NEOSHO BASIN TOTAL MAXIMUM DAILY LOAD

Water Body/Assessment Unit: Big Creek (Leroy)
Water Quality Impairment: Copper

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin:	Upper Neosho
Counties:	Coffey, Greenwood, and Lyon, Kansas
HUC 8:	11070204
HUC 11 (HUC 14s)**:**	010 (040, 050 and 060)
Drainage Area:	130.9 square miles
Main Stem Segments:	Segment 14 starting at confluence with the Neosho River in south-central Coffey County and upstream to confluence of North and South Big Creek in south-central Coffey County (**Figure 1**).
Tributary Segments:	North Big Creek (16) Varvel Creek (43) Dinner Creek (823)
Designated Uses:	Expected Aquatic Life Support, Primary Contact Recreation, Domestic Water Supply and Food Procurement for Main Stem Segment 14.

Impaired Use: Expected Aquatic Life Support

Water Quality Standard: acute criterion = WER[EXP[(0.9422*(ln(hardness)))-1.700]]

Hardness-dependent criteria (KAR 28-16-28e(c)(2)(F)(ii)). Aquatic Life (AL) Support formulae are: (where Water Effects Ratio (WER) is 1.0 and hardness is in mg/L).

2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Support for Designated Use under 2002 303(d): Not Supporting Aquatic Life

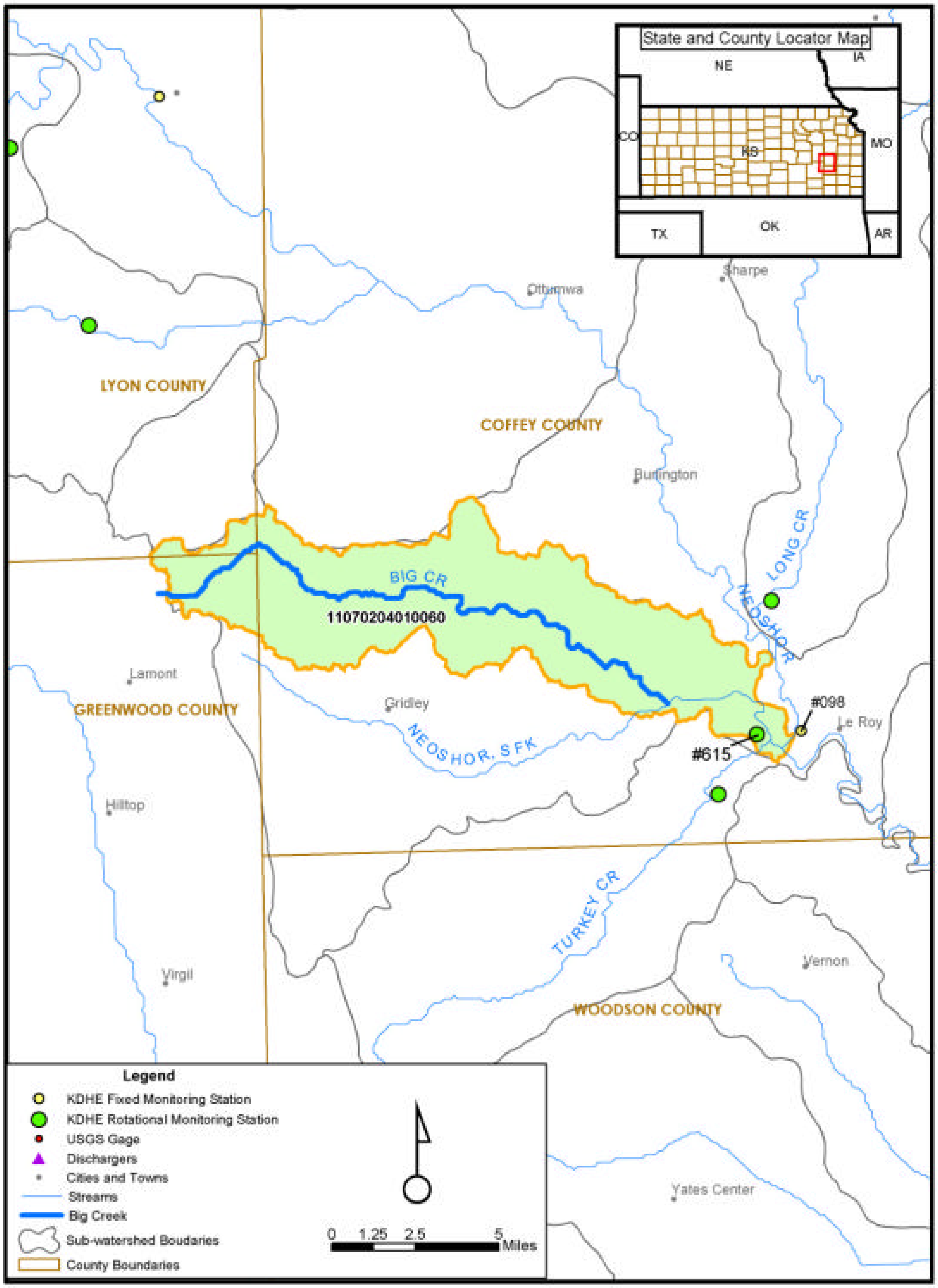
Monitoring Site: Station 615 near LeRoy

Period of Record Used for Monitoring and Modeling: 1992, 1996, and 2000 for Station 615. Generalized Watershed Loading Function (GWLF) modeling period for soils data is 1998 – 2002.

Flow Record: Pottawatomie Creek near Garnett (USGS Station 06914000) match to Big Creek near LeRoy (USGS 07182710). Flow duration curve for this TMDL was estimated by

USGS (2004) and a summary of the flow data used to generate the load duration curves are included in **Table A-1** of the TMDL report.

Figure 1 Big Creek Location Map



Long Term Flow Conditions: 10 % Exceedance Flows = 157.2 cfs, 95 % = 0.0786 cfs

Critical Condition: Wet weather and high flow

TMDL Development Tools: Load Duration Curve (LDC) Methodology and Generalized Watershed Loading Function (GWLF) Model

Summary of Current Conditions:
Estimated Average Non-Point Load of Copper from Sediment: **6.021 lb/day** (2,198 lb/yr)
(derived from GWLF annual estimate of sediment loading)

Estimated Point Source Load (Gridley MWTP): **0.0016 lb/day**
(assumed copper concentration multiplied by MWTP design flow [0.059 cfs])

Estimated Total Current Load: **6.023 lb/day**
(estimated non-point copper load from sediment (GWLF) + estimated point source load)

Summary of TMDL Results:

Average TMDL: **0.937 lb/day**

Waste Load Allocation (WLA): **0.0057 lb/day**

Average Load Allocation (LA): **0.838 lb/day**
(Average LA = average TMDL – WLA – average MOS; see **Figure 7** for LA at specific flow exceedance ranges)

Average Margin of Safety (MOS): **0.0937 lb/day**

TMDL Source Reduction:
WLA Sources (MWTP): No reduction necessary

Non-Point: **5.183 lb/day (86.1%)**
(equal to TMDL reduction)

GWLF Modeling and Non-Point Load Estimates

Existing non-point source loads of copper to Big Creek were estimated using the Generalized Watershed Loading Function (GWLF) (Haith et al. 1996) model. The model, in conjunction with some external spreadsheet calculations, estimates dissolved and total copper loads in surface runoff from complex watersheds such as Big Creek. Both surface runoff and groundwater sources are included in the simulations. The GWLF model requires daily precipitation and temperature data, runoff sources and transport, and chemical parameters. Transport parameters include areas, runoff curve numbers for antecedent moisture condition II, and the erosion product KLSCP (Universal Soil Loss Equation parameters) for each runoff source. Required watershed transport parameters are groundwater recession and seepage coefficients, available water capacity of the unsaturated zone, sediment delivery ratio, monthly values for evapotranspiration cover factors, average daylight hours, growing season indicators, and rainfall erosivity coefficients. Initial values must also be specified for unsaturated and shallow saturated zones, snow cover, and five-day antecedent rainfall plus snowmelt.

Input data for copper in soils were obtained from Soil Conservation Service (SCS) and USGS (*e.g.*, Juracek and Mau 2002, 2003). The model for Big Creek was run using a 5-year period, January 1998-December 2002, and first year results were ignored to eliminate effects of arbitrary initial conditions. Daily precipitation and temperature records for the period were obtained from the Western Regional Climate Center (Haith, *et al*. 1996). All transport and chemical parameters were obtained by general procedures described in the GWLF manual (Haith, *et al*. 1996), and values used in the model are in Appendix C. Parameters needed for land use were obtained from the State Soil Geographic (STATSGO) Database compiled by Natural Resources Conservation Service (NRCS) (Schwarz and Alexander 1995).

For each land use area shown on **Figure 4**, NRCS Curve Number (CN), length (L), and gradient of the slope (S) were estimated from intersected electronic geographic information systems (GIS) land use and soil type layers. Soil erodibility factors (K_k) were obtained from the STATSGO database (Schwarz and Alexander 1995). Cover factors (C) were selected from tables provided in the GWLF manual (Appendix C). Supporting practice factors of P = 1 were used for all source areas for lack of detailed data. Area-weighted CN and K_k, $(LS)_k$, C_k, and P_k values were calculated for each land use area. Coefficients for daily rainfall erosivity were selected from tables provided in the GWLF manual. Model input variables and model outputs are shown in **Appendix B**.

To calculate the watershed yield for copper, the GWLF model was run to generate the average annual runoff and average annual sediment load generated from each subwatershed. Average sediment copper concentrations were derived from several USGS studies of lake and river bottom sediments in Kansas (Mau 2004). The average sediment copper concentrations for this area are approximately 33.5 µg/g (ppm). This mass concentration of copper in sediments was used in conjunction with the total suspended solids (TSS) concentrations from ambient sampling to determine the particulate portion of the ambient total copper results that are attributable to copper in suspended sediments.

The ambient dissolved copper concentration was conservatively assumed to be the same concentration as in the runoff generated from the watershed. This fraction was estimated using partitioning assumptions implicit in the model. In addition, the average sediment concentration of 33.5 µg/g for copper in soil was used with the GWLF generated average annual sediment yield to calculate the average annual copper yield associated with sediment.

Load Duration Curves: Because loading capacity is believed to vary as a function of the flow present in the stream, **Table 1** was prepared to show the number of water quality samples exceeding the copper acute WQS as a function of flow during different seasons of the year. This table displays a continuum of desired loads over all flow exceedance ranges, rather than fixed at a single value. Ambient water quality data from the KDHE rotational sampling Station 615 were categorized for each of the three defined seasons: spring (Apr-Jul), summer-fall (Aug-Oct) and winter (Nov-Mar). Flow data and ambient water quality data for copper and hardness, collected between the period of February 1992, 1996, and 2000, from Station 615 are provided in **Appendix A, Table A-2**. High flows and runoff generally equate to lower flow exceedance (high flow) ranges; baseflow and point source influences generally occur in the 75-99 percent (low flow) range.

From **Table 1** a total of four acute WQS excursions can be seen in two of three defined seasons. There were no exceedances during the winter sampling season. The four exceedances account for the impaired water body designation and the inclusion of the Big Creek watershed on the 2002 Kansas §303(d) list.

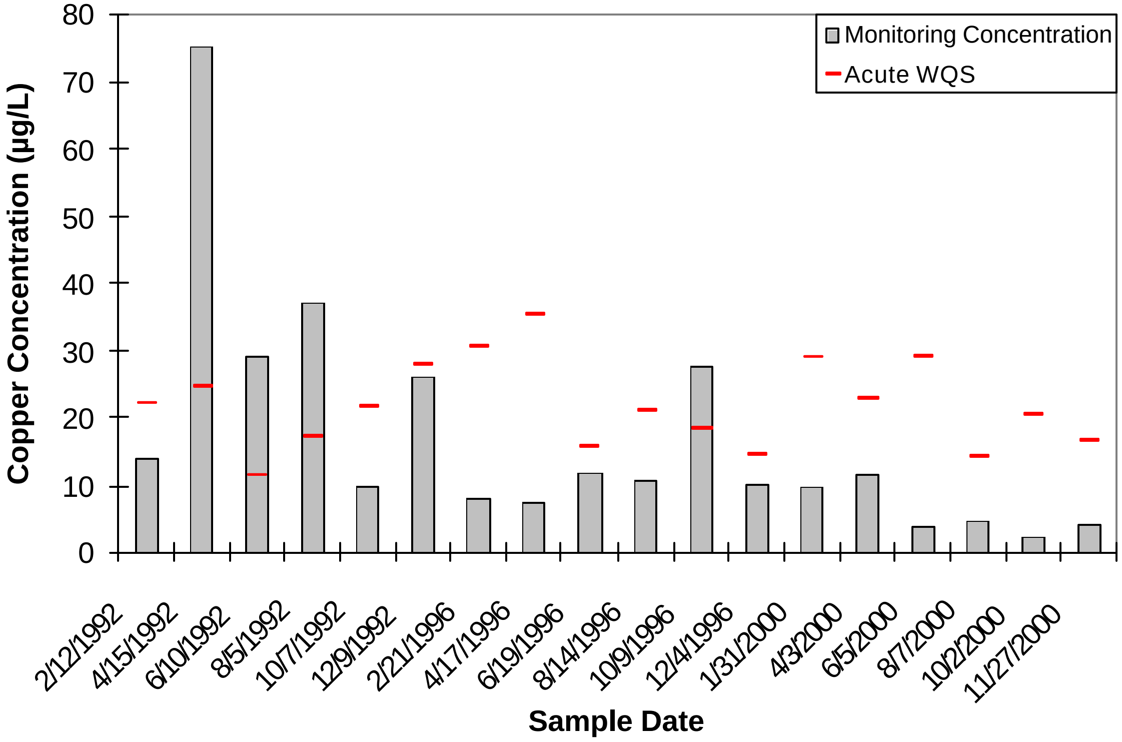
Table 1 Number of Samples Exceeding Copper WQS by Flow During Spring, Summer/Fall, and Winter

		Percent Flow Exceedance						
Station	**Season**	**0 to 10%**	**10 to 25%**	**25 to 50%**	**50 to 75%**	**75 to 90%**	**90 to 100%**	**Cumulative Frequency**
Big Creek near Le Roy (615)	Spring	1	0	1	0	0	0	2/6 (33.3%)
	Summer-Fall	0	1	1	0	0	0	2/6 (33.3%)
	Winter	0	0	0	0	0	0	0/6 (0%)

Figure 2 compares KDHE measured copper concentrations with paired hardness-specific acute WQS values for total copper. As can be seen on the diagram, a total of four exceedances were measured during that time. The most recent exceedance was measured in October 1996. Based on **Figure 2**, copper concentrations appear to have diminished considerably since 1996.

Estimated Big Creek flow data for the associated sample date was used to estimate both the observed load and the acute WQS load (**Figure 3**). Measured copper concentration and the paired hardness-specific WQS were used to calculate the observed load and the assimilative capacity based on the acute WQS, respectively. Differences in the observed load from the acute WQS load were calculated by subtracting the acute WQS load from the observed load and positive (i.e. above zero) differences indicate load exceedances.

Figure 2 **Comparison of Total Copper Concentrations with Paired Hardness-Specific Acute WQS for Monitoring Station 615**

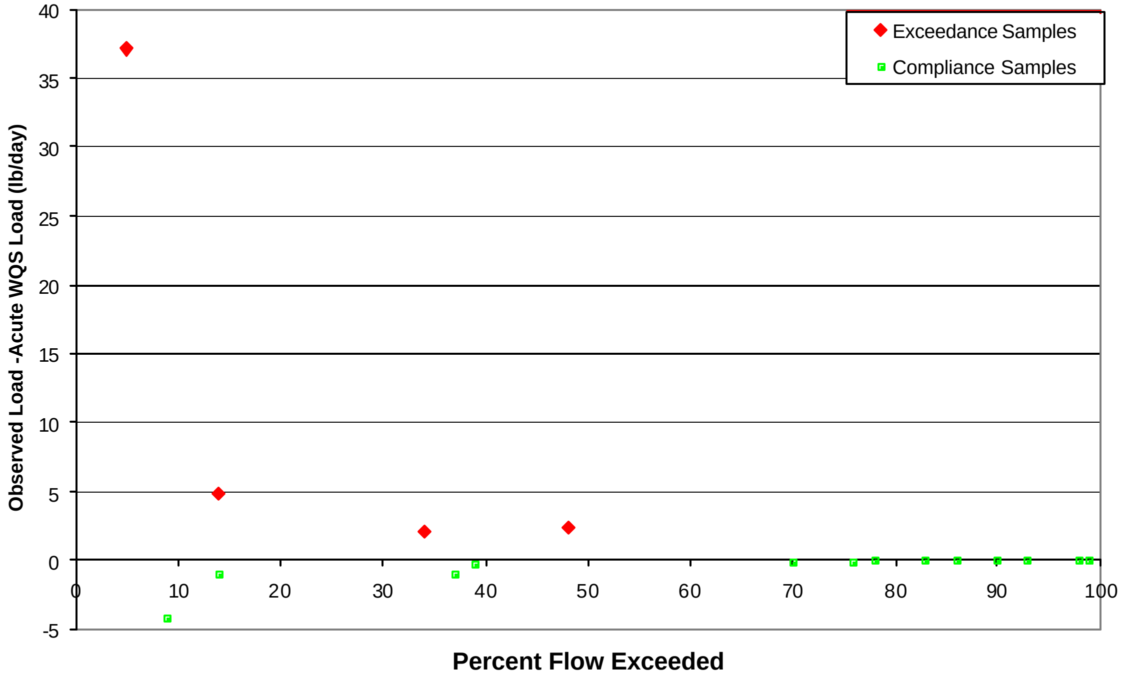


Compliance with chronic WQS for copper. This TMDL Report does not address compliance with the chronic copper toxicity because representative data for chronic conditions did not support a 2002 303(d) listing for Big Creek; the listing was based on exceedances of the acute WQS only. However, a general evaluation was also conducted to determine whether compliance with the acute WQS would be adequately protective of chronic toxicity. To perform this evaluation, the average copper concentration (representing the long-term average, or [LTA]) was divided by the standard deviation to yield the coefficient of variation (CV). If the CV is greater than 0.3 then the variation in the data is believed to be adequately addressed by the acute WQS, and no further evaluation of chronic toxicity would be necessary. For Big Creek, the CV for the copper concentrations was greater than 0.3 (0.63), suggesting that compliance with the acute WQS would be adequately protective of chronic toxicity as well.

Figure 3 summarizes the copper load exceedances plotted against percent flow exceedances, calculated by subtracting the observed load minus the acute WQS load. Excursions were observed at various flows, including those flows believed to be associated with both point and non-point sources of copper inputs. Only four excursions were observed, which occurred at 5 percent, 14 percent, 34 percent and 48 percent flow exceedance, respectively. This suggests that excursions only occur at high and somewhat medium flow, with no excursions observed in the low flow conditions. This observation therefore suggests that loading occurs from nonpoint sources.

It was not necessary to demonstrate stable hydrologic conditions because only transient (acute) excursions were considered in this comparison. In addition, there was no apparent statistical correlation between flow and hardness.

Figure 3 **Exceedances of Acute Total Copper WQS Load as a Function of Percent Flow**



Desired Endpoints of Water Quality (Implied Load Capacity) at Site 615 over 2007 – 2011

The KDHE 2002 303(d) list identifies the aquatic life use of Big Creek as impaired as a result of copper exceedances; accordingly, 40 CFR§130.7(c)(1) states that "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standard." The water quality standard for copper is calculated using the hardness-dependent equation (KDHE 2003):

$$\text{acute criterion (WQS)} = \text{WER}[\text{EXP}[(0.9422*(\ln(\text{hardness})))-1.700]]$$

The desired endpoint of the Big Creek watershed is for total copper concentrations attributed to identified potential sources of copper in the watershed to remain below the acute WQS in the stream. This desired endpoint should improve water quality in the creek at both low and high flows. Seasonal variation is accounted for by the TMDL, since the TMDL endpoint accounts for the low flow conditions usually occurring in the July-November months.

This endpoint will be reached as a result of expected, though unspecified, reductions in sediment loading from the watershed resulting from implementation of corrective actions and best management practices (BMP), as directed by this TMDL Report (see Implementation – Appendix A). Achievement of this endpoint will provide full support of the aquatic life function of the creek and attain the total copper WQS.

3. SOURCE INVENTORY AND ASSESSMENT

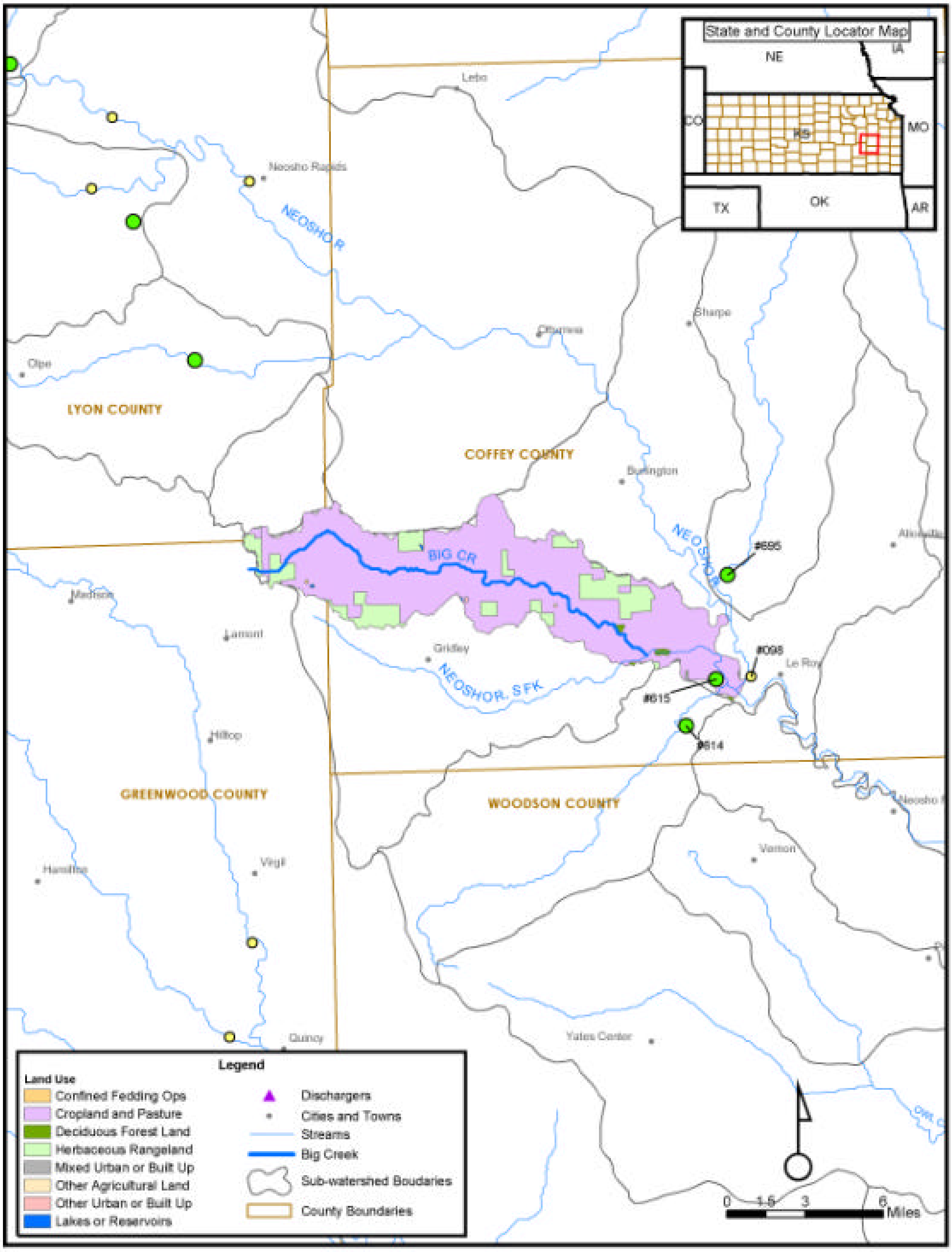
General Watershed Description: The Big Creek watershed lies within Coffey, Greenwood, and Lyon Counties, Kansas, with the majority lying within Coffey County. The Big Creek drainage area is approximately 131 square miles. The watershed's population density is low when compared to densities across the Neosho Basin (6-9 persons per square mile). The rural population projection for Coffey County, for example, through 2020 shows modest growth (17 percent increase). Population statistics for this part of Kansas show generally light densities (for example, all of Coffey County's population in 2000 was 8865). The annual average rainfall in the Big Creek watershed is approximately 32.4 inches (based on data from Topeka, Kansas). Approximately 70 percent of this precipitation falls between April and September. Ten to 18 inches of snow falls in an average winter. Average temperatures vary from 35 degrees Fahrenheit (°F) in the winter to 78°F in the summer.

Land Use. Table 2 shows the general land use categories within the Big Creek watershed derived from USEPA BASINS Version 3.0 land use/land cover data (USGS 1994). Cropland and pastures cover approximately 86 percent of the total acreage in the Big Creek watershed, with rangeland covering approximately 14 percent. **Figure 4** depicts the land use categories that occur within the Big Creek watershed.

Table 2 Land Use Categories

LANDUSE TYPE	Total Acres	% Of Total
CROPLAND AND PASTURE	33,377	86
DECIDUOUS FOREST LAND	157	0.40
HERBACEOUS RANGELAND	5,423	14
MIXED URBAN OR BUILT-UP	24	0.06
OTHER AGRICULTURAL LAND	8	0.02
OTHER URBAN OR BUILT-UP	13	0.03
RESERVOIRS	32	0.08
TOTALS	**39,034**	**100**

Figure 4 Big Creek Watershed Land Use Map

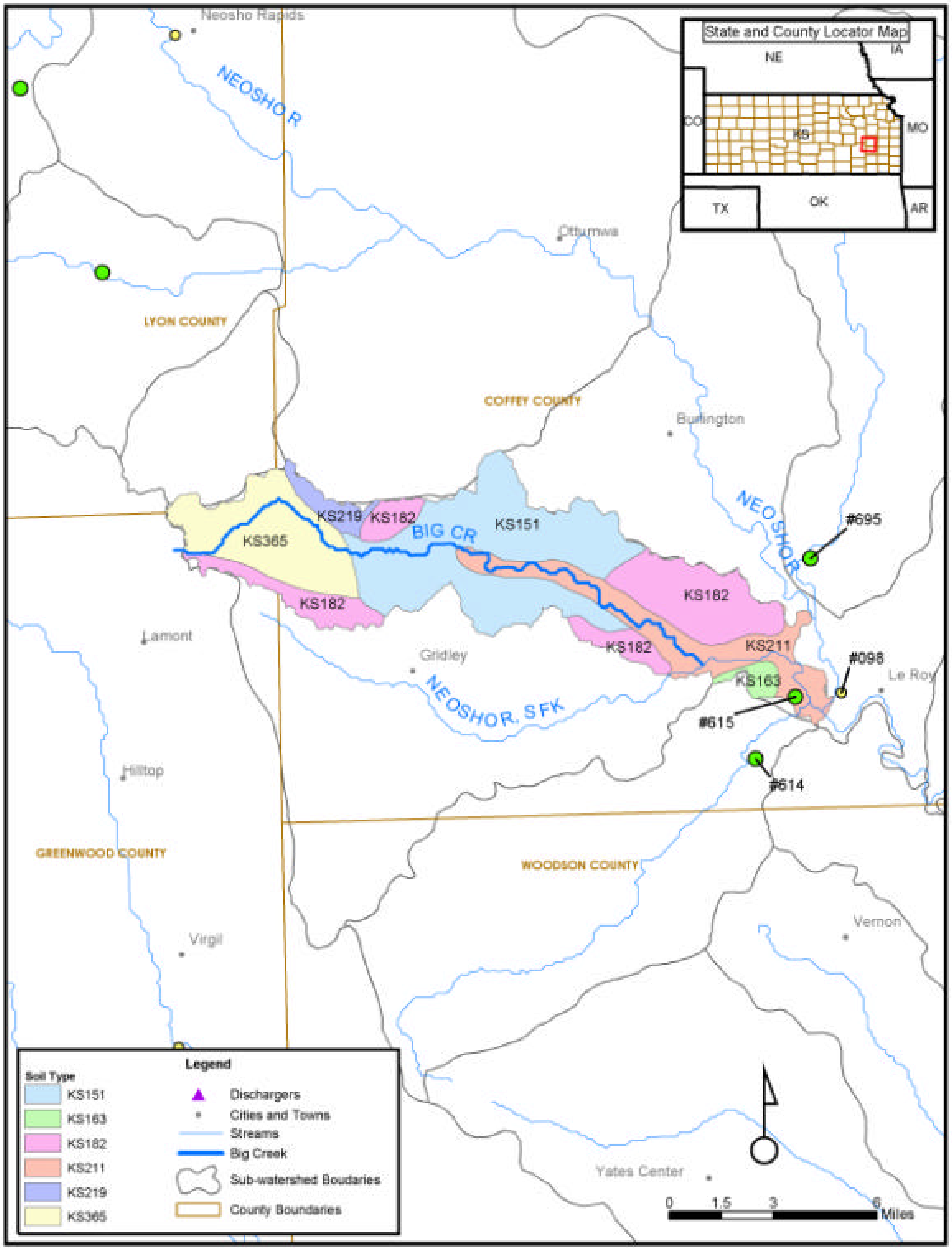


The grazing density estimate is low to average in the watershed when compared to densities elsewhere in the Neosho Basin (28-35 animals per square mile). The Office of Social and Economic Trend and analysis (SETA) (1997) reports about 31,000 combined head of poultry and livestock for all of Coffey County, the predominant county in which the Big Creek watershed is located. Given the small size of the rural population and the limited residential and commercial land use, land development impacts to water quality in Big Creek are expected to be limited.

Soils. Figure 5, derived from STATSGO data, generally represents soils types prevalent throughout the Big Creek watershed. Major soil types throughout the region of the Big Creek Watershed are silty clay loam, clay, and silt loam (Schwarz and Alexander 1995).

No copper data in soil or sediment was found specifically within the Big Creek watershed, but copper soil and sediment data were collected from Pottawatomie County (Whittemore and Switek 1977). In that study, copper concentrations were measured in rocks (two limestones and two shales), soils and stream sediments. The total and acid soluble fraction of copper concentrations found in rocks ranged from 16-34 parts per million (ppm) and 1.6-9.5 ppm, respectively. The total, exchangeable fraction, and acid soluble fraction of copper found in soils ranged from 18-56 ppm, 2.4-3.1 ppm and 5.0-6.8 ppm, respectively. The total, exchangeable fraction and acid soluble fraction of copper found in stream sediments from five locations in Pottawatomie County ranged from 15-28 ppm, 0.4-2 ppm, and 5.1-8.7 ppm, respectively.

Figure 5 Big Creek Watershed Soils Map



Point Source Discharges

One NPDES-permitted wastewater discharger is located within the watershed, the Gridley wastewater treatment plant (MWTP), with a design flow of 0.038 million gallons per day (mgd) (**Table 3**).

Table 3 NPDES Permitted Discharger to Big Creek

DISCHARGING FACILITY	STREAM REACH	SEGMENT	DESIGN FLOW	TYPE
Gridley MWTP	South Big Creek	17	0.059 cfs	Lagoon

The City of Gridley relies on a two-cell lagoon system with 150-day detention times for treatment of its wastewater. The population projection for Gridley to the year 2020 indicates a slight increase. Projections of future water use and resulting wastewater appear to be within the design flows for of the current system's treatment capacity. At Station 615, excursions from the copper WQS appear to occur primarily under runoff conditions or higher flows. Of significance to point sources is the lack of excursions under low flow in all seasons, especially during winter, therefore point sources are not seen as a significant source of copper loading in the watershed. The City of Gridley relies on a two-cell lagoon system with 150-day detention times for treatment of its wastewater.

Examination of the effluent monitoring information of the city of Gridley indicates that no permit limits have been set for copper, and thus no monitoring data were available from this MWTP. There are no NPDES permitted animal feeding operations within the Big Creek Watershed.

Non-point Sources

Non-point sources include those sources that cannot be identified as entering the water body at a specific location. Non-point sources for copper may originate from roads and highways, urban areas or agriculture lands. Some automobile brakepads are a source of copper as are some building products such as plumbing, wiring, and paints (Boulanger and Nikolaidis 2003).

In a University of Connecticut study, Boulanger and Nikolaidis (2003) found elevated concentrations of total copper in runoff from copper roofed areas (ranging from 1,460 µg/L to 3,630 µg/L). They also found moderately high concentrations of total copper in runoff from paved and lawn areas (about 16 µg/L and 20 µg/L, respectively). Automobile brake pad dust containing copper particles, automobile fluid leakage, and fertilizer and pesticide applications were reportedly responsible for the concentrations of copper on the paved and lawn areas. In a similar study conducted at the University of Maryland, Davis *et al*. (2001) found the largest contribution of copper to be from brake emissions (47 percent), building siding (22 percent), and atmospheric deposition (21 percent), with smaller contributions from copper roofing, tires and oil leakage (10 percent). Thus, although these studies suggest that residential, roadway, and commercial land uses may represent non-point pollutant source of copper, given the small proportion of these types of land use that occur in the Big Creek watershed, such copper contributions are assumed to be minimal.

Agricultural sources. The most probable non-point source of copper may be from the extensive amount of agriculture activity that occurs in the watershed. Two operations are registered, certified or permitted within the watershed. These facilities (beef or sheep) are in subwatersheds contributing to the listed main stem or tributaries of Big Creek. NPDES permits, also non-discharging, are issued for facilities with more than 1,000 animals. None of the facilities in the watershed are of this size. Total potential animals for all facilities is 238. Permitted livestock facilities have waste management systems designed to minimize runoff entering their operations or detaining runoff originating from these areas. Such systems are designed to retain the 25 year, 24 hour rainfall/runoff event, as well as an anticipated two weeks of normal wastewater from their operations. Such rainfall events typically coincide with stream flows which are exceeded less than 1 – 5 percent of the time. Requirements for maintaining the water level of the waste lagoons a certain distance below the lagoon berms ensures retention of the runoff from these intense, local storm events. However, no specific data is available on copper concentrations for any of these facilities. Copper sulfate is widely used for treatment and nutrition of livestock, treatment of orchard diseases, and removal of nuisance aquatic vegetation such as fungi and algae.

There are approximately 75,000 cattle in Lyon County (KASS 2002; SETA 1997). Dairy and beef cattle may suffer from various hoof diseases that is typically treated with a copper sulfate hoof bath (Davis 2004 and Ames 1996). Improper disposal of the copper sulfate bath water onto the land could subsequently infiltrate to groundwater and represent a possible nonpoint source of copper in the Big Creek watershed.

According to SETA (1997), there were approximately 6,400 hogs on 31 farms in Lyon County in 1997. It is common practice to feed copper supplements to hogs and to a lesser extent other livestock (Richert 1995). A hog grown to 250 pounds will have released approximately 1.5 tons of copper-containing waste (Richert 1995). Thus, past improper management of this waste may have created a legacy source of copper in the Big Creek watershed.

Soybean crops cover approximately 60,000 acres in Lyon County (SETA 1997). Copper deficiency in soybeans is corrected by application of three to six pounds of copper as copper sulfate per acre (Mengel 1990). In addition, copper-based pesticides are currently the 18th most widely used pesticide in the United States (Avery 2001). Such agricultural applications could therefore represent a nonpoint source of copper to the Big Creek watershed.

Non-point Source Assessment Conclusion

The above discussion concerning nonpoint sources of copper is a qualitative assessment of the potential anthropogenic sources of copper in the Big Creek watershed. It is possible that some copper may originate from automobile brake deposits, building materials, and copper-based pesticides and feed or fertilizers. Due to the relatively low density of human populations in the Big Creek watershed, copper loadings from urban land uses on the impaired portions of Big Creek may be quite limited, while those from agricultural land use may be more substantial.

Naturally occurring copper in soils may constitute a substantial portion of estimated loadings to Big Creek. To calculate the watershed yield for copper, the GWLF model was run to generate the average annual runoff and average annual sediment load discharged to Big Creek. This modeling was conducted based on average sediment copper concentrations derived from several U.S. Geological Survey (USGS) studies of lake and river bottom sediments in Kansas (Juracek and Mau 2002, 2003). The average sediment copper concentrations for this area are approximately 33.5 µg/g (ppm), which are elevated compared to soils in many other parts of the country.

4. ALLOCATION OF POLLUTION REDUCTION RESPONSIBILITY

Following is a discussion of the results of the TMDL process for total copper at Big Creek, and an evaluation of potential sources and responsibility.

TMDL Calculations

Figure 6 is a plot of hardness vs. flow to delineate any potential correlation between these variables in the Big Creek watershed. Although hardness is known to generally be inversely proportional to flow, there is no apparent statistical relationship between these two variables at Big Creek. This evaluation is important because it helps to define the effects of flow on copper bioavailability and toxicity, and in addition provides valuable insight into hydrologic flow conditions for the Big Creek watershed. Because the regression was not found to be statistically significant ($p > 0.05$), the 90 percent LCL value for measured hardness data (145.9 mg $CaCO_3$/L at Big Creek) was used to derive the acute WQS value for copper. This hardness value yielded an acute WQS value of 19.98 µg/L, which was derived to support the TMDL.

Figure 6 Correlation Between Hardness and Flow at Big Creek

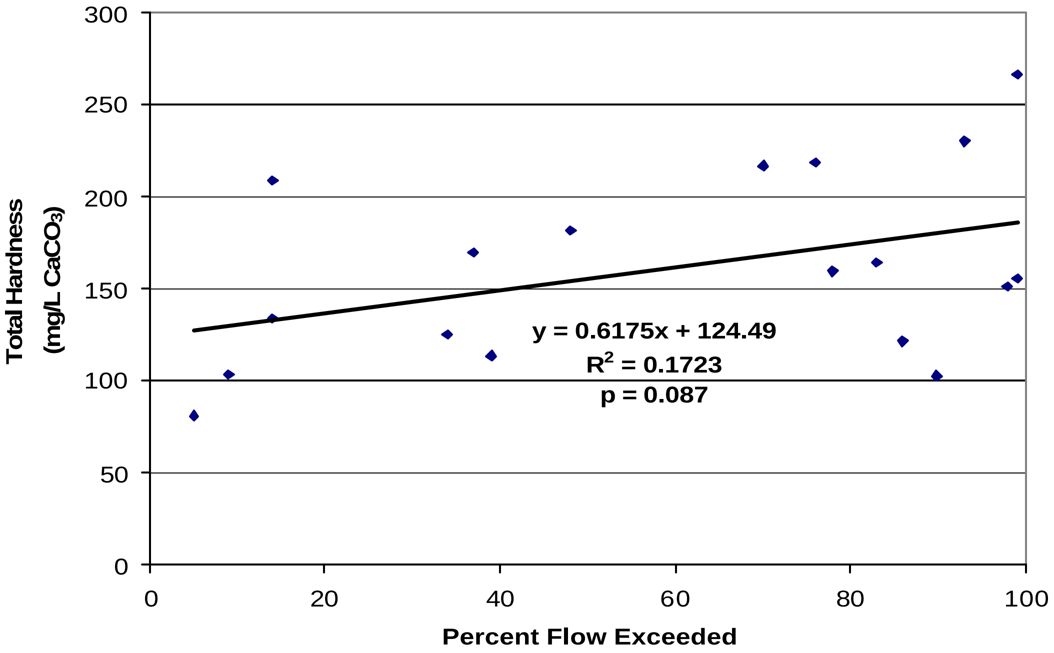
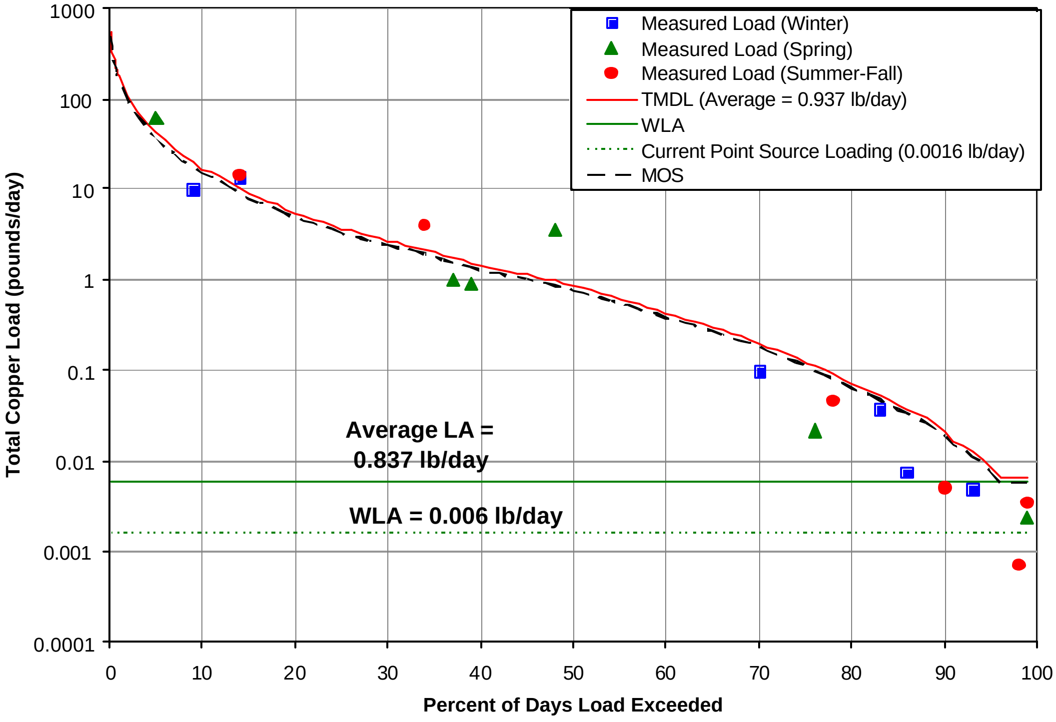


Figure 7 shows the load duration curve depicting the Big Creek TMDL, WLA, LA, and MOS. **Figure 7** also shows measured loading from the KDHE water quality monitoring station as well as estimated current loads. The TMDL was developed using the acute WQS derived using the 90 percent LCL total hardness (approximately 145.9 mg $CaCO_3$/L). The MOS is shown as the dotted line below the TMDL, and the area below the MOS and above the WLA represents the LA in **Figure 7**.

Figure 7 Load Duration Curve Used to Derive TMDL



The calculated average TMDL for total copper in Big Creek was computed as follows:

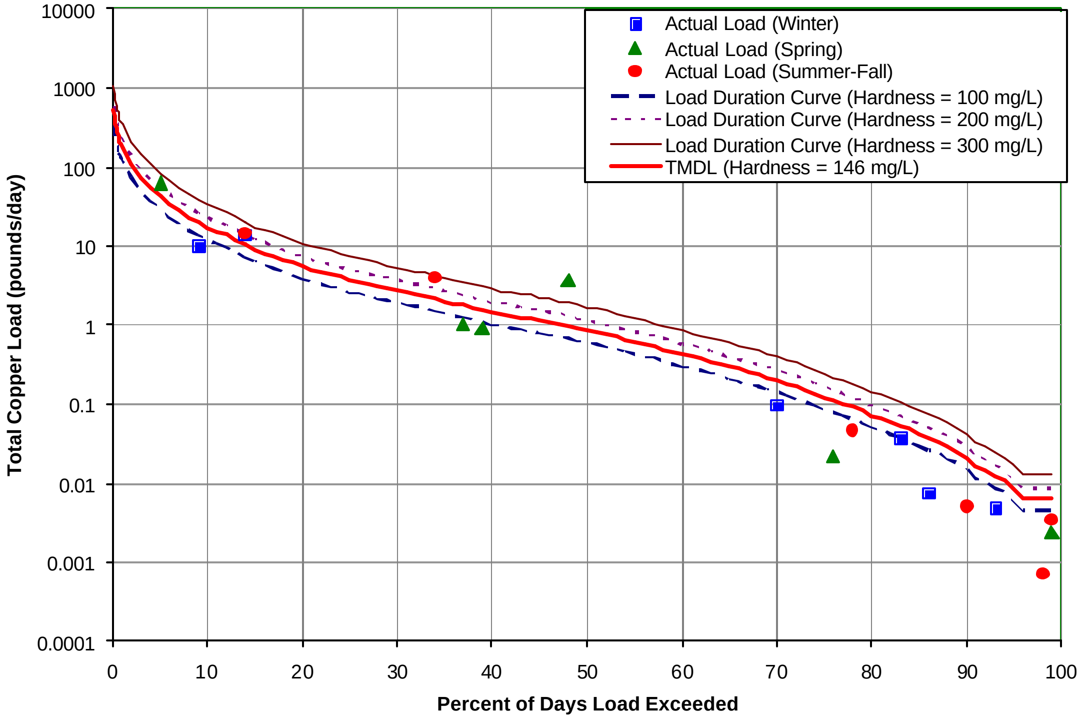
TMDL (0.937 lb/day) = LA (0.837 lb/day) + WLA (0.0057 lb/day) + MOS (0.0937 lb/day)

The current point source loading could be overestimated, especially at low flows (i.e. high percent load exceedance). The estimated point source loading was slightly higher than the observed loading.

Figure 8, which shows more potential WQS exceedances for total copper, compares the historical total copper loading to the load duration curve for three specific hardness values that are representative of typical seasonal variation in Big Creek. **Figure 8** appears to be an effective predictor of potential WQS exceedances in part because three representative hardness ranges are used to estimate total copper loadings to the watershed. No seasonal effects are apparent in either **Figure 7** or **Figure 8**.

Results of normality testing. Results of the normality testing for water hardness data from Big Creek indicated that all data normally distributed, and it was not necessary to log-transform these data to estimate the TMDL. For the data sets used to support all averaged load estimates such as TMDL, LA/WLA, MOS, and load reduction, results of normality testing indicating that these data were not normally distributed, and it was necessary to log-transform the data before the calculations could be completed.

Figure 8 Comparison of Measured total Copper Load by Season to Load Duration Curve at Specific Hardness Values



TMDL Pollutant Allocation and Reductions

Any allocation of wasteloads and loads will be made in terms of total copper reductions. Yet, because copper loadings are a manifestation of multiple factors, the initial pollution load reduction responsibility will be to decrease the total copper inputs over the critical range of flows encountered on the Big Creek system. Allocations relate to the average copper levels seen in the Big Creek system at Station 615 for the critical higher flow conditions. Additional monitoring over time will be needed to further ascertain the relationship between copper reductions of non-point sources, flow conditions, and concentrations within the stream.

In calculating the TMDL the average condition is considered across the seasons to establish goals of the endpoint and desired reductions. Therefore, the target average copper level was multiplied by the average daily flow for Big Creek across all hydrologic conditions. This is represented graphically by the integrated area under the copper load duration curve (**Figures 7 and 8**). The area is segregated into allocated areas assigned to point sources (WLA) and non-point sources (LA). Future increases in wasteloads should be offset by reductions in the loads contributed by non-point sources. This offset, along with appropriate limitations, is expected to eventually eliminate the impairment.

WLA for Big Creek

The WLA for the Big Creek TMDL used the design flow for the single permitted point source discharge (Gridley MWTP), and assumed a generalized copper concentration of 5 µg/L based on a nationwide study of copper discharges in treated wastewater (Tchobanoglous and Burton 1991). The total estimated WLA for the single NPDES discharge is 0.0057 lb/day. **Figure 7** clearly shows that based on the estimated WLA, there appears to be no historical excursions for copper from point sources.

LA for Big Creek

The LA was estimated by filling in the formula:

LA (0.837 lb/day) = TMDL (0.937 lb/day) – MOS (0.0937 lb/day) – WLA (0.0057 lb/day)

This calculation strongly suggests that the majority of copper loading occurs from non-permitted nonpoint discharges, and that the contribution from NPDES point source discharges is by comparison virtually negligible. The load from all non-point sources is contributed from miscellaneous land uses, although the majority of the LA appears to come from soil loading, which may be representative of natural background.

The LA assigns responsibility for maintaining the historical average in-stream copper levels at Station 615 to below acute hardness-dependent WQS values for specific flow exceedance levels. As seen on **Figure 7**, the assimilative capacity for LA equals zero for flows at 0.059 cfs (96 - 99 percent exceedance), since the flow at this condition may be entirely effluent created, and then increases to the TMDL curve with increasing flow beyond 0.06 cfs.

Point Source Load Reduction

Point sources are responsible for maintaining their systems in proper working condition and providing appropriate capacity to handle anticipated wasteloads of their respective populations. NPDES permits will continue to be issued on five year intervals, with inspection and monitoring requirements and conditional limits on the quality of effluent released from these facilities. Ongoing inspections and monitoring of the systems will be made to ensure that minimal contributions have been made by this source.

Based upon the preceding assessment, the only permitted point source discharge is the MWTP from the City of Gridley, which may contribute copper to the Big Creek watershed upstream of Station 615. This discharge was considered in the WLA estimate. The design flow of the discharging point source equals the lowest flows seen at Station 615 (96 - 99 percent flow exceedance), and the WLA equals the TMDL curve across this flow exceedance range (**Figure 7**). No reduction in point source loading is considered necessary under this TMDL.

Non-Point Source Load Reduction

Non-point source is regarded as the primary contributing factor to the occasional total copper excursions in the watershed. The LA is anticipated to be negligible (*i.e.,* equal to zero) for flows at 0.059 cfs, since the flow at this condition may be entirely created by the effluent from the point source discharger. The LA then increases as the TMDL curve increases with higher flow values (**Figure 7**). Sediment control practices such as buffer strips and grassed waterways should help reduce anthropogenic non-point copper loadings under higher flows as well as reduce the sediment transported to the stream that may occur during the critical flow period.

The anticipated average LA source reduction was calculated by subtracting the LA from the GWLF non-point loading estimate. This estimate is 5.18 lb/day, which represents an approximate 86 percent reduction from current non-point loading estimates.

Margin of Safety

Federal regulations [40 CFR §130.7(c)(1)] require that TMDLs take the MOS into consideration. The MOS is a conservative measure incorporated into the TMDL equation that accounts for the uncertainty associated with calculating the allowable copper pollutant loading to ensure water quality standards are attained. USEPA guidance allows for use of implicit or explicit expressions of the MOS, or both. When conservative assumptions are used in development of the TMDL, or conservative factors are used in the calculations, the MOS is implicit. When a specific percentage of the TMDL is set aside to account for uncertainty, then the MOS is considered explicit. This copper TMDL relies on both an implicit and explicit MOS derived from a variety of calculations and assumptions made which are summarized below. The net effect of the TMDL with MOS is that the assimilative capacity of the watershed is slightly reduced.

NPDES permitting procedures used by KDHE are conservative and provide an implicit MOS built into the calculations (*e.g.*,whether or not to allow a mixing zone). As an example, the calculation to determine the permit limit is based on the long term average treatment efficiency based on a 90 percent probability that the discharge will meet the WLA. It is common knowledge that the efficiency of a mechanical MWTP is greater during prolonged dry weather than under wet weather conditions. The log-normal probability distribution curves for treatment plant performance used by USEPA to determine the long-term average takes into account wet weather reduction in efficiency for calculating the 90th percentile discharge concentration of copper (USEPA 1996).

During wet weather periods there would be water flowing in Big Creek, thus reducing the effect of the MWTP discharge. Another conservative assumption is that the WLA calculation uses the design flow rather than actual effluent flows, which are lower.

Uncertainty Discussion

Key assumptions used. Following is a list of operating assumptions utilized to support the calculations due in part to the limited data set:

- The lowest stream flow was adjusted to assure that it would not drop below the design flow of the MWTP discharge.
- Discharged concentration of copper occurred at one-half the analytical detection limit; 5 µg/L is the assumed value.

- Matched flow data for USGS station for Pottawatomie Creek near Garnett (USGS Station 06914000) was used rather than actual flow data for Big Creek.
- 90 percent LCL value for water hardness used to calculate acute WQS for copper.
- Output from GWLF model for non-point source loading was compared to output from land duration curves (LDC) to estimate non-point load reduction.
- Total loading data was not normally distributed and required log-transformation to support the calculations.

The LDC method is used to calculate TMDLs in general because it relies on measured water quality data and paired water hardness data, and a wide range of "flow exceedance" data representing a complete range of flows anticipated at Big Creek. Given the lack of water quality data, GWLF is the most reliable method for deriving current non-point source loading and non-point load reduction because of the large non-point source data base throughout the watershed.

Using measured WQS excursions (Figure 5) to estimate load reduction. Load reduction is defined as the positive difference between the WQS and the measured load (exceedance), and may be estimated from the load exceedances shown on **Figure 5**. However, due to the small number of exceedances from the overall water quality monitoring data, the uncertainty was too large and therefore the GWLF model load estimate was preferable and was used instead.

Comparing GWLF output with LDC TMDL. It is possible to compare the non-point loads for copper using the GWLF and LDC methods. The three basic differences between the GWLF and LDC approaches to making these estimates are: (1) GWLF output is based on watershed precipitation data calibrated to flow rather than measured flow data and therefore results would not be expected to be completely consistent between the two methods; (2) the GWLF algorithms more completely account for copper loadings (including natural background concentrations of copper in soil) because GWLF estimates the total amount of sediment loading from the watershed to the receiving water; and (3) the ambient water quality data used to develop the LDC only accounts for the portion of copper detected in the water column and does not take into account copper loading from the watershed that resides in the bed load. Due to these factors, it is anticipated that the sediment and copper loads estimated using the GWLF model would be somewhat higher than estimates derived using the LDC method.

Seasonal Variability

Federal regulations [40 CFR §130.7(c)(1)] require that TMDLs take into consideration seasonal variability in applicable standards. Because the acute WQS for copper applies year around and because the observed WQS excursions occurred during several seasons of the year, seasonal variability is not expected to be a controlling factor within this TMDL.

State Water Plan Implementation Priority: Because the copper impairment is due to natural contributions, this TMDL will be a Low Priority for implementation.

Unified Watershed Assessment Priority Ranking: This watershed lies within the Upper Neosho Basin (HUC 8: 11070204) with a priority ranking of 20 (High Priority for restoration).

Priority HUC 11s and Stream Segments: Because the natural background affects the entire watershed, no priority subwatersheds or stream segments will be identified.

5. IMPLEMENTATION

Copper containing chemicals are used extensively in agriculture. Copper sulfate is probably the most common chemical used in the area. Copper sulfate is used as a feeding supplement or dip for hogs, cattle, and other farm animal. It is also is used to clear ponds and irrigation canals of algae.

Desired Implementation Activities

1. Identify sources of copper in stormwater runoff.
2. Install grass buffer strips where needed along streams.
3. Educate users of copper-containing chemicals concerning possible pollution problems

Implementation Programs Guidance

Non-Point Source Pollution Technical Assistance – KDHE

- Support Section 319 demonstration projects for pollution reduction from livestock operations in watershed.
- Provide technical assistance on practices geared to small livestock operations which minimize impact to stream resources.
- Investigate federal programs such as the Environmental Quality Improvement Program, which are dedicated to priority subbasins through the Unified Watershed Assessment, to priority stream segments identified by this TMDL.

Water Resource Cost Share & Non-Point Source Pollution Control Programs – SCC

- Install livestock waste management systems for manure storage.
- Implement manure management plans.
- Coordinate with USDA/NRCS Environmental Quality Improvement Program in providing educational, technical and financial assistance to agricultural producers.

Riparian Protection Program – SCC

- Develop riparian restoration projects along targeted stream segments, especially those areas with baseflow.
- Design winter feeding areas away from streams.

Buffer Initiative Program – SCC

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

Extension Outreach and Technical Assistance - Kansas State University

- Educate livestock producers on riparian and waste management techniques.
- Educate chemical and herbicide users on proper application rates and timing.
- Provide technical assistance on livestock waste management design.
- Continue Section 319 demonstration projects on livestock management.

Agricultural Outreach – KDA

- Provide information on livestock management to commodity advocacy groups.
- Support Kansas State outreach efforts.

Timeframe for Implementation: Continued monitoring over the years from 2002 to 2007.

Targeted Participants: Primary participants for implementation will be the landowners immediately adjacent to Big Creek that use copper-containing chemicals. Some inventory of copper uses should be conducted in 2005-2006 to identify such activities. Such an inventory would be done by local program managers with appropriate assistance by commodity representatives and state program staff in order to direct state assistance programs to the principal activities influencing the quality of the streams in the watershed during the implementation period of this TMDL.

Milestone for 2007: The year 2007 marks the midpoint of the ten-year implementation window for the watershed. At that point in time, sampled data from the Big Creek watershed should indicate no evidence of increasing copper levels relative to the conditions seen in 1993-2001. Should the case of impairment remain, source assessment, allocation and implementation activities will ensue.

Delivery Agents: The primary delivery agents for program participation will be the Kansas Department of Health and Environment and the State Conservation Commission.

Reasonable Assurances:

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

1. K.S.A. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.

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

3. K.S.A. 75-5657 empowers the State Conservation Commission to provide financial

assistance for local project work plans developed to control nonpoint source pollution.

4. 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.

5. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the *Kansas Water Plan.*

6. The *Kansas Water Plan* and the Neosho Basin Plan provide the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority in implementation.

Funding: The State Water Plan Fund, 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 watersheds 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 a Low Priority consideration.

Effectiveness: Buffer strips are touted as a means to filter sediment before it reaches a stream and riparian restoration projects have been acclaimed as a significant means of stream bank stabilization. The key to effectiveness is participation within a finite subwatershed to direct resources to the activities influencing water quality. The milestones established under this TMDL are intended to gauge the level of participation in those programs implementing this TMDL.

With respect to copper, should participation significantly lag below expectations over the next five years or monitoring indicates lack of progress in improving water quality conditions, the state may employ more stringent conditions on agricultural producers and urban runoff in the watershed in order to meet the desired copper endpoint expressed in this TMDL. The state has the authority to impose conditions on activities with a significant potential to pollute the waters of the state under K.S.A. 65-171. If overall water quality conditions in the watershed deteriorate, a Critical Water Quality Management Area may be proposed for the watershed.

6. MONITORING

KDHE will continue to collect bimonthly samples at rotational Station 615 in 2004 and 2008 including total copper samples in order to assess progress and success in implementing this TMDL. Should impaired status remain, the desired endpoints under this TMDL may be refined and more intensive sampling may need to be conducted under higher flow conditions between the period 2007-2011. Use of the real time flow data available at the Big Creek near LeRoy stream gaging station, or other appropriate station, can help direct these sampling efforts. Also, use of USEPA Method 1669 - Sampling Ambient Water for Trace Metals at USEPA Water Quality Criteria Levels for ultra-clean copper sampling and analysis could help to further define potentially bioavailable and toxic forms of copper occurring in the subwatershed.

7. FEEDBACK

Public Meetings: Public meetings to discuss TMDLs in the Neosho Basin were held January 9, 2002 in Burlington, March 4, 2002 in Council Grove, and July 30, 2004 in Marion. An active Internet Web site was established at http://www.kdhe.state.ks.us/tmdl/ to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Neosho Basin.

Public Hearing: Public Hearings on the TMDLs of the Neosho Basin were held in Burlington and Parsons on June 3, 2002.

Basin Advisory Committee: The Neosho Basin Advisory Committee met to discuss the TMDLs in the basin on October 2, 2001, January 9, March 4, and June 3, 2002.

Discussion with Interest Groups: Meetings to discuss TMDLs with interest groups include:

Kansas Farm Bureau: February 26 in Parsons and February 27 in Council Grove

Milestone Evaluation: In 2007, evaluation will be made as to the degree of implementation that has occurred within the watershed and current condition of the Big Creek watershed. Subsequent decisions will be made regarding the implementation approach and follow up of additional implementation in the watershed.

Consideration for 303(d) Delisting: The wetland will be evaluated for delisting under Section 303(d), based on the monitoring data over the period 2007-2011. Therefore, the decision for delisting will come about in the preparation of the 2012 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 the Kansas Water Planning Process: Under the current version of the Continuing Planning Process, the next anticipated revision will come in 2003 that will emphasize revision of the Water Quality Management Plan. At that time, incorporation of this TMDL will be made into both documents. Recommendations of this TMDL will be considered in *Kansas Water Plan* implementation decisions under the State Water Planning Process for Fiscal Years 2003-2007.

References

Ames 1996. *Hairy Heel Warts, Foot Rot, Founder: The Enemies*, N. Kent Ames, DVM, Michigan Dairy Review, May 1996, Veterinary Extension, Michigan State University.

Avery 2001. Nature's Toxic Tools: The Organic Myth of Pesticide-Free Farming, Alex A. Avery, Cinter for Global Food Issues, Hudson Institute, Churchville, Virginia.

Boulanger, Bryan and Nikolaos P. Nikolaidis. 2003. Mobility and Aquatic Toxicity of Copper in an Urban Watershed. Journal of the American Water Resources Association. 39(2):325-336.

Davis 2004. *From the Ground Up Agronomy News*, Jassica Davis and Bill Wailes, November-December 2001, Volume 21, Issue 6, Cooperative Extension, Colorado State University.

Davis, Allen, P. Mohammad Shokouhian, and Shubei Ni. 2001. Loading estimates of Lead, Cooper, Cadmium, and Zinc in Urban Runoff from Specific Sources. CHEMOSPHERE. 44(2001)997-1009.

Haith, D. A., R. Mandel, and R. S. Wu. 1996. GWLF: Generalized Watershed Loading Functions, Version 2.0, User's Manual. Department of Agricultural & Biological Engineering. Cornell University, Ithaca, NY.

Juracek, K. E. and D. P. Mau. 2002. Sediment Deposition and Occurrence of Selected Nutrients and Other Chemical Constituents in Bottom Sediment, Tuttle Creek Lake, Northeast Kansas, 1962-99. Water-Resources Investigations Report 02-4048. USGS. Lawrence, Kansas.

Juracek, K. E. and D. P. Mau. 2003. Sediment Deposition and Occurrence of Selected Nutrients, Other Chemical Constituents, and Diatoms in Bottom Sediment, Perry Lake, Northeast Kansas, 1969-2001. Water-Resources Investigations Report 03-4025. USGS. Lawrence, Kansas.

KASS 2002. *Kansas Farm Facts 2002 County Profiles: Agricultural Statistics and Rankings for 2002*, Kansas Agricultural Statistics Service, Kansas Department of Agriculture, U.S. Department of Agriculture

KDHE. 2002a. Kansas Water Quality Assessment 305(b) Report. Kansas Department of Health and Environment, Division of Environment. April 1, 2002.

KDHE. 2002b. Methodology for the Evaluation and Development of the 2002 Section 303(d) List of Impaired Water Bodies for Kansas. Kansas Department of Health and Environment, Watershed Planning Section. September 5, 2002.

KDHE. 2003. Kansas Administrative Regulations (KAR). Current Water Quality Standards KAR 28-16-28b through 28-16-28f.

Mau, D.P. 2004. Sediment Deposition and Trends and Transport of Phosphorus and Other Chemical Constituents, Cheney Reservoir Watershed, South-Central Kansas.

U.S. Geological Survey, Water-Resources Investigations Report 01-4085. http://ks.water.usgs.gov/kansas/pubs/reports .

Mengel 1990. *Role Of Micronutrients In Efficient Crop Production*, David B. Mengel, Agronomy Guide, Purdue University Cooperative Extension Service, West Lafayette, Indiana.

Richert 1995. Assessing Producer Awareness of the Impact of Swine Production on the Environment, Brian T. Richert, Mike D. Tokach, Robert D. Goodband, Jim Nelssen, August 1995, Journal of Extension, Volume 33 Number 4, Kansas State University, Manhattan, Kansas.

Schwarz, G.E., and R.B. Alexander. 1995. State Soil Geographic (STATSGO) Data Base for the Conterminous United States. U.S. Geological Survey, Reston, VA.

SETA (Office of Social and Economic Trend Analysis). 1997. Census of Agriculture for Lyon County, Kansas. http://www.seta.iastate.edu/agcensus.aspx?state=KS&fips=20111

Tchobanoglous, George and Franklin L. Burton 1991. *Wastewater Engineering, Treatment, Disposal, and Reuse*. Metcalf & Eddy, Inc. 3rd Ed. New York. McGraw-Hill, Inc.

USEPA 2003. Guidance for 2004 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d) and 305*(b) of the Clean Water Act; TMDL-01-03. Memorandum from Diane Regas, Director, Office of Wetlands, Oceans, and Watersheds, July 21, 2003.

USGS. 2001. Water Resources of the United States. NWIS web online hydrologic data: http://water.usgs.gov.

USGS. 1994 Land Use/Land Cover Data. http://edcwww.cr.usgs.gov/products/landcover/lulc.html

USGS. 2004. Estimated Flow Duration Curves for Selected Ungaged Sites in Kansas. Water Resources Investigations Report: No. 01-4142. http://ks.water.usgs.gov/Kansas/pubs/reports/wir.01-4142.html#HDR14

Whittemore, D.O. and Switek, J., 1977. Geochemical controls on trace element concentrations in natural waters of a proposed coal ash landfill site: Kansas Water Resources Research Institute, Contribution no. 188, Manhattan, KS, 76 p.

APPENDIX A
WATER QUALITY DATA

Table A-1: Data Used to Generate the Flow Duration Curve

P	Flow (cfs)	
	6914000	7182710
99	0.01	0.06
99	0.01	0.06
98	0.03	0.06
97	0.05	0.06
96	0.08	0.06
95	0.10	0.08
94	0.12	0.10
93	0.14	0.11
92	0.16	0.14
91	0.18	0.15
90	0.20	0.20
89	0.24	0.23
88	0.28	0.27
87	0.32	0.31
86	0.36	0.34
85	0.40	0.38
84	0.50	0.43
83	0.60	0.49
82	0.70	0.54
81	0.80	0.60
80	0.90	0.66
79	1.16	0.75
78	1.42	0.84
77	1.68	0.93
76	1.94	1.02
75	2.20	1.11
74	2.58	1.26
73	2.96	1.40
72	3.34	1.55
71	3.72	1.69
70	4.10	1.83
69	4.68	2.02
68	5.26	2.20
67	5.84	2.38
66	6.42	2.57
65	7.00	2.75
64	7.96	2.99
63	8.92	3.22
62	9.88	3.46
61	10.84	3.69
60	11.80	3.93
59	13.08	4.27
58	14.36	4.61
57	15.64	4.95
56	16.92	5.29
55	18.20	5.63

P	**Flow (cfs)**	
	6914000	**7182710**
54	19.76	6.08
53	21.32	6.52
52	22.88	6.97
51	24.44	7.41
50	26.00	7.86
49	27.86	8.38
48	29.72	8.91
47	31.58	9.43
46	33.44	9.96
45	35.30	10.48
44	37.58	11.00
43	39.86	11.53
42	42.14	12.05
41	44.42	12.58
40	46.70	13.10
39	49.30	14.15
38	51.90	15.20
37	54.50	16.24
36	57.10	17.29
35	59.70	18.34
34	63.84	19.65
33	67.98	20.96
32	72.12	22.27
31	76.26	23.58
30	80.40	24.89
29	85.98	26.72
28	91.56	28.56
27	97.14	30.39
26	102.72	32.23
25	108.30	34.06
24	116.54	37.20
23	124.78	40.35
22	133.02	43.49
21	141.26	46.64
20	149.50	49.78
19	167.00	56.07
18	184.50	62.36
17	202.00	68.64
16	219.50	74.93
15	237.00	81.22
14	281.62	96.42
14	281.62	96.42
13	326.24	111.61
12	370.86	126.81
11	415.48	142.00
10	460.10	157.20
9	613.50	180.78
8	766.90	209.60

P	**Flow (cfs)**	
	6914000	**7182710**
7	920.30	255.45
6	1073.70	314.40
5	1227.10	393.00
4	2062.83	497.80
3	2898.55	668.10
2	3734.28	982.50
1	4570.00	1624.40
0.9	-	1729.20
0.8	-	1860.20
0.7	-	2017.40
0.6	-	2227.00
0.5	-	2489.00
0.4	-	2751.00
0.3	-	3144.00
0.2	-	3930.00
0.1	-	4978.00

Notes: - indicates data not available

Source: USGS 2001

Table A-2: Water Quality Data for Station 615 and Matched Flow Data Used to Support the Load Duration Curve

Collection Date	Flow (cfs)	Copper Concentration (ug/L)	Hardness (mg/L $CaCO_3$)	Acute WQS (ug/L)
2/12/1992	0.64	14.0	164.00	22.31
4/15/1992	29	75.0	182.00	24.61
6/10/1992	1560	29.0	81.00	11.48
8/5/1992	65	37.0	125.00	17.27
10/7/1992	1.4	10.0	159.00	21.67
12/9/1992	266	26.0	209.00	28.04
2/21/1996	0.15	7.9	229.95	30.68
4/17/1996	0	7.4	266.22	35.22
6/19/1996	48	11.9	113.54	15.78
8/14/1996	0	10.7	155.57	21.23
10/9/1996	300	27.7	133.88	18.43
12/4/1996	568	10.2	103.65	14.48
1/31/2000	4	9.7	217.19	29.07
4/3/2000	55	11.4	169.76	23.05
6/5/2000	1.9	3.9	218.62	29.25
8/7/2000	0.21	4.7	102.41	14.32
10/2/2000	0.03	2.2	151.09	20.65
11/27/2000	0.37	4.0	120.90	16.74

APPENDIX B
INPUT AND OUTPUT DATA FOR GWLF MODEL

Big Creek Input

TRANSPRT DATA

LAND USE	AREA(ha)	CURVE NO	KLSCP
CROPLAND AND PASTURE	13503.	82.0	0.02000
DECIDUOUS FOREST LAND	64.	77.0	0.02000
HERBACEOUS RANGELAND	2195.	78.0	0.02000
OTHER AGRICULTURAL LAND	7.	86.0	0.02000
RESERVOIRS	13.	0.0	0.00000
MXD URBAN OR BUILT-UP	15.	98.0	0.02000

MONTH	ET CV()	DAY HRS	GROW. SEASON	EROS. COEF
JAN	0.500	9.7	0	.2
FEB	0.500	10.6	0	.2
MAR	0.500	11.8	0	.2
APR	0.500	13	0	.2
MAY	0.500	14	1	.3
JUNE	0.700	14.5	1	.3
JULY	0.700	14.3	1	.3
AUG	0.700	13.4	1	.3
SEPT	0.700	12.2	1	.3
OCT	0.700	11	1	.3
NOV	0.500	10	0	.2
DEC	0.500	9.4	0	.2

ANTECEDENT RAIN+MELT FOR DAY -1 TO DAY -5

0 0 0 0 0

INITIAL UNSATURATED STORAGE (cm) = 10

INITIAL SATURATED STORAGE (cm) = 0

RECESSION COEFFICIENT (1/day) = .01

SEEPAGE COEFFICIENT (1/day) = 0

INITIAL SNOW (cm water) = 0

SEDIMENT DELIVERY RATIO = 0.065

UNSAT AVAIL WATER CAPACITY (cm) = 10

Big Creek Output

```
YEAR   PRECIP       EVAPOTRANS   GR.WAT.FLOW      RUNOFF      STREAMFLOW

-------------------------------------------------------------(cm)--------------------------------------------

 1          88.2             42.3             33.7            7.6              41.3
 2          69.6             42.9             22.9            3.7              26.6
 3          108.5            47.5              41.0           17.0             57.9
 4          70.8             41.0             31.1            4.0              35.1
 5          74.8             41.1             20.1            11.4             31.5
```

```
YEAR        EROSION          SEDIMENT

------------------(1000 Mg)------------------

 1          117.9            7.7
 2          107.0            7.0
 3          191.5            12.4
 4          100.2            6.5
 5          132.8            8.6
```