Metals and pH TMDLs for the Tug Fork River Watershed, West Virginia

U.S. Environmental Protection Agency
Region 3
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1.0 Problem Understanding

The Clean Water Act in Section 303(d) and its implementing regulations (*Water Quality and Planning and Management Regulations* at 40 CFR 130) require a Total Maximum Daily Load (TMDL) to be developed for those waterbodies identified as impaired by the state where technology-based and other required controls did not provide for the attainment of water quality standards. As part of the consent decree requirements relating to *Ohio Valley Environmental Coalition, Inc., et al.* v. *Carol Browner, et al., No. 2:95-0529 (S.D. W.VA.)* entered on July 9, 1997, TMDLs will be completed by the U.S. Environmental Protection Agency for the waters included on West Virginia's operative Section 303(d) list of impaired waterbodies to the extent such TMDLs are not established by the State consistent with the schedule in the consent decree. The consent decree resulting from this lawsuit sets out a 10-year schedule for establishing TMDLs for certain portions of the Ohio River, including a TMDL for dioxin; 44 other "priority" water quality limited segments (WQLSs); and almost 500 WQLSs impaired by abandoned mine drainage. The objective of this study was to develop metals and pH TMDLs for waterbodies impaired by abandoned mine drainage and sediments in the Tug Fork watershed, West Virginia.

1.1 Watershed Description

The Tug Fork watershed (HUC 05070201) is located in the Big Sandy River basin, along the borders of West Virginia, Kentucky, and Virginia, (Figure 1-1). The heavily forested area drained by the Tug Fork River is approximately 1,500 square miles in area and lies within portions of the following counties, (Figure 1-2):

West Virginia:	McDowell, Mingo, Wayne
Kentucky:	Lawrence, Martin, Pike
Virginia:	Buchanan, Tazewell

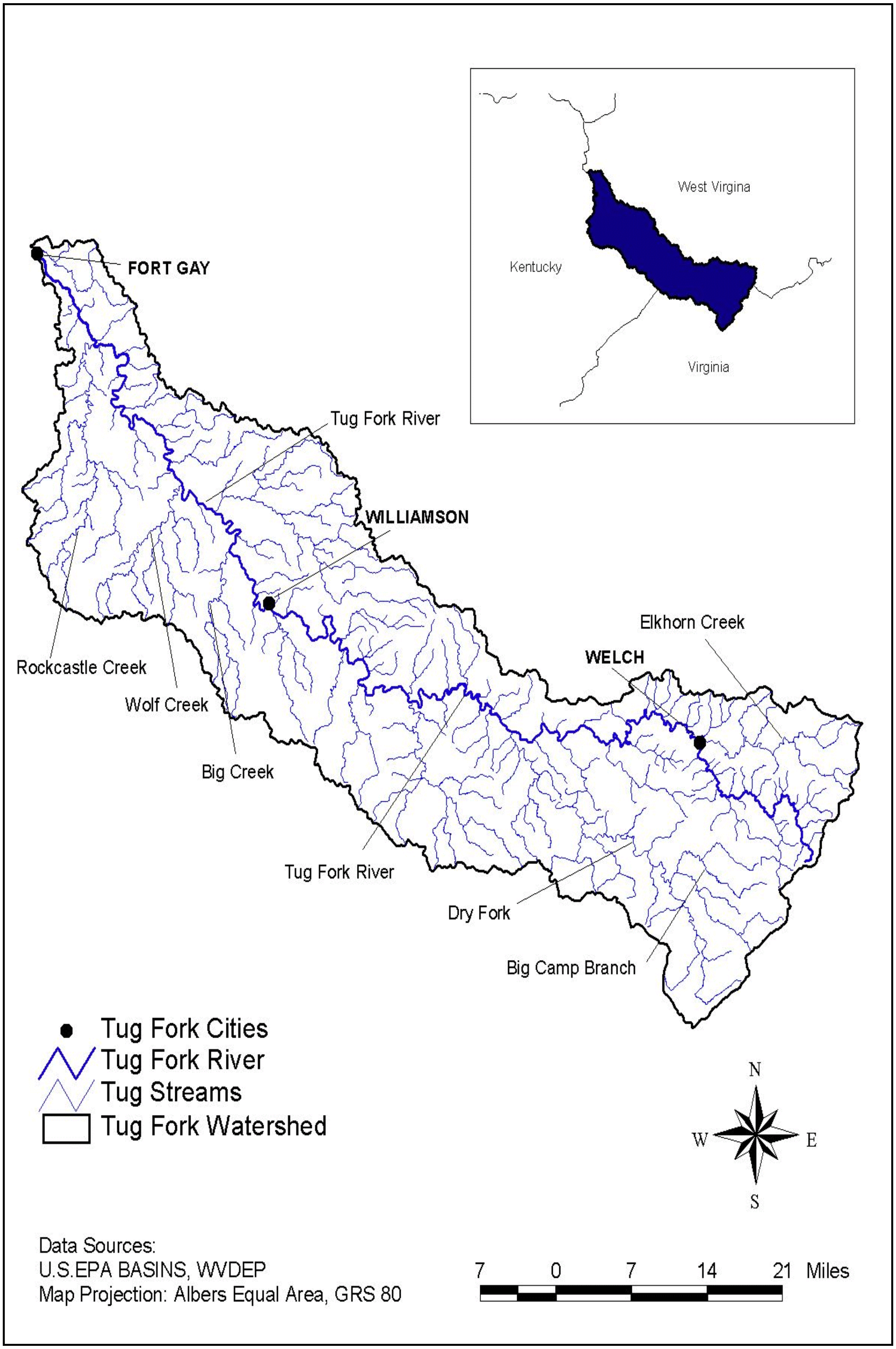


Figure 1-1. Tug Fork River watershed.

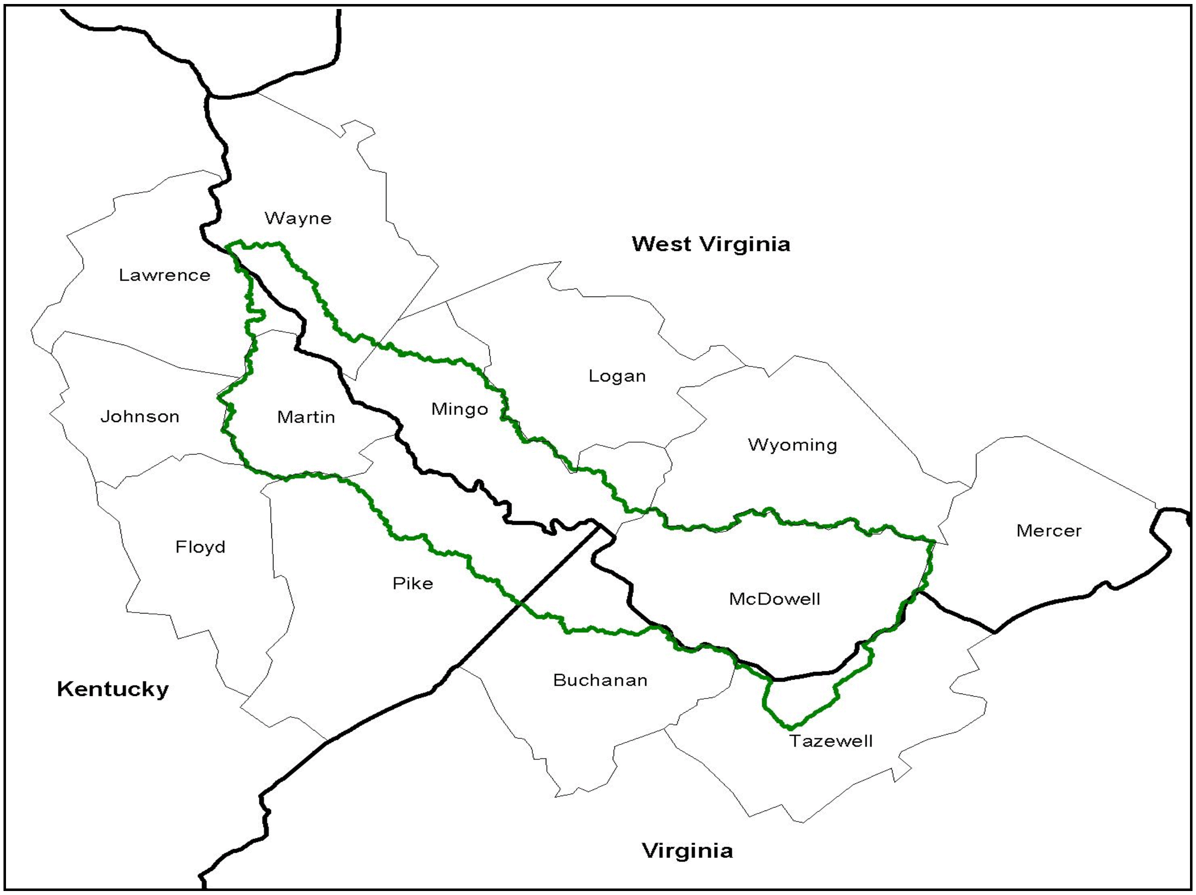


Figure 1-2. Counties in and surrounding the Tug Fork basin

The Tug Fork flows from its source in McDowell County, West Virginia, in a northwesterly direction to its confluence with the Levisa Fork in Fort Gay, where the two form the Big Sandy River. Figure 1-1 shows the major tributaries in the Tug Fork watershed. The major tributaries draining the West Virginia portion of the basin include Pigeon Creek, Dry Fork, Elkhorn Creek and Big Camp Branch. The larger tributaries draining the Kentucky region of the Tug Fork watershed are Rockcastle Creek, Wolf Creek, and Big Creek.

Principal cities in the Tug Fork basin include Williamson and Welch, West Virginia. However, no major metropolitan areas are located directly within the watershed. The Huntington, West Virginia / Ashland, Kentucky area, with an estimated population of 312,447, is about 20 miles to the north of the confluence of Levisa Fork and Tug Fork. The 1999 population estimates (based on 1990 census data) for counties within the basin are given in Table 1-1. Note that only portions of some of these counties lie within the Tug Fork watershed.

Table 1-1. Population Estimates in Tug Fork basin.

County	7/1/99 Estimate	4/1/90 Population Estimates Base	Numeric Population Change 1990-1999	Percent Population Change 1990-1999
McDowell County, WV	29,306	35,233	-5,927	-16.8
Mingo County, WV	31,480	33,739	-2,259	-6.7
Wayne County, WV	41,860	41,636	224	0.5
Total	**102,646**	**110,608**	**-7,962**	**-7.2**
West Virginia	*1,806,928*	*1,793,477*	*13,451*	*0.7*
Lawrence County, KY	15,800	13,998	1,802	12.9
Martin County, KY	11,901	12,526	-625	-5.0
Pike County, KY	71,526	72,584	-1,058	-1.5
Total	**99,227**	**99,108**	**119**	**0.1**
Kentucky	*3,960,825*	*3,686,892*	*273,933*	*7.4*
Buchanan County, VA	28,477	31,333	-2,856	-9.1
Tazewell County, VA	46,343	45,960	383	0.8
Total	**74,820**	**77,293**	**-2,473**	**-3.2**
Virginia	*6,872,912*	*6,189,197*	*683,715*	*11.0*
Overall Totals	**276,693**	**287,009**	**-10,316**	**-3.6**

Source: Population Estimates Program, Population Division, U.S. Census Bureau, Washington, DC.

Since 1990, the entire Tug Fork region has seen an overall decline in population of about three percent. This is in contrast to the population increase of other areas of all three states, which on average, have experienced population growth ranging from 0.7 to 11 percent over the last 10 years (Table 1-1).

1.2 Economy

Mining

A large portion of the Tug Fork basin lies in the southern coalfields of West Virginia, where extensive coal deposits represent the most economically valuable mineral resource in the area. There are approximately 30 commercially mineable coal seams in the basin. Other raw materials produced in the area include sandstone, shale, limestone, and gravel.

The southern portion of the Tug Fork basin is well-known for large deposits of high quality metallurgical coal. Metallurgical coal has a particularly high BTU, but low ash content and is used to make coke for steel manufacture. There has been continuous mining in the basin since the completion of the Norfolk and Western Railroad in the late 1800s. From 1883 to 1974 total coal production was approximately 1.6 billion tons. In the 1970s, approximately 90 percent of the coal was produced from underground mines and the remaining 10 percent came from surface mining. Surface mining activities have significantly increased since then, accounting for approximately 19 percent of total production during the 1980s, and 31 percent in 1997 (WVGES, 1998). The increase in surface mining is due to the increased demand for production of low sulfur coal.

The increase in production has come from the coal-bearing formations of the upper part of the Kanawha and the Allegheny formations, which are exposed at the surface over most of Mingo county (WVGES, 1998). Large mountain-top removal mining operations have contributed to the recent increase in surface-mined coal in the Kanawha Formation region. Mountain-top removal mining operations are large-scale surface mines in which rock layers are systemically removed starting from the top of mountain ridges to uncover the underlying coal beds (WVGES, 1998). Mountain-top removal operations boosted coal production in West Virginia to record levels in 1997 (WVGES, 1998). Even though mining employs fewer people than other industries in the basin, it contributes higher per capita dollars to the region (U.S. Census Bureau, 1997). Table 1-2 shows the total coal production of counties within the Tug Fork Watershed.

Table 1-2. Coal Production of West Virginia and Kentucky counties within Tug Fork watershed

County	Total Employees	Underground Production (tons)	Surface Production (tons)	Total Production (tons)
Mingo	1,589	1,320,896	8,771,504	2,198,046
Wayne	341	7,027,123	--------------	7,027,123
McDowell	875	3,307,190	1,197,766	4,504,956
Total	**2,805**	**11,655,209**	**9,969,270**	**13,730,125**
West Virginia	*14,254*	*109,395,146*	*59,975,456*	*169,371,450*
Lawrence	78	529,869	134,457	664,326
Martin	862	4,786,070	5,142,267	9,928,337
Pike	3,932	18,731,242	15,351,814	34,083,056
Total	**4,872**	**24,047,181**	**20,628,538**	**44,675,719**
Kentucky	*8,804*	*42,778,423*	*35,980,352*	*78,758,775*

Source: West Virginia Office of Miners' Health Safety and Training, 2002

Forestry

Forestry is another major industry in the Tug Fork watershed. According to the U.S. Forest Service Forest Inventory and Analysis Database Retrieval System, there are more than 3,800 square miles of forest land (approximately 2.4 million acres) in the 13 counties in and around the Tug Fork Basin. More than 600,000 of these acres are held under corporate (timber industry) ownership. Table 1-3 shows the estimated area of forested land (in square miles) for each of the counties within the Tug Fork basin.

Table 1-3. Forested area in and near the Tug Fork Basin

State	County	All_land (sq. Mi.)	Total Forest (sq. Mi.)	Timberland (sq. Mi.)	Residual Timberland (sq. Mi.)	Non-forest land (sq. Mi.)
Kentucky	Lawrence	268.8	190.8	190.8	0.0	78.0
Kentucky	Martin	147.5	111.2	111.2	0.0	36.3
Kentucky	Pike	502.2	423.1	423.1	0.0	79.0
Virginia	Buchanan	322.4	290.6	290.6	0.0	31.8
Virginia	Tazewell	332.8	213.9	207.9	6.0	118.9
West Virginia	McDowell	342.4	312.9	312.9	0.0	29.5
West Virginia	Mingo	271.3	238.4	238.4	0.0	32.9
West Virginia	Wayne	323.8	274.9	274.9	0.0	48.9
	All counties	**2,511.2**	**2,055.8**	**2,049.8**	**6.0**	**455.3**

Source: U.S. Department of Agriculture Forest Service, Forest Inventory and Analysis Retrieval System 1996

Agriculture

Economically, agriculture is less important than mining. With the exception of Wayne county, farming in the watershed is fairly small scale. However, most farming in Wayne county occurs outside of the Tug Fork basin. In the 1997 U.S. Department of Agriculture's Agricultural Census, there were five farms reported in Mingo County, 151 in Wayne, and seven in McDowell. From 1992 to 1997, the latest year for which data are available, farming in the region appears to be mirroring national trends in that the number of farms decreased, while the average size of the farms increased. For Wayne county, the number of full-time farms decreased 27 percent while the average size increased 14 percent.

1.3 Section 303(d) Listed Waterbodies

West Virginia's 1996 and 1998 Section 303(d) lists includes 64 waterbodies in the Tug Fork watershed because of metals and/or pH impairments. The impaired waterbodies include the mainstem of the Tug Fork as well as 63 additional stream segments in the watershed. These waterbodies are shown in Table1-4. The pH and metals impairments, which include total iron, aluminum, and manganese have been attributed to acid mine drainage (AMD). The main stem of the Tug Fork was on West Virginia's 1996 and 1998 Section 303(d) lists for zinc impairments. In 1999, West Virginia's Water Quality Standards were changed to use the dissolved method to test for zinc and the zinc water quality criteria were changed. Analysis of data since that change shows that the Tug Fork does not violate the water quality criteria for zinc, thus a TMDL is not necessary. This analysis is presented in Appendix B of this report.

Table 1-4. West Virginia 303(d) Listed Waterbodies in the Tug Fork Basin

DNR Name	DNR Code	Miles Affected	Human Health	Aquatic Life	Pollutant	Source	Year Listed
Tug Fork	BST	58.8	X (Iron)	X	Aluminum; Iron; Zinc*	Undetermined	1996, 1998
Little Indian Creek	BST-100	2.12		X	Metals	Mine Drainage	1996, 1998
Jed Branch	BST-102	0.95		X	Metals	Mine Drainage	1996, 1998
Rock Narrows Branch	BST-103	1.7		X	Metals	Mine Drainage	1996, 1998
Harris Branch	BST-104	1.15		X	Metals	Mine Drainage	1996, 1998
Mitchell Branch	BST-105	2.1		X	Metals	Mine Drainage	1996, 1998
Sugarcamp Branch	BST-106	2.58		X	Metals	Mine Drainage	1996, 1998
Grapevine Branch	BST-107	0.51		X	Metals	Mine Drainage	1996, 1998
Sandlick Creek	BST-109	5.25		X	Metals	Mine Drainage	1996, 1998
Right Fork / Sandlick Creek	BST-109-A	2.95		X	Metals	Mine Drainage	1996, 1998
Left Fork / Sandlick Creek	BST-109-B	2.18		X	Metals	Mine Drainage	1996, 1998
Adkin Branch	BST-110	2.15		X	Metals	Mine Drainage	1996, 1998
Belcher Branch	BST-111	1.45		X	Metals	Mine Drainage	1996, 1998
Turnhole Branch	BST-112	2.2		X	Metals	Mine Drainage	1996, 1998
Harmon Branch	BST-113	3.1		X	Metals	Mine Drainage	1996, 1998
South Fork / Tug Fork	BST-115	5.72		X	Metals	Mine Drainage	1996, 1998
Tea Branch	BST-115-A	1.14		X	Metals	Mine Drainage	1996, 1998
Mcclure Branch	BST-115-B	1.25		X	Metals	Mine Drainage	1996, 1998
Jump Branch	BST-115-D	1.67		X	Metals	Mine Drainage	1996, 1998
Spice Creek / South Fork	BST-115-E	3.18		X	Metals	Mine Drainage	1996, 1998
Laurel Branch / South Branch	BST-115-F	2.42		X	Metals	Mine Drainage	1996, 1998
Road Fork / South Fork	BST-115-G	1.25		X	Metals	Mine Drainage	1996, 1998
Belcher Branch	BST-116	1.75		X	Metals	Mine Drainage	1996, 1998
Loop Branch	BST-117	1.38		X	Metals	Mine Drainage	1996, 1998
Mill Branch	BST-118	2		X	Metals	Mine Drainage	1996, 1998
Dry Branch / Tug Fork	BST-119	0.95		X	Metals	Mine Drainage	1996, 1998
Little Creek	BST-120	4.2		X	Metals	Mine Drainage	1996, 1998
Indian Grave Branch	BST-120-A	2.08		X	Metals	Mine Drainage	1996, 1998
Puncheoncamp Branch / Little Creek	BST-120-B	2.05		X	Metals	Mine Drainage	1996, 1998
Millseat Branch	BST-121	1.4		X	Metals	Mine Drainage	1996, 1998
Ballard Harmon Branch	BST-122	2.03		X	Metals	Mine Drainage	1996, 1998
Sams Branch	BST-123	1.85		X	Metals	Mine Drainage	1996, 1998
Pigeon Creek	BST-24	30.76		X	pH; Metals	Mine Drainage	1996, 1998
Millstone Branch / Pigeon Creek	BST-24-O	1.78		X	Metals	Mine Drainage	1996, 1998
Powdermill Branch	BST-3	2.27		X	Metals	Mine Drainage	1996, 1998
Sugartree Creek	BST-32	2.42		X	Metals	Mine Drainage	1996, 1998
Williamson Branch	BST-33	1.52		X	Metals	Mine Drainage	1996, 1998
Sprouse Creek	BST-38	1.6		X	Metals	Mine Drainage	1996, 1998
Mate Creek	BST-40	9.9		X	Metals	Mine Drainage	1996, 1998
Rutherford Branch	BST-40-B	2		X	pH; Metals	Mine Drainage	1996, 1998
Mitchell Branch / Mate Creek	BST-40-C	2.82		X	Metals	Mine Drainage	1996, 1998
Chafin Branch	BST-40-D	0.87		X	Metals	Mine Drainage	1996, 1998
Thacker Creek	BST-42	2.95		X	pH; Metals	Mine Drainage	1996, 1998
Scissorsville Branch	BST-42-A	1.9		X	pH; Metals	Mine Drainage	1996, 1998
Mauchlinville Branch	BST-42-B	1.78		X	pH; Metals	Mine Drainage	1996, 1998
Grapevine Creek	BST-43	2.56		X	Metals	Mine Drainage	1996, 1998
Lick Fork / Grapevine Creek	BST-43-A	1.1		X	Metals	Mine Drainage	1996, 1998
Panther Creek	BST-60	9.4		X	Metals	Mine Drainage	1996, 1998
Cub Branch / Panther Creek	BST-60-D	0.7		X	Metals	Mine Drainage	1996, 1998
Grapevine Branch / Dry Fork	BST-70-F	1.75		X	Metals	Mine Drainage	1996, 1998
Beartown Branch	BST-70-I	1.7		X	Metals	Mine Drainage	1996, 1998
Atwell Branch	BST-70-O	1.93		X	Metals	Mine Drainage	1996, 1998
Clear Fork / Tug Fork	BST-76	11		X	Metals	Mine Drainage	1996, 1998
Shabbyroom Branch	BST-78-B	2.1		X	Metals	Mine Drainage	1996, 1998
Honeycamp Branch	BST-78-D	1.67		X	Metals	Mine Drainage	1996, 1998
Coontree Branch / Spice Creek	BST-78-E	0.95		X	Metals	Mine Drainage	1996, 1998
Stonecoal Branch / Spice	BST-78-F	1.33		X	Metals	Mine Drainage	1996, 1998

DNR Name	DNR Code	Miles Affected	Human Health	Aquatic Life	Pollutant	Source	Year Listed
Creek							
Badway Branch	BST-78-G	1.33		X	Metals	Mine Drainage	1996, 1998
Newson Branch	BST-78-H	1.05		X	Metals	Mine Drainage	1996, 1998
Moorecamp Branch	BST-78-I	0.91		X	Metals	Mine Drainage	1996, 1998
Left Fork / Davy Branch	BST-85-A	2.46		X	Metals	Mine Drainage	1996, 1998
Shannon Branch	BST-94	3.1		X	Metals	Mine Drainage	1996, 1998
Upper Shannon Branch	BST-95	2.45		X	Metals	Mine Drainage	1996, 1998
Puncheoncamp Branch / Browns Creek	BST-98-A	3		X	Metals	Mine Drainage	1996, 1998

* TMDL development for zinc is not necessary as no exccedances have been observed since the new criteria was put in effect in 1999. Metals: Iron, Aluminum, Manganese.
Source: West Virginia's 1996 & 1998 Section 303(d) Lists

In addition, the Tug Fork mainstem and one tributary are included on Kentucky's 1998 Section 303(d) list as impaired by pathogens, siltation and organic enrichment/low dissolved oxygen. The segment of the Tug Fork that is listed for siltation is not supporting the swimmable designated use, and is only partially supporting the aquatic life use. Kentucky has instituted the Watershed Management Framework approach to assessment monitoring and TMDL development. The Tug Fork watershed is included within the Big Sandy/Tygarts Creek Unit. This unit is the last of the five units in the state to be targeted for assessment monitoring and TMDL development. Assessment monitoring has just recently been initiated in this Watershed Unit, and TMDL development for stream segments in this Unit is not scheduled until 2005. According to Kentucky's 1998 Section 303(d) list, the schedule for the Tug Fork is:

2002	Scoping and data gathering
2003	Assessment set up modeling
2004	Prioritize/target calculate TMDLs
2005	Write TMDL
2006	Implement TMDL

As a result, the information necessary to adequately define loads of iron and aluminum to the mainstem of the Tug Fork for the Kentucky portion of the watershed was only partially available.

Additionally, two waterbodies are listed on Virginia's 303(d) list for benthic impairments caused by resource extraction. The Kentucky and Virginia Section 303(d) impaired waterbodies are listed in Table 1-5.

Table 1-5. Kentucky and Virginia 1998 303(d) Listed Waterbodies in the Tug Fork Basin

Kentucky					
Stream Name	**Segment Length (mi)**	**County**	**Pollutant**	**Impaired Use**	**Priority**
Tug Fork River	10.2	Martin	Pathogens	Swimmable	First
Tug Fork River	31.4	Martin, Lawrence	Pathogens, Siltation, Organic Enrichment/ Low DO	Aquatic Life, Swimmable	First
Knox Creek	7.6	Pike	Pathogens, Siltation	Aquatic Life, Swimmable	Second
Virginia					
Stream Name	**Segment Length (mi)**	**County**	**Cause**	**Source**	**Use Goal**
Knox Creek	18.0	Buchanan	Benthic	Resource Extraction	Aquatic Life - Partially Supporting
Pawpaw Creek	4.52	Buchanan	Benthic	Resource Extraction	Aquatic Life - Not Supporting

Sources: Kentucky 1998 303(d) List, Virginia 1998 303(d) List

This report presents pH and metals TMDLs for each of the 64 impaired waterbodies in the West Virginia regions of the Tug Fork watershed. This report does not present TMDLs for the Kentucky and Virginia impaired waterbodies, however, this study provides the necessary framework for further TMDL development to address specific impairments in Kentucky and Virginia. To develop the TMDLs and other pertinent watershed and waterbody information, the watershed was divided into 20 regions (Figure 1-3) representing hydrologic units. Each region was further divided into subwatersheds for modeling purposes, 455 total for the entire Tug Fork watershed. The 20 regions and their respective subwatersheds provide a good basis for georeferencing pertinent source information, and monitoring data, and for presenting TMDLs. This information is presented in Appendices A-1 through A-20 of this report. The numeric designation for each Appendix A section corresponds to the same numerically identified region of the Tug Fork watershed, e.g., A-3 corresponds to region 3 of the Tug Fork watershed.

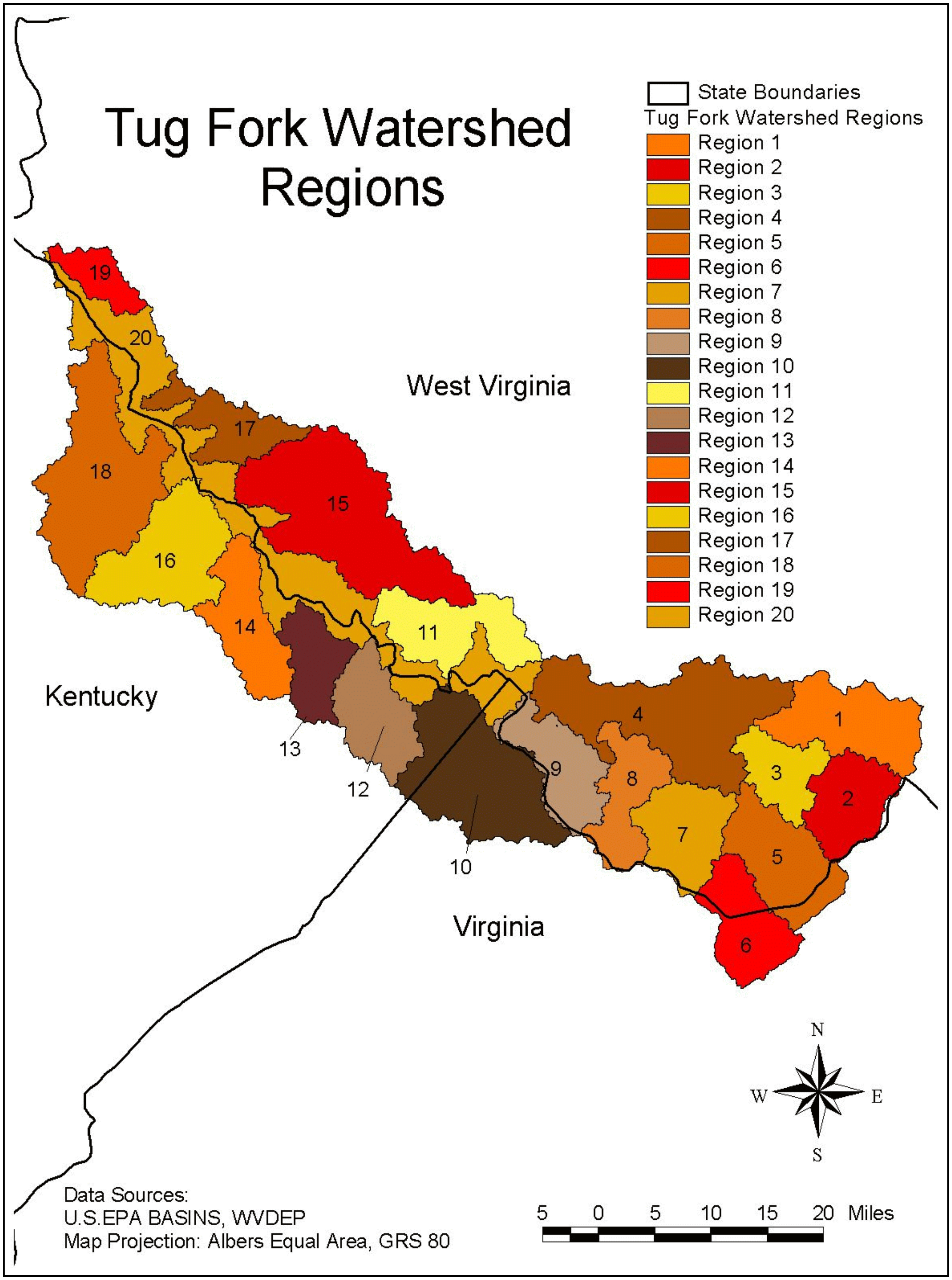


Figure 1-3. Tug Fork River watershed and its 20 regions

Executive Summary

The Tug Fork watershed is located in the Big Sandy River basin along the borders of West Virginia, Kentucky, and Virginia. The heavily forested area drained by the Tug Fork River is approximately 1,500 square miles and lies within portions of the following counties: McDowell, Mingo and Wayne in West Virginia; Lawrence, Martin and Pike in Kentucky; Buchanan and Tazewell in Virginia. A large portion of the Tug Fork basin lies in the southern coalfields of West Virginia, where extensive coal deposits are the most economically valuable mineral resource in the area. Forestry is another major industry in the Tug Fork watershed.

West Virginia's 1996 and 1998 Section 303(d) lists includes the main stem of the Tug Fork as well as 63 additional stream segments in the watershed because of metals and/or pH impairments. Total Maximum Daily Loads (TMDLs) were developed for each of the listed waterbodies in the West Virginia region of the Tug Fork watershed. TMDLs for the Kentucky and Virginia impaired waterbodies were not developed. However, the study provides the necessary framework for further TMDL development to address specific impairments in Kentucky and Virginia.

Requirements Governing West Virginia Water Quality Standards, West Virginia Code of State Rules, Title 46, Series 1 defines total aluminum, iron, manganese, and pH numeric criteria under the Aquatic Life and the Human Health use designation categories. The criteria for dissolved zinc is a numerical formula dependent on hardness. The listed waterbodies in the Tug Fork watershed have been designated as having an Aquatic Life and a Human Health use.

The Tug Fork watershed was divided into 20 regions representing hydrologic units. Each region was further divided into subwatersheds for modeling purposes, 455 total for the entire watershed. The 20 regions and their respective subwatersheds provided a basis for georeferencing pertinent source information and monitoring data, and for presenting TMDLs. The Mining Data Analysis System (MDAS) was used to represent the source-response linkage in the Tug Fork watershed for aluminum, manganese, and iron. The MDAS is a comprehensive data management and modeling system that is capable of representing loads from nonpoint and point sources found in the watershed and simulating in-stream processes. The MINTEQ modeling system was used to represent the source-response linkage in the Tug Fork watershed for pH.

Primary sources contributing to metals and pH impairments include an array of nonpoint or diffuse sources as well as discrete point sources/permitted discharges. Most of the permitted point sources in the watershed are mining-related. The nonpoint sources include abandoned mines (AMLs), revoked permits, harvested forest, oil and gas operations and roads.

West Virginia's numeric water quality criteria for aluminum, iron, manganese, and pH, and an explicit margin of safety (MOS) were used to identify endpoints for TMDL development. TMDL development for zinc was not neccessary, as it was shown that all monitoring samples obtained since May 1999 were meeting the hardness-based zinc criteria.

The following general methodology was used when allocating to sources for the Tug Fork watershed TMDLs:

- For watersheds with AMLs but no point sources, AMLs were reduced first, until in-stream water quality criteria were met or to natural (undisturbed) forest conditions. If further reductions were required, then the sediment sources (Harvested Forest, Oil and Gas operations, and Roads) were reduced until water quality criteria were met.

- For watersheds with AMLs and point sources, point sources were set at the precipitation induced load defined by the permit limits and AMLs were subsequently reduced. AMLs and revoked mining permits were reduced until in-stream water quality criteria were met, if possible. If further reduction was required, sediment sources were then reduced. If even further reduction was required, the point source discharge limits were then reduced.

- Source contributions from the Kentucky and Virginia regions of the Tug Fork watershed were reduced to meet the water quality criteria in the Tug Fork mainstem only. These source reductions may result in localized improved water quality. However, based on the coarse resolution of the modeling effort, compliance with the Kentucky and Virginia water quality criteria at the subwatershed level could not be determined.

Tables 1, 2, and 3 show the baseline and allocated loads, along with the margin of safety (MOS) and percent reduction by region. Figure 1 shows the Tug Fork watershed and the 20 regions.

Table 1. Aluminum Baseline and Allocated Loads by Region

Region	Baseline Load (lb/yr)		Allocated Load (lb/yr)		MOS	% Reduction
	NPS	PS	LA	WLA	(lb/yr)	
1	250,740	15,008	46,160	11,836	2,900	78
2	140,555	35,851	27,325	13,152	2,024	77
3	165,500	24,072	25,354	13,349	1,935	80
4	215,671	6,262	98,814	4,391	5,160	53
5	91,711	43,793	36,844	23,256	3,005	56
6	70,356	5,915	40,218	3,605	2,191	43
7	90,203	1,489	49,021	1,489	2,525	45
8	71,842	2,436	39,012	2,436	2,072	44
9	44,804	8,694	37,149	2,147	1,965	27
10	125,686	3,790	92,494	3,790	4,814	26
11	118,628	61,519	37,044	26,522	3,178	65
12	42,524	39,344	33,712	39,344	3,653	11
13	30,766	6,344	23,248	6,344	1,480	20
14	39,729	10,265	26,196	10,265	1,823	27
15	177,866	189,392	82,025	40,396	6,121	67
16	199,237	47,446	88,430	47,446	6,794	45
17	206,098	46,589	26,732	12,379	1,956	85
18	272,047	33,883	119,938	33,883	7,691	50
19	22,699	0	20,060	0	1,003	12
20	250,517	27,453	176,942	21,426	9,918	29

Table 2. Iron Baseline and Allocated Loads by Region

Region	Baseline Load (lb/yr) NPS	Baseline Load (lb/yr) PS	Allocated Load (lb/yr) LA	Allocated Load (lb/yr) WLA	MOS (lb/yr)	% Reduction
1	335,034	13,364	122,883	13,364	6,812	61
2	188,404	31,925	57,899	31,708	4,480	59
3	220,468	21,436	52,891	21,436	3,716	69
4	291,915	5,576	173,575	5,576	8,958	40
5	124,612	38,998	66,029	38,998	5,251	36
6	95,196	5,267	67,873	5,267	3,657	27
7	122,586	1,326	83,951	1,326	4,264	31
8	96,695	2,170	83,251	2,170	4,271	14
9	62,909	7,743	58,113	7,743	3,293	7
10	170,406	3,791	128,476	3,791	6,613	24
11	158,948	54,787	77,114	54,787	6,595	38
12	57,379	40,435	46,248	40,435	4,334	11
13	42,895	6,337	33,398	6,337	1,987	19
14	55,069	11,136	37,973	11,136	2,455	26
15	240,798	168,660	126,111	157,167	14,164	31
16	256,379	50,215	116,396	50,215	8,331	46
17	272,694	41,489	43,045	39,379	4,121	74
18	353,879	34,673	161,721	34,673	9,820	49
19	31,493	0	28,160	0	1,408	11
20	337,577	24,627	250,065	24,627	13,735	24

Table 3. Manganese Baseline and Allocated Loads by Region

Region	Baseline Load (lb/yr) NPS	Baseline Load (lb/yr) PS	Allocated Load (lb/yr) LA	Allocated Load (lb/yr) WLA	MOS (lb/yr)	% Reduction
1	108,840	8,326	64,974	8,326	3,665	37
2	61,466	19,889	30,277	19,889	2,508	38
3	72,538	13,354	27,327	13,354	2,034	53
4	95,254	3,473	61,412	3,473	3,244	34
5	37,090	24,294	30,621	24,294	2,746	11
6	22,259	3,282	20,562	3,282	1,192	7
7	39,803	826	29,423	826	1,512	26
8	33,645	1,351	31,795	1,351	1,657	5
9	19,003	4,823	17,202	4,823	1,101	8
10	-	-	-	-	-	-
11	48,469	34,125	32,140	34,125	3,313	20
12	-	-	-	-	-	-
13	-	-	-	-	-	-
14	-	-	-	-	-	-
15	59,700	105,062	38,349	99,171	6,876	17
16	-	-	-	-	-	-
17	88,786	25,844	13,477	25,844	1,966	66
18	-	-	-	-	-	-
19	9,265	0	9,048	0	452	2
20	89,979	15,344	66,860	15,344	4,110	22

Notes: (-) Because the Tug Fork main stem was not listed for manganese impairment, no allocation is made for regions that only contribute to the Tug Fork mainstem; NPS - Non-Point Sources, PS - Point Sources, LA - Load Allocation (for Non-Point Sources), WLA - Waste Load Allocation (for Point Sources), MOS - Margin of Safety

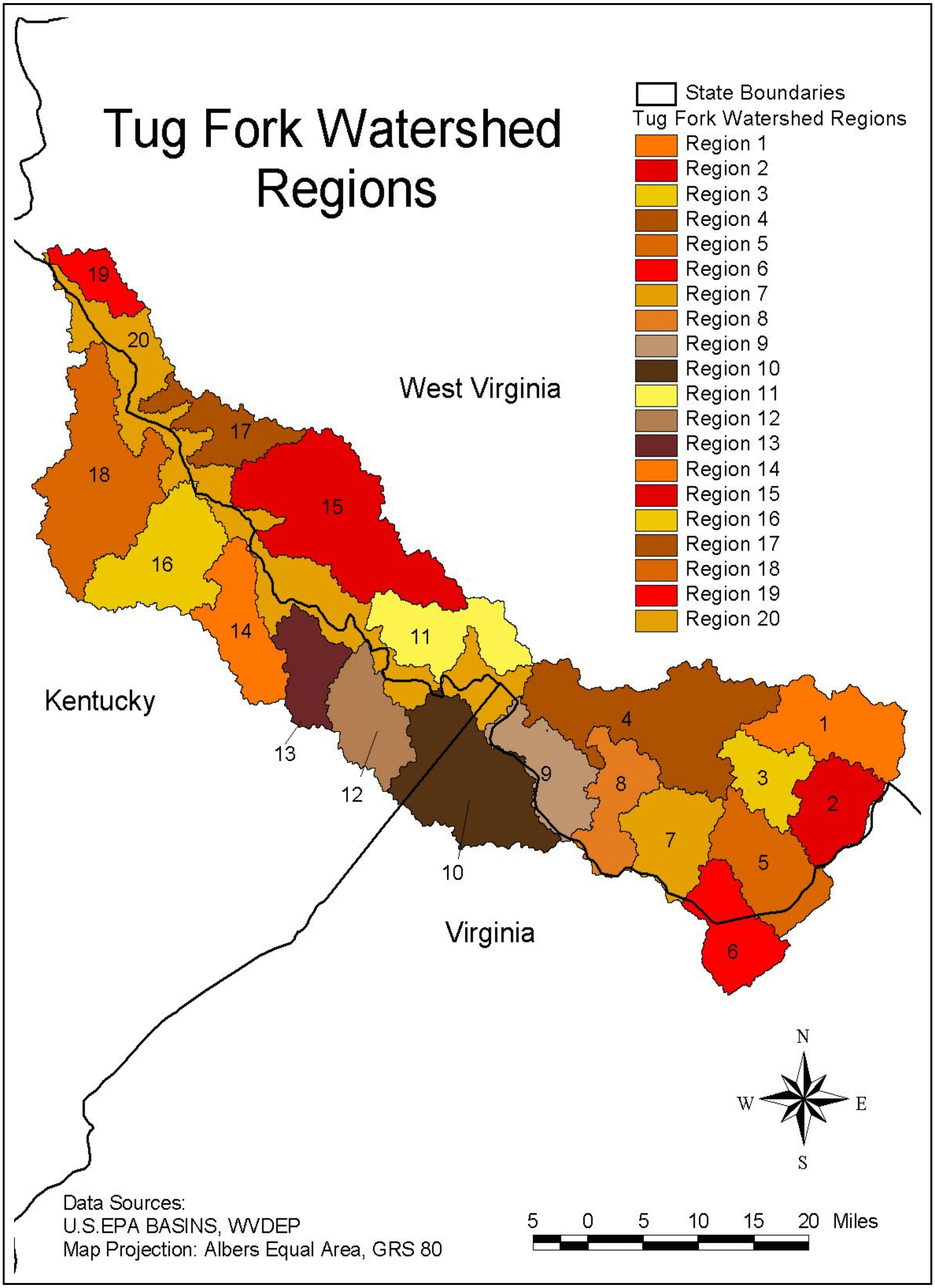


Figure 1. Tug Fork River watershed and its twenty regions

2.0 Water Quality Standards

Water Quality Standards consist of three components: designated and existing uses; narrative and/or numerical water quality criteria necessary to support those uses; and an anti-degradation statement. Furthermore, water quality standards serve two purposes. The first is establishing the water quality goals for a specific waterbody. And the second is establishing targets for water quality-based treatment controls and strategies beyond the technology-based levels of treatment required by section 301(b) and 306 of the Act (US EPA, 1991). In *Title 46, Legislative Rule, Environmental Quality Board, Series 1, Requirements Governing Water Quality Standards*, West Virginia sets forth designated and existing uses as well as numeric and narrative water quality criteria for waters in the state. Appendix E of the *Requirements Governing Water Quality Standards* displays the numeric water quality criteria for a wide range of parameters, while narrative water quality criteria are contained in Section §46-1-3 of the same document. Total aluminum, iron, manganese, and pH have numeric criteria under the Aquatic Life and the Human Health use designation categories (Table 2-1). The criteria for dissolved zinc is a numerical formula dependent on hardness. The listed waterbodies in the Tug Fork watershed have been designated as having an Aquatic Life and a Human Health use (WVDEP, 1998a).

Table 2-1. Applicable West Virginia water quality criteria

POLLUTANT	USE DESIGNATION				
	Aquatic Life				Human Health
	B1, B4		B2		A[c], C[c]
	Acute [a]	Chronic [b]	Acute [a]	Chronic [b]	
Aluminum, Total (ug/L)	750	-	750	-	-
Iron, Total (mg/L)	-	1.5	-	0.5	1.5
Manganese, Total (mg/L)	-	-	-	-	1.0
Zinc, dissolved (ug/L)	$(0.978)(e^{[(0.8473)(\ln[hardness†]) + 0.8604]})$	$(0.986)(e^{[(0.8473)(\ln[hardness†]) + 0.7614]})$	$(0.978)(e^{[(0.8473)(\ln[hardness†]) + 0.8604]})$	$(0.986)(e^{[(0.8473)(\ln[hardness†]) + 0.7614]})$	-
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

Source: WVWQS, 1999 or West Virginia Code of State Rules, Title 46, Series 1.
Note: B1 = warm water fishery streams, B4 = wetlands, B2 = trout waters, A = public water supply, C = water contact recreation.
[a] One-hour average concentration not to be exceeded more than once every three years on the average.
[b] Four-day average concentration not to be exceeded more than once every three years on the average
[c] Not to exceed.
† 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.

Title 401, Chapter 5, Section 031 of the *Kentucky Administrative Regulations* establishes water quality standards which consist of designated legitimate uses of the surface waters of the Commonwealth, and the associated narrative and numeric water quality criteria necessary to protect those uses. The water quality standards are minimum requirements that apply to all surface waters in the Commonwealth of Kentucky in order to maintain and protect designated uses (401 KAR 5:031). The applicable water quality standards for the Tug Fork watershed are summarized in Table 2-2. Note that the iron criteria is a "not to exceed" value.

Table 2-2. Applicable Kentucky water quality criteria

Parameter	Use Designation		
	Warm Water Aquatic Habitat Criteria		Human Health
	Acute	Chronic[B]	Domestic Water Supply Source
Iron, Total (mg/L)[A]	4.0	1.0	-
pH	6.0-9.0	6.0-9.0	6.0-9.0

Source: Kentucky Water Quality Standards, 401 KAR 5:031
A - Metal criteria, for purposes of this administrative regulation, are total recoverable metals to be measured in an unfiltered sample, unless it can be demonstrated to the satisfaction of the cabinet that a more appropriate analytical technique is available which provides a measurement of that portion of the metal present which causes toxicity to aquatic life.
B - The chronic criterion for iron shall not exceed three and five-tenths (3.5) mg/l if aquatic life has not been shown to be adversely affected.

In Virginia, water quality standards are defined as (9VAC 25-260),

> *Narrative statements that describe water quality requirements in general terms, and of numeric limits for specific physical, chemical, biological or radiological characteristics of water. These narrative statements and numeric limits describe water quality necessary to meet and maintain reasonable and beneficial uses such as swimming and other water based recreation, public water supply and the propagation and growth of aquatic life.*

The applicable Virginia water quality standards for the Tug Fork watershed are summarized in Table 2-3.

Table 2-3. Applicable Virginia water quality criteria

Parameter	Use Designation					
	Aquatic Life				Human Health	
	Freshwater		Salt Water		Public Water Supplies[C]	All other Surface Waters[D]
	Acute[A]	Chronic[B]	Acute[A]	Chronic[B]		
Iron, Total (µg/L)	-	-	-	-	300	-
pH	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0

Source: Virginia Water Quality Standards, 1997 (9VAC 25-260-140)
A - One-hour average concentration not to be exceeded more than once every three years on the average.
B - Four-day average concentration not to be exceeded more than once every three years on the average.
C - Unless otherwise noted, these criteria have been calculated to protect human health from toxic effects through drinking water and fish consumption.
D - Unless otherwise noted, these criteria have been calculated to protect human health from toxic effects through fish consumption.

There are approximately 685 existing water quality stations in the Tug Fork River watershed. Tables 3a, 3b, 3c, 3d, 3e and 3f in each of Appendices A-1 and A-20 summarize applicable water quality data for monitoring stations throughout the watershed. These results support the impairment listings for iron, aluminum, manganese, and pH in specified stream segments. The endpoints selected for development of these TMDLs were based on the applicable water quality criteria and are discussed in Section 5.1.

West Virginia water quality standards are applicable to all Tug Fork tributaries within West Virginia. The more stringent of the states' water quality standards are applicable to the Tug Fork main stem. All three states require that pH be between 6.0 and 9.0 inclusive. West Virginia's water quality standards for aluminum and manganese are applicable, i.e., 0.75 mg/l and 1.0 mg/l, respectively. The Kentucky criterion for iron is applicable, the not to exceed 1.0 mg/l.

3.0 Source Assessment

This section examines and identifies the potential sources of aluminum, iron, and manganese in the Tug Fork watershed. A variety of data sources were used to identify potential sources and to characterize the relationship between point and nonpoint source discharges and in-stream response at monitoring stations.

3.1 Data Inventory and Review

Data collection was a cooperative effort among various governmental groups and agencies in West Virginia, Kentucky, and Virginia, while U.S. EPA Regions 3 and 4 provided support and guidance for TMDL analysis and development. Since Kentucky is on a different schedule than West Virginia for TMDL development for the Tug Fork, data sets for the Kentucky portion are currently not as refined as those used in the West Virginia portion of the watershed.

The categories of data used in the development of these TMDLs include physiographic data that describe the physical conditions of the watershed, environmental monitoring data that identify pollutant sources and their contribution, and in-stream water quality monitoring data. Additional water quality monitoring data gathered by non-governmental groups were obtained through the WVDEP. Table 3-1 shows the various data types and data sources used in these TMDLs.

Table 3-1. Inventory of data and information used to develop the Tug Fork Watershed TMDLs

Data Category	Description	Data Source(s)
Watershed Physiographic Data	Land Use (MRLC)	U.S. Geological Survey (USGS)
	Abandoned Mining Coverage	WVDEP Division of Mining & Reclamation (DMR)
	Active and historical mining information	WVDEP DMR, KY Department for Surface Mining Reclamation and Enforcement (DSMRE)
	Soil data (STATSGO)	U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS)
	Stream Reach Coverage	USGS, WVDEP Division of Water Resources (DWR)
	Weather Information	National Climatic Data Center
	Oil and Gas Operations Coverage	WVDEP Office of Oil and Gas (OOG), KY Division of Oil and Gas, (DOG), University of Kentucky (UK)
	Paved and Unpaved Roads	WV Department of Transportation (DOT), KYDOT, VDOT, USDOT
	Timber Harvest Data	USDA, U.S. Forest Service (USFS)
Environmental Monitoring Data	NPDES Data	WVDEP DMR, WVDEP DWR, KY DEP Division of Water (DOW)

Data Category	Description	Data Source(s)
	Discharge Monitoring Report Data	WVDEP DMR, KY DSMRE
	Abandoned Mine Land Data	WVDEP DMR, WVDEP DWR
	303(d) Listed Waters	WVDEP DWR, VA DEQ, KYDEP DOW
	Water Quality Monitoring Data for 685 Sampling Stations	EPA STORET, WVDEP DWR, WVDEP DMR, KYDEP DOW, Mining Companies

3.2 Stream Flow Data

There are 24 U.S. Geological Survey (USGS) flow gauges in the Tug Fork watershed. Flow data from these USGS gauges were used to support flow analysis for the watershed. Table 3-2 shows the 24 flow gauging stations with available records of flow data and the corresponding period of record for each. These stations were used to characterize the stream flow in the watershed.

Table 3-2. Flow analysis for the Tug Fork watershed

Station	Stream Name	Start Date	End Date	Minimum (cfs)	Average (cfs)	Maximum (cfs)
3212558	Puncheon Camp Branch	8/7/80	9/30/82	0.1	1.0	12.0
3212567	Freeman Branch	7/30/80	9/30/82	0.0	0.2	5.2
3212580	Left Fork, Sandlick Creek	7/29/80	9/30/82	0.1	1.3	12.0
3212585	Right Fork, Sandlick Creek	7/31/80	9/30/82	0.0	0.5	16.0
3212600	Tug Fork at Welch	10/17/78	6/30/81	6.6	95.9	1,420.0
3212700	Elkhorn Creek (Maitland)	11/8/78	10/10/80	14.0	136.4	876.0
3212703	Elkhorn Creek Tributary	7/29/80	9/30/82	0.0	0.3	6.8
3212750	Tug Fork at Welch	1/29/93	9/30/98	29.0	235.0	3,230.0
3212980	Dry Fork at Beartown	2/11/85	9/30/98	15.0	227.8	6,130.0
3212985	Dry Fork	10/19/78	6/30/81	14.0	284.5	6,810.0
3213000	Tug Fork (Litwar)	6/1/30	9/30/84	11.0	528.6	19,000.0
3213495	Crane Creek	9/26/80	9/30/82	0.0	0.5	11.0
3213500	Panther Creek	8/1/46	9/30/86	0.0	36.2	2,250.0
3213577	Kershaw Branch	10/1/80	9/30/82	0.0	0.5	9.4
3213590	Knox Creek	4/1/80	10/6/81	1.3	84.2	2,100.0
3213594	Camp Creek	9/30/80	9/30/82	0.1	3.3	62.0
3213620	Tug Fork (Vulcan)	2/7/85	9/30/93	63.0	834.0	17,300.0
3213630	Right Fork, Hurricane Creek	10/1/80	9/30/83	0.0	0.6	15.0
3213700	Tug Fork (Williamson)	10/1/67	9/30/98	59.0	1,124.7	74,000.0
3213800	Pigeon Creek	10/20/78	9/30/81	7.5	155.5	6,660.0
3214000	Tug Fork (near Kermit)	8/1/34	9/30/85	27.0	1,334.0	52,900.0
3214500	Tug Fork (Kermit)	6/1/15	9/30/98	8.5	1,476.8	34,300.0
3214900	Tug Fork (Glenhayes)	3/16/76	9/30/93	2.4	1,640.8	45,800.0
3215000	Panther Creek	10/1/48	10/14/76	75.0	4,734.7	87,500.0

Source: USGS.

3.3 Water Quality

Water quality monitoring data for the Tug Fork watershed were obtained from a variety of sources, including the EPA STORET database, WVDEP DWR, KYDEP DOW and mining companies. Figure 3-1 shows the water quality stations in the Tug Fork watershed. Observations used to configure, calibrate, and test the model were taken from throughout the watershed. Additionally, as part of the NPDES program, mining companies are required to monitor in-stream water quality upstream and downstream of all discharging outlets. WVDEP requested that mining companies submit these monitoring data in electronic format from areas affected by TMDL development throughout the state. Monitoring data were received from 25 mining operations in the Tug Fork watershed and these data were used to characterize the in-stream water quality conditions. Figure 3-1 shows the locations of all water quality monitoring stations. The water quality monitoring data along with pertinent source information are summarized for each of the 20 regions in Appendices A-1 through A-20 of this report.

3.4 Point Sources

Point sources, according to 40 CFR 122.3, are defined as any discernible, confined, and discrete conveyance, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, and vessel or other floating craft from which pollutants are or may be discharged. The National Pollutant Discharge Elimination System (NPDES) Program, under Clean Water Act sections 318, 402, and 405, requires permits for the discharge of pollutants from point sources. Point sources can be classified into two major categories: permitted non-mining point sources and permitted mining point sources.

3.4.1 Permitted Non-mining Point Sources

Data regarding non-mining point sources were retrieved from EPA's Permit Compliance System (PCS), WVDEP and KYDEP. Seven non-mining point sources located in the Tug Fork watershed are permitted to discharge metals, six are permitted for zinc only and are required to discharge within the pH criteria range of 6 to 9 (inclusive). Mingo County PSD (WV0115444) is classified as a minor discharger (0.062 MGD average design flow) and is permitted to discharge aluminum to the Tug Fork main stem. These sources are shown in Table 3-3.

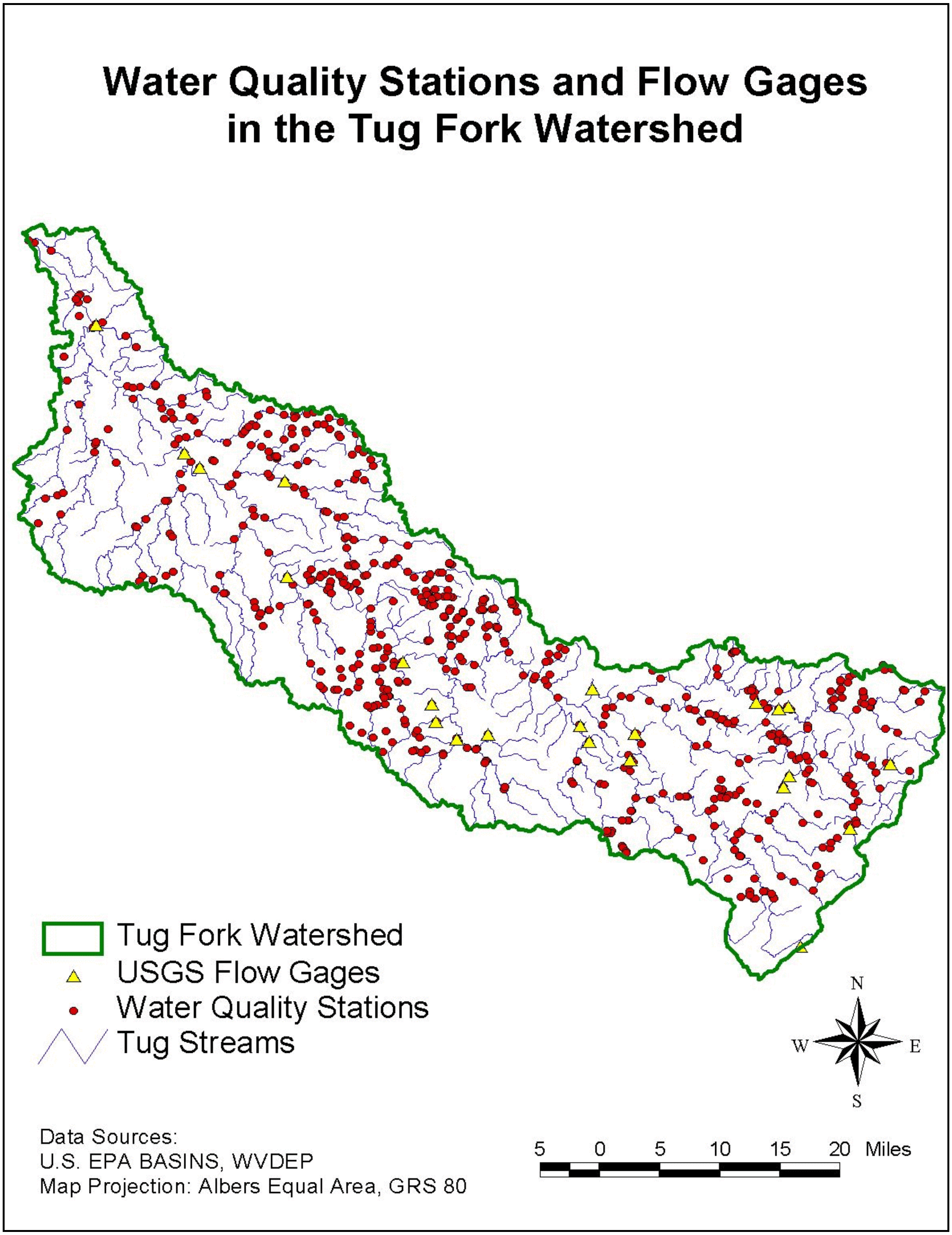


Figure 3-1. Water quality stations in the Tug Fork watershed

Table 3-3. Non-mining point sources in the Tug Fork watershed

NPDES ID	Facility Name	Facility Type	Receiving Water	Permitted pollutant discharged	Status	Major ID	Issue Date	Expire Date
KY0079316	Inez STP	Sewerage System	Rockcastle Creek	Zn	Active	Minor	6/11/98	7/31/03
WV0024589	City of Welch	Sewerage System	Tug Fork	Zn	Active	Major	4/05/96	4/04/01
WV0026271	City of Williamson	Sewerage System	Tug Fork	Zn	Active	Major	11/27/95	11/26/00
WV0037699	Chattaroy PSD	Sewerage System	Buffalo Creek	Zn	Active	Minor	2/26/99	2/25/03
WV0040371	City of War	Sewerage System	Dry Fork	Zn	Active	Minor	10/27/98	10/26/02
WV0042374	Town of Delbarton	Sewerage System	Pigeon Creek	Zn	Active	Minor	12/18/98	12/17/02
WV0115444	Mingo County PSD	Water Supply	Tug Fork	Al	Active	Minor	2/14/00	06/30/03

Source: U.S. EPA PCS.

3.4.2 Permitted Mining Point Sources

Untreated mining related discharges, from deep, surface, and other mines, typically contain low pH values and high concentrations of metals (iron, aluminum, and manganese). Consequently, mining related activities are issued discharge permits for iron, manganese, and pH, and are required to monitor aluminum concentrations. A spatial coverage of the mining permit data was provided by WVDEP Division of Mining and Reclamation (WVDEP DMR). 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 by mining status (seven categories) describing the status of each permitted discharge. WVDEP DMR 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 West Virginia 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: 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 potential impact to water quality

Source: WVDEP DMR

Kentucky Department for Surface Mining Reclamation and Enforcement (DSMRE) provided similar mining permit information that also includes both active and inactive mining facilities, which are classified by type of mine and facility status. The Kentucky mining permit types and facility status descriptions are shown in Table 3-5.

Table 3-5. Classification of Kentucky mining permit type and status

Type of Mining	Status Type
- Surface - Underground - Roads - Processing Facility - Other	Active, not currently being mined
	Actively producing coal
	Thirty Days Reclamation Deferred
	Six-Month Reclamation Deferred
	Final Forfeiture
	Inactive Permits
	No Disturbances
	Active Permits in Forfeiture
	Active Temporary Cessations
	Phase I Release
	Phase II Release
	Permits Completely Released
	Surety Failure
	Suspended Permit
	Mine Status Unknown
	Created During Conversion
	Prepermit
	Wildcat
	Active Currently Being Mined

Source: KY DSMRE

Coal mining operations and sandstone quarries in West Virginia typically have discharge permits which limit concentrations of total iron, total manganese and total nonfilterable residue concentrations, and pH. They are also required to monitor and report total aluminum concentrations. However, limestone quarries do not have discharge limits for total iron, total manganese, total nonfilterable residue and aluminum. In Kentucky, coal mining operations have discharge limits for total iron, total suspended solids and pH and monitor for acidity, alkalinity, and total manganese. There are a total of 762 mining permits from West Virginia and Kentucky in the Tug Fork watershed. A complete listing of mining permits in the Tug Fork watershed is located in Appendix E. Figure 3-2 illustrates the extent of the mining operations in the Tug Fork watershed.

Surface Mining Control and Reclamation Act

The Surface Mining Control and Reclamation Act of 1977 (SMCRA, Public Law 95-87) and its subsequent revisions were enacted to established a nationwide program to, among other things, protect the beneficial uses of land or water resources, and pubic health and safety from the adverse effects of current surface coal mining operations, as well as promote the reclamation of mined areas left without adequate reclamation prior to August 3, 1977. SMCRA requires a permit for the development of new, previously mined, or abandoned sites for the purpose of surface mining. Permittees are required to post a performance bond that will be sufficient to ensure the completion of reclamation requirements by the regulatory authority in the event that the applicant forfeits. Mines that ceased operating by the effective date of SMCRA, (often called "pre-law" mines) are not subject to the requirements of SMCRA.

Title IV of the Act is designed to provide assistance for reclamation and restoration of abandoned mines, while Title V states that any surface coal mining operations shall be required to meet all applicable performance standards. Some general performance standards include:

- Restoring the land affected to a condition capable of supporting the uses which it was capable of supporting prior to any mining,

- Backfilling and compacting (to insure stability or to prevent leaching of toxic materials) in order to restore the approximate original contour of the land with all highwalls, and

- Minimizing the disturbances to the hydrologic balance and to the quality and quantity of water in surface and ground water systems both during and after surface coal mining operations and during reclamation by avoiding acid or other toxic mine drainage.

For purposes of these TMDLs only, point sources are identified as NPDES-permitted discharge points, and nonpoint sources include discharges from abandoned mine lands, including but not limited to, tunnel discharges, seeps, and surface runoff. Abandoned and reclaimed mine lands were treated in the allocations as nonpoint sources because there are no NPDES permits associated with these areas. In the absence of an NPDES permit, the discharges associated with these land uses were assigned load allocations, as opposed to wasteload allocations. The decision to assign load allocations to abandoned and reclaimed mine lands does not reflect any determination by EPA as to whether there are, in fact, unpermitted point source discharges within these land uses. In addition, by establishing these TMDLs with mine drainage discharges treated as load allocations, EPA is not determining that these discharges are exempt from NPDES permitting requirements.

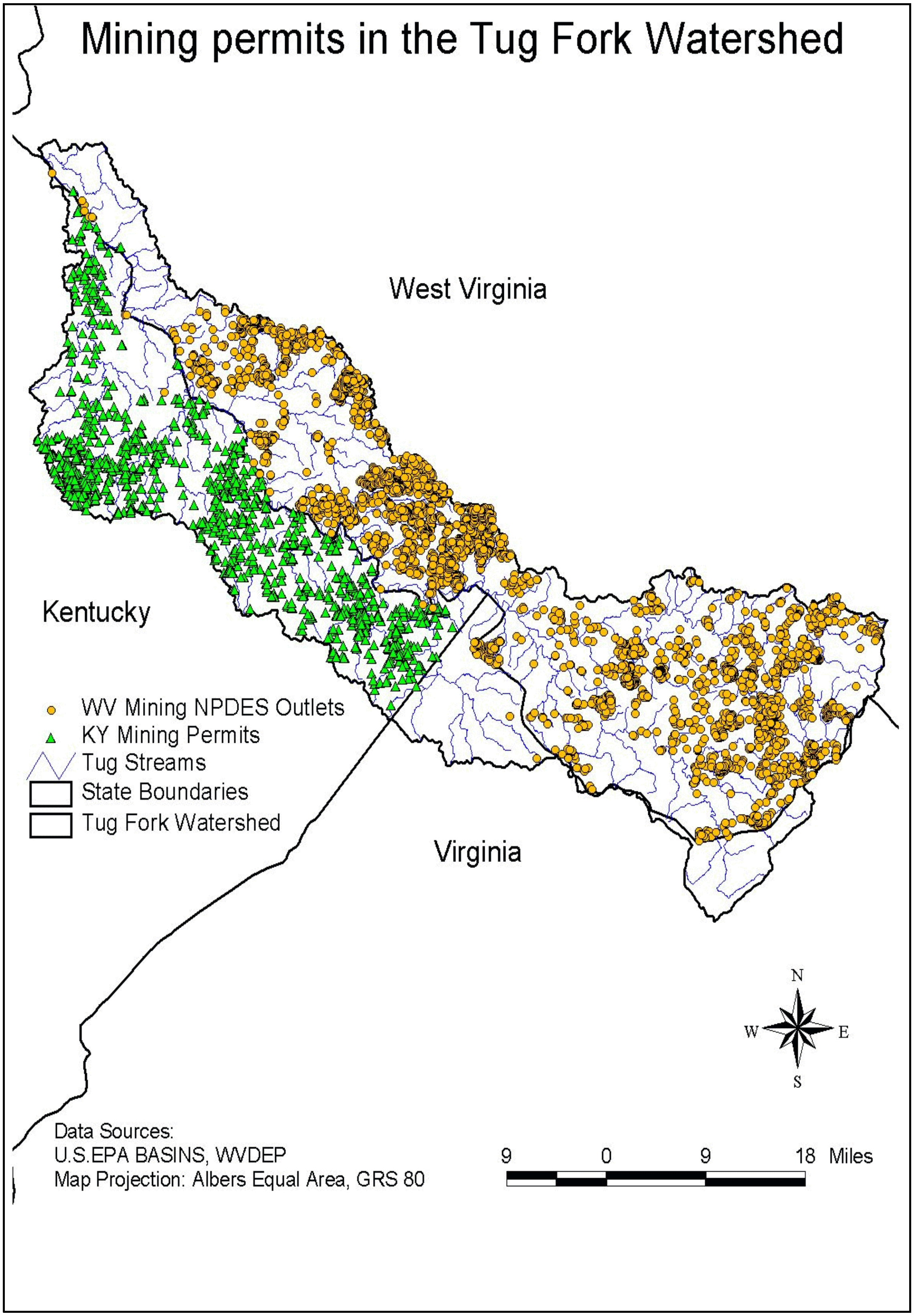


Figure 3-2. Mining permits in the Tug Fork River watershed

3.5 Nonpoint Sources

In addition to point sources, nonpoint sources also contribute to water quality impairments in the Tug Fork River watershed. Nonpoint sources represent contributions from diffuse, nonpermitted sources. Based on the identification of a number of abandoned mining activities in the Tug Fork River watershed, abandoned mine lands (AML) represent a significant nonpoint source. Abandoned mines contribute 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. Sediment produced from land-based activities is another potential source of high metal contamination in the Tug Fork River watershed.

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 reactions 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. A third reaction occurs 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).

The basin lies entirely in the Appalachian Plateau Physiographic Province. The topography of the Appalachian Plateau is characterized by steep slopes and narrow valleys. The majority of the Tug Fork watershed lies in the southern coal fields of West Virginia within the Pocahontas Geologic Basin. The rocks exposed at the surface of the watershed are Paleozoic Age and range from Pennsylvanian to Mississippian in age. The older, underlying Bluestone Formation of the Mississippian Age is exposed in the stream valleys of McDowell County. The coal bearing or carboniferous rocks in the basin were accumulated approximately 250 to 300 million years ago during the Pennsylvanian and Permian periods.

A significant folding of the earth's strata in the southern portion of the basin is represented by the Dry Fork anticline in McDowell county. The primary group of rocks that occur on either side of the anticline is the New River Formation composed of consolidated sandstone, siltstone, shale and coal. All other groups and formations comprising the Tug Fork basin include the same composition of rocks as the New River Formation as well as deposits of limestone.

The major geologic formations present in the Tug Fork watershed, from north to south, are described below:

- *Kanawha Formation:* Sandstone, shale, siltstone, and coal. Contains several marine zones. Becomes more shaly westward in the subsurface. Extends from the top of the Homewood Sandstone member to the top of the Nuttal Sandstone Member of the New River Formation. Includes the Stockton (Mercer), Coalburg, Winifrede, Chilton, Williamson, Cedar Grove, Alma, Peerless, Campbell Creek, Powellton, Eagle, Gilbert, and Douglas coals.

- *New River Formation:* Predominantly sandstone , with some shale, siltstone and coal. Grades to nearly all sandstone in the subsurface. Extends to the top of the Nuttall Sandstone member to the top of the Flattop Mountain Sandstone member of the Pocahontas Formation. Includes the Iaeger, Sewell, Welch, Raleigh, Beckley, Fire Creek and Pocahontas nos. 8 and 9 coals.

- *Southern: Pocahontas Formation:* Sandstone, with some shale, siltstone and coal. Extends from the top of the Flat Top Mountain Sandstone Member to the Top of the Mississippian System. Includes, from the bottom upward, Pocahontas coals nos. 1 through 7.

Watts et al. (1994) identified clays derived from shale units within drainage basins in West Virginia as the primary source of high aluminum concentrations in stream 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 3-3 presents a schematic of potential sources in the Tug Fork watershed. The land use distribution for the Tug Fork watershed is presented in Figure 3-4.

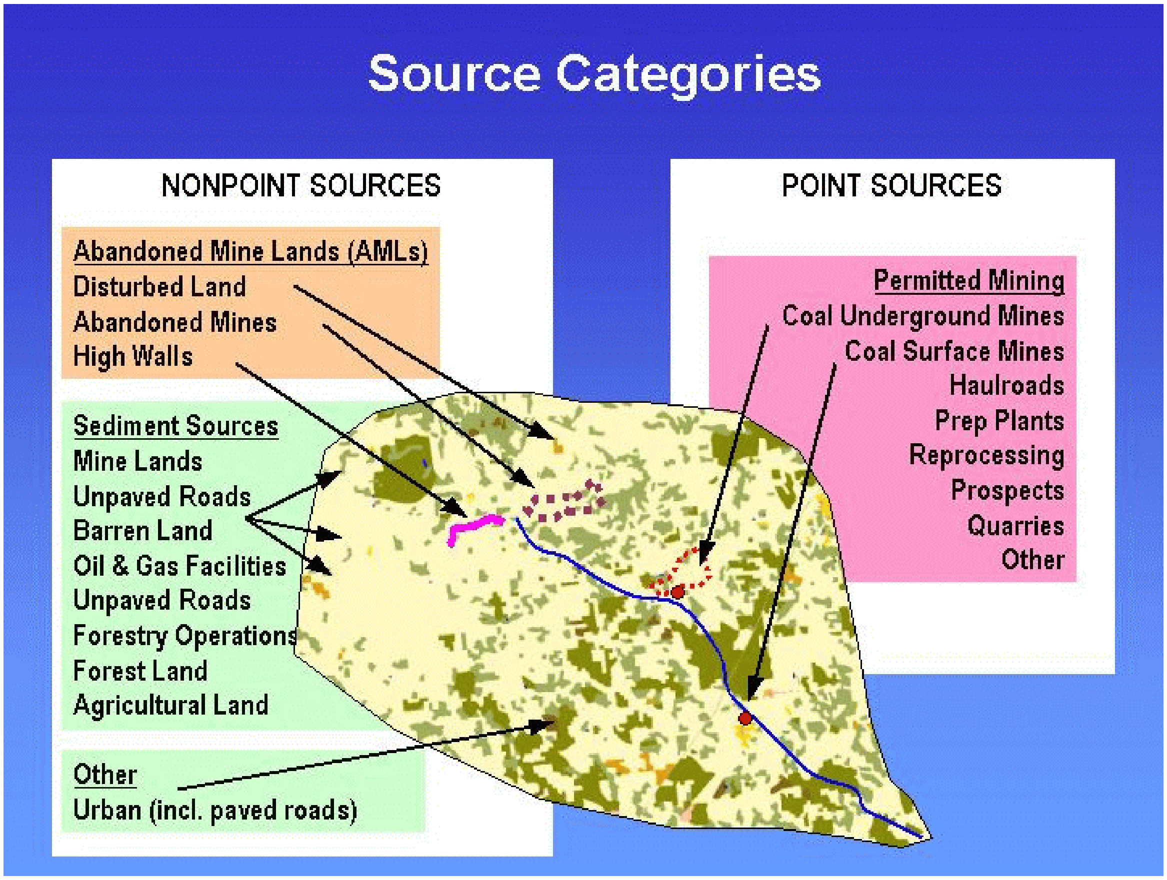


Figure 3-3. Potential sources contributing to impairments in the Tug Fork River watershed

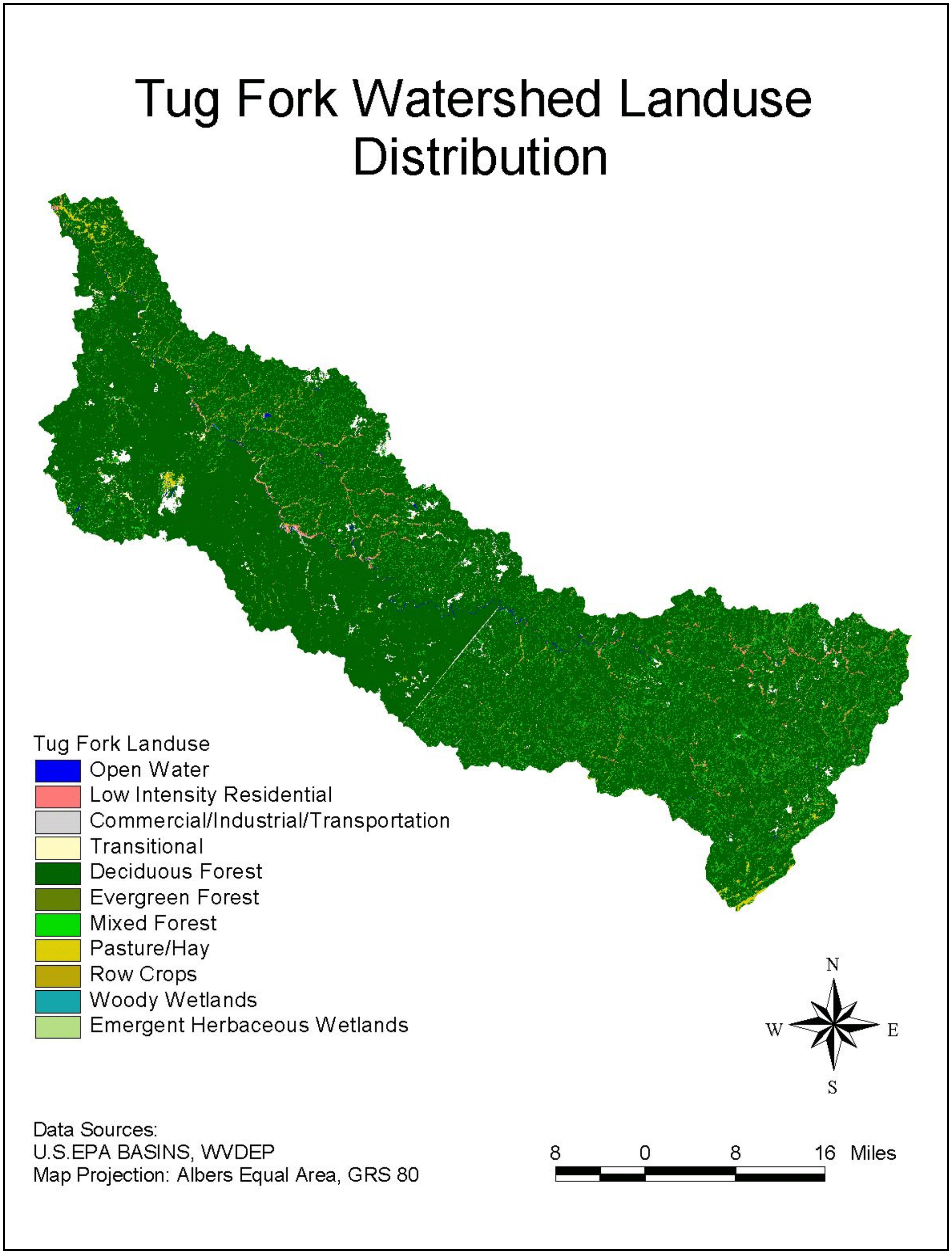


Figure 3-4. Land use distribution in the Tug Fork River watershed

3.5.1 Abandoned Mine Lands (AML) and *Revoked mines*

Generally, the abandoned surface and/or deep mines, collectively referred to as abandoned mine lands, produce AMD flows (WVDNR, 1985). Data regarding AML sites in the West Virginia portion of the Tug Fork watershed were compiled from spatial coverages provided by WVDEP DMR and the *Big Sandy River - Tug Fork Basin Plan* (WVDNR, 1986). AML information was not readily available for the Kentucky and Virginia portions of the watershed.

The AML sites were classified into three categories:

- High walls: generally vertical face of exposed overburden and coal from surface and underground mining activities.
- Disturbed land: disturbed land from both surface and underground mining activities.
- Abandoned mines: abandoned surface and underground mines.

Additional qualitative data were retrieved from WVDEP DMR Problem Area Data Sheets (PADS). Information regarding the subwatersheds with known AML sites is presented in Table 2 in each of Appendices A-1 through A-20.

Mines with revoked permits no longer have a permittee responsible for treating discharges from these mines which are typically untreated. Consequently, for purposes of this TMDL, mines with revoked permits are treated as nonpoint sources. In the absence of an NPDES permit, the discharges associated with these land uses were assigned load allocations, as opposed to wasteload allocations. The decision to assign load allocations to abandoned mine lands does not reflect any determination by EPA as to whether there are, in fact, unpermitted point source discharges within these land uses. In addition, by establishing these TMDLs with mine drainage discharges treated as load allocations, EPA is not determining that these discharges are exempt from NPDES permitting requirements.

3.5.2 Sediment Sources

Based on the review of existing literature, sediment was identified as a potential source of high metals concentrations in the Tug Fork River watershed (Watts et al., 1994). Visual observations by WVDEP indicated that the impaired segment of the main stem exhibited a high level of siltation. Water quality data from two stations on the impaired main stem and from multiple upstream tributary watersheds 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 Figures C-12 through C-14 of Appendix C.

Appendix C displays the data used to evaluate the linkage between loading sources and in-stream water quality targets for aluminum, iron, and manganese. The analysis is primarily conducted at two stations on the mainstem Tug Fork at Kermit and Fort Gay. In addition, data from upstream tributaries are grouped together and analyzed to determine the nature of the loading source/water quality relationship.

Figures C-1 through C-4 display the relationship between flow/TSS, flow/total iron, flow/total manganese, and flow/total aluminum, respectively, at Kermit on the Tug Fork mainstem. The period of record for all data used in Appendix C extends from 1985 through 1998 and includes at least 146 observations for each parameter.

Figure C-1 displays a plot of median TSS concentration in mg/l versus median flow in cfs (log scale) at USGS gage 03214500. Each observation represents a water quality sample measuring TSS associated with an observed flow. The data analysis shows a strong positive relationship between increasing concentrations of TSS and increasing flow. Based on this data, it is reasonable to conclude that sediment producing sources, and sediment, have a significant impact on water quality during high flow conditions.

Figure C-2, median total iron versus median flow, and Figure C-3, median total aluminum versus median flow, also show strong positive relationships between increased flow and increased pollutant concentration. Figure C-4, median total manganese versus median flow, also shows a positive relationship between increased flow and increased pollutant concentration, however, this relationship is not as strong as other parameters.

The data analysis at Fort Gay on the Tug Fork mainstem is similar to the analysis at Kermit. Figures C-5 through C-8 display the results of the analyses of flow/TSS, flow/total iron, flow/total aluminum, and flow/total manganese, respectively, at Fort Gay. The data analysis shows similar strong relationships between increasing median flow and increasing parameter concentrations. This provides further confirmation that high flow periods and metals-laden sediment represent critical conditions and that sediment producing sources must be controlled in order to attain and maintain water quality standards for total aluminum, total iron, and total manganese.

Similar analyses were also conducted on data from the upstream tributaries of the Tug Fork watershed. Data from upstream tributaries were grouped together to examine the relationship between TSS concentrations and concentrations of total aluminum, total iron, and total manganese. Figures C-9 through C-11 show the relationship between TSS/total iron, TSS/total aluminum, and TSS/total manganese. Each figure shows a positive relationship between increasing TSS concentrations and increasing pollutant concentrations. These analyses confirm that the conclusions from the data analysis on the Tug Fork mainstem also apply to the upstream tributaries of the Tug Fork. Further confirmation is provided in Figures C-12 through C-14 which show the correlation between TSS concentrations and parameter concentrations. The relationship between TSS/total iron and TSS/total manganese show strong correlations at 0.96 and 0.84, respectively. The correlation between TSS/total aluminum, shown in Figure C-12, is not quite as strong. However, this is most likely due to limitations imposed by detection limits of accepted sampling procedures which adversely affect the correlation analysis. The slope of the regression lines for both TSS/total iron (Figure C-12) and TSS/total aluminum (Figure C-13) show a strong positive relationship between increasing TSS concentrations and increasing metals concentrations.

In the Tug Fork 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 Tug Fork River, reductions in sediment loading will be required to meet in-stream metals criteria. 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 3-6. To spatially represent land-based nonpoint sources in the Tug Fork River watershed, the MRLC 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 3-6. Generalized sediment source characterization

	Sediment Contribution			Time Scale of impact on receiving water body	
Sources	High	Medium	Low	Long	Short
1. Forest (undisturbed)[A]			X	NA	NA
2. Forest operations	X				X
3. Access roads in forest	X			X	
4. Agriculture		X		X	
5. Oil and gas drilling		X			X
6. Oil and gas access road	X			X	
7. Mining (abandoned)		X		X	
8. Mining (active)			X	X	
9. Construction	X				X
10. Roadway construction	X				X
11. Paved roads and highways			X	X	
12. Unpaved roads	X			X	
13. Point sources (permitted)			X	X	

A - Undisturbed forest condition is the reference level condition.

The data analysis describe above and presented in Appendix C confirms that periods of high stream flow represent one critical condition for the Tug Fork watershed. The other critical condition in the Tug Fork watershed is low flow when abandoned mine lands and mining point source discharges also impact water quality. During high flow, water quality in the Tug Fork is vulnerable and violations of water quality criteria for aluminum, iron, and manganese are likely to occur (Bader, 1984). The data confirm the strong positive relationship between increasing TSS concentration and increasing concentrations of aluminum, iron, and manganese. Furthermore, based on previous watershed modeling experience in West Virginia, general scientific knowledge regarding sediment/metal interaction, and knowledge regarding soils in West Virginia, it is reasonable to conclude that sediments contain high levels of aluminum, iron, and to a lesser extent, manganese. In order to meet water quality criteria for total aluminum, total iron, and total manganese during critical high flow conditions, control of sediment producing sources is crucial.

3.5.3 Other Nonpoint Sources

The predominant land uses in the Tug Fork watershed are identified based on the USGS's MRLC land use data (representative of the mid-1990s). According to the MRLC data, the major land uses in the watershed are forest land, which constitutes approximately 95 percent of the watershed area, and agricultural land, which makes up 2% of the watershed area. In addition to forest land and agricultural land uses, other landuses which may contribute nonpoint source metals loads to the receiving streams include barren and urban land. The land use distribution for the Tug Fork watershed is presented in Figure 3-4 and Table 3-7.

Table 3-7. MRLC Landuse Distribution in the Tug Fork Watershed

MRLC Landuse Category	Area (Acres)	Percent
1 Open Water	2,374	0.24%
2 Low Intensity Residential	5,879	0.60%
3 High Intensity Residential	174	0.02%
4 Commercial/Industrial/Transportation	1,145	0.12%
5 Quarries/Strip Mines/Gravel Pits	13,478	1.36%
6 Transitional Baren	1,827	0.18%
7 Deciduous Forest	882,314	89.35%
8 Evergreen Forest	5,355	0.54%
9 Mixed Forest	54,758	5.55%
10 Pasture/Hay	10,788	1.09%
11 Row Crops	9,145	0.93%
12 Woody Wetlands	106	0.01%
13 Emergent Herbaceous Wetlands	90	0.01%
Total	**987, 433**	**100.00%**

4.0 Technical Approach

Establishing the relationship between the in-stream 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 a range of techniques, 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 in-stream response for TMDL development in the Tug Fork 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

Numeric water quality criteria for aluminum, manganese, and iron for aquatic life, such as those applicable here, require evaluation of magnitude, frequency, and duration. Magnitude refers to the criterion maximum concentration (CMC) to protect against short-term (acute) effects or the criterion continuous concentration (CCC) to protect against long-term (chronic) effects. Frequency indicates the number of water quality criteria violations over a specified time period. In this case, for aquatic life criterion, the water quality standards allow one exceedance every three years. Duration measures the time period of exposure to increased pollutant concentrations. Excursions may be measured over a one-hour period, four-day period, or be a “not to exceed.” In addition to these considerations, any technical approach must consider how numeric aquatic life criteria are expressed. West Virginia aquatic life criteria for metals are expressed as total recoverable metals concentrations. The approach or modeling technique must permit representation of in-stream concentrations under a variety of flow conditions, in order to evaluate critical periods for comparison to chronic and acute criteria.

Furthermore, according to 40 CFR Section 130, TMDLs must be designed to implement applicable water quality standards. The applicable water quality standards are discussed in Section 2.0.

The TMDL development approach must also consider the dominant processes regarding pollutant loadings and in-stream fate. For the Tug Fork watershed, primary sources contributing to metals and pH impairments include an array of nonpoint or diffuse 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 in-stream factors that are considered include routing of flow, dilution, transport of total metals, sediment adsorption/desorption, and precipitation of metals. In the stream systems of the Tug Fork watershed, the primary physical driving processes are the transport of total metals bounded to sediments during high flows, and diffusion and advection during low flows.

Scale of analysis and waterbody type must also be considered in the selection of the overall approach. The approach should have the capability to evaluate watersheds at multiple scales, particularly those of a few hundred acres in size. The listed waters in the Tug Fork watershed range from small headwater streams to larger tributaries and the mainstem of the Tug Fork 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 the available data. Occasionally, there are site specific and localized acute problems which may require more detailed segmentation or definition of detailed modeling grids.

Based on the considerations described above, 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 Tug Fork watershed for aluminum, manganese, and iron. The MDAS is a comprehensive data management and modeling system that is capable of representing loading from nonpoint and point sources found in the Tug Fork watershed and simulating in-stream processes. The MINTEQ modeling system is used to represent the source-response linkage in the Tug Fork watershed for pH. The methodology and technical approach for pH using MINTEQ is discussed in section 4.4.

4.2 Mining Data Analysis System (MDAS) Overview

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

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

The graphical interface supports basic geographic information systems (GIS) functions, including electronic geographic data importation and manipulation. Key data sets include stream networks, landuse, 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 Discharge Monitoring Reports (DMRs), as well as 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 in-stream flow and pollutant transport, and it is capable of representing time-variable point source contributions. The data analysis/post-processing 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 in-stream response. The HSPC is a comprehensive watershed model used to simulate watershed hydrology and pollutant transport as well as stream hydraulics and in-stream 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 re-coded 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* for a more detailed discussion of simulated processes and model parameters (Bicknell et al., 1996).

Table 4-1. Modules from HSPF[a] 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 quality constituent
	PHCARB	Simulates pH, carbon dioxide, total inorganic carbon, and alkalinity
PQUAL and IQUAL Modules	PWATER	Simulates water budget for a pervious land segment
	SEDMNT	Simulates production and removal of sediment
	PWTGAS	Estimates water temperature and dissolved gas concentrations
	IQUAL	Uses simple relationships with solids and water yield
	PQUAL	Simple relationships with sediment and water yield
	IWATER	Simulates water budget for impervious land segments

[a] Source: Bicknell et al., 1996

4.3 Model Configuration

The MDAS was configured for the Tug Fork 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 Tug Fork watershed into modeling units and continuous simulation of flow and water quality for these units using meteorological, landuse, point source loading, and stream data. Specific pollutants that were simulated by MDAS include total aluminum, total iron, and total manganese, while MINTEQ2 was used to evaluate pH, see Section 4.4. 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 Tug Fork River watershed, the watershed was divided into 455 subwatersheds. These subwatersheds are presented in Figure 1 in each of Appendices A-1 through A-20, and they represent hydrologic boundaries. The division was based on elevation data (7.5 minute Digital Elevation Model [DEM] from USGS), stream connectivity (from USGS's National Hydrography Dataset [NHD] stream coverage), and locations of monitoring stations.

4.3.2 Meteorological Data

Meteorological data are a critical component of the watershed model. Appropriate representation 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 Tug Fork watershed.

In general, hourly precipitation data are recommended for nonpoint source modeling. Therefore, only weather stations with hourly-recorded data were considered in development of a representative dataset. Long-term hourly precipitation data available from five National Climatic Data Center (NCDC) weather stations located in or near the watershed were used (Figure 4-1):

- Louisa 5 W
- Davella
- Logan
- Flat Top
- Hurley 4 S

Meteorological data for the remaining required parameters were available from the Huntington Tri-State Airport and the Bluefield Mercer County Airport stations. These data were applied based on subwatershed location relative to the weather stations.

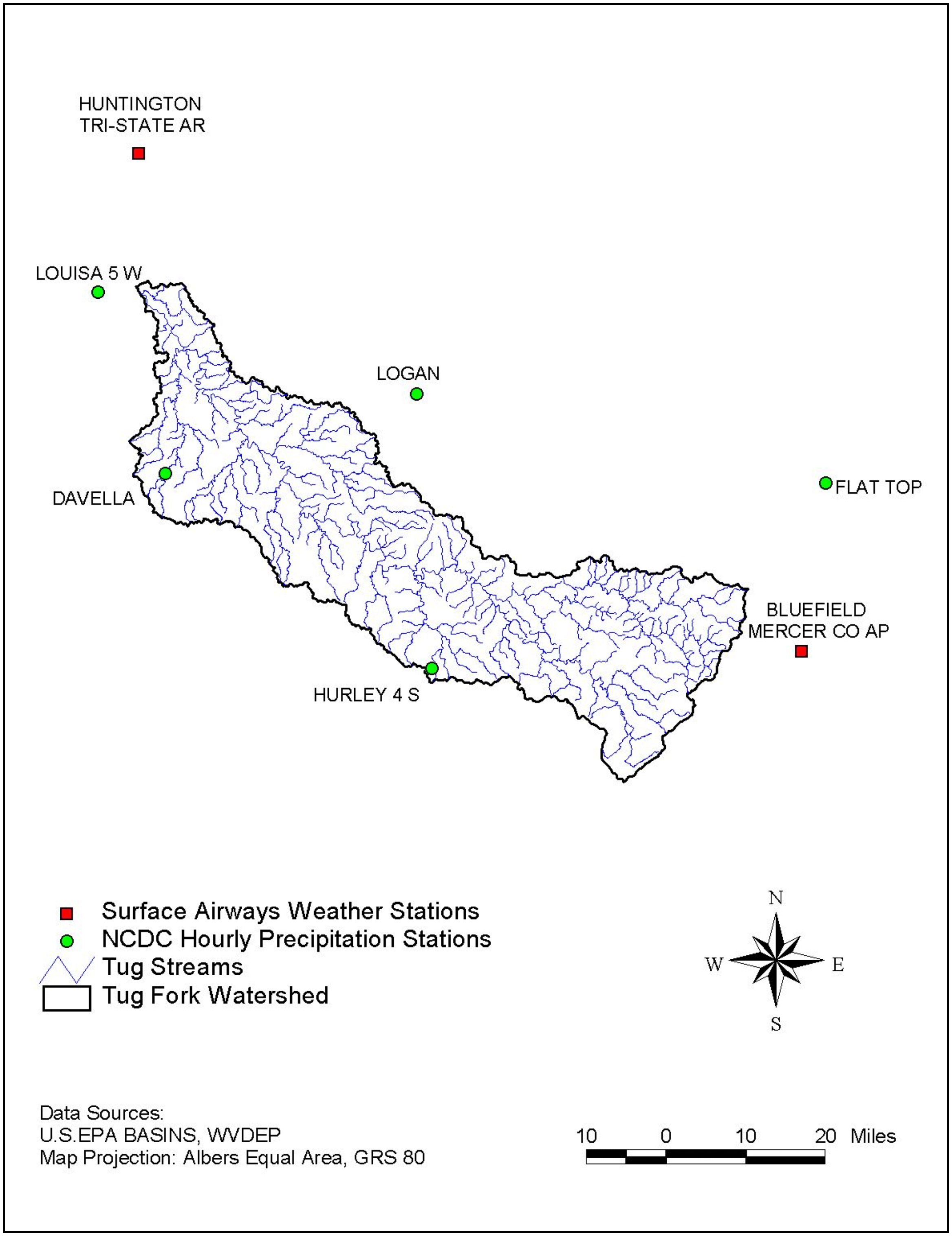


Figure 4-1. Weather stations used in modeling of the Tug Fork Watershed

4.3.3 Nonpoint Source Representation

To explicitly model nonpoint sources in the Tug Fork River watershed, several additional land use categories were created and added to the model land use grouping (MRLC) 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. Land use grouping

Model Category	MRLC Category
Mature Forest	Deciduous Forest
	Evergreen Forest
	Mixed Forest
Pasture	Pasture/Hay
Cropland	Row Crops
Strip Mines	Quarries/Strip Mines/Gravel Pits
Barren	Transitional Barren
Urban Impervious	Low Intensity Residential
	High Intensity Residential
	Commercial/Industrial/Transportation
Urban Pervious	Low Intensity Residential
	High Intensity Residential
	Commercial/Industrial/Transportation
Wetlands	Woody Wetlands
	Emergent Herbaceous Wetlands

In addition, contributions of relevant parameters from groundwater sources are also considered. In the case of naturally-occurring parameters, such as aluminum, iron, and manganese, it is important to consider and incorporate groundwater contributions for more accurate representations of actual conditions. Typical groundwater concentrations were assigned to each land use, including background concentrations to undisturbed areas (Bader, 1984).

Abandoned Mine Lands (AML)

In order to represent AMLs as nonpoint sources, the AML categories were broken down into three land use categories: high walls, disturbed land, and abandoned mines. The abandoned mines represent either discharge from abandoned deep mines or seeps and leachate from other abandoned mine sites. Specific data regarding the three AML land uses was not available from the MRLC land use coverage. WVDEP provided AML land use coverage data which were incorporated into the MRLC land use coverage. In order to incorporate these land uses to appropriately account for flow and loading characteristics, the existing MRLC land use coverage was modified on a subwatershed basis. For instance, assume that data from WVDEP indicated no active mining, 60 acres of abandoned mines, 40 acres of disturbed land, and 20 acres of high walls in a particular subwatershed, while available MRLC data indicated 900 acres of forested land and 100 acres of "active mining land" in the same watershed. The MRLC data would be modified such that the 100 acres of "active mining land" would become 120 acres of AML land use distributed according to the WVDEP data (i.e. 60 acres of abandoned mines, 40 acres of disturbed land, and 20 acres of high walls). Because the size of the new AML land use coverage exceeds the original "active mining land" coverage by 20 acres, the forested land use coverage is reduced by 20 acres such that the total size of the watershed remains constant. In no case, was the total size of any subwatershed modified as a result of including more accurate data regarding AML land uses, described below in the Other Nonpoint Sources section.

Sediment Sources

Additional land use categories were required to represent differences in the sediment loading and transport characteristics from various land use activities. 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 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) and Kentucky Division of Oil and Gas (KYDOG) provided information regarding oil and gas operations in the Tug Fork 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 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 categories as stated above.

Information on paved and unpaved roads in the watershed was obtained from the inventory surveys provided by West Virginia Department of Transportation (WVDOT), Kentucky Department of Transportation (KYDOT), Virginia Department of Transportation (VDOT), and the United States Department of Transportation (USDOT). These inventories provide the approximate length (in miles) of paved and unpaved roads in several subcategories for counties in West Virginia, Kentucky, and 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 forest lands. Paved road areas were subtracted from the urban impervious land use category and then from forest lands, if necessary. Paved roads contribute little sediment.

Pervious urban land areas were estimated using typical percent pervious/impervious assumptions for urban land categories (i.e. low intensity residential, high intensity residential and commercial/industrial/transportation).

Other Sources

Although urban areas are not a major source of sediment-related metals, impervious urban lands may 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. Metals contributions from urban lands have not been shown to be a significant source in the Tug Fork watershed.

4.3.4 Point Sources Representation

Permitted Non-mining Point Sources

With one exception, the non-mining point source permits in the Tug Fork watershed do not require monitoring or are not expected to be significant sources of iron, aluminum, or manganese, and therefore, were not considered in the modeling effort. The loading from the one minor discharger (Mingo County PSD, WV0115444) was included in the background conditions during the water quality calibration, baseline and allocation calculations. The WLA assigned to this facility was calculated based on the average flow and the the maximum allowable metal concentration.

Permitted Mining Point Sources

The permitted mining point sources from West Virginia and Kentucky were introduced as nine land use categories based on the type of mine and the current status of the mine. Phase II and Completely Released permitted facilities were modeled as pasture since reclamation of these mines is either completed or nearly complete, and they are assumed to have little potential water quality impact (WVDEP, 2000a). Table 4-3 shows the land uses representing current active mines that were modeled.

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

Type and status of active mine	Land use representation
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 (other, haulroad, prospect, quarry)	Other
Phase 1 released surface mines	PIRS
Revoked surface mines	RSM
Revoked other mines	ROM

To account for the additional deep mine land use categories that were not categorized in the MRLC landuse coverage (ADM, IADM, RDM and PIDM), the area of each permitted deep mine was subtracted from the existing MRLC landuse area as described in Section 4.3.3. The remaining additional land use categories (ASM, PIRS, RSM, ROM and Other) were subtracted from the strip mine land use areas. The size of each mine was assumed to be equivalent to the surface disturbed area, which were provided by WVDEP DMR and KY DSMRE mining permit database. These areas are shown in Appendix E. A summary of the land use distribution is shown in Tables 4-4a and 4-4b.

Table 4-4a. Modeled land use distribution in acres for Regions 1 through 10

Modeled Land Use	1	2	3	4	5	6	7	8	9	10
ADM	423	76	240	103	285	34	44	89	0	2
AML	2,392	1,420	1,709	1,193	484	111	543	279	68	0
ASM	164	1,454	799	0	2,018	32	0	0	519	695
Cropland	860	511	417	1,089	612	347	426	523	486	518
Harvested Forest	109	66	54	267	191	301	86	93	88	619
Highwall	356	83	187	225	49	51	126	82	26	0
IADM	51	23	58	22	258	89	12	25	11	0
Intermediate Forest	575	413	314	1,150	621	575	475	415	470	1,492
Mature Forest	38,587	26,176	19,705	81,167	37,814	31,633	33,529	29,132	33,371	67,326
Oil and Gas Wells	25	7	3	42	5	6	14	28	18	15
Other Mines	288	487	405	296	230	266	46	48	13	22
Pasture	329	226	159	352	532	853	125	338	207	562
Paved Roads	191	133	104	369	198	178	151	134	149	361
PIDM	78	10	12	30	90	4	5	14	0	16
PIRS	74	525	218	0	268	0	0	0	85	16
RDM	0	4	53	37	83	0	1	0	3	15
ROM	0	0	0	0	0	0	43	0	0	27
RSM	23	0	0	607	0	0	68	535	0	175
Unpaved Roads	57	40	31	111	48	27	45	40	45	56
Urban Impervious	242	26	113	158	14	19	63	38	7	12
Urban Pervious	716	104	272	626	59	80	226	154	28	50
Wetlands	20	10	30	8	40	2	1	1	0	0
Total	**45,559**	**31,796**	**24,883**	**87,852**	**43,898**	**34,609**	**36,030**	**31,968**	**35,590**	**71,980**

Table 4-4b. Modeled land use distribution in acres for Regions 11 through 20

Modeled Land Use	11	12	13	14	15	16	17	18	19	20
ADM	309	342	76	438	611	724	194	492	0	173
AML	674	0	0	0	487	0	2,403	0	55	544
ASM	2,080	5,489	14	1,022	7,626	8,231	2,193	5,901	0	495
Cropland	256	0	1	0	1,405	6	588	97	0	1,005
Harvested Forest	231	85	62	92	653	1,481	132	1,997	43	865
Highwall	151	0	0	0	99	0	104	0	13	128
IADM	40	0	0	13	117	0	63	0	0	93
Intermediate Forest	953	648	476	705	2,235	567	634	917	249	2,430
Mature Forest	32,732	25,778	23,407	33,928	74,726	37,949	20,893	69,161	13,065	114,154
Oil and Gas Wells	8	35	48	62	32	96	20	118	2	101
Other Mines	931	681	75	453	2,154	1,655	376	692	0	833
Pasture	532	137	224	210	871	782	334	805	1,804	2,448
Paved Roads	197	177	130	190	464	269	152	414	95	674
PIDM	305	82	15	68	152	51	0	48	0	13
PIRS	771	863	761	200	2,949	125	533	379	0	596

Modeled Land Use	11	12	13	14	15	16	17	18	19	20
RDM	63	138	0	92	0	368	0	73	0	270
ROM	10	110	0	8	0	0	19	4	0	19
RSM	199	320	10	2	0	361	251	28	0	478
Unpaved Roads	22	43	32	46	51	65	27	101	28	139
Urban Impervious	57	31	255	28	189	102	13	230	13	605
Urban Pervious	191	21	104	25	738	37	55	100	53	1,389
Wetlands	0	0	0	0	0	6	0	0	0	78
Total	**40,712**	**34,980**	**25,689**	**37,584**	**95,559**	**52,874**	**28,986**	**81,560**	**15,419**	**127,531**

Point sources were represented differently, depending on the modeling scenario for TMDL development. The two major scenarios, which are described in more detail later in this section and in Section 5, are the model calibration scenario and the allocation scenario.

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 Discharge Monitoring Report (DMR) data. Discharges that were issued permits after the calibration period were not considered during the calibration process. The DMR data includes monthly averages and maximums for flow, pH, total aluminum, total iron, and manganese. The DMR data indicated that the loads from the permitted mines are precipitation driven. Discharges from permitted mines were represented in the model by adjusting parameters affecting pollutant concentrations in the PQUAL (simulation of quality constituents for pervious land segments) and IQUAL (simulation of quality constituents for impervious land segments) modules of HSPC. These parameters were assigned to represent DMR concentrations of similar mining activities within the entire Tug Fork watershed. Concentrations from these mines were adjusted to be consistent with typical discharge characteristics from similar mining activities or to match site-specific in-stream 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 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 DMR'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. Under baseline conditions, the concentration of metals in discharges from point sources including NPDES mining permits was set to permit limits, i.e., the waste load allocation (WLA) based on permit limits. During the allocation scenario, reductions were applied to abandoned mine lands, sediment producing lands, and active mines in that order to achieve in-stream TMDL endpoints.

Mining discharge permits have either technology-based or water quality-based limits. Monthly average permit concentrations for technology-based limits are 3.0 mg/L and 2.0 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 in-stream water quality criteria at end-of-pipe. Point sources were assigned concentrations based on the appropriate limits. For discharges that are technology-based, the waste load concentration for aluminum was assumed to be the 99^{th} percentile value from the DMR data (3.6 mg/L).

Allocations were made to provide consistency with the technical and regulatory requirements of 40 CFR Section 130. For instance, following the data analysis and model calibration, it was determined that violations of applicable water quality criteria occur at both low-flow and high-flow conditions, indicating no one critical flow condition. Accordingly, the TMDL, model calibration, and allocation process were designed to consider both low-flow and high-flow conditions.

4.3.5 Stream Representation

Modeling subwatersheds and calibrating hydrologic and water quality model components required routing flow and pollutants through streams, and the resulting in-stream concentrations were compared to the water quality criteria. Each subwatershed was represented with a single stream. Stream segments were identified using the USGS NHD 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 natural streams). Slopes were calculated based on digital elevation model (DEM) data and stream lengths measured from the NHD 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

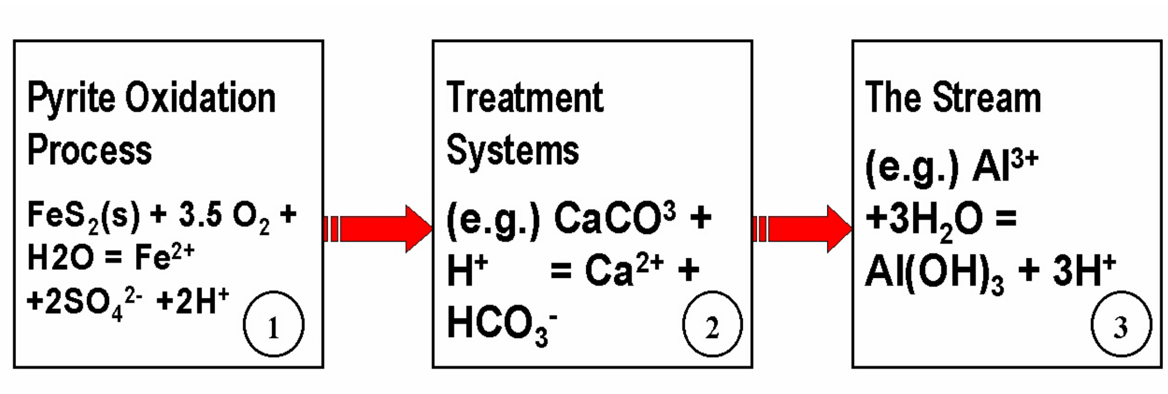
(Bicknell et al., 1996). Pollutant transport was represented in the streams using the GQUAL (simulation of behavior of a generalized quality constituent) module. Values for the pollutant representation were refined through the water quality calibration process. Descriptions of the unit area loadings for each landuse is shown in Appendix A.

The sediment/metals relationship described in Section 3.5.2 indicate that in-stream concentrations of total metals are a direct function of suspended sediment under high flow conditions. Sediment was not explicitly modeled in HSPC, but the derived correlation coefficients were used to estimate metals loadings associated with increased sediment delivery to the watershed from sediment sources, e.g., barren land. It is assumed that reduction in sediment would in turn result in a reduction of metals to the watershed.

4.4 pH TMDL Methodology Overview

4.4.1 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 compose 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_2O 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:

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

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 therefore the attenuation of pH depends on chemical constituents of the inflow, the age of the systems, and physical characteristics of the systems such as flow rate and detention rate (West Virginia University Extension Service, 2000).

It is assumed that implementing TMDLs in the Tug Fork 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. To estimate pH resulting from chemical reactions occurring in the stream, MINTEQA2, a geochemical equilibrium speciation model for dilute aqueous systems, was used.

4.4.2 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 inputs shown in Table 4-5.

Table 4-5. Input values for MINTEQA2

Species	Input Values (mg/L)
Ca	32.4
Mg	16.3
Na [(a)]	6.3
K [(a)]	2.3
Cl [(a)]	7.8
SO_4	114.1
Fe [(b)]	1.5 and 0.5
Al [(b)]	0.75
Mn [(b)]	1.0
Alkalinity	84.9 (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 alllowable limits). The alkalinity value was based on average in-stream concentrations for streams relatively unimpacted by mining activities in the Tug Fork 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. Additionally, the model was set to equilibrium with atmospheric CO_2. Based on the inputs presented, the resultant equilibrium pH was estimated to be 8.47 when the aquatic life criterion (1.5 mg/L total Fe and 0.75 mg/L total Al) was used, and 8.49 when the trout waters criterion (0.5 mg/L total Fe and 0.75 mg/L total Al) was used. For the moments when the iron and aluminum concentrations were allowed to exceeded criteria (once every three years), the resulting concentrations were never more than 3.0 mg/L for iron and 1.5 mg/L for aluminum. Using these concentrations, the resultant equilibrium pH was estimated as 8.37. 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 criterion of above 6 and below 9, provided that in-stream metals concentrations simultaneously meet applicable water quality criteria.

4.4.3 Assumptions

The conclusions presented above assume that TMDLs are implemented, so that metals concentrations from point and nonpoint sources result in the streams meeting metals criteria. Also, the chemical processes generating AMD and the processes to treat AMD are subject to variables which may or may not be addressed in the chemical equations modeled. Some of these variables are discussed below.

Iron (Fe)

Ferric iron was selected as total iron based on the assumption that the stream will be in equilibrium with the atmospheric oxygen. Because iron exhibits oxidized and reduced states, the redox part of the iron reactions 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 negligible. 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 streams. 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 following:

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

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 might 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.

4.5 Model Calibration

After the model was configured, calibration was performed at multiple locations throughout the Tug Fork 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, the calibrated dataset containing parameter values for modeled sources and pollutants was complete. This dataset 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 through A-20 show the modeled time-series for aluminum, iron and manganese along with corresponding sampling data for the period of January 1999 to December 2000. Only monitoring stations with data representing a range of hydrologic conditions, source types, and pollutants were selected. The locations selected for calibration are shown in Figure 4-2.

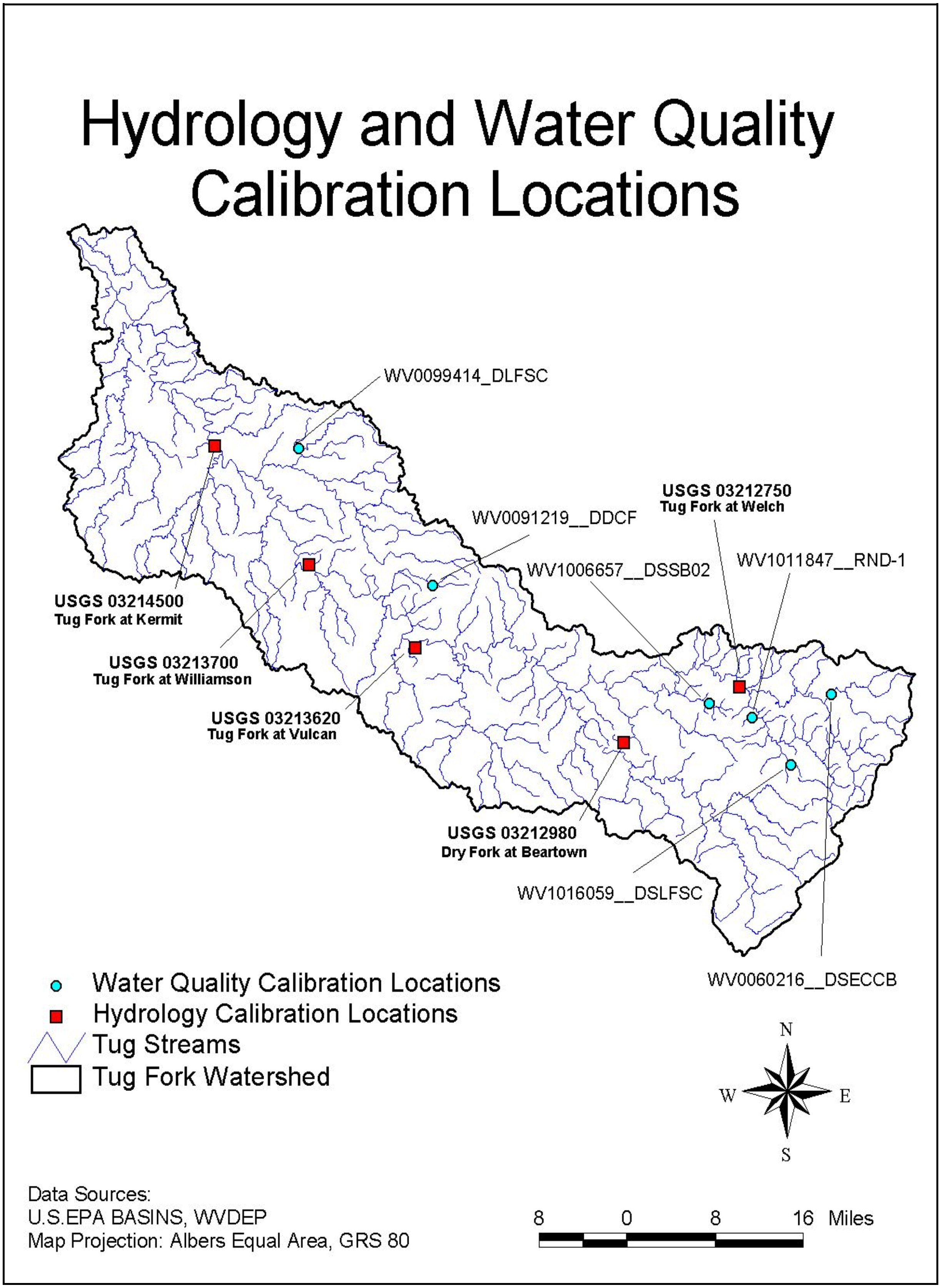


Figure 4-2. Calibration locations used in modeling

4.5.1 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.

In order to best represent hydrologic variability throughout the watershed, five locations with daily flow monitoring data were selected for calibration. The stations were USGS #03214500 Tug Fork at Kermit, USGS #03213700 Tug Fork at Williamson, USGS #03213620 Tug Fork at Vulcan, USGS #03212980 Dry Fork at Beartown, and USGS #03212750 Tug Fork at Welch. The model was calibrated at these five locations for the year 1990. 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. Hydrology calibration statistics are shown in Table 4-6 for USGS station 0321620.

Parameter values were validated for an independent, extended time period, October 1,1989, through September 30, 1999, after calibrating parameters at the stations. Validation involved comparison of 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.

Table 4-6. Comparison of Simulated and Observed Flow for 1990 (USGS#0321620, Tug Fork at Vulcan)

Simulated versus Observed Flow	Percent Error	Recommended Criterion[1]
Error in total volume	**-2.75**	+/- 10%
Error in 50% lowest flows	**10.04**	+/- 10%
Error in 10% highest flows	**-9.59**	+/- 15%
Seasonal volume error - Summer	**5.05**	+/- 30%
Seasonal volume error - Fall	**-39.81**	+/- 30%
Seasonal volume error - Winter	**4.50**	+/- 30%
Seasonal volume error - Spring	**-3.51**	+/- 30%
Error in storm volumes	**-4.08**	+/- 20%
Error in summer storm volumes	**2.14**	+/- 50%

[1] Recommended Criterion: HSPExp

4.5.2 Water Quality Calibration

After calibration for hydrology is complete, water quality calibration is performed. In the broadest sense, calibration consists 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. In order to establish reasonable ranges for use in water quality calibration, DMR and high flow data was analyzed to develop appropriate water quality parameters for active mines (surface, deep, and other mines, but not AML or revoked mines) and barren lands, respectively. Water quality parameters for AML lands were based on previous watershed modeling experience in areas with AML lands (*pH and Metals TMDLs in the Tygart Valley River* and *pH and Metals TMDL in the Elk River*). Parameters for background conditions were based on observed water quality data.

The approach taken to calibrate water quality focused on matching trends identified during the water quality analysis. Daily average in-stream concentration from the model was compared directly to observed data. Observed data were obtained from EPA's STORET database as well as from WV DEP Division of Water Resources, KY DEP Division of Water, and data submitted by various mining companies throughout the watershed. Mining companies data were obtained through 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 Tug Fork watershed) and loading source type. Results of the water quality calibration are presented in Appendix D.

5.0 Allocation Analysis

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. TMDLs can be expressed in terms of mass per time or by other appropriate measures. Conceptually, this definition is denoted by the equation:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

In order to develop aluminum, iron, manganese, and pH TMDLs for each of the waterbodies in the Tug Fork 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

5.1 TMDL Endpoints

TMDL endpoints represent the in-stream water quality targets used in quantifying TMDLs and their individual components. Different TMDL endpoints are necessary for aluminum, iron, manganese, and pH. West Virginia's numeric water quality criteria for aluminum, iron, manganese, and pH (identified in Section 2) and an explicit margin of safety (MOS), expressed in the TMDL as loadings set aside for the MOS, were used to identify endpoints for TMDL development for streams in West Virginia. Because the main stem of the Tug Fork is shared by West Virginia and Kentucky, the most stringent criteria of the two states was used to identify TMDL endpoints for the Tug Fork. No endpoints were defined for streams in Kentucky and Virginia.

5.1.1 Aluminum, Iron, and Manganese

The TMDL endpoints for total aluminum, total iron and total manganese were defined as follows:

- *Aluminum* - The endpoint for aluminum was selected as 712.5 ug/L (based on West Virginia's 750 ug/L criteria for aquatic life minus a 5% MOS).
- *Iron* - The endpoint for iron was selected as 0.475 mg/L for designated trout streams (based on West Virginia's 0.5 mg/L criteria for trout waters minus a 5% MOS) and 1.425 mg/L for all other streams (based on West Virginia's 1.5 mg/L aquatic life criteria minus 5% MOS). For the main stem of the Tug Fork, Kentuky's iron criteria was used because it is more stringent than West Virginia's. The endpoint for iron was selected as 0.95 mg/L (based on Kentucky's 1.0 mg/L aquatic life criteria minus a 5%MOS).

- *Manganese* - The endpoint for manganese was selected as 0.95 mg/L (based on West Virginia's 1.0 mg/L criteria for human health minus a 5% MOS).

Components of the TMDLs for aluminum, iron, and manganese are presented in terms of mass per time for nonpoint and point sources and also mass per volume for point sources 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 quality criteria for pH is to use the concentration of metal ions as a surrogate for pH. Through reducing in-stream metals, namely aluminum and iron, to meet water quality criteria (or TMDL endpoints), it is assumed that resulting pH will meet the WQS. This assumption is based on the application of MINTEQA2, a geochemical equilibrium speciation model, to aqueous systems representative of waterbodies in theTug Fork watershed. By inputting into the model the dissolved concentrations of metals, a pH value can be predicted. Refer to Section 4.4 for a detailed description of the modeling.

5.1.3 Margin of Safety

A five percent explicit MOS was used to account for uncertainties during the TMDL development process. In addition to the five percent explicit MOS, 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. For example, 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 in-stream conditions that occurred during the simulation period. Furthermore, TMDL conditions were evaluated using continuous time series model output, which allowed for an additional MOS.

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 maximum allowed loads whether or not the point source is discharging at its permitted loads. The baseline conditions allow for an evaluation of in-stream water quality under the "worst currently allowable" scenario.

The model was run for baseline conditions using hourly precipitation data for the period January 1, 1987 through December 31, 1992. Predicted in-stream concentrations of aluminum, iron, and manganese for the impaired waterbodies in the Tug Fork 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. Figure 5-1 presents the annual rainfall totals for the years 1970 through 2000 at the Davella weather station. The years from 1987-1992 are marked to indicate that a range of precipitation conditions was used for TMDL development in the Tug Fork watershed. The dry year, 1988, represents 3rd percentile of yearly rainfall since 1970. The wet year, 1989, represents the 97th percentile of yearly rainfall since 1970. Although the total rainfall of 1979 was grater than that of 1989, several storms during 1989 were greater than the largest storm of 1979.

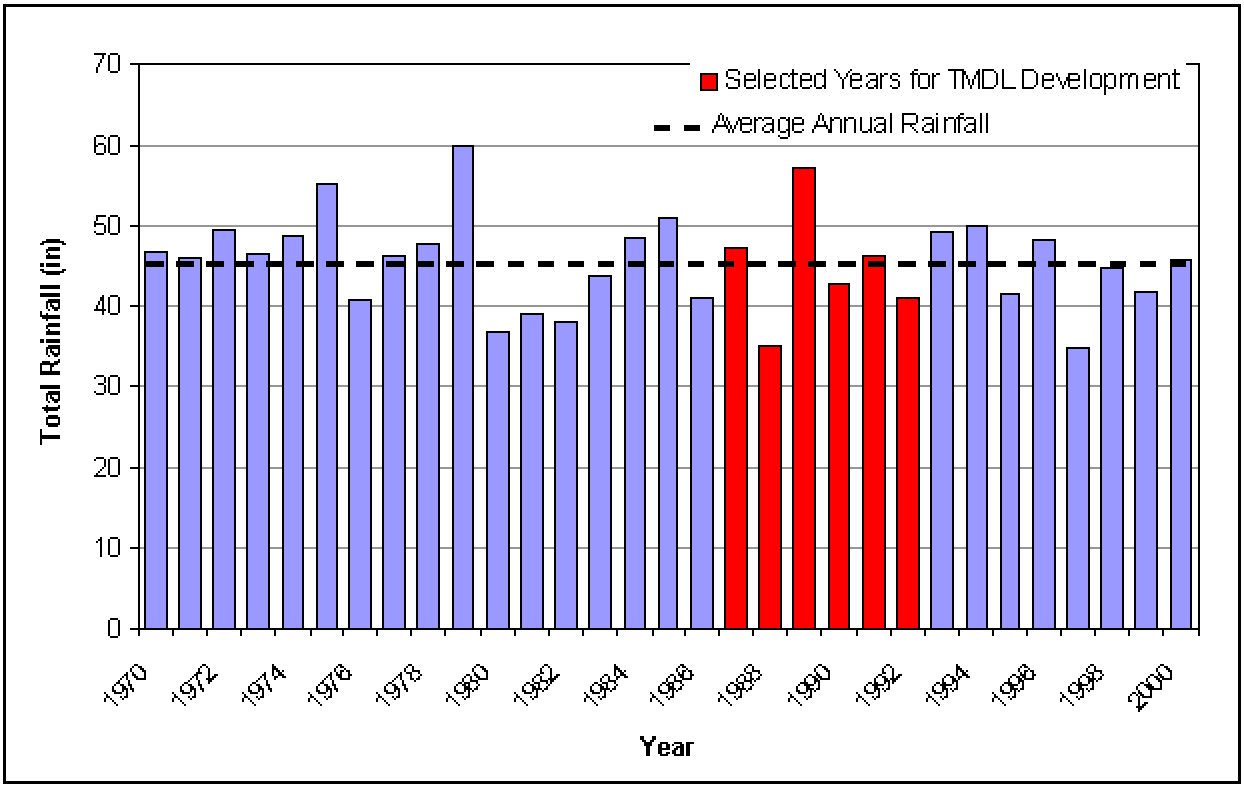


Figure 5-1. Annual Precipitation totals for the Davella, KY (KY2053) weather station

Permitted conditions for the West Virginia mining facilities mines were represented using precipitation-driven flow estimations and the metals concentrations presented in Table 5-1. The Kentucky mining permits were also represented by using precipitation-driven flow estimations, but representative DMR concentrations (calibration conditions) were used to represent metals concentrations.

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

Pollutant	Technology-based Permits	Water Quality-based Permits
Aluminum, total	3.6 mg/L (99th percentile DMR values)	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 in-stream metals concentrations. For example, loading contributions from abandoned mines, permitted facilities, and other nonpoint sources were individually adjusted and in-stream 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 (examples of TMDL plots for Left Fork of Sandlick Creek are shown in Figures 5-2 through 5-4). Exceedances for aluminum and iron were allowed once every three years. In general, loads contributed by abandoned mines and revoked mines were reduced first, because they generally had the greatest impact on in-stream concentrations. If additional load reductions were required to meet the TMDL endpoints, then subsequent reductions were made in sediment sources (Harvested Forest, Oil and Gas operations, and Roads) and in West Virginia, point source (permitted) contributions.

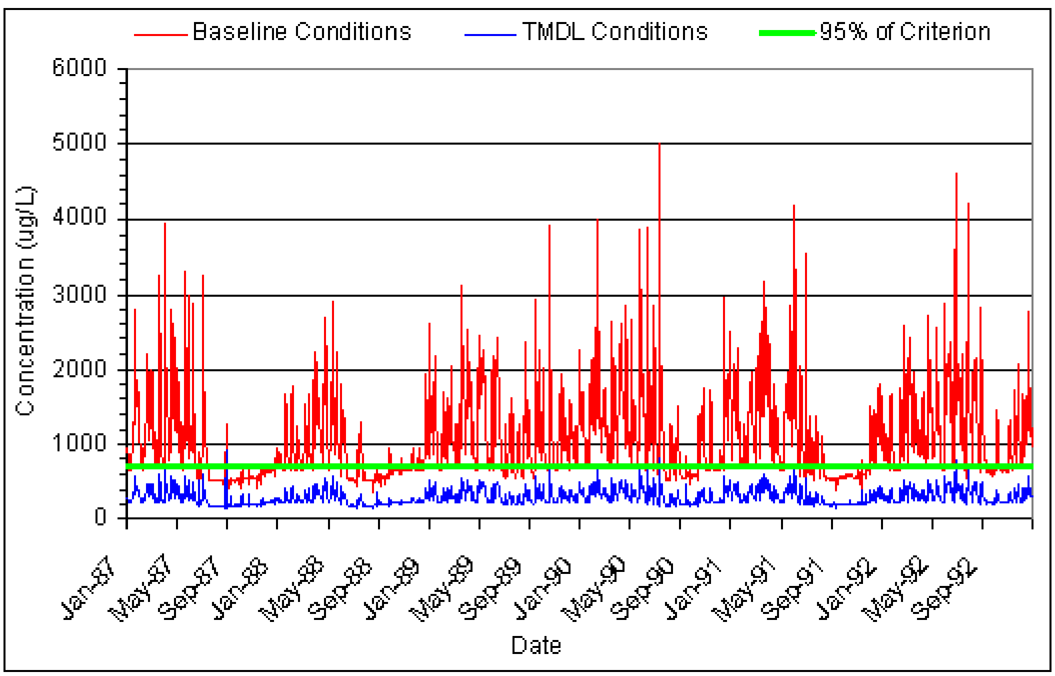


Figure 5-2. Total Aluminum baseline and TMDL conditions for Left Fork of Sandlick Creek (Sub ID 451).

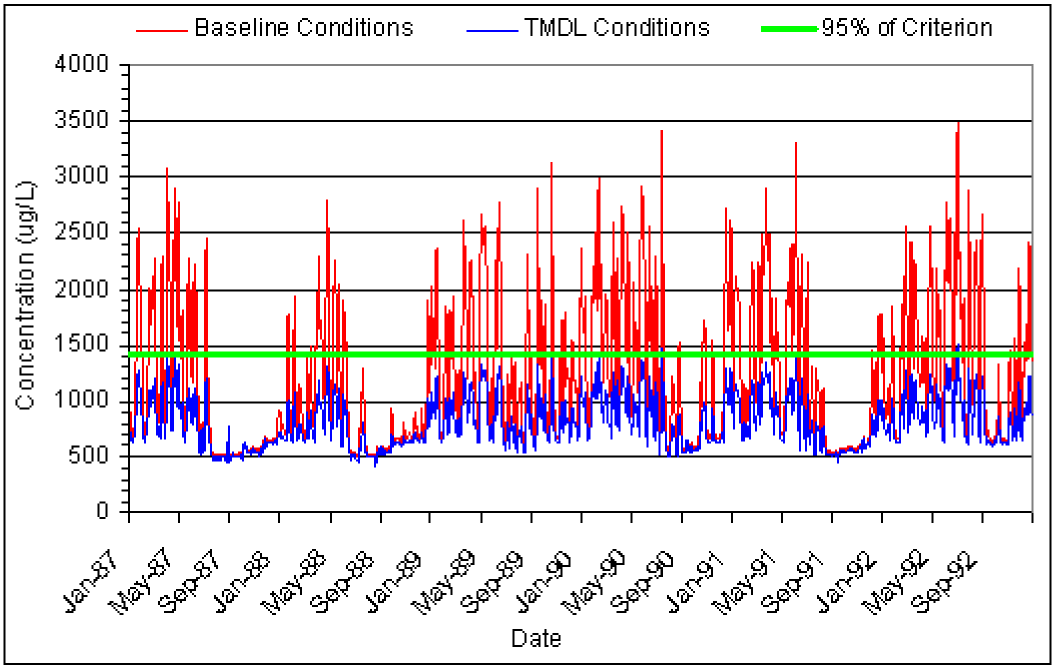


Figure 5-3. Total Iron baseline and TMDL conditions for Left Fork of Sandlick Creek (Sub ID 451).

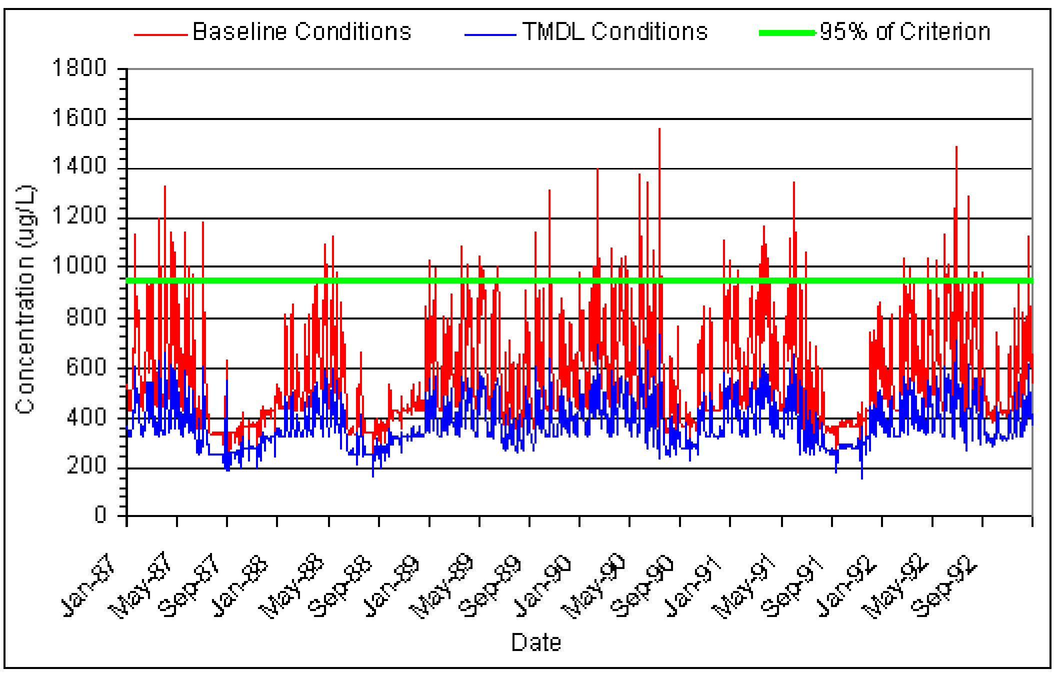


Figure 5-4. Total Manganese baseline and TMDL conditions for Left Fork of Sandlick Creek (Sub ID 451).

5.4 TMDLs and Source Allocations

A top-down methodology was followed to develop the TMDLs and allocate loads to sources. Headwaters were analyzed first, because their impact frequently had a profound effect on downstream water quality. In impaired subwatersheds, loading contributions were reduced to the extent necessary to ensure compliance with instream criteria, and the loading associated with that condition was transferred to downstream subwatersheds. Conversely, where MDAS indicated that the baseline condition was compliant with water quality criteria, the loading associated with the baseline condition was transferred to downstream subwatersheds. The required headwater reductions often led to downstream water quality improvements, effectively decreasing necessary loading reductions from downstream sources.

In some situations, reductions in sources contributing to unlisted stream segments have been determined necessary to ensure universal compliance with water quality criteria in the watershed. Recent water quality data is not available for all streams in the watershed and MDAS is the best technical tool available to determine if a particular permit is protective of water quality criteria. Other situations have been encountered where recent water quality data indicates that a particular stream segment is not impaired, yet the TMDL imposes point source wasteload allocations that represent a reduction of existing permit limitations. Certain permittees that are currently achieving discharge quality that is better than required by their permit may need to maintain such improved performance in order for the receiving water to consistently meet standards.

This methodology ensures water quality criteria compliance in all streams in the watershed, targets pollutant reductions from the primary causative sources of impairment, and minimizes the impact to existing point sources in the watershed.

The following general methodology was used when allocating to sources for the Tug Fork watershed TMDLs.

- For watersheds with AMLs but no permitted point sources, AMLs were reduced first, until in-stream water quality criteria were met or to conditions equivalent to undisturbed forest. If further reductions were required, then the sediment sources (Harvested Forest, Oil and Gas operations, and Roads) were reduced until water quality criteria were met. Source Reduction (AML) for SWS 301, Region 7 are shown in Table 5-2.

- For watersheds with AMLs and point sources, point sources were set at the precipitation induced load defined by the permit limits and AMLs were subsequently reduced. AMLs and revoked mining permits were reduced (point sources were not reduced) until in-stream water quality criteria were met, if possible. If further reduction was required once AMLs and revoked mines were reduced, sediment sources were then reduced. If even further reduction was required, the point source discharge limits were then reduced.

- Source contributions from the Kentucky and Virginia regions of the Tug Fork watershed were reduced to meet the water quality criteria in the Tug Fork mainstem only. These source reductions may result in localized improved water quality. However, the TMDL is neither intended nor designed to achieve compliance with the Kentucky and Virginia water quality criteria at the subwatershed level, nor based on the coarse resolution of the modeling effort can compliance be determined.

- A load allocation strategy for Kentucky and Virginia could not be developed because AML areas in the Kentucky and Virginia portion of the Tug Fork watershed have not been adequately defined to produce creditable allocations to a localized scale. Given that AML areas constitute a significant source of metals for the West Virginia portion of the watershed, it is expected that AML areas in Kentucky will produce significant loads, and these AML areas will need to be defined before an appropriate allocation strategy can be defined. Initial model runs indicate that even without the AML areas being included in the load reduction scenarios, reductions from nonpoint source contributions will result in the achievement of water quality standards for aluminum and iron in the main stem of the Tug Fork. Therefore, based on the results of this modeling project, it is not considered likely that permitted discharges from the Kentucky portion of the watershed will need to be reduced in order to meet water quality criteria in the Tug Fork main stem.

The TMDLs for the Tug Fork watershed were determined on a subwatershed basis for the subwatersheds located in West Virginia. The TMDLs for portions of the watershed in Kentucky and Virginia were determined on a regional basis.

Table 5-2. Source Reduction (AML) for SWS 301, Region 7 (Table 5-2)

Parameter	Landuse	Total Area (acres)	Base Load (lb/yr)	Base Unit Area Loading (lb/ac/yr)	Allocated Load (lb/yr)	Allocated Unit Area Loading (lb/ac/yr)
Iron	Mature Forest	2,462	2,170	0.88	2,170	0.88
Iron	Abandoned Mine Land	398	40,340	101.31	6,468	16.24
Manganese	Mature Forest	2,463	1,023	0.42	1,023	0.42
Manganese	Abandoned Mine Land	398	13,291	33.38	4,862	12.21
Aluminum	Mature Forest	2,464	1,384	0.56	1,384	0.56
Aluminum	Abandoned Mine Land	398	30,586	76.82	3,538	8.89

5.4.1 Wasteload Allocations (WLAs)

Waste load allocations (WLAs) were made for all facilities that are permitted to discharge aluminum, iron, and/or manganese. Limestone quarries are not permitted to discharge metals and therefore did not receive individual WLAs. Mining permits with a Completely released or Phase 2 released classification were represented as pasture land. For TMDL purposes, these 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.[1]

[1]The decision to assign load allocations to abandoned and reclaimed mine lands does not reflect any determination by EPA as to whether there are unpermitted point source discharges within these land uses. In addition, in establishing these TMDLs with mine drainage discharges treated as load allocations, EPA is not determining that these discharges are exempt from NPDES permitting requirements.

The WLAs for aluminum, iron, and manganese for the West Virginia permits are presented in Tables 4a, 4b, and 4c in Appendices A-1through A-5, A-7 through A-9, A-11, A-15 through A-17, and A-20. The WLAs are presented as annual loads, in terms of pounds per year and as constant concentrations. 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 as concentrations, 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 WLA concentration ranges are as follows: Al: 0.75-3.6 mg/L, Fe: 1.5 -3.2 mg/L, Mn: 1.0-2.0 mg/L.

5.4.2 Load Allocations (LAs)

Load allocations (LAs) for West Virginia were made for the dominant source categories, as follows:

- Abandoned mine lands - including abandoned mines (surface and deep) and high walls
- Revoked permits - loading from revoked permitted facilities
- Sediment sources - metals loading associated with sediment contributions from harvested forest, oil and gas well operations, and roads
- Other nonpoint sources - urban, agricultural, and forested land contributions (loadings from other nonpoint sources were not reduced)

The LAs for aluminum, iron, and manganese are presented in Tables 5a, 5b, and 5c of Appendices A-1 through A-5, A-7 through A-9, A-11, A-15 through A-17, and A-20. 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.

The allocations, by region, to the Kentucky and Virginia areas of the watershed are shown in Tables 6a and 6b of Appendices A-5, A-6, A-10, A-12, A-13, A-14, A-16, A-18 and A-20.

Tables 5-3, 5-4, and 5-5 present the sum of LAs and the sum of WLAs for aluminum, iron, and manganese, respectively, for each of the Section 303(d) listed segments. Table 5-6 presents the allocated loads to the Kentucky and Virginia areas of the watershed.

Table 5-3. West Virginia load and waste load allocations for aluminum

Region	SWS Outlet	WV DNR Code	WV DNR Name	LAs (lb/yr)	WLAs (lb/yr)	MOS (lb/yr)	TMDL (lb/yr)
20	1	BST	TUG FORK	622,132	168,253	39,519	1,516,381*
3	390	BST-100	LITTLE INDIAN CREEK	1,718	0	86	1,804
3	391	BST-102	JED BRANCH	127	193	16	336
3	394	BST-103	ROCK NARROWS BRANCH	878	222	55	1,154
3	395	BST-104	HARRIS BRANCH	241	0	12	253
3	397	BST-105	MITCHELL BRANCH	835	359	60	1,253
3	400	BST-106	SUGARCAMP BRANCH	1,578	114	85	1,777
4	399	BST-107	GRAPEVINE BRANCH	462	592	52	1,085
3	404	BST-109	SANDLICK CREEK	5,642	4,029	484	10,155

Region	SWS Outlet	WV DNR Code	WV DNR Name	LAs (lb/yr)	WLAs (lb/yr)	MOS (lb/yr)	TMDL (lb/yr)
3	450	BST-109-A	RIGHT FORK / SANLICK CK	1,158	584	87	1,829
3	451	BST-109-B	LEFT FORK / SANDLICK CR	1,420	1,435	143	2,997
3	405	BST-110	ADKIN BRANCH	831	431	63	1,325
3	408	BST-111	BELCHER BRANCH	566	385	48	999
3	409	BST-112	TURNHOLE BRANCH	788	201	49	1,039
3	411	BST-113	HARMON BRANCH	1,265	1,354	131	2,750
2	416	BST-115	SOUTH FORK / TUG FORK	8,290	9,479	888	18,658
2	437	BST-115-A	TEA BRANCH	286	0	14	300
2	439	BST-115-B	MCCLURE BRANCH	318	0	16	334
2	441	BST-115-D	JUMP BRANCH	543	721	63	1,327
2	444	BST-115-E	SPICE CREEK	1,871	1,795	183	3,849
2	446	BST-115-F	LAUREL BRANCH	1,175	1,523	135	2,832
2	447	BST-115-G	ROAD FORK	577	891	73	1,541
2	417	BST-116	BELCHER BRANCH	631	0	32	663
2	419	BST-117	LOOP BRANCH	1,091	0	55	1,145
2	422	BST-118	MILL BRANCH	549	0	27	576
2	423	BST-119	DRY BRANCH	319	0	16	335
2	425	BST-120	LITTLE CREEK	4,874	0	244	5,118
2	427	BST-120-A	INDIAN GRAVE BRANCH	867	0	43	910
2	429	BST-120-B	PUNCHEONCAMP BRANCH	895	0	45	939
2	431	BST-121	MILLSEAT BRANCH	1,454	0	73	1,527
2	434	BST-122	BALLARD HARMON BRANCH	863	698	78	1,639
2	435	BST-123	SAMS BRANCH	759	0	38	797
15	105	BST-24	PIGEON CREEK	77,430	35,913	5,667	119,010
15	129	BST-24-O	MILLSTONE BRANCH	833	47	44	923
20	10	BST-3	POWDERMILL BRANCH	904	0	45	950
20	146	BST-32	SUGARTREE CREEK	845	0	42	887
20	161	BST-33	WILLIAMSON BRANCH	627	0	31	658
20	166	BST-38	SPROUSE CREEK	662	956	81	1,699
11	177	BST-40	MATE CREEK	12,340	2,675	751	15,766
11	179	BST-40-B	RUTHERFORD BRANCH	662	0	33	695
11	181	BST-40-C	MITCHELL BRANCH	1,147	0	57	1,204
11	182	BST-40-D	CHAFIN BRANCH	234	0	12	246
11	190	BST-42	THACKER CREEK	4,301	0	215	4,516
11	191	BST-42-A	SCISSORSVILLE BRANCH	965	0	48	1,013
11	193	BST-42-B	MAUCHLINVILLE BRANCH	962	0	48	1,010
11	196	BST-43	GRAPEVINE CREEK	2,591	3,043	282	5,915
11	197	BST-43-A	LICK FORK	636	56	35	727
9	263	BST-60	PANTHER CREEK	30,352	323	1,534	32,209
9	270	BST-60-D	CUB BRANCH	355	0	18	373
8	289	BST-70-F	GRAPEVINE BRANCH	794	0	40	833
8	292	BST-70-I	BEARTOWN BRANCH	1,659	395	103	2,157
7	299	BST-70-O	ATWELL BRANCH	911	0	46	956
4	329	BST-76	CLEAR FORK	19,947	403	1,017	21,367
4	342	BST-78-B	SHABBYROOM BRANCH	933	0	47	980
4	344	BST-78-D	HONEYCAMP BRANCH	723	0	36	760

Region	SWS Outlet	WV DNR Code	WV DNR Name	LAs (lb/yr)	WLAs (lb/yr)	MOS (lb/yr)	TMDL (lb/yr)
4	347	BST-78-E	COONTREE BRANCH	443	0	22	465
4	348	BST-78-F	STONECOAL BRANCH	414	128	27	570
4	351	BST-78-G	BADWAY BRANCH	508	0	25	534
4	353	BST-78-H	NEWSON BRANCH	400	0	20	420
4	354	BST-78-I	MOORECAMP BRANCH	201	0	10	211
4	357	BST-85-A	LEFT FORK	1,178	0	59	1,237
4	362	BST-94	SHANNON BRANCH	1,788	0	89	1,878
4	364	BST-95	UPPER SHANNON BRANCH	1,683	0	84	1,767
4	369	BST-98-A	PUNCHEONCAMP BRANCH	1,893	0	95	1,988

* Represents the total aluminum loading for the entire Tug Fork watershed (including West Virginia, Kentucky, and Virginia)

Table 5-4. West Virginia load and waste load allocations for iron

Region	SWS Outlet	WV DNR Code	WV DNR Name	LAs (lb/yr)	WLAs (lb/yr)	MOS (lb/yr)	TMDL (lb/yr)
20	1	BST	TUG FORK	1,124,183	396,130	76,016	1,596,329
3	390	BST-100	LITTLE INDIAN CREEK	4,014	0	201	4,214
3	391	BST-102	JED BRANCH	583	172	38	792
3	394	BST-103	ROCK NARROWS BRANCH	1,259	198	73	1,530
3	395	BST-104	HARRIS BRANCH	647	0	32	679
3	397	BST-105	MITCHELL BRANCH	1,210	1,066	114	2,390
3	400	BST-106	SUGARCAMP BRANCH	2,248	102	117	2,467
3	399	BST-107	GRAPEVINE BRANCH	923	1,145	103	2,171
3	404	BST-109	SANDLICK CREEK	13,370	6,012	969	20,351
3	450	BST-109-A	RIGHT FORK / SANLICK CK	3,348	650	200	4,198
3	451	BST-109-B	LEFT FORK / SANDLICK CR	4,374	3,194	378	7,946
3	405	BST-110	ADKIN BRANCH	2,376	960	167	3,503
3	408	BST-111	BELCHER BRANCH	1,457	1,144	130	2,731
3	409	BST-112	TURNHOLE BRANCH	2,120	448	128	2,696
3	411	BST-113	HARMON BRANCH	3,706	4,823	426	8,955
2	416	BST-115	SOUTH FORK / TUG FORK	13,581	25,678	1,963	41,222
2	437	BST-115-A	TEA BRANCH	590	0	30	620
2	439	BST-115-B	MCCLURE BRANCH	777	0	39	816
2	441	BST-115-D	JUMP BRANCH	803	988	90	1,880
2	444	BST-115-E	SPICE CREEK	2,724	3,551	314	6,589
2	446	BST-115-F	LAUREL BRANCH	1,710	3,665	269	5,643
2	447	BST-115-G	ROAD FORK	1,889	2,644	227	4,760
2	417	BST-116	BELCHER BRANCH	911	0	46	956
2	419	BST-117	LOOP BRANCH	1,956	0	98	2,054
2	422	BST-118	MILL BRANCH	865	0	43	909
2	423	BST-119	DRY BRANCH	459	0	23	482
2	425	BST-120	LITTLE CREEK	7,836	0	392	8,228
2	427	BST-120-A	INDIAN GRAVE BRANCH	2,084	0	104	2,188
2	429	BST-120-B	PUNCHEONCAMP BRANCH	1,283	0	64	1,347

Region	SWS Outlet	WV DNR Code	WV DNR Name	LAs (lb/yr)	WLAs (lb/yr)	MOS (lb/yr)	TMDL (lb/yr)
2	431	BST-121	MILLSEAT BRANCH	2,092	0	105	2,196
2	434	BST-122	BALLARD HARMON BRANCH	2,371	1,243	181	3,794
2	435	BST-123	SAMS BRANCH	1,465	0	73	1,539
15	105	BST-24	PIGEON CREEK	119,484	146,939	13,321	279,744
15	129	BST-24-O	MILLSTONE BRANCH	1,196	41	62	1,299
20	10	BST-3	POWDERMILL BRANCH	1,297	0	65	1,362
20	146	BST-32	SUGARTREE CREEK	1,188	0	59	1,248
20	161	BST-33	WILLIAMSON BRANCH	892	0	45	936
20	166	BST-38	SPROUSE CREEK	956	3,406	218	4,579
11	177	BST-40	MATE CREEK	25,029	2,382	1,371	28,782
11	179	BST-40-B	RUTHERFORD BRANCH	955	0	48	1,003
11	181	BST-40-C	MITCHELL BRANCH	2,719	0	136	2,855
11	182	BST-40-D	CHAFIN BRANCH	344	0	17	361
11	190	BST-42	THACKER CREEK	9,269	0	463	9,733
11	191	BST-42-A	SCISSORSVILLE BRANCH	2,701	0	135	2,836
11	193	BST-42-B	MAUCHLINVILLE BRANCH	2,383	0	119	2,503
11	196	BST-43	GRAPEVINE CREEK	7,207	4,466	584	12,257
11	197	BST-43-A	LICK FORK	913	50	48	1,011
9	263	BST-60	PANTHER CREEK	46,038	288	2,316	48,642
9	270	BST-60-D	CUB BRANCH	505	0	25	530
8	289	BST-70-F	GRAPEVINE BRANCH	1,126	0	56	1,182
8	292	BST-70-I	BEARTOWN BRANCH	4,408	352	238	4,999
7	299	BST-70-O	ATWELL BRANCH	1,291	0	65	1,355
4	329	BST-76	CLEAR FORK	32,072	400	1,624	34,095
4	342	BST-78-B	SHABBYROOM BRANCH	2,224	0	111	2,335
4	344	BST-78-D	HONEYCAMP BRANCH	1,023	0	51	1,075
4	347	BST-78-E	COONTREE BRANCH	634	0	32	665
4	348	BST-78-F	STONECOAL BRANCH	1,053	114	58	1,226
4	351	BST-78-G	BADWAY BRANCH	718	0	36	754
4	353	BST-78-H	NEWSON BRANCH	974	0	49	1,023
4	354	BST-78-I	MOORECAMP BRANCH	289	0	14	304
4	357	BST-85-A	LEFT FORK	1,718	0	86	1,804
4	362	BST-94	SHANNON BRANCH	2,540	0	127	2,667
4	364	BST-95	UPPER SHANNON BRANCH	2,389	0	119	2,509
4	369	BST-98-A	PUNCHEONCAMP BRANCH	2,690	0	134	2,824

* Represents the total iron loading for the entire Tug Fork watershed (including West Virginia, Kentucky, and Virginia)

Table 5-5. West Virginia load and waste load allocations for manganese

Region	SWS Outlet	WV DNR Code	WV DNR Name	LAs (lb/yr)	WLAs (lb/yr)	MOS (lb/yr)	TMDL (lb/yr)
20	1	BST	TUG FORK	426,417	249,477	33,795	1,084,885*
3	390	BST-100	LITTLE INDIAN CREEK	2,674	0	134	2,808
3	391	BST-102	JED BRANCH	358	107	23	488
3	394	BST-103	ROCK NARROWS BRANCH	398	123	26	547
3	395	BST-104	HARRIS BRANCH	418	0	21	439
3	397	BST-105	MITCHELL BRANCH	406	664	53	1,123
3	400	BST-106	SUGARCAMP BRANCH	680	63	37	781
4	399	BST-107	GRAPEVINE BRANCH	148	357	25	529
3	404	BST-109	SANDLICK CREEK	6,451	3,746	510	10,706
3	450	BST-109-A	RIGHT FORK / SANLICK CK	1,965	405	118	2,488
3	451	BST-109-B	LEFT FORK / SANDLICK CR	1,387	1,990	169	3,546
3	405	BST-110	ADKIN BRANCH	952	598	78	1,628
3	408	BST-111	BELCHER BRANCH	860	713	79	1,652
3	409	BST-112	TURNHOLE BRANCH	931	279	60	1,270
3	411	BST-113	HARMON BRANCH	1,736	3,004	237	4,978
2	416	BST-115	SOUTH FORK / TUG FORK	4,670	16,132	1,040	21,842
2	437	BST-115-A	TEA BRANCH	191	0	10	200
2	439	BST-115-B	MCCLURE BRANCH	364	0	18	383
2	441	BST-115-D	JUMP BRANCH	298	615	46	959
2	444	BST-115-E	SPICE CREEK	934	2,212	157	3,304
2	446	BST-115-F	LAUREL BRANCH	586	2,283	143	3,012
2	447	BST-115-G	ROAD FORK	619	1,647	113	2,380
2	417	BST-116	BELCHER BRANCH	297	0	15	311
2	419	BST-117	LOOP BRANCH	688	0	34	723
2	422	BST-118	MILL BRANCH	280	0	14	294
2	423	BST-119	DRY BRANCH	147	0	7	155
2	425	BST-120	LITTLE CREEK	2,546	0	127	2,674
2	427	BST-120-A	INDIAN GRAVE BRANCH	724	0	36	760
2	429	BST-120-B	PUNCHEONCAMP BRANCH	404	0	20	425
2	431	BST-121	MILLSEAT BRANCH	671	0	34	704
2	434	BST-122	BALLARD HARMON BRANCH	1,181	774	98	2,053
2	435	BST-123	SAMS BRANCH	474	0	24	498
15	105	BST-24	PIGEON CREEK	36,170	92,800	6,448	135,418
15	129	BST-24-O	MILLSTONE BRANCH	379	26	20	425
20	10	BST-3	POWDERMILL BRANCH	415	0	21	435
20	146	BST-32	SUGARTREE CREEK	344	0	17	361
20	161	BST-33	WILLIAMSON BRANCH	270	0	14	284
20	166	BST-38	SPROUSE CREEK	314	2,121	122	2,557
11	177	BST-40	MATE CREEK	12,867	1,484	718	15,068
11	179	BST-40-B	RUTHERFORD BRANCH	311	0	16	326

Region	SWS Outlet	WV DNR Code	WV DNR Name	LAs (lb/yr)	WLAs (lb/yr)	MOS (lb/yr)	TMDL (lb/yr)
11	181	BST-40-C	MITCHELL BRANCH	1,751	0	88	1,838
11	182	BST-40-D	CHAFIN BRANCH	122	0	6	128
11	190	BST-42	THACKER CREEK	4,165	0	208	4,373
11	191	BST-42-A	SCISSORSVILLE BRANCH	1,804	0	90	1,895
11	193	BST-42-B	MAUCHLINVILLE BRANCH	1,276	0	64	1,340
11	196	BST-43	GRAPEVINE CREEK	3,437	2,782	311	6,529
11	197	BST-43-A	LICK FORK	289	31	16	336
9	263	BST-60	PANTHER CREEK	13,545	179	686	14,411
9	270	BST-60-D	CUB BRANCH	149	0	7	157
8	289	BST-70-F	GRAPEVINE BRANCH	331	0	17	348
8	292	BST-70-I	BEARTOWN BRANCH	1,523	219	87	1,829
7	299	BST-70-O	ATWELL BRANCH	378	0	19	396
4	329	BST-76	CLEAR FORK	13,971	249	711	14,931
4	342	BST-78-B	SHABBYROOM BRANCH	1,469	0	73	1,543
4	344	BST-78-D	HONEYCAMP BRANCH	296	0	15	311
4	347	BST-78-E	COONTREE BRANCH	197	0	10	207
4	348	BST-78-F	STONECOAL BRANCH	700	71	39	810
4	351	BST-78-G	BADWAY BRANCH	205	0	10	216
4	353	BST-78-H	NEWSON BRANCH	485	0	24	510
4	354	BST-78-I	MOORECAMP BRANCH	93	0	5	98
4	357	BST-85-A	LEFT FORK	553	0	28	581
4	362	BST-94	SHANNON BRANCH	754	0	38	792
4	364	BST-95	UPPER SHANNON BRANCH	725	0	36	761
4	369	BST-98-A	PUNCHEONCAMP BRANCH	799	0	40	838

* Represents the total manganese loading for the entire Tug Fork watershed (including West Virginia, Kentucky, and Virginia)

Table 5-6. Aluminum and iron allocations for the Kentucky and Virginia portions of the Tug Fork watershed

Parameter*	State	Σ(LAs+WLAs) (lb/yr)	MOS (lb/yr)
Total Aluminum	Kentucky	547,656	27,383
Total Aluminum	Virginia	106,131	5,307
Total Iron	Kentucky	695,969	34,798
Total Iron	Virginia	149.027	7,451
Total Manganese	Kentucky	316,002	15,800
Total Manganese	Virginia	41,328	2,066

*Tug Fork is not listed by West Virginia for manganese impairments.

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 Section 4.4), equilibrium pH was estimated to be 8.47 using the aquatic life standard (1.5 mg/L total Fe) and 8.49 using the trout waters standard (0.5 mg/L total Fe). For the scenario representative of mining areas, typical in-stream 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 if metals concentrations meet water quality criteria.

5.4.4 Critical Conditions and Seasonal Variation

A TMDL must consider seasonal variation in the derivation of the allocation. For the Tug Fork 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 critical conditions were 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.

5.4.5 Future Growth

This Tug Fork TMDL does not include specific future growth allocations to each subwatershed. Because of the general allocation philosophy used in this TMDL, such allocations would be made at the expense of active mining point sources in the subwatershed. However, the absence of specific future growth allocations does not prohibit new mining in the subwatersheds where the in-stream water quality is at the water quality criteria for the allocation scenario. Future growth could occur in the subwatershed under the following scenarios:

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.

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 West Virginia University, the West Virginia Division of Natural Resources, the United States Office of Surface 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 Division of Mining and Reclamation's Special Reclamation Program remedies sites where operating permits have been revoked and/or performance bonds have been forfeited. 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 tax 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 30 U.S.C. " 1231-1243) is designed to help reclaim and restore coal mine areas abandoned prior to 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 30 U.S.C. ' 1233.

Priorities:

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

effects related to coal mining practices.

- Priority Three: 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 One and Two 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 Three problem areas and on treating and abating water quality problems associated with abandoned mine lands. By 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 down-stream benefits to the ecosystem, and diverse cooperators and stakeholders, will be 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 utilize 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 subsequently 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 the establishment of post-construction sampling networks to assess the impacts of remediation efforts. The Protocol is iteratively implemented until all focus areas have been addressed and all feasible pollution abatement technologies have been applied.

Table 6-1 displays the status and costs of abandoned mine land projects occurring within the Tug Fork River watershed.

Table 6-1. Abandoned Mine Land Projects in the Tug Fork watershed.

Project	County	Cost	Status
Jacobs Fork Complex	McDowell	$375,000	In-Design
Maybeury (Hastings) Drainage	McDowell	$75,000	In-Design
Elkhorn (Gravely) Drainage	McDowell	$40,000	In-Design
War (Dash) Impoundment	McDowell	$100,000	In-Design
Twin Branch Portal	Mingo	$140,000	In-Design
Apple Grove Complex	McDowell	$188,000	In-Design
Jenkin Jones Refuse Piles	McDowell	$880,000	In-Design
Bearwallow Branch Refuse Pile	McDowell	$265,000	In-Design
North Matewan (Sipple) Drainage	Mingo	$115,000	In-Design
East Ragland Complex	Mingo	$142,000	In-Design
Bartley Dump	McDowell	$2,000,000	In-Design
North Fork Refuse Pile	McDowell	$659,000	Under Construction
Wilco (Johnson)	McDowell	$111,667	Under Construction
Carswell Hollow (Smith) Refuse	McDowell	$390,688	Under Construction
Superior (Poca Land) Complex	McDowell	$130,979	Under Construction
Turkey Gap Refuse Pile	McDowell	$440,100	Under Construction

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 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 insure 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 sub-divided into smaller groupings. The first sub-group 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 high loadings of acid mine drainage.

3b. The second sub-group would include 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 sub-group includes sites near high-use public recreation areas and major thoroughfares.

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

Reclamation construction contracts occur by submittal 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 one-year contract warranty period begins to insure 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 AMD, treatment operations are conducted pursuant to the authority granted in the West Virginia Surface Coal Mining and Reclamation Act. Due to funding deficits and regulatory restrictions on the amount of funding that could be applied to water treatment, the Special Reclamation Group historically conducted active treatment operations only at the highest priority bond forfeiture sites (i.e those with the highest potential for significant water quality impact). Recent legislation increased funding for the Special Reclamation Fund and removed restrictions relative to water treatment expenditures. The Special Reclamation plans to abate all impacting AMD from existing Bond Forfeiture sites over the next five years.

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 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 Tug Fork watershed are scheduled to be reissued in 2003.

7.0 Monitoring Plan

Follow-up monitoring of the Tug Fork River watershed is recommended. Future monitoring can be used to evaluate water quality conditions, changes or trends in water quality conditions, and 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 Tug Fork River (tributaries) via its established Watershed Management monitoring approach in 2002, 2007 and beyond.

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 Quality Control (QA/QC) protocols to avoid potential sample contamination during water sample collection and transfer

On the Kentucky portion of the watershed, chemical water quality data collection (which includes quantitative metals and total suspended solids information) has historically been done at 2 sites on the main stem of the Tug Fork. They are Tug Fork at Freeburn and Tug Fork at Kermit, which have been sampled at least every other month for the past several years. For the period April 2002 to March 2003, these sites will be sampled monthly. Additional sites will also be sampled monthly during this period for selected metals (including aluminum and iron) and for total suspended solids. Biological assessments are also being done on all 4th order streams within the Big Sandy River watershed during 2002. These assessments will not provide a determination of metals impairment, but should provide a qualitative determination of siltation in these streams. For additional information on the Kentucky Watershed Framework and the Big Sandy River Basin (including Tug Fork), visit the web page at http://kywatershed.org.

8.0 Public Participation

EPA 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, it is the intent of the West Virginia DEP to solicit public input by providing opportunities for public comment and review of the draft TMDLs. The public meetings pertaining to the Tug Fork waterrshed occurred as follows:

A 35-day public comment period began on July 22, 2002, and ended on August 26, 2002. WVDEP published notice of the public comment period in the *Williamson Daily News*, Williamson and *Welch Daily News*, Welch newspapers. A final public informational meeting was held Agust 13, 2002, in Welch or the Tug Fork River TMDLs.