MARAIS DES CYGNES BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody/Assessment Unit (AU): Louisburg State Fishing Lake

Water Quality Impairment: Eutrophication

1. INTRODUCTIONS AND PROBLEM IDENTIFICATION

Subbasin: Lower Marais Des Cygnes

County: Miami

HUC 8: 10290102

HUC 11 (HUC 14s): 10290102060(070)

Ecoregion: Central Irregular Plains, Wooded Osage Plains (40c)

Drainage Area: 7.4 square miles (19.1 square kilometers)

Conservation Pool: Surface Area = 281 acres (0.44 square miles, 1.14 square kilometers)
Maximum Depth = 6.5 meters (21.3 feet)
Mean Depth (feet) = 2.5 meters (8.2 feet)
Total Storage Volume = 2314 acre-feet
Retention Time = 0.77 years
Mean Annual Inflow = 5.6 cfs

Designated Uses: Primary Contact Recreation (B), Expected Aquatic Life Use, Domestic Water Supple Use, Food Procurement Use, Industrial Use, Irrigation Use, Livestock Watering Use

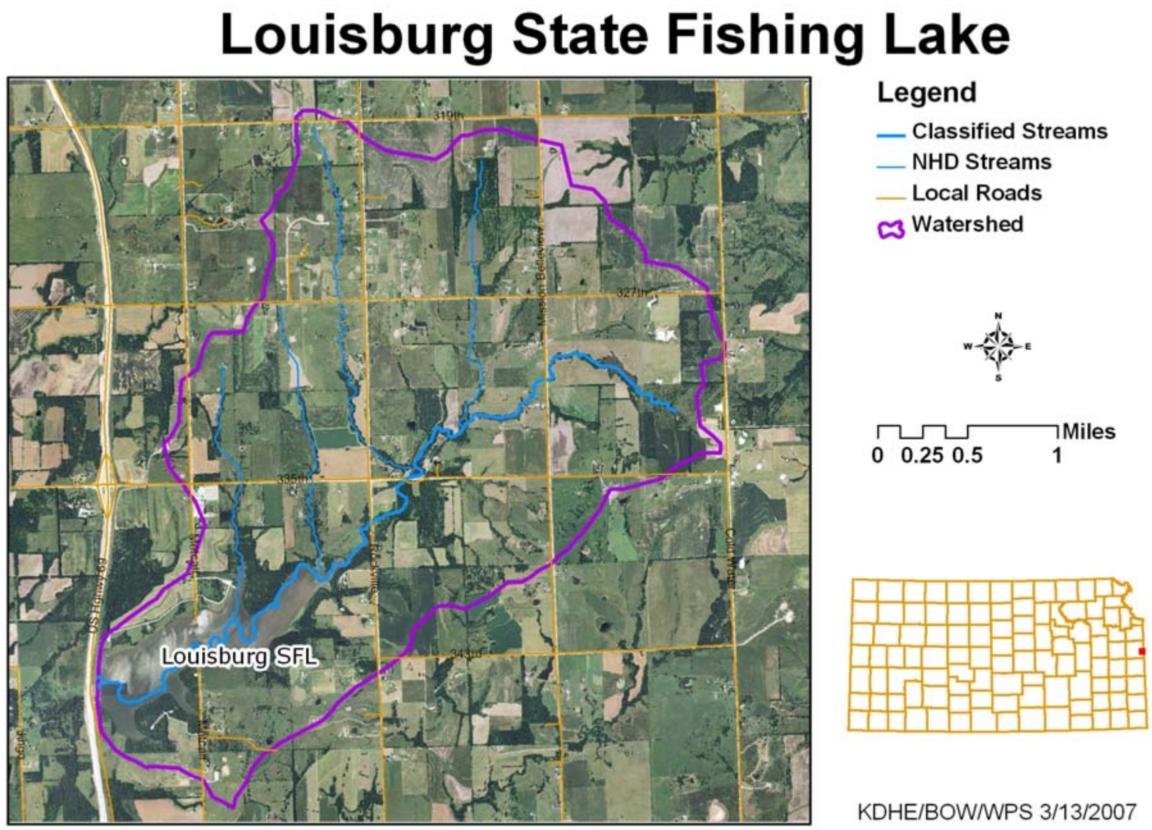
303(d) Listings: 2004 Marais Des Cygnes River Basin Lakes
2006 Marais Des Cygnes River Basin

Impaired Use: All uses are impaired to a degree by eutrophication

Water Quality Standard: 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(c)(2)(B)).

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)).

Figure 1. Map of the TMDL Area



2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Eutrophication: Slightly Eutrophic (SE), Trophic State Index (TSI) = 53.9 (average from 1986 to 2004, TSI ranging from 45.8 to 60.7)

The Trophic State Index (TSI) is derived from the chlorophyll *a* concentration (Chl-a). Trophic state assessments of potential algal productivity are made based on Chl-a, nutrient levels, and values of the Carlson Trophic State Index (TSI). Generally, some degree of eutrophic conditions is seen with Chl-a over 12 µg/L and hypereutrophy occurs at levels over 30 µg/L. The Carlson TSI derives from the Chl-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

Monitoring Site: KDHE Station LM043801

Table 1. Louisburg State Fishing Lake Water Quality Data Summary

Date	Layer	Depth m	DO mg/L	Temp oC	NH3 mgN/L	NO3 mgN/L	NO2 mgN/L	NO23 mgN/L	TKN mg/L	PO4 mg/L	TP mg/L	pH	S_COND us/cm	HARDNESS mg/L	TDS mg/L	TSS mg/L	TURB NTU	TOC mg/L	Chl-a ug/L	SECCHI m
7/22/86	Epilimnion	0.5	6	27	*<0.01*			*<0.01*			0.02	8.2	190	91	107		5		4.7	
7/22/86	Hypolimnion	8	0	15	0.86			0.03			0.07	7.2	200	85	114		28			
9/5/90	Epilimnion	0.5	7.8	28	0.15			*<0.01*			0.03	7.9	184	95	104	4	2.5		10.8	1.8
9/5/90	Hypolimnion	7	0.4	18	1.4			*<0.01*			0.03	7.1	215	101	116	12	7.3			
6/25/96	Epilimnion	0.5	8	28	0.3	*<0.01*	*<0.05*		1.07	*<0.01*	0.01	7.93	227	96.2	115	6	3.7		10.4	1.1
6/25/96	Hypolimnion	6	0	20	0.43	0.03	0.05		1.58	*<0.01*	0.01	6.98	245	101	123	13	6.5			
7/25/00	Epilimnion	0.5	7.4	26.5	0.02	*<0.01*	*<0.05*		1.63	*<0.02*	0.04	7.43	284	100.177	128.227	6	3.9	6.77	21.4	0.88
7/25/00	Hypolimnion	10	0.2	15	1.29	*<0.01*	*<0.05*		2.62	*<0.02*	0.12	6.91	357	124.198	162.028	9	9.6	7.44		
6/21/04	Epilimnion	0.5	6.6	24	*<0.1*	*<0.1*	*<0.05*		0.981	*<0.25*	0.037	7.6	230.5	120.309	136.557	12	9.15	4.558	12.9	1.34
6/21/04	Hypolimnion	9	0.2	16	0.288	*<0.1*	*<0.05*		1.185	*<0.25*	0.038	7.14	254.3	128.938	150.884	23	23.8	5.21		

Period of Record used: 1986 – 2004 (Sampling years: 1986, 1990, 1996, 2000, 2004)

Hydrologic Conditions: The drainage area for the Louisburg State Fishing Lake is only 7.4 square miles in size. The surface area of the Lake is about 0.44 square miles. According to the USGS Lake Hydro data, the mean runoff in the watershed is 9.14 inches per year; the mean precipitation in the watershed is 38.0 inches per year; and the mean loss due to evaporation for the Lake is 45.0 inches per year. The calculated mean outflow for the Lake is 3012 acre-feet per year; and the calculated lake retention time is 0.77 years.

Current Conditions: The water quality data for the Louisburg State Lake are summarized in **Table 1**. All of the samples were collected near the dam between June and September. The Lake stratifies during the summer months (see graphs in **Appendix A**). The depths of the epilimnion layer ranged from 2-4 meters on the sampling dates and were greatly influenced by local weather conditions like wind and temperature. This TMDL will focus on the surface water or the epilimnion layer of the Lake.

The average total nitrogen (TN) and total phosphorus (TP) concentrations are 1.272 mgN/L and 0.0274 mg/L, respectively. The chlorophyll-a is averaged at 12.0 ug/L, ranging from 4.7 ug/L in 1986 to 21.4 ug/L in 2000. The average secchi depth is around 1.28 meters (4.2 feet). The main concern for the Lake is the increasing trend of the chlorophyll-a levels and their corresponding Trophic State Indices (**Figures 2 and 3**).

The total cell counts and biovolumes of the algal community in the Lake are relatively low, although the algal community is composed mainly of cyanobacteria (Blue-green Algae) (**Tables 2 and 3**). 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 outcompete true algae[4]. **Table 4** lists the macrophyte communities in the Lake from 1996 to 2004.

Figure 2. Chlorophyll-a Levels Over the Years

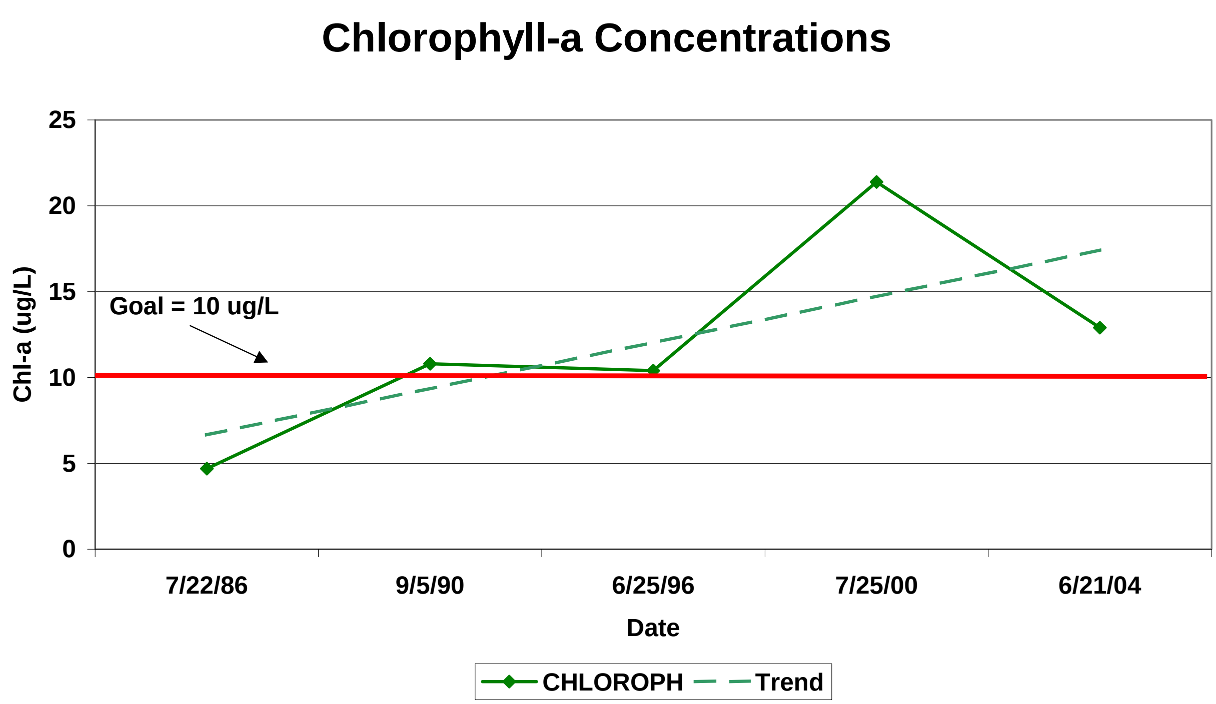


Figure 3. Trophic State Indices Over the Years

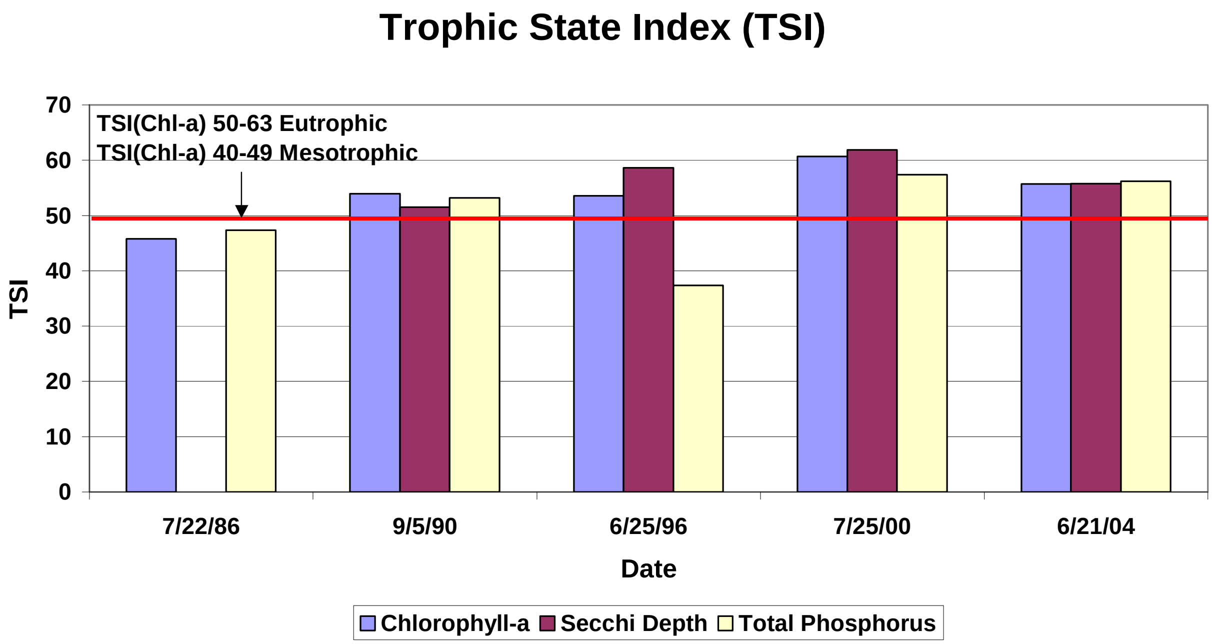


Table 2. Algal Communities Observed in the Lake

Year	Date	Total Count (cells/ml)	Percent Composition				Chl-a (ug/L)
			Green	Blue-Green	Diatom	Other*	
1996	**6/25/96**	13,734	12	83	2	3	10.4
2000	**7/25/00**	79,538	6	92	2	0	21.4
2004	**6/21/04**	31,973	3	95	1	1	12.9

* Refers to euglenoids, cryptophytes, dinoflagellates, and other single-celled flagellate groups of Algae.

Source: Lake and Wetland Monitoring Program Report/Summary

Table 3. Algal Biovolumes Calculated for the Lake

Year	Date	Biovolume (mm^3/L)	Percent Composition				Chl-a (ug/L)
			Green	Blue-Green	Diatom	Other*	
1996	**6/25/96**	3.722	5	41	1	53	10.4
2000	**7/25/00**	25.612	10	75	11	4	21.4
2004	**6/21/04**	7.961	3	80	4	13	12.9

* Refers to euglenoids, cryptophytes, dinoflagellates, and other single-celled flagellate groups of Algae.

Source: Lake and Wetland Monitoring Program Report/Summary

Table 4. Macrophyte Community Structure

Year	Date	% Total Cover	% Species Cover	Composition	Common Name
1996	**6/25/96**	20%	20%	*Chara zeylanica*	Stoneworts
			5%	*Nelumbo nucifera*	Eastern Asia Lotus
2000	**7/25/00**	35%	35%	*Nelumbo sp.*	Lotus
2004	**6/21/04**	25%	25%	*Nymphaea sp.*	Water Lily

* Submersed and floating-leaved aquatic plants, not including emergent shoreline community

Source: Lake and Wetland Monitoring Program Report/Summary

Table 5. Limiting Factor Determination for the Lake

Year	TN/TP	*Non-algal Turbidity* NAT	*Light Availability in the Mixed Layer* Zmix*NAT	*Partioning of Light Extinction between Algae & Non-algal Turbidity* Chl-a*SD	*Algal Use of Phosphorus Supply* Chl-a/TP	*Light Availability in the Mixed Layer for a Given Surface Light* Zmix/SD	*Shading in Water Column due to Algae and Inorganic Turbidity* Shading	Factors
1996	165.5	0.68	1.73	10.29	0.94			P
2000	35.9	0.61	2.22	18.48	0.53	4.12	6.15	P
2004	28.0	0.431	1.479	16.88	0.341	2.56	4.67	P

NAT: non-algal turbidity　　Chl-a: chlorophyll-a

Zmix: depth of mixed layer　　SD: secchi depth

Shading - calculated light attenuation coefficient times mean lake depth

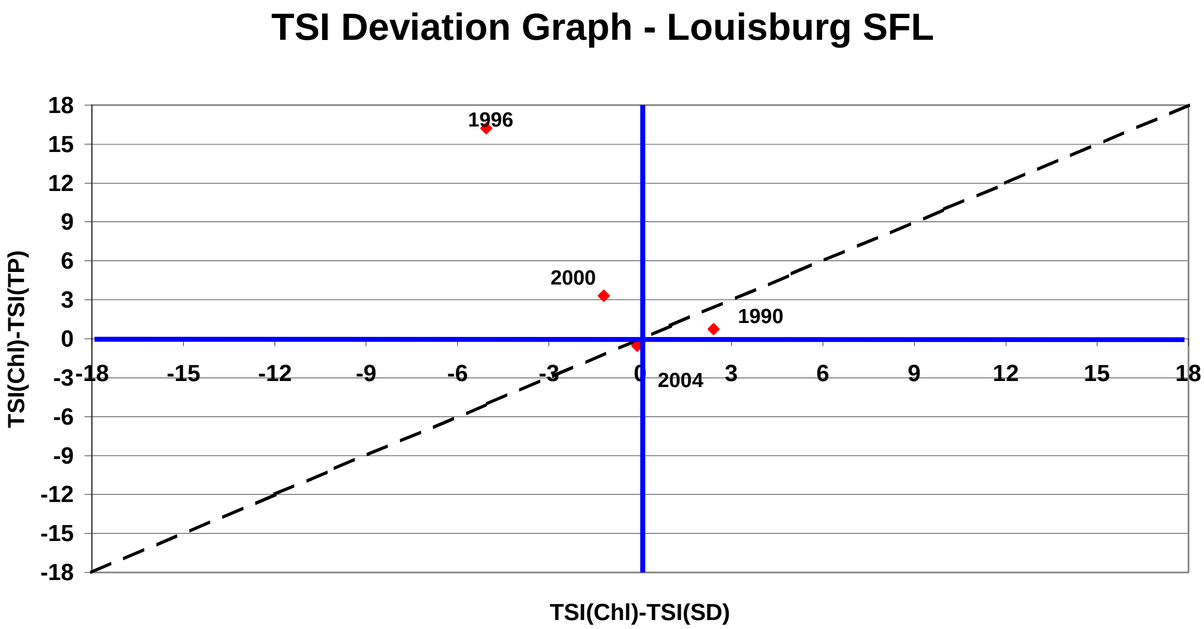
Source: Lake and Wetland Monitoring Program Report/Summary

Table 5 lists seven metrics measuring the roles of light and nutrient in the Lake. Typically, ***TN/TP mass ratios*** above 10-12 indicate increasing phosphorus limitation. ***Non-algal turbidity*** (NAT) values between 0.4 and 1.0 m^{-1} indicate inorganic turbidity assumes greater influence on water clarity but would not assume a significant limiting role until values exceed 1.0 m^{-1}. ***Light availability*** values in the mixed layer less than 3 indicate abundant light within the mixed layer of a lake and a high potential response by algae to nutrient inputs. Values of ***partitioning of light extinction between algae and non-algal turbidity*** that are greater than 16 indicate that inorganic turbidity is probably not responsible for light extinction in the water column and there is a strong algal response to changes in nutrient levels. Values of ***algal use of phosphorus supply*** that are above 0.4 indicate a strong algal response to changes in phosphorus level. Values of ***light availability in the mixed layer for a given surface light*** that are less than 3 indicate that light availability is high in the mixed zone and the probability of strong algal responses to changes in nutrient levels is high. ***Shading*** values less than 16 indicate that self-shading of algae does not significantly impede productivity and are most applicable to lakes with maximum depths of less than 5 meters. (Source: Lake and Wetland Monitoring Program 2004 Annual Report)

According to the above metrics, the Louisburg State Fishing Lake is likely to be phosphorus limited. The Lake also has low levels of inorganic turbidity (silt/clay), high light availability in the mixed layer, and potential high response of algae community to increases in nutrient levels. As the phosphorus levels increase in the lake water, the response of algal community to changes in phosphorus levels is not as intense as before.

Another method for evaluating limiting factors is the TSI deviation metrics (**Figure 5**). Differences of less than 5 units are considered **not** statistically significant different from zero[1]. Values of TSI(Chl-a)-TSI(SD) that are larger than 5 indicate that larger particles (zooplankton, algal colonies) exert more importance for a lake's light regime[1]. Values of TSI(Chl-a)-TSI(SD) that are less than -5 indicate small particle turbidity is important[1]. Values of TSI(Chl-a)-TSI(TP) that are larger than 5 indicate that phosphorus is limiting algal production and biomass[1]. Values of TSI(Chl-a)-TSI(TP) that are less than -5 indicate that phosphorus may not be the limiting factor for algal production and biomass[1]. The TSI deviation chart for the Louisburg State Fishing Lake suggests that the phosphorus might be the limiting factor for algal production in 1996. Neither small particles nor large particles dominate in the Lake.

Figure 5. TSI Deviation Chart



Desired Endpoints of Water Quality (Implied Load Capacity) at the Lake, over 2007 – 2015

To prevent further deterioration and reverse the trend in water quality, a goal of 10 µg/L of chlorophyll-a is set for the Louisburg State Fishing Lake. It will ensure long-term protection for the Lake and provide some buffering capacity in case of nutrients overload to the Lake. In support of the chlorophyll-a endpoint, in-lake average concentrations of total phosphorus will need to be at 27 µg/L (ppb) with a maximum level at 30 µg/L (ppb). A corroborating endpoint of average secchi disk depth greater than 1.3 m will also be used to assess the aesthetic quality of the lake for recreation.

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.

3. SOURCE INVENTORY AND ASSESSMENT

Eutrophication is generally described as the biological response of a lake to elevated nutrients, organic matter, and/or silt [2]. The nutrient loads can come from a variety of sources, including wastewater treatment plant effluent, untreated sewage, urban stormwater runoff, animal waste, pasture runoff, and cropland runoff.

The drainage area or watershed for the Louisburg State Fishing Lake is located approximately 7 miles south of the city of Louisburg. Currently, the Lake is the primary drinking water source for the city of Louisburg. There are no permitted point sources (NPDES or CAFO) in the watershed.

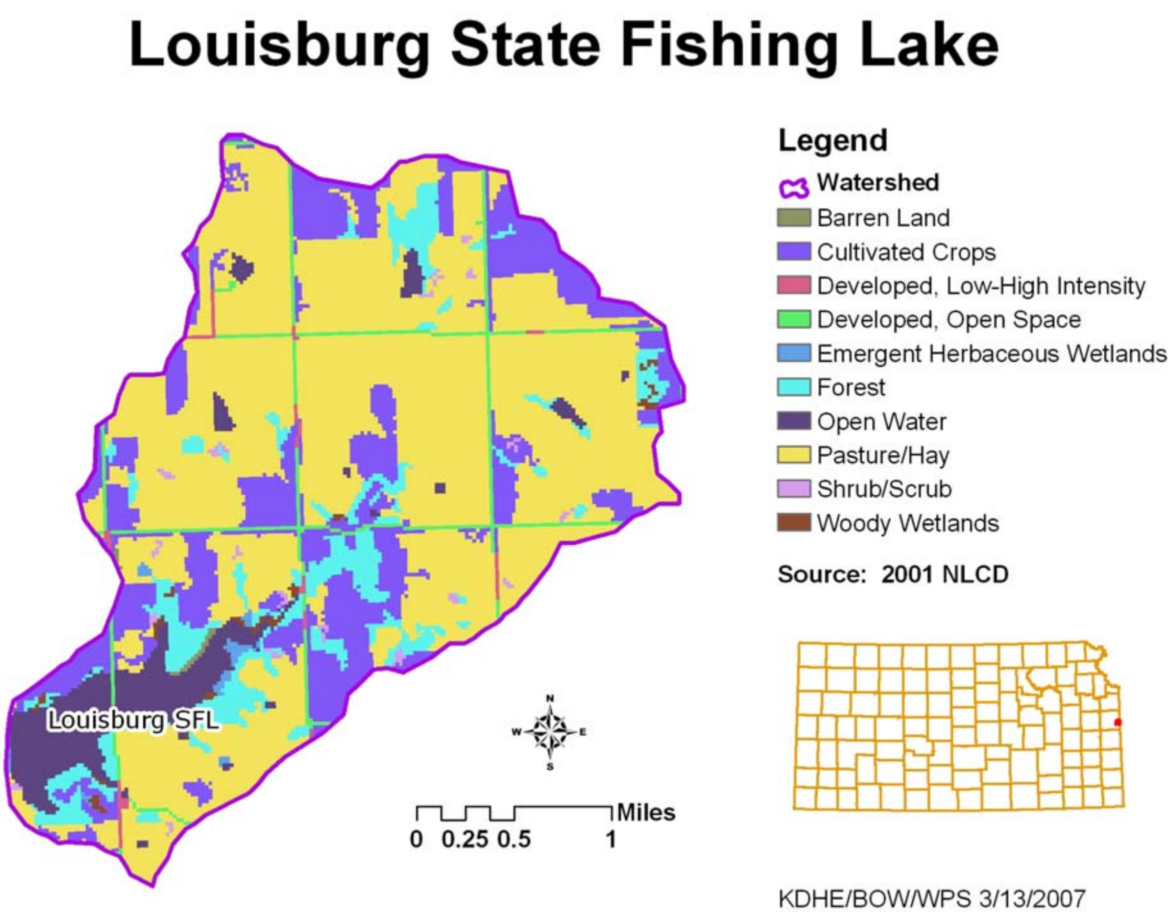
The land use data show that the watershed comprises mainly of pastures (59.3%), cropland (19.9%), and forest (6.9%) (**Table 5 and Figure 6**). Non-point sources are the main contributor of nutrients input to the Lake. Another possible source of nutrient input to the Lake might come from improper waste disposal by private boats on the Lake. It has been observed in some other lakes in Kansas that boat operators sometimes dump their waste tanks into the lake rather than using a pump station. Atmospheric deposition is also a small but constant source of nutrient input to the watershed.

Table 6. Land Use in 2001

Class	Percent
Pasture/Hay	59.3%
Cultivated Crops	19.9%
Deciduous Forest	8.7%
Open Water	6.9%
Developed, Open Space	3.0%

Source: NLCD 2001

Figure 6. Land Cover Map



4. ALLOCATION OF POLLUTION REDUCTION RESPONSIBILITY

Point Sources: Since there is no permitted point source in the watershed, a Wasteload Allocation of zero is assigned for nitrogen and phosphorus under this TMDL. Should a new point source appear in the watershed, the Load Allocation will need to be adjusted to create a WLA for the discharger.

Non-point Sources: Non-point sources are the main contributor for the nutrient input and impairment in Louisburg State Fishing Lake. The likely sources are the runoff from agricultural fields and pastures. The CNET model is used to estimate the current and potential loads of phosphorus to the Lake (**Table 6**). The CNET model summary and explanation sheet are in Appendix B. The maximum daily load calculation is summarized in Appendix C.

Table 6. Load Allocation for Non-point Sources

Type	Current	Goal	Percent Reduction	LA	MOS
TP Atmospheric Deposition Load (Ibs/year)	115	115	0%	115	0
TP Other NPS Load (Ibs/year)	1740	1110	36.2%	1000	110
Total Load (Ibs/year)	**1855**	**1215**	**34.5%**	**1115**	**110**
TP Maximum Daily Atmospheric Deposition Load (Ibs/day)	0.78	0.78	0%	0.78	0
TP Maximum Daily other NPS Load (Ibs/day)	11.8	7.5	36.2%	6.7	0.8
Total Maximum Daily Load (Ibs/day)	**12.6**	**8.3**	**34.1%**	**7.5**	**0.8**

Defined Margin of Safety: The Margin of Safety is explicitly set at 10% of the desired load capacity.

State Water Plan Implementation Priority: Since the water quality in the Lake is still in the initial stage of decline, prompt actions by the stakeholders are very likely to stop and reverse the trend. The water quality in the Lake is likely to be restored with moderate efforts. Furthermore the Lake is used for public water supply. This TMDL will be a High Priority for implementation.

Unified Watershed Assessment Priority Ranking: The watershed lies within the Marais des Cygnes Basin (HUC 8: part of 10290102) with a priority for restoration work ranking of 12.

Priority HUC 11s and Stream Segments: The whole watershed is located within a single HUC11, no priority sub-watersheds will be identified.

5. IMPLEMENTATION

Desired Implementation Activities

1. Continue to collect water quality data for the Lake.
2. Maintain and improve grass buffers and filter-strips along streams and channels in the watershed.
3. Employ Best Management Practices (BMPs) on pastures and cropland to minimize runoff.
4. Utilize State-supported Marais des Cygnes Basin WRAPS process to coordinate load reduction of nutrients to the Lake.

Implementation Programs Guidance

Watershed Management Program - KDHE

a. Support new and ongoing implementation projects conducted under Marais des Cygnes Basin WRAPS focused on Louisburg State Fishing Lake, including demonstration projects and outreach efforts dealing with erosion and sediment control, stormwater management and practices, pollution prevention, public outreach and studies of water quality impacts of new development.
b. Provide technical assistance on nutrient management and vegetative buffer development in vicinity of streams.

Water Resource Cost Share Nonpoint Source Pollution Control Program - SCC

a. Apply conservation farming practices, including terraces and waterways, sediment control basins, and constructed wetlands in cropland.
b. Provide sediment control practices to minimize erosion and sediment and nutrient transport from pastures and cropland in the lake watershed.

Riparian Protection Program - SCC

a. Establish or reestablish natural riparian systems, including vegetative filter strips and streambank vegetation along streams.
b. Develop riparian restoration projects.
c. Promote wetland construction to assimilate nutrient loadings.

Buffer Initiative Program - SCC

a. Install vegetative buffer strips along streams.

Public Education Program - KDWP

a. Educate boat owners on proper waste disposal.

Timeframe for Implementation: Development of implementation plans should start in 2007. Implementation should occur in 2008 - 2012.

Targeted Participants: Primary participants for implementation will be the stakeholders in the watershed.

Milestone for 2012: In 2012, sampled data from the watersheds should indicate evidence of reduced chlorophyll-at levels relative to those seen in 1991-2004. Should the case of impairment remain, source assessment, allocation, and implementation activities will ensue.

Delivery Agents: The primary delivery agents for program participation will be Kansas Department of Health & Environment, Kansas Department of Wildlife and Parks, the City of

Louisburg, conservation districts for programs of the State Conservation Commission and the Natural Resources Conservation Service.

Reasonable Assurances:

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

1. 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.

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

3. K.S.A. 75-5657 empowers the State Conservation Commission to provide financial assistance for local project work plans developed to control non-point source pollution.

4. 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.

5. 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.

6. The *Kansas Water Plan* and the Marais des Cygnes 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 in implementation.

Funding: The State Water Plan Fund, 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 watersheds and water resources of highest priority. Typically, the state allocates at least 50% of the fund to programs supporting water quality protection. Additionally, $2 million has been allocated between the State Water Plan Fund and EPA 319 funds to support implementation of Watershed Restoration and Protection Strategies. This TMDL is a High Priority consideration.

Effectiveness: Nutrient control has been proven effective through conservation tillage, contour farming and use of grass waterways and buffer strips. The key to success will be widespread utilization of BMPs in the watershed.

6. MONITORING

KDHE will continue its 3-year sampling schedule in order to assess the impairment that drives this TMDL. Based on that sampling, the priority status of 303(d) listing will be evaluated in

2012. Should impairment become evident, the desired allocations under this TMDL will be refined and more intensive sampling will need to be conducted over the period of 2012-2015 to assess progress in this TMDL's implementation.

7. FEEDBACK

Public Meetings: Public meetings to discuss TMDLs in the Marais des Cygnes Basin have been held since 2001. An active Internet Web site was established at www.kdheks.gov/tmdl/ to convey information to the public on the general establishment of TMDLs in the Marais des Cygnes Basin and these specific TMDLs.

Public Hearing: A Public Hearing on these Marais des Cygnes Basin TMDLs was held in Ft. Scott on May 31, 2007.

Basin Advisory Committee: The Marais des Cygnes Basin Advisory Committee met to discuss these TMDLs on June 22, 2006 in Pomona, November 29, 2006 in Williamsburg, December 18, 2006 in Ft. Scott, January 30, 2007 in Ottawa, March 13, 2007 in Ft. Scott and May 17, 2007 in Ottawa.

Milestone Evaluation: In 2012, evaluation will be made as to implementation of management practices to minimize the non-point source runoff contributing to this impairment. Subsequent decisions will be made regarding the implementation approach, priority of allotting resources for implementation and the need for additional or follow up implementation in this watershed at the next TMDL cycle for this basin in 2012.

Consideration for 303d Delisting: The lake will be evaluated for delisting under Section 303d, based on the monitoring data over the period 2008-2015. Therefore, the decision for delisting will come about in the preparation of the 2016 303d list. Should modifications be made to the applicable water quality criteria during the 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 2007 which will emphasize revision of the Water Quality Management Plan. At that time, incorporation of this TMDL will be made into both documents. Recommendations of this TMDL will be considered in *Kansas Water Plan* implementation decisions under the State Water Planning Process for Fiscal Years 2008-2015.

Revised 10/24/07

Bibliography

1. Carney, Edward. 1996, 2000, 2004. Lake and Wetland Monitoring Program Annual Report/Summary. Kansas Dept of Health & Environment.

2. Carney, Edward. 1998. A Primer on Lake Eutrophication and Related Pollution Problems. Kansas Dept. of Health & Environment.

3. U.S. EPA. 1991. Technical Support Document for Water Quality-based Toxics Control (EPA/505/2-90-001). http://www.epa.gov/npdes/pubs/owm0264.pdf

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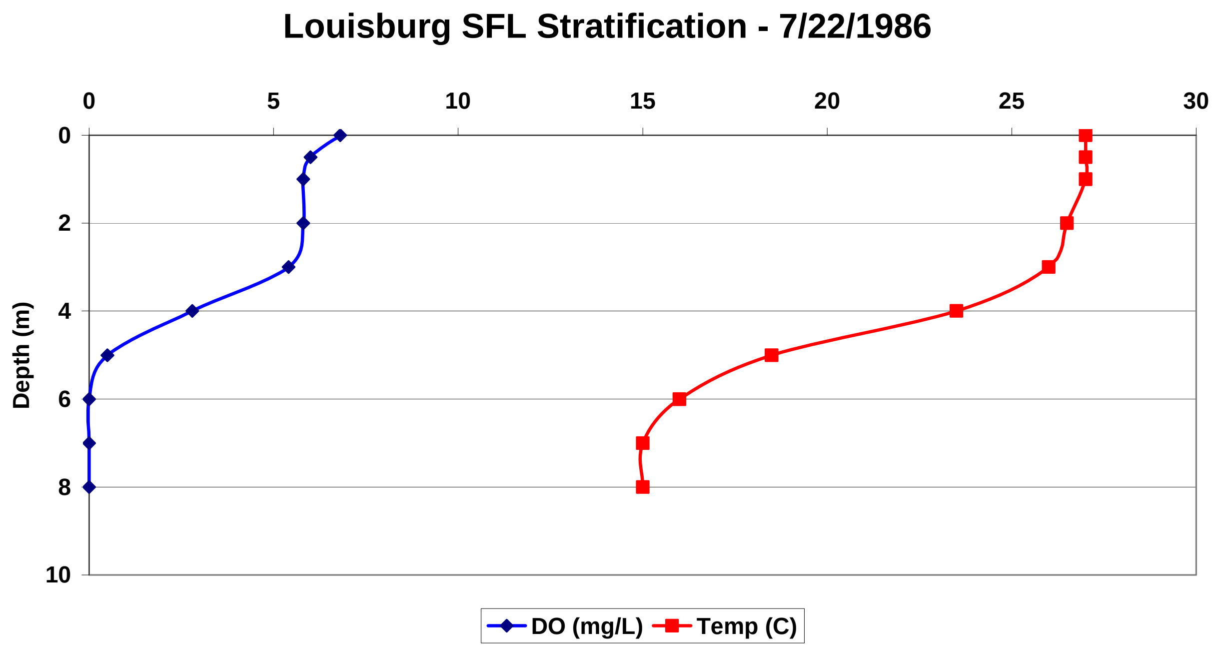
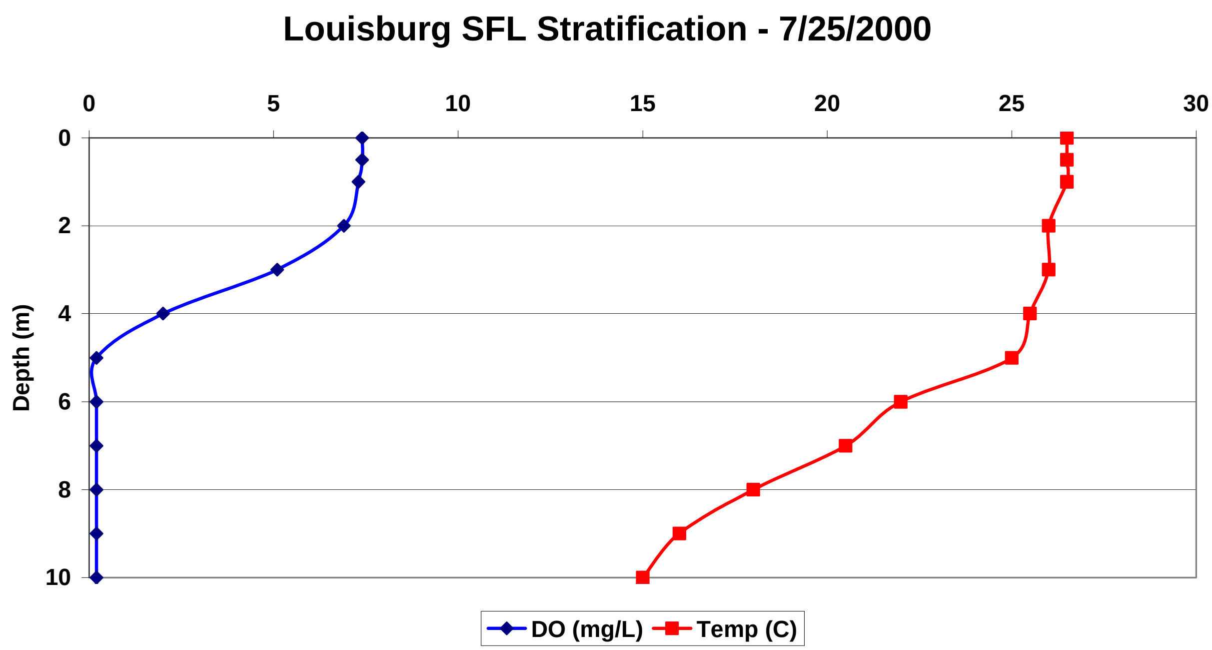
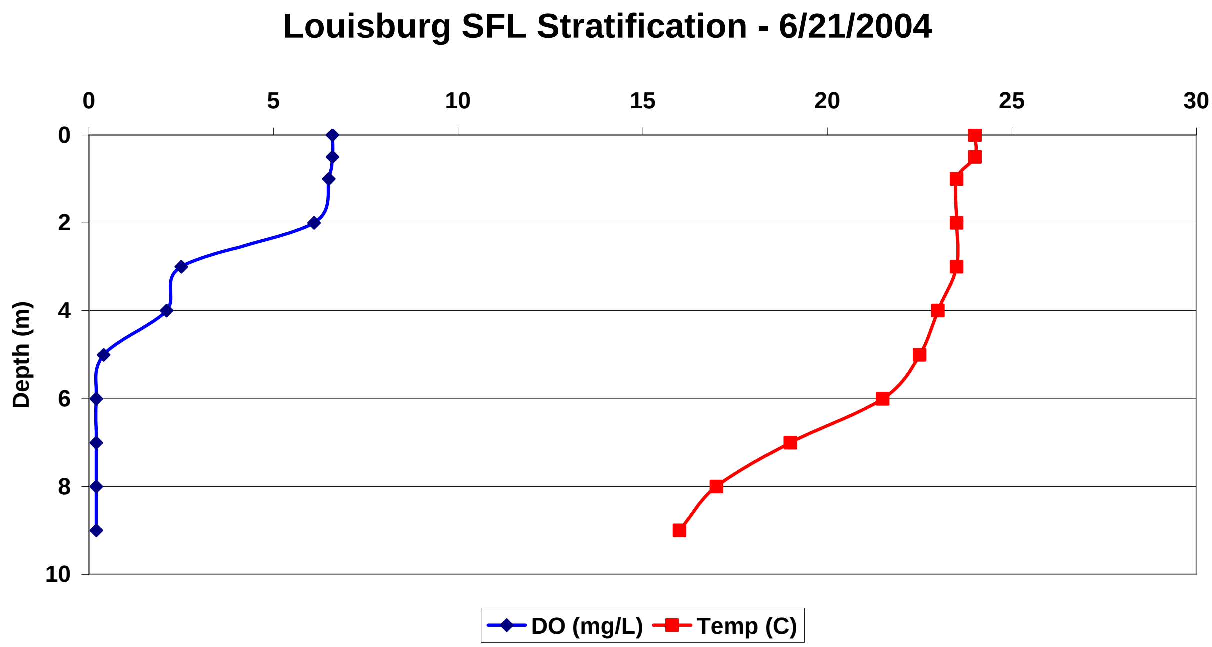
Appendix A. Lake Profiles






Louisburg SFL Stratification - 6/21/2004
0
5
10
15
20
25
30
0
2
4
6
8
10
Depth (m)
DO (mg/L)
Temp (C)

Appendix B. CNET Model

The CNET model is a simplified version of the Bathtub model. The CNET model utilizes three and eight empirical models to predict levels of chlorophyll-a (chl-a) and total phosphorus (TP), respectively. These empirical models and their equations are listed in **Tables I-II**. The combination of the first-order settling model and Jones & Bachman model gives the best prediction for the TP and chl-a levels in the Lake. The Jones & Bachman model predicts chl-a levels based on the power of TP. The model works well for the Louisburg State Fishing Lake probably due to the potential strong algal response to phosphorus input that is determined by the Lake's low levels of inorganic turbidity and high light availability in the mixed layer. The first-order settling model outperforms the other models for TP probably due to the fact that the lake depth has a negative impact on the sedimentation rates of phosphorus in the lake and thus resulting higher TP concentrations in the water.

Table I. Chlorophyll-a Options in CNET Model (Source: Bathtub Model Help)

Chlorophyll-a Models			Applicability Constraints			
Option	**Description / Limiting Factors**	**Equations**	**a**	**(N-150)/P**	**Ninorg/Portho**	**Fs**
2	P, Light, Flushing [default]	$Bp = P^{1.37}/4.88$ $G = Zmix\ (0.19 + 0.0042\ Fs)$ $B = K\ Bp\ /\ [(1 + b\ Bp\ G)\ (1 + Ga)]$		>12	>7	
4	P, Linear	$B = K\ 0.28\ P$	<0.9	>12	>7	<25
5	**P, Exponential, Jones & Bachman (1976)**	$B = K\ 0.081\ P^{1.46}$	**<.4**	**>12**	**>7**	**<25**

See Table III for symbol definitions.

Table II. Chlorophyll-a Options in CNET Model (Source: Bathtub Model Help)

Phosphorus Sedimentation Models

Unit P Net Sedimentation Rate (mg/m^3-year) = $CP\ A1\ P^{A2}$

Solution for Mixed Segment:

Second-Order Models (A2 = 2):

$$P = [-1 + (1 + 4\ K\ A1\ Pi\ T)^{0.5}] / (2\ K\ A1\ T)$$

First-Order Models (A2 = 1):

$$P = Pi / (1 + K\ A1\ T)$$

Option	Model Description	A1	A2
1	Second-Order, Available P [default] *Inflow Avail P = 0.33 Pi + 1.93 Pio* *See options for specification of available P*	*0.17 Qs/(Qs + 13.3)* *Qs = Max(Z/T,4)*	2
2	Second-Order Decay Rate Function *Fot = Tributary Ortho P / Total P Load* *Requires specification of inflow total & ortho P loads*	*0.056* Fot^{-1}*Qs/(Qs + 13.3)* *Qs = Max(Z/T,4)*	2
3	Second-Order	*0.10*	2
4	Canfield & Bachman (1981), Reservoirs	$0.114\ (Wp/V)^{0.589}$	1
5*	Vollenweider (1976), Northern Lakes	$T^{-0.5}$	1
6*	Simple First-Order	*1*	1
7*	**First-Order Settling**	**1/Z**	**1**
8*	Canfield & Bachman (1981), Natural Lakes	$0.162\ (Wp/V)^{0.458}$	

See Table III for symbol definitions.

Table III. Definition of Symbols Used in Model Equations

Symbol	Definition
a	Non-Algal Turbidity (m^{-1}) = 1/S - b B , minimum value = 0.08 1/m]
b	Algal Light Extinction Coef = Slope of 1/Secchi vs. Chl-a [default = 0.025 1/m]
As	Surface Area of Segment (km^2)
Ac	Cross-Sectional Area of Segment (km*m)
A1	Intercept of Phosphorus Sedimentation Term
A2	Exponent of Phosphorus Sedimentation Term
B1	Intercept of Nitrogen Sedimentation Term
B2	Exponent of Nitrogen Sedimentation Term
B	Chlorophyll a Concentration (mg/m^3)
Bm	Reservoir Area-Weighted Mean Chlorophyll a Concentration (mg/m^3)
Bp	Phosphorus-Potential Chlorophyll a Concentration (mg/m^3)
Bx	Nutrient-Potential Chlorophyll a Concentration (mg/m^3)
D	Dispersion Rate (km^2/year)
Dn	Numeric Dispersion Rate (km^2/year)
E	Diffusive Exchange Rate between Adjacent Segments (hm^3/year)
Fs	Summer Flushing Rate = (Inflow + Precip -Evaporation)/Volume ($year^{-1}$)
Fin	Tributary Inorganic N Load/Tributary Total N Load
Fot	Tributary Ortho-P Load/Tributary Total P Load
G	Kinetic Factor Used in Chlorophyll a Model
HODv	Near-Dam Hypolimnetic Oxygen Depletion Rate (mg/m^3-day)
K	Calibration Factor (Global Factor x Segment Factor) *
KD	Calibration Factor for Longitudinal Dispersion
L	Segment Length (km)
MODv	Near-Dam Metalimnetic Oxygen Depletion Rate (mg/m^3-day)
N	Reservoir Total Nitrogen Concentration (mg/m^3)
Ni	Inflow Total Nitrogen Concentration (mg/m^3)
Nin	Inflow Inorganic N Concentration (mg/m^3)
Nia	Inflow Available N Concentration (mg/m^3)
Ninorg	Inorganic Nitrogen Concentration (mg/m^3)
Norg	Organic Nitrogen Concentration (mg/m^3)
P	Total Phosphorus Concentration (mg/m^3)
Pi	Inflow Total P Concentration (mg/m^3)
Pio	Inflow Ortho-P Concentration (mg/m^3)
Pia	Inflow Available P Concentration (mg/m^3)
Portho	Ortho-Phosphorus Concentration (mg/m^3)
PC-1	First Principal Component of Trophic Response Measurements
PC-2	Second Principal Component of Trophic Response Measurements
Q	Segment Total Outflow (hm^3/year)
Q_S	Surface Overflow Rate (m/year)
S	Secchi Depth (m)
T	Hydraulic Residence Time (years)
TSIp	Carlson Trophic State Index (Phosphorus)
TSIc	Carlson Trophic State Index (Chlorophyll a)
TSIs	Carlson Trophic State Index (Transparency)
U	Mean Advective Velocity (km/year)
V	Total Volume (hm^3)
W	Mean Segment Width (km)
Wp	Total Phosphorus Loading (kg/year)
Wn	Total Nitrogen Loading (kg/year)
Xpn	Composite Nutrient Concentration (mg/m^3)
Z	Total Depth (m)
Zx	Maximum Total Depth (m)
Zh	Mean Hypolimnetic Depth of Entire Reservoir (m)
Zmix	Mean Depth of Mixed Layer (m)

Table IV. CNET Output:

RESERVOIR EUTROPHICATION MODELING WORKSHEET   TITLE -> Louisburg State Fishing Lake, Average 00 & 04   Based on CNET.WK1 VERSION 1.0

VARIABLE	UNITS	Current	LC
WATERSHED CHARACTERISTICS...		Latitude	36
Drainage Area	km2	19.1	19.1
Precipitation	m/yr	0.97	0.97
Evaporation	m/yr	1.14	1.14
Unit Runoff	m/yr	0.23	0.23
Stream Total P Conc.	ppb	180	115
Stream Ortho P Conc.	ppb	0	0
Atmospheric Total P Load	kg/km2-yr	46	46
Atmospheric Ortho P Load	kg/km2-yr	0	0
POINT SOURCE CHARACTERISTICS...			
Flow	hm3/yr	0	0.0
Total P Conc	ppb	0	0.0
Ortho P Conc	ppb	0	0
RESERVOIR CHARACTERISTICS...			
Surface Area	km2	1.14	1.14
Max Depth	m	6.5	6.5
Mean Depth	m	2.5	2.5
Non-Algal Turbidity	1/m	0.47	0.52
Mean Depth of Mixed Layer	m	2.5	2.5
Mean Depth of Hypolimnion	m	0.92	0.92
Observed Phosphorus	ppb	38.5	27.0
Observed Chl-a	ppb	17.2	10.0
Observed Secchi	meters	1.11	1.30
MODEL PARAMETERS...			
BATHTUB Total P Model Number	(1-8)	7	7
BATHTUB Total P Model Name		SETTLING	
BATHTUB Chl-a Model Number	(2,4,5)	5	5
BATHTUB Chl-a Model Name		JONES	
Beta = 1/S vs. C Slope	m2/mg	0.05238	0.077
P Decay Calibration (normally =1)		1	1
Chlorophyll-a Calib (normally = 1)		1	1
Chla Temporal Coef. of Var.		0.35	0.35
Chla Nuisance Criterion	ppb	12	12
WATER BALANCE...			
Precipitation Flow	hm3/yr	1.11	1.11
NonPoint Flow	hm3/yr	4.39	4.39
Point Flow	hm3/yr	0.00	0.00
Total Inflow	hm3/yr	5.50	5.50
Evaporation	hm3/yr	1.30	1.30
Outflow	hm3/yr	4.20	4.20

VARIABLE	UNITS	Current	LC
AVAILABLE P BALANCE...			
Precipitation Load	kg/yr	26	26
NonPoint Load	kg/yr	182	116
Point Load	kg/yr	0	0
Total Load	kg/yr	208	142
Sedimentation	kg/yr	44	30
Outflow	kg/yr	164	112
PREDICTION SUMMARY...			
P Retention Coefficient	-	0.214	0.214
Mean Phosphorus	ppb	39.0	26.7
Mean Chlorophyll-a	ppb	17.0	9.8
Algal Nuisance Frequency	%	79.5	22.4
Mean Secchi Depth	meters	0.73	0.79
Hypol. Oxygen Depletion A	mg/m2-d	990.2	750.7
Hypol. Oxygen Depletion V	mg/m3-d	1076.3	816.0
Organic Nitrogen	ppb	580.5	419.3
Non Ortho Phosphorus	ppb	37.3	25.6
Chl-a x Secchi	mg/m2	12.5	7.7
Principal Component 1	-	2.73	2.45
Principal Component 2	-	0.86	0.72
	Observed	Pred	Target
Carlson TSI P	56.8	57.0	51.5
Carlson TSI Chl-a	58.5	58.4	53.0
Carlson TSI Secchi	58.5	64.5	63.5
OBSERVED / PREDICTED RATIOS...			
Phosphorus		0.99	1.01
Chlorophyll-a		1.01	1.02
Secchi		1.51	1.65
OBSERVED / PREDICTED T-STATISTICS...			
Phosphorus		-0.05	0.04
Chlorophyll-a		0.04	0.08
Secchi		1.52	1.85

VARIABLE	UNITS	Current	LC
RESPONSE CALCULATIONS...			
Reservoir Volume	hm3	2.85	2.85
Residence Time	yrs	0.6787	0.6787
Overflow Rate	m/yr	3.7	3.7
Total P Availability Factor		1	1
Ortho P Availability Factor		0	0
Inflow Ortho P/Total P		0.000	0.000
Inflow P Conc	ppb	49.6	33.9
P Reaction Rate - Mods 1 & 8		1.2	0.8
P Reaction Rate - Model 2		#DIV/0!	#DIV/0!
P Reaction Rate - Model 3		3.4	2.3
1-Rp Model 1 - Avail P		0.581	0.646
1-Rp Model 2 - Decay Rate		#DIV/0!	#DIV/0!
1-Rp Model 3 - 2nd Order Fixed		0.417	0.477
1-Rp Model 4 - Canfield & Bachman		0.516	0.571
1-Rp Model 5 - Vollenweider 1976		0.548	0.548
1-Rp Model 6 - First Order Decay		0.596	0.596
1-Rp Model 7 - First Order Setting		0.786	0.786
1-Rp Model 8 - 2nd Order Tp Only		0.581	0.646
1-Rp - Used		0.786	0.786
Reservoir P Conc	ppb	39.0	26.7
Gp		0.490	0.490
Bp	ppb	31.0	18.4
Chla vs. P, Turb, Flushing	2	14.0	8.7
Chla vs. P Linear	4	10.9	7.5
Chla vs. P 1.46	5	17.0	9.8
Chla Used	ppb	17.0	9.8
ml - Nuisance Freq Calc.		2.8	2.2
z		-0.824	0.758
v		0.284	0.299
w		0.785	0.799
x		0.205	0.224

ORTHO P LOADS...				TOTAL P LOADS... BAF Override (KS)	OrP %		
Precipitation	kg/yr	0	0	0.5	0%	52	52
NonPoint	kg/yr	0	0	0.23	0%	791	505
Point	kg/yr	0	0	0.8	0%	0	0
Total	kg/yr	0	0			843	558
Total	#/year	0	0			1855	1227

Appendix C.

Conversion to Daily Loads as Regulated by EPA Region VII

This TMDL has estimated an annual average load for TP that if achieved should meet the water quality targets. A recent court decision often referred to as Anacostia decision has dictated that TMDL includes a "daily" load (Friends of the Earth, Inc v. EPA, et al.)

Expressing this TMDL in daily load could be misleading in implying 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 loads, and algal response.

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

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

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

CV = Coefficient of variation = Standard Deviation/Mean

Z = 2.326 for 99th percentile probability basis

Current Annual TP Load = 1740 lbs/yr

Annual TP Load (Goal) = 1110 lbs/yr

CV = 0.45 (for TP)

e $^{[Z\sigma - 0.5\sigma^2]}$ = 2.475 (99% Multiplier)

Current or Goal Maximum Daily Atmospheric Deposition TP Load = [(115 lbs/yr)/(365 days/yr)] * 2.475 = 0.78 lbs/day

Current Maximum Daily TP Load = [(1740 lbs/yr)/(365 days/yr)] * 2.475

= 11.8 lbs/day

Maximum Daily TP Load (Goal) = [(1110 lbs/yr)/(365 days/yr)] * 2.475

= 7.5 lbs/day