WALNUT RIVER BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody: Augusta City Lake
Water Quality Impairment: Eutrophication

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Upper Walnut **County:** Butler

HUC 8: 11030017 **HUC 10 (12):** 02 (07)

Ecoregion: Flint Hills (28)

Drainage Area: 7.98 square miles

Conservation Pool: Surface Area = 190 acres
Watershed/Lake Ratio: 26:1
Maximum Depth = 6 meters
Mean Depth = 3 meters
Storage Volume = 1,860 acre-feet
Estimated Retention Time = 0.68 year
Constructed: 1930

Designated Uses: Primary Contact Recreation Class A; Expected Aquatic Life Support; Domestic Water Supply; Food Procurement; Groundwater Recharge; Industrial Water Supply; Irrigation Use; Livestock Watering Use.

303(d) Listings: 2002, 2004, 2008, 2010, 2012, & 2014 Walnut River Basin Lakes

Impaired Use: All uses in Augusta City Lake are impaired to a degree by eutrophication

Water Quality Criteria: General – Narrative: Taste-producing and odor-producing substances of artificial origin shall not occur in surface waters at concentrations that interfere with the production of potable water by conventional water treatment processes, that impart an unpalatable flavor to edible aquatic or semiaquatic life or terrestrial wildlife, or that result in noticeable odors in the vicinity of surface waters (KAR 28-16-28e(b)(7)).

Nutrients - Narrative: The introduction of plant nutrients into streams, lakes, or wetlands from artificial sources shall be controlled to prevent the accelerated succession or replacement of aquatic biota or the production of undesirable quantities or kinds of aquatic life (KAR 28-16-28e(d)(2)(A)).

The introduction of plant nutrients into surface waters designated for domestic water supply use shall be controlled to prevent interference with the production of drinking water (KAR 28-16-28e(c)(3)(D)).

The introduction of plant nutrients into surface waters designated for primary or secondary contact recreational use shall be controlled to prevent the development of objectionable concentrations of algae or algal by-products or nuisance growths of submersed, floating, or emergent aquatic vegetation (KAR 28-16-28e(c)(7)(A)).

2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Eutrophication: Hypereutrophic, Trophic State Index = 64.8

The Trophic State Index (TSI) is derived from the chlorophyll *a* concentration. Trophic state assessments of potential algal productivity were made based on chlorophyll *a*, nutrient levels, and values of the Carlson Trophic State Index (TSI). Generally, some degree of eutrophic condition is seen with chlorophyll *a* over 12 µg/L and hypereutrophy occurs at levels over 30 µg/L. The Carlson TSI derives from the chlorophyll *a* concentrations and scales the trophic state as follows:

1. Oligotrophic TSI < 40
2. Mesotrophic TSI: 40 - 49.99
3. Slightly Eutrophic TSI: 50 - 54.99
4. Fully Eutrophic TSI: 55 - 59.99
5. Very Eutrophic TSI: 60 - 63.99
6. Hypereutrophic TSI: $\geq$ 64

Lake Chemistry Monitoring Site and Period of Record Used: KDHE Station LM040001 in Augusta Lake (Figure 1). Period of Record: Six surveys conducted by KDHE in calendar years: 1985, 1987, 1991, 1998, 2006 and 2013.

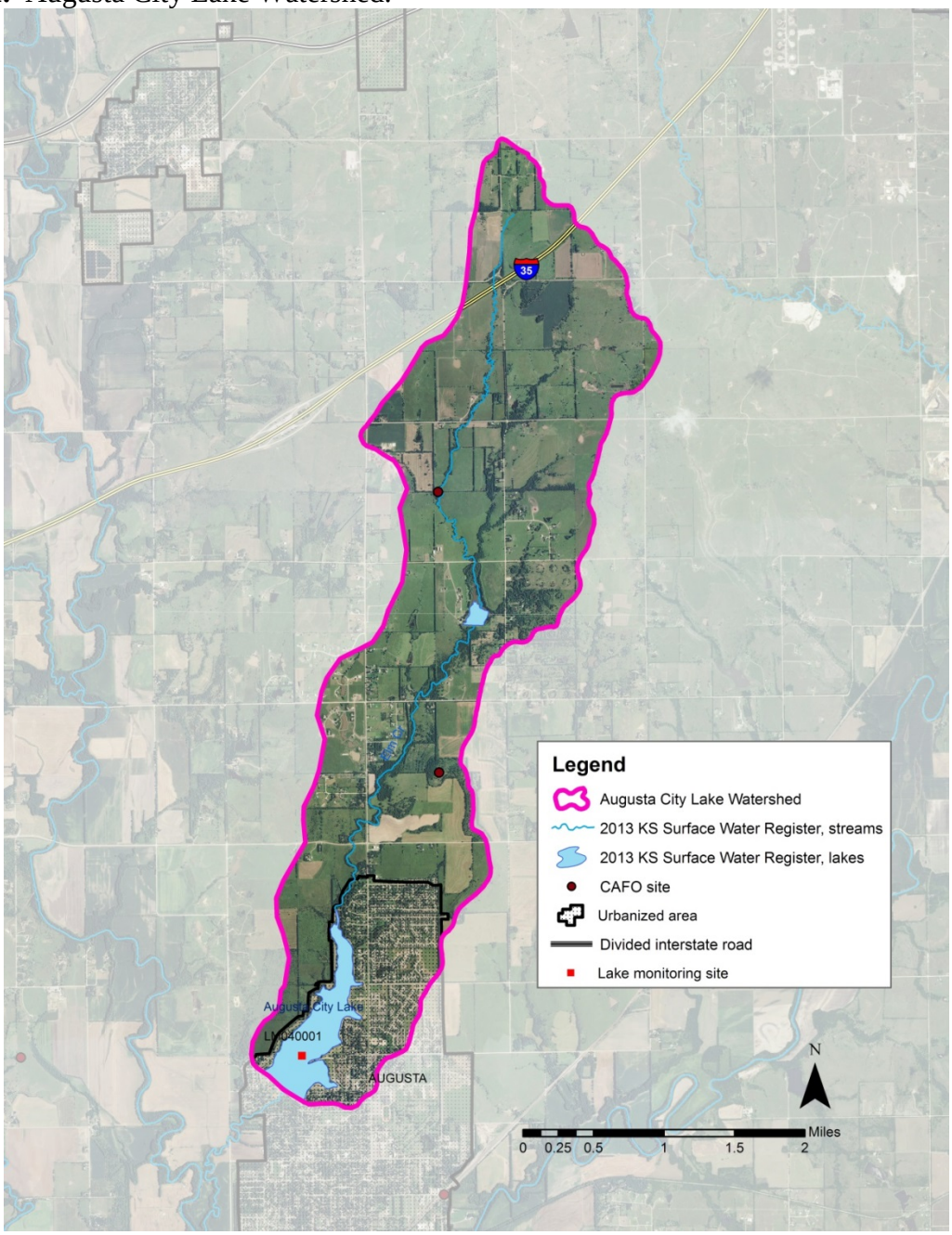
Flow Gages and Period of Record Used: USGS Gage 07147070, Whitewater Creek at Towanda. Period of Record: 1/1/1990 through 12/31/2013.

Hydrologic Conditions: Elm Creek above Augusta City Lake (Figure 1) is the only registered stream directly feeding the lake with estimated flow durations listed in Table 1 (Perry et al., 2004). Daily flow values and flows for the BATHTUB model were developed by applying the ratio of the watershed size of USGS 07147070 (426 mi^2) to the watershed size of Elm Creek (7.70 mi^2) to the flows seen at USGS 07147070 (1/1/1990-12/31/2013, Table 1). According to the USGS Lake Hydro data, the mean runoff in the watershed is 5.81 inches/year; the mean precipitation in the watershed is 31.5 inches/year and the mean loss due to evaporation for the lake is 57.7 inches/year.

Table 1. Estimated flow-duration values for Elm Creek above Augusta City Lake. Flow values are in units of cubic-feet per second.

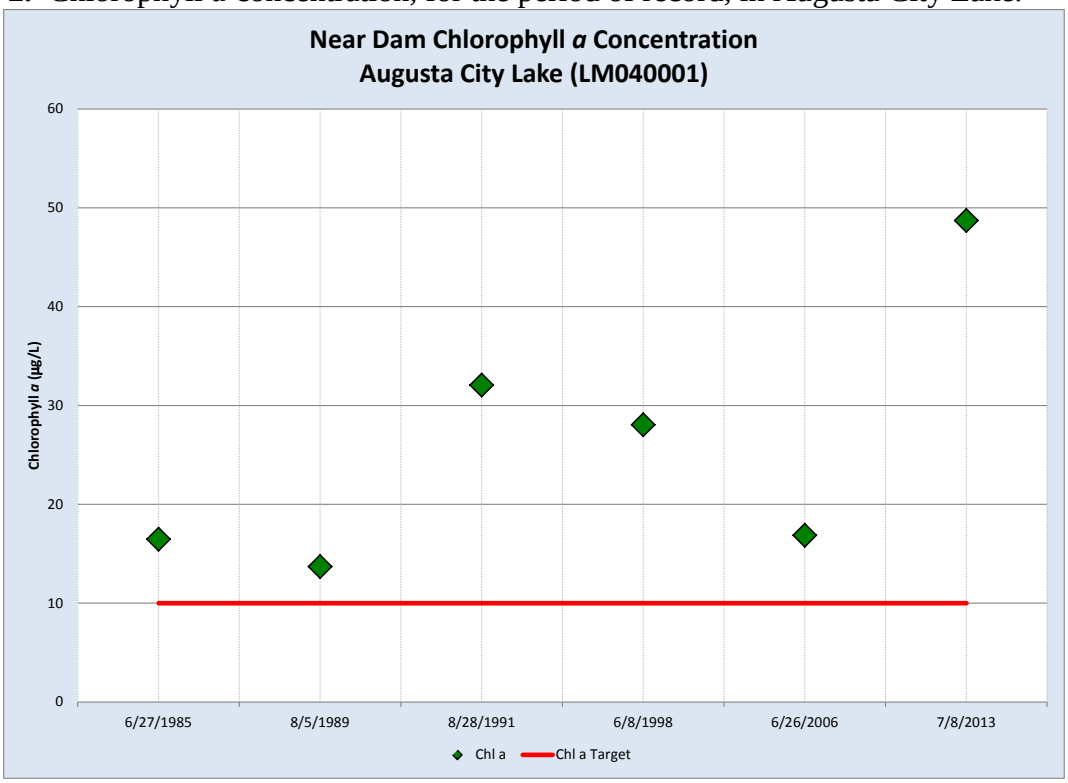
Stream	CUSEGA Segment	Source	Average Flow	2-year Peak	90%	75%	50%	25%	10%
Elm Creek	1103001743	Perry et al., 2004	4.49	1,060	0	0	0	0.52	3.47
Elm Creek	1103001743	USGS 07147070	4.38	893	0.14	0.33	0.67	1.64	5.22

Figure 1. Augusta City Lake Watershed.



Current Conditions: Chlorophyll *a* (chl a) concentrations average 26.0 µg/L in Augusta City Lake for the entire period of record (1985-2013). For the recent period of record (2006-2013), however, the average chlorophyll *a* concentration climbs to 32.8 µg/L resulting in a corresponding Trophic State Index (TSI) value of 64.8 indicating Augusta City Lake is in a Hypereutrophic state. Chlorophyll *a* concentrations were measured in duplicate samples taken once during the summers of 1985, 1989, 1991, 1998, 2006, and 2013. The values displayed in Figure 2 are the average of the replicates. For the period of record, chlorophyll *a* concentrations were greater than the chlorophyll *a* target of 10 µg/L with the 2013 sample measuring an average of 48.7 µg/L (Table 2). In 2011, a 10 µg/L chlorophyll *a* target was established by KDHE as the source water threshold for significantly reducing occurrences of taste and odor problems in public water supplies (KDHE, 2011).

Figure 2. Chlorophyll *a* concentration, for the period of record, in Augusta City Lake.



The period of record average Secchi depth (SD) in Augusta City Lake is 0.53 meters with a slight improvement to 0.58 meters for the recent period of record. The lowest Secchi depth measurement was taken in August 1989 at 0.43 meters while the highest reading of 0.70 meters was measured in 2006 (Figure 3).

Total phosphorus (TP) concentration in Augusta City Lake averages 0.071 mg/L for the entire period of record (Figure 4). The influence of the 2013 measurement of 0.18 mg/L TP contributed to a concentration of 0.12 mg/L total phosphorus in Augusta City Lake for the recent period of record.

Figure 3. Secchi depth values for Augusta City Lake. Mean depth in the lake is 3 m.

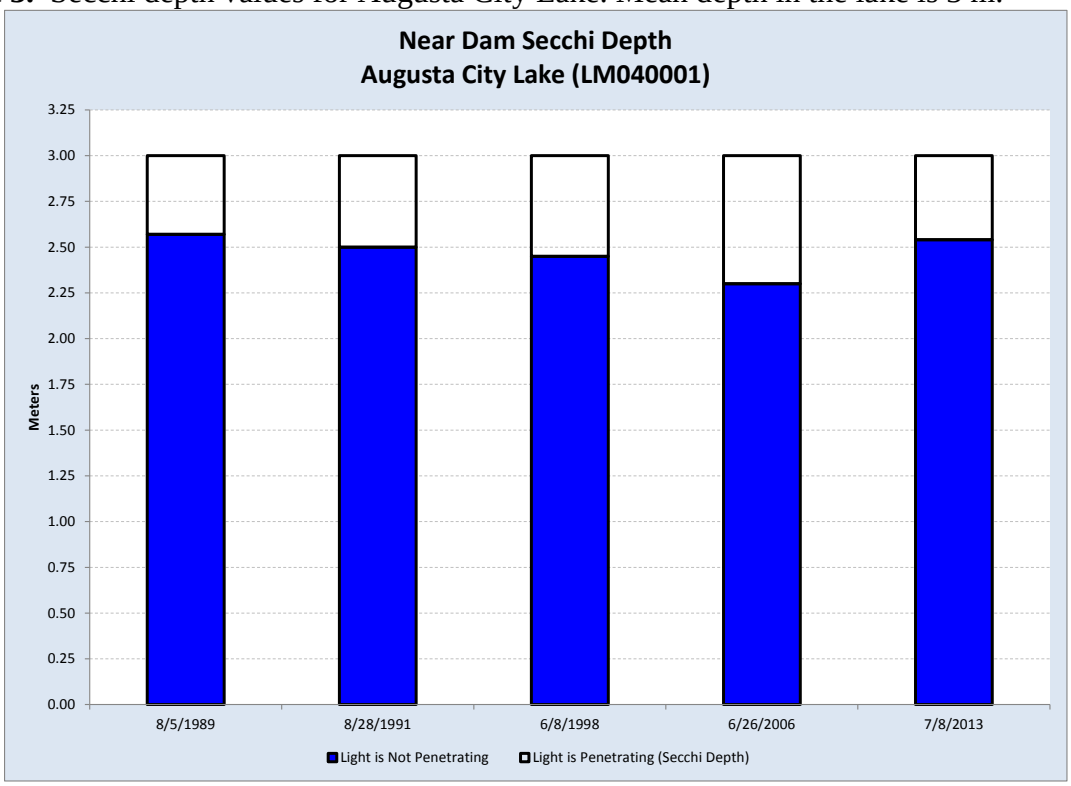
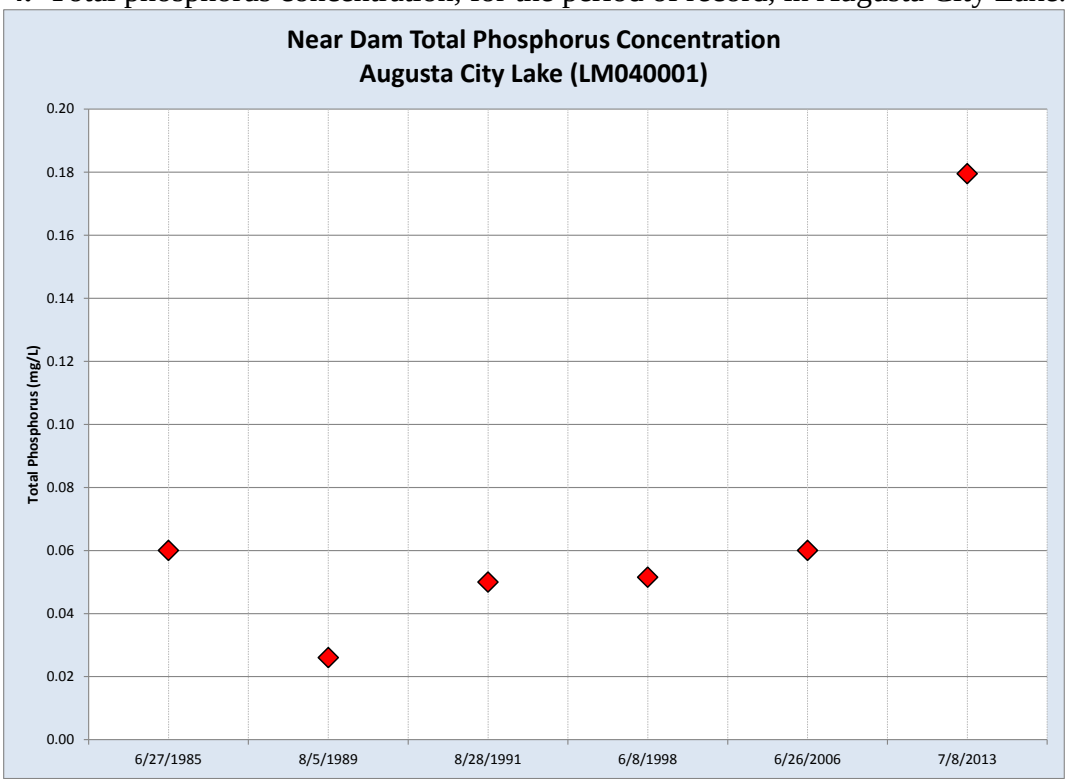
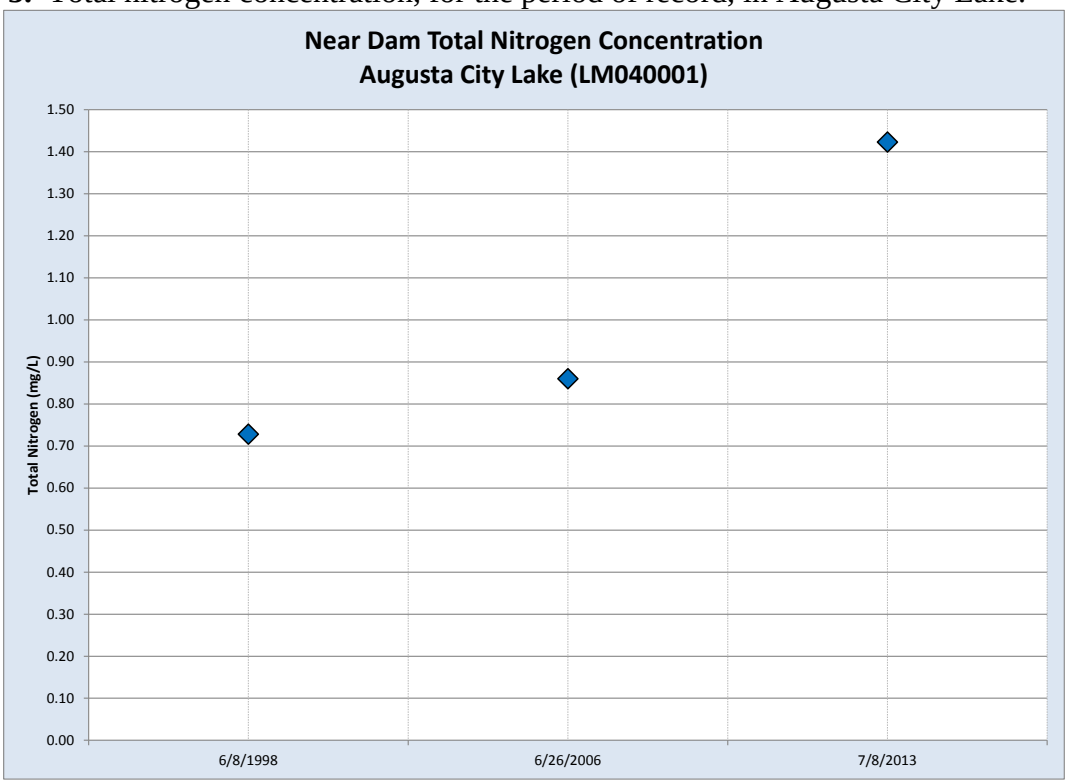


Figure 4. Total phosphorus concentration, for the period of record, in Augusta City Lake.



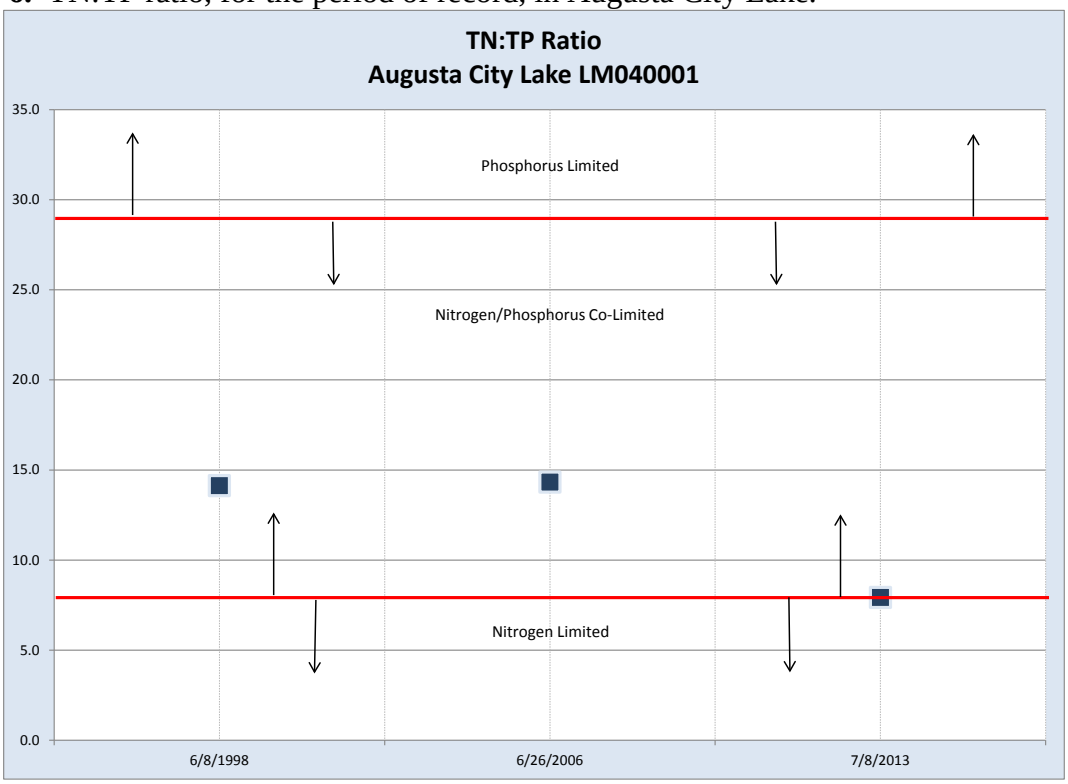
Total nitrogen (TN) values were available for the samples taken in 1998, 2006, and 2013 resulting in an entire period of record (1998-2013) average of 1.0 mg/L TN. TN has ticked upward over the period of record concluding with the 2013 sample measuring 1.42 mg/L total nitrogen (Figure 5). The recent period of record average is 1.14 mg/L TN.

Figure 5. Total nitrogen concentration, for the period of record, in Augusta City Lake.



The ratio of total nitrogen to total phosphorus has been used to determine which of these nutrients is most likely limiting plant growth in Kansas aquatic ecosystems. Generally, lakes that are nitrogen limited have water column TN:TP ratios < 8 (mass); lakes that are co-limited by nitrogen and phosphorus have water column TN:TP ratios between 8 and 29; and lakes that are phosphorus limited have water column TN:TP ratios > 29 (Dzialowski et al., 2005). The TN:TP ratio in Augusta City Lake indicates the lake was co-limited by phosphorus and nitrogen in 1998 and 2006 while the 2013 ratio indicates the lake may have been moving toward a nitrogen limited state (Figure 6). However, the limited data set makes it difficult to determine which of the nutrients may be limiting plant growth in the lake.

Figure 6. TN:TP ratio, for the period of record, in Augusta City Lake.



Turbidity in Augusta City Lake averaged 17.6 NTU for the entire period of record and 22.6 NTU for the recent period of record (Figure 7). The entire period of record average for total suspended solids (TSS) was 21.3 mg/L while the recent period of record average came in slightly higher at 25.0 mg/L (Figure 8). Both the level of turbidity and the concentration of TSS increased significantly in the 2013 sampling of the lake.

Figure 7. Turbidity, for the period of record, in Augusta City Lake.

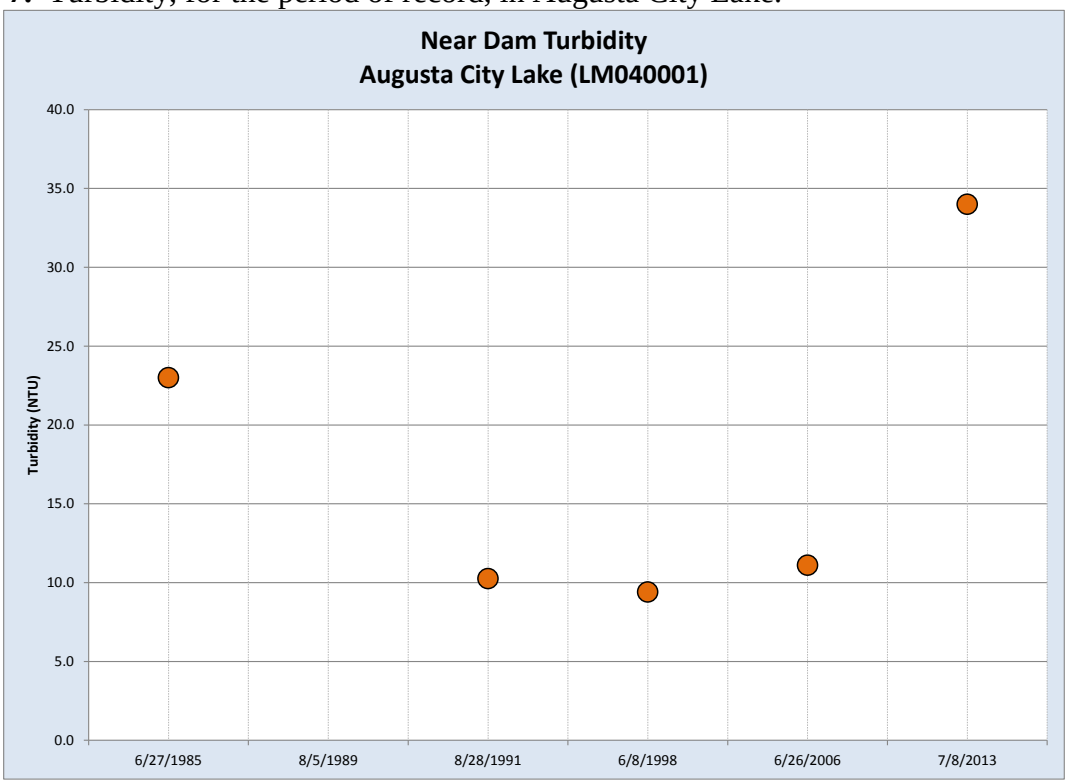


Figure 8. Total suspended solids (TSS) concentration, for the period of record, in Augusta City Lake.

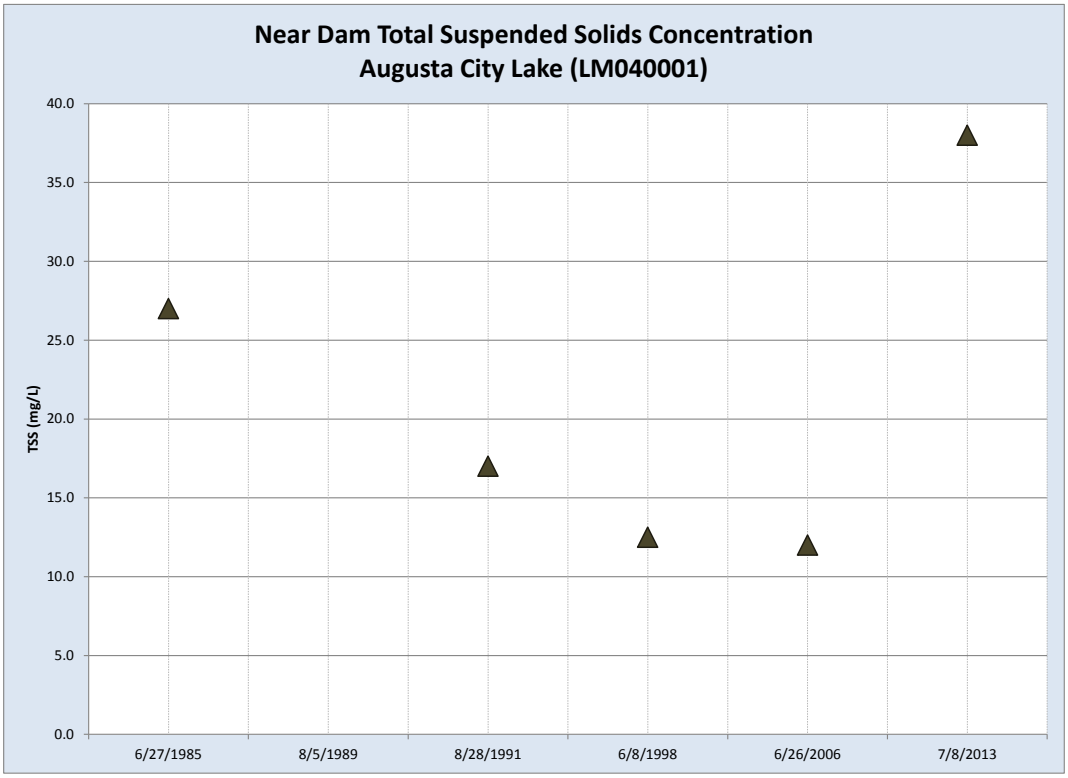


Table 2. Augusta City Lake data for the period of record.

Sample Date	Chl-a (µg/L)	Secchi Depth (m)	TP (mg/L)	TN (mg/L)	TN:TP ratio	Turbidity (NTU)	TSS (mg/L)
6/27/1985	16.5		0.060	*	*	23.0	27.0
8/5/1989	13.7	0.43	0.026	*	*	*	*
8/28/1991	32.1	0.50	0.050	*	*	10.3	17.0
6/8/1998	28.1	0.55	0.052	0.73	14.1	9.4	12.5
6/26/2006	16.9	0.70	0.060	0.86	14.3	11.1	12.0
7/8/2013	48.7	0.46	0.180	1.42	7.9	34.0	38.0
1985-1999 Average	22.6	0.49	0.047	0.73	15.5	14.2	18.8
2000-2013 Average	32.8	0.58	0.120	1.14	9.5	22.6	25.0

*No data available

Due to the limited data set, it is difficult to draw any conclusions about stratification in Augusta City Lake. During the 1991 sampling, however, dissolved oxygen did stratify in spite of very little stratification in temperature (Figure 9).

Figure 9. Dissolved oxygen and temperature profiles in Augusta City Lake.

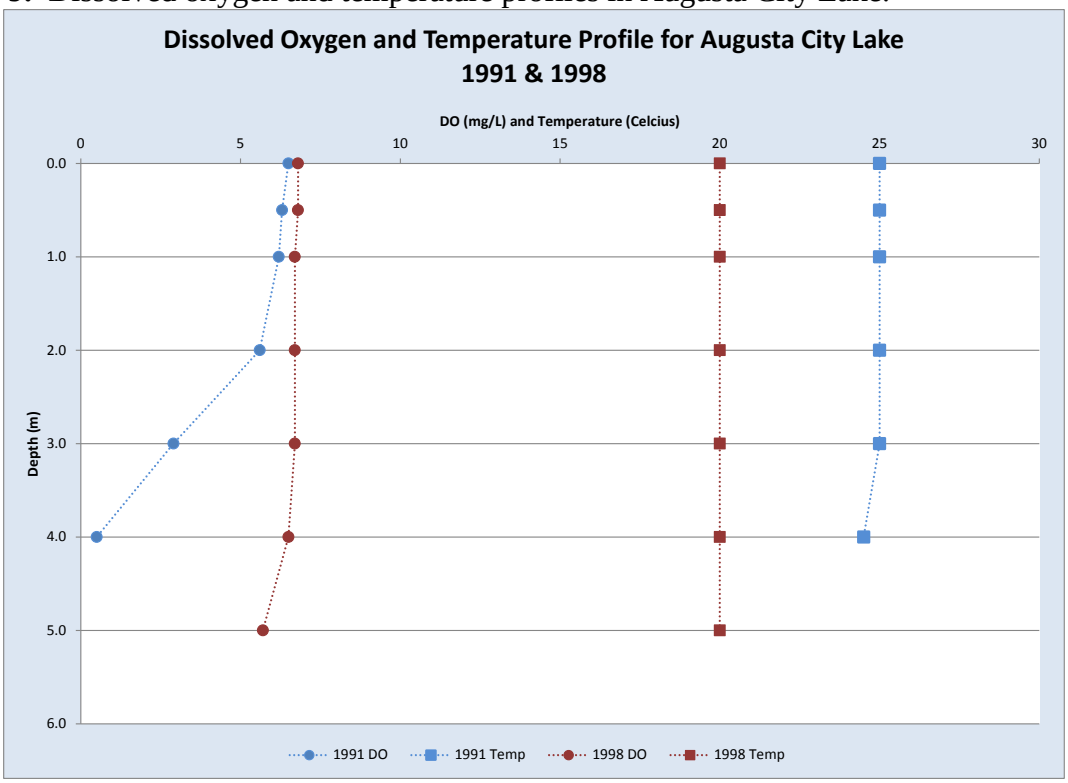


Table 3 lists the six metrics measuring the roles of light and nutrients in Augusta City Lake. Non-algal turbidity (NAT) values <0.4m^{-1} indicates there are very low levels of suspended silt and/or clay. The values between 0.4 and 1.0m^{-1} indicate turbidity assumes greater influence on water clarity but would not assume a significant limiting role until values exceed 1.0m^{-1}.

Table 3. Limiting factor metrics in Augusta City Lake.

Sampling Year	Non-algal Turbidity	Light Availability in the Mixed Layer	Partitioning of Light Extinction between Algae & Non-algal Turbidity	Algal use of Phosphorus Supply	Light Availability in the Mixed Layer for a Given Surface Light	Shading in Water Column due to Algae and Inorganic Turbidity	Chl-*a* (µg/L)
	NAT	**Zmix*NAT**	**Chl-a*SD**	**Chl-a/TP**	**Zmix/SD**	**Shading**	
6/27/1985	*	*	*	0.28	*	*	16.5
8/5/1989	1.92	5.2	5.9	0.53	6.3	7.6	13.7
8/28/1991	1.29	3.5	16.0	0.64	5.4	8.1	32.1
6/8/1998	1.17	3.2	15.4	0.54	4.9	7.5	28.1
6/26/2006	0.97	2.6	11.8	0.29	3.9	6.3	16.9
7/8/2013	1.21	3.3	22.4	0.27	5.9	9.3	48.7

*No data available

The depth of the mixed layer in meters (Z) multiplied by the NAT value assesses light availability in the mixed layer. There is abundant light within the mixed layer of the lake and potentially a high response by algae to nutrient inputs when this value is less than 3. Values greater than 6 would indicate the opposite.

The partitioning of light extinction between algae and non-algal turbidity is expressed as Chl-*a**SD (Chlorophyll *a* * Secchi Depth). Turbidity is not responsible for light extinction in the water column and there is a strong algal response to changes in nutrient levels when this value is greater than 16. Values less than 6 indicate that turbidity is primarily responsible for light extinction in the water column and there is a weak algal response to changes in nutrient levels.

Values of algal use of phosphorus supply (Chl-a/TP) that are greater than 0.4 indicate a strong algal response to changes in phosphorus levels, where values less than 0.13 indicate a limited response by algae to phosphorus.

The light availability in the mixed layer for a given surface light is represented as Zmix/SD. Values less than 3 indicate that light availability is high in the mixed zone and there is a high probability of strong algal responses to changes in nutrient levels.

Shading values less than 16 indicate that self-shading of algae does not significantly impede productivity. This metric is most applicable to lakes with maximum depths of less than 5 meters (Carney, 2004).

The degree of NAT in the lake indicates that suspended silt and/or clay is contributing to diminished light availability in Augusta City Lake. The Zmix*NAT and Chl a*SD values indicate the reduction of light availability is likely moderate while the Chl a/TP and Zmix/SD

values indicate the response to changes in phosphorus levels by algae in the lake are also moderate. Self-shading does not appear to be impeding algal productivity in Augusta City Lake.

Another method for evaluating limiting factors is the trophic state index (TSI) deviation metrics. Figure 10 (Multivariate Deviation Graph) summarizes the current trophic conditions in Augusta City Lake using a multivariate TSI comparison chart for the period of record. Where TSI(Chl-a) is greater than TSI(TP), the situation indicates phosphorus is limiting chlorophyll *a*, whereas negative values indicate turbidity limits chlorophyll *a*. Where TSI(Chl-a)-TSI(SD) is plotted on the horizontal axis, if the Secchi depth (SD) trophic index is less than the chlorophyll *a* trophic index, then there is dominant zooplankton grazing. Transparency would be dominated by non-algal factors such as color or inorganic turbidity if the Secchi depth index were more than the chlorophyll *a* index. Points near the diagonal line occur in turbid situations where phosphorus is bound to clay particles and therefore turbidity values are closely associated with phosphorus concentrations.

The multivariate TSI comparison chart in Figure 10 reveals that during the 1989-1998 time period the lake was increasing in phosphorus limitation while transparency was strongly diminished by non-algal turbidity. During the current period of record, however, the lake has moved toward nitrogen limitation and NAT appears to be affecting light availability in the lake.

Comparing the trophic state indices for total phosphorus, chlorophyll *a* and Secchi depth in Augusta City Lake reveals the lake has been in a fully eutrophic state, with respect to chlorophyll *a*, for the period of record and has reached a state of hypereutrophy in 1991 and 2013 (Figure 11). The Secchi depth TSI scores show the lake in a hypereutrophic state for the period of record while the TP TSI score reached a state of hypereutrophy for the first time in 2013.

Figure 10. Multivariate TSI comparison chart for Augusta City Lake.

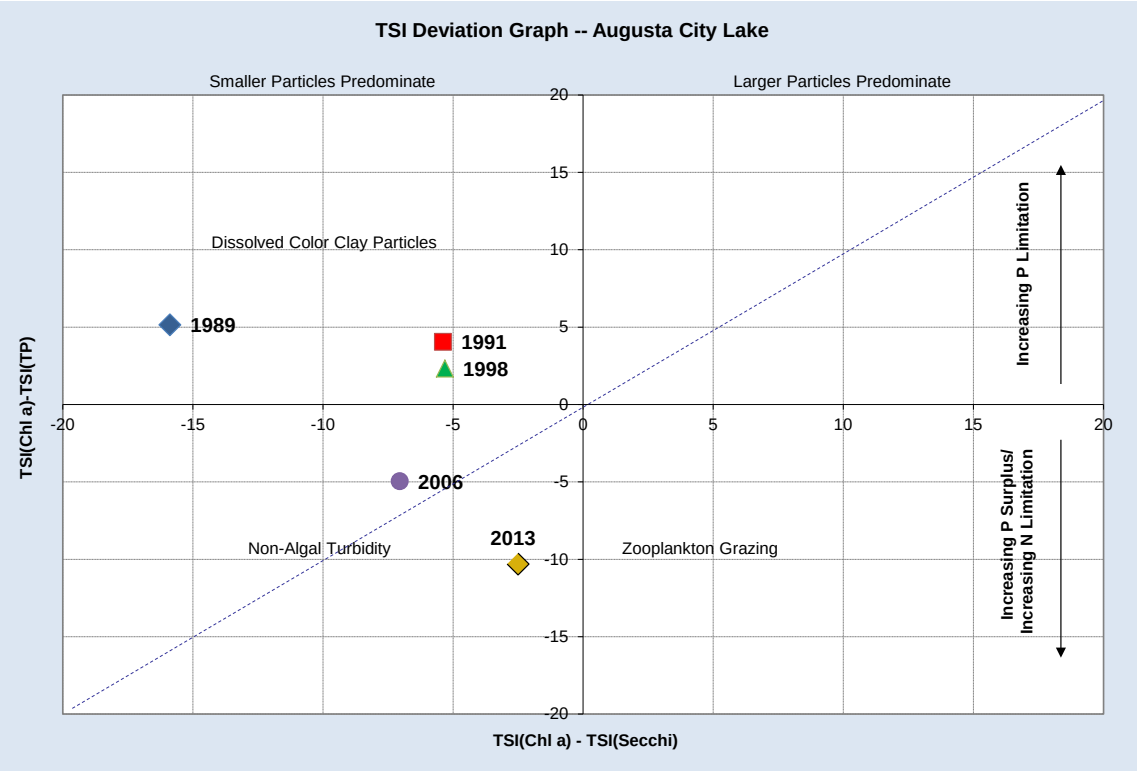
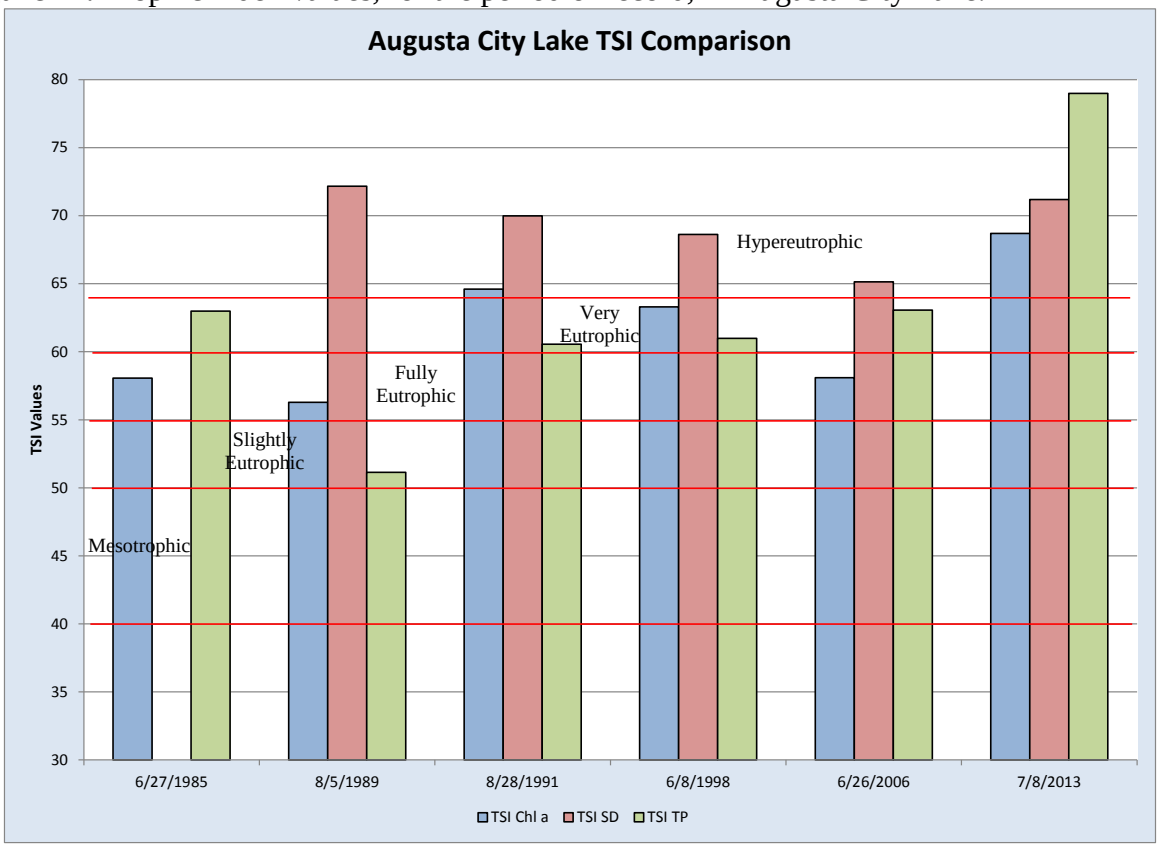


Figure 11. Trophic index values, for the period of record, in Augusta City Lake.



A comparison of the median values for trophic conditions in Augusta City Lake to the benchmarks established for lakes in Kansas reveals that none of the trophic indicators in Augusta City Lake measure up to the benchmarks detailed in Table 4. The statewide benchmarks and benchmarks for Kansas lakes in the Flint Hills region were derived from analysis of trophic conditions in the lakes and reservoirs in Kansas (Dodds et al., 2006). RTAG benchmarks were established by the USEPA Region 7 Regional Technical Assistance Group (RTAG) and are for lakes and reservoirs in Kansas, Iowa, Missouri and Nebraska excluding the Sand Hills ecoregion (USEPA, 2011).

Table 4. Median trophic indicator values of Augusta City Lake (2000-2013) in comparison with other federal lakes and nutrient benchmarks in Kansas.

Trophic Indicator	Augusta City Lake (2000-2013)	Federal Lake	Flint Hills	Statewide Benchmark	RTAG
Secchi Depth (cm)	58	95	149	129	N/A
TN (µg/l)	1,140	903	301	625	700
TP (µg/l)	124	76	19	23	35
Chlorophyll *a* (µg/l)	33	12	9	8	8

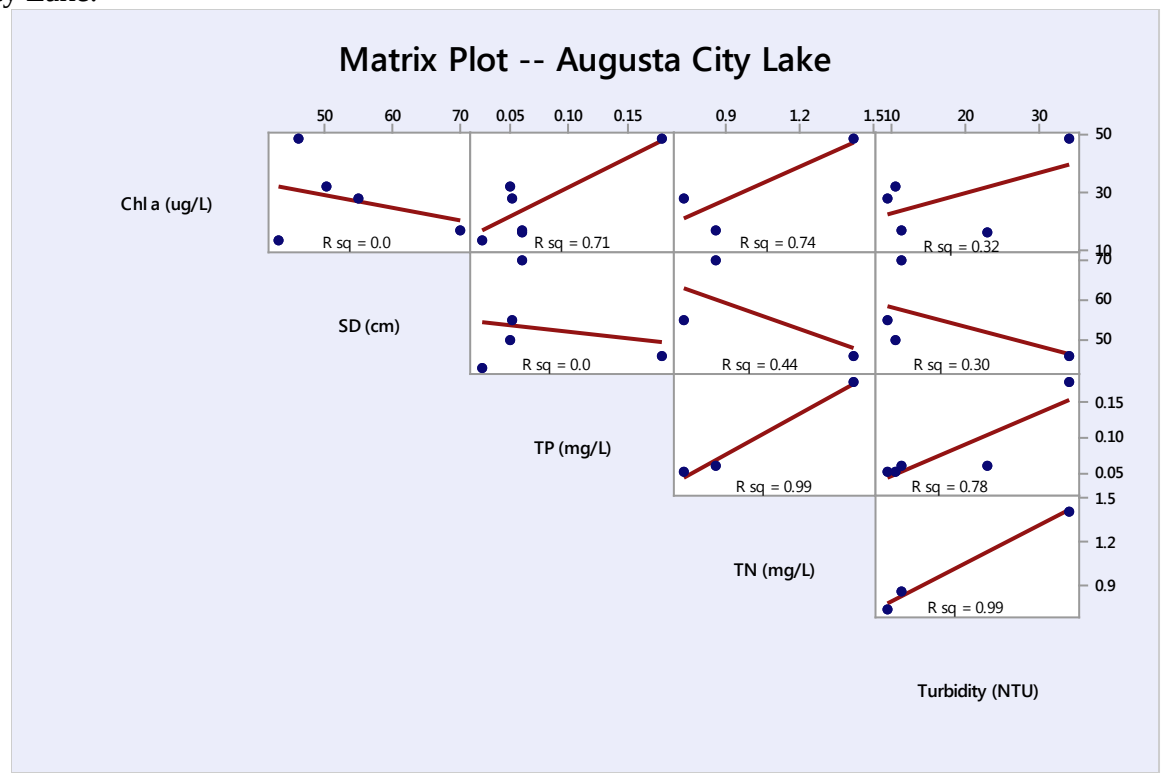
Algal Communities: As seen in Table 5, algal communities in Augusta City Lake were dominated by blue-green algae, or cyanobacteria, in 1991 and 2006. An increasing supply of nutrients, especially phosphorus and possibly nitrogen, will often result in higher growth of blue-green algae because they possess certain adaptations that enable them to out compete true algae (Soil and Water Conservation Society of Metro Halifax, 2007). Several of the cyanobacteria species possess gas vacuoles that allow them to move within the water column vertically. This selective advantage allows for some species to move within the water column to avoid predation and reach optimal primary productivity. Their movement within the water column may influence chlorophyll *a* levels within the lake at various depths during the diel cycle.

Table 5. Algal communities observed in Augusta City Lake.

Sampling Date	Total Cell Count cells/mL	Percent Composition				Chl-*a* µg/L
		Green	Blue Green	Diatom	Other	
8/28/1991	81,585	8	88	4	0	32.1
6/8/1998	9,860	11	7	76	6	28.1
6/26/2006	49,707	4	93	3	0	16.9
7/8/2013	34,745	47	0	52	1	48.7

Relationships: Because of the limited size of the data set, it is difficult to make firm conclusions about the relationships between the water quality parameters in Augusta City Lake. However, Figure 12 displays that there may be poor relationships between chlorophyll *a* and Secchi depth and Secchi depth and TP. There may be a moderate relationship between Secchi depth and TN; Secchi depth and turbidity and chlorophyll *a* and turbidity. In addition, there may be strong relationships between chlorophyll *a* and TP; chlorophyll *a* and TN; TP and TN; TP and turbidity and TN and turbidity (Figure 12).

Figure 12. Matrix plot displaying the relationships between water quality parameters in Augusta City Lake.



Stream Data: No water quality data was available for Elm Creek (CUSEGA 1103001743).

Bathymetric Survey: A bathymetric and sediment survey was performed by Kansas Biological Survey in 2010 (Figure 13). During the course of the survey, sediment cores from fifteen sites distributed across the length of reservoir (Figure 14) were collected and subsequently analyzed for bulk density, percent sand/silt/clay, organic matter, total nitrogen, total phosphorus, and radionuclides (Table 6). The radionuclides ^{137}Cs, $^{239+240}$Pu, and ^{241}Americum are often used as chronostratigraphic dating tools. The testing of nuclear weapons in the post-World War II period resulted in atmospheric fallout of radionuclides that were deposited on land and in lake sediments. 1963-1964 saw the highest peak of accumulation of these radionuclides while post 1963 concentrations diminish due to the ratification of the Limited Test Ban Treaty of 1963 that banned aboveground testing of nuclear devices (KBS, 2011). In practice, a series of samples along the sediment core can be tested for the presence of radionuclides; and if a spike in concentration occurs at some point along the core, one can assume that the point at which that spike occurs indicates 1963-1964 on the core (KBS, 2011). In Augusta City Lake, radionuclide

testing revealed the peak concentration of $^{239+240}Pu$ occurred at the 50 cm point in core ACL-15 marking it as being deposited around 1963, implying the sedimentation rate between 1930 and 1963 was 1.6 cm/year. The remaining 60 cm of sediment, therefore, was deposited between 1964 and 2010 at a slightly lower rate of 1.3 cm/year (KBS, 2011). Analysis for total phosphorus and total nitrogen performed along the sediment column indicates there may have been an increase in nutrient loading to the lake during the decade prior to the bathymetric survey (Figure 15 & 16).

Figure 13. Bathymetric survey of Augusta City Lake performed in December 2010 by the Kansas Biological Survey (KBS, 2011). Depth based on a pool elevation of 1,259.23 feet.

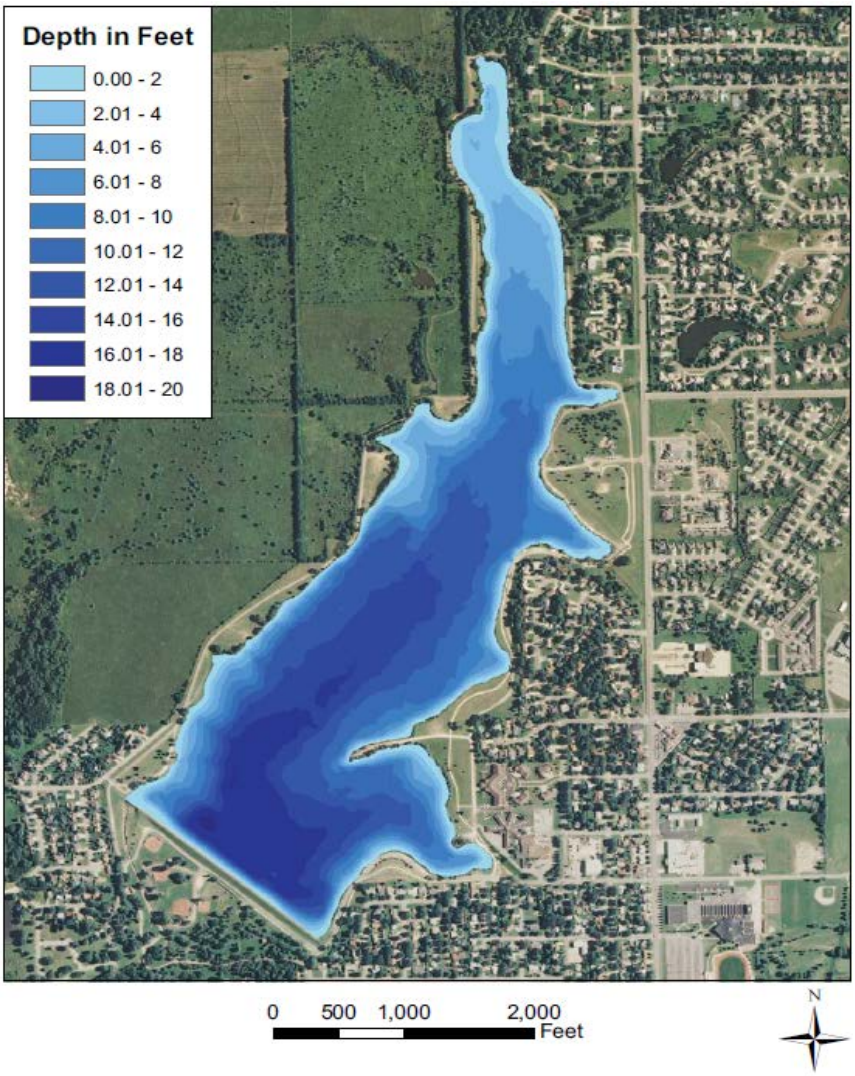


Figure 14. Location of coring sites with representation of the results of the particle size analysis of each core in Augusta City Lake, July 2010 (KBS, 2011).

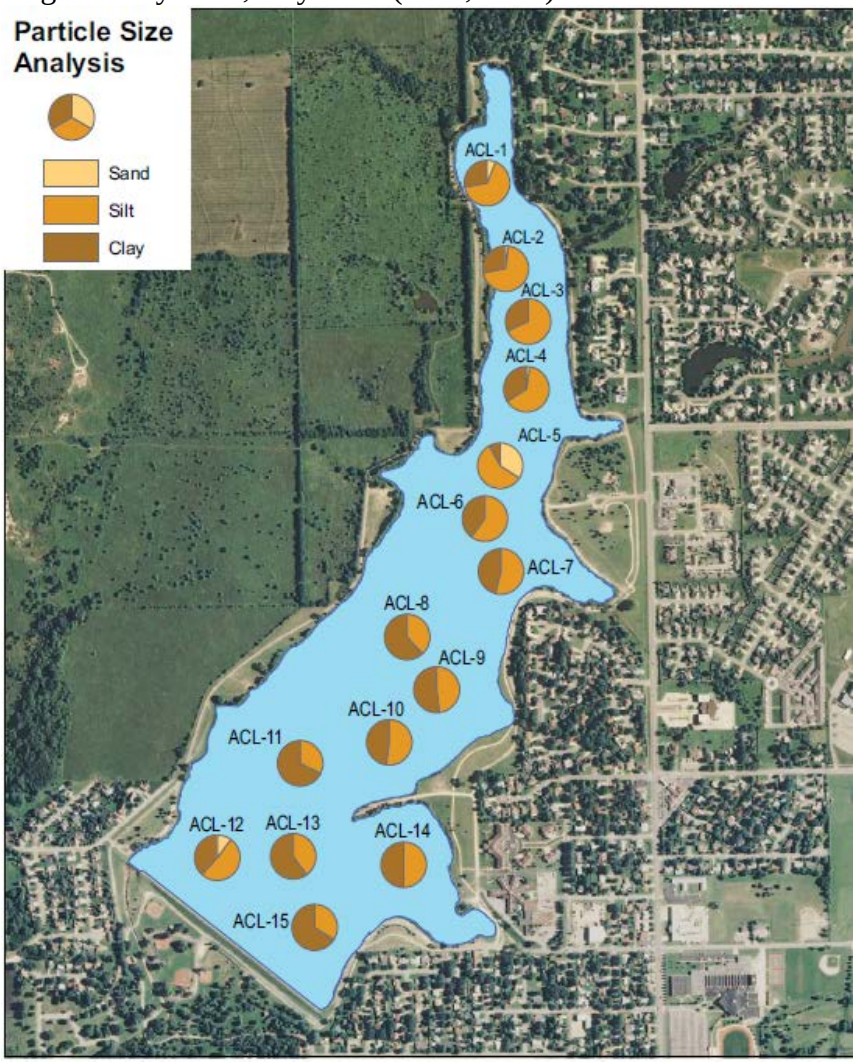


Table 6. Augusta City Lake sediment coring site data.

Sample ID	Mean Bulk Density g/cm^3	% Organic Matter	TN (mg/L)	TP (mg/L)	% Sand	% Silt	% Clay
ACL-1	1.00	2.9	1,400	336	6	66	28
ACL-2	1.04	2.7	1,330	289	2	70	28
ACL-3	*	2.7	1,198	307	0	68	32
ACL-4	1.10	2.7	1,330	323	2	64	34
ACL-5	1.19	2.1	1,071	260	34	58	8
ACL-6	1.02	2.9	1,572	354	0	60	40
ACL-7	0.93	2.6	1,108	346	0	54	46
ACL-8	0.53	3.2	1,732	387	0	38	62
ACL-9	0.58	2.9	1,505	356	0	48	52
ACL-10	1.22	2.6	1,514	342	0	52	48
ACL-11	0.54	2.9	2,138	409	0	32	68
ACL-12	1.28	3.0	1,161	270	10	52	38
ACL-13	0.49	3.0	1,539	390	0	40	60
ACL-14	0.60	3.7	1,911	402	0	50	50
ACL-15	0.45	3.0	1,909	442	0	34	66

Figure 15. Total phosphorus concentration in core ACL-15. The radionuclide peak occurred in sample ACL-15-50.

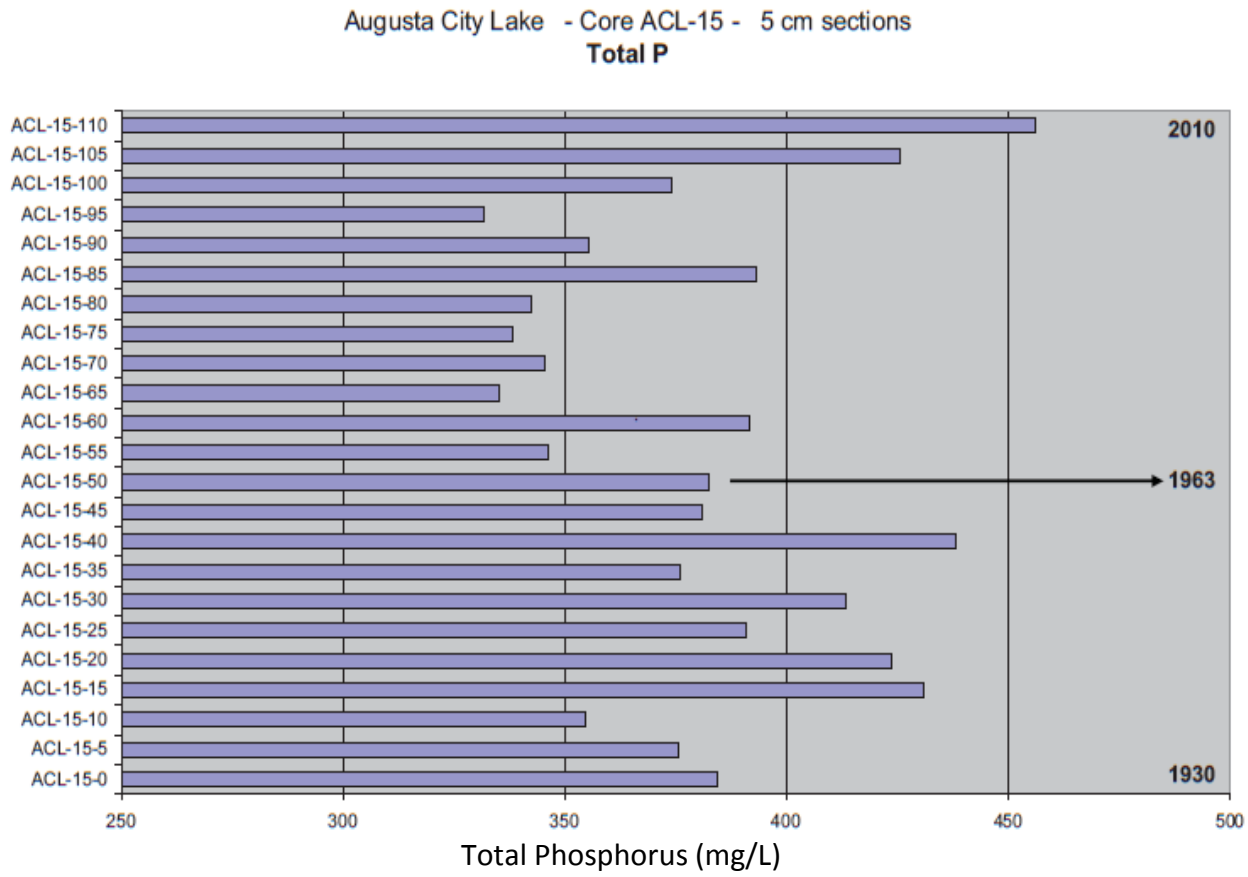
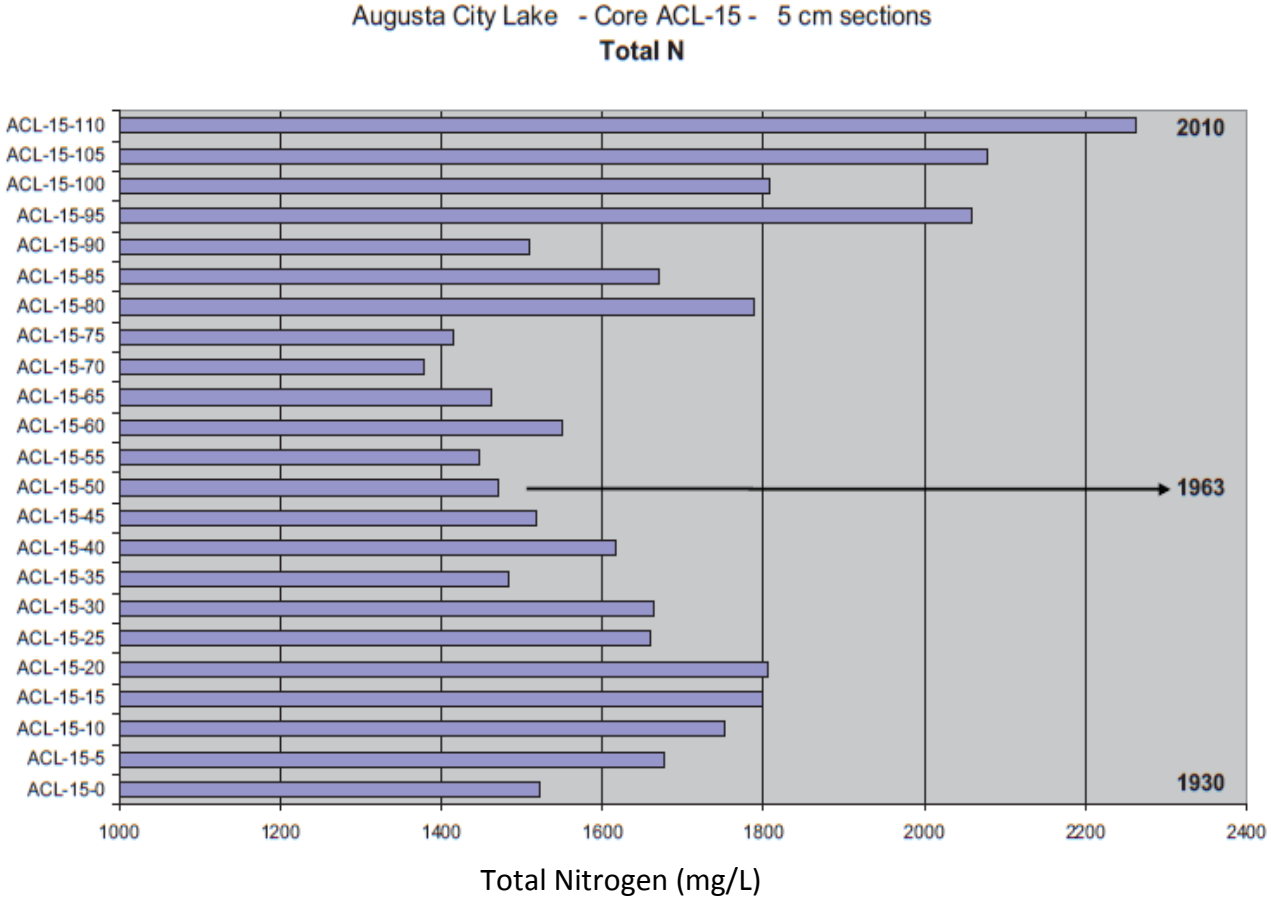


Figure 16. Total nitrogen concentrations in core ACL-15. The radionuclide peak occurred in sample ACL-15-50.



Desired Endpoints of Water Quality (Implied Load Capacity) in Augusta City Lake:

The ultimate endpoint for this TMDL will be to achieve the Kansas Surface Water Quality Standards fully supporting the designated uses in Augusta City Lake by eliminating impacts associated with excessive eutrophication. In order to improve the trophic condition of Augusta City Lake from its current Hypereutrophic status, the desired endpoint will be to maintain summer chlorophyll *a* average concentrations below 10 µg/L, corresponding to a Carlson Trophic State Index of 53.2, with the reductions focused on nutrients (TN and TP) entering the lake. Reduction in nutrient loading will address the accelerated succession of aquatic biota and the development of objectionable concentrations of algae and algae by-products as determined by the chlorophyll *a* concentrations in the lake. A chlorophyll *a* endpoint of 10 µg/L will also ensure long-term protection to fully support Primary contact Recreation within the lake.

Achievement of the endpoints indicates loads are within the loading capacity of the lake, the water quality standards are attained, and full support of the designated uses of the lake has been achieved. Seasonal variation has been incorporated in this TMDL since the peaks of algal growth occur in the summer months. The current average condition for Augusta City Lake utilized in the model input was based on 2000-2013 data from the KDHE lake station LM040001 with calibration and reductions focused on area-weighted means generated by the BATHTUB

model. Based on the BATHTUB reservoir eutrophication model (Appendix B), the total phosphorus and total nitrogen entering Augusta City Lake must be reduced by 81% and 76%, respectively. These reductions at the inflow to Augusta City Lake will result in a 64% reduction of the concentration in total phosphorus, a 61% reduction in the concentration of total nitrogen, and a 70% reduction in the concentration of Chlorophyll *a* within the lake (Table 7).

Table 7. Augusta City Lake current average condition (2006-2013) and TMDL. Current condition and TMDL nutrient concentrations reflect BATHTUB area weighted means.

	Current Avg. Condition	**TMDL**	**Reduction**
Total Phosphorus – Annual Load (lbs/year)	2,654	568.1	79%
Total Phosphorus – Daily Load* (lbs/day)	19.5	4.2	78%
Total Phosphorus – Lake Concentration (μg/L)	120	44.2	63%
Total Nitrogen – Annual Load (lbs/year)	21,607	5,195	76%
Total Nitrogen – Daily Load* (lbs/day)	159	38.2	76%
Total Nitrogen – Lake Concentration (mg/L)	1.14	0.437	62%
Chlorophyll *a* Concentration (μg/L)	32.8	10	70%

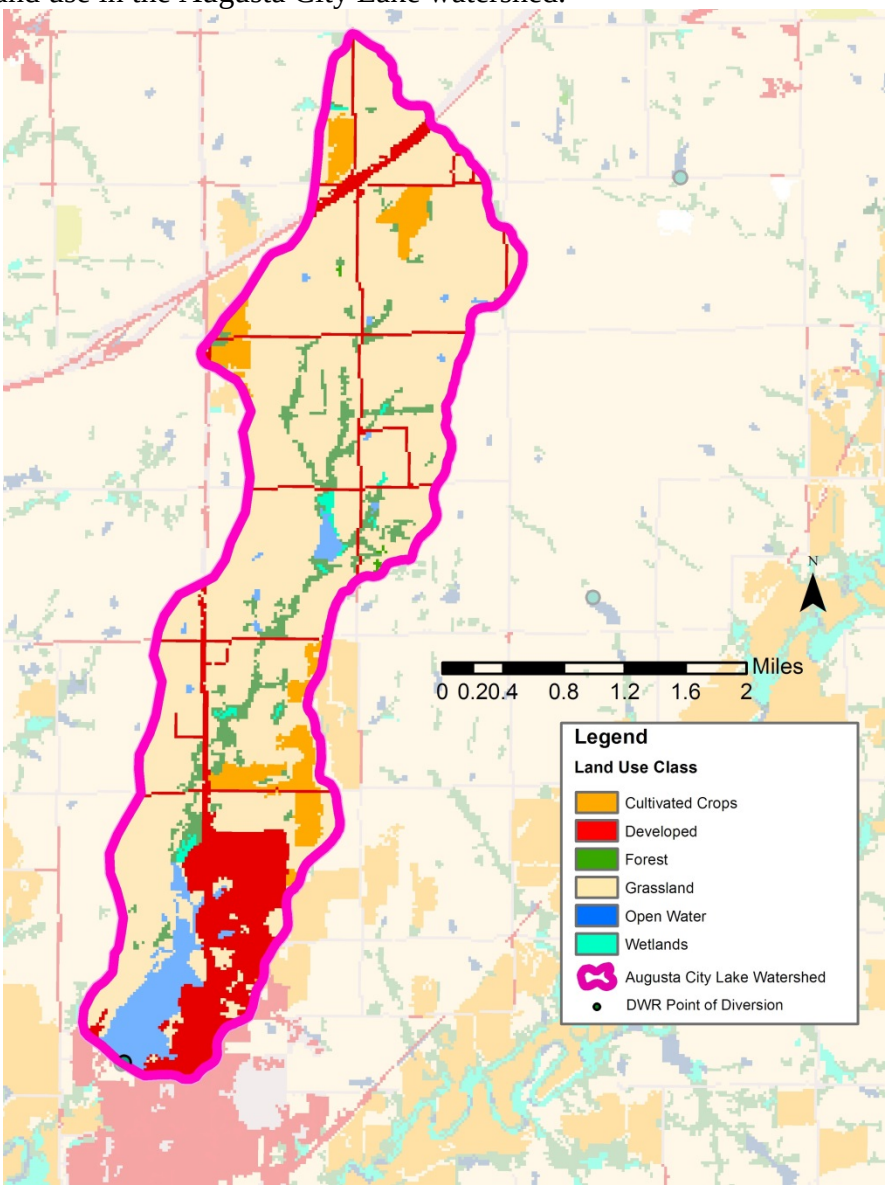
*See Appendix B for Daily Load Calculations

3. SOURCE INVENTORY AND ASSESSMENT

Point Sources: There are no point sources in the watershed.

Land Use: The predominant land uses in the Augusta City Lake watershed are grassland (69%) and developed land (14%), according to the 2001 National Land Cover Data. Together they account for 83% of the total land area in the watershed with the remaining land area composed of cultivated crops (6%), forest (6%), open water (5%), and wetlands (< 1%) (Figure 17). During precipitation runoff events, grasslands in the watershed may contribute to the nutrient and sediment loads in the lake, particularly on livestock grazing lands located in the riparian areas of the watershed. The watershed is also 14% developed due to about 700 acres of the City of Augusta lying within the watershed. The urbanized area in the watershed may generate substantial nutrient loading from lawn fertilizers, domestic pet waste and other toxics found in the urban environment particularly during storm runoff events.

Figure 17. Land use in the Augusta City Lake watershed.



Livestock Waste Management Systems: There are two certified confined animal feeding operations (CAFO) in the Augusta City Lake watershed (Table 8). According to the United States Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS), on January 1, 2013 there were 100,000 head of cattle (including calves) in Butler County. On December 1, 2012, according to NASS, there were 38,000 head of hogs in Butler County. These permitted or certified livestock facilities have waste management systems designed to minimize runoff entering their operation or detaining runoff emanating from their facilities. In addition, they are designed to retain a 25-year, 24-hr rainfall/runoff event as well as an anticipated two weeks of normal wastewater from their operations. Typically, this rainfall event coincides with stream flow occurring less than 1-5% of the time. It is likely that there are some smaller, unregistered livestock operations in the area. Depending on their proximity to the streams in the watershed, runoff from feedlots and grazing lands may be contributing to the nutrient load in Augusta City Lake.

Table 8. Registered, certified or permitted confined animal feeding operations (CAFOs) in the Augusta City Lake watershed. There are no federally permitted CAFOs in the watershed.

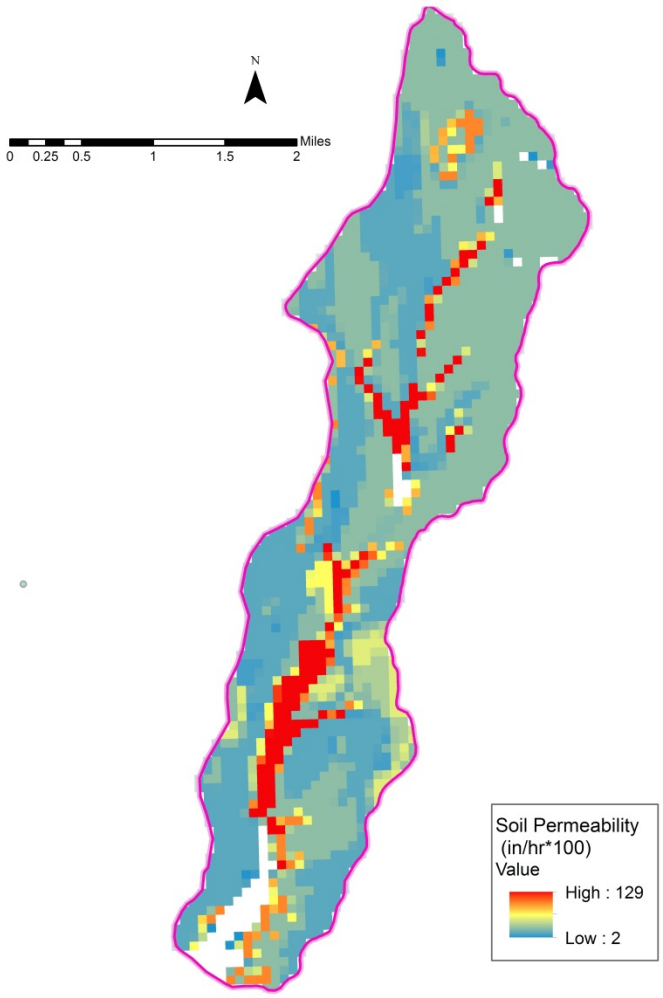
Kansas Permit Number	Animal Type	County	Animal Total
A-WABU-SA01	Swine	Butler	10
A-WABU-M003	Beef	Butler	350

On-Site Waste Systems: A portion of the Augusta City Lake watershed is a rural agricultural area. It can be assumed that all of the rural residences in the watershed are not connected to public sewer systems and according to the Spreadsheet Tool for Estimating Pollutant Load (STEPL), there are a total of 188 septic systems in the HUC 12 that contains the watershed (110300170207) with a 0.93% failure rate. Failing on-site septic systems have the potential to contribute to nutrient loading in the lake.

Population: According to the 2010 census data from the U.S. Census Bureau, the population of the Augusta City Lake watershed is approximately 3, 136 people giving a population density of about 393 people/square mile. This is an increase of about 17% over the 2000 census results. Population growth in the watershed is expected to continue.

Contributing Runoff: The watershed of Augusta City Lake has an extremely low mean soil permeability value of 0.27 inches/hour (Figure 18). Permeability ranges from 0.02 inches/hour to 1.29 inches/hour according to NRCS STATSGO database with nearly 50% of the watershed having permeability value less than 0.21 inches/hour, which contributes to runoff during extremely low rainfall intensity events. According to a USGS open-file report (Juracek, 2000), the threshold soil-permeability values are set at 3.43 inches/hour for very high, 2.86 inches/hour for high, 2.29 inches/hour for moderate, 1.71 inches/hour for low, 1.14 inches/hour for very low, and 0.57 inches/hour for extremely low soil-permeability. Runoff is primarily generated as infiltration excess when soil profiles become saturated and produce excess overland flow due to rainfall intensities that are greater than soil permeability.

Figure 18. Soil permeability in the Augusta City Lake watershed.



Background and Natural Sources: Undissolved nutrients bound to suspended solids in the inflow to Augusta City Lake are potentially significant sources of nutrients that may endure in the sediment layer until they are removed by dredging. These internal nutrient loads can undergo remineralization and resuspension and may be a continuing source of nutrients in Augusta City Lake. In addition, geological formations (i.e. soil and bedrock) may also contribute to nutrient loads and, with deciduous forest making up about 6% of the land cover in the watershed, leaf litter and wastes derived from natural wildlife in the area are also likely to add to the nutrient loads in the lake. Further nutrient loading is also occurring through the atmospheric deposition of nitrogen and phosphorus compounds to Augusta City Lake and its watershed.

Internal Loading: Due to inadequate data for Augusta City Lake on the potential for internal nutrient loading, no estimates of internal loading were made outside those inherently contained within the BATHTUB modeling of the lake. Internal loading is a complex function of hydrologic conditions, lake morphometry and lake sediment nutrient availability. Should the lake stratify during the summer growing season, internal loading of nutrients may play a role in the eutrophic state of the lake.

Stormwater runoff: Although there is no municipal separate storm sewer (MS4) general permit in the watershed, the lake does lay within the boundaries of the City of Augusta resulting in about 14% of the watershed being designated as developed. During storm runoff events, the urban area of Augusta may contribute nutrient loads from lawn fertilizers and domestic pet waste along with sediment loads and other toxics found in the urban environment to Augusta City Lake.

4. ALLOCATION OF POLLUTANT REDUCTION RESPONSIBILITY

Augusta City Lake is co-limited by nitrogen and phosphorus; therefore, both are allocated under this TMDL. The general inventory of sources within the drainage area of the lake indicates load reductions should be focused on nonpoint source runoff contributions attributed to fertilizer applicators, livestock operations, and stormwater runoff contributions in the urban areas of the watershed.

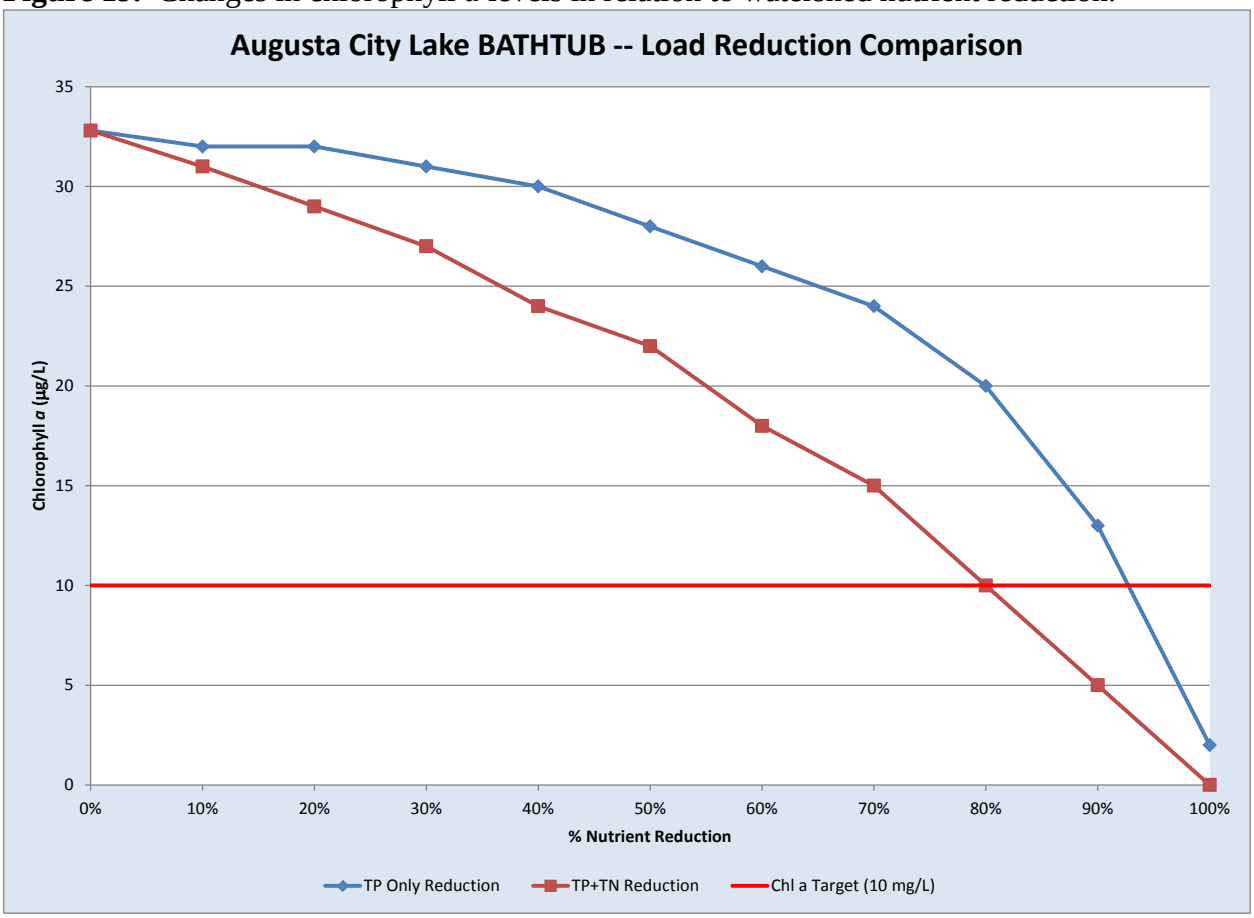
Nutrients: The lake model utilized for the development of the eutrophication TMDL was BATHTUB (Appendix B). BATHTUB is an empirical receiving water quality model, that was developed by the U.S. Army Corps of Engineers (Walker, 1996), and has been commonly applied in the nation to address many TMDLs relating to issues associated with morphometrically complex lakes and reservoirs (Mankin et al., 2003; Wang et al., 2005).

Atmospheric total nitrogen was obtained from the Clean Air Status and Trends Network (CASTNET), which is available at http://www.epa.gov/castnet. The CASTNET station from the Konza Prairie (KS) was used to estimate the atmospheric TN concentration for the model. Total phosphorus atmospheric loading was estimated using the 1983 study of Rast and Lee.

For modeling purposes, Augusta City Lake was considered one segment. Water quality data for the main basin segment was populated using the average of the 2006-2013 data from the KDHE lake monitoring station on Augusta City Lake (LM040001). Segment depth was estimated using the KBS 2010 bathymetric study on Augusta City Lake. Model input data for the tributary Elm Creek was estimated by applying the nutrient concentrations measured at KDHE's permanent stream station SC038 located on the Walnut River in the same HUC 12 (11030070207) as Augusta City Lake. Flow for Elm Creek was estimated by applying the ratio of the watershed size of the Elm Creek watershed to the watershed size of USGS 07147070 watershed to the flows seen at USGS 07147070. The BATHTUB model was calibrated for Augusta City Lake and results estimate that the lake retains 73% of the TP and 63% of the TN load annually. Based on modeling results, the combined reduction of TP and TN results in reaching the chlorophyll *a* endpoint more readily than reducing TP alone (Figure 19).

Hence, a 81% reduction of TP and a 76% reduction of TN within the inflow to Augusta City Lake are necessary to achieve the TMDL endpoint of an area-weighted mean of 10 µg/L chlorophyll *a* in the lake.

Figure 19. Changes in chlorophyll *a* levels in relation to watershed nutrient reduction.



Point Sources: There are no point sources in the watershed, hence, there is no wasteload allocation assigned by this TMDL.

Nonpoint Sources: Nonpoint sources are significant contributors for the nutrient input and impairment in Augusta City Lake. Background levels may be attributed to nutrient recycling and leaf litter. The assessment suggests that runoff transporting nutrients associated with animal wastes and pastureland is contributing to the eutrophication of the lake. Additionally, nonpoint source loads are being generated in the developed portion of the watershed during stormwater runoff events. Nutrient load allocations were calculated using the BATHTUB model (Appendix A) and are detailed in Table 9.

Table 9. Augusta City Lake Total Phosphorus and Total Nitrogen TMDL.

Description	Allocations (lbs/year)	Allocations (lbs/day)*
Total Phosphorus Atmospheric Load	38.0	0.3
Total Phosphorus Nonpoint Source Load Allocation	473.3	3.6
Total Phosphorus Margin of Safety	56.8	0.3
Total Phosphorus TMDL	568.1	4.2
Total Nitrogen Atmospheric Load	1,092	8.0
Total Nitrogen Nonpoint Source Load Allocation	3,584	26.4
Total Nitrogen Margin of Safety	519.0	3.8
Total Nitrogen TMDL	5,195	38.2

*See Appendix B for daily load calculation.

Defined Margin of Safety: The margin of safety provides some hedge against the uncertainty of variable annual total phosphorus and total nitrogen loads and the chlorophyll *a* endpoint. Therefore, the margin of safety is explicitly set at 10% of the total allocations for total phosphorus and total nitrogen, which compensates for the lack of knowledge about the relationship between the allocated loadings and the resulting water quality. The margin of safety for TP and TN is 0.3 lbs/day and 3.8 lbs/day, respectively, as detailed in Table 9.

State Water Plan Implementation Priority: Because Augusta City Lake serves as a drinking water supply and because it has a regional benefit for recreation, this TMDL will be a **High** Priority for implementation.

Nutrient Reduction Framework Priority Ranking: This watershed lies within the Lower Walnut Subbasin (HUC8: 11030017) which is among the top sixteen HUC8s targeted for state action to reduce nutrients.

Priority HUC12s: The entire watershed is within HUC12 110300170207.

5. IMPLEMENTATION

Desired Implementation Activities: There is potential that urban, construction, and agricultural best management practices will improve the condition of the City of Augusta Lake.

Some of the recommended urban practices are as follows:

1. Educate watershed residents on appropriate lawn fertilizer application.
2. Install grass buffer strips along drainage channels in the watershed.
3. Promote proper management of construction sites to minimize sediment and nutrient runoff.
4. Investigate feasibility of installing storm water wetlands and ponds in the watershed to remove nutrients prior to entering the lake.
5. Promote installation of porous and concrete grid pavement in the watershed.
6. Promote proper application (right product, right time, right place and right rate) of fertilizer to the golf course.

Some of the recommended agricultural practices are as follows:

1. Implement and maintain conservation farming, including conservation tilling, contour farming, and no-till farming to reduce runoff and cropland erosion.
2. Improve riparian conditions along stream systems by installing grass and/or forest buffer strips along the stream and drainage channels in the watershed.
3. Perform extensive soil testing to ensure excess phosphorus is not applied.
4. Ensure land applied manure is being properly managed and is not susceptible to runoff by implementing nutrient management plans.
5. Install pasture management practices, including proper stock density to reduce soil erosion and storm runoff.
6. Ensure proper on-site waste system operations in proximity to the main stream segments.
7. Ensure that labeled application rates of chemical fertilizers are being followed and implement runoff control measures.

Implementation Program Guidance:
Nonpoint Source Pollution Technical Assistance – KDHE

a. Support Section 319 implementation projects for reduction of phosphorus runoff from agricultural activities as well as nutrient management.
b. Provide technical assistance on practices geared to the establishment of vegetative buffer strips.
c. Provide technical assistance on nutrient management for livestock facilities in the watershed and practices geared towards small livestock operations, which minimize impacts to stream resources.

Urban Stormwater Runoff Controls – KDHE

a. Encourage the City of Augusta to retrofit media filters and wetland channels along flow paths of stormwater coming from developed areas around the lake.
b. Support construction of retention ponds and wetland basins to reduce particulate phosphorus, organic nitrogen and nitrates from stormwater.
c. Promote good housekeeping in developed areas near the lake, including street sweeping and prudent fertilizer use on lawns in residential areas.

Water Resource Cost Share and Nonpoint Source Pollution Control Program – KDA-DOC

a. Apply conservation farming practices and/or erosion control structures, including no-till, terraces, and contours, sediment control basins, and constructed wetlands.
b. Provide sediment control practices to minimize erosion and sediment transport from cropland and grassland in the watershed.
c. Install livestock waste management systems for manure storage.
d. Implement manure management plans.

Riparian Protection Program – KDA-DOC

a. Establish or reestablish natural riparian systems, including vegetative filter strips and streambank vegetation.
b. Develop riparian restoration projects along targeted stream segments, especially those areas with baseflow.
c. Promote wetland construction to reduce runoff and assimilate sediment loadings.
d. Coordinate riparian management within the watershed and develop riparian restoration projects.

Buffer Initiative Program – KDA-DOC

a. Install grass buffer strips near streams.
b. Leverage Conservation Reserve Enhancement Program to hold riparian land out of production.

Extension Outreach and Technical Assistance – Kansas State University

a. Educate agricultural producers on sediment, nutrient, and pasture management.
b. Educate livestock producers on livestock waste management, land applied manure applications, and nutrient management planning.
c. Provide technical assistance on livestock waste management systems and nutrient management planning.
d. Provide technical assistance on buffer strip design and minimizing cropland runoff.
e. Encourage annual soil testing to determine capacity of field to hold phosphorus.
f. Educate residents, landowners, and watershed stakeholders about nonpoint source pollution.

Timeframe for Implementation: Initial implementation will proceed over the years 2015-2021.

Targeted Participants: The primary participants for implementation will be the agricultural producers, construction activities, and new and existing development within the Augusta City Lake watershed.

Targeted Activities to focus attention toward include:

1. Overused grazing land adjacent to the streams.
2. Sites where drainage runs through or adjacent to livestock areas.
3. Sites where livestock have full access to the stream as a primary water supply.
4. Poor riparian area and denuded riparian vegetation along the stream.
5. Unbufferred cropland adjacent to the stream.
6. Conservation compliance on highly erodible areas.
7. Total row crop acreage and gully locations.

8. High-density urban and residential development in proximity to streams and tributary areas.

Milestone for 2026: In 2026, evaluation of the chlorophyll *a* endpoint and nutrient levels in the lake will be assessed. At that point in time, data from LM040001 in Augusta City Lake will be reexamined to assess improved conditions in the lake.

Delivery Agents: The primary delivery agents for program participation will be the City of Augusta, KDHE and Kansas State Extension.

Reasonable Assurances:

Authorities: The following authorities may be used to direct activities in the watershed to reduce pollution:

1. K.S.A. 65-164 and 165 empowers the Secretary of KDHE to regulate the discharge of sewage into the waters of the state.

2. K.S.A. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.

3. K.S.A. 2002 Supp. 82a-2001 identifies the classes of recreation use and defines impairment for streams.

4. K.A.R. 28-16-69 through 71 implements water quality protection by KDHE through the establishment and administration of critical water quality management areas on a watershed basis.

5. K.S.A. 2-1915 empowers the Kansas Department of Agriculture, Division of Conservation to develop programs to assist the protection, conservation and management of soil and water resources in the state, including riparian areas.

6. K.S.A. 75-5657 empowers the Kansas Department of Agriculture, Division of Conservation to provide financial assistance for local project work plans developed to control nonpoint source pollution.

7. K.S.A. 82a-901, et. seq. empowers the Kansas Water Office to develop a state water plan directing the protection and maintenance of surface water quality for the waters of the state.

8. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the Kansas Water Plan, including selected Watershed Restoration and Protection Strategies.

9. The Kansas Water Plan and the Walnut Basin Plan provide the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority implementation.

Funding: The State Water Plan annually generates $16-18 million and is the primary funding mechanism for implementing water quality protection and pollution reduction activities in the state through the Kansas Water Plan. The state water planning process, overseen by the Kansas Water Office, coordinates and directs programs and funding toward watershed and water resources of highest priority. Typically, the state allocates at least 50% of the fund to programs supporting water quality protection. This watershed and its TMDL are located within a High Priority area and should receive support for pollution abatement practices that lower the loading of sediment and nutrients.

Effectiveness: Nutrient control has been proven effective through proper implementation of comprehensive livestock waste management plans that effectively abate nutrient runoff associated with livestock facilities. Urban best management practices are important to implement due to their effectiveness at abating nutrient runoff particularly during storm runoff events. The key to success will be widespread utilization of proper livestock waste management within the watershed and implementation of urban best management practices in the developed area of the watershed.

6. MONITORING

KDHE will continue its 3-year sampling schedule in order to assess the trophic state of Augusta City Lake. Based on the sampling results, the 303(d) listing will be evaluated in 2026. Should impairment status continue, the desired endpoints under this TMDL will be refined and more intensive sampling will be conducted over the period 2026-2036 to assess progress in this implementation.

7. FEEDBACK

Public Notice: An active Internet Web site is established at http://www.kdheks.gov/tmdl/index.htm to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Walnut Basin.

Public Hearing: A Public Hearing on the Walnut River Basin TMDLs was held in Emporia, Kansas on August 28, 2014 to receive comments on this TMDL.

Milestone Evaluation: In 2020, evaluation will be made as to the degree of implementation that occurred within the watershed. Subsequent decisions will be made through regarding the implementation approach and follow up of additional implementation in the watershed.

Consideration for 303(d) Delisting: Augusta City Lake (LM040001) will be evaluated for delisting under Section 303(d), based on the monitoring data over the period 2016-2025. Therefore, the decision for delisting will come about in the preparation of the 2026-303(d) list. Should modifications be made to the applicable water quality criteria during the ten-year

implementation period, consideration for delisting, desired endpoints of this TMDL and implementation activities may be adjusted accordingly.

Incorporation into Continuing Planning Process, Water Quality Management Plan and the Kansas Water Planning Process: Under the current version of the Continuing Planning Process, the next anticipated revision would come in 2015, which will emphasize implementation of WRAPS activities. At that time, incorporation of this TMDL will be made into the WRAPS. Recommendations of this TMDL will be considered in the Kansas Water Plan implementation decisions under the State Water Planning Process for Fiscal Years 2015-2025.

Developed 8/24/15

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Appendix A. BATHTUB Modeling Results

Current Condition -- Case Data

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.8	0.2
Evaporation (m)	1.47	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	25	0.10
Total N	644	0.50
Ortho P	6.25	0.10
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	1	2ND ORDER, AVAIL P
Nitrogen Balance	1	2ND ORDER, AVAIL N
Chlorophyll-a	1	P, N, LIGHT, T
Secchi Depth	1	VS. CHLA & TURBIDITY
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Augusta City Lake	0	1	0.769	3	2	3	0.12	0	0.1	1.4	0.5	0	0	0	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	120	0.5	1140	0.5	32.8	0.5	0.58	0.5	1046	0.5	90	0.5	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Elm Creek	1	1	19.9	3.91	0.1	0	0	303	0.5	2380	0.5	149	0.5	1370	0.5

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	0.566	0.45
Total Nitrogen	1.157	0.55
Chl-a Model	1.411	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Current Condition -- Diagnostics for the Area Weighted Mean

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 1 Augusta City Lake

	Predicted Values--->			Observed Values--->		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	120.0	0.35	84.6%	120.0	0.50	84.6%
TOTAL N MG/M3	1140.0	0.36	58.0%	1140.0	0.50	58.0%
C.NUTRIENT MG/M3	68.0	0.30	79.0%	68.0	0.50	79.0%
CHL-A MG/M3	32.8	0.41	94.8%	32.8	0.50	94.8%
SECCHI M	0.5	0.29	12.5%	0.6	0.50	20.7%
ORGANIC N MG/M3	1010.3	0.31	93.1%	1046.0	0.50	94.0%
TP-ORTHO-P MG/M3	87.5	0.29	87.0%	90.0	0.50	87.6%
ANTILOG PC-1	1415.3	0.50	91.0%	1271.3	0.50	89.6%
ANTILOG PC-2	8.3	0.36	69.0%	10.0	0.50	79.7%
(N - 150) / P	8.3	0.53	14.4%	8.3	0.75	14.4%
INORGANIC N / P	4.0	3.29	2.2%	3.1	8.58	1.2%
TURBIDITY 1/M	1.4	0.50	82.8%	1.4	0.50	82.8%
ZMIX * TURBIDITY	4.2	0.51	64.5%	4.2	0.51	64.5%
ZMIX / SECCHI	6.7	0.31	71.7%	5.2	0.50	55.5%
CHL-A * SECCHI	14.8	0.50	70.0%	19.0	0.71	81.1%
CHL-A / TOTAL P	0.3	0.47	69.9%	0.3	0.70	69.9%
FREQ(CHL-a>10) %	94.6	0.08	94.8%	94.6	0.09	94.8%
FREQ(CHL-a>20) %	68.7	0.34	94.8%	68.7	0.40	94.8%
FREQ(CHL-a>30) %	43.4	0.60	94.8%	43.4	0.72	94.8%
FREQ(CHL-a>40) %	26.4	0.82	94.8%	26.4	1.00	94.8%
FREQ(CHL-a>50) %	16.1	1.01	94.8%	16.1	1.23	94.8%
FREQ(CHL-a>60) %	10.0	1.17	94.8%	10.0	1.44	94.8%
CARLSON TSI-P	73.2	0.07	84.6%	73.2	0.10	84.6%
CARLSON TSI-CHLA	64.8	0.06	94.8%	64.8	0.07	94.8%
CARLSON TSI-SEC	71.5	0.06	87.5%	67.8	0.10	79.3%

Current Condition -- Overall Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seq	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	Elm Creek	19.9	3.9	1.53E-01	0.10	0.20
PRECIPITATION				0.8	0.6	1.51E-02	0.20	0.80
TRIBUTARY INFLOW				19.9	3.9	1.53E-01	0.10	0.20
***TOTAL INFLOW				20.7	4.5	1.68E-01	0.09	0.22
ADVECTIVE OUTFLOW				20.7	3.4	2.83E-01	0.16	0.16
***TOTAL OUTFLOW				20.7	3.4	2.83E-01	0.16	0.16
***EVAPORATION					1.1	1.15E-01	0.30	

Overall Mass Balance Based Upon **Predicted** **Outflow & Reservoir Concentrations**
Component: **TOTAL P**

Trb	Type	Seq	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Elm Creek	1184.7	98.4%	3.65E+05	100.0%	0.51	303.0	59.5
PRECIPITATION				19.2	1.6%	3.70E+00	0.0%	0.10	31.3	25.0
TRIBUTARY INFLOW				1184.7	98.4%	3.65E+05	100.0%	0.51	303.0	59.5
***TOTAL INFLOW				1204.0	100.0%	3.65E+05	100.0%	0.50	266.1	58.2
ADVECTIVE OUTFLOW				407.4	33.8%	2.22E+04		0.37	120.0	19.7
***TOTAL OUTFLOW				407.4	33.8%	2.22E+04		0.37	120.0	19.7
***RETENTION				796.6	66.2%	2.34E+05		0.61		

Overflow Rate (m/yr)	4.4	Nutrient Resid. Time (yrs)	0.2299
Hydraulic Resid. Time (yrs)	0.6796	Turnover Ratio	4.3
Reservoir Conc (mg/m3)	120	Retention Coef.	0.662

Overall Mass Balance Based Upon **Predicted** **Outflow & Reservoir Concentrations**
Component: **TOTAL N**

Trb	Type	Seq	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Elm Creek	9305.8	94.9%	2.25E+07	99.7%	0.51	2380.0	467.6
PRECIPITATION				495.2	5.1%	6.13E+04	0.3%	0.50	805.0	644.0
TRIBUTARY INFLOW				9305.8	94.9%	2.25E+07	99.7%	0.51	2380.0	467.6
***TOTAL INFLOW				9801.0	100.0%	2.26E+07	100.0%	0.48	2165.9	474.2
ADVECTIVE OUTFLOW				3870.0	39.5%	2.18E+06		0.38	1140.0	187.2
***TOTAL OUTFLOW				3870.0	39.5%	2.18E+06		0.38	1140.0	187.2
***RETENTION				5931.0	60.5%	1.33E+07		0.61		

Overflow Rate (m/yr)	4.4	Nutrient Resid. Time (yrs)	0.2683
Hydraulic Resid. Time (yrs)	0.6796	Turnover Ratio	3.7
Reservoir Conc (mg/m3)	1140	Retention Coef.	0.605

Appendix A. BATHTUB Modeling Results

Reduced -- Case Data

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.8	0.2
Evaporation (m)	1.47	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	25	0.10
Total N	644	0.50
Ortho P	6.25	0.10
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	1	2ND ORDER, AVAIL P
Nitrogen Balance	1	2ND ORDER, AVAIL N
Chlorophyll-a	1	P, N, LIGHT, T
Secchi Depth	1	VS. CHLA & TURBIDITY
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Augusta City Lake	0	1	0.769	3	2	3	0.12	0	0.1	1.4	0.5	0	0	0	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	120	0.5	1140	0.5	32.8	0.5	0.58	0.5	1046	0.5	90	0.5	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Elm Creek	1	1	19.9	3.91	0.1	0	0	61	0.5	476	0.5	30	0.5	274	0.5

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	0.566	0.45
Total Nitrogen	1.157	0.55
Chl-a Model	1.411	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Reduced Condition -- Diagnostics for the Area Weighted Mean

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 1 Augusta City Lake

	Predicted Values--->			Observed Values--->		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	44.2	0.36	46.4%	120.0	0.50	84.6%
TOTAL N MG/M3	437.2	0.34	9.7%	1140.0	0.50	58.0%
C.NUTRIENT MG/M3	21.0	0.41	25.4%	68.0	0.50	79.0%
CHL-A MG/M3	10	0.57	54.2%	32.8	0.50	94.8%
SECCHI M	0.6	0.41	22.2%	0.6	0.50	20.7%
ORGANIC N MG/M3	494.8	0.28	53.3%	1046.0	0.50	94.0%
TP-ORTHO-P MG/M3	47.2	0.38	68.3%	90.0	0.50	87.6%
ANTILOG PC-1	251.7	0.66	50.8%	1271.3	0.50	89.6%
ANTILOG PC-2	5.2	0.49	33.7%	10.0	0.50	79.7%
(N - 150) / P	6.5	0.61	7.9%	8.3	0.75	14.4%
INORGANIC N / P	1.0		0.0%	3.1	8.58	1.2%
TURBIDITY 1/M	1.4	0.50	82.8%	1.4	0.50	82.8%
ZMIX * TURBIDITY	4.2	0.51	64.5%	4.2	0.51	64.5%
ZMIX / SECCHI	5.0	0.43	52.7%	5.2	0.50	55.5%
CHL-A * SECCHI	6.2	0.74	23.8%	19.0	0.71	81.1%
CHL-A / TOTAL P	0.2	0.61	60.1%	0.3	0.70	69.9%
FREQ(CHL-a>10) %	39.0	0.91	54.2%	94.6	0.09	94.8%
FREQ(CHL-a>20) %	8.1	1.73	54.2%	68.7	0.40	94.8%
FREQ(CHL-a>30) %	2.0	2.28	54.2%	43.4	0.72	94.8%
FREQ(CHL-a>40) %	0.6	2.68	54.2%	26.4	1.00	94.8%
FREQ(CHL-a>50) %	0.2	3.01	54.2%	16.1	1.23	94.8%
FREQ(CHL-a>60) %	0.1	3.28	54.2%	10.0	1.44	94.8%
CARLSON TSI-P	58.8	0.09	46.4%	73.2	0.10	84.6%
CARLSON TSI-CHLA	53.4	0.10	54.2%	64.8	0.07	94.8%
CARLSON TSI-SEC	67.3	0.09	77.8%	67.8	0.10	79.3%

Reduced -- Overall Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seq	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	Elm Creek	19.9	3.9	1.53E-01	0.10	0.20
PRECIPITATION				0.8	0.6	1.51E-02	0.20	0.80
TRIBUTARY INFLOW				19.9	3.9	1.53E-01	0.10	0.20
***TOTAL INFLOW				20.7	4.5	1.68E-01	0.09	0.22
ADVECTIVE OUTFLOW				20.7	3.4	2.83E-01	0.16	0.16
***TOTAL OUTFLOW				20.7	3.4	2.83E-01	0.16	0.16
***EVAPORATION					1.1	1.15E-01	0.30	

Overall Mass Balance Based Upon **Predicted** **Outflow & Reservoir Concentrations**
Component: **TOTAL P**

Trb	Type	Seq	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Elm Creek	238.5	92.5%	1.48E+04	100.0%	0.51	61.0	12.0
PRECIPITATION				19.2	7.5%	3.70E+00	0.0%	0.10	31.3	25.0
TRIBUTARY INFLOW				238.5	92.5%	1.48E+04	100.0%	0.51	61.0	12.0
***TOTAL INFLOW				257.7	100.0%	1.48E+04	100.0%	0.47	57.0	12.5
ADVECTIVE OUTFLOW				149.9	58.2%	3.04E+03		0.37	44.2	7.3
***TOTAL OUTFLOW				149.9	58.2%	3.04E+03		0.37	44.2	7.3
***RETENTION				107.8	41.8%	5.47E+03		0.69		

Overflow Rate (m/yr)	4.4	Nutrient Resid. Time (yrs)	0.3952
Hydraulic Resid. Time (yrs)	0.6796	Turnover Ratio	2.5
Reservoir Conc (mg/m3)	44	Retention Coef.	0.418

Overall Mass Balance Based Upon **Predicted** **Outflow & Reservoir Concentrations**
Component: **TOTAL N**

Trb	Type	Seq	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Elm Creek	1861.2	79.0%	9.01E+05	93.6%	0.51	476.0	93.5
PRECIPITATION				495.2	21.0%	6.13E+04	6.4%	0.50	805.0	644.0
TRIBUTARY INFLOW				1861.2	79.0%	9.01E+05	93.6%	0.51	476.0	93.5
***TOTAL INFLOW				2356.4	100.0%	9.62E+05	100.0%	0.42	520.7	114.0
ADVECTIVE OUTFLOW				1484.1	63.0%	2.67E+05		0.35	437.2	71.8
***TOTAL OUTFLOW				1484.1	63.0%	2.67E+05		0.35	437.2	71.8
***RETENTION				872.3	37.0%	3.25E+05		0.65		

Overflow Rate (m/yr)	4.4	Nutrient Resid. Time (yrs)	0.4280
Hydraulic Resid. Time (yrs)	0.6796	Turnover Ratio	2.3
Reservoir Conc (mg/m3)	437	Retention Coef.	0.370

Appendix B. Conversion to Daily Loads as Regulated by EPA Region VII

The TMDL has estimated annual average loads for TN and TP that if achieved should meet the water quality targets. A recent court decision often referred to as the "Anacostia decision" has dictated that TMDLs include a "daily" load (Friend of the Earth, Inc v. EPA, et al.).

Expressing this TMDL in daily time steps could be misleading to imply a daily response to a daily load. It is important to recognize that the growing season mean chlorophyll *a* is affected by many factors such as: internal lake nutrient loading, water residence time, wind action and the interaction between light penetration, nutrients, sediment load and algal response.

To translate long-term averages to maximum daily load values, EPA Region 7 has suggested the approach describe in the Technical Support Document for Water Quality Based Toxics Control (EPA/505/2-90-001)(TSD).

Maximum Daily Load (MDL) = (Long-Term Average Load) * $e^{[Z\sigma - 0.5\sigma^2]}$

where $\sigma^2 = \ln(CV^2 + 1)$

CV = Coefficient of variation = Standard Deviation / Mean

Z = 2.326 for 99th percentile probability basis

LTA= Long Term Average
LA= Load Allocation
MOS= Margin of Safety

Parameter	LTA lbs/year	CV	$e^{[Z\sigma - 0.5\sigma^2]}$	MDL lbs/day	Atm LA lbs/day	LA lbs/day	MOS (10%) lbs/day
TP	568.1	0.5	2.68	4.2	0.3	3.6	0.3
TN	5,195	0.5	2.68	38.2	8.0	26.4	3.8

Maximum Daily Load Calculation

Annual TP Load = 568.1 lbs/yr

Maximum Daily TP Load = [(568.1 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.472) - 0.5*(0.472)^2]}$
= 4.2 lbs/day

Annual TN Load = 5,195 lbs/yr

Maximum Daily TN Load = [(5,195 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.472) - 0.5*(0.472)^2]}$
= 38.2 lbs/day

Margin of Safety (MOS) for Daily Load

Annual TP MOS = 38.0 lbs/yr

Daily TP MOS = [(38.0 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.472)-0.5*(0.472)^2]}$
= 0.3 lbs/day

Annual TN MOS = 519 lbs/yr

Daily TN MOS = [(519 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.472)-0.5*(0.472)^2]}$
= 3.8 lbs/day

Source- *Technical Support Document for Water Quality-based Toxics Control (EPA/505/2-90-001)*