Final Report

Metals and pH TMDLs for the Elk River Watershed, West Virginia

United States Environmental Protection Agency
Region 3
1650 Arch Street
Philadelphia, PA

September 2001

Acknowledgments

This study was developed and prepared by Tetra Tech, Inc., in Fairfax, Virginia , under EPA Contract Number 68-C-99-24, Work Assignment 1-93. The EPA Regional Coordinator was Mr. Thomas Henry of EPA Region 3. The EPA Work Assignment Manager was Mr. Leo Essenthier of EPA Region 3. EPA Region 3 support was provided by Ms. Mary Beck and Ms. Carol Ann Davis. Completion of this study depended upon the generous informational and data support of various groups. The following people are especially acknowledged:

Mary Beck	U.S. Environmental Protection Agency, Region 3
Pat Campbell	West Virginia Department of Environmental Protection, Division of Water Resources
Carol Ann Davis	U.S. Environmental Protection Agency, Region 3
Angela Dorsey	West Virginia Department of Environmental Protection, Division of Mining and Reclamation
Thomas Henry	U.S. Environmental Protection Agency, Region 3
J.R. Hodel	West Virginia Department of Environmental Protection, Division of Mining and Reclamation
James Laine	West Virginia Department of Environmental Protection, Division of Water Resources
Ken Politan	West Virginia Department of Environmental Protection, Division of Mining and Reclamation
Steve Stutler	West Virginia Department of Environmental Protection, Division of Water Resources
David Vande Linde	West Virginia Department of Environmental Protection, Division of Mining and Reclamation
Jerry Tephabock	West Virginia Department of Environmental Protection, Office of Oil and Gas
Dave Montali	West Virginia Department of Environmental Protection, Division of Water Resources

Contents

Figures . . . iv
Tables . . . iv
1.0 Problem Understanding . . . 1-1
2.0 Water Quality Standards . . . 2-1
3.0 Source Assessment . . . 3-1
3.1 Data Inventory . . . 3-1
3.2 Stream Flow Data . . . 3-2
3.3 Point Sources . . . 3-2
3.3.1 Permitted Nonmining Point Sources . . . 3-3
3.3.2 Permitted Mining Point Sources . . . 3-3
3.4 Nonpoint Sources . . . 3-4
3.4.1 Abandoned Mine Lands (AML) . . . 3-5
3.4.2 Sediment Sources . . . 3-6
3.4.3 Other Nonpoint Sources . . . 3-7
4.0 Technical Approach . . . 4-1
4.1 Model Framework Selection . . . 4-1
4.2 Mining Data Analysis System (MDAS) Overview . . . 4-2
4.3 Model Configuration . . . 4-3
4.3.1 Watershed Subdivision . . . 4-3
4.3.2 Meteorological Data . . . 4-4
4.3.3 Nonpoint Source Representation . . . 4-7
4.3.4 Point Source Representation . . . 4-9
4.3.5 Stream Representation . . . 4-12
4.3.6 Hydrologic Representation . . . 4-12
4.3.7 Pollutant Representation . . . 4-12
4.4 Model Calibration . . . 4-12
4.4.1 Hydrology Calibration . . . 4-13
4.4.2 Sediment Calibration for Nonpoint Sources . . . 4-15
4.4.3 Water Quality Calibration . . . 4-15
5.0 Allocation Analysis . . . 5-1
5.1 TMDL Endpoints . . . 5-1
5.1.1 Aluminum, Iron, Manganese, and Lead . . . 5-1
5.1.2 pH . . . 5-2
5.1.3 Margin of Safety . . . 5-2
5.2 Baseline Conditions . . . 5-2
5.3 Source Loading Alternatives . . . 5-3
5.4 TMDLs and Source Allocations . . . 5-3
5.4.1 Wasteload Allocations (WLAs) . . . 5-4
5.4.2 Load Allocations (LAs) . . . 5-5
5.4.3 pH Modeling Results . . . 5-5
5.4.4 Seasonal Variation . . . 5-6

5.4.5 Future Growth . . . 5-7
5.4.6 Remining and Water Quality Trading . . . 5-7
6.0 Reasonable Assurance . . . 6-1
6.1 Reclamation . . . 6-1
6.1.1 Office of Abandoned Mine Lands and Reclamation . . . 6-1
6.1.2 Special Reclamation Group . . . 6-3
6.2 Permitting . . . 6-4
7.0 Monitoring Plan . . . 7-1
8.0 Public Participation . . . 8-1

References . . . R-1

Appendix A-1. Elk River Watershed Data and TMDLs - Region 1 . . . A-1-1
Appendix A-2. Elk River Watershed Data and TMDLs - Region 2 . . . A-2-1
Appendix A-3. Elk River Watershed Data and TMDLs - Region 3 . . . A-3-1
Appendix B. Mining Permits in the Elk River Watershed . . . B-1
Appendix C. Water Quality Data Analysis: Sediment/Metals Relationships . . . C-1
Appendix D. Hydrology and Water Quality Calibration and Validation Results . . . D-1
Appendix E. Modeling pH for TMDL Development . . . E-1
Appendix F. Dissolved Zinc Impairments in the Elk River Watershed . . . F-1

Figures

Figure 1-1 Location of the Elk River watershed 1-2
Figure 1-2 Elk River watershed and its Three regions 1-4
Figure 3-1 Potential sources contributing to impairments in the Elk River watershed 3-8
Figure 3-2 Land use distribution in the Elk River watershed 3-9
Figure 4-1 Elk River subwatersheds 4-5
Figure 4-2 Weather stations used in modeling 4-6
Figure 4-3 Calibration locations used in modeling 4-14

Tables

Table 1-1 Section 303(d) listed waterbodies and corresponding impairments 1-3
Table 2-1 Applicable West Virginia water quality criteria 2-2
Table 3-1 Inventory of data and information used to develop the Elk River watershed TMDLs 3-1
Table 3-2 Flow analysis for the Elk River watershed 3-2
Table 3-3 Nonmining point source facilities discharging to the Elk River watershed 3-3
Table 3-4 Classification of mining permit type and status 3-4
Table 3-5 Sediment source characterization 3-7
Table 4-1 Modules from HSPF converted to HSPC 4-3
Table 4-2 Model land use grouping 4-7
Table 4-3 Model nonpoint source representation of different permitted mines 4-9
Table 4-4 Modeled land use distribution in acres for subwatersheds 1 through 12 4-10
Table 4-5 Modeled land use distribution in acres for subwatersheds 13 through 24 4-10
Table 5-1 Metals concentrations used in representing permitted conditions for mines 5-3
Table 5-2 Load and waste load allocations for aluminum 5-6
Table 5-3 Load and waste load allocations for iron 5-6
Table 5-4 Load and waste load allocations for manganese 5-6
Table 5-4 Load and waste load allocations for zinc 5-6

1.0 Problem Understanding

The Elk River in central West Virginia originates near Slaty Fork, West Virginia, and flows westward for approximately 190 miles before it empties into the Kanawha River near Charleston, West Virginia (Figure 1-1). The Elk River watershed drains approximately 1,530 square miles (979,724 acres) and covers parts of nine counties in West Virginia: Braxton, Calhoun, Clay, Kanawha, Nicholas, Pocahontas, Randolph, Roane, and Webster. Major tributaries of the Elk River include Birch River, Big Sandy Creek, and Buffalo Creek. In addition, Sutton Lake, a reservoir managed by the U.S. Army Corps of Engineers, is located in the central portion of the watershed.

The population of the watershed is distributed throughout small towns and rural unincorporated communities. The City of Charleston, the state capital, is the largest community in the watershed. The watershed is dominated by forest and agricultural lands, and common industrial practices include coal mining, oil and natural gas production, forest activities, recreational development, and agricultural activities. Counties in the watershed contain active surface and deep mining operations, and many of the coal fields in the watershed contain abandoned coal mines. Active oil and gas wells are present in the western portion of the watershed. Before the implementation of the West Virginia Surface Coal Mining and Reclamation Act (WVSCMRA) and the Surface Mining Control and Reclamation Act (SMCRA), little consideration was given to the environmental degradation that resulted from these activities. Currently, the quality of the Elk River and its tributaries are being negatively affected by acidic drainage from mines that were abandoned before the WVSCMRA and SMRCA.

Five waterbodies in the Elk River watershed have been included on West Virginia's 1998 Section 303(d) list of impaired waters because of metals and pH impairments (Table 1-1). These listed waterbodies include the mainstem of the Elk River and four additional stream segments in the watershed as shown in Figure 1-2. The mainstem of the Elk River is listed as impaired for iron (Fe), aluminum (Al), lead (Pb), and zinc (Zn). The upstream tributaries are listed for metals (aluminum, iron, and manganese), except for Buffalo Creek which listed for pH. The source of the metals and pH impairments in the upstream tributaries was identified as mine drainage on the 1998 Section 303(d) list; the source of the mainstem iron, aluminum, lead, and zinc impairments was undetermined. Water quality analyses were performed to confirm the impairment status of monitored streams and examine spatial trends in the Elk River watershed. Metals data, in general, indicate an increasing trend in metals concentrations from upstream to downstream areas.

EPA's *Water Quality Planning and Management Regulations* (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waters that exceed water quality standards. The objective of this study was to develop TMDLs for the impaired waterbodies in the Elk River watershed. All potential sources of metals in the watershed were considered in the TMDL development process. Sediment sources were considered to be an important factor, because of the relatively higher concentration of metals in the soils of the Elk River watershed and the extent of land disturbance, especially in downstream areas (Elk mainstem). All sources, including mining areas and disturbed lands, were represented in modeling efforts to evaluate the relative contribution of metals from each source category.

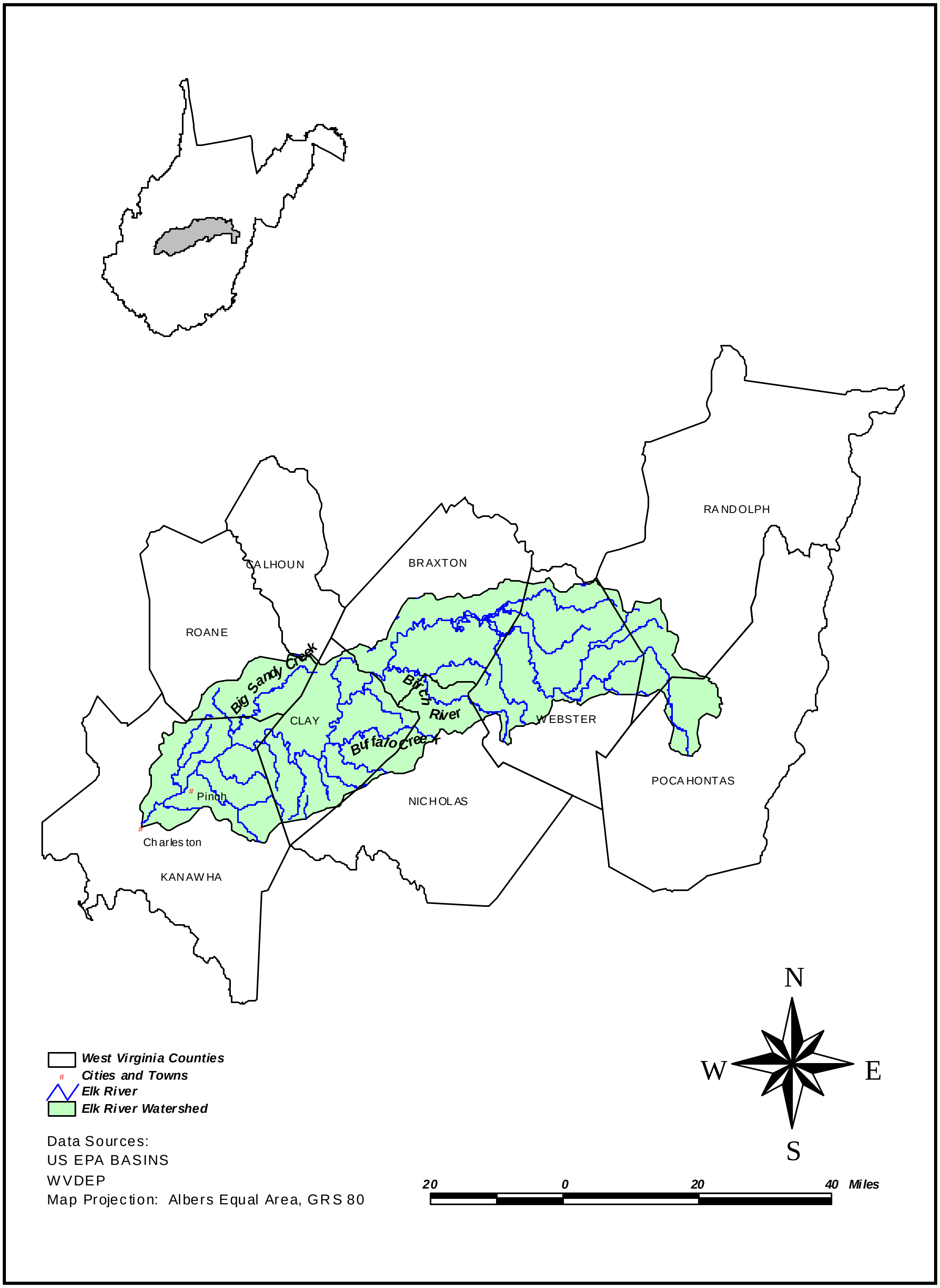


Figure 1-1. Location of the Elk River watershed

Table 1-1. Section 303(d) listed waterbodies and corresponding impairments

Listed Segment ID	Stream Name	Length (mi)	Trout Waters	Al	Fe	Mn	Pb	Zn	Metals[a]	pH	Year Listed[b]
K-43	Elk River	21.77		x	x		x	x			1998
KE-26	Morris Creek	0.97							x	x	1998
KE-26-A	Left Fork/Morris Creek	2.15							x	x	1998
KE-50	Buffalo Creek	23.81							x		1996
KE-50-T	Pheasant Run	1.50							x	x	1996

[a] Metals include Al, Fe, and Mn as designated by West Virginia Department of Environmental Protection
[b]Elk River, Morris Creek ,and Left Fork/Morris Creek were first listed on West Virginia's Section 303(d) list in 1998.

This report presents TMDLs for each of the five listed segments in the Elk River watershed. To develop the TMDLs and other pertinent watershed and waterbody information, the watershed was divided into three regions based on the distribution of water quality monitoring stations (Figure 1-2). Region 1 is the only region that does not include stream impairments. Each region was further divided into subwatersheds (24 total for the entire Elk River watershed) for modeling purposes. The three regions and their respective subwatersheds provide a good basis for georeferencing pertinent source information, monitoring data, and presenting TMDLs. This information is presented in Appendices A-1 through A-3 of this report. Information contained in Appendices A-1, A-2, and A-3 corresponds to regions 1, 2 and 3, respectively.

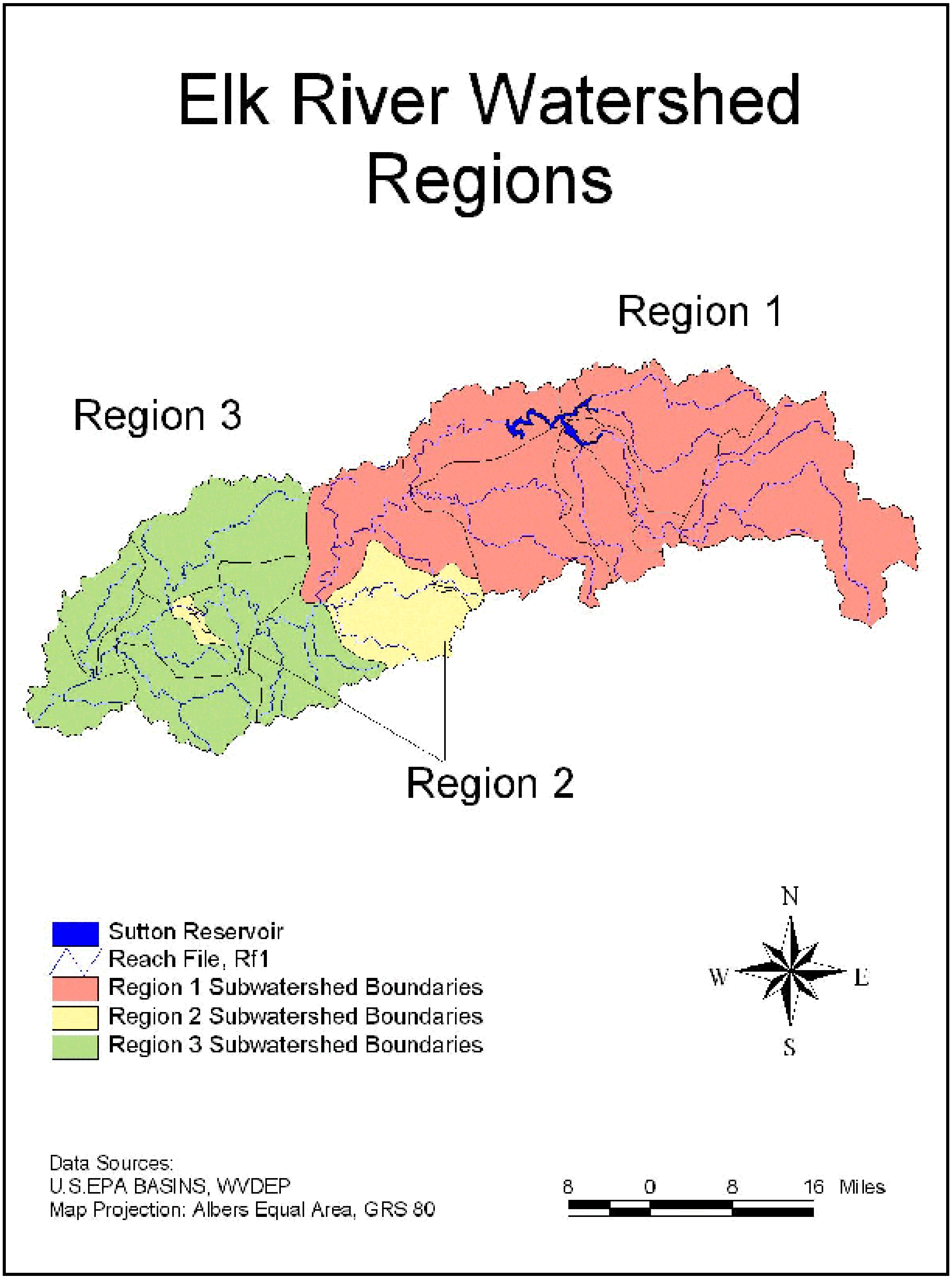


Figure 1-2. Elk River watershed and its three regions

2.0 Water Quality Standards

West Virginia's *Requirements Governing Water Quality Standards* (WVWQS, 2000) have defined water quality criteria for surface waters as a numeric constituent concentration or a narrative statement representing a quality of water that supports a designated use or uses of the waterbody. Total aluminum, iron, and manganese, and pH are given numeric criteria under the aquatic life and the human health use designation categories (Table 2-1). All listed waterbodies in the Elk River watershed have been designated as having an aquatic life and human health use.

There are approximately 598 existing water quality stations in the Elk River watershed. Examination of the data for the listed segments confirms that water quality criteria were exceeded. Tables 3a, 3b, and 3c in each of Appendices A-1 and A-2 summarize applicable water quality data for monitoring stations throughout the watershed. These results support the impairment listings for iron, aluminum, magnesium, lead, and pH in specified stream segments; however, zinc concentrations in the main stem of the Elk River did not exceed the hardness-based water quality criteria (Appendix F). These findings suggest that the main stem of the Elk River is not impaired for zinc and therefore TMDL development for this pollutant is not necessary. This will be addressed in the development of the West Virginia 2002 Section 303(d) list.

Table 2-1. Applicable West Virginia water quality criteria

POLLUTANT	USE DESIGNATION				
	Aquatic Life				Human Health
	B1, B4		B2		A[c]
	Acute[a]	Chronic[b]	Acute[a]	Chronic[b]	
Aluminum, Total (µg/L)	750	-	750	-	-
Iron, Total (mg/L)	-	1.5	-	0.5	1.5
Manganese, Total (mg/L)	-	-	-	-	1.0
Lead, dissolved (µg/L)	d	e	d	e	-
Zinc, dissolved (mg/L)	$(0.978)(e^{[(0.8473)(\ln[\text{hardness}†]) + 0.8604]})$	$(0.978)(e^{[(0.8473)(\ln[\text{hardness}†]) + 0.7614]})$	$(0.978)(e^{[(0.8473)(\ln[\text{hardness}†]) + 0.8604]})$	$(0.978)(e^{[(0.8473)(\ln[\text{hardness}†]) + 0.7614]})$	-
pH	No values below 6.0 or above 9.0	No values below 6.0 or above 9.0	No values below 6.0 or above 9.0	No values below 6.0 or above 9.0	No values below 6.0 or above 9.0

Note: B1 = warm water fishery streams, B4 = wetlands, B2 = trout waters, A = public water supply.
[a] One-hour average concentration not to be exceeded more than once every 3 years on the average.
[b] Four-day average concentration not to be exceeded more than once every 3 years on the average
[c] Not to exceed.
[d]The 1-hour average concentration of dissolved lead shall not exceed the value determined by the following equation:
$Pb = e^{(1.237[\ln(\text{hardness})]-4.705)} \times 1.46203-[(\ln \text{hardness})(0.145712)]^{5}$
[e]The 4-day average concentration of dissolved lead shall not exceed the value determined by the following equation:
$Pb = e^{(1.237[\ln(\text{hardness})]-1.46)} \times 1.46203-[(\ln \text{hardness})(0.145712)]^{5}$
† Hardness as calcium carbonate (mg/L). The minimum hardness allowed for use in this equation shall not be less than 25 mg/l, even if the actual ambient hardness is less than 25 mg/l. The maximum hardness value for use in this equation shall not exceed 400 mg/l even if the actual hardness is greater than 400 mg/l.

Source: WVWQS, 1999.

3.0 Source Assessment

This section examines and identifies the potential sources of aluminum, iron, and manganese in the Elk River watershed. A wide range of data was used to identify potential sources and to characterize the relationship between point and nonpoint source discharges and instream response at monitoring stations. Sources of lead and zinc in the watershed were not identified in the assessment process detailed below.

3.1 Data Inventory

Data and information from various sources were used in the development of TMDLs for the impaired streams in the Elk River watershed. The categories of data used include physiographic data that describe the physical conditions of the watershed and environmental monitoring data that identify potential pollutant sources and their contribution. Table 3-1 shows the various data types used to develop TMDLs.

Table 3-1. Inventory of data and information used to develop Elk River watershed TMDLs

Data Category	Description	Data Source(s)
Watershed Physiographic Data	Land Use (GAP2000)	USGS
	Abandoned Mining Coverage	WVDEP OMR
	Soil data (STATSGO)	USDA, NRCS
	Stream Reach Coverage	USGS, WVDEP DWR
	Weather Information	National Climatic Data Center
	Oil and Gas Operations Coverage	WVDEP OOG
	Paved and Unpaved Roads	WVDOT, USDOT
	Timber Harvest Data	USDA, US Forest Serice
Environmental Monitoring Data	NPDES Data	WVDEP OMR, WVDEP DWR
	Discharge Monitoring Report Data	WVDEP OMR
	Abandoned Mine Land Data	WVDEP OMR, WVDEP DWR
	Section 303(d) Listed Waters	WVDEP DWR
	Water Quality Monitoring Data for 598 Sampling Stations	EPA STORET, WVDEP DWR

3.2 Stream Flow Data

There are 18 USGS flow gages in the Elk River watershed, as well as one flow gage station operated by the National Weather Service. Flow data from 12 of these USGS gages were used to support flow analyses for the watershed. Table 3-2 shows the12 flow gaging stations with available records of flow data and the corresponding period of record for each. These 12 stations were used because they were the only stations which include sufficient long-term records to characterize the stream flow in the watershed.

Table 3-2. Flow analysis for the Elk River watershed

Station	Stream Name	Start Date	End Date	Min (cfs)	Mean (cfs)	Max (cfs)
03195600	Granny Creek at Sutton, WV	06/01/1967	09/30/1977	0.03	9.33	281.00
03197000	Elk River at Queen Shoals, WV	10/01/1928	09/30/1998	0.30	2090.64	58100.00
03196800	Elk River at Clay, WV	10/01/1958	09/30/1978	1.80	1925.24	32100.00
03195100	Right Fork Holly River at Guardian, WV	10/01/1985	09/30/1987	0.03	98.15	1670.00
03195500	Elk River at Sutton, WV	10/01/1938	09/30/1993	0.40	1145.52	20400.00
03195000	Elk River at Centralia, WV	10/01/1934	09/30/1963	1.30	664.64	14700.00
03194700	Elk River below Webster Springs, WV	09/20/1985	09/30/1998	4.90	709.09	15200.00
03196600	Elk River near Frametown, WV	10/01/1994	09/30/1995	82.00	1109.64	10000.00
03196500	Birch River at Herold, WV	10/01/1978	09/30/1984	1.80	242.14	5630.00
03197440	Left Hand Creek near Clendenin, WV	01/24/1974	02/14/1975	0.91	31.46	202.00
03193830	Gilmer Run near Marlinton, WV	06/12/1968	09/30/1977	0.01	3.83	153.00
03195250	Left Fork Holly River near Replete, WV	10/01/1985	09/30/1987	0.03	124.82	2020.00

3.3 Point Sources

In order to characterize the contributing point sources in the Elk watershed, the point sources were classified into two major categories: permitted non-mining point sources and permitted mining point sources.

3.3.1 Permitted Nonmining Point Sources

Data regarding nonmining point sources were retrieved from EPA's Permit Compliance System (PCS) and WVDEP. There are a total of 143 nonmining point sources in the Elk River watershed. Three of these facilities are permitted to discharge one or more of the listed pollutants to the Elk River watershed. The three facilities are listed in Table 3-3 along with the pollutants they are permitted to discharge. The discharges from these nonmining point sources are required to be within a pH range of 6 to 9, inclusive.

Table 3-3. Nonmining point source facilities discharging to the Elk River watershed

NPDES ID	Facility Name	Permitted Pollutant Discharged
WV0002631	Columbia Gas Transmission	Iron
WV0072249	Appalachian Timber Services	Iron
WV0080900	Elk Pinch PSD	Aluminum, lead, zinc

3.3.2 Permitted Mining Point Sources

Mining-related point source discharges, from deep mines, surface mines, and other mining activities, if untreated, typically have low pH values and contain high concentrations of metals (iron, aluminum, and manganese). Consequently, mining-related activities are commonly issued discharge permits for these parameters. A spatial coverage of the mining permit data was provided by the West Virginia Office of Mining and Reclamation (OMR). The coverage includes both active and inactive mining facilities, which are classified by type of mine and facility status. The mines are classified into eight different categories: coal surface mine, coal underground mine, haulroad, coal preparation plant, coal reprocessing, prospective mine, quarry, and other. The haulroad and prospective mine categories represent mining access roads and potential coal mining areas, respectively. The permits were also classified into 7 categories describing the status of each permitted discharge. OMR provided a brief description regarding classification and associated potential impact on water quality. Mining types and status descriptions are shown in Table 3-4.

Table 3-4. Classification of mining permit type and status

Type of Mining	Status Code	Description
Coal surface mine Coal underground mine Haulroad Coal preparation plant Coal reprocessing Prospective mine Quarry Other	Completely Released	Completely reclaimed, revegetated; should not be any associated water quality problems
	Phase II Released	Sediment and ponding are gone, partially revegetated, very little water quality impact
	Phase I Released	Regraded and reseeded; in initial phase of the reclamation process; could potentially impact water quality
	Renewed	Active mining facility, assumed to be discharging according to the permit limits
	New	Newly issued permit; could be currently active or inactive; assumed to be discharging according to permit limits
	Inactive	Currently inactive; could become active anytime; assumed to be discharging according to discharge limits
	Revoked	Bond forfeited; forfeiture may be caused by poor water quality; highest impact on water quality

Coal mining operations and sandstone quarries typically have permits limiting total iron, total manganese, total nonfilterable residue, and pH. They are also required to monitor for total aluminum discharges. However, limestone quarries do not have permits for discharge concentrations of total iron, total manganese, total nonfilterable residue, and aluminum discharges. There are a total of 256 mining discharge permits in the Elk River watershed. A complete list is provided in Appendix B.

3.4 Nonpoint Sources

In addition to point sources, nonpoint sources might also contribute to water quality impairments in the Elk River watershed. Nonpoint sources represent contributions from diffuse, nonpermitted sources. Based on the identification of a number of abandoned mining activities in the Elk River watershed, abandoned mine lands (AML) represent a critical nonpoint source. Abandoned mines can contribute significant amounts of acid mine drainage (AMD), which produces low pH and high metals concentrations in surface and subsurface water in areas where mining activities are or once were present.

AMD occurs when surface and subsurface water percolates through coal-bearing minerals containing high concentrations of pyrite and marcasite, which are crystalline forms of iron sulfide (FeS_2). It is these chemical reactions of the pyrite that generate acidity in water. A synopsis of these reaction is as follows: Exposure of pyrite to air and water causes the oxidation of pyrite. The sulfur component of pyrite is oxidized releasing dissolved ferrous (Fe^{2+}) ions and also hydrogen (H^+) ions. It is these H^+ ions that cause the acidity. The intermediate reaction with the dissolved Fe^{2+} ions generates a precipitate, ferric hydroxide, $Fe(OH)_3$, and also releases more H^+ ions, thereby causing more acidity. Another reaction is one between the pyrite and generated ferric (Fe^{3+}) ions, in which more acidity (H^+) is released as well as Fe^{2+} ions, which then can enter the reaction cycle (Stumm and Morgan, 1996).

Sediment produced from land-based activities is another potential source of high metal contamination in the Elk River watershed. region 3. West Virginia is composed of two basic geologic areas: the western two-thirds has relatively flat-lying rocks and the eastern one-third has folded and faulted rocks. The Appalachian Plateau Province is located in the west and the Valley and Ridge Province in the east, separated by the Allegheny Front. The oldest formation, the Catoctin Formation (late Precambrian), is found in the eastern part of the state, with younger formations (Paleozoic) in the west. Quaternary alluvium overlays much of the formations.

The Appalachian Plateau, composed mostly of Pennsylvanian and Permian strata, is where much of the minable coal is located. The rocks of the Pennsylvanian System are widely exposed at the surface, having been extensively mined for coal and drilled extensively for oil and gas. Lower and Middle Pennsylvanian rocks that are exposed in the east-central part of the state (Kanawha, Clay, and western Roan counties) consist primarily of sandstone with clayey sediments and coal found in the subsurface. From east to west, shale and coal are commonly exposed in the younger Pennsylvanian formations (Watts et al., 1994).

The Lower Pocahontas basin is in the southern part of the state and is the older of two sedimentary basins in West Virginia. Alternating units of sandstone, shale, limestone, and coal of the Kanawha, New River, and Pocahontas Formations are found in the sediments in the Pocahontas basin. The Dunkard basin, the northern sedimentary basin, overlaps the Pocahontas basin in central West Virginia (Calhoun, Gilmer, Kanawha, and Roan counties). Sediments of the Dunkard basin consist of sandstone and shale from the Conemaugh Formation with small amounts of coal from the Monongahela and Dunkard Groups.

Watts et al. (1994) identified clays derived from shale units within the drainage basins as the primary source of high aluminum concentrations instream sediments. In addition, correlation coefficients indicate that iron and manganese are associated with aluminum as a result of precipitated iron oxides and oxyhydroxides in the streambeds (Watts et al., 1994).

Nonpoint source contributions were grouped for assessment into three separate categories: AML, sediment sources, and other nonpoint sources. Figure 3-1 presents a schematic of potential sources in the Elk River watershed. The land use distribution for the Elk watershed is presented in Figure 3-2.

3.4.1 Abandoned Mine Lands (AML)

Historically, there have been both surface and deep mining activities in the Elk River watershed, and consequently numerous AML sites that produce AMD flows remain. Data regarding AML sites in the Elk River watershed were compiled from spatial coverages provided by WVDEP OMR. The AML sites were classified into three categories:

High walls: the face of exposed overburden and coal in an open cut of a surface coal mining activity or for entry to underground mining activities
Disturbed land: disturbed land associated to both surface and underground mining activities
Abandoned mines: abandoned surface and underground mines

Additional qualitative data were retrieved from WVDEP OMR Problem Area Data Sheets (PADS). Table 2 in Appendices A-1 and A-2 presents information regarding the locations of the most critical sources, abandoned mines.

3.4.2 Sediment Sources

Based on the review of existing literature, sediment was identified as a potential source of high metals concentrations in the Elk River watershed. Visual observations by WVDEP in April 2001 indicated that the impaired segment of the main stem exhibited a high level of siltation. However, increased siltation was not observed in the upstream impaired segments (Buffalo Creek, Morris Creek, Left Fork Morris Creek and Pheasant Run). Water quality data from 42 stations on the impaired main stem and 25 stations on the upstream segments were evaluated to determine whether a relationship between total metals and total suspended solids (TSS) concentrations exists. The results of these analyses are presented in Appendix C.

For the Elk River main stem, results of a comparison of the water quality data for total aluminum, total iron, and total manganese concentrations showed that concentrations appeared to closely follow suspended solids concentrations, increasing as flow increased (Figures C-1 through C-4). Regression analysis indicated that a good linear relationship exists between total aluminum, total iron, and total manganese and sediment concentrations during the 30 percent highest flows (Figures C-7 through C-9). However, dissolved iron and manganese concentrations are shown to decrease during high-flow events and increase during periods of low flow (Figures C-5 and C-6). The increase in metals concentrations during high flow, the linear relationship between metals and total suspended solids, and the decrease in dissolved metals concentrations during high flow indicate that sediment is a significant contributor to the high metals concentrations in the impaired main stem of the Elk River. Therefore, potential sources of sediment must be considered in the development of metals TMDLs for the main stem segment.

Similar analyses were performed using water quality data from the upstream impaired segments to determine whether land-based nonpoint sources were significant sources of metals in these watersheds. Higher total metals concentrations were shown to occur during low-flow conditions for each stream (Figures C-10 and C-11). These data confirm WVDEP observations in April 2001 regarding instream siltation and suggest that land-based activities are not significant contributors of metals, as has been shown for the Elk River mainstem. AMD and other sources are likely the primary sources of metals in these streams.

In the Elk River watershed, land-based nonpoint sources of sediment include abandoned and active mine areas, forestry operations, oil and gas operations, unpaved roads, agricultural land uses, barren land, and forestland. Because sediment transport is considered to be a primary source of metals in the main stem segment of the Elk River, reductions in sediment loading will be required to meet instream metals criteria. Reductions in sediment loading from these areas will be based on the sediment transport characteristics of each of these nonpoint source categories. High-sediment-yield areas include disturbed lands such as unpaved roads, forest harvest areas and access roads, oil and gas operations, agricultural land, barren land, and active mine areas. Mature forestland and other

undisturbed areas have the lowest sediment yield and therefore have the lowest impact on receiving waters. A conceptual representation of sediment loading from nonpoint sources relative to the natural or undisturbed forest condition is presented in Table 3-5. To spatially represent land-based nonpoint sources in the Elk River watershed, the
GAP2000 land use coverage for each subwatershed was updated to include paved and unpaved road areas, forest harvest areas, oil and gas operations, and mining areas.

Table 3-5. Sediment source characterization

	Sediment Contribution			Time Scale of impact on receiving water body	
Sources	**High**	**Medium**	**Low**	**Long**	**Short**
Forest (undisturbed)[a]			X	NA	NA
Forest operations	X				X
Access roads in forest	X			X	
Agriculture		X		X	
Oil and gas drilling		X			X
Oil and gas access road	X			X	
Mining (abandoned)		X		X	
Mining (active)			X	X	
Construction	X				X
Roadway construction	X				X
Paved roads and highways			X	X	
Unpaved roads	X			X	
Point sources (permitted)			X	X	

[a] Undisturbed forest condition is the reference level condition.

3.4.3 Other Nonpoint Sources

In addition to land uses that contribute metals through sediment loading, urban lands can contribute nonpoint source metals loads to the receiving streams through the washoff of metals that build up in industrial areas and other urban areas due to human activities. Urban lands in the Elk River watershed include paved roads, populated areas, and high-, moderate-, and light-intensity urban areas.

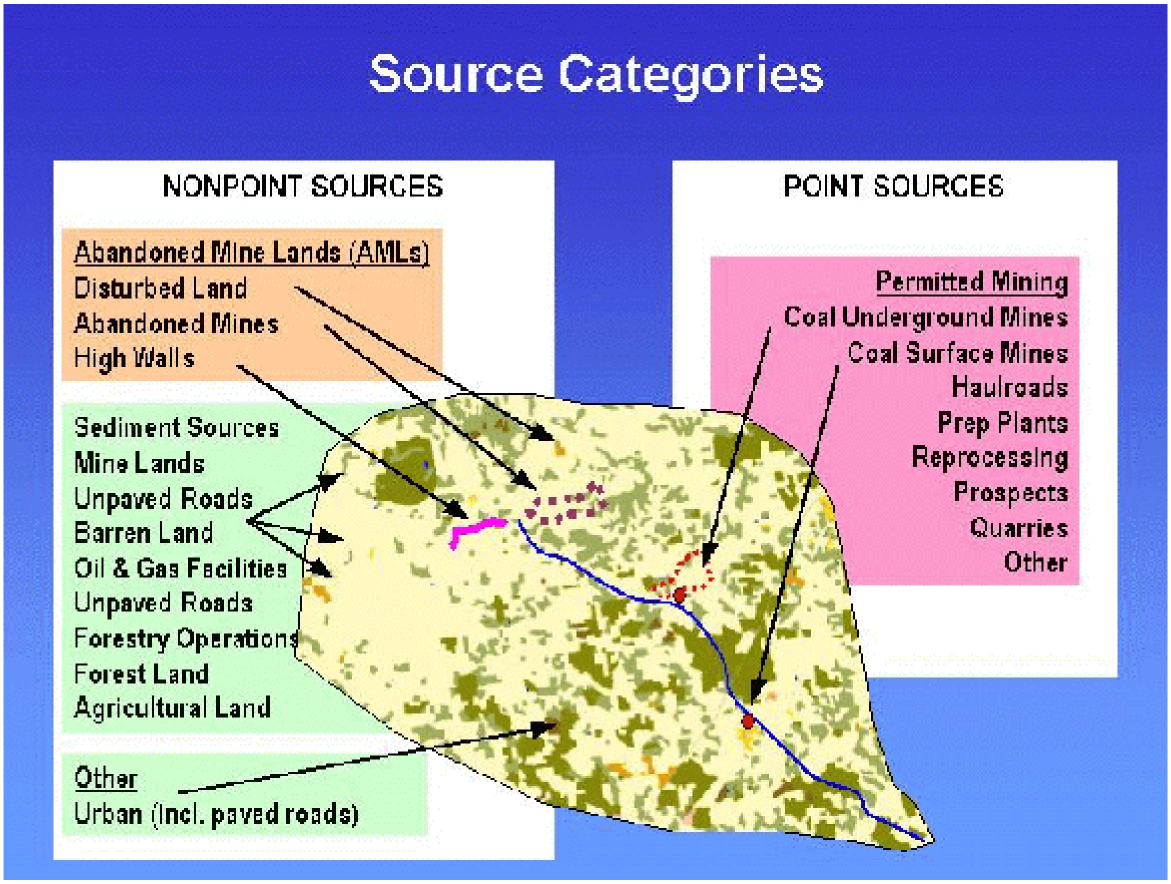


Figure 3-1. Potential sources contributing to impairments in the Elk River watershed

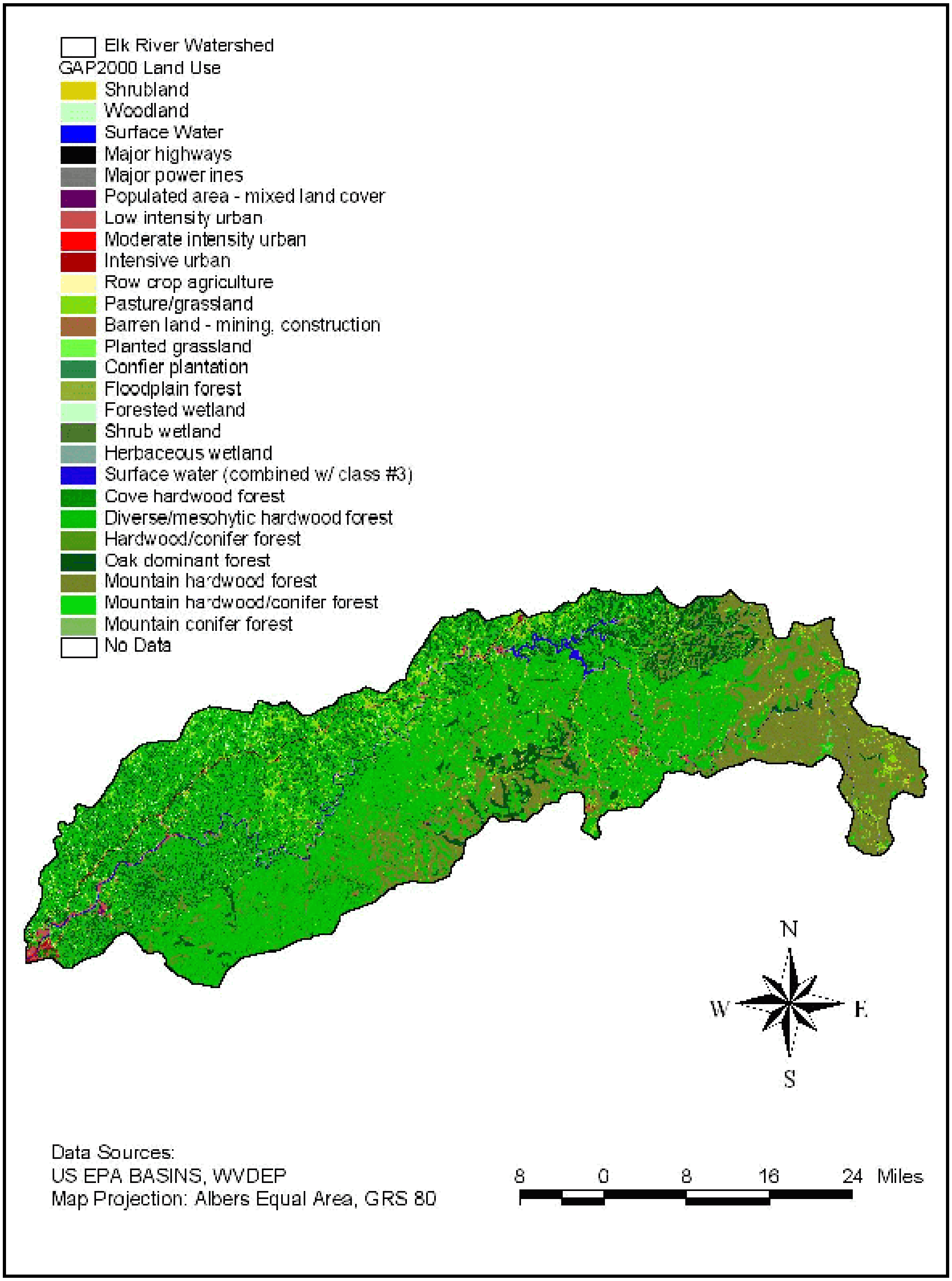


Figure 3-2. Land use distribution in the Elk River watershed

4.0 Technical Approach

Establishing the relationship between the instream water quality targets and source loadings is a critical component of TMDL development. It allows for evaluation of management options that will achieve the desired source load reductions. The link can be established through techniques ranging from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain waterbody responses to flow and loading conditions. The objective of this section is to present the approach taken to develop the linkage between sources and instream response for TMDL development in the Elk River watershed.

4.1 Model Framework Selection

Selection of the appropriate approach or modeling technique required consideration of the following:

- Expression of water quality criteria
- Dominant processes
- Scale of analysis

The relevant criteria for metals and pH were presented in Section 2. Numeric criteria, such as those applicable here, require evaluation of magnitude, frequency, and duration. For metals, the West Virginia criteria are expressed as total metals. This dictates that the methodology predict the total metals concentration in the water column of the receiving water. Thresholds of a numeric measure are evaluated for frequency of exceedance (e.g., not to exceed more than once every 3 years on average). Acute standards typically require evaluation over short time periods, and violations may occur under variable flow conditions. Chronic criteria require the evaluation of the response over a 4-day averaging period. The approach or modeling technique must permit representation of instream concentrations under a variety of flow conditions in order to evaluate critical periods for comparison to chronic and acute criteria.

The approach must also consider the dominant processes regarding pollutant loadings and instream fate. For the Elk watershed, primary sources contributing to metals and pH impairments include an array of nonpoint or diffuse (nonpermitted) sources, as well as discrete point sources/permitted discharges. Loading processes for nonpoint sources or land-based activities are typically rainfall-driven and thus relate to surface runoff and subsurface discharge to a stream. Permitted discharges may or may not be dependent on rainfall; however, they are controlled by permit limits.

Key instream factors that must be considered include routing of flow, dilution, and transport of total metals. Within the stream system of the Elk watershed, the primary physical driving process is the transport of total metals by diffusion and advection in the stream. Significant chemical processes are the speciation, precipitation of metals followed by sediment adsorption/desorption, and redox reactions related to the precipitation reactions.

Scale of analysis and waterbody type must also be considered in the selection of the overall approach. The approach should be able to evaluate watersheds at multiple scales, particularly those of a few hundred acres in size. The listed waters in the Elk watershed range from small streams to the mainstem of the river. Selection of scale should be sensitive to locations of key features, such as abandoned mines and point source discharges. At the larger watershed scale, land areas are lumped into subwatersheds for practical representation of the system, commensurate with available data. Occasionally, there are site specific and localized problems that might require more detailed segmentation or definition of detailed modeling grids.

Based on the considerations described previously, analysis of the monitoring data, review of the literature, and past pH and metals modeling experience, the Mining Data Analysis System (MDAS) was used to represent the source-response linkage in the Elk watershed. The MDAS is a comprehensive data management and modeling system that is capable of representing loading from nonpoint and point sources found in the Elk watershed and simulating instream processes.

4.2 Mining Data Analysis System (MDAS) Overview

The MDAS is a system designed to support TMDL development for areas affected by AMD. The system integrates the following:

- Graphical interface
- Data storage and management system
- Dynamic watershed model
- Data analysis/postprocessing system

The graphical interface supports basic geographic information system (GIS) functions, including electronic geographic data importation and manipulation. Key data sets include stream networks, land use, flow and water quality monitoring station locations, weather station locations, and permitted facility locations. The data storage and management system functions as a database and supports storage of all data pertinent to TMDL development, including water quality observations, flow observations, permitted facility DMRs, and stream and watershed characteristics used for modeling. The system also includes functions for inventorying the data sets. The Dynamic Watershed Model, also referred to as the Hydrological Simulation Program - C++ (HSPC), simulates nonpoint source flow and pollutant loading as well as instream flow and pollutant transport, and it is capable of representing time-variable point source contributions. The data analysis/postprocessing system conducts correlation and statistical analyses and enables the user to plot model results and observation data.

The most critical component of the MDAS to TMDL development is the HSPC model because it provides the linkage between source contributions and instream response. The HSPC is a comprehensive watershed model used to simulate watershed hydrology and pollutant transport as well as stream hydraulics and instream water quality. It is capable of simulating flow, sediment, metals, nutrients, pesticides, and other conventional pollutants, as well as temperature and pH for pervious and impervious lands and waterbodies. The HSPC is essentially a recoded C++ version of selected Hydrologic Simulation Program-FORTRAN (HSPF) modules. HSPC's algorithms are identical to those in HSPF. Table 4-1 presents the modules from HSPF used in HSPC. Refer to the *Hydrologic Simulation Program FORTRAN User's Manual for Release 11* (Bicknell et al., 1996) for a more detailed discussion of simulated processes and model parameters.

Table 4-1. Modules from HSPF converted to HSPC

RCHRES Modules	HYDR	Simulates hydraulic behavior
	CONS	Simulates conservative constituents
	HTRCH	Simulates heat exchange and water
	SEDTRN	Simulates behavior of inorganic sediment
	GQUAL	Simulates behavior of a generalized
	PHCARB	Simulates pH, carbon dioxide, total
PQUAL and IQUAL Modules	PWATER	Simulates water budget for a pervious
	SEDMNT	Simulates production and removal of
	PWTGAS	Estimates water temperature and
	IQUAL	Uses simple relationships with solids and
	PQUAL	Simple relationships with sediment and

Source: Bicknell et al., 1996.

4.3 Model Configuration

The MDAS was configured for the Elk watershed, and the HSPC model was used to simulate the watershed as a series of hydrologically connected subwatersheds. Configuration of the model involved subdivision of the Elk watershed into modeling units and continuous simulation of flow and water quality for these units using meteorological, land use, point source loading, and stream data. Specific pollutants simulated include total aluminum, total iron, total manganese, and pH. Sediment was also modeled because of the critical relationship between sediment transport and metals loading. This section describes the configuration process and key components of the model in greater detail.

4.3.1 Watershed Subdivision

To represent watershed loadings and resulting concentrations of metals in the Elk Rver, the watershed was divided into 24 subwatersheds. These subwatersheds, shown in Figure 4-1, represent hydrologic boundaries. The division was based on elevation data (7.5-minute Digital Elevation Model [DEM] from the U.S. Geological Survey [USGS]), stream connectivity (from the Environmental Protection Agency's [EPA] Reach File, Version 3 [RF3] stream coverage), and locations of monitoring stations.

4.3.2 Meteorological Data

Meteorological data are a critical component of the watershed model. Appropriate representations of precipitation, wind speed, potential evapotranspiration, cloud cover, temperature, and dewpoint are required to develop a valid model. Meteorological data were accessed from a number of sources in an effort to develop the most representative dataset for the Elk River watershed.

In general, hourly precipitation data are recommended for nonpoint source modeling. Therefore, only weather stations with hourly recorded data were considered in developing a representative dataset. After evaluation of local National Climatic Data Center (NCDC) weather stations, meteorological data from the Valley Head and Charleston AP weather stations were used in modeling (Figure 4-2). Initially, data from the Valley Head station were applied to subwatersheds in Region 1, while data from Charleston AP were applied to subwatersheds in Regions 2 and 3. These assignments were based on the proximity of the weather stations to the simulated subwatersheds. During model calibration, which is discussed later in this section, these assignments were revisited. Because of data gaps and discrepancies between simulated and observed flow caused by localized storms, many of the subwatersheds assigned data from Charleston AP were reassigned data from Valley Head. This was a necessary step to obtain an acceptable calibration and appropriately represent meteorological conditions for TMDL calculation.

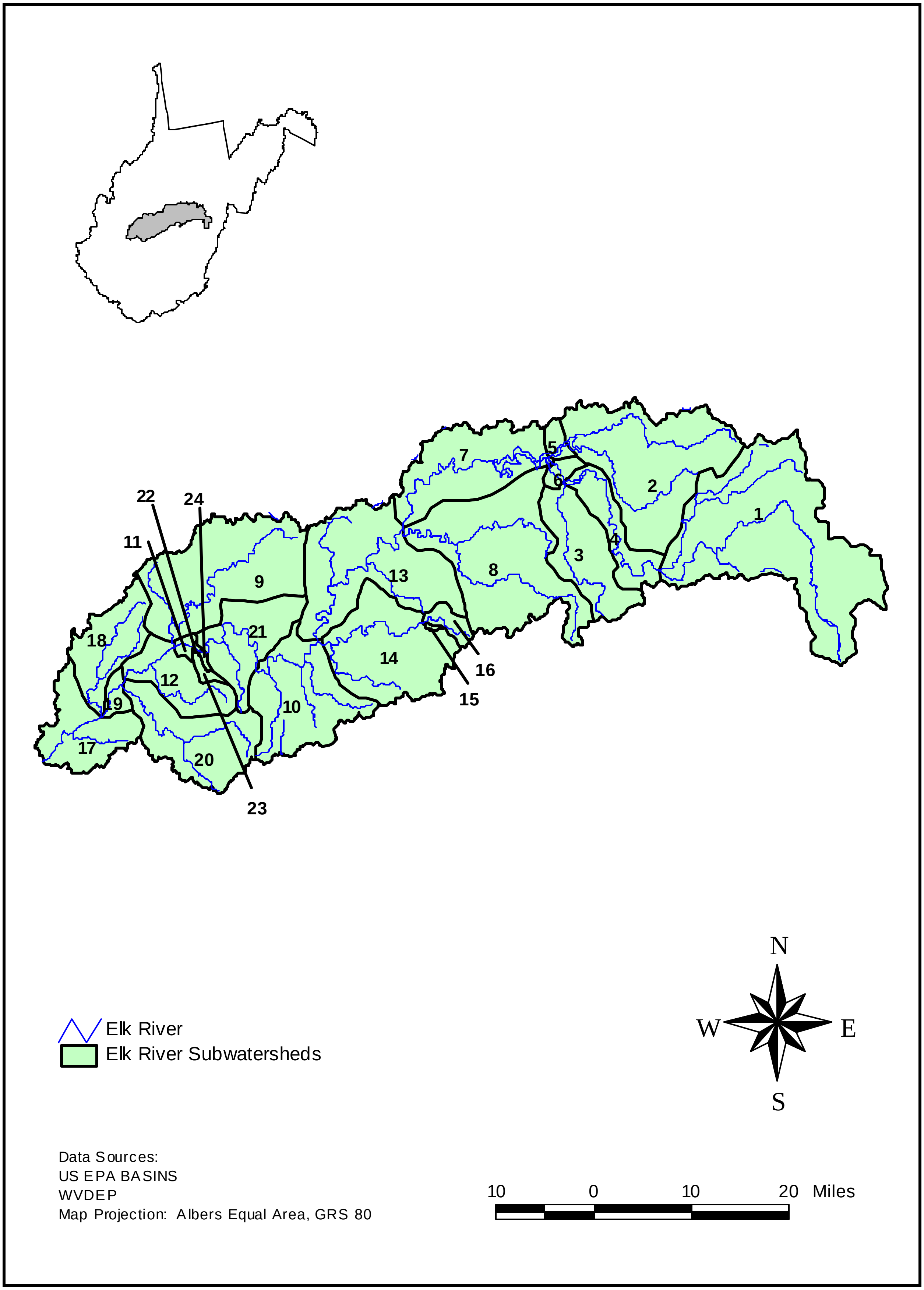


Figure 4-1. Elk River subwatersheds

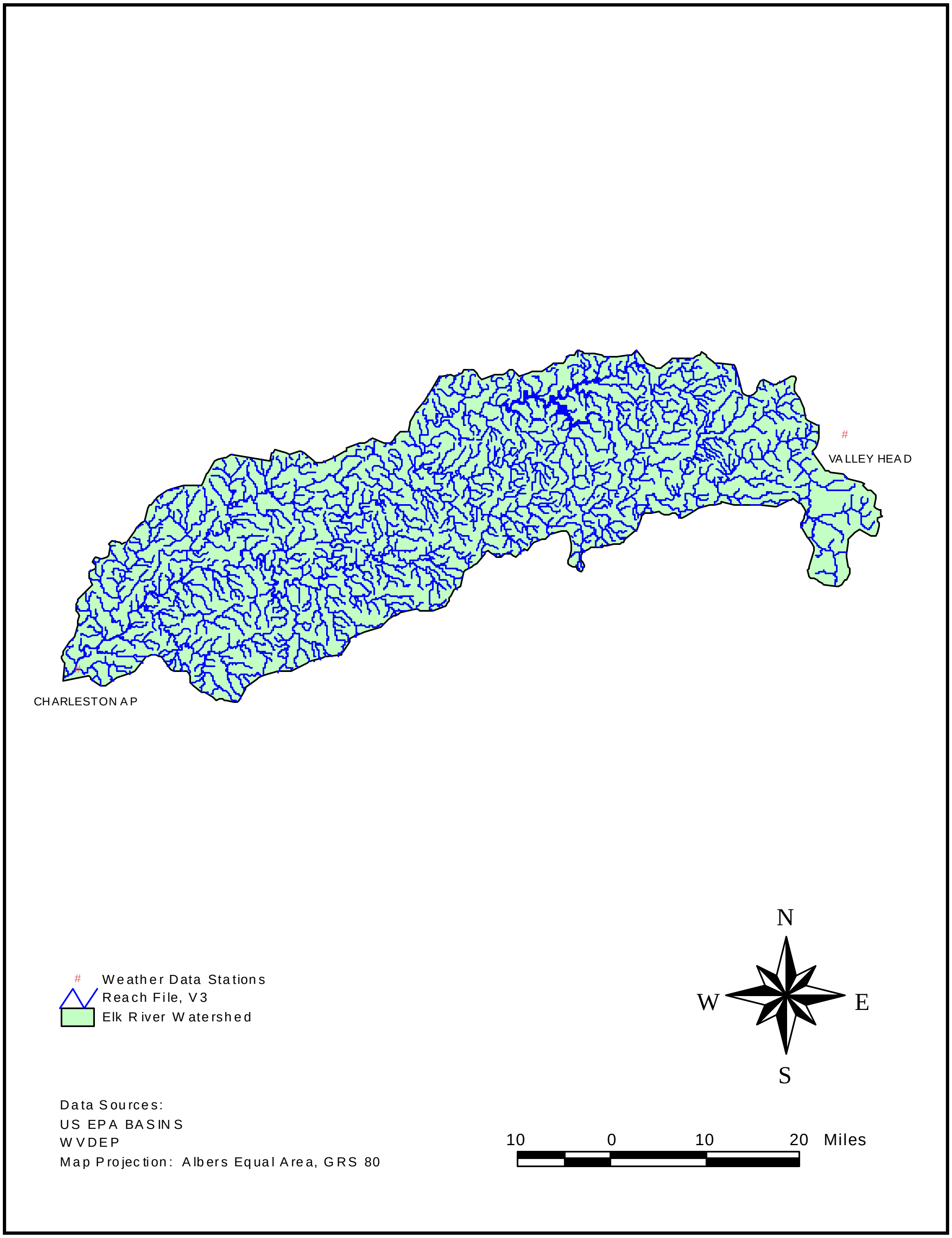


Figure 4-2. Weather stations used in modeling

4.3.3 Nonpoint Source Representation

To explicitly model nonpoint sources in the Elk River watershed, several additional land use categories were created and added to the model land use grouping (GAP2000) shown in Table 4-2. The additional land use categories are explained in the following sections. The updated land use coverage provided the basis for estimating and distributing total aluminum, iron, and manganese loadings associated with conventional land uses.

Table 4-2. Model land use grouping

Model Category	GAP2000 Category
Barren	Barren Land, Mining and Construction
Crop land	Row Crops Agriculture
	Small Grains
Mature Forest	Shrubland
	Woodland
	Conifer Plantation
	Floodplain Forest
	Cove Hardwood Forest
	Diverse/Mesophytic Hardwood Forest
	Hardwood/Conifer Forest
	Oak Dominant Forest
	Mountain Hardwood Forest
	Mountain Hardwood/Conifer Forest
	Mountain Conifer Forest
Intermediate Forest	Woodland
Pasture	Power Lines
	Pasture/Grassland
	Planted Grassland
Strip Mining	Quarries/Strip Mines/Gravel Pits
Urban Impervious	Major Highways (assume 90% impervious)
	Populated Areas (assume 65% impervious)
	Light Intensity Urban (assume 19% impervious)
	Moderate Intensity Urban (assume 65% impervious)
	Intensive Urban (assume 85% impervious)
Urban Pervious	Major Highways (assume 10% impervious)
	Populated Areas (assume 35% impervious)
	Light Intensity Urban (assume 81% impervious)
	Moderate Intensity Urban (assume 35% impervious)
	Intensive Urban (assume 15% impervious)
Water	Surface Water
Wetlands	Forested Wetland
	Shrub Wetland
	Herbaceous Wetland

Abandoned Mine Lands (AML)

To represent AMLs as nonpoint sources, AMLs were represented as three unique land use categories: high walls, disturbed land, and abandoned mines. The abandoned mines represent either discharges from abandoned deep mines or seeping and leaching from other abandoned mine sites. Forestland areas attributed to abandoned mine lands were subtracted from forestlands, according to the proportion of mature forestland to intermediate forestland in each subwatershed.

Sediment Sources

Additional land use categories were required to better represent differences in the sediment loading and transport characteristics of land use activities in the Elk River watershed. Separate land use categories were designated for forest harvest areas (recent timber removal), oil and gas operations, paved roads, and unpaved roads.

The USDA Forest Service FIA Database Retrieval System provided information on annual timber removal for softwood and hardwood species by county. Forest harvest areas were calculated by area-weighting the softwood and hardwood timber removal estimates for counties located within each subwatershed. Harvested areas then were subtracted from the corresponding softwood and hardwood land use categories in the GAP2000 coverage before land use consolidation. The annual forest harvest land use category represents the total annual timber harvest in each subwatershed. Remaining forestlands were then aggregated and reclassified as mature forest.

WVDEP Office of Oil and Gas (WVDEP OOG) provided information regarding oil and gas operations in the Elk River watershed. Active oil and gas operations were assumed to have a well site and access road area of approximately 6,400 square feet. Results from a random well survey conducted by WVDEP OOG in the Elk River watershed during the summer of 2001 showed very similar average well site and access road areas. The cumulative area for oil and gas operations in each subwatershed was subtracted from the mature forest and intermediate forest categories as detailed above.

Information on paved and unpaved roads in the watershed was obtained from the 2000 Annual Inventory Tables Report, produced by West Virginia Department of Transportation (WVDOT) and United States Department of Transportation (USDOT). This report provides the approximate length (in miles) of paved and unpaved roads in several subcategories for counties in West Virginia. Paved and unpaved roads were assumed to have an average width of 20 feet and 12 feet, respectively. The area of paved and unpaved roads was calculated by area-weighting the total paved and unpaved road area given for counties located within each subwatershed. Unpaved road areas were subtracted from mature and intermediate forestlands as described above. Paved road areas were subtracted from the urban impervious land use category (then from forestlands if necessary). Paved roads contribute little sediment because of the high percentage of impervious surface.

Pervious urban land areas were estimated using typical percent pervious/impervious assumptions for urban land categories.

Other Sources

Impervious urban lands contribute nonpoint source metals loads to the receiving streams through the washoff of metals that build up in industrial areas, on paved roads, and in other urban areas because of human activities. Percent impervious estimates for urban land use categories were used to calculate the total area of impervious urban land in each subwatershed.

4.3.4 Point Source Representation

Permitted Nonmining Point Sources

There are a total of 143 nonmining point sources in the Elk River watershed, none of which are located in the Buffalo and Morris Creek watersheds. Three of these facilities are permitted to discharge one or more of the listed pollutants to the Elk River watershed. Pollutant loading from these small facilities was not considered to be a significant source of metals contamination based on typical effluent flows. Therefore, nonmining facility discharges were not considered in the modeling effort.

Permitted Mining Point Sources

The permitted mining point sources were introduced as nine unique land use categories based on the type of mine and the current status of the mine. Phase II and Completely Released permitted facilities were not modeled since reclamation of these mines is either complete or nearly complete, and they are assumed to have little potential water quality impact (WVDEP, 2000a). Table 4-3 shows the land uses representing the current active mines that were modeled.

To account for the additional mining land use categories listed in Table 4-3, the area of each permitted mine was subtracted from the forestland use categories as described in Section 4.3.3. The size of each mine was assumed to be equivalent to the surface disturbed area. A summary of the land use distribution is shown in Tables 4-4 and 4-5.

Table 4-3. Model nonpoint source representation of different permitted mines

Type and Status of Active Mine	Land Use Categories
Active deep mines	ADM
New/inactive deep mines	IADM
Phase I released deep mines	PIDM
Revoked deep mines	RDM
Active/inactive/revoked surface mines	ASM
Other mines (haulroad, prospect, quarry, other)	Other
Phase 1 released surface mines	PIRS
Revoked surface mines	RSM
Revoked other mines	ROM

Table 4-4. Modeled land use distribution in acres for Subwatersheds 1 through 12

Consolidated Land Uses	1	2	3	4	5	6	7	8	9	10	11	12
Barren	311	212	1,331	201	25	31	263	1,037	55	713	3	9
Cropland	86	140	0	0	0	0	3	153	0	4	0	0
Mature Forest	138,326	87,147	36,000	22,921	3,968	3,930	45,684	90,894	65,339	46,985	1,899	23,925
Pasture	6,094	3,637	1,739	467	463	93	6,917	3,780	8,403	912	85	635
Strip Mining	0	0	0	0	0	0	0	0	0	0	0	0
Urban Impervious	0	0	0	0	0	0	256	0	188	0	0	0
Urban Pervious	423	79	98	55	2	5	1,154	262	569	126	111	324
Water	843	865	144	878	463	746	2,075	57	26	640	111	424
Wetlands	290	32	4	6	0	1	6	15	0	7	0	7
Intermediate Forest	138	233	55	9	41	0	217	32	1,961	66	17	251
Annual Forest Harvest	532	668	302	194	6	6	73	277	77	198	5	65
Paved Roads	1,102	634	203	161	36	30	570	767	736	478	38	251
Unpaved Roads	622	445	143	112	28	23	444	468	410	221	7	48
Oil&Gas Operations	0	0	0	0	0	0	68	578	7,927	4,933	119	3,028
ADM	0	0	0	0	0	0	0	0	0	0	0	0
IADM	0	0	35	0	0	0	0	123	0	0	0	0
RDM	118	0	0	0	0	0	0	5	0	0	0	0
PIDM	10	0	0	0	0	0	0	30	0	8	0	0
ASM	8	0	1,339	115	0	0	0	1,260	0	3,074	0	0
RSM	162	0	0	0	0	0	0	0	0	2	0	0
PIRS	0	0	0	0	0	0	0	158	0	0	0	0
OTHER	16	0	467	5	0	0	0	120	0	353	0	0
ROM	33	0	0	0	0	0	0	0	0	0	0	0
AML	19	22	0	1	0	0	0	7	0	181	0	0
Disturbed	0	0	0	0	0	0	0	0	0	0	0	0
Highwall	268	9	0	19	0	0	0	47	0	217	0	27

Table 4-5. Modeled land use distribution in acres for Subwatersheds 13 through 24

Consolidated Land Uses	13	14	15	16	17	18	19	20	21	22	23	24
Barren	124	468	0	126	69	10	2	194	44	0	1	0
Cropland	45	19	0	0	8	0	0	5	0	0	0	0
Mature Forest	68,210	57,413	413	5,764	27,000	23,323	3,210	43,556	29,809	295	2,270	692
Pasture	6,860	844	0	8	2,028	2,531	568	512	2,054	18	12	9
Strip Mining	0	0	0	0	0	0	0	0	0	0	0	0
Urban Impervious	0	0	0	0	1,275	110	147	0	0	0	0	0
Urban Pervious	373	59	0	13	2,281	239	461	109	150	0	0	0
Water	1,178	36	1	3	581	20	302	32	866	23	0	2
Wetlands	2	16	0	0	1	0	0	10	8	0	2	0
Intermediate Forest	281	0	0	0	727	691	102	125	203	2	3	0
Annual Forest Harvest	227	192	1	15	79	66	12	119	121	1	6	2
Paved Roads	740	537	2	59	551	355	92	446	355	4	21	0
Unpaved Roads	381	240	1	25	99	77	16	92	143	1	4	0
Oil&Gas Operations	2,449	1,701	34	34	1,361	6,022	731	4,984	4,542	51	204	85
ADM	0	0	0	0	0	0	0	0	0	0	0	0
IADM	0	10	0	0	0	0	0	0	0	0	0	0
RDM	3	0	0	0	0	0	0	14	2	0	0	0
PIDM	0	55	0	0	0	0	0	0	0	0	0	0
ASM	0	2,161	0	470	0	0	0	0	0	0	0	0
RSM	0	476	0	0	0	0	0	200	15	0	0	0
PIRS	0	107	0	0	0	0	0	0	0	0	0	0
OTHER	0	294	0	0	0	0	0	101	0	0	0	0
ROM	0	14	0	0	0	0	0	0	0	0	0	0
AML	884	92	0	103	170	0	0	0	14	0	0	0
Disturbed	0	0	0	0	0	0	0	0	0	0	0	0
Highwall	11	301	0	69	37	0	0	174	19	0	0	0

Point sources were represented differently, depending on the stage of modeling for TMDL development. The two major stages, which are described in more detail later in this section and in Section 5, are the calibration condition and the allocation conditions.

Calibration Condition

For matching model results to historical data, which is described in more detail in the Model Calibration section, it was necessary to represent the existing point sources using available historical data. Discharges that were issued permits after the calibration period were not considered during the calibration process. If Discharge Monitoring Report (DMR) data were available, permitted mines were represented in the model using average flows and pollutant loads. The DMR data include monthly averages and maximums for flow, pH, total aluminum, total iron, and manganese. The monthly average metals concentrations were multiplied by the discharge flows to estimate average loadings for these point sources.

In most cases, DMRs were insufficient to support representation in the model. When DMR data were available for point sources in a region, the average flow and monthly average concentrations were used to represent point sources throughout that particular region in order to estimate the point source loadings. In cases where there were no available DMR data in a region, the average point source flow from the entire Elk River watershed and the permitted average concentrations were used to estimate the loadings for the point sources. Parameters affecting pollutant concentrations from these mines were adjusted to be consistent with typical discharge characteristics from similar mining activities or to match site-specific instream monitoring data.

Allocation Conditions

Modeling for allocation conditions required running multiple scenarios, including a baseline scenario and multiple allocation scenarios. This process is further explained in Section 5. For the allocation conditions, all permitted mining facilities (including deep mines) were represented using precipitation-driven nonpoint source processes in the model. Under this nonpoint source representation, flow was estimated in a manner similar to other nonpoint sources in the watershed (i.e., based on precipitation and hydrologic properties). This is consistent with OMR's estimation that discharges from most surface mines and some deep mines are precipitation-driven (WVDEP, 2000b). Flow was typically present at all times, and it increased during storm events. The metals concentrations were assigned based on permit limits for the baseline condition modeling and based on required reductions to achieve instream TMDL endpoints for the allocation scenarios.

Mining discharge permits have either technology-based or water quality-based limits. Permitted monthly average concentrations, Waste Load Allocation (WLA), for technology-based limits are 3.2 mg/L and 1.0 mg/L for total iron and manganese, respectively, with a "report only" limit for total aluminum. Permitted discharges with water quality-based limits must meet instream water quality criteria at end-of-pipe. Point sources were assigned concentrations based on the appropriate limits.

For those discharges that are technology-based, a constant concentration (WLA) for aluminum was assumed to be 4.3 mg/L.

4.3.5 Stream Representation

Modeling subwatersheds and calibrating hydrologic and water quality model components required routing flow and pollutants through streams, which were compared to the water quality criteria. Each subwatershed was represented with a single stream. Stream segments were identified using EPA's RF3 stream coverage.

To route flow and pollutants, development of rating curves was required. Rating curves were developed for each stream using Manning's equation and representative stream data. Required stream data include slope; Manning's roughness coefficient; and stream dimensions, including mean depths and channel widths. Manning's roughness coefficient was assumed to be 0.05 for all streams (representative of mountain streams). Slopes were calculated based on digital elevation model (DEM) data and stream lengths measured from the RF3 stream coverage. Stream dimensions were estimated using regression curves that relate upstream drainage area to stream dimensions (Rosgen, 1996).

4.3.6 Hydrologic Representation

Hydrologic processes were represented in the HSPC using algorithms from the PWATER (water budget simulation for pervious land segments) and IWATER (water budget simulation for impervious land segments) modules of HSPF (Bicknell et al., 1996). Parameters associated with infiltration, groundwater flow, and overland flow were designated during model calibration.

4.3.7 Pollutant Representation

In addition to flow, three pollutants were modeled with the HSPC:

- Total aluminum
- Total iron
- Total manganese

The loading contributions of these pollutants from different nonpoint sources were represented in the HSPC using the PQUAL (simulation of quality constituents for pervious land segments) and IQUAL (simulation of quality constituents for impervious land segments) modules in HSPF (Bicknell et al., 1996). Pollutant transport was represented in the streams using the GQUAL (simulation of behavior of a generalized quality constituent) module. Values for the pollutant representation were refined through the water quality calibration process.

4.4 Model Calibration

After the model was configured, calibration was performed at multiple locations throughout the Elk River watershed. Calibration refers to the adjustment or fine-tuning of modeling parameters to reproduce observations. Model calibration focused on two main areas: hydrology and water quality. Upon completion of the calibration at selected locations, a calibrated dataset containing parameter values for modeled sources and pollutants was developed. This data set was applied to areas where calibration data were not available.

A significant amount of time-varying monitoring data were necessary to calibrate the model. Available monitoring data in the watershed were identified and assessed for application to calibration (Tables 3a, 3b, and 3c in each of Appendices A-1 and A-2). Only monitoring stations with data representing a range of hydrologic conditions, source types, and pollutants were selected. The locations selected for calibration are presented in Figure 4-3.

4.4.1 Hydrology Calibration

Hydrology was the first model component calibrated. The hydrology calibration involved a comparison of model results to in-stream flow observations at selected locations and the subsequent adjustment of hydrologic parameters. Key considerations included the overall water balance, the high-flow low-flow distribution, storm flows, and seasonal variation.

Historical flow data with extended periods of record were very limited (refer to Table 3-4). To best represent hydrologic variability throughout the watershed, two locations with daily flow monitoring data were selected for calibration. The stations were USGS #03197000 on Elk River at Queen Shoals and USGS # 03194700 on Elk River below Webster Springs. The model was calibrated for the years 1996 and 1997. Flow-frequency curves, temporal comparisons (daily and monthly), and comparisons of high flows and low flows were developed to support calibration. The calibration involved adjustment of infiltration, subsurface storage, evapotranspiration, surface runoff, and interception storage parameters.

After adjusting the appropriate parameters within acceptable ranges, good correlations were found between model results and observed data for the comparisons made. Flow-frequency curves and temporal analyses are presented in Appendix D.

Parameter values were validated for a separate, extended time period (1990 to 1998) after calibrating parameters at the stations. Validation involved comparing model results and flow observations without further adjustment of parameters. The validation comparisons also showed a good correlation between modeled and observed data. Refer to Appendix D for validation results.

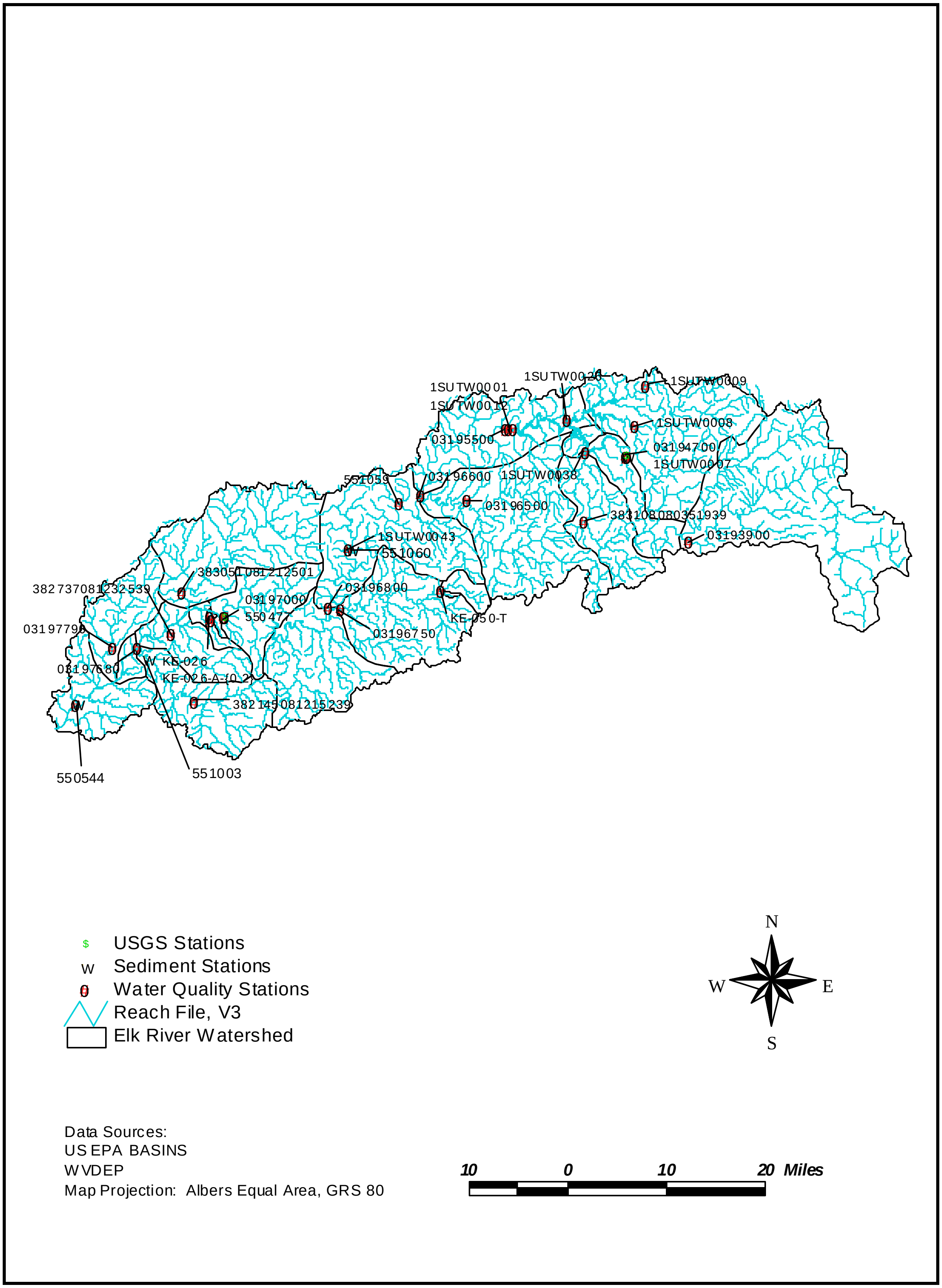


Figure 4-3. Calibration locations used in modeling

4.4.2 Sediment Calibration for Nonpoint Sources

The sediment module of MDAS was applied to simulate the production and removal of sediment from both pervious and impervious lands. To quantify sediment yield from land surfaces accurately, land uses were divided into 26 categories (Tables 4-4 and 4-5). The amount of sediment removal from land surfaces was computed through washoff and scour (erosion) processes. The amount of metals removed from the land surfaces is assumed to be proportional to the amount of sediment removed from the surface. The algorithms adopted are similar to those used in the SEDMNT module and the QUALSD model of HSPF. Once sediment is transported into the reaches, it will be deposited on the streambed when the shear stress is below the critical shear stress (flow velocity function) for deposition. The deposited sediment will be resuspended if the shear stress is above the critical shear stress for erosion. Because the model only simulates total Fe, Al, and Mn, the sorption and desorption processes between sediment and pollutants are not simulated explicitly in the stream. Rather, a net settling of pollutant is used to account for the loss of metals due to the settling of sediment-associated particulates in the stream.

4.4.3 Water Quality Calibration

After hydrology had been sufficiently calibrated, water quality calibration was performed. Modeled versus observed in-stream concentrations were directly compared during model calibration. The water quality calibration consisted of executing the watershed model, comparing water quality time series output to available water quality observation data, and adjusting water quality parameters within a reasonable range.

The approach taken to calibrate water quality focused on matching trends identified during the water quality analysis. Daily average instream concentration from the model was compared directly to observed data. Historical observed data were obtained from EPA's STORET database as well as recently collected data from WVDEP. The objective was to best simulate low flow, mean flow, and storm peaks at representative water quality monitoring stations. Representative stations were selected based on both location (distributed throughout the Elk River watershed) and source type. These stations were typically WVDEP monitoring stations. The results of the water quality calibration are presented in Appendix C.

5.0 Allocation Analysis

A TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality standards. TMDLs can be expressed in terms of mass per time or by other appropriate measures. TMDLs are comprised of the sum of individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving water body. Conceptually, this definition is denoted by the equation:

$$\text{TMDL} = \sum \text{WLAs} + \sum \text{LAs} + \text{MOS}$$

In order to develop aluminum, iron, manganese, lead and pH TMDLs for each of the waterbodies in the Elk watershed listed on the West Virginia Section 303(d) list, the following approach was taken:

- Define TMDL endpoints
- Simulate baseline conditions
- Assess source loading alternatives
- Determine the TMDL and source allocations

As discussed in Section 3, the source of lead in the Elk River watershed (mainstem segment) remains undetermined. As a result, TMDL development did not include an assessment of source loading alternatives and allocations. In addition, baseline conditions could not be simulated given the lack of source data.

5.1 TMDL Endpoints

TMDL endpoints represent the instream water quality targets used in quantifying TMDLs and their individual components. Different TMDL endpoints are necessary for each impairment type (i.e., aluminum, iron, manganese, lead, and pH). West Virginia's numeric water quality criteria for aluminum, iron, manganese, lead, and pH (identified in Section 2) and an explicit margin of safety (MOS) were used to identify endpoints for TMDL development.

5.1.1 Aluminum, Iron, Manganese, and Lead (mainstem only)

The TMDL endpoint for aluminum was selected as 712.5 µg/L (based on the 750 µg/L criteria for aquatic life minus a 5% MOS). The endpoint for iron was selected as 1.425 mg/L (based on the 1.5 mg/L criteria for aquatic life minus a 5% MOS). The endpoint for manganese was selected as 0.95 mg/L (based on the 1.0 mg/L criteria for human health minus a 5% MOS). The endpoint for lead, 0.81 µg/L, was calculated based on total hardness data for the Elk River mainstem (Data period: 5/99 - 4/01).

Components of the TMDLs for aluminum, iron, manganese, and lead are presented in terms of mass per time in this report.

5.1.2 pH

The water quality criteria for pH requires it to be above 6 and below 9 (inclusive). In the case of acid mine drainage, pH, is not a good indicator of the acidity in a waterbody and can be a misleading characteristic. Water with near neutral pH (~7) but containing elevated concentrations of dissolved ferrous (Fe^{2+}) ions can become acidic after oxidation and precipitation of the iron (PADEP, 2000). Therefore, a more practical approach to meeting the water standards of pH is to use the concentration of metal ions as a surrogate for pH. Through reducing instream metals, namely aluminum and iron, to meet water quality criteria (or TMDL endpoints), it is assumed that the pH will result in meeting the WQS. This assumption is based on the application of MINTEQA2, a geochemical equilibrium speciation model, to aqueous systems representative of waterbodies in the Elk watershed. By inputting into the model the dissolved concentrations of metals, a pH value can be predicted. Refer to Appendix D for a more detailed description of the modeling.

5.1.3 Margin of Safety

An implicit MOS was included in TMDL development through application of a dynamic model for simulating daily loading over a wide range of hydrologic and environmental conditions, and through the use of conservative assumptions in model calibration and scenario development. In addition to this implicit margin of safety, a 5% explicit MOS was used to account for the differences between modeled and monitored data. Long-term water quality monitoring data were used for model calibration. While these data represented actual conditions, they were not continuous time series and may not have captured the full range of instream conditions that occurred during the simulation period. The explicit 5% MOS also accounts for those cases where monitoring data may not have captured the full range of instream conditions.

5.2 Baseline Conditions

The calibrated model provided the basis for performing the allocation analysis. The first step in this analysis involved simulation of baseline conditions. Baseline conditions represent existing nonpoint source loading conditions and permitted point source discharge conditions. The baseline conditions allow for an evaluation of instream water quality under the “worst currently allowable” scenario.

The model was run for baseline conditions for the period January 1, 1990 through December 31, 1999. Predicted instream concentrations of aluminum, iron, and manganese for the impaired waterbodies in the Elk River watershed were compared directly to the TMDL endpoints. This comparison allowed evaluation of the expected magnitude and frequency of exceedances under a range of hydrologic and environmental conditions, including dry periods, wet periods, and average periods.

Permitted conditions for mines were represented using precipitation-driven flow estimations and the metals concentrations presented in Table 5-1.

Table 5-1. Metals concentrations used in representing permitted conditions for mines

Pollutant	Technology-based Permits	Water Quality-based Permits
Aluminum, total	4.3 mg/L (assumed for "report only")	0.75 mg/L
Iron, total	3.2 mg/L	1.5 mg/L
Manganese, total	2.0 mg/L	1.0 mg/L

5.3 Source Loading Alternatives

Simulation of baseline conditions provided the basis for evaluating each stream's response to variations in source contributions under virtually all conditions. This sensitivity analysis gave insight into the dominant sources and how potential decreases in loads would affect instream metals concentrations. For example, loading contributions from abandoned mines, permitted facilities, and other nonpoint sources were individually adjusted and instream concentrations were observed.

Multiple scenarios were run for the impaired waterbodies. Successful scenarios were those that achieved the TMDL endpoints under all conditions for aluminum, iron, and manganese (through comparison of model results for the 1990-1999 modeling period). Exceedances for aluminum and iron were allowed once every three years. The averaging period was taken into consideration during these assessments (e.g., a four-day average was used for iron).

- For the upstream tributaries (Region 2), loads contributed by abandoned mines and revoked mines were reduced first, because they generally had the greatest impact on instream concentrations. If additional load reductions were required to meet the TMDL endpoints, then reductions were made in point source (permitted) contributions.
- For the impaired mainstem of the Elk River (Region 3), loads contributed by active oil and gas operations were reduced, because they generally had the greatest impact on instream concentrations. If additional load reductions were required to meet the TMDL endpoints, reductions were made to other sediment-producing nonpoint sources (forest harvest areas and roads).
- Load reductions from nonpoint sediment sources to meet water quality criteria for metals in the Elk River mainstem were based on sediment transport literature values for the undisturbed forest condition, which is the primary land use type in the Elk River watershed. Correlations between sediment transport and metals concentrations in the impaired segment of the Elk River are discussed in Section 3.4.2.

5.4 TMDLs and Source Allocations

For aluminum, iron, and manganese, a top-down methodology was followed to develop the TMDLs and allocate loads to sources. Impaired headwaters were first analyzed, because their impact frequently had a profound effect on downstream water quality. Loading contributions were reduced from applicable sources for these waterbodies and TMDLs were developed. Model results from the selected successful scenarios were then routed through down-stream waterbodies. Therefore, when

TMDLs were developed for downstream impaired waterbodies, up-stream contributions were representing conditions meeting water quality criteria. Using this method, contributions from all sources were weighted equitably. In some situations, reductions in sources impacting unimpaired headwaters were required in order to meet downstream water quality criteria. In other situations, reductions in sources impacting impaired headwaters ultimately led to improvements far downstream. This effectually decreased required loading reductions from many potential downstream sources.

The following general methodology was used when allocating to mining-related (upstream tributaries) sources for the Elk River TMDL.

- For watersheds with AMLs but no point sources, AMLs were reduced until in-stream water quality criteria were met.

- For watersheds with AMLs and point sources, point sources were set at permit limits (WLA) and AMLs were subsequently reduced. AMLs were reduced (point sources were not reduced) until in-stream water quality criteria were met. If further reduction was required, then reductions were made from revoked mines until instream water quality criteria were met. If further reduction was required once AMLs and revoked mines were reduced, point source discharge limits were then reduced. When reductions were maximized for AMLs, the resulting contribution was considered to be equivalent to background levels.

The following general methodology was used when allocating to the sediment-related (Elk mainstem) sources for the Elk River TMDL.

- Sediment-producing nonpoint sources (oil and gas wells, forest harvest areas, and roads) were reduced until in-stream water quality criteria were met.
- The resulting load allocations for nonpoint sediment sources in the Elk River main stem were based on the undisturbed forest condition, which is the prodominant land use type in the watershed. The correlation between sediment loading and metals concentration in the Elk River main stem was discussed in section 4.3.2.

TMDLs for aluminum, iron, and manganese for the Elk River watershed were determined on a subwatershed basis (for each of the 3 defined regions).

The TMDL for lead for the mainstem Elk River was calculated based on the mean annual flow for the mainstem (2,494 cfs) and the hardness-based water quality criteria. The TMDL for lead is presented in Table 5-5. Additional water quality monitoring will be needed to confirm the impairment listing for lead and to identify sources in the watershed for modeling and allocation purposes.

5.4.1 Wasteload Allocations (WLAs)

Waste load allocations (WLAs) were made for all Region 2 permitted facilities except for limestone quarries and those with a Completely Released or Phase 2 released classification. For TMDL purposes these point sources are assumed to be compliant with water quality criteria, since they were assumed to have little potential water quality impact. Loading from revoked permitted facilities was assumed to be a nonpoint source contribution based on the absence of a permittee.

The WLAs for aluminum, iron, and manganese (for each permit) are presented in Tables 4a, 4b, and 4c for each of Appendix 2. The WLAs are presented as annual loads, in terms of pounds per year and as constant concentrations equivalent to permit limits. They are presented on an annual basis (as an average annual load), because they were developed to meet TMDL endpoints under a range of conditions observed throughout the year. Using the WLAs presented, permit limits can be derived using EPA's *Technical Support Document for Water Quality-based Toxics Control* (USEPA, 1991) to find the monthly average discharge concentration. The ranges are as follows: Al: 0.75-4.3mg/L, Fe:1.5 -3.0 mg/L, Mn: 1.0-2.0 mg/L.

5.4.2 Load Allocations (LAs)

For the upstream watersheds, load allocations (LAs) were made for the dominant source categories, as follows:

- Abandoned mine lands (including abandoned mines (deep), high walls, and disturbed areas), strip mines (areas represented in the land use coverage, but not accounted for by permits or AMLs)
- Revoked permits - (loading from revoked permitted facilities)
- Other nonpoint sources (urban, agricultural, and forest land contributions)

For the impaired mainstem of the Elk River, LAs were made for the dominant source categories, as follows:

- Oil and Gas wells - (loading from active oil and gas facilities)
- Harvested forest areas - (loading from annual forest harvest areas)
- Mining Related - (loading from active, inactive and revoked mining activities)
- Roads - (loading from unpaved and paved roads)
- Nonpoint Sources - (loading from cropland, mature forest, pasture, urban impervious, urban pervious)

The LAs for aluminum, iron, manganese are presented in Tables 5a, 5b 5c for each of Appendices A-2 and A-3. The LAs are presented as annual loads, in terms of pounds per year. They are presented on an annual basis (as an average annual load), because they were developed to meet TMDL endpoints under a range of conditions observed throughout the year. Tables 5-2, 5-3, and 5-4 present the $\sum$ LAs and $\sum$ WLAs for aluminum, iron, and manganese, respectively, for each of the Section 303(d) listed segments.

5.4.3 pH Modeling Results

As described in section 5.1.2, aluminum, iron, and manganese concentrations were input into MINTEQA2 to simulate various scenarios including conditions with metals concentrations meeting water quality standards and conditions in proximity to mining activities. MINTEQA2 was run using the water quality criteria for aquatic life. Based on the inputs (described in more detail in Appendix D), pH was estimated to be 7.81. For the scenario representative of mining areas, typical instream metals concentrations were used, and pH was estimated to be 4.38. Results from MINTEQA2 imply that pH will meet the West Virginia pH criteria of above 6 and below 9 (inclusive) if metals concentrations meet water quality criteria.

5.4.4 Seasonal Variation

A TMDL must consider seasonal variation in the derivation of the allocation. For the Elk River watershed metals TMDLs, seasonal variation was considered in the formulation of the modeling analysis. By using continuous simulation (modeling over a period of several years), seasonal hydrologic and source loading variability was inherently considered. The metals concentrations simulated on a daily time step by the model were compared to TMDL endpoints. An allocation which meets these endpoints throughout the year was developed.

Table 5-2. Load and waste load allocations for aluminum

Region	Stream Name	List ID	LAs (lbs/yr)	WLAs (lbs/yr)
2	Morris Creek	KE-26	5,006	0
2	Left Fork, Morris Creek	KE-26A	782	0
2	Buffalo Creek	KE-50	64,475	48,003
2	Pheasant Run	KE-50T	550	0
3	Elk River	KE-43	2,227,530	48,003

Table 5-3. Load and waste load allocations for iron

Region	Stream Name	List ID	LAs (lbs/yr)	WLAs (lbs/yr)
2	Morris Creek	KE-26	8,114	0
2	Left Fork, Morris Creek	KE-26A	2,172	0
2	Buffalo Creek	KE-50	130,556	49,245
2	Pheasant Run	KE-50T	1,428	0
3	Elk River	KE-43	1,194,977	49,245

Table 5-4. Load and waste load allocations for manganese

Region	Stream Name	List ID	LAs (lbs/yr)	WLAs (lbs/yr)
2	Morris Creek	KE-26	3,676	0
2	Left Fork, Morris Creek	KE-26A	1,092	0
2	Buffalo Creek	KE-50	82,391	28,109
2	Pheasant Run	KE-50T	721	0
3	Elk River	KE-43	Not listed for Mn	Not listed for Mn

Table 5-5. Total maximum daily load for zinc

Region	Stream Name	List ID	Lead criteria (µg/L)	TMDL (lbs/yr)
3	Elk River	KE-43	0.81	3975.10

5.4.5 Future Growth

This Elk River TMDL does not include specific future growth allocations to each subwatershed in region 2. Because of the general allocation philosophy used in this TMDL, such allocations would be made at the expense of active sources in the watershed, including mining areas and landuse activities which cause excessive erosion and the subsequent transport of metals to streams. The absence of specific future growth allocations, however, does not prohibit new mining or other activities in the watershed. Future growth could occur in the watershed under the following scenarios, depending on the analysis of contributing sources:

1. A new facility could be permitted anywhere in the watershed, provided that effluent limitations are based upon the achievement of water quality standards end-of-pipe for the pollutants of concern in the TMDL.

2. Remining could occur without a specific allocation to the new permittee, provided that the requirements of existing State remining regulations are achieved. Remining activities are viewed as a partial nonpoint source load reduction from Abandoned Mine Lands.

3. Reclamation and release of existing permits could provide an opportunity for future growth provided that permit release is conditioned upon achieving discharge quality better than the wasteload allocation prescribed by the TMDL.

4. The effective implementation of erosion and sediment control practices in watersheds affected by the nonpoint source contribution of metals from disturbed lands could provide for future growth, depending on the nature of the landuse activity and proximity to streams.

5.4.6 Remining and Water Quality Trading

It is also possible that the TMDL may be refined in the future through remodeling. Such refinement may incorporate new information and/or to the redistribute pollutant loads. Trading may provide an additional opportunity for future growth, contingent upon the State’s development of a statewide or watershed-based trading program

6.0 Reasonable Assurance

Two primary programs that provide reasonable assurance for maintenance and improvement of water quality in the watershed are in effect. The WVDEP's efforts to reclaim abandoned mine lands, coupled with its duties and responsibilities for issuing NPDES permits, will be the focal points in water quality improvement.

Additional opportunities for water quality improvement are both ongoing and anticipated. Historically, a great deal of research into mine drainage has been conducted by scientists at WestVirginia University, the West Virginia Division of Natural Resources, the United States Office ofSurface Mining, the National Mine Land Reclamation Center, the National Environmental Training Laboratory, and many other agencies and individuals. Funding from EPA's 319 Grant program has been used extensively to remedy mine drainage impacts. These many activities are expected to continue and result in water quality improvement.

6.1 Reclamation

Two distinct units of WVDEP reclaim land and water resources impacted by abandoned mines. The Office of Abandoned Mine Lands and Reclamation remedies eligible sites under Title IV of the Surface Mining Control and Reclamation Act of 1977. The Office of Mining and Reclamation's Special Reclamation Program remedies sites where operating permits and bonds have been revoked. Funding of the Office of Abandoned Mine Lands and Reclamation is derived from a federal tax on coal producers. The Special Reclamation Program is funded by the Special Reclamation Fund, which has primary sources of income from civil penalties, forfeited bonds, and a 3-cent per ton fee on all coal produced. A description of the operating procedures and accomplishments of each program follows.

6.1.1 Office of Abandoned Mine Lands and Reclamation

Title IV of the Surface Mining Control and Reclamation Act (Public Law 95-87) is designed to help reclaim and restore coal mine areas abandoned before August 3, 1977, throughout the country. The AML Program supplements existing state programs and allows the state of West Virginia to correct many abandoned mine-related problems that would otherwise not be addressed. The major purpose of the AML Program is to reclaim and restore abandoned mine areas so as to protect the health, safety, and general welfare of the public and the environment.
The AML Program corrects abandoned mine-related problems in accordance with the prioritization process specified in Public Law 95-87, Section 403 (a), 1-3. The priorities are as follows:

Priority 1: The protection of public health, safety, general welfare, and property from extreme danger of adverse effects related to coal mining practices.

Priority 2: The protection of public health, safety, and general welfare from adverse effects related to coal mining practices.

Priority 3: The restoration of the environment, including the land and water resources that were degraded by adverse effects related to coal mining practices. This restoration involves the conservation and development of soil, water (not channelization), woodland, fish and wildlife, recreational resources, and agricultural productivity.

Priority 1 and 2 problem areas include unsafe refuse piles, treacherous highwalls, pollution of domestic water supplies from mine drainage, mine fires, subsidence, and other abandoned mine-related problems. The AML Program is now also focused on Priority 3 problem areas and on treating and abating water quality problems associated with AMLs, but it is not required by law or any statutory authority to do so. Recognizing the need to protect and, in many cases, improve the quality of the state's water resources from the impacts of mine drainage pollution from abandoned coal mines, coordinated efforts are now being employed to deal with this nonpoint source pollution problem.

Although OAML&R has been actively involved in the successful remediation of mine drainage pollution, inadequate funding and the lack of cost-effective mine drainage pollution treatment and abatement technologies have limited water quality improvement efforts. In 1990 the Surface Mining Control and Reclamation Act was amended to include a provision allowing states and tribes to establish an Acid Mine Drainage Treatment and Abatement Program and Fund. States and tribes may set aside up to 10 percent of their annual grant to begin to address abandoned polluted coal mine drainage problems. Money from the Acid Mine Drainage Treatment and Abatement Fund can be used to clean up mine drainage pollution at sites where mining ceased before August 3, 1977, and where no continuing reclamation responsibility can be determined. To qualify and be eligible, qualified hydrologic units or watersheds must be identified and water quality must adversely affect biological resources. A plan must be prepared and presented to the Natural Resources Conservation Service for review and the Office of Surface Mining for approval. Plans that include the most cost-effective treatment and abatement alternatives, the greatest downstream benefits to the ecosystem, and diverse cooperators and stakeholders have the highest priority for approval.

AML&R has created an Acid Mine Drainage Abatement Policy to guide efforts in treating and abating mine drainage pollution. The Policy acts to guide the expenditure of funds to achieve the maximum amount of mine drainage pollution treatment within the boundaries imposed by budgetary and statutory constraints. The goal is to use existing technologies and practical economic considerations to maximize the amount of treatment for dollars expended.

The policy includes a holistic watershed characterization and remediation procedure known as the Holistic Watershed Approach Protocol. The Protocol involves diverse stakeholders in the establishing various sampling networks and subsequent generating water quality data that focus remediation efforts. The Protocol is first used to subdivide the watershed into focus areas. More specific data are then generated to allow identification of the most feasible pollution sources to address and the best available pollution abatement technology to apply. The Protocol also includes establishing post construction sampling networks to assess the effects of remediation efforts. The Protocol is iteratively implemented until all focus areas have been addressed and all feasible pollution abatement technologies have been applied. A detailed description of the Protocol is provided in Appendix E.

6.1.2 Special Reclamation Group

When notice of permit revocation is received from the Director, a liability estimate is completed within 60 days of the revocation. The liability estimate notes any special health and safety characteristics of the site and calculates the cost to complete reclamation according to the permit reclamation plan. At sites where acid mine drainage is present, the permit is flagged for water quality characterization and a priority index is assigned. The reclamation plan at all sites includes the application of the best professional judgment to address the site specific problems, including acid mine drainage. Any change or modification to the permit reclamation plan is done by or under the supervision of a Registered Professional Engineer. All construction requires application of best management practices to ensure quality work and protect the environment.

Prioritization of bond forfeiture sites is consistent with the criteria used in the Abandoned Mine Land and Reclamation (AML&R) program. The criteria, as described below, have been used successfully for many years on abandoned mine areas with similar characteristics to bond forfeiture sites.

Priority	**Description**
1.	The highest priority sites are those that entail protection of public health, safety, general welfare, and property from extreme danger. There are relatively few of these types of bond forfeiture sites; however, they are unquestionably first-order priorities and receive a ranking of 1.
2.	Second-order priority sites are those where public health, safety, welfare, and property values are judged to be threatened. Examples include sites with a high potential for landslides or flooding or the presence of dangerous highwalls, derelict buildings, or other structures.
3a.	Third-order priorities comprise the bulk of bond forfeiture sites. Therefore, this ranking level is subdivided into smaller groupings. The first subgroup is sites that are causing or have a high potential for causing off-site environmental damage to the land and water resources. Such off-site damage would most likely be from heavy erosion or from high loadings of acid mine drainage.
3b.	The second subgroup includes sites that are of a lower priority but are in close geographic proximity to first or second priority sites. It is more efficient and cost-effective to "cluster"projects where possible.
3c.	The third subgroup includes sites near high-use public recreation areas and major thoroughfares.

3d. The fourth subgroup includes sites that are nearly fully reclaimed by the operator and require only monitoring of vegetative growth or other parameters. Sites that have a real potential for repermitting by another operator or reclamation by a third party, will also be placed in this subgroup.

Reclamation construction contracts occur by submission of a detailed Project Requisition to the State Purchasing Division. All state purchasing policies and procedures are applicable, and the contract is awarded to the lowest qualified bidder. Special Reclamation personnel perform inspection and contract management activities through the life of the contract. When all reclamation work is satisfactorily completed, a 1-year contract warranty period begins to ensure adequate vegetative growth and drainage system operation. Upon completion of the contract warranty period and recommendation of the Regional Supervisor, the permit status is classified as "completed." A completed status removes the liability of the forfeited site and terminates WVDEP jurisdiction and responsibility as a Phase III bond release.

At the sites with significant and high-priority AMD, treatment operations are conducted to the extent of available funding, pursuant to the authority granted in 22-3-11 (g) of the West Virginia Surface Coal Mining and Reclamation Act. That regulation limits the annual expenditure of funds for designing, constructing, and maintaining water treatment systems to 25 percent of the annual amount of the fees collected.

6.2 Permitting

NPDES permits in the watershed will be issued, reissued, or modified by the Office of Water Resources in close cooperation with the Office of Mining and Reclamation. Because both offices have adjusted permitting schedules to accommodate the State's Watershed Management Framework, implementation of TMDL requirements at existing facilities will generally occur at the time of scheduled permit reissuance. Permits for existing facilities in the Elk watershed are scheduled to be reissued in 2002.

7.0 Monitoring Plan

Follow-up monitoring of the Elk River watershed is recommended. Future monitoring can be used to evaluate water quality conditions and changes or trends in water quality conditions and will contribute to an improved understanding of the source loading behavior. The following monitoring activities are recommended for this TMDL:

- West Virginia DEP should continue monitoring the impaired segments of the Elk River (tributaries) through its established Watershed Management monitoring approach in 2002, 2007, and beyond.

- Additional water quality monitoring will be needed to confirm the impairment listing for lead and to identify sources in the watershed for modeling and allocation purposes.

- West Virginia DEP should continue monitoring in advance of, during, and after installation of reclamation activities affecting water quality at abandoned mine sites.

- West Virginia DEP should consider additional stations and more frequent sampling of water quality in the impaired reaches and continue to encourage participation by active watershed organizations.

- West Virginia DEP should emphasize the use of proper quality assurance and quality control (QA/QC) protocols to avoid potential sample contamination during water sample collection and transfer.

8.0 Public Participation

EPA's policy is that there must be full and meaningful public participation in the TMDL development process. Each state must, therefore, provide for public participation consistent with its own continuing planning process and public participation requirements. As a result, West Virginia DEP and EPA solicited public input by providing opportunities for public comment and review of the draft TMDLS.

February 20, 2001	WVDEP held an informational meeting.
July 25, 2001 - September 7, 2001	45-day public comment period noticed in the Charleston Gazette.
August 28, 2001	WVDEP and EPA held a public hearing.

References

Bicknell, B.R., J.C. Imhoff, J. Kittle, A.S. Donigian, and R.C. Johansen. 1996. *Hydrological Simulation Program - FORTRAN, User's Manual for Release H.* U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, GA.

Corbit, R. A. 1990. *Standard Handbook of Environmental Engineering*. 2nd Edition. McGraw Hill, Inc., New York.

Evangelou, V.P. 1995. *Pyrite Oxidation and Its Control*. CRC Press, Boca Raton, FL.

Evangelou, V.P. 1998. *Environmental Soil and Water Chemistry*. John Wiley, New York.

PADEP. 2000. *Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania*. Pennsylvania Department of Environmental Protection, Harrisburg, PA.

Langmuir, Donald. 1997. *Aqueous Environmental Geochemistry*. Prentice Hall, Englewood Cliffs, NJ.

Livingstone, D. A. 1963. *Chemical Composition of Rivers and Lakes*. 6th ed. United States Geological Survey Professional Paper 440.

McKnight, Diane M. and Kenneth E, Bencala. 1990. The Chemistry of Iron, Aluminum, and Dissolved Organic Material in Three Acidic, Metal-Enriched, Mountain Streams as Controlled by Watershed and In-Stream Processes. *Water Resources Research* 26:3087-3100.

McKnight, D.M., B. A.Kimball, and K.E. Bencala. 1988. Iron Photoreduction and Oxidation in an Acidic Mountain Stream. *Science* 240:637-640.

Rosgen, D. 1996. *Applied River Morphology*. Wildland Hydrology, Pagosa Springs, CO.

Stumm and Morgan. 1996. *Aquatic Chemistry*. John Wiley, New York.

USDA. 1986. *Urban Hydrology for Small Watersheds*. United States Department of Agriculture, Soil Conservation Service.

USEPA. 2000. *Metals TMDLs for the Little Kanawha Watershed, West Virginia*.

USEPA. 1998. Water Quality Planning and Management (40 CFR Part 130).

USEPA. 1991. *Guidance for Water Quality Based Decisions: The TMDL Process*. EPA 440/49 1-

001. United States Environmental Protection Agency; Assessment and Watershed Protection Division, Washington, DC.

USEPA. 1991. *MINTEQA2 PRODEFA2: A Geochemical Assessment Model for Environmental Systems: Version 3.0 User's Manual*. EPA/600/3-91/021. United States Environmental Protection Agency.

USEPA. 1991. *Technical Support Document for Water Quality-based Toxics Control*. EPA/505/2-90-001. United States Environmental Protection Agency, Office of Water, Washington, D.C.

Watts, K.C. Jr., M.E. Hinkle and W.R. Griffitts. 1994. *Isopleth Maps of Titanium, Aluminum and Associated Elements in Stream Sediments of West Virginia*. United States Department of the Interior, United States Geological Survey.

West Virginia University Extension Service. *Overview of Passive Systems for Treating Acid Mine Drainage*. http://www.wvu/edu/~agexten/landrec/passtrt/passtrt.htm.

WVDEP. 1982. *Tygart Valley River Subbasin Abandoned Mine Drainage Assessment*. West Virginia Division of Environmental Protection, Charleston, WV.

WVDEP. 1998a. Decision Guidance for Listing Waterbodies on West Virginia's 1998 Draft 303(d) List. West Virginia Division of Environmental Protection, Charleston, WV.

WVDEP. 1998b. 1998 303(d) List. West Virginia Division of Environmental Protection, Charleston, WV.

WVDEP. 2000a. Personal communication with Ken Politan, WVDEP OMR. October 2000.

WVDEP. 2000b. Personal communication with Dave Vande Linde, WVDEP OMR. October 2000.

WVDEP. 2000c. Personal communication with Steve Stutler, WVDEP OWR. October 2000.

WVSQS. 2000. Code of State Rules, Title 46: Legislative Rule Environmental Quality Board, Series 1, Requirements Governing Water Quality Standards. West Virginia Secretary of State, Charleston, WV.

Appendix A

Elk River Watershed Data and TMDLs

Appendix A is divided into 3 separate sections. Each section provides information for a different region of the Elk River watershed. The map on the following page presents the watershed's 2 regions (Figure A). Numeric designation for each Appendix A section corresponds to the same numerically identified region of the Elk River watershed (e.g., Appendix A-1 corresponds to Region 1 of the Elk River watershed).

The structure and content of the appendices are as follows:

- **Figure 1—**presents a map of the region, including impaired waterbodies, RF3 stream segments, and subwatersheds used in the model. The subwatershed IDs provide a basis for presenting information in the subsequent tables.

- **Table 1—**lists each impaired waterbody, its corresponding impairment and use designation, all subwatersheds in the region that drain into the impaired waterbody (contributing SWS), and any other regions that drain into the impaired waterbody (contributing regions). Use designations are presented in Section 2 of the main report.

- **Table 2—**lists the subwatersheds in the region that are assumed to contain abandoned mines. These abandoned mines refer to seeps, deep mines, and leaching. They do not include highwall locations or disturbed areas.

- **Tables 3a, 3b, 3c and 3d—**summarize water quality data for water quality monitoring stations in the region. Each table summarizes data for a different metal (aluminum, iron, and manganese). Data are summarized by subwatershed (SWS) and the summary includes averages, minimum, and maximum observed values, as well as the total number of observations (count) and the start and end date of sampling.

- **Tables 4a, 4b, and 4c—**present baseline and allocation information for permitted mine point sources in the region and future growth allocations. Tables a through c present information for different metals. The information is presented by mine permit for each subwatershed. Baseline loads (in lbs/yr) are presented for each mine. The baseline load represents the load estimated under baseline conditions, assuming a constant permitted concentration. This load represents the monthly average permitted discharge (based on existing permit limits), and does <u>not</u> necessarily represent current conditions. This load is presented for comparative purposes. Allocation loads (in lbs/yr) and allocation concentrations (in mg/L) are also presented for each mine. The allocation load represents the WLA. The allocation concentration represents the constant concentration that will meet the water quality criteria for all conditions. Using the WLAs presented, permit limits can be derived using EPA's *Technical Support Document for Water Quality-based Toxics Control* (USEPA, 1991) to find the monthly average discharge concentration.

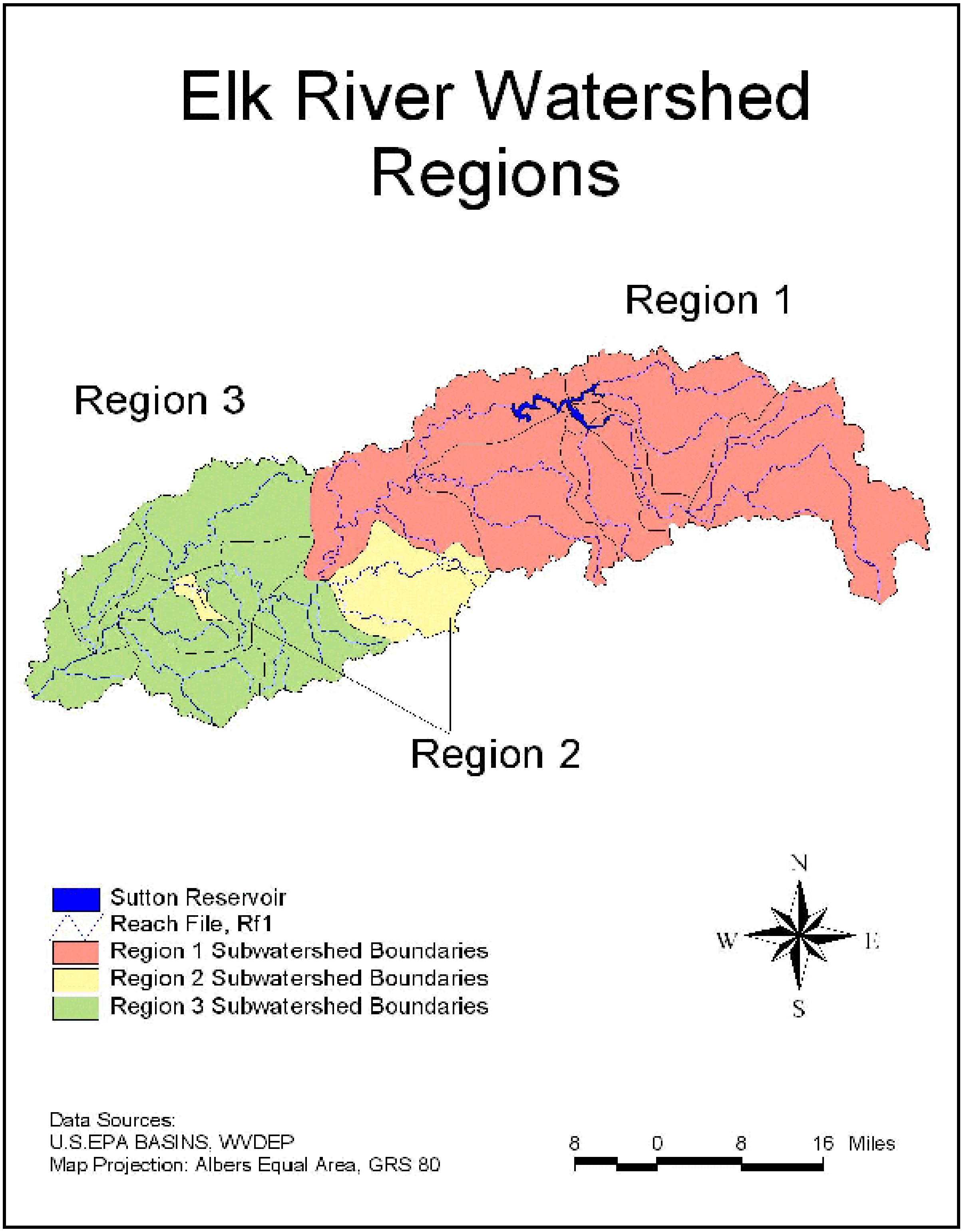


Figure A. Elk River watershed and its 3 regions

- **Tables 5a, 5b, and 5c**—present baseline and allocation information for nonpoint sources in the region. Each table presents information for a different metal. Baseline and allocation loads (in lbs/yr) are presented by subwatershed for the following nonpoint source categories: AML, other nonpoint sources, and revoked mines. The AML category represents highwalls, disturbed land, strip mines, and abandoned mines. The other nonpoint sources category represents contributions from forest, pasture, cropland, urban (impervious and pervious), wetlands, and barren land. The revoked mines category represents the loading contribution from revoked mines. The baseline loads presented represent nonpoint source contributions under existing conditions. The allocation loads represent the LAs for individual categories. A column entitled "Requires Reduction" is also included to conveniently identify subwatersheds requiring nonpoint source load reductions to meet water quality criteria.

Appendix A-1

Region 1

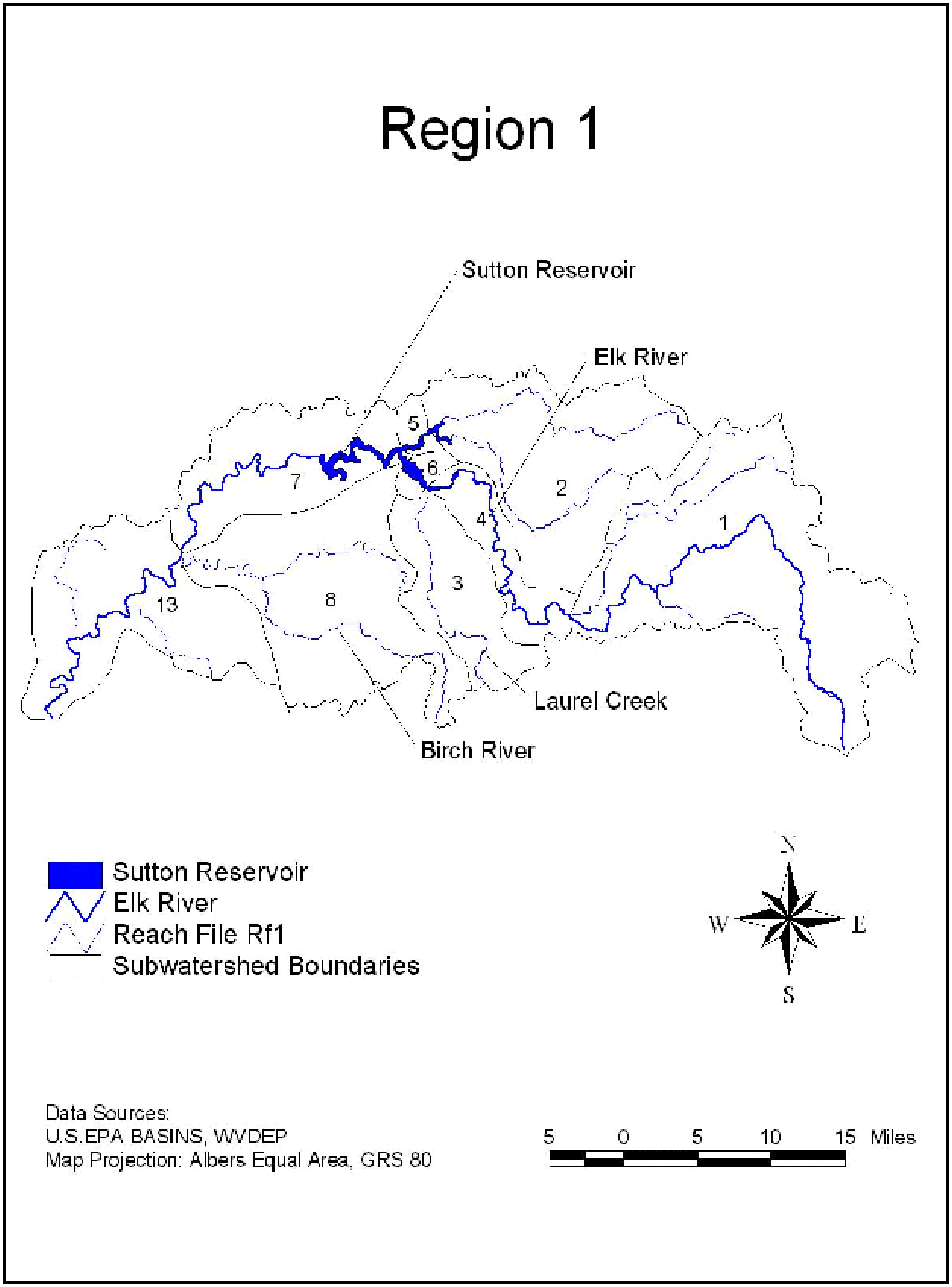


Figure 1. Region 1 - Upstream Elk River

Table 1. Impaired waterbodies in Region 1
(not applicable in this region)

Table 2. Locations of abandoned mines (seep, deep mine, and/or leaching)

SWS
1
2
5
6

Table 3a. Water quality data for aluminum

SWS	WQ station	Avg (ug/L)	Min (ug/L)	Max (ug/L)	Count	Start Date	End Date
1	03193900	740.0	100	2300	4	10/17/73	7/8/74
1	03194200	285.0	40	900	4	10/18/73	7/8/74
1	211401	145.2	7	320	12	2/5/70	12/3/78
1	211402	1141.3	100	11200	15	5/27/76	7/7/81
1	211403	242.1	60	700	14	5/27/76	7/7/81
1	211404	158.6	50	400	14	5/27/76	7/7/81
1	211405	232.9	90	700	14	5/27/76	7/7/81
1	211406	1180.0	100	5900	14	5/27/76	7/7/81
1	2C046015L	414.0	177	651	2	4/28/86	5/11/86
1	2C046015U	117.5	50	185	2	4/28/86	5/11/86
1	550603	237.0	50	1400	10	2/26/74	6/6/95
1	550604	103.0	50	210	10	2/26/74	6/6/95
1	551137	135.6	50	345	8	11/15/94	6/6/95
1	KE-111-K	50.0	50	50	1	7/9/97	7/9/97
1	KE-111-Q	50.0	50	50	1	7/9/97	7/9/97
1	KE-118	56.0	56	56	1	7/8/97	7/8/97
1	KE-137	56.0	56	56	1	7/7/97	7/7/97
1	KE-138	130.0	130	130	1	7/14/97	7/14/97
1	KE-139-B	50.0	50	50	1	7/22/97	7/22/97
2	03195100	200.0	100	500	6	10/18/73	7/9/74
2	03195250	141.7	50	400	6	10/18/73	7/9/74
2	1SUTW0008	182.5	3	780	44	6/2/76	5/11/98
2	1SUTW0009	169.6	3	1130	47	6/2/76	5/11/98
2	2C046005L	235.5	203	268	2	4/22/86	5/8/86
2	2C046013L	123.0	55	191	2	4/23/86	5/9/86
2	2C046013U	101.5	51	152	2	4/23/86	5/9/86
3	KE-102-A	60.0	60	60	1	7/9/97	7/9/97
4	03194700	198.5	1	390	6	10/18/73	7/8/74
4	03195050	112.5	50	200	4	10/19/73	7/9/74
4	1SUTW0007	323.6	3	3710	45	6/2/76	5/11/98

SWS	WQ station	Avg (ug/L)	Min (ug/L)	Max (ug/L)	Count	Start Date	End Date
4	1SUTW0038	655.9	3	17040	45	7/17/79	5/11/98
4	551138	70.6	50	115	8	11/15/94	6/6/95
5	1SUTW0026	109.3	50	210	20	5/19/83	5/27/87
5	1SUTW0027	284.3	50	1590	12	5/19/83	8/15/84
5	1SUTW0045	324.2	50	1580	12	4/25/84	9/12/84
5	2C046005U	187.5	129	246	2	4/22/86	5/8/86
6	1SUTW0006	2350.0	2350	2350	1	9/30/76	9/30/76
6	1SUTW0028	116.5	48	226	4	4/15/98	5/12/98
6	1SUTW0030	1130.2	410	2105	6	5/12/81	8/11/81
7	03195500	211.7	70	500	6	10/19/73	7/9/74
7	1SUTW0001	347.7	30	3415	210	6/3/76	5/12/98
7	1SUTW0002	500.0	500	500	6	9/14/78	9/14/78
7	1SUTW0004	210.0	210	210	1	10/16/86	10/16/86
7	1SUTW0010	500.0	500	500	2	6/2/76	9/30/76
7	1SUTW0011	665.4	500	2750	78	3/20/74	10/31/74
7	1SUTW0012	192.6	3	1130	63	6/2/76	5/12/98
7	1SUTW0022	255.8	30	563	12	9/29/76	5/12/98
7	1SUTW0023	505.5	50	2054	33	5/12/81	9/12/84
7	1SUTW0025	161.1	50	341	9	6/21/89	8/15/89
7	2C046004L	1462.0	82	2842	2	4/22/86	5/8/86
7	2C046004U	1825.0	88	3562	2	4/22/86	5/8/86
7	KE-082	50.0	50	50	1	7/21/97	7/21/97
7	KE-094	280.0	280	280	1	7/28/97	7/28/97
8	03196500	135.0	40	300	4	10/19/73	7/9/74
8	2C046011L	275.0	19	531	2	4/22/86	5/6/86
8	2C046011U	256.5	23	490	2	4/22/86	5/6/86
8	2C046021L	10074.0	235	19913	2	4/22/86	5/6/86
8	2C046021U	439.0	209	669	2	4/22/86	5/6/86
8	551057	336.3	50	1900	12	10/13/93	9/29/94
8	KE-076-O	50.0	50	50	1	7/23/97	7/23/97
8	KE-076-W	71.0	71	71	1	7/15/97	7/15/97
13	2C046009L	104.5	102	107	2	4/18/86	5/5/86
13	2C046009U	437.5	429	446	2	4/18/86	5/5/86
13	551058	914.3	50	9071	12	10/13/93	9/29/94
13	551059	1647.4	50	15030	12	1/31/91	9/29/94
13	551060	684.5	50	2566	12	10/13/93	9/24/94
13	KE-064-E	50.0	50	50	1	7/21/97	7/21/97

Table 3b. Water quality data for iron

SWS	WQ station	Avg (ug/L)	Min (ug/L)	Max (ug/L)	Count	Start Date	End Date
1	03193900	1088.0	90	4600	5	9/11/73	7/8/74
1	03194200	802.0	150	3100	5	9/11/73	7/8/74
1	03990050	100.0	90	110	2	7/9/74	10/10/74
1	03990060	25.0	10	40	2	10/15/73	7/9/74
1	03990100	1745.0	190	3300	2	10/16/73	7/9/74
1	03990140	570.0	470	670	2	10/16/73	7/9/74
1	03990160	200.0	200	200	1	10/15/73	10/15/73
1	03990260	45.0	20	70	2	10/17/73	7/9/74
1	03990300	280.0	150	410	2	10/17/73	7/9/74
1	03990310	350.0	200	500	2	10/17/73	7/9/74
1	03990320	855.0	210	1500	2	10/17/73	7/9/74
1	211401	154.2	10	630	13	2/5/70	12/3/78
1	211402	1002.7	50	10360	15	5/27/76	7/7/81
1	211403	178.6	50	410	14	5/27/76	7/7/81
1	211404	95.7	20	220	14	5/27/76	7/7/81
1	211405	141.4	50	440	14	5/27/76	7/7/81
1	211406	905.7	50	4560	14	5/27/76	7/7/81
1	550603	395.5	45	2340	10	2/26/74	6/6/95
1	550604	120.0	25	370	10	2/26/74	6/6/95
1	551137	198.1	30	555	8	11/15/94	6/6/95
2	03195100	454.5	150	1900	11	9/12/73	8/20/80
2	03195250	215.5	50	470	11	9/12/73	8/20/80
2	03990620	320.0	320	320	2	10/17/73	7/9/74
2	03990650	170.0	170	170	2	10/17/73	7/9/74
2	03990690	570.0	490	650	2	10/17/73	7/9/74
2	03990730	145.0	120	170	2	10/18/73	7/9/74
2	03990760	130.0	80	180	2	10/18/73	7/10/74
2	03990770	140.0	80	200	2	10/18/73	7/11/74
2	03990810	10.0	10	10	1	10/18/73	10/18/73
2	03990900	160.0	130	190	2	10/17/73	7/10/74
2	1SUTW0008	404.8	29	9440	74	6/2/76	9/28/98
2	1SUTW0009	328.4	7	8860	78	8/26/75	9/28/98
2	1SUTW0036	100.0	100	100	1	8/26/75	8/26/75
2	1SUTW0037	380.0	380	380	1	8/26/75	8/26/75
3	03990470	105.0	100	110	2	10/18/73	7/8/74
3	03990490	860.0	420	1300	2	10/18/73	7/8/74
3	03990520	463.3	350	690	3	10/19/73	7/8/74
3	03990580	250.0	250	250	1	10/19/73	10/19/73
4	03194700	851.0	80	18000	30	9/18/72	7/20/81
4	03195050	275.0	90	480	4	10/19/73	7/9/74

SWS	WQ station	Avg (ug/L)	Min (ug/L)	Max (ug/L)	Count	Start Date	End Date
4	1SUTW0007	450.9	12	8510	75	6/2/76	9/28/98
4	1SUTW0038	953.2	39	13900	72	5/9/79	9/28/98
4	551138	155.6	75	395	8	11/15/94	6/6/95
5	1SUTW0026	278.7	100	1200	20	5/19/83	5/27/87
5	1SUTW0027	786.3	100	6200	12	5/19/83	8/15/84
5	1SUTW0045	346.2	100	1300	13	4/25/84	9/12/84
6	1SUTW0006	3755.0	3755	3755	1	9/30/76	9/30/76
6	1SUTW0028	1158.1	62	8670	9	4/24/75	5/12/98
6	1SUTW0030	909.5	300	2033	4	5/12/81	8/11/81
7	03195500	895.7	80	2800	7	9/12/73	7/9/74
7	03195600	590.0	390	760	3	10/15/73	7/10/74
7	03990970	195.0	190	200	2	10/15/73	7/15/74
7	03991015	590.0	390	760	3	10/15/73	7/10/74
7	03991060	525.0	300	750	2	10/16/73	7/11/74
7	1SUTW0001	590.9	7	24000	277	6/3/76	5/12/98
7	1SUTW0002	318.3	165	525	6	9/14/78	9/14/78
7	1SUTW0004	350.0	200	500	2	6/4/80	10/16/86
7	1SUTW0010	462.3	220	760	8	4/22/75	6/28/77
7	1SUTW0011	455.5	100	2550	93	3/20/74	8/26/75
7	1SUTW0012	490.8	39	18250	93	6/2/76	9/28/98
7	1SUTW0022	253.9	18	1100	15	9/29/76	5/12/98
7	1SUTW0023	525.7	100	1800	31	5/12/81	9/12/84
7	1SUTW0025	475.6	100	2289	9	6/21/89	8/15/89
7	1SUTW0039	677.5	300	1055	4	6/12/79	6/4/80
7	550889	366.7	100	800	3	8/14/50	8/29/50
8	03196500	1085.0	230	4600	6	10/19/73	8/19/80
8	03991150	275.0	240	310	2	10/18/73	7/8/74
8	03991200	195.0	130	260	2	10/16/73	7/8/74
8	03991220	345.0	250	440	2	10/16/73	7/8/74
8	03991260	410.0	120	700	2	10/17/73	7/8/74
8	03991310	300.0	210	390	2	10/16/73	7/8/74
8	03991350	260.0	230	290	2	10/16/73	7/15/74
8	03991360	270.0	260	280	2	10/16/73	7/11/74
8	03991370	180.0	180	180	1	7/11/74	7/11/74
8	03991400	385.0	320	450	2	10/18/73	7/11/74
8	550065	675.0	400	1000	4	10/12/64	10/29/64
8	550066	475.0	400	600	4	10/12/64	10/29/64
8	550067	533.3	400	700	3	10/12/64	10/16/64
8	551057	605.7	60	3800	12	10/13/93	9/29/94
8	KE-076-W	58.0	58	58	1	7/15/97	7/15/97

SWS	WQ station	Avg (ug/L)	Min (ug/L)	Max (ug/L)	Count	Start Date	End Date
13	03991470	250.0	240	260	2	10/18/73	7/11/74
13	03991490	2200.0	2200	2200	1	10/18/73	10/18/73
13	03991500	945.0	790	1100	2	10/18/73	7/9/74
13	03991550	95.0	90	100	2	10/18/73	7/9/74
13	03991600	445.0	350	540	2	10/19/73	7/9/74
13	551058	286.2	55	1900	12	10/13/93	9/29/94
13	551059	402.0	60	1900	12	1/31/91	9/29/94
13	551060	829.9	140	4800	12	10/13/93	9/24/94

Table 3c. Water quality data for manganese

SWS	WQ station	Avg (ug/L)	Min (ug/L)	Max (ug/L)	Count	Start Date	End Date
1	03193900	85.0	20	230	4	10/17/73	7/8/74
1	03194200	184.0	20	730	5	9/11/73	7/8/74
1	03990050	20.0	10	30	2	7/9/74	10/10/74
1	03990060	10.0	10	10	2	10/15/73	7/9/74
1	03990100	190.0	10	370	2	10/16/73	7/9/74
1	03990140	50.0	20	80	2	10/16/73	7/9/74
1	03990160	30.0	30	30	1	10/15/73	10/15/73
1	03990260	10.0	10	10	2	10/17/73	7/9/74
1	03990300	45.0	10	80	2	10/17/73	7/9/74
1	03990310	10.0	10	10	2	10/17/73	7/9/74
1	03990320	150.0	10	290	2	10/17/73	7/9/74
1	211401	16.1	7	60	11	2/5/70	12/3/78
1	211402	25.0	10	190	14	5/27/76	7/7/81
1	211403	11.9	10	20	14	5/27/76	7/7/81
1	211404	10.8	10	20	13	5/27/76	7/7/81
1	211405	18.0	10	90	14	5/27/76	7/7/81
1	211406	57.5	10	290	13	5/27/76	7/7/81
1	550603	24.3	5	78	10	2/26/74	6/6/95
1	550604	11.4	5	27	10	2/26/74	6/6/95
1	551137	11.3	5	20	8	11/15/94	6/6/95
2	03195100	36.4	10	130	11	9/12/73	8/20/80
2	03195250	19.1	10	20	11	9/12/73	8/20/80
2	03990620	15.0	10	20	2	10/17/73	7/9/74
2	03990650	15.0	10	20	2	10/17/73	7/9/74
2	03990690	45.0	30	60	2	10/17/73	7/9/74
2	03990730	10.0	10	10	2	10/18/73	7/9/74
2	03990760	15.0	10	20	2	10/18/73	7/10/74
2	03990770	15.0	10	20	2	10/18/73	7/11/74
2	03990810	10.0	10	10	2	10/18/73	7/10/74
2	03990900	15.5	10	21	2	10/17/73	7/10/74
2	1SUTW0008	39.5	10	500	71	6/2/76	9/28/98

SWS	WQ station	Avg (ug/L)	Min (ug/L)	Max (ug/L)	Count	Start Date	End Date
2	1SUTW0009	27.5	3	390	74	8/26/75	9/28/98
2	1SUTW0036	130.0	130	130	1	8/26/75	8/26/75
2	1SUTW0037	47.0	47	47	1	8/26/75	8/26/75
3	03990470	15.0	10	20	2	10/18/73	7/8/74
3	03990490	65.0	40	90	2	10/18/73	7/8/74
3	03990520	86.7	60	100	3	10/19/73	7/8/74
3	03990580	30.0	30	30	1	10/19/73	10/19/73
4	03194700	20.3	0	90	30	9/18/72	7/20/81
4	03195050	17.5	10	30	4	10/19/73	7/9/74
4	1SUTW0007	36.2	2	530	72	6/2/76	9/28/98
4	1SUTW0038	62.7	7	720	70	5/9/79	9/28/98
4	551138	11.3	5	25	8	11/15/94	6/6/95
5	1SUTW0026	239.9	10	1010	15	5/19/83	5/27/87
5	1SUTW0027	340.3	10	2170	12	5/19/83	8/15/84
5	1SUTW0045	72.0	10	200	10	4/25/84	8/15/84
6	1SUTW0006	160.0	160	160	1	9/30/76	9/30/76
6	1SUTW0028	265.6	7	2190	9	4/24/75	5/12/98
6	1SUTW0030	50.6	30	66	5	6/17/81	8/11/81
7	03195500	160.0	0	470	9	8/30/60	7/9/74
7	03195600	96.7	50	140	3	10/15/73	7/10/74
7	03990970	20.0	10	30	2	10/15/73	7/15/74
7	03991015	96.7	50	140	3	10/15/73	7/10/74
7	03991060	65.0	20	110	2	10/16/73	7/11/74
7	1SUTW0001	186.7	1	2460	265	6/3/76	5/12/98
7	1SUTW0002	75.0	20	170	6	9/14/78	9/14/78
7	1SUTW0004	100.0	10	190	2	6/4/80	10/16/86
7	1SUTW0010	103.9	30	185	8	4/22/75	6/28/77
7	1SUTW0011	79.9	20	1510	93	3/20/74	8/26/75
7	1SUTW0012	59.6	8	570	90	6/2/76	9/28/98
7	1SUTW0022	86.6	6	875	15	9/29/76	5/12/98
7	1SUTW0023	274.1	10	1150	26	6/17/81	8/15/84
7	1SUTW0025	389.1	10	2025	9	6/21/89	8/15/89
7	1SUTW0039	82.8	20	140	5	6/12/79	10/31/96
7	1SUTW0041	73.0	73	73	1	10/31/96	10/31/96
7	1SUTW0048	72.0	72	72	1	10/31/96	10/31/96
8	03196500	65.0	30	160	6	10/19/73	8/19/80
8	03991150	35.0	10	60	2	10/18/73	7/8/74
8	03991200	20.0	10	30	2	10/16/73	7/8/74
8	03991220	25.0	10	40	2	10/16/73	7/8/74
8	03991260	85.0	10	160	2	10/17/73	7/8/74
8	03991310	20.0	10	30	2	10/16/73	7/8/74

SWS	WQ station	Avg (ug/L)	Min (ug/L)	Max (ug/L)	Count	Start Date	End Date
8	03991350	25.0	20	30	2	10/16/73	7/15/74
8	03991360	25.0	10	40	2	10/16/73	7/11/74
8	03991370	30.0	30	30	1	7/11/74	7/11/74
8	03991400	45.0	40	50	2	10/18/73	7/11/74
8	551057	39.4	8	145	12	10/13/93	9/29/94
8	KE-076-W	1800.0	1800	1800	1	7/15/97	7/15/97
13	03991470	45.0	10	80	2	10/18/73	7/11/74
13	03991490	300.0	300	300	1	10/18/73	10/18/73
13	03991500	175.0	120	230	2	10/18/73	7/9/74
13	03991550	40.0	20	60	2	10/18/73	7/9/74
13	03991600	30.0	30	30	2	10/19/73	7/9/74
13	1SUTW0042	55.0	55	55	1	10/31/96	10/31/96
13	1SUTW0043	39.0	39	39	1	10/31/96	10/31/96
13	1SUTW0050	40.0	40	40	1	10/31/96	10/31/96
13	551058	23.0	5	75	12	10/13/93	9/29/94
13	551059	27.7	5	90	12	1/31/91	9/29/94
13	551060	33.2	15	120	12	10/13/93	9/24/94

Table 3d. Water quality data for TSS

SWS	WQ station	Avg (mg/L)	Min (mg/L)	Max (mg/L)	Count	Start Date	End Date
1	211402	11.0	0.05	36	4	5/27/76	12/21/78
1	211403	14.3	0.02	52	4	5/27/76	12/21/78
1	211404	3.5	0.02	8	4	5/27/76	12/21/78
1	211405	6.0	0.02	11	5	5/27/76	12/21/78
1	211406	44.1	0.01	142	9	5/27/76	12/21/78
1	550603	10.2	1	61	10	2/26/74	6/6/95
1	550604	4.3	1	13	9	2/26/74	6/6/95
1	551137	4.5	1	9	8	11/15/94	6/6/95
1	KE-111-K	5.0	5	5	1	7/9/97	7/9/97
1	KE-111-Q	5.0	5	5	1	7/9/97	7/9/97
1	KE-118	33.0	33	33	1	7/8/97	7/8/97
1	KE-137	5.0	5	5	1	7/7/97	7/7/97
1	KE-138	5.0	5	5	1	7/14/97	7/14/97
1	KE-139-B	5.0	5	5	1	7/22/97	7/22/97
2	1SUTW0008	11.7	1	66	66	6/2/76	6/15/98
2	1SUTW0009	16.3	1	349	71	8/26/75	6/15/98
2	1SUTW0036	5.0	5	5	1	8/26/75	8/26/75
2	1SUTW0037	5.0	5	5	1	8/26/75	8/26/75
3	KE-102-A	5.0	5	5	1	7/9/97	7/9/97
4	1SUTW0007	23.5	1	276	65	6/2/76	6/15/98
4	1SUTW0038	41.2	1	589	63	7/13/81	6/15/98

SWS	WQ station	Avg (mg/L)	Min (mg/L)	Max (mg/L)	Count	Start Date	End Date
4	551138	3.8	2	12	8	11/15/94	6/6/95
5	1SUTW0026	19.4	10	46	20	5/19/83	5/27/87
5	1SUTW0027	27.8	10	48	12	5/19/83	8/15/84
5	1SUTW0045	11.2	10	25	13	4/25/84	9/12/84
6	1SUTW0005	8.2	0	45	24	5/7/74	10/10/74
6	1SUTW0006	110.0	110	110	1	9/30/76	9/30/76
6	1SUTW0028	22.1	3	130	9	4/24/75	5/12/98
6	1SUTW0030	50.0	24	72	6	5/12/81	8/11/81
7	1SUTW0001	17.2	0	198	365	3/18/74	5/12/98
7	1SUTW0002	12.1	0	77	131	3/18/74	9/14/78
7	1SUTW0003	8.8	0	37	99	4/4/74	10/10/74
7	1SUTW0004	7.1	0	34	60	5/7/74	10/16/86
7	1SUTW0010	9.6	5	22	14	9/5/74	8/13/81
7	1SUTW0011	10.8	0	50	93	3/20/74	8/26/75
7	1SUTW0012	18.9	1	271	94	8/28/74	6/15/98
7	1SUTW0013	10.3	5	25	7	9/10/74	9/10/74
7	1SUTW0014	5.0	5	5	4	9/10/74	9/10/74
7	1SUTW0018	37.7	14	50	3	9/4/74	9/4/74
7	1SUTW0022	7.5	1	24	16	9/29/76	5/12/98
7	1SUTW0023	22.3	10	94	33	5/12/81	9/12/84
7	1SUTW0025	17.0	10	52	6	6/21/89	8/15/89
7	1SUTW0039	18.0	10	26	2	7/16/81	8/13/81
7	1SUTW0040	36.0	34	38	2	7/16/81	8/13/81
7	1SUTW0041	26.0	18	34	2	7/16/81	8/13/81
7	550889	18.0	0	108	83	7/19/50	12/1/63
7	KE-082	8.0	8	8	1	7/21/97	7/21/97
7	KE-094	9.0	9	9	1	7/28/97	7/28/97
8	551057	13.3	1	89	12	10/13/93	9/29/94
8	KE-076-O	5.0	5	5	1	7/23/97	7/23/97
13	1SUTW0042	30.0	16	44	2	7/16/81	8/13/81
13	1SUTW0043	26.0	16	36	2	7/16/81	8/13/81
13	551058	7.8	1	47	12	10/13/93	9/29/94
13	551059	7.8	1	32	12	1/31/91	9/29/94
13	551060	11.6	1	85	12	10/13/93	9/24/94
13	KE-064-E	5.0	5	5	1	7/21/97	7/21/97

Table 4a. Aluminum baseline conditions and allocations (WLAs) for permitted mining point sources (not applicable in this region)

Table 4b. Iron baseline conditions and allocations (WLAs) for permitted mining point sources (not applicable in this region)

Table 4c. Manganese baseline conditions and allocations (WLAs) for permitted mining point sources (not applicable in this region)

Table 5a. Aluminum baseline conditions (LAs) for nonpoint sources (allocations not required)

SWS	AML Baseline (lbs/yr)	Nonpoint Baseline (lbs/yr)	Revoked Mine Baseline (lbs/yr)
1	600	1303140	7593
2	12	26617	0
3	0	11222	0
4	42	214484	0
5	0	1318	0
6	0	1175	0
7	0	17145	0
8	21	28298	105
13	165	23250	70

Table 5b. Iron baseline conditions (LAs) for nonpoint sources (allocations not required)

SWS	AML Baseline (lbs/yr)	Nonpoint Baseline (lbs/yr)	Revoked Mine Baseline (lbs/yr)
1	154	45042	476
2	0	5415	0
3	0	2592	0
4	11	7196	0
5	0	280	0
6	0	238	0
7	0	7445	0
8	0	5892	0
13	7	4762	0

Table 5c. Manganese baseline conditions (LAs) for nonpoint sources (allocations not required)

SWS	AML Baseline (lbs/yr)	Nonpoint Baseline (lbs/yr)	Revoked Mine Baseline (lbs/yr)
1	65	20119	3383
2	2	24455	0
3	0	10243	0
4	5	3221	0
5	0	1218	0
6	0	1080	0
7	0	16094	0
8	3	26208	1
13	114	11272	32

Appendix A-2

Region 2

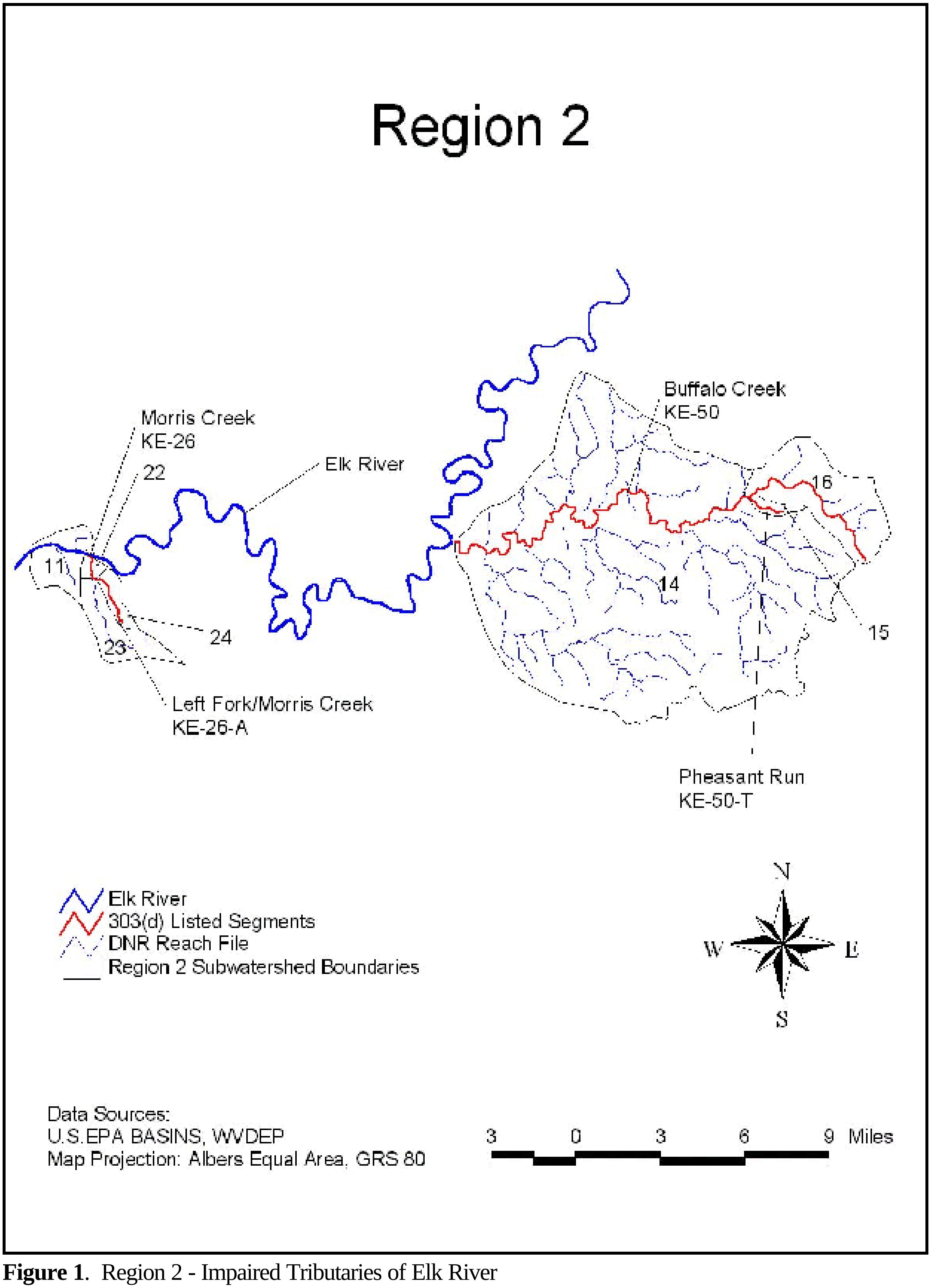


Figure 1. Region 2 - Impaired Tributaries of Elk River

Table 1. Impaired waterbodies in Region 2

Stream Name	Stream Code	Pollutant	Contributing SWS	Contributing Regions	Aquatic Life
Morris Creek	KE-26	pH, Metals	22,23,24	NA	x
Left Fork/Morris Creek	KE-26A	pH, Metals	24	NA	x
Buffalo Creek	KE-50	Metals	14,15,16	NA	x
Pheasant Run	KE-50-T	pH, Metals	15	NA	x

Table 2. Locations of abandoned mines (seep, deep mine, and/or leaching)

SWS
16
23
24

Table 3a. Water quality data for aluminum

SWS	WQ station	Avg (ug/L)	Min (ug/L)	Max (ug/L)	Count	Start Date	End Date
14	03196750	502.5	100	710	4	10/19/73	7/10/74
14	551061	951.6	50	6900	12	10/13/93	9/29/94
14	KE-050-G	50.0	50	50	1	7/30/97	7/30/97
14	KE-050-O	70.0	70	70	1	7/29/97	7/29/97
14	KE-050-P	1200.0	1200	1200	1	7/29/97	7/29/97
14	KE-050-S	1700.0	1700	1700	1	7/29/97	7/29/97
22	KE-026	2500.0	2500	2500	1	7/14/97	7/14/97

Table 3b. Water quality data for iron

SWS	WQ station	Avg (ug/L)	Min (ug/L)	Max (ug/L)	Count	Start Date	End Date
14	03196750	272.0	60	790	5	10/19/73	7/21/81
14	03991690	2130.0	160	4100	2	10/17/73	7/9/74
14	03991730	280.0	80	480	2	10/17/73	7/10/74
14	03991780	120.0	60	180	2	10/19/73	7/10/74
14	03991790	140.0	140	140	2	10/19/73	7/10/74
14	03991800	80.0	60	100	2	10/19/73	7/10/74
14	03991810	100.0	60	140	2	10/20/73	7/10/74
14	03991820	85.0	50	120	2	10/20/73	7/10/74
14	551061	643.4	70	5200	12	10/13/93	9/29/94
14	KE-050-P	1100.0	1100	1100	1	7/29/97	7/29/97
14	KE-050-S	68.0	68	68	1	7/29/97	7/29/97
16	03991660	1070.0	340	1800	2	10/17/73	7/9/74
22	KE-026	540.0	540	540	1	7/14/97	7/14/97

Table 3c. Water quality data for manganese

SWS	WQ station	Avg (ug/L)	Min (ug/L)	Max (ug/L)	Count	Start Date	End Date
14	03196750	414.0	180	840	5	10/19/73	7/21/81
14	03991690	2165.0	930	3400	2	10/17/73	7/9/74
14	03991730	35.0	20	50	2	10/17/73	7/10/74
14	03991780	475.0	200	750	2	10/19/73	7/10/74
14	03991790	40.0	20	60	2	10/19/73	7/10/74
14	03991800	10.0	10	10	2	10/19/73	7/10/74
14	03991810	75.0	10	140	2	10/20/73	7/10/74
14	03991820	75.0	10	140	2	10/20/73	7/10/74
14	551061	232.5	106	339	12	10/13/93	9/29/94
14	KE-050-P	1000.0	1000	1000	1	7/29/97	7/29/97
14	KE-050-S	660.0	660	660	1	7/29/97	7/29/97
16	03991660	2650.0	1200	4100	2	10/17/73	7/9/74
22	KE-026	720.0	720	720	1	7/14/97	7/14/97

Table 3d. Water quality data for TSS

SWS	WQ station	Avg (mg/L)	Min (mg/L)	Max (mg/L)	Count	Start Date	End Date
17	550061	31.5	1	62	2	3/27/73	6/5/73
17	550544	22.5	0	393	250	7/19/50	6/6/95
17	WA96-K04	55.0	5	310	12	3/26/96	10/26/98
19	550602	31.4	0	122	13	7/19/50	1/7/74
19	551004	17.4	2	108	10	8/29/50	10/2/91
20	551003	21.0	1	112	14	8/29/50	10/2/91
21	1SUTW0044	28.0	10	46	2	7/16/81	8/13/81
21	550477	21.7	0	688	187	7/19/50	10/31/84

Table 4a. Aluminum baseline conditions and allocations (WLAs) for permitted mining point sources

SWS	PERMIT ID	Baseline(lbs/yr)	Allocation(lbs/yr)	Allocation (mg/l)
14	o302292	2977	2977	4.3
14	o303391	564	564	4.3
14	s008776	1683	1683	4.3
14	s200494	9566	9566	4.3
14	s300889	1961	1961	4.3
14	s302193	22199	22199	4.3
14	s601089	447	447	4.3
14	u026900	54	54	4.3
14	u045800	236	236	4.3
14	u065700	73	73	4.3
14	u067600	36	36	4.3
14	u200694	182	182	4.3
14	u304091	598	598	4.3
16	s301794	2514	2514	4.3
16	s601089	4913	4913	4.3

Table 4b. Iron baseline conditions and allocations (WLAs) for permitted mining point sources

SWS	PERMIT ID	Baseline(lbs/yr)	Allocation(lbs/yr)	Allocation (mg/L)
14	o302292	9219	4518	1.6
14	o303391	1746	856	1.6
14	s008776	3117	3117	3.2
14	s200494	19121	9369	1.6
14	s300889	3919	1920	1.6
14	s302193	44374	21743	1.6
14	s601089	893	437	1.6
14	u026900	41	41	3.2
14	u045800	178	178	3.2
14	u065700	55	55	3.2
14	u067600	27	27	3.2
14	u200694	138	138	3.2
14	u304091	453	453	3.2
16	s301794	4416	2164	1.6
16	s601089	8631	4229	1.6

Table 4c. Manganese baseline conditions and allocations (WLAs) for permitted mining point sources

SWS	PERMIT ID	Baseline(lbs/yr)	Allocation(lbs/yr)	Allocation (mg/L)
14	o302292	1387	1040	1.5
14	o303391	263	197	1.5
14	s008776	1000	750	1.5
14	s200494	8273	6205	1.5
14	s300889	1696	1272	1.5
14	s302193	19199	14399	1.5
14	s601089	386	290	1.5
14	u026900	25	19	1.5
14	u045800	108	81	1.5
14	u065700	33	25	1.5
14	u067600	17	12	1.5
14	u200694	84	63	1.5
14	u304091	274	205	1.5
16	s301794	1503	1202	1.6
16	s601089	2937	2349	1.6

Table 5a. Aluminum baseline conditions and allocations (LAs) for nonpoint sources

SWS	AML		Nonpoint		Revoked Mine		Require Reduction
	Baseline (lbs/yr)	Allocation (lbs/yr)	Baseline (lbs/yr)	Allocation (lbs/yr)	Baseline (lbs/yr)	Allocation (lbs/yr)	
11	0	0	2111	2111	0	0	
14	1916	1380	46538	46538	7718	7718	X
15	1491	298	252	252	0	0	X
16	6178	3489	4800	4800	0	0	X
22	937	937	533	533	0	0	
23	0	0	2754	2754	0	0	
24	394	394	388	388	0	0	

Table 5b. Iron baseline conditions and allocations (LAs) for nonpoint sources

SWS	AML		Nonpoint		Revoked Mine		Require Reduction
	Baseline (lbs/yr)	Allocation (lbs/yr)	Baseline (lbs/yr)	Allocation (lbs/yr)	Baseline (lbs/yr)	Allocation (lbs/yr)	
11	0	0	4112	4112	0	0	
14	36476	17873	86117	86117	14145	14145	X
15	2120	848	580	580	0	0	X
16	6173	3025	7968	7968	0	0	X
22	2606	1668	579	579	0	0	X
23	0	0	3695	3695	0	0	
24	1900	1045	1127	1127	0	0	X

Table 5c. Manganese baseline conditions and allocations (LAs) for nonpoint sources

SWS	AML		Nonpoint		Revoked Mine		Require Reduction
	Baseline (lbs/yr)	Allocation (lbs/yr)	Baseline (lbs/yr)	Allocation (lbs/yr)	Baseline (lbs/yr)	Allocation (lbs/yr)	
11	0	0	2158	2158	0		
14	34715	17357	50305	50305	6631	6631	X
15	2972	297	424	424	0		X
16	6641	3985	3392	3392	0		X
22	932	653	230	230	0		X
23	0	0	1701	1701	0		
24	1887	283	809	809	0		X

Appendix A-3

Region 3

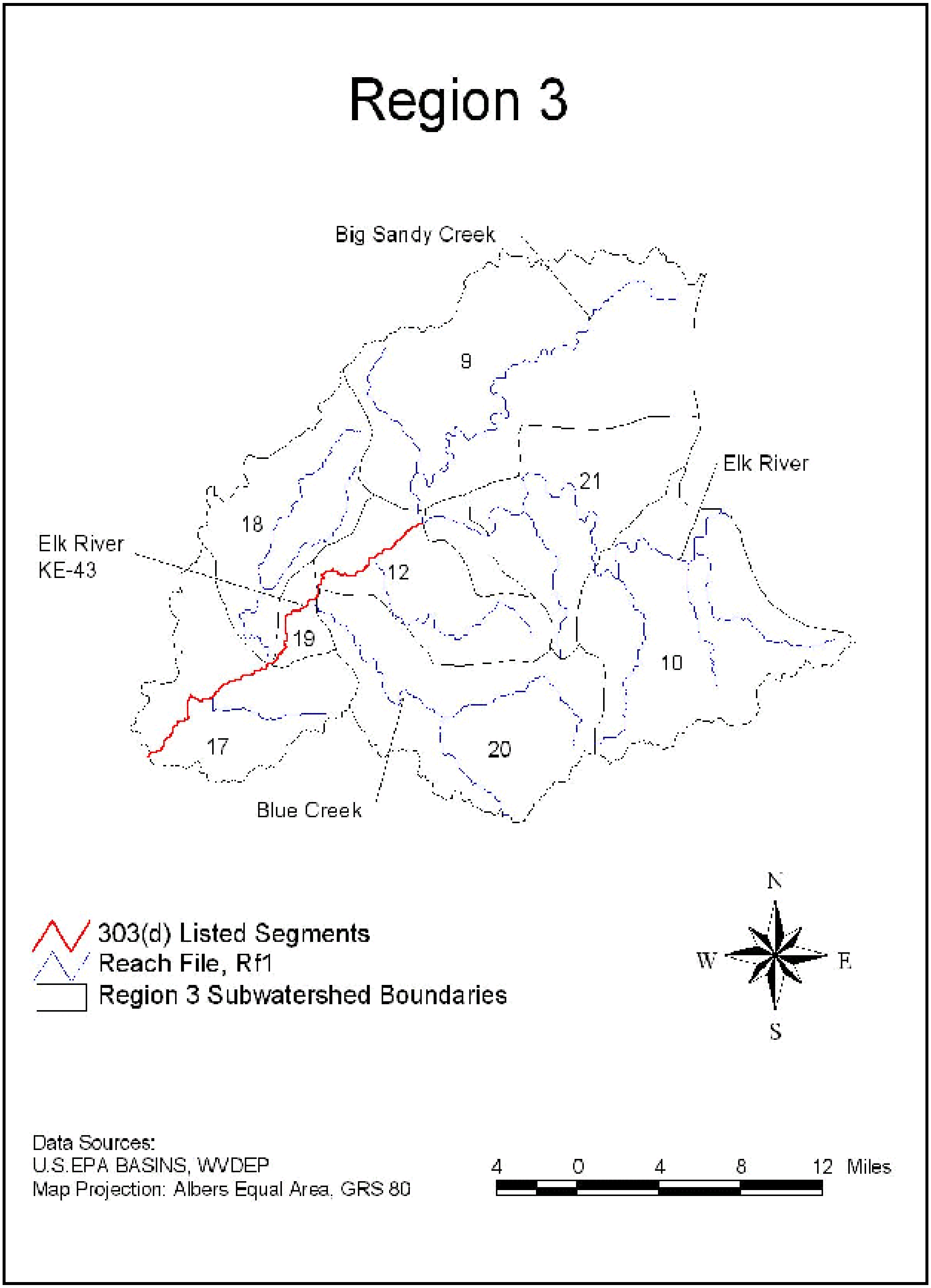


Figure . Region 3- Impaired Mainstem of the Elk River

Table 1. Impaired waterbodies in Region 3

Stream Name	Stream Code	Pollutant	Contributing SWS	Contributing Regions	Aquatic Life
Elk River	KE-43	Aluminum, Iron, Lead, Zinc	9,10,12,17,18,19,20,21	1,2	x
Elk River	KE-43	Iron	9,10,12,17,18,19,20,21	1,2	

Table 2. Locations of abandoned mines (seep, deep mine, and/or leaching)

SWS
10
12
18
21

Table 3a. Water quality data for aluminum

SWS	WQ station	Avg (ug/L)	Min (ug/L)	Max (ug/L)	Count	Start Date	End Date
9	03197450	2240.0	100	10000	5	9/13/73	7/11/74
10	2C046018L	163.0	115	211	2	4/18/86	5/5/86
10	2C046018U	132.0	121	143	2	4/18/86	5/5/86
12	2C046016L	254.0	54	454	2	4/21/86	5/9/86
12	2C046016U	858.0	235	1481	2	4/21/86	5/9/86
17	03197950	698.3	100	2500	6	10/19/73	7/10/74
17	03993000	500.0	500	500	1	10/18/73	10/18/73
17	550544	719.9	40	7000	142	11/13/73	6/6/95
17	WA96-K04	1776.1	50	9900	12	3/26/96	10/26/98
18	03197800	1233.3	100	2500	3	10/19/73	7/11/74
19	03197700	686.7	100	1100	3	10/19/73	7/11/74
19	550602	450.0	450	450	1	1/7/74	1/7/74
19	551004	488.3	50	2000	9	10/18/90	10/2/91
20	551003	714.1	50	5200	11	10/18/90	10/2/91
21	03197000	115.0	90	200	6	10/19/73	7/11/74
21	2C046017L	474.5	308	641	2	4/21/86	5/9/86
21	2C046017U	167.5	96	239	2	4/21/86	5/9/86
21	550477	360.8	50	2760	51	12/3/69	9/13/84

Table 3b. Water quality data for iron

SWS	WQ station	Avg (ug/L)	Min (ug/L)	Max (ug/L)	Count	Start Date	End Date
9	03197440	1900.0	1300	2500	2	7/16/74	10/10/74
9	03197450	4216.0	380	18000	5	9/13/73	7/11/74
9	03992260	895.0	490	1300	2	10/17/73	7/11/74
9	03992270	690.0	580	800	2	10/17/73	7/11/74
9	03992280	955.0	710	1200	2	10/17/73	7/11/74
9	03992290	1675.0	250	3100	2	10/17/73	7/11/74

SWS	WQ station	Avg (ug/L)	Min (ug/L)	Max (ug/L)	Count	Start Date	End Date
9	03992380	365.0	210	520	2	10/17/73	7/11/74
9	03992400	630.0	300	960	2	10/17/73	7/11/74
9	03992410	645.0	620	670	2	10/17/73	7/11/74
9	03992413	1900.0	1300	2500	2	7/16/74	10/10/74
10	03196800	285.0	260	310	2	7/12/74	10/11/74
10	03991828	285.0	260	310	2	7/12/74	10/11/74
10	03991880	55.0	50	60	2	10/19/73	7/12/74
10	03991910	105.0	70	140	2	10/19/73	7/12/74
10	03991970	235.0	120	350	2	10/15/73	7/12/74
10	03992020	515.0	170	860	2	7/16/74	10/10/74
10	03992050	645.0	90	1200	2	7/16/74	10/10/74
10	03992060	480.0	120	840	2	7/16/74	10/10/74
12	03992450	1175.0	750	1600	2	7/16/74	10/11/74
17	03197950	1571.7	430	5600	6	10/19/73	7/10/74
17	03992720	480.0	310	650	2	7/15/74	10/15/74
17	03992730	1385.0	470	2300	2	7/15/74	10/16/74
17	03992800	3420.0	440	6400	2	7/15/74	10/16/74
17	550061	1100.0	1100	1100	1	10/12/64	10/12/64
17	550088	500.0	500	500	1	10/12/64	10/12/64
17	550544	802.8	15	9400	154	11/13/73	6/6/95
17	WA96-K04	1996.3	140	10000	12	3/26/96	10/26/98
18	03197800	920.0	400	1800	3	10/19/73	7/11/74
18	03992635	510.0	510	510	1	7/15/74	7/15/74
18	03992650	940.0	680	1200	2	7/15/74	10/15/74
18	03992675	1470.0	540	2400	2	7/15/74	10/15/74
18	550070	242.9	100	700	7	11/12/64	11/19/64
19	03197700	1286.7	460	1800	3	10/19/73	7/11/74
19	550602	530.0	200	820	4	7/19/50	1/7/74
19	551004	320.0	55	1200	9	10/18/90	10/2/91
20	03992520	915.0	430	1400	2	7/12/74	10/15/74
20	03992530	330.0	110	550	2	7/15/74	10/15/74
20	551003	250.9	75	590	11	10/18/90	10/2/91
21	03197000	663.4	10	2400	29	9/13/73	7/21/81
21	03992080	175.0	130	220	2	10/16/73	7/12/74
21	03992100	165.0	150	180	2	10/16/73	7/12/74
21	03992160	764.0	28	1500	2	10/18/73	7/16/74
21	03992170	820.0	40	1600	2	10/18/73	7/16/74
21	550064	373.3	100	700	15	10/12/64	11/10/64
21	550477	547.2	10	4800	100	7/26/67	9/13/84

Table 3c. Water quality data for manganese

SWS	WQ station	Avg (ug/L)	Min (ug/L)	Max (ug/L)	Count	Start Date	End Date
9	03197440	170.0	110	230	2	7/16/74	10/10/74
9	03197450	156.0	20	410	5	9/13/73	7/11/74
9	03992260	250.0	100	400	2	10/17/73	7/11/74
9	03992270	80.0	60	100	2	10/17/73	7/11/74
9	03992280	135.0	70	200	2	10/17/73	7/11/74
9	03992290	710.0	20	1400	2	10/17/73	7/11/74
9	03992380	195.0	120	270	2	10/17/73	7/11/74
9	03992400	55.0	50	60	2	10/17/73	7/11/74
9	03992410	42.5	15	70	2	10/17/73	7/11/74
9	03992413	170.0	110	230	2	7/16/74	10/10/74
10	03196800	40.0	40	40	2	7/12/74	10/11/74
10	03991828	40.0	40	40	2	7/12/74	10/11/74
10	03991880	10.0	10	10	2	10/19/73	7/12/74
10	03991910	55.0	10	100	2	10/19/73	7/12/74
10	03991970	25.0	10	40	2	10/15/73	7/12/74
10	03992020	55.0	50	60	2	7/16/74	10/10/74
10	03992050	30.0	30	30	2	7/16/74	10/10/74
10	03992060	55.0	50	60	2	7/16/74	10/10/74
10	1SUTW0049	34.0	34	34	1	10/31/96	10/31/96
12	03992450	125.0	100	150	2	7/16/74	10/11/74
17	03197950	118.3	40	400	6	10/19/73	7/10/74
17	03992720	115.0	110	120	2	7/15/74	10/15/74
17	03992730	165.0	50	280	2	7/15/74	10/16/74
17	03992800	375.0	350	400	2	7/15/74	10/16/74
17	03993000	30.0	30	30	1	10/18/73	10/18/73
17	550544	63.0	5	620	154	11/13/73	6/6/95
17	WA96-K04	74.3	24	190	12	3/26/96	10/26/98
18	03197800	146.7	80	250	3	10/19/73	7/11/74
18	03992635	190.0	190	190	1	7/15/74	7/15/74
18	03992650	325.0	320	330	2	7/15/74	10/15/74
18	03992675	865.0	430	1300	2	7/15/74	10/15/74
19	03197700	200.0	130	240	3	10/19/73	7/11/74
19	550602	58.0	58	58	1	1/7/74	1/7/74
19	551004	106.1	25	240	9	10/18/90	10/2/91
20	03992520	1140.0	580	1700	2	7/12/74	10/15/74
20	03992530	915.0	850	980	2	7/15/74	10/15/74
20	551003	121.4	10	300	11	10/18/90	10/2/91
21	03197000	58.3	10	120	30	5/1/61	7/21/81
21	03992080	40.0	40	40	2	10/16/73	7/12/74
21	03992100	40.0	40	40	2	10/16/73	7/12/74

21	03992160	75.0	40	110	2	10/18/73	7/16/74
21	03992170	35.0	30	40	2	10/18/73	7/16/74
21	1SUTW0044	27.0	27	27	1	10/31/96	10/31/96
21	550477	55.9	10	240	94	1/24/68	9/13/84

Table 3d. Water quality data for TSS

SWS	WQ station	Avg (mg/L)	Min (mg/L)	Max (mg/L)	Count	Start Date	End Date
17	550061	31.5	1	62	2	3/27/73	6/5/73
17	550544	22.5	0	393	250	7/19/50	6/6/95
17	WA96-K04	55.0	5	310	12	3/26/96	10/26/98
19	550602	31.4	0	122	13	7/19/50	1/7/74
19	551004	17.4	2	108	10	8/29/50	10/2/91
20	551003	21.0	1	112	14	8/29/50	10/2/91
21	1SUTW0044	28.0	10	46	2	7/16/81	8/13/81
21	550477	21.7	0	688	187	7/19/50	10/31/84

Table 4a. Aluminum baseline conditions and allocations (WLAs) for permitted mining point sources (not applicable to this region)

Table 4b. Iron baseline conditions and allocations (WLAs) for permitted mining point sources (not applicable to this region)

Table 4c. Manganese baseline conditions and allocations (WLAs) for permitted mining point sources (not applicable to this region)

Table 5a. Aluminum baseline conditions and allocations (LAs) for nonpoint sources

	Harvested Forest		Oil and Gas		Road		Nonpoint Source		Mining Related		AML		
SWS	Baseline (lbs/yr)	Allocation (lbs/yr)	Baseline (lbs/yr)	Allocation (lbs/yr)	Baseline (lbs/yr)	Allocation (lbs/yr)	Baseline (lbs/yr)	Allocation (lbs/yr)	Baseline (lbs/yr)	Allocation (lbs/yr)	Baseline (lbs/yr)	Allocation (lbs/yr)	Requires Reduction
9	44	44	148133	80260	1596	1596	39564	39564	0	0	0	0	X
10	113	113	38739	38739	1007	1007	25292	25292	2110	2110	192	192	
12	53	53	56583	30657	689	689	18413	18413	0	0	1676	1676	X
17	64	64	25431	13779	1506	1506	26912	26912	0	0	6246	6246	X
18	37	37	112531	60970	691	691	13951	13951	0	0	0	0	X
19	10	10	13669	7406	251	251	3613	3613	0	0	0	0	X
20	68	68	93140	50464	864	864	22987	22987	196	196	108	108	X
21	93	93	84875	45986	933	933	22578	22578	268	268	295	295	X

Table 5b. Iron baseline conditions and allocations (LAs) for nonpoint sources

	Harvested Forest		Oil and Gas		Road		Nonpoint Source		Mining Related		AML		
SWS	Baseline (lbs/yr)	Allocation (lbs/yr)	Baseline (lbs/yr)	Allocation (lbs/yr)	Baseline (lbs/yr)	Allocation (lbs/yr)	Baseline (lbs/yr)	Allocation (lbs/yr)	Baseline (lbs/yr)	Allocation (lbs/yr)	Baseline (lbs/yr)	Allocation (lbs/yr)	Requires Reduction
9	330	330	178616	133147	5004	5004	95628	95628	0	0	0	0	X
10	848	848	52712	52712	3057	3057	60320	60320	46367	46367	1526	1526	
12	280	280	68227	50859	1312	1312	30070	30070	0	0	69	69	X
17	339	339	30664	22858	2851	2851	43055	43055	0	0	3289	3289	X
18	282	282	135687	101146	1894	1894	33369	33369	0	0	0	0	X
19	52	52	16482	12286	475	475	6060	6060	0	0	0	0	X
20	510	510	112306	83717	2359	2359	53094	53094	4029	4029	872	872	X
21	520	520	102340	76288	2180	2180	39284	39284	231	231	116	116	X

Table 5c. Manganese baseline conditions (LAs) for nonpoint sources (allocations not required)

	Harvested Forest	Oil and Gas	Road	Nonpoint Source	Mining Related	AML
SWS	Baseline (lbs/yr)	Baseline (lbs/yr)	Baseline (lbs/yr)	Baseline (lbs/yr)	Baseline (lbs/yr)	Baseline (lbs/yr)
9	46	97907	1605	41206	0	0
10	117	38838	1012	26319	5512	202
12	29	37398	350	10117	0	442
17	35	16808	765	14630	0	1625
18	39	74376	692	14528	0	0
19	6	9034	127	1961	0	0
20	71	61559	866	23925	496	111
21	72	56097	737	17385	127	731

Appendix B

Mining Permits
in the Elk River Watershed

Mining Permits

All mining operations in the Elk River watershed were represented in the MDAS model. However, based on the sediment/metals relationship (discussed in Section 3.4.2 and presented in Appendix C), sediment sources were found to contribute significant metals loading to the impaired Elk River main stem. Therefore, reductions in load allocations (LAs) were assigned to sediment source categories (harvested forest, oil and gas and roads). Individual mining permits were assigned waste load allocations only in impaired watersheds where a sediment/metals relationship did not exist (Buffalo Creek). Tables B-1 and B-2 show the mining permits in the that were represented in the MDAS model for the Buffalo Creek watershed and the entire Elk River watershed, respectively.

Table B-1. Buffalo Creek watershed mining permits

Article III Permit ID	NPDES ID	Mine Type	Article III Permit Status	Current Area (ac) [A]	Original Area (ac) [B]	Facility Name [C]	NPDES Status
s006379	WV0049352	Coal Surface Mine	Completely Released	10	103	HICA CORPORATION	Comp. Released
u067600	WV0055433	Coal Underground	Phase 1 Released	2	4	MAJESTIC MINING INC	Renewed, active
s008776	WV0055433	Coal Surface Mine	Phase 1 Released	107	107	MAJESTIC MINING INC	Renewed, active
o006682	WV0060089	Other	Revoked	0	14	SUMMERSVILLE FIVE BLOCK COAL	Comp. Released
s601089	WV0094650	Coal Surface Mine	Renewed	339	392	TERRY EAGLE COAL COMPANY LLC	Renewed, active
s016678	WV0096580	Coal Surface Mine	Phase 2 Released	119	100	LODESTAR ENERGY, INC.	Renewed, active
d012682	WV0096776	Coal Underground	Completely Released	0	4	MAJESTIC MINING INC	Comp. Released
s017977	WV0096806	Coal Surface Mine	Phase 2 Released	105	105	LODESTAR ENERGY, INC.	Renewed, active
u065700	WV0096814	Coal Underground	Phase 1 Released	4	4	MAJESTIC MINING INC	Renewed, active
u026900	WV0096822	Coal Underground	Phase 1 Released	3	3	MAJESTIC MINING INC	Renewed, active
u045800	WV0096849	Coal Underground	Phase 1 Released	13	13	MAJESTIC MINING INC	Renewed, active
d012482	WV0096849	Coal Underground	Completely Released	0	4	MAJESTIC MINING INC	new, active
h032600	WV0096849	Haulroad	Completely Released	0	42	MAJESTIC MINING INC	new, active
o010983	WV0096865	Other	Phase 1 Released	10	15	MAJESTIC MINING INC	Renewed, active
p064500	WV0096890	Prep Plant	Revoked	0	15	DAY MINING INC	Comp. Released
s001385	WV0099244	Coal Surface Mine	Completely Released	38	38	LODESTAR ENERGY, INC.	Renewed, active
s308386	WV0099245	Coal Surface Mine	Renewed	74	74	LODESTAR ENERGY, INC.	Renewed, active
s305188	WV1001795	Coal Surface Mine	Revoked	476	630	CHLOE RIDGE COAL CO	Comp. Released
o300589	WV1002031	Other	Renewed	10	10	PEERLESS EAGLE COAL CO	Renewed, active
s300889	WV1002031	Coal Surface Mine	Renewed	124	148	U. S. CONSTRUCTION CO., INC	
u304091	WV1002031	Coal Underground	Phase 1 Released	33	33	RADEC, INC	
u300489	WV1002040	Coal Underground	Renewed	17	11	RADEC, INC	Renewed, active
s300689	WV1002139	Coal Surface Mine	Renewed	122	100	LODESTAR ENERGY, INC.	Renewed, active
s601989	WV1009290	Coal Surface Mine	Renewed	644	596	STEAR AUGER MINING INC	Extended, active
o303391	WV1012517	Other	Renewed	68	69	VANDALIA RESOURCES, INC.	Comp. Released
u200694	WV1012517	Coal Underground	New	10	10	COPPERAS COAL CORP	Comp. Released
s016177	WV1012967	Coal Surface Mine	Phase 2 Released	23	59	LAND USE CORPORATION	Extended, active

Article III Permit ID	NPDES ID	Mine Type	Article III Permit Status	Current Area (ac) [A]	Original Area (ac) [B]	Facility Name [C]	NPDES Status
o302292	WV1013742	Other	Renewed	256	256	VANDALIA RESOURCES, INC.	Extended, active
s200494	WV1013882	Coal Surface Mine	Renewed	605	605	STEAR AUGER MINING INC	Extended, active
u200694	WV1013882	Coal Underground	New	10	10	COPPERAS COAL CORP	Extended, active
o300992	WV1013882	Other	Renewed	61	61	MOLLOY MINING INC	Extended, active
s302193	WV1014587	Coal Surface Mine	Renewed	1404	1334	INTREPID MINING COMPANY	Renewed, active
u302194	WV1014587	Coal Underground	New	11	11	WHITE BUCK COAL COMPANY	Renewed, active
s300793	WV1014650	Coal Surface Mine	Phase 2 Released	30	30	TERRY EAGLE COAL COMPANY LLC	Renewed, active
s301794	WV1014889	Coal Surface Mine	Inactive	159	159	TERRY EAGLE COAL COMPANY LLC	Extended, active
s200697	WV1017888	Coal Surface Mine	New	846	808	MOLLOY MINING INC	new, active
e009700		Coal Underground	Revoked	0	11	BRADY-CLINE COAL CO	
h017900		Haulroad	Completely Released	0	20	MAJESTIC MINING INC	
o010083		Other	Revoked	0	18	SUMMERSVILLE FIVE BLOCK COAL	
p200695		Prospect	Completely Released	37	37	VANDALIA RESOURCES, INC.	
p201697		Prospect	Completely Released	1	1	JULIANA MINING COMPANY, INC.	
p302599		Prospect	New	3	3	PEERLESS EAGLE COAL CO	
p303597		Prospect	New	8	8	PEERLESS EAGLE COAL CO	

Table B-2. Elk River watershed mining permits

Article III Permit ID	NPDES ID	Mine Type	Article III Permit Status	Current Area (ac) [A]	Original Area (ac) [B]	Facility Name [C]	NPDES Status
d008782		Coal Underground	Revoked	0	9	TANGLEWOOD ENERGY, INC	
d011082	WV0060194	Coal Underground	Inactive	6	6	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active
d011282	WV0060186	Coal Underground	Revoked	0	6	ELKHEAD SEWELL INC	Comp. Released
e001600		Coal Underground	Revoked	0	5	JAGRTI COAL CO., INC	
e001600		Coal Underground	Revoked	0	5	PREMIUM SEWELL, INC	
e004400	WV0048151	Coal Underground	Phase 1 Released	17	17	MARSON COAL COMPANY	Renewed, active
e007600	WV0056936	Coal Underground	Phase 1 Released	30	30	GAULEY EAGLE HOLDINGS INC	Renewed, active
e009100	WV1003241	Coal Underground	Phase 1 Released	6	6	MARSON COAL COMPANY	Comp. Released
e009700		Coal Underground	Revoked	0	11	BRADY-CLINE COAL CO	
h023700		Haulroad	Revoked	0	12	PREMIUM SEWELL, INC	
h039200		Haulroad	Revoked	0	1	PREMIUM SEWELL, INC	
h047100	WV0050318	Haulroad	Renewed	170	170	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active
h050000		Haulroad	Revoked	0	8	ELK RIVER SEWELL COAL CO	
h050200		Haulroad	Revoked	0	11	PREMIUM SEWELL, INC	
h050500	WV0051845	Haulroad	Inactive	28	28	JULIANA MINING COMPANY, INC.	Renewed, active
h052900	WV0050857	Haulroad	Renewed	18	18	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active
h052900	WV0052833	Haulroad	Renewed	18	18	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active
h056200	WV0050857	Haulroad	Renewed	27	27	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active
h057700		Haulroad	Revoked	0	22	ELK RIVER SEWELL COAL CO	
i033400		Coal Surface Mine	Revoked	0	17	PREMIUM SEWELL, INC	
i044900	WV0051845	Coal Surface Mine	Inactive	0	0	JULIANA MINING COMPANY, INC.	Renewed, active
i048200	WV0050318	Coal Surface Mine	Inactive	7	7	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active

Article III Permit ID	NPDES ID	Mine Type	Article III Permit Status	Current Area (ac) [A]	Original Area (ac) [B]	Facility Name [C]	NPDES Status
o000783		Other	Revoked	0	61	PHOENIX RESOURCES, INC.	
o000783		Other	Revoked	0	61	PREMIUM SEWELL, INC	
o001981	WV0047198	Other	Inactive	23	19	JULIANA MINING COMPANY, INC.	Renewed, active
o003784	WV0050318	Other	Renewed	69	69	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active
o005882	WV0066231	Other	Renewed	41	41	APPALACHIAN MINING INC	Extended, active
o006682	WV0060089	Other	Revoked	0	14	SUMMERSVILLE FIVE BLOCK COAL	Comp. Released
o008082	WV0066231	Other	Renewed	60	60	APPALACHIAN MINING INC	Extended, active
o010083		Other	Revoked	0	18	SUMMERSVILLE FIVE BLOCK COAL	
o010983	WV0096865	Other	Phase 1 Released	10	15	MAJESTIC MINING INC	Renewed, active
O012783	WV0053961	Other	Revoked	0	32	ELK RIVER SEWELL COAL CO	Comp. Released
o013783	WV1000276	Other	Revoked	0	15	MOUNTAIN CARBON INC	
o103091	WV1011162	Other	Renewed	22	22	EVERGREEN MINING COMPANY	Renewed, active
o105891	WV1011162	Other	Renewed	93	85	EVERGREEN MINING COMPANY	Renewed, active
o200787	WV0060194	Other	Inactive	5	5	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active
o201497	WV0047198	Other	New	7	7	JULIANA MINING COMPANY, INC.	Renewed, active
o202287	WV0056995	Other	Inactive	85	64	JULIANA MINING COMPANY, INC.	Renewed, active
o300893	WV1013815	Other	Renewed	70	58	FOLA COAL COMPANY, L.L.C.	Renewed, active
o300992	WV1013882	Other	Renewed	61	61	MOLLOY MINING INC	Extended, active
o302292	WV1013742	Other	Renewed	256	256	VANDALIA RESOURCES, INC.	Extended, active
o303391	WV1012517	Other	Renewed	68	69	VANDALIA RESOURCES, INC.	Comp. Released
o601388	WV0093114	Other	Renewed	125	55	CHICOPEE COAL COMPANY, INC.	Renewed, active
o602189	WV0093114	Other	Renewed	46	46	CHICOPEE COAL COMPANY, INC.	Renewed, active
o603288	WV0094439	Other	Renewed	72	72	APPALACHIAN MINING INC	Extended, active
p052600	WV0050318	Prep Plant	Inactive	24	24	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active
p058500	WV0051845	Prep Plant	Inactive	30	29	JULIANA MINING COMPANY, INC.	Renewed, active
p061200	WV0050857	Prep Plant	Renewed	316	154	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active
p200700		Prospect	New	0	0	POLARIS COAL JOINT VENTURE	
p201000		Prospect	New	1	1	COASTAL COAL-WEST VIRGINIA, LLC	
p201099		Prospect	New	7	7	COASTAL COAL-WEST VIRGINIA, LLC	
p302599		Prospect	New	3	3	PEERLESS EAGLE COAL CO	
p303597		Prospect	New	8	8	PEERLESS EAGLE COAL CO	
q001283	WV1013904	Quarry	Inactive	16	16	WACO OIL & GAS CO., INC.	Extended, active
r062000	WV0050318	Other	Renewed	47	47	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active
r072800	WV0051845	Other	Inactive	227	227	JULIANA MINING COMPANY, INC.	Renewed, active
r203187	WV0094943	Reprocessing	Revoked	17	47	SPRING RIDGE COAL CO	Comp. Released
s002584	WV0069191	Coal Surface Mine	Revoked	306	311	PRINCESS SUSAN COAL CO	
s002978	WV1015141	Coal Surface Mine	Renewed	48	48	GAULEY EAGLE HOLDINGS INC	
s003576	WV0098868	Coal Surface Mine	Renewed	605	555	BATTLE RIDGE COMPANIES	Renewed, active
s004381	WV0056421	Coal Surface Mine	Revoked	0	64	PISGAH RIDGE COAL CORP	
s005578		Coal Surface Mine	Revoked	45	164	PHOENIX RESOURCES, INC.	
s007185	WV0068306	Coal Surface Mine	Renewed	149	107	COASTAL COAL-WEST VIRGINIA, LLC	Extended, active
s007385	WV0093114	Coal Surface Mine	Phase 1 Released	217	219	CHICOPEE COAL COMPANY, INC.	Renewed, active

Article III Permit ID	NPDES ID	Mine Type	Article III Permit Status	Current Area (ac) [A]	Original Area (ac) [B]	Facility Name [C]	NPDES Status
s008583	WV0056421	Coal Surface Mine	Revoked	0	8	D & R TRUCKING, INC.	
s008583	WV0056421	Coal Surface Mine	Revoked	0	8	PHOENIX RESOURCES, INC.	
s008583	WV0056421	Coal Surface Mine	Revoked	0	8	PREMIUM SEWELL, INC	
s008776	WV0055433	Coal Surface Mine	Phase 1 Released	107	107	MAJESTIC MINING INC	Renewed, active
s010072	WV1014536	Coal Surface Mine	Phase 1 Released	32	400	GAULEY EAGLE HOLDINGS INC	
s010779		Coal Surface Mine	Revoked	0	80	PHOENIX RESOURCES, INC.	
s013079		Coal Surface Mine	Revoked	0	77	PHOENIX RESOURCES, INC.	
s013680		Coal Surface Mine	Revoked	0	99	PHOENIX RESOURCES, INC.	
s023576	WV0098868	Coal Surface Mine	Renewed	432	432	EVERGREEN MINING COMPANY	Renewed, active
s023876	WV0098868	Coal Surface Mine	Renewed	490	490	EVERGREEN MINING COMPANY	Renewed, active
s024076	WV0098868	Coal Surface Mine	Renewed	542	542	EVERGREEN MINING COMPANY	Renewed, active
s046200	WV0063134	Coal Surface Mine	Revoked	0	7	PREMIUM SEWELL, INC	
s100491	WV1010352	Coal Surface Mine	Phase 1 Released	158	158	TAMMIE LYNN COAL CO., INC	Renewed, active
s100691	WV1010409	Coal Surface Mine	Revoked	15	40	DOVE ENTERPRISES OF WV INC	
s102190		Coal Surface Mine	Revoked	0	260	ELK RIVER SEWELL COAL CO	
s102690	WV1010221	Coal Surface Mine	Renewed	133	113	GRAFTON COAL COMPANY	Renewed, active
s200294	WV1013874	Coal Surface Mine	Renewed	960	960	BUNDY AUGER MINING, INC.	Renewed, active
s200396	WV1014064	Coal Surface Mine	New	695	695	MOLLOY MINING INC	new, active
s200487	WV1003470	Coal Surface Mine	Renewed	108	130	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active
s200494	WV1013882	Coal Surface Mine	Renewed	605	605	STEAR AUGER MINING INC	Extended, active
s200697	WV1017888	Coal Surface Mine	New	846	808	MOLLOY MINING INC	new, active
s200798	WV1017934	Coal Surface Mine	New	295	336	MOLLOY MINING INC	
s200995	WV1014005	Coal Surface Mine	New	1654	1619	MINING TECHNOLOGIES INC	
s201189		Coal Surface Mine	Phase 1 Released	367	425	FENTON MINING CORP	
s201199	WV1018001	Coal Surface Mine	New	896	896	FOLA COAL COMPANY, L.L.C.	
s201293	WV1013840	Coal Surface Mine	Renewed	1213	1225	MINING TECHNOLOGIES INC	new, active
s201392	WV1013700	Coal Surface Mine	Renewed	327	319	BUNDY AUGER MINING, INC.	Renewed, active
s201492	WV0098868	Coal Surface Mine	Renewed	179	179	EVERGREEN MINING COMPANY	Renewed, active
s201496	WV1013840	Coal Surface Mine	New	143	192	FOLA COAL COMPANY, L.L.C.	new, active
s203488	WV0094943	Coal Surface Mine	Revoked	73	74	R. H. HELMICK, INC	Comp. Released
s203688	WV0094943	Coal Surface Mine	Revoked	10	20	SPRING RIDGE COAL CO	Comp. Released
s300889	WV1002031	Coal Surface Mine	Renewed	124	148	U. S. CONSTRUCTION CO., INC	
s301393	WV1013815	Coal Surface Mine	Renewed	212	206	FOLA COAL COMPANY, L.L.C.	Renewed, active
s301794	WV1014889	Coal Surface Mine	Inactive	159	159	TERRY EAGLE COAL COMPANY LLC	Extended, active
s302193	WV1014587	Coal Surface Mine	Renewed	1404	1334	INTREPID MINING COMPANY	Renewed, active
s305188	WV1001795	Coal Surface Mine	Revoked	476	630	CHLOE RIDGE COAL CO	Comp. Released
s600188	WV0094129	Coal Surface Mine	Revoked	17	27	PROSPERITY ENERGY, INC	Comp. Released
s601089	WV0094650	Coal Surface Mine	Renewed	339	392	TERRY EAGLE COAL COMPANY LLC	Renewed, active
s601489	WV0094692	Coal Surface Mine	Renewed	167	166	STEAR AUGER MINING INC	Renewed, active
s601989	WV1009290	Coal Surface Mine	Renewed	644	596	STEAR AUGER MINING INC	Extended, active
s603386	WV0093581	Coal Surface Mine	Revoked	0	200	PRINCESS SUSAN COAL CO	new, active
u000683	WV0060577	Coal Underground	Revoked	0	5	JAGRTI COAL CO., INC	Comp. Released
u002300	WV0094633	Coal Underground	Revoked	0	3	POCA RIVER MINING CO., INC	Comp. Released

Article III Permit ID	NPDES ID	Mine Type	Article III Permit Status	Current Area (ac) [A]	Original Area (ac) [B]	Facility Name [C]	NPDES Status
u006200	WV1003194	Coal Underground	Revoked	0	5	POCAHONTAS SECOND CORP	Comp. Released
u006200	WV1003194	Coal Underground	Revoked	0	5	PREMIUM SEWELL, INC	Comp. Released
u006284		Coal Underground	Revoked	0	13	PHOENIX RESOURCES, INC.	
u006284		Coal Underground	Revoked	0	13	PREMIUM SEWELL, INC	
u006300		Coal Underground	Revoked	0	21	POCAHONTAS SECOND CORP	
u006300		Coal Underground	Revoked	0	21	PREMIUM SEWELL, INC	
u007984	WV0090611	Coal Underground	Revoked	0	11	TESTA COAL CO, INC	
u008783	WV0094056	Coal Underground	Renewed	84	84	APPALACHIAN MINING INC	Extended, active
u009084	WV0090093	Coal Underground	Phase 1 Released	10	6	MARSON COAL COMPANY	Comp. Released
u019583		Coal Underground	Revoked	0	52	PHOENIX RESOURCES, INC.	
u019583		Coal Underground	Revoked	0	52	PREMIUM SEWELL, INC	
u026900	WV0096822	Coal Underground	Phase 1 Released	3	3	MAJESTIC MINING INC	Renewed, active
u035900	WV0050318	Coal Underground	Renewed	19	7	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active
u042500	WV0064149	Coal Underground	Revoked	0	9	MICINDE COAL COMPANY	Comp. Released
u042500	WV0064149	Coal Underground	Revoked	0	9	PREMIUM SEWELL, INC	Comp. Released
u042500	WV0064149	Coal Underground	Revoked	0	9	SEWELL MINING ASSOCIATES LP	Comp. Released
u045800	WV0096849	Coal Underground	Phase 1 Released	13	13	MAJESTIC MINING INC	Renewed, active
u047600		Coal Underground	Revoked	3	13	S.S. "JOE" BURFORD, INC	
u051600	WV0050911	Coal Underground	Renewed	19	16	D & K COAL COMPANY	Renewed, active
u052200	WV0053961	Coal Underground	Revoked	0	8	ELK RIVER SEWELL COAL CO	Comp. Released
u052400	WV0052051	Coal Underground	Inactive	10	10	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active
u058600		Coal Underground	Revoked	0	7	FAITH COAL CO	
u062000	WV0052248	Coal Underground	Inactive	45	32	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active
u065700	WV0096814	Coal Underground	Phase 1 Released	4	4	MAJESTIC MINING INC	Renewed, active
u067600	WV0055433	Coal Underground	Phase 1 Released	2	4	MAJESTIC MINING INC	Renewed, active
u069000	WV0053961	Coal Underground	Revoked	0	5	WEST LEATHERWOOD MINING, INC	Comp. Released
u101991	WV1010506	Coal Underground	Inactive	10	10	COASTAL COAL-WEST VIRGINIA, LLC	Extended, active
u102691	WV1010514	Coal Underground	Renewed	17	11	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active
u102991	WV1010531	Coal Underground	Revoked	0	2	JACK RUN COAL CORP, INC	Comp. Released
u103791		Coal Underground	Revoked	0	10	COAL TECHNOLOGY, INC	
u200200	WV1017977	Coal Underground	New	47	47	COASTAL COAL-WEST VIRGINIA, LLC	
u200286	WV0098728	Coal Underground	Revoked	0	17	PREMIUM SEWELL, INC	Comp. Released
u200300	WV1017977	Coal Underground	New	11	11	COASTAL COAL-WEST VIRGINIA, LLC	
u200393	WV1013785	Coal Underground	Renewed	29	29	BJM COAL COMPANY	Renewed, active
u200400	WV1017977	Coal Underground	New	12	12	D.M.D. MINING, INC.	
u200493	WV1013793	Coal Underground	Renewed	12	12	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active
u200593	WV1013793	Coal Underground	Renewed	11	11	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active
u200694	WV1012517	Coal Underground	New	10	10	COPPERAS COAL CORP	Comp. Released
u200694	WV1013882	Coal Underground	New	10	10	COPPERAS COAL CORP	Extended, active
u200900	WV1017977	Coal Underground	New	23	23	COASTAL COAL-WEST VIRGINIA, LLC	
u200998	WV1014145	Coal Underground	New	13	13	JULIANA MINING COMPANY, INC.	new, active
u201000	WV1017977	Coal Underground	New	20	20	COASTAL COAL-WEST VIRGINIA, LLC	

Article III Permit ID	NPDES ID	Mine Type	Article III Permit Status	Current Area (ac) [A]	Original Area (ac) [B]	Facility Name [C]	NPDES Status
u201098	WV1014145	Coal Underground	New	19	19	JULIANA MINING COMPANY, INC.	new, active
u201486	WV0098825	Coal Underground	Revoked	0	9	TANGLEWOOD ENERGY, INC	Comp. Released
u201498	WV1017977	Coal Underground	New	12	12	PAMMLID COAL CO	
u201586	WV0098094	Coal Underground	Revoked	0	6	BRIARWOOD ENERGY, INC	Comp. Released
u201689	WV0068306	Coal Underground	Inactive	11	10	COASTAL COAL-WEST VIRGINIA, LLC	Extended, active
u202386	WV1003054	Coal Underground	Revoked	0	9	C & C MINING, INC	Comp. Released
u202589		Coal Underground	Revoked	0	24	ELK RIVER SEWELL COAL CO	
u202987	WV1003631	Coal Underground	Revoked	8	8	MARSON COAL COMPANY	Comp. Released
u203786	WV1003127	Coal Underground	Revoked	8	11	PREMIUM SMOKELESS COAL CO	Renewed, active
u204788		Coal Underground	Revoked	0	10	ELK RIVER SEWELL COAL CO	
u300393	WV1014421	Coal Underground	New	9	9	COASTAL COAL-WEST VIRGINIA, LLC	Extended, active
u300690	WV1009362	Coal Underground	Revoked	0	2	CARBON RIDGE MINING CO	Renewed, active
u301291	WV0097225	Coal Underground	Renewed	16	16	GAULEY EAGLE HOLDINGS INC	new, active
u302090	WV0096768	Coal Underground	Revoked	0	4	KMADER ENTERPRISES CORP	Comp. Released
u304091	WV1002031	Coal Underground	Phase 1 Released	33	33	RADEC, INC	
u307186	WV1000527	Coal Underground	Phase 1 Released	30	30	COASTAL COAL-WEST VIRGINIA, LLC	Renewed, active
u601886	WV0093114	Coal Underground	Phase 1 Released	32	32	CHICOPEE COAL COMPANY, INC.	Renewed, active
u602288	WV0094374	Coal Underground	Phase 1 Released	8	8	DIVITA COAL CO	Renewed, active
u603086		Coal Underground	Revoked	0	10	EASTERN ENERGY INVESTMENTS	
z001181		Coal Surface Mine	Revoked	0	81	M & H COAL CO/POVAL CORP	
z007881	WV0056073	Coal Surface Mine	Revoked	0	71	FISHER RUN COAL COMPANY, INC.	Comp. Released

[A] Current Area - Surface disturbed area of permitted mines(April 2001)
[B] Original Area - Surface disturbed area when mining permit was originally issued
[C] Facility Name can represent either the permittee or the operator.
* Article III permits designated as “Completely Released” or “Phase 2 Released” are not listed in the above table. Phase II and Completely Released permitted facilities were not modeled since reclamation of these mines is either complete or nearly complete.

Appendix C

Water Quality Data Analysis
Sediment/Metals Relationships

Elk River Mainstem

(Big Sandy to mouth)

Location: Elk River, Big Sandy to mouth
Pollutant: TSS (mg/L)
Data from: 7/19/1950 to 10/22/1996 (214 Observations)

Flow Range	# Obs	Flow (cfs)			Concentration (mg/L)		
Percentile	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
0-10	22	155.273	67.000	218.000	12.23	1.00	133.00
10-20	21	320.476	225.000	392.000	8.67	1.00	32.00
20-30	22	479.727	395.000	550.000	6.99	1.00	28.00
30-40	23	739.348	551.000	878.000	7.83	1.00	18.00
40-50	20	1137.250	880.000	1420.000	12.11	1.00	76.00
50-60	23	1647.130	1450.000	1859.000	10.30	1.00	55.00
60-70	19	2081.579	1900.000	2250.000	12.64	1.00	38.00
70-80	21	2730.857	2380.000	3310.000	18.49	1.00	93.00
80-90	21	4256.762	3400.000	5790.000	29.36	1.00	127.00
90-100	22	8024.545	6000.000	14385.000	76.57	1.00	290.00

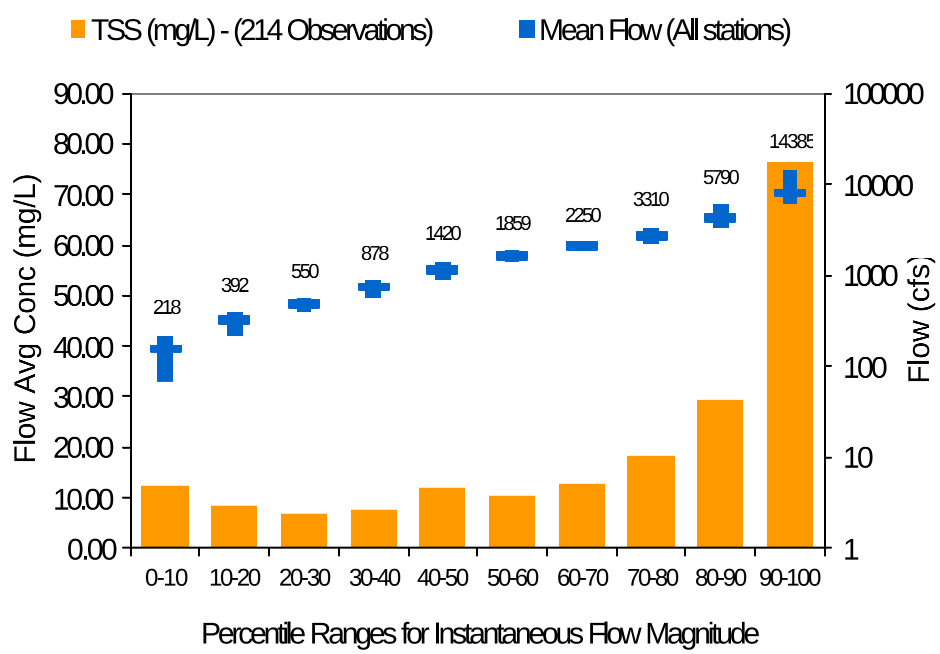


Figure C-1. Elk River mainstem - Flow/TSS relationship

Location: Elk River, Big Sandy to mouth
Pollutant: Iron, Total (ug/L)
Data from: 9/13/1973 to 10/22/1996 (201 Observations)

Flow Range	# Obs	Flow (cfs)			Concentration (ug/L)		
Percentile	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
0-10	22	46.834	0.050	128.000	848.23	28.00	6400.00
10-20	19	197.474	146.000	280.000	586.76	30.00	4000.00
20-30	20	365.000	282.000	443.000	370.68	35.00	1600.00
30-40	20	559.750	447.000	649.000	426.66	180.00	1580.00
40-50	20	865.000	653.000	1090.000	313.97	50.00	760.00
50-60	22	1452.636	1120.000	1700.000	444.90	60.00	2540.00
60-70	18	2098.611	1788.000	2420.000	625.53	60.00	1700.00
70-80	20	2935.050	2460.000	3690.000	492.09	10.00	1640.00
80-90	20	4714.800	3750.000	6340.000	1154.29	170.00	5300.00
90-100	20	8967.150	6360.000	21800.000	3550.39	160.00	9400.00

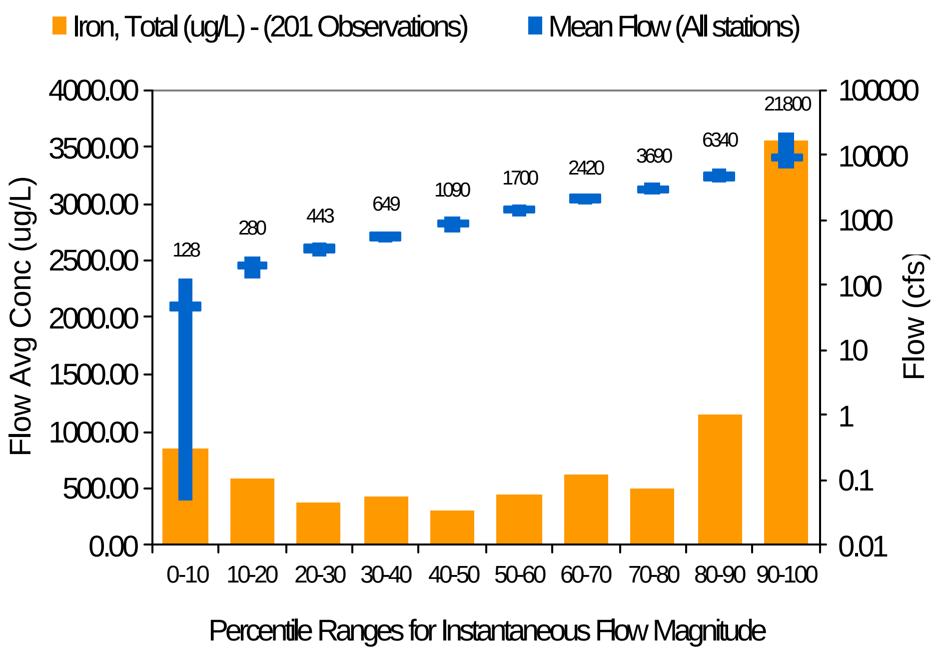


Figure C-2. Elk River mainstem - Flow/Total Iron relationship

Location: Elk River, Big Sandy to mouth
Pollutant: Aluminum, Total (ug/L)
Data from: 10/18/1973 to 10/22/1996 (131 Observations)

Flow Range	# Obs	Flow (cfs)			Concentration (ug/L)		
Percentile	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
0-10	14	107.286	2.000	169.000	996.83	50.00	5600.00
10-20	13	234.154	200.000	286.000	773.18	80.00	5171.00
20-30	13	366.231	292.000	447.000	220.48	50.00	1100.00
30-40	13	580.462	452.000	696.000	226.60	50.00	1100.00
40-50	13	974.692	706.000	1330.000	223.44	50.00	500.00
50-60	13	1619.077	1420.000	1870.000	583.34	70.00	2550.00
60-70	13	2243.462	1900.000	2460.000	827.80	160.00	7000.00
70-80	13	2996.231	2540.000	3690.000	550.77	70.00	1160.00
80-90	12	4333.000	3750.000	5200.000	872.62	50.00	3460.00
90-100	14	9205.143	6000.000	21800.000	2564.21	40.00	5400.00

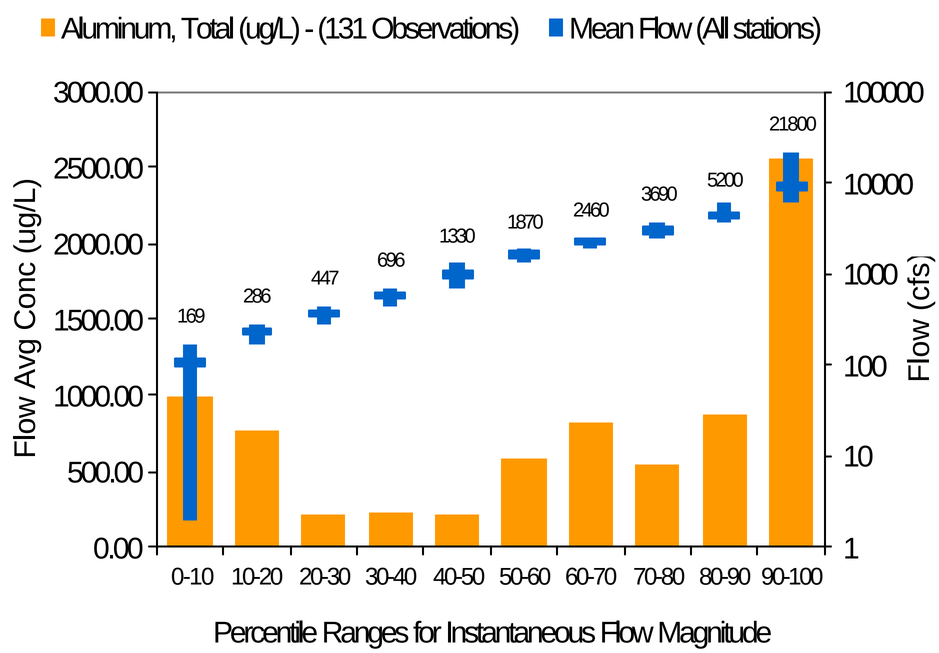


Figure C-3. Elk River mainstem - Flow/Total Aluminum relationship

Location: Elk River, Big Sandy to mouth
Pollutant: Manganese, Total (ug/L)
Data from: 9/13/1973 to 10/22/1996 (202 Observations)

Flow Range	# Obs	Flow (cfs)			Concentration (ug/L)		
Percentile	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
0-10	22	46.834	0.050	128.000	76.44	25.00	400.00
10-20	19	193.263	146.000	258.000	60.67	10.00	130.00
20-30	20	356.850	280.000	435.000	55.15	10.00	240.00
30-40	20	549.450	443.000	649.000	53.93	34.00	110.00
40-50	20	842.950	649.000	1080.000	47.25	5.00	86.00
50-60	20	1397.400	1090.000	1670.000	42.20	5.00	80.00
60-70	20	2022.750	1700.000	2415.000	50.93	10.00	120.00
70-80	20	2871.550	2420.000	3660.000	35.65	5.00	84.00
80-90	20	4582.300	3690.000	6250.000	64.78	5.00	192.00
90-100	21	8842.048	6340.000	21800.000	196.00	10.00	620.00

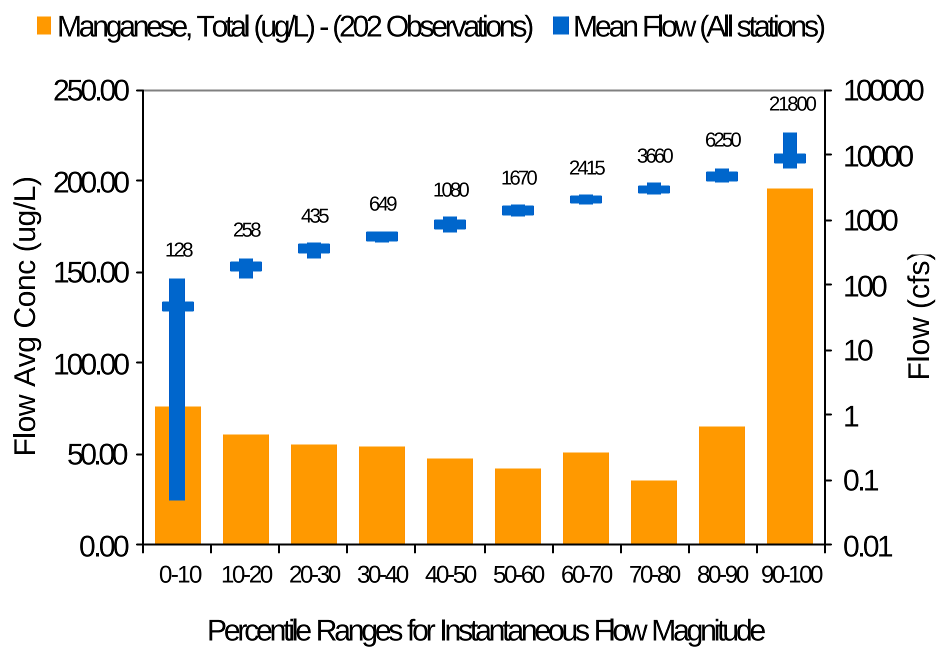


Figure C-4. Elk River mainstem - Flow/Total Manganese relationship

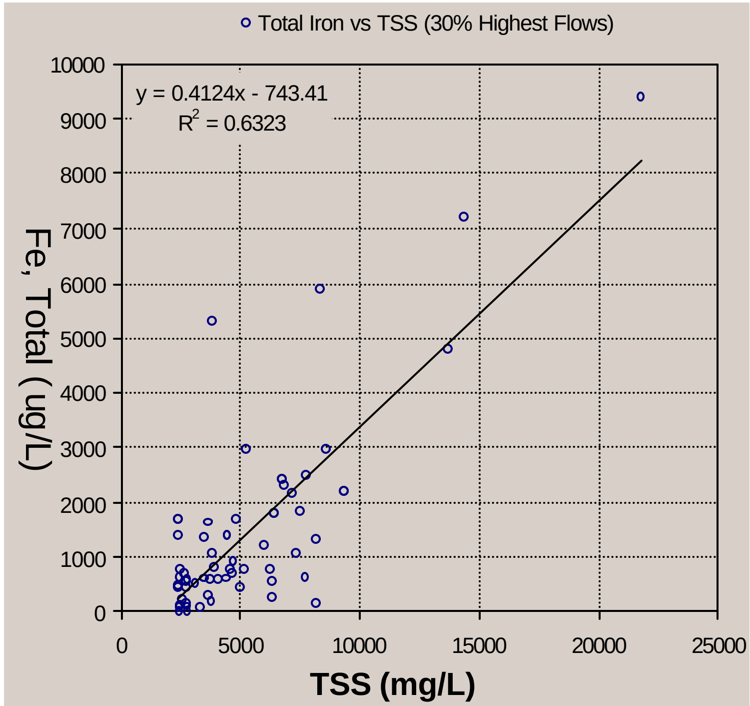


Figure C-5. Elk River mainstem - Total Iron/TSS correlation (30% highest flows)

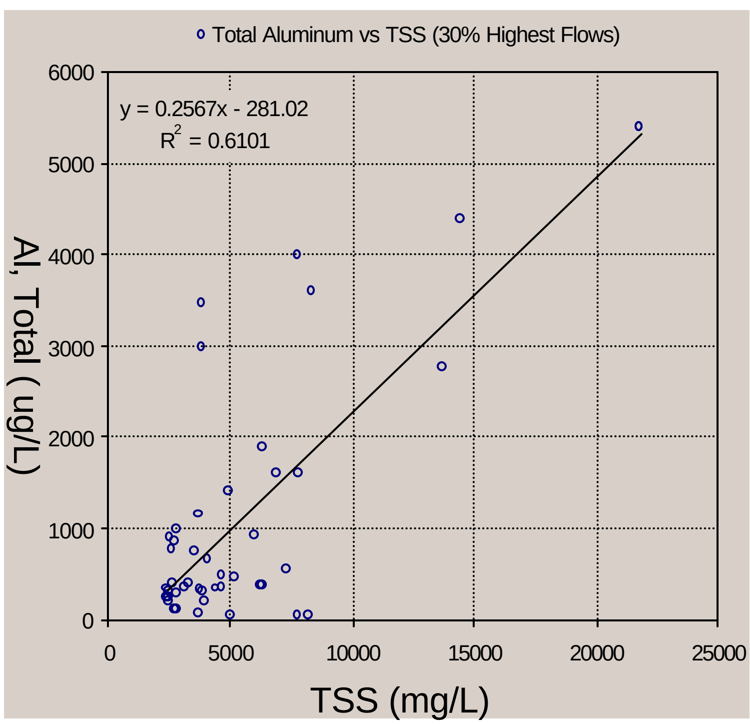


Figure C-6. Elk River mainstem - Total Aluminum/TSS correlation (30% highest flows)

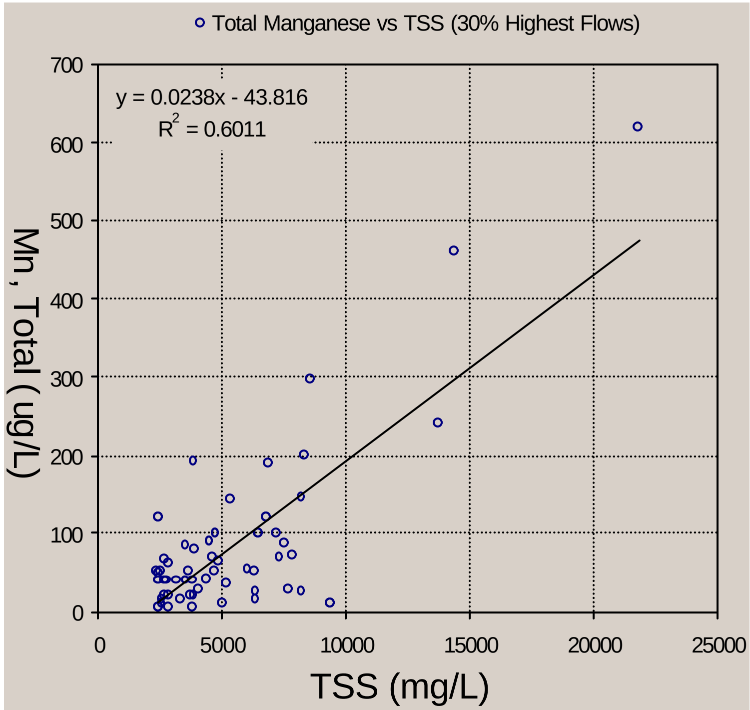


Figure C-7. Elk River mainstem - Total Manganese/TSS correlation (30% highest flows)

Location: Elk River, Big Sandy to mouth
Pollutant: Iron, Dissolved (ug/L)
Data from: 10/18/1973 to 10/30/1986 (59 Observations)

Flow Range	# Obs	Flow (cfs)			Concentration (ug/L)		
Percentile	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
0-10	6	2.850	0.400	8.000	237.78	60.00	350.00
10-20	6	129.667	44.000	208.000	135.96	30.00	370.00
20-30	6	393.833	286.000	470.000	77.42	40.00	120.00
30-40	6	555.167	470.000	608.000	64.00	40.00	130.00
40-50	6	669.833	624.000	820.000	98.91	30.00	210.00
50-60	5	1120.000	1000.000	1260.000	45.21	30.00	60.00
60-70	7	1851.143	1440.000	2410.000	48.57	21.00	60.00
70-80	6	2979.667	2530.000	3540.000	51.75	33.00	80.00
80-90	5	4472.000	3940.000	4740.000	51.19	10.00	60.00
90-100	6	7546.667	6480.000	9390.000	68.49	30.00	130.00

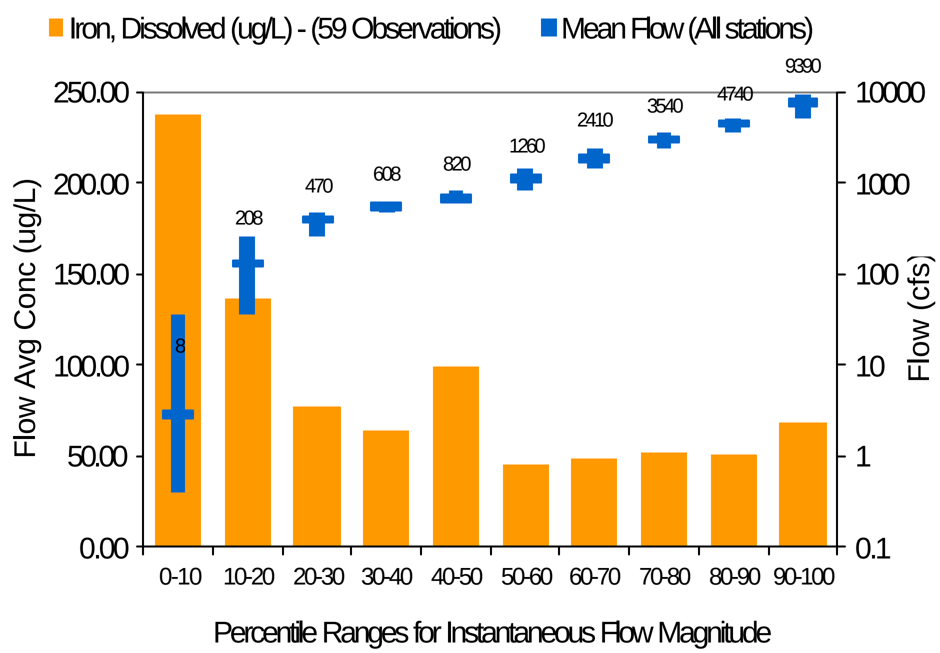


Figure C-8. Elk River mainstem - Flow Dissolved Iron relationship

Location: Elk River, Big Sandy to mouth
Pollutant: Manganese, Dissloved (ug/L)
Data from: 10/19/1973 to 10/30/1986 (57 Observations)

Flow Range	# Obs	Flow (cfs)			Concentration (ug/L)		
Percentile	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
0-10	6	2.850	0.400	8.000	115.61	40.00	210.00
10-20	6	159.167	44.000	377.000	48.08	20.00	100.00
20-30	5	434.000	390.000	470.000	33.33	27.00	40.00
30-40	6	580.833	518.000	624.000	27.16	10.00	40.00
40-50	7	770.714	624.000	1000.000	39.28	10.00	60.00
50-60	4	1260.000	1080.000	1440.000	30.71	25.00	40.00
60-70	6	1919.667	1510.000	2410.000	40.65	7.00	66.00
70-80	6	2979.667	2530.000	3540.000	24.93	14.00	30.00
80-90	5	4472.000	3940.000	4740.000	7.50	6.00	10.00
90-100	6	7546.667	6480.000	9390.000	10.41	1.00	20.00

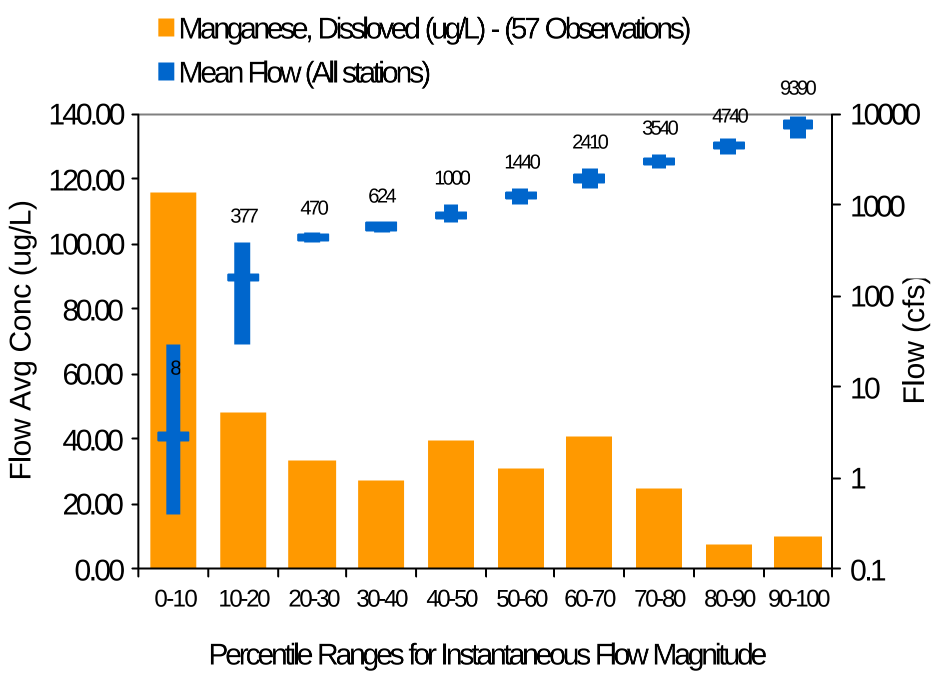


Figure C-9. Elk River mainstem - Flow/Dissolved Manganese relationship

Upstream Tributaries

(Morris Creek, Left Fork Morris Creek, Pheasant Run, Buffalo Creek)

Location: Upstream Listed Segments
Pollutant: Iron, Total (ug/L)
Data from: 10/17/1973 to 7/31/1997 (35 Observations)

Flow Range	# Obs	Flow (cfs)			Concentration (ug/L)		
Percentile	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
0-10	4	0.103	0.003	0.300	3389.49	0.00	0.00
10-20	3	0.567	0.300	0.800	196.47	0.00	0.00
20-30	4	1.500	1.000	2.000	366.00	0.00	0.00
30-40	3	3.667	3.000	4.000	532.73	0.00	0.00
40-50	4	6.750	5.000	8.000	180.00	0.00	0.00
50-60	3	12.333	8.000	19.000	638.38	0.00	0.00
60-70	3	21.333	19.000	25.000	387.66	0.00	0.00
70-80	4	37.000	28.000	47.000	157.97	0.00	0.00
80-90	3	119.667	112.000	124.000	694.15	0.00	0.00
90-100	4	352.750	205.000	613.000	808.22	0.00	0.00

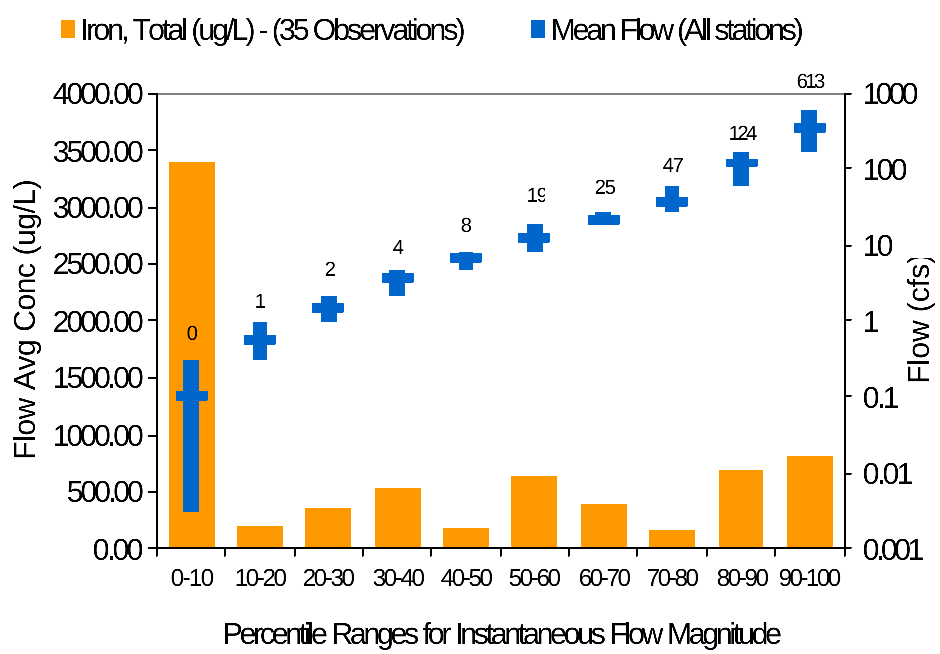


Figure C-10. Upstream Impaired Segments - Flow/Total Iron relationship

Location: Upstream Listed Segments
Pollutant: Aluminum, Total (ug/L)
Data from: 10/19/1973 to 7/31/1997 (9 Observations)

Flow Range	# Obs	Flow (cfs)			Concentration (ug/L)		
Percentile	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
0-10	1	0.080	0.080	0.080	8000.00	0.00	0.00
10-20	1	0.300	0.300	0.300	2500.00	0.00	0.00
20-30	1	2.000	2.000	2.000	1700.00	0.00	0.00
30-40	1	3.000	3.000	3.000	1200.00	0.00	0.00
40-50	1	8.000	8.000	8.000	500.00	0.00	0.00
50-60	0	No Data	No Data	No Data	No Data	No Data	No Data
60-70	1	41.000	41.000	41.000	67.00	0.00	0.00
70-80	1	47.000	47.000	47.000	710.00	0.00	0.00
80-90	1	205.000	205.000	205.000	100.00	0.00	0.00
90-100	1	324.000	324.000	324.000	700.00	0.00	0.00

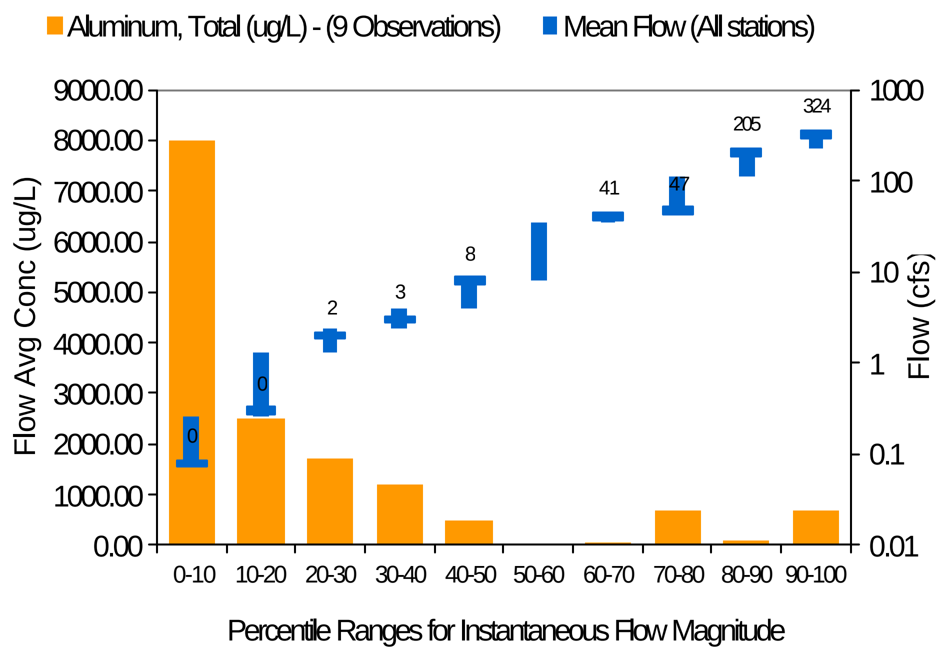


Figure C-11. Upstream Impaired Segments - Flow/Total Aluminum relationship

Location: Upstream Listed Segments
Pollutant: Manganese, Total (ug/L)
Data from: 10/17/1973 to 7/31/1997 (35 Observations)

Flow Range	# Obs	Flow (cfs)			Concentration (ug/L)		
Percentile	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
0-10	4	0.103	0.003	0.300	2867.38	0.00	0.00
10-20	3	0.567	0.300	0.800	401.18	0.00	0.00
20-30	4	1.500	1.000	2.000	971.67	0.00	0.00
30-40	3	3.667	3.000	4.000	629.09	0.00	0.00
40-50	4	6.750	5.000	8.000	576.30	0.00	0.00
50-60	3	12.333	8.000	19.000	483.78	0.00	0.00
60-70	3	21.333	19.000	25.000	629.84	0.00	0.00
70-80	4	37.000	28.000	47.000	433.88	0.00	0.00
80-90	3	119.667	112.000	124.000	233.90	0.00	0.00
90-100	4	352.750	205.000	613.000	148.60	0.00	0.00

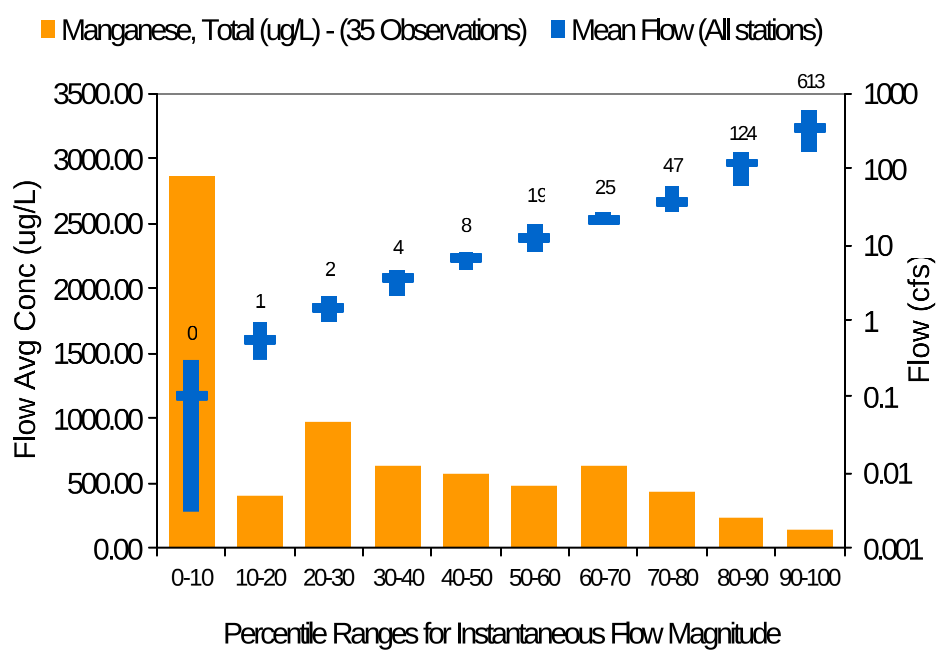


Figure C-12. Upstream Impaired Segments - Flow/Total Manganese relationship

Appendix D

Hydrology and Water Quality Calibration and Validation Results

Hydrology Calibration

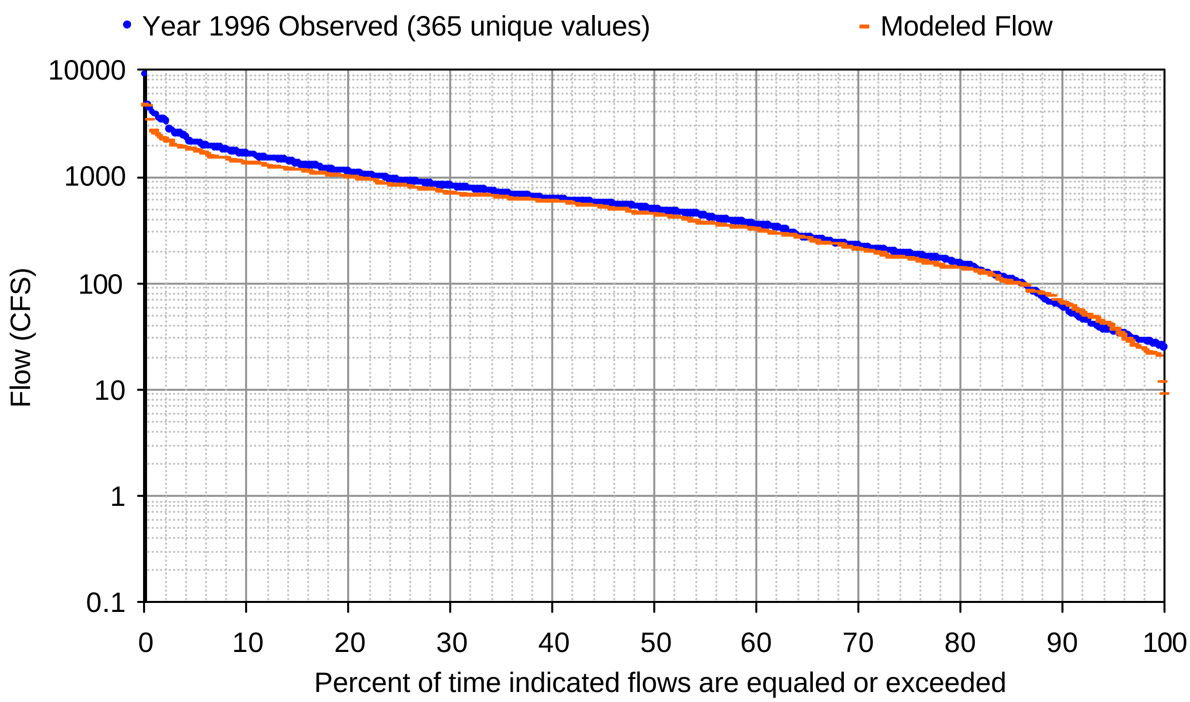


Figure C-1. Elk River (USGS 03194700) flow-frequency curve for year 1996

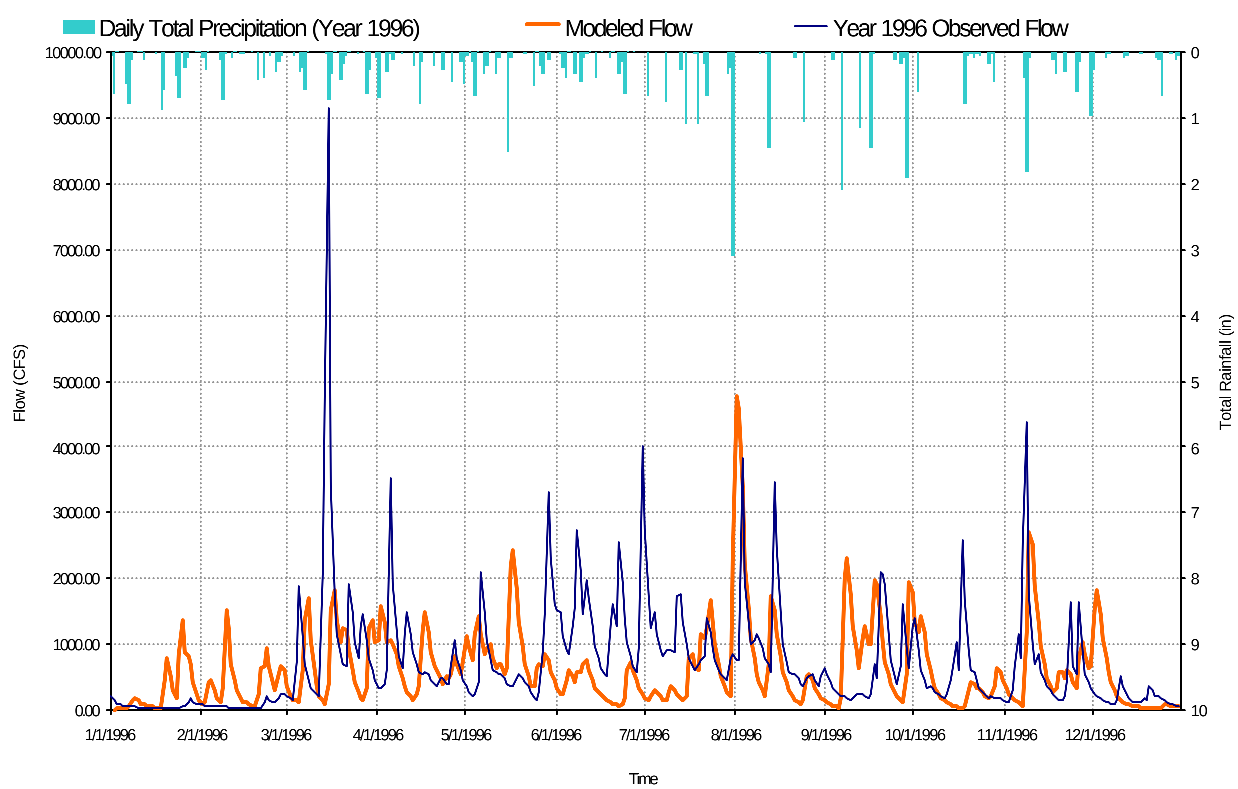


Figure C-2. Temporal calibration results for Elk River (USGS 03194700) for year 1996

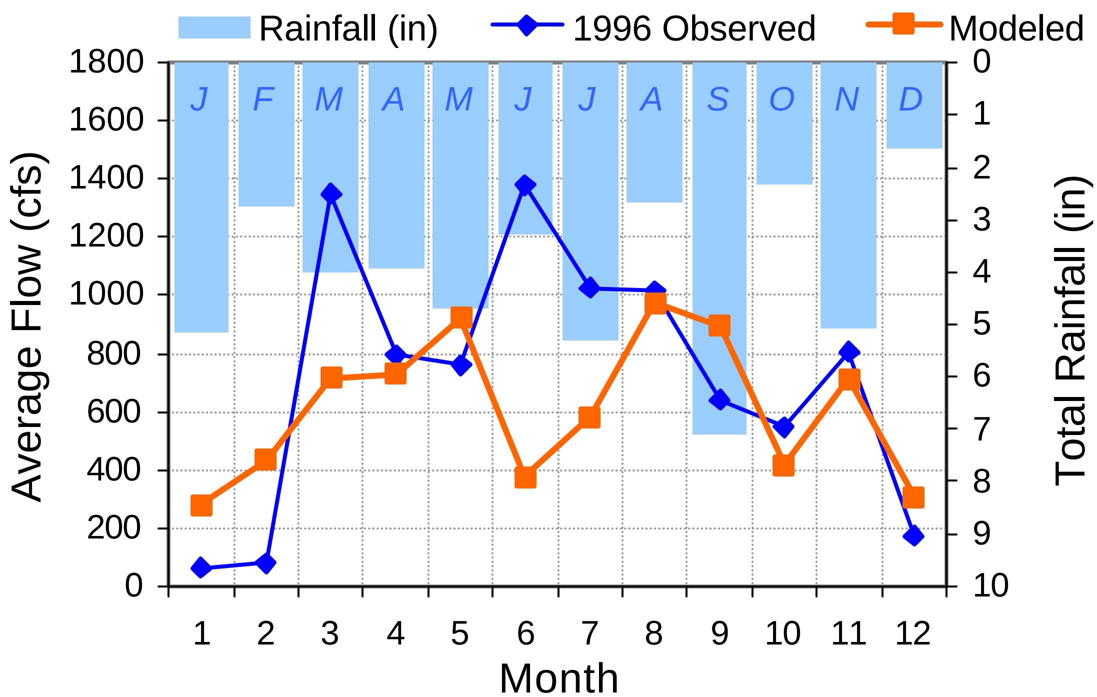


Figure C-3. Temporal calibration results for Elk River (USGS 03194700) for year 1996

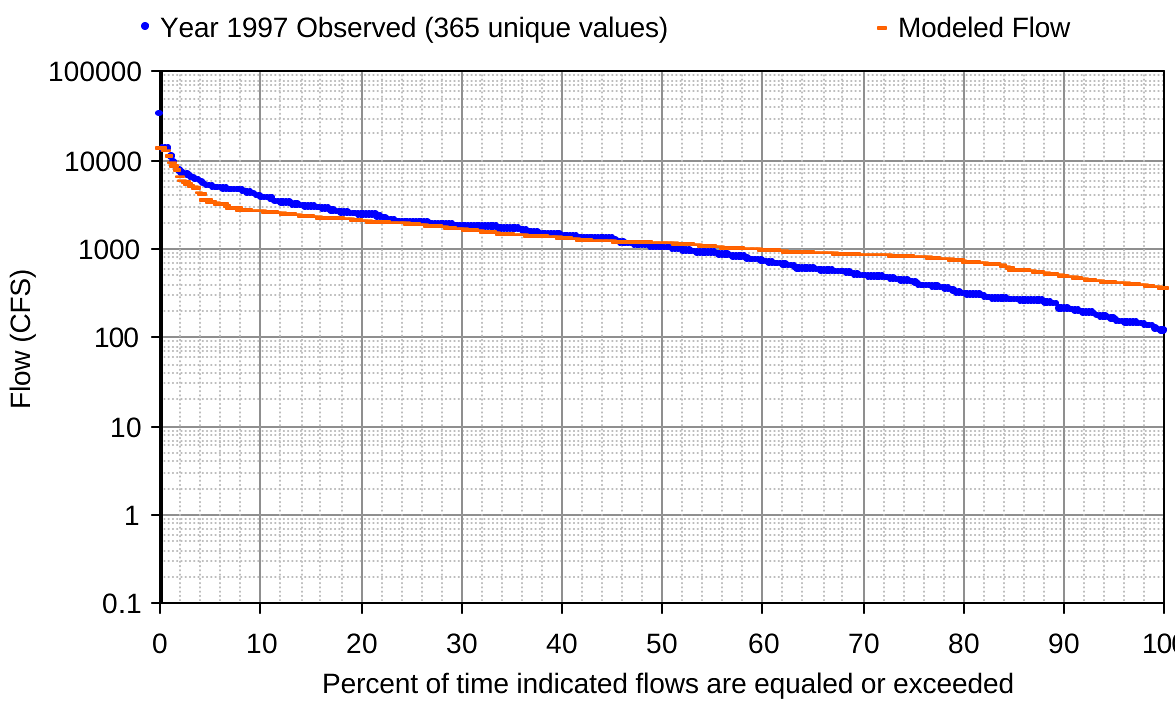


Figure C-4. Elk River (USGS 03197000) flow-frequency curve for year 1997

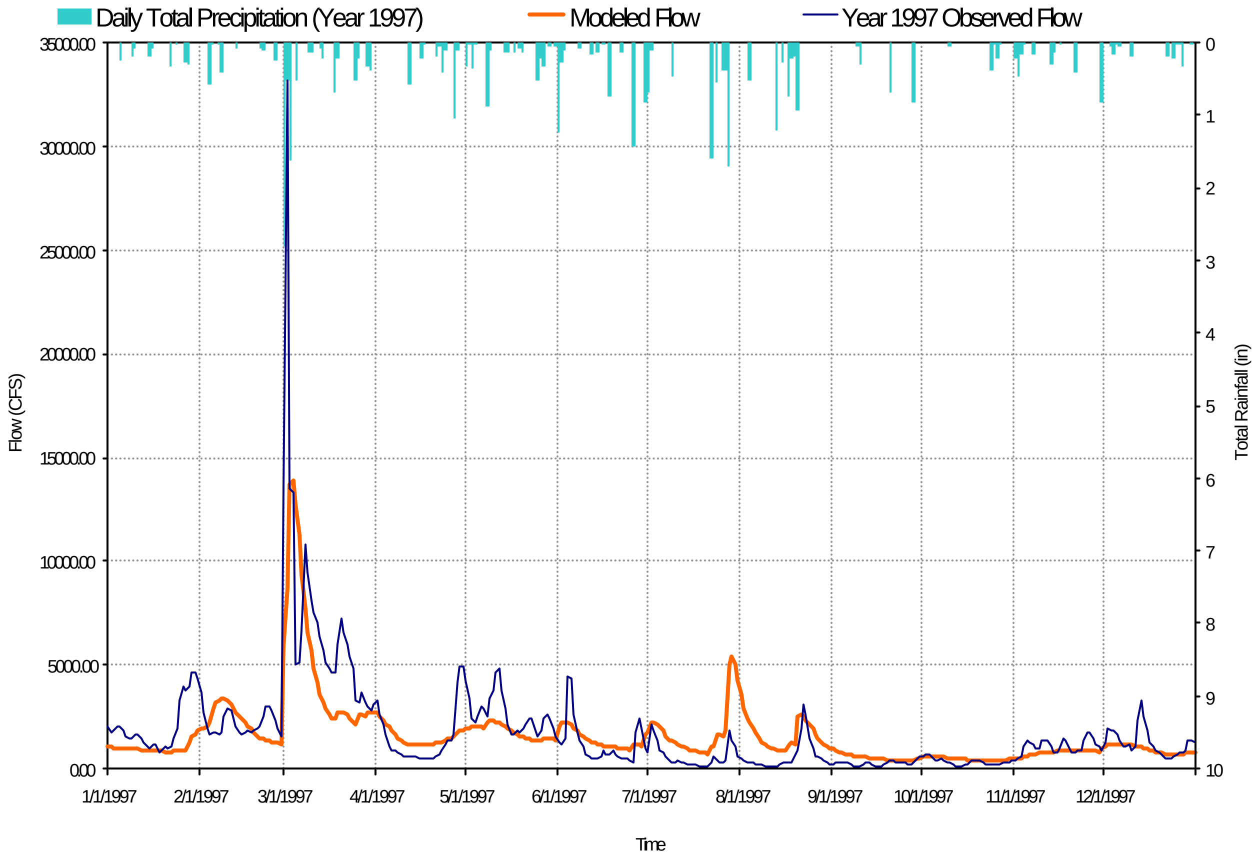


Figure C-5. Temporal calibration results for Elk River (USGS 03197000) for year 1997

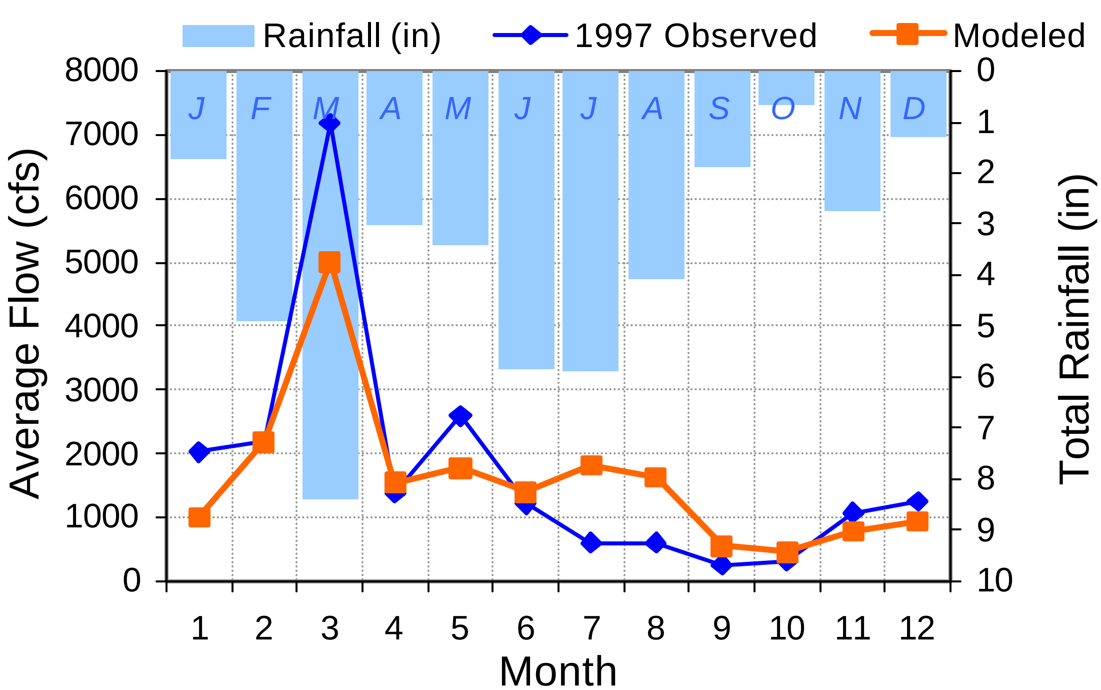
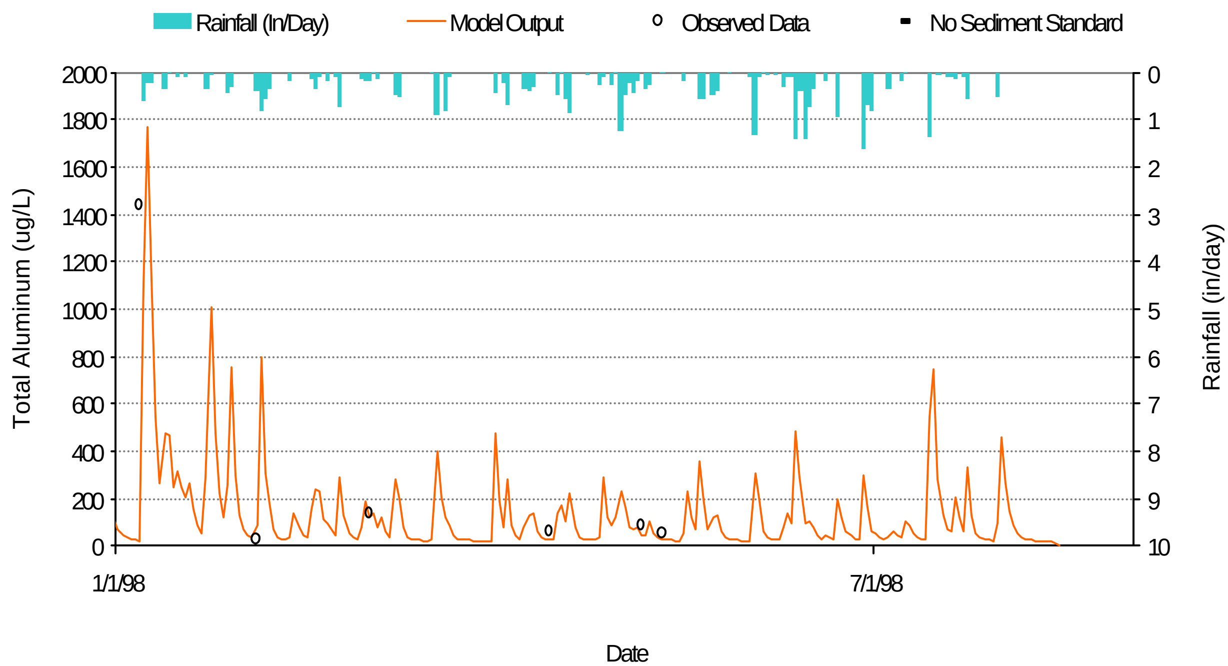


Figure C-6. Temporal calibration results for Elk River (USGS 03197000) for year 1997

Water Quality Calibration



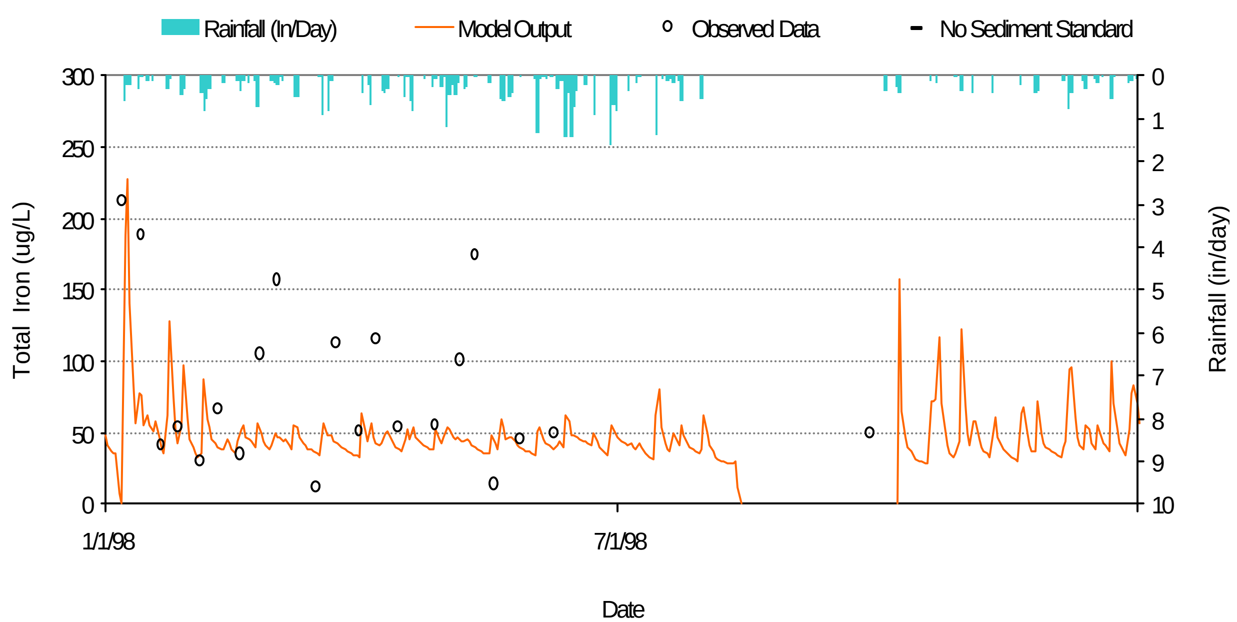
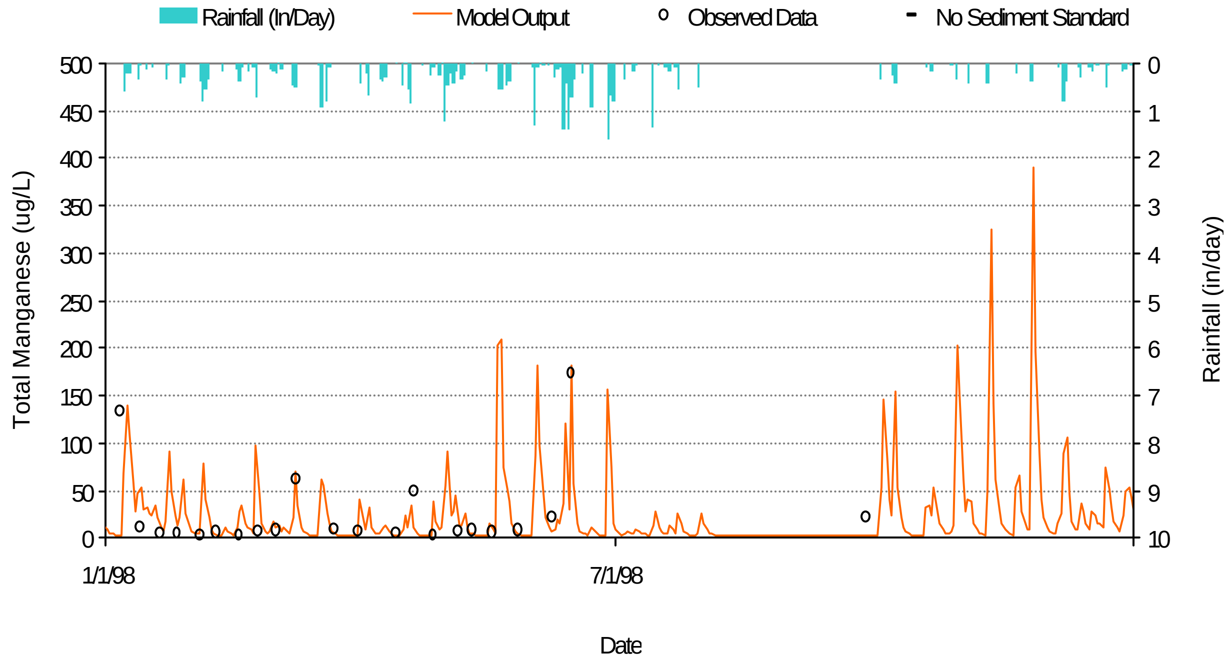


Figure C-7(1). Water Quality Calibration for Aluminum and Iron at Elk River station 1SUTW007 (Subwatershed 4)



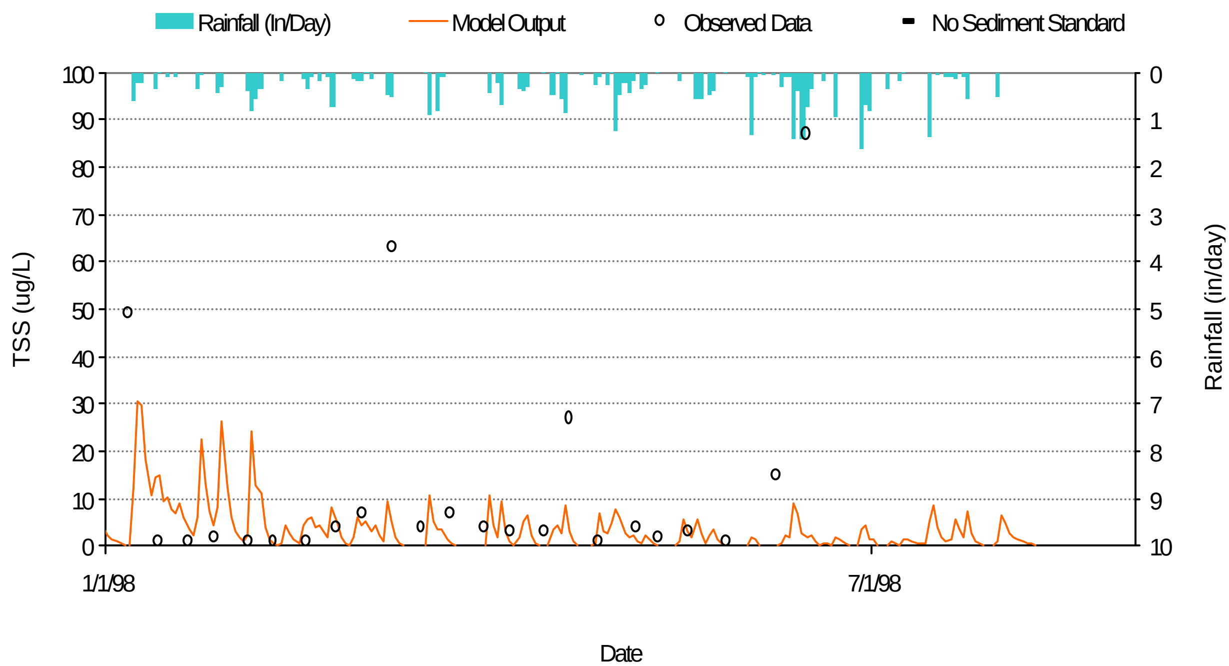
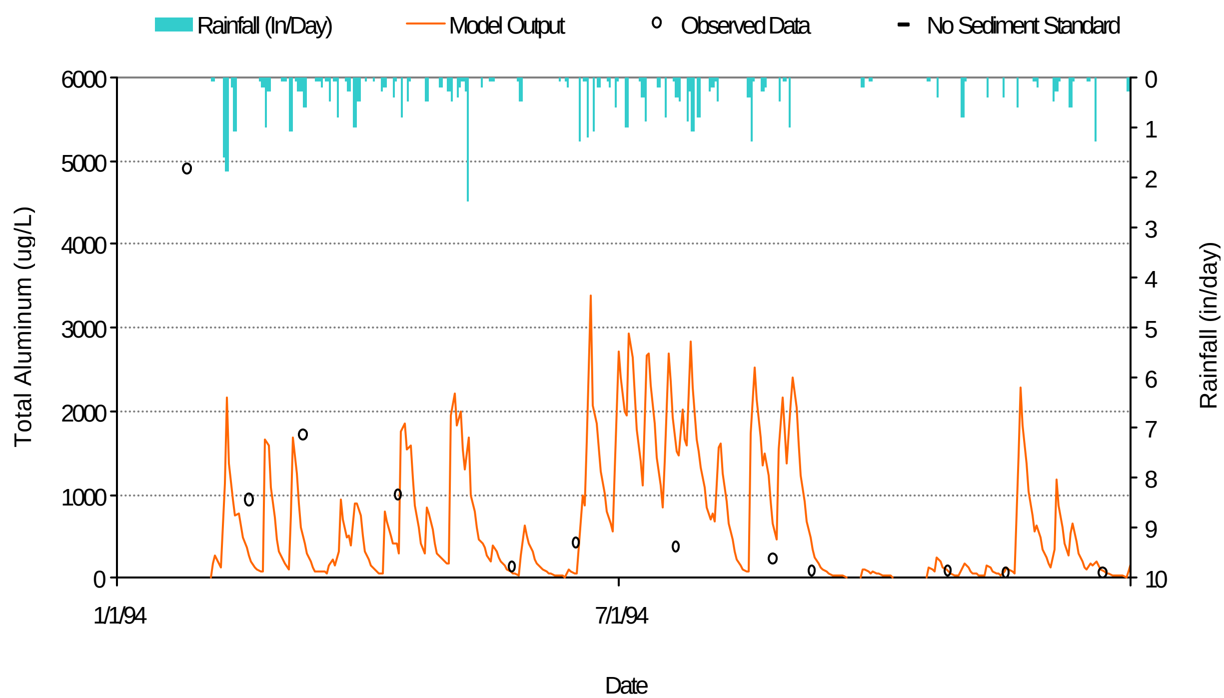


Figure C-7(2). Water Quality Calibration for Manganese and TSS at Elk River station 1SUTW007 (Subwatershed 4)



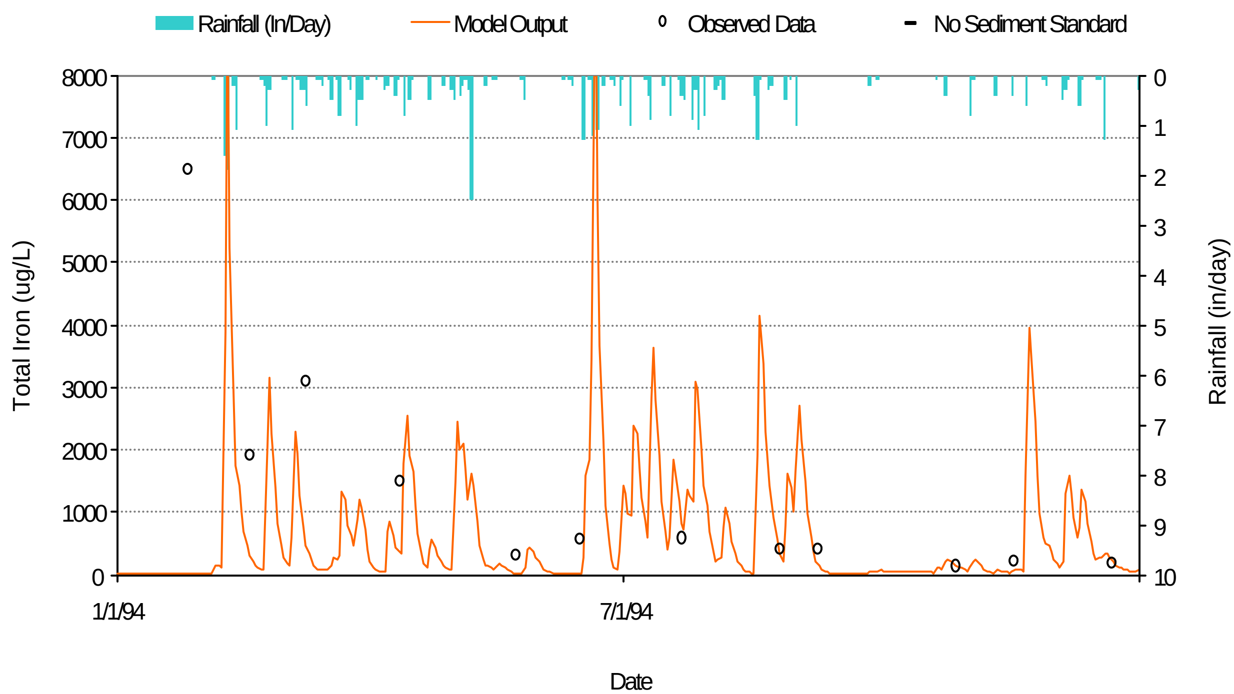
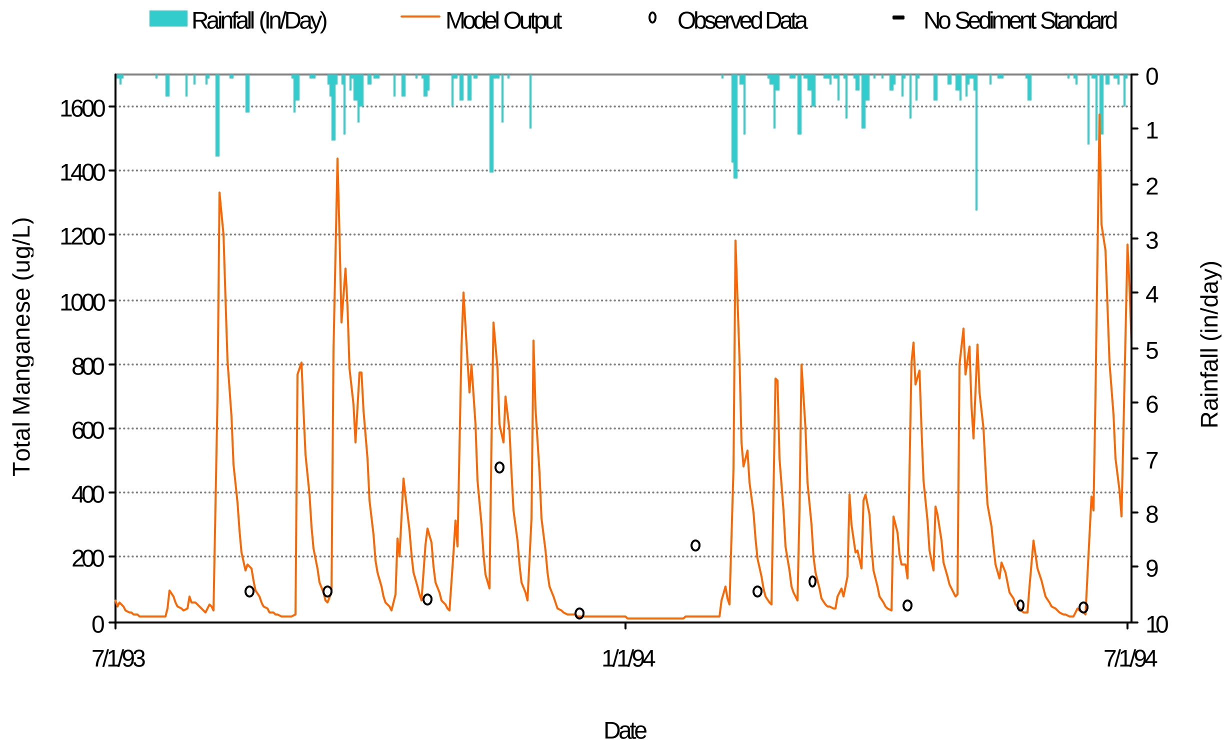


Figure C-8(1). Water Quality Calibration for Aluminum and Iron at Elk River station 550544 (Subwatershed 17 - Elk River mouth)



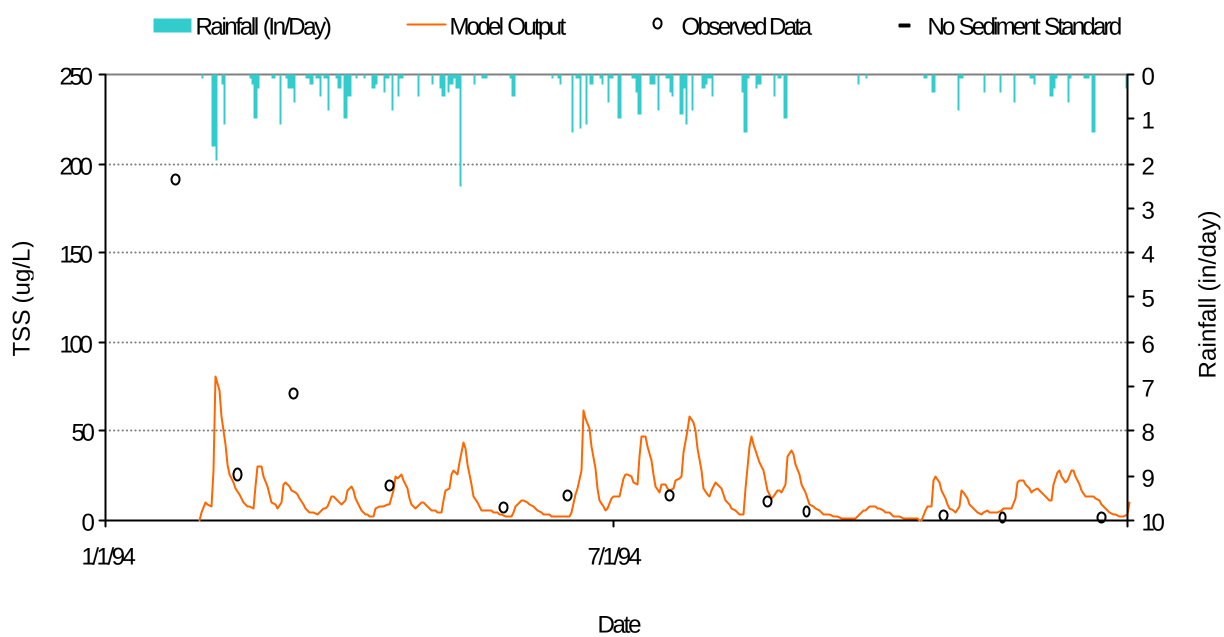


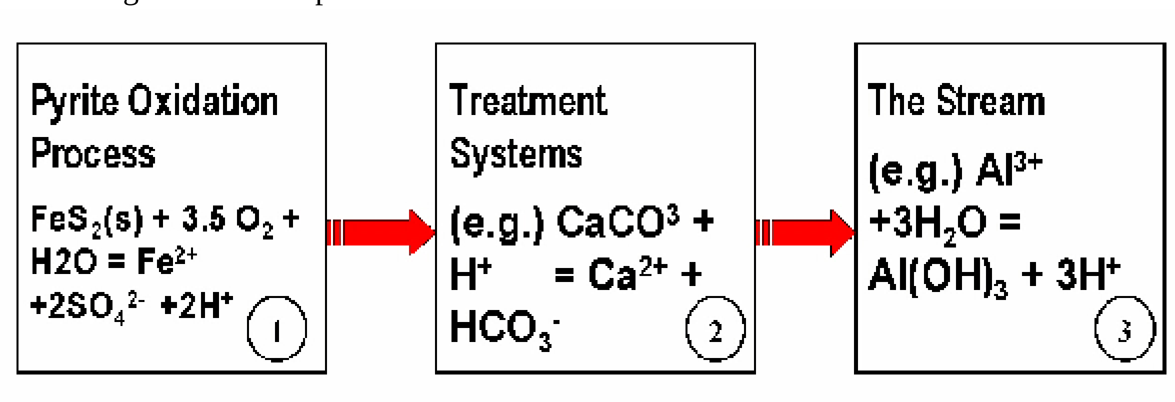
Figure C-8(2). Water Quality Calibration for Manganese and TSS at Elk River station 550544 (Subwatershed 17 - Elk River mouth)

Appendix E

Modeling pH for TMDL Development

Overview

Streams affected by acid mine drainage often exhibit high metals concentrations (specifically for iron [Fe], aluminum [Al], and manganese [Mn]) along with low pH. The relationship between these metals and pH provides justification for using metals TMDLs as a surrogate for a separate pH TMDL calculation. The following figure shows three representative physical components that are critical to establishing this relationship.



Note: Several major ions comprise the water chemistry of a stream. The cations are usually Ca^{2+}, Mg^{2+}, Na^+, K^+, and H^+, and the anions consist of HCO_3^-, CO_3^{2-}, NO_3^-, Cl^-, SO_4^{2-}, and OH^- (Stumm and Morgan, 1996).

Component 1 describes the beginning oxidation process of pyrite (FeS_2) resulting from its exposure to H_2 O and O_2. This process is common in mining areas. The kinetics of pyrite oxidation processes are also affected by bacteria (Thiobacillus ferrooxidans), pH, pyrite surface area, crystallinity, and temperature (PADEP, 2000). The overall stoichiometric reaction of the pyrite oxidation process is as follows:

$$FeS_2(s) + 3.75\ O_2 + 3.5\ H_2O \rightarrow Fe(OH)_3\ (s) + 2SO_4^{2-}\ + 4H+$$

Lower pH and higher metals concentrations from Component 1 should be treated effectively with applicable systems.

Component 2 presents an example chemical reaction occurring within a mining treatment system. Examples of treatment systems include wetlands, successive alkalinity producing systems, and open limestone channels. Carbonate and other bases (e.g., hydroxide) created in treatment systems consume hydrogen ions produced by pyrite oxidation and hydrolysis of metals, thereby increasing pH. The increased pH of the solution will precipitate metals as metal hydroxides. Treatment systems may not necessarily work properly, however, because the removal rate of metals, and attenuation of pH depends on chemical constituents of the inflow, the age of the systems, and physical characteristics of the systems (e.g., flow rate, detention rate) (West Virginia University Extension Service, 2000).

It is assumed that implementation of TMDLs in the Elk watershed for aluminum, iron, and manganese will result in in-stream metals concentrations meeting the water quality criteria. This assumes that treatment systems are implemented properly and effectively increase pH, in order to precipitate and thus lower metals concentrations.

After treatment, the focus shifts to Component 3 and the relationship between metals concentrations and pH in the stream. The chemical process that needs to be considered is the hydrolysis reaction of metals in the stream. Component 3 presents an example of this reaction. In order to estimate pH resulting from chemical reactions occurring in the stream, MINTEQA2 (a geochemical equilibrium speciation model for dilute aqueous systems) was used.

MINTEQA2 Application

MINTEQA2 is an EPA geochemical equilibrium speciation model capable of computing equilibrium aqueous speciation, adsorption, gas phase partitioning, solid phase saturation states, and precipitation-dissolution of metals in an environmental or lab setting. The model includes an extensive database of reliable thermodynamic data. The MINTEQA2 model was run using the following inputs:

Species	Input Values (mg/L)
Ca	43.2
Mg	14.5
Na [(a)]	6.3
K [(a)]	2.3
Cl [(a)]	7.8
SO_4	86.6
Fe [(b)]	1.5
Al [(b)]	0.75
Mn [(b)]	1.0
Alkalinity	20.5 (as $CaCO_3$)

[(a)] source: Livingstone (1963)
[(b)] allowable maximum concentrations (TMDL endpoints)

Input values for Fe, Al, and Mn were based on TMDL endpoints (maximum allowable limits). The alkalinity value was based on average in-stream concentrations for rivers relatively unimpacted by mining activities in the Monongahela River watershed. Mean observation values were used for the remaining ions requiring input for MINTEQA2. Where observation data were not available, literature values were used for the chemical species. The model was additionally set to equilibrium with atmospheric CO_2. Based on the inputs presented, the resultant equilibrium pH was estimated to be 7.81 using the aquatic life standard (1.5 mg/L total Fe).

The model was also run using typical in-stream metals concentrations found in the vicinity of mining activities (10 mg/L for total Fe, 10 mg/L for Al, 5 mg/L for Mn, and 3 mg/L as $CaCO_3$ for alkalinity). These inputs resulted in an equilibrium pH of 4.38.

Results from MINTEQA2 imply that pH will be within the West Virginia criteria of above 6 and below 9, provided that in-stream metals concentrations simultaneously meet applicable water quality criteria.

Assumptions

The conclusions presented above assume that TMDLs are implemented properly, so that metals concentrations from point and nonpoint sources result in the stream meeting metals criteria (implying that pH from these sources has already been increased, in order to decrease metals). Additional assumptions (and facts) that were considered in this process are as follows:

Iron (Fe)

Ferric iron was selected as total iron based on the assumption that the stream will be in equilibrium with the atmospheric oxygen. Since iron exhibits oxidized and reduced states, the redox part of the iron reactions may additionally need to be considered. The reduced state of iron, ferrous iron, can be oxidized to ferric iron through abiotic and biotic oxidation processes in the stream. The first process refers to oxidation by increasing the dissolved oxygen because of the mixing of flow. The other process is oxidation by microbial activity in acidic conditions on bedrock (Mcknight and Bencala, 1990). Photoreduction of hydrous oxides also can increase the dissolved ferrous form. This reaction could increase pH of the stream followed by oxidation and hydrolysis reactions of ferrous iron (Mcknight, Kimball and Bencala, 1988). Since water quality data are limited, the concentration of total Fe was assumed to be constant at 1.5 mg/L, and it was assumed that total Fe increase by photoreduction would be negligent. (This assumption could ignore pH changes during daytime.)

Sodium (Na), Potassium (K), and Chloride (Cl)

The concentration of Na, K, and Cl can be higher in streams affected by acid mine drainage. These ions are conservative and are not reactive in natural water, however, so it is likely that the pH of the stream would not be affected.

Calcium (Ca), Magnesium (Mg)

These ions may have higher concentrations than the values used for the modeling in this study due to the dissolution of minerals under acidic conditions and the reactions within treatment systems. Increasing the concentrations of these ions in the stream, however, could result in more complex forms with sulfate in the treatment system and in the river. This should not affect pH.

Manganese (Mn)

Manganese oxide (MnO_2) can have a redox reaction with ferrous iron and produce ferric iron (Evangelou, 1998). This ferric iron can go through a hydrolysis reaction and produce hydrogen ions, thereby decreasing pH.

Biological Activities

Biological activities such as photosynthesis, respiration, and aerobic decay can influence the pH of localized areas in the stream. Biological reactions such as the one below:

$$CO_2 + H_2O \longleftrightarrow 1/6\ C_6H_{12}O_6 + O_2$$

will assimilate CO_2 during photosynthesis and produce CO_2 during respiration or aerobic decay. Reducing CO_2 levels will increase the pH and increasing CO_2 levels will lower the pH of the water (Langmuir, 1997). It is possible that as a result of these biological activities, the pH standards may be violated even though metals concentrations are below in-stream water quality standards.

Kinetic Considerations

The kinetic aspect of metal reactions in the stream is an important factor that also needs to be considered. For example, Fe and Mn can be oxidized very rapidly if the pH of the solution is 7.5 to 8.5; otherwise the oxidization process is much slower (Evangelou, 1995). Having a violation of metals concentrations, but no pH violation might be a result of the kinetic aspect of the reactions.

Appendix F

Dissolved Zinc Impairments in the Elk River Watershed

Problem Understanding and Conclusions

The mainstem of the Elk River was listed as impaired for zinc on West Virginia's 1996 and 1998 303(d) list. Dissolved zinc data collected from stations located on the mainstem of the Elk River are shown in Figure E-1. There were no exceedances of the hardness-based water quality criteria for zinc. These findings suggest that the mainstem of the Elk River is not impaired for zinc and TMDL development for this pollutant is not necessary. This impairment will be addressed in the development of the West Virginia 2002 303(d) List.

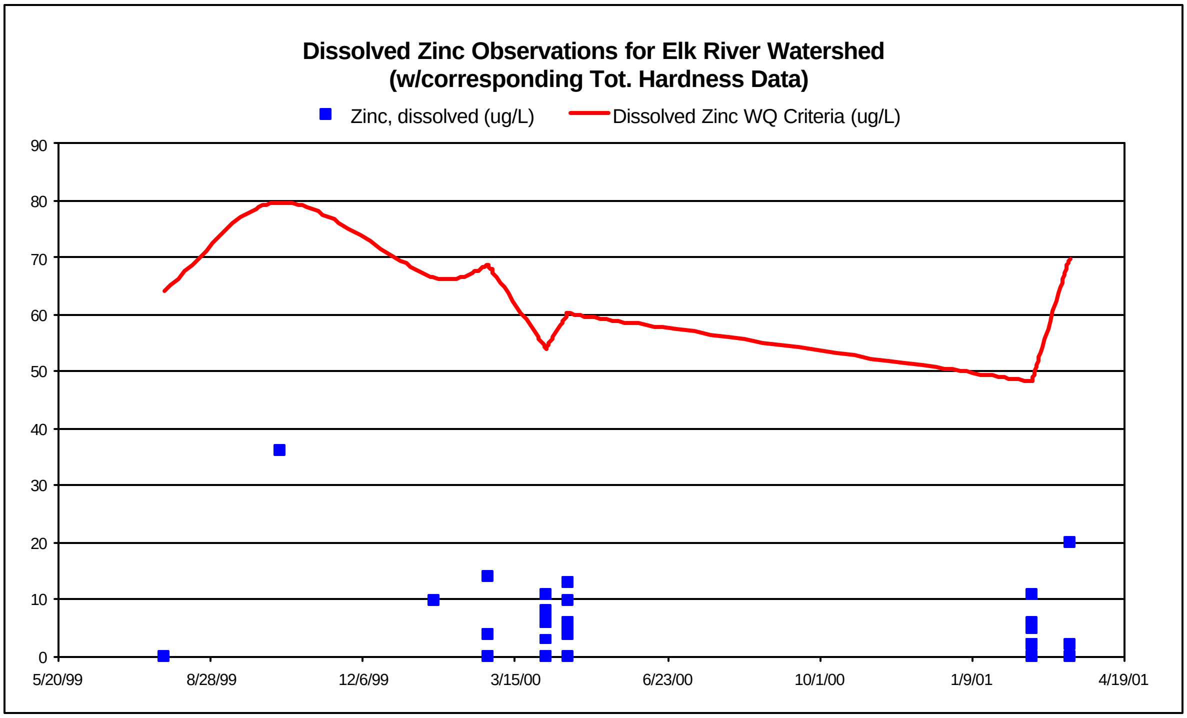


Figure 1. Dissolved zinc observations for the Elk River watershed (with corresponding total hardness data

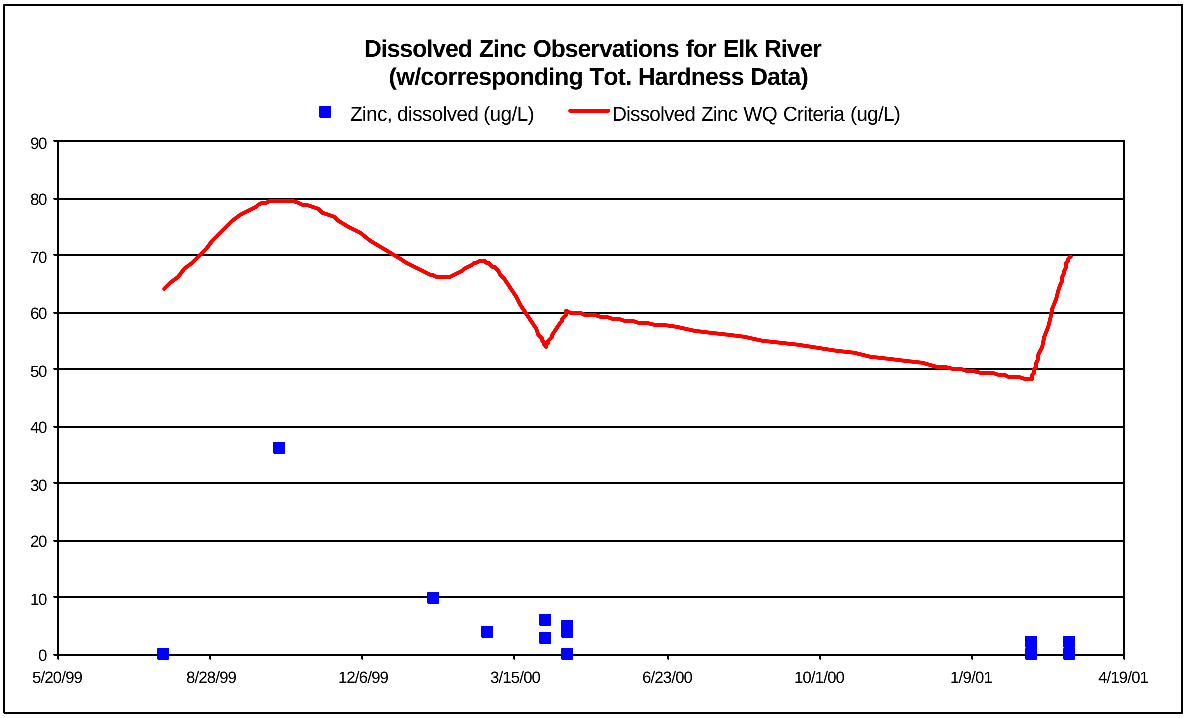


Figure 2. Dissolved zinc observations for the Elk River (with corresponding total hardness data

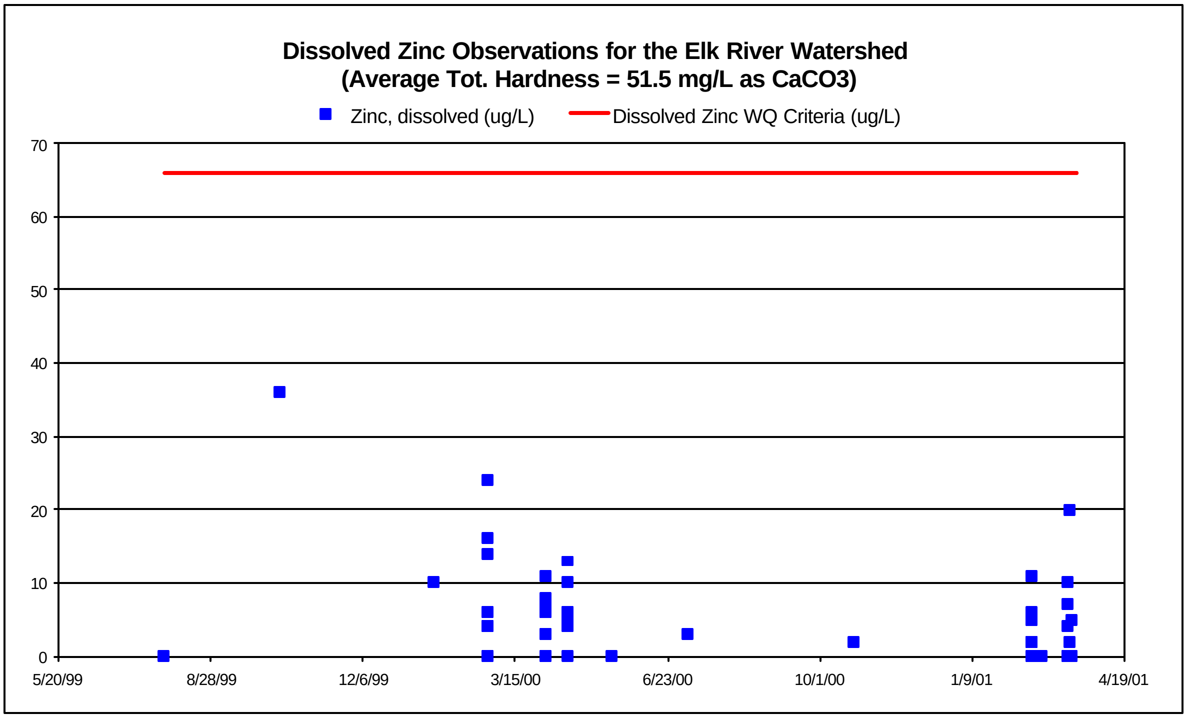


Figure 3. All dissolved zinc observations for the Elk River watershed (using average total hardness of 51.5 mg/L to calculate the wq criteria