2012 Lewis Smith Reservoir Report

Rivers and Reservoirs Monitoring Program

Alabama Department of Environmental Management

Field Operations Division
Environmental Indicators Section
Aquatic Assessment Unit
January 2016

Rivers and Reservoirs Monitoring Program

2012

Lewis Smith Reservoir

Black Warrior River Basin

Alabama Department of Environmental Management
Field Operations Division
Environmental Indicators Section
Aquatic Assessment Unit

January 2016

Table of Contents

LIST OF ACRONYMS

A&I	Agriculture and Industry water supply use classification
ADEM	Alabama Department of Environmental Management
AGPT	Algal Growth Potential Test
BW	Black Warrior
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

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Lewis Smith Reservoir's (Smith Reservoir) 21,200 acre water body was established in 1961 by Alabama Power with the completion of Lewis Smith Dam as the first and largest reservoir in the Black Warrior system. Still owned and operated by Alabama Power, Smith Reservoir fulfills multiple purposes like fishing, recreation, drinking water and power supply.

The Alabama Department of Environmental Management (ADEM) monitored Smith Reservoir as part of the assessment of the Black Warrior (BW) and Cahaba 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 ADEM. The current objectives of this program are to provide data that can be used to assess current water quality conditions, 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 2012 Monitoring Strategy (ADEM 2012).

Specific water quality criteria for nutrient management was implemented in 2004 at three locations on Smith Reservoir. These criteria represent the maximum growing season (April-October) mean chlorophyll *a* (chl *a*) concentration allowable while still fully supporting the reservoir's Public Water Supply, Swimming, and Fish and Wildlife (PWS/S/F&W) use classifications.

The purpose of this report is to summarize data collected at eleven stations at Smith Reservoir during the 2012 growing season and to evaluate growing season 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 existing data and established criteria.

METHODS

Sampling stations were selected using historical data and previous assessments (Fig. 1). Specific location information can be found in Table 1. Smith Reservoir was sampled at the dam forebay with additional stations in mid and upper reservoir. Monitoring sites were also established in the Ryan Creek, Rock Creek, Brushy Creek, Clear Creek, Dismal Creek, Crooked Creek, and Sipsey Fork embayments.

Water quality assessments were conducted at monthly intervals, April-October. All samples were collected, preserved, stored, and transported according to procedures in the ADEM Field Operations Division Standard Operating Procedures (ADEM 2012), Surface Water Quality Assurance Project Plan (ADEM 2012), and Quality Management Plan (ADEM 2008).

Mean growing season 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 USGS flow data and ADEM's previously collected data to help interpret the 2012 results.

Figure 1. Lewis Smith Reservoir with 2012 sampling locations. A description of each sampling location is provided in Table 1.

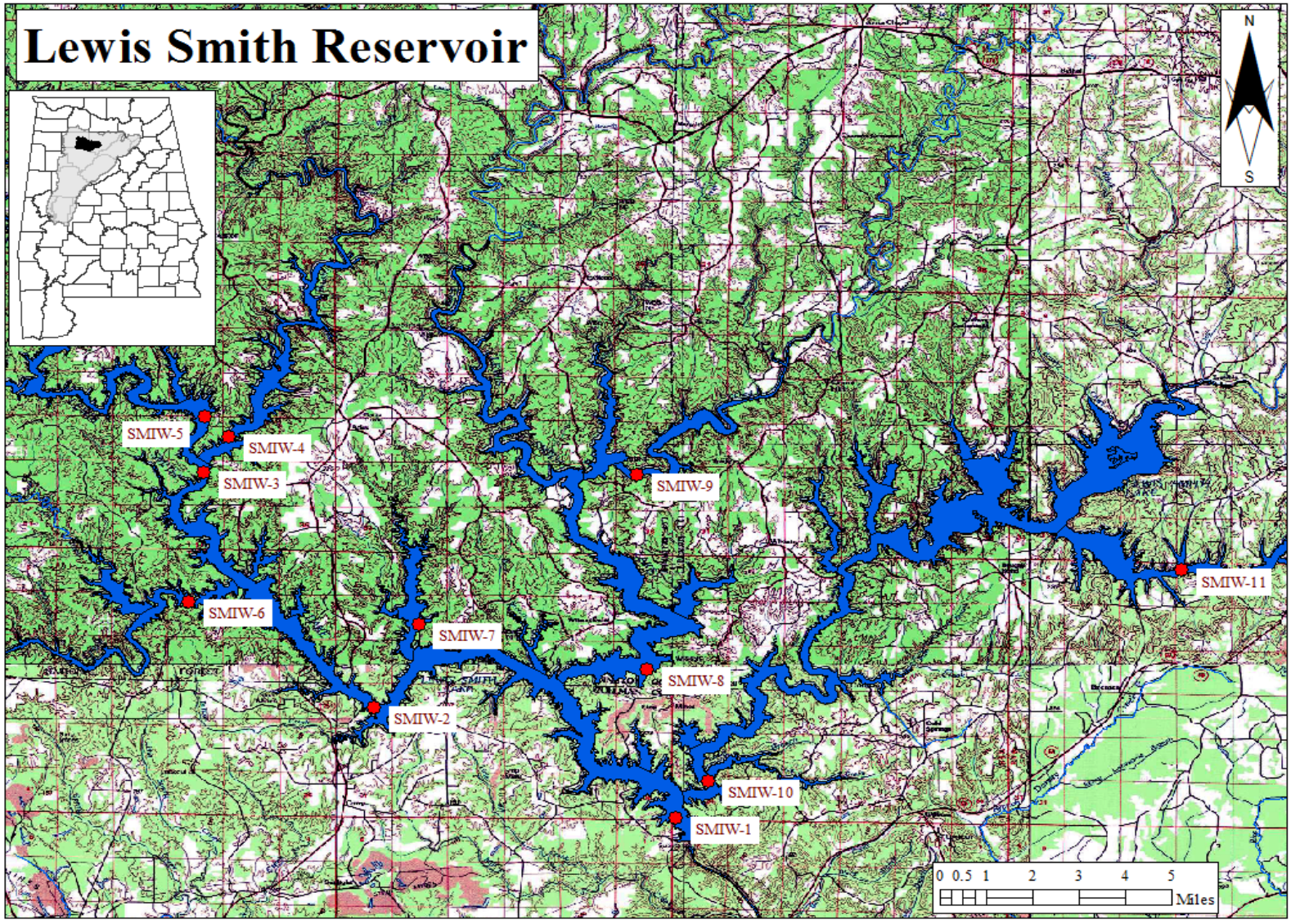


Table 1. Descriptions of the 2012 monitoring stations in Smith Reservoir.

HUC	County	Station Number	Report Designation	Waterbody Name	Station Description	Chl *a* Criteria	Latitude	Longitude
Smith Reservoir								
031601100507	Cullman	SMIW-1	Lower	Black Warrior R	Deepest point, main river channel, dam forebay.	5 µg/l*	33.9495	-87.1108
031601100306	Winston	SMIW-2	Mid	Black Warrior R	Deepest point, main river channel, at Duncan Creek/Sipsey River confluence. Downstream of Alabama Hwy 257 bridge.	5 µg/l*	33.9860	-87.2052
031601100203	Winston	SMIW-3	Upper	Black Warrior R	Deepest point, main river channel, immed. downstream of Brushy Creek confluence.	5 µg/l*	34.0635	-87.2584
031601100203	Winston	SMIW-4	Brushy Ck	Brushy Ck	Deepest point, main creek channel, Brushy Creek embayment.		34.0754	-87.2505
031601100105	Winston	SMIW-5	Sipsey	Sipsey R	Deepest point, main river channel, approx. 0.5 miles downstream of the Sipsey Fork, Yellow Creek confluence.		34.0821	-87.2580
031601100305	Winston	SMIW-6	Clear Ck	Clear Ck	Deepest point, main creek channel, Clear Creek embayment.		34.0210	-87.2630
031601100306	Winston	SMIW-7	Dismal Ck	Dismal Ck	Deepest point, main creek channel, Dismal Creek embayment.		34.0135	-87.1912
031601100408	Winston	SMIW-8	Rock Ck	Rock Ck	Deepest point, main creek channel, Rock Creek embayment.		33.9987	-87.1197
031601100407	Winston	SMIW-9	Crooked Ck	Crooked Ck	Deepest point, main creek channel, Crooked Creek embayment. Approx. 1.5 miles upstream of Winston Co. Rd. 22 bridge.		34.0627	-87.1230
031601100505	Cullman	SMIW-10	Ryan Ck	Ryan Ck	Deepest point, main creek channel, Ryan Creek embayment.		33.9619	-87.1008
031601100504	Cullman	SMIW-11	Simpson Ck	Simpson Ck	Deepest point, main creek channel, Simpson Creek embayment, approx. 2.5 mi upstream of Ryan Creek.		34.0313	-86.9527

*Growing season mean chl *a* criteria implemented at this station in 2004.

RESULTS

Growing season mean graphs for TN, TP, chl *a*, and TSS are provided in this section (Figs. 2 and 3). Monthly graphs for TN, TP, chl *a*, TSS, DO and TSI are also provided (Figs. 4-7 and 11) with mean monthly discharge is included as an indicator of flow and retention time in the months sampled. Algal growth potential test (AGPT) results appears in Table 2. Depth profile graphs of temperature, DO and conductivity appear in Figs. 9 and 10. Summary statistics of all data collected during 2012 are presented in Appendix Table 1. The table contains the minimum, maximum, median, mean, and standard deviation of each parameter analyzed. Results for TKN, TP and TN analyses in Smith Reservoir mainstem stations in 2011 were not included because of data quality concerns.

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

In 2012, the highest growing season mean TN was calculated for the Simpson Ck station (Fig. 2). The mean TN concentrations at the Simpson Ck and upper stations were higher in 2012 than in 2007 while the mean TN concentrations at all other stations decreased. Highest monthly TN concentrations occurred in May for mid, June for upper and July for the lower stations (Fig.4). An historic high monthly TN concentration occurred at the upper station in June. Monthly TN concentrations at the lower and mid stations were generally below historic means.

In 2012, the highest growing season mean TP was calculated for the Crooked Ck station (Fig. 2). The mean TP concentrations all stations decreased from previous growing season means. Monthly TP concentrations were similar April-October. All monthly TP concentrations at mainstem stations were at or below historic mean values (Fig. 5).

In 2012, the highest growing season mean chl *a* was calculated for the Crooked Ck station (Fig 3). The mean chl *a* concentrations for the Sipsey, Dismal Ck, Crooked Ck, Rock Ck, Simpson and Ryan Ck stations increased from the previous growing season sampling seasons. The growing season mean chl *a* concentration in lower, mid, and upper Smith stations were

below the established criterion. Historic high values were observed in April for upper and mid stations, while the remaining monthly concentrations were at or below historic means (Fig. 6).

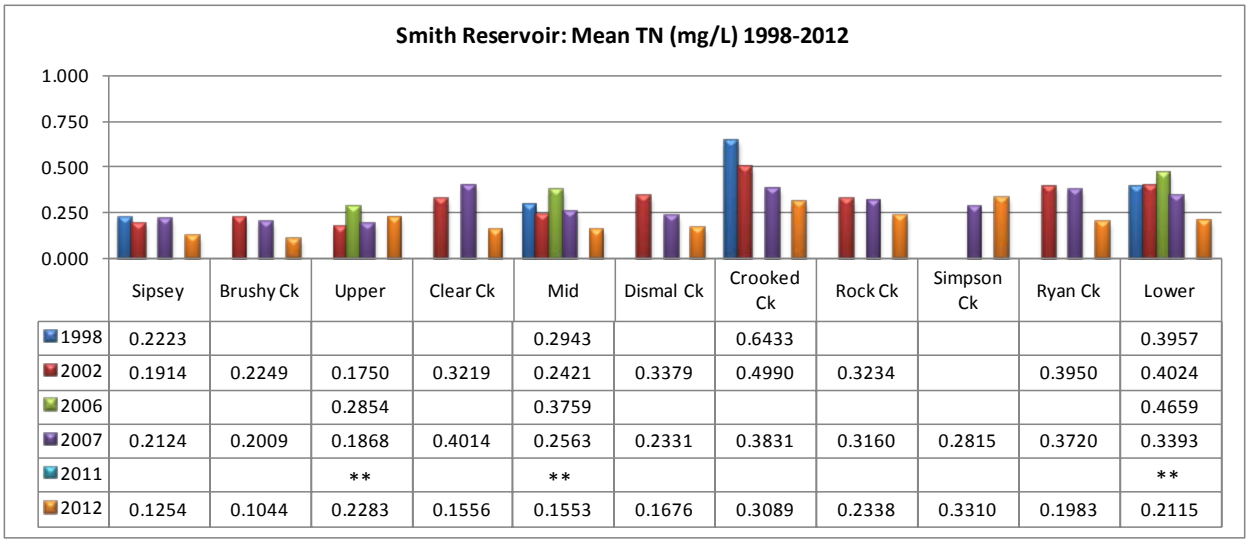
In 2012, highest growing season mean TSS values were calculated for the upper, lower and Crooked Ck stations (Fig. 3). All stations growing season mean TSS values were lower in 2012 than in the previous sampling year. Monthly TSS concentrations at the mainstem stations were below historic means every month except August, reaching historic lows in most months (Fig. 7).

AGPT results for the upper, mid, and lower stations indicated phosphorus limited conditions in 2012, similar to 1998 and 2002 (Table 2). In 2012, mean standing crop at all mainstem stations were below 5.0 mg/L, the value that Raschke and Shultz (1987) defined as protective of reservoir and lake systems.

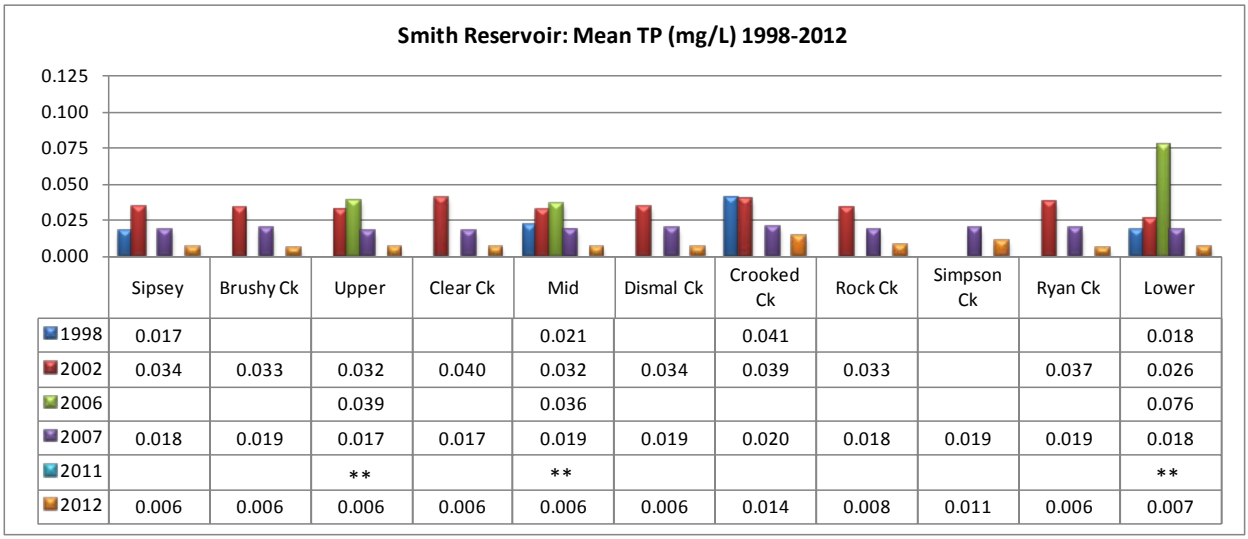
Dissolve oxygen concentrations at the all stations were above the ADEM criteria limit of 5.0 mg/L at 5 ft (1.5m) April-October (ADEM Admin. Code R. 335-6-10-.09) (Fig. 8). Profiles of the mainstem stations show both locations were thermally and chemically stratified throughout the sampling season and highest temperatures were reached in July-August (Fig. 9 and 10).

TSI values were calculated using monthly chl *a* concentrations and Carlson's Trophic State Index. The mainstem stations were oligotrophic to mesotrophic all sampling season. The embayment stations were generally oligotrophic to mesotrophic with the exception of Crooked Ck, which reached eutrophic conditions in April, June, and October (Fig. 11).

Figure 2. Growing season mean TN and TP concentrations measured in Smith Reservoir, April-October 1998-2012. Bar graphs consist of mainstem and embayment stations, illustrated from upstream to downstream as the graph is read from left to right.



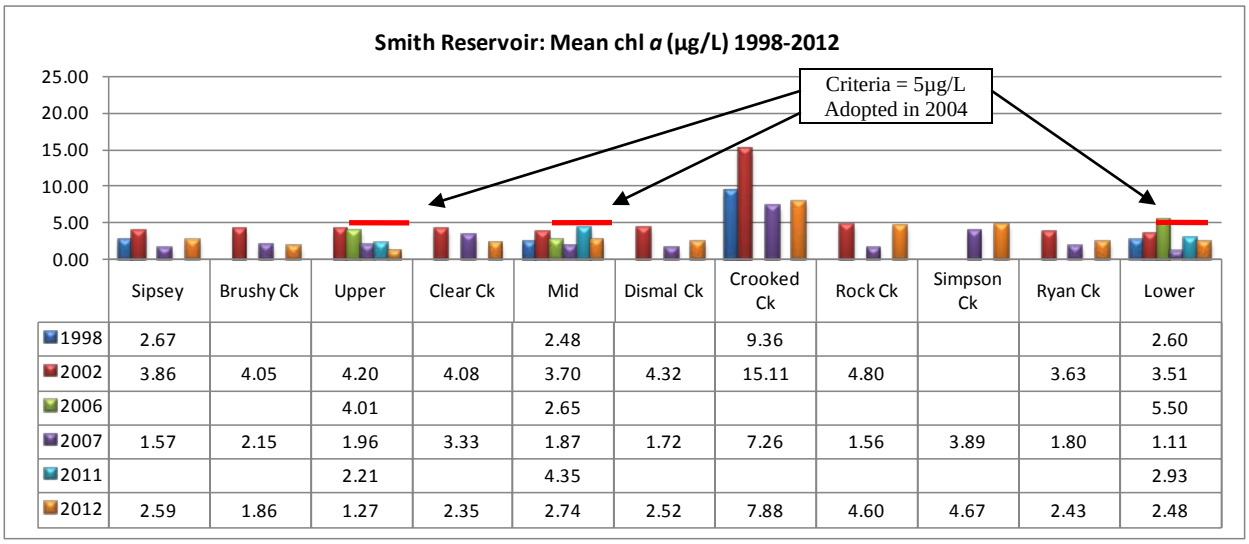
	Sipsey	Brushy Ck	Upper	Clear Ck	Mid	Dismal Ck	Crooked Ck	Rock Ck	Simpson Ck	Ryan Ck	Lower
1998	0.2223				0.2943		0.6433				0.3957
2002	0.1914	0.2249	0.1750	0.3219	0.2421	0.3379	0.4990	0.3234		0.3950	0.4024
2006			0.2854		0.3759						0.4659
2007	0.2124	0.2009	0.1868	0.4014	0.2563	0.2331	0.3831	0.3160	0.2815	0.3720	0.3393
2011			**		**						**
2012	0.1254	0.1044	0.2283	0.1556	0.1553	0.1676	0.3089	0.2338	0.3310	0.1983	0.2115



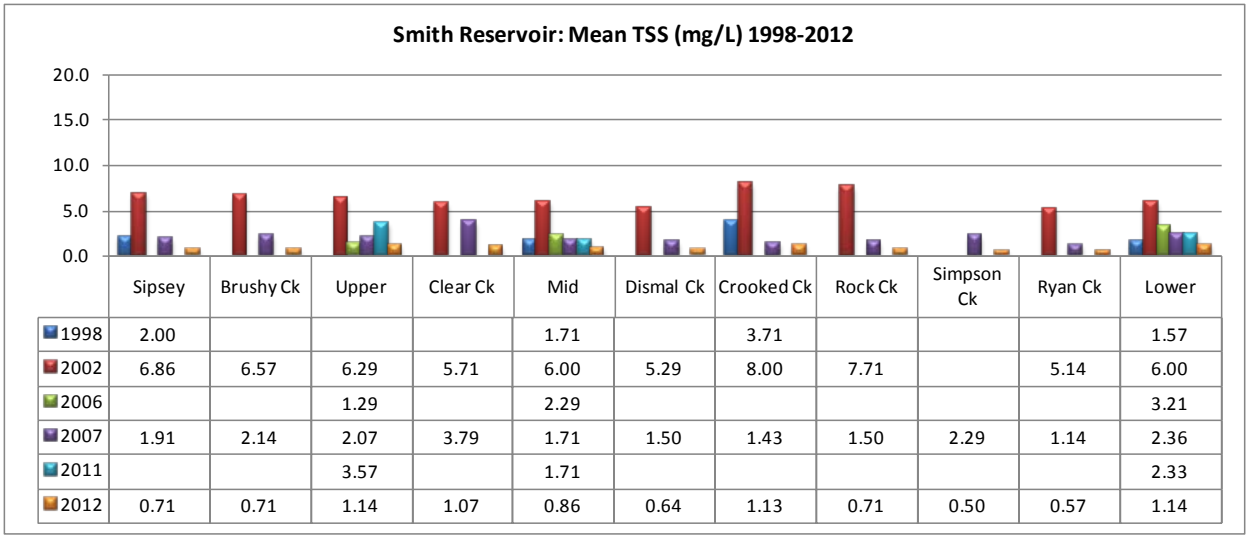
	Sipsey	Brushy Ck	Upper	Clear Ck	Mid	Dismal Ck	Crooked Ck	Rock Ck	Simpson Ck	Ryan Ck	Lower
1998	0.017				0.021		0.041				0.018
2002	0.034	0.033	0.032	0.040	0.032	0.034	0.039	0.033		0.037	0.026
2006			0.039		0.036						0.076
2007	0.018	0.019	0.017	0.017	0.019	0.019	0.020	0.018	0.019	0.019	0.018
2011			**		**						**
2012	0.006	0.006	0.006	0.006	0.006	0.006	0.014	0.008	0.011	0.006	0.007

** Data data did not meet ADEM's laboratory QC requirements.

Figure 3. Growing season mean chl *a* and TSS concentrations measured in Smith Reservoir, April-October 1998-2012. Bar graphs consist of mainstem and embayment stations, illustrated from upstream to downstream as the graph is read from left to right. Chl *a* criteria applies to the growing season mean of the upper, mid, and lower stations only.



	Sipsey	Brushy Ck	Upper	Clear Ck	Mid	Dismal Ck	Crooked Ck	Rock Ck	Simpson Ck	Ryan Ck	Lower
1998	2.67				2.48		9.36				2.60
2002	3.86	4.05	4.20	4.08	3.70	4.32	15.11	4.80		3.63	3.51
2006			4.01		2.65						5.50
2007	1.57	2.15	1.96	3.33	1.87	1.72	7.26	1.56	3.89	1.80	1.11
2011			2.21		4.35						2.93
2012	2.59	1.86	1.27	2.35	2.74	2.52	7.88	4.60	4.67	2.43	2.48



	Sipsey	Brushy Ck	Upper	Clear Ck	Mid	Dismal Ck	Crooked Ck	Rock Ck	Simpson Ck	Ryan Ck	Lower
1998	2.00				1.71		3.71				1.57
2002	6.86	6.57	6.29	5.71	6.00	5.29	8.00	7.71		5.14	6.00
2006			1.29		2.29						3.21
2007	1.91	2.14	2.07	3.79	1.71	1.50	1.43	1.50	2.29	1.14	2.36
2011			3.57		1.71						2.33
2012	0.71	0.71	1.14	1.07	0.86	0.64	1.13	0.71	0.50	0.57	1.14

Figure 4. Monthly TN concentrations of the mainstem stations in Smith Reservoir, April-October 2012. Each bar graph depicts monthly changes in each station. The historic mean (1990-2012) 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 (Smith Dam, information provided by Alabama Power).

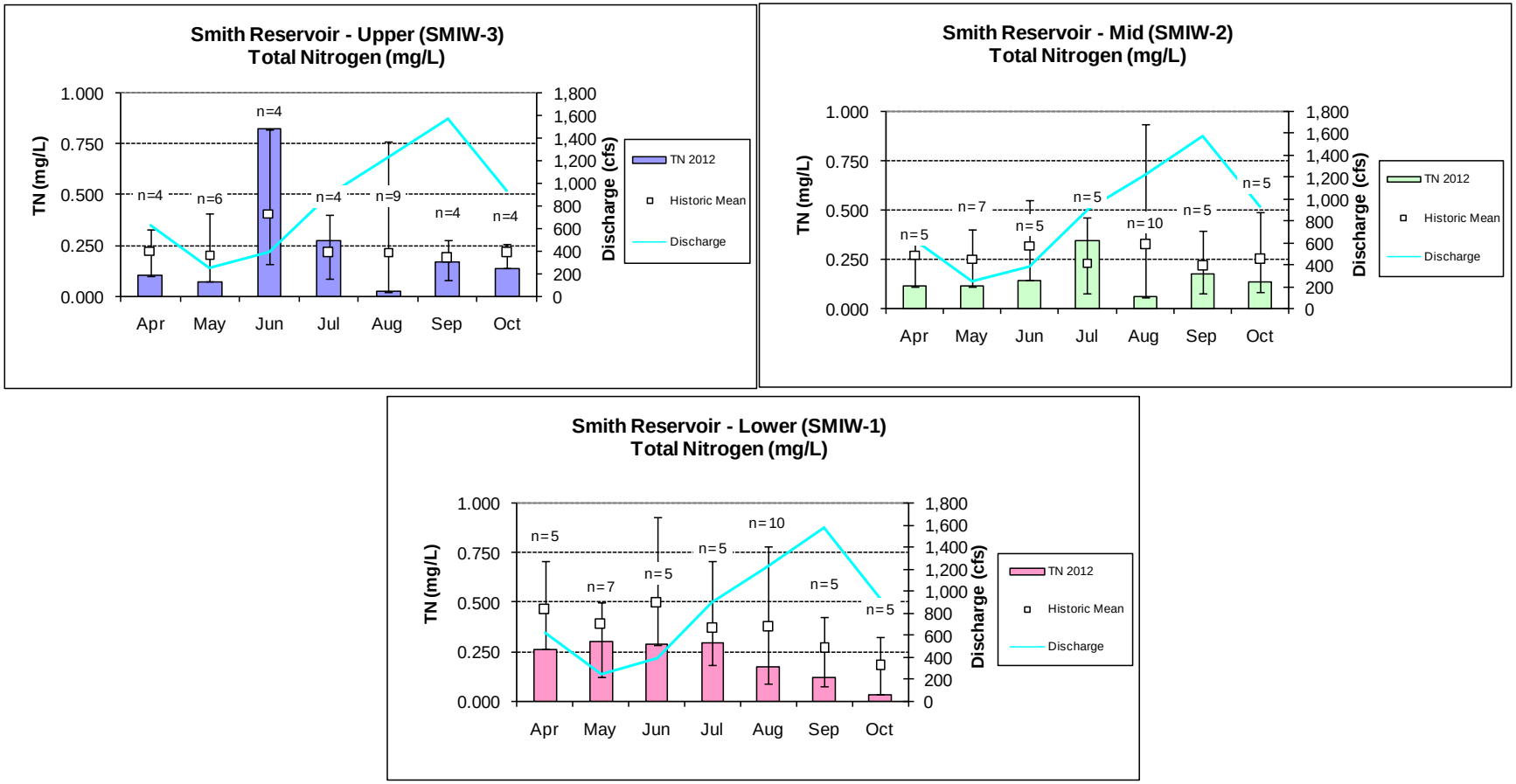


Figure 5. Monthly TP concentrations of the mainstem stations in Smith Reservoir, April-October 2012. Each bar graph depicts monthly changes in each station. The historic mean (1990-2012) and min/max ranges are also displayed for comparison. The "n" value equals the number of datapoints included in the monthly historic calculations. TP was plotted vs. the closest discharge (Smith Dam, information provided by Alabama Power).

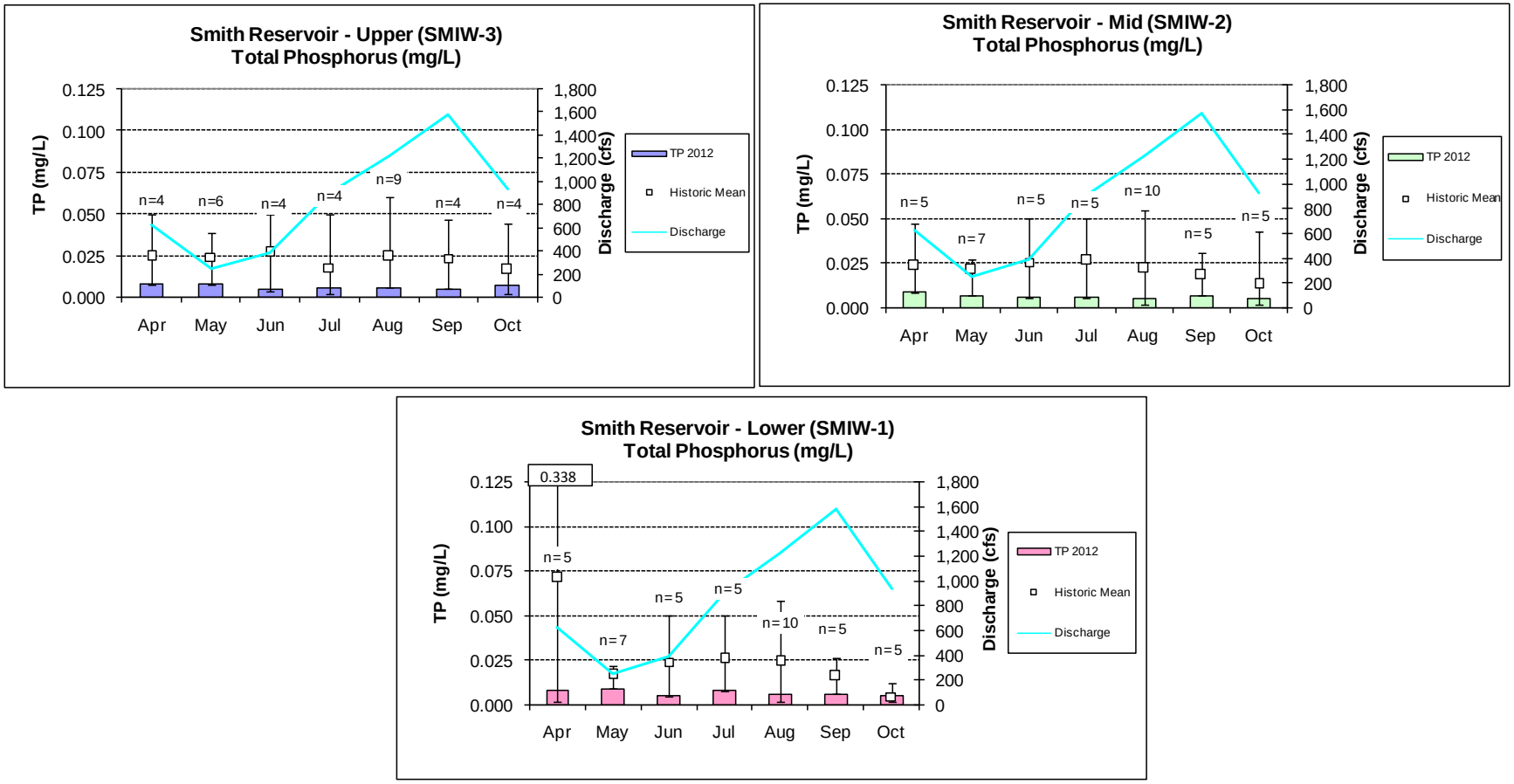


Figure 6. Monthly chl *a* concentrations of the mainstem stations in Smith Reservoir, April-October 2012. Each bar graph depicts monthly changes in each station. The historic mean (1990 -2012) and min/max ranges are also displayed for comparison. The "n" value equals the number of datapoints included in the monthly historic calculations. Chl *a* was plotted vs. the closest discharge (Smith Dam, information provided by Alabama Power).

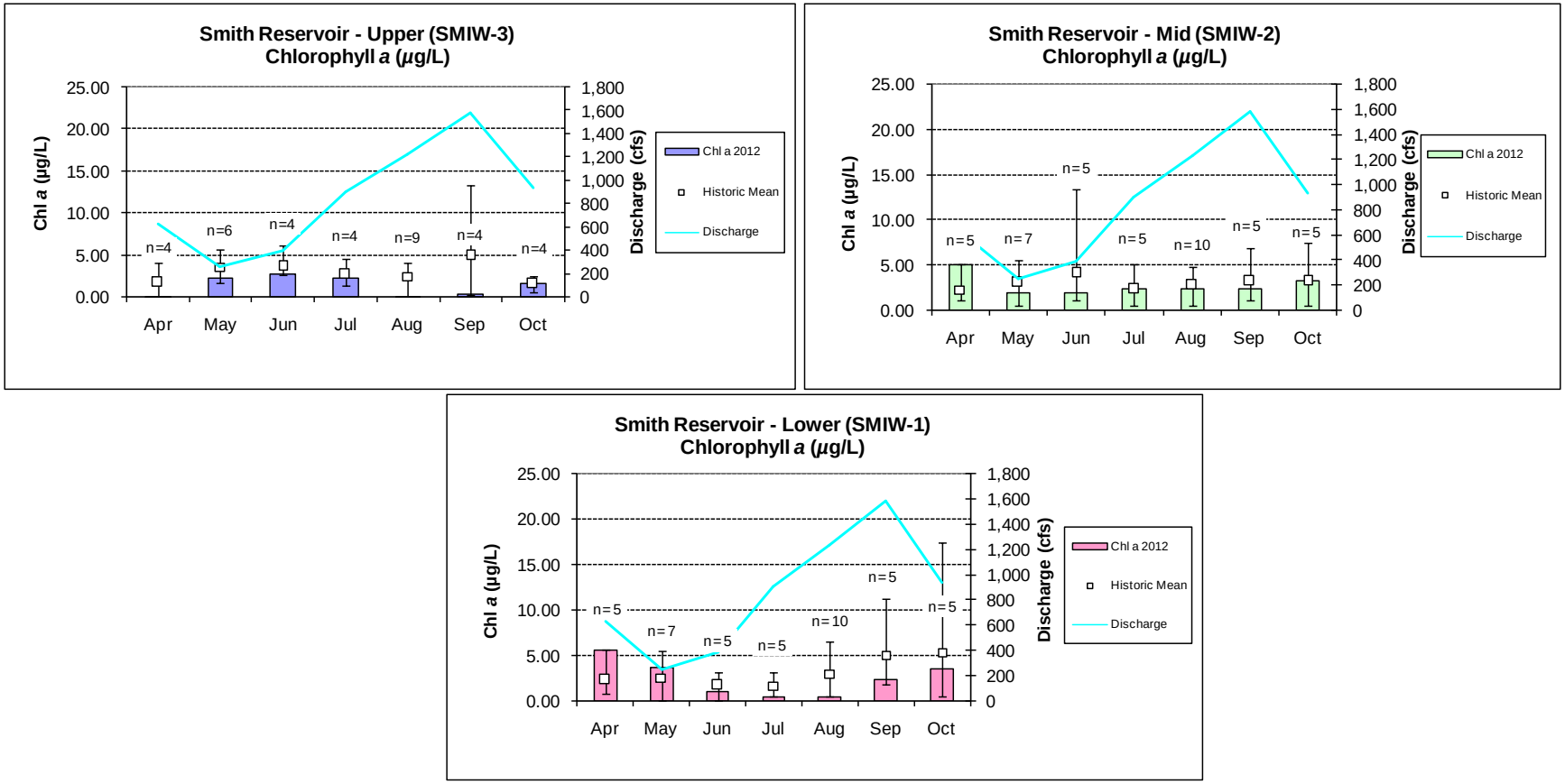


Figure 7. Monthly TSS of the mainstem stations in Smith Reservoir, April-October 2012. Each bar graph depicts monthly changes in each station. The historic mean (1990-2012) and min/max ranges are also displayed for comparison. The "n" value equals the number of datapoints included in the monthly historic calculations. TSS was plotted vs. the closest discharge (Smith Dam, information provided by Alabama Power).

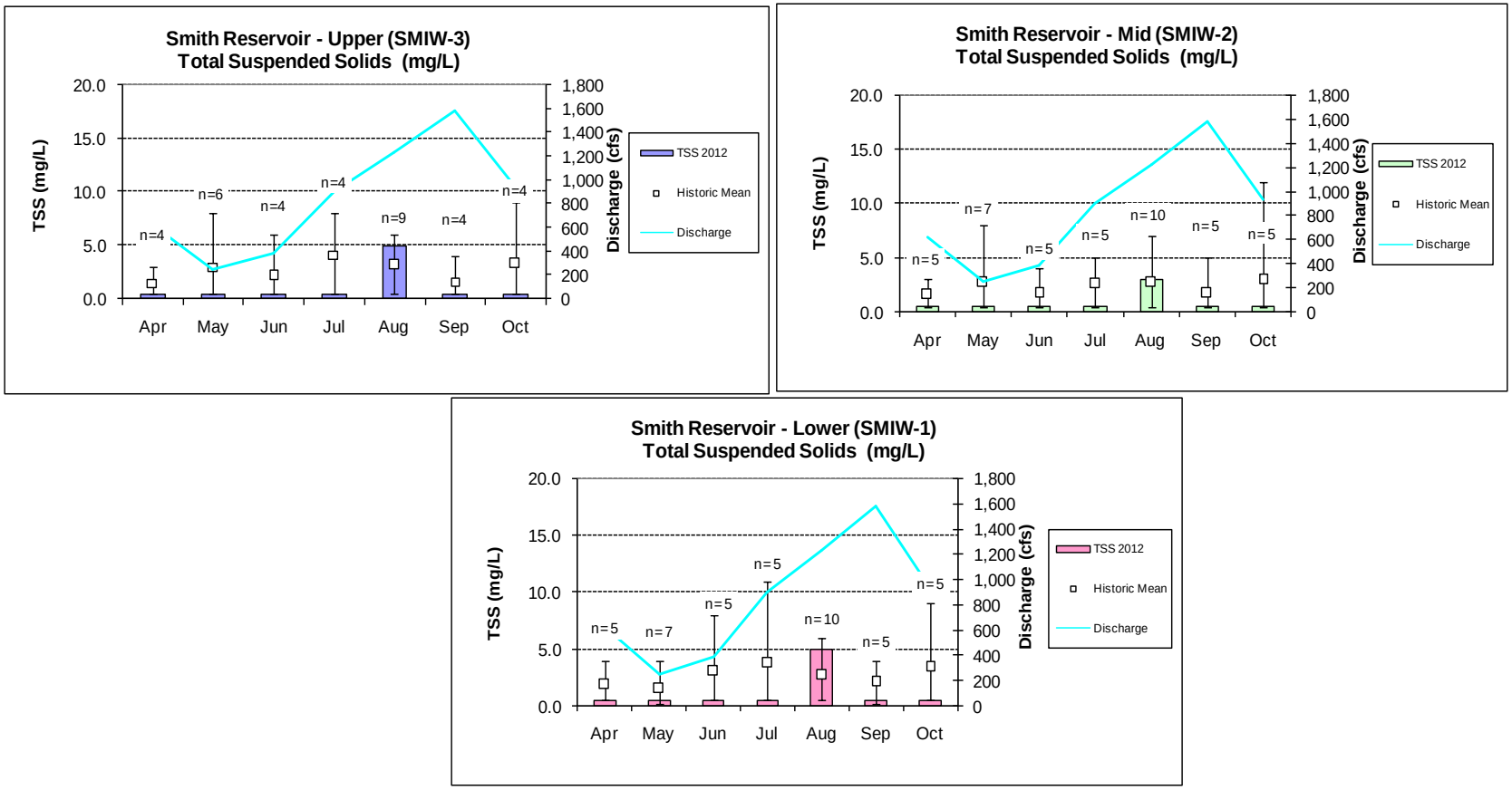


Table 2. Algal growth potential test results (expressed as mean Maximum Standing Crop (MSC) dry weights of *Selenastrum capricornutum* in mg/L) and limiting nutrient status. MSC values below 5 mg/L are considered to be protective in reservoirs and lakes; values below 20 mg/L MSC are considered protective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

Station	Upper		Mid		Lower	
	MSC	Limiting Nutrient	MSC	Limiting Nutrient	MSC	Limiting Nutrient
August 1998	---	---	1.62	Phosphorus	1.29	Phosphorus
August 2002	1.69	Co-limiting	1.41	Phosphorus	1.44	Phosphorus
June 2012	3.13	Phosphorus	3.28	Phosphorus	3.36	Phosphorus
July 2012	3.24	Phosphorus	3.37	Phosphorus	3.77	Phosphorus
August 2012	2.70	Phosphorus	3.03	Phosphorus	2.79	Phosphorus

Figure 8. Monthly DO concentrations at 1.5 m (5 ft) for Smith Reservoir stations collected April-October 2012. ADEM Water Quality Criteria pertaining to reservoir waters require a DO concentration of 5.0 mg/L at this depth (ADEM 2010).

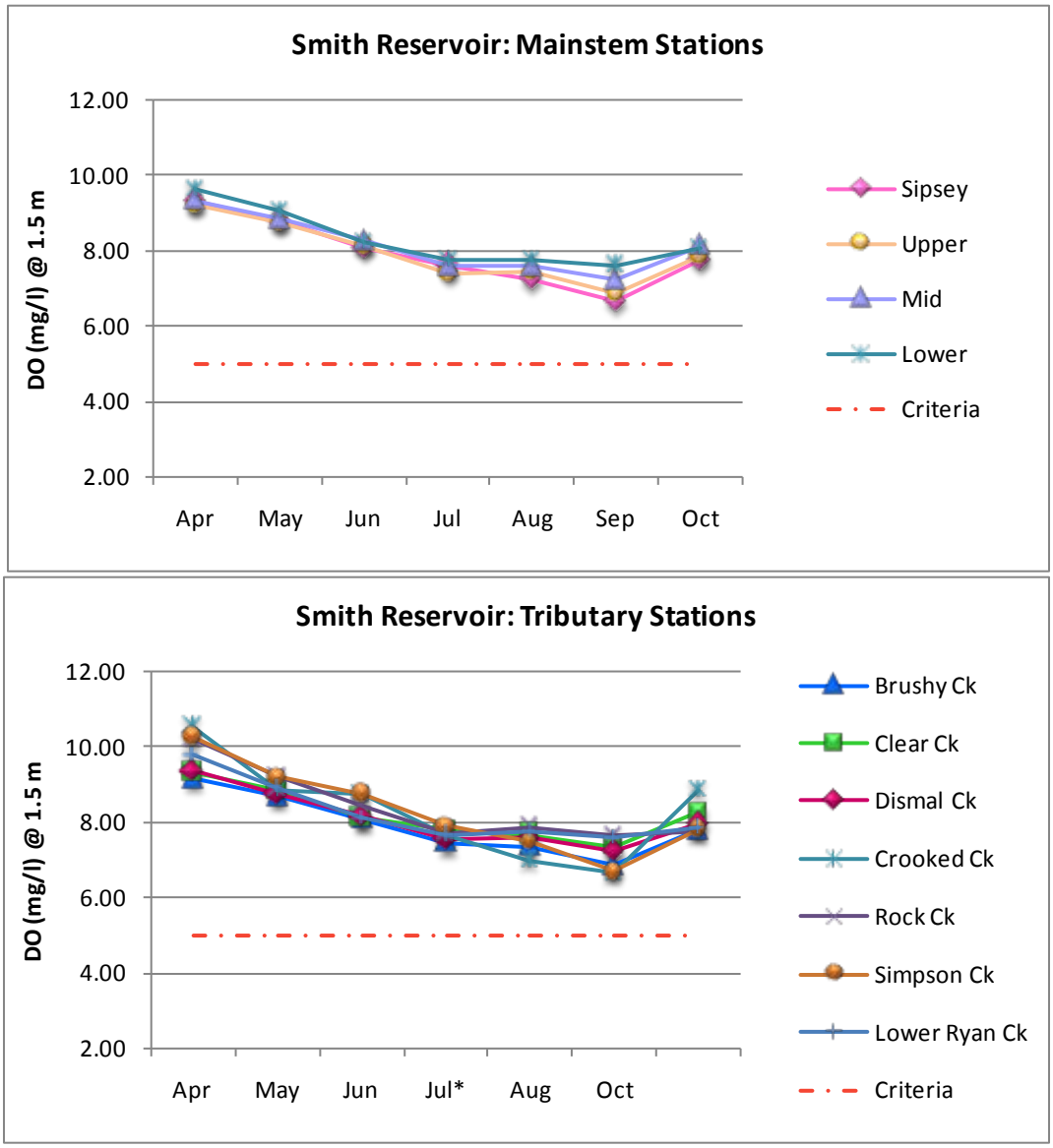


Figure 9. Monthly depth profiles of dissolved oxygen, temperature and conductivity in lower Smith Reservoir, April-October 2012.

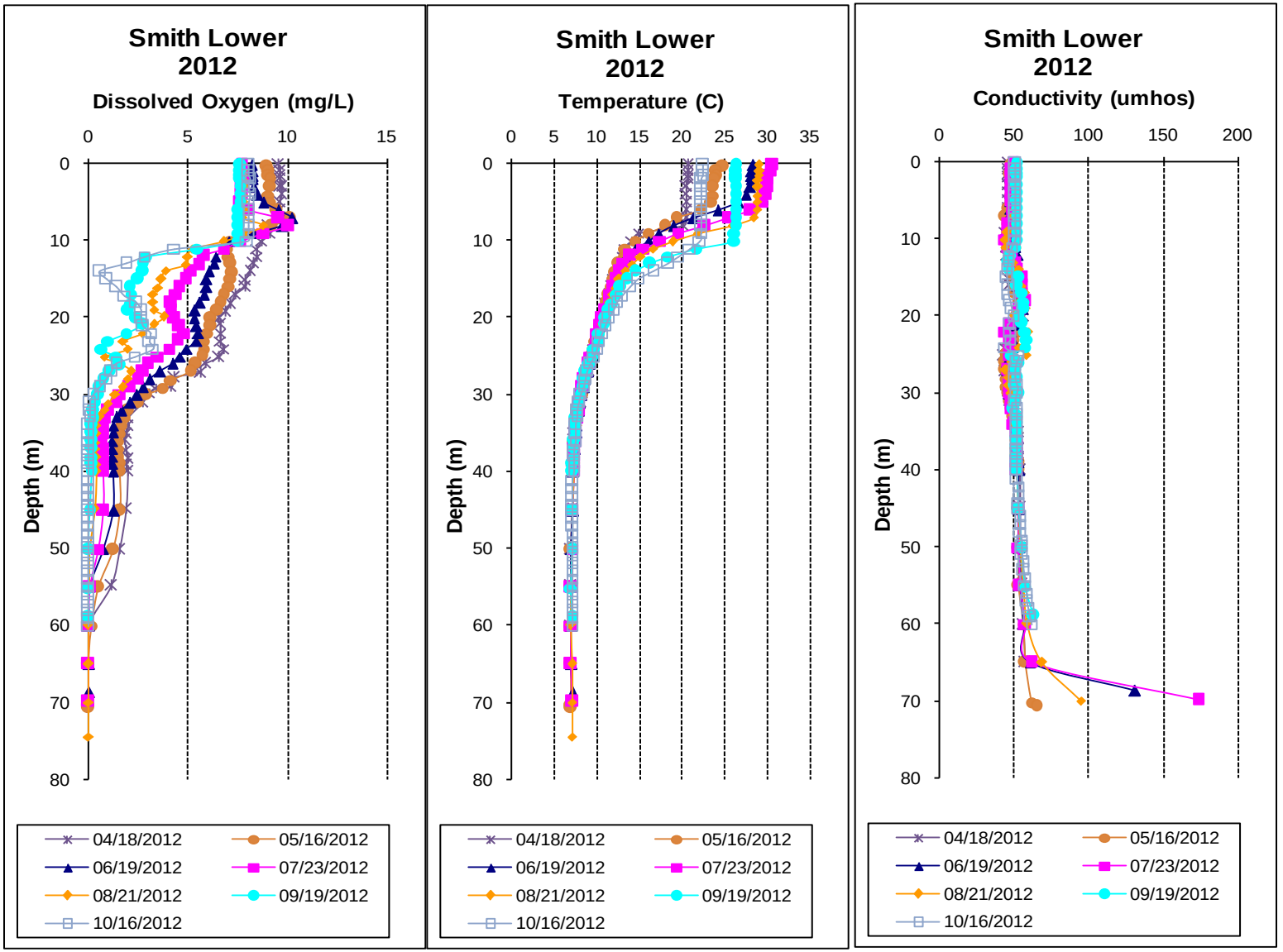


Figure 10. Monthly depth profiles of dissolved oxygen, temperature and conductivity in mid Smith Reservoir, April-October 2012.

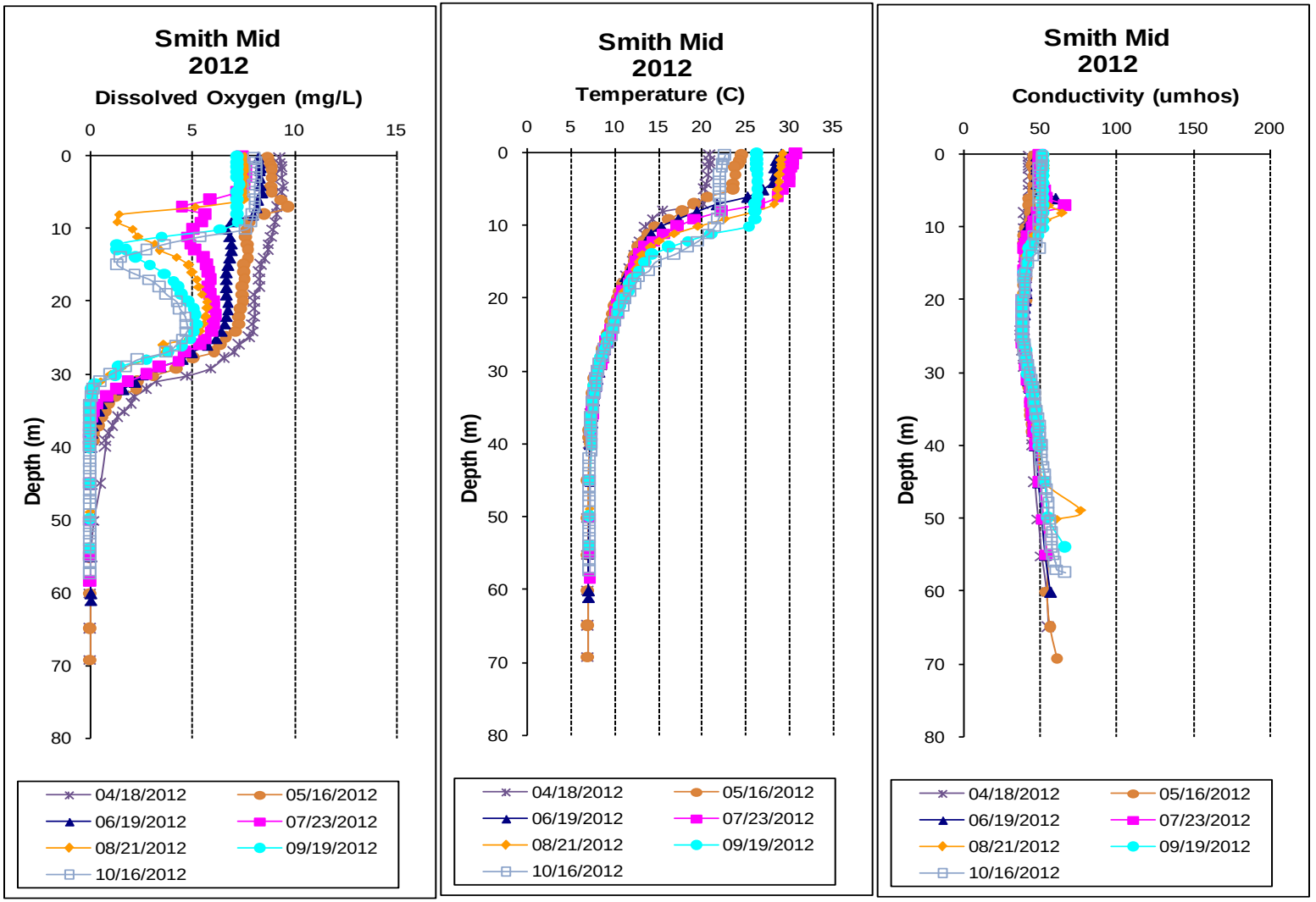
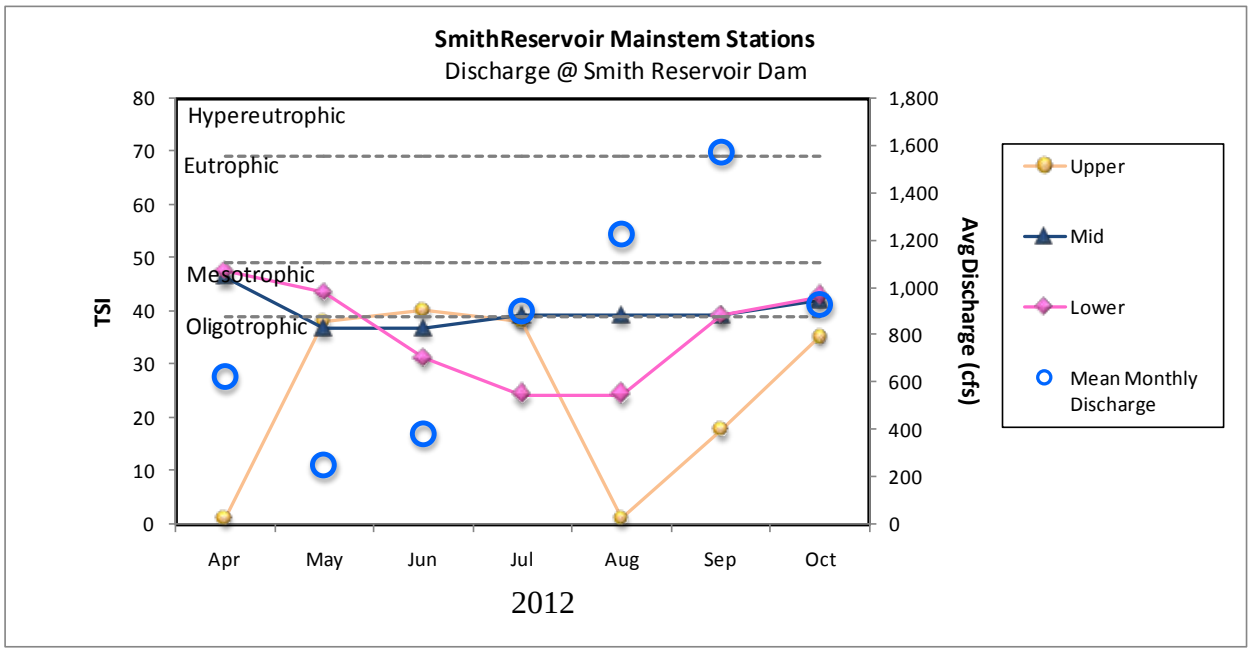
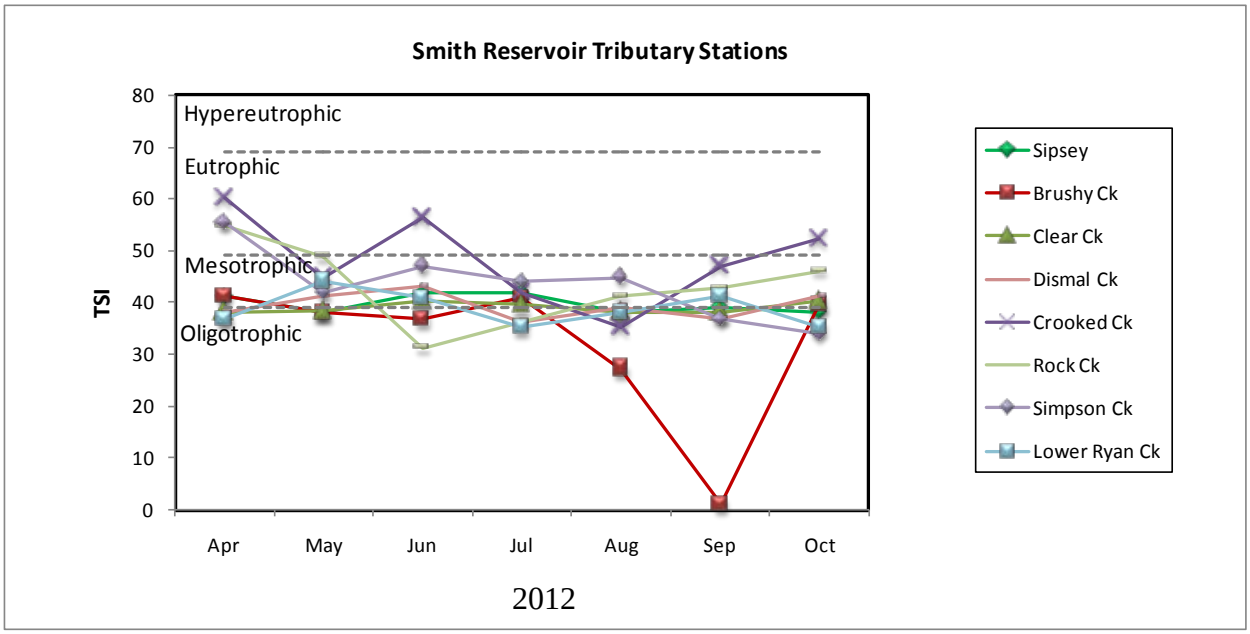


Figure 11. Monthly growing season TSI values, April-October 2012 for mainstem and tributary stations using chl *a* concentrations and Carlson's Trophic State Index calculation.





REFERENCES

ADEM. 2008. Quality Management Plan (QMP) For The Alabama Department Of Environmental, Alabama Department of Environmental Management (ADEM), Montgomery, AL. 58 pp.

ADEM. 2012 (as amended). Standard Operating Procedures #2041 *In Situ* Surface Water Quality Field Measurements-Temperature, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

ADEM. 2012 (as amended). Standard Operating Procedures #2044 *In Situ* Surface Water Quality Field Measurements–Turbidity, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

ADEM. 2012 (as amended). Standard Operating Procedures #2046 Photic Zone Measurement and Visibility Determination, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

ADEM. 2012 (as amended). Standard Operating Procedures #2047 *In Situ* Surface Water Quality Field Measurements–By Datasonde, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

ADEM. 2012 (as amended). Standard Operating Procedures #2061 General Surface Water Sample Collection, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

ADEM. 2012 (as amended). Standard Operating Procedures #2062 Dissolved Reactive Phosphorus (DRP) Surface Water Sample Collection and Field Processing, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

ADEM 2012 (as amended). Standard Operating Procedures #2063 Water Column Chlorophyll *a* Sample Collection and Field Processing, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

ADEM. 2012. State of Alabama Water Quality Monitoring Strategy June 19, 2012. Alabama Department of Environmental Management (ADEM), Montgomery, AL. 88 pp. http://www.adem.alabama.gov/programs/water/wqsurvey/2012WQMonitoringStrategy

ADEM. 2013. Quality Assurance Project Plan (QAPP) for Surface Water Quality Monitoring in Alabama. Alabama Department of Environmental Management (ADEM), Montgomery, AL. 78 pp.

Alabama Department of Environmental Management Water Division (ADEM Admin. Code R. 335-6-10-.09). 2010. 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). 2010. Water Quality Criteria Applicable to Specific Lakes. Water Quality Program. Chapter 10. Volume 1. Division 335-6.

American Public Health Association, American Water Works Association and Water Pollution Control Federation. 1998. Standard methods for the examination of water and wastewater. 20th edition. APHA, Washington, D.C.

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

Lind, O.T. 1979. Handbook of common methods in limnology. The C.V. Mosby Co., St. Louis, Missouri. 199 pp.

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.

Raschke, R. L., H. S. Howard, J. R. Maudsley, and R. J. Lewis. 1996. The Ecological Condition of Small Streams in the Savannah River Basin: A REMAP Progress Report. EPA Region 4, Science and Ecosystem Support Division, Ecological Assessment Branch, Athens, GA.

U.S. Environmental Protection Agency. 1990. The lake and reservoir restoration guidance manual. 2nd edition. EPA-440/4-90-006. U.S.E.P.A. Office of Water. Washington, D.C. 326 pp.

Welch, E.B. 1992. Ecological Effects of Wastewater. 2nd edition. Chapman and Hall Publishers. London, England. 425 pp.

Wetzel, R.G. 1983. Limnology. 2nd edition. Saunders College Publishing. Philadelphia, Pennsylvania. 858 pp.

APPENDIX

Appendix Table 1. Summary of water quality data collected April-October, 2012. 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		N	Min	Max	Med	Mean	SD
SMIW-1	**Physical**						
	Turbidity (NTU)	7	0.7	1.7	1.3	1.2	0.3
	Total Dissolved Solids (mg/L)[J]	7	< 1.0	58.0	46.0	39.5	20.7
	Total Suspended Solids (mg/L)	7	< 1.0	5.0	0.5	1.1	1.7
	Hardness (mg/L)	4	15.3	17.6	16.4	16.4	1.0
	Alkalinity (mg/L)	7	12.0	14.0	12.9	12.8	0.8
	Photic Zone (m)	7	10.92	16.06	11.54	12.45	1.89
	Secchi (m)	7	3.48	5.28	3.95	4.13	0.58
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.007	0.008	0.004	0.004	0.000
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	0.014	0.192	0.066	0.086	0.067
	Total Kjeldahl Nitrogen (mg/L)[J]	7	< 0.041	0.250	0.112	0.125	0.071
	Total Nitrogen (mg/L)[J]	7	< 0.034	0.304	0.265	0.212	0.104
	Dissolved Reactive Phosphorus (mg/L)[J]	7	< 0.005	0.005	0.002	0.003	0.001
	Total Phosphorus (mg/L)[J]	7	0.005	0.009	0.006	0.007	0.002
	CBOD-5 (mg/L)[J]	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	1.8	1.9	1.8	1.9	0.0
	Biological						
	Chlorophyll a (ug/L)	7	0.53	5.61	2.40	2.48	1.91
	E. coli (mpn/DL)[J]	3	< 1	1	1	1	0.0
SMIW-2	**Physical**						
	Turbidity (NTU)	7	1.4	2.4	1.5	1.7	0.4
	Total Dissolved Solids (mg/L)	7	< 1.0	56.0	32.0	32.9	21.9
	Total Suspended Solids (mg/L)	7	< 1.0	3.0	0.5	0.9	0.9
	Hardness (mg/L)	4	15.3	18.0	17.4	17.0	1.2
	Alkalinity (mg/L)	7	10.8	14.7	13.2	12.8	1.5
	Photic Zone (m)	7	8.22	12.56	9.48	9.80	1.59
	Secchi (m)	7	2.68	4.29	3.67	3.65	0.63
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.007	0.008	0.004	0.004	0.000
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	< 0.005	0.095	0.029	0.039	0.036
	Total Kjeldahl Nitrogen (mg/L)[J]	7	< 0.041	0.313	0.091	0.116	0.101
	Total Nitrogen (mg/L)[J]	7	< 0.060	0.342	0.133	0.155	0.090
	Dissolved Reactive Phosphorus (mg/L)[J]	7	< 0.005	0.006	0.002	0.003	0.001
	Total Phosphorus (mg/L)[J]	7	0.005	0.009	0.006	0.006	0.001
	CBOD-5 (mg/L)[J]	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	1.5	1.7	1.6	1.6	0.1
	Biological						
	Chlorophyll a (ug/L)	7	1.87	5.07	2.40	2.74	1.12
	E. coli (mpn/DL)[J]	3	< 1	27	1	10	15

Station		N		Min	Max	Med	Mean	SD
SMIW-3	**Physical**							
	Turbidity (NTU)	7		1.4	2.0	1.7	1.7	0.3
	Total Dissolved Solids (mg/L)	7	<	1.0	54.0	32.0	28.1	19.6
	Total Suspended Solids (mg/L)	7	<	1.0	5.0	0.5	1.1	1.7
	Hardness (mg/L)	4		15.2	16.7	16.2	16.1	0.6
	Alkalinity (mg/L)	7		11.5	13.9	13.1	12.8	0.9
	Photic Zone (m)	7		8.11	12.42	8.93	9.66	1.66
	Secchi (m)	7		2.95	3.85	3.53	3.43	0.36
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.007	0.008	0.004	0.004	0.000
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	<	0.004	0.064	0.012	0.024	0.025
	Total Kjeldahl Nitrogen (mg/L)[J]	7	<	0.041	0.793	0.126	0.204	0.275
	Total Nitrogen (mg/L)[J]	7	<	0.023	0.824	0.138	0.228	0.274
	Dissolved Reactive Phosphorus (mg/L)[J]	7	<	0.005	0.006	0.002	0.003	0.001
	Total Phosphorus (mg/L)[J]	7		0.005	0.008	0.006	0.006	0.001
	CBOD-5 (mg/L)	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		1.4	1.5	1.5	1.5	0.1
	Biological							
	Chlorophyll a (ug/L)	7	<	0.10	2.67	1.60	1.27	1.12
	E. coli (mpn/DL)[J]	3	<	1	1	1	1	0
SMIW-4	**Physical**							
	Turbidity (NTU)	7		1.4	2.2	1.8	1.8	0.3
	Total Dissolved Solids (mg/L)	7	<	1.0	48.0	26.0	22.6	18.9
	Total Suspended Solids (mg/L)	7	<	1.0	2.0	0.5	0.7	0.6
	Hardness (mg/L)	4		13.5	16.3	15.8	15.4	1.3
	Alkalinity (mg/L)	7		10.5	14.0	13.0	12.7	1.2
	Photic Zone (m)	7		7.63	12.53	8.80	9.33	1.74
	Secchi (m)	7		2.70	3.65	3.46	3.33	0.34
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.007	0.008	0.004	0.004	0.000
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	<	0.002	0.078	0.006	0.023	0.031
	Total Kjeldahl Nitrogen (mg/L)[J]	7	<	0.041	0.323	0.038	0.082	0.109
	Total Nitrogen (mg/L)[J]	7	<	0.023	0.324	0.082	0.104	0.101
	Dissolved Reactive Phosphorus (mg/L)[J]	7	<	0.005	0.006	0.002	0.003	0.001
	Total Phosphorus (mg/L)[J]	7		0.004	0.008	0.005	0.006	0.002
	CBOD-5 (mg/L)[J]	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		1.3	1.6	1.5	1.5	0.1
	Biological							
	Chlorophyll a (ug/L)	7	<	0.10	2.94	2.14	1.86	1.10
	E. coli (mpn/DL)[J]	3	<	1	2	1	1	1

Station		N		Min	Max	Med	Mean	SD
SMIW-5	**Physical**							
	Turbidity (NTU)	8		1.1	2.9	1.6	1.7	0.6
	Total Dissolved Solids (mg/L)	7	<	1.0	66.0	30.0	27.8	21.1
	Total Suspended Solids (mg/L)	7	<	1.0	2.0	0.5	0.7	0.6
	Hardness (mg/L)	4		15.7	18.0	16.6	16.8	1.0
	Alkalinity (mg/L)	7		12.9	14.5	13.9	13.8	0.6
	Photic Zone (m)	7		7.19	14.77	8.36	9.33	2.53
	Secchi (m)	7		3.16	4.33	3.70	3.65	0.42
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.007	0.008	0.004	0.004	0.000
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	<	0.002	0.078	0.007	0.023	0.031
	Total Kjeldahl Nitrogen (mg/L)[J]	7	<	0.041	0.427	0.038	0.102	0.148
	Total Nitrogen (mg/L)[J]	7	<	0.028	0.428	0.096	0.125	0.138
	Dissolved Reactive Phosphorus (mg/L)	7	<	0.005	0.006	0.002	0.003	0.001
	Total Phosphorus (mg/L)[J]	7		0.005	0.009	0.006	0.006	0.001
	CBOD-5 (mg/L)[J]	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		1.3	1.5	1.4	1.4	0.1
	Biological							
	Chlorophyll a (ug/L)	7		2.14	3.20	2.40	2.59	0.50
	E. coli (mpn/DL)[J]	3	<	1	3	1	2	1
SMIW-6	**Physical**							
	Turbidity (NTU)	8		2.0	3.7	2.4	2.6	0.5
	Total Dissolved Solids (mg/L)	7	<	1.0	60.0	42.0	32.4	23.1
	Total Suspended Solids (mg/L)	7	<	1.0	4.0	0.5	1.1	1.3
	Hardness (mg/L)	4		16.1	20.9	18.1	18.3	2.0
	Alkalinity (mg/L)	7		10.4	14.9	13.3	13.0	1.4
	Photic Zone (m)	7		6.31	8.88	7.06	7.25	0.83
	Secchi (m)	7		2.11	3.53	2.87	2.87	0.57
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.007	0.008	0.004	0.004	0.000
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	<	0.005	0.059	0.013	0.021	0.020
	Total Kjeldahl Nitrogen (mg/L)[J]	7	<	0.041	0.570	0.020	0.135	0.203
	Total Nitrogen (mg/L)[J]	7	<	0.023	0.599	0.050	0.156	0.208
	Dissolved Reactive Phosphorus (mg/L)[J]	7	<	0.005	0.007	0.002	0.004	0.002
	Total Phosphorus (mg/L)[J]	7		0.004	0.009	0.006	0.006	0.002
	CBOD-5 (mg/L)[J]	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		1.5	1.6	1.6	1.6	0.1
	Biological							
	Chlorophyll a (ug/L)	7		2.14	2.67	2.20	2.35	0.25
	E. coli (mpn/DL)[J]	3	<	1	2	1	1	1

Station		N		Min	Max	Med	Mean	SD
SMIW-7	**Physical**							
	Turbidity (NTU)	7		1.1	2.6	1.6	1.7	0.5
	Total Dissolved Solids (mg/L)[J]	7		18.0	64.0	40.0	41.1	17.6
	Total Suspended Solids (mg/L)[J]	7	<	1.0	1.0	0.5	0.6	0.2
	Hardness (mg/L)	4		15.0	17.6	16.5	16.4	1.1
	Alkalinity (mg/L)	7		10.4	13.1	12.7	12.1	1.0
	Photic Zone (m)	7		7.30	10.30	9.09	9.16	1.01
	Secchi (m)	7		2.41	4.14	3.68	3.51	0.65
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.007	0.008	0.004	0.004	0.000
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7		0.004	0.115	0.013	0.032	0.040
	Total Kjeldahl Nitrogen (mg/L)[J]	7	<	0.041	0.408	0.068	0.135	0.135
	Total Nitrogen (mg/L)[J]	7	<	0.034	0.412	0.153	0.168	0.124
	Dissolved Reactive Phosphorus (mg/L)[J]	7	<	0.005	0.006	0.002	0.003	0.001
	Total Phosphorus (mg/L)[J]	7		0.004	0.008	0.005	0.006	0.002
	CBOD-5 (mg/L)[J]	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		1.6	1.7	1.6	1.6	0.0
	Biological							
	Chlorophyll a (ug/L)	7		1.78	3.56	2.40	2.52	0.65
	E. coli (mpn/DL)[J]	3	<	1	31	1	11	17
SMIW-8	**Physical**							
	Turbidity (NTU)	8		0.6	5.1	1.3	1.8	1.4
	Total Dissolved Solids (mg/L)	7		12.0	52.0	42.0	38.9	13.8
	Total Suspended Solids (mg/L)	7	<	1.0	2.0	0.5	0.7	0.6
	Hardness (mg/L)	4		14.3	17.0	16.0	15.8	1.2
	Alkalinity (mg/L)	7		11.9	14.6	13.1	13.1	1.1
	Photic Zone (m)	7		4.22	11.54	9.73	9.26	2.46
	Secchi (m)	7		1.58	5.69	4.84	4.41	1.36
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.007	0.008	0.004	0.004	0.000
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	<	0.005	0.080	0.015	0.032	0.030
	Total Kjeldahl Nitrogen (mg/L)[J]	7		0.044	0.510	0.130	0.201	0.177
	Total Nitrogen (mg/L)[J]	7	<	0.079	0.523	0.210	0.234	0.170
	Dissolved Reactive Phosphorus (mg/L)[J]	7	<	0.005	0.006	0.002	0.003	0.001
	Total Phosphorus (mg/L)[J]	7		0.005	0.012	0.007	0.008	0.002
	CBOD-5 (mg/L)[J]	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		1.8	2.0	1.9	1.9	0.1
	Biological							
	Chlorophyll a (ug/L)	7		1.07	11.75	3.47	4.60	3.63
	E. coli (mpn/DL)[J]	3	<	1	10	1	4	5

Station		N		Min	Max	Med	Mean	SD
SMIW-9	**Physical**							
	Turbidity (NTU)	7		1.8	8.3	3.2	3.7	2.2
	Total Dissolved Solids (mg/L)	7		18.0	70.0	36.0	39.4	18.6
	Total Suspended Solids (mg/L)	7	<	1.0	4.0	0.5	1.2	1.4
	Hardness (mg/L)	4		15.4	17.1	16.0	16.2	0.8
	Alkalinity (mg/L)	7		13.2	21.9	14.5	15.3	3.0
	Photic Zone (m)	7		3.17	7.44	6.80	6.27	1.47
	Secchi (m)	7		1.25	3.41	2.23	2.30	0.73
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.007	0.065	0.004	0.013	0.023
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	<	0.002	0.182	0.014	0.049	0.070
	Total Kjeldahl Nitrogen (mg/L)[J]	7		0.142	0.536	0.213	0.267	0.143
	Total Nitrogen (mg/L)[J]	7	<	0.158	0.537	0.258	0.316	0.154
	Dissolved Reactive Phosphorus (mg/L)[J]	7	<	0.005	0.006	0.002	0.003	0.001
	Total Phosphorus (mg/L)[J]	7		0.008	0.018	0.014	0.013	0.003
	CBOD-5 (mg/L)[J]	7	<	2.0	2.5	1.0	1.2	0.6
	Chlorides (mg/L)	7		2.2	2.5	2.3	2.3	0.1
	Biological							
	Chlorophyll a (ug/L)	7		1.60	20.29	5.34	8.24	6.72
	E. coli (mpn/DL)	3	<	1	36	2	13	20
SMIW-10	**Physical**							
	Turbidity (NTU)	8		0.6	2.0	1.3	1.2	0.6
	Total Dissolved Solids (mg/L)	7		16.0	66.0	40.0	40.3	17.6
	Total Suspended Solids (mg/L)	7	<	1.0	1.0	0.5	0.6	0.2
	Hardness (mg/L)	4		16.3	18.9	16.8	17.2	1.2
	Alkalinity (mg/L)	7		12.4	15.1	13.7	13.6	1.0
	Photic Zone (m)	7		9.05	10.64	9.87	9.83	0.66
	Secchi (m)	7		3.54	6.00	4.45	4.61	0.79
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.007	0.008	0.004	0.004	0.000
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	<	0.005	0.104	0.007	0.034	0.040
	Total Kjeldahl Nitrogen (mg/L)[J]	7	<	0.041	0.503	0.091	0.164	0.169
	Total Nitrogen (mg/L)[J]	7	<	0.028	0.509	0.129	0.198	0.174
	Dissolved Reactive Phosphorus (mg/L)[J]	7	<	0.005	0.006	0.002	0.003	0.001
	Total Phosphorus (mg/L)[J]	7		0.004	0.007	0.005	0.006	0.001
	CBOD-5 (mg/L)[J]	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		1.8	1.9	1.9	1.9	0.0
	Biological							
	Chlorophyll a (ug/L)	7		1.60	4.01	2.14	2.43	0.89
	E. coli (col/100mL)[J]	3	<	1	2	1	1	1

Station		N		Min	Max	Med	Mean	SD
SMIW-11	**Physical**							
	Turbidity (NTU)	7		1.6	3.5	2.0	2.3	0.7
	Total Dissolved Solids (mg/L)	7		10.0	68.0	56.0	46.6	21.2
	Total Suspended Solids (mg/L)	7	<	1.0	1.0	0.5	0.5	0.0
	Hardness (mg/L)	4		18.1	21.1	19.5	19.6	1.5
	Alkalinity (mg/L)	7		17.0	20.4	17.9	18.3	1.4
	Photic Zone (m)	7		5.82	8.54	7.78	7.53	1.07
	Secchi (m)	7		1.89	4.28	3.16	3.06	0.84
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.007	0.008	0.004	0.004	0.000
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	<	0.002	0.034	0.005	0.013	0.013
	Total Kjeldahl Nitrogen (mg/L)[J]	7		0.081	0.747	0.268	0.318	0.254
	Total Nitrogen (mg/L)[J]	7	<	0.086	0.781	0.294	0.331	0.261
	Dissolved Reactive Phosphorus (mg/L)[J]	7	<	0.005	0.006	0.002	0.003	0.001
	Total Phosphorus (mg/L)[J]	7		0.008	0.013	0.010	0.011	0.002
	CBOD-5 (mg/L)[J]	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		2.5	2.6	2.6	2.6	0.0
	Biological							
	Chlorophyll a (ug/L)	7		1.42	12.68	3.92	4.67	3.78
	E. coli (col/100mL)[J]	3		1	51	1	18	28

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