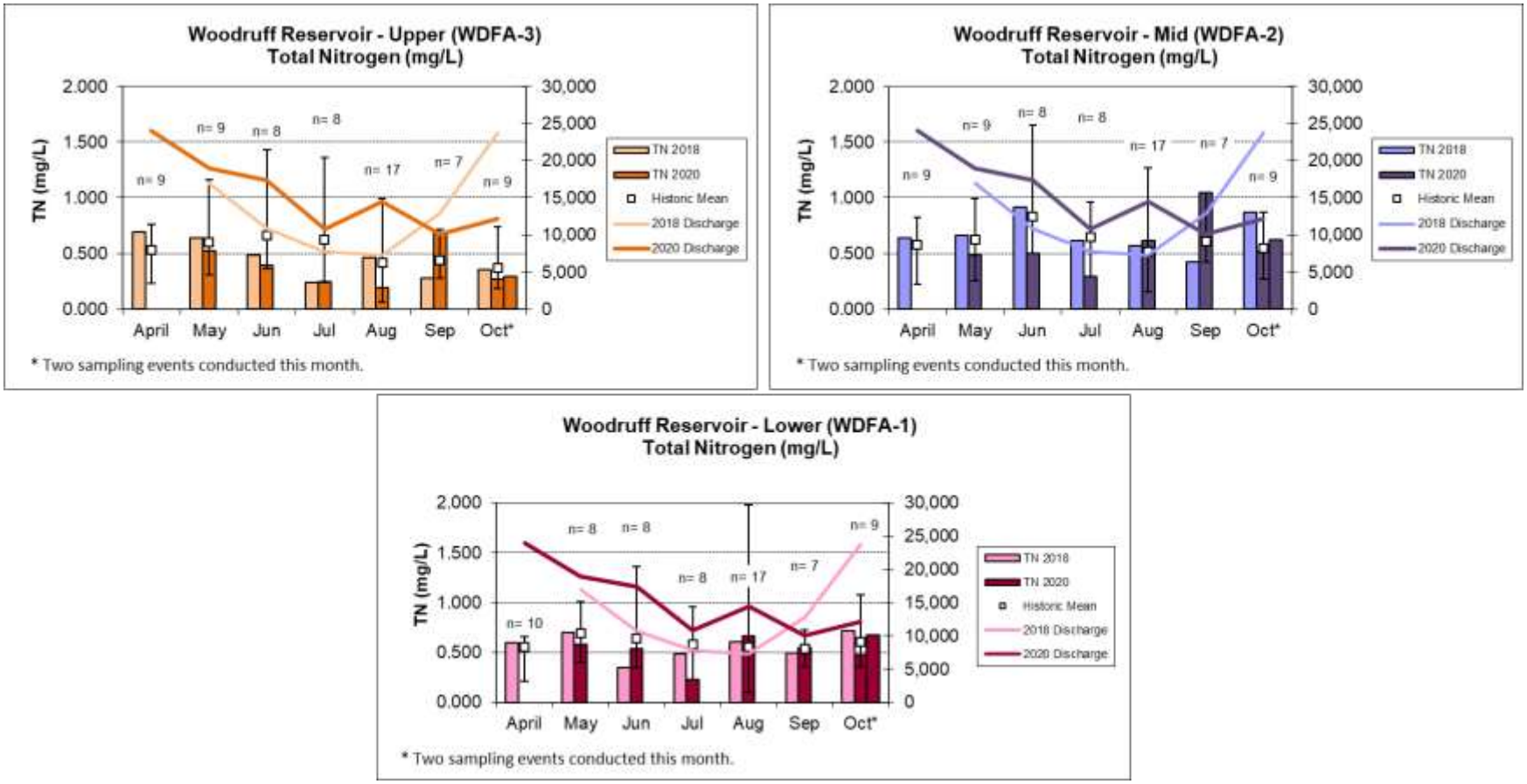


Figure 5. Monthly TP concentrations of the mainstem stations in Woodruff Reservoir, April-October 2018 and 2020. Each bar graph depicts monthly changes in each station. The historic mean and min/max range are also displayed for comparison. The "n" value equals the number of data points included in the monthly historic calculations. TP was plotted vs. the closest discharge (COE Alabama River at Robert F. Henry L&D near Benton, AL).

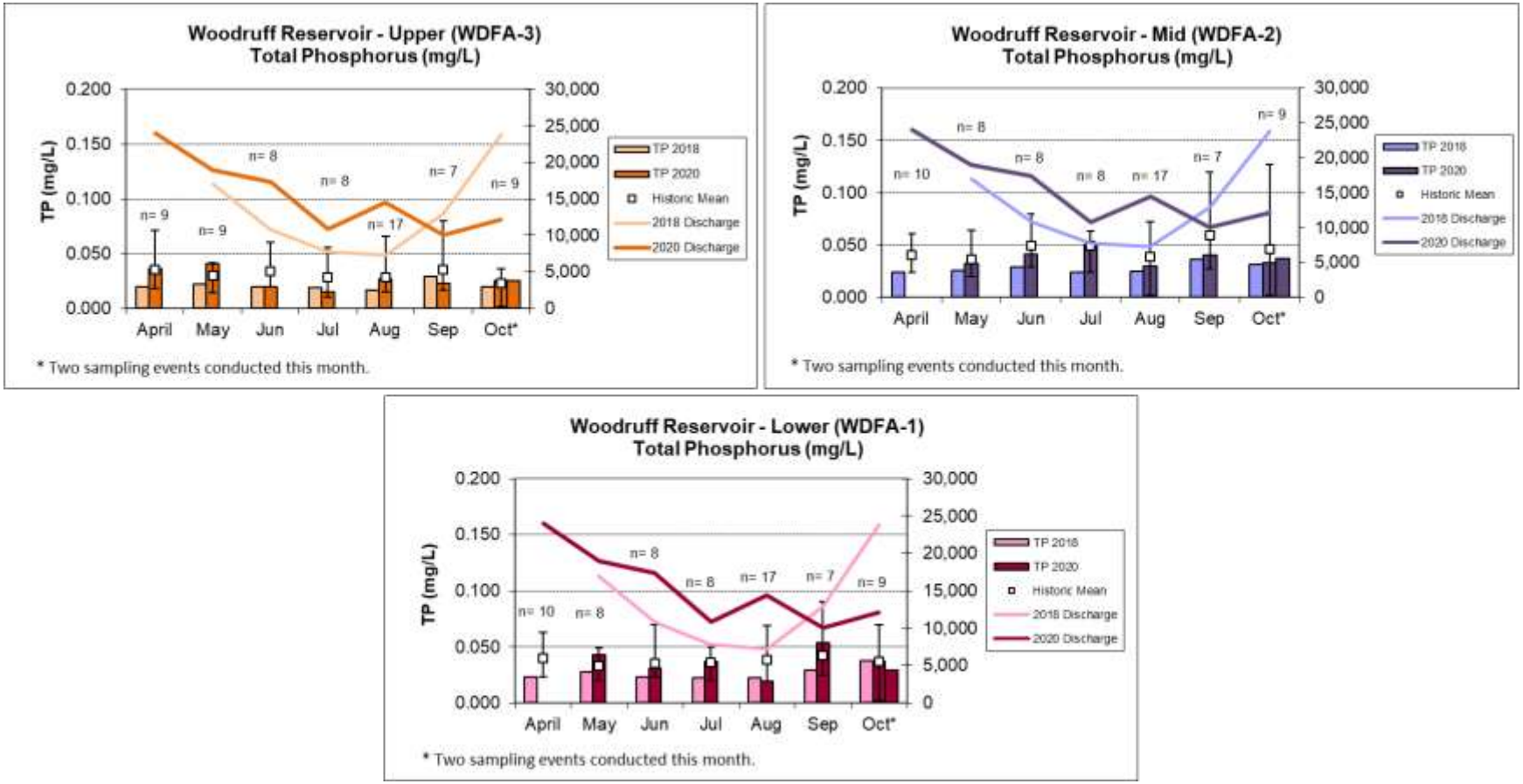


Figure 6. Monthly chl a concentrations of the mainstem stations in Woodruff Reservoir, April-October 2018 and 2020. Each bar graph depicts monthly changes in each station. The historic mean and min/max range are also displayed for comparison. The "n" value equals the number of data points included in the monthly historic calculations. Chl a was plotted vs. the closest discharge (COE Alabama River at Robert F. Henry L&D near Benton, AL).

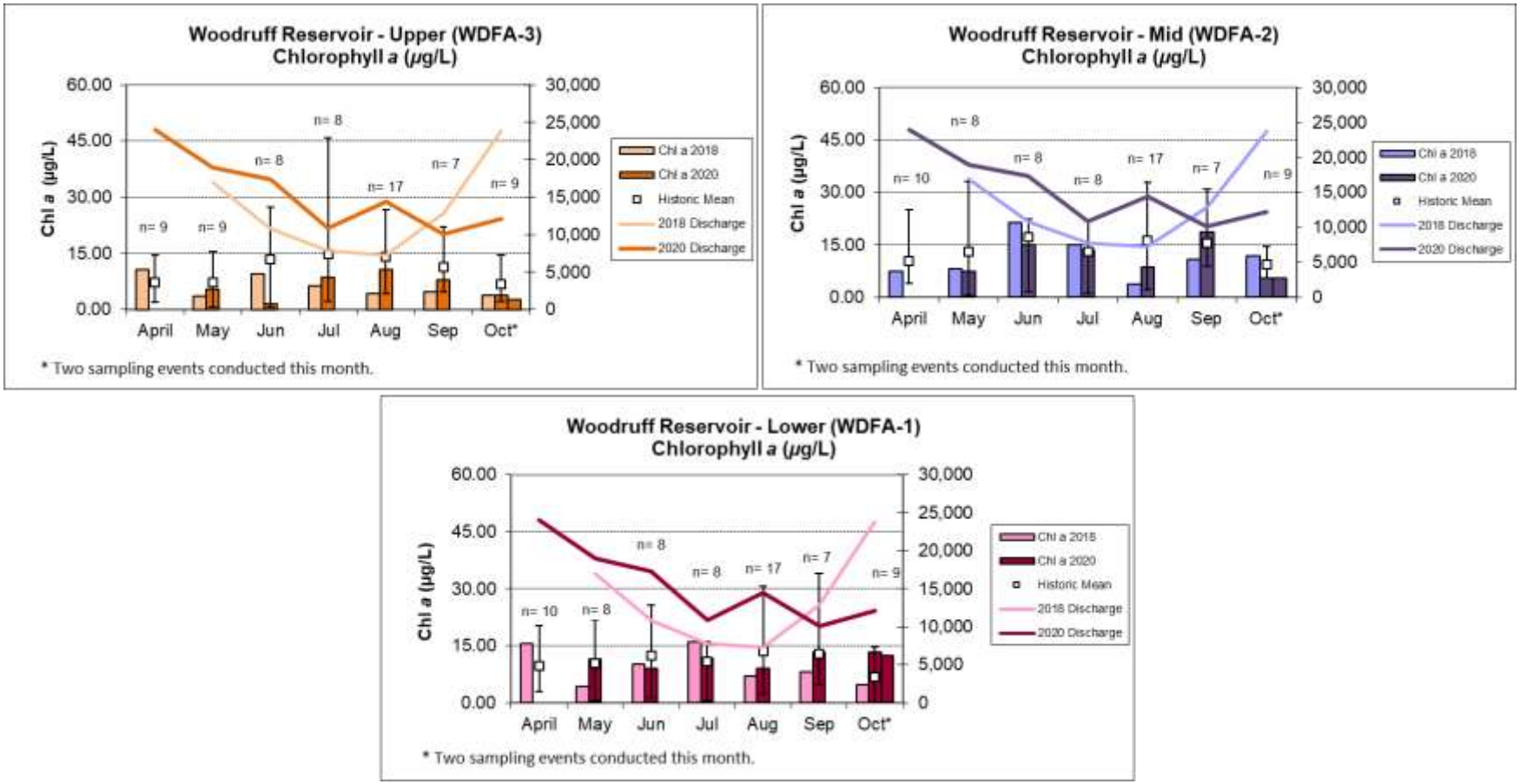
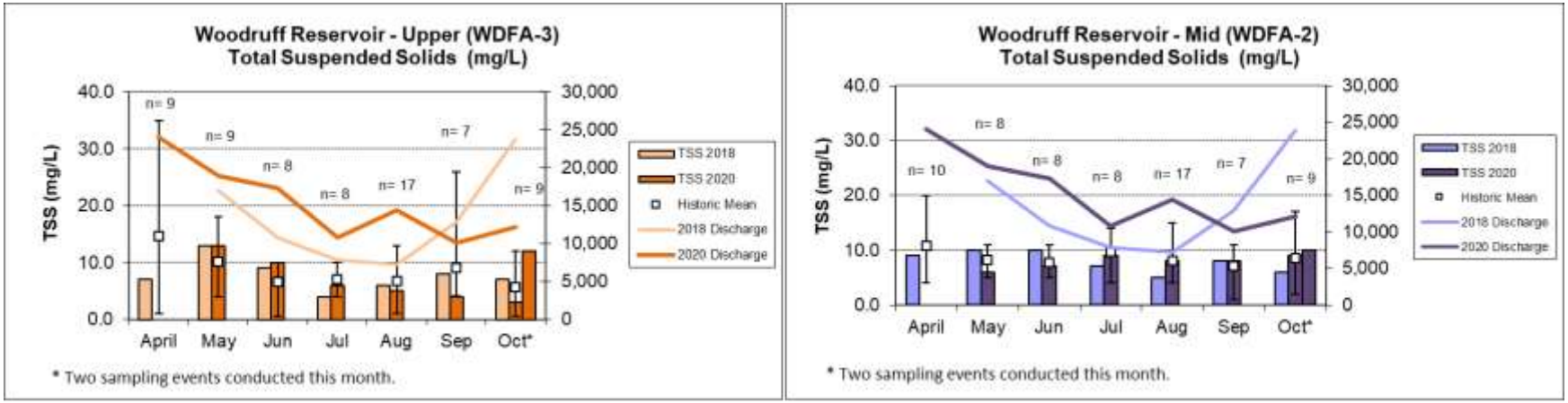


Figure 7. Monthly TSS concentrations of the mainstem stations in Woodruff Reservoir, April-October 2018 and 2020. Each bar graph depicts monthly changes in each station. The historic mean and min/max range are also displayed for comparison. The "n" value equals the number of data points included in the monthly historic calculations. TSS was plotted vs. the closest discharge (COE Alabama River at Robert F. Henry L&D near Benton, AL).



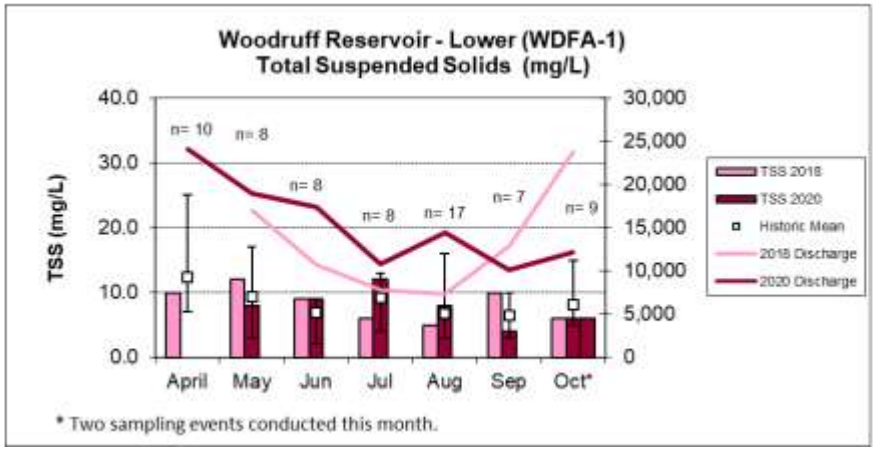


Table 2. Algal growth potential test results, Woodruff Reservoir, 2000-2018 (expressed as mean Maximum Standing Crop (MSC) dry weights of *Selenastrum capricornutum* in mg/L) and limiting nutrient status. MSC values below 5 mg/L are considered to be protective in reservoirs and lakes; values below 20 mg/L MSC are considered protective of flowing streams and rivers. (Raschke and Schultz 1987).

Station	WDFA-1 (Lower)		WDFA-2 (Mid)		WDFA-3 (Upper)	
	MSC	Limiting Nutrient	MSC	Limiting Nutrient	MSC	Limiting Nutrient
2000	5.22	NITROGEN	6.79	NITROGEN	4.36	PHOSPHORUS
2005	5.33	PHOSPHORUS	8.63	CO-LIMITING	6.11	PHOSPHORUS
2010	---	---	---	---	3.29	NITROGEN
2018	10.22	NITROGEN	10.75	CO-LIMITING	6.62	CO-LIMITING

Figure 8. Monthly DO concentrations at 1.5 m (5 ft) for Woodruff Reservoir stations collected April-October 2018. ADEM Water Quality Criteria pertaining to reservoir waters require a minimum DO concentration of 5.0 mg/L at this depth (ADEM Admin. Code R. 335-6-10-.09).

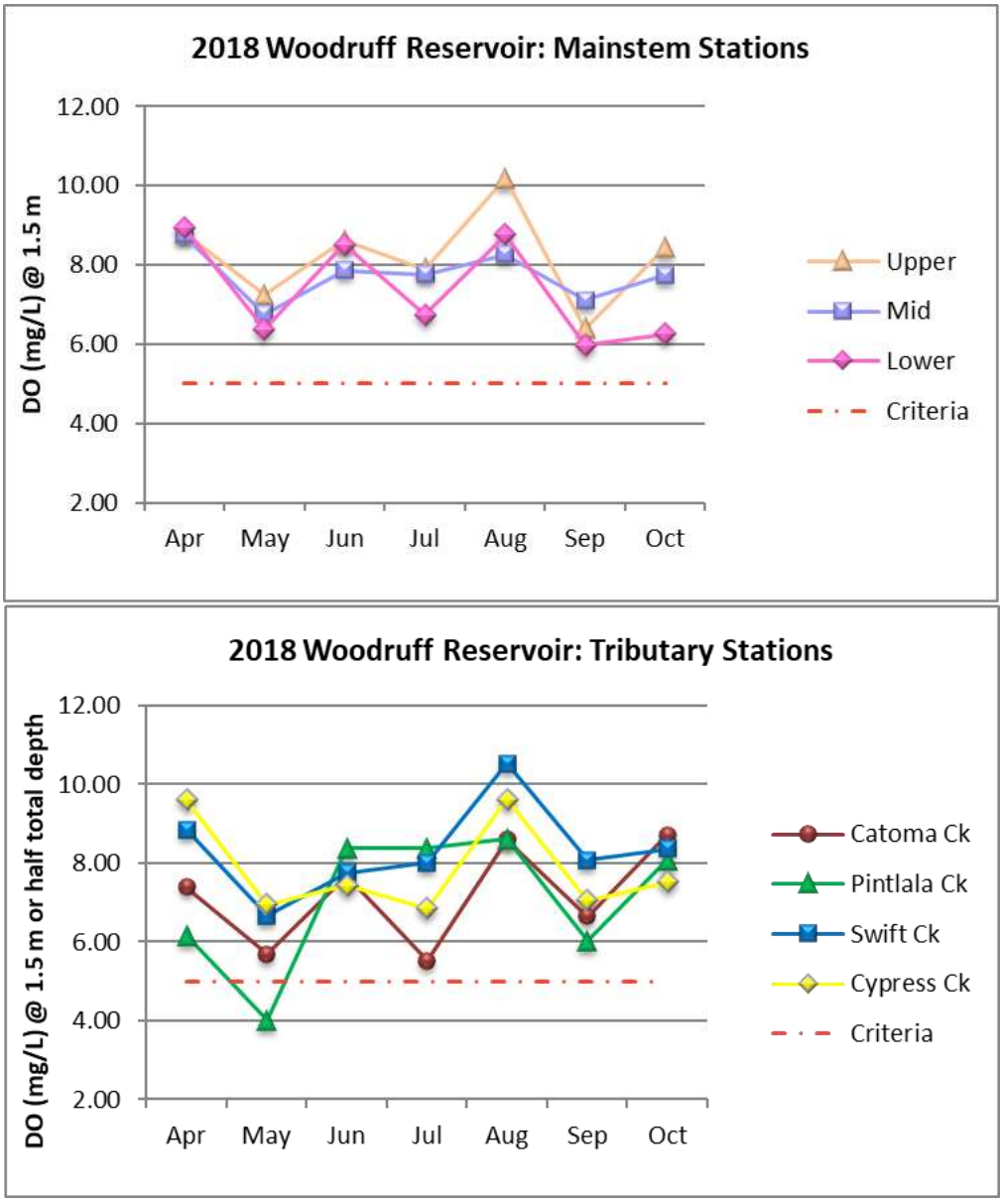


Figure 9. Monthly DO concentrations at 1.5 m (5 ft) for Woodruff Reservoir stations collected April-October 2020. ADEM Water Quality Criteria pertaining to reservoir waters require a minimum DO concentration of 5.0 mg/L at this depth (ADEM Admin. Code R. 335-6-10-.09).

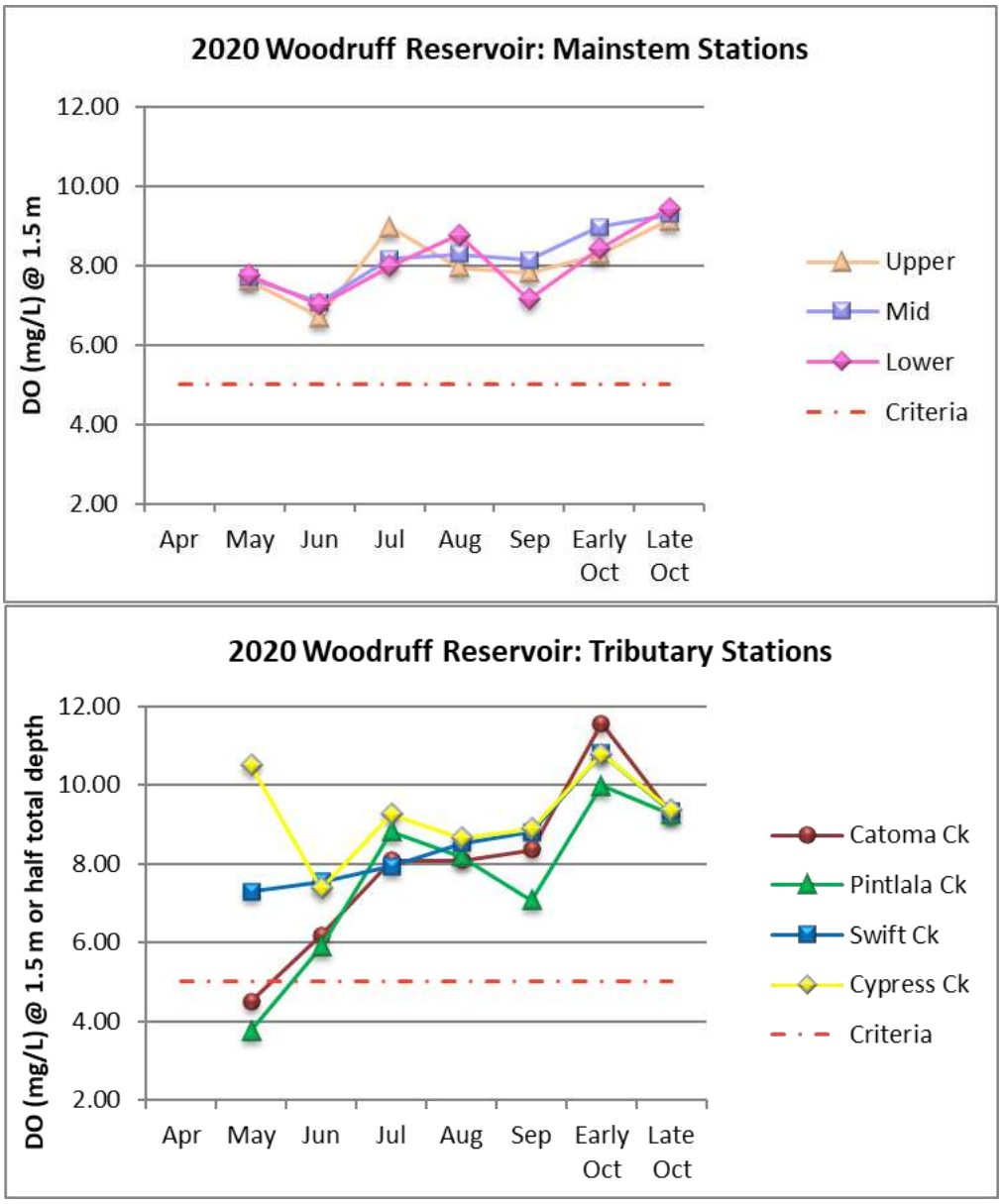


Figure 10. Monthly depth profiles of dissolved oxygen (mg/L), temperature (C), and conductivity (umhos) in lower Woodruff Reservoir, April-October 2018.

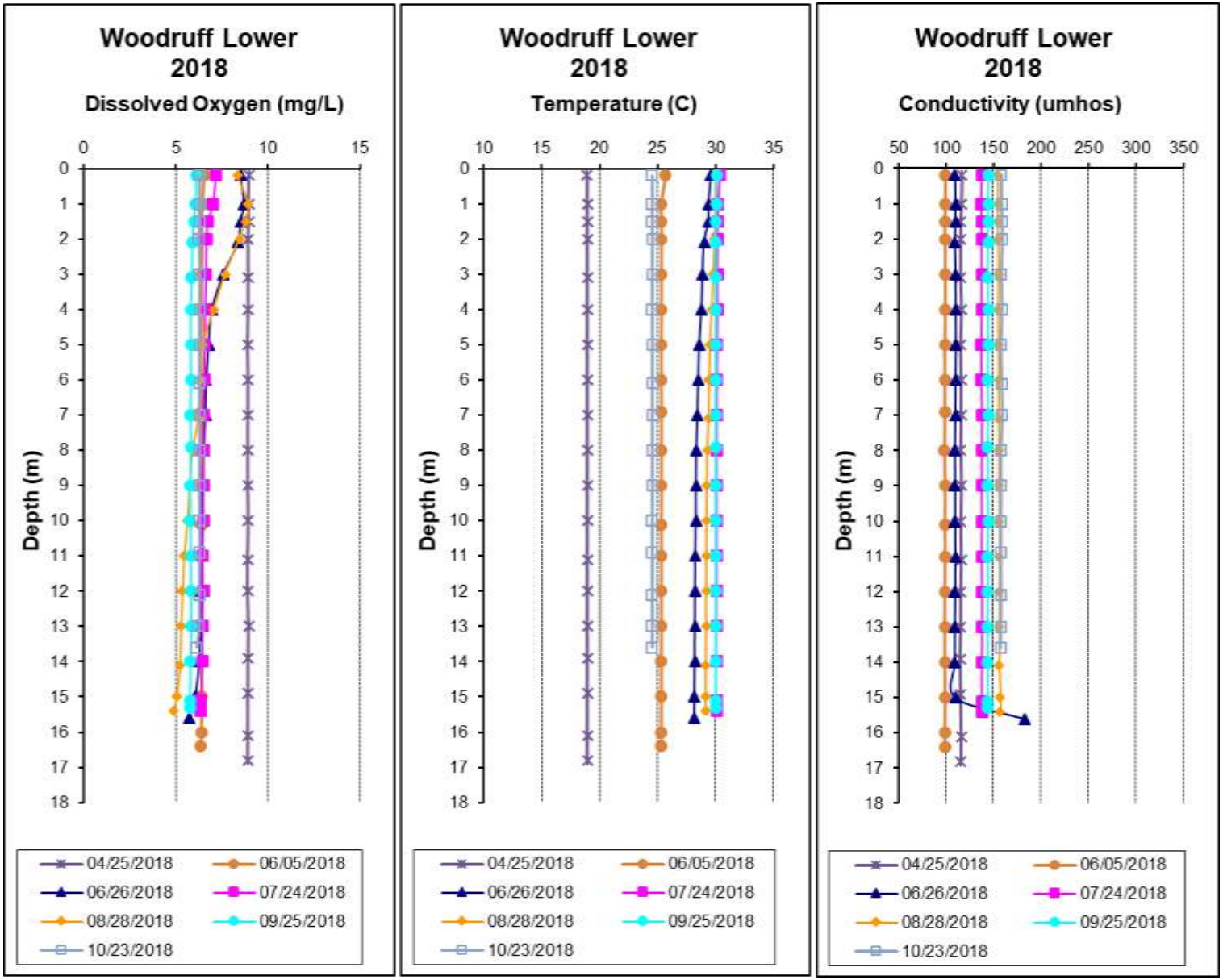


Figure 11. Monthly depth profiles of dissolved oxygen (mg/L), temperature (C), and conductivity (umhos) in mid Woodruff Reservoir, April-October 2018.

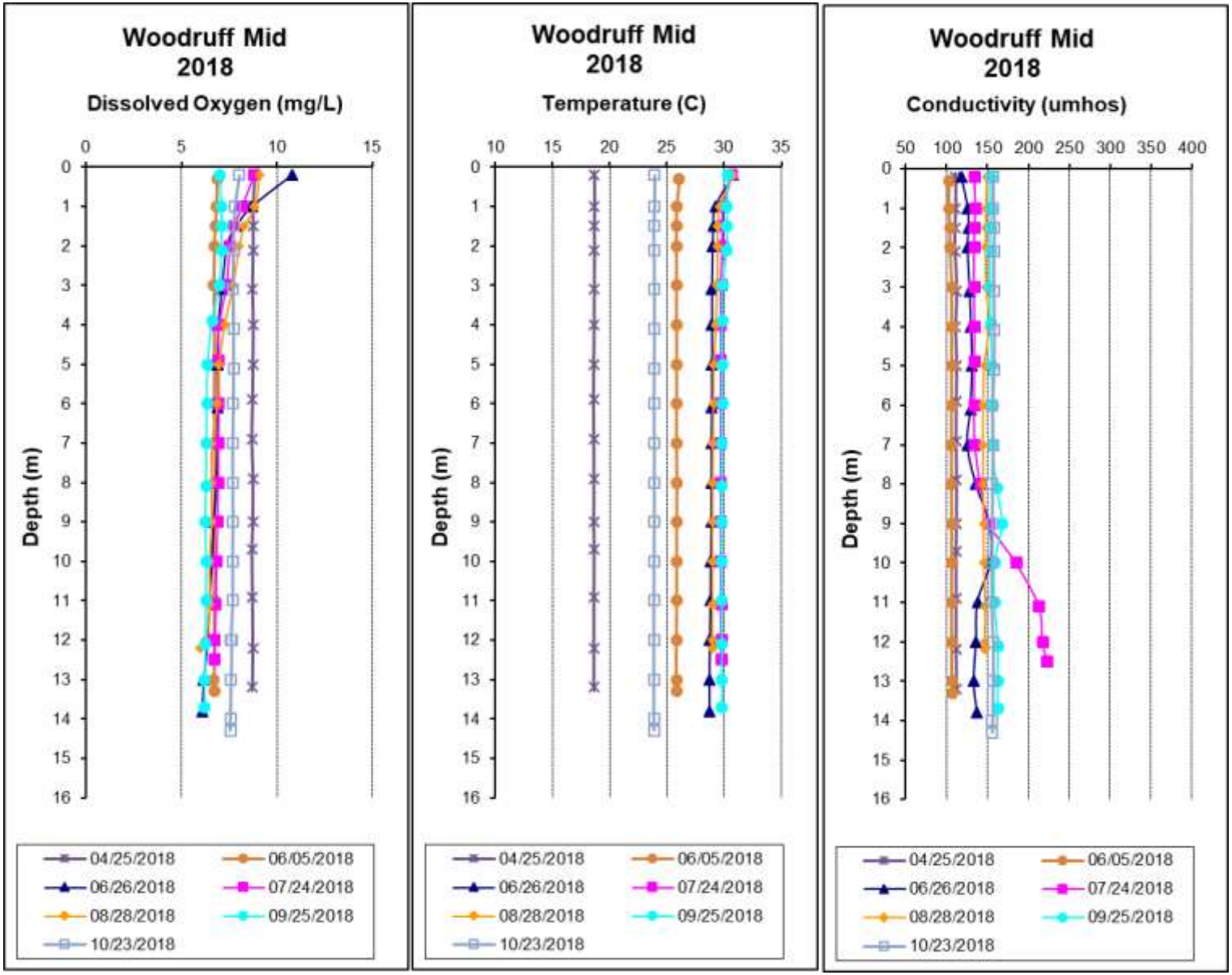


Figure 12. Monthly depth profiles of dissolved oxygen (mg/L), temperature (C), and conductivity (umhos) in lower Woodruff Reservoir, April-October 2020.

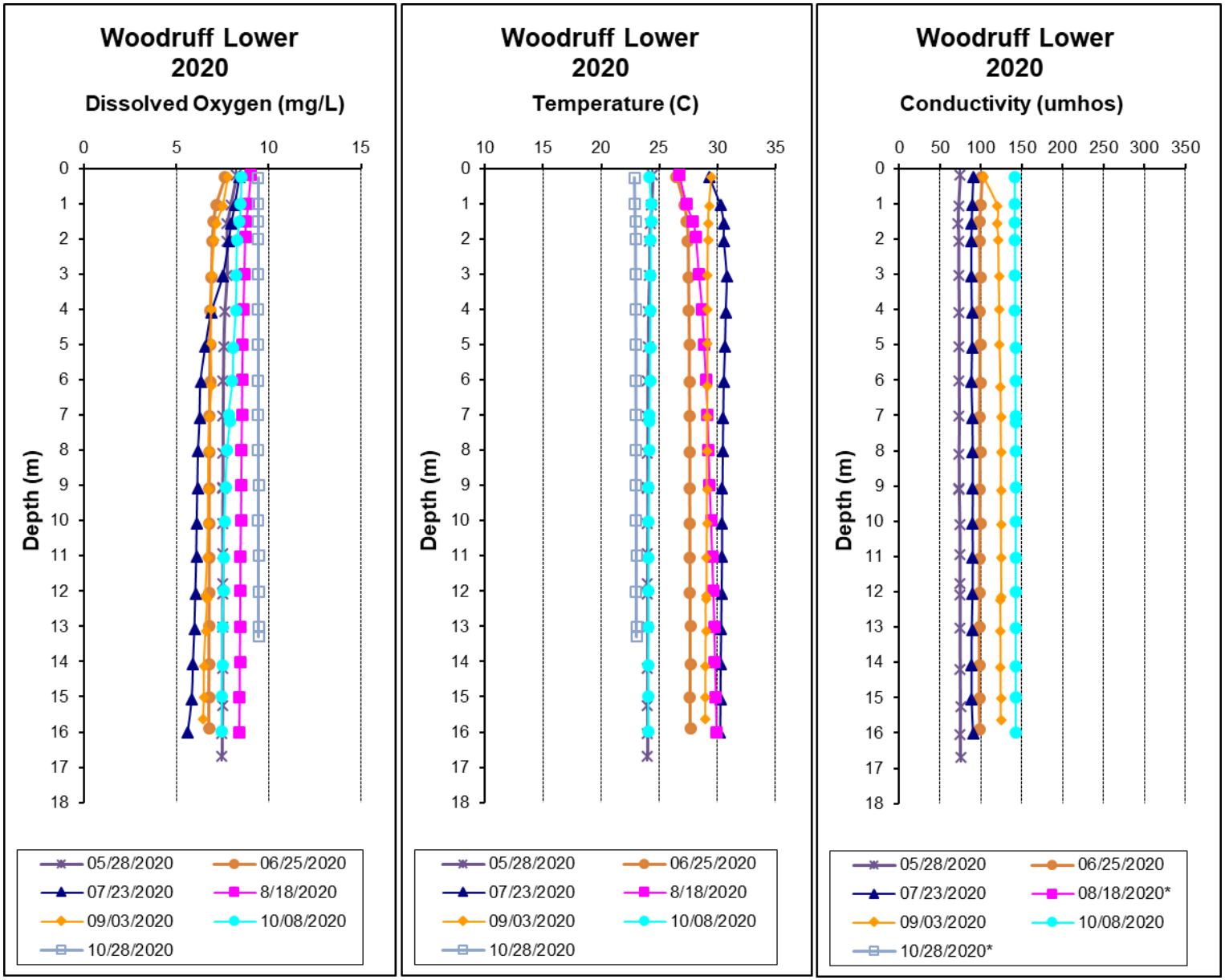


Figure 13. Monthly depth profiles of dissolved oxygen (mg/L), temperature (C), and conductivity (umhos) in mid Woodruff Reservoir, April-October 2020.

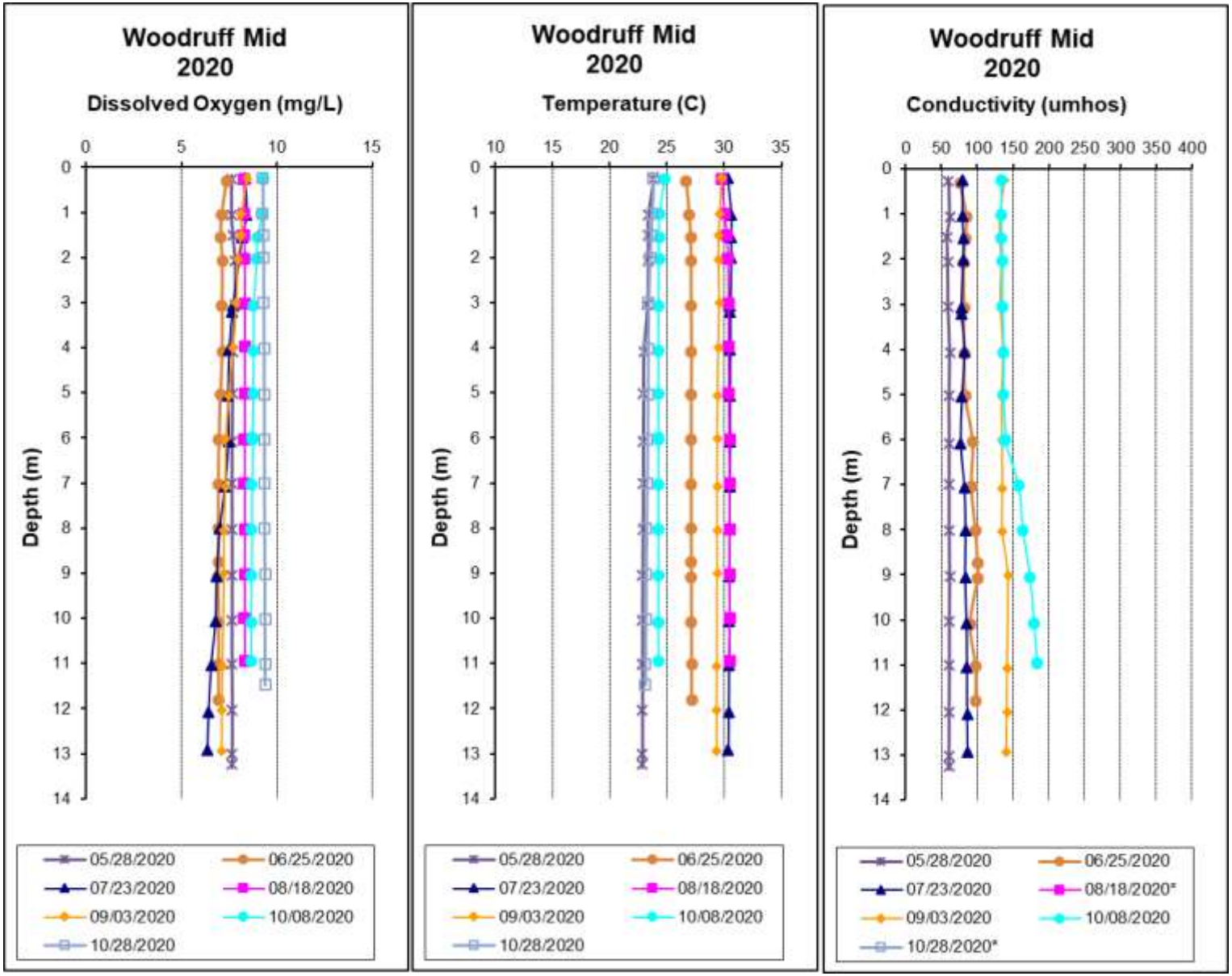


Figure 14. Monthly TSI values calculated for mainstem and tributary Woodruff Reservoir stations in 2018 using chl *a* concentrations and Carlson's Trophic Index calculation (Carlson 1977). Monthly discharge data from nearest gage station (COE Alabama River at Robert F. Henry L&D near Benton, AL).

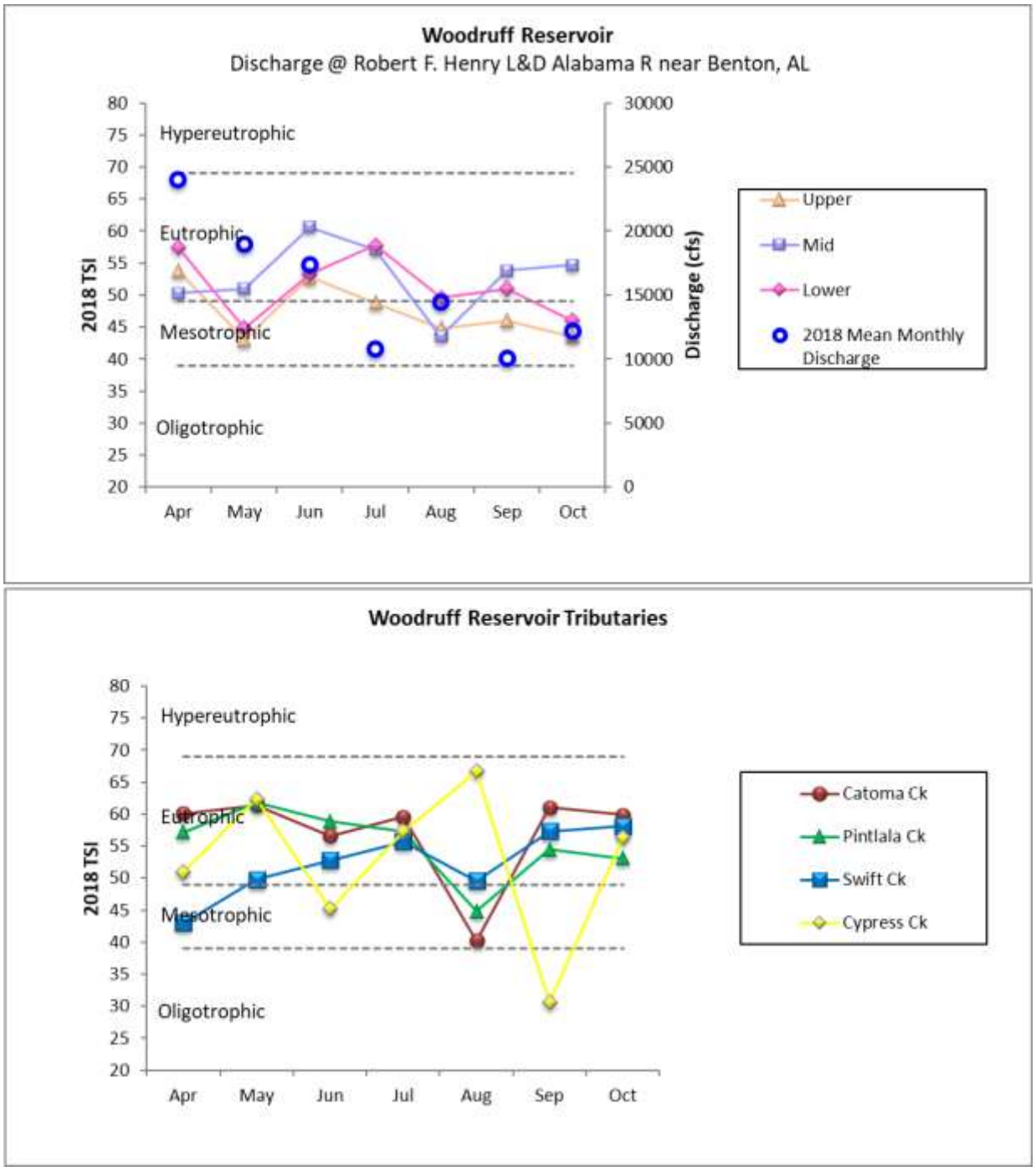
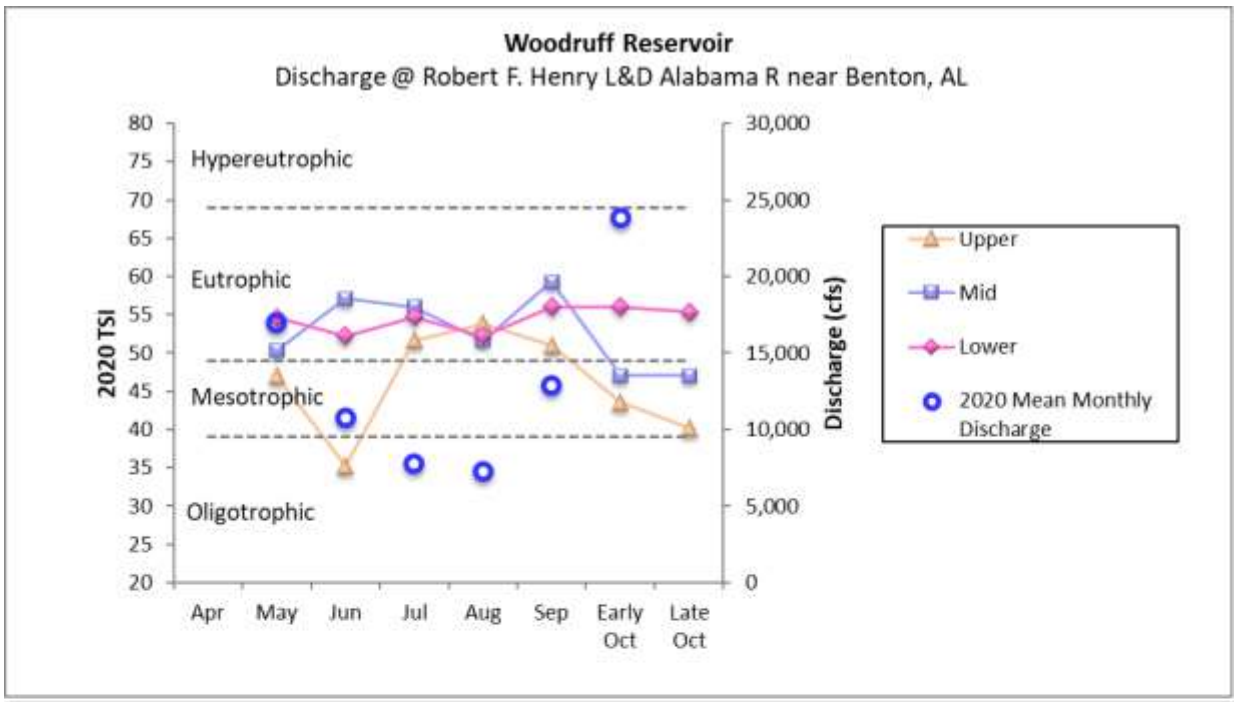
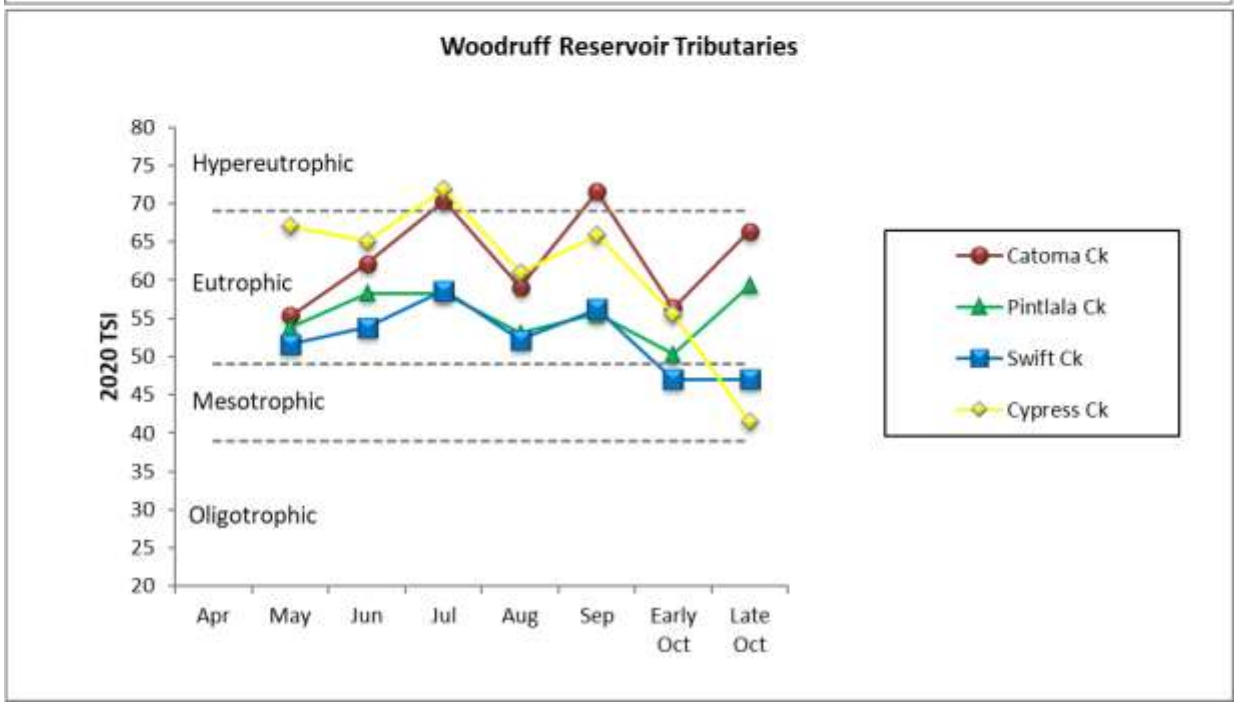


Figure 15. Monthly TSI values calculated for mainstem and tributary Woodruff Reservoir stations in 2020 using chl *a* concentrations and Carlson's Trophic Index calculation (Carlson 1977). Monthly discharge data from nearest gage station (COE Alabama River at Robert F. Henry L&D near Benton, AL).





REFERENCES

ADEM. 2017. State of Alabama Water Quality Monitoring Strategy. Alabama Department of Environmental Management (ADEM), Montgomery, AL. 108 pp.

ADEM. 2018a. Quality Assurance Project Plan (QAPP) for Surface Water Quality Monitoring in Alabama Rev 2. Alabama Department of Environmental Management (ADEM), Montgomery, AL. 176 pp.

ADEM. 2018b. Quality Management Plan (QMP) for the Alabama Department of Environmental Management (ADEM) Rev 5.0, Montgomery, AL. 72 pp.

ADEM. 2020. Standard Operating Procedures Series #2000, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

Alabama Department of Environmental Management Water Division (ADEM Admin. Code R. 335-6-10-.09). 2017. Specific Water Quality Criteria. Water Quality Program. Chapter 10. Volume 1. Division 335-6.

Alabama Department of Environmental Management Water Division (ADEM Admin. Code R. 335-6-10-.11). 2017. Water Quality Criteria Applicable to Specific Lakes. Water Quality Program. Chapter 10. Volume 1. Division 335-6.

Carlson, R.E. 1977. A trophic state index. Limnology and Oceanography. 22(2):361-369.

Raschke, R.L. and D.A. Schultz. 1987. The use of the algal growth potential test for data assessment. Journal of Water Pollution Control Federation 59(4):222-227.

APPENDIX

Appendix Table 1. Summary of water quality data collected April-October, 2018. Minimum (min) and maximum (max) values calculated using minimum detection limits when results were less than this value. Median (med), mean, and standard deviation (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
WDFA-1	**Physical**							
	Turbidity (NTU)	7		7.1	17.1	8.8	9.6	3.4
	Total Dissolved Solids (mg/L)	7		56.0	112.0	78.0	79.3	18.5
	Total Suspended Solids (mg/L)[J]	7		5.0	12.0	9.0	8.3	2.6
	Hardness (mg/L)	4		39.1	55.1	48.0	47.6	6.6
	Alkalinity (mg/L)	7		35.9	53.4	48.1	46.2	6.7
	Photic Zone (m)	7		2.21	3.31	3.12	3.00	0.38
	Secchi (m)	7		0.81	1.61	0.91	1.05	0.29
	Bottom Depth (m)	7		13.6	16.8	15.4	15.5	1.0
	Chemical							
	Ammonia Nitrogen (mg/L)[J]	7	<	0.007	0.053	0.017	0.018	0.018
	Nitrate+Nitrite Nitrogen (mg/L)	7		0.055	0.176	0.143	0.135	0.044
	Total Kjeldahl Nitrogen (mg/L)	7		0.240	0.551	0.426	0.430	0.118
	Total Nitrogen (mg/L)	7		1.038	2.154	0.599	0.564	0.131
	Dis Reactive Phosphorus (mg/L)[J]	7	<	0.004	0.015	0.007	0.008	0.004
	Total Phosphorus (mg/L)	7		0.022	0.038	0.023	0.026	0.006
	CBOD-5 (mg/L)	7	<	2.0	2.1	1.0	1.2	0.4
	Chlorides (mg/L)	7		4.4	8.3	6.3	6.3	1.5
	Biological							
	Chlorophyll a (mg/m³)	7		4.27	16.00	8.01	9.38	4.77
	E. coli (MPN/DL)	4		1	2	2	2	1
WDFA-2	**Physical**							
	Turbidity (NTU)	7		7.3	13.6	7.9	8.8	2.2
	Total Dissolved Solids (mg/L)	7		52.0	132.0	77.0	80.9	24.5
	Total Suspended Solids (mg/L)	7		5.0	10.0	8.0	7.9	2.0
	Hardness (mg/L)	4		43.8	55.5	51.5	50.6	5.2
	Alkalinity (mg/L)	7		39.7	55.0	49.7	48.6	5.9
	Photic Zone (m)	7		2.70	3.81	3.11	3.19	0.41
	Secchi (m)	7		0.85	1.12	1.04	0.99	0.11
	Bottom Depth (m)	7		12.2	14.3	13.3	13.3	0.7
	Ammonia Nitrogen (mg/L)	7	<	0.007	0.026	0.004	0.007	0.008
	Nitrate+Nitrite Nitrogen (mg/L)	7		0.076	0.166	0.153	0.129	0.039
	Total Kjeldahl Nitrogen (mg/L)	7		0.329	0.762	0.509	0.543	0.146
	Total Nitrogen (mg/L)	7		1.266	2.757	0.639	0.672	0.172
	Dis Reactive Phosphorus (mg/L)[J]	7		0.004	0.009	0.004	0.005	0.002
	Total Phosphorus (mg/L)	7		0.024	0.036	0.026	0.028	0.004
	CBOD-5 (mg/L)	7	<	2.0	2.9	1.0	1.3	0.7
	Chlorides (mg/L)	7		3.7	9.3	5.0	5.5	1.9
	Biological							
	Chlorophyll a (mg/m³)	7		3.74	21.40	10.70	11.15	5.75
	E. coli (MPN/DL)	4		2	3	2	2	1

Station	Parameter	N		Min	Max	Med	Avg	SD
WDFA-3	**Physical**							
	Turbidity (NTU)	7		4.6	14.8	6.9	7.8	3.3
	Total Dissolved Solids (mg/L)	7		38.0	84.0	62.0	63.7	16.3
	Total Suspended Solids (mg/L)	7		4.0	13.0	7.0	7.7	2.8
	Hardness (mg/L)	4		36.0	57.1	55.4	51.0	10.0
	Alkalinity (mg/L)	7		28.8	56.7	46.4	44.7	10.9
	Photic Zone (m)	7		2.69	4.89	3.60	3.75	0.75
	Secchi (m)	7		1.00	1.65	1.13	1.21	0.22
	Bottom Depth (m)	7		10.7	12.7	12.0	11.8	0.6
	Chemical							
	Ammonia Nitrogen (mg/L)[J]	7	<	0.007	0.016	0.004	0.005	0.003
	Nitrate+Nitrite Nitrogen (mg/L)	7		0.036	0.171	0.146	0.111	0.054
	Total Kjeldahl Nitrogen (mg/L)	7		0.201	0.549	0.311	0.340	0.143
	Total Nitrogen (mg/L)	7		0.711	2.085	0.463	0.451	0.173
	Dis Reactive Phosphorus (mg/L)[J]	7	<	0.004	0.006	0.004	0.004	0.002
	Total Phosphorus (mg/L)	7		0.017	0.029	0.020	0.021	0.004
	CBOD-5 (mg/L)	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		3.2	5.9	3.8	4.4	1.1
	Biological							
	Chlorophyll a (mg/m³)	7		3.56	10.70	4.81	6.16	2.90
	E. coli (MPN/DL)	4		1	461	5	118	229
WDFA-4	**Physical**							
	Turbidity (NTU)	7		10.2	29.0	16.9	17.8	6.1
	Total Dissolved Solids (mg/L)	7		76.0	128.0	87.0	93.7	21.5
	Total Suspended Solids (mg/L)	7		9.0	20.0	18.0	15.9	4.2
	Hardness (mg/L)	4		53.7	66.4	60.1	60.1	5.4
	Alkalinity (mg/L)	7		54.2	78.4	61.1	63.9	9.9
	Photic Zone (m)	7		1.39	2.61	1.81	2.00	0.49
	Secchi (m)	7		0.39	1.12	0.62	0.66	0.23
	Bottom Depth (m)	7		3.9	4.7	4.4	4.3	0.3
	Chemical							
	Ammonia Nitrogen (mg/L)[J]	7	<	0.007	0.016	0.004	0.005	0.003
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7		0.007	0.105	0.020	0.043	0.043
	Total Kjeldahl Nitrogen (mg/L)	7		0.430	1.610	0.732	0.837	0.399
	Total Nitrogen (mg/L)[J]	7		1.605	4.869	0.747	0.879	0.392
	Dis Reactive Phosphorus (mg/L)[J]	7	<	0.004	0.022	0.011	0.011	0.007
	Total Phosphorus (mg/L)	7		0.034	0.087	0.052	0.058	0.021
	CBOD-5 (mg/L)	7	<	2.0	3.5	2.9	2.6	0.8
	Chlorides (mg/L)	7		4.2	6.5	5.3	5.2	0.8
	Biological							
	Chlorophyll a (mg/m³)	7		2.67	23.10	19.80	17.38	7.10
	E. coli (MPN/DL)[J]	4	<	1	9	4	4	4

Station	Parameter	N		Min	Max	Med	Avg	SD
WDFA-5	**Physical**							
	Turbidity (NTU)	7		8.0	26.4	12.0	13.9	6.4
	Total Dissolved Solids (mg/L)	7		59.0	147.0	78.0	93.6	36.7
	Total Suspended Solids (mg/L)	7		3.0	21.0	10.0	10.7	5.5
	Hardness (mg/L)	4		44.3	59.0	53.0	52.3	6.4
	Alkalinity (mg/L)	7		45.9	93.6	55.1	62.7	18.0
	Photic Zone (m)	7		1.33	2.77	2.39	2.26	0.48
	Secchi (m)	7		0.60	1.12	0.75	0.81	0.20
	Bottom Depth (m)	7		5.9	6.7	6.5	6.4	0.2
	Chemical							
	Ammonia Nitrogen (mg/L)[J]	7	<	0.007	0.062	0.004	0.015	0.022
	Nitrate+Nitrite Nitrogen (mg/L)	7		0.020	0.378	0.110	0.133	0.116
	Total Kjeldahl Nitrogen (mg/L)	7		0.321	2.300	0.426	0.743	0.711
	Total Nitrogen (mg/L)	7		1.152	6.960	0.552	0.877	0.697
	Dis Reactive Phosphorus (mg/L)[J]	7		0.004	0.059	0.008	0.019	0.021
	Total Phosphorus (mg/L)	7		0.024	0.102	0.034	0.048	0.031
	CBOD-5 (mg/L)	7	<	2.0	2.8	1.0	1.7	0.8
	Chlorides (mg/L)	7		3.8	5.8	5.3	5.0	0.8
	Biological							
	Chlorophyll a (mg/m³)	7		4.27	24.00	15.00	13.96	6.26
	E. coli (MPN/DL)	4		3	26	9	12	10
WDFA-6	**Physical**							
	Turbidity (NTU)	7		6.4	92.7	9.0	21.9	31.4
	Total Dissolved Solids (mg/L)	7		21.0	96.0	64.0	58.7	24.5
	Total Suspended Solids (mg/L)	7		4.0	42.0	8.0	12.1	13.4
	Hardness (mg/L)	4		21.7	43.5	36.2	34.4	9.6
	Alkalinity (mg/L)	7		3.7	46.3	32.9	27.9	17.4
	Photic Zone (m)	7		0.76	3.65	2.65	2.45	0.89
	Secchi (m)	7		0.26	1.19	0.89	0.82	0.32
	Bottom Depth (m)	7		5.9	7.0	6.8	6.7	0.4
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.007	0.026	0.004	0.007	0.008
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7		0.017	0.145	0.102	0.080	0.049
	Total Kjeldahl Nitrogen (mg/L)	7		0.363	0.594	0.470	0.462	0.079
	Total Nitrogen (mg/L)[J]	7		1.140	2.118	0.591	0.542	0.121
	Dis Reactive Phosphorus (mg/L)[J]	7	<	0.004	0.005	0.002	0.003	0.001
	Total Phosphorus (mg/L)	7		0.013	0.034	0.020	0.021	0.007
	CBOD-5 (mg/L)	7	<	2.0	2.1	1.0	1.2	0.4
	Chlorides (mg/L)	7		1.6	6.7	5.0	4.5	2.0
	Biological							
	Chlorophyll a (mg/m³)	7		3.56	16.60	9.61	10.30	4.82
	E. coli (MPN/DL)[J]	4	<	1	1	1	1	0

Station	Parameter	N		Min	Max	Med	Avg	SD
WDFA-7	**Physical**							
	Turbidity (NTU)	7		7.2	13.5	7.5	9.3	2.7
	Total Dissolved Solids (mg/L)	7		59.0	125.0	74.0	82.3	23.9
	Total Suspended Solids (mg/L)	7	<	1.0	15.0	6.0	7.8	5.0
	Hardness (mg/L)	4		37.3	53.2	47.8	46.5	6.7
	Alkalinity (mg/L)	7		40.0	53.3	48.5	48.8	4.4
	Photic Zone (m)	7		1.84	3.49	2.73	2.73	0.49
	Secchi (m)	7		0.70	1.09	0.96	0.94	0.14
	Bottom Depth (m)	7		5.0	5.8	5.5	5.5	0.3
	Chemical							
	Ammonia Nitrogen (mg/L)[J]	7	<	0.007	0.018	0.004	0.006	0.006
	Nitrate+Nitrite Nitrogen (mg/L)	7	<	0.004	0.122	0.049	0.048	0.038
	Total Kjeldahl Nitrogen (mg/L)	7		0.290	0.705	0.489	0.517	0.141
	Total Nitrogen (mg/L)	7	<	0.942	2.292	0.557	0.565	0.147
	WDFA-7	**N**		**Min**	**Max**	**Med**	**Avg**	**SD**
	Chemical							
	Dis Reactive Phosphorus (mg/L)[J]	7	<	0.004	0.006	0.002	0.003	0.002
	Total Phosphorus (mg/L)	7		0.018	0.037	0.027	0.028	0.006
	CBOD-5 (mg/L)	7	<	2.0	4.0	2.6	2.4	1.1
	Chlorides (mg/L)	7		4.3	7.7	6.4	6.2	1.3
	Biological							
	Chlorophyll a (mg/m³)	7	<	0.10	39.50	13.90	15.26	13.52
	E. coli (MPN/DL)[J]	4	<	1	4	2	2	2

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, 2020. Minimum (min) and maximum (max) values calculated using minimum detection limits when results were less than this value. Median (med), mean, and standard deviation (SD) values were calculated by multiplying the MDL by 0.5 when results were less than this value.

Station	Parameter	N		Min	Max	Med	Mean	SD
WDFA-1	**Physical**							
	Turbidity (NTU)	7		5.5	10.0	7.1	7.4	1.4
	Total Dissolved Solids (mg/L)[J]	7		52.0	102.0	74.0	74.0	15.0
	Total Suspended Solids (mg/L)[J]	7		4.0	12.0	8.0	7.6	2.6
	Hardness (mg/L)	4	<	0.4	43.9	41.9	32.0	21.3
	Alkalinity (mg/L)	7		36.4	53.2	42.6	44.1	5.3
	Photic Zone (m)	7		2.76	3.72	3.40	3.33	0.35
	Secchi (m)	7		0.97	1.27	1.02	1.09	0.11
	Bottom Depth (m)	7		13.3	16.7	16.0	15.6	1.1
	Chemical							
	Ammonia Nitrogen (mg/L)[J]	7	<	0.016	0.092	0.008	0.029	0.032
	Nitrate+Nitrite Nitrogen (mg/L)	7		0.067	0.156	0.118	0.116	0.037
	Total Kjeldahl Nitrogen (mg/L)[J]	7	<	0.324	0.545	0.427	0.414	0.126
	Total Nitrogen (mg/L)[J]	7	<	0.687	2.013	0.542	0.530	0.149
	Dis Reactive Phosphorus (mg/L)[J]	6		0.004	0.011	0.006	0.007	0.002
	Total Phosphorus (mg/L)[J]	7		0.019	0.054	0.037	0.036	0.011
	CBOD-5 (mg/L)	6	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)[J]	7		4.1	8.8	5.5	5.8	1.5
	Biological							
	Chlorophyll a (mg/m³)	7		9.08	13.40	11.70	11.54	1.82
	E. coli (MPN/DL)	4		1	8	3	4	3
WDFA-2	**Physical**							
	Turbidity (NTU)	7		6.7	15.7	8.3	9.2	3.0
	Total Dissolved Solids (mg/L)	7		44.0	87.0	71.0	67.9	14.5
	Total Suspended Solids (mg/L)[J]	7		6.0	10.0	8.0	8.1	1.4
	Hardness (mg/L)	4		40.8	169.0	46.2	75.6	62.3
	Alkalinity (mg/L)	7		29.9	54.4	42.6	43.2	7.8
	Photic Zone (m)	7		2.32	4.27	3.40	3.53	0.66
	Secchi (m)	7		0.83	1.21	1.10	1.07	0.14
	Bottom Depth (m)	7		11.0	13.2	11.8	12.0	1.0
	Chemical							
	Ammonia Nitrogen (mg/L)[J]	7	<	0.016	0.025	0.008	0.010	0.006
	Nitrate+Nitrite Nitrogen (mg/L)	7		0.080	0.216	0.134	0.144	0.047
	Total Kjeldahl Nitrogen (mg/L)	7	<	0.283	0.964	0.410	0.440	0.259
	Total Nitrogen (mg/L)	7	<	0.888	3.132	0.515	0.584	0.230
	Dis Reactive Phosphorus (mg/L)[J]	6	<	0.004	0.014	0.006	0.007	0.004
	Total Phosphorus (mg/L)	7		0.030	0.050	0.037	0.038	0.007
	CBOD-5 (mg/L)	6	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		3.0	8.0	4.8	4.8	1.6
	Biological							
	Chlorophyll a (mg/m³)	7		5.34	18.70	8.54	10.54	5.20
	E. coli (MPN/DL)[J]	4	<	1	19	5	7	8

Station	Parameter	N		Min	Max	Med	Mean	SD
WDFA-3	**Physical**							
	Turbidity (NTU)	7		5.3	16.8	6.1	9.5	5.1
	Total Dissolved Solids (mg/L)	7		51.0	96.0	69.0	70.9	15.7
	Total Suspended Solids (mg/L)[J]	7		3.0	13.0	6.0	7.6	4.0
	Hardness (mg/L)	4		12.3	48.1	45.0	37.6	16.9
	Alkalinity (mg/L)	7		33.0	55.8	41.5	43.8	7.5
	Photic Zone (m)	7		2.74	4.20	3.68	3.54	0.59
	Secchi (m)	7		0.81	1.44	1.01	1.10	0.25
	Bottom Depth (m)	7		8.7	11.8	10.9	10.4	1.1
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.016	0.054	0.008	0.015	0.017
	Nitrate+Nitrite Nitrogen (mg/L)	7		0.035	0.161	0.115	0.112	0.043
	Total Kjeldahl Nitrogen (mg/L)[J]	7	<	0.232	0.568	0.162	0.260	0.156
	Total Nitrogen (mg/L)[J]	7	<	0.591	2.049	0.290	0.371	0.175
	Dis Reactive Phosphorus (mg/L)[J]	6	<	0.004	0.010	0.005	0.005	0.003
	Total Phosphorus (mg/L)	7		0.015	0.041	0.025	0.027	0.009
	CBOD-5 (mg/L)	6	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)[J]	7		2.8	4.8	3.6	3.7	0.7
	Biological							
	Chlorophyll a (mg/m³)	7		1.60	10.70	5.34	5.80	3.37
	E. coli (MPN/DL)	4		3	111	17	37	51
WDFA-4	**Physical**							
	Turbidity (NTU)	7		10.7	39.2	15.9	19.9	9.7
	Total Dissolved Solids (mg/L)	7		55.0	126.0	80.0	88.6	23.5
	Total Suspended Solids (mg/L)[J]	7		12.0	28.0	19.0	20.1	6.3
	Hardness (mg/L)	4		53.1	72.9	57.0	60.0	8.8
	Alkalinity (mg/L)	7		45.2	76.6	55.6	58.7	10.6
	Photic Zone (m)	7		1.15	2.25	1.76	1.75	0.38
	Secchi (m)	7		0.31	0.71	0.56	0.56	0.13
	Bottom Depth (m)	7		4.0	4.8	4.3	4.3	0.3
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.016	0.072	0.008	0.017	0.024
	Nitrate+Nitrite Nitrogen (mg/L)	7	<	0.003	0.115	0.020	0.033	0.042
	Total Kjeldahl Nitrogen (mg/L)[J]	7		0.229	1.120	0.705	0.656	0.288
	Total Nitrogen (mg/L)[J]	7	<	1.032	3.364	0.739	0.689	0.266
	Dis Reactive Phosphorus (mg/L)[J]	6		0.004	0.028	0.006	0.010	0.009
	Total Phosphorus (mg/L)	7		0.029	0.146	0.086	0.082	0.040
	CBOD-5 (mg/L)	6	<	2.0	3.6	2.7	2.4	1.2
	Chlorides (mg/L)[J]	7		3.1	6.3	4.3	4.3	1.0
	Biological							
	Chlorophyll a (mg/m³)	7		12.50	65.10	24.90	32.97	21.36
	E. coli (MPN/DL)[J]	4	<	1	42	6	14	19

Station	Parameter	N		Min	Max	Med	Mean	SD
WDFA-5	**Physical**							
	Turbidity (NTU)	7		7.3	25.0	12.5	14.7	6.8
	Total Dissolved Solids (mg/L)[J]	7		57.0	98.0	82.0	81.0	14.3
	Total Suspended Solids (mg/L)[J]	7		7.0	18.0	12.0	12.7	3.9
	Hardness (mg/L)	4		42.9	63.5	52.8	53.0	10.0
	Alkalinity (mg/L)	7		40.8	61.8	53.3	52.3	6.7
	Photic Zone (m)	7		1.33	2.97	2.59	2.36	0.56
	Secchi (m)	7		0.41	1.02	0.80	0.73	0.20
	Bottom Depth (m)	7		3.7	6.5	6.2	5.8	1.0
	Chemical							
	Ammonia Nitrogen (mg/L)[J]	7	<	0.016	0.109	0.008	0.031	0.037
	Nitrate+Nitrite Nitrogen (mg/L)	7		0.054	0.219	0.088	0.108	0.056
	Total Kjeldahl Nitrogen (mg/L)	7	<	0.324	0.904	0.646	0.623	0.235
	Total Nitrogen (mg/L)	7	<	0.891	2.955	0.755	0.731	0.228
	Dis Reactive Phosphorus (mg/L)[J]	6	<	0.004	0.022	0.011	0.012	0.008
	Total Phosphorus (mg/L)	7		0.021	0.140	0.052	0.066	0.038
	CBOD-5 (mg/L)	6	<	2.0	2.0	1.0	1.2	0.4
	Chlorides (mg/L)[J]	7		3.2	4.8	3.8	3.9	0.6
	Biological							
	Chlorophyll a (mg/m³)	7		7.48	18.70	12.80	13.34	4.23
	E. coli (MPN/DL)	4		1	5	4	3	2
WDFA-6	**Physical**							
	Turbidity (NTU)	7		5.1	16.9	8.9	9.8	4.0
	Total Dissolved Solids (mg/L)[J]	7		24.0	77.0	51.0	52.1	16.1
	Total Suspended Solids (mg/L)[J]	7		5.0	9.0	6.0	6.7	1.4
	Hardness (mg/L)	4		21.4	32.4	24.6	25.8	4.8
	Alkalinity (mg/L)	7		6.8	48.6	22.3	25.7	12.8
	Photic Zone (m)	7		1.95	3.47	2.64	2.77	0.49
	Secchi (m)	7		0.73	1.03	0.97	0.93	0.11
	Bottom Depth (m)	7		4.9	6.9	6.6	6.3	0.7
	Chemical							
	Ammonia Nitrogen (mg/L)[J]	7	<	0.016	0.023	0.008	0.010	0.006
	Nitrate+Nitrite Nitrogen (mg/L)	7	<	0.003	0.152	0.063	0.065	0.050
	Total Kjeldahl Nitrogen (mg/L)[J]	7	<	0.200	0.722	0.468	0.423	0.231
	Total Nitrogen (mg/L)[J]	7	<	0.750	2.244	0.470	0.488	0.195
	Dis Reactive Phosphorus (mg/L)[J]	6	<	0.004	0.004	0.002	0.002	0.001
	Total Phosphorus (mg/L)	7		0.015	0.035	0.030	0.028	0.007
	CBOD-5 (mg/L)	6	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)[J]	7		2.4	5.7	4.0	4.0	1.0
	Biological							
	Chlorophyll a (mg/m³)	7		5.34	17.50	9.08	10.03	4.41
	E. coli (MPN/DL)	4		3	63	8	20	29

Station	Parameter	N		Min	Max	Med	Mean	SD
WDFA-7	**Physical**							
	Turbidity (NTU)	7		4.8	8.8	8.2	7.6	1.4
	Total Dissolved Solids (mg/L)[J]	7		52.0	80.0	68.0	67.3	9.1
	Total Suspended Solids (mg/L)[J]	7		5.0	9.0	7.0	7.3	1.5
	Hardness (mg/L)	4		39.2	43.2	42.2	41.7	1.8
	Alkalinity (mg/L)	7		33.5	52.1	42.2	43.2	5.9
	Photic Zone (m)	7		2.43	3.48	2.84	2.85	0.35
	Secchi (m)	7		0.87	1.03	0.89	0.92	0.06
	Bottom Depth (m)	7		5.0	5.5	5.3	5.3	0.2
	Chemical							
	Ammonia Nitrogen (mg/L)[J]	7	<	0.016	0.022	0.008	0.010	0.005
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7		0.003	0.123	0.028	0.035	0.042
	Total Kjeldahl Nitrogen (mg/L)[J]	7	<	0.324	1.060	0.597	0.575	0.288
	Total Nitrogen (mg/L)[J]	7	<	0.495	3.198	0.629	0.609	0.298
	Dis Reactive Phosphorus (mg/L)[J]	6	<	0.004	0.004	0.003	0.003	0.001
	Total Phosphorus (mg/L)	7		0.026	0.056	0.040	0.041	0.011
	CBOD-5 (mg/L)	6	<	2.0	2.3	2.0	1.7	0.6
	Chlorides (mg/L)	7		4.0	6.8	5.8	5.6	0.9
	Biological							
	Chlorophyll a (mg/m³)	7		3.05	67.30	33.60	30.95	21.02
	E. coli (MPN/DL)[J]	4	<	1	29	8	12	13

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