Total Maximum Daily Load (TMDL) Synopsis

State: Kentucky
Major River Basin: Green/Tradewater
USGS HUC8 #: 05140205
County(s): Hopkins
Pollutant(s) of Concern: pH, Cadmium, Iron, Nickel and Zinc

Table S.1 Impaired Waterbodies Addressed in this TMDL Document

Waterbody Name	Pollutant	County	GNIS Number	Suspected Sources	Impaired Use (Support Status)
Caney Creek of Tradewater River 0.0 to 8.2	pH	Hopkins	KY488837_01	Acid Mine Drainage; Surface Mining	WAH, PCR, SCR (not supporting)
Copper Creek of Richland Creek 0.0 to 2.7	pH, Iron, Zinc	Hopkins	KY490078_01	Coal Mining	WAH, PCR, SCR (not supporting)
Copperas Creek of Caney Creek 0.0 to 3.6	pH, Cadmium, Iron, Nickel, Zinc	Hopkins	KY490083_01	Coal Mining	WAH, PCR, SCR (not supporting)
Fox Run of Caney Creek 0.0 to 1.1	pH	Hopkins	KY492415_01	Coal Mining	WAH, PCR, SCR (not supporting)
Hurricane Creek of Tradewater River 0.0 to 1.8	pH, Iron, Zinc	Hopkins	KY494821_01	Coal Mining	WAH, PCR, SCR (not supporting)
UT to Hurricane Creek at 1.2 RM 0.0 to 0.6	pH, Iron, Zinc	Hopkins	KY494821-0.3_01	Coal Mining	WAH, PCR, SCR (not supporting)

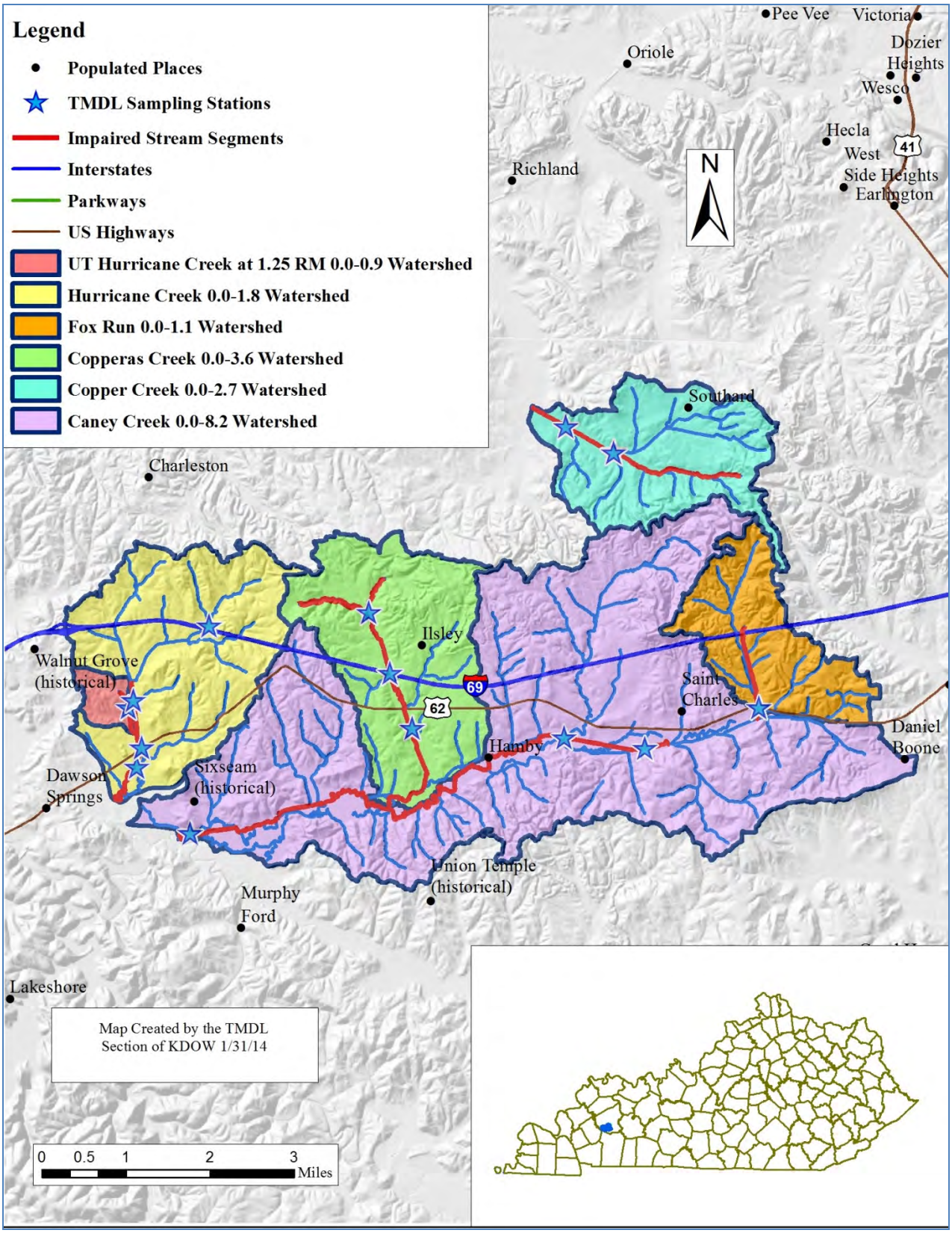

Figure S.1 Location of the TMDL Watershed, Sampling Stations and Assessed Stream Segments

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Kentucky Water Quality Criteria (WQC) and the TMDL Endpoint (i.e. Water Quality Standard/ TMDL Target):

Table S.2 pH WQC and TMDL Endpoint

Condition	WQC, pH standard units	TMDL Load, Hydrogen Ions, lb/day [1]
All Conditions	6.0 (upper limit of hydrogen ion loading)	$Q_S \times 2.067$
All Conditions	9.0 (lower limit of hydrogen ion loading)	$Q_S \times 2.067E\text{-}3$

[1] QS is the flow in the stream in ft^3/s.

Table S.3 Iron WQC and TMDL Endpoint

Condition	WQC, mg/L	TMDL Load, lb/day[1]
Chronic–aquatic life is adversely affected	1.0	$Q_S \times 5.3938$
Acute	4.0	$Q_S \times 21.575$

[1] QS is the flow in the stream in ft^3/s.

Table S.4 Cadmium, Nickel and Zinc WQCs and TMDL Endpoints

Condition	WQC, µg/L[1]	TMDL Load, lb/day[2]
Cadmium		
Chronic	$e^{(0.7409*(\ln(hardness))-4.719)}$	$Q_S \times 0.005394 \times e^{(0.7409*(\ln(hardness))-4.719)}$
Acute	$e^{(1.0166*(\ln(hardness))-3.924)}$	$Q_S \times 0.005394 \times e^{(1.0166*(\ln(hardness))-3.924)}$
Nickel		
Chronic	$e^{(0.846*(\ln(hardness))+0.0584)}$	$Q_S \times 0.005394 \times e^{(0.846*(\ln(hardness))+0.0584)}$
Acute	$e^{(0.846*(\ln(hardness))+2.255)}$	$Q_S \times 0.005394 \times e^{(0.846*(\ln(hardness))+2.255)}$
Zinc		
Chronic	$e^{(0.8473*(\ln(hardness))+0.884)}$	$Q_S \times 0.005394 \times e^{(0.8473*(\ln(hardness))+0.884)}$
Acute	$e^{(0.8473*(\ln(hardness))+0.884)}$	$Q_S \times 0.005394 \times e^{(0.8473*(\ln(hardness))+0.884)}$

[1] Hardness is in units of mg/L as $CaCO_3$.
[2] Q_S is the flow in the stream in ft^3/s.

Table S.5 Net Alkalinity TMDL Endpoint

Condition	Net Alkalinity[1], lb/day
All Conditions	≥ 0

[1] Net alkalinity is defined as the alkalinity in mg/L as $CaCO_3$ minus the calculated acidity; the calculated acidity is determined using the following equation: Calculated Acidity, mg/L as $CaCO_3$ = $50 \times ((10^{(3\text{-}pH)}) + (3 \times Fe\ mg/L/55.8) + (2 \times Mn\ mg/L/54.9) + (3 \times Al\ mg/L/27))$.

TMDL Equation and Calculations:

A TMDL calculation is performed as follows:

$$TMDL = WLA + LA + MOS$$
Equation S.1

The WLA has two components:

$$WLA = Mining\text{-}WLA + Future\ Growth\text{-}WLA$$
Equation S.2

Where:
TMDL: the WQC, expressed as a load.
MOS: the Margin of Safety, which can be an implicit or explicit additional reduction applied to sources of pollutants that accounts for uncertainties in the relationship between effluent limits and water quality. For this TMDL, the MOS is implicit.
TMDL Target: the TMDL minus the MOS.
WLA: the Wasteload Allocation, which is the allowable loading of pollutants into the stream from KPDES-permitted sources, such as surface and subsurface mines.
Mining-WLA: the allowable loading for current KPDES-permitted mining sources which discharge the pollutants of concern, whether or not they have a permit limit for the pollutants of concern.
Future Growth-WLA: the allowable loading for future KPDES-permitted sources, including new mining permits, new discharges under existing mining permits as further permitted acreage is mined and discharges from mines under reclamation by the Kentucky Division of Abandoned Mine Lands (AML). Also includes the allocation for the KPDES-permitted sources that existed but were not known at the time the TMDL was written.
LA: the Load Allocation, which is the allowable loading of pollutants into the stream from sources not permitted by KPDES, such as formerly permitted mines, prelaw mines, and from natural background.
Seasonality: yearly factors that affect the relationship between pollutant inputs and the ability of the stream to meet its designated uses.
Critical Condition: the time period when the pollutant conditions are expected to be at their worst.
Existing Conditions: the load that exists in the watershed at the time of TMDL development (i.e., sampling) and is causing the impairment.
Load: concentration * flow * conversion factor.
Concentration: milligrams per liter (iron, alkalinity, acidity), micrograms per liter (cadmium, nickel, zinc) or standard units (pH).
Flow (i.e., stream discharge): cubic feet per second (cfs).

Table S.6 TMDLs and Allocations by Impaired Segment

Pollutant	Units	TMDL[1]	MOS[2]	Mining-WLA[3]	Future Growth - WLA[4]	LA[5]
Caney Creek 0.0 to 8.2						
pH[6]	standard units	$6.0 \le pH \le 9.0$	Implicit	$6.0 \le pH \le 9.0$	$6.0 \le pH \le 9.0$	$6.0 \le pH \le 9.0$
Alkalinity, Acidity[7]	mg/L as $CaCO_3$	Net Alkalinity ≥ 0	Implicit	Net Alkalinity ≥ 0	Net Alkalinity ≥ 0	Net Alkalinity ≥ 0
Copper Creek 0.0 to 2.7						
pH[6]	standard units	$6.0 \le pH \le 9.0$	Implicit	$6.0 \le pH \le 9.0$	$6.0 \le pH \le 9.0$	$6.0 \le pH \le 9.0$
Alkalinity, Acidity[7]	mg/L as $CaCO_3$	Net Alkalinity ≥ 0	Implicit	Net Alkalinity ≥ 0	Net Alkalinity ≥ 0	Net Alkalinity ≥ 0
Iron Chronic[8]	pounds/ day	$Q_S \times 5.3938$	Implicit	$Q_M \times 5.3938$	$Q_{FG} \times 5.3938$	$Q_{LA} \times 5.3938$
Iron Acute	pounds/ day	$Q_S \times 21.575$	Implicit	$Q_M \times 21.575$	$Q_{FG} \times 21.575$	$Q_{LA} \times 21.575$
Zinc Acute and Chronic[9]	pounds/ day	$Q_S \times 0.005394 \times e^{(0.8473*(\ln(\text{hardness}))+0.884)}$	Implicit	$Q_M \times 0.005394 \times e^{(0.8473*(\ln(\text{hardness}))+0.884)}$	$Q_{FG} \times 0.005394 \times e^{(0.8473*(\ln(\text{hardness}))+0.884)}$	$Q_{LA} \times 0.005394 \times e^{(0.8473*(\ln(\text{hardness}))+0.884)}$
Copperas Creek 0.0 to 3.6						
pH[6]	standard units	$6.0 \le pH \le 9.0$	Implicit	$6.0 \le pH \le 9.0$	$6.0 \le pH \le 9.0$	$6.0 \le pH \le 9.0$
Alkalinity, Acidity[7]	mg/L as $CaCO_3$	Net Alkalinity ≥ 0	Implicit	Net Alkalinity ≥ 0	Net Alkalinity ≥ 0	Net Alkalinity ≥ 0
Cadmium Chronic	pounds/ day	$Q_S \times 0.005394 \times e^{(0.7409*(\ln(\text{hardness}))-4.719)}$	Implicit	$Q_M \times 0.005394 \times e^{(0.7409*(\ln(\text{hardness}))-4.719)}$	$Q_{FG} \times 0.005394 \times e^{(0.7409*(\ln(\text{hardness}))-4.719)}$	$Q_{LA} \times 0.005394 \times e^{(0.7409*(\ln(\text{hardness}))-4.719)}$
Cadmium Acute	pounds/ day	$Q_S \times 0.005394 \times e^{(1.0166*(\ln(\text{hardness}))-3.924)}$	Implicit	$Q_M \times 0.005394 \times e^{(1.0166*(\ln(\text{hardness}))-3.924)}$	$Q_{FG} \times 0.005394 \times e^{(1.0166*(\ln(\text{hardness}))-3.924)}$	$Q_{LA} \times 0.005394 \times e^{(1.0166*(\ln(\text{hardness}))-3.924)}$
Iron Chronic[8]	pounds/ day	$Q_S \times 5.3938$	Implicit	$Q_M \times 5.3938$	$Q_{FG} \times 5.3938$	$Q_{LA} \times 5.3938$

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Pollutant	Units	TMDL[1]	MOS[2]	Mining-WLA[3]	Future Growth - WLA[4]	LA[5]
Copperas Creek 0.0 to 3.6						
Iron Acute	pounds/ day	$Q_S \times 21.575$	Implicit	$Q_M \times 21.575$	$Q_{FG} \times 21.575$	$Q_{LA} \times 21.575$
Nickel Chronic	pounds/ day	$Q_S \times 0.005394 \times e^{(0.846*(\ln(\text{hardness}))+0.0584)}$	Implicit	$Q_M \times 0.005394 \times e^{(0.846*(\ln(\text{hardness}))+0.0584)}$	$Q_{FG} \times 0.005394 \times e^{(0.846*(\ln(\text{hardness}))+0.0584)}$	$Q_{LA} \times 0.005394 \times e^{(0.846*(\ln(\text{hardness}))+0.0584)}$
Nickel Acute	pounds/ day	$Q_S \times 0.005394 \times e^{(0.846*(\ln(\text{hardness}))+2.255)}$	Implicit	$Q_M \times 0.005394 \times e^{(0.846*(\ln(\text{hardness}))+2.255)}$	$Q_{FG} \times 0.005394 \times e^{(0.846*(\ln(\text{hardness}))+2.255)}$	$Q_{LA} \times 0.005394 \times e^{(0.846*(\ln(\text{hardness}))+2.255)}$
Zinc Acute and Chronic[9]	pounds/ day	$Q_S \times 0.005394 \times e^{(0.8473*(\ln(\text{hardness}))+0.884)}$	Implicit	$Q_M \times 0.005394 \times e^{(0.8473*(\ln(\text{hardness}))+0.884)}$	$Q_{FG} \times 0.005394 \times e^{(0.8473*(\ln(\text{hardness}))+0.884)}$	$Q_{LA} \times 0.005394 \times e^{(0.8473*(\ln(\text{hardness}))+0.884)}$
Fox Run 0.0 to 1.1						
pH[6]	standard units	$6.0 \le pH \le 9.0$	Implicit	$6.0 \le pH \le 9.0$	$6.0 \le pH \le 9.0$	$6.0 \le pH \le 9.0$
Alkalinity, Acidity[7]	mg/L as $CaCO_3$	Net Alkalinity ≥ 0	Implicit	Net Alkalinity ≥ 0	Net Alkalinity ≥ 0	Net Alkalinity ≥ 0
Hurricane Creek 0.0 to 1.8						
pH[6]	standard units	$6.0 \le pH \le 9.0$	Implicit	$6.0 \le pH \le 9.0$	$6.0 \le pH \le 9.0$	$6.0 \le pH \le 9.0$
Alkalinity, Acidity[7]	mg/L as $CaCO_3$	Net Alkalinity ≥ 0	Implicit	Net Alkalinity ≥ 0	Net Alkalinity ≥ 0	Net Alkalinity ≥ 0
Iron Chronic[8]	pounds/ day	$Q_S \times 5.3938$	Implicit	$Q_M \times 5.3938$	$Q_{FG} \times 5.3938$	$Q_{LA} \times 5.3938$
Iron Acute	pounds/ day	$Q_S \times 21.575$	Implicit	$Q_M \times 21.575$	$Q_{FG} \times 21.575$	$Q_{LA} \times 21.575$
Zinc Acute and Chronic[9]	pounds/ day	$Q_S \times 0.005394 \times e^{(0.8473*(\ln(\text{hardness}))+0.884)}$	Implicit	$Q_M \times 0.005394 \times e^{(0.8473*(\ln(\text{hardness}))+0.884)}$	$Q_{FG} \times 0.005394 \times e^{(0.8473*(\ln(\text{hardness}))+0.884)}$	$Q_{LA} \times 0.005394 \times e^{(0.8473*(\ln(\text{hardness}))+0.884)}$
UT to Hurricane Creek at 1.2 RM 0.0 to 0.6						
pH[6]	Standard Units	$6.0 \le pH \le 9.0$	Implicit	$6.0 \le pH \le 9.0$	$6.0 \le pH \le 9.0$	$6.0 \le pH \le 9.0$

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Pollutant	Units	TMDL[1]	MOS[2]	Mining-WLA[3]	Future Growth - WLA[4]	LA[5]
UT to Hurricane Creek at 1.2 RM 0.0 to 0.6						
Alkalinity, Acidity[7]	mg/L as $CaCO_3$	Net Alkalinity ≥ 0	Implicit	Net Alkalinity ≥ 0	Net Alkalinity ≥ 0	Net Alkalinity ≥ 0

(1) TMDLs for metals are expressed as the flow in the stream, Q_S in ft^3/s, multiplied by the WQC in mg/L or µg/L and the appropriate conversion factor to convert the multiple of flow and the WQC into to units of load (pounds/day). The conversion factors are:

1. 5.3938 for a WQC in units of mg/L (i.e., for iron).
2. 0.005394 for a WQC in units of µg/L (i.e., for zinc, cadmium and nickel).

Also, pH must remain between 6.0 and 9.0 standard units, inclusive.

(2) The MOS is implicit: When in compliance, KPDES-permitted sources seldom discharge at their allowable limits for the pollutants addressed by this TMDL.

(3) The Mining-WLA is expressed as the flow in the stream due to KPDES-permitted sources with permit limits for the pollutants addressed by this TMDL, Q_M, in ft^3/s, multiplied by the WQC and the appropriate conversion factor. All dischargers must meet both the chronic and acute criteria for pollutants whose WQCs are expressed in both chronic and acute terms.

(4) The Future Growth-WLA is expressed as the flow in the stream due to future KPDES-permitted sources with permit limits for the pollutants addressed by this TMDL, Q_{FG}, in ft^3/s, multiplied by the WQC and the appropriate conversion factor. All dischargers must meet both the chronic and acute criteria for pollutants whose WQCs are expressed in both chronic and acute terms.

(5) The LA is expressed as the flow in the stream due to legal but non-KPDES-permitted sources of the pollutants addressed by this TMDL, Q_{LA}, in ft^3/s, multiplied by the WQC and the appropriate conversion factor. The LA includes mining sources in operation prior to May 3, 1978 and any natural background concentrations of the pollutants addressed by this TMDL.

(6) pH can be converted to a range of allowable loads of hydrogen ions in units of g/day; a pH of 6.0 represents a maximum allowable load of hydrogen ions equal to $Q_S \times 2.067$ g/day, and a pH of 9.0 represents a minimum allowable load of $Q_S \times 2.067E\text{-}3$ g/day, where Q_S is the flow in the stream in ft^3/s. The TMDL can then be allocated to the Mining-WLA, the Future Growth-WLA and the LA based on the fraction of the streamflow each contributes.

(7) Net alkalinity is defined as the alkalinity in mg/L as $CaCO_3$ minus the calculated acidity; the calculated acidity is determined using the following equation: Calculated Acidity, mg/L as $CaCO_3 = 50 \times ((10^{(3\text{-}pH)}) + (3 \times Fe\ mg/L/55.8) + (2 \times Mn\ mg/L/54.9) + (3 \times Al\ mg/L/27))$. Monitoring and reporting of net alkalinity will be required both instream and at outfalls at the same frequency as iron and manganese are monitored and reported. Aluminum must be added to KPDES mining permits as report-only in order to determine the calculated acidity. Net alkalinity must be greater than or equal to zero (in both mg/L and pounds/day) in order to buffer metals hydrolysis which can lower pH below acceptable levels.

(8) The chronic iron WQC is 3.5 mg/L where there are no demonstrated impacts to aquatic life, and 1.0 mg/L where there are demonstrated impacts. This means for any WAH-impaired stream, the iron limit is 1.0 mg/L. Because all segments addressed by this document are WAH-impaired, the chronic iron TMDL is based on 1.0 mg/L as opposed to 3.5 mg/L. The acute WQC for iron is not dependent on impacts to aquatic life; it is 4.0 mg/L in all streams.

(9) The chronic and acute WQCs for zinc are identical.

Translation of WLAs into Permit Limits

Mining facilities must meet the discharge limits set in their KPDES permits, see Section 5.2.5.2, Coal General Permits, and 5.2.5.3, Coal Individual Permits. Pre-SMCRA facilities were not required to treat AMD subsequent to the cessation of mining.

The following changes to KPDES mining permits are required by this TMDL:

1. Permittees must report alkalinity in mg/L as $CaCO_3$ and aluminum in units of mg/L whenever and wherever iron and manganese are reported. However, for aluminum this report-only, no discharge limit is established. See below for alkalinity.

2. There must be sufficient net alkalinity present to buffer metals hydrolysis whenever and wherever iron and manganese are reported. Net alkalinity is defined as the alkalinity of the discharge water minus the calculated acidity, which must be greater than or equal to zero. The calculated acidity will be determined using Equation S.3, from Hedin et al. (1991), which conservatively assumes iron is in the form of Fe^{+3}:

$$\text{Calculated Acidity, mg/L as } CaCO_3 = 50 \times ((10^{(3\text{-pH})}) + (3 \times \text{Fe mg/L}/55.8) + (2 \times \text{Mn mg/L}/54.9) + (3 \times \text{Al mg/L}/27.0))$$

Equation S.3

   If the net alkalinity is below zero, then a violation has occurred. See Section 6.2 for further explanation.

These changes will be made to the single existing mining permit in the watershed, the Don Bowles Corporation St. Charles Prep Plant/Can Do #1 Mine, KY0067121, when its permit is renewed. The facility's current permit is valid until 2017. These requirements will also apply to any future mining permits.