KANSAS-LOWER REPBULICAN BASIN TOTAL MAXIMUM DAILY LOAD

Water Body / Assessment Unit: Lower Kansas River, Lecompton to Kansas City
Water Quality Impairment: Total Phosphorus

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Lower Kansas **Counties**: Johnson, Wyandotte, Leavenworth, Douglas, and Jefferson

HUC8: 10270104 **HUC10**(12): 02 (02, 04, 05)
05 (01, 02, 03, 05)
06 (01, 02, 03, 04, 05, 06, 07)

Ecoregion: Central Irregular Plains, Osage Cuestas 40b

Drainage Area: Approximately 588.6 square miles between Kansas City and Lecompton (see figure 1).

Main Stem Water Quality Limited Segments:

Station	***Main Stem***	***Tributary***
SC203	Kansas R (1)	Brenner Heights Cr (1175)
		Mattoon Cr (1178)
		Barber Cr (373)
		Tooley Creek (379)
		Muncie Creek (55)
		Little Turkey Cr (62)
		Turkey Cr (77)
		Mill Cr (39)
	Kansas R (2)	Piper Cr (1154)
		Mission Cr, West (1164)
		Clear Cr (383)
		Hays Cr (406)
		Wolf Cr (53)
		Little Kaw Cr (59)
		Mission Cr, East (61)
	Kansas R (3)	Cedar Cr (38)
		Camp Cr (74)
SC254	Kansas R (4, 18)	

SC255	Kansas R (19)	Kent Cr (73) Mud Cr (20) Plum Cr (50)
	Kansas R (21)	Buck Cr (22) Baldwin Cr (69)
	Kansas R (23)	Oakley Cr (56) Stone House Cr (57) Stone House Cr, West (830) Stone House Cr, East (9057)
SC251	Mill Cr (39)	Little Mill Cr (78)
SC252	Cedar Cr (38)	Little Cedar Cr (76)

Non-Water Quality Limited Segments Covered Under this TMDL:

Station	***Main Stem***	***Tributary***
SC500	Wakarusa R (24, 25)	Yankee Tank Cr (70) Little Wakarusa Cr (71)
SC253	Kill Cr (37)	Hanson Cr (437) Spoon Cr (75) Unnamed Stream (452)

303(d) Listings: SC203: 2008, 2010, 2012, 2014 & 2016
SC254: 2008, 2010, 2012, 2014 & 2016
SC255: 2010, 2012, 2014 & 2016

SC251: 2008, 2010, 2012, 2014 & 2016
SC252: 2008, 2010, 2012, 2014 & 2016
SC500: Not listed
SC253: Not listed

Impaired Use: Expected Aquatic Life, Contact Recreation and Domestic Water Supply

Water Quality Criteria:
Nutrients – Narrative: 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(d)(3)(D)).

The introduction of plant nutrients into streams, lakes, or wetlands from artificial sources shall be controlled to prevent the accelerated succession or replacement or aquatic biota or the production of undesirable quantities or kinds of aquatic life (K.A.R. 28-16-28e(d)(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 (K.A.R. 28-16-28e(d)(7)(A))

Designated Uses: The Kansas River is designated for Special Aquatic Life use and all other streams in the watershed, as detailed in the TMDL watershed in Figure 1, are designated for Expected Aquatic Life. All other designated uses are detailed in Table 1.

Figure 1. Lower Kansas River Watershed base map.

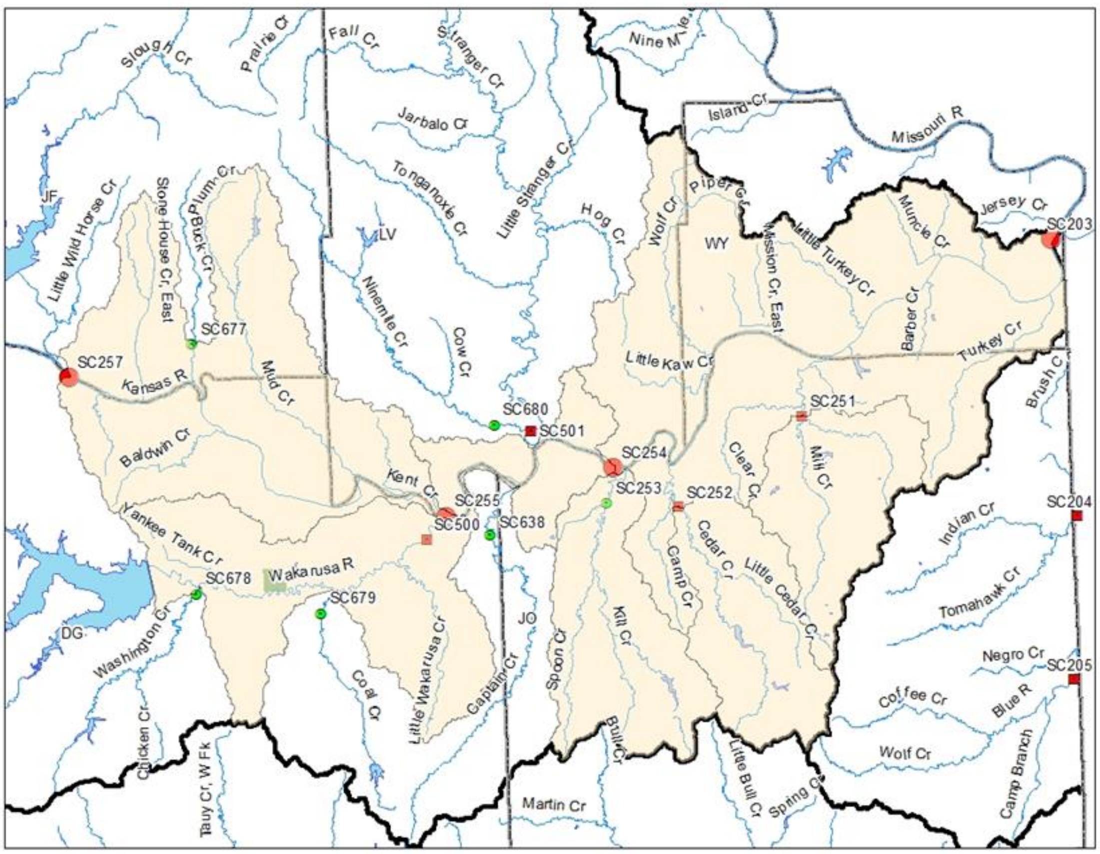


Table 1. Designated uses for main stem water quality limited segments. Y= Yes (Use designated); N=No (use is not designated); E= Expected aquatic life; S=Special Aquatic Life.

Stream Name	Segment #	Aquatic Life Use	Contact Recreation Use	Domestic Water Supply Use	Food Procurement Use	Ground Water Recharge	Industrial Water Use	Irrigation Use	Livestock Watering Use
Kansas R	1	S	B	Y	Y	Y	Y	Y	Y
Brenner Heights Cr	1175	E	B	Y	Y	Y	Y	Y	Y
Mattoon Cr	1178	E	B	Y	Y	Y	Y	Y	Y
Barber Cr	373	E	b	Y	Y	Y	Y	Y	Y
Tooley Cr	379	E	b	Y	Y	Y	Y	Y	Y
Mill Cr	39	E	B	Y	Y	Y	Y	Y	Y
Little Mill Cr	78	E	B	N	Y	Y	Y	Y	Y
Muncie Cr	55	E	b	Y	N	Y	Y	Y	Y
Little Turkey Cr	62	E	C	Y	Y	Y	Y	Y	Y
Turkey Cr	77	E	B	Y	Y	Y	Y	Y	Y
Kansas R	2	S	B	Y	Y	Y	Y	Y	Y
Piper Cr	1154	E	B	N	Y	N	N	Y	Y
Mission Cr, West	1164	E	b	N	N	N	N	Y	Y
Clear Cr	383	E	B	N	Y	Y	N	Y	Y
Hays Cr	*406*	*E*	*b*	N	N	N	N	Y	Y
Wolf Cr	53	E	C	Y	Y	Y	Y	Y	Y
Little Kaw Cr	59	E	C	Y	Y	Y	Y	Y	y
Mission Cr, East	61	E	b	N	N	N	N	Y	Y
Kansas R	3	S	B	Y	Y	Y	Y	Y	Y
Cedar Cr	38	E	B	Y	Y	Y	Y	Y	Y
Little Cedar Cr	76	E	B	N	Y	Y	N	Y	Y
Camp Cr	74	E	b	N	Y	N	N	Y	Y
Kansas R	18	S	B	Y	Y	Y	Y	Y	Y
Kansas R	4	S	B	Y	Y	Y	Y	Y	Y
Kansas R	19	S	B	Y	Y	Y	Y	Y	Y
Mud Cr	20	E	C	Y	Y	Y	Y	Y	Y
Kent Cr	73	E	b	Y	Y	Y	Y	Y	Y
Plum Cr	50	E	b	Y	N	Y	Y	Y	Y
Kansas R	21	S	B	Y	Y	Y	Y	Y	Y
Buck Cr	22	S	b	Y	Y	Y	Y	Y	Y
Baldwin Cr	69	E	b	Y	N	Y	Y	y	Y
Kansas R	23	S	B	Y	Y	Y	Y	Y	Y
Oakley Cr	56	E	b	Y	N	Y	Y	Y	Y
Stone House Cr	57	E	b	Y	N	Y	Y	Y	Y
Stone House Cr, West	830	E	b	Y	N	Y	Y	Y	Y
Stone House Cr, East	9057	E	b	Y	N	Y	Y	Y	Y
Wakarusa R	24	E	B	Y	Y	Y	Y	Y	Y
Wakarusa R	25	E	B	Y	Y	Y	Y	Y	Y
Yankee Tank Cr	70	E	B	Y	Y	Y	Y	Y	Y
Little Wakarusa Cr	71	E	C	y	Y	Y	Y	Y	Y
Kill Cr	37	E	B	Y	Y	Y	Y	Y	Y
Hanson Cr	437	E	b	Y	Y	Y	Y	Y	Y
Unnamed Stream	452	E	b	Y	Y	Y	Y	Y	Y

2. CURRENT WATER QUALITY CONDITIONS AND DESIRED ENDPOINT

Level of Support for Designated Uses under 2016-303(d): Phosphorus levels on the Kansas River are consistently high. Excessive nutrients are not being controlled and are thus impairing aquatic life, domestic water supply, and contact recreation.

Stream Monitoring Sites and Period of Record:
Station SC203: Active KDHE permanent station located on the Kansas River at Kansas City, KS. Period of Record: Samples obtained bimonthly or quarterly from 1990-2016.

Station SC254: Active KDHE permanent station located on the Kansas River at De Soto. Period of Record: Samples obtained bimonthly or quarterly from 1990-2016.

Station SC255: Active KDHE rotational station located on the Kansas River at Eudora. Period of Record: Samples obtained monthly during intensive sampling during 1996, 1997, and 1998. Samples obtained bimonthly or quarterly during 2003, 2007, 2011, and 2015.

Hydrology: Long term flow conditions for the Lower Kansas River were based on USGS gages on the Kansas River, including the USGS Gage 06891000 at Lecompton and USGS Gage 06892350 at De Soto as displayed in Table 2 for the period of record of 1990 through July of 2016. These gages have been utilized for an extended period as the Lecompton gage has been in use since 1936 and the De Soto gage has been active since 1917. Drainage area ratios were utilized to determine flow at the respective KDHE sampling stations along the Kansas River. Kansas River Tributary inflows were calculated based on drainage area ratios within the watershed relative to the USGS gage information to assess steady state conditions for modeling and mass balance scenarios associated with this TMDL. Long term flow conditions for the tributaries in the watershed were derived from the USGS Scientific Investigations Report 2004-5033 (Perry, 2004), which are displayed in Table 3.

Table 2. Long term flow conditions as calculated from USGS gages 06891000 and 06892350 (1990-2016).

Stream	Drainage Area (sq. miles)	Mean Flow (cfs)	Percent of Flow Exceedance				
			90% (cfs)	75% (cfs)	50% (cfs)	25% (cfs)	10% (cfs)
Kansas R @ USGS Gage 06891000	55888	6715	1060	1640	3160	7058	16000
Kansas R @ SC255	57755	6939	1095	1695	3266	7293	16535
Kansas R @ USGS Gage 06892350 & SC254	58354	7405	1160	1820	3500	8020	17600
Kansas R @ SC203	58740	7454	1168	1832	3523	8073	17716

Table 3. Estimated tributary flow values as estimated from USGS (Perry, 2004).

Stream	Drainage Area (sq. miles)	Mean Flow (cfs)	Percent of Flow Exceedance				
			90% (cfs)	75% (cfs)	50% (cfs)	25% (cfs)	10% (cfs)
Oakley Cr	13.84	15.64	0	0.54	3.27	9.71	24.23
Stone House Cr	19.92	20.95	0	1.09	4.72	13.42	32.82
Buck Cr	17.56	19.77	0	0.97	4.53	13	31.64
Baldwin Cr	16.43	16.77	0	0.5	3.15	9.61	24.74
Mud Cr	46.88	46.88	0	1.99	9.06	28.38	74.38
Kent Cr	10.52	10.46	0	0.1	1.78	5.49	14.53
Wakarusa R	521.54	274.96	7.17	16.63	34.01	271.78	919.44
Captain Cr	44.02	34.7	0	0.76	4.72	16.46	47.45
Stranger Cr	540.96	332.95	3.06	12.45	56.05	188.91	601.94
Kill Cr	62.15	49.01	0	1.12	6.46	23.22	68.42
Cedar Cr	55.44	49.13	0	1.28	7.22	25.33	72.25
Little Kaw Cr	18.06	15.64	0	0	2.02	7.24	20.88
Wolf Cr	34.46	29.85	0	0.82	4.81	15.84	43.34
Mission Cr, East	13.51	14.77	0	0.95	3.85	10.18	23.76
Mill Cr	65.92	65.92	0	2.29	10.94	36.63	101.82
Tooley Cr	2.55	3.49	1.01	1.42	2.21	3.59	6.39
Little Turkey Cr	19.89	20.84	0	1.56	5.59	14.64	33.93
Barber Cr	10.05	12.3	0	1.33	4.09	9.66	20.83
Muncie Cr	14.59	16.19	0	1.33	4.61	11.7	26.53
Mattoon Cr	2.2	2.68	0.685	1.37	1.8	2.64	4.61
Turkey Cr	31.43	31.09	0	1.61	6.64	19.41	48.56

Flow duration curves over the period of record from 1990-2016 are illustrated for the USGS gages in Figure 2. Annual average and median flows for the De Soto gage are detailed in Figure 3. Monthly average and median flows are detailed in Figure 4. Annual peak flows are detailed in Figure 5 for the De Soto gage. Extremely dry years were observed in 1991, 2000, 2002, 2003, 2004, 2006, 2012, 2013, and 2014. Annual peak flows were the greatest during 1993, 1995, 1998, 1999, 2007, and 2015. Throughout the year on the Kansas River, streamflow averages are the highest during the months of April, May, June, July and August.

Figure 2. Flow duration at USGS gages 06891000 at Lecompton and 06892350 at De Soto on the Kansas River.

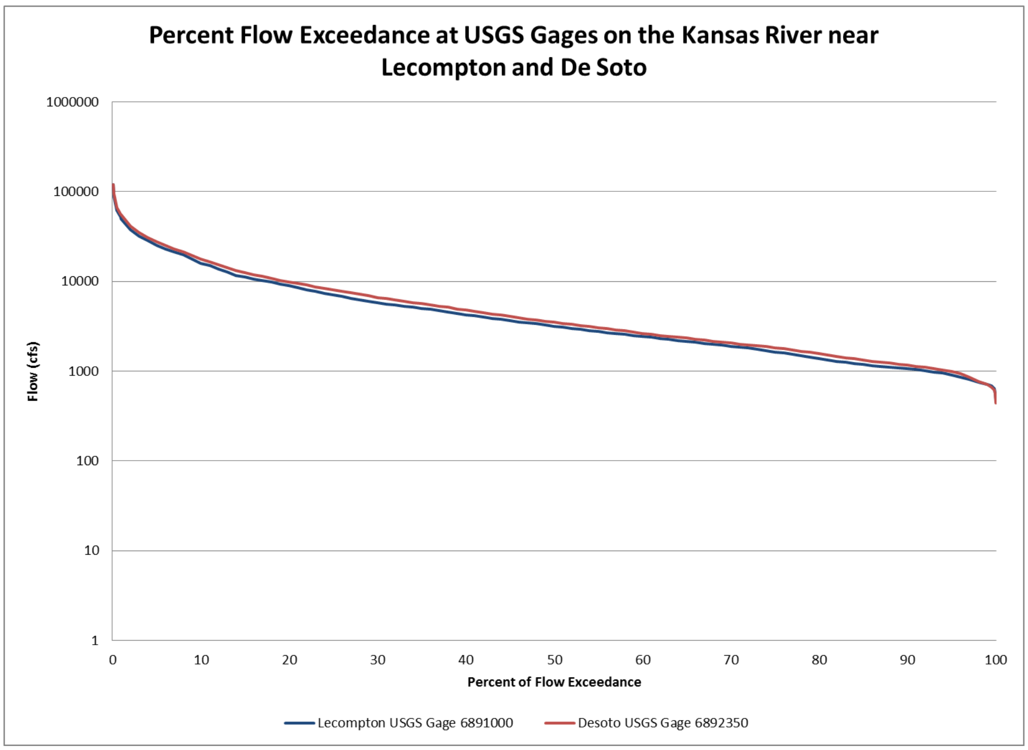


Figure 3. Annual average and median flows for USGS gage 06892350 on the Kansas River.

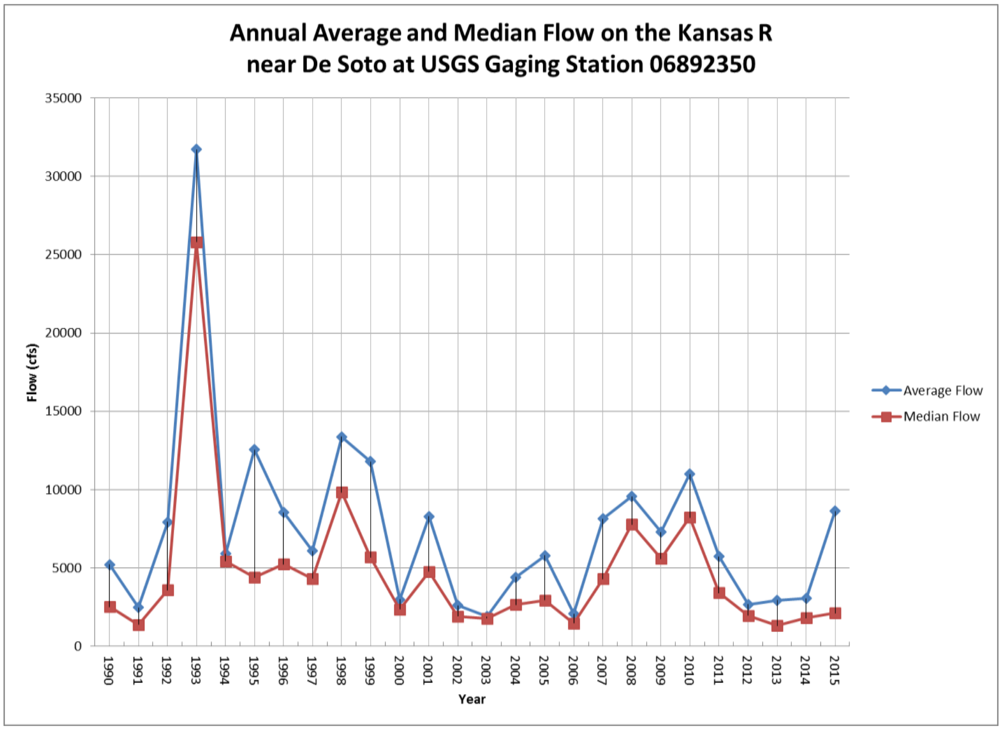


Figure 4. Monthly average and median flow at USGS gage 06892350.

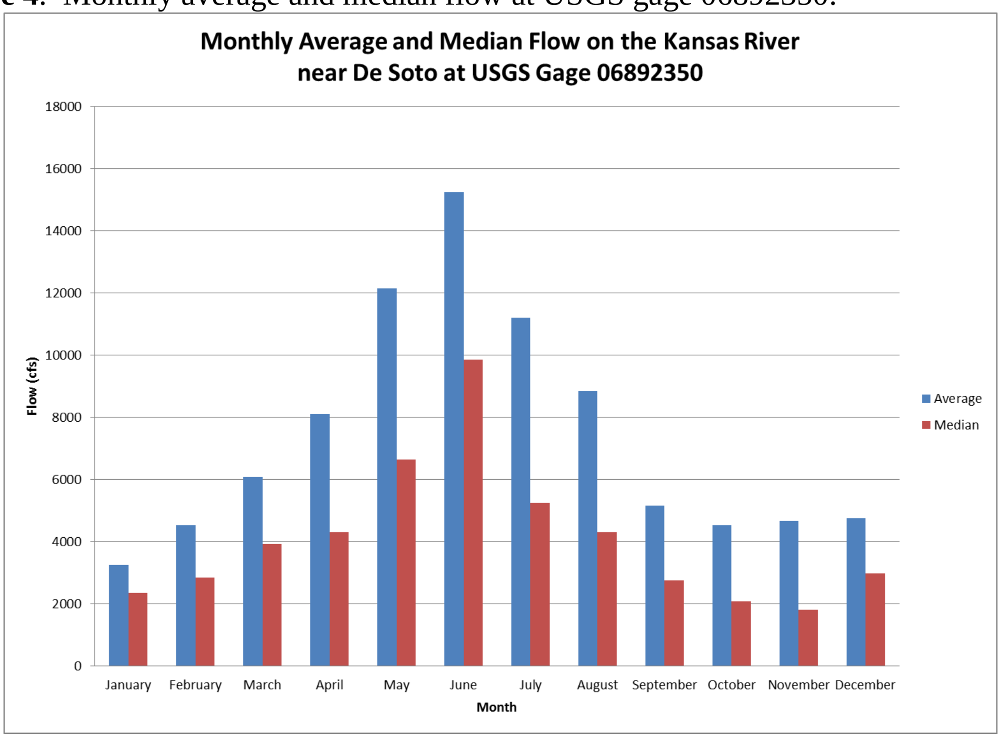
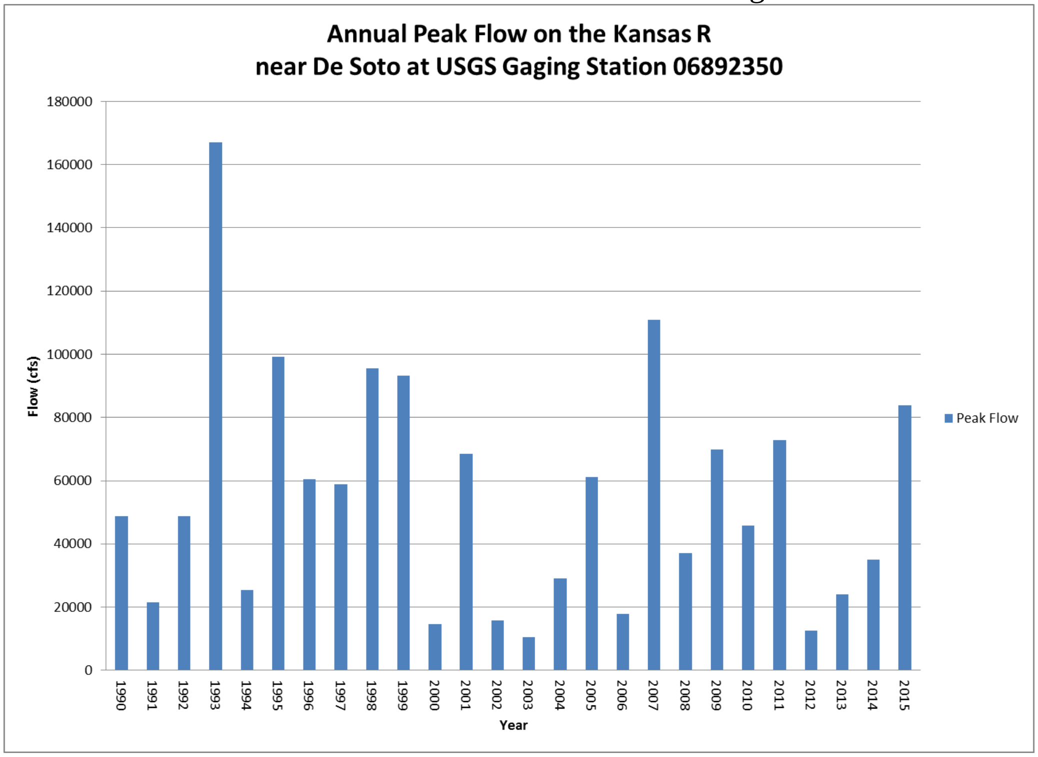


Figure 5. Peak annual flows on the Kansas River at USGS Gage 06892350.



Assessment Season: Seasonal variability has been accounted for in this TMDL. A three season approach was utilized to include: the Spring season consisting of the months of April, May, and June; the Summer-Fall season consisting of the months of July, August, September, and October; and the Winter season that includes January, February, March, November and December.

Phosphorus Concentrations: The overall Total Phosphorus (TP) concentration average at SC254 on the Kansas River at De Soto is 0.409 mg/L, with a median concentration of 0.335 mg/L. Seasonal TP averages range from a low of 0.353 mg/L in the Winter season to a high of 0.453 mg/L in the Spring season. Seasonal median concentrations at SC254 range from a low of 0.286 mg/L in the Winter to 0.358 mg/L in the Spring season, to a high of 0.381 mg/L in the Summer-Fall season.

The overall TP concentrations at SC203 on the Kansas River at Kansas City are similar to those at De Soto. The TP average concentration at SC203 is 0.409 mg/L, with a median concentration of 0.330 mg/L. Seasonal TP averages are similar between the three seasons and range from a low of 0.400 mg/L in the Winter season to a high of 0.416 mg/L in the Spring season. Seasonal median concentrations at SC203 range from a low of 0.316 mg/L in the Winter to 0.336 mg/L in the Spring season, to a high of 0.380 mg/L in the Summer-Fall season. Median TP concentrations are similar in the Spring and Summer-Fall seasons at Kansas City and De Soto, where median concentrations during the Winter are considerably higher at Kansas City (SC203) than De Soto (SC254). Seasonal concentrations are detailed in Figure 6.

Figure 6. Boxplot of seasonal TP concentrations at SC254 and SC203 on the Kansas River.

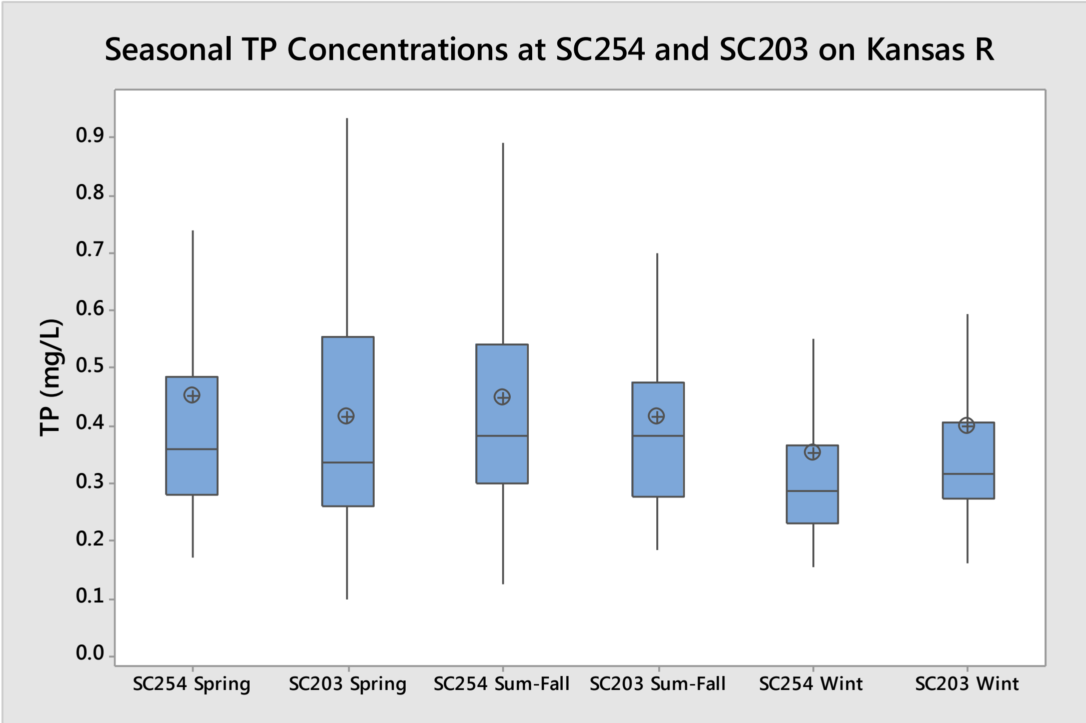
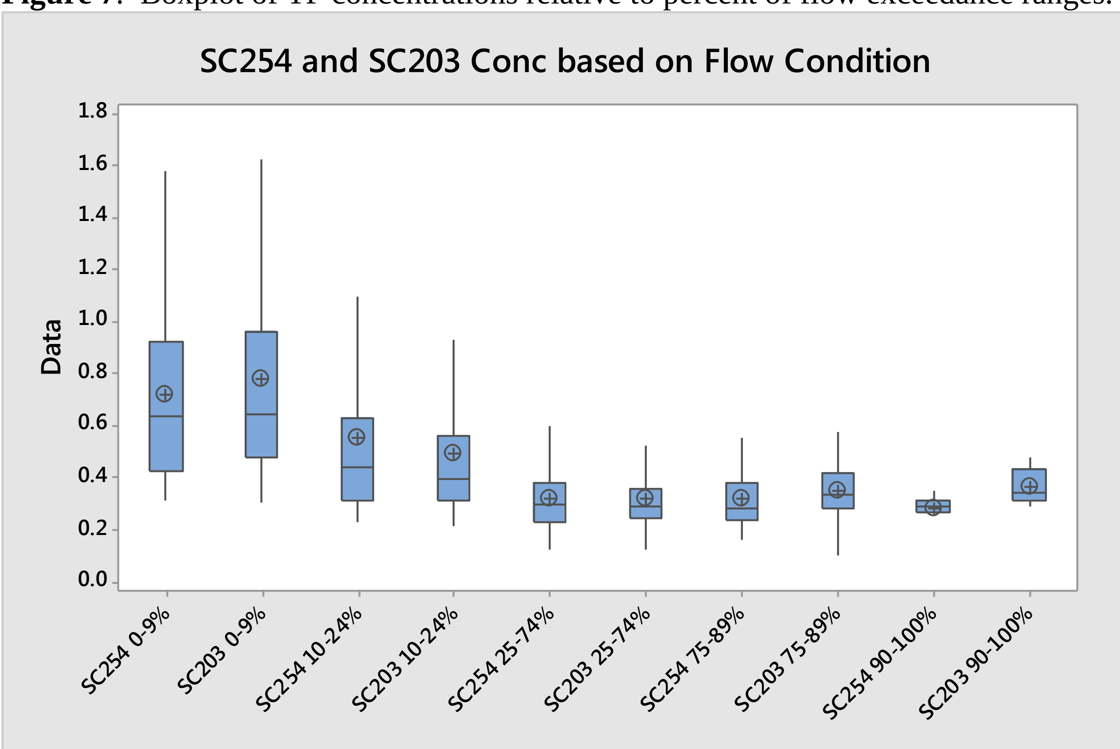


Figure 7. Boxplot of TP concentrations relative to percent of flow exceedance ranges.



Tables 4 and 5 detail the TP averages and medians based on various flow conditions at sampling stations SC254 and SC203. Additionally Figure 7 details the TP concentrations based on the flow conditions at SC254 and SC203. Phosphorus concentration averages relative to flow are the highest during the high flow condition (0-9% flow exceedance) at SC254 and SC203, with an average of 0.722 mg/L and 0.777 mg/L respectively. The lowest TP concentration average of 0.317 mg/L is seen during lower flow conditions (75-89% flow exceedance) at SC254. Whereas the lowest TP average at SC203 occurs during normal flow conditions (25-74% flow exceedance), averaging 0.314 mg/L. TP average and median concentrations at SC203 increase from the normal flow condition as flows decrease, which is indicative of point source loading in the lower end of the watershed. Median concentrations at SC254 are slightly lower as flows decrease from the normal flow condition to the lower flow condition (75-89% flow exceedance), but then median concentrations slightly increase during the low flow (90-100% flow exceedance) condition. TP average and median concentrations respectively rise from the normal flow condition to the high flow condition at both stations, indicating an increase of nonpoint source loading during higher flow and runoff conditions.

Table 4. SC254 TP average and median concentrations relative to percent of flow exceedance.

% of Flow Exceedance	TP Avg (mg/L)	TP Median (mg/L)
0-9%	0.722	0.632
10-24%	0.550	0.437
25-74%	0.320	0.297
75-89%	0.317	0.280
90-100%	0.278	0.285

Table 5. SC203 TP average and median concentrations relative to percent of flow exceedance.

% of Flow Exceedance	TP Avg (mg/L)	TP Median (mg/L)
0-9%	0.777	0.643
10-24%	0.488	0.392
25-74%	0.314	0.290
75-89%	0.349	0.330
90-100%	0.364	0.338

Seasonal TP concentrations based on flow conditions are further detailed in Tables 6 and 7 and Figures 8, 9 and 10. The highest TP concentrations are observed during the high flow conditions during the winter season at both SC254 and SC203. During the normal and low flow conditions, TP concentrations are the highest during the Summer-Fall season at both sampling sites. The higher TP concentrations during the low flow (90-100% flow exceedance) conditions during all three seasons at SC203 are indicative of wastewater loading from discharging facilities in the lower Kansas River below De Soto.

At SC254, TP concentrations increase as flows decrease from the normal flow condition (25-74% flow exceedance) to the lower flow condition (75-89% flow exceedance) during the Summer-Fall and Winter seasons. TP concentrations then dip back below those seen during normal flow conditions when the river is at the low flow condition during these seasons. In the Spring season at SC254, TP concentrations during the low flow condition are higher than those observed during the lower flow condition. The seasonal pattern of TP concentrations relative to flow at SC254 indicates point sources influence concentrations during the low flow condition enough that the concentrations do not significantly decrease and remain relatively similar to the concentrations observed during normal flows. However, the point source impact on the concentrations observed at SC254 are somewhat negated by the volume of flow in the Kansas River relative to the volume of effluent being input by discharging facilities since TP concentrations do not increase during the low flow condition, as is the case at SC203.

Table 6. SC254 Seasonal Average TP concentrations based on Flow Conditions.

% of Flow Exceedance	Spring TP Avg (mg/L)	Summer-Fall TP Avg. (mg/L)	Winter TP Avg (mg/L)	All Seasons TP Avg (mg/L)
0-9 %	0.651	0.695	1.020	0.722
10-24 %	0.600	0.565	0.503	0.550
25-74 %	0.334	0.359	0.279	0.320
75-89%	0.259	0.410	0.284	0.317
90-100 %	0.290	0.342	0.256	0.278
All Average	0.453	0.444	0.353	0.409
All Median	0.358	0.381	0.286	0.335

Table 7. SC203 Seasonal Average TP concentrations based on Flow Conditions.

% of Flow Exceedance	Spring TP Avg (mg/L)	Summer-Fall TP Avg. (mg/L)	Winter TP Avg (mg/L)	All Seasons TP Avg (mg/L)
0-9 %	0.707	0.771	1.020	0.777
10-24 %	0.471	0.443	0.538	0.488
25-74 %	0.301	0.331	0.307	0.314
75-89%	0.243	0.389	0.354	0.349
90-100 %	0.303	0.400	0.365	0.364
All Average	0.416	0.410	0.400	0.409
All Median	0.336	0.380	0.316	0.330

Figure 8. TP concentrations at De Soto and Kansas City relative to percent flow exceedance.

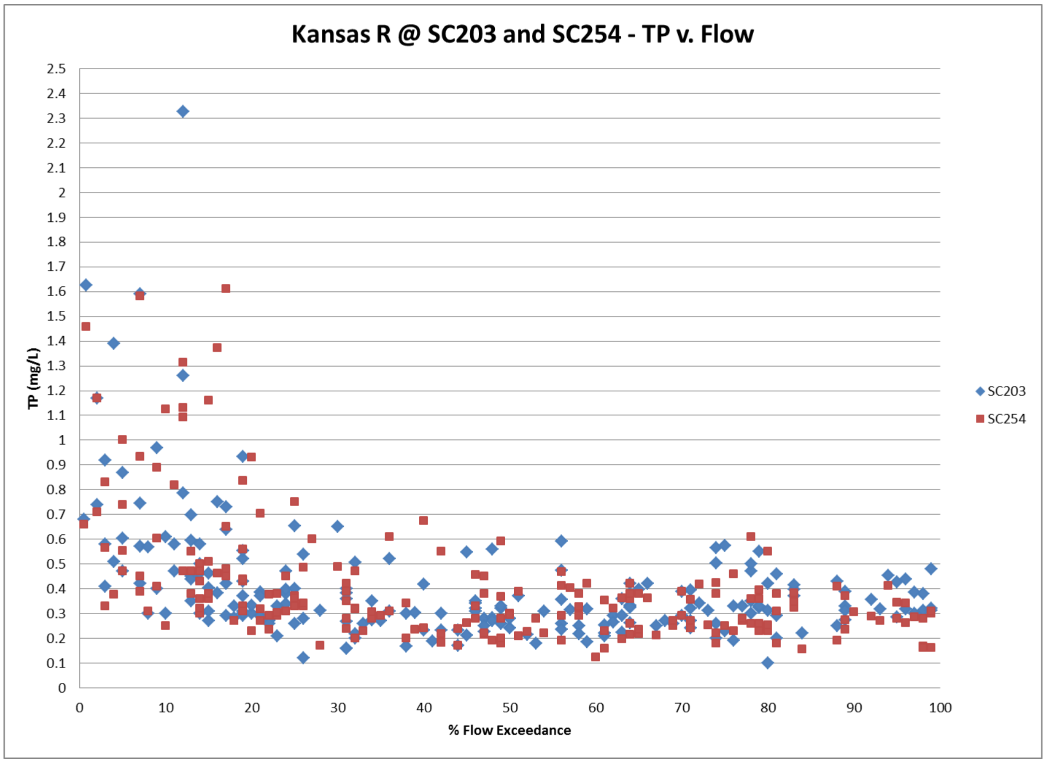


Figure 9. Seasonal TP concentration relative to percent flow exceedance at SC254 De Soto.

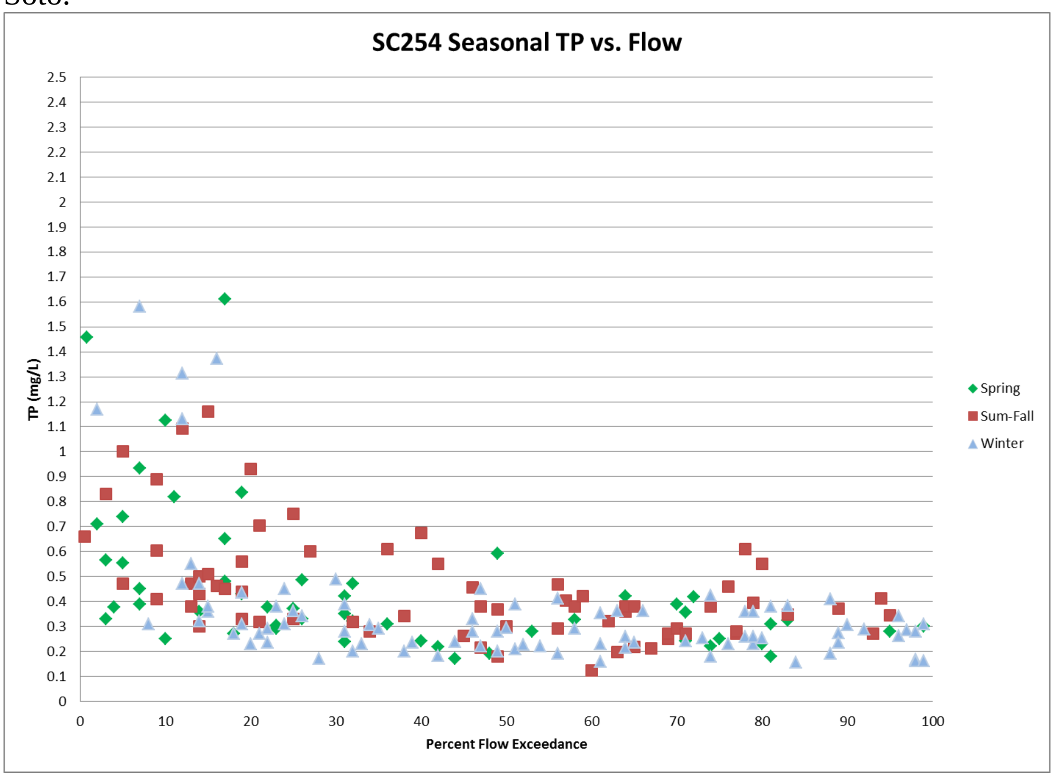
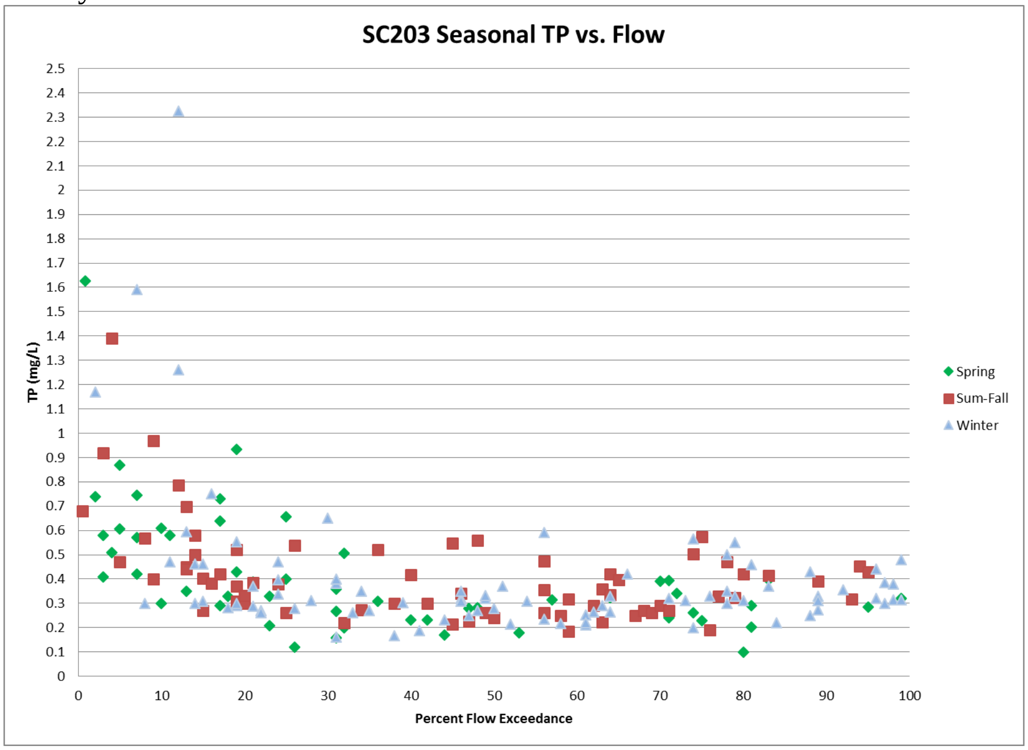


Figure 10. Seasonal TP concetrations relative to percent flow exceedance at SC203 Kansas City.



Annual average and TP concentrations at SC203 and SC254 are detailed in Figures 11 and 12. At SC254 annual averages and median are the highest during 2008 and 2011, in which TP was detected at an elevated concentration during high flow conditions. The lowest annual median concentrations were observed during 1994, 1995 and 2000. As SC203 the highest annual TP averages and median concentrations were observed in 2001, 2007, and 2008. The lowest annual median concentrations were observed during 1995, 2000, and 2009 at SC203. At both stations, the years with the highest annual TP averages are influenced by samples collected during high flow conditions.

Figure 11. Annual average TP and median concentrations at SC254.

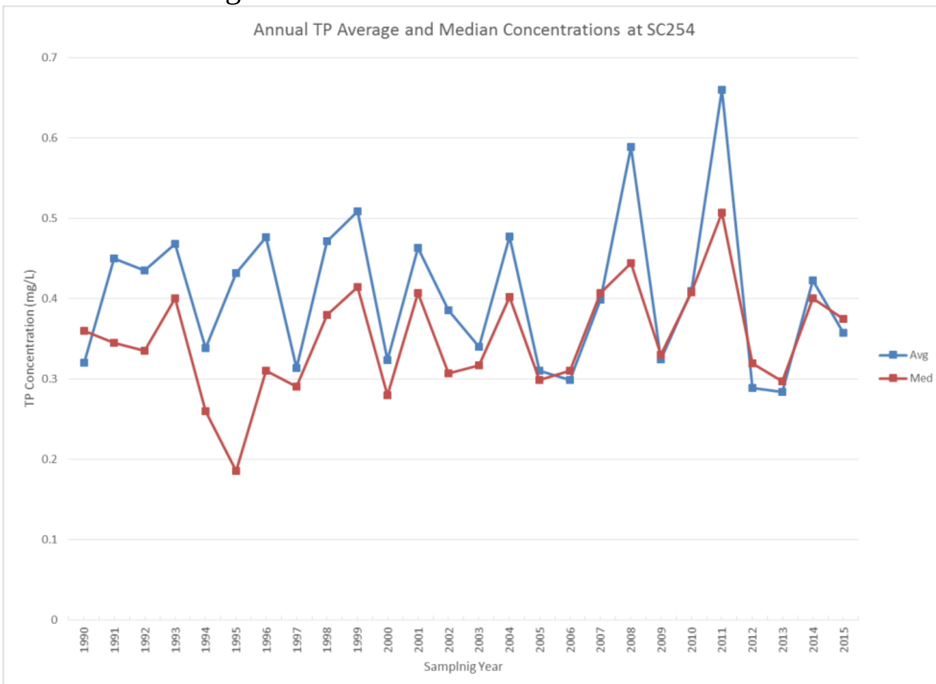
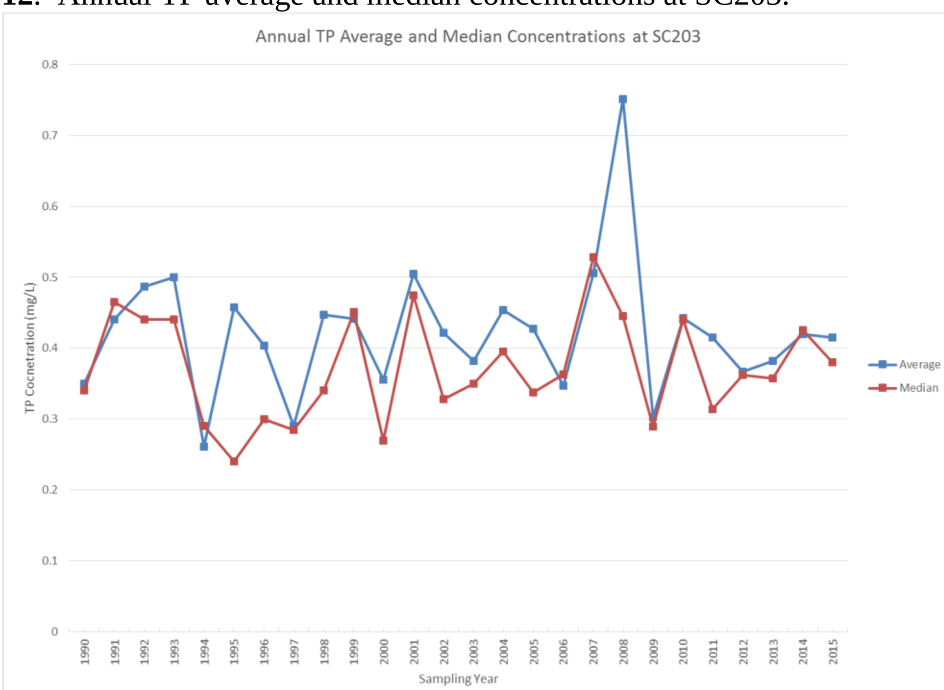


Figure 12. Annual TP average and median concentrations at SC203.



Monthly average and median TP concentrations at SC203 and SC254 are detailed in Figures 13 and 14. At SC254, higher TP concentrations occur during the months of May, June, July, and August, which coincide with the months with the higher flows at SC254. The months of October, November, December, and February have elevated median TP concentrations and November and March have elevated TP average concentrations. The TP concentrations at SC254 during the winter months are influenced by point sources as these are the months with the lowest flow averages in the Kansas River. Whereas nonpoint sources are highly influential to the TP concentrations observed at SC254 during the summer months indicative of the relationship between the higher stream flows and TP concentrations during these months.

Monthly average and median TP concentrations at SC203 do not correlate as well with the average and monthly median flows, which is indicative of when point sources have a greater influence on water quality. Monthly TP concentration averages are the highest during March, June, July, and November. Monthly TP concentration medians are the highest during June, July and October. Based on the monthly flow averages, the TP concentrations during the months of May, June and July are likely influenced by nonpoint sources when monthly flow averages and medians remain the highest. Whereas point sources have a greater influence during other months of year when median monthly flows are less robust in the Kansas River.

Figure 13. Monthly average and median TP concentrations at SC254.

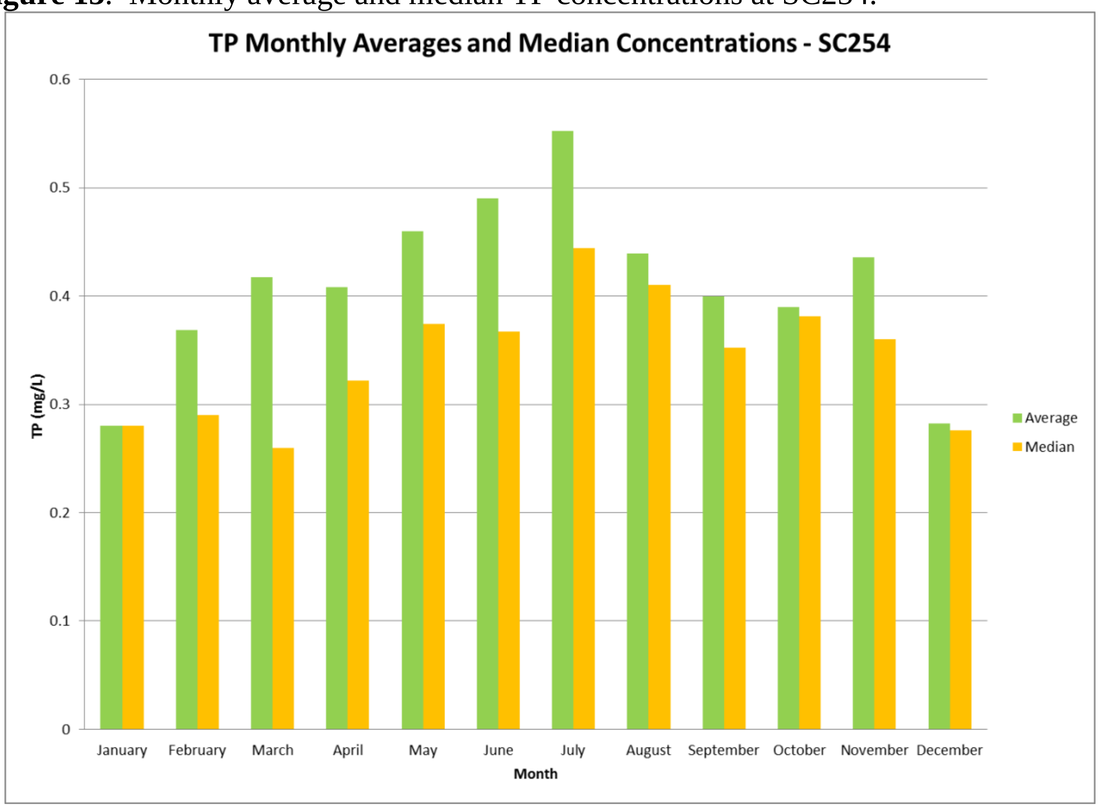
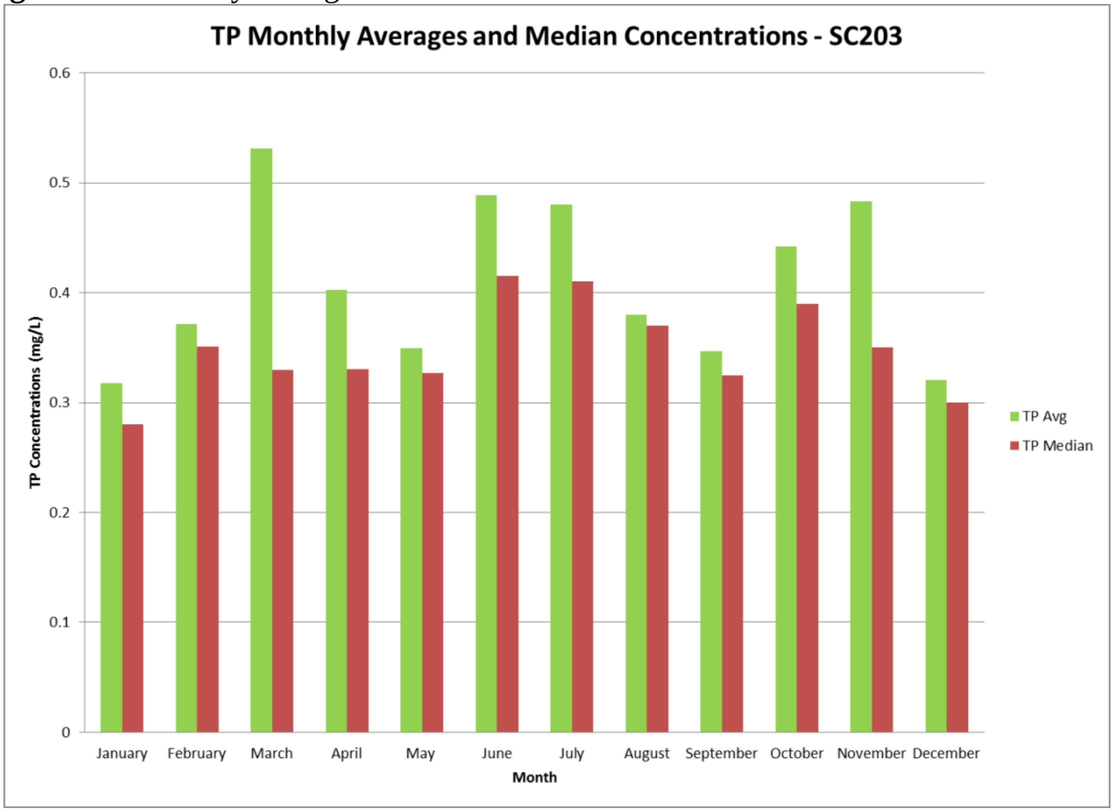


Figure 14. Monthly average and median TP concentrations at SC203.



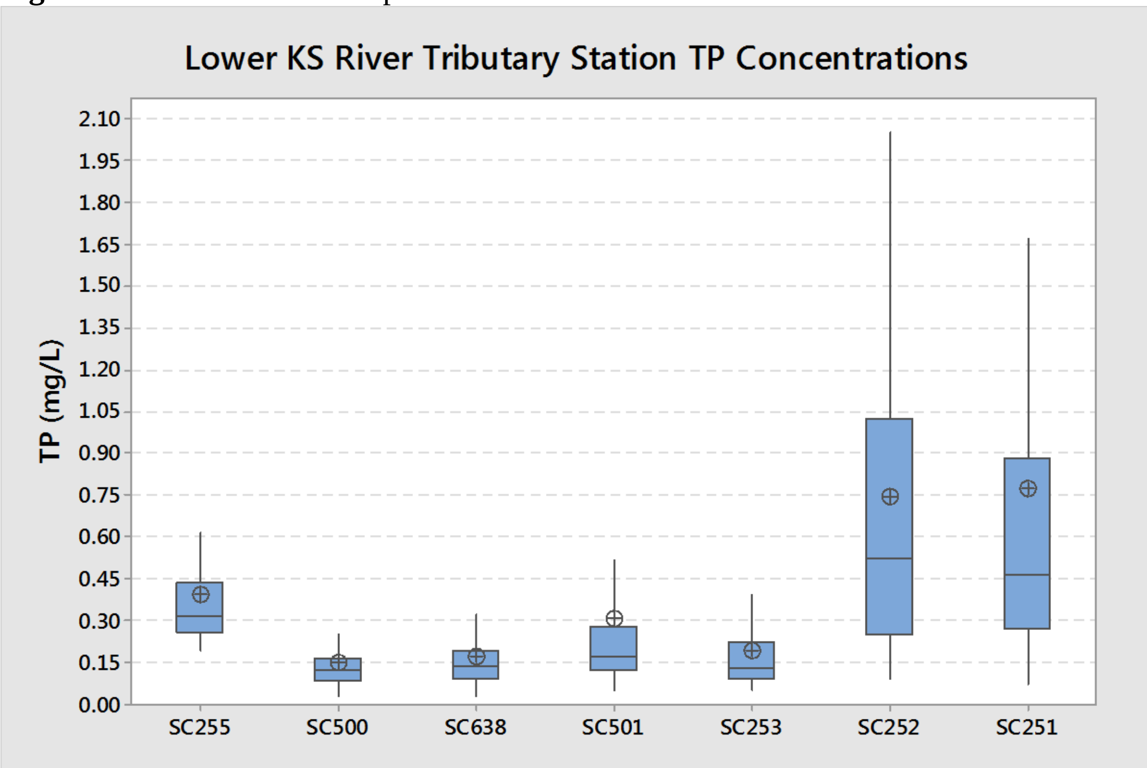
TP concentrations for the tributaries and the rotational station in the Kansas River are detailed in Table 8 and Figure 15. The Kansas River station at Eudora has a similar TP average and median concentrations as the permanent stations on the Kansas River at De Soto and Kansas City. The TMDL assessment focuses on the data from the permanent stations SC254 and SC203 since the data set is more robust over a longer period of record.

TP median and average concentrations are the highest in the tributaries that are influenced by large point source discharges, as is the case with SC252 on Cedar Creek and SC251 on Mill Creek. TP median and average concentrations are the lowest at station SC500 on the Wakarusa River, which receives flow from the Clinton Lake outlet discharge. Stranger Creek contributes the most flow of the tributaries within the Lower Kansas River watershed and has a TP average concentration that is much higher than the median concentration. This suggests that Stranger Creek is susceptible to high intensity drainage events during runoff events.

Table 8. TP concentration averages and medians for Kansas R main stem and tributary monitoring stations.

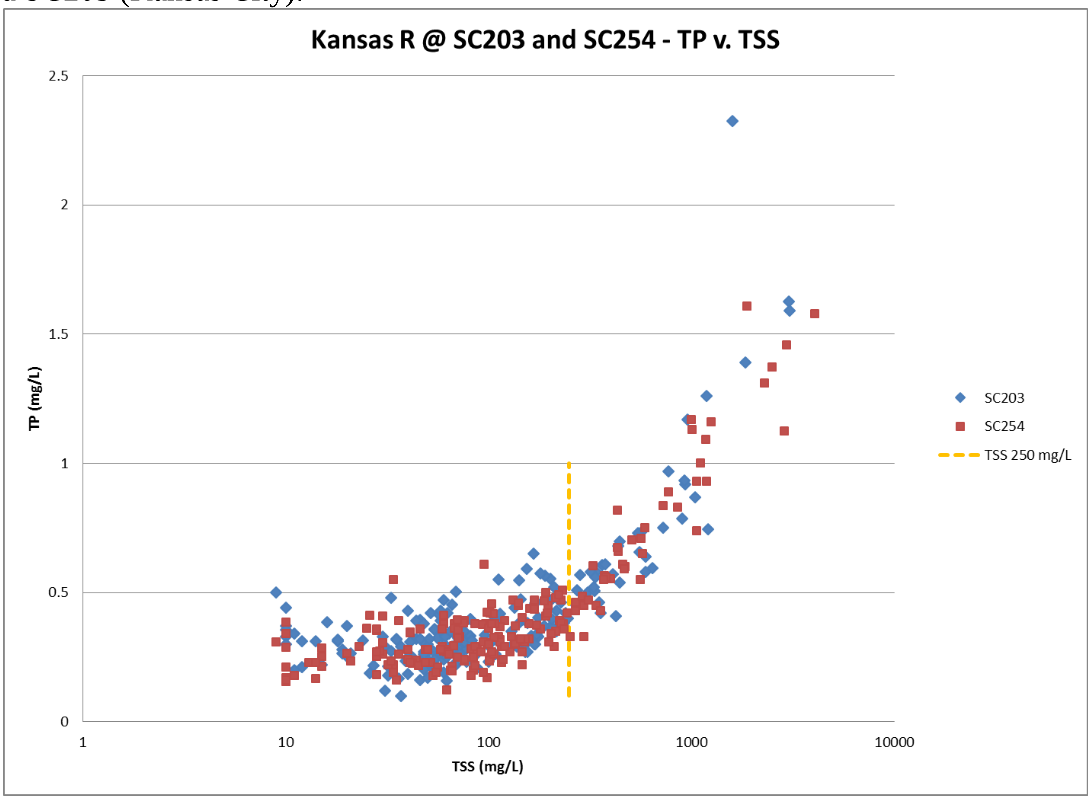
Station	Stream	TP Avg. (mg/L)	TP Median (mg/L)
SC255	KS River at Eudora	0.397	0.318
SC500	Wakarusa River near Eudora	0.150	0.120
SC638	Captain Cr near Eudora	0.173	0.138
SC501	Stranger Cr near Lindwood	0.310	0.169
SC253	Kill Cr at De Soto	0.192	0.129
SC254	Kansas R at De Soto	0.409	0.335
SC252	Cedar Cr near Cedar Junction	0.743	0.524
SC251	Mill Cr near Shawnee	0.772	0.463
SC203	Kansas R at Kansas City	0.409	0.330

Figure 15. TP concentration profile of monitored tributaries in the TMDL watershed.



Relationship with other parameters: There is a strong relationship between TP and TSS concentrations when point source contributions are minimized and nonpoint source loading dominates. This relationship indicates phosphorus is linked to sediment because of the propensity of those solids to adsorb phosphorus. Additionally, TSS concentrations increase proportionally to flow. As seen in Figure 16, there is a strong relationship between TP and TSS when TSS concentrations are elevated above 250 mg/L. This affirms higher flow conditions are influenced by nonpoint source loads. Point source influence is indicated when high phosphorus concentrations are independent of the sediment or TSS concentrations, which occurs when the point source discharge increases the influence of water quality proportionally as stream flows decrease. The scatter, particularly at SC203, associated with the TP and TSS relationship when TSS concentrations are below 250 mg/L suggest that point sources are influencing water quality during the lower flow conditions, and even more so when TSS concentrations are below 100 mg/L.

Figure 16. Relationship between TP and TSS on the Kansas River at SC254 (De Soto) and SC203 (Kansas City).



Levels of ortho-phosphate (o-P), the soluble portion of total phosphorus that is readily available for biological uptake, along with the TP concentrations at De Soto and Kansas City are illustrated in Figures 17 and 18. The reporting limit has increased several times over the period of record, which began in 1995 for o-P. The initial reporting limit increased from 0.01 mg/L to 0.02 mg/L, which later increased to a reporting limit of 0.25 mg/L in 2002. Only samples with o-P values greater than the reporting limit were plotted. Prior to 2010, there were no samples that measured greater than 0.25 mg/L at SC254 and there was only one sample at SC203 that exceeded this value back in 1996. Assessing the o-P concentrations relative to flow and seasons at SC203, as seen in Figure 19, the recent detections of o-P appears to be driven by two contributing factors. The first being during high flows, when the o-P concentrations increase in the upper portions of the watershed. The second factor is likely due to the point source influence during the low flow condition, however it is undetermined on the impact associated with o-P from the discharging facilities in the Lower Kansas River Watershed since o-P concentrations are elevated at the stations on the Kansas River upstream of the Lower Kansas TMDL watershed. The majority of the detections occur during the Summer-Fall and Winter seasons.

Figure 17. Total Phosphorus and detected ortho-phosphorus concentrations relative to sampling date at SC254.

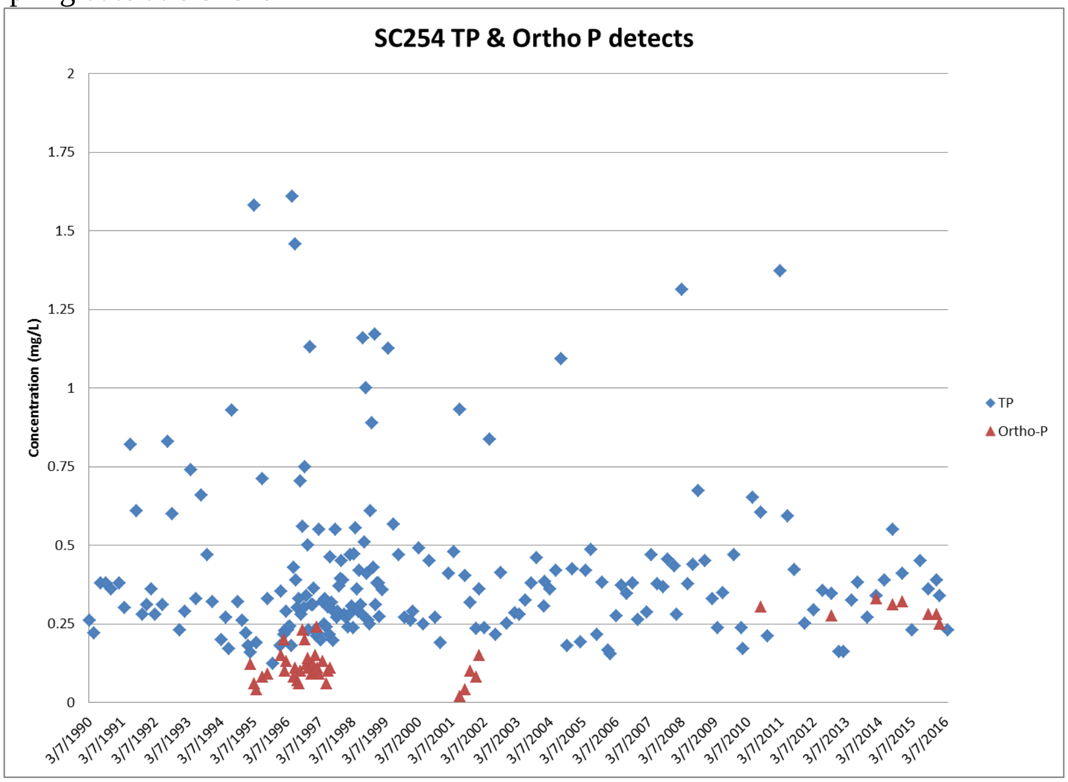


Figure 18. Total Phosphorus and detected ortho-Phosphorus concentrations relative to sampling date at SC203.

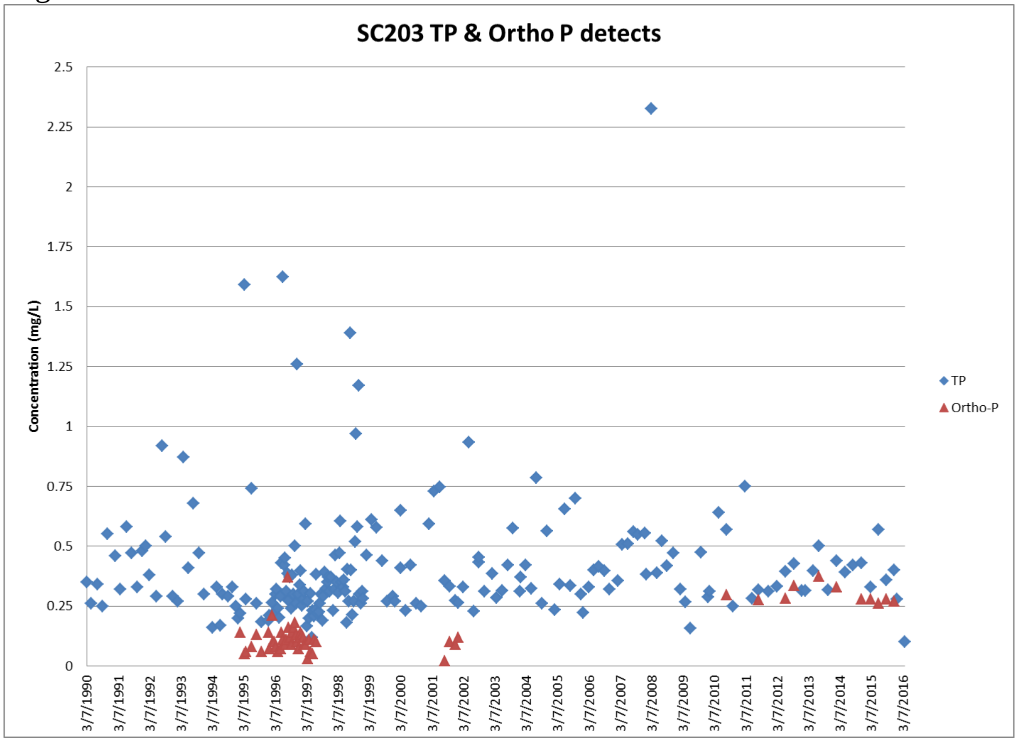
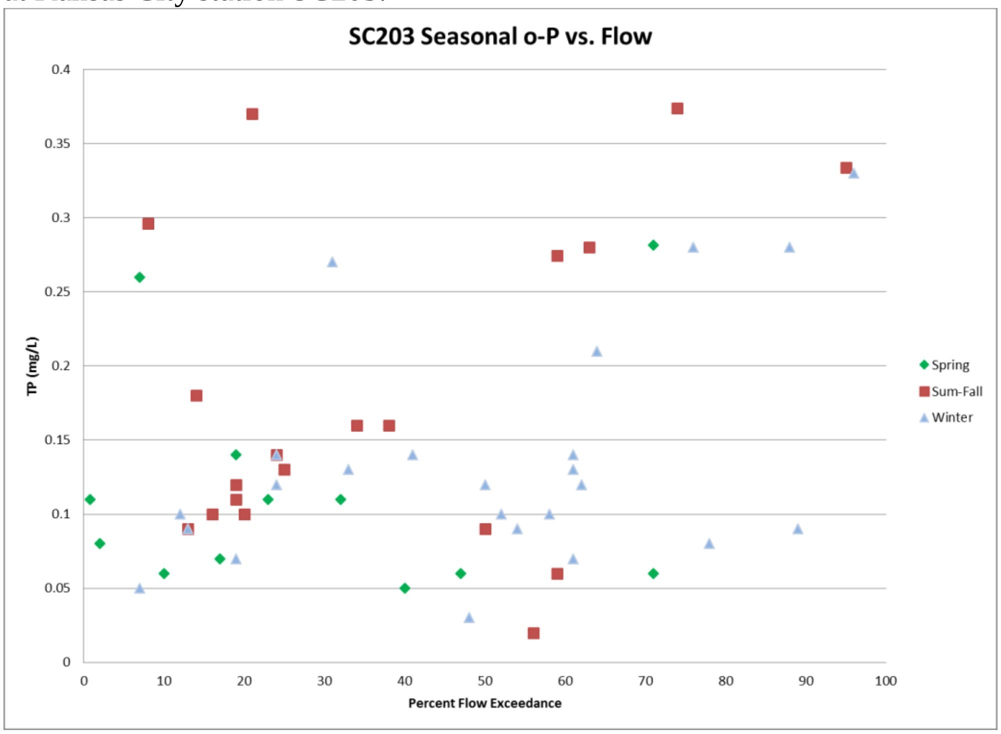


Figure 19. Seasonal ortho-Phosphorus concentration relative to flow on the Kansas River at Kansas City station SC203.



Relationship between Phosphorus and Biological Indicators at Main Stem Stations: The narrative criteria of the Kansas Surface Water Quality Standards are based on conditions of the prevailing biological community. Excessive primary productivity may be indicated by extreme swings in dissolved oxygen or pH as the chemical reaction of photosynthesis and respiration alter the ambient levels of oxygen or acid-base balance of the stream. Dissolved oxygen is inversely related to the ambient temperature in the stream at SC254 and SC203 as seen in Figure 20.

Higher pH values tend to occur during periods when photosynthesis is ramped up, indicative of nutrient loading contributing to primary productivity. As seen in Figure 21, there is a nominal relationship between pH and dissolved oxygen at SC203 indicating that there may be a slight increase in primary productivity on the lower reaches of the Kansas River.

As seen in Table 9, the average DO concentrations during the Spring and Summer-Fall seasons are lower at SC203 relative to concentrations observed at De Soto. Additionally stream temperatures are warmer at SC203 during all three seasons, which may be indicative of the larger contribution from point sources on the lower portion of the watershed.

To discount the impacts of temperature on the solubility of oxygen in the water column, the percent of saturated dissolved oxygen was computed from the data collected at the De Soto and Kansas City stations. There is a high percentage of dissolved oxygen saturation during all seasons at SC254. At SC203, a seasonal pattern indicates there is a high percentage of dissolved oxygen saturation during the cooler months in the Spring and Winter, while there is a decline in percent saturation associated with the Summer-Fall season at SC203.

Table 9. Average dissolved oxgen, temperature, percent dissolved oxygen saturation and pH by season in the Kansas River at De Soto (SC254) and Kansas City (SC203).

Parameter	Site	Spring	Summer-Fall	Winter
Dissolved) Oxygen (mg/L	SC254	9.2	8.3	12.3
	SC203	8.7	7.5	12.3
Temperarture (C)	SC254	17.6	22.7	5.1
	SC203	18.2	23.6	5.7
Oxygen Saturation (%)	SC254	96%	95%	96%
	SC203	91%	86%	96%
pH	SC254	8.1	8.2	8.1
	SC203	8.0	8.1	8.0

Figure 20. Relationship between Dissolved oxygen and stream temperature at SC254 and SC203.

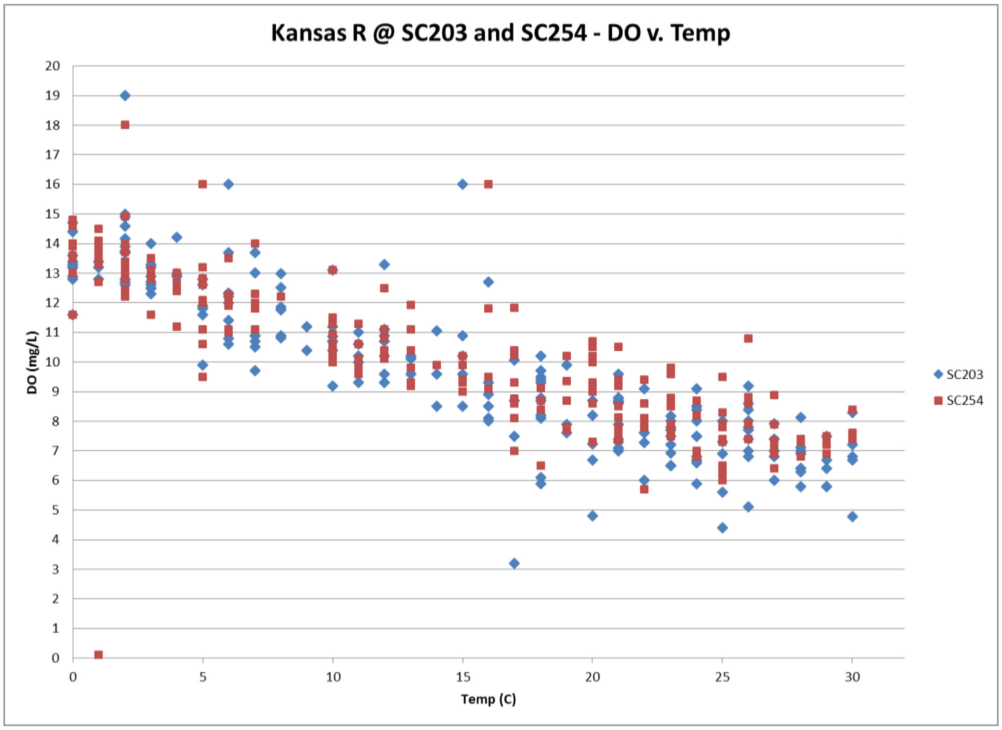
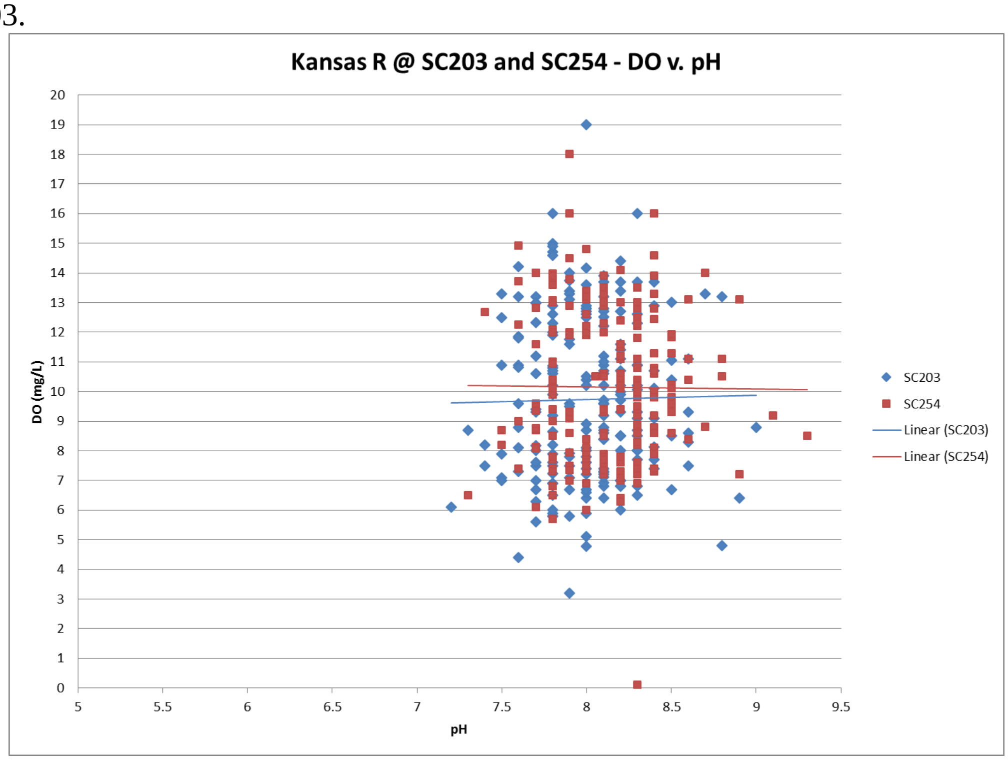


Figure 21. Relationship between Dissolved oxygen concentrations and pH at SC254 and SC203.



The seasonal relationship between pH and stream temperature at SC254 and SC203 are illustrated in Figures 22 and 23. Higher pH values tend to occur during higher photosynthesis periods. Levels of pH exceeded the criterion of 8.5 at SC254 during 12 sampling events, whereas the criterion was exceeded during 11 sampling events at SC203 over the period of record. Figures 24 and 25 illustrate the seasonal relationship between the stream pH and the TP concentration at these two stations.

Figure 22. Seasonal relationship between pH and Temperature at SC254.

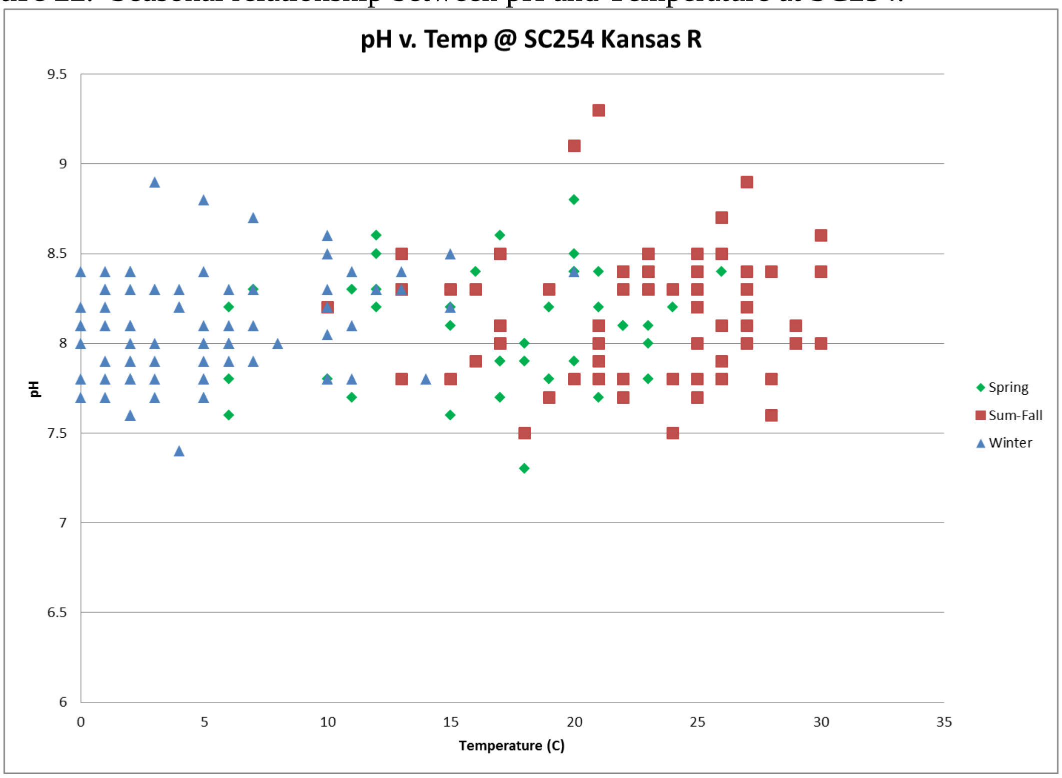


Figure 23. Seasonal relationship between pH and Temperature at SC203.

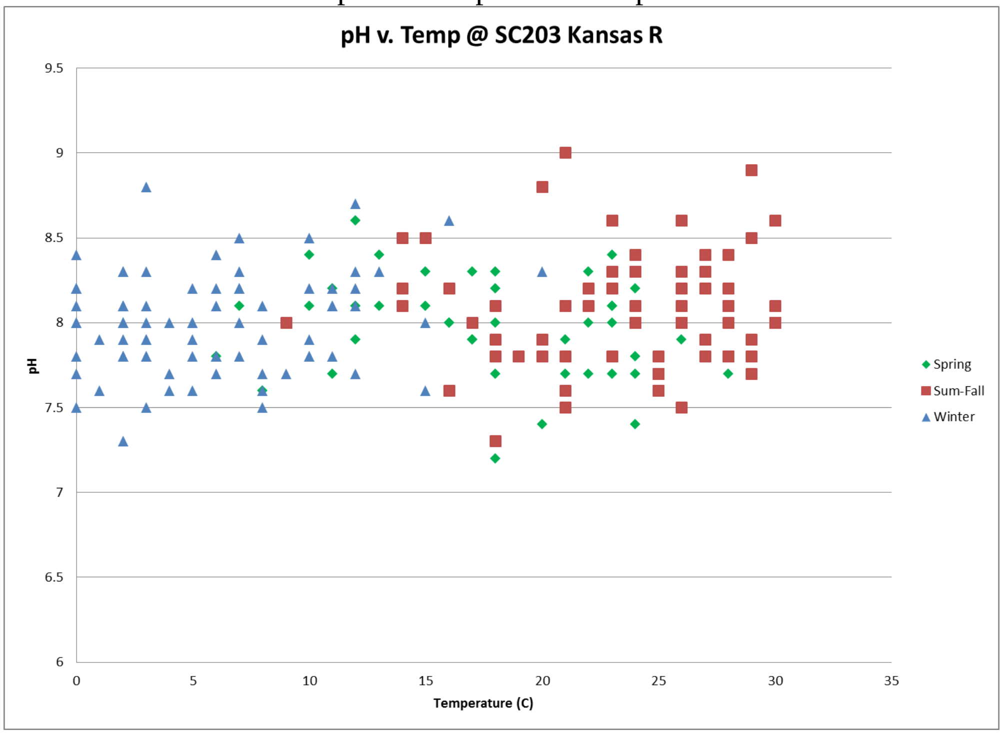


Figure 24. Seasonal relationship between pH and TP and SC254.

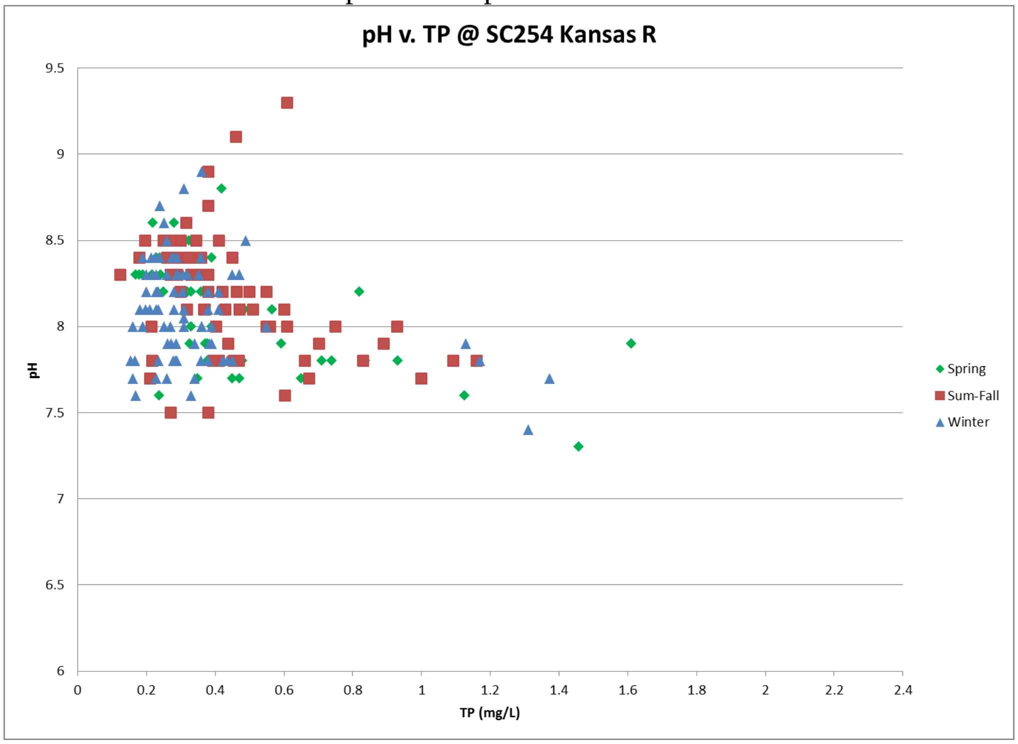
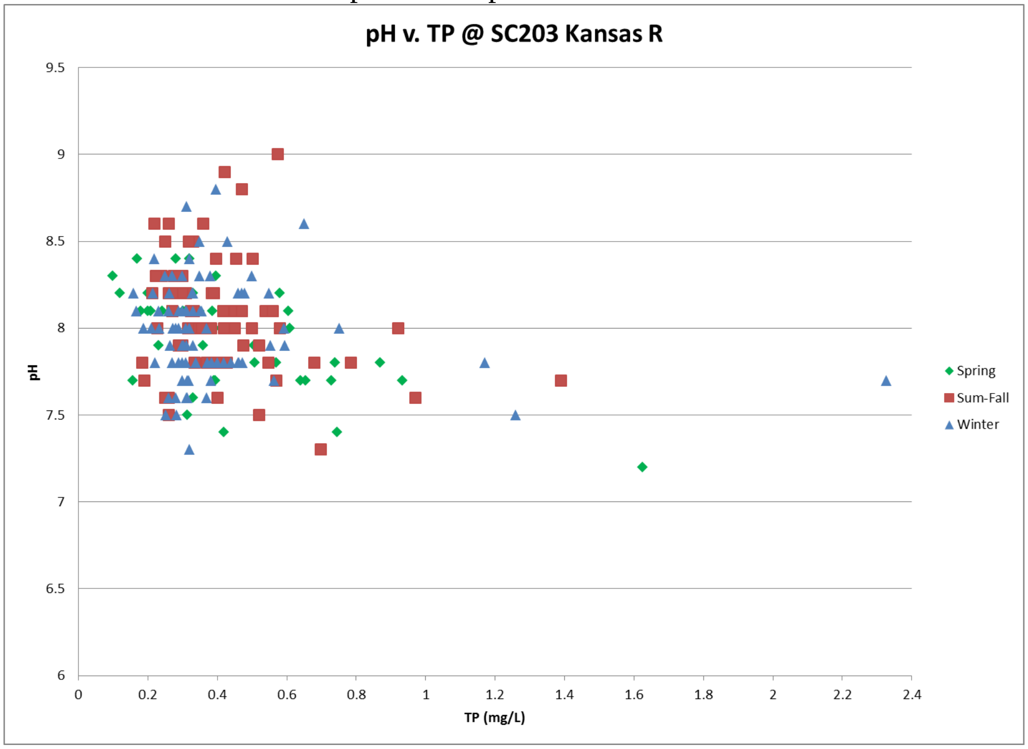


Figure 25. Seasonal relationship between pH and TP at SC203.



Sestonic chlorophyll *a* concentrations in the Kansas River are detailed in Figure 26 and Table 10. Chlorophyll data was collected at the upstream KDHE sampling station SC257 and USGS gage 06891000, which are both located at Lecompton on the Kansas River. Within the Lower Kansas River TMDL area, chlorophyll data was collected at De Soto by KDHE and USGS. Chlorophyll concentration averages are similar at both the Lecompton and De Soto sampling locations for those samples collected and analyzed by KDHE. The USGS samples indicate a slightly higher chlorophyll average concentration at the De Soto gage, though the data set at De Soto is robust (99 samples) relative to the USGS data set available at Lecompton (12 samples).

KDHE has sampled sestonic chlorophyll *a* at SC254 since 2004. The average chlorophyll concentration at SC254 is 53.2 µg/L and the median concentration is 32.15 µg/L. Chlorophyll levels generally do not respond linearly to increases in phosphorus as seen in Figure 27, other than when TP and Chlorophyll concentrations are less than 0.2 mg/L and 20 µg/L respectively. This may be because of the flushing of chlorophyll and nutrients downstream of the monitoring station and a lag in the response. Figure 28 details chlorophyll concentrations relative to the percent of flow exceedance. It is difficult to establish the relationship between the flow and chlorophyll concentrations likely due to the lag in the response to the key factors influencing chlorophyll concentrations or due to the dynamics of the larger Kansas River system. EPA's guidance on nutrient criteria for streams (2000) indicated trophic issues in streams with sestonic chlorophyll concentrations over the range of 8-15 µg/L.

Figure 26. Chlorophyll a concentrations on the Kansas River at Lecompton and De Soto.

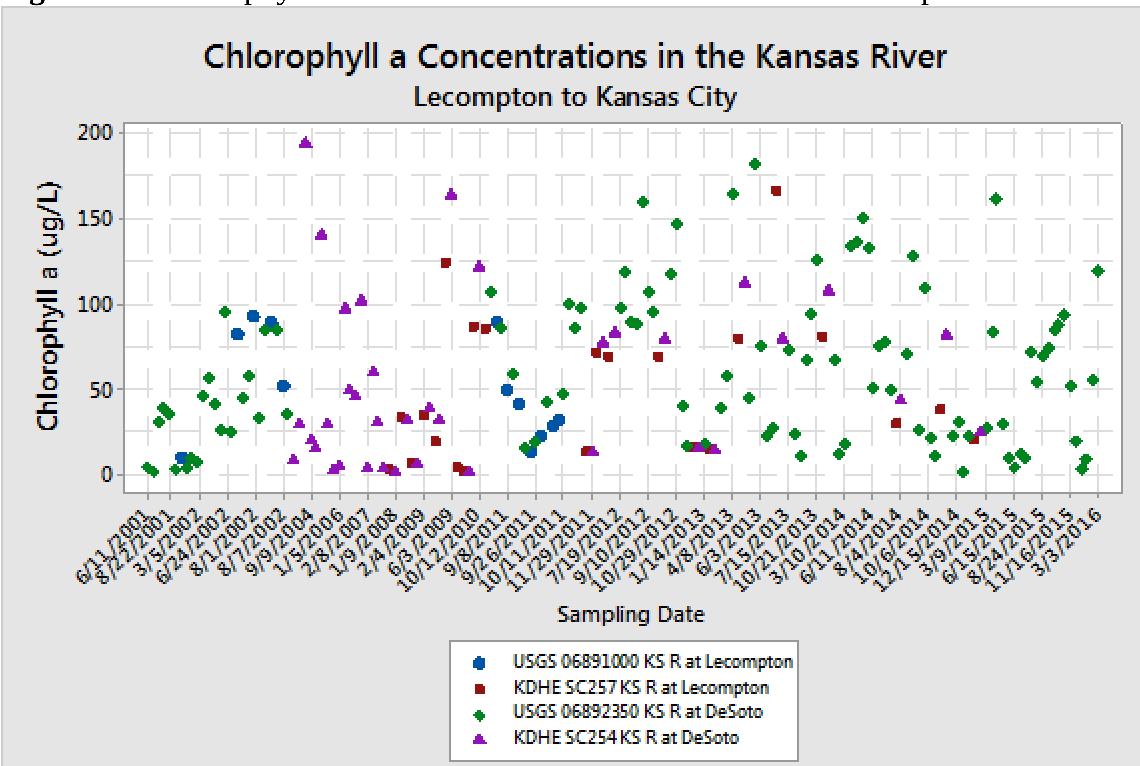


Table 10. Chlorophyll *a* concentrations on the Kansas River.

Site	Period of Record	# of Samples	Minimum Concentration (µg/L)	Maximum Concentration (µg/L)	Average Concentration (µg/L)
USGS 06891000 KS R at Lecompton	11/2001 to 10/2011	12	10.1	93.2	50.27
KDHE SC257 KS R at Lecompton	1/2008 to 3/2015	22	1.75	166.7	48.43
USGS 06892350 KS R at De Soto	6/2001 to 3/2016	99	1.4	181	60.51
KDHE SC254 KS R at Des Soto	1/2004 to 3/2015	37	1.7	194.3	53.22

Figure 27. Relationship between stream chlorophyll *a* and Total Phosphorus at SC254.

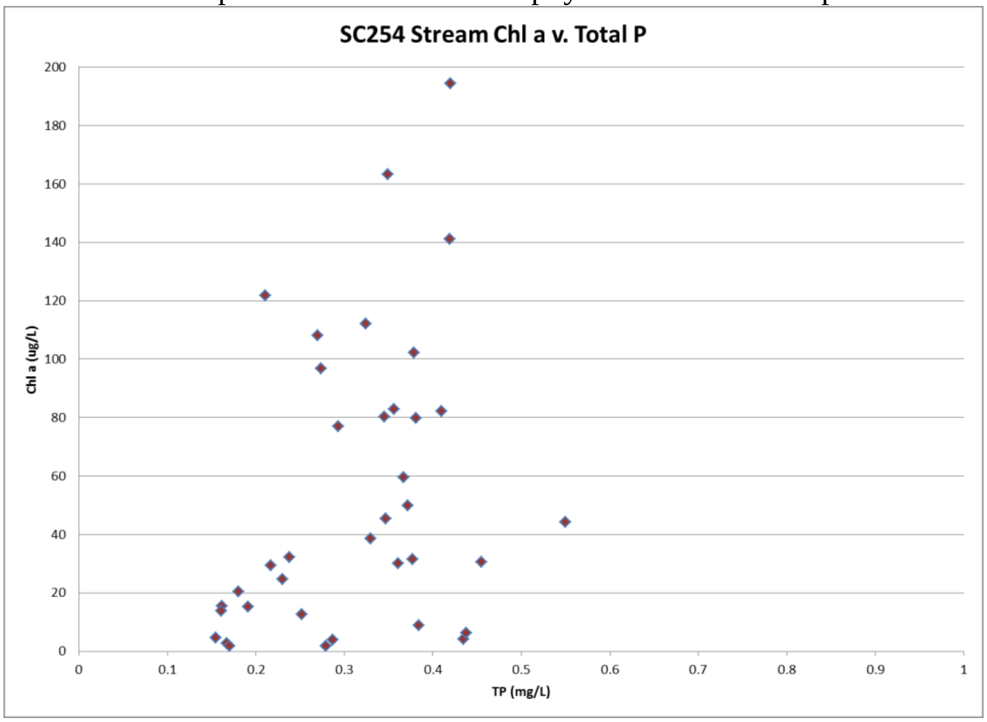
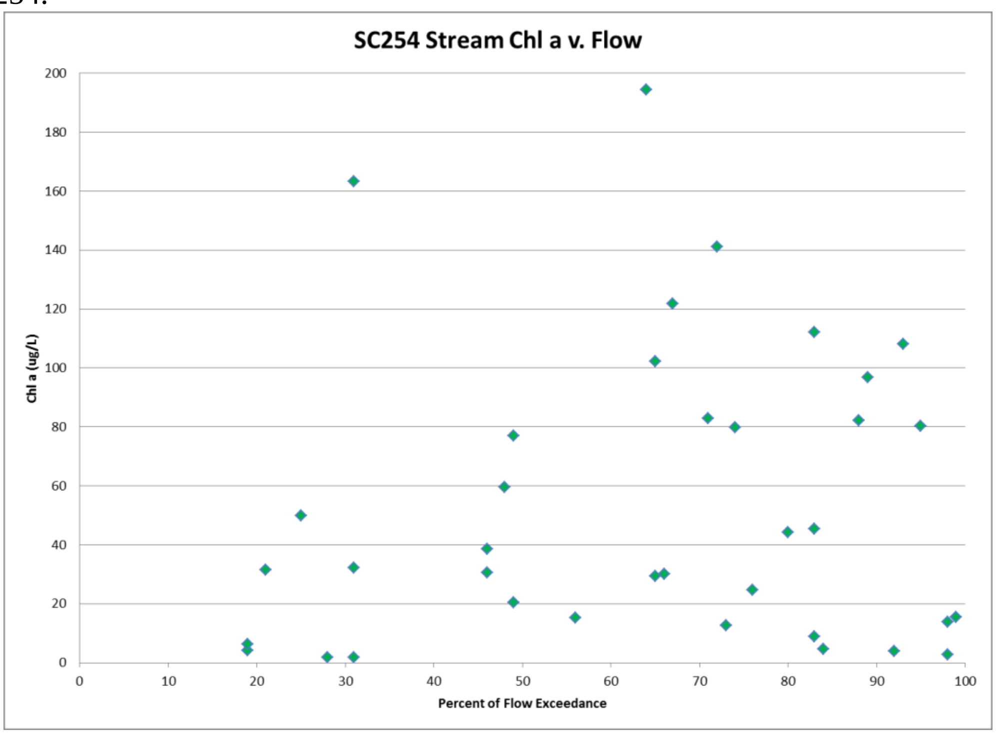


Figure 28. Relationship between stream chlorophyll *a* and Percent of Flow Exceedance at SC254.



KDHE's Stream Biological Monitoring Program has four stations in the Lower Kansas River watershed that have been assessed using the Aquatic Life Support Index (ALUS Index) as described in Kansas' 2016 303(d) Methodology. The ALUS Index score consists of five categorizations of biotic conditions:

1. Macroinvertebrate Biotic Index (MBI): A statistical measure that evaluates the effects of nutrients and oxygen demanding substances on macroinvertebrates based on the relative abundance of certain indicator taxa (orders and families).
2. Ephemeroptera, Plecoptera and Trichoptera (EPT) abundance as a percentage of the total abundance of macroinvertebrates.
3. Kansas Biotic Index for Nutrients (KBI-N): Mathematically equivalent to the MBI, however, the tolerance values are species specific and restricted to aquatic insect orders.
4. EPT Percent of Count (EPT % CNT) – The percentage of organisms in a sample consisting of individuals belonging to the EPT orders.
5. Shannon's Evenness (SHN EVN) – A measure of diversity that describes how evenly distributed the numbers of individuals are among the taxa in a sample

Once measured, the metrics detailed above are then assigned a score according to Table 11. The scores are tallied and a support category is assigned according to Table 12.

Table 11. ALUS Index metrics with scoring ranges.

MBI	KBI-N	EPT	EPT % CNT	SHN EVN	Score
<= 4.18	<= 2.52	>= 16	>= 65	>= 0.849	4
4.19-4.38	2.53-2.64	14-15	56-64	0.826-0.848	3
4.39-4.57	2.65-2.75	12-13	48-55	0.802-0.825	2
4.58-4.88	2.76-2.87	10-11	38-47	0.767-0.801	1
>= 4.89	>= 2.88	< = 9	<= 37	<= 0.766	0

Table 12. ALUS Index score range, interpretation of biotic condition, and supporting, partial and no supporting categories.

ALUS Index Score	Biotic Condition	Support Category
17-20	Very Good	Supporting
14-16	Good	
7-13	Fair	Partially Supporting
4-6	Poor	Non-supporting
1-3	Very Poor	

There are four biological stations in the Lower Kansas River TMDL watershed; SB203, SB251, SB252, and SB254, which all correspond with the locations of stream chemistry stations. Site SB254 at De Soto has the largest data set, and the ALUS index indicates that biotic conditions are fair and partially supported in the Kansas River at De Soto. SB251 on Mill Creek has been sampled 15 times, where biological conditions are poor resulting in a non-support designation. The other two stations, SB203 and SB252, only have one biological sampling event on record, which both indicated very poor biotic conditions. A summary of the biological data sets at these stations is detailed in Table 13.

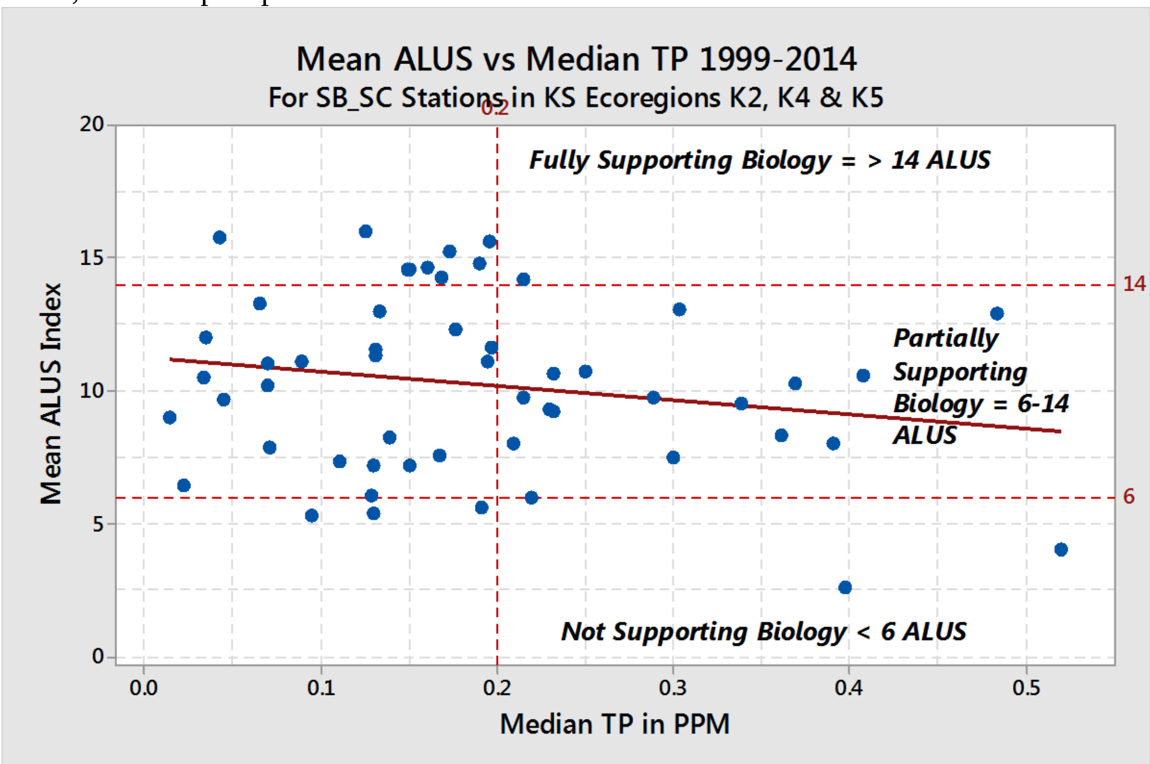
Table 13. Summary of biology data with corresponding mean ALUS Index scores for biological monitoring stations in the lower Kansas River TMDL watershed.

Site	Biology Period of Record	# Biology Samples	Avg ALUS Index Score	ALUS Support Category
SB254/SC254 Kansas River at De Soto	1990-2014	19	10	Partially Supporting
SB203/SC203 Kansas River at KC	2013	1	2	Non-Supporting
SB251/SC251 Mill Cr	1993-2014	15	3	Non-Supporting
SB252/SC252 Cedar Cr	1993	1	1	Non-Supporting

Desired Endpoint: The ultimate endpoint of the TMDL will be to achieve the Kansas Water Quality Standards by eliminating the objectionable flora and any of the impacts to aquatic life, domestic water supply or recreation associated with excessive phosphorus and objectionable amounts of algae as described in the narrative criteria pertaining to nutrients. There are no existing numeric phosphorus criteria currently in Kansas.

Ecoregions specific to Kansas and delineated in the Kansas Reference Streams Report (KDHE, 2010) were used to develop the total phosphorus benchmark for the stations covered by this TMDL (**Appendix A**). First, stream biology sites located in the K2, K4 and K5 ecoregions were identified. Second, the average ALUS index was determined for those sites that had a stream biology data set greater than two samplings. Third, the median total phosphorus concentration was determined for those biology sites that had a corresponding total phosphorus data set at the stream biology site. The resulting plot in **Figure 29** reveals the relationship between the mean ALUS condition and median TP concentrations at these sites. Conditions of full support span total phosphorus levels of 0.031mg/L to 0.215 mg/L. However, once total phosphorus concentrations are greater than about 0.200 mg/L, conditions of full support are no longer observed.

Figure 29. Mean aquatic life use score (ALUS) versus the median total phosphorus for stream chemistry/stream biology stations located in Kansas ecoregions K2, K4 and K5 for the 1999-2014 period of record. This data set comprises 563 biology sampling events and 3,982 total phosphorus values at 53 SB/SC stations.



An analysis of the relationship between chlorophyll *a* and total phosphorus at KDHE stream chemistry stations in the K2, K4 and K5 Kansas Ecoregions reveals a statistically significant relationship between the two (**Figure 30**) with a total phosphorus concentration of 0.200 mg/l (log10 = -0.699) equating to about 10.6 µg/L (log10 = 1.03) chlorophyll *a* (**Figure 31**).

Figure 30. Scatterplot of chlorophyll *a* vs total phosphorus values at stream chemistry sites in the K2, K4 and K5 Kansas Ecoregions for the 1/6/2003 through 3/18/2015 period of record. Data set is comprised of 1,001 stream chemistry samples from 49 sites that had both total phosphorus and chlorophyll *a* values reported for the sample.

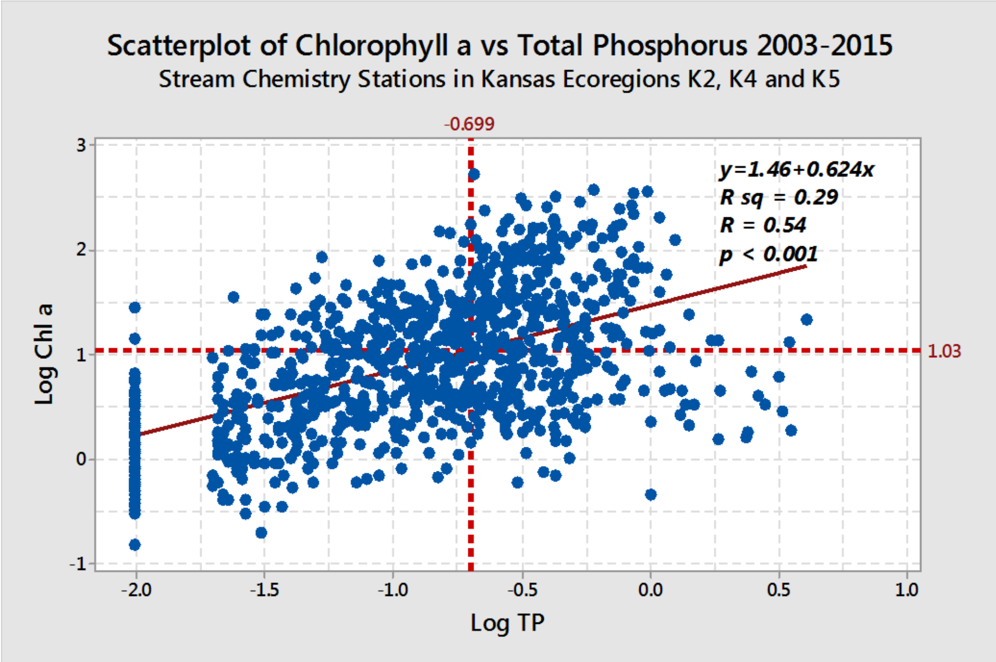
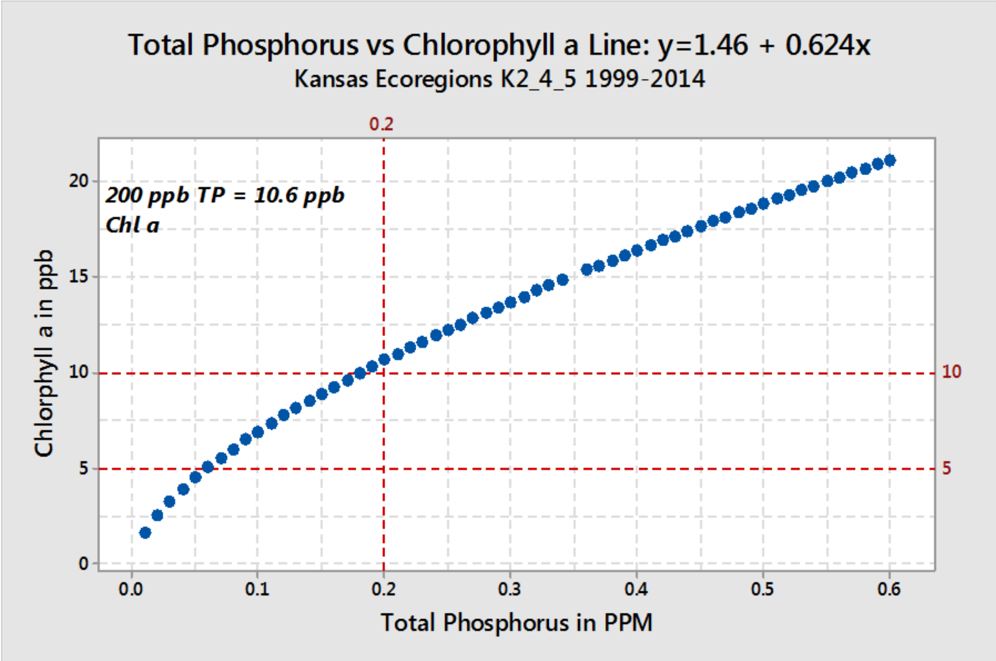


Figure 31. Line developed from the regression of total phosphorus and chlorophyll *a* values at stream chemistry stations located in Kansas ecoregions K2, K4 and K5 for the 2003-2015 period of record.



One of the complications in setting a total phosphorus endpoint is establishing the linkage of phosphorus levels to applicable biologic response variables. Although **Figure 29** shows a somewhat noisy relationship with phosphorus in the partially supporting range, there is a clear delineation below 0.200 mg/L total phosphorus where streams move into the fully supporting category. Hence, the total phosphorus milestone for this TMDL will be a median of 0.200 mg/L in the Kansas River, with the primary outcome of reduced nutrient loading being improved ALUS Index scores. The ALUS Index will serve to indicate if the biological community at the SC stations on the Lower Kansas River reflects recovery, renewed diversity, and minimal disruption by the impacts described in the narrative criteria for nutrients on aquatic life.

Additionally, the concentration of floating sestonic phytoplankton in the water column at SC254, SC255 and SC203, as determined by measuring the sestonic chlorophyll *a* concentrations in the Kansas River will indicate if primary productivity has moderated to reduce the impacts described in the narrative criteria for nutrients on aquatic life, recreation, and domestic water supply along the lower reaches of the Kansas River.

Secondary indicators of the health of the in-stream biological community include:

1. Dissolved oxygen concentrations greater than 5 mg/L and the percent dissolved oxygen no more than 110%. Percent dissolved oxygen saturation is the measure of oxygen in the water relative to the water's potential dissolved oxygen concentration. Dissolved oxygen concentrations below 5.0 mg/L put aquatic life under stress, additionally indicated when dissolved oxygen saturation levels are below 90%. While dissolved oxygen percent saturation levels greater than 110% are indicative of over-active primary productivity.
2. Instream pH values remain below 8.5. Excessive nutrients can induce vigorous photosynthesis which will cause pH to rise above 8.5, the current Kansas criterion.

Therefore, the numeric endpoints for this TMDL, as measured at the main stem monitoring stations (SC255, SC254, and SC203) indicating attainment of water quality standards within the watershed are:

1. An ALUS Index score greater than or equal to 14.
2. Maintain sestonic chlorophyll *a* concentration below 10 µg/l.
3. Dissolved oxygen concentrations greater than 5.0 mg/L
4. Dissolved oxygen saturation below 110% and above 90%.
5. pH below 8.5.

All five endpoints have to be initially maintained over three consecutive years at SC255, SC254 and SC203 to constitute full support of the designated uses of the lower Kansas River. After the endpoints are attained, simultaneous digression of these endpoints more than once every three years, on average, constitutes a resumption of impaired conditions at the respective station.

These endpoints will be evaluated periodically as phosphorus levels decline in the watershed over time. This TMDL looks to establish a management milestone of a median total phosphorus concentration of 0.200 mg/L in the lower Kansas River that would be the cue to examine for improved biological conditions at SC255, SC254 and SC203.

Achievement of the biological endpoints indicate phosphorus loads are within the loading capacity of the stream, water quality standards are attained, and full support of the designated uses of the stream has been restored.

Table 14. Current median and TMDL TP median concentration targets on the Lower Kansas River main stem permanent stations.

Station	Current TP Median TP (mg/L)	TMDL target TP (mg/L)	TP Concentration Reduction (%)
SC254 Kansas R. at De Soto	0.335	0.200	40.3
SC203 Kansas R. at KC	0.330	0.200	39.4

3. SOURCE INVENTORY AND ASSESSMENT

Point Sources: There are a total of 77 NPDES permitted facilities located within the TMDL watershed, as seen in Figure 32. The permitted facilities are categorized as follows: one pre-treatment facility, 40 industrial facilities, nine commercial facilities, and 27 municipal facilities. Of these there are 11 "non-overflowing" lagoons that are prohibited from discharging and ten MS4 stormwater permits. The permitted facilities are detailed in Appendix B.

Of the permitted facilities in the watershed covered by this TMDL, there are 22 that currently are required to monitor Total Phosphorus in their effluent as part of their NPDES permit. These facilities and their effluent TP and flow averages are detailed in Table 15. The facilities that currently discharge more than 5 lbs/day are detailed in Table 16 and contribute consistent TP loading to the Kansas River.

Figure 32. NPDES facility locations in the TMDL watershed.

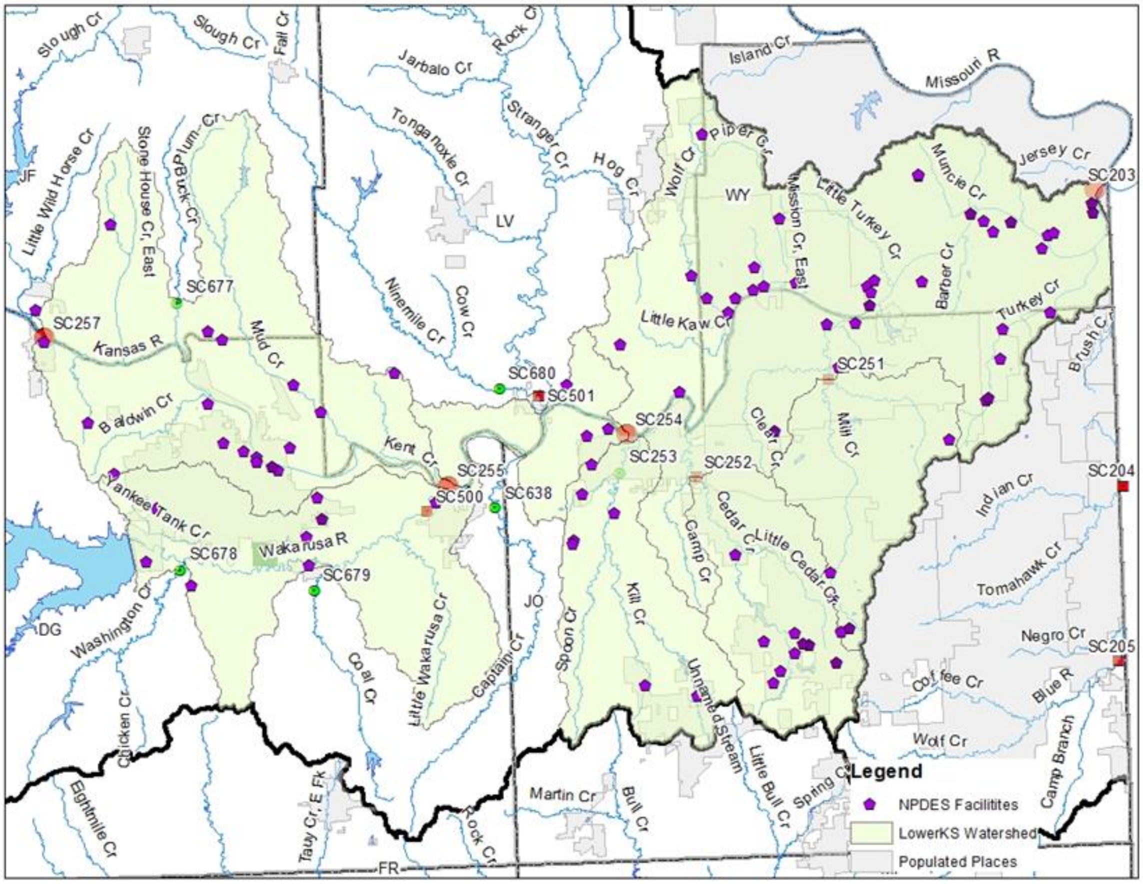


Table 15. NPDES facilities that are currently required to monitor TP.

Permit_ No.	Facility_Name	TP Monitoring Frequency	TP Conc. Avg (mg/L)	Flow Avg. (MGD)	Station
I-KS06-PO07	Bonner Springs Water Treatment Plant	Monthly	0.929	NA	SC203
I-KS27-CO09	FUCHS Lubricants Co.	Once	NA	NA	SC203
I-KS27-PO43	THAN / Harcros Groundwater Remediation Project	Monthly	0.135	0.197	SC203
M-KS06-OO02	Bonner Springs Wastewater Treatment Plant	Monthly	2.16	0.531	SC203
M-KS06-OO03	Leavenworth County S.D. #2 (Timberlake)	Quarterly	NA	NA	SC203
M-KS27-OO14	Municipal Treatment Plant No. 14	Monthly	2.84	0.041	SC203
M-KS27-OO20	Kansas City Treatment Plant #20	Monthly	3.94	3.5	SC203
M-KS45-OO01	Nelson Complex Wastewater Treatment Plant	Monthly	2.97	14.45	SC203
M-KS68-OO04	Mill Creek Regional Wastewater Treatment Facility	Monthly	3.01	9.35	SC203
I-KS52-PO02	Exxon Mobil Corp. - Olathe Grease Plant	Annual	0.412	0.02	SC251
M-KS52-IO01	Harold Street Wastewater Treatment Plant	Monthly	2.29	2.59	S251
M-KS52-OO06	Olathe Cedar Cr WWTF	Weekly	1.95	4.5	SC252
M-KS12-OO03	DeSoto Wastewater Treatment Facility	Monthly	1.77	0.6	SC254
C-KS31-OO02	KTA - Lawrence Service Area	Monthly	NA	NA	SC255
I-KS31-PO06	ICL Performance Products LP (fka Astaris)	Daily	18.9	0.37	SC255
I-KS31-PO09	Westar Lawrence Energy Center	Quarterly	1.38 / 1.99	0.8 / 0.064	SC255
I-KS31-PO20	Jefferson County RWD No. 13 Wastewater Treatment Facility	Quarterly	0.1	NA	SC255
M-KS31-IO01	Lawrence Kansas River Wastewater Treatment Facility	Monthly	4.7	9.7	SC255
M-KS33-OO01	Lecompton Wastewater Treatment Facility	Monthly	3.63	NA	SC255
M-KS17-OO02	Eudora Municipal Wastewater Treatment Facility	Monthly	3.13	0.473	SC500
M-KS31-OO03	Lawrence Wakarusa River Wastewater Treatment Facility	Weekly	NA	NA	SC500
M-KS20-OO01	GARDNER - KILL CREEK	Monthly	1.88	1.43	SC253

Table 16. NPDES facilities that currently discharge more than 5 lbs/day of TP in the Lower KS River Watershed.

Permit_ No.	Facility_Name	TP Monitoring Frequency	TP Conc. Avg (mg/L)	Flow Avg. (MGD)	Current TP Load (lbs/day)
M-KS06-OO02	Bonner Springs Wastewater Treatment Plant	Monthly	2.16	0.531	9.58
M-KS27-OO20	Kansas City Treatment Plant #20	Monthly	3.94	3.5	115.20
M-KS45-OO01	Nelson Complex Wastewater Treatment Plant	Monthly	2.97	14.45	358.52
M-KS68-OO04	Mill Creek Regional Wastewater Treatment Facility	Monthly	3.01	9.35	235.11
M-KS52-IO01	Harold Street Wastewater Treatment Plant	Monthly	2.29	2.59	49.55
M-KS52-OO06	Olathe Cedar Cr WWTF	Weekly	1.95	4.5	73.30
M-KS12-OO03	DeSoto Wastewater Treatment Facility	Monthly	1.77	0.6	8.87
I-KS31-PO06	ICL Performance Products LP (fka Astaris)	Daily	18.9	0.37	58.42
I-KS31-PO09	Westar Lawrence Energy Center	Quarterly	1.38 / 1.99	0.8 / 0.064	10.10
M-KS31-IO01	Lawrence Kansas River Wastewater Treatment Facility	Monthly	4.7	9.7	380.85
M-KS17-OO02	Eudora Municipal Wastewater Treatment Facility	Monthly	3.13	0.473	12.37
M-KS20-OO01	GARDNER - KILL CREEK	Monthly	1.88	1.43	22.46

The largest permitted facilities in the Lower Kansas River watershed include; the Nelson Complex Wastewater Treatment Plant (WWTP), Mill Creek Regional Wastewater Treatment Facility (WWTF), and the Lawrence Kansas River WWTF, which all currently contribute over a 100 lbs/day of TP. Both the Nelson Complex WWTP and the Mill Creek Regional WWTF are owned and operated by Johnson County Wastewater. Nelson Complex WWTP discharges to Turkey Creek which does not have an active KDHE monitoring station. The Mill Creek Regional WWTF discharges to the Kansas River above SC203 and the Lawrence Kansas River WWTF discharges to the Kansas River above KDHE monitoring site SC254.

Livestock and Waste Management Systems: There are 15 certified or permitted confined animal feeding operations (CAFOs) within the TMDL watershed, none of which are large enough to require a federal permit. All of these livestock facilities have waste management systems designed to minimize runoff entering their operation and detain runoff emanating from their facilities. These facilities are designed to retain a 25-year, 24-hour rainfall/runoff event as well as an anticipated two weeks of normal wastewater from their operations. Typically, this rainfall event coincides with streamflow that occurs less than 1-5% of the time. It is unlikely TP loading would be attributable to properly operating permitted facilities, though extensive loading may occur if any of these facilities were in violation and discharged. Table 17 details the facilities within the TMDL watershed.

Table 17. Registered or Permitted Animal Feeding Operations in the watershed.

KS Permit #	County	Animal Total	Permit Type	Animal Type	WLA (lbs/day)
A-KSDG-BA01	Douglas	344	Certification	Beef	0
A-KSDG-M008	Douglas	75	Certification	Dairy	0
1304	Douglas	245	Registration	Beef	0
A-KSDG-B002	Douglas	900	Renewal	Beef	0
A-KSJF-BA02	Jefferson	600	Certification	Beef	0
A-KSJF-B005	Jefferson	125	Permit	Beef	0
A-KSJO-BA04	Johnson	135	Certification	Beef	0
A-KSJO-BA01	Johnson	152	Certification	Beef	0
A-KSJO-MA05	Johnson	60	Certification	Dairy	0
A-KSJO-B001	Johnson	1354	Permit	Beef,Swine	0
A-KSLV-MA08	Leavenworth	45	Certification	Dairy	0
A-KSLV-S001	Leavenworth	1705	Permit	Swine	0
958	Leavenworth	300	Registration	Dairy,Swine	0
A-KSLV-E001	Leavenworth	6000	Renewal	Exotic	0
A-KSWY-BA01	Wyandotte	200	Certification	Beef	0

Though the total potential number of animals is approximately 12,240 head in the watershed, the actual number of animals at the feedlot operations is typically less than the allowable permitted number.

According to the United States Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS) Kansas Farm Facts 2012 report, there were 44,000 and 25,000 head of cattle (including calves) in Jefferson and Leavenworth counties respectively, which are the two counties within the watershed with the most cattle. There were also 2,500 (Jefferson) and 2,200 (Leavenworth) head of hogs reported in these counties as well. The number of cattle and hogs in the remaining counties in the Lower Kansas watershed are detailed in Table 18, which also details the number of reported horses and goats in these counties from the 2007 Census of Agriculture. Johnson County reported the most horses with 2,303, whereas the highest reported number of goats was in Jefferson County with 948.

Table 18. Number of cattle, hogs, horses and goats in the counties within the Lower KS watershed.

County	Cattle (2012)	Hogs (2012)	Horses (2007)	Goats (2007)
Douglas	18,000	Not reported	1,946	466
Jefferson	44,000	2,500	1,374	948
Johnson	11,500	2,200	2,303	659
Leavenworth	25,000	2,200	1,796	367
Wyandotte	1,500	Not reported	368	225

On-Site Waste Systems: The majority of the population base in the TMDL watershed is served by municipal waste water treatment plants. The Spreadsheet Tool for Estimating Pollutant Load (STEPL) was utilized to identify the number of septic systems within the HUC12s within the watershed. According to STEPL, there are approximately 11,702 septic systems within the watershed with an anticipated failure rate of 0.93%. Failing on-site septic systems do not likely contribute to the total phosphorus impairment within the watershed.

Population Density: According to the 2010 Census Block information, the TMDL watershed has approximately 455,943 people, with a population density of 783 people / square mile. There are several municipalities that are partially within the watershed that are detailed in Table 19. Population changes from the 2000 to 2010 census show that the population changes have increased in many of the municipalities within the watershed.

Table 19. U.S. Census Population Data within the Lower Kansas River watershed.

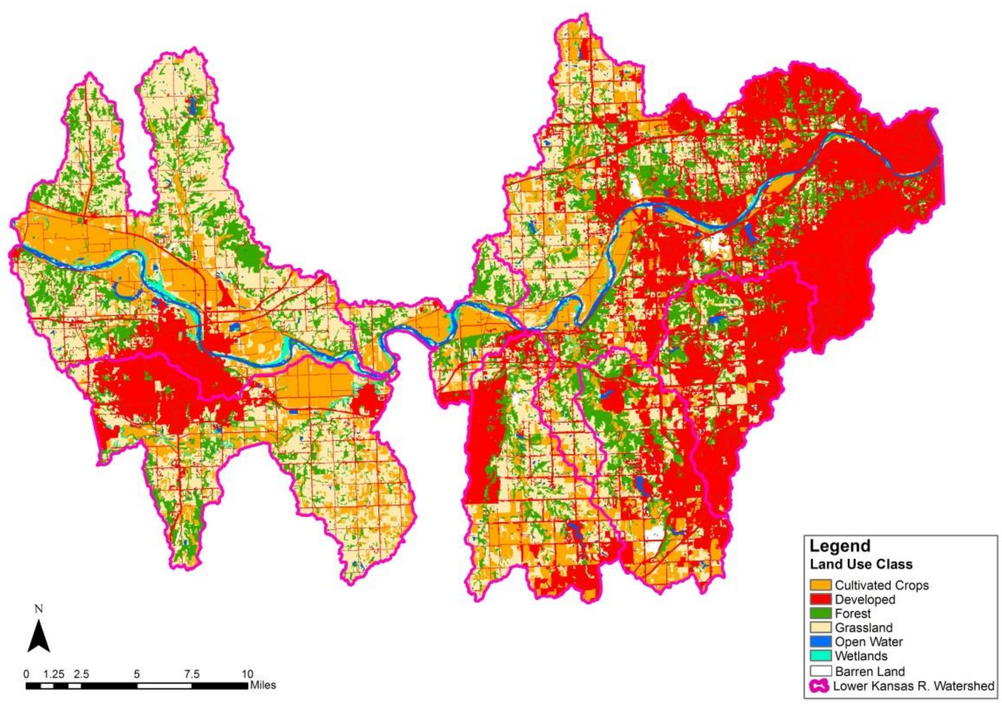
City	COUNTY	2010 US Census Population	2000 US Census Population	10 Year Popluation Change in %
Westwood	Johnson	1506	1533	-1.79
Overland Park	Johnson	173372	149080	14.01
Lecompton	Douglas	625	608	2.72
De Soto	Johnson	5720	4561	20.26
Perry	Jefferson	929	901	3.01
Lawrence	Douglas	87643	80098	8.61
Eudora	Douglas	6136	4307	29.81
Merriam	Johnson	11003	11008	-0.05
Lenexa	Johnson	48190	40238	16.50
Basehor	Leavenworth	4613	2238	51.48
Linwood	Leavenworth	375	374	0.27
Kansas City	Wyandotte	145786	146866	-0.74
Edwardsville	Wyandotte	4340	4146	4.47
Roeland Park	Johnson	6731	6817	-1.28
Mission	Johnson	9323	9727	-4.33
Gardner	Johnson	19123	9396	50.87
Lake Quivira	Johnson	906	932	-2.87
Bonner Springs	Wyandotte	7314	6768	7.47
Shawnee	Johnson	62209	47996	22.85
Olathe	Johnson	125872	92962	26.15

Land Use: Land use within the watershed is dominated by developed land (35%) according to the 2011 National Land Cover Data Set (NLCD). Grassland and cropland areas comprise about 29% and 17% of the watershed respectively. The land use percentages and acres within the watershed are in Table 20 and are further illustrated in the land use map (Figure 33). Figure 33 illustrates the location of the cropland within the watershed, which is in the low lying areas adjacent to the stream corridors. Runoff from the cropland and developed areas could contribute significant sources of total phosphorus loading.

Table 20. Landuse acres and percentages in the TMDL Watershed

Land Use	Acres	Percent of Watershed
Developed	133588	35.46
Grassland	109693.4	29.12
Cropland	62502.71	16.59
Forest	56070.4	14.89
Open Water	8529.2	2.26
Wetlands	3808.1	1.01
Barren Land	2509.3	0.67
Total	376701.11	100.00

Figure 33. Landuse map for the Lower Kansas River TMDL watershed.



Contributing Runoff: The TMDL watershed has a mean soil permeability value of 0.87 inches/hour, ranging from 0.01 to 13 inches/hour according to the NRCS STATSGO database. About 80% of the watershed has a permeability value less than 1.71 inches/hour, which contributes runoff during low rainfall intensity events. According to an 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. As the watersheds' soil profiles become saturated, excess overland flow is produced. The majority of the nonpoint source nutrient runoff will be associated with cropland areas throughout the watershed that are in close proximity to the stream corridors.

Background: Phosphorus is present over the landscape, in the soil profile as well as terrestrial and aquatic biota. Wildlife can contribute phosphorus loadings, particularly if they congregate to a density that exceeds the assimilative capacity of the land or water.

4. ALLOCATION OF POLLUTION REDUCTION RESPONSIBILITY

This TMDL will be established to progressively reduce phosphorus loadings and ambient concentrations with periodic assessment of the biological endpoints on the lower reaches of the Kansas River. The TMDL is detailed in Tables 22 and 23 and displayed in Figures 34 and 35. The initial phase will entail reductions in phosphorus loading of the permitted discharging facilities in the watershed. TP load reductions will occur throughout the main stem of the Kansas River and will be monitored at SC255, SC254, and SC203. Reduced upstream TP loading will be indicative as the TP concentrations approach the TP target concentrations, which will result in favorable biological support throughout the lower Kansas River. Additionally, riparian management in areas adjacent to cropland and livestock management in the vicinity of streams within the watershed should reduce nonpoint source loads under conditions of moderate flows. Furthermore, efforts to achieve all nutrient TMDLs in contributing watersheds and controlling nonpoint sources will be key to achieve the nonpoint source load reductions necessary for success of this TMDL.

Once the concentrations in the Kansas River approaches the target TP median concentration of 0.200 mg/L and sestonic chlorophyll concentrations of < 10 µg/L, an intensive assessment of macroinvertebrate abundance and diversity will be made to determine compliance with the narrative nutrient criteria.

Point Sources: The Wasteload Allocations (WLA) associated with the wastewater treatment facilities are detailed in Table 21. The WLA for the municipal permitted facilities that utilize mechanical treatment processes is based on the permitted design flow and a discharge TP concentration of 1.0 mg/L. The WLA for municipal and commercial wastewater facilities that utilize a lagoon system is based on the permitted design flow and a discharge TP concentration of 2.0 mg/L, an achievable effluent TP concentration for Kansas lagoon systems.

The WLA associated with industrial permitted facilities has been established based on site specific data and loading potential. Facilities with minimal loading potential have been assigned a WLA based on the permitted discharge flow and an effluent TP concentration of 0.2 mg/L as a conservative measure. TP concentrations from these facilities is presumed to be background and reflective of the concentrations within their source water, hence TP loading associated with processes from these facilities is nominal. The Westar Lawrence Energy Center; Bonner Springs Water Treatment Plant; and the Exxon Mobil Grease Plant are industrial permitted facilities with an assigned WLA based on maintaining current effluent TP concentrations. Hence, WLAs for these three facilities are based on permitted flow and current effluent TP concentration as detailed in Table 21. The ICL Performance Products LP facility is an industrial facility that currently discharges elevated TP concentrations in their effluent. The WLA for this facility is based on their current permitted flow and a discharge effluent TP concentration of 3.0 mg/L.

NPDES permitted facilities within the watershed that either do not discharge or do not contribute to the TP loading and impairment within the Kansas River have been assigned a WLA of zero. These facilities are detailed in Appendix B.

Since the lower portion of the Kansas River is highly developed, growth must be accounted for in the WLA for this TMDL. A reserve WLA of 37 lbs/day, accounting for an additional 5% of the current WLA, will be set aside to accommodate growth in the watershed. The reserve, along with the existing WLA from the facilities that will discharge well under the assigned WLA will provide adequate coverage under this WLA to accommodate growth.   The total TP WLA for this TMDL is 768 lbs/day.

Table 21. WLA Table for the Lower Kansas River TMDL.

KS Permit	Facility	NPDES	TP WLA Conc (mg/L)	Design Flow (cfs)	WLA (lbs/day)
M-KS33-OO01	Lecompton Wastewater Treatment Facility	KS0038644	2.00	0.11	1.19
I-KS31-PO09	Westar Lawrence Energy Center	KS0079821	1.50	1.39	11.27
I-KS31-CO06	Hallmark Cards, Inc.	KS0091481	0.20	0.02	0.02
I-KS31-PO16	Kaw River Water Treatment Plant	KS0088234	0.20	0.66	0.71
M-KS31-IO01	Lawrence Kansas River Wastewater Treatment Facility	KS0038644	1.00	19.34	104.42
I-KS31-PO06	ICL Performance Products LP (fka Astaris)	KS0001511	3.00	0.68	11.03
I-KS31-PO20	Jefferson County RWD No. 13 Wastewater Treatment Facility	KS0096814	0.20	0.01	0.02
I-KS31-PO04	Former Farmland Industries - Lawrence	KS0001601	0.20	0.56	0.60
C-KS31-OO02	KTA - Lawrence Service Area	KS0053694	2.00	0.05	0.50
I-KS31-PO23	Clinton Reservoir Public Water Supply Treatment Plant	KS0099121	0.20	0.97	1.05
M-KS31-OO03	Lawrence Wakarusa River Wastewater Treatment Facility	KS0099031	1.00	10.83	58.48
M-KS17-OO02	Eudora Municipal Wastewater Treatment Facility	KS0094609	1.00	1.39	7.52
M-KS12-OO03	DeSoto Wastewater Treatment Facility	KS0098167	1.00	2.01	10.86
I-KS06-PO02	National Cold Storage, Inc.	KS0003085	0.20	0.02	0.02
M-KS06-OO03	Leavenworth County S.D. #2 (Timberlake)	KS0087157	2.00	0.11	1.20
I-KS06-PO07	Bonner Springs Water Treatment Plant	KS0099791	1.00	0.15	0.84
M-KS06-OO02	Bonner Springs Wastewater Treatment Plant	KS0082881	1.00	2.17	11.70
M-KS68-OO04	Mill Creek Regional Wastewater Treatment Facility	KS0088269	1.00	29.01	156.63
I-KS27-CO09	FUCHS Lubricants Co.	KS0086665	0.20	0.09	0.10
M-KS27-OO20	Kansas City Treatment Plant #20	KS0080195	1.00	10.83	58.48
M-KS27-OO14	Municipal Treatment Plant No. 14	KS0080209	1.00	0.19	1.00
I-KS27-PO43	THAN / Harcros Groundwater Remediation Project	KS0096709	0.20	2.32	2.51
I-KS27-BO01	KAW Power Station	KS0080179	0.20	47.99	51.83
M-KS45-OO01	Nelson Complex Wastewater Treatment Plant	KS0055492	1.00	23.21	125.31
I-KS52-PO02	Exxon Mobil Corp. - Olathe Grease Plant	KS0082988	0.50	0.03	0.08
M-KS52-IO01	Harold Street Wastewater Treatment Plant	KS0045802	1.00	4.95	26.73
M-KS52-OO06	Olathe Cedar Cr WWTF	KS0081299	1.00	11.99	64.74
M-KS20-OO01	GARDNER - KILL CREEK	KS0095605	1.00	3.87	20.88
I-KS12-PO07	DESOTO (SAAP) WATER TREATMENT PLT	KS0094536	0.20	0.15	0.17
C-KS12-OO01	CLEARVIEW VILLAGE	KS0090671	2.00	0.09	0.94
	RESERVE WLA				37.00
TOTAL WLA					**767.81**

Use of wastewater for irrigation and efficient operation of the treatment processes will assist lowering phosphorus loading and concentrations seen in the Kansas River. In addition, consideration of assimilation rates of wastewater phosphorus, wasteload trading opportunities among cities, opportunities to further irrigate with wastewater and actual efficiency in phosphorus removal by the mechanical and lagoon systems should be evaluated, along with the resulting downstream total phosphorus concentrations at monitoring stations along the Kansas River.

Actual wasteload allocations attributed to ambient concentrations seen at SC254 and SC203 under normal conditions are anticipated to be less than the allocations of Tables 22 and 23 because of the adsorption to sediments and absorption by biota. Under low flow conditions, wasteloads will largely be reduced through efficient treatment and alternative disposal such as irrigation, so that they match up with the overall Load Capacity. In-stream wasteloads at the low flow condition assimilate, but still account for a large percentage of the load.

MS4 Stormwater: As noted in Appendix B, there are ten permitted MS4 permits issued within the watershed. The Wasteload Allocation for the MS4 stormwater permits is provided by proportioning the remaining load capacity, after accounting for the NPDES WLA, between MS4 and nonpoint source loads. This was done by assuming load contributions would arise from the developed areas within the TMDL watershed. Thus, the MS4 WLA is based on the proportion of developed land in the watershed, which accounts for about 35 % of the lower Kansas River TMDL area and 8.69% of the larger Kansas River TMDL area that covers the upper, middle, and lower Kansas River TMDL watersheds. The developed acreage above SC254 and SC203 accounts for 2.02% and 6.68% of the watershed area associated with the upper, middle, and lower Kansas River TMDL watersheds respectively. Therefore the MS4 allocations for SC254 corresponds the 2.02% and the MS4 allocation at SC203 is 8.69% (based on the cumulative MS4 allocations for both stations) of the load capacity at these stations, after accounting for the NPDES WLA, and only applies to flows at or above median flow conditions.

Table 22. Load Capacity and Allocations (lb/day) at SC254 at De Soto.

Percent Flow	*Flow (cfs)*	*Load Capacity*	*WLA (lbs/day)*	*LA (lbs/day)*	*MS4 Allocation (lbs/day)*
90	1170	1263.6	207.66	1055.94	0
75	1830	1976.4	207.66	1768.74	0
50	3520	3801.6	207.66	3521.34	72.60
25	8105	8753.4	207.66	8373.12	172.62
10	18000	19440	207.66	18843.85	388.49

Table 23. Load Capacity and Allocations (lbs/day) at SC203 at Kansas City.

Percent Flow	*Flow (cfs)*	*Load Capacity*	*WLA (lbs/day)*	*LA (lbs/day)*	*MS4 Allocation (lbs/day)*
90	1177.74	1271.96	767.81	504.15	0
75	1842.11	1989.47	767.81	1221.66	0
50	3543.28	3826.75	767.81	2793.12	265.82
25	8158.61	8811.30	767.81	7344.51	698.98
10	18119.10	19568.59	767.81	17166.99	1633.79

Figure 34. Kansas River TMDL at SC254.

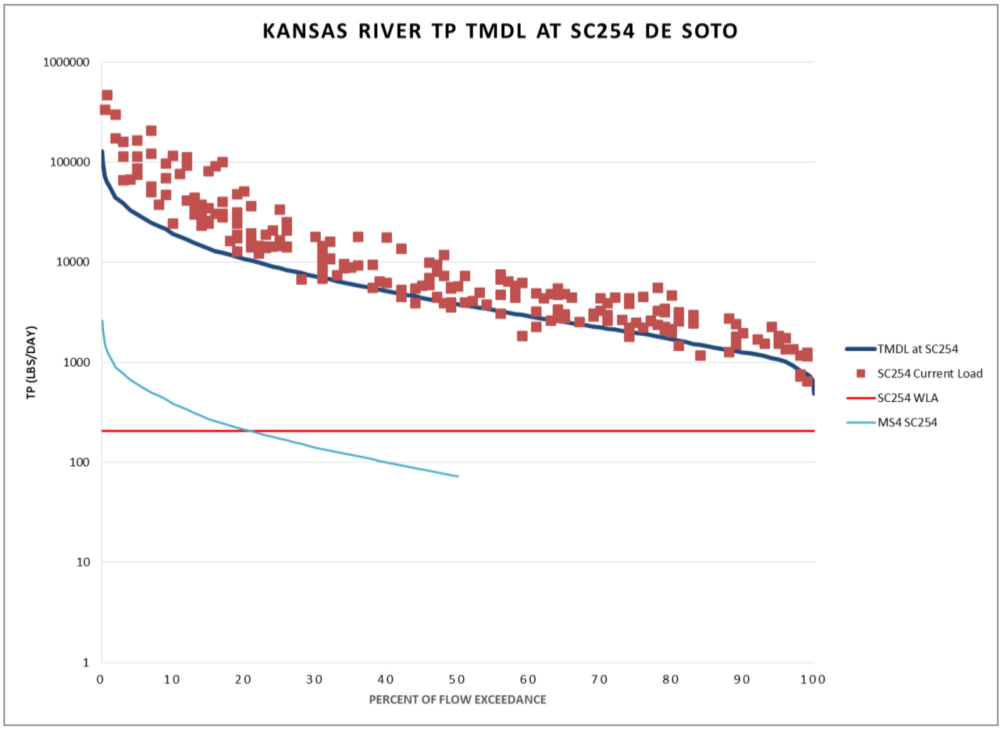
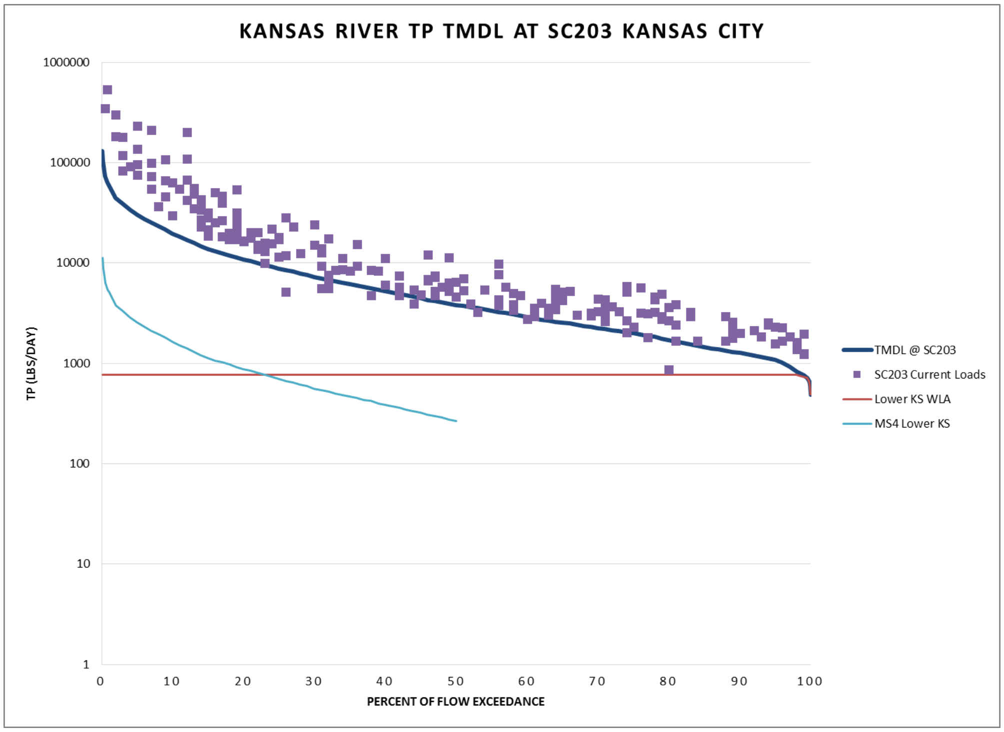


Figure 35. Kansas River TMDL at SC203.



Nonpoint Source Load Allocation: The load allocation for nonpoint sources is the remaining load capacity after assimilating wasteloads for NPDES wastewater and MS4 stormwater have been accounted (Tables 22 and 23). Nonpoint sources are assumed to be minimal at times during low flow and drier conditions. The load allocation grows proportionately as normal conditions occur. The allocation and contributing areas increase as wet weather ensues.

Defined Margin of Safety: The Margin of Safety provides some hedge against the uncertainty in phosphorus loading into the TMDL watershed, predominantly from the point source dischargers. This TMDL uses an implicit margin of safety, relying on conservative assumption to be assured that future wasteload allocations will not cause further excursion from the nutrient criteria. First, design flows are used for the municipal wastewater discharging facilities to set wasteload allocations, although the majority of the facilities are discharging well under their design flow. Additionally, wasteloads have been conservatively set for discharging facilities that are not wastewater treatment facilities, where several of these do not likely contribute any nutrient loads. Furthermore, biological endpoints are used to assess the narrative criteria and have to be maintained for three consecutive years before attainment of water quality standards can be claimed. Finally, because there is often a synergistic effect of phosphorus and nitrogen on in-stream biological activity, concurrent efforts to reduce nitrogen content of wastewater should complement the effect of phosphorus load reduction in improving the biological condition of the TMDL watershed.

State Water Plan Implementation Priority: Early implementation of this TMDL will focus on wastewater treatment at the major municipal wastewater treatment facilities in the watershed along with riparian management to effectively reduce the phosphorus loading to the Kansas River. Additionally further reduction in wastewater phosphorus loads will occur along with implementation of stormwater abatement practices. Due to the need to reduce the high nutrient loads in the Kansas River, this TMDL will be **High Priority** for implementation.

Nutrient Reduction Framework Priority Reduction Ranking: Most of this watershed lies within the Lower Kansas Subbasin (HUC8: 10270104) which is among the top sixteen HUC8s targeted for state action to reduce nutrients.

Priority HUC12s: Although this TMDL will initially be driven by implementation of point source treatment improvements, priority HUC12s within the TMDL watershed can be identified based on the cropland areas adjacent to the streams. All of the HUC12s associated with this TMDL contain priority areas, however the top five HUC12s in the watershed are detailed in Table 24 and prioritized by the number of cropland acres. Nonpoint source reduction efforts are further prioritized to the areas of the riparian corridors on the main stem of the Kansas River adjacent to cropland or livestock facilities.

Table 24. Priority HUC12s with the highest amount of cropland acres in the TMDL watershed.

Rank	HUC12	Cropland Acres
1	102701040205	10,051
2	102701040504	9,216
3	102701040501	8,590
4	102701040603	8,441
5	102701040503	7,587

5. IMPLEMENTATION

Point Source Implementation Supporting Information: Qual2K is a steady-state model that was utilized to evaluate nutrient responses under the hydrologic flow conditions representing the 75th and 95th percent flow exceedance conditions in the Kansas River. The model run during the 95th percent flow exceedance value represents a critical low flow condition, where NPDES point source contributions could be assessed for their load contributions into the Kansas River system. Under the 75th percent flow exceedance model runs, the additional flow established a condition that introduces additional contributions from nonpoint source loads while maintaining a noticeable influence from the point sources. The primary purpose of the model was to assess the contribution from discharging point sources to the Kansas River during the more critical lower flow conditions. Model runs with additional flow were evaluated, however the additional flow in the river overwhelms any point source signal nullifying the primary utility of the Qual2K model in assessing point source contribution for this TMDL. The modeling assessment concluded that the established wasteloads will likely achieve the numeric TP median concentration target of 0.200 mg/L within the Kansas River when flow conditions in the river are achieving the 75th percent flow exceedance value. Under the modeling scenario that achieves optimal load reductions from the discharging point sources, the TMDL watersheds contributing flow to the Kansas River watershed were modeled at their respective TMDL total phosphorus concentrations. Therefore inflows contributing to the total phosphorus load within the Kansas River reflect the TMDL endpoint concentrations for the respective nutrient TMDLs contributing total phosphorus loads to the Kansas River. The Qual2K model was not utilized to develop the TMDL, rather it was utilized to support and validate that the respective wasteload allocations set in the TMDL are appropriate to accommodate achievement of the Kansas River TP TMDL and represent optimal conditions under low flow conditions.

Several scenarios were incorporated into the model runs for the two flow conditions, as detailed in Figures 36 and 37. The variability of the TP concentrations are highly dependent upon the discharge of the reservoirs and point source facilities, particularly during the 95th percent flow exceedance run. The modeling scenario that represents the wasteload allocations associated with this TMDL, is noted by the navy line with gold markers in each of the figures, noted by "Dischargers Set at Design Flow & WLA TP

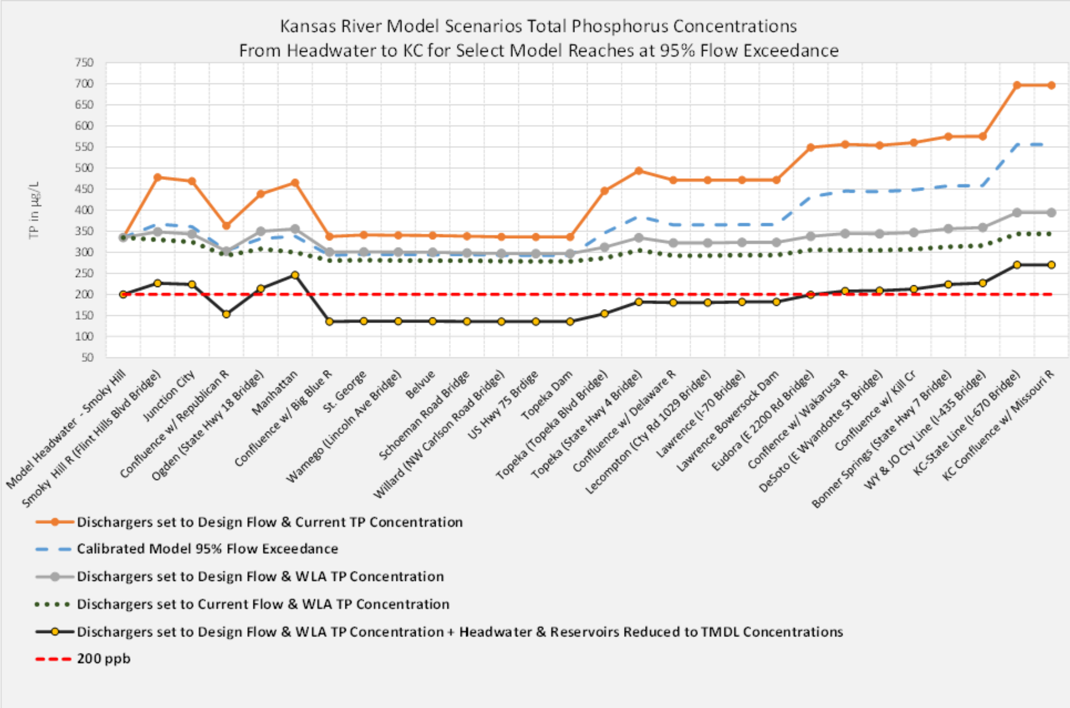
Conc. + Headwater & Reservoirs Meeting TMDLs". The description of the scenario references the WLA calculations for the municipal discharging wastewater facilities in the watershed, whereas industrial permitted facilities were assigned site specific wasteload allocations relative to their nutrient loading potential and discharge history.

During the aforementioned scenario for the 95^{th} percentile flow exceedance model run the TP concentrations in the upper Kansas River are influenced by Milford Lake releases and are then diluted by the Tuttle Lake inflows. Concentrations slightly increase in the Middle Kansas River watershed as concentrations reach 0.200 mg/L at Lecompton. The numerous discharging facilities influence an increase in the TP concentration in the Lower Kansas River watershed and concentrations observed at the terminus of the watershed are just under 0.300 mg/L according to the model. This model scenario represents the best possible condition that could be achieved with the successful implementation of the associated wasteload allocations of the Kansas River TMDLs during the low flow condition.

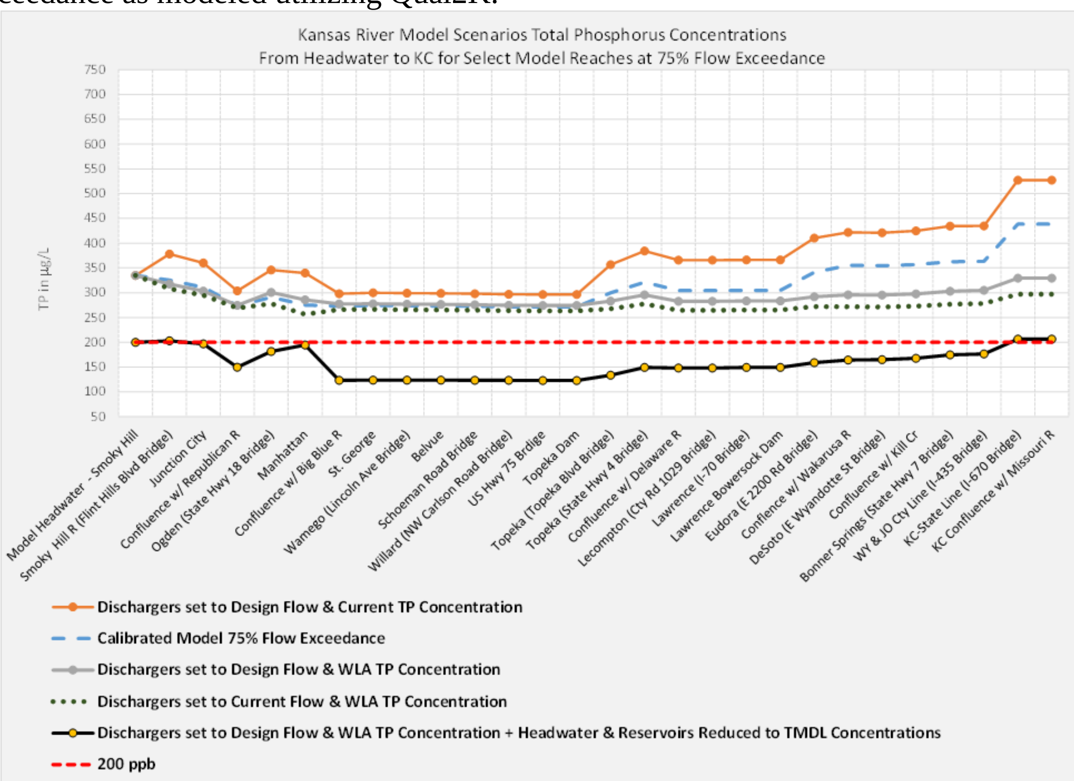
Under the respective scenario for the 75^{th} percentile flow exceedance model run, the TP concentrations are significantly less but the relative pattern of the concentrations throughout the river remain similar, although muted. The increase in flow adds dilution to the system and the TP concentrations reaching Kansas City are modeled at 0.200 mg/L under this scenario. This scenario further validates and supports the 0.200 mg/L TP median concentration target noted in TMDL endpoint relative to the ecoregional ALUS index assessment.

Though the modeled concentrations are steady state, when the point sources within the watershed comply with the assigned wasteload allocations and the existing nutrient TMDLs associated with Milford, Tuttle, and Perry Lake are achieved, the resulting modeled concentrations within the Kansas River should be achieved. When this comes to fruition, the TP loading during critical flow conditions will be optimally reduced and the numeric median target concentration of 0.200 mg/L will likely be achieved for data under all flow conditions. If the TMDL endpoints are not achieved at this point, the focus will shift to nonpoint source load contributions associated with higher flow conditions.

Figures 36. Total Phosphorus concentrations along the Kansas River at 95% flow exceedance as modeled utilizing Qual2K.



Figures 37. Total phosphorus concentrations along the Kansas River at 75% flow exceedance as modeled utilizing Qual2K.



Desired Implementation Activities:

1. Implement and maintain conservation farming, including conservation tilling, contour farming, and no-till farming to reduce runoff and cropland erosion.
2. Improve riparian conditions along stream systems by installing grass and/or forest buffer strips along the stream and drainage channels in the watershed.
3. Perform extensive soil testing to ensure excess phosphorus is not applied.
4. Ensure land applied manure is being properly managed and is not susceptible to runoff by implementing nutrient management plans.
5. Install pasture management practices, including proper stock density to reduce soil erosion and storm runoff.
6. Ensure proper on-site waste system operations in proximity to the main stream segments.
7. Ensure that labeled application rates of chemical fertilizers are being followed and implement runoff control measures.
8. Make operational changes in wastewater treatment and alternative disposal such as irrigation and, if necessary, install enhanced nutrient reduction technology to reduce wasteloads.
9. Renew state and federal permits and inspect permitted facilities for permit compliance.
10. Facilitate urban stormwater management to abate pollutant loads.
11. The stakeholder leadership team for the Lower Kansas watershed WRAPS will coordinate BMPs to address:
    a. Livestock: vegetative filter strips, relocate feeding sites, relocate pasture feeding sites off-stream and alternate watering system.
    b. Cropland: waterways, terraces, conservation crop rotations and water retention structures.

NPDES and State Permits – KDHE

a. Monitor influent into and effluent from the major discharging permitted wastewater treatment facilities, continue to encourage wastewater reuse and irrigation disposal and ensure compliance and proper operation to control phosphorous levels in wastewater discharges.
b. Establish applicable permit limits and conditions after 2021, with the initial implementation of goals and appropriate schedules of compliance for permits issued prior.
c. Establish TP concentration goal of 1.0 mg/L for all mechanical municipal wastewater treatment facilities in accordance with the WLA.
d. Establish appropriate TP concentration goals for ICL Performance Products LP and establish schedules of compliance to facilitate operational changes in wastewater treatment to meet permit conditions. Establish applicable permit limits in permit issued after 2027.
e. Manage the sum of WLA for the watershed to accommodate population growth as needed.
f. Inspect permitted livestock facilities to ensure compliance.

g. New livestock permitted facilities will be inspected for integrity of applied pollution prevention technologies.
h. New registered livestock facilities with less than 300 animal units will apply pollution prevention technologies.
i. Manure management plans will be implemented, to include proper land application rates and practices that will prevent runoff of applied manure.
j. Reduce runoff in MS4 permitted areas through stormwater management programs.
k. Establish nutrient reduction practices among urban homeowners to manage application on lawns and gardens, through the respective stormwater management programs.
l. Interact with the Lower Kansas WRAPS on opportunities for trading and offsets of loads between municipalities and agricultural producers within the watershed.

Nonpoint Source Pollution Technical Assistance – KDHE

a. Support Section 319 implementation projects for reduction of phosphorus runoff from agricultural activities as well as nutrient management.
b. Provide technical assistance on practices geared to the establishment of vegetative buffer strips.
c. Provide technical assistance on nutrient management for livestock facilities in the watershed and practices geared toward small livestock operations, which minimize impacts to stream resources.
d. Support the implementation efforts of the Lower Kansas WRAPS and incorporate long-term objectives of this TMDL into their 9-element watershed plan.
e. Engage the municipalities in the watershed to discuss stormwater load trading opportunities.

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

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

Riparian Protection Program – KDA-DOC

a. Establish or re-establish natural riparian systems, including vegetative filter strips and streambank vegetation.
b. Develop riparian restoration projects along targeted stream segments, especially those areas with baseflow.
c. Promote wetland construction to reduce runoff and assimilate sediment loadings.

d. Coordinate riparian management within the watershed and develop riparian restoration projects.

Buffer Initiative Program – KDA-DOC

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

Extension Outreach and Technical Assistance – Kansas State University

a. Educate agricultural producers on sediment, nutrient, and pasture management.
b. Educate livestock producers on livestock waste management, land applied manure applications, and nutrient management planning.
c. Provide technical assistance on livestock waste management systems and nutrient management planning.
d. Provide technical assistance on buffer strip design and minimizing cropland runoff.
e. Encourage annual soil testing to determine capacity of field to hold phosphorus.
f. Educate resident, landowners, and watershed stakeholders about nonpoint source pollution.
g. Promote and utilize the WRAPS efforts for pollution prevention, runoff control and resource management. The WRAPS coordinator is also an extension watershed specialist that will provide technical assistance and outreach to producers for BMP implementation. Other entities for this task include NRCS and local conservation districts.

Timeframe for Implementation: Reduction strategies for wastewater should be evaluated by mid-2018 with subsequent planning, design, and construction of any necessary enhance treatment by the next permit cycle starting in 2022. Urban stormwater and rural runoff management should expand in 2017 to ensure nutrients are addressed. Pollutant reduction practices should be installed within the priority subwatersheds before 2022, with follow-up implementation over 2022-2027.

Targeted Participants: The primary participants for implementation will be municipal wastewater and stormwater programs, and agricultural and livestock producers operating immediately adjacent to the main stems of the Kansas River and its tributaries. Watershed coordinators and technical staff of the WRAPS, along with Conservation District personnel and county extension agents should assess possible sources adjacent to streams. Implementation activities to address nonpoint sources should focus on those areas with the greatest potential to impact nutrient concentrations adjacent to these streams.

Targeted Activities to focus attention toward include:

1. Overused grazing land adjacent to the streams.
2. Sites where drainage runs through or adjacent to livestock areas.

3. Sites where livestock have full access to the stream as a primary water supply.
4. Poor riparian area and denuded riparian vegetation along the stream.
5. Unbuffered cropland adjacent to the stream.
6. Conservation compliance on highly erodible areas.
7. Total row crop acreage and gully locations.
8. High-density urban and residential development in proximity to streams and tributary areas.
9. Urban residents should be informed on fertilizer and waste management through their respective municipal Stormwater Management Program to reduce urban runoff loads.

Milestone for 2028: By 2028, the municipal wastewater facilities should be fully implementing the appropriate measures to decrease the phosphorus content of their wastewater. At that point in time, phosphorus data from the Kansas River stream chemistry stations (SC255, SC254 and SC203) should show indications of declining concentrations relative to the pre-2016 data, particularly during normal flow conditions.

Delivery Agents: The primary delivery agents for program participation will be municipalities within the watershed, KDHE, and the Lower Kansas WRAPS.

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

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

2. K.S.A. 65-117d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.

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

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

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

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

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

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

9. The Kansas Water Plan and the 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 implementation.

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

Effectiveness: Use of Biological Nutrient Removal technology has been well established to reduce nutrient levels in wastewater, including phosphorus. Additionally, 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.

6. MONITORING

Future stream sampling will continue at sampling stations SC255, SC254 and SC203. The monitoring will include the continuation of sestonic chlorophyll sampling at SC254. Monitoring of tributary levels of TP for streams with existing KDHE monitoring stations will continue. Monitoring of TP should be a condition of the MS4 permits within the TMDL watershed.

Macroinvertebrate sampling will occur at accessible locations on tributaries being influenced by major dischargers near the confluence with the Kansas River. Additionally the existing biological monitoring sites on the Kansas River will be sampled routinely. If the biological endpoints are achieved over 2023-2027, the conditions described by the narrative nutrient criteria will be viewed as attained and the Lower Kansas River watershed stream stations will be moved to Category 2 on the 2028-303(d) list.

Once the water quality standards are attained, the adjusted ambient phosphorus concentrations on the Lower Kansas River will be the bases for establishing numeric phosphorus criteria through the triennial water quality standards process to protect the restored biological and chemical integrity of the Kansas River.

7. FEEDBACK

Public Notice: An active Internet Web site is established at http://www.kdheks.gov/tmdl/planning_mgmt.htm to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Kansas Lower Republican Basin. This TMDL was posted to this site on November 1, 2016 for public review.

Public Hearing: A public Hearing on this TMDL was held on November 18, 2016 in Lawrence to receive public comments.

Milestone Evaluation: In 2023, evaluation will be made as to the degree of implementation that occurred within the TMDL watershed. Subsequent decisions will be made through the WRAPS, regarding the implementation approach and follow up of additional implementation in the watershed.

Consideration for 303(d) Delisting: The Kansas River stations will be evaluated for delisting under Section 303(d), based on the monitoring data over the period 2017-2027. Therefore, the decision for delisting will come about in the preparation of the 2028-303(d) list. Should modifications be made to the applicable water quality criteria during the ten-year implementation period, consideration for delisting, desired endpoints of this TMDL and implementation activities may be adjusted accordingly.

Incorporation into Continuing Planning Process, Water Quality Management Plan and he Kansas Water Planning Process: Under the current version of the Continuing Planning Process, the next anticipated revision would come in 2022, which will emphasize implementation of WRAPS activities. At that time, incorporation of this TMDL will be made into the WRAPS plan. Recommendations for this TMDL will be considered in the *Kansas Water Plan* implementation decisions under the State Water Planning Process for Fiscal Years 2017-2025.

November 15, 2016

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Appendix A. Kansas Ecoregions as defined in the Kansas Reference Stream Report (KDHE, 2010) and tables of stream biology and stream chemistry stations used to generate the Total Phosphorus / ALUS Index and Total Phosphorus / chlorophyll *a* relationships.

Figure A1. Kansas Ecoregions as defined in the Kansas Reference Stream Report (KDHE, 2010). The Kansas River watershed is dimmed.

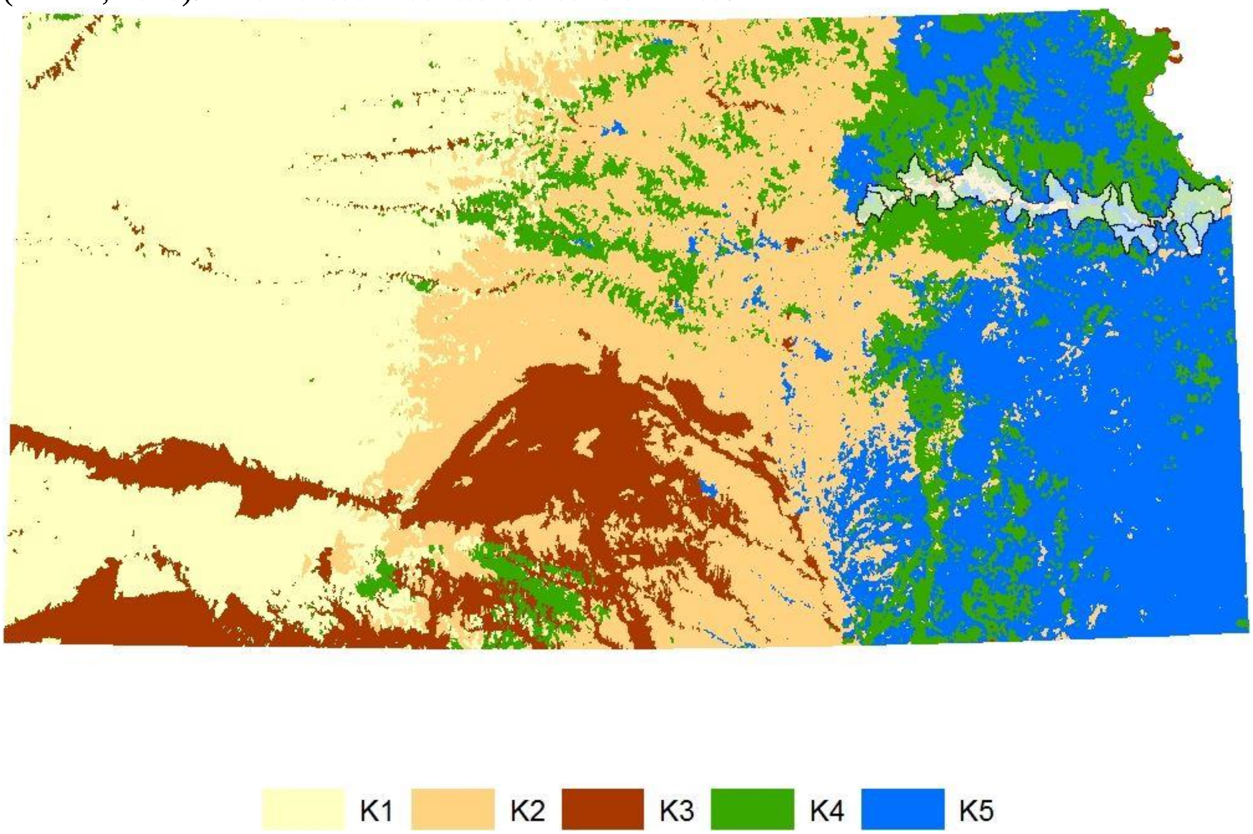

Table A1. KDHE Stream Biology (SB) and Stream Chemistry (SC) sites used to develop the total phosphorus vs. ALUS Index relationship.

SB Site	SC Site	KS Ecoregion	SB Site	SC Site	KS Ecoregion
SB217	SC217	K5	SB267	SC267	K5
SB289	SC289	K5	SB269	SC269	K2
SB531	SC531	K4	SB503	SC503	K4
SB559	SC559	K5	SB325	SC208	K5
SB357	SC582	K4	SB014	SC014	K2
SB718	SC718	K5	SB106	SC106	K5
SB719	SC719	K4	SB257	SC257	K4
SB206	SC206	K5	SB268	SC268	K2
SB726	SC726	K4	SB273	SC273	K5
SB745	SC745	K5	SB520	SC520	K5
SB315	SC532	K4	SB346	SC730	K2
SB360	SC554	K5	SB205	SC205	K5
SB367	SC538	K4	SB232	SC232	K2
SB128	SC128	K5	SB233	SC234	K4
SB212	SC212	K4	SB234	SC234	K4
SB277	SC277	K5	SB260	SC260	K2
SB364	SC207	K5	SB270	SC270	K5
SB251	SC251	K4	SB274	SC274	K5
SB370	SC648	K4	SB109	SC109	K5
SB098	SC098	K5	SB683	SC683	K5
SB105	SC106	K5			
SB215	SC215	K5			
SB568	SC568	K5			
SB378	SC501	K4			
SB214	SC214	K5			
SB299	SC299	K5			
SB543	SC543	K2			
SB368	SC556	K5			
SB213	SC213	K5			
SB218	SC218	K2			
SB254	SC254	K4			
SB264	SC264	K4			
SB266	SC266	K5			

Table A2. KDHE Stream Chemistry (SC) sites used to develop the total phosphorus vs. chlorophyll *a* relationship.

SC Site	KS Ecoregion
SC011	K4
SC201	K5
SC212	K4
SC214	K5
SC215	K5
SC217	K5
SC218	K2
SC233	K4
SC251	K4
SC252	K4
SC254	K4
SC257	K4
SC260	K2
SC268	K2
SC274	K5
SC509	K4
SC521	K5
SC529	K2
SC531	K4
SC535	K2
SC538	K2
SC553	K2
SC559	K5
SC562	K5
SC564	K5
SC583	K5
SC601	K5
SC617	K5
SC621	K5
SC630	K5

SC Site	KS Ecoregion
SC654	K2
SC656	K2
SC673	K2
SC680	K2
SC684	K5
SC686	K5
SC687	K5
SC689	K5
SC711	K5
SC714	K5
SC718	K5
SC719	K4
SC726	K4
SC731	K4
SC745	K5
SC750	K5
SC752	K5
SC757	K5
SC759	K5

Appendix B. All NPDES Facilities in the Lower Kansas River TMDL watershed.

Permit_ No.	Facility_Name	Receivng_Stream	Expiration_Date	Facility_Type	NPDES NO	WLA (lbs/day)
C-KS04-NO02	Ma Belle's Southwest Country Restaurant	Non- Overflowing	31-Oct-17	Two Cell Wastewater Stabilization Lagoon System	KSJ000581	0.00
C-KS06-NO02	Camp Daniel Wastewater Treatment Facility	Non- Overflowing	31-Jan-17	Two Cell Wastewater Stabilization Lagoon System	KSJ000582	0.00
I-KS06-PO02	National Cold Storage, Inc.	Kansas River via Drainage Ditch, Kansas River Basin	31-Dec-16	Non-Contact cooling / Domestic waste	KS0003085	0.02
I-KS06-PO04	Bonner Springs Quarry-Plant #3	Kansas River via West Mission Creek via Unnamed Tributary, Kansas River Basin	31-Dec-17	Quarry	KS0001546	0.00
I-KS06-PO07	Bonner Springs Water Treatment Plant	Kansas River, Kansas River Basin	28-Feb-21	Pre- Treatment plant	KS0099791	0.84
I-KS14-PR01	Century Concrete - Edwardsville Plant	Kansas River, Kansas	30-Sep-17	Concrete plant	KSG110001	0.00
I-KS27-BO01	KAW Power Station	Kansas River, Kansas River Basin	30-Jun-13	Industrial	KS0080179	51.83
I-KS27-CO09	FUCHS Lubricants Co.	Kansas River via storm sewer Kansas River Basin	30-Nov-16	Industrial- Non Contact Cooling	KS0086665	0.10
I-KS27-CO34	P Q Corporation	Kansas River via ½ mile of storm sewer Kansas River Basin	31-Dec-16	Non Contact Cooling - Stormwater	KS0089061	0.00
I-KS27-PO02	BNSF Railway - Argentine Facility	Kansas River, Kansas River Basin	31-Dec-16	Overflow	KS0003221	0.00
I-KS27-PO27	Shawnee Pit #1	Kansas River via Mill Creek via Hayes Creek, Kansas River Basin	31-Jul-16	Quarry with stomwater and pit water	KS0086932	0.00
I-KS27-PO43	THAN / Harcros Groundwater Remediation Project	Kansas River, Kansas River Basin	31-Dec-16	Remediation	KS0096709	2.51
I-KS27-PR01	Geiger Ready-Mix - K.C. Facility	Kansas City Municipal Storm Drain System to the Kansas River, Kansas River Basin	30-Sep-17	Concrete plant	KSG110015	0.00
I-KS27-PR02	Kansas City Readymix - 3Rd Street	Kansas River, Kansas River Basin	30-Sep-17	Concrete plant	KSG110160	0.00
I-KS27-PR03	Omega Concrete Systems	Storm Sewer System to the Kansas River, Kansas River Basin	30-Sep-17	Concrete plant	KSG110024	0.00
I-KS27-PR04	Fordyce Concrete Company	Combined Sewer System, Kansas City, Ks To Kansas River, Kansas River Basin	30-Sep-17	Concrete plant	KSG110193	0.00
I-KS44-PR01	Concrete Materials-Merriam Plant	Turkey Creek, Kansas River Basin	30-Sep-17	Concrete plant	KSG110026	0.00
I-KS68-PR01	Penny's Concrete	Unnamed Intermittent Tributary to Clear Creek, Kansas River Basin	30-Sep-17	Concrete plant	KSG110040	0.00
M-KS06-OO02	Bonner Springs Wastewater Treatment Plant	Kansas River Basin	30-Sep-21	Activated sludge plant	KS0082881	11.70
M-KS06-OO03	Leavenworth County S.D. #2 (Timberlake)	Kansas River via Wolf Creek, Kansas River Basin	31-Dec-16	Three Cell Wastewater Stabilization Lagoon System	KS0087157	1.20
M-KS06-SU01	Bonner Springs, City of	Kansas River Basin	31-Jan-19	MS4	KSR410003	*
M-KS27-OO14	Municipal Treatment Plant No. 14	Kansas River via Unnamed Tributary, Kansas River Basin	31-Dec-16	Mechanical	KS0080209	1.00
M-KS27-OO20	Kansas City Treatment Plant #20	Kansas River, Kansas River Basin	31-Dec-16	Activated sludge plant	KS0080195	58.48
M-KS27-SU01	Kansas Department of Trasportation-Kansas City	Kansas River Basin	31-Jan-19	MS4	KSR410008	*
M-KS44-SU01	Merriam, City of	Kansas River Basin	31-Jan-19	MS4	KSR410019	*
M-KS45-OO01	Nelson Complex Wastewater Treatment Plant	Kansas River via Turkey Creek, Kansas River Basin	30-Sep-06	Mechanical	KS0055492	125.31
M-KS68-OO04	Mill Creek Regional Wastewater Treatment Facility	Kansas River, Kansas River Basin	31-Dec-18	Six Cell Aerated Lagoon Operated in Parallel with the Mechanical Plant	KS0088269	156.63
M-KS68-SU01	Shawnee, City of	Kansas River Basin	31-Jan-19	MS4	KSR410033	*
M-MO25-SO01	Unified Government of Wyandotte County	Missouri River Basin	31-Dec-19	MS4	KS0095656	*
I-KS52-PO02	Exxon Mobil Corp. - Olathe Grease Plant	Kansas River via Mill Creek & Basin: Kansas River Basin	28-Feb-17	Industrial- Oil and Grease	KS0082988	0.08
I-KS52-PR01	Geiger Ready-Mix - Olathe Facility	South Frisco Lake, Kansas	30-Sep-17	Concrete plant	KSG110011	0
M-KS34-SU01	Lenexa, City of	Kansas River	31-Jan-19	MS4	KSR410016	*
M-KS52-IO01	Harold Street Wastewater Treatment Plant	Kansas River via Mill Creek , Kansas River Basin	31-Mar-18	Mechanical	KS0045802	26.73
M-KS52-SU01	Olathe, City of	Kansas River	31-Jan-19	MS4	KSR410025	*

*- MS4 allocations noted in TMDL Section 4

Permit_ No.	Facility_Name	Receivng_Stream	Expiration_Date	Facility_Type	NPDES NO	WLA (lbs/day)
I-KS52-PO08	Olathe/Lone Elm Site	Kansas River via Cedar Creek via Unnamed Tributary, Kansas River Basin	31-Dec-16	Quarry Stormwater	KS0089303	0
I-KS52-PO09	Olathe Quarry (Jo Co Aggregates LLC)	Kansas River via Cedar Creek via New Olathe Lake via Unnamed Tributary, Kansas River Basin	31-Dec-16	Quarry	KS0089478	0
I-KS52-PO10	Olathe Quarry (APAC - Kansas, Inc)	Kansas River via Cedar Creek via New Olathe Lake via Unnamed Tributary, Kansas River Basin	31-Dec-16	Quarry	KS0092321	0
I-KS52-PR02	D.K. Leasing Llc - Kincaid Ready Mix	Cedar Creek, Kansas	30-Sep-17	Concrete plant	KSG110030	0
I-KS52-PR04	Audubon Readymix - 149th Street	Cedar Creek, Kansas	30-Sep-17	Concrete plant	KSG110070	0
I-KS52-PR05	Century Concrete - Olathe Facility	Cedar Creek, Kansas	30-Sep-17	Concrete plant	KSG110005	0
M-KS52-NO01	Lakestone Estates Municipal Wastewater Treatment Facility		31-Aug-16	Non-Overflowing	KSJ000398	0
M-KS52-OO06	Olathe Cedar Cr WWTF	Cedar Creek, Kansas River Basin	31-Dec-19	Mechanical	KS0081299	64.74
M-KS52-SU02	Johnson County	Kansas, Marais des Cygnes and Missouri Rivers	31-Jan-19	MS4	KSR410007	*
C-KS36-NO01	Tall Oaks Christian Church Camp Wastewater Treatment		31-Jul-17	Non overflowing	KSJ000587	0
I-KS12-PO08	Former Sunflower Army Ammunition Plant	Kansas River Basin	31-Oct-19	Remediation/ Lagoon	KS0028321	0
M-KS12-OO03	DeSoto Wastewater Treatment Facility	Kansas River, Kansas River Basin	31-Dec-17	Mechanical	KS0098167	10.86
C-KS31-NO07	Heritage Baptist Church		30-Sep-17	Non Overflowing	KSJ000107	0
C-KS31-OO02	KTA - Lawrence Service Area	Kansas River via Stranger Creek via Nine Mile Creek via Unnamed Tributary, Kansas River Basin	30-Sep-21	Four Cell Wastewater Stabilization Lagoon System	KS0053694	0.5
C-KS58-NO06	Chihowa Retreat Center Wastewater Treatment Facility		31-Dec-17	Non Overflowing	KSJ000173	0
I-KS31-CO06	Hallmark Cards, Inc.	Kansas River via Unnamed Tributary, Kansas River Basin	31-Dec-16	Non contact cooling Stormwater	KS0091481	0.02
I-KS31-NO01	Honey Creek Disposal Service (Wastewater Treatment Facility)		31-Aug-19	Non Overflowing	KSJ000507	0
I-KS31-PO04	Former Farmland Industries - Lawrence	Kansas River Basin	28-Feb-15	Industrial / Stormwater	KS0001601	0.6
I-KS31-PO06	ICL Performance Products LP (fka Astaris)	Kansas River Basin	31-Jan-21	Industrial	KS0001511	11.03
I-KS31-PO09	Lawrence Energy Center	Kansas River Basin	31-Aug-19	Industrial	KS0079821	11.27
I-KS31-PO16	Kaw River Water Treatment Plant	Kansas River, Kansas River Basin	30-Sep-16	Treatment plant	KS0088234	0.71
I-KS31-PO18	North Lawrence Quarry	Kansas River via Mud Creek via unnamed tributary, Kansas River Basin	31-Dec-16	Quarry	KS0117455	0
I-KS31-PO20	Jefferson County RWD No. 13 Wastewater Treatment Facility	Mud Creek Kansas River Basin	30-Sep-21	Lagoon	KS0096814	0.02
I-KS31-PR01	Penny'S Concrete - Lawrence	Kansas River, kansas	30-Sep-17	Concrete plant	KSG110039	0
I-KS89-PO01	Ousdahl Quarry # 70	Kansas River via Mud Creek, Kansas River Basin	30-Jun-21	Quarry	KS0096326	0
M-KS31-IO01	Lawrence Kansas River Wastewater Treatment Facility	Kansas River, Kansas River Basin	31-Jul-19	Mechanical	KS0038644	104.42
M-KS33-OO01	Lecompton Wastewater Treatment Facility	Kansas River, Kansas River Basin	31-Dec-16	3 Cell Lagoon System	KS0038644	1.19

*- MS4 allocations noted in TMDL Section 4

Permit_ No.	Facility_Name	Receivng_Stream	Expiration_Date	Facility_Type	NPDES NO	WLA (lbs/day)
C-KS31-NO01	O'Connell Youth Ranch Wastewater Treatment Facility	Non- Overflowing	31-Oct-17	Two Cell Wastewater Stabilization Lagoon System	KSJ000586	0
C-KS31-NO08	First United Methodist Church Wastewater Lagoon	Non- Overflowing	31-Oct-17	Single Cell Wastewater Stabilization Lagoon	KSJ000627	0
I-KS31-PO23	Clinton Reservoir Public Water Supply Treatment Plant	Yankee Tank Creek/Kansas River Basin	31-Dec-16	Two Single Cell Wastewater Treatment Lagoon System	KS0099121	1.05
I-KS31-PR02	Midwest Concrete-K-10 Ready Mix Plant	Unnamed Intermittent Stream to the Wakarusa River Kansas	30-Sep-17	Concrete Plant	KSG110003	0
M-KS17-OO02	Eudora Municipal Wastewater Treatment Facility	Wakarusa River Kansas River Basin	31-Dec-16	Mechanical	KS0094609	7.52
M-KS31-NO02	The Villages, Inc. Wastewater Treatment Facility	Non- Overflowing	31-May-17	Two Cell Wastewater Stabilization Lagoon System	KSJ000401	0
M-KS31-NO07	Eagle Bend Golf Course	Non- Overflowing	31-Jan-17	Two cell Wastewater Stabilization Lagoon System	KSJ000156	0
M-KS31-OO03	Lawrence Wakarusa River Wastewater Treatment Facility	Wakarusa River Kansas River Basin	31-Aug-19	Integrated Municipal Stormwater and Wastewater Planning	KS0099031	58.48
M-KS31-SU01	Lawrence, City of	Kansas River	31-Jan-19	MS4	KSR410014	*
M-KS31-SU02	Kansas Department of Transportation-Lawrence	Kansas River	31-Jan-19	MS4	KSR410009	*
M-KS20-OO01	GARDNER - KILL CREEK	KANSAS RIVER VIA KILL CREEK	31-Oct-21	Mechanical	KS0095605	20.88
P-KS12-OO01	INTERVET, INC.	DeSoto MWWTP	30-Jun-18	PRE_TREATMENT	KSP000053	0
C-KS12-OO01	CLEARVIEW VILLAGE	KANSAS RIVER VIA KILL CREEK VIA HANSON CREEK	31-Dec-16	3-cell Lagoon	KS0090671	0.94
I-KS12-PO07	DESOTO (SAAP) WATER TREATMENT PLT	KANSAS RIVER VIA KILL CREEK	30-Sep-16	2-cell Lagoon	KS0094536	0.17
I-KS12-PO01	HUNT MARTIN MATERIALS - SUNFLOWER	KANSAS RIVER VIA KILL CREEK	30-Nov-20	Quarry	KS0087947	0
I-KS20-PO01	APAC-KANSAS / GARDNER QUARRY	KANSAS RIVER VIA KILL CREEK VIA UNNAMED TRIB	31-Dec-16	Quarry	KS0098957	0

*- MS4 allocations noted in TMDL Section 4