UPPER ARKANSAS BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody: Lake Charles
Water Quality Impairment: Eutrophication

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Arkansas – Dodge City **County:** Ford

HUC 8: 11030003 **HUC 10 (12):** 03 (05)

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

Drainage Area: 106 acres

Conservation Pool: Surface Area = 1 acre
Watershed/Lake Ratio: 110:1
Maximum Depth = 3.0 meters
Mean Depth = 1.3 meters
Storage Volume = 4.1 acre-feet
Mean Annual Discharge = 1.93 acre-feet
Estimated Retention Time = 2.13 years
Mean Annual Precipitation = 20.5 inches
Mean Annual Evaporation = 66.6 inches

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

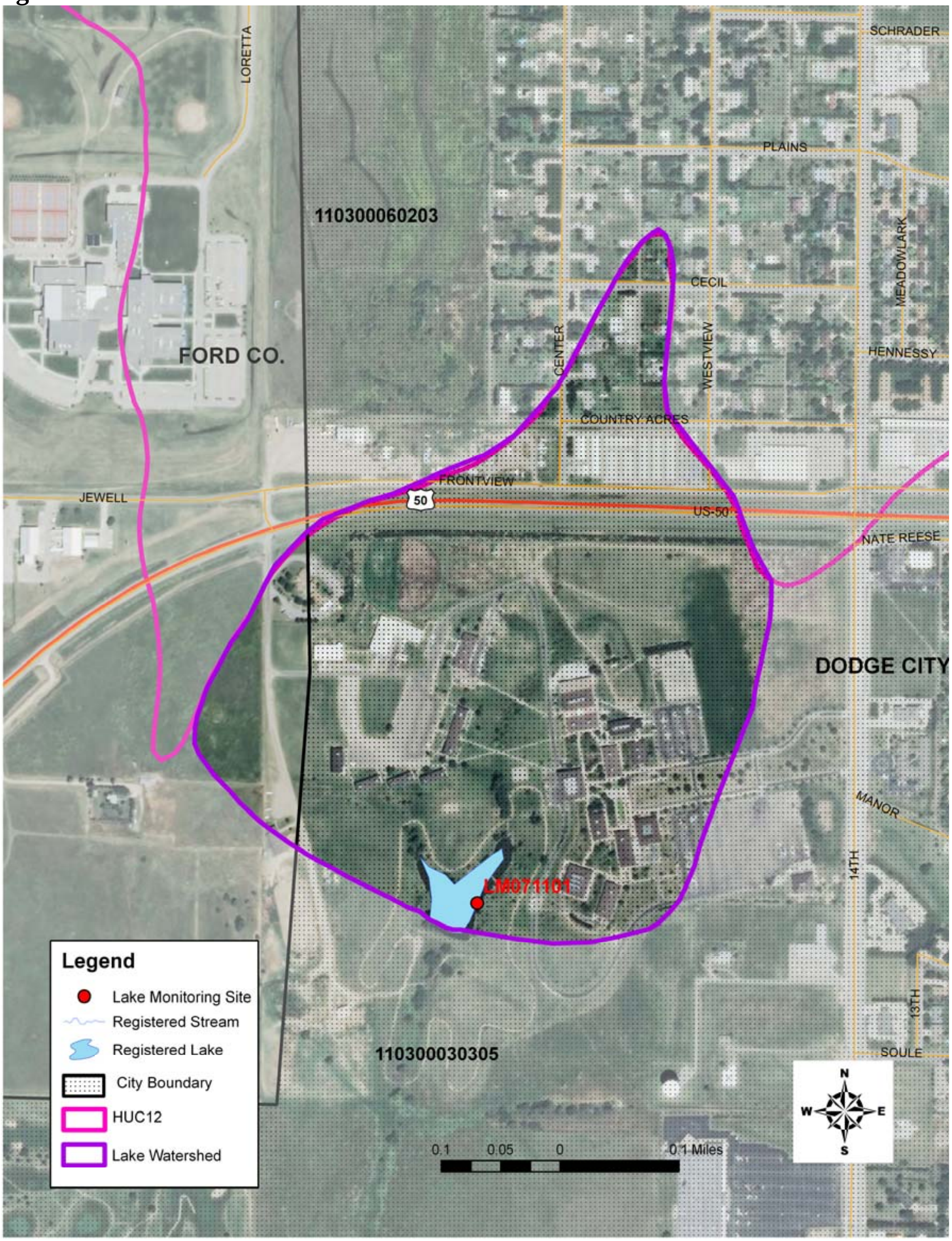
303(d) Listings: Lake Charles Eutrophication: 2002, 2004, 2008, 2010 Kansas Upper Arkansas River Basin Lakes.

Impaired Use: All uses in Lake Charles 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 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. Lake Charles Watershed.



2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Support for Designated Uses under 2012 303(d): Excessive nutrients are not being controlled and are thus impairing aquatic life use and contributing to eutrophication which is impairing aquatic life use by supporting objectionable types and quantities of algae which also leads to impairment of contact recreation within Lake Charles. Lake Charles has no municipal water rights attached to its storage, it is not being used for domestic water supply, nor is it planned as a reserve for a municipal water supply. The chlorophyll *a* endpoint of 12 μg/L is appropriate to protect the immediate uses of aquatic life support and contract recreation in Lake Charles. Should the lake serve as a domestic or municipal water supply in the future, as evidenced by the installation of a point of diversion within the lake, a subsequent use attainability analysis will be conducted to ascertain if the 12 μg/L endpoint adequately supports such use in the lake.

Level of Eutrophication: Very Eutrophic, Trophic State Index = 63.7

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 LM071101 at Lake Charles.
Period of Record: Two surveys conducted by KDHE in 1989 and 1990.

Long-Term Hydrologic Conditions: Lake Charles is located on the campus of Dodge City Community College (DCCC) and, as there is no stream flow into the lake, the college maintains water level by pumping from a nearby well. Records of the amount of water pumped into the lake were available for 2008, 2009, 2010 and January through April of 2011 (Table 1) and, when averaged, result in an annual inflow from pumping of 5.95 acre-feet per year. Although there is no water quality data available for the well that is being used by the community college to fill Lake Charles, historical ground water monitoring results for a well located in Dodge City (SG13 Dodge City #16) shows a concentration of 0.925 mg/L of Nitrate-Nitrite and a total phosphorus level of 12.5 μg/L (Table 2). CNET reservoir eutrophication modeling estimates inflow to the lake at 13.4 acre feet per year, based on the drainage area and DCCC pumping records. According to the USGS Lake Hydro data, the mean runoff in the watershed is 0.63 inches/year; the mean precipitation in the watershed is 20.5 inches/year; the mean loss due to evaporation for the lake is 66.6 inches/year; and the calculated mean annual outflow for the lake is 1.93 acre feet/year.

Table 1. Well water in acre-feet pumped in to Lake Charles.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2008	0	2.72	0	0	0.980	0	0.980	0	0.150	0	0	0	4.83
2009	1.80	0	0	0	0	0	0	0	0	0	0	0	1.80
2010	0	0	2.16	1.18	0	0	2.36	0	1.72	1.77	0	0	9.18
2011	2.60	0	1.43	0	*	*	*	*	*	*	*	*	4.03

*Data Not Available

Table 2. Ground Water Data in units of mg/L for Ford County at site: SG13 Dodge City #16, 1 mile East-1 mile North.

mg/L	1986	1987	1988	1989	1990	1991	1993	1995	1997	2000	*Avg.*
Nitrate+Nitrite	0.620	1.29	0.883	1.10	0.585	0.690	1.32	1.09	1.29	1.34	***0.925***
Total Phosphorus	*	*	*	*	0.010	*	0.0025	0.030	0.010	0.010	***0.0125***

*Data Not Available

Current Condition: Chlorophyll *a* concentrations were 31.9 μg/L and 27.0 μg/L in 1989 and 1990, respectively, resulting in an average chlorophyll *a* concentration of 29.4 μg/L for the period of record. Total phosphorus, nitrate-nitrite, turbidity and TSS data are available for sampling year 1990 (Table 3).

Table 3. Select Water Quality Data for Lake Charles for the period of record.

Sample Year	Chl-a (ug/L)	TP (mg/L)	Nitrite+Nitrate (mg/L)	Secchi Depth (m)	Turbidity (NTU)	TSS (mg/L)
1989	31.9	*	*	0.460	*	*
1990	27.0	0.167	0.487	0.300	40.7	39.8
Average	*29.4*	*0.167*	*0.487*	*0.380*	*40.7*	*39.8*

* Data not available.

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

In order to improve the trophic condition of Lake Charles from its current, Very Eutrophic status, the desired endpoint of this TMDL will be to maintain summer chlorophyll *a* average concentrations below 12 μg/L, with the reductions focused on phosphorus loading. Reductions in phosphorus loading will address the accelerated succession of aquatic biota and the development of objectionable concentrations of algae and algae by-products as determined by the chlorophyll *a* concentrations in the lake. The chlorophyll *a* endpoint of 12 μg/L will ensure long-term protection to fully support Primary Contact Recreation and aquatic life use within the lake. If and when Lake Charles becomes an active or reserve municipal water supply, as determined by the addition of a point of diversion, a use attainability analysis will be conducted to ascertain if the12 μg/L endpoint adequately supports such use in the lake.

Based on the CNET reservoir eutrophication model (Appendix A), the total phosphorus concentration entering the lake must be reduced by 94%. With this reduction, the endpoint for Lake Charles will be met. This reduction will result in an 85% reduction of total phosphorus, and a 60% reduction of Chlorophyll *a* within Lake Charles (Table 4). 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. The current average condition for Lake Charles utilized in the model input was based on data from KDHE station LM071101 for sampling years 1989 and 1990. The pumping records supplied by Dodge County Community College were used to calculate the average yearly flow from the well at 0.0073 hm^3/year and entered as a point source in CNET. Water quality data for the inflow in Lake Charles was estimated by calibrating the stream total phosphorus concentration input in CNET to the current lake mean phosphorus concentration of 167 μg/L resulting in an estimated total phosphorus concentration at the inflow of 1242 μg/L before reductions (Appendix A).

Table 4. Lake Charles current average condition and TMDL based on CNET.

	Current Avg. Condition	**TMDL**	**Percent Reduction**
Total Phosphorus – Annual Load (lbs/year)	19.5	1.18	94%
Total Phosphorus – Daily Load* (lbs/day)	0.144	0.00870	94%
Total Phosphorus – Lake Concentration (μg/L)	167	26.1	85%
Chlorophyll *a* Concentration (μg/L)	29.4	12	60%

*See Appendix B for Daily Load Calculations

3. SOURCE INVENTORY AND ASSESSMENT

Point Sources: The only discharge permit that applies to this TMDL is the Dodge City stormwater discharge (MS4) permit (Table 5) which requires the implementation of best management practices in order to attenuate the discharge of total phosphorus into the Dodge City stormwater discharge system's receiving streams and lakes. A little over 95% of the Lake Charles watershed lies within the boundary of Dodge City.

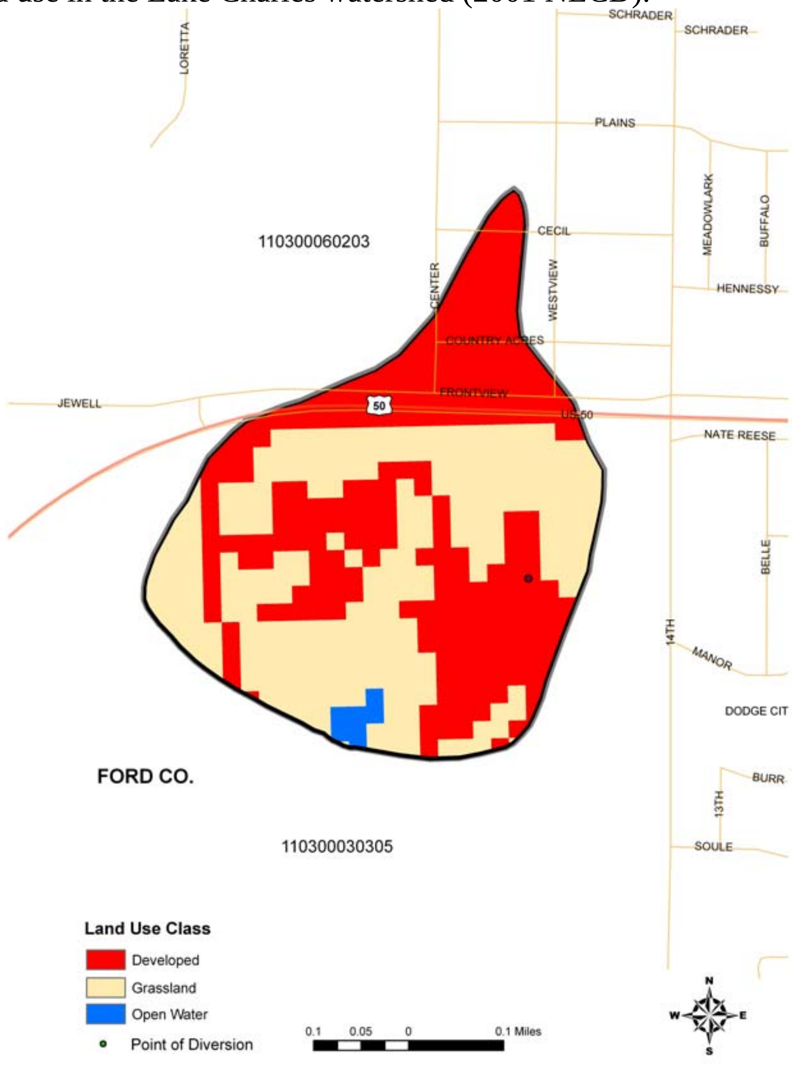
Table 5. Discharge permits in the Lake Charles watershed.

Permittee	**NPDES Permit #**	**State Permit #**	**Type**	**Expiration Date**
City of Dodge City	KSR044003	M-UA11-SN01	Stormwater	September 30, 2009*

*Permit Pending

Land Use: The predominant land uses in the Lake Charles watershed are developed land (51%) and grassland (48%). Together they account for 99% of the total land area in the watershed with the remaining 1% of land area comprised of open water (Lake Charles).

Figure 2. Land use in the Lake Charles watershed (2001 NLCD).



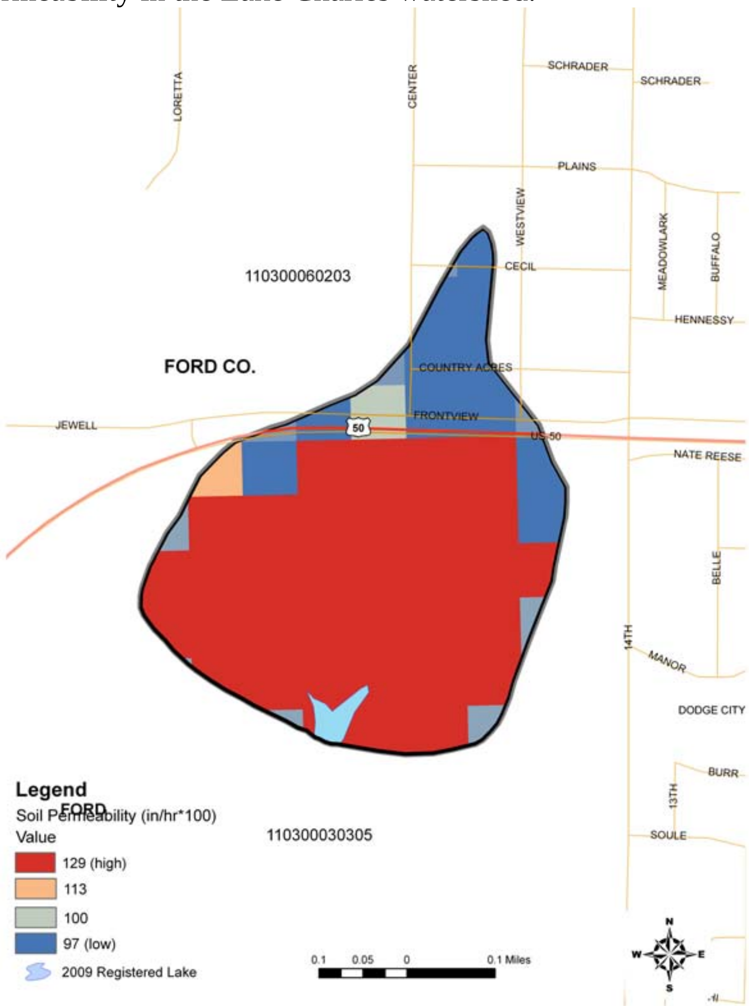
Livestock Waste Management Systems: There are no active permitted or certified confined animal feeding operations (CAFOs) in the Lake Charles watershed. However, according to USDA National Agricultural Statistics Service, on January 1, 2010, cattle inventory for Ford County was 165,000 head.

Points of Diversion: There are 1,050 unique points of diversion in Ford County. One of these points of diversion, a ground water right designated for use in irrigating authorized to pump up to 120 acre-feet annually, is owned by Dodge City Community College and is located in the Lake Charles watershed (Figure 2).

On-Site Waste Systems and Population: According to the 2000 U.S. Census, the total population of Dodge City was 25,176 with the density of the Lake Charles watershed approximately 1.8 people/acre. The 2010 U.S. Census registered an 8.6% increase in the population of Dodge City with a count of 27,340 residents. 1990 census data reveals that about 16% of households in Ford County utilize septic or other on-site systems. However, Lake Charles is located on the campus of Dodge City Community College and the watershed lies mostly within the city limits of Dodge City making nutrient impairment due to failing septic systems unlikely.

Contributing Runoff: The watershed of Lake Charles has a mean soil permeability value of 1.21 inches/hour, ranging from 0.97 inches/hour to 1.29 inches/hour according to NRCS STATSGO database (Figure 3). The entire watershed has a permeability value equal to or less than 1.29 inches/hour, with about 19% having a permeability value of 0.97 inches/hour, and 77% having 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.

Figure 3. Soil permeability in the Lake Charles watershed.



Background: Atmospheric deposition from geological formations may also contribute to nutrient loads. The suspension of sediment and nutrients may be influenced by the wind. Because Lake Charles is a small lake, nutrient cycling of the sediment is likely contributing available nutrients to the lake for algal uptake.

4. ALLOCATION OF POLLUTANT REDUCTION RESPONSIBILITY

The limited data suggest total phosphorus is limiting the production of algal growth in Lake Charles; therefore, total phosphorus will be allocated under this TMDL. The general inventory of sources within the drainage area of the lake indicates load reductions should be focused on nonpoint source runoff contributions attributed to domestic animal waste and lawn fertilizer applications. Because of atmospheric deposition, the allocation of phosphorus will include a proportional decrease in phosphorus between the current condition and the desired endpoint (Table 6).

Point Sources: A wasteload allocation is assigned to the Dodge City stormwater discharge (MS4) permit for phosphorus under this TMDL. 95.8% of the Lake Charles watershed lies within the city limits of Dodge City, therefore, 95.8% of the phosphorus load under this TMDL is allocated as wasteload to the Dodge City MS4 permit (Table 6). The assessment suggests urban fertilizer application practices and domestic animal waste contribute to the very eutrophic state of the lake and reductions should be focused on these stormwater runoff contributors. Using the CNET reservoir eutrophication modeling worksheet (Appendix A), a wasteload allocation of 0.936 pounds/year of total phosphorus entering the lake, accounting for a 95% reduction, was found to be necessary to reach the endpoint (Table 6).

Nonpoint Sources: 4.2% of the Lake Charles watershed falls outside the Dodge City city limits and this portion of the TMDL is assigned as a nonpoint source load allocation of 0.041 pounds/year of total phosphorus (Table 6).

Table 6. Lake Charles TMDL

Description	Allocations (lbs/year)	Allocations (lbs/day)*
Total Phosphorus Atmospheric Load	0.0880	0.000647
Total Phosphorus Wasteload Allocation	0.936	0.00688
Total Phosphorus Nonpoint Source Load Allocation	0.0410	0.000302
Total Phosphorus Margin of Safety	0.118	0.000870
Total Phosphorus TMDL	1.18	0.00870

*See Appendix B for Daily Load Calculations

Defined Margin of Safety: The margin of safety provides some hedge against the uncertainty of variable annual total phosphorus loads and the chlorophyll *a* endpoint. Therefore, the margin of safety is explicitly set at 10% of the original calculated total phosphorus load allocation, 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 6.

State Water Plan Implementation Priority: This TMDL will be a Low Priority for implementation.

Unified Watershed Assessment Priority Ranking: This watershed lies within the Arkansas-Dodge City Subbasin (HUC 8: 11030003) with a priority ranking of 8 (High Priority for restoration work).

Priority HUC 12: The entire watershed is within HUC 12: 110300030305.

5. IMPLEMENTATION

Desired Implementation Activities: There is some potential that urban and agricultural best management practices will improve the condition of Lake Charles.

Some of the recommended urban practices are as follows:

1. Educate watershed residents on appropriate lawn fertilizer application.
2. Install grass buffer strips along drainage channels in the watershed.

3. Promote proper management of construction sites to minimize sediment and nutrient runoff.
4. Investigate feasibility of installing a storm water wetland in the watershed to aid in the removal of nutrients.
5. Promote installation of porous and concrete grid pavement in the watershed.

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.

Implementation Program Guidance:

NPDES – MS4

a. It is a condition of the Dodge City stormwater permit to install best management practices (BMPs) that will attenuate the discharge of TMDL regulated parameters; hence, the city should implement BMPs that will reduce the nutrient load to Lake Charles.
b. Sample storm events to Lake Charles for nutrients in order assess baseline nutrient inputs and any post-BMP improvement.
c. Encourage the City of Dodge City to retrofit media filters and wetland channels along flow paths of stormwater coming from developed areas around the lake
d. Support construction of retention ponds and wetland basins to reduce particulate phosphorus, organic nitrogen and nitrates from stormwater.
e. Promote good housekeeping in developed areas near the lake, including street sweeping and prudent fertilizer use on lawns in residential areas.

Watershed Management Program – KDHE

a. Support Section 319 project activities by Dodge City Community College for Lake Charles, 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.

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.

Time Frame for Implementation: Initial implementation will proceed over the years from 2012-2020. Additional implementation may be required over 2021-2030 to achieve the endpoints of this TMDL.

Targeted Participants: Primary participants for implementation will be Dodge City Community College, Dodge City Public Works and residents within the Lake Charles watershed. A detailed assessment of sources conducted over 2013-2014 should include local assessments by conservation district personnel and county extension agents to survey, locate, and assess the sources of stormwater runoff within the lake drainage area.

Milestone for 2016: In accordance with the TMDL development schedule for the State of Kansas, the year 2016 marks a future cycle of 303(d) activities in the Upper Arkansas Basin. At that point in time, sampled data from Lake Charles 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 Kansas Department of Agriculture – Division of Conservation, the Kansas Department of Parks and Wildlife, the Natural Resources Conservation Service, the Kansas State University Extension Service, the Ford County Conservation District and the City of Dodge City. Producer outreach and awareness will be delivered by Kansas State University Extension Office.

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.

7. The Kansas Water Plan and the Upper Arkansas 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. This TMDL is Low Priority for implementation.

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

Lake Charles will be sampled after it refills and sustains depth, hopefully during the 2012 to 2021 time period. Additionally, a future MS4 NPDES permit for Dodge City may include a condition to sample the lake for nutrients.

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 Upper Arkansas Basin.

Public Hearing: A Public Hearing was held on September 20th, 2012 in Garden City to receive comments on this TMDL.

Basin Advisory Committee: The Upper Arkansas River Basin Advisory Committee met to discuss these TMDLs on April 4th, 2012 in Jetmore and September 20th 2012 in Garden City.

Milestone Evaluation: In 2016, evaluation will be made as to any 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 2016 with consultation from local stakeholders.

Consideration for 303d Delisting: Lake Charles will be evaluated for delisting under Section 303d, based on the monitoring data over 2012-2021. Therefore, the decision for delisting will come about in the preparation of the 2022-303d 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 2012-2021.

Developed 10/17/12

References

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WIMAS Query. Kansas Geological Survey. April 27, 2011. http://hercules.kgs.ku.edu/geohydro/wimas/query_setup.cfm

Appendix A. Appendix A – CNET Eutrophication Model for Lake Charles.
Input for CNET Model

Parameter	Value Input into CNET Model
Drainage Area (km^2)	0.445
Precipitation (m/yr)	0.52
Evaporation (m/yr)	1.69
Unit Runoff (m/yr)	0.016
Surface Area (km^2)	0.004
Max Depth (m)	3
Mean Depth (m)	1.3
Depth of Mixed Layer (m)	1.23
Depth of Hypolimnion (m)	0.50
Observed Phosphorus (ppb)	167
Observed Chlorophyl *a* (ppb)	29.4
Observed Secchi Disc Depth	0.38

Output from CNET Model

Parameter	Output from CNET Model
Load Capacity (LC)*	1.18 lbs/year
Waste Load Allocations (WLA)	0.936 lbs/year
Atmospheric Air Deposition (LA)	0.0880 lbs/ year
Other Nonpoint (LA)	0.0410 lbs/year
Total Load Allocation (LA+WLA)	1.06 lbs/year
Margin of Safety (MOS)	0.118 lbs/year

*LC=WLA + LA + MOS

CNET Eutrophication Model for Lake Charles.

RESERVOIR EUTROPHICATION MODELING WORKSHEET TITLE -> **Lake Charles** Based on CNET.WK1 VERSION 1.0

VARIABLE	UNITS	Current	LC
WATERSHED CHARACTERISTICS...		Latitude	37
Drainage Area	km2	0.445	0.445
Precipitation	m/yr	0.52	0.52
Evaporation	m/yr	1.69	1.69
Unit Runoff	m/yr	0.016	0.016
Stream Total P Conc.	ppb	1240	70
Stream Ortho P Conc.	ppb	248	14
Atmospheric Total P Load	kg/km2-yr	10	10
Atmospheric Ortho P Load	kg/km2-yr	0	0
POINT SOURCE CHARACTERISTICS...			
Flow	hm3/yr	0.0073	0.0073
Total P Conc	ppb		0.0
Ortho P Conc	ppb	0	0
RESERVOIR CHARACTERISTICS...			
Surface Area	km2	0.004	0.004
Max Depth	m	3	3
Mean Depth	m	1.3	1.3
Non-Algal Turbidity	1/m	1.9	0.47
Mean Depth of Mixed Layer	m	1.23	1.23
Mean Depth of Hypolimnion	m	0.50	0.50
Observed Phosphorus	ppb	167	24.9
Observed Chl-a	ppb	29.4	12.0
Observed Secchi	meters	0.38	1.30
MODEL PARAMETERS...			
BATHTUB Total P Model Number	(1-8)	1	1
BATHTUB Total P Model Name		AVAIL P	
BATHTUB Chl-a Model Number	(2,4,5)	2	2
BATHTUB Chl-a Model Name		P L Q	
Beta = 1/S vs. C Slope	m2/mg	0.089509	0.064103
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	0.0021	0.0021
NonPoint Flow	hm3/yr	0.0071	0.0071
Point Flow	hm3/yr	0.0073	0.0073
Total Inflow	hm3/yr	0.0165	0.0165
Evaporation	hm3/yr	0.0068	0.0068
Outflow	hm3/yr	0.0097	0.0097

VARIABLE	UNITS	Current	LC
AVAILABLE P BALANCE...			
Precipitation Load	kg/yr	0	0
NonPoint Load	kg/yr	5	0
Point Load	kg/yr	0	0
Total Load	kg/yr	5	0
Sedimentation	kg/yr	4	0
Outflow	kg/yr	2	0
PREDICTION SUMMARY...			
P Retention Coefficient	-	0.701	0.259
Mean Phosphorus	ppb	167.3	24.9
Mean Chlorophyll-a	ppb	26.1	11.9
Algal Nuisance Frequency	%	98.0	42.2
Mean Secchi Depth	meters	0.24	0.81
Hypol. Oxygen Depletion A	mg/m2-d	1226.8	828.4
Hypol. Oxygen Depletion V	mg/m3-d	2453.5	1656.8
Organic Nitrogen	ppb	895.8	464.0
Non Ortho Phosphorus	ppb	87.4	28.2
Chl-a x Secchi	mg/m2	6.2	9.7
Principal Component 1	-	3.37	2.52
Principal Component 2	-	0.60	0.79
	Observed	Pred	Target
Carlson TSI P	78.0	78.0	50.5
Carlson TSI Chl-a	63.8	62.6	54.9
Carlson TSI Secchi	74.0	80.8	63.0
OBSERVED / PREDICTED RATIOS...			
Phosphorus		1.00	1.00
Chlorophyll-a		1.13	1.01
Secchi		1.61	1.60
OBSERVED / PREDICTED T-STATISTICS...			
Phosphorus		-0.01	0.00
Chlorophyll-a		0.43	0.03
Secchi		1.75	1.74
ORTHO P LOADS...			
Precipitation	kg/yr	0	0
NonPoint	kg/yr	2	0
Point	kg/yr	0	0
Total	kg/yr	2	0
Total	#/year	4	0

VARIABLE	UNITS	Current	LC
RESPONSE CALCULATIONS...			
Reservoir Volume	hm3	0.0052	0.0052
Residence Time	yrs	0.5339	0.5339
Overflow Rate	m/yr	2.4	2.4
Total P Availability Factor		1	1
Ortho P Availability Factor		1.93	1.93
Inflow Ortho P/Total P		0.199	0.185
Inflow P Conc	ppb	560.4	33.6
P Reaction Rate - Mods		7.9	0.5
P Reaction Rate - Model 2		13.0	0.8
P Reaction Rate - Model 3		29.9	1.8
1-Rp Model 1 - Avail P		0.299	0.741
1-Rp Model 2 - Decay Rate		0.241	0.648
1-Rp Model 3 - 2nd Order Fixe		0.167	0.518
1-Rp Model 4 - Canfield & Bacl		0.219	0.597
1-Rp Model 5 - Vollenweider 1		0.578	0.578
1-Rp Model 6 - First Order De		0.652	0.652
1-Rp Model 7 - First Order Set		0.709	0.709
1-Rp Model 8 - 2nd Order Tp O		0.299	0.741
1-Rp - Used		0.299	0.741
Reservoir P Conc	ppb	167.3	24.9
Gp		0.243	0.243
Bp	ppb	227.9	16.7
Chla vs. P, Turb, Flus	2	26.1	11.9
Chla vs. P Linear	4	46.8	7.0
Chla vs. P 1.46	5	142.8	8.8
Chla Used	ppb	26.1	11.9
m1 - Nuisance Freq Calc.		3.2	2.4
z		-2.048	0.196
v		0.049	0.391
w		0.595	0.939
x		0.020	0.422
TOTAL P LOADS...			
BAF Override (KS)	OrP %		
0.5	0%	0.04	0.040
0.23	20%	8.83	0.498
0.8	0%	0.00	0.000
		8.87	0.538
		19.51	1.184

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

The TMDL has estimated annual average loads for 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	Point WLA lbs/day	NonPoint LA lbs/day	MOS (10%) lbs/day
TP	1.18	0.5	2.68	0.00870	0.000647	0.00688	0.000302	0.000870

Maximum Daily Load Calculation
Annual TP Load = 1.18 lbs/yr

Maximum Daily TP Load = [(1.18 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.472) - 0.5*(0.472)^2]}$
= 0.00870 lbs/day

Margin of Safety (MOS) for Daily Load
Annual TP MOS = 0.118 lbs/yr

Daily TP MOS = [(0.118 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.472) - 0.5*(0.472)^2]}$
= 0.000870 lbs/day

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