2010 Logan Martin Reservoir Report

Rivers and Reservoirs Monitoring Program

Alabama Department of Environmental Management

Field Operations Division
Environmental Indicators Section
Aquatic Assessment Unit
May 2013

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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

Logan Martin Reservoir is located in east central Alabama on the Coosa River approximately 30 miles east of Birmingham, Alabama. It is the second dam built as a part of an Alabama Power Company construction program in the late 1950s and the 1960s. Construction started on the 15,260 acre reservoir on July 18, 1960 and it was placed in service August 10, 1964. The lake borders St. Clair and Talladega counties and offers boating, skiing and swimming.

The Alabama Department of Environmental Management (ADEM) monitored Logan Martin Reservoir as part of the 2010 assessment of the Alabama, Coosa, and Tallapoosa (ACT) 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, 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).

Logan Martin Reservoir was placed on Alabama's 1996 Clean Water Act (CWA) §303(d) list of impaired waters for not meeting its Swimming (S)/Fish & Wildlife (F&W) water use classifications. The reservoir was listed in 1996 for impairments caused by priority organics (PCBs), nutrients, and organic enrichment/dissolved oxygen (OE/DO). A TMDL developed to address the nutrient and OE/DO impairment in Logan Martin, as well as the entire Coosa River reservoir chain, was approved by the USEPA in 2008 (ADEM 2008c). A TMDL for the last three segments of Logan Martin that remain on the §303(d) list with impairments due to PCBs will be developed based upon ongoing RCRA/CERCLA program activities.

In 2010, the ADEM implemented specific water quality criteria for nutrient management at the forebay and mid stations of Logan Martin Reservoir. These criteria represent the maximum growing season mean (April-October) chlorophyll *a* (chl *a*) concentration allowable while still fully supporting Logan Martin Reservoir's S/F&W use classifications.

The purpose of this report is to summarize data collected at nine stations in Logan Martin Reservoir during the 2010 growing season and to evaluate trends in mean lake trophic status and nutrient concentrations using ADEM's historic 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 historical 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. Logan Martin Reservoir was sampled in the dam forebay, mid and upper reservoir along with six tributary stations; Cane, Blue Eye, Choccolocco, Dye, Cropwell and Clear Creeks.

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 2010), Surface Water Quality Assurance Project Plan (ADEM 2008a), and Quality Management Plan (ADEM 2008b).

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 Alabama Power Company's (APCo) dam discharge data and ADEM's previously collected data to help interpret the 2010 results.

Figure 1. Logan Martin Reservoir with 2010 sampling locations.

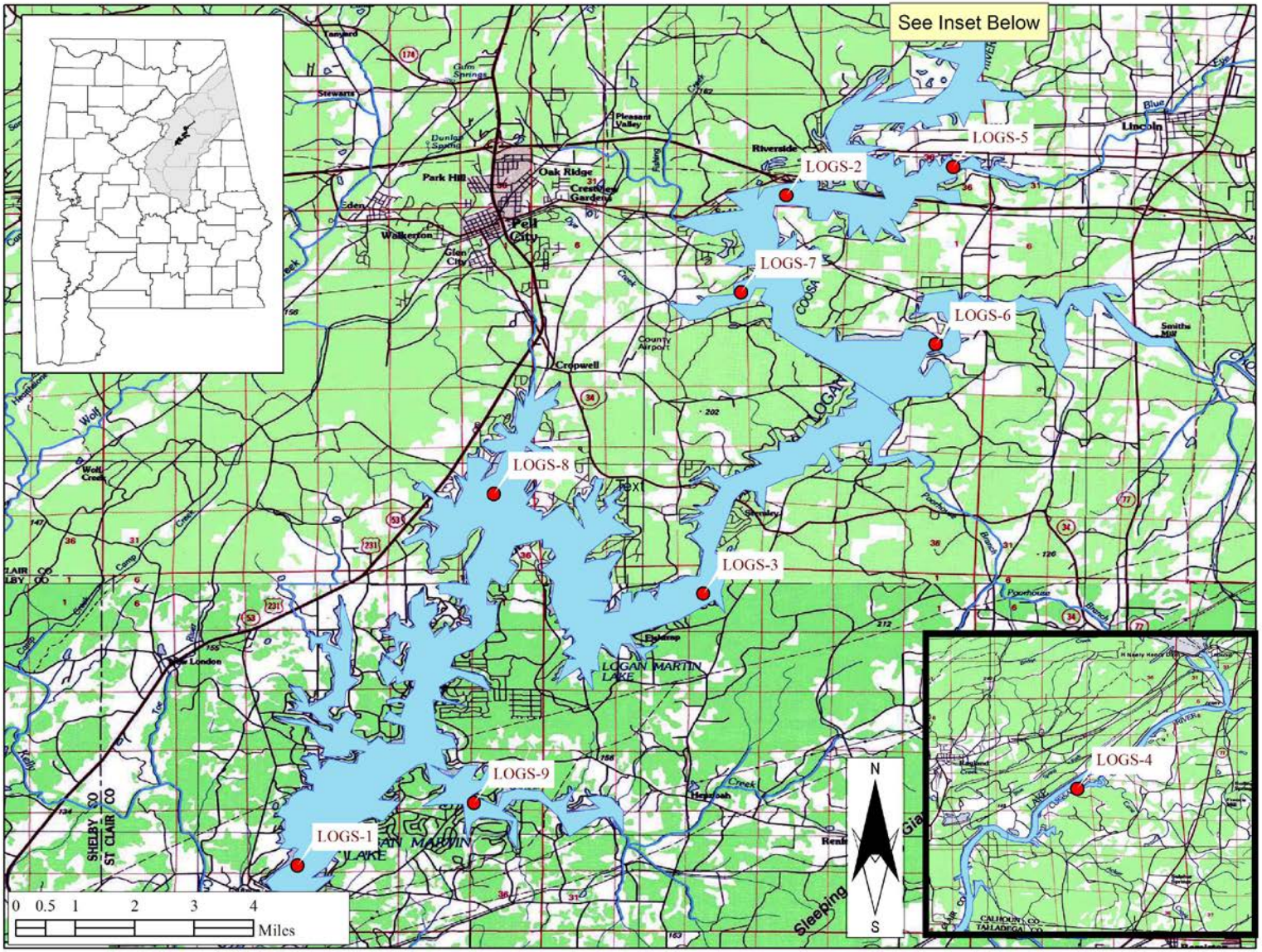


Table 1. Descriptions of the 2010 monitoring stations in Logan Martin Reservoir.

HUC	County	Station Number	Report Designation	Waterbody Name	Station Description	Chl *a* Criteria	Latitude	Longitude
031501060803	St Clair	LOGS-1	Lower	Coosa R	Deepest point, main river channel, dam forebay.	17 µg/L	33.43158	-86.33055
031501060605	Talladega	LOGS-2	Upper	Coosa R	Deepest point, main river channel. Downstream of I-20 bridge, immediately upstream of Riverside Marina.		33.59443	-86.21167
031501060803	St Clair	LOGS-3	Mid	Coosa R	Deepest point, main river channel. Approx. 1.5 miles downstream of Alabama Hwy 34 bridge.	17 µg/L	33.49759	-86.23190
031501060408	Calhoun	LOGS-4	Cane Ck	Cane Ck	Deepest point, main creek channel, Cane Creek embayment, approx. 0.25 miles upstream of Coosa River confluence.		33.73065	-86.10230
031501060604	Talladega	LOGS-5	Blue Eye Ck	Blue Eye Ck	Deepest point, main creek channel, Blue Eye Creek embayment, approx. 0.5 miles upstream of lake confluence.		33.60139	-86.17107
031501060514	Talladega	LOGS-6	Choccolocco Ck	Choccolocco Ck	Deepest point, main creek channel, Choccolocco Creek embayment, approx. 1.0 miles upstream of lake confluence.		33.55822	-86.17536
031501060605	St Clair	LOGS-7	Dye Ck	Dye Ck	Deepest point, main creek channel, Dye Creek embayment, approx. 0.5 miles upstream of lake confluence.		33.57086	-86.22271
031501060803	St Clair	LOGS-8	Cropwell Ck	Cropwell Ck	Deepest point, main creek channel, Cropwell Creek embayment, approx. 0.5 miles upstream of lake confluence.		33.52186	-86.28285
031501060802	Talladega	LOGS-9	Clear Ck	Clear Ck	Deepest point, main creek channel, Clear Creek embayment, immediately upstream of Talladega Co. Rd. 191 bridge.		33.44679	-86.28765

*Growing season mean chl *a* criteria implemented at this station in 2010.

RESULTS

Growing season mean graphs for TN, TP, chl *a*, and TSS are provided in this section (Figs. 2-5). Monthly graphs for TN, TP, chl *a*, TSS, DO, and TSI are also provided (Figs. 6-10, and 13). 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. AGPT results appear in Table 2. Depth profile graphs of temperature, DO, and conductivity appear in Figs. 11-12. Summary statistics of all data collected during 2010 are presented in Appendix Table 1. The table contains the minimum, maximum, median, mean, and standard deviation of each parameter analyzed.

Stations with the highest concentrations of nutrients, chlorophyll, 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 2010, the highest mean growing season TN values were calculated for the Dye Cr, Choccolocco Cr and Blue Eye Cr stations (Fig. 2). Growing season mean TN concentrations at all mainstem stations have decreased overall from 2005-2010. Mean concentrations in all tributaries decreased from 2005 to 2010. Monthly TN concentrations were highest at the upper station in September, at the mid station in July and the lower station in May (Fig. 6). The lower and upper stations showed a record high TN value in September and the lower station had a record low value in October.

In 2010, the highest mean growing season TP value was calculated for the Choccolocco Cr station (Fig. 3). The 2010 mean TP concentrations in the upper and mid mainstem stations were the lowest of the years monitored. The lower station has decreased mean TP concentrations since 2004. Mean concentrations in all tributaries except Clear Cr show a decreasing trend 2000-2010. Mean TP concentrations at Clear Cr decreased from 2005. Monthly TP concentrations at all mainstem stations were below historic means in all months sampled, reaching a historic low in the mid station in August and September (Fig. 7).

In 2010, the highest mean growing season chl *a* value was calculated for the mid station (Fig. 4). Choccolocco Cr and Dye Cr mean chl *a* concentrations increased from 2005 to 2010. Concentrations for the remaining embayment stations decreased 2000-2010. The growing season mean chl *a* concentration for the mid station was above the criteria limit in 2010 placing this area of the reservoir in category 4A[1]. The growing season mean chl *a* value for the lower station during 2010 was in compliance with the criteria limit. Monthly concentrations in the upper station were at or below historic means in all months sampled (Fig. 8). Historic high values were measured in May and October at the lower station and May and July at the mid station.

In 2010, highest mean growing season TSS value was calculated for Cane Ck station (Fig. 5). Growing season mean TSS concentrations show a decreasing trend overall at each station since 2000. Values were similar 2008-2010 at the upper and lower mainstem stations. Monthly TSS concentrations at both the mid and lower station were below historic means in all month sampled (Fig. 9). Historic lows occurred in April and June at the mid station, and May at the lower station. At the upper station, historic lows were measured in April-June and October.

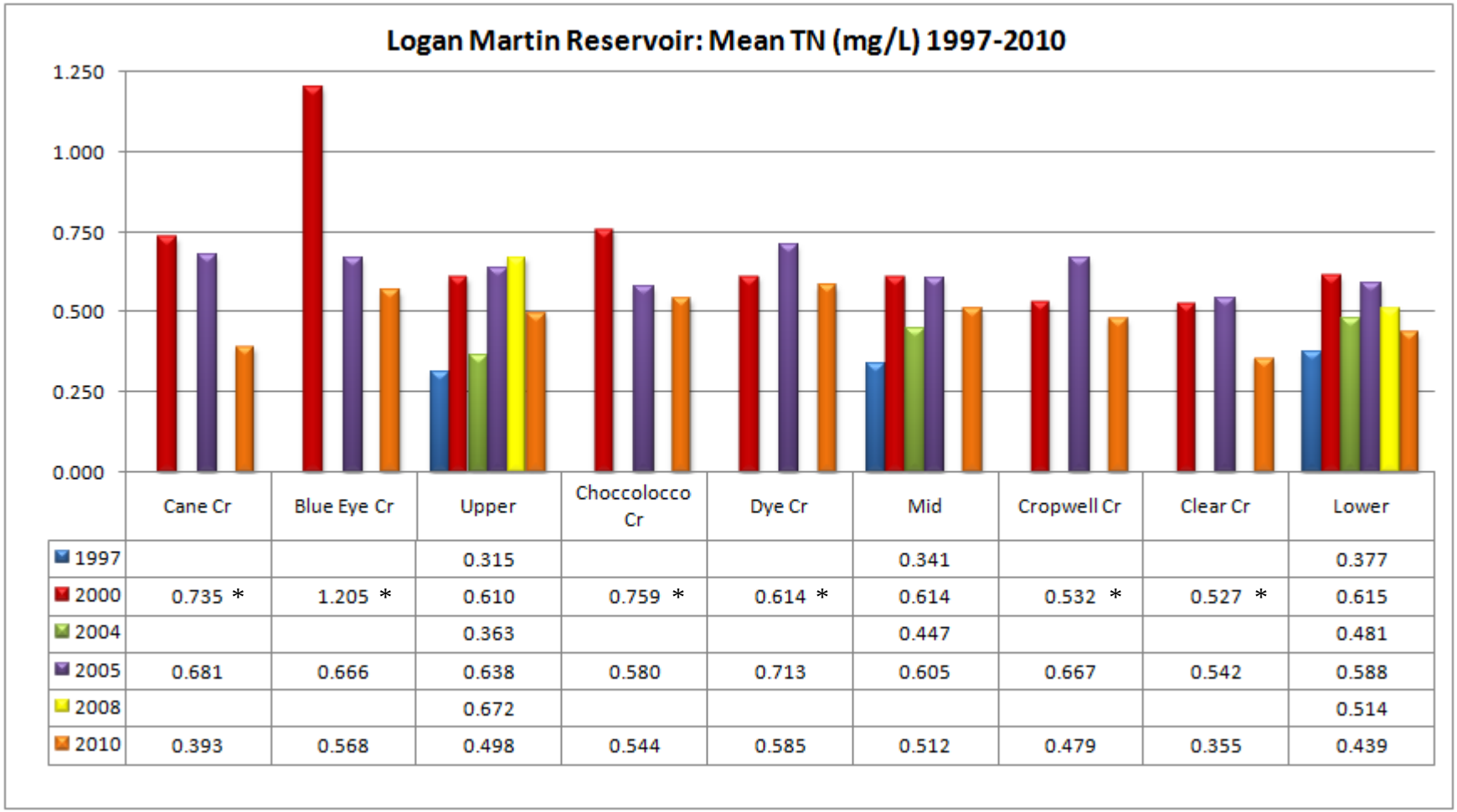
AGPT results for the upper station showed the reservoir to be phosphorus limited in 2010 (Table 2). Due to resource constraints, AGPT was not collected in 2010 for the mid and lower stations. The limiting nutrient has varied over the previous years but all MSC values were below 5.0 mg/L, the value that Raschke et al. (1996) defined as protective of reservoir and lake systems.

All measurements of dissolved oxygen concentrations in Logan Martin Reservoir met the ADEM Criteria (ADEM Admin. Code R. 335-6-10-.09) limit of 5.0 mg/l at 5.0 ft (1.5 m) though Dye and Cane Ck were near 5.0 mg/L in August (Fig. 10). The lower and mid stations showed stratification May-Oct (Figs. 11-12). The water columns at both stations were completely deoxygenated below 11m from June-September, while the conductivity and temperature varied little throughout the water column in most months. Highest temperatures were recorded in July and August.

[1]*Category 4A:* Waters in which one or more applicable water quality standards are not met but all TMDLs needed to result in attainment of all applicable WQSs have been approved or established by EPA (ADEM 2010).

Monthly TSI values calculated using chl *a* concentrations and Carlson's Trophic State Index show the mid station was hypereutrophic in May and eutrophic all other months (Fig. 13). The upper and mid stations were eutrophic from April/May-October. Choccolocco, Dye and Blue Eye Creeks were eutrophic all months monitored. Cropwell and Clear Creeks were mesotrophic in April and reached mid-eutrophic range by May. Cane Cr was oligotrophic in April, mesotrophic in May and eutrophic the remainder of the growing season.

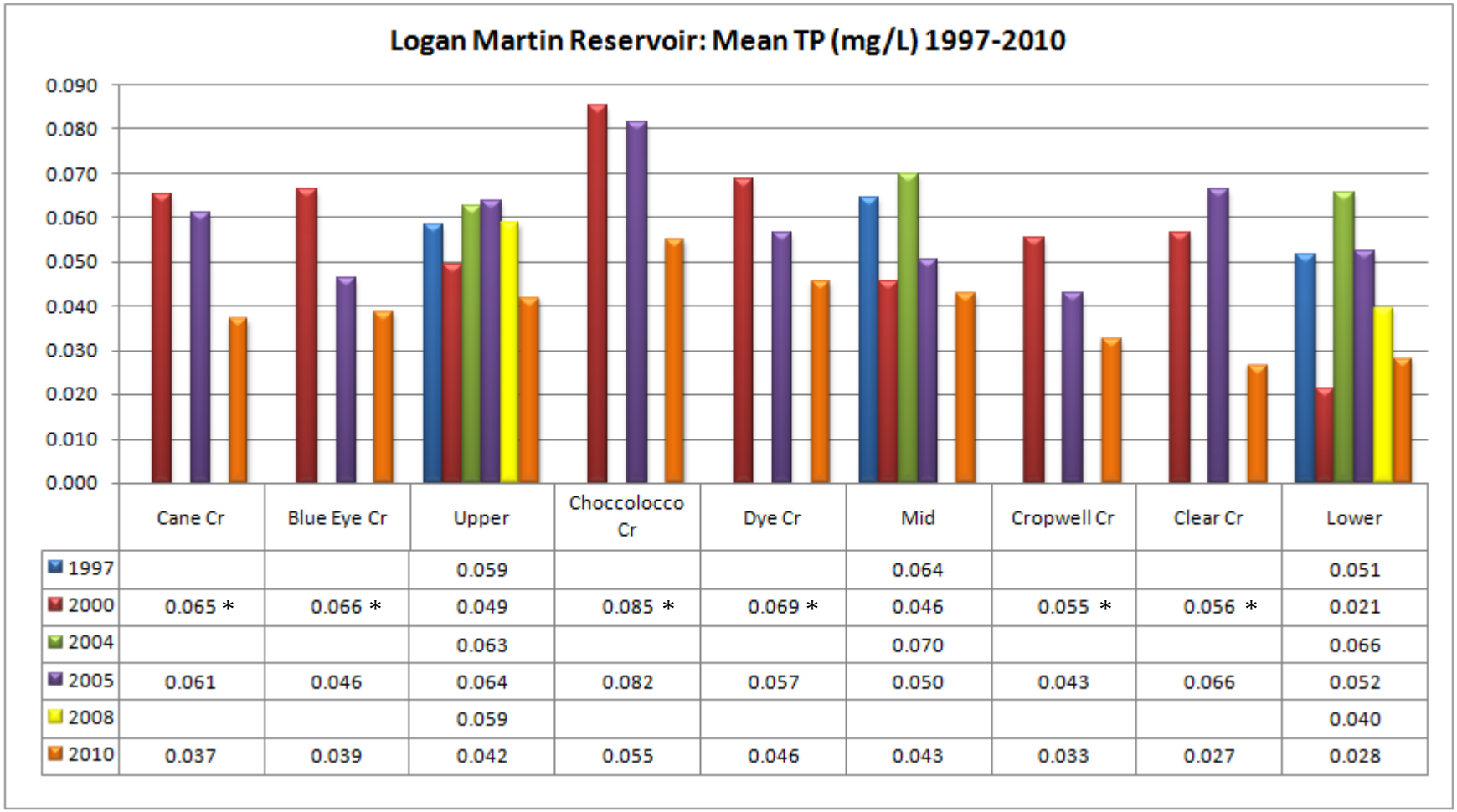
Figure 2. Mean growing season TN measured in Logan Martin Reservoir, April-October, 1997-2010. Stations are illustrated from upstream to downstream as the graph is read from left to right.



	Cane Cr	Blue Eye Cr	Upper	Choccolocco Cr	Dye Cr	Mid	Cropwell Cr	Clear Cr	Lower
1997			0.315			0.341			0.377
2000	0.735 *	1.205 *	0.610	0.759 *	0.614 *	0.614	0.532 *	0.527 *	0.615
2004			0.363			0.447			0.481
2005	0.681	0.666	0.638	0.580	0.713	0.605	0.667	0.542	0.588
2008			0.672						0.514
2010	0.393	0.568	0.498	0.544	0.585	0.512	0.479	0.355	0.439

*Mean of April/June/August only.

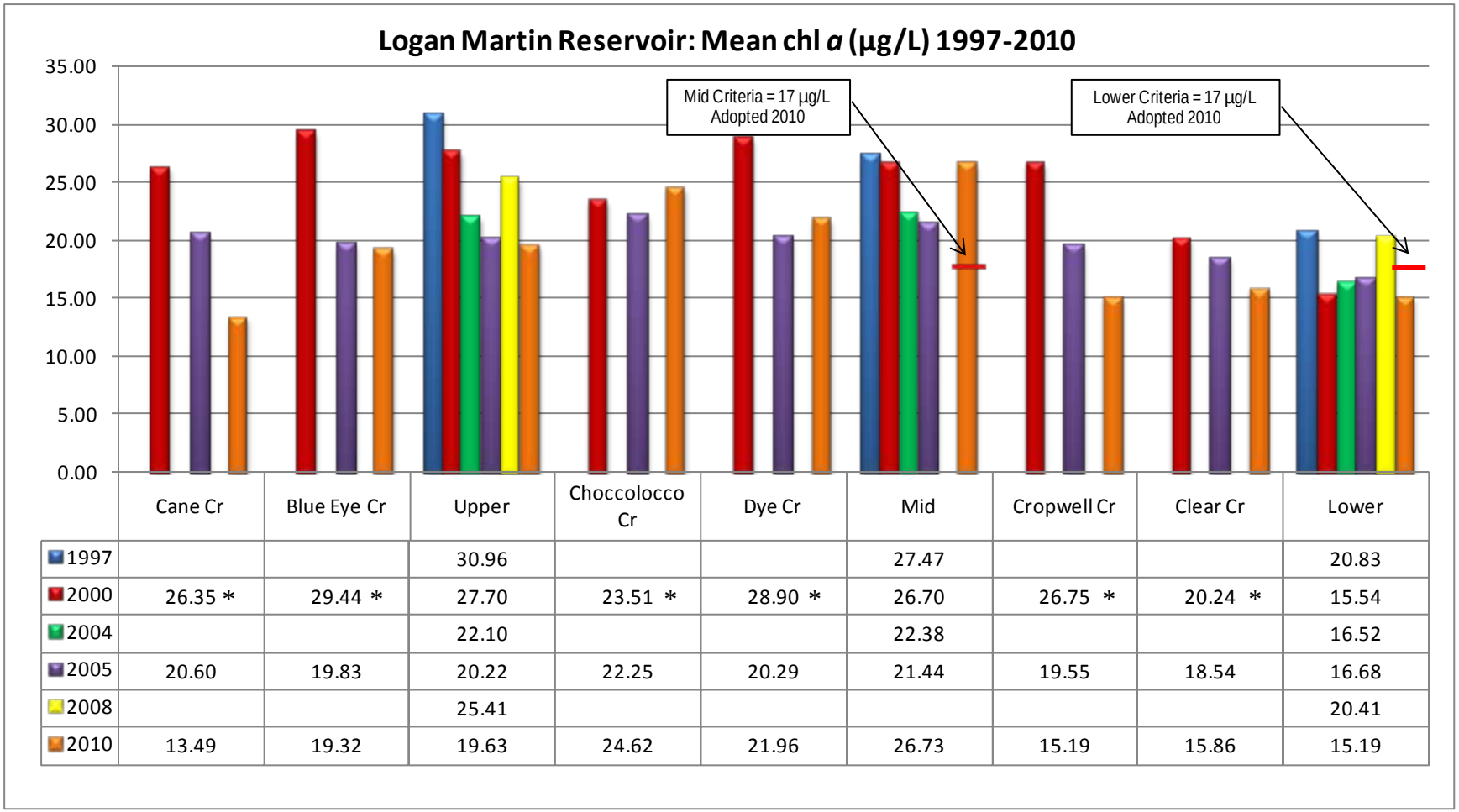
Figure 3. Mean growing season TP measured in Logan Martin Reservoir, April-October, 1997-2010. Stations are illustrated from upstream to downstream as the graph is read from left to right.



	Cane Cr	Blue Eye Cr	Upper	Choccolocco Cr	Dye Cr	Mid	Cropwell Cr	Clear Cr	Lower
1997			0.059			0.064			0.051
2000	0.065 *	0.066 *	0.049	0.085 *	0.069 *	0.046	0.055 *	0.056 *	0.021
2004			0.063			0.070			0.066
2005	0.061	0.046	0.064	0.082	0.057	0.050	0.043	0.066	0.052
2008			0.059						0.040
2010	0.037	0.039	0.042	0.055	0.046	0.043	0.033	0.027	0.028

*Mean of April/June/August only.

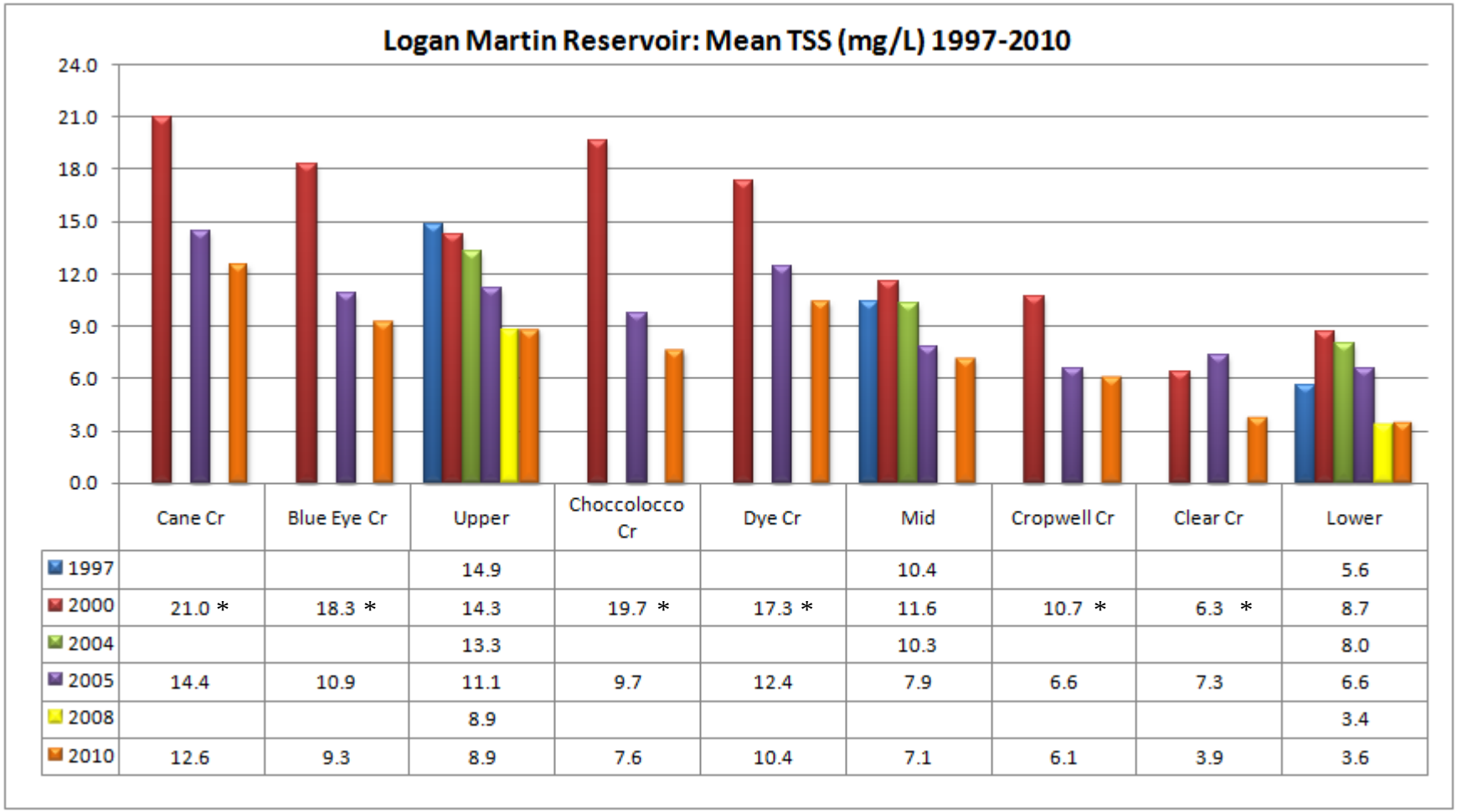
Figure 4. Mean growing season chl *a* measured in Logan Martin Reservoir, April-October, 1997-2010. Stations are illustrated from upstream to downstream as the graph is read from left to right. Chl *a* criteria applies to the growing season mean of the mid and lower stations only.



	Cane Cr	Blue Eye Cr	Upper	Choccolocco Cr	Dye Cr	Mid	Cropwell Cr	Clear Cr	Lower
1997			30.96			27.47			20.83
2000	26.35 *	29.44 *	27.70	23.51 *	28.90 *	26.70	26.75 *	20.24 *	15.54
2004			22.10			22.38			16.52
2005	20.60	19.83	20.22	22.25	20.29	21.44	19.55	18.54	16.68
2008			25.41						20.41
2010	13.49	19.32	19.63	24.62	21.96	26.73	15.19	15.86	15.19

*Mean of April/June/August only.

Figure 5. Mean growing season TSS measured in Logan Martin Reservoir, April-October, 1997-2010. Stations are illustrated from upstream to downstream as the graph is read from left to right.



	Cane Cr	Blue Eye Cr	Upper	Choccolocco Cr	Dye Cr	Mid	Cropwell Cr	Clear Cr	Lower
1997			14.9			10.4			5.6
2000	21.0 *	18.3 *	14.3	19.7 *	17.3 *	11.6	10.7 *	6.3 *	8.7
2004			13.3			10.3			8.0
2005	14.4	10.9	11.1	9.7	12.4	7.9	6.6	7.3	6.6
2008			8.9						3.4
2010	12.6	9.3	8.9	7.6	10.4	7.1	6.1	3.9	3.6

*Mean of April/June/August only.

Figure 6. Monthly TN concentrations measured in Logan Martin Reservoir, April-October 2010 vs. average monthly discharge. Monthly discharge acquired from APCo at Logan Martin Dam. Each bar graph depicts monthly changes in each station. The historic mean (1990-2010) and min/max ranges are also displayed for comparison. The "n" value equals the number of datapoints included in the monthly historic calculations.

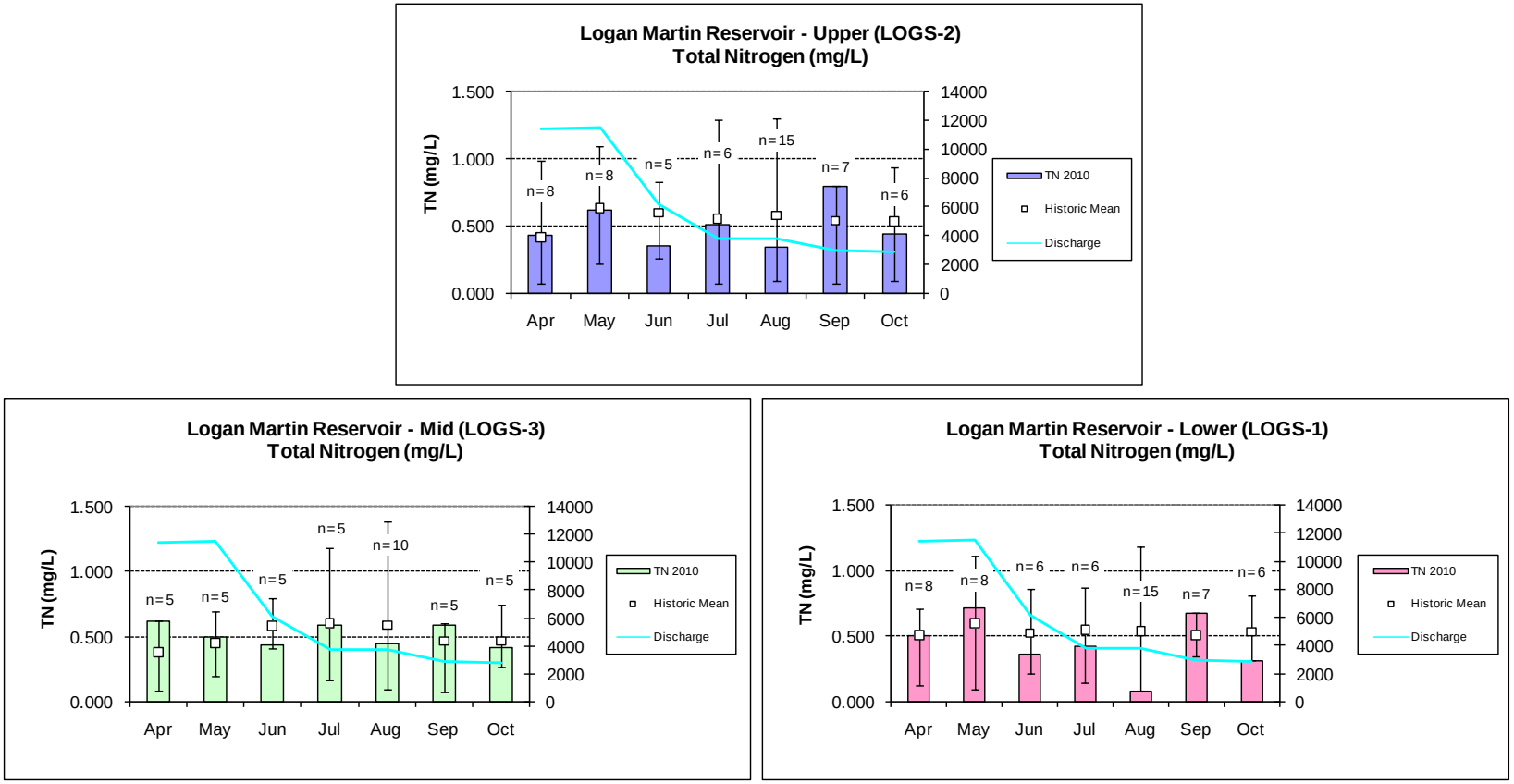


Figure 7. Monthly TP concentrations measured in Logan Martin Reservoir, April-October 2010 vs. average monthly discharge. Monthly discharge acquired from APCo at Logan Martin Dam. Each bar graph depicts monthly changes in each station. The historic mean (1990-2010) and min/max ranges are also displayed for comparison. The "n" value equals the number of datapoints included in the monthly historic calculations.

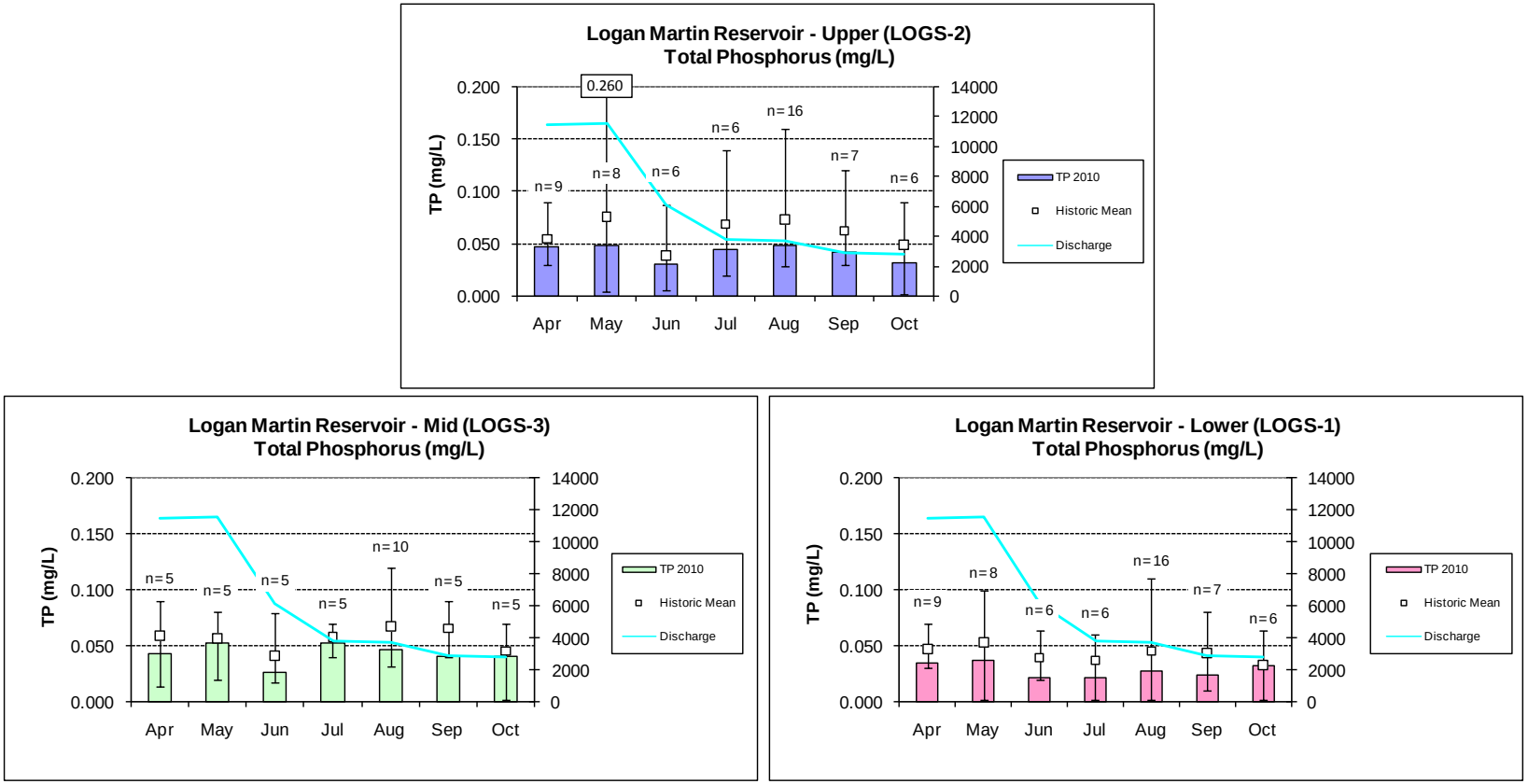


Figure 8. Monthly chl *a* concentrations measured in Logan Martin Reservoir, April-October 2010 vs. average monthly discharge. Monthly discharge acquired from APCo at Logan Martin Dam. Each bar graph depicts monthly changes in each station. The historic mean (1990-2010) and min/max ranges are also displayed for comparison. The "n" value equals the number of datapoints included in the monthly historic calculations.

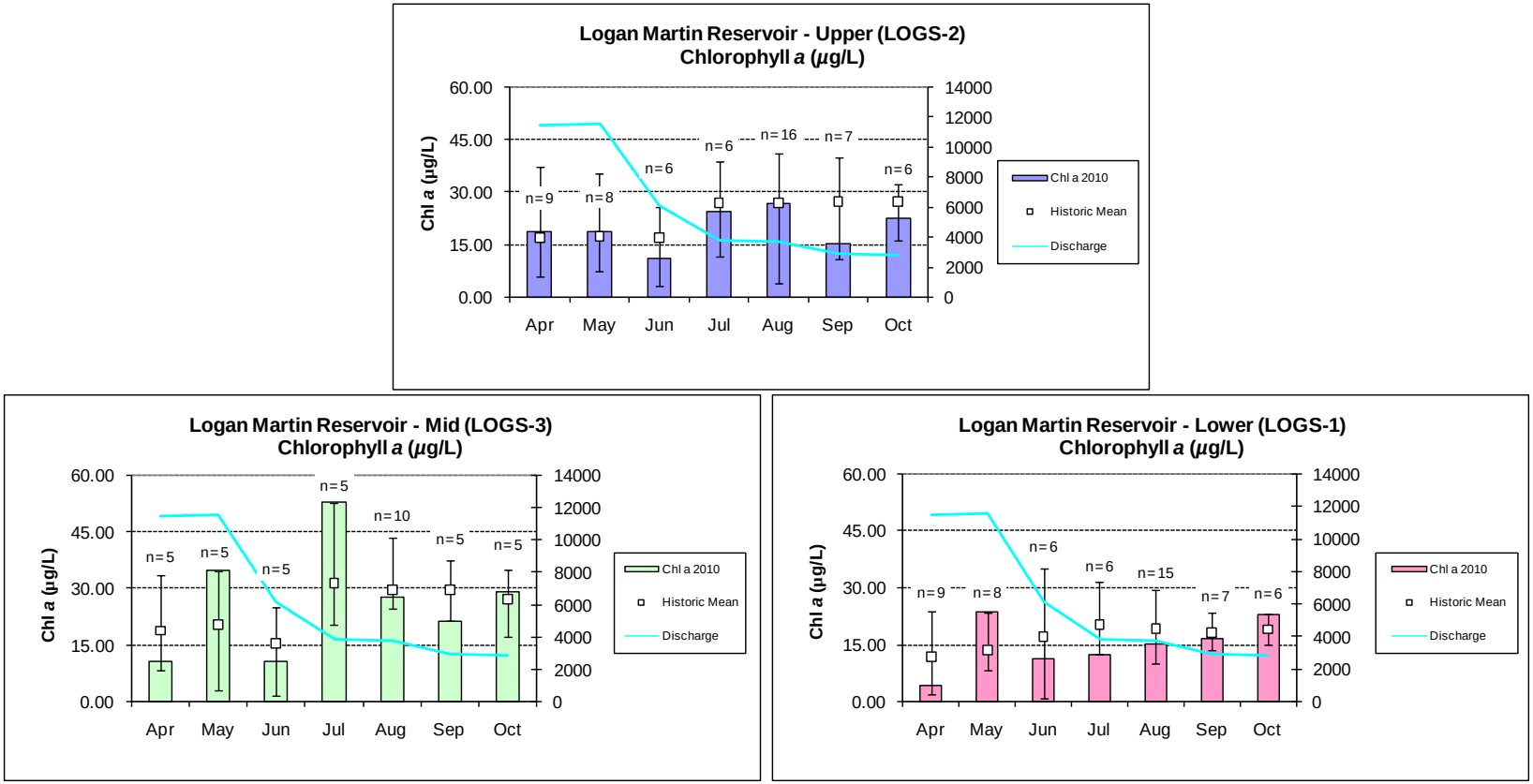


Figure 9. Monthly TSS concentrations measured in Logan Martin Reservoir, April-October 2010 vs. average monthly discharge. Monthly discharge acquired from APCo at Logan Martin Dam. Each bar graph depicts monthly changes in each station. The historic mean (1990-2010) and min/max range are also displayed for comparison. The "n" value equals the number of datapoints included in the monthly historic calculations.

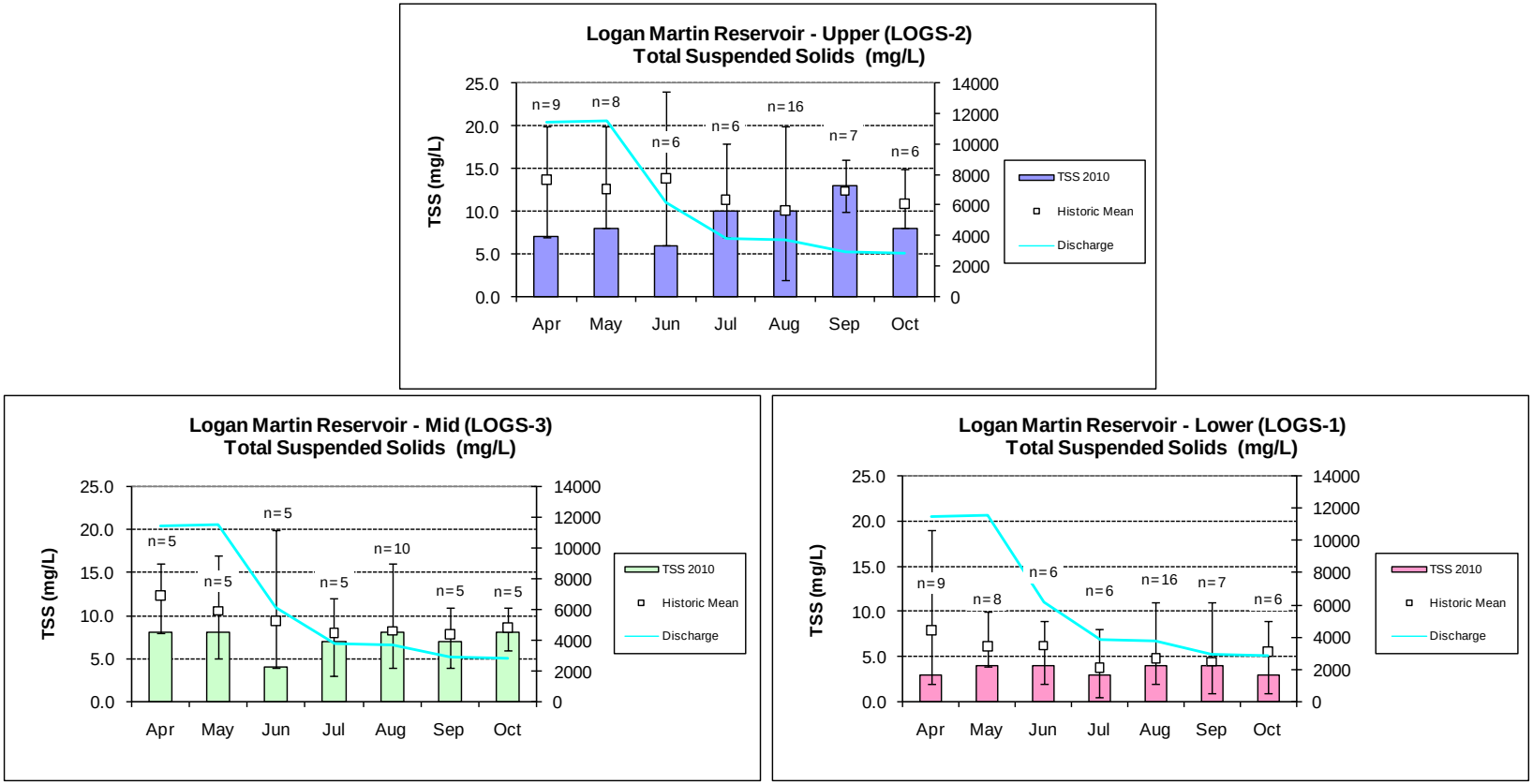
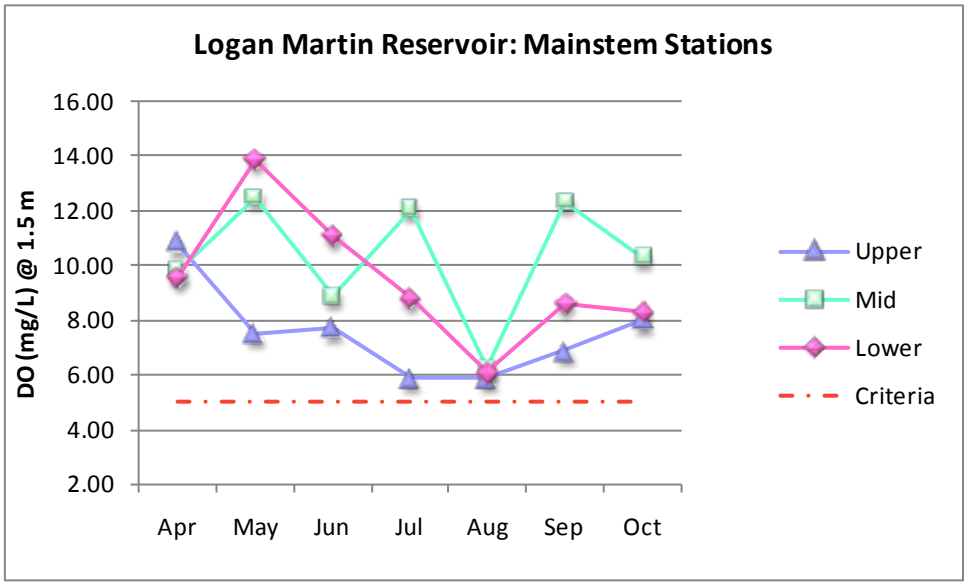


Table 2. Algal growth potential test results, Logan Martin Reservoir, 1999-2010 (expressed as mean Maximum Standing Crop (MSC) dry weights of *Selenastrum capricornutum* in mg/L) and limiting nutrient status. MSC values below 5 mg/L are considered to be protective in reservoirs and lakes; values below 20 mg/L MSC are considered protective of flowing streams and rivers. (Raschke and Schultz 1987).

Station	**Upper (LOGS-2)**		**Mid (LOGS-3)**		**Lower (LOGS-1)**	
	Control mean MSC	**Limiting Nutrient**	**Control mean MSC**	**Limiting Nutrient**	**Control mean MSC**	**Limiting Nutrient**
1997	2.71	NITROGEN	2.42	CO-LIMITING	2.26	CO-LIMITING
2000	4.23	NON-LIMITING	3.7	NITROGEN	1.17	PHOSPHORUS
2005	2.75	NON-LIMITING	2.25	NITROGEN	2.93	NITROGEN
2010	4.98	PHOSPHORUS	---	---	---	---

Figure 10. Monthly DO concentrations at 1.5 m (5 ft) for Logan Martin Reservoir stations collected April-October 2010. ADEM Water Quality Criteria pertaining to reservoir waters require a DO concentration of 5.0 mg/L at this depth (ADEM 2010).



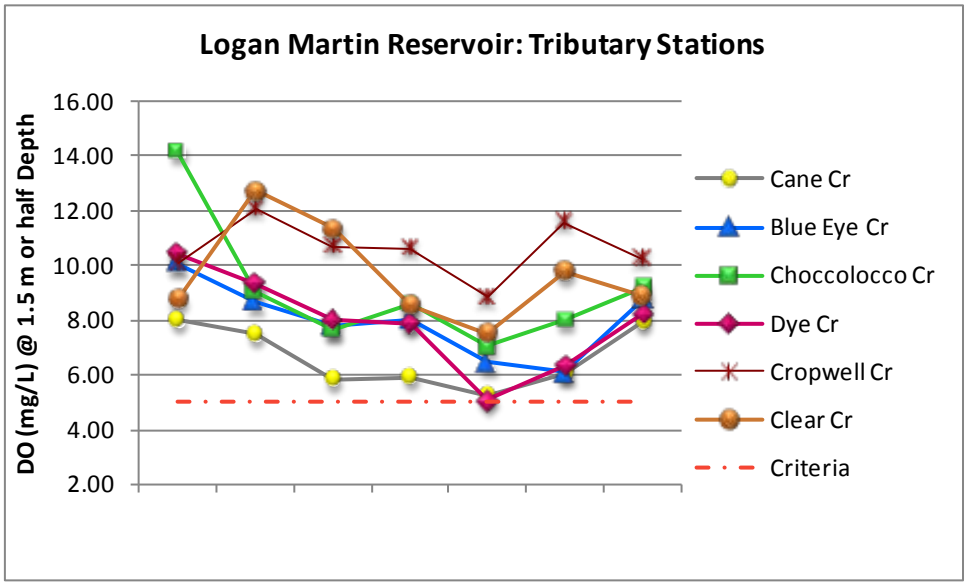


Figure 11. Monthly depth profiles of dissolved oxygen (mg/L), temperature (C), and conductivity (umhos) in the lower Logan Martin Reservoir station, April-October 2010.

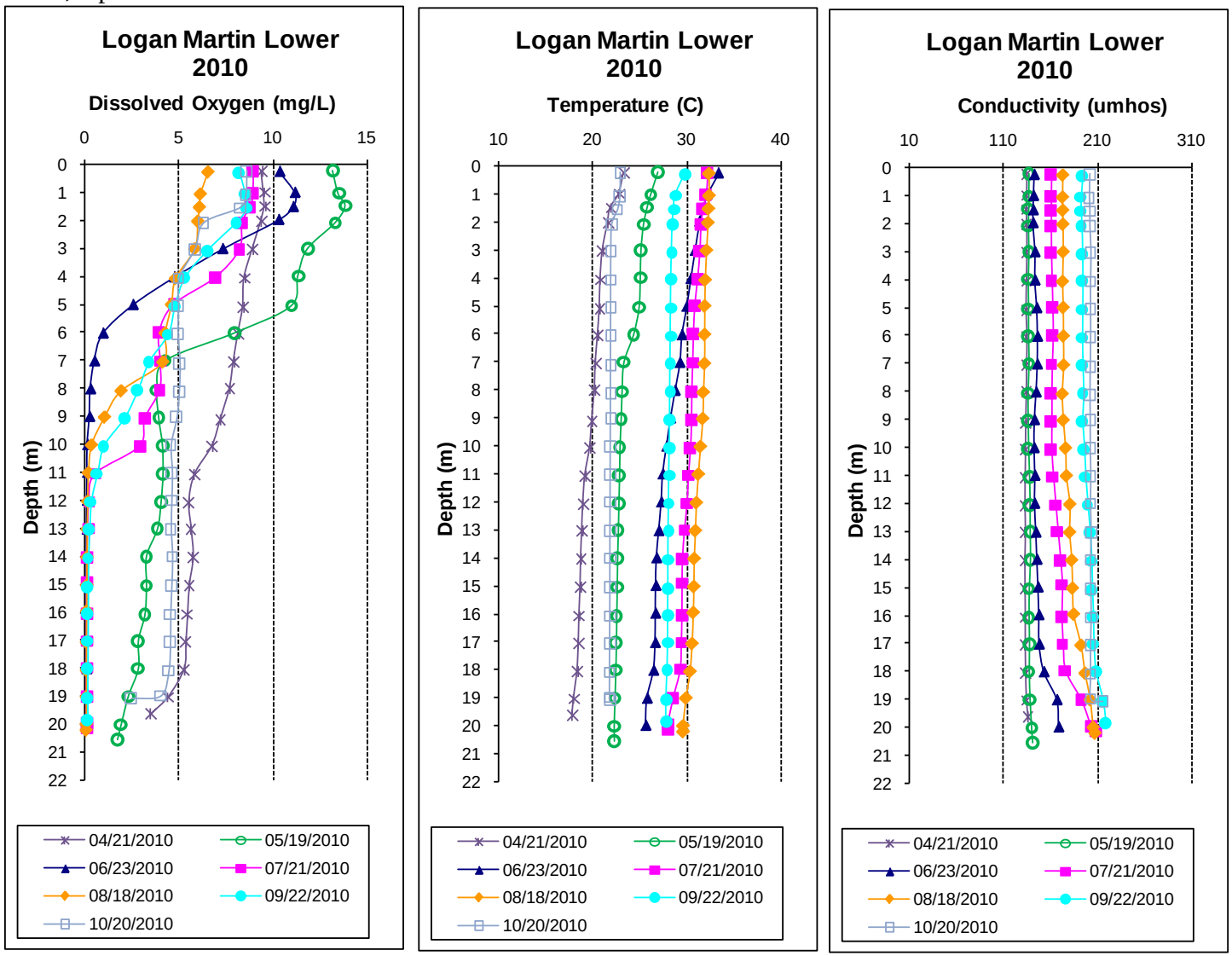


Figure 12. Monthly depth profiles of dissolved oxygen (mg/L), temperature (C), and conductivity (umhos) in the mid Logan Martin Reservoir station, April-October 2010.

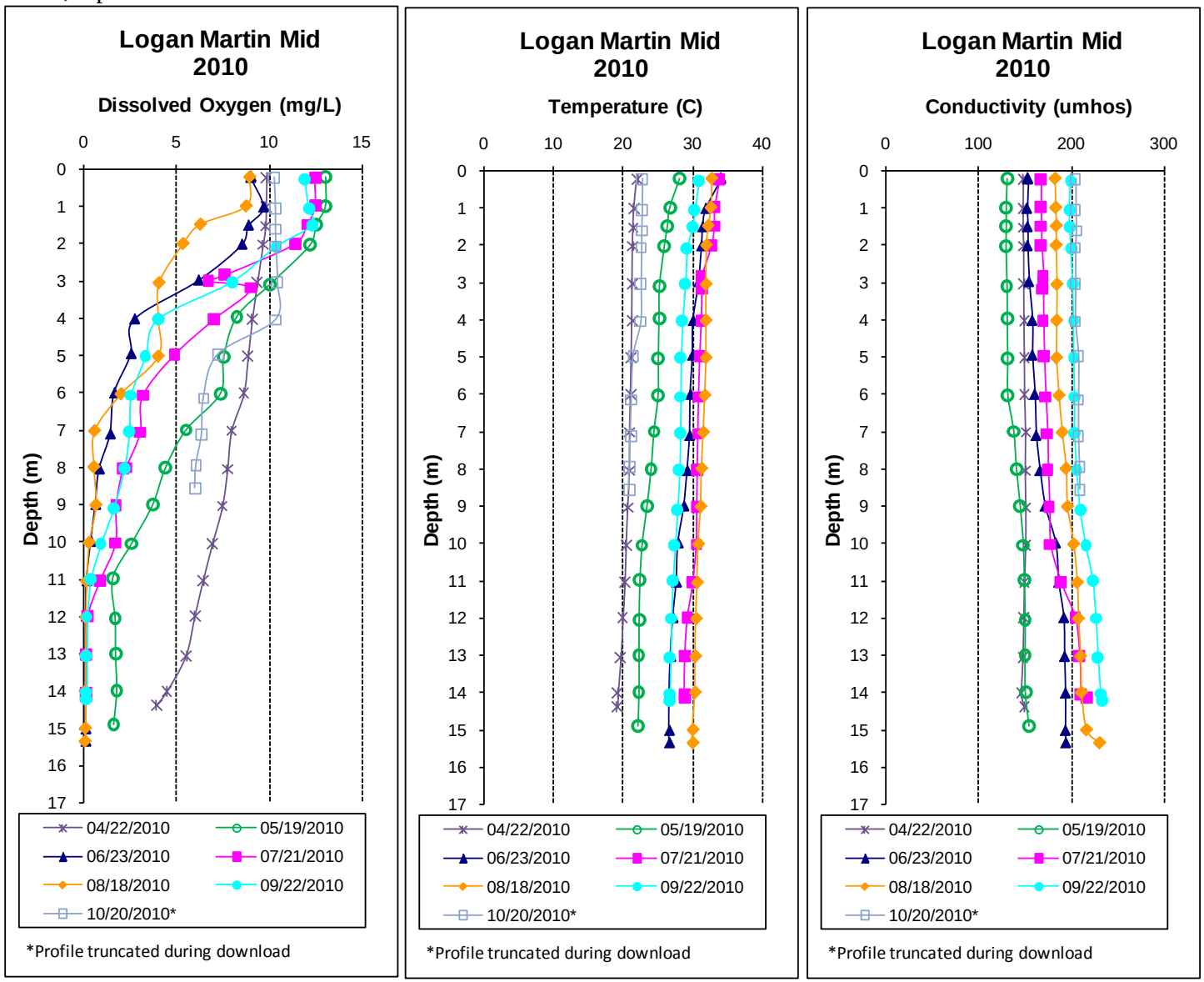
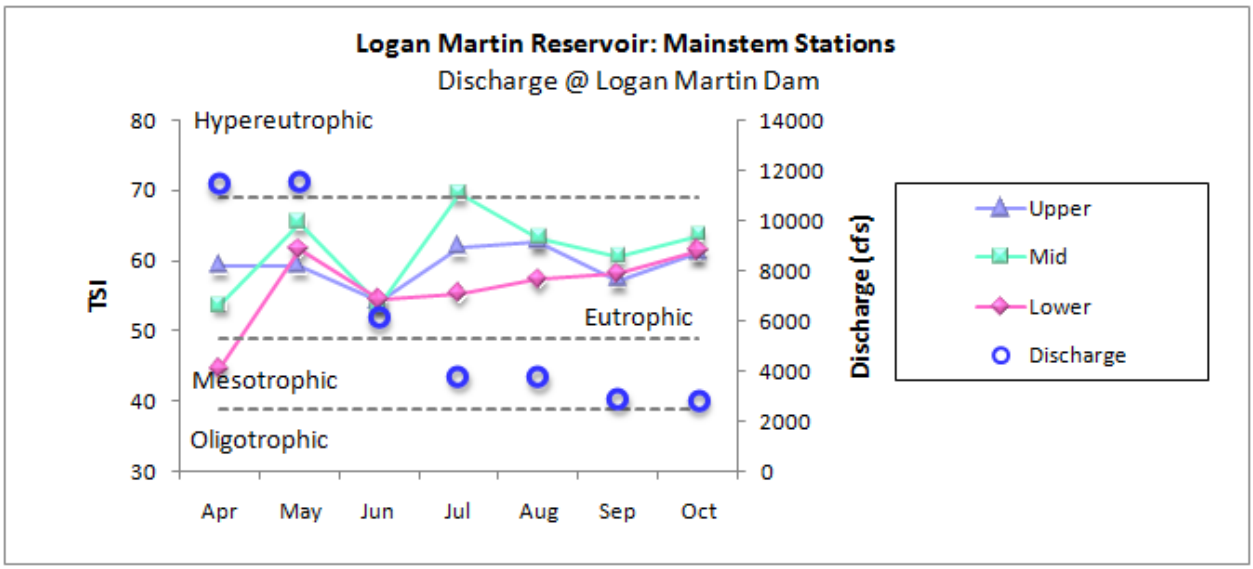
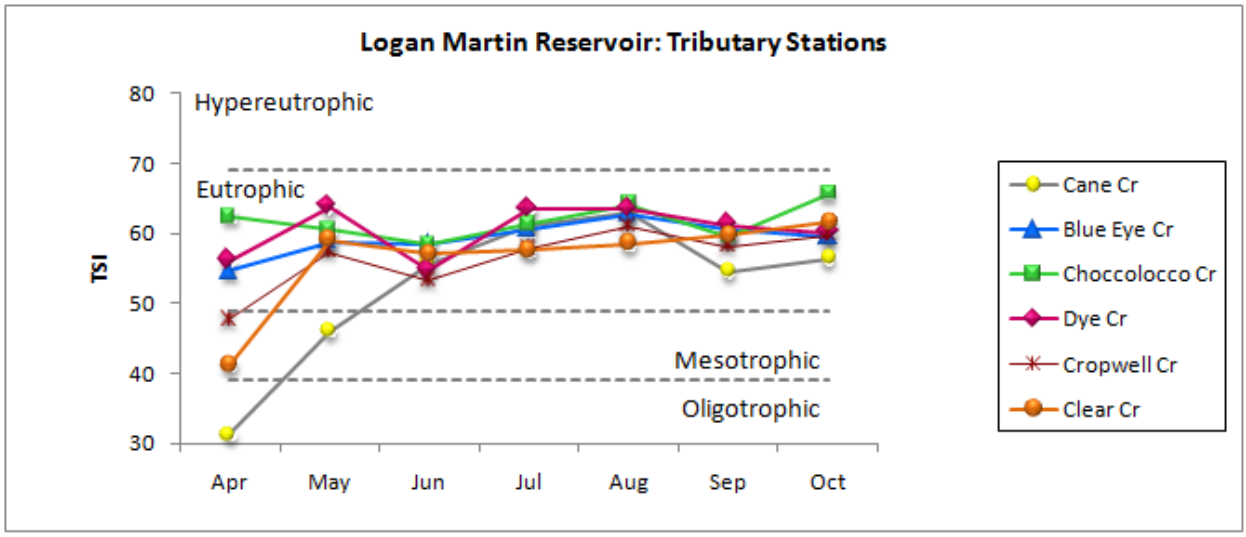


Figure 13. Monthly TSI values calculated for mainstem and tributary Logan Martin Reservoir stations using chl *a* concentrations and Carlson's Trophic State Index calculation. Monthly discharge acquired from APCo at Logan Martin Dam.





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APPENDIX

Appendix Table 1. Summary of Logan Martin Reservoir water quality data collected April-October, 2010. 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
LOGS-1	**Physical**						
	Turbidity (NTU)	7	2.4	11.1	3.3	4.5	3.0
	Total Dissolved Solids (mg/L)[J]	7	66.0	124.0	94.0	95.4	21.5
	Total Suspended Solids (mg/L)[J]	7	3.0	4.0	4.0	3.6	0.5
	Hardness (mg/L)	4	56.2	77.2	62.6	64.6	10.2
	Alkalinity (mg/L)	7	56.0	80.2	67.6	67.8	10.5
	Photic Zone (m)	7	3.32	6.33	5.15	5.11	1.05
	Secchi (m)	7	0.86	2.49	1.71	1.69	0.55
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.021	0.021	0.010	0.010	0.000
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	< 0.003	0.048	0.007	0.018	0.020
	Total Kjeldahl Nitrogen (mg/L)	7	< 0.080	0.714	0.417	0.421	0.230
	Total Nitrogen (mg/L)[J]	7	< 0.079	0.716	0.418	0.438	0.220
	Dissolved Reactive Phosphorus (mg/L)[J]	7	< 0.003	0.007	0.003	0.004	0.002
	Total Phosphorus (mg/L)	7	0.022	0.037	0.027	0.028	0.006
	CBOD-5 (mg/L)	7	< 2.0	4.1	1.0	1.6	1.2
	Chlorides (mg/L)	7	3.6	8.1	4.4	5.1	1.7
	Biological						
	Chlorophyll a (ug/L)	7	4.27	23.50	15.20	15.19	6.74
	E. coli (mpn/100mL)[J]	3	< 1	<1	0.5	0.5	0
LOGS-2	**Physical**						
	Turbidity (NTU)	7	6.8	16.3	10.1	10.9	3.0
	Total Dissolved Solids (mg/L)	7	< 1.0	118.0	104.0	88.1	40.3
	Total Suspended Solids (mg/L)[J]	7	6.0	13.0	8.0	8.9	2.3
	Hardness (mg/L)	4	61.9	76.4	68.4	68.8	7.0
	Alkalinity (mg/L)	7	53.7	79.6	71.0	69.1	8.8
	Photic Zone (m)	7	2.36	3.20	2.56	2.67	0.31
	Secchi (m)	7	0.66	1.02	0.89	0.86	0.14
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.021	0.021	0.010	0.010	0.000
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	< 0.002	0.129	0.006	0.027	0.047
	Total Kjeldahl Nitrogen (mg/L)	7	0.303	0.791	0.437	0.471	0.159
	Total Nitrogen (mg/L)[J]	7	< 0.341	0.794	0.438	0.498	0.162
	Dissolved Reactive Phosphorus (mg/L)[J]	7	< 0.003	0.012	0.003	0.004	0.004
	Total Phosphorus (mg/L)	7	0.031	0.049	0.045	0.042	0.008
	CBOD-5 (mg/L)	7	< 2.0	2.9	1.0	1.7	0.9
	Chlorides (mg/L)	7	3.6	10.0	5.3	6.1	2.4
	Biological						
	Chlorophyll a (ug/L)	7	11.21	26.70	18.70	19.63	5.36
	E. coli (mpn/100mL)	3	< 1	4	3	3	2

Station	Parameter	N	Min	Max	Med	Mean	SD
LOGS-3	**Physical**						
	Turbidity (NTU)	7	3.6	11.7	6.3	6.7	2.7
	Total Dissolved Solids (mg/L) [J]	7	58.0	138.0	102.0	100.0	28.0
	Total Suspended Solids (mg/L) [J]	7	4.0	8.0	8.0	7.1	1.5
	Hardness (mg/L)	4	60.4	77.4	66.9	67.9	8.4
	Alkalinity (mg/L)	7	53.0	80.4	70.5	69.3	9.5
	Photic Zone (m)	7	2.77	4.84	3.05	3.38	0.71
	Secchi (m)	7	0.67	1.81	0.96	1.11	0.37
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.021	0.021	0.010	0.010	0.000
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	< 0.002	0.025	0.006	0.010	0.010
	Total Kjeldahl Nitrogen (mg/L)	7	0.413	0.598	0.475	0.502	0.085
	Total Nitrogen (mg/L) [J]	7	< 0.414	0.623	0.493	0.512	0.086
	Dissolved Reactive Phosphorus (mg/L) [J]	7	< 0.003	0.005	0.004	0.004	0.001
	Total Phosphorus (mg/L)	7	0.026	0.052	0.043	0.043	0.009
	CBOD-5 (mg/L)	7	< 2.0	3.8	2.4	2.3	1.0
	Chlorides (mg/L)	7	3.6	9.1	4.9	5.7	2.2
	Biological						
	Chlorophyll a (ug/L)	7	10.68	52.87	27.77	26.73	14.70
	E. coli (mpn/100mL)	3	< 1	<1	0.5	0.5	
LOGS-4	**Physical**						
	Turbidity (NTU)	7	7.2	18.9	17.7	14.8	4.7
	Total Dissolved Solids (mg/L)	7	84.0	146.0	118.0	118.3	18.7
	Total Suspended Solids (mg/L)	7	4.0	21.0	12.0	12.6	5.6
	Hardness (mg/L)	4	90.7	116.0	99.0	101.2	10.6
	Alkalinity (mg/L)	7	92.1	118.0	104.0	102.7	8.4
	Photic Zone (m)	7	1.63	2.08	1.93	1.85	0.19
	Secchi (m)	7	0.60	1.52	0.82	0.89	0.30
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.021	0.021	0.010	0.010	0.000
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	0.013	0.225	0.078	0.103	0.086
	Total Kjeldahl Nitrogen (mg/L)	7	< 0.080	0.535	0.284	0.289	0.176
	Total Nitrogen (mg/L) [J]	7	0.166	0.637	0.405	0.393	0.154
	Dissolved Reactive Phosphorus (mg/L) [J]	7	0.005	0.011	0.009	0.008	0.002
	Total Phosphorus (mg/L)	7	0.017	0.049	0.041	0.037	0.010
	CBOD-5 (mg/L)	7	< 2.0	2.2	1.0	1.2	0.4
	Chlorides (mg/L)	7	2.1	5.9	4.4	4.1	1.5
	Biological						
	Chlorophyll a (ug/L)	7	1.07	27.46	12.97	13.49	9.28
	E. coli (mpn/100mL)	3	9	30	23	21	11

Station	Parameter	N	Min	Max	Med	Mean	SD
LOGS-5	**Physical**						
	Turbidity (NTU)	7	6.9	14.2	9.9	10.5	2.9
	Total Dissolved Solids (mg/L)	7	46.0	138.0	108.0	104.6	29.0
	Total Suspended Solids (mg/L)	7	6.0	12.0	9.0	9.3	2.4
	Hardness (mg/L)	4	80.9	94.4	87.2	87.4	5.8
	Alkalinity (mg/L)	7	69.2	108.0	89.8	89.4	12.3
	Photic Zone (m)	7	1.86	3.20	2.71	2.55	0.53
	Secchi (m)	7	0.58	1.44	0.99	0.98	0.29
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.021	0.021	0.010	0.010	0.000
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	< 0.002	0.071	0.002	0.017	0.028
	Total Kjeldahl Nitrogen (mg/L)	7	0.401	0.944	0.513	0.551	0.184
	Total Nitrogen (mg/L) [J]	7	< 0.452	0.945	0.514	0.568	0.172
	Dissolved Reactive Phosphorus (mg/L) [J]	7	< 0.003	0.006	0.003	0.004	0.002
	Total Phosphorus (mg/L)	7	0.029	0.049	0.038	0.039	0.007
	CBOD-5 (mg/L)	7	< 2.0	2.8	2.1	1.8	0.8
	Chlorides (mg/L)	7	3.3	7.8	3.8	4.8	1.8
	Biological						
	Chlorophyll a (ug/L)	7	11.70	26.70	19.22	19.32	4.62
	E. coli (mpn/100mL)	3	9	10	9	8	1
LOGS-6	**Physical**						
	Turbidity (NTU)	7	6.2	12.4	9.8	9.2	2.2
	Total Dissolved Solids (mg/L)	7	76.0	114.0	94.0	96.3	11.7
	Total Suspended Solids (mg/L)	7	< 1.0	10.0	10.0	7.6	3.6
	Hardness (mg/L)	4	60.3	84.7	77.2	74.9	10.4
	Alkalinity (mg/L)	7	65.5	87.0	80.8	77.1	8.7
	Photic Zone (m)	7	2.18	3.13	2.80	2.66	0.39
	Secchi (m)	7	0.64	1.13	0.96	0.90	0.18
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.021	0.021	0.010	0.010	0.000
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	< 0.002	0.091	0.002	0.026	0.039
	Total Kjeldahl Nitrogen (mg/L)	7	0.333	0.686	0.534	0.518	0.117
	Total Nitrogen (mg/L) [J]	7	< 0.335	0.696	0.536	0.544	0.124
	Dissolved Reactive Phosphorus (mg/L) [J]	7	< 0.003	0.006	0.005	0.005	0.001
	Total Phosphorus (mg/L)	7	0.033	0.070	0.052	0.055	0.013
	CBOD-5 (mg/L)	7	< 2.0	3.3	2.3	2.3	0.7
	Chlorides (mg/L)	7	3.0	8.2	5.0	5.5	2.1
	Biological						
	Chlorophyll a (ug/L)	7	17.09	35.85	22.89	24.62	6.62
	E. coli (mpn/100mL)	3	2	5	2	3	2

Station	Parameter	N	Min	Max	Med	Mean	SD
LOGS-7	**Physical**						
	Turbidity (NTU)	7	6.2	18.9	10.0	10.8	4.1
	Total Dissolved Solids (mg/L) [J]	7	44.0	128.0	106.0	97.1	27.5
	Total Suspended Solids (mg/L) [J]	7	6.0	18.0	10.0	10.4	3.9
	Hardness (mg/L)	4	60.9	76.4	68.8	68.7	7.3
	Alkalinity (mg/L)	7	54.0	84.2	70.3	70.2	10.0
	Photic Zone (m)	7	1.88	3.17	2.69	2.58	0.49
	Secchi (m)	7	0.59	1.24	0.91	0.89	0.19
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.021	0.021	0.010	0.010	0.000
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	< 0.002	0.008	0.002	0.003	0.002
	Total Kjeldahl Nitrogen (mg/L)	7	0.191	0.989	0.594	0.583	0.254
	Total Nitrogen (mg/L) [J]	7	< 0.199	0.990	0.596	0.585	0.253
	Dissolved Reactive Phosphorus (mg/L) [J]	7	< 0.003	0.005	0.004	0.004	0.001
	Total Phosphorus (mg/L)	7	0.035	0.060	0.045	0.046	0.008
	CBOD-5 (mg/L)	7	< 2.0	2.9	1.0	1.7	0.8
	Chlorides (mg/L)	7	3.6	9.8	5.0	6.0	2.4
	Biological						
	Chlorophyll a (ug/L)	7	11.75	29.37	22.43	21.96	7.24
	E. coli (mpn/100mL) [J]	3	< 1	2	2	2	1
LOGS-8	**Physical**						
	Turbidity (NTU)	7	3.5	6.8	4.1	4.6	1.2
	Total Dissolved Solids (mg/L) [J]	7	80.0	134.0	92.0	97.4	18.1
	Total Suspended Solids (mg/L)	7	3.0	9.0	6.0	6.1	2.5
	Hardness (mg/L)	4	56.9	76.8	64.2	65.5	9.3
	Alkalinity (mg/L)	7	56.3	82.1	68.0	68.6	10.6
	Photic Zone (m)	7	3.32	5.00	4.30	4.23	0.53
	Secchi (m)	7	0.95	1.77	1.32	1.40	0.29
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.021	0.021	0.010	0.010	0.000
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	< 0.002	0.029	0.002	0.006	0.010
	Total Kjeldahl Nitrogen (mg/L)	7	0.321	0.889	0.394	0.473	0.197
	Total Nitrogen (mg/L) [J]	7	< 0.322	0.890	0.396	0.479	0.196
	Dissolved Reactive Phosphorus (mg/L) [J]	7	< 0.003	0.006	0.003	0.003	0.001
	Total Phosphorus (mg/L)	7	0.022	0.039	0.034	0.033	0.006
	CBOD-5 (mg/L)	7	< 2.0	3.8	2.3	2.2	1.0
	Chlorides (mg/L)	7	3.6	8.3	4.4	5.3	1.9
	Biological						
	Chlorophyll a (ug/L)	7	5.70	22.43	16.02	15.19	5.66
	E. coli (mpn/100mL) [J]	3	< 1	<1	0.5	0.5	0

Station	Parameter	N	Min	Max	Med	Mean	SD
LOGS-9	**Physical**						
	Turbidity (NTU)	7	2.8	7.3	4.2	4.4	1.4
	Total Dissolved Solids (mg/L) [J]	7	60.0	124.0	88.0	92.3	20.2
	Total Suspended Solids (mg/L) [J]	7	1.0	7.0	4.0	3.9	2.0
	Hardness (mg/L)	4	51.6	75.7	58.2	60.9	11.3
	Alkalinity (mg/L)	7	50.6	78.1	61.5	63.3	10.8
	Photic Zone (m)	7	3.64	5.67	5.16	4.85	0.76
	Secchi (m)	7	1.08	2.92	1.57	1.67	0.61
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.021	0.074	0.010	0.020	0.024
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	< 0.002	0.047	0.002	0.008	0.017
	Total Kjeldahl Nitrogen (mg/L)	7	0.222	0.542	0.328	0.347	0.126
	Total Nitrogen (mg/L) [J]	7	< 0.223	0.543	0.331	0.355	0.134
	Dissolved Reactive Phosphorus (mg/L) [J]	7	< 0.003	0.010	0.003	0.004	0.003
	Total Phosphorus (mg/L)	7	0.022	0.032	0.027	0.027	0.004
	CBOD-5 (mg/L)	7	< 2.0	2.5	1.0	1.4	0.7
	Chlorides (mg/L)	7	3.3	7.6	3.8	4.7	1.6
	Biological						
	Chlorophyll a (ug/L)	7	2.94	23.50	17.09	15.86	6.37
	E. coli (mpn/100mL) [J]	3	< 1	2	1	1	1

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