Trophic State Analysis of Pottawatomie State Fishing Lake No. 1;

Water Quality Impairment: Eutrophication, Dissolved Oxygen

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by

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1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Lower Kansas **County: Pottawatomie**

Drainage Area: ~1.5 sq. mi.

Conservation Pool: 168 ac-ft

Designated Uses: Secondary Recreational Contact, Aquatic Life Support

Impaired Use: Both uses potentially impaired

Background: Pottawatomie State Fishing Lake No. 1 is mainly used for fishing and, in some ways, is managed as a fishery. According to data collected intermittently between 1981 and 2001 by the Kansas Department of Health and Environment (KDHE), chlorophyll *a* levels ranged from 2.1 to 33.6 μg/L. However, the last survey conducted in 2005 shows a substantial increase in the chlorophyll *a* level (203.4 μg/L). Pottawatomie State Fishing Lake No. 1 was listed under the KDHE 2008 303(d) List[1] as a water-quality impaired reservoir for dissolved oxygen (DO) and eutrophication. Together, fluctuations in chlorophyll *a* levels, nutrient enrichment and low dissolved oxygen illustrate the instability of this reservoir and its resulting inefficiency as an aquatic ecosystem capable of sustaining an ecological balance between biota and vegetation. There is a need to monitor current water-quality conditions and evaluate management priorities with respect to the causes of these impairments, i.e., if impairment persists, a total maximum daily load (TMDL) has to be developed for this lake by KDHE, as required by the Clean Water Act.

2. CURRENT WATER QUALITY CONDITION

Level of Eutrophication: Very Eutrophic – Trophic State Index = 61.9

Table 1. Interpolated values for Carlson (1977) TSI parameters.

Variable	2008 AVG	TSI
Chl *a*	21.3 ppb	60.4
TP	60.8 ppb	62.7
Secchi	0.87 m	62.6

Current Condition: During the summer of 2008, Pottawatomie SFL #1 had elevated levels of chlorophyll *a* and total phosphorous (Table 1). Chlorophyll *a* and total phosphorous levels in addition to the average recorded Secchi depth all indicate that the lake is *Very Eutrophic* according to the Carlson TSI.[2] The Trophic State Index was derived by averaging TSIs for chlorophyll *a*, total phosphorous and Secchi disk measurements.

[1] http://www.kdheks.gov/tmdl/download/2008_303d_List.pdf
[2] Carlson, R.E. 1977. A Trophic State Index for Lakes. *Limnology and Oceanography*: 22(2) 361-369.

Dissolved Oxygen averaged 6 mg/L during the summer. In late July, DO levels of 0.13 were detected in a stratified segment of the lake at a depth of 5 m.

Based on a nutrient limitation bioassay, little to no NO_3-N in the water column and an average TN:TP ratio of 11.8, the lake appears to be N-limited. PO_4-P showed an average concentration of about 13.3 ppb. Laboratory bioassay experiments were conducted in algal fluorescence was measured for four groups of lake samples, three treated with nutrients (N, P, N+P) and one control. The bottles spiked with P showed no response, whereas bottles spiked with N and N+P showed slight increases in algal fluorescence, indicating algal growth had occurred with the addition of N (Figure 1). Furthermore, dissolved N concentrations (NO_3-N) within the lake were near or below the detection limit of 0.01 mg/L from July to September of 2008.

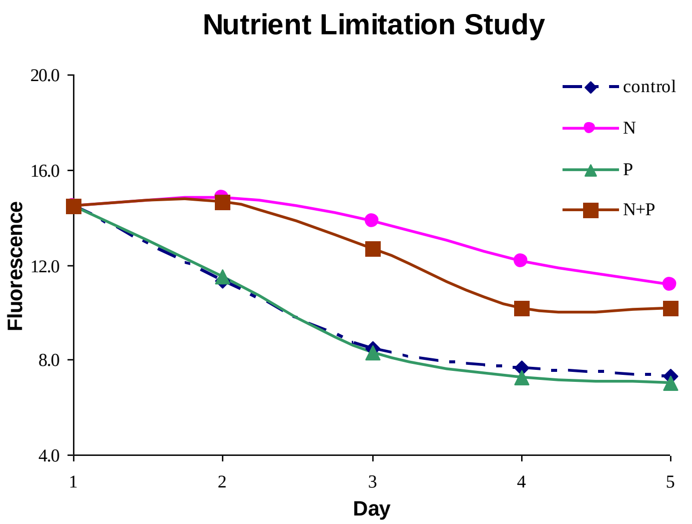

Figure 1. Bioassay results for nutrient limitation study represented as average of three replicates per treatment.

The N:P ratio by weight was between 10 and 14 during the study period, where <10 is generally considered N-limiting and between 10 and 20 indicates co-limitation by N and P. Therefore normal lake conditions may favor organisms that can fix nitrogen from the atmosphere, like cyanobacteria. Together with an average excess of organically available phosphate between 10 and 20 μg/L, any influx of nitrate via migratory birds, sediment resuspension or artificial mixing of anoxic and oxic layers may stimulate excessive algal growth.

3. SOURCE AND INVENTORY ASSESSMENT

External loading: The lake is located five miles north of Westmoreland in northeast Kansas. The lake surface area is 24 acres and the average depth is 6 to 8 feet, with the maximum depth of about 17 feet. The lake's ~1.5 sq. mi. watershed is mostly natural, dominated by woodlands and prairie that are mainly used for hunting or pasture. Of the two tributaries that feed the lake, one is intermittent, with flowing water only occasionally throughout the year and the other is spring-fed. Tributary 1 is the spring-fed tributary located on the north edge of the lake. During baseflow conditions, the tributary carries approximately 0.5 m^3/s or about 17.6 cfs. The stream was sampled 4 times during the study and had average total N and P of 0.16 mg/L and 17.5 μg/L respectively. Organically available N and P comprised 60-70% of the totals. One run-off event was captured using an Sigma® autosampler, which yielded average total N and P concentrations of 0.21 mg/L and 11.9 μg/L. For the western tributary (Tributary 2) standing water was observed once during the study along the lower 150 meters prior to it entering into the lake. Total N and P concentrations of 0.12 mg/L and 8.7 μg/L were recorded for Tributary 2 during this observation. Both tributaries had chlorophyll *a* levels below 1 μg/L. More often, the lake showed average total N and P concentrations that exceeded 0.719 mg/L and 60.8 μg/L. Hence, the northern and western tributaries and their watersheds are unlikely sources of nutrient loading.

Onsite Loading: Channel catfish, large mouth bass, crappie, and bluegill are common game fish species in the lake. Each year the lake is stocked with channel catfish. Fish are fed approximately 250 lbs of CLASSICALF 14% calf feed (Hubbard Feeds Inc., Mankato, MN 56001) every two weeks from late May to early September from a fish feeder. About 2000 lbs of food are loaded into the lake every year. Together with the sediment study discussed below, a sample of fish food was obtained from the lake manager and dissolved in water at concentrations of 1g/L and 0.1g/L to determine total nutrient loads from known concentrations of fish food. The total phosphorous of the fish food is 0.62% by weight and the total nitrogen content is 1.65%, which translates to 12 lbs P/year and 33 lbs N/year. While this is not a significant loading source of nitrogen, at roughly 0.07 mg/L per year with the estimated lake volume, the fish food does appear to be a major source of phosphorous, at 26.3 μg/L per year with the estimated lake volume, which may account for over half the total P detected in the lake during the study.

Internal Loading: A destratification unit was installed in the 1980's to help control aquatic vegetation and enhance the lake's capacity to sustain large populations of fish. At present, two of the three original Helixor model pump outlets placed around the basin area are functioning and must be adjusted throughout the season (Figure 3). Currently the pump is operated for 2 hours a day, during the day in May and at night from June to September (Figure 2).

The lake was found to be thermally stratified in late July of 2008 at a depth of 5m. This observation was made in the basin area and although it did not show an increase in nitrate relative to the rest of the lake (0.01 mg/L), other parameters were consistent with anoxic layers of stratified water bodies (i.e. 1060 μg/L NH_3; 0.13 mg/L DO; total N and P of 2.01 mg/L and 246 μg/L). These values were several times those detected in the rest of the lake and indicate that internal nutrient loading might be aided by the destratification unit. The pump outlets may not be at sufficient depth and not all of them are functioning, so the unit may need repairs if it is to fulfill its intended purpose.

Figure 2. Pictures of destratification unit (top left); pipes to diffusers (top right); surface above two functioning Helixor diffusers (bottom).

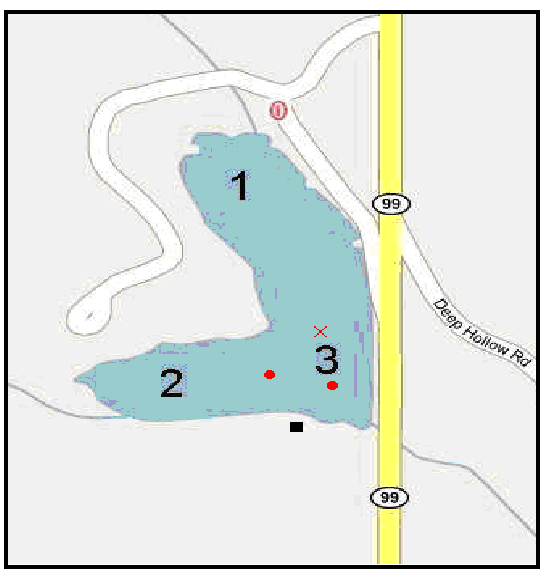

Figure 3. Map with sampling points (numbered) and pump outlets (functional – red dot, dysfunctional – red "x").

After sampling the lake from July to September of 2008 and determining that nutrient loading was most likely a result of internal sources, a sediment study was conducted in late April of 2009. Researchers collected sediment cores at the three main sampling sites in the lake and dissolved 1 g of dried sediment in 1 L of lake water. Bottles were filled in replicates of two, left covered on the lab bench and mixed for about 10 min a day for 5 days. They were then analyzed for total N and P (Table 2).

Table 2. Average results for total N and P of 1g dry sediment dissolved in 1 L lake water.

Site	Description	TP (ppb)	TN (ppm)
1	Boat Ramp	67.6	0.855
2	Fish Feeder	99.4	1.06
3	Basin	82.6	0.969
3	Control	26.2	0.519

4. SUMMARY OF MANAGEMENT PRIORITIES AND RECOMMENDATIONS

Impairments to Pottawatomie SFL #1 result from the lake being managed beyond its natural carrying capacity as a fishing lake. It appears that the external nutrient loadings to this lake are very limited in nature and the watershed is mostly in permanent ground cover (e.g. woodland, prairie, rangeland and pasture) with more intensely cropped areas having terraces and contour farming practices in place. However, loads of calf feed and artificial attempts to destratify the lake in the summer months collectively make the lake unstable with regard to water quality and possible long-term ecological health. Thus, our recommendations focus on lake management options that could reduce other sources of nutrients made available to the lake and increase DO levels during the summer months. Recommendations below should be conducted for a two-year period along with monitoring until the lake is restored to a more stable trophic state.

1) **Reduce feed volume by 50-75% and change to fish food**

   Smaller volumes of feed will reduce the cost so that a higher quality fish food might be purchased.

2) **Repair and extend the daily operation the destratification unit**

   It appears that the lake is allowed to stratify despite the use of a dysfunctional destratification unit and its faulty diffusers. At its present operational capacity and schedule, the unit may be limited in its ability to maintain stable DO concentrations and ultimately detrimental to the lake’s ecological health. DO levels during summer of 2008 were around 6 ppm, however with respect to the trophic state of the lake this level is insufficient to buffer against a sudden influx of nitrate and the resulting algal growth and die-off. By repairing and running the destratification unit for more time during the summer months, the DO in the lake should increase and the long-term oxygen demand of the sediment should decrease.

APPENDIX A: In-situ measurements for July-Sept 2008

Site ID	Depth m	Date	Temp °C	pH	Conductivity mS/cm	Turbidity NTU	DO mg/L	Secchi m
1	0.25	7/23/2008	28.2	8	0.258	17	6.2	0.9
1	1	7/23/2008	28.3	7.9	0.258	16	6	
1	3	7/23/2008	28	7.7	0.258	21	4.7	
1	0.25	8/27/2008	25	7.95	0.3	20	6.3	0.9
1	1	8/27/2008	24.7	7.69	0.301	20	6.3	
1	2.5	8/27/2008	24.6	7.69	0.301	19	6.3	
1	0.25	9/22/2008	21	8.15	0.296	14	8.4	0.93
1	1	9/22/2008	20.9	8.04	0.296	15	8.3	
1	2.5	9/22/2008	20.9	7.83	0.296	14	8.3	
2	0.25	7/23/2008	28.1	7.7	0.257	14	4.6	0.9
2	1	7/23/2008	28.1	7.6	0.257	14	4.8	
2	2.5	7/23/2008	27.8	7.2	0.307	70	3.9	
2	0.25	8/27/2008	25.4	7.94	0.3	21	6.2	0.85
2	1	8/27/2008	24.8	7.76	0.3	25	5.7	
2	2.25	8/27/2008	24.4	7.63	0.301	24	4	
2	0.25	9/22/2008	21.1	8	0.294	15	8.5	0.82
2	1	9/22/2008	20.8	7.82	0.294	14	8.2	
2	2.5	9/22/2008	20.4	7.31	0.295	14	6	
3	0.25	7/23/2008	28.3	7.9	0.259	19	4.8	0.75
3	1	7/23/2008	28	7.7	0.259	19	4.3	
3	3	7/23/2008	27.5	7.2	0.259	19	1.7	
3	5	7/23/2008	23.5	6.7	0.259	13	0.13	
3	0.25	8/27/2008	24.7	7.82	0.301	23	5.2	0.8
3	1	8/27/2008	24.5	7.3	0.3	23	5.4	
3	3	8/27/2008	24.2	7.18	0.301	19	4.6	
3	4	8/27/2008	24.1	7.14	0.302	19	5	
3	0.25	9/22/2008	21.2	8.2	0.294	18	8.4	0.93
3	1	9/22/2008	21	8.18	0.294	14	8.9	
3	3	9/22/2008	20.6	7.65	0.295	15	7.4	
3	4	9/22/2008	20.2	7.27	0.299	16	3.9	
Tribs								
S1*	-	7/23/2008	23.1	8	0.458	24	7.7	
S1	-	8/27/2008	20.5	8.1	0.538	16	8.2	
S1	-	9/15/2008	15.6	7.96	0.453	32	8.5	
S1	-	9/22/2008	18.6	8.01	0.517	5	8.5	
S2*	-	9/15/2008	18.7	7.78	0.489	2	6.18	

*S1 refers to the northern tributary and S2 to the western.

APPENDIX B: Laboratory results

Site ID	Depth m	Date	NO_3+NO_2 mg-N/L	NO_2 mg-N/L	NH_3 µg-N/L	TN mg-N/L	PO_4 µg-P/L	TP µg-P/L	Chl *a* µg/L	Pheo *a* µg/L
1	0.25	6/25/2008	-	-	-	-	-	-	99.6	5.8
1	0.25	7/23/2008	< 0.01	< 0.01	55.8	0.77	13.9	56.9	31.4	5.7
1	1	7/23/2008	< 0.01	< 0.01	42.1	0.82	18.1	61.0	32.9	6.4
1	3	7/23/2008	< 0.01	< 0.01	42.4	0.71	16.5	58.6	17.9	6.1
1	0.25	8/27/2008	< 0.01	< 0.01	16.7	0.59	10.9	43.0	17.6	6.2
1	1	8/27/2008	< 0.01	< 0.01	23.8	0.55	11.6	49.8	23.9	6.6
1	2.5	8/27/2008	0.02	< 0.01	31.4	0.68	12.4	51.7	21.7	5.6
1	0.25	9/22/2008	< 0.01	< 0.01	15.7	0.59	4.1	49.3	15.3	3.8
1	1	9/22/2008	0.01	< 0.01	18.3	0.63	3.8	49.3	16.4	3.5
1	2.5	9/22/2008	0.05	0.01	16.3	0.61	6.4	51.9	16.4	3.7
2	0.25	7/23/2008	< 0.01	< 0.01	47.0	0.75	11.9	52.3	22.4	6.2
2	1	7/23/2008	< 0.01	< 0.01	66.1	0.76	12.5	51.3	25.4	3.5
2	2.5	7/23/2008	0.02	0.01	46.3	0.75	12.2	59.0	26.9	9.4
2	0.25	8/27/2008	0.04	< 0.01	26.0	0.63	19.8	47.4	21.3	5.2
2	1	8/27/2008	0.05	< 0.01	90.9	0.81	19.2	65.4	24.3	6.0
2	2.25	8/27/2008	0.01	< 0.01	50.9	0.69	16.7	58.4	20.5	7.5
2	0.25	9/22/2008	0.05	< 0.01	45.1	0.79	13.8	56.3	13.4	4.0
2	1	9/22/2008	0.06	< 0.01	19.4	0.62	8.0	49.5	14.2	4.3
2	2.5	9/22/2008	0.04	0.01	41.3	0.63	16.7	56.6	16.1	4.4
3	0.25	7/23/2008	0.02	< 0.01	47.3	0.76	16.4	60.2	34.4	10.4
3	1	7/23/2008	< 0.01	< 0.01	44.1	0.79	19.5	66.2	47.8	< 1
3	3	7/23/2008	< 0.01	< 0.01	53.0	0.65	14.5	51.4	8.6	7.2
3	5	7/23/2008	0.01	< 0.01	1060	2.01	27.1	246	19.4	34.0
3	0.25	8/27/2008	0.01	< 0.01	34.9	0.58	12.1	47.8	19.8	5.8
3	1	8/27/2008	< 0.01	< 0.01	27.2	0.63	18.9	54.7	26.5	6.7
3	3	8/27/2008	0.01	< 0.01	30.5	0.63	15.2	54.1	18.3	6.5
3	4	8/27/2008	< 0.01	< 0.01	27.8	0.62	13.9	55.1	16.6	7.2
3	0.25	9/22/2008	0.03	0.01	13.9	0.61	3.6	50.0	15.7	3.9
3	1	9/22/2008	0.02	0.01	35.3	0.65	18.3	61.3	18.7	4.2
3	3	9/22/2008	0.09	0.01	19.4	0.63	6.4	56.7	17.6	4.5
3	4	9/22/2008	0.01	< 0.01	18.9	0.64	4.7	52.7	17.2	2.2
Lake Averages			0.03	0.01	70.26	0.72	13.30	60.80	21.3	6.6
Tribs										
S1*	-	7/23/2008	0.16	0.01	42.9	0.22	6.6	16.7	< 1	< 1
S1	-	8/27/2008	0.12	< 0.01	14.4	0.18	14.3	15.0	< 1	< 1
S1	-	9/15/2008	0.21	0.01	37.5	0.29	10.7	24.1	< 1	< 1
S1	-	9/22/2008	0.16	< 0.01	12.1	0.18	13.7	14.0	< 1	< 1
S2*	-	9/15/2008	0.04	< 0.01	17.2	0.12	6.5	8.7	< 1	< 1

*S1 refers to the northern tributary and S2 to the western.