NEOSHO BASIN TOTAL MAXIMUM DAILY LOAD
Water Body/ Assessment Unit: Eagle Creek
Water Quality Impairment: Copper

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Neosho Headwaters

Counties: Lyon, Coffey and Greenwood

HUC 8: 11070201

HUC 11 (HUC 14s)**:** 040 (030, 040 and 050)

Drainage Area: 113.6 square miles

Main Stem Segments: 25 (Eagle Creek) starting at confluence with the Neosho River and upstream to headwaters in south-central Lyon County (**Figure 1**).

Tributary Segments: South Eagle Creek (47)
Fourmile Creek (48)

Designated Uses: Expected Aquatic Life Support, Secondary Contact Recreation, and Food Procurement.

2002 303(d) Listing: Category 5: Predominant Non-point Source Impacts

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).

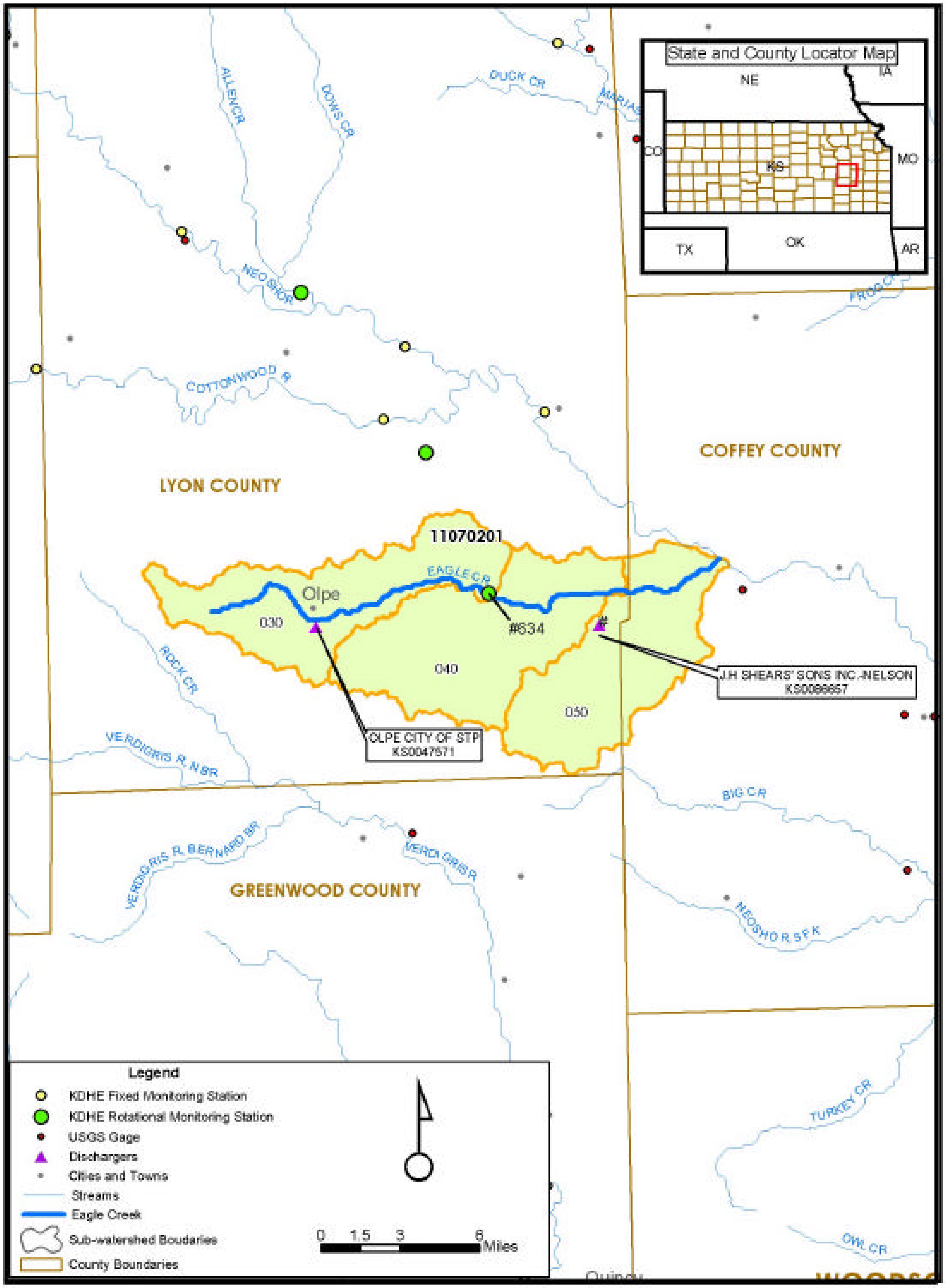
2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

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

Monitoring Site: Station 634

Period of Record Used for Monitoring and Modeling: January 1993 through July 2001 for Station 634. Generalized Watershed Loading Function (GWLF) modeling period for soil data is 1998 – 2002.

Figure 1 Eagle Creek Location Map



Flow Record: Pottawatomie Creek near Garnett (USGS Station 06914000) match to Big Creek near LeRoy (USGS 07182710) whose runoff was proportioned to Eagle Creek near Olpe. 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.

Long Term Flow Conditions: 10 percent Exceedance Flows = 43.7 cfs**,** 95% = 0.167 cfs

Critical Condition: All season; wet weather in particular

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

Summary of Current Conditions:

Estimated Average Non-Point Load of Copper from Sediment: **5.533 lb/day** (2,020 lb/yr)
(derived from GWLF annual estimate of sediment loading)

Estimated Point Source Load: **0.0045 lb/day**
(assumed copper concentration multiplied by Olpe MWTP design flow [0.1671 cfs])

Estimated Total Current Load: **5.538 lb/day**
(estimated non-point copper load from sediment (GWLF) + estimated point source load)

Summary of TMDL Results:

Average TMDL: **0.467 lb/day**

Waste Load Allocation (WLA): **0.0285 lb/day**
(Olpe Wastewater Treatment Plant MWTP)

Average Load Allocation (LA): **0.392 lb/day**
(Average LA = average TMDL – WLA – average MOS; see **Figure 7** for LA at specific flow exceedance ranges)

Average Margin of Safety (MOS): **0.047 lb/day**

TMDL Source Reduction:

WLA Sources (MWTP): No reduction necessary

Non-Point: **5.141 lb/day** (93%)
(equal to TMDL reduction)

GWLF Modeling for Generating Load Estimates

Existing non-point source loads of copper to Eagle Creek were estimated using the 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 Eagle 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 SCS and USGS (*e.g.*, Juracek and Mau 2002, 2003). For modeling purposes, Eagle Creek was divided into several subwatersheds. The model was run for each subwatershed separately 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 B**. 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 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 B**). 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. 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 in the ambient sampling to determine the particulate portion of the ambient total copper results that are attributable to copper in suspended sediments.

The remainder of the ambient total copper sampling results are, therefore, dissolved copper concentrations.

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 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. Ambient water quality data from the KDHE rotational sampling Station 634 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 in 1993, 1997, and 2001, from Station 634 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% (low flow) range.

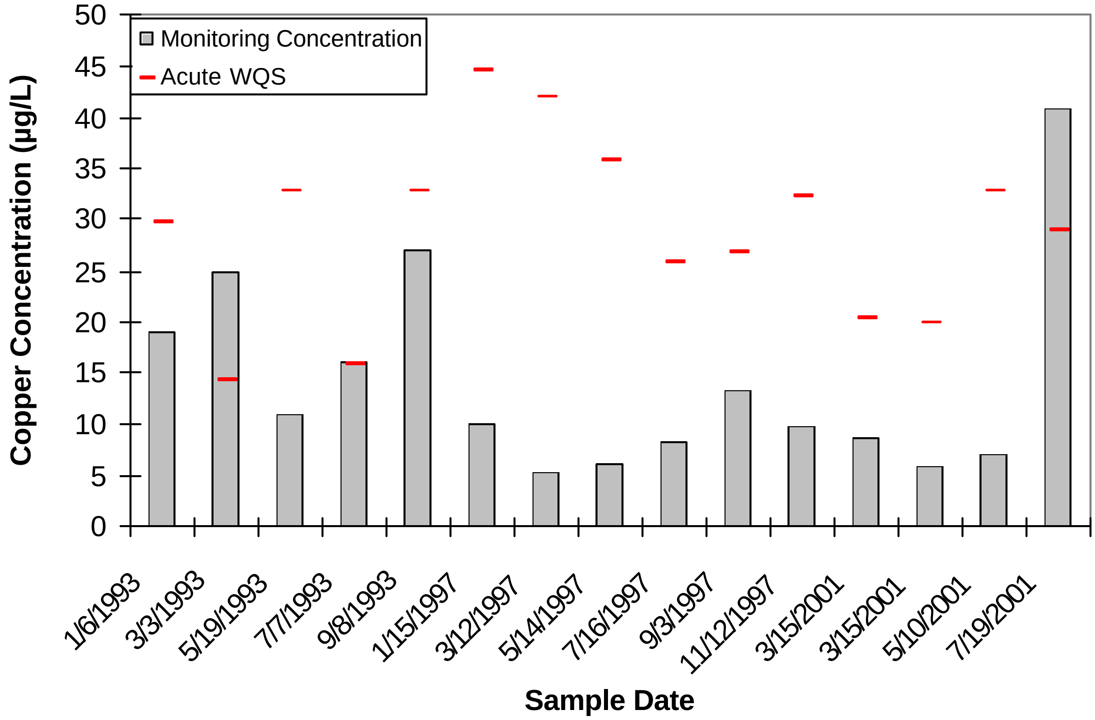
From **Table 1**, a total of three acute WQS excursions for total copper were observed (of 15 samples collected) during rotational monitoring, consisting of one during March 1993, one during July 1993, and one during July 2001. It is difficult to discern whether significant differences occurred between each of the seasons evaluated due, in part, to the small number of samples, although the majority of exceedances (2 of 3) occurred during very high springtime flows. These three exceedances account for the impaired water body designation and inclusion 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						Cumulative
Station	**Season**	**0 to 10%**	**10 to 25%**	**25 to 50%**	**50 to 75%**	**75 to 90%**	**90 to 100%**	**Frequency**
Eagle	Spring	1	0	0	1	0	0	2/6 (33.3%)
Creek	Summer-Fall	0	0	0	0	0	0	0/2 (0%)
(634)	Winter	1	0	0	0	0	0	1/7 (14.3%)

Figure 2 compares KDHE measured copper concentrations with paired hardness-specific acute WQS values for total copper. As can be seen in **Figure 2**, a total of three exceedances were measured out of 15 samples taken, consisting of two during 1993 and one, most recently, during July 2001.

Figure 2 Comparison of Total Copper Concentrations with Paired Hardness-Specific Acute WQS for Monitoring Station 634

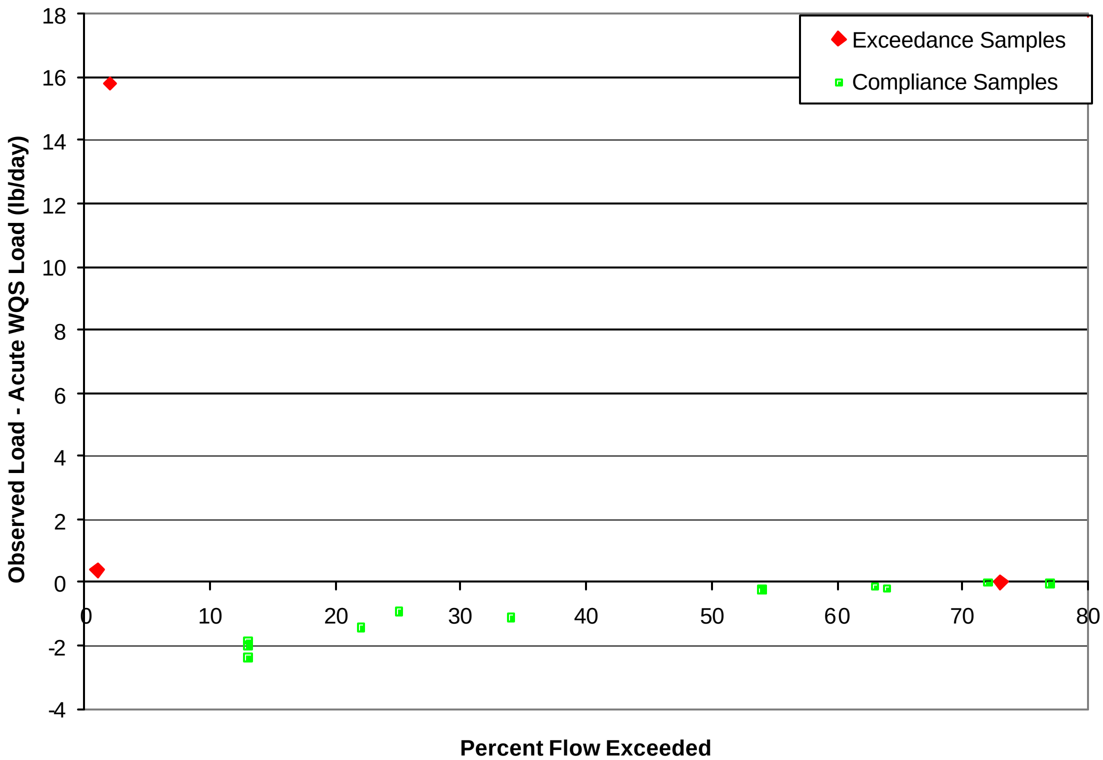


Estimated Eagle Creek flow data for the associated sample date were used to estimate both the observed load and the acute WQS load (**Figure 3**). Measured copper concentration and the paired hardness-specific WQS were used to calculate the observed load and the assimilative capacity based on the acute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

Compliance with chronic WQS for copper. This document does not address compliance with the chronic copper toxicity because representative data for chronic conditions did not support a 2002 303(d) listing for Eagle Creek; the listing was based on exceedences of the acute criteria. However, a brief analysis was also conducted to generally evaluate 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) 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 Eagle Creek, the CV for the copper concentrations was greater than 0.3 (0.73), 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. Excursions were observed at various flows, including those believed to be associated with both point and non-point sources of copper inputs. Only three excursions were observed, which occurred at 1 percent, 2 percent, and 73 percent flow exceedance, respectively. This suggests that excursions only occur at high and somewhat medium flow, with no excursions observed in low flow conditions. This observation, therefore, suggests that loading occurs from non-point sources. It was not necessary to demonstrate stable hydrologic conditions because only transient (acute) excursions were considered in this comparison.

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 634 over 2007 – 2011

The KDHE 2002 303(d) list identifies the aquatic life use of Eagle Creek as impaired as a result of copper exceedances; accordingly, Eagle Creek was targeted for TMDL development. 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 is calculated using the hardness-dependent equation (KDHE 2003):

acute criterion (WQS) = WER[EXP[(0.9422*(LN(hardness)))-1.700]]

The desired endpoint of the Eagle Creek TMDL is for total copper concentrations attributed to identified potential sources of copper in the watershed remain below the acute WQS in the stream. This desired endpoint should improve water quality in the creek at both low and high flows, although WQS exceedances at Eagle Creek generally occurred during periods of high flow. Seasonal variation is accounted for by this 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. Achievement of this endpoint is expected to provide full support of the aquatic life function of the creek and attain the acute WQS for copper.

3. SOURCE INVENTORY AND ASSESSMENT

General Watershed Description: The Eagle Creek watershed lies within Lyon, Greenwood, and Coffey Counties, although most of the watershed and drainage area, consisting of approximately 113 square miles, lies within Lyon County. The watershed's population density is low to average when compared to densities across the Neosho Basin (8-19 persons per square mile). The rural population projection for Lyon County through 2020 shows slight to modest growth (8 percent increase). Lyon County had a population of 26,928 in 1960 and a population of 35,935 in 2000. The annual average rainfall in the Eagle 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 fall in an average winter. Average temperatures vary from 35 degrees Fahrenheit (°F) in the winter to 78°F in the summer.

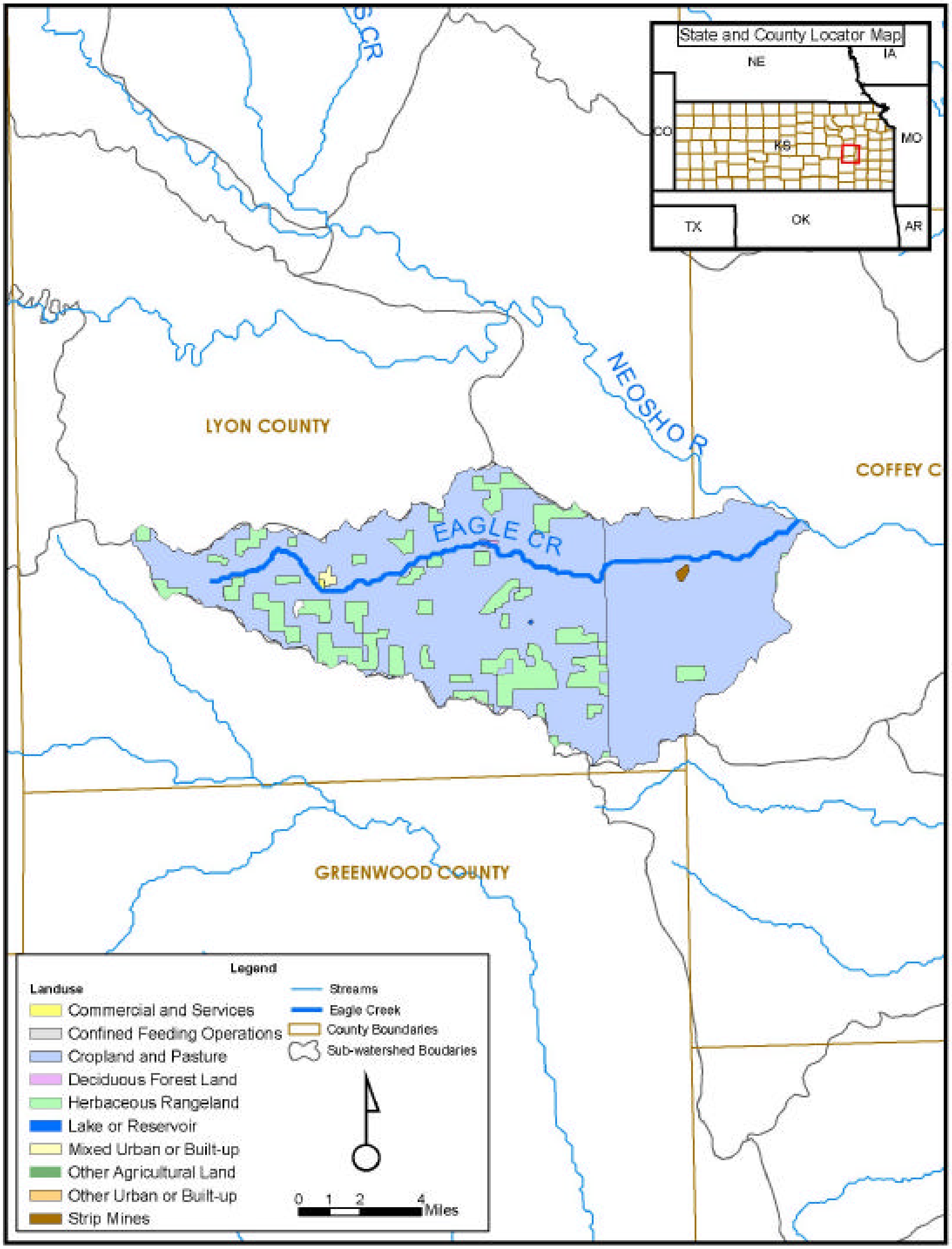
Land Use. **Table 2** shows the general land use categories within the Eagle Creek watershed derived from USEPA BASINS Version 3.0 data (USGS 1994). **Figure 4** depicts the land use categories that occur within the Eagle Creek watershed. Most of the watershed is harvested cropland and pasture. Most of the riparian corridor traverses through cropland and pastureland, and there is an insignificant amount of commercial or developed land in the watershed. Given the small size of the rural population and the limited residential and commercial land use, land development impacts to water quality in Eagle Creek are generally limited.

Table 2 Land Use Categories

LANDUSE TYPE	Total Acres	% of Total
CROPLAND AND PASTURE	62,871	85
DECIDUOUS FOREST LAND	80	0.11
HERBACEOUS RANGELAND	10,414	14

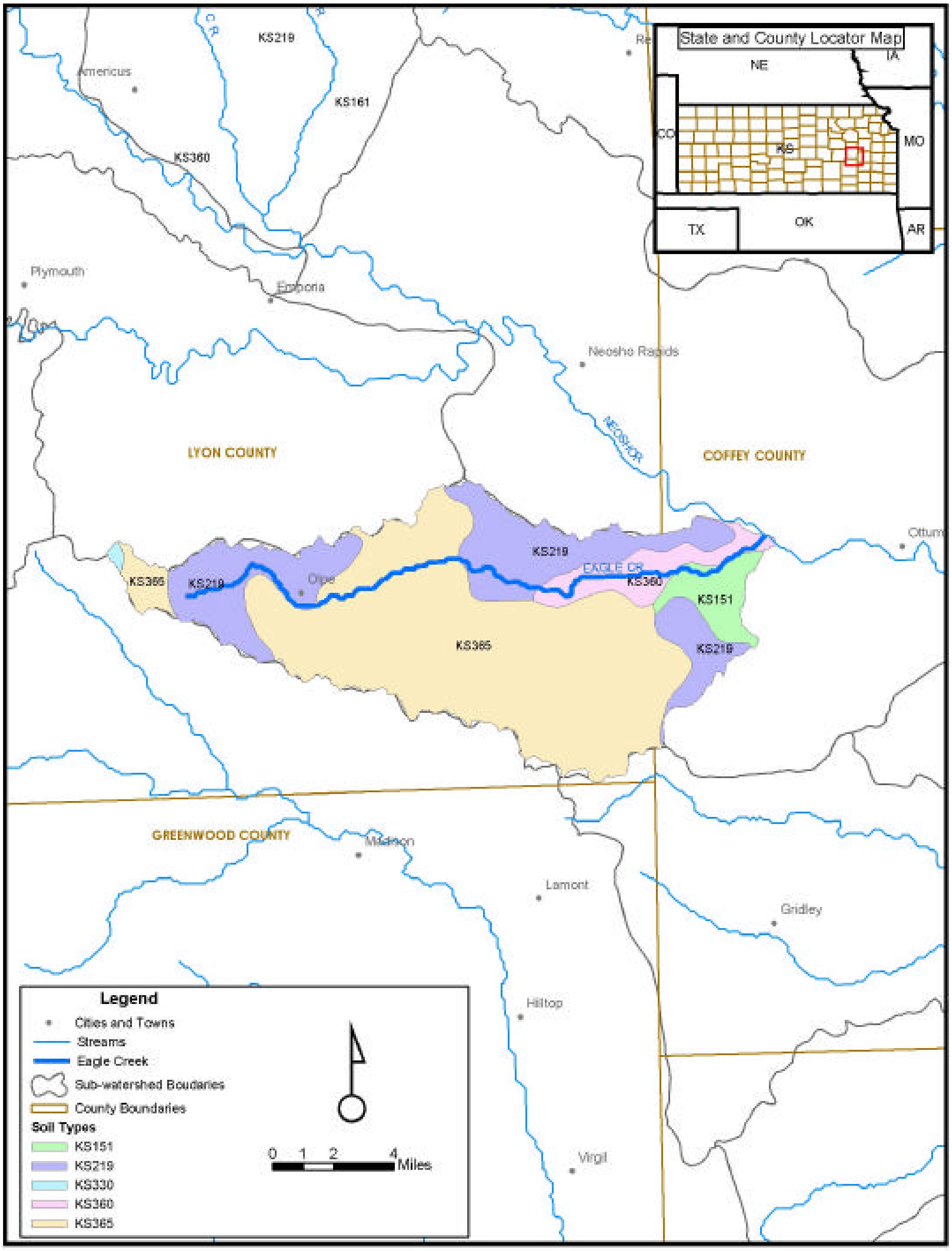
LAKES/RESERVOIRS	81	0.11
MIXED URBAN OR BUILT-UP	137	0.19
STRIP MINES	86	0.12
TOTALS	**73,668**	**100**

Figure 4 Eagle Creek Watershed Land Use Map



Soil. **Figure 5**, derived from STATSGO data, generally represents soils types prevalent throughout the Eagle Creek watershed. Major soil types in Lyon County and the adjoining counties are silty clay loam and silt loam (Schwarz and Alexander 1995).

Figure 5 Eagle Creek Watershed Soil Map



No data for copper in soil or sediment were found specifically within the Eagle 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 limestone and two shale), soil, 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 soil 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.

Point Source Discharges

One NPDES-permitted wastewater discharger, the Olpe Wastewater Treatment Plant (WWT), is located within the Eagle Creek watershed (**Table 3**).

Table 3 NPDES Permitted Discharger to Eagle Creek

DISCHARGING FACILITY	STREAM REACH	SEGMENT	DESIGN FLOW	TYPE
Olpe MWTP	Eagle Creek (25)	25	0.1671 cfs	Lagoon

The City of Olpe relies on a three-cell lagoon system with 120-day detention times for treatment of wastewater. The population projection for Olpe 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. Examination of 1998, 1999, 2000 and 2001 effluent monitoring of the City of Olpe 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 Eagle 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, and agriculture lands. Some automobile brake pads 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 micrograms per liter (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 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 sources of copper, given the small proportion of these types of land use that occur in the Eagle Creek watershed, such copper contributions are assumed to be minimal.

Agricultural sources. The most probable non-point source of copper may be associated with the extensive amount of agriculture activity that occurs in the watershed. Livestock operations are operating in Eagle Creek watershed. Three operations are registered or certified within the watershed upstream of Station 634. These facilities (dairy or chicken) are located within 1 mile of a listed stream in the watershed. NPDES permits are issued for facilities with more than 1,000 animals; however, none of the facilities in the Eagle Creek watershed are of this size. Each of these livestock facilities has waste management systems designed to minimize runoff entering the facility or detaining runoff originating from the facility. Such systems are designed for the 25-year, 24-hour rainfall/runoff event, which typically coincides with stream flows being exceeded less than 1-5 percent of the time. 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. However, no specific data are available on copper concentrations from waste management systems.

Following is a brief discussion of agricultural land use activities in Lyon County. Although the Eagle Creek watershed represents only a small fraction of the entire county, county census data are expected to be relatively accurate and provide a qualitative indication of the agricultural land uses activities in the watershed that may be primary pathways for copper loading to the receiving waters. There are approximately 75,000 cattle in Lyon County (KASS 2002; SETA 1997). Dairy and beef cattle may suffer from various hoof diseases that are 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 represents a possible non-point source pathway of copper in the Eagle 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 250 pound hog 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 Eagle Creek watershed.

Soybean crops cover approximately 60,000 acres in Lyon County (SETA 1997). Copper deficiency in soybeans is corrected by application of 3 to 6 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 non-point source of copper to the Eagle Creek watershed.

Non-point Source Assessment Conclusion

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

Naturally occurring copper in soil may constitute a substantial portion of estimated loadings to Eagle 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 Eagle 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 micrograms per gram (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 Eagle Creek, and an evaluation of potential sources and responsibility.

TMDL Calculations

Figure 6 is a plot of hardness versus flow designed to define any potential correlation between these variables in the Eagle Creek watershed. Hardness is known to generally be inversely proportional to flow. This assertion is supported by **Figure 6**, which demonstrates an apparent relationship between these two variables in Eagle Creek ($p<0.05$).

This evaluation is important because it helps define the effects of flow on copper bioavailability and toxicity and, in addition, provides valuable insight into hydrologic flow conditions for the watershed. Because the regression was found to be statistically significant ($p < 0.05$), the regression equation ($y = 1.2321x + 159.42$) was used to define hardness at any particular flow exceedance range. This allowed for derivation of "interim" WQS values for copper within individual flow exceedance ranges and used to estimate TMDL loads within each of these ranges. The average of these TMDL estimates across all flow ranges was used as the TMDL for the watershed.

Figure 6 Correlation Between Hardness and Flow at Eagle Creek

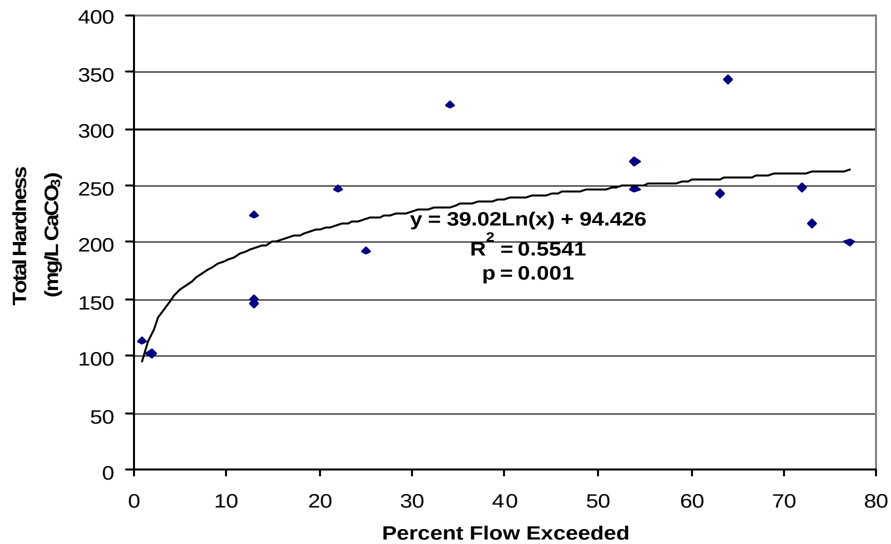


Figure 7 shows the load duration curve for copper which also defines the Eagle Creek TMDL, WLA, LA, and MOS. The Information Sheet at the beginning of this document summarizes all the numbers and calculations. **Figure 7** also depicts loading from the KDHE water quality monitoring station of copper in relation to the TMDL. The TMDL was developed using the acute WQS derived from the flow-hardness regression equation.

The area below the TMDL with MOS and above the WLA represents the LA in **Figure 7**. The diagram shows the LA range based on flow exceedance. Current point source loading is shown on **Figure 7** as a line below the WLA estimate, indicating that no point source load reduction would be necessary. The current non-point loading estimate is not shown in **Figure 7** because the GWLF estimate is based on average loadings rather than flow exceedance ranges. Therefore, the current non-point loading estimate was only compared to the average TMDL value. Based on these calculations, the calculated average TMDL for total copper in Eagle Creek is 0.467 lb/day (170.5 lb/yr).

The calculated average TMDL for total copper in Eagle Creek was computed:

TMDL (0.467 lb/day) = LA (0.392 lb/day) + WLA (0.029 lb/day) + MOS (0.047 lb/day)

Figure 7 Load Duration Curve Used to Derive TMDL

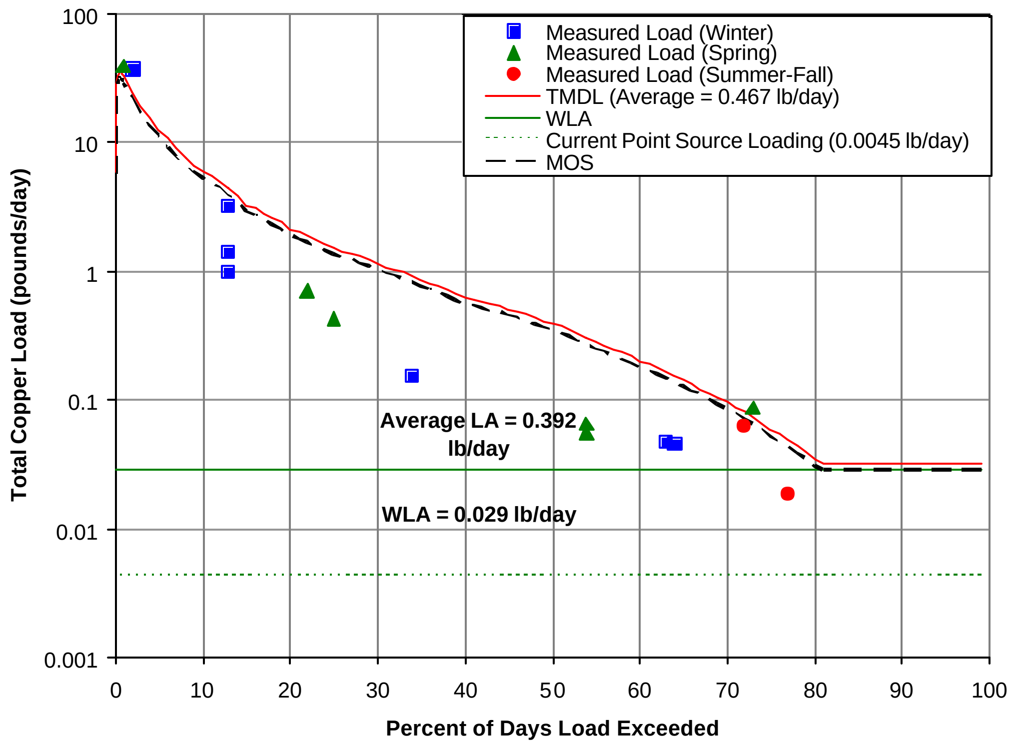
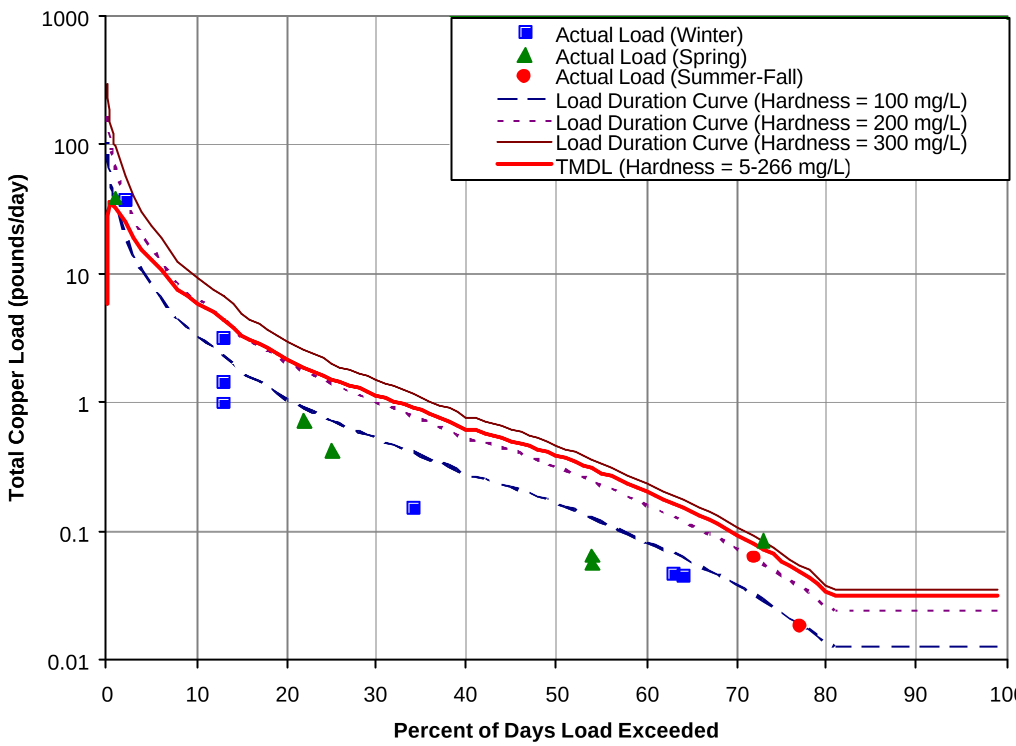


Figure 8, which shows more potential WQS exceedances for total copper, compares the measured total copper loading to the load duration curve for three specific hardness values that are representative of typical seasonal variation in Eagle Creek. **Figure 8** appears to be an effective predictor of potential WQS exceedances in part because three representative hardness ranges are used to estimate total copper loadings to the watershed. In an evaluation of possible seasonal effects of copper loading in Eagle Creek, it is apparent from **Table 1** that no WQS exceedances were observed in the summer or fall for the years evaluated, while each of the three exceedances observed were during spring and winter of the monitoring years.

Results of normality testing. Water hardness data were not subjected to normality testing due to the positive correlation between flow and hardness as indicated by the regression equation (**Figure 6**). Copper concentration data were tested for normality in order to generate the CV value needed to evaluate whether compliance with the acute WQS would be adequately protective of chronic toxicity as well. For the data sets used to support all averaged load estimates such as TMDL, LA/WLA, MOS, and load reduction, results of normality testing indicated that these data were not normally distributed, and log-transformation of the data was necessary 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 Eagle Creek system. Allocations relate to the average copper levels seen in the Eagle Creek system at Station 634 for the critical lower flow conditions (represented by the 95 percent flow exceedance value of 0.167 cfs). 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 mean of all TMDL values across different flow ranges was used. TMDL at each percent flow exceedance range was calculated by multiplying the associated flow and copper WQS at the particular flow exceedance range. This is represented graphically by the integrated area under the copper LDC (**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 Eagle Creek

Since the lowest flows of Eagle Creek were adjusted to the design flow of 0.1671 cfs, the total WLA for the watershed is equal to the minimum TMDL with MOS, *i.e.,* 90 percent of the acute TMDL load at the design flow. The estimated WLA for the Olpe MWTP, the sole point source discharger, is 0.0285 lbs/day. **Figure 7** clearly shows that based on the estimated WLA, there appear to be no historical excursions for copper from this point source discharger.

Based upon this assessment, the Olpe MWTP may contribute a load of total copper into the Eagle Creek watershed upstream of Station 634. This discharge was incorporated into the WLA estimate. The design flow of the discharging point source equals the lowest flows seen at Station 634 (81-99 percent exceedance), and the WLA equals the TMDL curve across this flow exceedance range (**Figure 7**).

LA for Eagle Creek

The LA was estimated by filling in the formula:

LA (0.392 lb/day). = TMDL (0.467 lb/day) – MOS (0.047 lb/day) – WLA (0.029 lb/day)

This calculation strongly suggests that the majority of copper loading occurs from un-permitting non-point sources, and that the contribution from NPDES discharges is, by comparison, 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 includes contributions of natural background sources of copper.

The LA assigns responsibility for maintaining the historical average in-stream copper levels at Station 634 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 flow at 0.17 cfs (81-99 percent exceedance), since the flow at this condition may be entirely effluent created, and then increases to the TMDL curve with increasing flow beyond 0.17 cfs.

Point Source Load Reduction

A point source discharger is responsible for maintaining its system in proper working condition and an appropriate capacity to handle anticipated wasteloads of its populations. The State and NPDES permits will continue to be issued at 5-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 on the preceding assessment, the sole permitted point source discharge is the Olpe MWTP, which may be a minor source of copper loading to the Eagle Creek watershed upstream of Station 634. The design flow of the discharging point sources equals the lowest flows seen at station 634 (81-99 percent flow exceedance), and the WLA equals the TMDL curve with MOS across this flow condition (**Figure 7**). No reduction in point source loading is considered necessary under this TMDL.

Non-Point Source Load Reduction

Non-point sources are regarded as the primary contributing factor to the occasional total copper excursions in the watershed. The LA equals zero for flows at 0.167 cfs (81-9 percent exceedances, as seen on **Table 4** and **Figure 7**), since the flow at this condition may be entirely created by the effluent, and then increases to the TMDL curve with increasing flow beyond 0.167 cfs (**Figure 7**). Sediment control practices such as buffer strips and grassed waterways should help reduce any 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 5.141 lbs/day, which represents an approximate 93 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 Eagle Creek, further diluting the MWTP discharge. Another conservative assumption that is 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 Olpe MWTP
- Concentration of copper in wastewater effluent 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 was used rather than actual flow data for Eagle Creek.
- Water hardness values used for flow-hardness regression equation to calculate WQS for copper.
- Output from GWLF model output from LDCs, for non-point source loading was compared to estimate non-point load reduction.
- Total loading data was not normal 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 Eagle 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 3) 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 3**. 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 preferred 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 rather than measured flow data and therefore results would not be expected to be comparable 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 the copper loading from the watershed that resides in the bed load. This fact also partially explains the higher copper loading estimates provided by the GWLF output.

Seasonal Variability: Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs take into consideration seasonal variability in applicable standards. WQS exceedances occurred during winter and spring (higher flows) rather than during summer and fall (lower flows), and as such it appears that seasonal variability, especially during periods of higher flows, is 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 Neosho Headwaters Basin (HUC 8: 11070201) with a priority ranking of 38 (Medium 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 Eagle 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 Eagle 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 634 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 specified high flow conditions over the period 2007-2011. Use of the real time flow data available at the Big Creek near Leroy stream gaging 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 Eagle 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/wrir.01-4085.html

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 Assesment, 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	Eagle Cr
99	0.01	0.00
98	0.05	0.00
97	0.07	0.00
96	0.10	0.00
95	0.10	0.00
94	0.12	0.00
93	0.14	0.00
92	0.16	0.00
91	0.18	0.00
90	0.20	0.00
89	0.24	0.00
88	0.28	0.00
87	0.32	0.09
86	0.36	0.10
85	0.40	0.11
84	0.50	0.12
83	0.60	0.14
82	0.70	0.15
81	0.80	0.17
80	0.90	0.18
79	1.16	0.21
78	1.42	0.23
77	1.68	0.26
76	1.94	0.28
75	2.20	0.31
74	2.58	0.35
73	2.96	0.39
72	3.34	0.43
71	3.72	0.47
70	4.10	0.51
69	4.68	0.56
68	5.26	0.61
67	5.84	0.66
66	6.42	0.71
65	7.00	0.76
64	7.96	0.83
63	8.92	0.90
62	9.88	0.96
61	10.84	1.03
60	11.80	1.09
59	13.08	1.19
58	14.36	1.28
57	15.64	1.38
56	16.92	1.47

P	Flow (cfs)	
	6914000	Eagle Cr
55	18.20	1.57
54	19.76	1.69
54	19.76	1.69
53	21.32	1.81
52	22.88	1.94
51	24.44	2.06
50	26.00	2.18
49	27.86	2.33
48	29.72	2.48
47	31.58	2.62
46	33.44	2.77
45	35.30	2.91
44	37.58	3.06
43	39.86	3.20
42	42.14	3.35
41	44.42	3.49
40	46.70	3.64
39	49.30	3.93
38	51.90	4.22
37	54.50	4.51
36	57.10	4.80
35	59.70	5.10
34	63.84	5.46
33	67.98	5.82
32	72.12	6.19
31	76.26	6.55
30	80.40	6.92
29	85.98	7.43
28	91.56	7.94
27	97.14	8.44
26	102.72	8.95
25	108.30	9.46
24	116.54	10.34
23	124.78	11.21
22	133.02	12.08
21	141.26	12.96
20	149.50	13.83
19	167.00	15.58
18	184.50	17.33
17	202.00	19.07
16	219.50	20.82
15	237.00	22.57
14	281.62	26.79
13	326.24	31.01
13	326.24	31.01
13	326.24	31.01

P	Flow (cfs)	
	6914000	Eagle Cr
12	370.86	35.24
11	415.48	39.46
10	460.10	43.68
9	613.50	50.23
8	766.90	58.24
7	920.30	70.98
6	1073.70	87.36
5	1227.10	109.20
4	2062.83	138.32
3	2898.55	185.64
2	3734.28	273.00
1	4570.00	451.36
0.9	-	480.48
0.8	-	516.88
0.7	-	560.56
0.6	-	618.8
0.5	-	691.6
0.4	-	764.4
0.3	-	873.6
0.2	-	1092
0.1	-	1383.2

Notes: - indicates data not available
Source: USGS 2001

Table A-2 Water Quality Data for Station 634 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)
1/6/1993	351	19.0	224.00	29.9
3/3/1993	3660	25.0	102.00	14.3
5/19/1993	136	11.0	247.00	32.8
7/7/1993	11200	16.0	114.00	15.8
9/8/1993	3.2	27.0	248.00	32.9
1/15/1997	8.1	10.0	343.23	44.7
3/12/1997	63	5.3	320.75	42.0
5/14/1997	20	6.1	271.74	35.9
7/16/1997	112	8.3	192.24	25.9
9/3/1997	1.8	13.2	199.51	26.8
11/12/1997	8.6	9.8	243.09	32.3
3/15/2001	328	8.6	150.11	20.5
3/15/2001	328	5.9	146.37	20.0
5/10/2001	19	7.1	247.61	32.9
7/19/2001	3	40.9	216.87	29.0

APPENDIX B
INPUT AND OUTPUT DATA FOR GWLF MODEL

Eagle Creek Input

LAND USE	AREA(ha)	CURVE NO	KLSCP
CROPLAND AND PASTURE	25430.	87.0	0.02000
DECIDUOUS FOREST LAND	32.	83.0	0.02000
HERBACEOUS RANGELAND	4214.	87.0	0.02000
STRIP MINES	35.	98.0	0.02000
LAKES	4.	0.0	0.00000
RESERVOIRS	29.	0.0	0.00000
COMMERCIAL AND SERVICES	13.	98.0	0.02000
MXD URBAN OR BUILT-UP	55.	98.0	0.02000

MONTH	ET CV()	DAY HRS	GROW. SEASON	EROS. COEF
JAN	.000	9.7	0	.2
FEB	.000	10.6	0	.2
MAR	.000	11.8	0	.2
APR	9.000	13	0	.2
MAY	.000	14	1	.3
JUNE	.000	14.5	1	.3
JULY	.000	14.3	1	.3
AUG	9.000	13.4	1	.3
SEPT	9.000	12.2	1	.3
OCT	9.000	11	1	.3
NOV	9.000	10	0	.2
DEC	9.000	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

Eagle Creek Output

EAGLE_CREEK YEAR SIMULATION

YEAR	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
---(cm)--					
1	88.2	85.0	0.0	13.2	13.2
2	69.6	60.8	0.0	7.8	7.8
3	108.5	83.3	0.0	26.1	26.1
4	70.8	63.0	0.0	7.8	7.8
5	74.8	58.4	0.0	16.4	16.4

YEAR	EROSION	SEDIMENT
-------------------------------(1000 Mg)-----------------------------		
1	222.1	14.4
2	201.7	13.1
3	360.8	23.4
4	188.8	12.3
5	250.2	16.3