UPPER REPUBLICAN BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody: Lovewell Lake (Lovewell Reservoir)
Water Quality Impairment: Eutrophication and pH

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Middle Republican **Counties:** Jewell and Smith

HUC 8: 10250016 **HUC 10 (12):** 07 (01, 02, 03, 04, 05, 06, 07)

Ecoregion: Central Great Plains, Rolling Plains and Breaks (27b)

Drainage Area: 345 square miles

Conservation Pool: Surface Area = 2986 acres
Watershed/Lake Ratio: 72:1
Maximum Depth = 9.0 meters
Mean Depth = 3.6 meters
Storage Volume = 35,666 acre-feet
Mean Annual Inflow = 59,350 acre-feet/year
Mean Annual Discharge = 48,234 acre-feet/year
Constructed: 1957

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

303(d) Listings: Lovewell Lake Eutrophication and pH: 2002, 2004, 2008, 2010 Kansas Lower Republican River Basin Lakes. Total Phosphorus impairment for White Rock Creek: 2008 and 2010 Kansas Lower Republican River Basin Streams.

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

Water Quality Criteria: 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)(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 (K.A.R. 28-16-28e(c)(3)(A)).

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)).

The pH range outside the zone of initial dilution: 6.5-8.5 (K.A.R 28-16-28e(d), Table 1g).

2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Support for Designated Uses under 2010-303(d): Excessive nutrients are not being controlled and are thus impairing aquatic life, domestic water supply and contributing to objectionable algal blooms that contribute to the Eutrophication and impairment of contact recreation within Lovewell Lake.

Level of Eutrophication: Hypereutrophic, Trophic State Index = 64.9

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 conditions is seen with chlorophyll *a* over 12 ppb and hypereutrophy occurs at levels over 30 ppb. 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: 64

Lake Monitoring Sites: KDHE Station LM015001 at Lovewell Reservoir.
Period of Record: Six surveys conducted by KDHE in calendar years 1992, 1995, 1998, 2001, 2004 2007 and 2010.

Stream Chemistry Sites: KDHE Rotational Station SC508 at White Rock Creek near Burr Oak.
Period of Record: Every four years 1990-2010.

Courtland Canal: Nebraska DEQ Station SRE1CTLNK102.
Period of Record: May, June, July, August and September of 2007.

Flow Record: U.S. Bureau of Reclamation: Lovewell total inflow and total discharge (1992-2007).
Kansas-Bostwick Irrigation District No. 2: Courtland Canal diversions above and below Lovewell Lake (1992-2007).

USGS Gage 06853800: White Rock Creek near Burr Oak (1992-2007).

Long-Term Flow Conditions: Lovewell Lake stores water from White Rock Creek and diversions from the Republican River by way of the Courtland Canal. The Courtland Canal is operated by the Kansas Bostwick Irrigation District No. 2 (KBID), and supplies water for irrigation to 12,800 acres in Kansas above Lovewell Lake and 25,150 acres below Lovewell Lake. Water is released from Harlan County Lake in Nebraska for KBID and flows down the Republican River where it is diverted at the Superior-Courtland Diversion Dam to the Courtland Canal, which transports the release to Lovewell Lake for storage. The Courtland Canal then distributes Lovewell releases downstream for irrigation. According to the USGS Lake Hydro data, the mean runoff in the watershed is 2.0 inches per year; the mean precipitation in the watershed is 26.0 inches per year and the mean loss due to evaporation for the Lake is 53.7 inches per year. U.S. Bureau of Reclamation flow records for the years in which KDHE sampling took place are shown in Table 1. Total average inflow to Lovewell was split between flow from White Rock Creek (32,157 AF) and the Courtland Canal (29,912 AF) while the average discharge from Lovewell Lake to the Courtland Canal (36,878 AF) was nearly three times that of the average discharge to White Rock Creek (12,337 AF) highlighting Lovewell Lake's role as an irrigation storage facility. The mean annual discharge for the period of record is 49,215 acre-feet per year and the average computed mean inflow for the lake is 60,069 acre-feet per year (Table 1).

Table 1. USBR Inflow & Discharge records. White Rock Creek Inflow and Total Inflow are calculated values (Appendix A). Change in storage is the difference between the storage volume on January 1st and the storage volume on December 31st of the specified year.

	Inflow (acre-feet)			Discharge (acre-feet)			Change in Storage (acre-feet)	Total Phosphorus (µg/L)	Chl *a* (µg/L)
	White Rock Creek	Courtland Canal	Total	White Rock Creek	Courtland Canal	Total			
1992	28,522	27,875	56,397	22,659	12,074	34,733	14,840	85.0	34.5
1995	21,626	45,974	67,600	7,262	46,493	53,755	6,255	70.0	13.8
1998	48,730	28,570	77,300	23,499	49,058	72,557	-1,978	132	13.2
2001	40,883	26,117	67,000	9,208	47,244	56,452	2,487	239	45.9
2004	16,673	14,127	30,800	5,109	30,134	35,243	-12,454	59.5	42.5
2007	22,313	34,687	57,000	1,561	35,101	36,662	11,667	55.0	35.5
2010	46,356	18,030	64,386	17,061	38,043	55,104	526	299	45.7
Avg.	*32,157*	*27,912*	*60,069*	*12,337*	*36,878*	*49,215*	*3,049*	*134*	*33.0*

Figure 1. Total inflow and discharge in Lovewell Lake for 1992-2010.

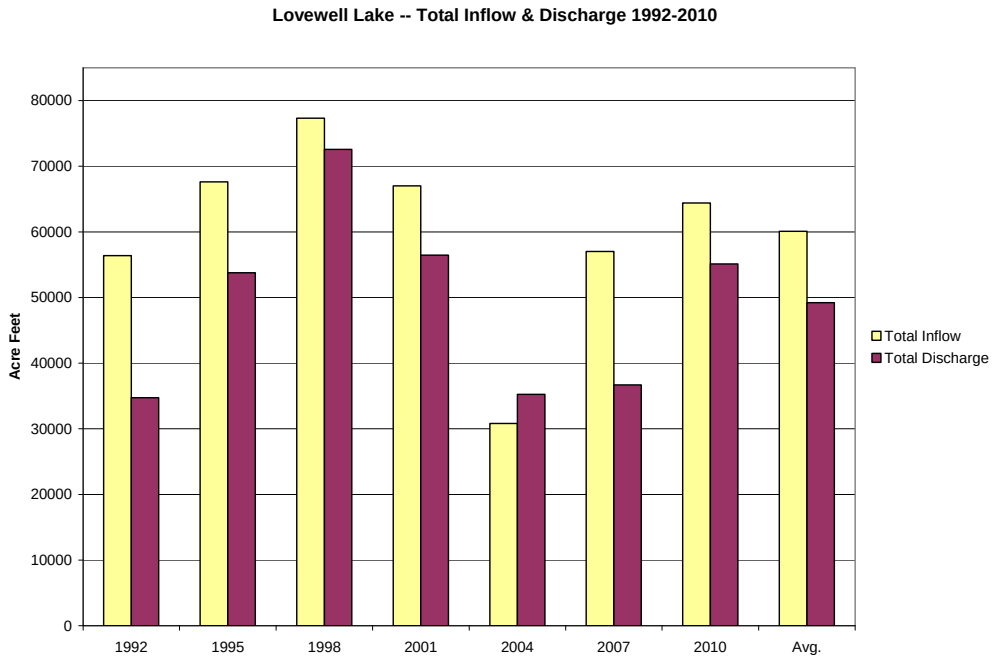
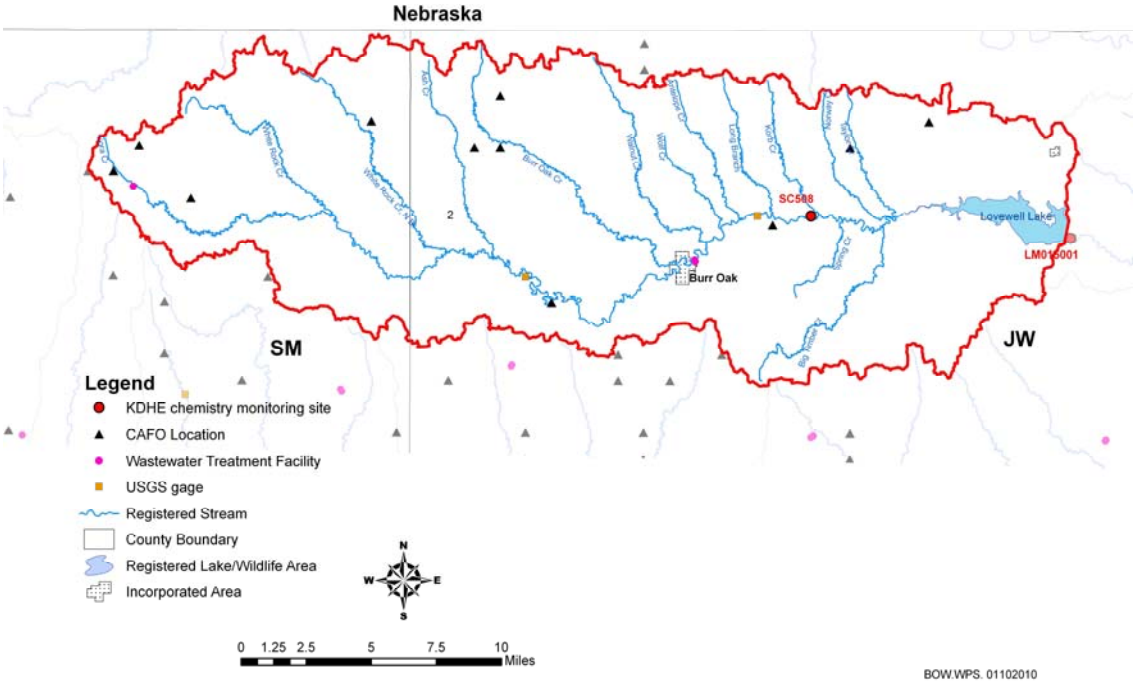
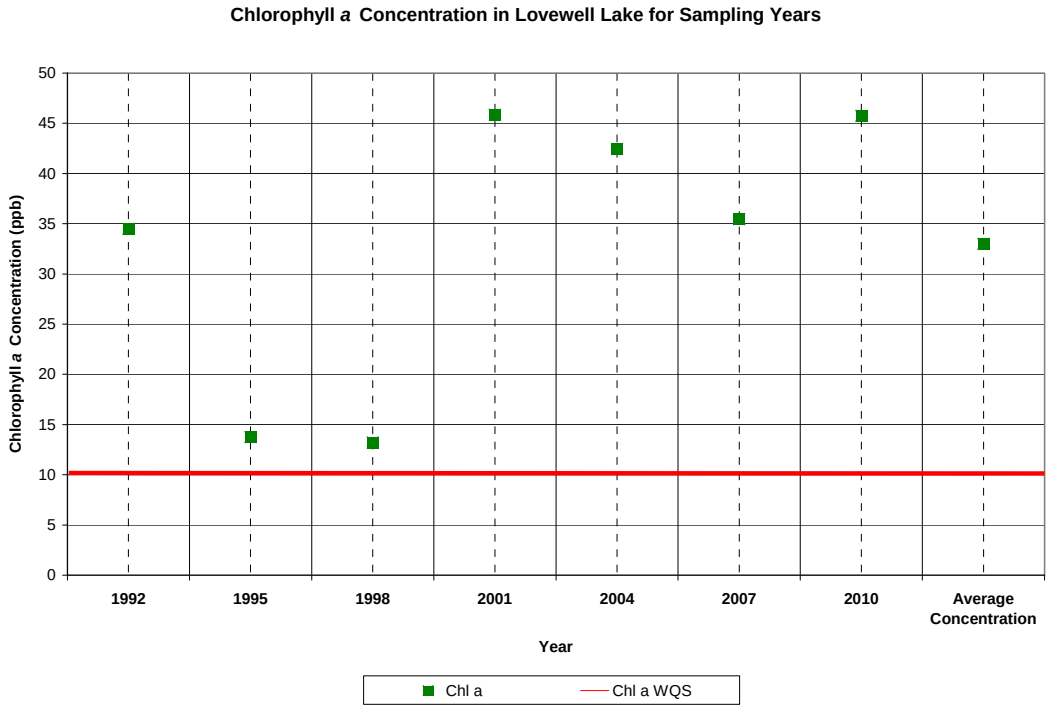


Figure 2. Lovewell Lake Watershed.



Current Conditions: Lovewell Lake has chlorophyll *a* concentrations averaging 33.0 µg/L, with a corresponding Trophic State Index (TSI) value of 64.9, for the period of record. Chlorophyll *a* concentrations were measured in samples taken during a single sampling event in the summers of 1992, 1995, 1998, 2001, 2004, 2007 and 2010 (Figure 3). As indicated, chlorophyll *a* concentrations decreased after 1992 but sharply rose to 45.7 ppb in 2001 and remained above 35.0 ppb through 2010.

Figure 3. Chlorophyll *a* concentrations at Lovewell Lake during 1992 – 2010 sampling years.



The average Secchi depth in Lovewell Lake is 0.66 meters, with the lowest reading occurring in 2010 at 0.38 meters (Figure 4). Turbidity in Lovewell Lake for the period of record averaged 11.9 NTU with a range of 5.90 to 28.0 NTU. Total suspended solids (TSS) ranged from 9.00 to 38.5 mg/L with an average of 18.6 mg/L (Table 2). Total phosphorus (TP) concentrations average 134 µg/L, ranging from 55.0 µg/L in 2007 to 299 ug/L in 2010, while total nitrogen (TN) concentrations over these years ranged from 0.91 mg/L in 1992 to 2.22 mg/L in 1995, with an average of 1.27 mg/L (Figure 5).

Figure 4. Secchi Depth at Lovewell Lake for the period of record.

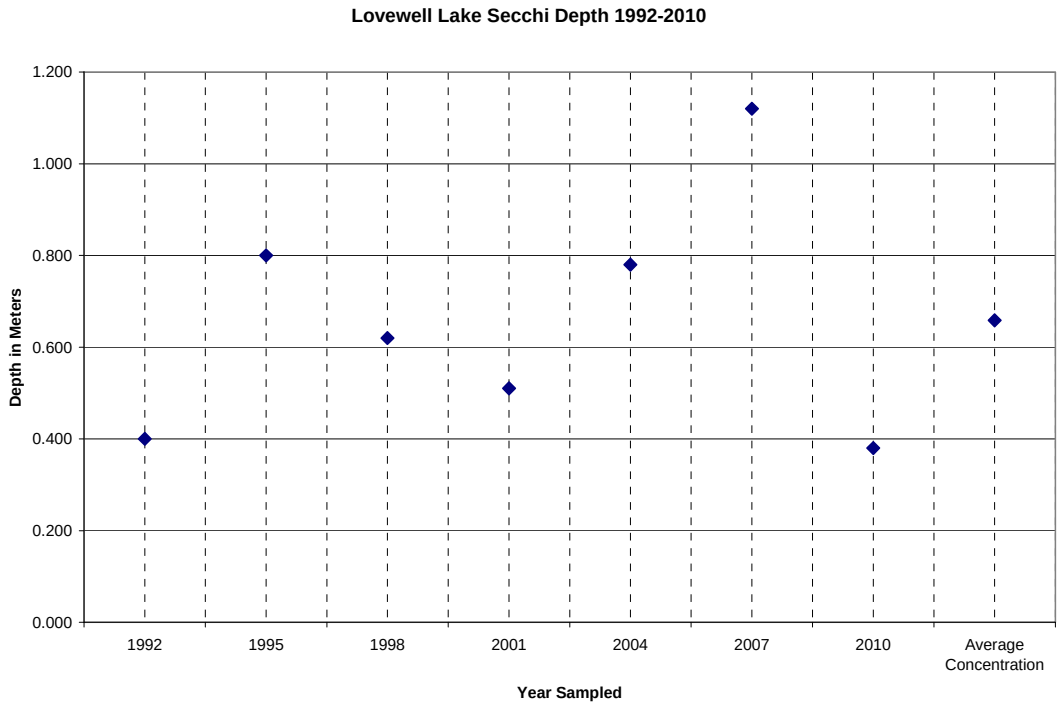
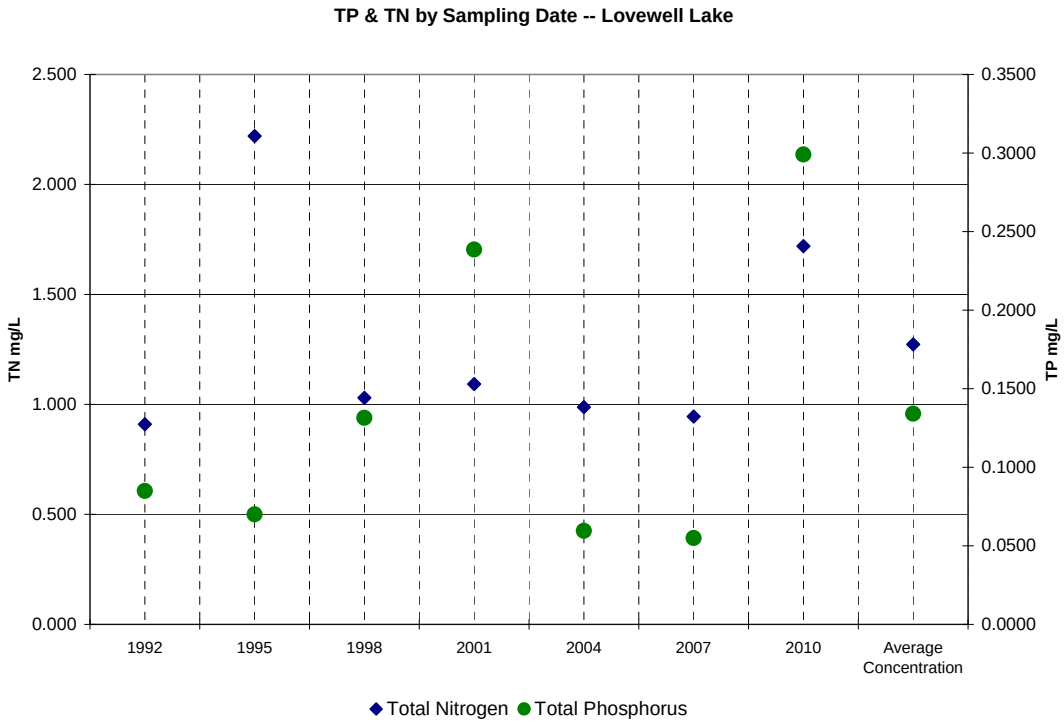
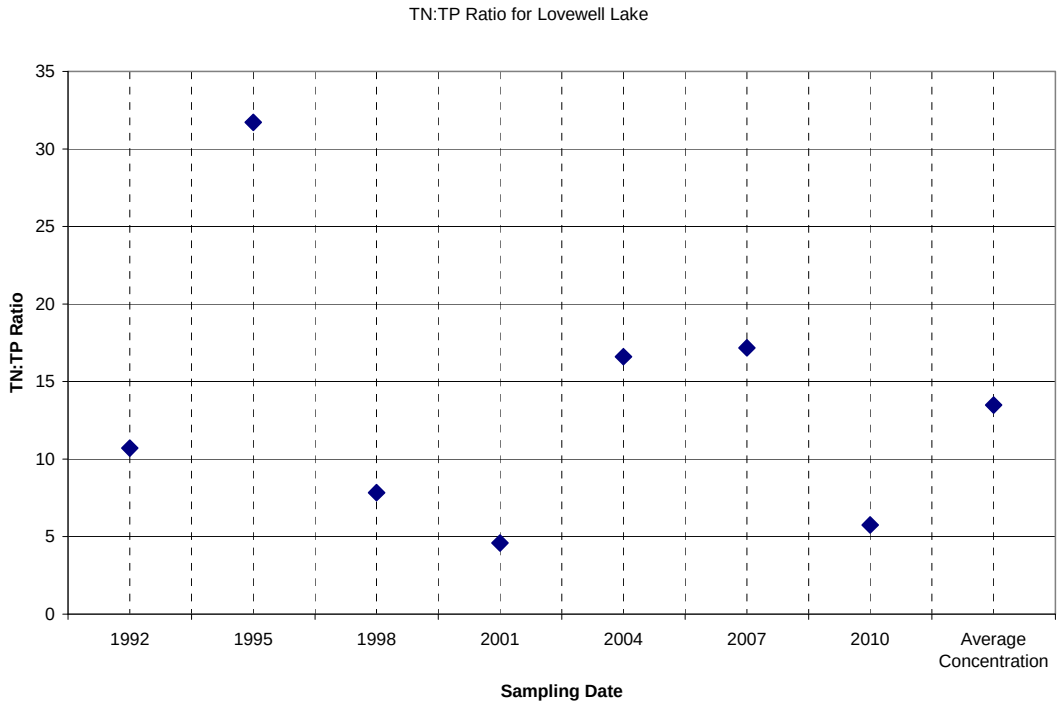


Figure 5. Average Total Phosphorus and Total Nitrogen concentration by sampling date.



The ratio of total nitrogen and 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 9 and 21; and lakes that are phosphorus limited have water column TN:TP ratios > 29 (Dzialowski et al., 2005). A ratio of 31.7 in 1996 is the only measurement for the period of record pointing to phosphorus limitation in Lovewell Lake. All other measurements indicate either a nitrogen limitation or nitrogen, phosphorus co-limitation with ratios ranging from 4.58 in 2001 to 17.2 in 2007 (Figure 6). Average TN:TP ratio for the period of record is 13.5.

Figure 6. TN:TP ratio for period of record at Lovewell Lake.



There is a weak correlation between chlorophyll *a* concentration and the TN:TP ratio with Figure 7 highlighting the nutrient limitation that exists in Lovewell Lake.

Figure 7. Chlorophyll *a* concentration vs. TN:TP Ratio

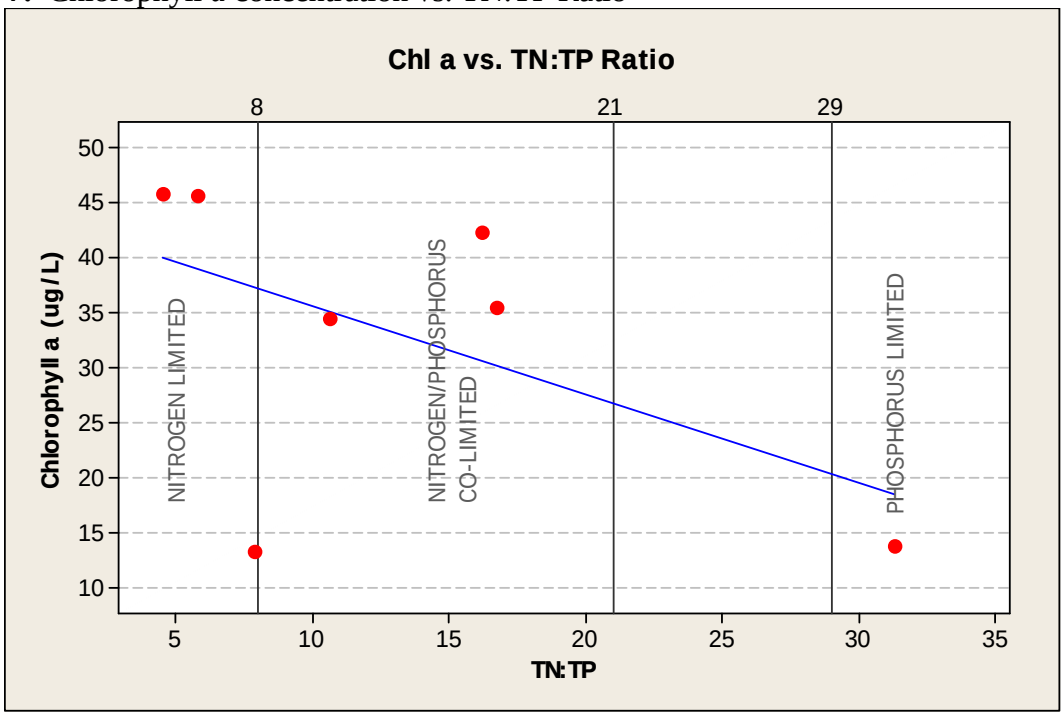


Table 2. Concentration averages for Lovewell Lake for the period of record.

Sample Year	Chl-a (µg/L)	TN (mg/L)	TP (mg/L)	TN:TP ratio	Secchi Depth (m)	Turbidity (NTU)	TSS (mg/L)	pH
1992	34.5	0.91	0.085	10.7	0.40	9.80	20.0	8.25
1996	13.8	2.22	0.070	31.7	0.80	5.90	9.00	8.20
1998	13.2	1.03	0.132	7.83	0.62	10.5	13.5	7.55
2001	45.9	1.09	0.239	4.58	0.51	11.8	16.0	8.55
2004	42.5	0.988	0.060	16.6	0.78	6.94	22.5	8.19
2007	35.5	0.945	0.055	17.2	1.12	10.4	10.5	7.83
2010	45.7	1.72	0.299	5.75	0.38	28.0	38.5	8.03
Average	*33.0*	*1.27*	*0.134*	*13.5*	*0.66*	*11.9*	*18.6*	*8.08*

A water quality standard violation for pH was observed once in 2001 with a value of 8.55 (Figure 8). In 2001, the observed chlorophyll *a* and phosphorus concentration were high at 45.9 µg/L and 239 µg/L, respectively. This likely influenced the pH within the lake at that time as increasing algal communities within a lake commonly leads to an increase in the level of pH due to photosynthesis. Algal communities can be reduced through nutrient reduction leading to pH concentrations that fall within the water quality standard of 6.5 to 8.5.

Figure 8. pH values for Lovewell Lake during period of record.

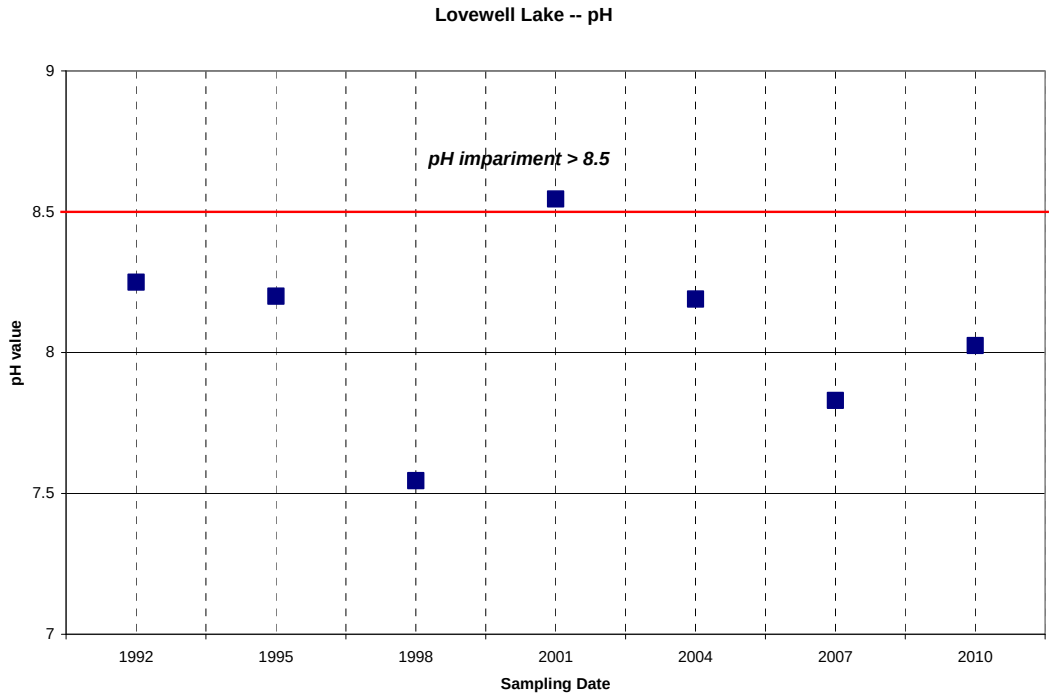


Table 3 lists the six metrics measuring the roles of light and nutrients in Lovewell Lake. Non-algal turbidity (NAT) values <0.4m^{-1} indicates there are very low levels of suspended silt and/or clay. The values between 0.4 and 1.0m^{-1} indicate inorganic turbidity assumes greater influence on water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

Table 3. Lovewell Lake limiting factor metrics.

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**	
1992	1.64	5.83	13.8	0.16	8.90	9.04	34.5
1995	0.91	3.23	11.0	0.20	4.45	5.78	13.8
1998	1.28	4.57	8.18	0.10	5.74	6.35	13.2
2001	0.82	2.90	23.4	0.19	6.98	8.80	45.9
2004	0.22	0.79	33.1	0.71	4.56	7.48	42.5
2007	0.01	0.24	39.7	0.64	3.18	6.44	35.5
2010	1.41	5.01	17.4	0.15	9.37	9.91	45.7

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). Inorganic 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 inorganic 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.

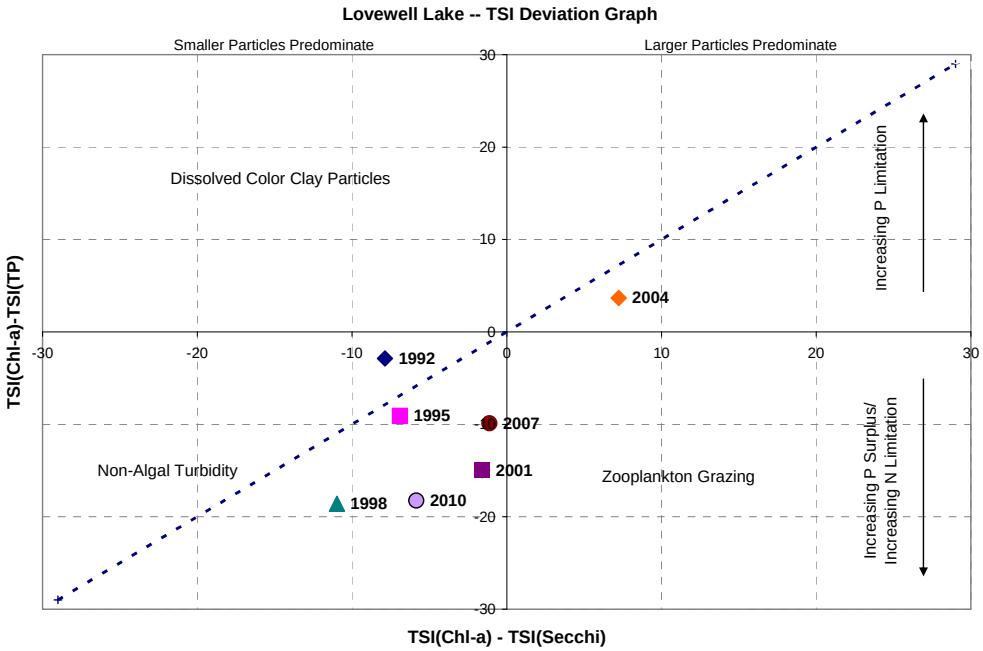
Shading values less than 16 indicate that self-shading of algae does not significantly impede productivity. This metric is most applicable to lakes with maximum depths of less than 5 meters (Carney, 2004).

The above metrics indicate that Lovewell Lake has abundant light in the mixed layer; inorganic turbidity is not responsible for light extinction in the water column; there is strong algal response to changes in nutrient levels and self shading of algae does not impede productivity.

Another method for evaluating limiting factors is the TSI deviation metrics. Figure 9 (Multivariate Deviation Graph) summarizes the current trophic conditions at Lovewell 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.

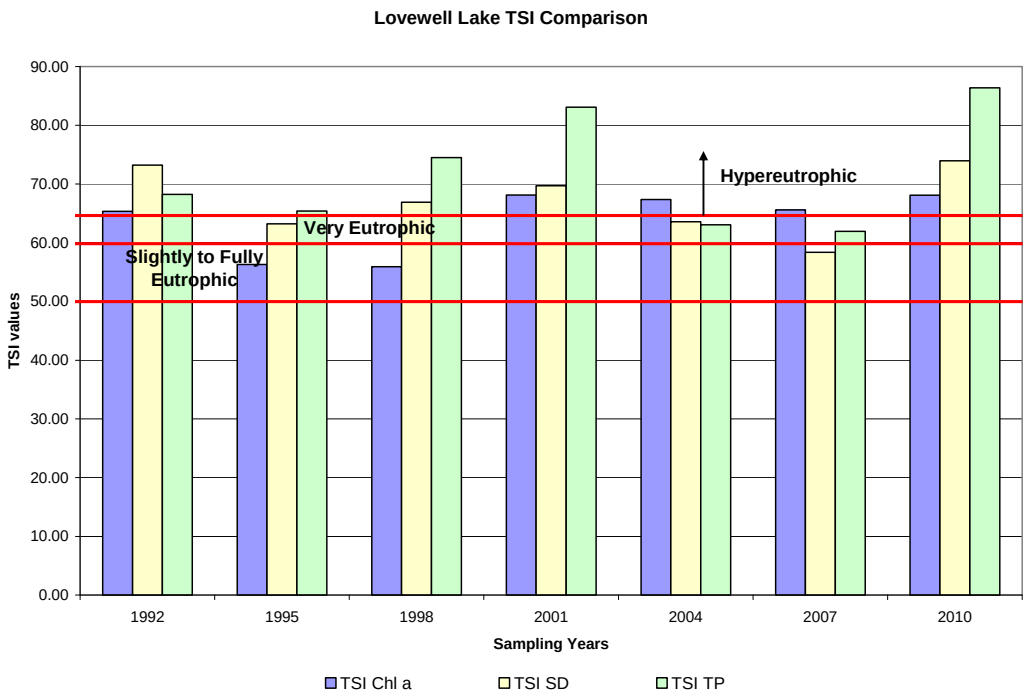
The multivariate TSI comparison chart in Figure 9 shows that for the years 1992, 1995, 1998, 2001, 2007 and 2010 non-algal turbidity limits Chlorophyll *a* concentration while inorganic turbidity is dominating transparency. 2004 data shows there is zooplankton grazing and phosphorus concentration may be limiting the production of Chlorophyll *a*.

Figure 9. Multivariate TSI comparison chart for Lovewell Lake.



The Carlson Trophic State Indices for Chlorophyll *a*, Secchi depth and total phosphorus in Lovewell Lake (Figure 10) shows a state of hypereutrophy for at least one of the three parameters each year Lovewell Lake samples were collected and analyzed. Conditions showed slight improvement in 2004 and 2007 but TSI values for all three parameters reached a state of hypereutrophy in 2010.

Figure 10. Lovewell Lake Trophic State Indices.



The median trophic conditions within Lovewell Lake compared to other Federal lakes in the state are summarized in Table 4. The trophic indicator values within Lovewell Lake do not meet any of the statewide or Central Great Plains benchmarks. Total phosphorus, however, is slightly better than the median value for Federal Lakes in Kansas.

Table 4. Median trophic indicator values of Lovewell Lake in comparison with other federal lakes and draft nutrient benchmarks in Kansas. The nutrient benchmarks were derived from 47-58 lakes and reservoirs, based on the data collected between 1985-2002 (Dodds et al., 2006).

Trophic Indicator	Lovewell Lake	Federal Lake	Central Great Plains	Statewide Benchmark
Secchi Depth (cm)	70.0	95	117	129
TN (µg/l)	1009	903	695	625
TP (µg/l)	77.5	76	44	23
Chlorophyll *a* (µg/l)	35.0	12	11	8

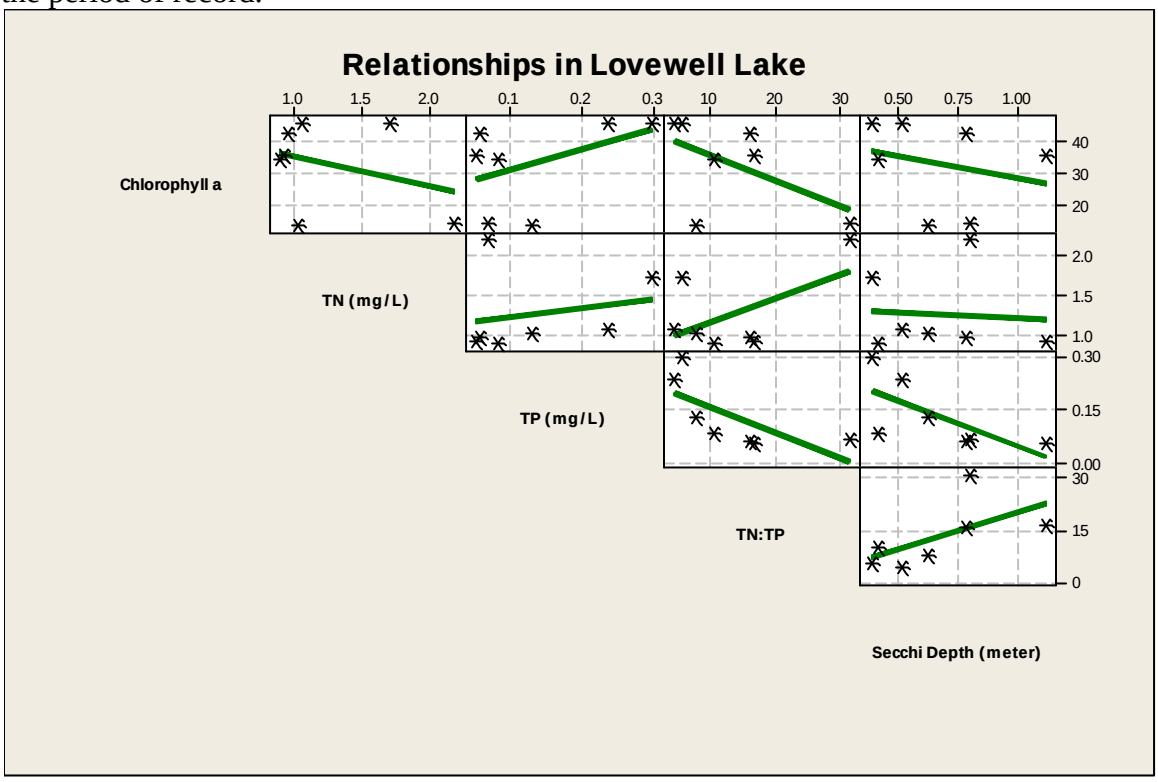
Algal Communities: As seen in Table 5, algal communities in Lovewell Lake have been dominated by blue-green algae, or cyanobacteria, since at least 2001. According to the 2007 survey of Lovewell Lake, algal communities, based on both cell count and biovolume, were dominated by blue-green algae (Carney, 2007). 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. It has been known that the blooms of blue-green algae are a major issue for Lovewell Lake and the intense episodic algal blooms required KDHE to issue public health advisories instructing the public to avoid contact with the water, avoid consuming fish or shellfish from the lake and to avoid watering livestock from the irrigation canals during the summer of 2010.

Table 5. Algal communities observed in Lovewell Lake during KDHE sampling years.

Sampling Date	Total Cell Count cells/mL	Percent Composition				Chl-*a* μg/L
		Green	Blue Green	Diatom	Other	
1992	15,500	48	30	19	<3	34.5
1995	11,030	45	0	43	12	13.8
1998	4,032	50	0	34	16	13.2
2001	93,177	5	93	1	<1	45.9
2004	178,196	10	89	1	<1	42.5
2007	140,616	0	100	0	<1	35.5
2010	127,780	<1	99	<1	0	45.7

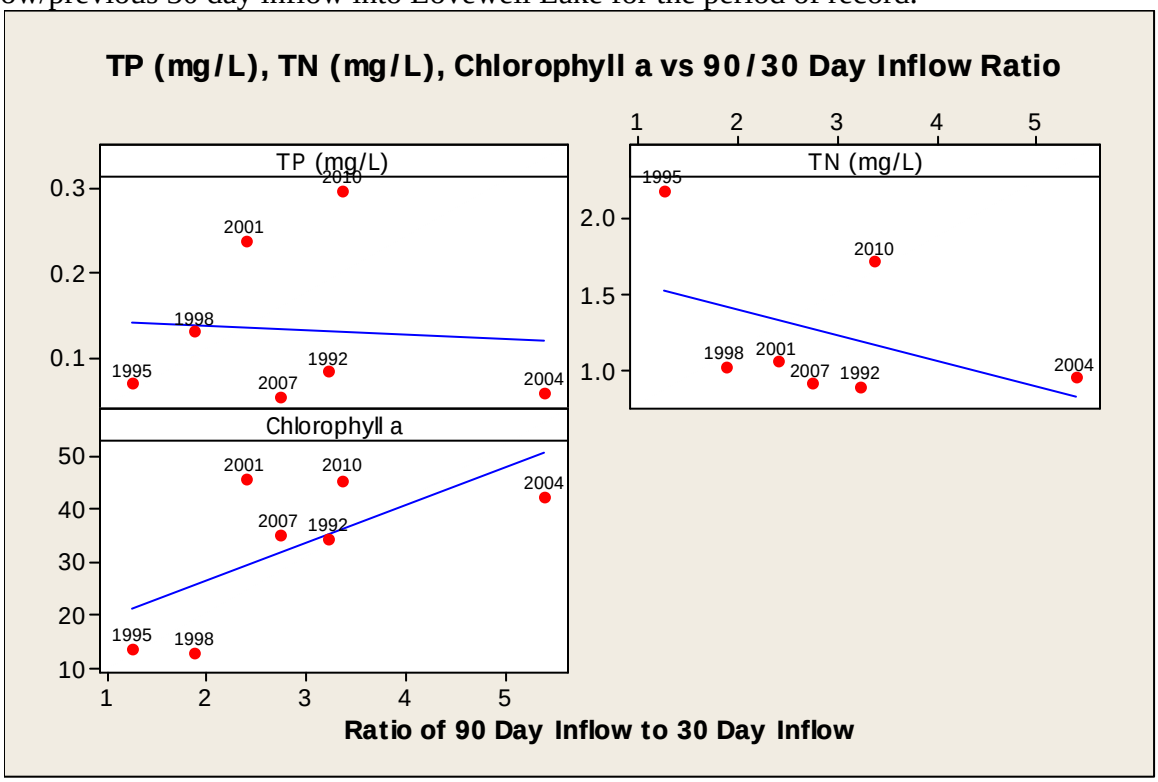
Relationships: Within Lovewell Lake there are poor relationships between: chlorophyll *a* and secchi depth; total nitrogen and total phosphorus; and total nitrogen and secchi depth. There is a minor relationship between: chlorophyll *a* and total nitrogen; chlorophyll *a* and total phosphorus and between chlorophyll *a* and the TN:TP ratio. There is a moderate relationship between: the TN:TP ratio and secchi depth and total phosphorus and secchi depth (Figure 11).

Figure 11. Relationship of Chlorophyll *a*, TN, TP, TN:TP and Secchi Depth in Lovewell Lake for the period of record.



A comparison of nutrients and chlorophyll *a* concentrations to the ratio of the inflow 90 days before sampling and the inflow 30 days before sampling (Figure 12) shows chlorophyll *a* concentrations increase as the 90 day to 30 day inflow ratio increases. This correlation indicates algae blooms in Lovewell Lake are stimulated by the nutrient loading that occurs during the first 60 days of the 90 day period, when inflows are higher, followed by 30 days of relatively low inflow when turbidity subsides allowing light into the mixed layer.

Figure 12. Relationship of TP, TN and Chlorophyll *a* to ratio of previous 90 day inflow/previous 30 day inflow into Lovewell Lake for the period of record.



Stream Data: The KDHE rotational site SC508 is the only KDHE stream monitoring station within the Lovewell Lake Watershed. SC508, located on White Rock Creek near Burr Oak, is scheduled to be sampled every four years and is listed as impaired by total phosphorus. Total nitrogen and inorganic nitrogen values for White Rock Creek are averages of the data generated from the 2002, 2006 and 2010 White Rock Creek collections at SC508 while the average total phosphorus value for White Rock Creek also includes samplings from 1990, 1994, and 1998. Ortho-phosphorus concentration in White Rock Creek was estimated by generating the ortho-phosphorus to phosphorus ratio in samples from 2002 (0.357) and 2010 (0.561). The ratios were then averaged (0.459) and used to estimate an ortho-phosphorus concentration for those samples that were below the reporting limit of 0.25 mg/L. The Nebraska Department of Environmental Quality sampled the Courtland Canal at the Nebraska-Kansas State line in May, June, July, August and September of 2007 and supplied results for inorganic nitrogen concentration in the Courtland Canal. The ratio of the inorganic nitrogen concentration in the Courtland Canal to the inorganic nitrogen in White Rock Creek at SC508 was generated (0.885) and used to estimate total phosphorus, ortho-phosphorus and total nitrogen in the Courtland Canal (Table 6).

Table 6. White Rock Creek and Courtland Canal average concentrations (µg/L).

Year	Number of Samples	TP	*o*-P	TN	N_{inorg}
White Rock Creek					
1990	5	272	No Data Available		
1994	7	323			
1998	6	388			
2002	5	278	107*	1724	713
2006	5	206	113*	1312	360
2010	4	367	181*	2869	2751
Total Average	32	307	131*	2068	1169
Courtland					
2007	21	272*	116*	1830*	1035

*Estimated concentration

USGS gage 06853800 is located on White Rock Creek near Burr Oak, Kansas. Flow data from 1990 to 2010 (Figure 13) shows an average flow of 26.2 cfs, a flow of 0.17 cfs at 90% flow exceedance and a flow of 41.4 cfs at 10% exceedance. With an increase in drainage area by 41 square miles, the estimated flow conditions on White Rock Creek near Lovewell Lake (Table 7) increases to an average flow of 42.1 cfs, a flow of 1.02 cfs at 90% flow exceedance and a flow of 62.2 cfs at 10% flow exceedance.

Figure 13. White Rock Creek at USGS 06853800, 1990-2010.

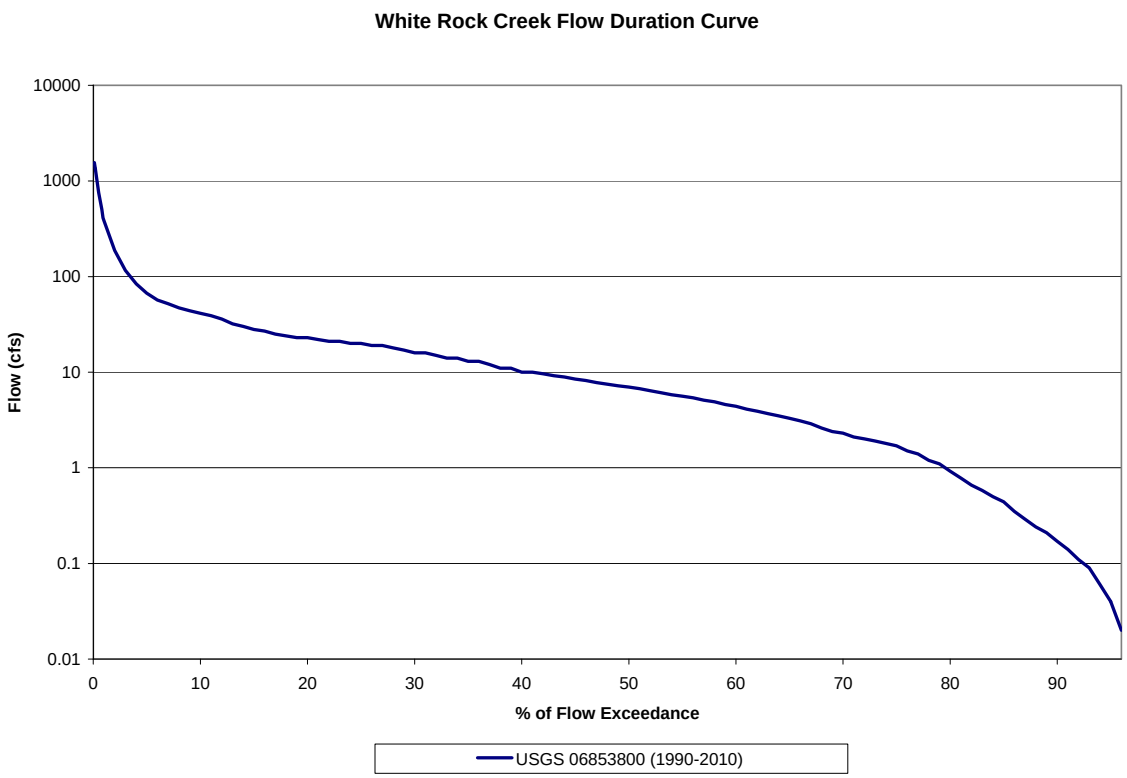
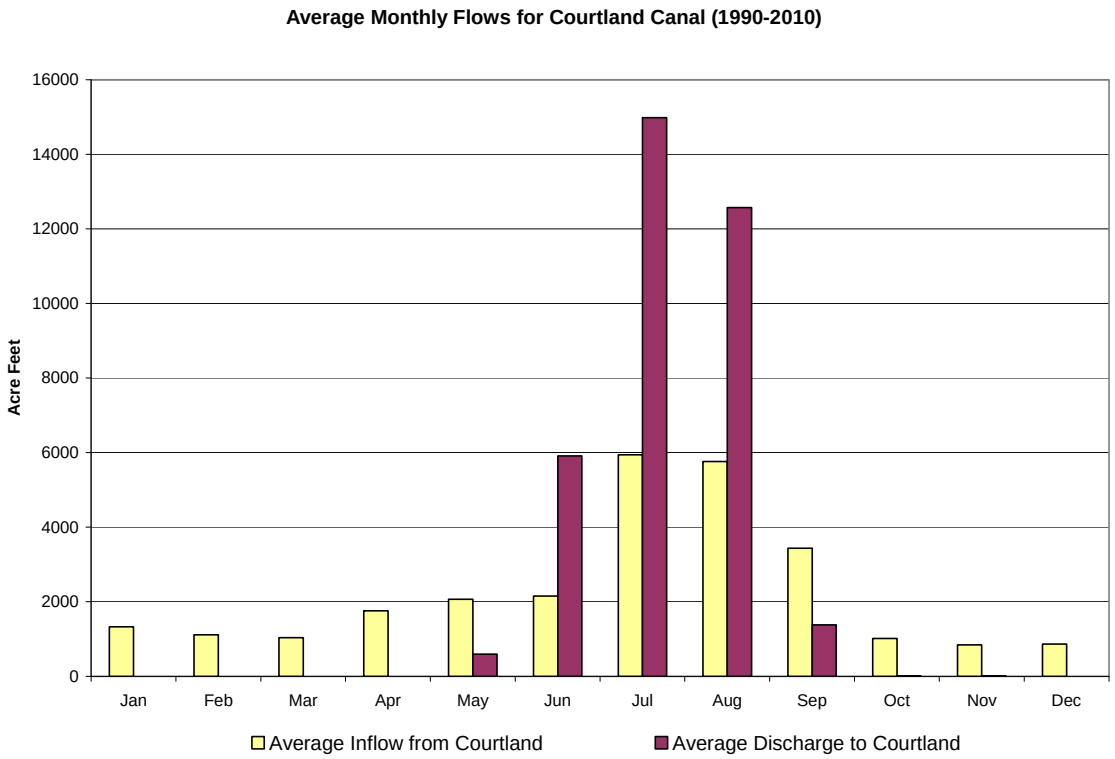


Table 7. Estimated flow-duration values, mean flow values, and peak-discharge frequency values for White Rock Creek (Perry, C.A., D.M. Wolock and J.C. Artman, 2004).

Stream Name	USGS Site ID	Drainage Area (mi^2)	Estimated Mean Flow (cfs)	90% (cfs)	75% (cfs)	50% (cfs)	25% (cfs)	10% (cfs)
White Rock Creek	259	288	42.1	1.02	3.27	9.87	26.2	62.2

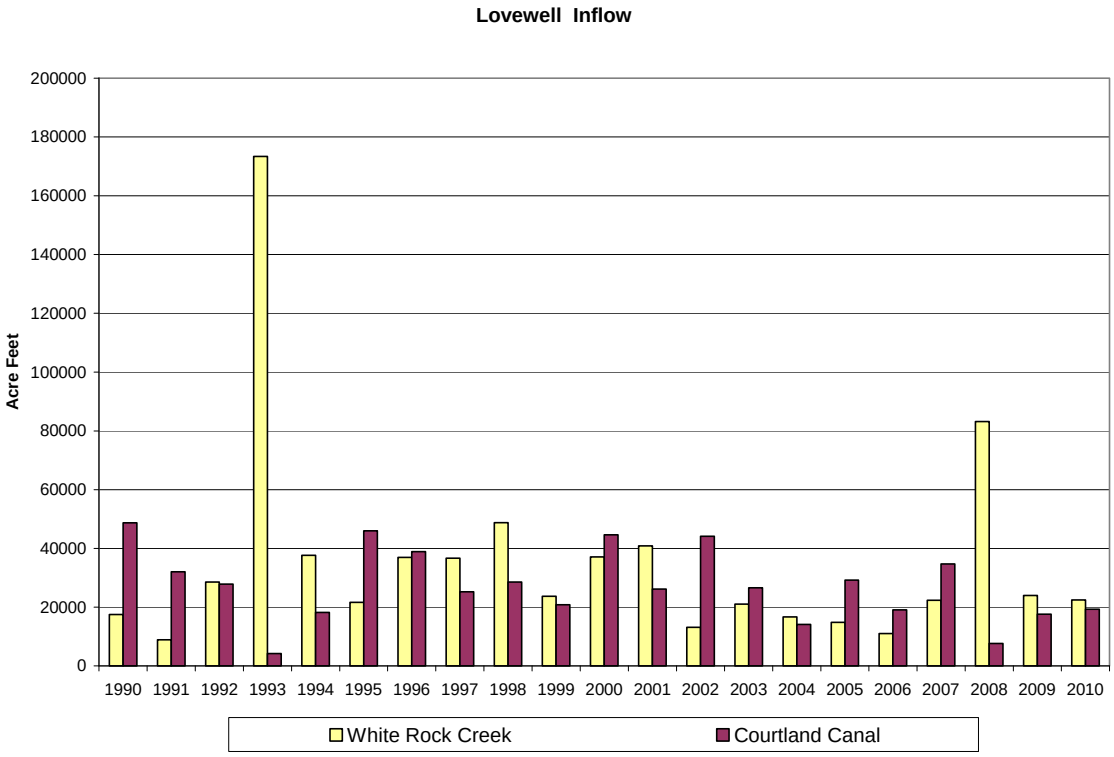
In order to maintain the active conservation level of 24,022 acre-feet while meeting irrigation demands, Courtland Canal diversions to Lovewell Lake usually occur over the course of the year with flow being the highest during the months of July, August and September. Diversions from Lovewell Lake to the Courtland Canal occur from May through September to meet agricultural demands below Lovewell Lake (Figure 14).

Figure 14. Average inflow and discharge by month for the Courtland Canal.



Flow into Lovewell Lake is split fairly equally between White Rock Creek and the Courtland Canal (Figure 15). The average flow into Lovewell Lake for the time period 1990 to 2010 is 35,253 AF/year for White Rock Creek and 27,316 AF/year for the Courtland Canal. If flow from 1993 is removed from the averages, they become nearly equal at 28,346 AF/year for White Rock Creek and 28,470 AF/year for the Courtland Canal.

Figure 15. Lovewell Lake inflow in acre-feet for White Rock Creek & Courtland Canal.



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

In order to improve the trophic condition of Lovewell Lake from its current Hypertrophic status, the desired endpoint will be to maintain summer chlorophyll *a* average concentrations below 10 µg/L, with the reductions focused on nutrients (TN and TP) entering the lake. Achievement of this endpoint should also result in pH values between 6.5 and 8.5. Improving the trophic condition of the lake should resolve the pH impairment since this impairment was observed in 2001 when the chlorophyll *a* concentration within the lake was at its maximum observed concentration through the sampling years. The reduction of chlorophyll *a* will lower photosynthesis rates within Lovewell Lake as higher photosynthesis rates cause pH levels to rise over 8.5.

The chlorophyll *a* endpoint of 10 µg/L is the statewide goal for Federal Lakes and lakes serving as Public Water Supplies, which will also ensure long-term protection to fully support Primary Contact Recreation within the lake. Based on the BATHTUB reservoir eutrophication model (see Appendix B), total phosphorus and total nitrogen concentrations entering the lake must be reduced by 79% for White Rock Creek and the Courtland Canal. In addition ortho-phosphourus must be reduced by 94% and 91% and inorganic nitrogen must be reduced by 91% and 90% in White Rock Creek and the Courtland Canal, respectively. These reductions at the inflows to Lovewell Lake will result in a 79% reduction of total phosphorus, 75% reduction of total nitrogen, and a 76% reduction of Chlorophyll *a* within the lake (Table 8). Achievement of the endpoint 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. Water quality data for the White Rock Creek tributary was averaged based on data from 1990-2010 from KDHE sampling station SC508. Inflowing water quality data for the Courtland Canal was estimated from data collected by the Nebraska Department of Environmental Quality in 2007.

Table 8. Predicted area-weighted mean concentrations for the current condition and the TMDL for Lovewell Lake based on BATHTUB eutrophication modeling.

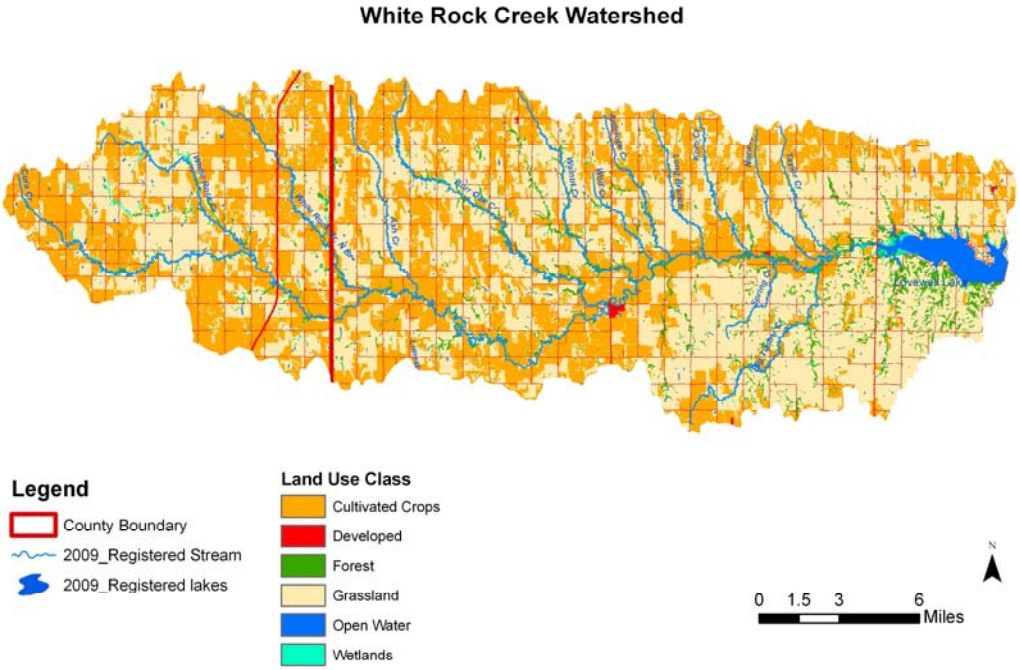
	Current Avg. Condition	**TMDL**	**Percent Reduction**
Total Phosphorus – Annual Load (lbs/year)	47,710	10,205	79%
Total Phosphorus – Daily Load* (lbs/day)	442	94.5	79%
Total Phosphorus – Lake Concentration (mg/L)	0.121	0.0297	75%
Total Nitrogen – Annual Load (lbs/year)	336,249	83,691	75%
Total Nitrogen – Daily Load* (lbs/day)	2,472	615	75%
Total Nitrogen – Lake Concentration (mg/L)	1.217	0.396	67%
Chlorophyll *a* Concentration (μg/L)	41.7	10	76%
pH	8.08	6.5 – 8.5	N/A

*See Appendix C for nutrient Daily Load Calculations

3. SOURCE INVENTORY AND ASSESSMENT

Land Use: The predominant land uses in the Lovewell Lake watershed are grassland (50%) and cultivated cropland (39%), according to the 2001 National Land Cover Data. Together they account for 89% of the total land area in the watershed. Approximately 4.5% of the land is deciduous forest, where as open water and wetlands account for 2.5%. Developed areas, such as residential, commercial and industrial land as well as roads, makes up about 4% of the watershed (Figure 16).

Figure 16. Land use in the Lovewell Lake watershed.



Point Sources: There are two NPDES permitted facilities in the Lovewell Lake watershed (Table 9). Both facilities are non-overflowing lagoon systems that are prohibited from discharging and would only contribute a phosphate load under extreme precipitation or flooding events. Such events would not occur at a frequency or for duration sufficient to cause impairment in the watershed.

Table 9. NPDES permitted facilities in the Lovewell Lake watershed.

Discharging Facility	NPDES Permit #	State Permit #	Type	Expiration Date
Burr Oak WWTP	KSJ000380	M-LR04-NO01	2 Cell Lagoon Non-Overflowing	April 30, 2014
Global Country World of Peace	KSJ000651	C-SO23-NO01	1 Cell Lagoon Non-Overflowing	September 30, 2014

Livestock: There are eleven active confined animal feeding operations (CAFOs) within the Lovewell Lake watershed amounting to 2,975 head of cattle and 1,400 head of swine (Table 10). All of these 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.

Table 10. CAFOs within the Lovewell Lake watershed.

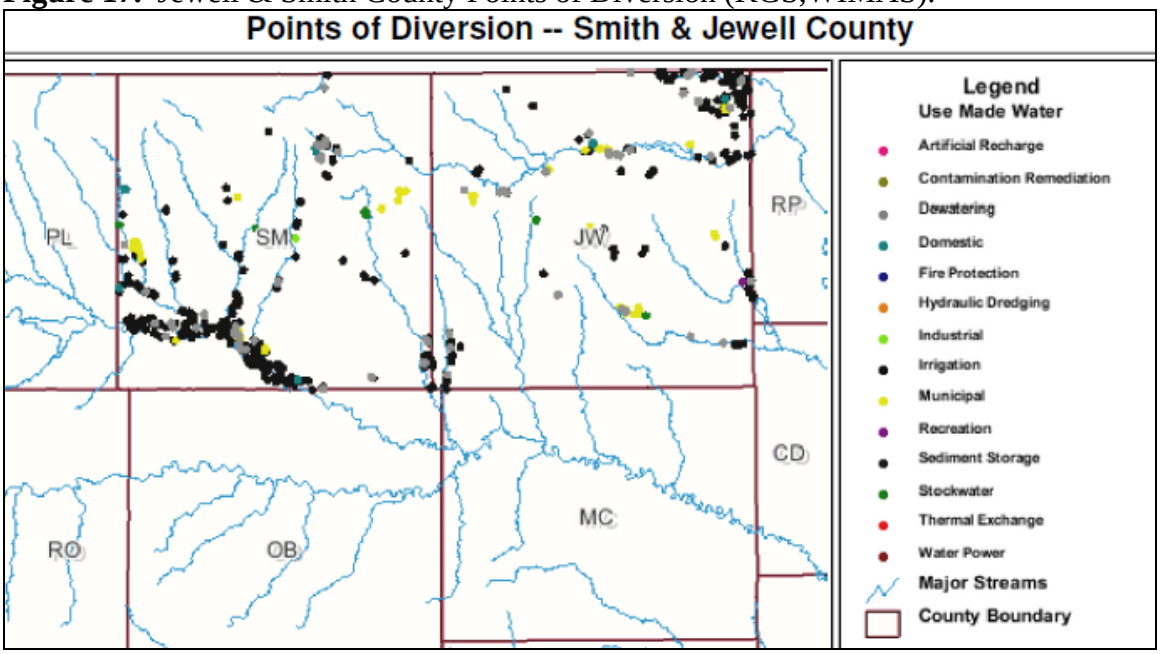
Permit Number	Type	County	Animal Total
A-LRSM-BA01	Beef	Smith	500
A-LRSM-BA02	Beef	Smith	400
A-LRJW-B004	Beef	Jewell	600
A-LRJW-B003	Beef	Jewell	500
N-LRJW-6621	Beef	Jewell	100
A-LRJW-BA05	Beef	Jewell	400
A-LRJW-BA10	Beef	Jewell	300
A-LRSM-M001	Beef	Smith	175
N-LRJW-4927	Swine	Jewell	100
A-LRJW-S008	Swine	Jewell	950
A-SOSM-SA02	Swine	Smith	350

According to the USDA NAAS, as of January 1, 2011, Jewell County had a livestock inventory of 35,000 head of cattle and 3,100 head of hogs while Smith County had an inventory of 32,000 head of cattle and 6,400 head of hogs.

Fertilizer Application: According to the Kansas Department of Agriculture, in 2010 there were 18,448 tons of total fertilizer applied in Jewell County contributing 6,320 tons of nitrogen and 562 tons of P_2O_5 (commonly referred to as phosphoric acid) and accounting for 0.70% of the fertilizer applied in Kansas in 2010. Smith County reported the application of 30,156 tons of total fertilizer contributing 12,252 tons of nitrogen and 3,811 tons of P_2O_5 to and accounting for 1.1% of the fertilizer applied in Kansas in 2010.

Points of Diversion: There are 115 and 210 unique points of diversion in Jewell and Smith Counties, respectively. However, the majority of the points of diversion are located outside of this watershed and likely have little effect on nutrient concentration in the Lovewell Lake watershed (Figure 17).

Figure 17. Jewell & Smith County Points of Diversion (KGS,WIMAS).



On-Site Waste Systems: The Lovewell Lake watershed is a rural agricultural area that falls into both Jewell and Smith counties and includes the City of Burr Oak (pop. 265). It can be assumed that all of the rural residences in the watershed are not connected to public sewer systems and failing on-site septic systems may contribute nutrient loadings and aggravate eutrophication problems. According to the 2000 census data from the U.S. Census Bureau, the population within the watershed is approximately 1516 people (4.4 people/mi^2). Projections predict a population decrease of 8% by 2020 and a decrease of nearly 25% by 2040 for Jewell and Smith counties.

Contributing Runoff: The watershed of Lovewell Lake has a mean soil permeability value of 1.23 inches/hour, ranging from 0.01 inches/hour to 2.15 inches/hour according to NRCS STATSGO database. Less than 1% of the watershed has a permeability value less than 0.57 inches/hour, which contributes to runoff during extremely low rainfall intensity events. 78% of the Lovewell Lake watershed has a permeability value of 1.29 inches/hour. 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 with rainfall intensities greater than soil permeability. As the watersheds' soil profiles become saturated, excess overland flow is produced.

Background: Undissolved nutrients bound to suspended solids in the inflow to Lovewell 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 Lovewell Lake. In addition, geological formations (i.e. soil and bedrock) may also contribute to nutrient loads and with deciduous forest making up about 5% 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 load in the Lovewell Lake.

4. ALLOCATION OF POULLUTANT REDUCTION RESPONSIBILITY

Phosphorus and nitrogen are co-limiting nutrients in Lovewell Lake and, as such, both phosphorus and nitrogen will both be allocated under this TMDL. Reductions in phosphorus and nitrogen will lead to meeting the pH endpoint of 6.5 to 8.5 by reducing the rate of photosynthesis. 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 smaller livestock facilities and fertilizer applicators.

The lake model utilized for the development of the TMDL was BATHTUB. BATHTUB is an empirical receiving water quality model, that was developed by the U.S. Army C orps 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).

Lovewell Lake was segmented into four sections for the BATHTUB model, which included the upper lake (riverine area), middle lake (transitional area), Courtland arm (canal inflow section), and the Lovewell Lake dam site (main basin) (Figure 18). 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. Water quality data for the main basin segment was averaged using the 1992-2010 data from KDHE (LM015001). Model input data for the tributary White Rock Creek was estimated using the averages of the 1990-2010 data from KDHE (SC508). Model input data for the Courtland Canal was estimated using 1997 data from NEDEQ. The BATHTUB model was calibrated for the main basin and results (see Appendix B) estimate that the lake retains 59% of the TP and 45% 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 79% reduction of TP and TN within the inflow of White Rock creek and the Courtland Canal is necessary to achieve the TMDL endpoint of 10 ug/L of Chlorophyll *a* within Lovewell Lake.

Figure 18. Lovewell Lake BATHTUB Segmentation

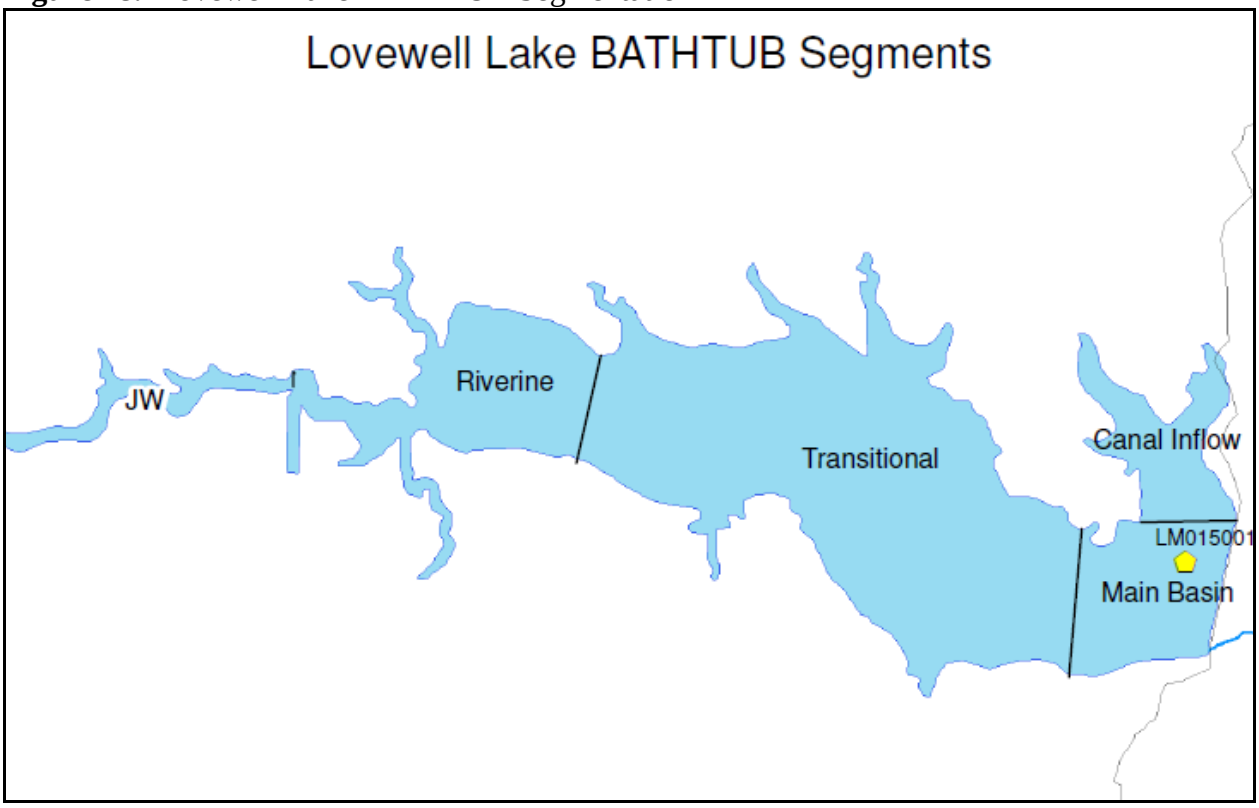
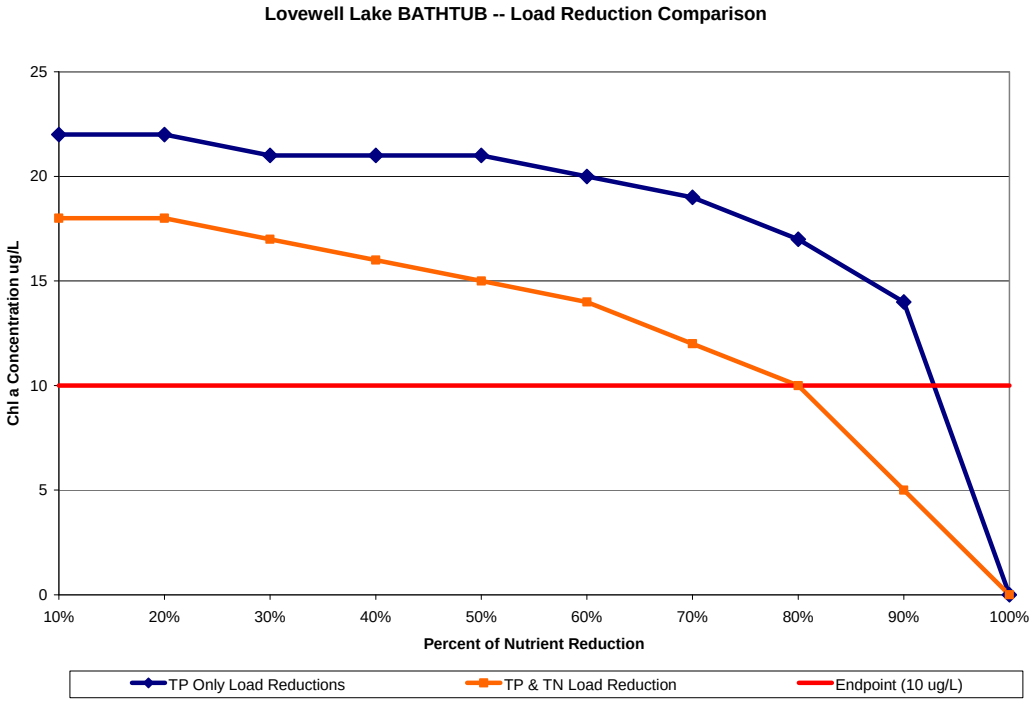


Figure 19. Changes in Chlorophyll *a* levels in relation to watershed nutrient reduction.



Point Sources: A current Wasteload Allocation of zero is assigned for nitrogen and phosphorus under this TMDL because of the lack of point sources in the watershed. Should future sources be proposed in the watershed, the current wasteload allocations will be revised by adjusting current load allocations to account for the presence and impact of these new point source dischargers.

Nonpoint Sources: Nonpoint sources are the main contributor for the nutrient input and impairment in Lovewell Lake. Background levels may be attributed to nutrient recycling and leaf litter. The assessment suggests that runoff transporting nutrient loads associated with animal wastes and cultivated crops where fertilizer has been applied, to include pasture and hay, contribute to the hypereutrophic condition of the lake. Load Allocations for Lovewell Lake were calculated using the BATHTUB model (see Appendix B).

Table 11. Lovewell Lake nutrient TMDL

Description	Allocations (lbs/year)	Allocations (lbs/day)*
Total Phosphorus Atmospheric Load	234	2.17
Total Phosphorus Nonpoint Source Load Allocation	8,950	82.88
Total Phosphorus Margin of Safety	1,021	9.45
Total Phosphorus TMDL	10,205	94.5
Total Nitrogen Atmospheric Load	16,615	122
Total Nitrogen Nonpoint Source Load Allocation	58,707	431.5
Total Nitrogen Margin of Safety	8,369	61.5
Total Nitrogen TMDL	83,691	615

*See Appendix D for nutrient Daily Load Calculations

With reduced nutrient loads trophic conditions in the lake will improve leading the pH level to stabilize and remain in the 6.5 to 8.5 range prescribed by the Kansas Surface Water Quality Standards.

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 original calculated total phosphorus and total nitrogen load allocations, which compensates for the lack of knowledge about the relationship between the allocated loadings and the resulting water quality. The margin of safety is expressed in Table 11.

State Water Plan Implementation Priority: Immediate actions by the stakeholders within the Lovewell Lake watershed are very likely to improve the trophic status of the lake. Furthermore, because KDHE issued public health advisories due to blue-green algae blooms in the summer of 2010 urging the public to avoid contact with the water in Lovewell Lake which is utilized for primary contact recreation, this TMDL will be a **High** Priority implementation.

Unified Watershed Assessment Priority Ranking: This watershed lies within the Middle Republican Basin (HUC 8: 10250016) with a priority ranking of 48 (Medium Priority for restoration work).

Priority HUC 12: The Spreadsheet Tool for Estimating Pollutant Load (STEPL) was utilized to identify priority HUC12s within the watershed. STEPL is a simple watershed model that provides both agricultural and urban annual average sediment and nutrient simulations as well as implementation evaluation of best management practices. Preliminary STEPL results for phosphorus and nitrogen are illustrated in Figures 20 and 21. Based on these results initial priorities should focus on the top three HUC 12 subwatersheds in Table 12.

Table 12. Priority HUC 12 subwatersheds as identified through STEPL.

HUC 12	Acres	TP Load (lbs/year)	TP Acre (lbs/acre/year)	TN Load (lbs/year)	TN Acre (lbs/acre/year)	Preliminary Implementation Priority Ranking
102500160703	33,207	49,966	1.50	204,656	6.16	1
102500160704	32,978	45,450	1.38	192,976	5.85	2
102500160702	30,126	40,026	1.33	162,391	5.39	3
102500160705	30,379	39,281	1.29	172,758	5.69	4
102500160701	33,039	38,748	1.17	164,975	4.99	5
102500160706	29,406	32,735	1.11	152,618	5.19	6
102500160707	28,056	28,810	1.03	138,107	4.92	7

Figure 20. STEPL results for Phosphorus loading in the Lovewell Lake Watershed.

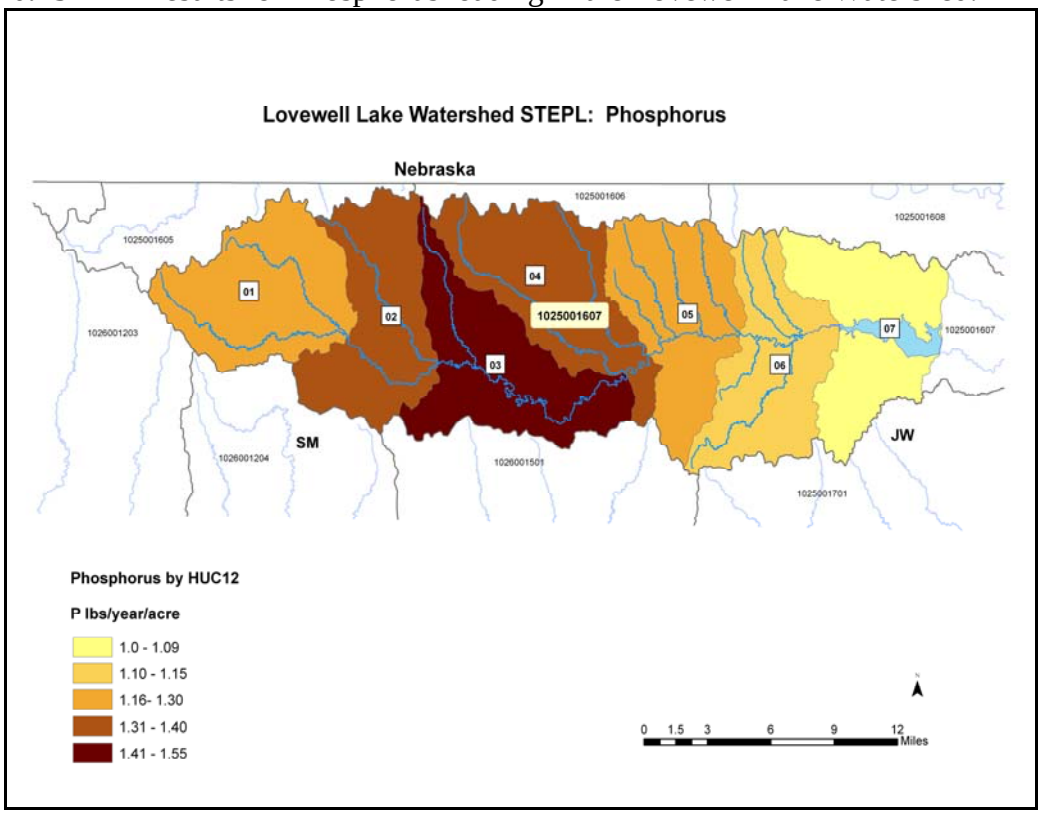
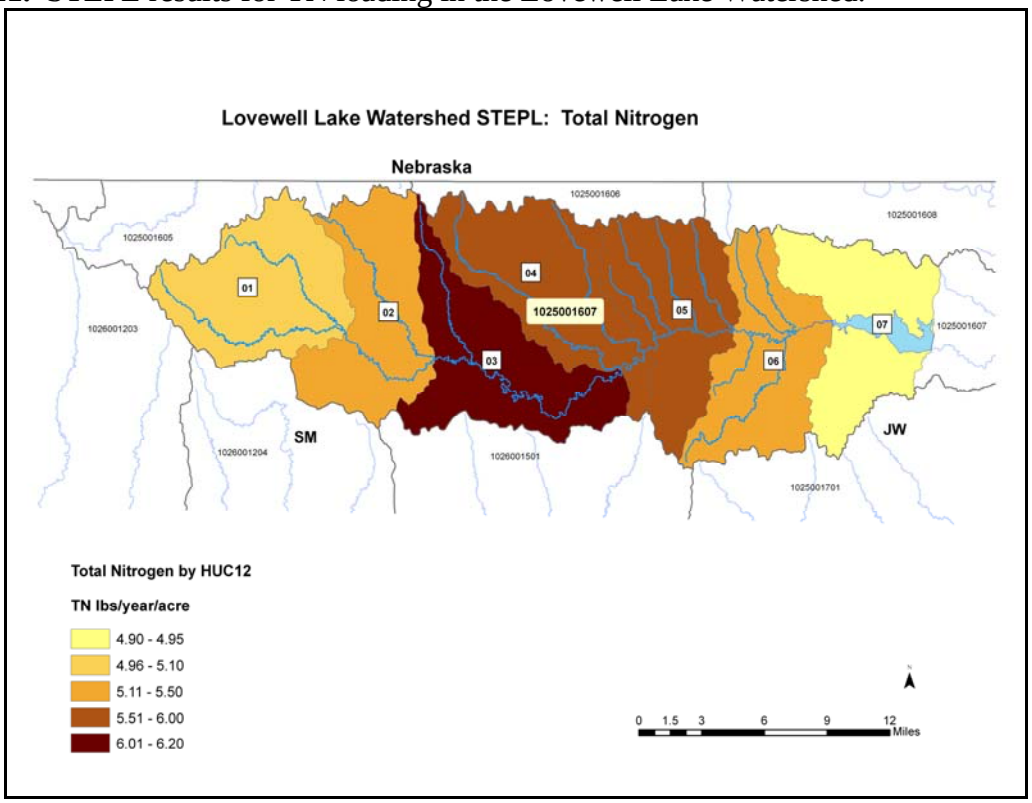


Figure 21. STEPL results for TN loading in the Lovewell Lake Watershed.



5. IMPLEMENTATION

Desired Implementation Activities: There is good potential that agricultural best management practices will improve the condition of Lovewell Lake. Some of the recommended agricultural practices are as follows:

1. Implement soil sampling to recommend appropriate fertilizer applications on cultivated cropland.
2. Maintain conservation tillage and contour farming to minimize cropland erosion.
3. Promote and adopt continuous no-till cultivation to increase the amount of water infiltration and minimize cropland soil erosion and nutrient transports.
4. Install grass buffer strips along streams and drainage channels in the watershed.
5. Reduce activities within riparian areas.
6. Implement nutrient management plans to manage manure land applications and runoff potential.
7. Adequately manage fertilizer utilization in the watershed and implement runoff control measures.
8. Utilize state-supported Kansas-Lower Republican Basin WRAPS process to coordinate load reduction of nutrients to the lake.

Implementation Program Guidance:

Watershed Management Program – KDHE

a. Support Section 319 project activities conducted under the Watershed Restoration and Protection Strategy (WRAPS) for Lovewell Lake, including demonstration projects and outreach efforts dealing with erosion and sediment control and nutrient management.
b. Provide technical assistance on practices geared to the establishment of vegetative buffer strips.
c. Provide technical assistance on nutrient management in the vicinity of streams.
d. Incorporate the provisions of this TMDL into WRAPS documents relating to Lovewell Lake.

Water Resource Cost Share and Nonpoint Source Pollution Control Programs – KDA Division of Conservation

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 and nutrient transport.
c. Re-evaluate nonpoint source pollution control methods.

Riparian Protection Program – KDA Division of Conservation

a. Establish, protect or re-establish natural riparian systems, including vegetative filter strips and streambank vegetation.
b. Develop riparian restoration projects
c. Promote wetland construction to assimilate nutrient loadings.

Buffer Initiative Program – KDA Division of Conservation

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 and 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 nutrients.
f. Support outreach efforts by Middle Republican WRAPS projects and continue to educate residents, landowners, and watershed stakeholders about nonpoint source pollution.

Time Frame for Implementation: Initial implementation will proceed over the years from 2011-2015. Additional implementation may be required over 2016-2020 to achieve the endpoints of this TMDL.

Targeted Participants: Primary participants for implementation will be agricultural producers and stakeholders within the Lovewell Lake watershed. A detailed assessment of sources conducted over 2011-2012 should include local assessments by conservation district personnel and county extension agents to survey, locate, and assess the following within the lake drainage area:

1. Total row crop acreage and fertilizer application rates,
2. Cultivation alongside lake,
3. Livestock use of riparian areas,
4. Fields with manure applications.

Milestone for 2015: In accordance with the TMDL development schedule for the State of Kansas, the year 2015 marks the next cycle of 303(d) activities in the Kansas-Lower Republican Basin. At that point in time, data from 2013 at site LM015001 at Lovewell Lake will be reexamined to assess improved conditions in the lake. Should the impairment remain adjustments to source assessment, allocation, and implementation activities may occur.

Delivery Agents: The primary delivery agents for program participation will be the Kansas Department of Health and Environment, the State Conservation Commission, the Natural Resources Conservation Service, the Kansas State University Extension Service, and the Kansas-Lower Republican Basin WRAPS teams. Producer outreach and awareness will be delivered by Kansas State Extension and/or coordinated through Kansas-Lower Republican Basin WRAPS teams. Implementation decisions and scheduling will be guided by planning documents prepared through Kansas-Lower Republican Basin WRAPS projects.

Reasonable Assurances:
Authorities: The following authorities may be used to direct activities in the watershed to reduce pollutants and to assure allocations of pollutant to point and nonpoint sources can be attained.

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

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

5. 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.

6. 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.

7. The Kansas Water Plan and the Kansas-Lower Republican 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.

8. K.S.A. 32-807 authorizes the Kansas Department of Wildlife and Parks to manage lake resources.

Funding: The State Water Plan Fund annually generates $16-18 million and is the primary funding mechanism for implementing water quality protection and pollutant 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 watershed and its TMDL are a High priority consideration for funding.

Effectiveness: Nutrient control has been proven effective through conservation tillage, contour farming and use of grass waterways and buffer strips. In addition, the proper implementation of comprehensive livestock waste management plans has proven effective at reducing nutrient runoff associated with livestock facilities. The key to success will be widespread utilization of conservation farming and proper livestock waste management within the watershed cited in this TMDL.

6. MONITORING

KDHE will continue its 3-year sampling schedule in order to assess the trophic state of Lovewell Lake. Based on the sampling results, the 303(d) listing will be evaluated in 2020. Should impairment status continue, the desired endpoints under this TMDL will be refined and more intensive sampling will be conducted over the period 2015-2020 to assess progress in this implementation.

7. FEEDBACK

Public Notice: An active Internet Web site was established at www.kdheks.gov/tmdl/ to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Kansas-Lower Republican Basin.

Public Hearing: A Public Hearing on this TMDL was held on August 31, 2011 in Topeka to receive comments on this TMDL.

Basin Advisory Committee: The Kansas-Lower Republican Basin Advisory Committee met to discuss the TMDLs in the basin on September 30, 2010 in Lawrence, March 17, 2011 in Manhattan, June 16, 2011 in Lawrence and September 29, 2011 in Topeka.

Milestone Evaluation: In 2015, evaluation will be made as to implementation of management practices to minimize the nonpoint 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 2015 with consultation from local stakeholders and WRAPS teams.

Consideration for 303d Delisting: Lovewell Lake will be evaluated for delisting under Section 303d, based on the monitoring data over 2013-2019. Therefore, the decision for delisting will come about in the preparation of the 2020-303d 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 might 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 2012. Recommendations of this TMDL

will be considered in the Kansas Water Plan implementation decisions under the State Water Planning Process for Fiscal Years 2011-2020.

Developed 6/21/2011
Revised 12/01/2011

References

Carney, E.. 1992, 1995, 1998, 2001, 2004, 2007. Lake and Wetland Monitoring Program Annual Report/ Summary. Kansas Department of Health and Environment.

Dzialowski, A.R., S.H. Wang, N.C. Lim, W.W. Spotts and D.G. Huggins. 2005; Nutrient Limitation of Phytoplankton Growth in Central Plains Reservoirs, USA; Journal of Plankton Research; 27 (6): 587-595.

Kansas Department of Agriculture Fertilizer Reports. October 19, 2011 http://www.ksda.gov/pesticides_fertilizer/content/165

Kansas Water Plan Atlas. January 25, 2011. Kansas Water Office. January 25, 2011. http://www.kwo.org/Kansas%20Water%20Plan/SWP/KWP_2008/KWP_Atlas.htm

Perry, C.A., D.M. Wolock and J.C. Artman, 2004. Estimates of Flow Duration, Mean Flow, and Peak-Discharge Frequency Values for Kansas Stream Location, USGS Scientific Investigations Report 2004-5033.

Soil and Water Conservation Society of Metro Halifax. 2007. The Blue-Green Algae (Cyanobacteria). Accessed on October 15, 2007 at http://lakes.chebucto.org/cyano.html

USDA National Agricultural Statistics Service. October 19, 2011. http://www.nass.usda.gov/QuickStats/Create_County_All.jsp

Walker, W.W. Jr., 1996. Simplified procedures for eutrophication assessment and prediction: user manual. Instructional Report W-96-2. U.S. Army Engineer Waterways Experiment Station. Vicksburg, MS.

WIMAS Query. Kansas Geological Survey. February 9, 2011. http://hercules.kgs.ku.edu/geohydro/wimas/query_setup.cfm

Appendix A. USBR Inflow calculation

United States Bureau of Reclamation records were used for Lovewell Lake, White Rock Creek and Courtland Canal inflow/outflow values.

USBR monthly computed inflow calculation for Lovewell Lake:

Monthly computed inflow = (Change in Storage) + (White Rock Creek Outflow) + (Courtland Canal Outflow) + (Reservoir Evaporation)

Example: June 2009

Storage Change = -1195 AF
White Rock Creek Outflow = 12 AF
Courtland Canal Outflow = 5326 AF
Evap = 1332 AF

Monthly Inflow = (-1195) + 12 + 5326 + 1332
= 5475 AF

White Rock Creek flow into Lovewell Lake calculation:

White Rock Creek Inflow = (Monthly computed inflow for Lovewell Reservoir) – (Courtland Canal at mile 34.8 total monthly flow)

Courtland Canal at 34.8 = 1296 AF
Monthly computed inflow = 5475 AF

White Rock Creek Inflow = 5475 AF – 1296 AF
= 4179 AF

Appendix B. BATHTUB Model Summary

Model Inputs

Current Condition, Lovewell Lake

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.66	0.2
Evaporation (m)	1.364	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km²-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	10	0.10
Total N	709	0.05
Ortho P	10	0.10
Inorganic N	709	0.05

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	2	2ND ORDER, DECAY
Nitrogen Balance	2	2ND ORDER, DECAY
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	km²	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Upper Pool	2	1	1.7	2.1	2.455	2.1	0.12	0	0	0.6	0.2	0	0	0	0	0	0
2	Mid Pool	3	1	6.76	4	8.832	3.9	0.12	0	0	0.6	0.2	0	0	0	0	0	0
3	Near Dam	0	1	1.38	4.4	1.554	4.2	0	0	0	0.897	0.9	0	0	0	0	0	0
4	Courtland Arm	3	1	0.79	2	1.315	2	0	0	0	0.6	0	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	134	0.66	1272	0.5	33	0.46	0.66	0.36	1049	0.55	41	0.7	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	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
2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
3	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
4	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm³/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km²	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	White Rock Creek	1	1	7.46	39.65	0.5	0	0	307	0.5	2068	0.5	131	0.5	1169	0.5
2	Courtland Canal	4	1	52	34.42	0.5	0	0	272	0.5	1830	0.5	116	0.5	1035	0.5

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	0.548	0.45
Total Nitrogen	0.928	0.55
Chl-a Model	1.478	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	0.500	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m²/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

Model Output – Current Condition
Main Basin
Current Condition, Lovewell Lake

Segment: 3 Near Dam

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	134.0	0.35	87.3%	134.0	0.66	87.3%
TOTAL N MG/M3	1272.0	0.31	64.5%	1272.0	0.50	64.5%
C.NUTRIENT MG/M3	76.7	0.26	83.0%	76.7	0.57	83.0%
CHL-A MG/M3	33.0	0.44	94.9%	33.0	0.46	94.9%
SECCHI M	0.6	0.36	20.7%	0.7	0.36	25.8%
ORGANIC N MG/M3	976.9	0.32	92.2%	1049.0	0.55	94.0%
TP-ORTHO-P MG/M3	37.9	0.28	59.8%	41.0	0.70	62.9%
ANTILOG PC-1	1334.3	0.44	90.2%	1288.3	0.49	89.7%
ANTILOG PC-2	9.7	0.48	78.0%	10.6	0.42	83.1%
(N - 150) / P	8.4	0.48	14.9%	8.4	0.86	14.9%
INORGANIC N / P	3.1	1.49	1.1%	2.4	3.97	0.6%
TURBIDITY 1/M	0.9	0.90	67.0%	0.9	0.90	67.0%
ZMIX * TURBIDITY	3.8	0.90	59.1%	3.8	0.90	59.1%
ZMIX / SECCHI	7.2	0.36	76.3%	6.4	0.35	69.0%
CHL-A * SECCHI	19.2	0.65	81.3%	21.8	0.58	85.8%
CHL-A / TOTAL P	0.2	0.51	64.0%	0.2	0.79	64.0%
FREQ(CHL-a>10) %	94.7	0.08	94.9%	94.7	0.08	94.9%
FREQ(CHL-a>20) %	69.1	0.36	94.9%	69.1	0.37	94.9%
FREQ(CHL-a>30) %	43.8	0.64	94.9%	43.8	0.66	94.9%
FREQ(CHL-a>40) %	26.8	0.88	94.9%	26.8	0.91	94.9%
FREQ(CHL-a>50) %	16.3	1.08	94.9%	16.3	1.13	94.9%
FREQ(CHL-a>60) %	10.1	1.25	94.9%	10.1	1.32	94.9%
CARLSON TSI-P	74.8	0.07	87.3%	74.8	0.13	87.3%
CARLSON TSI-CHLA	64.9	0.07	94.9%	64.9	0.07	94.9%
CARLSON TSI-SEC	67.8	0.08	79.3%	66.0	0.08	74.2%

Model Output – Current Condition
Area Weighted Mean
Current Condition, Lovewell Lake

Segment: 5 Area-Wtd Mean

	Predicted Values--->			Observed Values--->		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	121.1	0.35	84.9%	134.0	0.66	87.3%
TOTAL N MG/M3	1216.6	0.32	61.9%	1272.0	0.50	64.5%
C.NUTRIENT MG/M3	71.6	0.27	80.8%	76.7	0.57	83.0%
CHL-A MG/M3	41.7	0.33	97.3%	33.0	0.46	94.9%
SECCHI M	0.6	0.23	22.3%	0.7	0.36	25.8%
ORGANIC N MG/M3	1154.8	0.30	96.0%	1049.0	0.55	94.0%
TP-ORTHO-P MG/M3	42.6	0.32	64.4%	41.0	0.70	62.9%
ANTILOG PC-1	1551.2	0.49	92.1%	1288.3	0.49	89.7%
ANTILOG PC-2	11.9	0.15	87.9%	10.6	0.42	83.1%
(N - 150) / P	8.8	0.50	16.8%	8.4	0.86	14.9%
INORGANIC N / P	1.6	2.37	0.2%	2.4	3.97	0.6%
TURBIDITY 1/M	0.6	0.21	52.1%	0.6	0.21	52.1%
ZMIX * TURBIDITY	2.3	0.25	33.6%	2.3	0.25	33.6%
ZMIX / SECCHI	5.7	0.23	62.3%	6.4	0.35	69.0%
CHL-A * SECCHI	24.6	0.18	89.3%	21.8	0.58	85.8%
CHL-A / TOTAL P	0.3	0.41	81.0%	0.2	0.79	64.0%
FREQ(CHL-a>10) %	96.9	0.04	97.3%	94.7	0.08	94.9%
FREQ(CHL-a>20) %	78.4	0.19	97.3%	69.1	0.37	94.9%
FREQ(CHL-a>30) %	56.5	0.35	97.3%	43.8	0.66	94.9%
FREQ(CHL-a>40) %	39.1	0.49	97.3%	26.8	0.91	94.9%
FREQ(CHL-a>50) %	27.0	0.62	97.3%	16.3	1.13	94.9%
FREQ(CHL-a>60) %	18.7	0.72	97.3%	10.1	1.32	94.9%
CARLSON TSI-P	73.3	0.07	84.9%	74.8	0.13	87.3%
CARLSON TSI-CHLA	66.9	0.05	97.3%	64.9	0.07	94.9%
CARLSON TSI-SEC	67.3	0.05	77.7%	66.0	0.08	74.2%

Model Output – Current Condition
Overall Water and Nutrient Balances
Current Condition, Lovewell Lake

Segment:	5	Area-Wtd Mean				
	Predicted Values--->			Observed Values--->		
Variable	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	29.7	0.34	29.7%	134.0	0.66	87.3%
TOTAL N MG/M3	396.1	0.28	7.3%	1272.0	0.50	64.5%
C.NUTRIENT MG/M3	16.8	0.33	17.4%	76.7	0.57	83.0%
CHL-A MG/M3	9.9	0.47	52.5%	33.0	0.46	94.9%
SECCHI M	1.1	0.20	52.8%	0.7	0.36	25.8%
ORGANIC N MG/M3	430.0	0.27	42.4%	1049.0	0.55	94.0%
TP-ORTHO-P MG/M3	28.6	0.33	48.0%	41.0	0.70	62.9%
ANTILOG PC-1	153.2	0.58	36.0%	1288.3	0.49	89.7%
ANTILOG PC-2	7.9	0.25	65.3%	10.6	0.42	83.1%
(N - 150) / P	8.3	0.57	14.7%	8.4	0.86	14.9%
INORGANIC N / P	0.8	5.21	0.0%	2.4	3.97	0.6%
TURBIDITY 1/M	0.6	0.21	52.1%	0.6	0.21	52.1%
ZMIX * TURBIDITY	2.3	0.25	33.6%	2.3	0.25	33.6%
ZMIX / SECCHI	3.1	0.23	23.1%	6.4	0.35	69.0%
CHL-A * SECCHI	11.3	0.38	55.5%	21.8	0.58	85.8%
CHL-A / TOTAL P	0.3	0.50	79.7%	0.2	0.79	64.0%
FREQ(CHL-a>10) %	36.7	0.76	52.5%	94.7	0.08	94.9%
FREQ(CHL-a>20) %	7.6	1.42	52.5%	69.1	0.37	94.9%
FREQ(CHL-a>30) %	1.9	1.85	52.5%	43.8	0.66	94.9%
FREQ(CHL-a>40) %	0.6	2.18	52.5%	26.8	0.91	94.9%
FREQ(CHL-a>50) %	0.2	2.44	52.5%	16.3	1.13	94.9%
FREQ(CHL-a>60) %	0.1	2.66	52.5%	10.1	1.32	94.9%
CARLSON TSI-P	53.0	0.09	29.7%	74.8	0.13	87.3%
CARLSON TSI-CHLA	53.0	0.09	52.5%	64.9	0.07	94.9%
CARLSON TSI-SEC	58.2	0.05	47.2%	66.0	0.08	74.2%

Model Output with 79% TP and TN Concentration Reductions at Inflow
Area Weighted Mean
TMDL BATHTUB, Lovewell Lake

Segment:	5	Area-Wtd Mean				
	Predicted Values--->			Observed Values--->		
Variable	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	29.7	0.34	29.7%	134.0	0.66	87.3%
TOTAL N MG/M3	396.1	0.28	7.3%	1272.0	0.50	64.5%
C.NUTRIENT MG/M3	16.8	0.33	17.4%	76.7	0.57	83.0%
CHL-A MG/M3	9.9	0.47	52.5%	33.0	0.46	94.9%
SECCHI M	1.1	0.20	52.8%	0.7	0.36	25.8%
ORGANIC N MG/M3	430.0	0.27	42.4%	1049.0	0.55	94.0%
TP-ORTHO-P MG/M3	14.3	0.33	21.8%	41.0	0.70	62.9%
ANTILOG PC-1	153.2	0.58	36.0%	1288.3	0.49	89.7%
ANTILOG PC-2	7.9	0.25	65.3%	10.6	0.42	83.1%
(N - 150) / P	8.3	0.57	14.7%	8.4	0.86	14.9%
INORGANIC N / P	0.1	0.66	0.0%	2.4	3.97	0.6%
TURBIDITY 1/M	0.6	0.21	52.1%	0.6	0.21	52.1%
ZMIX * TURBIDITY	2.3	0.25	33.6%	2.3	0.25	33.6%
ZMIX / SECCHI	3.1	0.23	23.1%	6.4	0.35	69.0%
CHL-A * SECCHI	11.3	0.38	55.5%	21.8	0.58	85.8%
CHL-A / TOTAL P	0.3	0.50	79.7%	0.2	0.79	64.0%
FREQ(CHL-a>10) %	36.7	0.76	52.5%	94.7	0.08	94.9%
FREQ(CHL-a>20) %	7.6	1.42	52.5%	69.1	0.37	94.9%
FREQ(CHL-a>30) %	1.9	1.85	52.5%	43.8	0.66	94.9%
FREQ(CHL-a>40) %	0.6	2.18	52.5%	26.8	0.91	94.9%
FREQ(CHL-a>50) %	0.2	2.44	52.5%	16.3	1.13	94.9%
FREQ(CHL-a>60) %	0.1	2.66	52.5%	10.1	1.32	94.9%
CARLSON TSI-P	53.0	0.09	29.7%	74.8	0.13	87.3%
CARLSON TSI-CHLA	53.0	0.09	52.5%	64.9	0.07	94.9%
CARLSON TSI-SEC	58.2	0.05	47.2%	66.0	0.08	74.2%

Model Output with 79% TP and TN Concentration Reductions at Inflow
Main Basin
TMDL BATHTUB, Lovewell Lake

Segment:	3	Near Dam				
	Predicted Values--->			Observed Values--->		
Variable	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	32.1	0.33	32.8%	134.0	0.66	87.3%
TOTAL N MG/M3	391.2	0.27	7.1%	1272.0	0.50	64.5%
C.NUTRIENT MG/M3	17.0	0.33	17.8%	76.7	0.57	83.0%
CHL-A MG/M3	8.3	0.56	43.6%	33.0	0.46	94.9%
SECCHI M	0.9	0.67	40.8%	0.7	0.36	25.8%
ORGANIC N MG/M3	413.8	0.24	39.5%	1049.0	0.55	94.0%
TP-ORTHO-P MG/M3	16.0	0.52	25.3%	41.0	0.70	62.9%
ANTILOG PC-1	153.8	0.57	36.1%	1288.3	0.49	89.7%
ANTILOG PC-2	6.0	0.71	44.3%	10.6	0.42	83.1%
(N - 150) / P	7.5	0.55	11.5%	8.4	0.86	14.9%
INORGANIC N / P	0.1	0.80	0.0%	2.4	3.97	0.6%
TURBIDITY 1/M	0.9	0.90	67.0%	0.9	0.90	67.0%
ZMIX * TURBIDITY	3.8	0.90	59.1%	3.8	0.90	59.1%
ZMIX / SECCHI	4.6	0.68	48.1%	6.4	0.35	69.0%
CHL-A * SECCHI	7.5	1.04	33.3%	21.8	0.58	85.8%
CHL-A / TOTAL P	0.3	0.59	66.8%	0.2	0.79	64.0%
FREQ(CHL-a>10) %	27.1	1.11	43.6%	94.7	0.08	94.9%
FREQ(CHL-a>20) %	4.2	1.94	43.6%	69.1	0.37	94.9%
FREQ(CHL-a>30) %	0.9	2.48	43.6%	43.8	0.66	94.9%
FREQ(CHL-a>40) %	0.2	2.87	43.6%	26.8	0.91	94.9%
FREQ(CHL-a>50) %	0.1	3.18	43.6%	16.3	1.13	94.9%
FREQ(CHL-a>60) %	0.0	3.44	43.6%	10.1	1.32	94.9%
CARLSON TSI-P	54.2	0.09	32.8%	74.8	0.13	87.3%
CARLSON TSI-CHLA	51.4	0.11	43.6%	64.9	0.07	94.9%
CARLSON TSI-SEC	61.4	0.16	59.2%	66.0	0.08	74.2%

Model Output with 79% TP and TN Concentration Reductions at Inflow
Overall Water and Nutrient Balances
TMDL BATHTUB, Lovewell Lake

Overall Water & Nutrient 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	White Rock Creek	746.0	39.7	3.93E+02	0.50	0.05
2	1	4	Courtland Canal	52.0	34.4	2.96E+02	0.50	0.66
PRECIPITATION				10.6	7.0	1.97E+00	0.20	0.66
TRIBUTARY INFLOW				798.0	74.1	6.89E+02	0.35	0.09
***TOTAL INFLOW				808.6	81.1	6.91E+02	0.32	0.10
ADVECTIVE OUTFLOW				808.6	66.6	7.10E+02	0.40	0.08
***TOTAL OUTFLOW				808.6	66.6	7.10E+02	0.40	0.08
***EVAPORATION					14.5	1.89E+01	0.30	

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

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	White Rock Creek	2557.4	55.2%	3.27E+06	62.9%	0.71	64.5	3.4
2	1	4	Courtland Canal	1965.4	42.5%	1.93E+06	37.1%	0.71	57.1	37.8
PRECIPITATION				106.3	2.3%	1.13E+02	0.0%	0.10	15.2	10.0
TRIBUTARY INFLOW				4522.8	97.7%	5.20E+06	100.0%	0.50	61.1	5.7
***TOTAL INFLOW				4629.1	100.0%	5.20E+06	100.0%	0.49	57.1	5.7
ADVECTIVE OUTFLOW				2137.8	46.2%	1.24E+06		0.52	32.1	2.6
***TOTAL OUTFLOW				2137.8	46.2%	1.24E+06		0.52	32.1	2.6
***RETENTION				2491.3	53.8%	2.15E+06		0.59		

Overflow Rate (m/yr)	6.3	Nutrient Resid. Time (yrs)	0.2451
Hydraulic Resid. Time (yrs)	0.5746	Turnover Ratio	4.1
Reservoir Conc (mg/m3)	30	Retention Coef.	0.538

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

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	White Rock Creek	17208.1	45.3%	1.48E+08	62.9%	0.71	434.0	23.1
2	1	4	Courtland Canal	13217.3	34.8%	8.73E+07	37.1%	0.71	384.0	254.2
PRECIPITATION				7536.7	19.9%	1.42E+05	0.1%	0.05	1074.2	709.0
TRIBUTARY INFLOW				30425.4	80.1%	2.35E+08	99.9%	0.50	410.8	38.1
***TOTAL INFLOW				37962.1	100.0%	2.36E+08	100.0%	0.40	468.2	46.9
ADVECTIVE OUTFLOW				26051.2	68.6%	1.26E+08		0.43	391.2	32.2
***TOTAL OUTFLOW				26051.2	68.6%	1.26E+08		0.43	391.2	32.2
***RETENTION				11910.8	31.4%	4.55E+07		0.57		

Overflow Rate (m/yr)	6.3	Nutrient Resid. Time (yrs)	0.3992
Hydraulic Resid. Time (yrs)	0.5746	Turnover Ratio	2.5
Reservoir Conc (mg/m3)	396	Retention Coef.	0.314

Appendix C. 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	NonPoint LA lbs/day	MOS (10%) lbs/day
TP	10,205	0.66	3.38	94.5	2.17	82.88	9.45
TN	83,691	0.5	2.68	615	122	431	61.5

Maximum Daily Load Calculation

Annual TP Load = 10,205 lbs/yr

Maximum Daily TP Load = [(10,205 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.601) - 0.5*(0.601)^2]}$
= 75 lbs/day

Annual TN Load = 83,691 lbs/yr

Maximum Daily TN Load = [(83,691 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0..472) - 0.5*(0.472)^2]}$
= 615 lbs/day

Margin of Safety (MOS) for Daily Load

Annual TP MOS = 1021 lbs/yr

Daily TP MOS = [(1021 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.601)-0.5*(0.601)^2]}$
= 7.50 lbs/day

Annual TN MOS = 8,369 lbs/yr

Daily TN MOS = [(8,369 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.472)-0.5*(0.472)^2]}$
= 61.5 lbs/day

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