STATE OF OKLAHOMA

DEPARTMENT OF ENVIRONMENTAL QUALITY
(DEQ)
WATER QUALITY DIVISION

FY 2005/2006 Section 106 Water Quality Management Program
I-006400-05 Project #4 Tar Creek Water Quality, Flow and Sediment Monitoring
QTRAK #04-505

Surface-Water Quality in the Grand-Neosho River Basin, Northeastern Oklahoma

Draft Final Report

Submitted by:

Oklahoma Department of Environmental Quality
Water Quality Division
707 North Robinson
P.O. Box 1677
Oklahoma City, OK 73101-1677
Telephone: (405) 702-8100

Acknowledgements

The Oklahoma Department of Environmental Quality would like to thank the United States Geological Survey for their help in training and developing sampling methodologies for this study. We would also like to thank the Seneca-Cayuga Tribe in making this a truly cooperative effort between the Federal, State and Tribal entities in the basin.

Executive Summary

The Oklahoma Department of Environmental Quality Water Quality Division (WQD), in cooperation with the United States Geological Survey (USGS) and the Seneca-Cayuga Tribe, collected base flow and high flow water-quality and sediment data for two years from Tar Creek, Spring River, and Neosho River to characterize water and sediment quality entering Grand Lake O' the Cherokees. This was done under two separate Quality Assurance Project Plans as a joint endeavor.

The primary purpose of this project was to collect the second set of a set of flow-weighted samples in Tar Creek, and the Spring and Neosho Rivers to evaluate the movement of both total and dissolved metals in these water bodies into Grand Lake O' the Cherokees. This data has been combined with data from samples collected in FY 2005 and is beginning to show trends in the movement of these metals in the water column and sediment in Tar Creek and the Spring and Neosho Rivers.

In addition to the water quality and sediment samples, one team comprised of two samplers collected species of fish and macro-invertebrates for a bio-assessment. This occurred on two occasions at three locations within Tar Creek. Sites were selected in order to assess impact and recovery of mine discharges on biota. The results of the fish collections are discussed in the results and data analysis section of this report. We are awaiting results of the macro-invertebrates portion of the data analysis of this bio-assessment.

In addition to these data that were collected, the USGS collected fourteen sediment cores using a Geoprobe in the Tar Creek floodplain where Tar Creek intersects the 22nd Street Bridge in Miami, OK during FY 2005. All of the core samples had detectable concentrations of aluminum, barium, chromium, copper, iron, lead, magnesium, manganese, nickel and zinc. Two cores that were collected in a slough that runs on the west side of Tar Creek had larger concentrations of arsenic, cadmium, lead, iron and zinc than the other cores.

A seepage run was also conducted during FY 2005 by the USGS on Tar Creek near Commerce and Tar Creek near the 22nd Street Bridge to determine changes in surface-water discharge and water-quality throughout a 24 hour period. The only constituent that showed a notable change in concentration was iron (Fe), which showed a 50 percent change in concentration over the 24 hour period. This is contrasted by only a 5 to 10 percent change in concentration between most of the other constituents.

Trends are beginning to appear in the data collected from Tar Creek which show sites of particular concern for certain metals such as Douthat Bridge and Hwy 69. These are showing elevated lead and zinc loading values. The data are also showing that iron is precipitating out in

Tar Creek particularly between Veterans Boulevard and Central Street in Miami. Furthermore, there are seasonal trends in both the Spring and Neosho Rivers. Metals concentrations appear to fluctuate on a cyclical pattern according to certain times of the year and the associated flows during those times. There is a little more erratic fluctuation in the zinc concentrations than in the other metals of concern. However, even with this variation, zinc loading follows the same trend.

Table of Contents

Background and Statement of Issues……1

Monitoring Methods

Sample Collection…….. 2

Sampling Methods…… 5

Sample Handling and Custody……..... 6

Analytical Methods

Field Methods…….....6

Laboratory Methods…….....7

Quality Assurance……...8

Results and Data Analysis…… 9

USGS

High Flow Samples…… 15

Sediment Cores…….. 17

Seepage Run……..... 19

Conclusions and Recommendations…… 19

References…… 20

Appendices

Appendix A. Summarized High-Flow Data …..…… A-1

Appendix B. Summarized Sediment Core Data…… B-1

Appendix C. Summarized Seepage Run Data…… C-1

Appendix D. Summarized Base-Flow Data……... D-1

Appendix E. Summarized Suspended Sediment Data…….. E-1

Figures

Figure 1. Map of ODEQ Sampling Sites…… 4

Figure 2. Estimated Metal Loading Values for May 2004……..... 12

Figure 3. Estimated Metal Loading Values for June 2004……..... 12

Figure 4. Estimated Metal Loading Values for July 2004……..…12

Figure 5. Estimated Metal Loading Values for August 2004……..…12

Figure 6. Estimated Metal Loading Values for September 2004…….....12

Figure 7. Estimated Metal Loading Values for October 2004…….....12

Figure 8. Estimated Metal Loading Values for November 2004……13

Figure 9. Estimated Metal Loading Values for March 2005……13

Figure 10. Estimated Metal Loading Values for May 2005……..... 13

Figure 11. Estimated Metal Loading Values for June 2005……13

Figure 12. Estimated Metal Loading Values for July 2005……..13

Figure 13. Estimated Metal Loading Values for June 2005……14

Figure 14. Estimated Metal Loading Values for July 2005……..14

Figure 15. Location Map of High Flow Sampling Sites In The Grand-Neosho River Basin……15

Figure 16. Plots of Surface Water Discharge and Selected Total Constituent Concentrations…….....16

Figure 17. Location of Sediment Cores Collected From the Floodplain at Tar Creek at 22nd Street Bridge, Miami, OK……17

Tables

Table 1. ODEQ Sampling Regimen and Number of Samples….....2

Table 2. Site Locations……..…….. 3

Table 3. Containers, Preservatives, and Holding Times for Each Analysis……. 6

Table 4. Field Analysis Methods……. 6

Table 5. Parametric Coverage, Methods, Precision and Accuracy, MDLs and Other Reporting Limits…….....7

Table 6. Fish Community Collections in Tar Creek……10

Table 7. Site Designations on Tar Creek for Figures 2 through 5……..11

Table 8. Concentration of Constituents in the Top Layer of Each Sediment Core Collected From the Floodplain at Tar Creek at 22nd Street, Oklahoma 2004.....18

Table 9. Summary Results of Sediment Core Samples Collected From the Floodplain At Tar Creek at 22nd Street, Oklahoma, 2004……..18

Background and Statement of Issues

The land included in the Tar Creek Basin located in northeast Oklahoma and southeast Kansas was a major provider of lead and zinc ores in the early to mid 20th century. The underground mines are now closed and abandoned. The native sulfide minerals that remained in the mines, subsequently were oxidized and dissolved, creating acid mine water with relatively high metals concentrations and low pH. By 1979, a majority of the mine workings were flooded from ground water infiltration and surface water inflow. As the piezometric surface exceeded the land elevation in low lying areas along Tar Creek in Oklahoma, acid mine water discharged to the surface through abandoned mine shaft openings and boreholes. Tar Creek, the main drainage system at the site and a major tributary of the Neosho River became severely impacted by both acid mine water discharges and soluble metals.

Current estimates are that 75 million tons of mine tailings (chat) remain of the original 170 million tons of the Tri-State Mining District. Some approach several hundred feet in height and cover large areas of land. The chat piles were created from the milling process of the ore and in general lead concentration tends to increase with decreasing chat particle size. Water draining from these piles forms leachate with relatively high metals concentrations that flows into Tar Creek. Water discharging from the mines since the 1970's is a major source of contamination to Tar Creek. Estimates of the volume of the acid mine water within the mine workings and surrounding Boone formation are in excess of 100,000 acre feet.

The purpose of this project was to set forth a plan to collect and analyze surface water from Tar Creek basin and a portion of Grand Lake basin. Field parameters including flow data, pH, D.O., Specific Conductance, and Temperature will be measured along with general chemical and metals analysis.

The primary objective of this investigation was to evaluate metals loading to Tar Creek from lead and zinc mining activities at the Tri-State Mining District. We evaluated metals loading on the surface waters at six sites on Tar Creek, one on Lytle Creek, two discharge points, and two sites each on Spring River and the Neosho River.

A secondary objective of this study is to meet basic requirements for conducting a Total Maximum Daily Loading evaluation (TMDL). The watershed planning segments being studied are listed as impaired on Oklahoma's 303(d) list.

Monitoring Methods

Sample Collection

Base flow samples were collected at six surface water sites on Tar Creek, one on Lytle Creek, two discharge points, and two sites each on Spring River and the Neosho River. A map of these sample sites is found on page 4 in Figure 1. Locations and descriptions of these sites are found on Table 2 on page 3. When possible all sample collection activities were accompanied by either flow data or gauging station data. Site selection was based on the points of inflow of mine drainage into Tar Creek, location of surface ore piles that will influence water quality, and water outflow from the basin. The sampling regimen that was used for this study is found below in Table 1.

Table 1 – ODEQ Sampling Regimen and Number of Samples

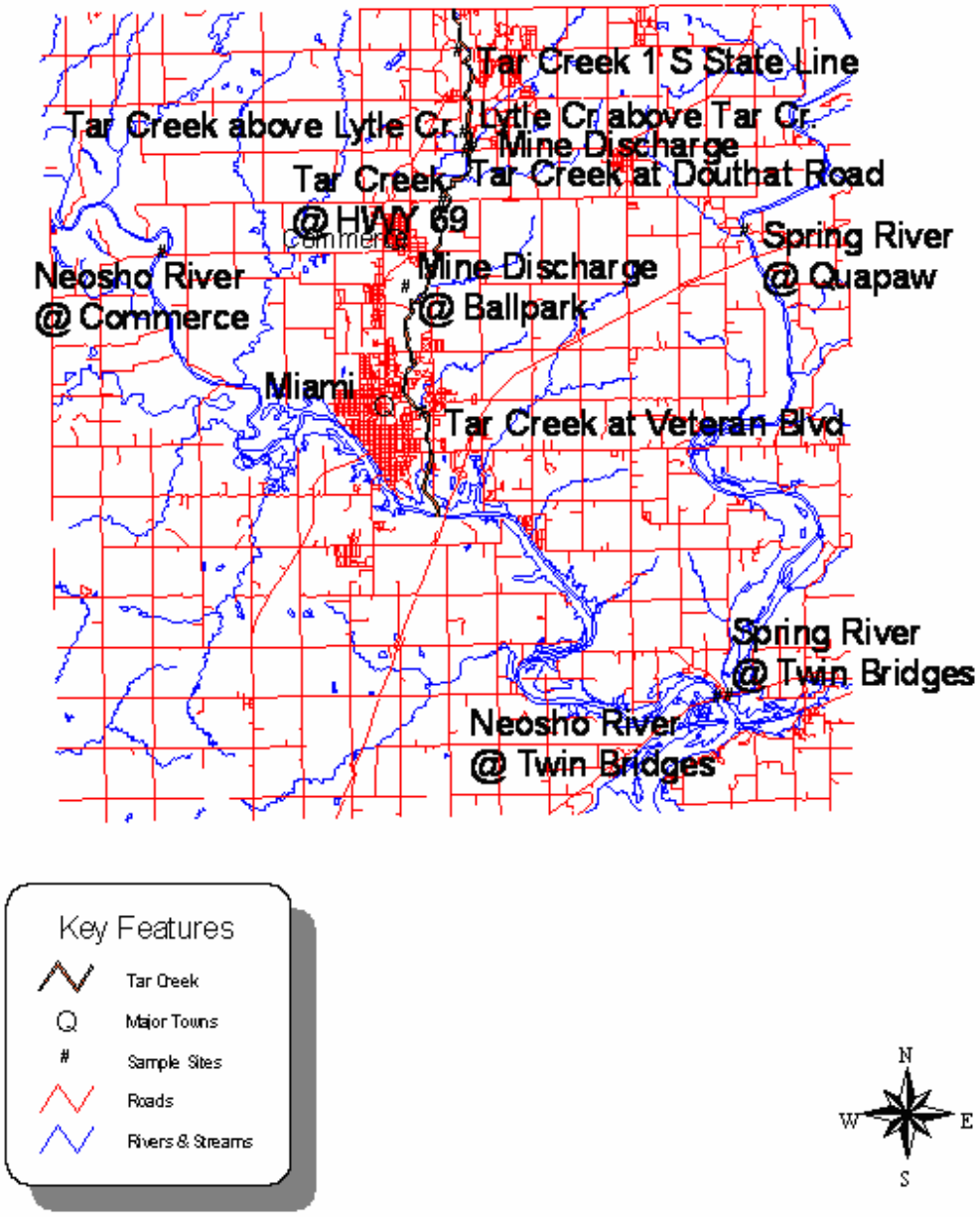
	Tar Creek 1 Mile south of State Line	Tar Creek Above Con-fluence	Lytle Creek Above Con-fluence	Mine Dis-charge Near Douthat	Tar Creek at Douthat Road	Tar Creek at Hwy 66	Mine Dis-Charge at Ball-Park	Tar Creek at Veter-an Blvd	Tar Creek at Central St	Neosho River at Com-merce	Spring River at Quapaw	Neosho River at Twin Bridges	Spring River at Twin Bridges
Number of Month **Sampling In**													
#1	1	1	1	1	1	1	1	1	1	1	1	2	2
#2	1	1	1	1	1	1	2	1	1	1	1	1	2
#3	1	1	2	2	1	1	1	1	1	1	1	1	1
#4	1	2	1	2	1	1	1	1	1	1	1	1	1
#5	1	1	1	1	1	1	1	2	1	1	2	1	1
#6	3	1	1	1	1	1	1	1	1	1	1	1	1
#7	1	1	1	1	1	1	1	1	1	1	2	1	2
#8	1	1	1	1	1	1	1	1	1	1	3	1	1
#9	1	1	1	1	2	1	1	2	1	1	1	1	1
#10	1	1	1	2	1	1	1	1	2	1	1	1	1
#11	1	1	1	1	2	1	1	1	1	1	1	2	1
#12	2	1	1	1	1	1	1	1	1	1	1	2	1
#13	1	1	1	1	1	1	1	1	2	1	2	1	1
#14	1	2	2	1	1	1	1	1	1	1	1	1	1

Table 2 – Site Locations

Site	Latitude	Longitude	County
1. Tar Creek 1 mile S of State line	36° 59’ 13.321	94° 50’ 55.529	Ottawa
2. Tar Creek above Lytle Confluence	36° 57’ 51.54	94° 50’ 45.768	Ottawa
3. Lytle Creek above Confluence	36° 57’ 51.29	94° 50’ 22.692	Ottawa
4. Mine discharge near Lytle Ck	36° 57’ 49.386	94 50’ 38.076	Ottawa
5. Tar Creek below Douthat Rd	36° 57’ 30.921	94° 50’ 45.768	Ottawa
6. Tar Creek at Hwy 66	36° 56’ 37.052	94° 61’ 11.919	Ottawa
7. Mine discharge at Ballpark	36° 55’ 31.862	94° 52’ 17.382	Ottawa
8. Tar Creek at Veterans Blvd	36° 54’ 00.303	94° 52’ 05.711	Ottawa
9. Tar Creek at Central Street	36° 52’ 28.879	94° 51’ 45.025	Ottawa
10. Neosho River at Commerce	36° 55’ 43.000	94° 57’ 26.000	Ottawa
11. Spring River at Quapaw	36° 56’ 04.000	94° 44’ 49.000	Ottawa
12. Neosho River at Twin Bridges	36° 47’ 56.000	94° 45’ 21.000	Ottawa
13. Spring River at Twin Bridges	36° 47’ 59.000	94° 45’ 05.000	Ottawa

Site 1 was chosen due to its location within the area of mining activity but above the major mine discharges.
Site 2 was chosen due to its location below Cardin STP and above Lytle Creek (Picher STP). Site 3 contains Picher effluent and urban runoff.
Site 4 is a mine discharge.
Site 5, Tar Creek is collectively mine discharge mixing zone, and Lytle creek.
Site 6, Tar Creek is below the majority of direct surface runoff, and above the Commerce mine discharge and STP.
Site 7 is mine discharge.
Site 8 is Tar Creek in Miami, above its confluence with the Neosho River.
Site 9 is at Central Street and is the lowest point of collection on Tar Creek.
Site 10 is the Neosho River above Tar Creek Confluence.
Site 11 is Spring River above its confluence with Beaver Creek.
Site 12 is the Neosho above its confluence with Spring River.
Site 13 is Spring River above its confluence with the Neosho River.

Figure 1. Map of Sampling Sites



Sampling Methods

A total of 210 base flow water samples were collected and analyzed over the course of twelve sample collection events to assess metals loading from historical mining activities in the Tar Creek area. Along with these collections, ninety-seven (97) "sediment size and concentration" sample were also collected. One sample from each site was collected and sent to Rolla Lab for analysis.

Water samples collected for metals analysis were depth and width-integrated where possible. The samples were collected in plastic, 1-Liter bottles.

All water sampling equipment was cleaned and washed prior to each field collection series. Equipment was pre-rinsed with ambient water prior to collection of samples at each site. Using the clean hands dirty hands protocol, sample bottles were also pre-rinsed inside a chamber bag according to the USGS National Field Manual for the Collection of Water-Quality Data. This eliminated contamination potential. A field blank water sample was collected at one site per exercise. Samples were collected in sequence from downstream to upstream. Flow measurements were taken at each site immediately following sample collection.

Field measurements for pH, water temperature, dissolved oxygen, specific conductivity and stream-flow rates were collected *in situ* during each site visit. Temperature and DO measurements were taken using an YSI Model 550. Specific Conductivity measurements were measured with an YSI Model 30 meter. An YSI Model 60 was used to sample pH. A Hach digital titrator was used to analyze alkalinity. Manufacturer's instructions were employed in the calibration and use of meters.

Flow measurements were taken using a Marsh-McBirney Model 2000 portable flow meter. Manufacturer's instructions were employed in the use of the meter. Stream cross sectional area was measured and multiplied times the flow meter reading to get volumetric flow rate. Where necessary, a bucket and stop watch method was employed at the mine discharge pipes.

One team comprised of two samplers collected species of fish and macro-invertebrates for a bio-assessment. This occurred on two occasions at three locations within Tar Creek, with the exception of September 2004, when there was no collection made at site #1 due to low flow and heavy aquatic vegetation. Sites were selected in order to assess impact and recovery of mine discharges on biota. We are awaiting results of the macro-invertebrates portion of the data analysis of this bio-assessment.

Sample Handling and Custody

Each sample container was labeled onsite with indelible ink as to site name, site identification number; date and time of collection; and preservation method used. The collector was responsible for labeling each sample container. Samples were preserved, as they were collected.

Table 3 summarizes, by analytical method, the containers, preservative, sample volume, and holding times of the samples for the analyses.

Table 3 – Containers, Preservatives, and Holding Times for Each Analysis

Analyte	***Preservative***	***Holding Time***	***Sample Volume***	***Container***
Specific Conductance	*Insitu*	*N/A*	*N/A*	*N/A*
Dissolved Oxygen	*Insitu*	*N/A*	*N/A*	*N/A*
Water Temperature	*Insitu*	*N/A*	*N/A*	*N/A*
PH	*Insitu*	*N/A*	*N/A*	*N/A*
Metals (water)	*HNO3/Ice*	*28 days*	*1000 ml*	*1 Liter Plastic*
General Chemistry (water)	*Ice*	*48 hours*	*1000 ml*	*1 Liter Plastic*

Incoming samples were accounted for via chain-of-custody (COC) forms. Sample collectors had the responsibility for properly completing this form.

Laboratory samples were sequentially numbered and cross-referenced to a numbered worksheet form. Sample custody was maintained in the sample receiving area until disbursement for analysis. All samples were stored in the laboratory area until all analyses have been performed and results verified. The SEL complies with sample control requirements of the Public Water Supply program, which is sufficiently stringent for the project.

Field Analytical Methods

The methods and meters required to perform field water quality analyses are listed in Table 4.

Table 4 – Field Analysis Methods

Analyte	***Method***	***Meter***	***Method Detection Limit***
Specific Conductance	*2510B*	*YSI 30*	*1.0 umho/m3*
Dissolved Oxygen	*4500G*	*YSI 550*	*0.1 mg/l*
Water Temperature		*YSI 550*	*-5 C*
pH	*4500H-B*	*YSI 60*	*1 S.U.*

Laboratory Analytical Methods

The methods and meters required to perform laboratory water quality analyses are listed in Table 5.

Table 5 – Parametric Coverage, Methods, Precision and Accuracy, MDLs and Reporting Limits

Parameter	Method	Meter / Lab	Laboratory Precision Std. Dev.	Laboratory Accuracy Std. Dev.	Method Detection Limit	Reporting Limit
Dissolved Oxygen	4500-G	Field YSI 55D	N/A	N/A	0.1 mg/L	0.1 mg/L
Conductance	2510-B	Field YSI 30	N/A	N/A	1.0 uS/cm	1.0 uS/cm
pH	4500 H-B	Field YSI 60	N/A	N/A	1.0 S.U.	1.0 S.U.
Temperature		Field YSI 55D	N/A	N/A	-0.5^{o}C	-0.5^{o}C
Iron in Water	200.7	ODEQ – SEL	10%	85-115%	2.2 ug/L	10.0 ug/L
Lead in Water	200.7	ODEQ – SEL	10%	85-115%	1.67 ug/L	5.0 ug/L
Zinc in Water	200.7	ODEQ – SEL	10%	85-115%	1.5 ug/L	5.0 ug/L
Cadmium in water	200.7	ODEQ – SEL	10%	85-115%	0.34 ug/L	1.0 ug/L
Arsenic in Water	200.7	ODEQ – SEL	10%	85-115%	4.1 ug/L	10.0 ug/L
Chromium in Water	200.7	ODEQ – SEL	10%	85-115%	1.25 ug/L	5.0 ug/L
Copper in Water	200.7	ODEQ – SEL	10%	85-115%	0.57 ug/L	5.0 ug/L
Manganese in Water	200.7	ODEQ – SEL	10%	85-115%	0.3 ug/L	5.0 ug/L
Nickel in Water	200.7	ODEQ – SEL	10%	85-115%	1.21 ug/L	5.0 ug/L
Magnesium in Water	200.7	ODEQ – SEL	10%	85-115%	0.023 mg/L	1.0 mg/L
Sodium in Water	200.7	ODEQ – SEL	10%	85-115%	0.12 mg/L	10.0 mg/L
Potassium in Water	200.7	ODEQ – SEL	10%	85-115%	0.02 ppm	1.0 ppm

Aluminum in Water	200.7	ODEQ – SEL	10%	85-115%	7.0 ppb	300.0 ppb
Antimony in Water	200.7	ODEQ – SEL	10%	85-115%	6.4 ppb	20 ppb
Barium in Water	200.7	ODEQ – SEL	10%	85-115%	9.5 ppb	30 ppb
Beryllium in Water	200.7	ODEQ – SEL	10%	85-115%	1.8 ppb	5 ppb
Cobalt in Water	200.7	ODEQ – SEL	10%	85-115%	3.8 ppb	20 ppb
Molybdenum in Water	200.7	ODEQ – SEL	10%	85-115%	2.7 ppb	10 ppb
Selenium in Water	200.7	ODEQ – SEL	10%	85-115%	3.3 ppb	20 ppb
Silver in Water	200.7	ODEQ – SEL	10%	85-115%	1.1 ppb	5 ppb
Calcium in Water	200.7	ODEQ – SEL	10%	85-115%	0.033 mg/L	1.0 mg/L
Alkalinity	310.1	ODEQ – SEL	10%	80-120%	1.8 mg/L	10.0 mg/L
Hardness	130.2	ODEQ – SEL	10%	80-120%	3.9 mg/L	10.0 mg/L
Chloride	325.1	ODEQ – SEL	10%	80-120%	0.5 mg/L	5.0 mg/L
Nitrate	353.2	ODEQ – SEL	10%	80-120%	0.03 mg/L	0.05 mg/L
Sulfate	375.4	ODEQ – SEL	10%	80-120%	1.2 mg/L	5.0 mg/L
COD	410.1	ODEQ – SEL	10%	80-120%	2.2 mg/L	5.0 mg/L
TSS	160.2	ODEQ – SEL	10%	80-120%	N/A	5.0 mg/L
TDS	160.1	ODEQ – SEL	10%	80-120%	N/A	5.0 mg/L
Turbidity	180.1	ODEQ – SEL	10%	80-120%	.09 mg/L	0.20 mg/L

Quality Assurance

A randomly selected field blank and duplicate water sample was submitted for one site per 10 samples collected. The sites selected for Field Blank, Duplicate and Deionized Blank sample collection were determined by a random numbering system from Microsoft EXCEL, with fourteen base flow events and thirteen sample sites. Two duplicates were needed since more than ten sites were sampled, so the random number generator feature was applied twice.

Quality control of field-analyzed parameters was achieved through regular field calibration of meters as outlined in the user manuals. Each of the samples fell within the acceptable standard deviations for laboratory precision and accuracy. In addition, bench calibration of meters occurred before each sampling event. Other aspects of QC are covered in various unit SOP's and methods. See method numbers in Table 5.

Results and Data Analysis

It is important to note that this has been the accumulation of data over a two year period. Although this is a short period of time, it helps to begin to establish trends that are occurring in these water bodies.

The data show that iron concentrations in Tar Creek are highest at where Tar Creek intersects Douthat Road and Hwy 69. Iron precipitates out in Tar Creek particularly between Veterans Boulevard and Central Street in Miami. In May 2004, both lead and zinc concentrations in Tar Creek trended upwards from the State line towards its confluence with the Neosho River. Furthermore, there are seasonal trends in both the Spring and Neosho Rivers. In the Neosho River, metals concentrations were the highest during the fall months of July, August, and November with the lowest loading rates being found in October 2004. A similar trend was shown in the Spring River, with loading rates peaking in July and November, and reaching their lowest rates in September and October. Metals concentrations appear to fluctuate on an annual pattern according to the associated flows during those times. There is a little more erratic fluctuation in the zinc concentrations than in the other metals of concern. However, even with this variation, zinc loading follows the same trend.

Bioassay collections have been completed. Analysis of the macro-invertebrate collections will be complete by the end of the year. Fish collection data showed the further downstream in Tar Creek, the greater the diversity of species. This is shown in Table 6. However there is no significant statistical correlation shown between metals in sediments or metals in the water column with species diversity.

Table 6. Fish Community Collections in Tar Creek

	TC-1 Tar Creek @ 1mi.South of State Line	TC-6 Tar Creek @ HWY66/69		TC-9 Tar Creek @ Central Street, Miami		Times Collected
SPECIES NAME	**7/23/2005**	**7/23/2005**	**9/30/2005**	**7/23/2005**	**9/30/2005**	
F.LEPISOSTEIDAE (GARS)						
Lepisosteus osseus				x		1
F.CYPRINIDAE (MINNOWS)						
Campostoma anomalum		x		x	x	3
Erimystax x-punctatus					x	1
Notemigonus crysoleucas			x			1
Notropis atherinoides		x				1
Cyprinella lutrensis		x		x	x	3
F.ICTALURIDAE (CATFISHES)						
Ictalurus furcatus				x		1
Ictalurus punctatus		x	x	x	x	4
F.CYPRINODONTIDAE (TOPMINNOWS)						
Fundulus notatus	x	x	x	x	x	5
F.POECILIIDAE (LIVEBEARERS)						
Gambusia affinis	x	x	x	x	x	5
F.CENTRARCHIDAE (SUNFISHES)						
Lepomis cyanellus	x	x	x	x	x	5
Lepomis sp.- *hybrids*	xx	xx	xx	xx		4
Lepomis gulosus			x	x	x	3
Lepomis macrochirus	x	x	x	x	x	5
Lepomis megalotis			x	x		2
Lepomis microlophus					x	1
Micropterus salmoides	x	x	x	x	x	5

Pomoxis annularis	x	x				2
F.PERCIDAE (PERCHES)						
Etheostoma whipplei					x	1
Percina phoxocephala					x	1
Total # Species	6	10	9	12	13	

Stream loading for any parameter concentration is calculated by multiplication of analytical concentration and the estimated volumetric flow rate. Loading values are reported in Kg/day.

The principal use of this loading data (load is calculated as concentration **X** flow) is to ensure that sampling events are truly comparable across the time frame encompassed by this project. The use of load data is to determine the amount of contaminant that is moving past a plane in the stream at a point in time. Then we can estimate the load for periods of time carried by the stream.

Estimated Contaminant Loading for each month sampled in 2004 and 2005 for Iron (Fe), Zinc (Zn), Lead (Pb), and Cadmium (Cd) are plotted in Figures 2 through 12 below:

There was no flow recorded for the base flow sampling events in late August, September or October at Site number 1. Therefore loading could not be calculated for these sampling events. Site designations for each of the following figures are listed in order from upstream toward downstream on Tar Creek in Table 7.

Table 7. Site Designations on Tar Creek.

Site Number	**1**	**2**	**3**	**4**	**5**	**6**
Site Location	1 Mile South of State Line	Above the Confluence of Lytle Creek	Douthat Bridge	Hwy 69	Veterans Boulevard	Central Street

Figure 2. Estimated Metal Loading Values For May 2004.

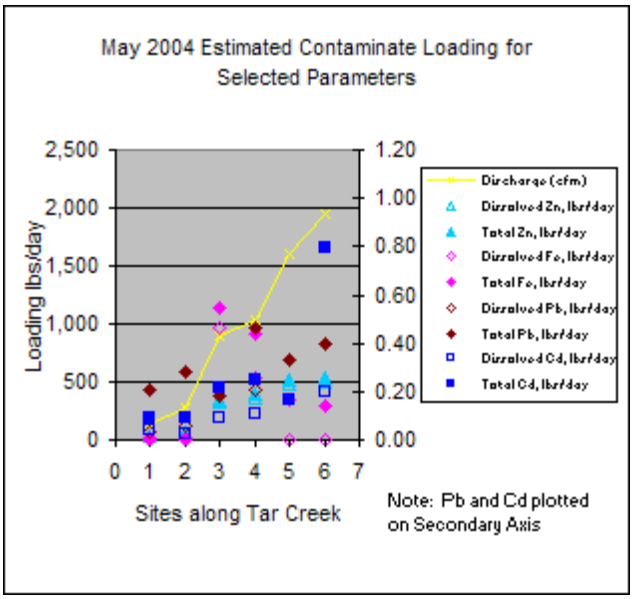


Figure 3. Estimated Metal Loading Values For June 2004.

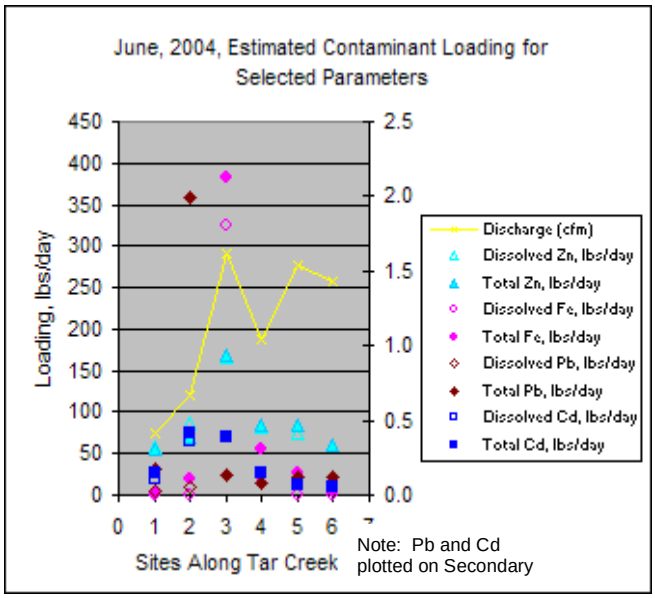


Figure 4. Estimated Metal Loading Values For July 2004.

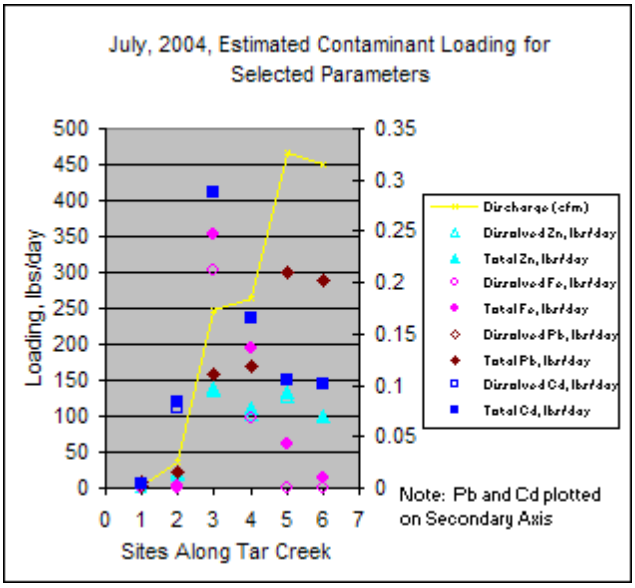


Figure 5. Estimated Metal Loading Values For August 2004.

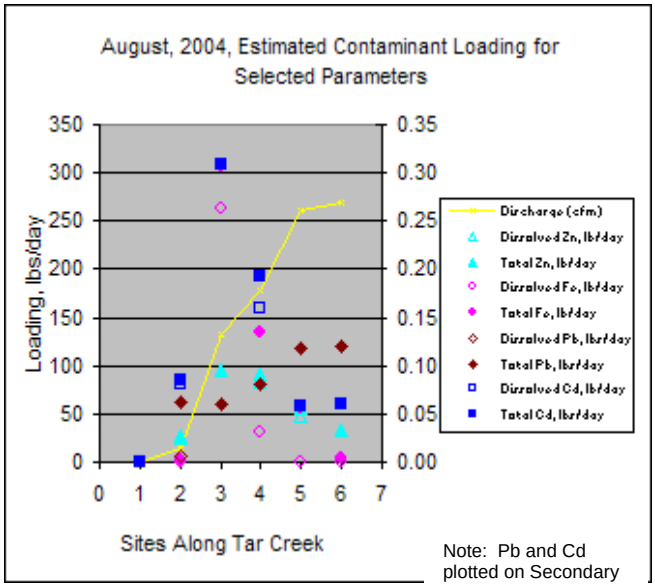


Figure 6. Estimated Metal Loading Values For September 2004.

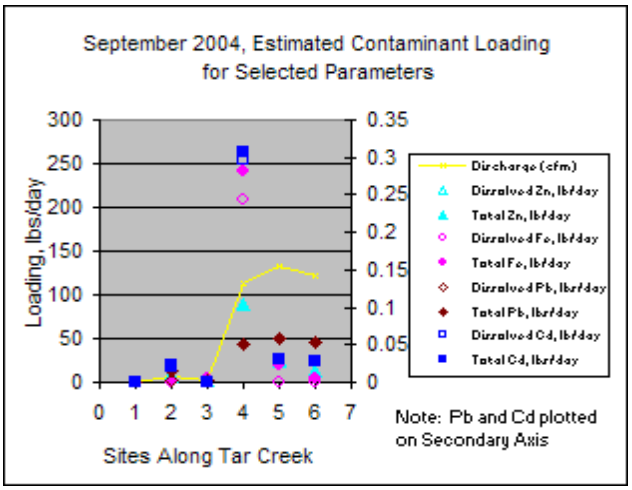


Figure 7. Estimated Metal Loading Values For October 2004.

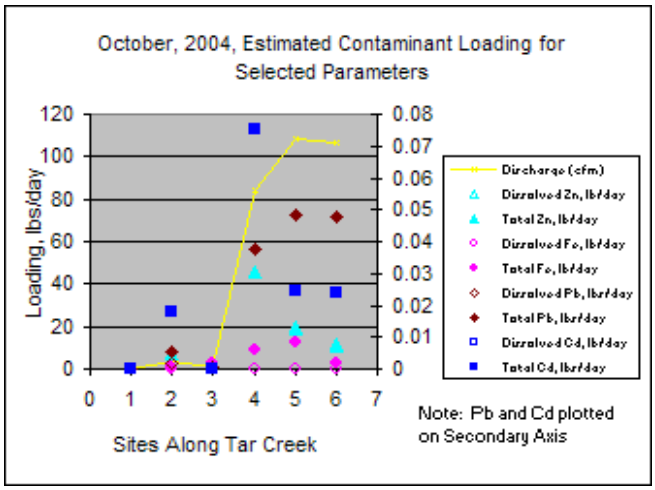


Figure 8. Estimated Metal Loading Values For November 2004.

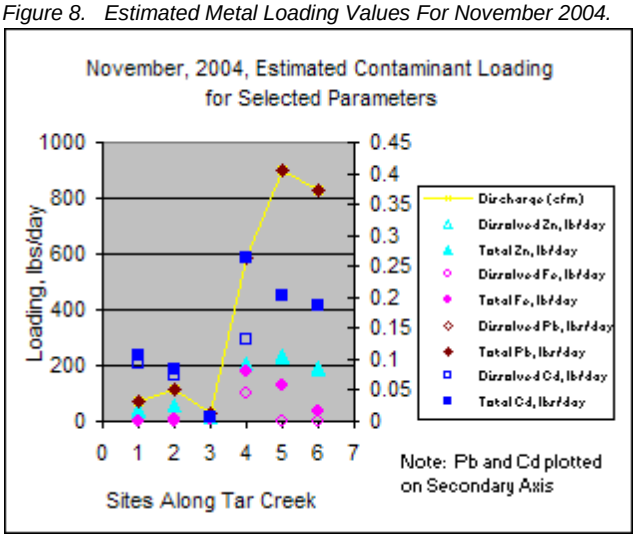


Figure 9. Estimated Metal Loading Values For March 2005.

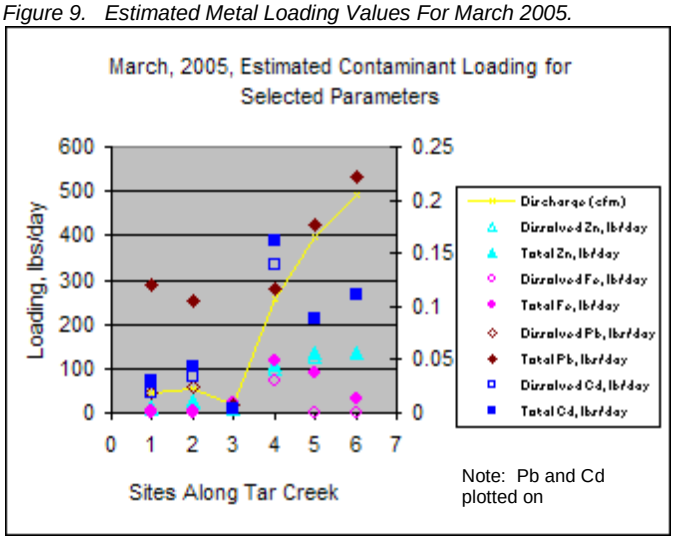


Figure 10. Estimated Metal Loading Values For May 2005.

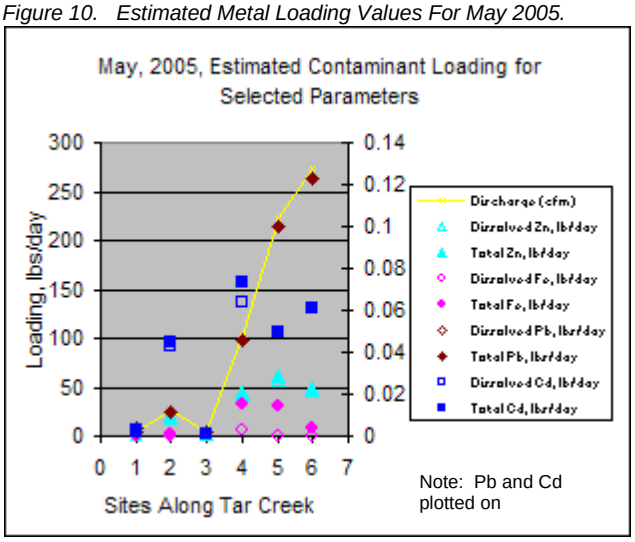


Figure 11. Estimated Metal Loading Values For June 2005.

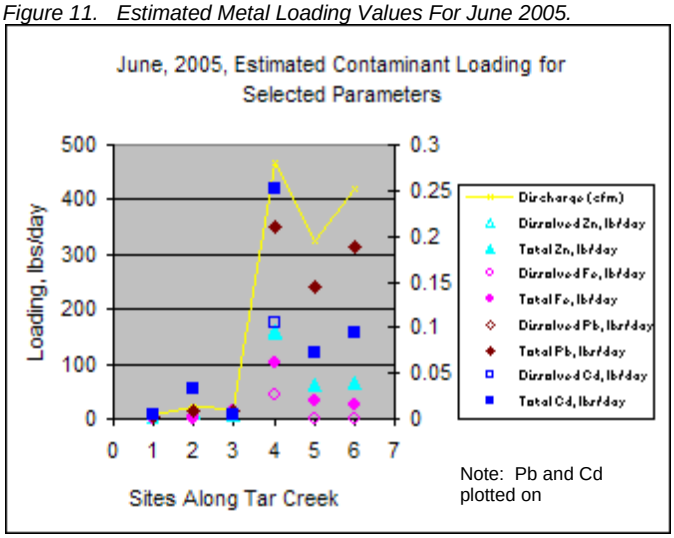


Figure 12. Estimated Metal Loading Values For July 2005.

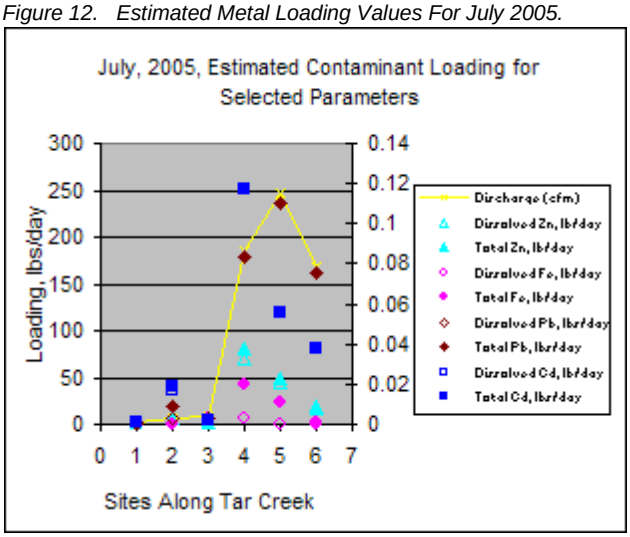
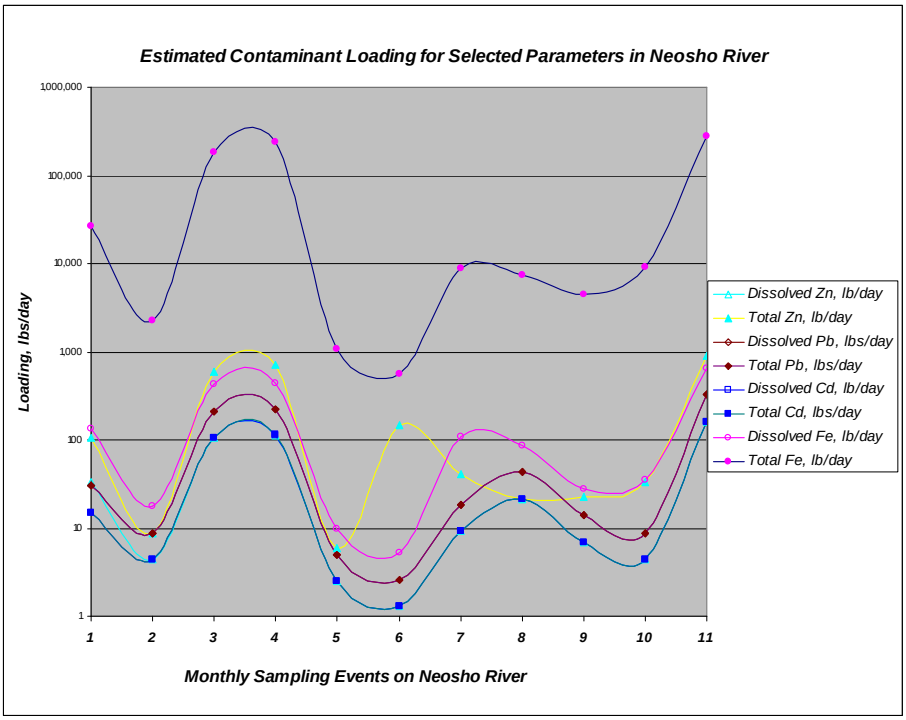
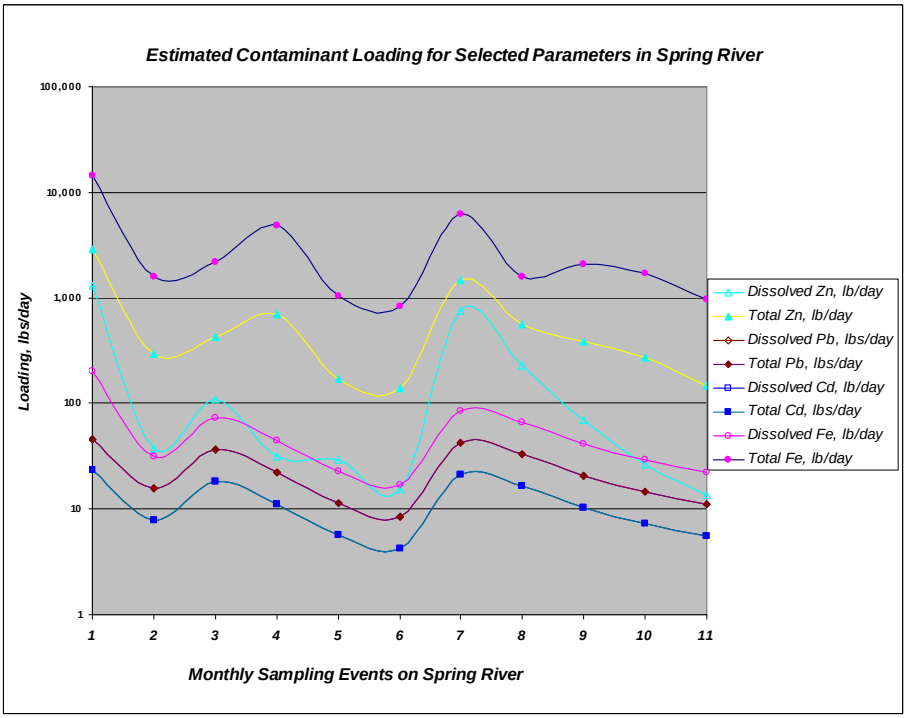


Figure 13. Estimated Contaminant Loading for Selected Parameters in Neosho River



Event #	Corresponding Month
1	May 2004
2	June 2004
3	July 2004
4	August 2004
5	September 2004
6	October 2004
7	November 2004
8	March 2005
9	May 2005
10	June 2005
11	July 2005

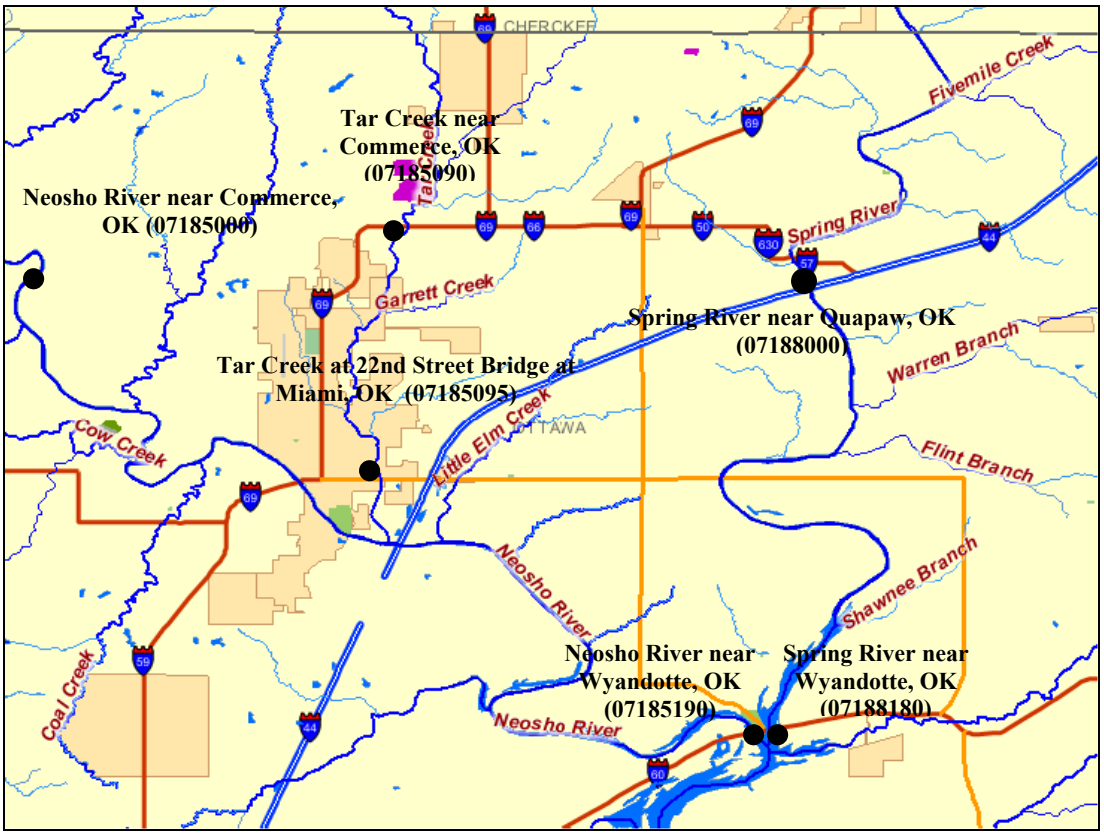
Figure 14. Estimated Contaminant Loading for Selected Parameters in Spring River



High-flow Samples

The United States Geological Survey (USGS), in cooperation with the Oklahoma Department of Environmental Quality (ODEQ) and the Seneca-Cayuga Tribe, collected high flow water-quality and sediment data from Tar Creek, Spring River, and Neosho River to characterize water and sediment quality entering Grand Lake O' the Cherokees. High-flow water-quality samples and discharge measurements were collected from six sites on Tar Creek, Spring River and Neosho River (fig.15). Lack of significant rain prevented the collection of all five water-quality samples at some of the sites. Bed sediment samples were collected at four of the six sites. At Neosho River near Commerce and Tar Creek near 22nd Street there was not enough bed sediment available to collect an adequate sediment sample at high flow. Water-quality and bed sediment samples from the sites were analyzed for general water properties, trace metals, and major ions by the ODEQ's State Environmental Lab. Water-quality samples were also analyzed for suspended sediment size and concentration by the USGS Sediment Lab in Rolla, MO. Water-quality and bed sediment results from the six sites are listed in Appendices A, D, and E.

Figure 15. Location map of high-flow sampling sites in the Grand-Neosho River Basin.



Plots were created comparing the measured surface-water discharge at the sites and the total concentration of selected water-quality constituents of metals of concern (fig. 16).

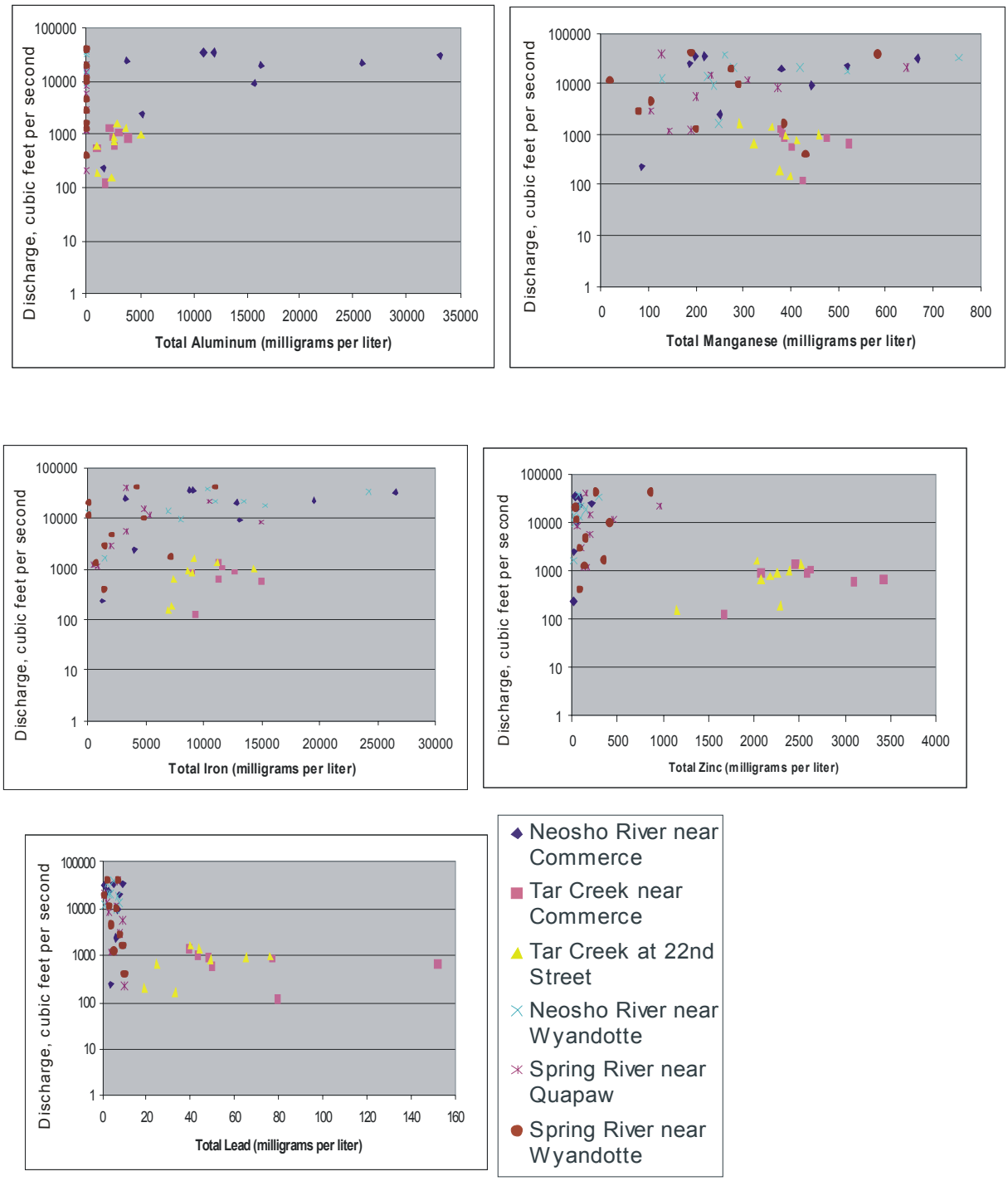
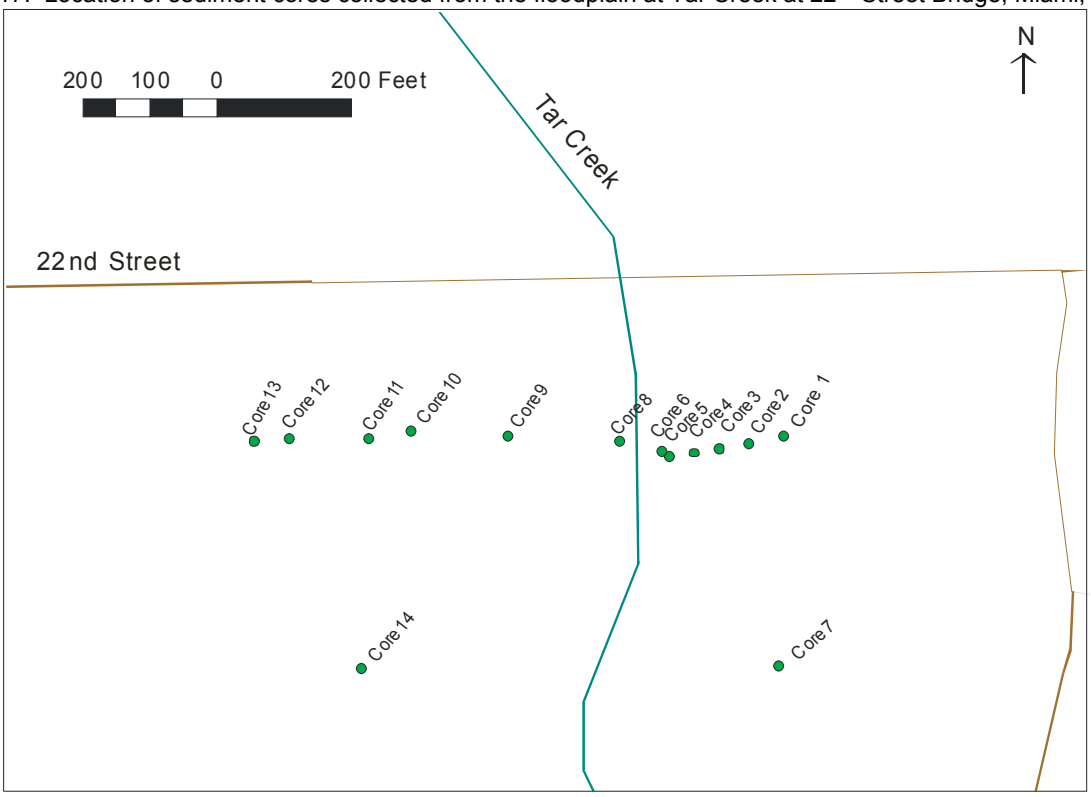


Figure 16. Plots of surface-water discharge and selected total constituent concentrations.

Sediment Cores

Fourteen sediment cores were collected from the Tar Creek floodplain at Tar Creek at 22nd Street Bridge, Miami, OK (fig. 17). The cores were collected in an east-west cross section using a Geoprobe. Each sediment core was 2 inches in diameter and approximately 2 to 3 feet of sediment was recovered from each core. The cores were brought back to the Tulsa Field Office and processed in the lab. The plastic core liner was split open and the cores were photographed and described. All but three of the cores were subsampled three times based on lithology. The other three cores were shorter than the others and did not have the same lithology changes with depth. These three cores were closer to the creek (cores 6, 8, 9). For the purpose of this update the top layer was selected for comparison of concentrations between sediment cores. The concentrations of the constituents in the top layer of each sediment core are listed in Table 8. The top layer in most of the cores was 0 to 0.20 of a foot thick. The minimum, median, and maximum concentrations of constituents detected in the floodplain were calculated also and are listed in the following table (Table 9). Summarized data are found in Appendix B.

Figure 17. Location of sediment cores collected from the floodplain at Tar Creek at 22nd Street Bridge, Miami, OK.



All of the core samples had detectable concentration of aluminum, barium, chromium, copper, iron, lead, magnesium, manganese, nickel and zinc. Sediment cores 8 and 9 were collected

from a slough that runs on the west side of Tar Creek. These two sediment cores had larger concentrations of arsenic, cadmium, lead, iron and zinc in the top layer than the other cores (Table 8).

Table 8. Concentration of constituents in the top layer of each sediment core collected from the floodplain at Tar Creek at 22nd Street, Oklahoma, 2004.

Top Layer	Al (µg/g)	Ar (ug/g)	Ba (ug/g)	Cd (µg/g)	Ca (µg/g)	Cr (µg/g)	Cu (µg/g)	Fe (µg/g)	Pb (µg/g)	Mg (µg/g)	Mn (µg/g)	Ni (µg/g)	Na (µg/g)	Zn (µg/g)
Sed 1	7060	<10	80	<1	1330	11	7	11600	24	1000	389	8	<1000	146
Sed 2	10000	<10	72	<1	1550	15	8	12800	30	1000	332	8	<1000	223
Sed 3	9840	<10	95	1	1580	14	9	14100	45	1000	603	10	<1000	315
Sed 4	11100	<10	87	2	1440	17	7	12500	46	1000	502	10	<1000	310
Sed 5	7570	<10	74	1	1210	13	6	10400	29	1000	701	8	<1000	203
Sed 6	6250	<10	62	1	1360	11	5	11300	24	1000	490	8	<1000	194
Sed 7	14300	<10	101	1	2200	19	10	13400	31	1070	372	10	<1000	227
Sed 8	19600	13	91	24	2520	24	25	56800	264	1370	182	36	<1000	4400
Sed 9	11900	11	66	21	1660	21	23	47600	306	1000	154	32	<1000	3410
Sed 10	9260	<10	91	2	1300	19	7	13400	24	1060	358	9	<1000	153
Sed 11	9370	<10	94	1	1170	16	8	14900	36	1000	504	8	<1000	184
Sed 12	18700	<10	141	<1	1650	26	10	15900	27	1260	453	11	<1000	154
Sed 13	13500	<10	115	2	1500	18	10	16100	45	1000	638	11	<1000	297
Sed 14	9890	12	90	2	1400	17	8	11600	36	1000	448	8	<1000	257

Table 9. Summary results of sediment core samples collected from the floodplain at Tar Creek at 22nd Street, Oklahoma, 2004.

	Al (µg/g)	Ar (ug/g)	Ba (ug/g)	Cd (µg/g)	Ca (µg/g)	Cr (µg/g)	Cu (µg/g)	Fe (µg/g)	Pb (µg/g)	Mg (µg/g)	Mn (µg/g)	Ni (µg/g)	Na (µg/g)	Zn (µg/g)
Min	6250	<10	62	<1	<1000	11	5	10400	9	1000	154	8	<1000	17
Median	13600	11	94	2	1495	22	8	14850	20	1015	435	9	<1000	118
Max	22400	26	190	48	6730	50	52	134000	729	3210	954	62	<1000	6820

Seepage Run

A one time seepage run was performed on Tar Creek near Commerce and Tar Creek near 22nd Street Bridge to determine changes in surface-water discharge and water-quality throughout a 24 hour period (Figure 15). Surface-water discharge measurements and water-quality samples were collected three times during a 24-hour period at the two sites. Surface-water discharge did not change considerably during the 24-hour period. Stream flow at Tar Creek near Commerce ranged from 1.9 to 2.1 cubic feet per second (cfs), and stream flow at Tar Creek at 22nd Street ranged from 2.3 to 2.6 cfs. Neither of the streams had large changes in pH and specific conductance during the 24-hour period. The pH values at Tar Creek near Commerce did not change, and pH values at Tar Creek near 22nd Street ranged from 7.2 to 7.3. Specific conductance values at Tar Creek near Commerce ranged from 2,060 to 2,100 microsiemens per centimeter (µS/cm), and specific conductance values at Tar Creek near Commerce ranged from 1,730 to 1,780 µS/cm.

At Tar Creek near Commerce the dissolved oxygen and turbidity values steadily declined through the day and into the next morning, but at Tar Creek at 22nd Street the dissolved oxygen and turbidity values increased between the first and second samples and decreased again between the last samples. Iron was the only constituent that had a large change in concentration between samples at the sites. Most of the other constituents detected in the samples only had about a 5 to 10 percent change in concentrations between samples. Summarized data are found in Appendix C.

Conclusions and Recommendations

Data that have been collected during this two year period show that metals loading is occurring in Tar Creek and in both the Spring and Neosho Rivers at least as far as the confluence of these rivers at Twin Bridges, near Wyandotte. Trends are beginning to emerge with the completion of the first of two years of sampling. These trends indicate that there are areas of specific concern with regard to metals. These include Tar Creek at Douthat Bridge and Tar Creek at Hwy 69, where metals loading is greatest along Tar Creek. Also, there is an indication that loading fluctuates seasonally. This would be an expected pattern; however, the rates during specific periods of 2004 are fairly consistent with rates during the same periods in 2005. This would indicate a reasonably predictable annual pattern of metals loading in both the Spring and Neosho Rivers. The third year of sampling that is currently proposed will allow these trends to be statistically analyzed to begin to set a baseline for this aquatic system with regards to metals of concern.

References

APHA, AWWA, WPCF. 1992. Standard Methods for Examination for Water and Waste Water 18th edition. American Public Health Association, Washington, D.C.

ODEQ (Oklahoma Department of Environmental Quality) 1999. State Environmental Laboratory Quality Assurance Plan, FY2000. Oklahoma City, OK.

ODEQ (Oklahoma Department of Environmental Quality) 1999. Toxics and Reservoirs Program: Method and Procedures, December 22, 1999. Oklahoma City, OK.

U.S. Environmental Protection Agency, Region 6, Office of Quality Assurance. Data Quality Objectives Workshop-Manual. August 15, 1994.

U.S. Environmental Protection Agency. Compendium of ERT Surface Water and Sediment Sampling Procedures. 2.0 Surface Water Sampling: Sop #2013. EPA/540/P-91/005. January 1991.

U.S. Environmental Protection Agency. Manual for the Certification of Laboratories Analyzing Drinking Water. 1997.

Appendix A
Summarized High-Flow Data

Appendix B
Summarized Sediment Core Data

Appendix C
Summarized Seepage Run Data

Appendix D
Summarized Base-Flow Data

Appendix E
Summarized Suspended-Sediments Data