SMOKY-SALINE RIVER BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody: Mud Creek
Water Quality Impairment: Total Phosphorous

1. INTRODUCTION

Subbasin: Lower Smoky Hill

Counties: Dickinson (DK) and Ottawa (OT)

HUC8: 10260008 **HUC10** (12)**: 04** (04, 05)

Ecoregions: Smoky Hills (27a)

Drainage Area: 93 mi^2

Main Stem Water Quality Limited Segments and Tributaries (designated uses are detailed in **Table 1**)**:**

Main Stem
HUC8 10260008
Mud Creek (8)

Table 1. Designated uses for main stem and tributary segments in the watershed (Kansas Department of Health and Environment, 2013).

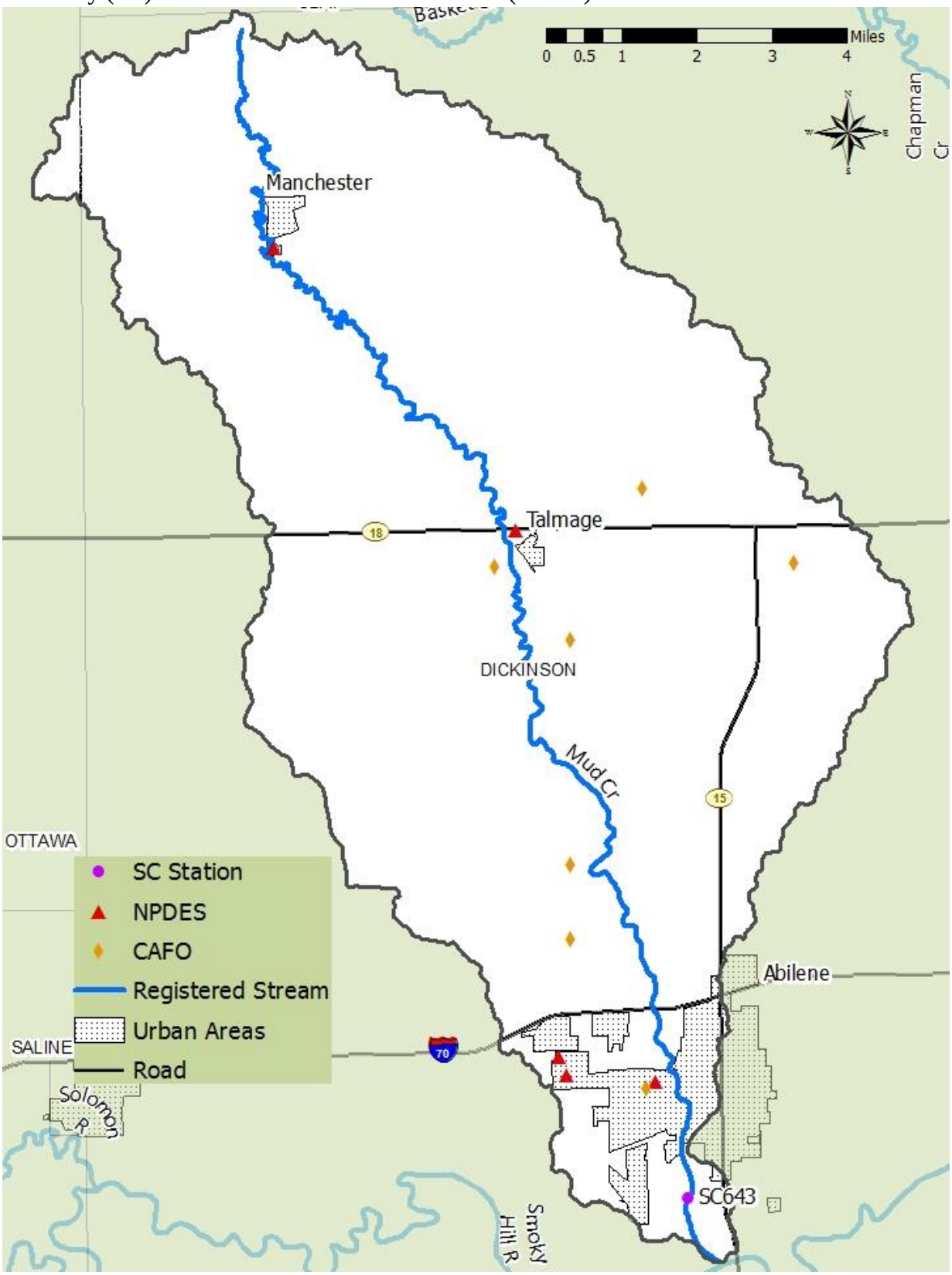
Stream	Segment	Aquatic Life	Contact Recreation	Domestic Supply	Food Procurement	Groundwater Recharge	Industrial	Irrigation	Livestock Watering
Mud Creek	8	E	a	Y	N	Y	Y	Y	Y

Definitions: E - expected aquatic life use water; a - secondary contact recreation stream; Y - referenced stream segment is assigned the indicated designated use; N - referenced stream segment does not support the indicated designated use

303(d) Listings
Station SC643 (**Figure 1**), Mud Creek near Abilene.
Total Phosphorus Impairment, Category 5: 2008, 2010, 2012, 2014, 2016, and 2018.

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

Figure 1. Map of contributing area for Kansas Department of Health and Environment stream chemistry (SC) station in Mud Creek near Abilene (SC643).



Water Quality Criteria

Narrative Nutrient Criteria

The introduction of plant nutrients into streams, lakes, or wetlands from artificial sources shall be controlled to prevent the accelerated succession or replacement of aquatic biota or the production of undesirable quantities or kinds of aquatic life (K.A.R. 28-16-28e(d)(2)(A)).

The introduction of plant nutrients into surface waters designated for domestic water supply use shall be controlled to prevent interference with the production of drinking water (K.A.R. 28-16-28e(d)(3)(D)).

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. 28-26-28e(d)(7)(A)).

Taste-producing and odor-producing substances of artificial origin shall not occur in surface waters at concentrations that interfere with the production of potable water by conventional water treatment processes, that impart an unpalatable flavor to edible aquatic or semiaquatic life or terrestrial wildlife, or that result in noticeable odors in the vicinity of surface waters (K.A.R. 28-16-28e(b)(7)).

Numeric Dissolved Oxygen Criteria

The concentration of dissolved oxygen in surface waters shall not be lowered by the influence of artificial sources of pollution. The Dissolved Oxygen criterion is 5 mg/L (K.A.R. 28-16-28e(e)).

Numeric pH Criteria

Artificial sources of pollution shall not cause the pH of any surface water outside of a zone of initial dilution to be below 6.5 and above 8.5 (K.A.R. 28-16-28e: Tables of Numeric Criteria).

2. CURRENT WATER QUALITY CONDITIONS AND DESIRED ENDPOINT

Level of Support for Designated Uses under 2018 303(d)

Phosphorus levels in the watershed of Mud Creek near Abilene (SC643) are consistently high. Excessive nutrients are not being controlled and are thus impairing aquatic life, contact recreation, and domestic water supply. The ultimate endpoint of this Total Maximum Daily Load (TMDL) will be to achieve the Kansas Surface Water Quality Standards by eliminating excessive primary productivity and impairment to aquatic life, recreation, and domestic water supply associated with excessive phosphorus.

Station Location and Period of Record

Stream Chemistry (SC) Monitoring Station

SC643: Active rotational station at Mud Creek near Abilene, located on County Road Bridge, 1.25 miles south and 0.5 mile west of Abilene. Period of record: February 26, 1991 to April 9, 2018.

Streamflow Gage

U.S. Geological Survey 06878000: Chapman Cr near Chapman. Period of record: January 1, 1991 to April 30, 2018. Located near Mud Creek (SC643).

Hydrology:

Streamflow conditions for this TMDL were analyzed using U.S. Geological Survey (USGS) streamgage data from Chapman Creek near Chapman (06878000). This USGS gage is located near Kansas Department of Health and Environment (KDHE) stream chemistry (SC) station Mud Creek near Abilene (SC643) and has streamflow data available for the period of record January 1, 1991 to April 30, 2018. A watershed ratio between Chapman Creek and Mud Creek, based upon USGS watershed areas, is used to estimate streamflow in Mud Creek (**Table 2**; **Table 3**; Perry et al., 2004). By this estimation, streamflow in Mud Creek near Abilene (SC643) has at least 6.4 cubic feet per second (cfs) flowing through it 75% of the time and exceeds 22 cfs 25% of the time. Long-term, estimated USGS flows for Mud Creek are also displayed in **Table 3**. A flow duration curve for the estimated streamflow in Mud Creek near Abilene (SC643) is displayed in **Figure 2**.

Table 2. Kansas Department of Health and Environment estimated flow conditions at stream chemistry (SC) station Mud Creek near Abilene (SC643) and monitored flow conditions at U.S. Geological Survey gage Chapman Creek near Chapman (06878000).

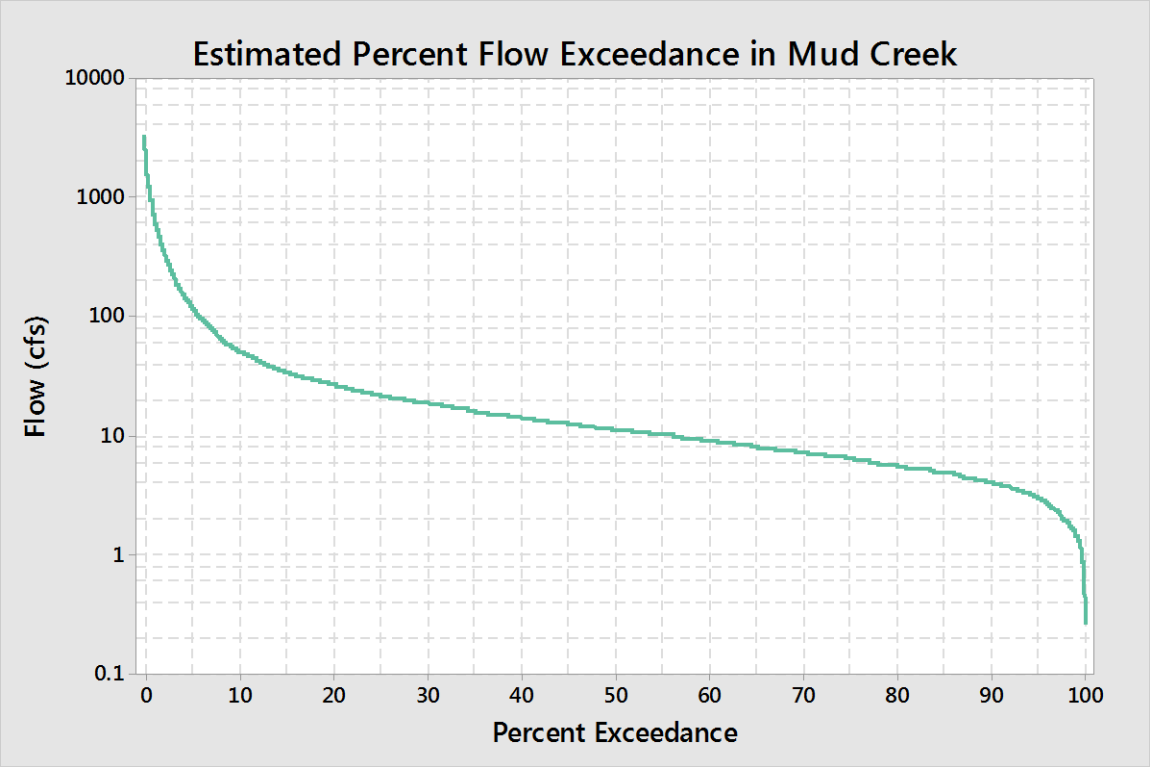
Stream	Station	Contributing Drainage Area (mi^2)	Mean Flow (cfs)	Percent Flow Exceedance (cfs)				
				90%	75%	50%	25%	10%
Mud Cr	SC643	93	40	4.0	6.4	11	22	50
Chapman Cr	06878000	300	92	9.2	15	25	50	116

Table 3. U.S. Geological Survey (USGS) long-term estimated flows for Mud Creek (Perry et.al, 2004).

Stream	USGS Site	KSWR CUSEGA Number	County	Drainage Area (mi^2)	Mean Flow (cfs)	Percent Flow Exceedance (cfs)					2-year Peak (cfs)
						90%	75%	50%	25%	10%	
Mud Cr	1876	102600088	CY, DK	66.8	21.3	0	1.08	4.04	10.8	27.8	1,870
Mud Cr	2127	102600088	DK	130	45.4	0.77	4.12	11.6	28.4	68.2	2,570

Definitions: CY - Clay; DK - Dickinson

Figure 2. Estimated flow duration curve for Kansas Department of Health and Environment station Mud Creek near Abilene (SC643) based upon U.S. Geological Survey gaged site located in Chapman Creek near Chapman (06878000).



The highest mean annual flows in Mud Creek near Abilene (SC643) occurred in 1993 and 1998, with flows of 140 and 95 cfs, respectively (**Figure 3**). The highest median annual flows occurred in 1993 and 1998, as well, with flows of 39 and 33 cfs. The lowest mean annual flows occurred in 2002, 2003, and 2006, with flows ranging from 5.6 to 7.5 cfs. The lowest median annual flows occurred in 1991, 2003, 2004, and 2006, with flows ranging from 4.2 to 4.8 cfs. Trends in annual flows generally coincide with National Oceanic and Atmospheric Administration (NOAA) annual total precipitation from station USC00140010 in Abilene. The highest annual precipitation occurred in 1993, 1998, and 2013, corresponding to some of the years with highest annual flows. The lowest annual precipitation occurred in 2002 and 2012, corresponding to one of the lowest years of flow. The highest peak annual flows occurred in 1999 and 2011, with flows of 3,016 and 3,263 cfs, respectively (**Figure 4**). Seasonally, high flows occur in spring (April through June) and low flows occur in summer-fall (July through October) and winter (November through March; **Figure 5**). Spring flows are skewed by high flow events, likely due to precipitation and runoff events, and coincide with higher mean flows in May (**Figure 6**). Meanwhile, winter low flows coincide with lower mean flows in January.

Figure 3. Estimated annual mean and median flows for Mud Creek near Abilene (SC643) and annual total precipitation at the National Oceanic and Atmospheric Administration station in Abilene (USC00140010).

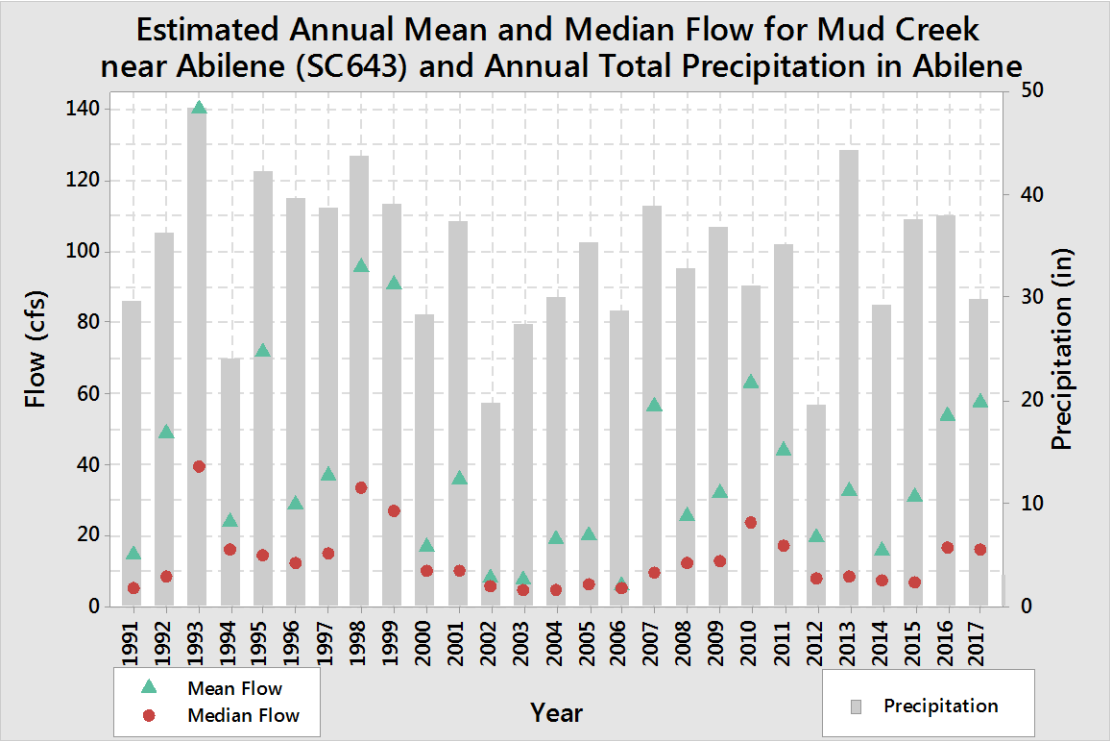


Figure 4. Estimated annual peak flow for Mud Creek near Abilene (SC643) and annual total precipitation at the National Oceanic and Atmospheric Administration station in Abilene (USC00140010).

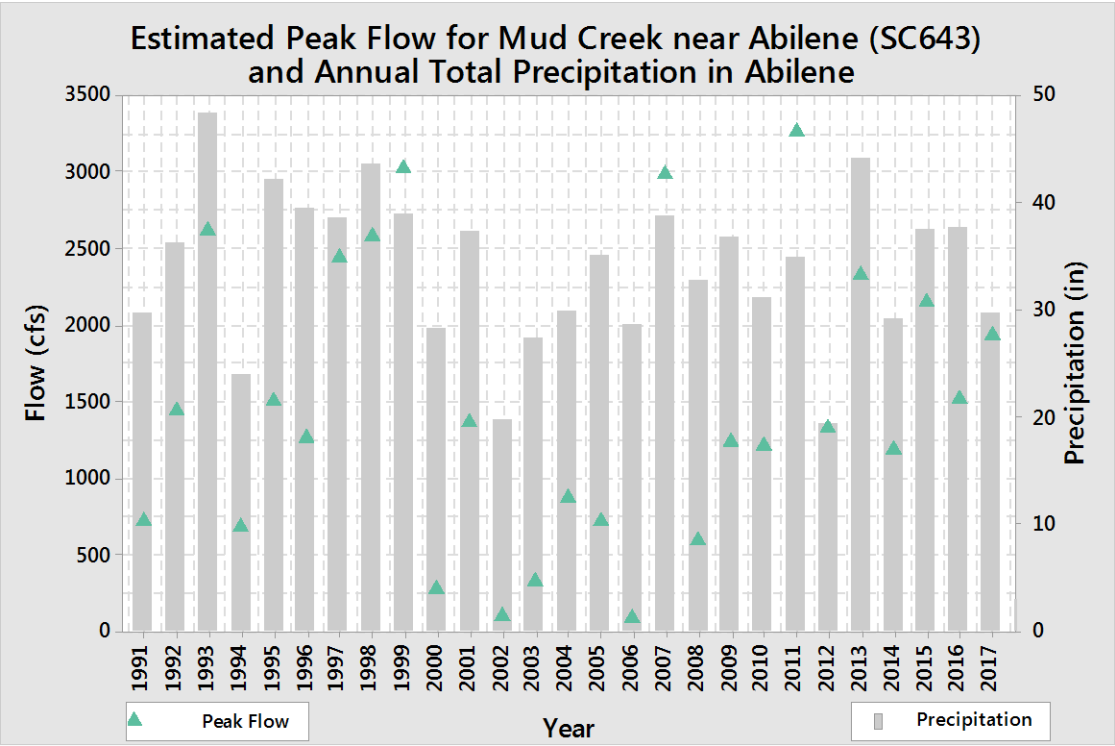


Figure 5. Estimated flow by season for Mud Creek near Abilene (SC643).

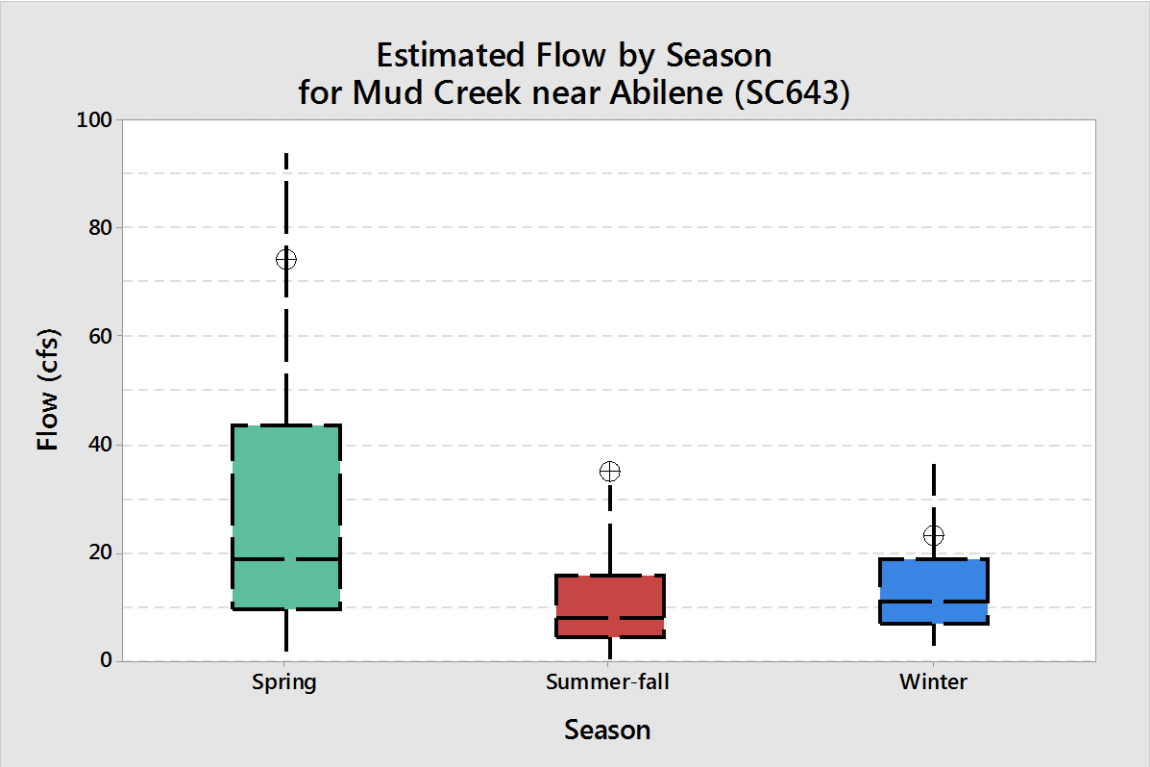
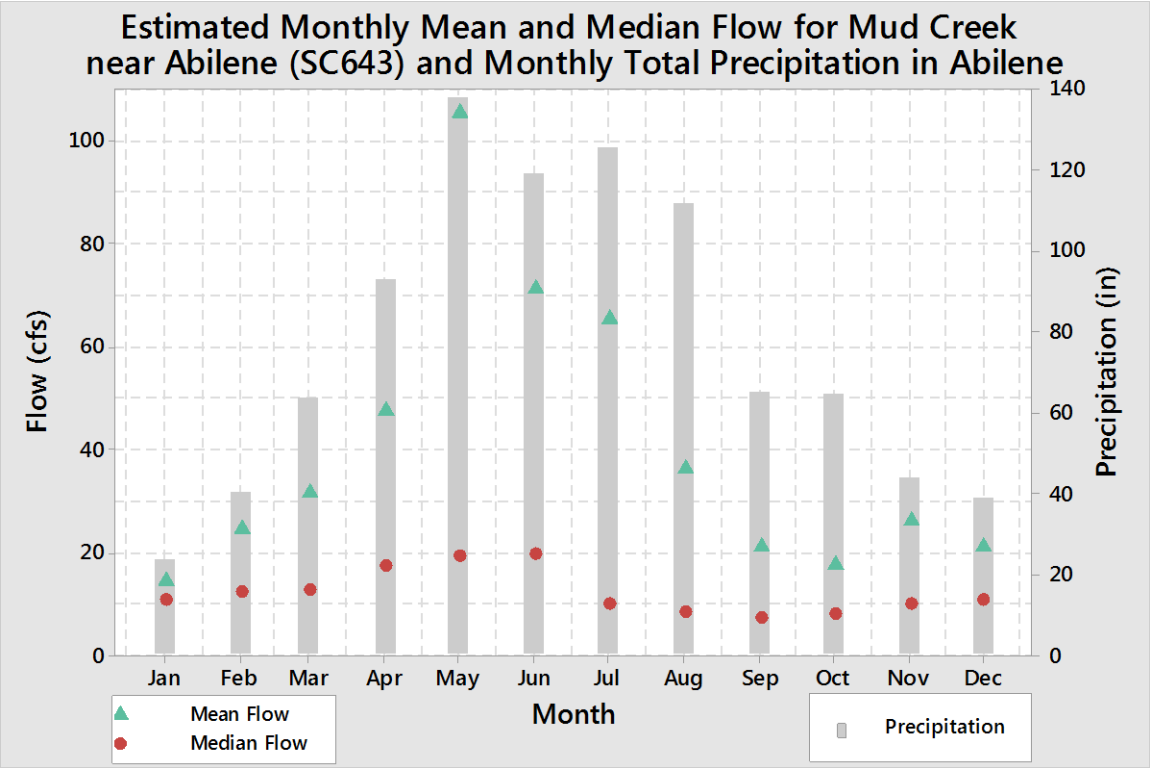


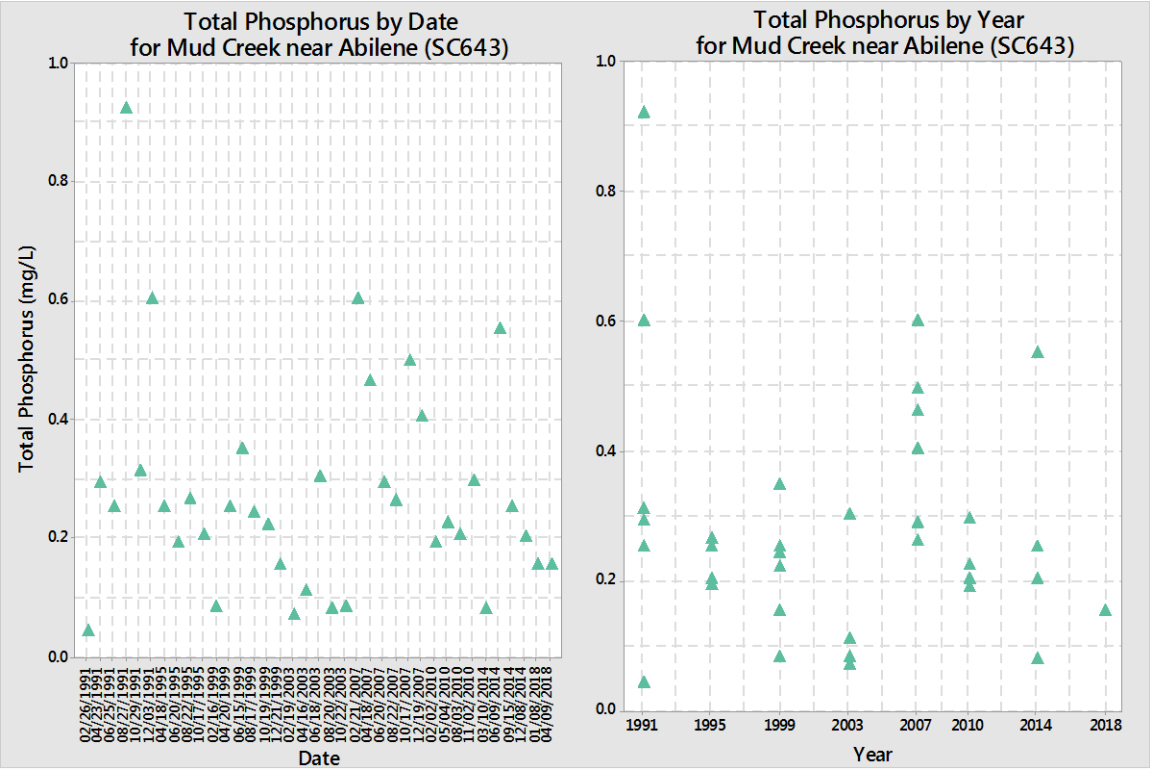
Figure 6. Estimated monthly mean and median flows for Mud Creek near Abilene (SC643) and annual total precipitation at the National Oceanic and Atmospheric Administration station in Abilene (USC00140010).



Total Phosphorus Concentrations

Mud Creek near Abilene (SC643) is an active, rotational KDHE SC station with samples collected every four years since 1991 (**Figure 7**). The maximum annual total phosphorus (TP) concentration of 0.920 milligrams per liter (mg/L) occurred in 1991. From 1991 to 2018, Mud Creek near Abilene (SC643) has a mean TP concentration of 0.271 mg/L and a median TP concentration of 0.250 mg/L (**Table 4**). From 1991 to 1999, TP concentrations were higher than the mean and equal to the median for the entire period of record. However, TP concentrations from 2000 to 2018 have decreased, with a mean of 0.258 mg/L and a median of 0.221 mg/L. The highest annual TP concentration mean of 0.417 mg/L and median of 0.431 mg/L occurred in 2007. The lowest annual TP concentration mean of 0.127 mg/L and median of 0.080 mg/L occurred in 2003, one of the dryer years with low mean and median flows.

Figure 7. Total phosphorus by sampling date and year for Mud Creek near Abilene (SC643).



Throughout the period of record for Mud Creek near Abilene (SC643), mean and median TP concentrations are higher during spring and summer-fall than in winter (**Figure 8**; **Table 5**). The seasons of spring and summer-fall typically have more precipitation and runoff events, which elevate TP concentrations due to nonpoint sources of TP loading. Additionally, there are four TP outliers throughout the overall period of record: 0.920 mg/L collected August 1991; 0.600 mg/L collected December 1991 and February 2007; and 0.550 mg/L collected June 2014. These outliers span all seasons, irrespective of typical precipitation patterns.

Table 4. Total phosphorus concentration annual mean, median, maximum, and sample number (N) for Mud Creek near Abilene (SC643).

Year	Total Phosphorus (mg/L)			
	Mean	Median	Maximum	N
1991	0.402	0.300	0.920	6
1995	0.226	0.226	0.263	4
1999	0.215	0.230	0.347	6
2003	0.127	0.080	0.300	5
2007	0.417	0.431	0.600	6
2010	0.225	0.211	0.292	4
2014	0.269	0.225	0.550	4
2018	0.150	0.150	0.150	2
1991-2018	*0.271*	*0.250*	*0.920*	*37*
1991-1999	*0.288*	*0.250*	*0.920*	*16*
2000-2018	*0.258*	*0.221*	*0.600*	*21*

Figure 8. Total phosphorus by season for Mud Creek near Abilene (SC643).

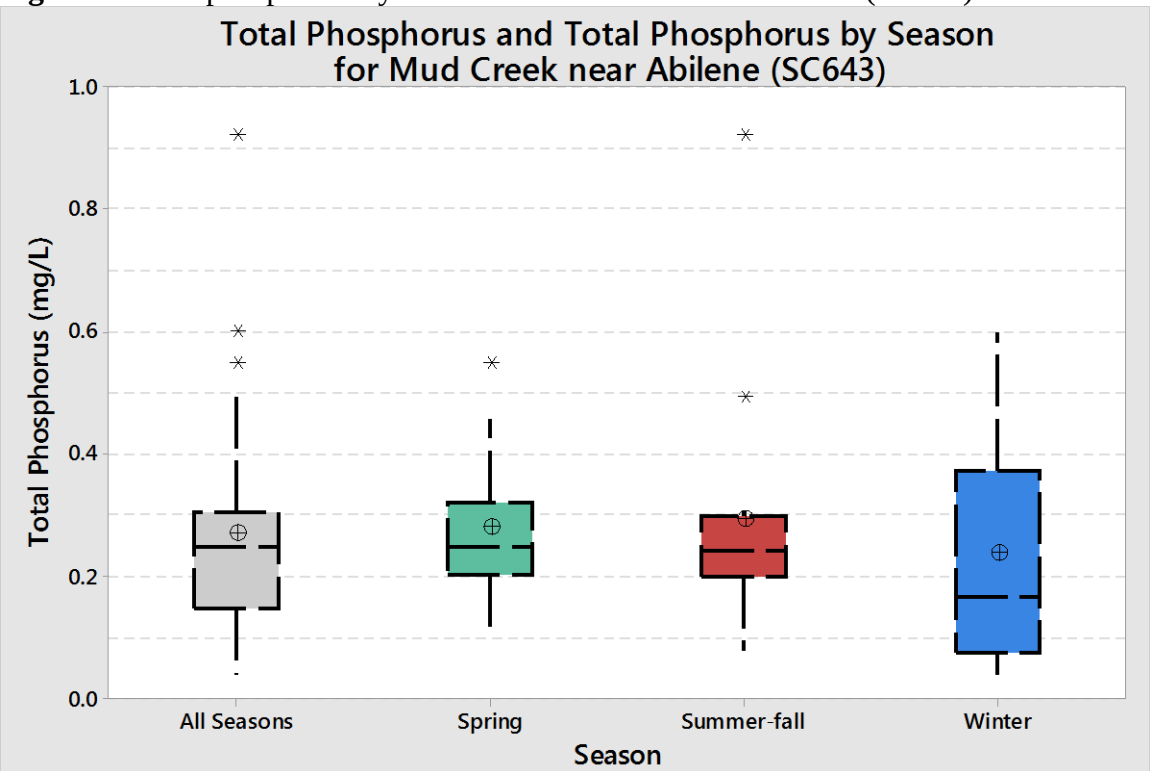
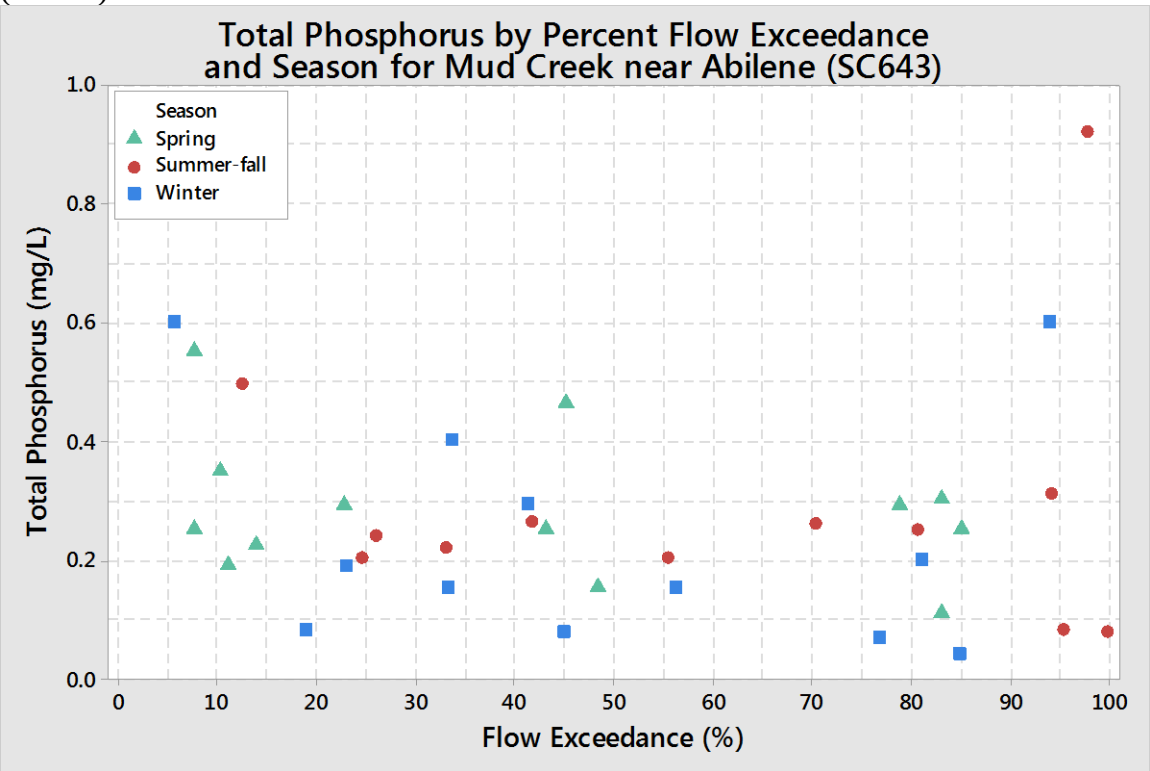


Table 5. Total phosphorus concentration mean, median, maximum, and number of samples (N) by season (spring: April through June, summer-fall: July through October, winter: November through March) and percent flow exceedance range for Mud Creek near Abilene (SC643).

Flow Exceedance (%)	**Total Phosphorus (mg/L)**			
	Mean	Median	Maximum	N
Spring				
0-25	0.308	0.269	0.550	6
26-75	0.287	0.250	0.460	3
76-100	0.237	0.270	0.300	4
0-100	0.281	0.250	0.550	13
Summer-Fall				
0-25	0.348	0.348	0.495	2
26-75	0.237	0.240	0.263	5
76-100	0.328	0.250	0.920	5
0-100	0.293	0.245	0.920	12
Winter				
0-25	0.289	0.187	0.600	3
26-75	0.214	0.150	0.402	5
76-100	0.227	0.134	0.600	4
0-100	0.237	0.169	0.600	12
All				
0-25	0.310	0.250	0.600	11
26-75	0.240	0.240	0.460	13
76-100	0.269	0.250	0.920	13
0-100	0.271	0.250	0.920	37

Throughout all seasons, mean and median TP concentrations are highest during high flow conditions (0 to 25% flow exceedance), with the exception of the median for spring which has a similar TP concentration for high flow and low flow (76 to 100% flow exceedance) conditions (**Table 5**). Throughout all flow conditions and seasons, TP concentrations typically remain below 0.5 mg/L in Mud Creek near Abilene (SC643; **Figure 9**). The outliers exceeding this concentration are concentrated at extremely high and low flow exceedances. Two of the previously mentioned outliers occurred during low flow conditions and two occurred during high flow conditions. This variability in high TP concentrations during low flow conditions may be due to localized events in Mud Creek near Abilene (SC643) which are not captured by the use of the streamflow gage at Chapman Creek near Chapman.

Figure 9. Total phosphorus by percent flow exceedance and season for Mud Creek near Abilene (SC643).



Total Phosphorus and Water Quality Parameters

Total phosphorus has well-established and defined relationships with orthophosphate (OP) and total suspended solids (TSS). These relationships are examined further in order to delineate potential sources of TP loading to Mud Creek near Abilene (SC643).

Orthophosphate

The soluble portion of TP that is readily available for biological use is OP. It is commonly found in higher concentrations in the discharge of municipal wastewater treatment plants (WWTPs) and can therefore be indicative of point source contributions of phosphorus in streams; however, it can also be contributed from livestock operations near waterways, especially if streams are used for watering or during winter feeding. Only samples measuring above the reporting limit are included in the analysis presented, resulting in a left censored data set which may overestimate true OP concentration means (**Table 6**). In addition, reporting limits for OP have changed throughout the period of record: 0.01 mg/L from 1995-1996, 0.02 mg/L from 1997 to February 2002, and 0.25 mg/L from March 2002 to 2014. Generally, OP concentrations in Mud Creek near Abilene (SC643) are less than their respective reporting limits. Mud Creek near Abilene (SC643) has a total of six OP concentrations greater than the reporting limit, two of which occurred from March 2002 to 2014. Overall, 25% of all samples had OP concentrations greater than the reporting limit and the mean of these OP concentrations is 0.232 mg/L.

Table 6. Mean of detected orthophosphate (OP) samples, mean ratio of OP and total phosphorous (OP:TP), sample number (N), and percentage of samples greater than the analytical reporting limit (> RL) separated by reporting limit increases for Mud Creek near Abilene (SC643), April 18, 1995 to June 9, 2014.

Sample Information	**Period of Record**			
	1995 (0.01 mg/L)	1999 (0.02 mg/L)	Mar. 2002-2014 (0.25 mg/L)	1995-2014
Mean (mg/L)	0.115	–	0.465	0.232
Mean Ratio OP:TP	0.514	–	0.816	0.615
N	4	–	2	6
Sample Percent > RL	100%	–	10%	25%

Definition: – - no data

Total Suspended Solids

Phosphorus has a high affinity for fixation in soils, where it is adsorbed from soil solution. Erosion of phosphorus-laden soil particles is a common means for phosphorus to enter streams, where it is then desorbed. This natural propensity for adsorbtion and desorbtion to soil particles creates a positively correlated relationship between TP and TSS that is evident in Mud Creek near Abilene (SC643; **Figure 10**). The previously noted four TP concentration outliers are identified, as well, to emphasize their relatively high TSS concentrations; such concentrations are indicative of high flow conditions, demonstrating that the two samples represented as outliers under low flow conditions likely were collected under higher flow conditions due to a localized precipitation event near Mud Creek near Abilene (SC643).

Additionally, the relationship between TP and TSS becomes stronger during lower flow conditions (**Figure 11**). A station with a weak relationship between TP and TSS during low flows is generally influenced by municipal point source effluent, which increases TP concentrations irrespective of TSS concentrations due to elevated TP concentrations in the effluent. Meanwhile, a strong TP and TSS correlation during high flows is generally influenced by nonpoint and runoff conditions. Available data at Mud Creek near Abilene (SC643) suggests that TP concentrations at this station are most strongly influenced by nonpoint source loading during high flow conditions, rather than point source effluent during low flow conditions.

Figure 10. Total phosphorus versus total suspended solids for Mud Creek near Abilene (SC643).

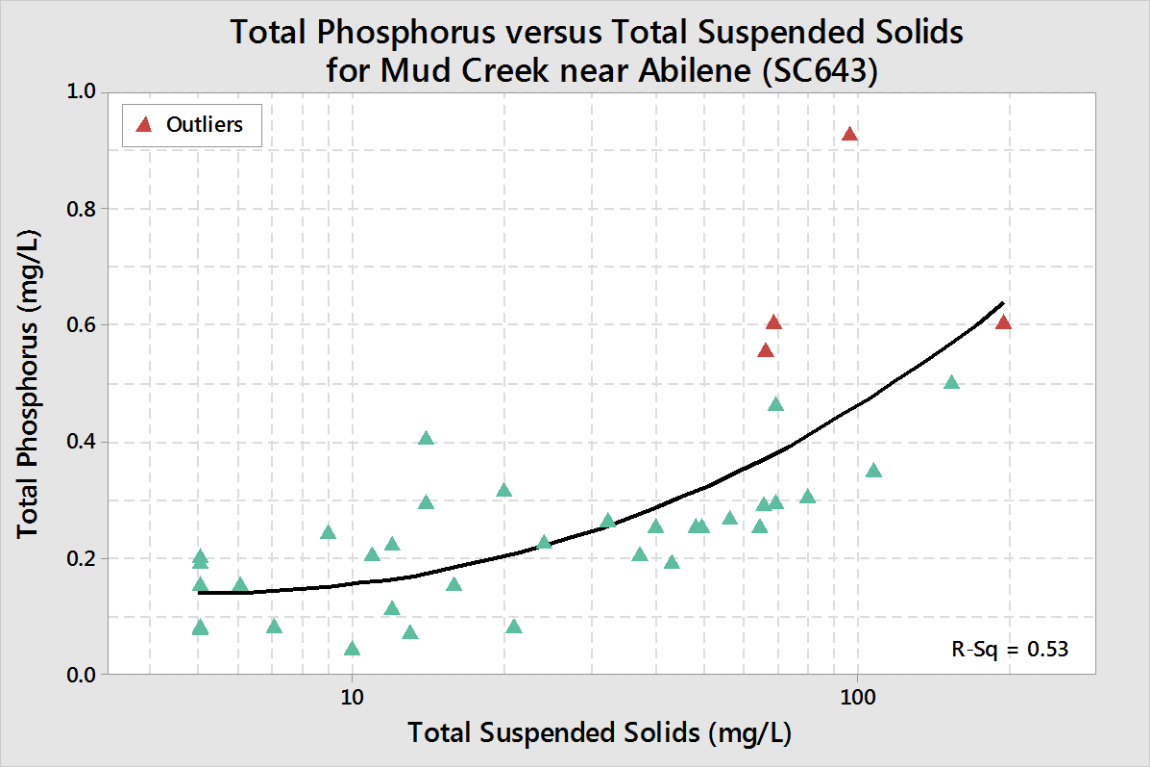
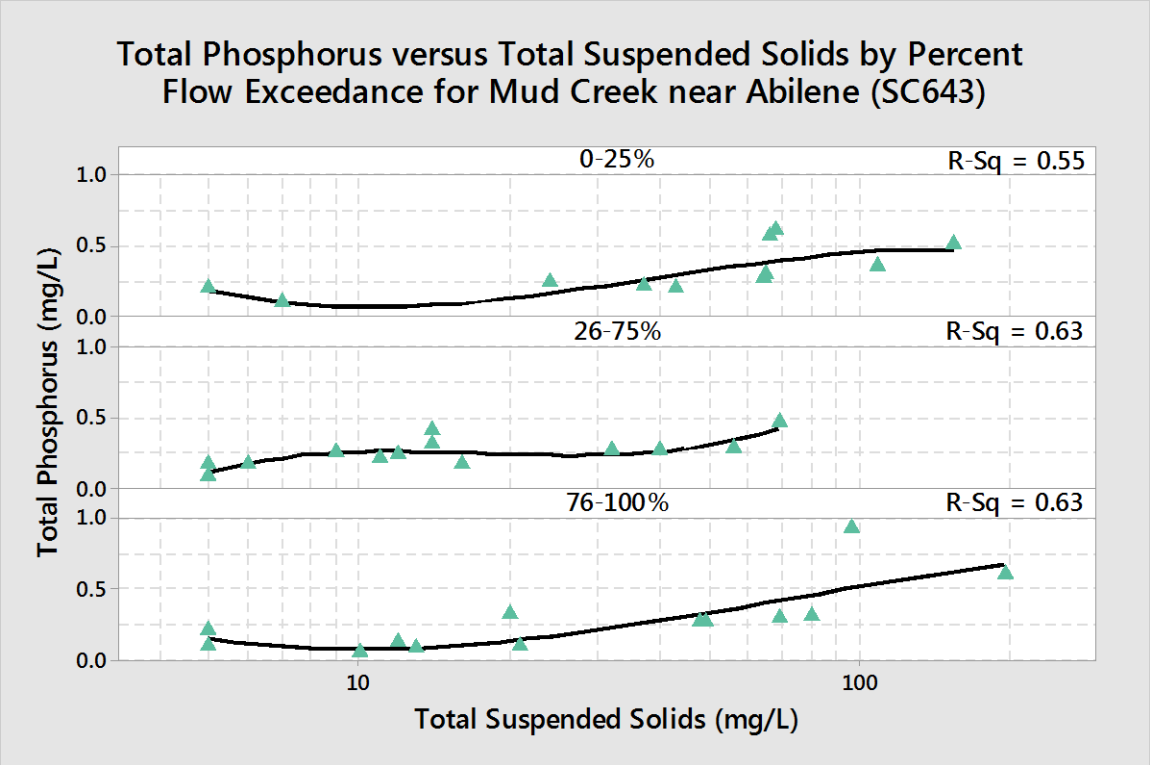


Figure 11. Total phosphorus versus total suspended solids by percent flow exceedance for Mud Creek near Abilene (SC643).



Total Phosphorus and Biological Indicators

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 shifts in dissolved oxygen (DO), dissolved oxygen saturation (DO saturation), and pH as the chemical reactions of photosynthesis and respiration alter the ambient levels of oxygen and acid-base balance of the stream. These extreme shifts, in turn, can result in undesirable regime shifts in the algal biomass and biological community within the stream.

Dissolved Oxygen

Dissolved oxygen and temperature are inversely related for Mud Creek near Abilene (SC643) (**Figure 12**). This corresponds to seasonal changes in DO and temperature, where low mean DO concentrations occur in spring and summer-fall when temperatures are highest, and high mean DO concentrations occur in winter when temperatures are lowest (**Table 7**). This relationship is expected because oxygen becomes less soluble in water as temperatures increase. Additionally, DO exhibits a diel trend due to daily fluctuations in photosynthetic activity. The presented data captures this daily variability based upon whether a sample was collected in the morning (8:35 am to 12:00 pm) or afternoon (12:00 to 16:54 pm); morning samples tend to have lower DO concentrations and afternoon samples tend to have higher DO concentrations. Mud Creek near Abilene (SC643) exhibits these seasonal and diel trends. This station also has two DO excursions below the water quality criterion of 5 mg/L, the first in October 1991 with a concentration of 1.90 mg/L and the second in August 2003 with a concentration of 4.5 mg/L.

Figure 12. Dissolved oxygen and the relationship between dissolved oxygen and temperature for Mud Creek near Abilene (SC643).

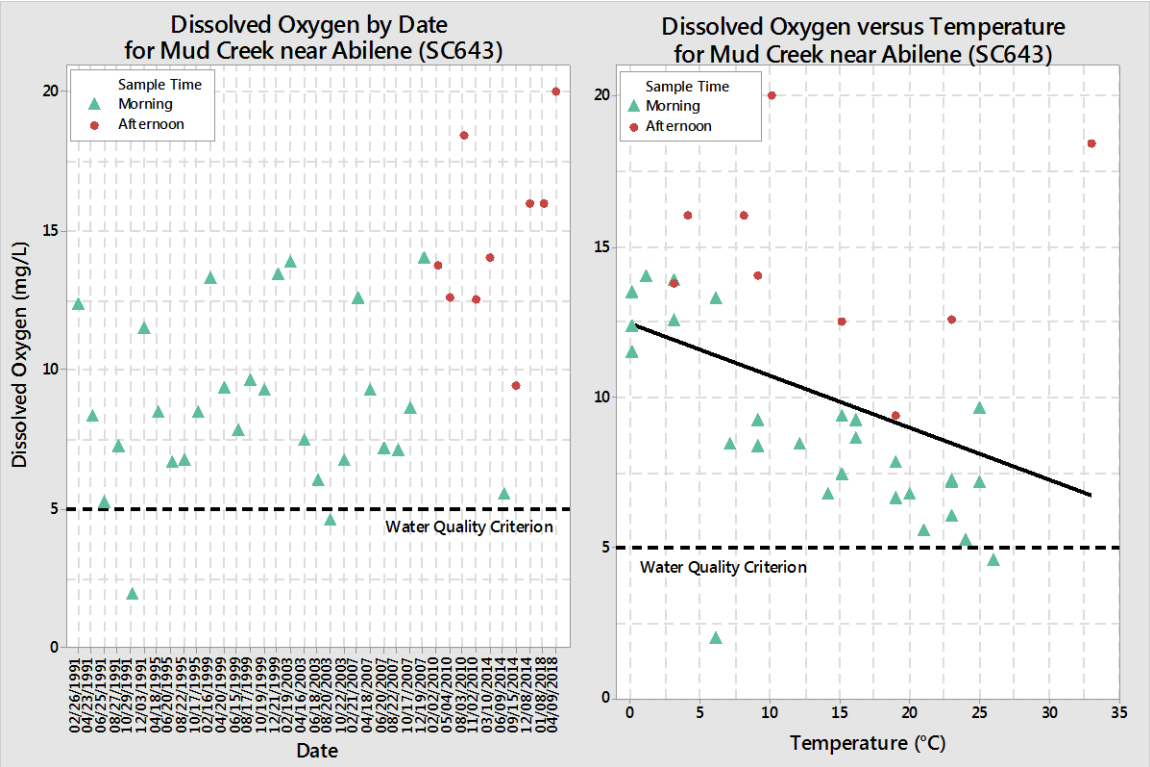


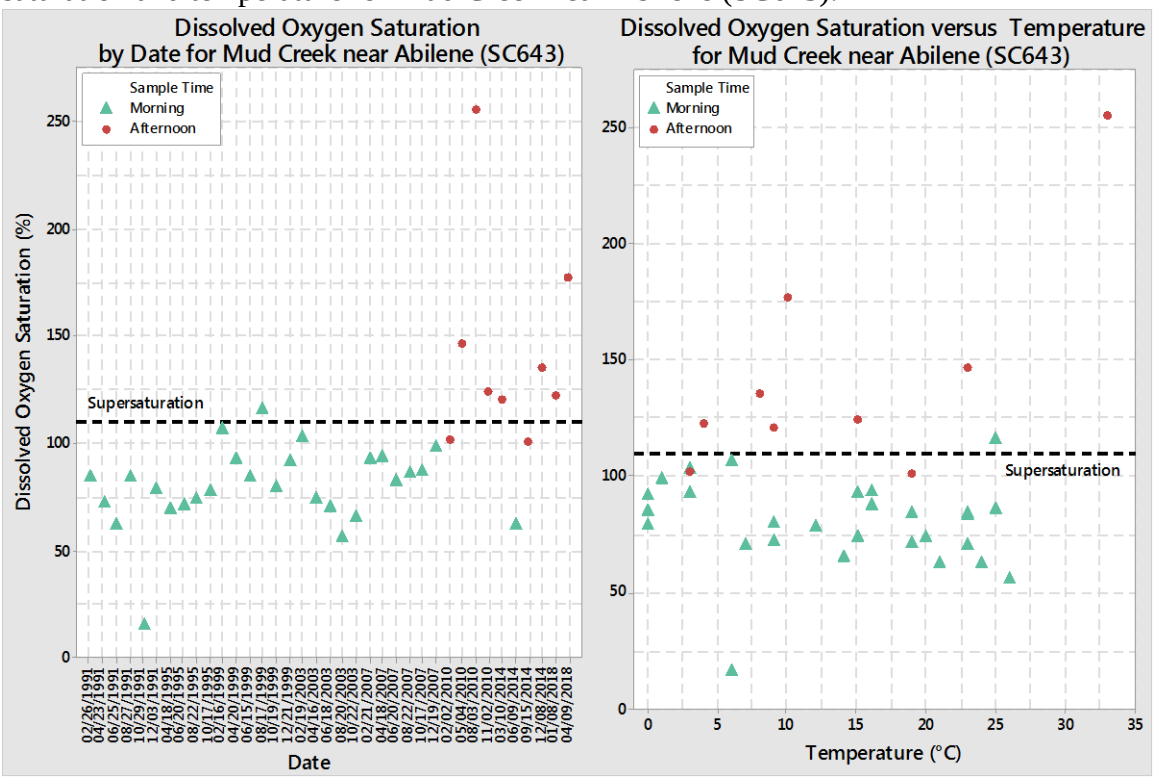
Table 7. Mean temperature, dissolved oxygen, and dissolved oxygen saturation, as well as median pH, by season for Mud Creek near Abilene (SC643).

Water Quality Parameter	Season			
	Spring	Summer-Fall	Winter	All Seasons
Temperature (°C)	17.2	19.0	4.33	13.6
Dissolved Oxygen (mg/L)	8.72	8.14	13.6	10.1
Dissolved Oxygen Saturation (%)	88.7	91.2	105	94.7
pH	8.0	8.0	8.0	8.0

Dissolved Oxygen Saturation

Primary productivity increases in the spring and summer-fall, when temperatures are higher and DO concentrations are lower. When primary productivity is excessive, oxygen from aquatic photosynthesis can create DO concentrations that exceed the natural oxygen equilibrium of the stream at a given temperature. Supersaturated conditions occur when the ratio of the oxygen capacity of the stream at a given temperature to the oxygen concentration in the stream exceeds 110%. Because of the system's diel characteristics, supersaturated conditions are more likely to be detected in the afternoon when photosynthesis and temperatures are at their peak. Throughout the period of record, Mud Creek near Abilene (SC643) has DO saturation samples collected in the morning until 2010, with one DO saturation value greater than 110% occurring in August 1999. After 2010, the majority of DO saturation samples were collected in the afternoon, with the majority of samples exceeding a DO saturation of 110%.

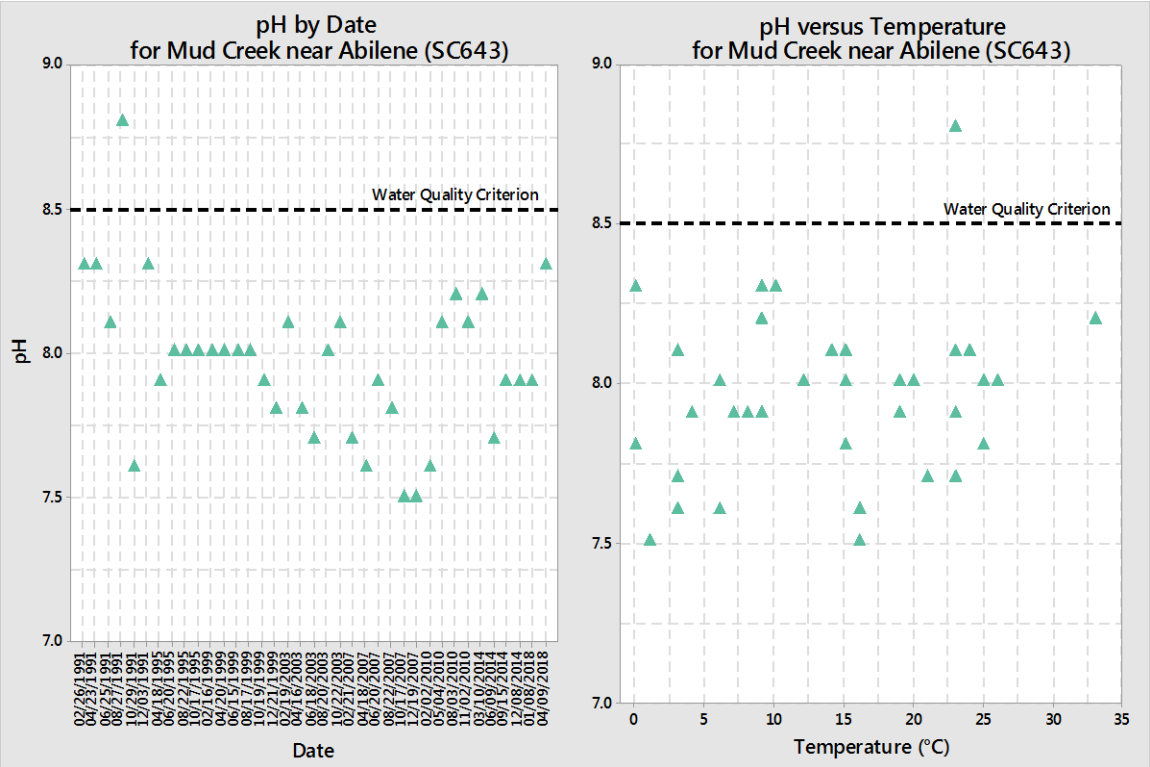
Figure 13. Dissolved oxygen saturation and the relationship between dissolved oxygen saturation and temperature for Mud Creek near Abilene (SC643).



pH

Another water quality indicator of primary productivity is pH, as photosynthesis can increase pH by removing carbon dioxide from the water. The numeric water quality criteria for pH is a range from 6.5 to 8.5. There is one pH excursion for Mud Creek near Abilene (SC643) that occurred in August 1991.

Figure 14. The pH and the relationship between pH and temperature for Mud Creek near Abilene (SC643).



Desired Endpoints for Water Quality (Implied Load Capacity) in Mud Creek near Abilene (SC643)

The ultimate desired water quality endpoints of this TMDL for Mud Creek near Abilene (SC643) will be to achieve the Kansas Water Quality Standards by eliminating the impacts to aquatic life, domestic water supply, and contact recreation associated with excessive phosphorus and objectionable flora as described in the narrative criteria pertaining to nutrients. There are currently no existing numeric phosphorus criteria in Kansas.

Current USEPA nutrient philosophy is predicated upon 25th percentile stream TP concentrations within an ecoregion to indicate reference conditions. This generalization is not tied to specific biological conditions but represents water quality protection policy guiding USEPA's administration of clean water programs. The USEPA suggested TP reference benchmark for streams within the Level III Ecoregion Central Great Plains is a 25th percentile of 0.090 mg/L (U.S. Environmental Protection Agency, 2000). Assessment of 129 KDHE SC stations within

the Level III Ecoregion Central Great Plains with TP data from 2000 to 2017 indicates a 25th percentile of medians of 0.131 mg/L and a 50th percentile of medians of 0.210 mg/L (**Table 8**).

Table 8. Summary of Kansas Department of Health and Environment (KDHE) stream chemistry stations located in the Level III Ecoregion Central Great Plains from 2000 to 2017.

USEPA Ecoregion	Number of KDHE Stations	Number of Samples	25th Percentile of Medians (mg/L)	50th Percentile of Medians (mg/L)	75th Percentile of Medians (mg/L)
Central Great Plains	129	6,821	0.131	0.210	0.384

Of the 129 KDHE SC stations within the Level III Ecoregion Central Great Plains used for the TP milestone analysis, 21 have corresponding KDHE stream biology (SB) stations. Biological data regarding macroinvertebrate organisms and community are collected at these SB stations. These SB stations are assessed using the Aquatic Life Use Support (ALUS) Index as described in Kansas' 2018 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 aquatic and semi-aquatic maroinvertebrates based on the relative abundance of certain indicator taxa that is specific to the level of order and family.
2. Kansas Biotic Index for Nutrients (KBI-N): A statistical measure mathematically equivalent to the MBI that is restricted to aquatic insect macroinvertebrates and is species specific.
3. Ephemeroptera, Plecoptera, and Trichoptera (EPT): A measure of the richness of the intolerant aquatic EPT taxa wihin a macroinvertebrate sample used to evaluate the diversity within the sample.
4. EPT Percent of Count (EPT% CNT): The percentage of individuals belonging to the EPT orders in a sample of macroinvertebrates.
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.

These metrics are used to establish a score (**Table 9**) which is then translated into an indication of the biotic condition and support category available for aquatic life in the stream (**Table 10**).

Table 9. Aquatic Life Use Support Index metrics with scoring ranges and standardized scores.

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

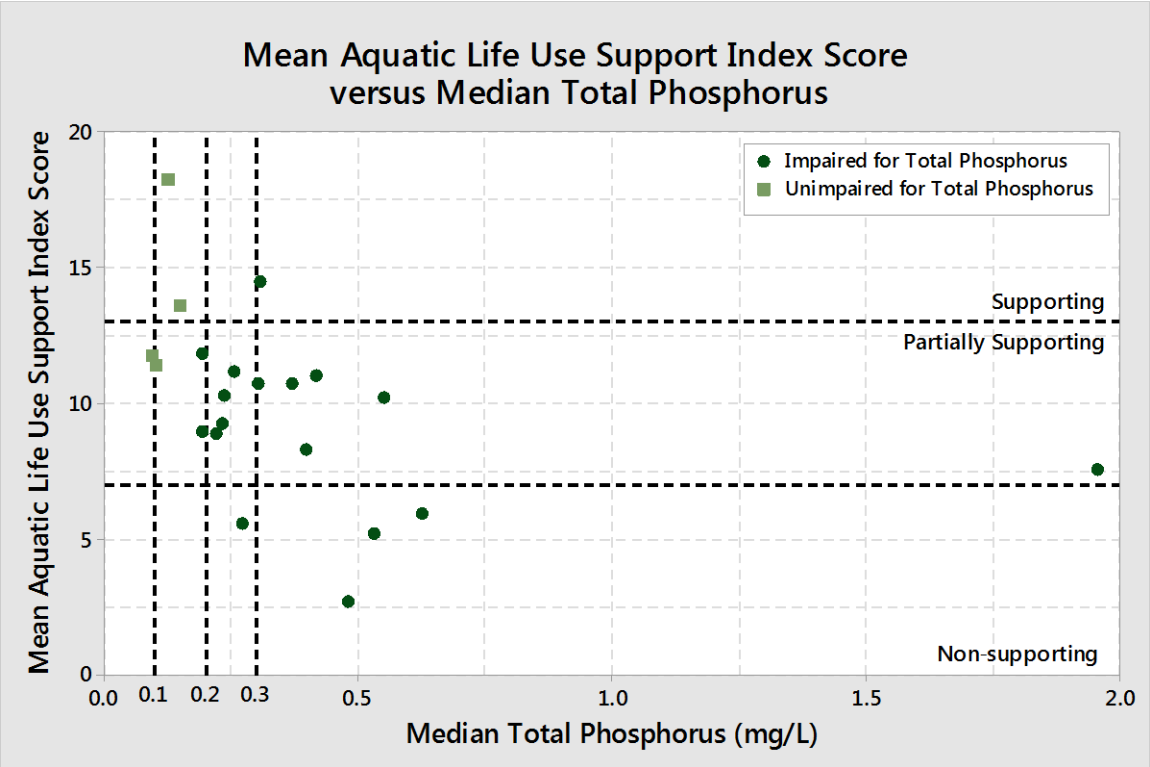
Table 10. Aquatic Life Use Support (ALUS) Index score range, interpretation of biotic condition, and aquatic life support category.

ALUS Index Score	Biotic Condition	Support Category
≥ 16-20	Very Good	Supporting
≥ 13-16	Good	
≥ 7-13	Fair	Partially Supporting
≥ 4-6	Poor	Non-supporting
0-3	Very Poor	

An analysis of the mean ALUS Index versus the median TP concentration indicates that there are three SB stations supporting biology (**Figure 15**). Median TP concentrations for SB stations supporting biology range from 0.124 to 0.306 mg/L. The mean ALUS Index for stations supporting aquatic life is 15, while the mean ALUS Index for stations not supporting aquatic life is 9. In general, the analysis of the mean ALUS Index versus the median TP concentration indicates that stations with greater TP concentrations are less supportive of biology. This relationship is variable, however. Such variability supports an adaptive management approach to reduce current TP concentrations and loads, rather than establishing a single, definitive threshold. Therefore, this TMDL seeks to establish an adaptive management approach in order to observe and respond to biological metrics to assess the impact of TP reductions. As such, the primary measure of phosphorus load reduction in the TMDL for Mud Creek near Abilene (SC643) will be an improved ALUS Index. An ALUS Index score greater than 13 at an SB station will serve to establish that the biological community reflects recovered or renewed diversity and minimal disruption by the impacts described in the narrative criteria for nutrients on aquatic life, recreation, and domestic water supply.

Furthermore, secondary indicators of the health of the aquatic biological community will be assessed at the SC station. Dissolved oxygen concentrations will be monitored to ensure concentrations are greater than 5 mg/L. According to the Kansas Water Quality Standards, concentrations below this are low enough to put aquatic life under stress. Dissolved oxygen saturation will also be monitored for indication of overactive primary productivity, as indicated by supersaturated values greater than 110%. The pH will be monitored, as well, to ensure that overactive primary productivity is not altering stream chemistry; values should remain between 6.5 and 8.5 in order to protect aquatic life according to the Kansas Water Quality Standards. The chlorophyll-*a* concentration will serve as an additional biological measure of nutrient loading reduction in order to assess improvements in primary productivity and address its impacts as described in the narrative criteria for nutrients on aquatic life, recreation, and domestic water supply.

Figure 15. Aquatic Life Use Support (ALUS) Index versus median total phosphorus for stream biology and stream chemistry stations in the Level III Ecoregion Central Great Plains from 2000 to 2017.



The numeric endpoints for stream segments in this TMDL, as measured at Mud Creek near Abilene (SC643), indicating attainment of water quality standards within the watershed are:

1. An ALUS Index score greater than 13 at the SB station.
2. Dissolved oxygen concentrations greater than 5.0 mg/L at the SC station.
3. Dissolved oxygen saturation less than 110% at the SC station.
4. Values within the range of 6.5 to 8.5 for pH at the SC station.
5. Median sestonic chlorophyll-*a* concentrations less than or equal to 10 µg/L at the SC station.

As there are currently no numeric phosphorus criteria in Kansas, the series of endpoints established by this TMDL will be the measure used to indicate full support of aquatic life, domestic water supply, and contact recreation in Mud Creek. All five endpoints must initially be maintained over three consecutive years to constitute full support of the designated uses of the impaired stream segment in this TMDL, as measured at KDHE station Mud Creek near Abilene (SC643). These endpoints will be evaluated periodically as phosphorus levels decline in the watershed, with achievement of the ALUS Index endpoint indicating the restored status of the aquatic life use in the river. Simultaneous achievement of the DO, DO saturation, pH, and chlorophyll-*a* endpoints will signal that TP reductions are addressing the accelerated succession of aquatic biota and the development of objectionable concentrations of algae and algae by-

products, thereby restoring the domestic water supply and contact recreation uses in the river. After the endpoints are attained, simultaneous digression of these endpoints more than once every three years on average constitutes a resumption of the TP impairment at the respective station unless the TP impairment is delisted through the 303(d) process.

This TMDL seeks to establish an adaptive management approach for TP by establishing phased TP milestones (**Table 11**). The Phase I milestone will be a TP concentration of 0.210 mg/L, reflecting the 50th percentile of medians for KDHE SC stations within the Level III Ecoregion Central Great Plains. Total phosphorus concentrations approaching the Phase I milestone will cue the examination for altered, improved biological conditions. Should aquatic life not respond, a Phase II milestone will commence with a TP concentration of 0.131 mg/L, reflecting the 25th percentile of medians for KDHE SC stations within the Level III Ecoregion Central Great Plains.

Table 11. Current total phosphorus (TP) condition from 2000 to 2018 and Phase I and II TP milestones for Mud Creek near Abilene (SC643).

Current Condition: Median TP (mg/L)	Phase I		Phase II	
	Total Phosphorus Milestone (mg/L)	Total Phosphorus Reduction (%)	Total Phosphorus Milestone (mg/L)	Total Phosphorus Reduction (%)
0.221	0.210	5	0.131	41

3. SOURCE INVENTORY AND ASSESSMENT

Point Sources

There are a total of five National Pollution Discharge Elimination System (NPDES) permits in the Mud Creek (SC643) Watershed (**Figure 1**; **Table 12**). Of the five permitted facilities, two are non-discharging lagoons, one is a concrete operation, one is an industrial pretreatment facility, and one is a water treatment plant (WTP). There are no Municipal Separate Storm Sewer System (MS4) permits in the Mud Creek (SC643) Watershed.

The two non-discharging lagoons in the watershed are operated by the City of Manchester and Dickinson County Sewer District #1 – Talmage. Both facilities are two-cell lagoon systems that are prohibited from discharging. They do not monitor for TP and are not expected to contribute to the TP impairment in the watershed.

The concrete operation in the watershed is Midwest Concrete – Abilene #2. Midwest Concrete – Abilene #2 is a ready-mix dry batch concrete plant that generates wastewater from washing concrete equipment and from stormwater runoff. Process water from rinsing equipment is contained in one of two basins and may not be discharged. Stormwater runoff, however, may be discharged. All domestic waste is processed by the City of Abilene. This facility does not monitor for TP and is not expected to contribute to the TP impairment in the watershed.

The industrial pretreatment facility in the watershed is Great Plains Manufacturing – Abilene. The discharge is required to meet pretreatment standards for metal finishing before discharging to the City of Abilene's wastewater treatment plant (WWTP). Although physically located within the Mud Creek (SC643) Watershed, this facility does not discharge to the watershed and is not expected to contribute to the TP impairment in the watershed.

The WTP in the watershed is operated by the City of Abilene. This facility processes drinking water for the City of Abilene using reverse osmosis. Concentrated discharge from this procedure is retained in a two-cell lagoon. According to their permit, this facility currently discharges at a rate of 0.318 million gallons per day (MGD). The facility has monitored quarterly for TP since 2015 and discharges a mean TP concentration of 0.2 mg/L, or 0.531 pound per day (lb/day). The City of Abilene WTP is assigned a WLA in this TMDL.

Table 12. National Pollution Discharge Elimination System (NPDES) facilities in the Mud Creek (SC643) Watershed.

Permitee	Kansas Permit Number	NPDES Permit Number	Facility Type	Receiving Stream	Permit Expiration	Monitoring Frequency	Current Flow (MGD)	Current TP Mean (mg/L)	Current TP Load (lbs/day)
City of Manchester	M-SH24-NO01	KSJ000323	Non-discharging lagoon	NA	05/31/2020	NA	NA	NA	NA
Dickinson County Sewer District #1 - Talmage	M-SH47-NO01	KSJ000315	Non-discharging lagoon	NA	09/30/2020	NA	NA	NA	NA
Midwest Concrete - Abilene #2	I-SH01-PR01	KSG110141	Concrete operation pit dewatering	Mud Cr	09/30/2022	NA	–	–	–
Great Plains Manufacturing - Abilene	P-SH01-OO01	KSP000029	Industrial Pre-treatment	WWTF	06/30/2021	NA	–	–	–
City of Abilene	I-SH01-PO04	KS0091936	Water treatment plant	Mud Cr	12/31/2019	Quarterly	0.318	0.2	0.531

Definitions: NA - not applicable; – - no data

Livestock and Waste Management Systems

There are seven certified or permitted Animal Feeding Operations (AFOs) within the Mud Creek (SC643) Watershed (**Figure 1**; **Table 13**). None of these facilities are large enough to require federal permits. All of these livestock facilities have waste management systems designed to retain an anticipated two weeks of normal wastewater from their operations and contain a 25-year, 24-hour rainfall/runoff event, as well. Typically, this rainfall event coincides with streamflow that occurs less than 1-5% of the time. Additionally, facility waste management systems are designed to minimize runoff entering operations and detain runoff emanating from

operations. 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 13. Certified or permitted Animal Feeding Operations in the Mud Creek (SC643) Watershed.

Kansas Permit Number	County	Livestock Type	Livestock Total
A-SHDK-BA27	Dickinson	Beef	300
N-SHDK-5521	Dickinson	Beef	600
A-SHDK-BA44	Dickinson	Beef	280
A-SHDK-S019	Dickinson	Swine, Beef	781
A-SHDK-S020	Dickinson	Swine	1,110
A-SHDK-BA16	Dickinson	Beef	260
A-SHDK-BA39	Dickinson	Beef	950

The total number of livestock within Dickinson County is approximately 76,000 head (**Table 14**; U.S. Department of Agriculture, 2012). The primary livestock industry is cattle, with cattle and calves numbering approximately 69,000 in Dickinson County. From 2007 to 2012, cattle and calves have declined by 10%. Overall, sheep and lambs and poultry are increasing in the county, with increases of 136 and 80%, respectively. However, there is an overall decline in livestock of 18%, with the largest decline of 89% in hogs and pigs.

Table 14. Agricultural census results for livestock in Dickinson County from 2007 and 2012 (U.S. Department of Agriculture, 2012).

Livestock	Total, 2007	Total, 2012	Percent Change
Cattle and Calves	76,813	68,864	-10
Sheep and Lambs	1,746	4,115	136
Poultry	571	1,029	80
Hogs and Pigs	13,244	1,496	-89
Goats	550	761	38
Total	**92,924**	**76,265**	-18

Land Use

Dickinson County has an approximate total of 980 farms and 335,000 acres of cropland (**Table 15**; U.S. Department of Agriculture, 2012). Overall, there is a trend of declining numbers of farms and acres in cropland of 2 and 4%, respectively. The 2011 National Land Cover Database corroborates that the dominant land use in the watershed is agricultural, with 46% used for crop cultivation and 42% used as grassland (**Table 16**; **Figure 16**). Cultivated cropland has an increased potential for nutrient runoff from fertilizers, which can contribute to TP loads in the watershed. Additionally, 7% of the watershed is developed, with the most development occurring near Abilene. Built infrastructure and impervious surfaces in urban environments increase runoff, which can potentially contribute to TP loads in the watershed, as well.

Table 15. Agricultural census results for farms and cropland in Dickinson County from 2007 and 2012 (U.S. Department of Agriculture, 2012).

Year	Total Farms in Cropland	Total Farms with Pastureland	Total Cropland (acres)	Total Pastureland (acres)
2007	896	742	350,401	171,365
2012	878	668	335,353	150,691
Percent Change	-2	-10	-4	-12

Table 16. The 2011 National Land Cover Database data for land cover by percent in the Mud Creek (SC643) Watershed.

Land Use (percent)						
Open Water	Developed	Barren	Forest	Grassland	Cultivated Crops	Wetlands
1	7	0	4	42	46	0

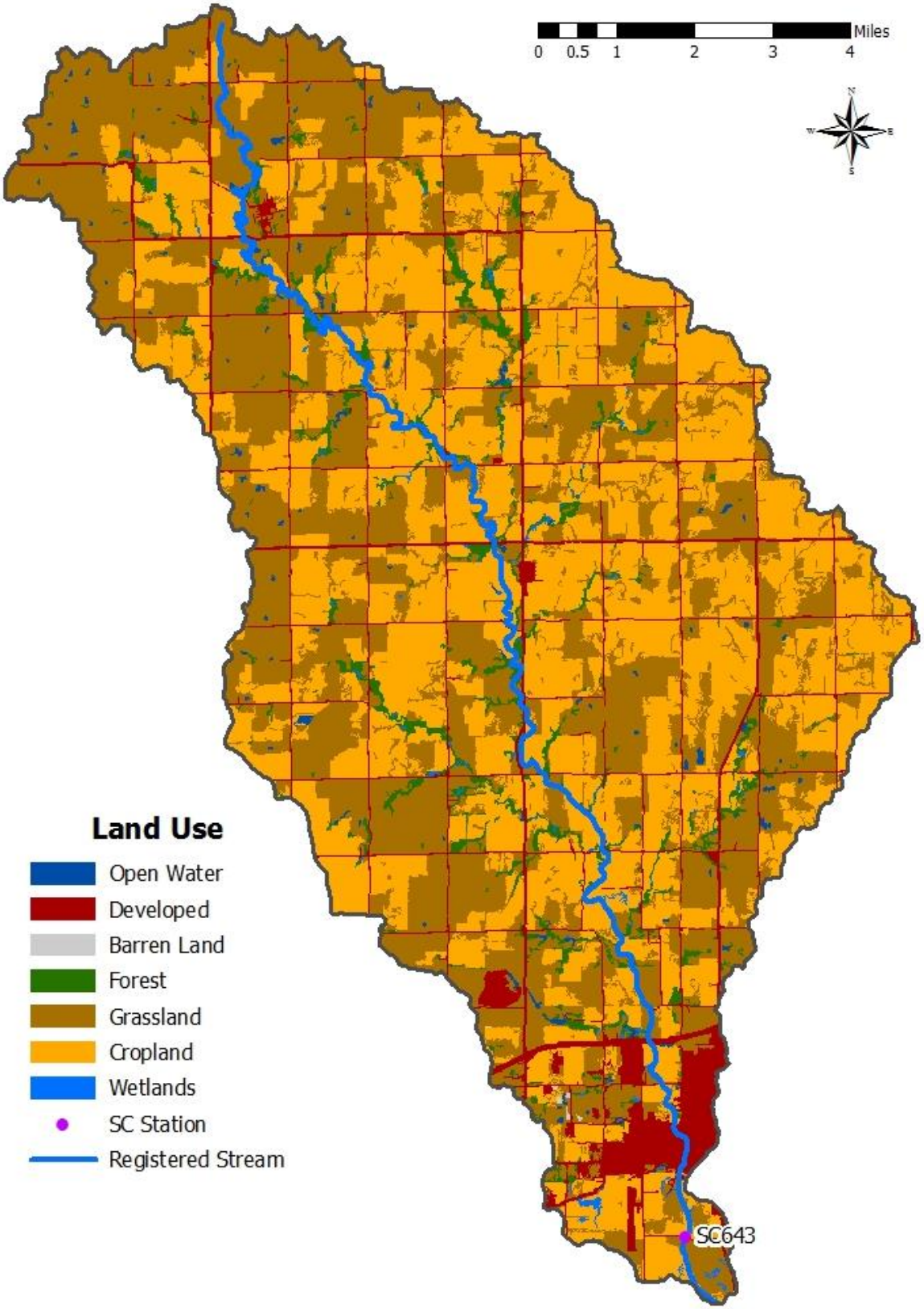
Population Density

According to the 2010 U.S. Census Bureau, Dickinson County has a population of approximately 19,800 as of 2010 and has grown by 2% since 2000 (**Table 17**). The incorporated cities within the watershed are Abilene and Manchester. Of the two, the City of Abilene is the largest urban center with a population of approximately 6,800 and a projected population of approximately 10,600 by 2040 (Kansas Water Office, 2002). The City of Manchester has a population of 102 which has declined by 7% from 2000 to 2010.

Table 17. City and county census results from 2000 and 2010 (U.S. Census Bureau, 2010) and population projections for 2040 (Kansas Water Office, 2002).

Location	Population, 2000	Population, 2010	Population Projection, 2040	Population Change, 2000 to 2010 (%)
City of Abilene	6,543	6,844	10,634	5
City of Manchester	102	95	110	-7
Dickinson County	19,344	19,754	25,833	2

Figure 16. The 2011 National Land Cover Database map for land cover in the Mud Creek (SC643) Watershed.



On-Site Waste Systems

The population of Dickinson County is predominantly rural, with 64% of the county classified as rural (U.S. Census Bureau, 2012; **Table 18**). Urban populations are typically served by municipal sewer systems; however, rural populations may not be connected to the municipal sewer system. According to the Spreadsheet Tool for Estimating Pollutant Load (STEPL), there are a total of 266 septic systems located in the Mud Creek (SC643) Watershed. Septic systems in the state of Kansas typically have an estimated 10 to 15% failure rate (Electric Power Research Institute provided by U.S. Environmental Protection Agency, 2017). Failing on-site septic systems have the potential to contribute to nutrient loading in the watershed. However, because of their small flows and the proclivity of phosphorus to adsorb to soil, failing on-site septic systems are considered a minor source of TP loading within the watershed and are not expected to significantly contribute to TP impairment in Mud Creek.

Table 18. Census results by urban and rural population in Dickinson County from 2010 (U.S. Census Bureau, 2010).

Dickinson County	Population, 2010	Percent
Urban	7,054	36
Rural	12,700	64

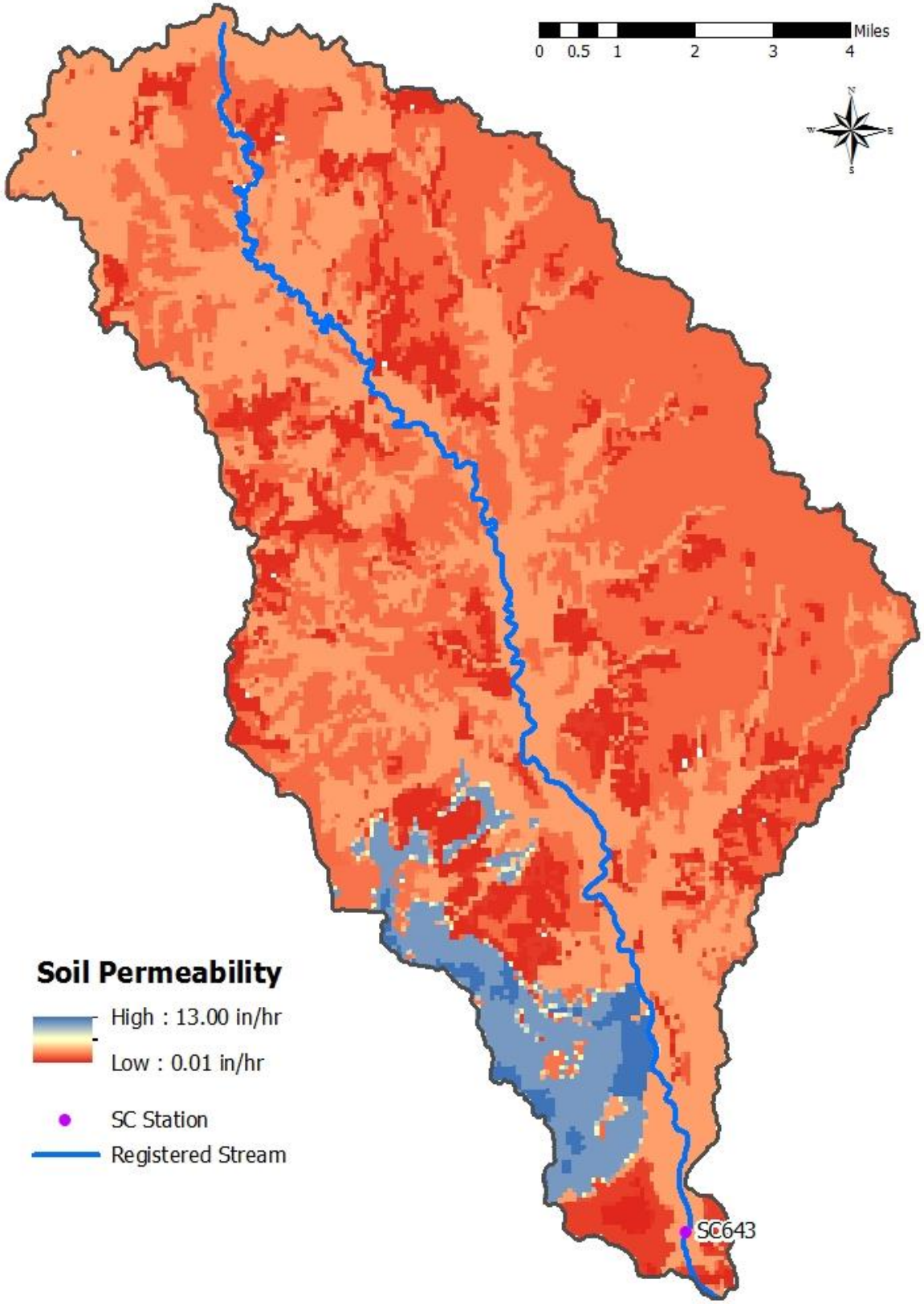
Contributing Runoff

Runoff conditions can occur as a result of either infiltration-excess (precipitation exceeds the infiltration rate of the soil) or saturation-excess (precipitation falls on soils saturated due to an elevated water table), causing overland flow (Juracek, 2000). Overland flow can impact the quality of water entering streams, thereby impacting water-quality loads. Soil permeability categories in Kansas have been defined by the following criteria in inches per hour (in/hr): very high (3.43 in/hr), high (2.86 in/hr), moderate (2.29 in/hr), low (1.71 in/hr), very low (1.14 in/hr), and extremely low (0.57 in/hr). According to the Natural Resources Conservation Service (NRCS) State Soil Geographic Database (STATSGO), the Mud Creek (SC643) Watershed has a soil permeability range of 0.01 to 13 in/hr (**Figure 17**). Within the watershed, 70% of the area has a soil permeability less than 1.71 in/hr. Overall, the watershed has a mean soil permeability of 1.15 in/hr, placing the watershed in the low soil permeability category.

Background Levels

Phosphorus is present over the landscape and in the soil profile. It is also present in terrestrial and aquatic biota. These wildlife can contribute to phosphorus loadings, particularly if they congregate to a density that exceeds the assimilative capacity of the land or water.

Figure 17. Map of Natural Resources Conservation Service State Soil Geographic Database soil permeability in the Mud Creek (SC643) Watershed.



4. ALLOCATION OF POLLUTANT REDUCTION RESPONSIBILITY

The following TMDL, and associated load capacity (LC), is based upon the desired endpoints for aquatic life condition, dissolved oxygen concentration, dissolved oxygen saturation, pH, and chlorophyll-*a* concentration. All of these endpoints should improve to a level that provides full attainment of designated uses as phosphorus concentrations decrease in Mud Creek.

Load Capacity

This TMDL is established in two phases to reduce TP concentrations and loadings within the river and will require periodic assessment of aquatic life conditions to determine compliance with the narrative nutrient criteria as TP concentrations and loadings decline. The Phase I TP milestone is set at 0.210 mg/L, which is the 50th percentile of the median concentrations of KDHE SC stations within the Level III Ecoregion Central Great Plains. Presuming one or more of the endpoints are not met at the end of Phase I, Phase II will commence with a TP milestone of 0.131 mg/L, which is the 25th percentile of the median concentrations of KDHE SC stations within the Level III Ecoregion Central Great Plains. Further reductions in TP concentrations and loads for Phase II will be accomplished through enhanced implementation of controls of nonpoint sources in the watershed. For both Phase I and Phase II, total LCs are calculated according to the previously described TP milestones and the estimated flow conditions in Mud Creek.

For purposes of comparing current TP loading conditions in the creek to the expected reduction in TP loading, the current condition was evaluated using the median TP concentration from 2000 to 2018. Sampled TP concentrations at Mud Creek near Abilene (SC643) were converted to loads for seasonal comparison with the respective TMDL.

Point Source Wasteload Allocations

The total Phase I and II TP WLA for point sources in the Mud Creek (SC643) Watershed is 1.031 lbs/day (**Table 19**). The TP WLAs assigned to all permitted facilities are based upon permitted design flows for each facility, where available. Facilities with no design flow specified in the permit and reported discharge are assigned a flow equal to their current permitted discharge rate. Discharging facilities with no design flow and no reported discharge are assigned a flow of 0 MGD.

The non-discharging lagoons operated by the City of Manchester and Dickinson County Sewer District #1 – Talmage and the concrete operation Midwest Concrete – Abilene #2 are assigned a Phase I and Phase II TP WLA of 0 lb/day. The industrial pretreatment facility operated by Great Plains Manufacturing – Abilene in not assigned a Phase I and Phase II TP WLA as this facility's discharge is treated by the municipal WWTP operated by the City of Abilene. The Phase I and Phase II TP WLA for the municipal WTP operated by the City of Abilene is calculated at the facility's mean Discharge Monitoring Report (DMR) TP concentration of 0.2 mg/L and its permitted discharge volume of 0.318 MGD. Accordingly, the Phase I and II TP WLA assigned to this facility is 0.531 lb/day, or 194 pounds per year (lbs/year).

Table 19. Total phosphorus (TP) wasteload allocations for permitted facilities in the Mud Creek (SC643) Watershed.

Permitee	Kansas Permit Number	NPDES Permit Number	Facility Type	Design Flow (MGD)	Anticipated TP Wasteload Allocation Concentration (mg/L)	TP Daily Wasteload Allocation (lbs/day)	TP Annual Wasteload Allocation (lbs/year)
City of Manchester	M-SH24-NO01	KSJ000323	Non-discharging lagoon	0	NA	0	0
Dickinson County Sewer District #1 - Talmage	M-SH47-NO01	KSJ000315	Non-discharging lagoon	0	NA	0	0
Midwest Concrete - Abilene #2	I-SH01-PR01	KSG110141	Concrete operation pit dewatering	–	0	0	0
Great Plains Manufacturing - Abilene	P-SH01-OO01	KSP000029	Pretreatment	–	NA	NA	NA
City of Abilene	I-SH01-PO04	KS0091936	Water treatment plant	0.318	0.2	0.531	194
Total Phosphorus Total Reserve Wasteload Allocation						**0.500**	**183**
Total Phosphorus Total Wasteload Allocation						**1.031**	**377**

Definitions: – - no data; NA - not applicable

Reserve Wasteload Allocation
A reserve WLA of 0.5 lb/day is established to accommodate future development within the watershed. The reserve WLA may be apportioned throughout the Mud Creek (SC643) Watershed.

Municipal Separate Storm Sewer System
There are no permitted MS4 entities or allocations within the Mud Creek (SC643) Watershed.

Nonpoint Source Load Allocation
The LA is established to account for nonpoint sources of TP in the watershed. The LA is the remainder of the LC after all other allocations are accounted for. Loads from nonpoint source TP are assumed to be minimal during low flow conditions and grow proportionately as flow conditions increase, thereby accounting for increased runoff during precipitation events. As the Mud Creek (SC643) Watershed is primarily influenced by nonpoint sources, the application of agricultural Best Management Practices (BMPs) in riparian zones near cropland and livestock areas should be emphasized in order to abate and reduce nonpoint source TP loading in this watershed.

Defined Margin of Safety

The margin of safety safeguards against the uncertainty in TP loading in the Mud Creek (SC643) Watershed. This TMDL uses conservative assumptions and relies on an implicit margin of safety. First, five endpoints are established by this TMDL to asses compliance with the narrative nutrient criteria. Second, the established endpoints must be maintained for three consecutive years before attainment of water quality standards can be claimed.

The described TMDL, and associated LC, is delineated below for the Mud Creek (SC643) Watershed (**Figure 18**; **Table 20**).

Figure 18. Total phosphorus Total Maximum Daily Load for the Mud Creek (SC643) Watershed.

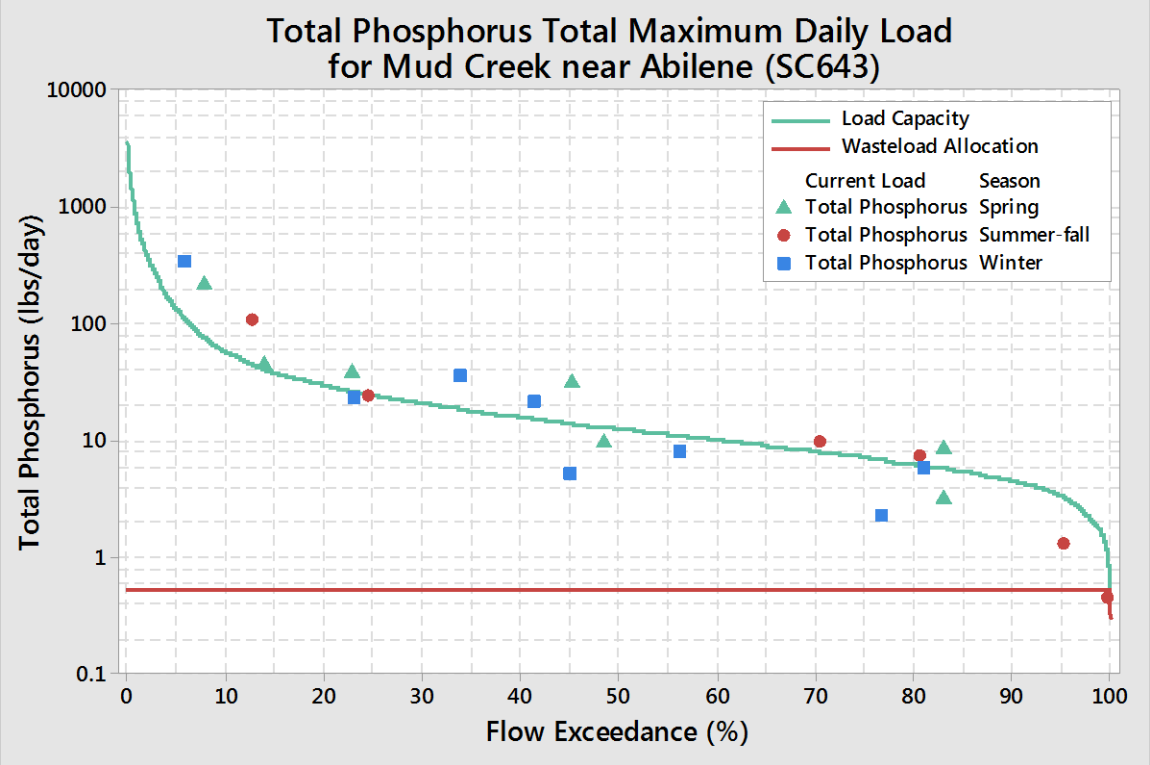


Table 20. Current load conditions (based upon the median total phosphorus concentration from 2000 to 2018), total load capacity, and load capacity allocations for the Mud Creek (SC643) Watershed.

Flow Exceedance (%)	Estimated Flow at Terminus (cfs)	Current Condition (lbs/day)	Load Capacity (lbs/day)	Wasteload Allocation (lbs/day)	Reserve Wasteload Allocation (lbs/day)	Load Allocation (lbs/day)
Phase I						
90	4.0	4.747	4.511	0.531	0.500	3.480
75	6.4	7.602	7.224	0.531	0.500	6.193
50	11	13.14	12.482	0.531	0.500	11.451
25	22	25.86	24.570	0.531	0.500	23.539
10	50	59.99	57.002	0.531	0.500	55.971
Phase II						
90	4.0	4.747	2.814	0.531	0.500	1.783
75	6.4	7.602	4.506	0.531	0.500	3.475
50	11	13.14	7.786	0.531	0.500	6.755
25	22	25.86	15.327	0.531	0.500	14.296
10	50	59.99	35.559	0.531	0.500	34.528

Priority HUC12s

The Mud Creek (SC643) Watershed consists of two HUC12s (**Table 21**; **Figure 19**). According to STEPL, HUC12 102600080404 contributes 1.76 pounds per year per acre (lbs/year/acre) and HUC12 102600080405 contributes 1.45 lbs/year/acre. Reductions in nonpoint sources will be the primary source of TP load reduction in this watershed. Implementation of BMPs should reduce the main source of TP loading. Proactive entities may implement BMPs at any time, with the ultimate goal of reducing TP loads to Mud Creek and the Smoky Hill River.

Table 21. Priority HUC12s by total phosphorus load according to estimations from the Spreadsheet Tool for Estimating Pollutant Load in the Mud Creek (SC643) Watershed.

Watershed	Land Area (acres)	Total Phosphorus (lbs/year)	Total (lbs/year/acre)
102600080404	29,841	52,372	1.76
102600080405	26,815	38,786	1.45

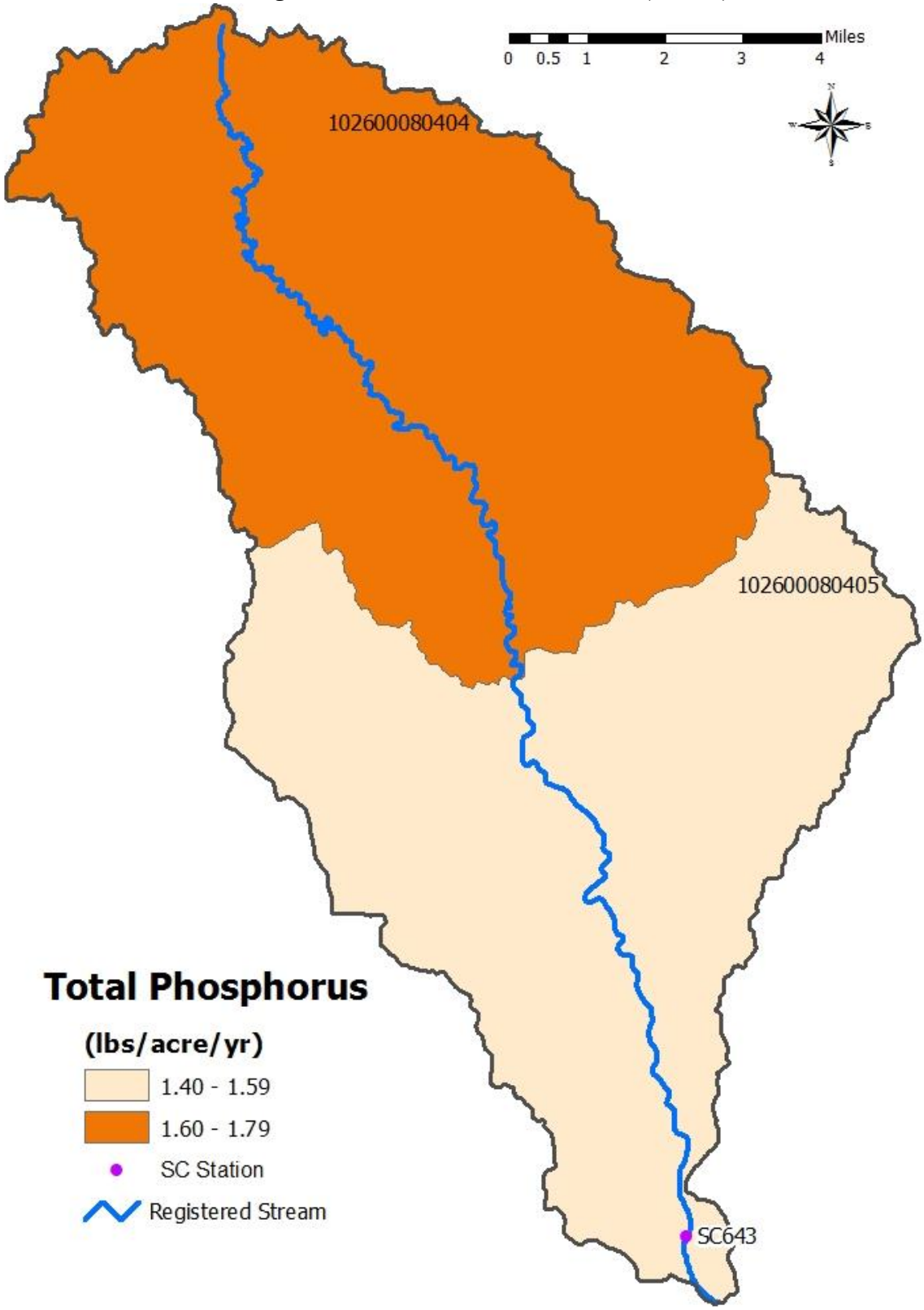
State Water Plan Implementation Priority

Due to the prevalence of high phosphorus concentrations in Mud Creek, a tributary to the Smoky Hill River, this TMDL focuses on reducing nonpoint phosphorus contributions to the watershed. Due to the need to reduce the high nutrient loads in the Smoky Hill River, this TMDL will be **High Priority** for implementation.

Nutrient Reduction Framework Priority Ranking

This watershed lies within the Lower Smoky Hill Subbasin (HUC8 10260008), which is among the top sixteen HUC8s targeted for state action to reduce nutrients.

Figure 19. Map of priority HUC12s by total phosphorus load according to estimations from the Spreadsheet Tool for Estimating Pollutant Load in the Mud Creek (SC643) Watershed.



5. IMPLEMENTATION

Desired Implementation Activities

Point Source Reduction

1. Renew state and federal permits and inspect permitted facilities for permit compliance.

Nonpoint Source Reduction

1. Improve riparian conditions along stream systems by installing grass and/or forest buffer strips along the streams and drainage channels in the watershed.
2. Implement and maintain conservation farming practices—including conservation tilling, contour farming, and no-till farming—in order to reduce runoff and cropland erosion of agricultural areas in the watershed.
3. Perform extensive soil testing to ensure excess phosphorus is not unnecessarily applied.
4. Ensure labeled application rates for chemical fertilizers are followed to reduce runoff.
5. Implement nutrient management plans and ensure that land-applied manure is properly managed to reduce runoff.
6. Establish pasture management practices, including proper stock density, to reduce soil erosion and storm runoff.
7. Ensure proper on-site waste system operations in proximity to main stream and tributary segments.
8. Support implementation efforts of the Lower Lower Smoky Hill River Watershed Restoration and Protection Strategy (WRAPS).

Implementation Program Guidance

NPDES and State Permits – KDHE

1. Continue to monitor, ensure compliance, and confirm proper operation of wastewater facilities in this watershed.
2. Manage the WLA for the watershed to accommodate growth as needed.
3. Manure management plans, detailing proper land application rates and practices, will be implemented to prevent runoff of applied manure.
4. Inspect permitted livestock facilities to ensure compliance.
5. Inspect new permitted livestock facilities for integrity of applied pollution prevention technologies.
6. Apply pollution prevention technologies to new registered livestock facilities with less than 300 animal units.

Nonpoint Source Pollution Technical Assistance – KDHE

1. Support Section 319 implementation projects for nutrient management through reduction of phosphorus runoff from agricultural activities.
2. Provide technical assistance on practices to establish vegetative buffer strips.
3. Support implementation efforts of the Smoky Hill River WRAPS, and incorporate long term objectives of this TMDL into their 9-element watershed plan.

4. Provide technical assistance on nutrient management for livestock facilities and practices which minimize impacts of small livestock operations in the watershed to reduce impacts to stream resources.

Water Resource Cost Share and Nonpoint Source Pollution Control Program – Kansas Department of Agriculture-Division of Conservation (KDA-DOC)

1. Apply conservation farming practices—including no-till, terraces, and contours—and/or erosion control structures, including sediment control basins and constructed wetlands.
2. Provide sediment control practices to minimize erosion and sediment transport from cropland and grassland in the watershed.
3. Encourage residue management to reduce phosphorus loss and transport from cropland runoff in the watershed.
4. Implement manure management plans.
5. Install livestock waste management systems for manure storage.

Riparian Protection Program – KDA-DOC

1. Establish or re-establish natural riparian systems, including vegetative filter strips and streambank vegetation.
2. Develop riparian restoration projects along targeted stream segments, especially those areas with baseflow.
3. Promote wetland construction to reduce runoff and assimilate loadings.
4. Coordinate riparian management within the watershed and develop riparian restoration projects.

Buffer Initiative Program – KDA-DOC

1. Install grass buffer strips near streams.
2. Leverage Conservation Reserve Enhancement Programs to hold riparian land out of production.

Extension Outreach and Technical Assistance – Kansas State University

1. Educate agricultural producers on sediment, nutrient, and pasture management.
2. Provide technical assistance on buffer strip design and minimizing cropland runoff.
3. Encourage annual soil testing to determine capacity of field to hold phosphorus.
4. Educate residents, landowners, and watershed stakeholders about nonpoint source pollution.
5. Promote and utilize the WRAPS efforts for pollution prevention, runoff control, and resource management.
6. Educate livestock producers on livestock waste management, land applied manure applications, and nutrient management planning.
7. Provide technical assistance on livestock waste management systems and nutrient management planning.
8. Repair or replace failing septic systems which are located within 100 feet of the Smoky Hill River or its tributaries.

Timeframe for Implementation
There are no major dischargers in this watershed. However, rural runoff management should expand from 2019 to 2029 to ensure nutrients are addressed. Pollutant reduction practices should be installed within the priority subwatersheds after 2019 with follow-up implementation and monitoring continuing through 2029.

Targeted Participants
The primary participants for implementation of BMPs will be agricultural projects to address nonpoint sources of nutrients. Agricultural operations immediately adjacent to Mud Creek will be encouraged to implement appropriate practices to reduce phosphorus loads. Watershed coordinators, technical staff of the WRAPS group, conservation district personnel, and county extension agents should coordinate to assess possible nutrient sources adjacent to streams. Implementation activities to address nonpoint sources should focus on those areas with the greatest potential to impact nutrient loading to the river.

Targeted activities to focus attention toward include:
1. Denuded riparian vegetation and poor riparian areas along the stream.
2. Conservation compliance on highly erodible areas.
3. Unbuffered cropland adjacent to the stream.
4. Total row crop acreage and gully locations.
5. No till or residue management on cropland.
6. Increasing no-till and precision agricultural practices, including cover crops.
7. Sites where drainage runs through or adjacent to livestock areas.
8. Sites where livestock have full access to the stream and it is their primary water supply.

Milestone for 2029
Advancement of necessary and appropriate measures to decrease phosphorus in the Mud Creek (SC643) Watershed should be widely implemented by the end of 2024. At that time, TP data from Mud Creek near Abilene (SC643) should show indication of declining TP concentrations relative to the pre-2018 data, particularly during normal and lower flow conditions. Aquatic life, too, should show improvement at Mud Creek near Abilene (SC643).

Delivery Agents
The primary delivery agents for program participation will be KDHE and the Lower Lower Smoky Hill River WRAPS group.

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. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage

and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.

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 State Conservation Commission 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 State Conservation Commission 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 WRAPS.
9. The *Kansas Water Plan* provides the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority in implementation.

Funding

The State Water Plan annually generates $12-13 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 by 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

Agricultural nutrient control has been proven effective through conservation tillage, contour farming, and use of grass waterways and buffer strips; additionally, the proper implementation of comprehensive livestock waste management plans has proven effective at reducing nutrient runoff associated with livestock facilities. Presuming the Phase I milestone is not met, this TMDL will be evaluated after 2025 to assess the reductions in phosphorus loads that have taken place with guidance provided to targeted participants regarding follow-up implementation activities.

6. MONITORING

Monitoring will continue for TP at the KDHE station in Mud Creek near Abilene (SC643). Biological monitoring at Mud Creek near Abilene (SC643) will commence once TP concentrations approach TP milestones to assess compliance with the narrative nutrient criteria in the river. Based on the sampling data, the status of the watershed will be re-evaluated during the 303(d) listing process in 2030.

7. FEEDBACK

Public Notice

An active website is established at http://www.kdheks.gov/tmdl/planning_mgmt.htm to convey information to the public on the general establishment of TMDLs and to provide specific TMDLs by river basin. This TMDL was posted to the Smoky-Saline River Basin on this site on November 30, 2018 for public review.

Public Hearing

A public hearing on this TMDL will be held on December 14, 2018 in Salina, Kansas to receive public comments.

Milestone Evaluation

In 2029, evaluation will be made as to the degree of implementation that occurred within the watershed. Subsequent decisions will be made through consultation with local stakeholders and the WRAPS team regarding implementation of nonpoint source reduction strategies and development of additional implementation strategies for the watershed.

Consideration for 303(d) Delisting

The Mud Creek segment covered by this TMDL will be evaluated for delisting under Section 303(d) based on the monitoring data from 2019 to 2029. Therefore, the decision for delisting will ensue in the preparation for the 2030 Section 303(d) list. Should modifications be made to the applicable water quality criteria during the implementation period, consideration for delisting, desired endpoints of this TMDL, and implementation activities may be adjusted accordingly.

Incorporation into the TMDL Vision Process, Water Quality Management Plan, and the Kansas Water Planning Process

Under the current version of the Kansas TMDL Vision Process, the next anticipated revision will be after 2024. At that time, the revision will emphasize implementation of WRAPS activities and this TMDL will be incorporated 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 2019 to 2029.

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