west virginia dep department of environmental protection

Tug Fork Watershed

A summary of the Watershed Assessment Section's 1998 & 2003 monitoring efforts

INTRODUCTION

The West Virginia Department of Environmental Protection's (DEP) Watershed Assessment Section (WAS) assesses watersheds of the state by monitoring biological integrity, water quality, and habitat condition. Each watershed is monitored on a five-year cycle. Tug Fork watershed was monitored in 1998 and again in 2003. This summary report is based upon data generated from these efforts.

DESCRIPTION

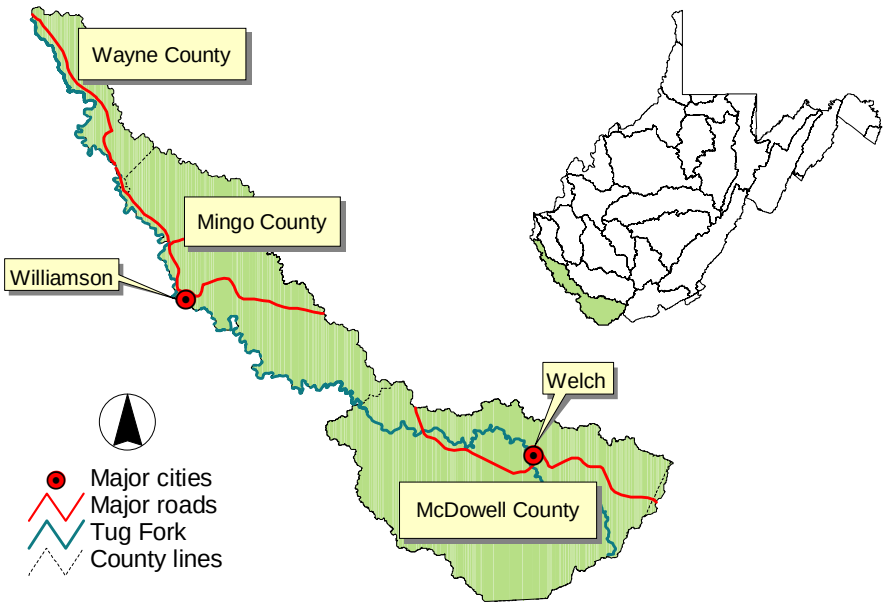
The Tug Fork of Big Sandy River received its name during the 1756 winter campaign of Cherokees and Virginians against the Shawnees during the French & Indian War. A few companies of soldiers returning home against orders followed the north fork of "Sandy Creek," as the stream was commonly called. Near starvation, the men boiled their rawhide "tugs" (straps/laces) used for tying gear to their packs and drank the soup (Brown 1851). This fork became known as the "Tug" Fork, to distinguish it from the Dry Fork. Eventually, the name also was applied to that portion of "Sandy Creek" downstream of the forks all the way to the confluence with Levisa Fork.

The portion of the Tug Fork watershed that lies within West Virginia drains lands in McDowell, Mingo, and Wayne counties, and it encompasses a 932 square mile area (Figure 1). Steep-sided hills and mountains with numerous rock cliffs make this watershed one of the most rugged in West Virginia.

Almost all the rock strata exposed in the watershed are classified as Pennsylvanian Age. The alkaline nature of most of the strata has resulted in soils and streams well-buffered against acidic atmospheric deposition.

Photo by Doug Wood

Figure 1. Location map



Streams of the Cumberland Mountains Subecoregion of the Central Appalachians Ecoregion (Omernik, et. al. 1992) typically have moderate to steep gradients and substrates composed of significant amounts of sand. The streams within the Tug Fork watershed are no different than other streams in this subecoregion, with alternating riffle/run/pool habitats sporting sand deposits in the pools and slower runs.

In the early part of the 20th Century, railroads opened up the watershed for extensive coal mining (Williams 1976). Human population increased dramatically during the first coal boom period and inadequate sewage disposal has contributed to water quality degradation ever since. Metal-laden mine water from deep and surface mines continues to impact the

SAMPLING SUMMARY

Named streams in watershed	522
Named streams visited	119
Sites visited	207
Habitat assessment sites	174
Water quality sampling sites	176
Benthic sample sites	173
Comparable benthic sites	167
Random sites	63
Reference sites	6

streams of the Tug Fork watershed. The Tug Fork watershed has numerous valley fills (Fig. 16), some represented well in the DEP database, some under-represented (Shank 2004).

ECO-ASSESSMENT

The watershed was assessed in 1998 and 2003 using biological, water quality, and habitat evaluation techniques. The evaluation of these three key ecological components allows the agency to generate a clearer picture of stream health than single component assessment would allow. The sampling techniques and assessment methods for each of the components are presented in the following paragraphs. These techniques and methods are based upon Rapid Bioassessment Protocols (RBPs) developed for the U.S. Environmental Protection Agency (EPA) and published in a document titled *Rapid Bioassessment Protocols for Use in Streams and Rivers - Benthic Macroinvertebrates and Fish* (Plafkin et al. 1989). An updated version of this document can be viewed and downloaded from the following website: http://www.epa.gov/owow/monitoring/rbp/download.html. The diversity of applications provided by the RBPs was the primary reason they were adopted by the Watershed Assessment Section for use in assessing watersheds.

BIOLOGICAL SAMPLING

Benthic macroinvertebrates are small animals without backbones that live on the bottoms of streams and lakes. Insects comprise the largest diversity of these animals, but snails, mussels, aquatic worms, and crayfish are also members of the benthic community. These animals are important in the processing and cycling of nutrients, and are major food sources for fish and other aquatic animals. In general, a clean stream has a diverse array of benthic organisms that occupy a variety of ecological niches. Polluted streams generally have a lower diversity and often are devoid of pollution sensitive species.

Photo by Mike Sovic

Benthic macroinvertebrates can be collected using several techniques. The Watershed Assessment Section used the EPA's RBP II with some modifications. Because the vast majority of stream miles in the state have riffle/run habitat, the "Single Habitat Approach" was the benthic collection method adopted by the Watershed Assessment Section. In each stream with adequate riffle/run habitat, the Watershed Assessment Section used a rectangular-frame kick-net to capture organisms dislodged by kicking and brushing substrate objects in a specified area (two square meters in 1998 and one square meter in 2003).

Determining the biological condition of each site involved calculating and summarizing six community metrics based upon the benthic macroinvertebrate data:

- Total taxa
- EPT index (See glossary)
- % 2 dominant taxa
- % EPT (See glossary)
- % Chironomids
- Hilsenhoff's biotic index (modified)

The six benthic community metrics were combined into a single index, the West Virginia Stream Condition Index (WVSCI) developed by Tetra Tech Inc. (Gerritsen et. al. 2000) using the DEP's watershed assessment data. The WVSCI has proven itself a useful and cost effective tool for assessing the health of West Virginia's streams. The impairment categories developed within the WVSCI are important tools the Watershed Assessment Section uses in making management decisions and in allocating limited resources to the streams that need them most.


Photo by Karen Maes


Photo by Ashley Thomas

WATER QUALITY SAMPLING

Numerous disease-causing organisms may accompany fecal coliform bacteria, which are released to the environment in feces. Therefore, the presence of such bacteria in a water sample indicates the potential presence of human pathogens. A fecal coliform bacteria sample was collected at nearly every assessment site during this study.

Physicochemical samples were collected at each site to help determine what types of stressors, if any, were negatively impacting each benthic community. The physicochemical data were helpful in providing clues about the sources of stressors. Some of the more important physicochemical parameters studied are found in the tables at the back of this document.

Assessment teams measured stream flow when field readings indicated there was mine drainage impacting the stream. These measurements helped in the calculation of total maximum daily loads (TMDL) of mine pollutants in a subsequent study.

Photo by Doug Wood

HABITAT EVALUATION

An eight-page stream assessment form was completed at each site. At most sites, a 100-meter section of stream and the land in its immediate vicinity were qualitatively evaluated for instream and streamside habitat conditions. The teams recorded physical stream measurements, erosion potential, possible point and nonpoint sources of pollution, and any anthropogenic activities and disturbances. They also recorded observations about the substrate, water, and riparian zone.

SUMMARY OF KEY STRESSORS

Alkaline mine drainage (metals & dissolved solids).

Acid mine drainage (pH & metals).

Inadequately treated sewage.

Excess sediment deposition.

Inadequate riparian buffer zone.

Dredging & channelization.

Photo by Maggie Montali

An important part of each assessment was the completion of a two-page rapid habitat assessment form, which produced a numerical score of the habitat conditions most likely to affect aquatic life. The following 10 parameters were evaluated:

- Epifaunal substrate/fish cover
- Riffle frequency
- Embeddedness
- Channel flow status
- Velocity/depth regimes
- Bank stability
- Channel alteration
- Bank vegetative protection
- Sediment deposition
- Width of undisturbed vegetation zone

While all the parameters measure important aspects of stream habitat, some affect the benthic community at the specific location more than others. *Embeddedness* is the measurement of the amount of silt and sand surrounding the larger substrate particles (cobbles and boulders). Embedding limits the interstitial space (areas between and below cobbles and boulders) that benthic organisms depend on for shelter and for finding food. Figure 2 illustrates stream substrate embeddedness.

Another important habitat parameter is the *width of undisturbed vegetation zone*. The condition of the land next to a stream has an important effect on the instream conditions (see Figure 3). An intact riparian zone, (i.e., one with a combination of mature trees, saplings, and ground cover), serves as a buffer to pol-

Figure 2. Illustration of embeddedness (cross section)

The view on the left is heavily embedded with sand and silt. Notice the different amounts of interstitial space (the space between the rocks and gravel).

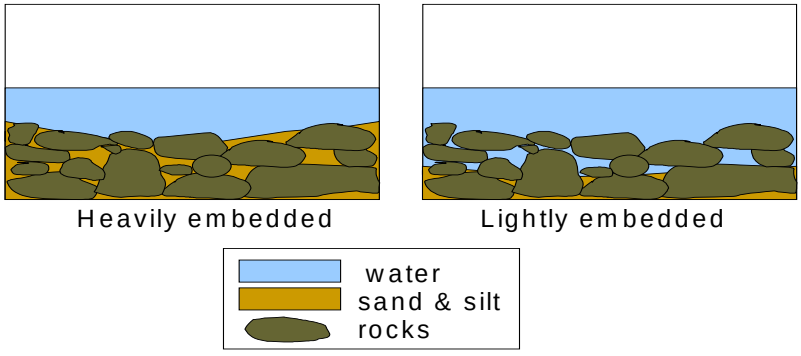
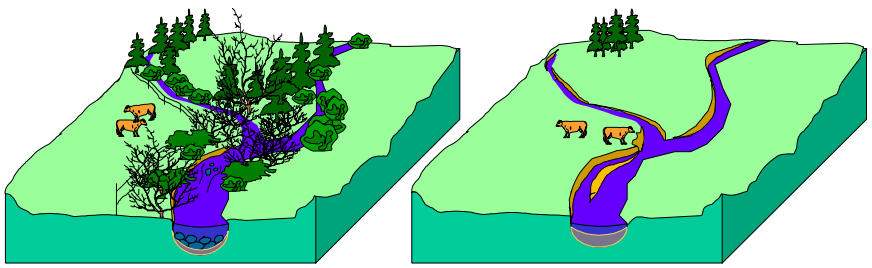


Figure 3. Stream with and without riparian buffer zone



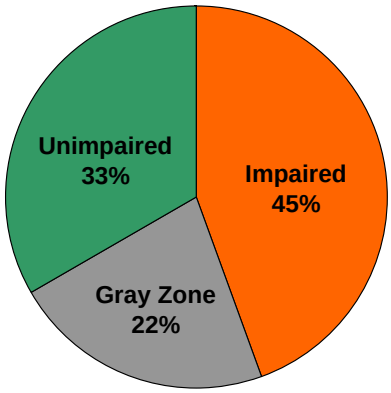
lutants entering a stream from runoff, controls erosion, and provides habitat and slow-release nutrient input into the stream.

ASSESSMENT RESULTS

This section discusses the results of the three ecological components assessed at each stream sampling site within the Tug Fork watershed. A variety of techniques were used to evaluate the results of the sampling efforts. Essentially, three data sets were used in this evaluation: (1) data from all comparably sampled sites (targeted and randomly selected) within the Tug Fork watershed for the years 1998 and 2003, (2) data from only randomly selected sites within the Tug Fork watershed for 1998, and (3) data from all randomly selected sites statewide (including Tug) for the years 1997 through 2001. Differences in stream site selection criteria (e.g., criteria for targeted site selection or criteria for random site selection) require separate consideration of individual sampling sites if detailed analyses are to be performed. Such detailed, individual analyses of each data set have been performed in the development of (TMDL's), 303(d) impaired stream reach lists, stream protection category lists (such as Tier 2.5), and 305(b) water quality assessments.

Greater confidence in data evaluation can be achieved by selecting sampling sites in a random fashion. Several of the charts and graphs in this report compare the results of data analyses between the random samples collected from the Tug Fork watershed in 1998 and those collected statewide (including Tug Fork in 1998) within the five-year cycle (1997-2001). These analyses are identified in the graphs as *random data* and in the text as either *random data* or *random weighted data*.

Fig. 4. % sites in WVSCI ranges, Tug Fk., 98 & 03



BIOLOGICAL SAMPLING

Of the 124 comparable samples collected in 1998, 59 (approximately 48%) had WVSCI scores of 60.6 or lower, thus placing them in the impaired category. Forty-five (approximately 36%) samples scored in the unimpaired category. The "gray zone" is the range in which a definitive call cannot be made because the variability in results found in duplicate sampling indicates that, within this range, certainty of impairment status is low. Further sampling is often conducted on streams with gray zone sites. The remaining 20 (approximately 16%) samples had WVSCI scores in the "gray zone."

In 2003, only 43 comparable benthic samples were collected. Of these, nine (approximately 21%) scored in the unimpaired category, and 25 (approximately 58%) fell within the impaired category. Those samples within the gray zone comprised approximately 21% of the total.

Figure 5 illustrates the ranges of the

Fig. 5. Relative rank of Avg. WVSCI of subwatersheds

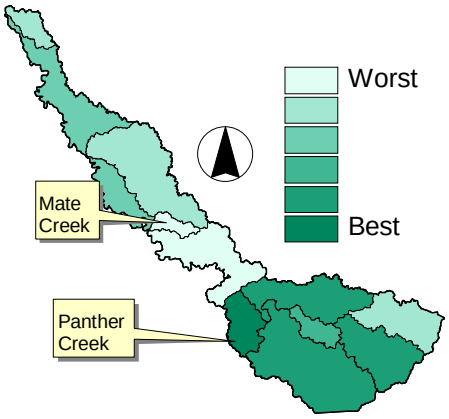
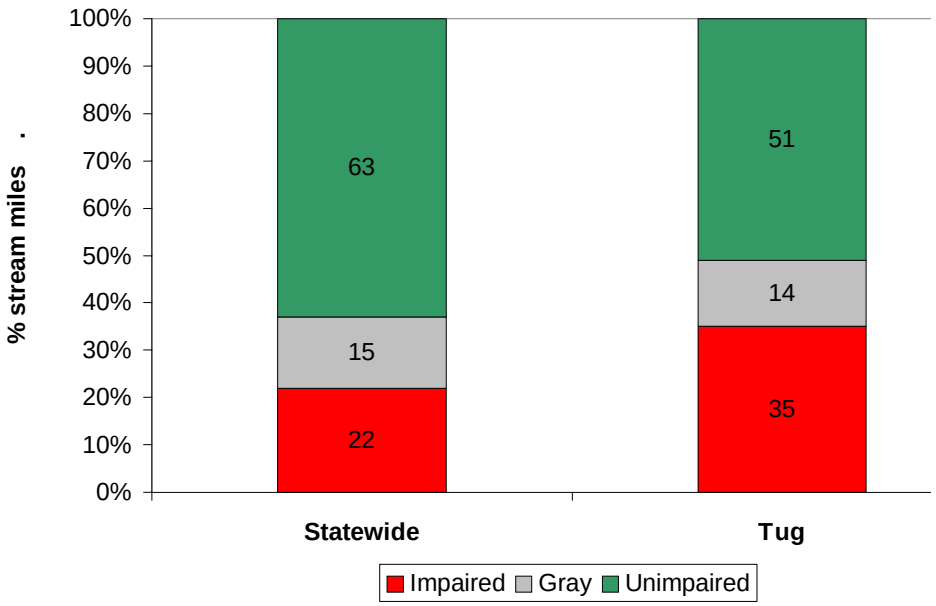


Fig. 6. Random data,% stream miles in WVSCI ranges, Tug Fork vs. statewide



WVSCI score averages by subwatershed for the combined 1998 and 2003 data. The *Panther Creek* subwatershed had the highest average score (approximately 73.13) and the *Mate Creek* subwatershed had the lowest average score (46.08).

Figure 6 contrasts the Tug Fork watershed's showing in the WVSCI categories relative to the statewide random dataset. A greater percentage of stream miles in the Tug Fork watershed were impaired than statewide.

WATER QUALITY SAMPLING

Water was collected from 129 sites in 1998 and 41 sites in 2004 to measure fecal coliform bacteria concentrations. Many sites had very high levels, 12 with 20,000 or more/100mL. The majority of sites (nearly 57%) in 1998 had levels above 400/100mL, which is a flag value based upon the state's water quality standard for contact recreation. In order for a stream to meet the water quality standard, bacteria cannot exceed this level in more than 10 percent of all samples taken during a month. In 2003, approximately 48% exceeded this flag value.

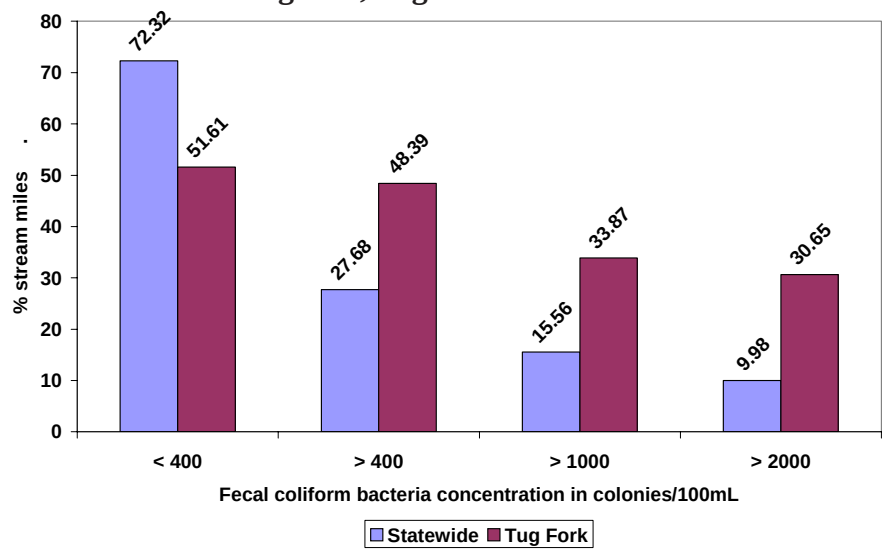
The percentage of stream miles that exceeded this bacteria threshold in the Tug Fork watershed was greater than that in the statewide random data set (Fig. 7). Note also the higher percentage in the Tug Fork watershed over even higher levels of bacteria concentration (1,000/100mL and 2,000/100mL).

Most of the high bacteria levels were found near residential areas. It is sometimes difficult to determine the sources of bacterial contamination. However, the Tug Fork watershed hosted very little farm livestock (and that mostly in the northwestern one-fifth of the watershed) and wildlife populations were not considered overabundant. Therefore, untreated and inadequately treated sewage were the most likely primary sources of high bacteria concentrations. Many assessment forms' notes support this reasoning.

In 1998, 56 of the specific conductance readings (approximately 42%) from all sample sites were greater than 500 µmhos/cm, and only 13 (approximately 9%) produced values below 100 µmhos/cm. These percentages were approximately 60% and 2%, respectively, in 2003.

In 1998, approximately 9% of the samples had iron concentrations greater than the acute criterion for warmwater fisheries of 1.5 mg/L, and approximately 4% had manganese levels above the human health criterion of 1.0 mg/L. However, this criterion is only applicable in stream reaches extending five miles above drinking water source points. No samples were collected for dissolved aluminum in 1998, but in 2003, 26 samples (see table 12), including two duplicates, were analyzed for that constituent. None violated the chronic water quality standard for warmwater fisheries (not to exceed 750 µg/L). In 2003, only approximately 3% of the iron samples exceeded the water quality standard and none violated the human health standard for manganese.

Fig. 7. Random data,% stream miles in various FC bacteria categories, Tug Fork vs. statewide

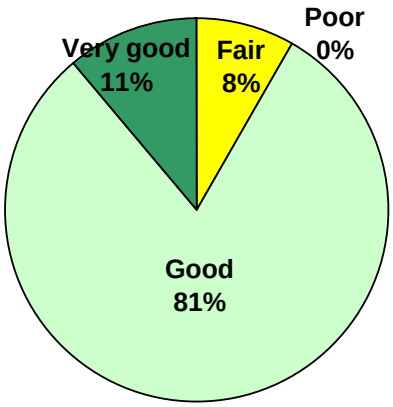


HABITAT EVALUATION

The average scores for most RBP habitat parameters were in the good range. One parameter, *riffle frequency*, was in the very good range and another, *width of undisturbed vegetation zone* was in the fair range. Ten sites had very good total habitat scores (160 or greater out of a total of 200). Twenty-six sites had total habitat scores in the fair range (below 100) and the rest (171 sites) had totals in the good range. Figure 8 illustrates the percentages of total habitat scores within the four ranges.

At each site, field crews noted the presence of activities and disturbances that could have been affecting the streams. The type of disturbance observed most often was roadways. Other fairly common disturbances, in descending order, were power lines, residences, and lawns. Coal mines or preparation plants were located near a few sites. Many streams were physically altered by channelization and by the addition of riprap. None of the sampling sites were adjacent to hayfields or pastures.

Fig. 8. % sites in RBP habitat ranges, Tug Fk., 98 & 03



Many environmentally-aware and community-minded citizens within the watershed have formed civic organizations, watershed associations, and other groups to help solve environmental problems that plague the watershed. A notable problem these groups are currently tackling through stream sweep cleanups, often in conjunction with DEP's and Division of Natural Resources' "litter gitter" enforcement efforts, is the illegal dumping of human refuse. The extent of this problem is reflected in the watershed's aesthetic/trash

visual rating compared to those in other watersheds throughout the state (Fig. 9). In recent years, the actions of these groups have shown hopeful outcomes.

It should be noted that the results of non-random sampling are biased towards more developed areas because of one of the sample site selection methods used by the Watershed Assessment Section. Many streams were sampled at the road crossings nearest to their mouths and upstream of bridges or culverts. Often, this practice puts assessment teams in locations with a good deal of human disturbances. This is especially true in watersheds like Tug Fork's where razor-backed ridges and steep slopes limit residential, industrial, and business developments to the narrow stream valleys.

However, the random weighted data do not have this bias. Figure 10 indicates that the Tug Fork watershed fared slightly better in the RBP categories than did the statewide data set. A slightly higher percentage of Tug Fork stream miles had total RBP habitat scores in the very good range and a slightly lower percentage had scores in the fair range.

The random data set also shows slightly better conditions overall in the combined habitat parameter category of embeddedness plus sediment deposition. Figure 11 indicates that the percentage of Tug Fork watershed stream miles in the very good category was less than that percentage statewide (approximately 10% less). However, nearly 20% more Tug Fork stream miles than statewide stream miles scored in the good category. In addition, nearly 9% fewer Tug Fork stream miles than statewide stream miles scored in the fair category.

Figure 12 shows the relationship between the WVSCI scores and the total scores from the RBP Habitat Assessments for all comparably sampled sites in 1998 and 2003. There is only a weak positive correlation between the two scores (R = +0.3793341 at the 95% confidence interval). In most ecological assessments this usually indicates that factors (e.g., water quality or unusual climatological events) other than habitat quality are determining the condition of many biological communities within the study area. In the Tug Fork watershed, water quality is probably the driving force behind benthic community conditions at most of the sites sampled.

Fig. 9. Random data, % stream miles with poor aesthetic/trash visual rating for all watersheds statewide

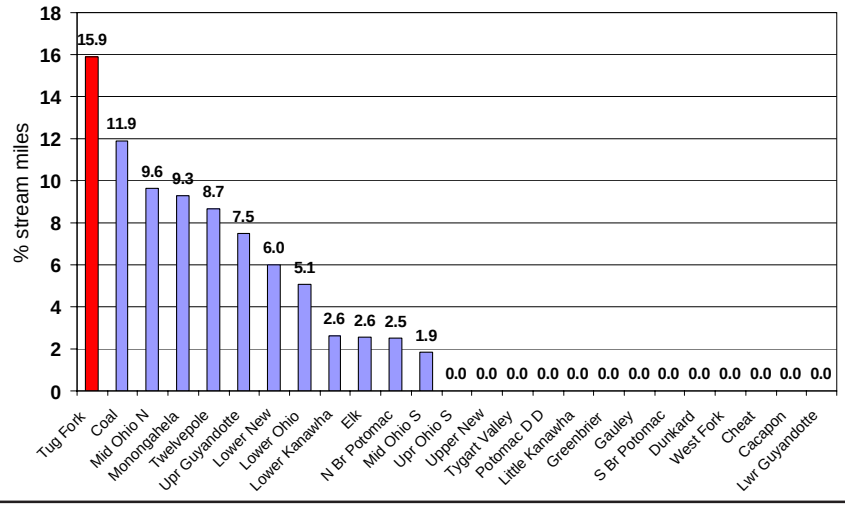


Fig. 10. Random data,% stream miles in RBP habitat categories, Tug Fork vs. statewide

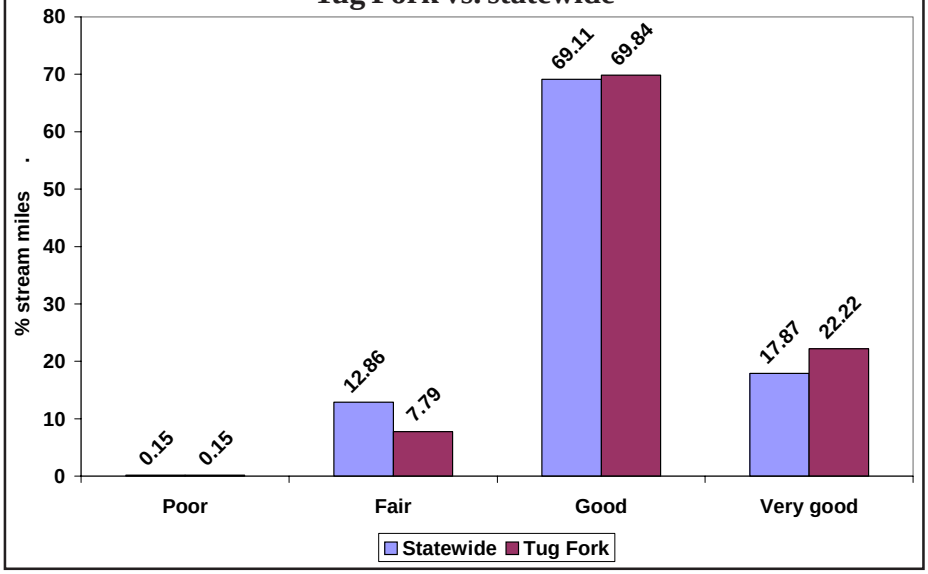


Fig. 11. Random data,% stream miles in categories of embeddedness + sediment

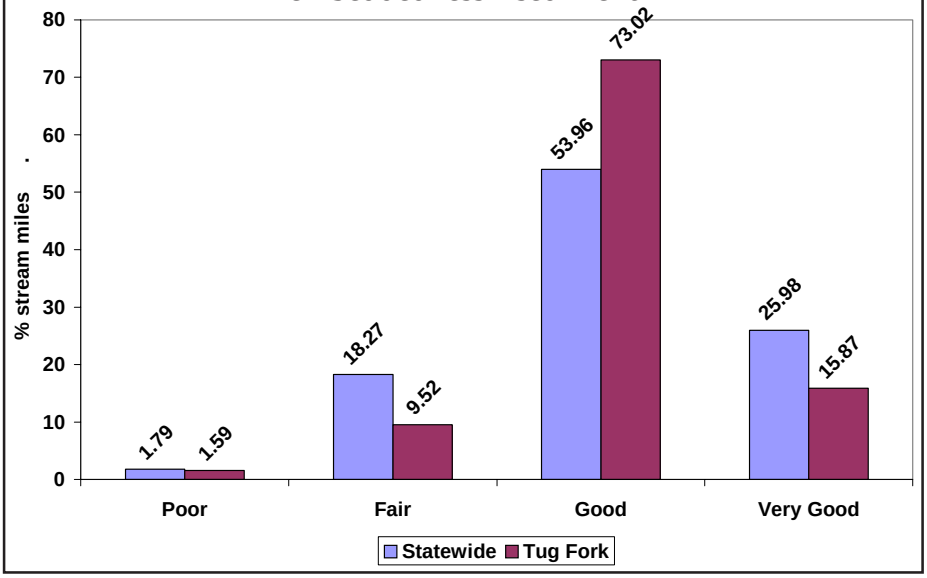
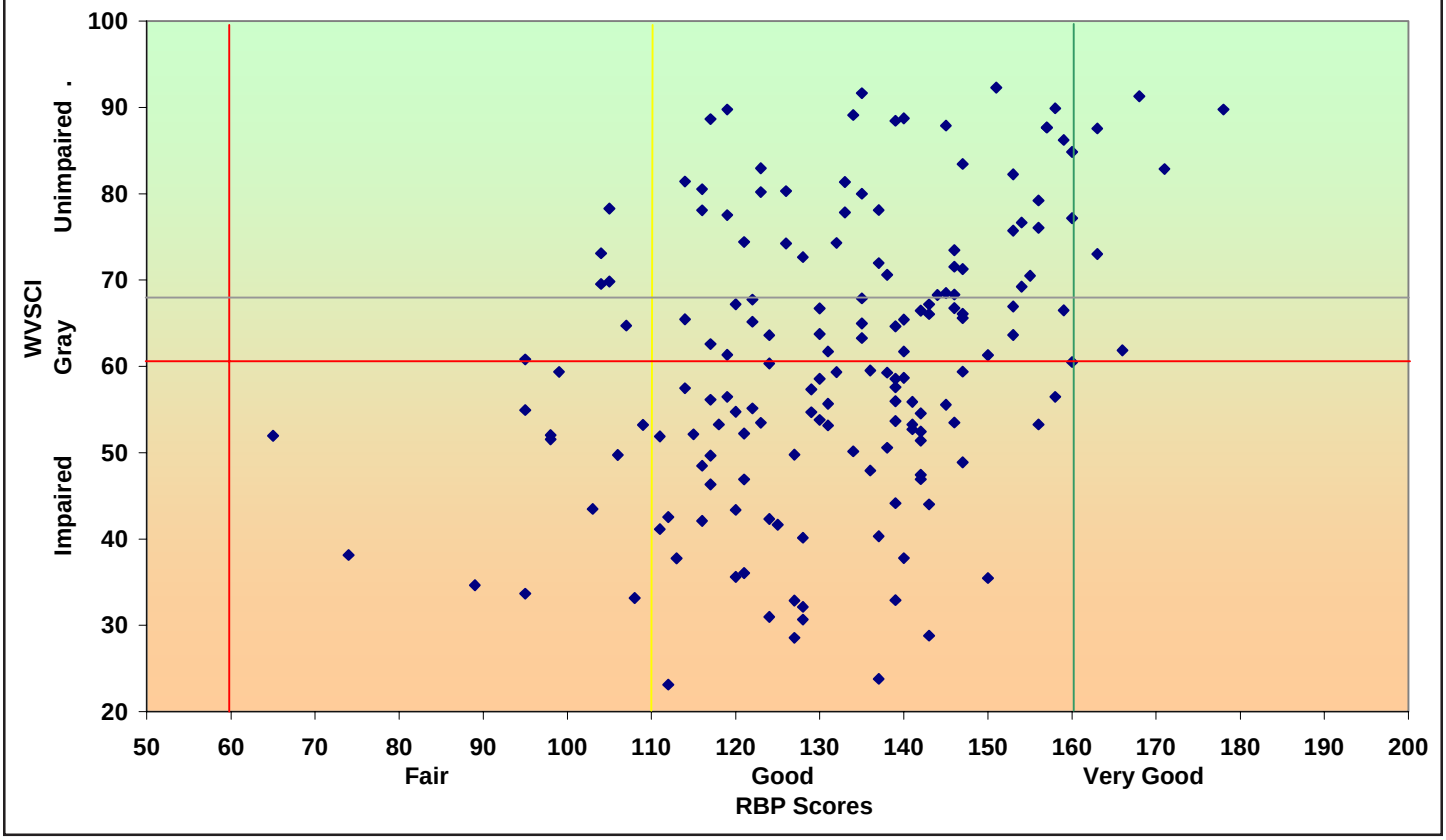


Fig. 12. Tug Fork 1998 & 2003 data, WVSCI scores vs. RBP habitat scores



IMPLICATIONS

Numerous sites sampled during this watershed assessment provided evidence of negative impacts to benthic macroinvertebrate communities from coal mining activities, both past and ongoing. Even mine drainage recipient sites with pH values well within the range required by the state's water quality standards produced impaired WVSCI scores.

Similar results were found in three independent studies of other watersheds in southern Appalachian coalfields (Chambers and Messinger 2001; Green et. al. 2000; and Pond 2004).

A succinct explanation of the basis for the physicochemical impacts of mining upon streams is found in the Chambers and Messinger report of the Kanawha River watershed (borders Tug Fork watershed on the southeast) study by the U. S. Geological Survey.

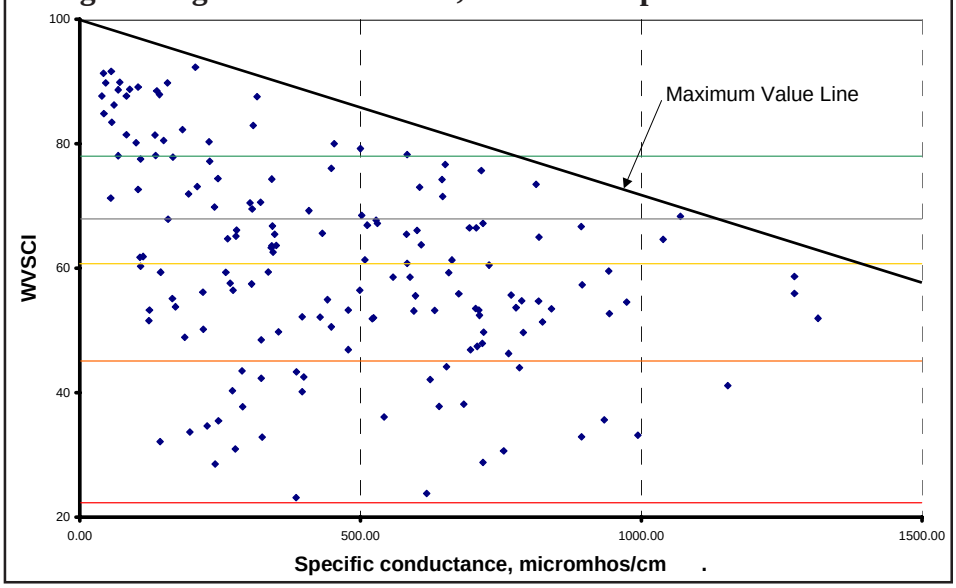
The Kentucky Eastern Coal Field (ECF) study reported by Greg Pond revealed, "Dissolved solids emanating from hollowfills are a primary cause of biological impairment because of their severe impact to mayflies (a key component of headwater stream communities) and other sensitive taxa." (Pond 2004:2). The study pointed out, "Sulfate and conductivity is probably the most useful chemical indicator of the condition of a stream in mined watersheds in the ECF...and its concentration reflects the extent of watershed disturbance." (Pond 2004:6-7).

Similar effects of coal mining were seen on streams in the *Tug Fork* watershed during this study period. Figure 13 shows that of the 59 comparably sampled sites that scored in the unimpaired WVSCI range and at which specific conductance was measured, only 10 (approximately 17%) had conductivities greater than 500 µmhos/cm. Compare this to approximately 56% of impaired and gray zone WVSCI sites in the same specific conductance range.

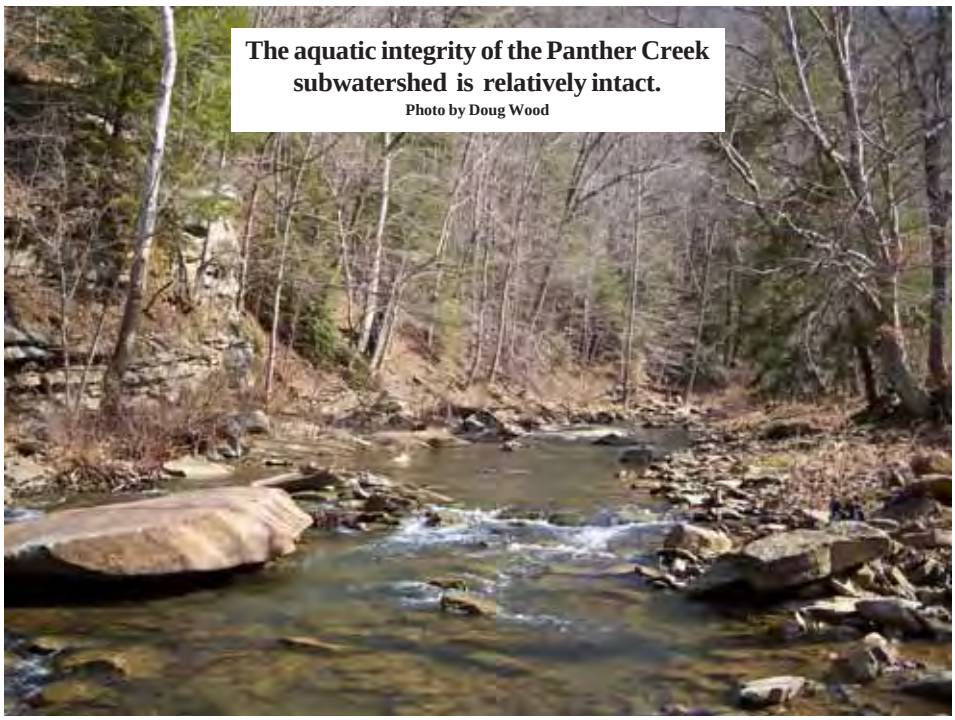
Figure 14 shows the average conductivity of random sites in the Tug Fork watershed compared to the statewide random data. The Tug Fork data indicate that there were likely higher averages of certain dissolved solids, including metals and sulfate, in the Tug Fork watershed than in the statewide data set. Indeed, the Tug Fork watershed had a higher percentage of stream miles with sulfate concentrations indicating mine drainage (> 50 mg/l) when compared to the statewide random weighted data set (Fig. 15).

Mountaintop removal, and other, older forms of mining are the primary contributors of dissolved solids to streams throughout the Tug Fork watershed. The watershed has hosted large-scale mining activities since the beginning of the 20th Century (see Fig. 16). This has resulted not only in water quality alterations due directly to mining waste, but also to changes due to the presence of mining communities. A typical mining town in the watershed concentrates residences and businesses in a narrow river bottom that is frequently flooded and has little room for expansion without negative impacts to the near stream environment. Many of the communities have sewers that carry storm runoff along with household wastes. The great bulk of these combined storm overflows carry wastes to the lower ends of the towns they serve, where there is inadequate treatment, if any treatment at all, before discharging into a stream. Within the watershed there are 149 communities identified by name in *General Highway County Maps West Virginia* produced by the West Virginia Department of Transportation. There are only 10 publicly owned wastewater treatment facilities and one of these is merely a

Fig. 13. Tug Fork 98 & 03 data, WVSCI vs. specific conductance



sewage collection system with no treatment. Only a fraction of the 149 communities are served by these treatment facilities. Inadequate sewage treatment is believed to be the primary reason why approximately half of the fecal coliform bacteria samples collected in both 1998 and 2003 exceeded the state water quality standard.



The aquatic integrity of the Panther Creek subwatershed is relatively intact.
Photo by Doug Wood

In 1998, the DEP placed 64 streams from the Tug Fork watershed on the 303(d) list of impaired streams because of violations of water quality standards for certain metals. Total maximum daily loads were developed for these streams in 2002. The TMDL document implicated coal mining as a major source of these violations. The document indicated that most of the primary point sources of metals impairments were mining-related (U.S. EPA 2002:1.11). It also explained that abandoned mine lands represented a significant nonpoint source of water quality impairments. Sediment produced from mining and other land-based activities (e.g., harvested forest, oil and gas operations, and roads) was identified as a potential source of high metal contamination (U.S. EPA 2002:3.9, 3.10, & 3.12). Only one nonmining, permitted point source was considered in the wasteload allocation calculations. All others were not expected to be significant sources of metals (U.S. EPA 2002:4.8).

Although there were many streams negatively impacted by coal mining and other activities within the Tug Fork watershed during the currently reported ecological assessment, there were also some streams with few impacts. Reference streams are considered the least impacted by human disturbances. None of the sites sampled in 2003 met the criteria established for reference streams, but six met those criteria in 1998 (see Fig.17). Four of the six are in the Panther Creek subwatershed.

The Panther Creek subwatershed, which had the highest average WVSCI score (Fig. 5) and the lowest average specific conductance (Fig. 18), also had one of the lowest percent land coverages by mining activities (less than 1%).

Fig. 14. Random data, average conductivity

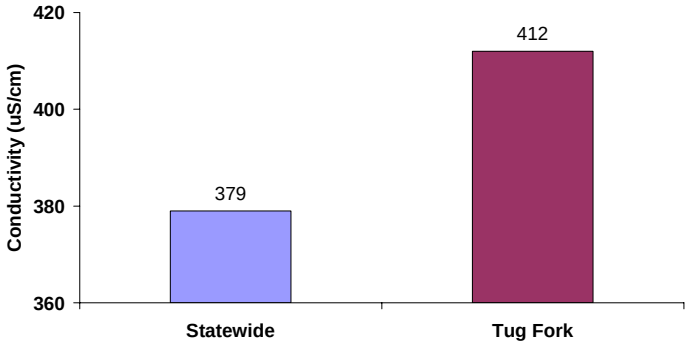
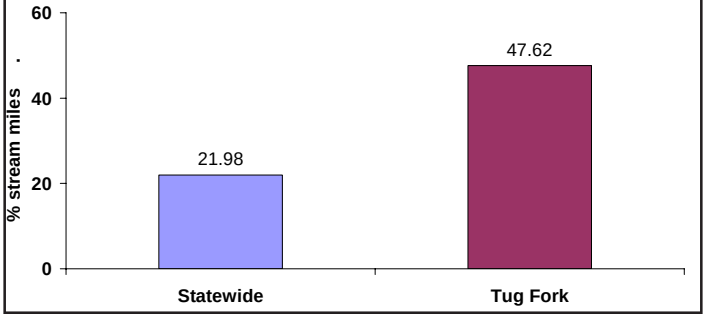


Fig. 15. Random data, % stream miles with sulfate >50 mg/L



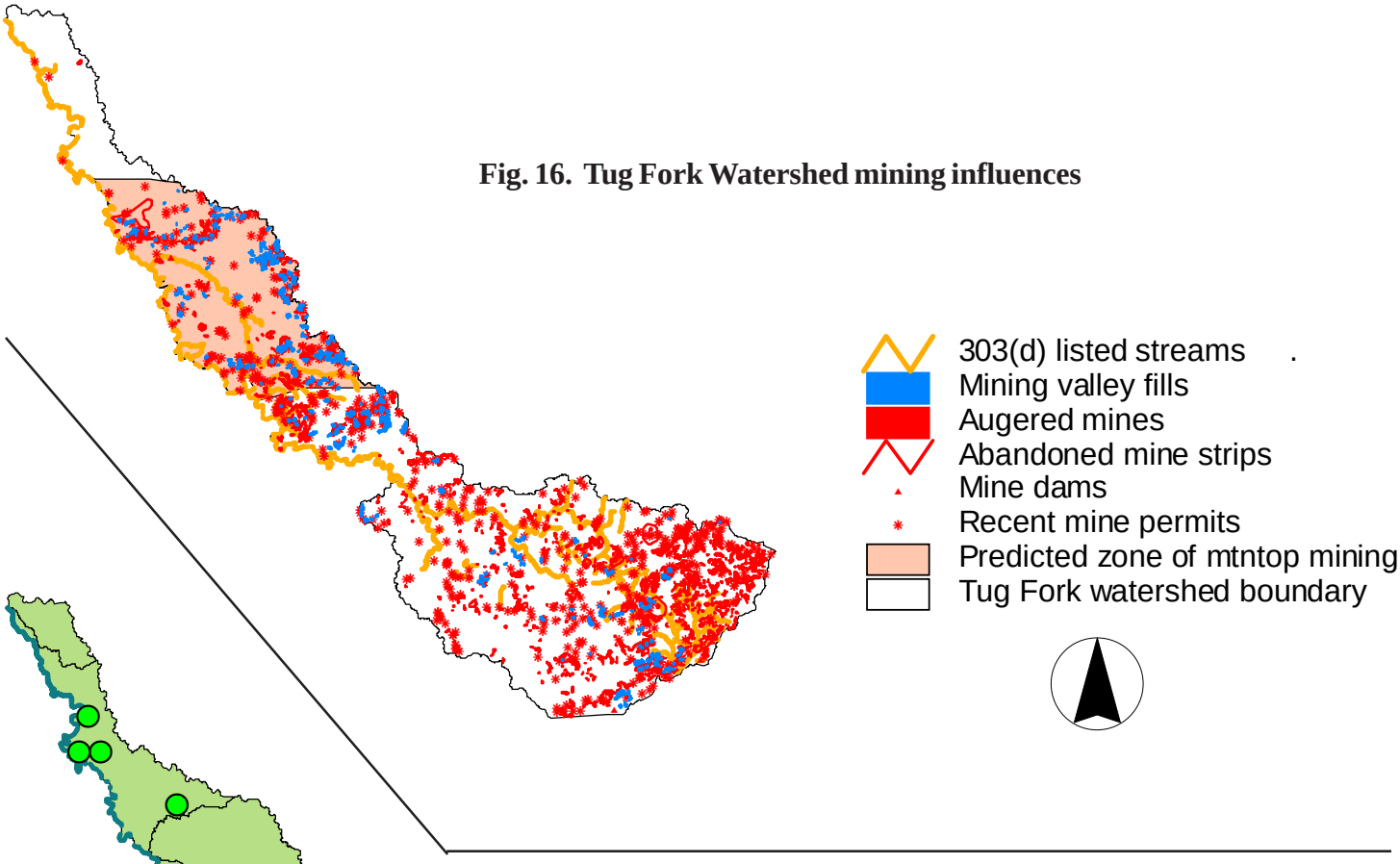


Fig. 16. Tug Fork Watershed mining influences

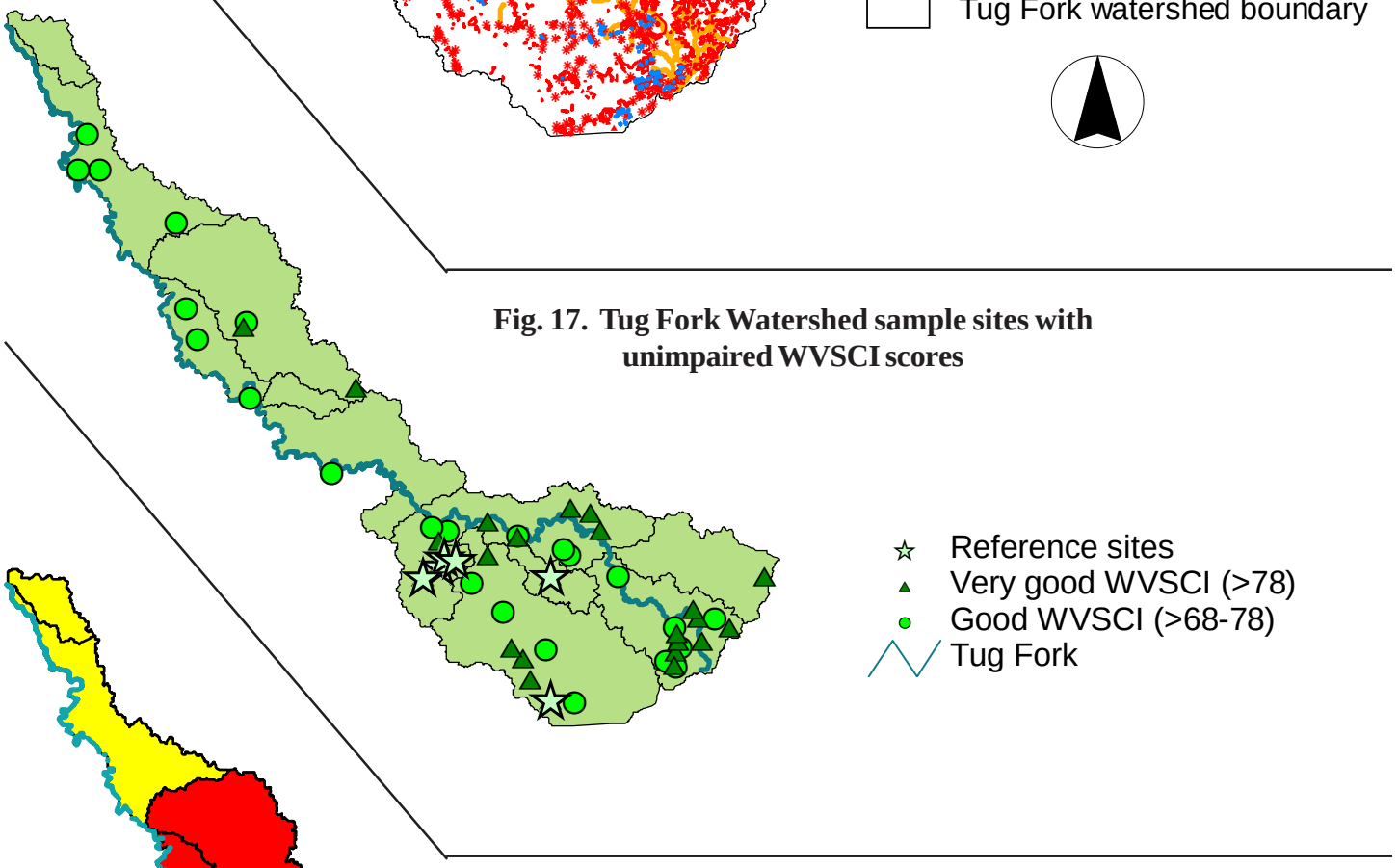


Fig. 17. Tug Fork Watershed sample sites with unimpaired WVSCI scores

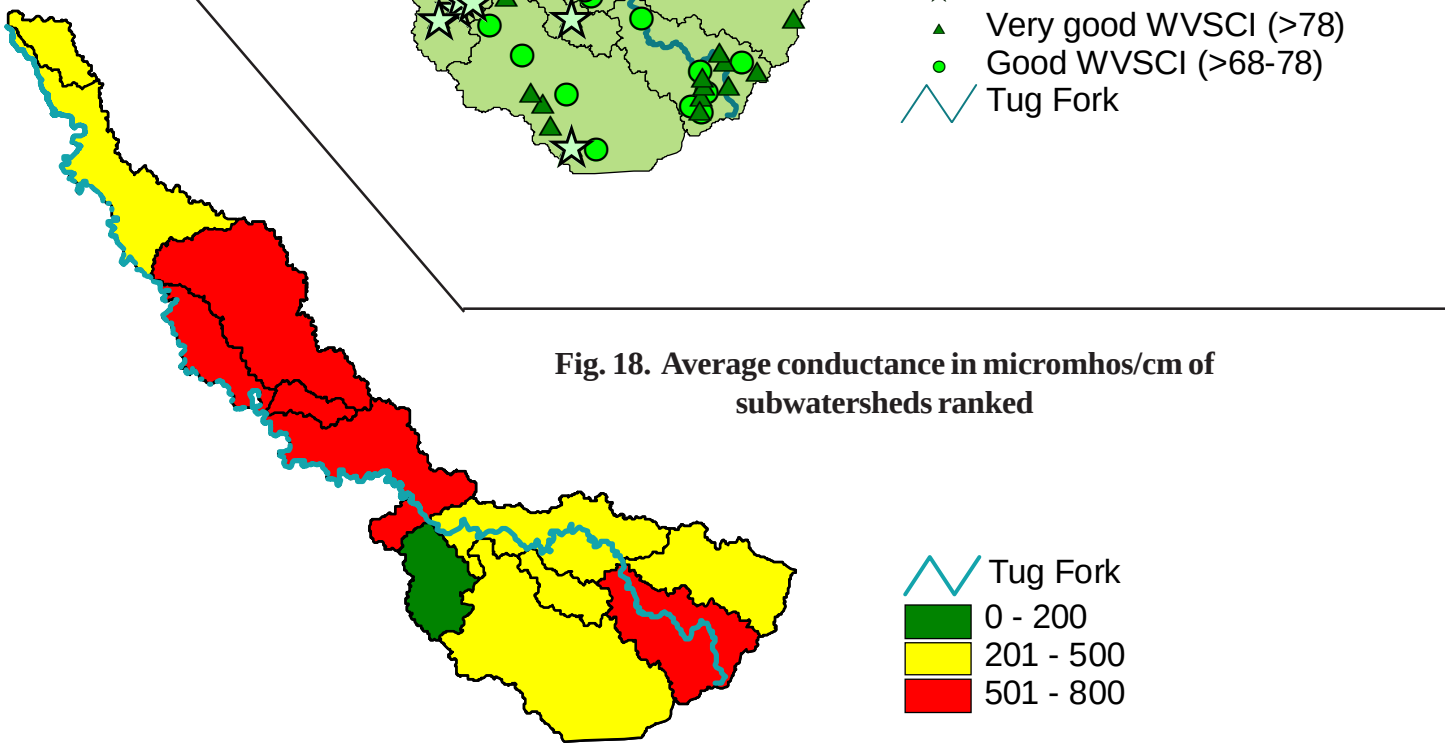


Fig. 18. Average conductance in micromhos/cm of subwatersheds ranked

GLOSSARY

DEP - West **V**irginia **D**epartment of **E**nvironmental **P**rotection.
EPA - Environmental **P**rotection **A**gency.
EPT - Ephemeroptera, **P**lecoptera, & **T**richoptera taxonomic orders of insects generally considered sensitive to pollution.
parameter - a factor that restricts what is possible or what results.
RBP - Rapid **B**ioassessment **P**rotocol.
TMDL - Total **M**aximum **D**aily **L**oad.
WVSCI - West **V**irginia **S**tream **C**ondition **I**ndex.

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Figure 19.

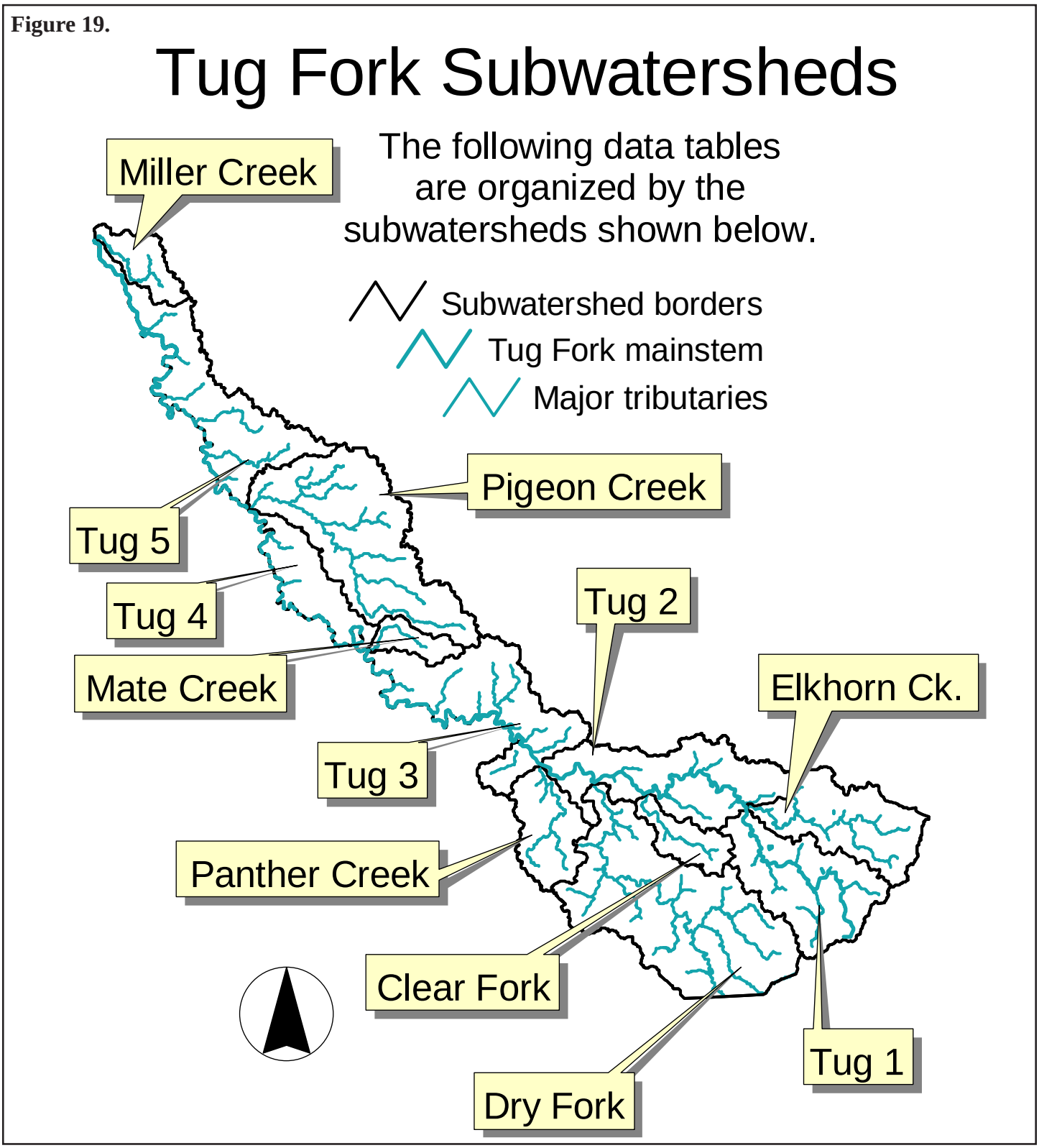
Tug Fork Subwatersheds
The following data tables are organized by the subwatersheds shown below.
Subwatershed borders
Tug Fork mainstem
Major tributaries
Miller Creek
Pigeon Creek
Tug 5
Tug 4
Tug 2
Mate Creek
Elkhorn Ck.
Tug 3
Panther Creek
Clear Fork
Tug 1
Dry Fork

TABLE 1. Tug Fork 1 Subwatershed												
Date	Stream Name	ANCode	Mile Point	WVSCI	RBP	pH	Sp Cond (umhos/cm)	Sulfate (mg/L)	TSS (mg/L)	Total Al (mg/L)	Total Fe (mg/L)	Fecal (col./ 100mL)
7/6/1998	Tug Fork River	WVBST	104.2	42.10	116	8.40	624	200		0.056	0.113	4400
6/17/1998	Little Indian Creek	WVBST-100		49.78	127	7.80	354	52		<0.05	0.05	70
6/23/1998	Rock Narrows Branch	WVBST-103		46.93	142	7.90	478	150		0.147	0.657	1300
6/18/1998	Harris Branch	WVBST-104		73.44	146	8.00	813	300		<0.05	0.204	40
7/1/1998	Mitchell Branch	WVBST-105		61.33	119	7.60	508	180		0.145	0.309	170
6/17/1998	Sandlick Creek	WVBST-109	0	53.23	109	7.20	632	250		0.127	0.256	290
7/1/1998	Sandlick Creek	WVBST-109	1.7	54.69	129	7.80	817	280		0.202	0.29	160
7/1/1998	Right Fork/Sandlick Ck	WVBST-109-A		42.54	112	7.70	399	100		0.406	0.283	290
7/1/1998	Left Fork/Sandlick Creek	WVBST-109-B		54.75	120	7.50	787	340		0.532	0.357	17
6/17/1998	Adkin Branch	WVBST-110		57.46	114	7.20	306	100		<0.05	0.05	27
6/17/1998	Belcher Branch	WVBST-111		61.31	150	7.40	663	220		<0.05	0.05	4
6/30/1998	Turnhole Branch	WVBST-112		66.69	130	7.80	893	310		0.127	0.479	480
6/30/1998	Harmon Branch	WVBST-113		53.48	123	8.10	840	220		<0.05	0.254	21
6/30/1998	Harmon Branch	WVBST-113		41.66	125			200		<0.05	0.288	21
7/6/1998	South Fork/Tug Fork	WVBST-115		67.73	122	8.20	528	180		<0.05	0.142	4100
7/1/1998	Tea Branch	WVBST-115-A		80.17	123	7.60	100	21		<0.05	0.2	1900
6/25/1998	McClure Branch	WVBST-115-B		88.72	140	7.20	89	18		0.51	0.967	200
6/25/1998	Jump Branch	WVBST-115-D		77.52	119	7.30	108	37		0.159	0.394	1200
6/24/1998	Spice Creek	WVBST-115-E		79.98	135	7.40	453	180		<0.05	0.225	17
7/6/1998	Laurel Branch	WVBST-115-F		81.36	133	7.90	134	32		0.611	1.18	16
6/25/1998	Road Fork	WVBST-115-G		74.23	126	7.60	645	240		0.654	1.47	700
6/24/1998	Loop Branch	WVBST-117		58.55	139	8.00	558	140		0.0743	0.295	4
6/24/1998	Mill Branch	WVBST-118		79.21	156	7.90	500	81		0.114	0.391	40
6/24/1998	Dry Branch	WVBST-119		92.27	151	6.70	206	58		0.183	0.475	1300
6/23/1998	Little Creek	WVBST-120	0	40.31	137	7.20	272	35		<0.05	0.256	600
6/23/1998	Little Creek	WVBST-120	2	87.89	145	6.60	142	21		<0.05	0.167	200
6/23/1998	Indian Grave Branch	WVBST-120-A		63.27	135	7.10	341	53		0.118	0.539	6700
6/16/1998	Puncheoncamp Branch	WVBST-120-B		73.10	104	7.20	209	37		0.333	0.481	3600
6/24/1998	Millseat Branch	WVBST-121		89.09	134	6.70	104	12		<0.05	0.285	2230
5/14/2003	Right Fork/Sandlick Ck	WVBST-109-A	0.3	52.21	121	7.57	396	126	6	0.12	0.23	82
5/14/2003	Laurel Branch	WVBST-115-F	1.2	69.24	154	7.44	408	148		<0.02	0.1	3
9/17/2003	Tug Fork River	WVBST	122.3	53.28	141	8.43	711					1200
9/17/2003	Tug Fork River	WVBST	122.3	53.28	141	8.43	711					1200
9/16/2003	Tug Fork River	WVBST	139.9	67.20	120	8.25	718					580
9/16/2003	Tug Fork River	WVBST	158.8	43.37	120	8.40	386					1500
9/16/2003	South Fork/Tug Fork	WVBST-115	0.5	76.66	154	8.18	651					750
9/18/2003	Little Creek	WVBST-120	0	48.50	116	8.42	323					2200
9/18/2003	Little Creek	WVBST-120	0	42.31	124	8.42	323					2800
9/18/2003	Little Creek	WVBST-120	0	42.31	124	8.42	323					800

TABLE 2. Tug Fork 2 Subwatershed

Date	Stream Name	ANCode	Mile Point	WVSCI	RBP	pH	Sp Cond (umhos/cm)	Sulfate (mg/L)	TSS (mg/L)	Total Al (mg/L)	Total Fe (mg/L)	Fecal (col./ 100mL)
7/7/1998	Horse Creek	WVBST-63	1.2	77.83	133	8.50	166	25		<0.05	0.161	650
6/25/1998	Lick Branch	WVBST-71		30.67	128	7.70	755					2900
6/25/1998	Harmon Branch	WVBST-72		81.41	114	7.40	83					480
7/7/1998	Clear Fork	WVBST-76	0	76.05	156	7.30	448	130		0.171	0.42	20
7/7/1998	Clear Fork	WVBST-76	0	82.84	171			140		0.153	0.455	19
7/8/1998	Shabbyroom Branch	WVBST-78-B		56.46	119	8.00	273	48		0.102	0.339	>20000
7/9/1998	HoneyCamp Branch	WVBST-78-D		74.30	132	7.60	342	100		<0.05	0.775	300
7/9/1998	Coontree Branch	WVBST-78-E		51.40	142	8.40	824	120		0.319	0.835	3000
6/30/1998	Stonecoal Branch	WVBST-78-F		75.70	153	8.20	715	230		<0.05	0.2	480
7/1/1998	Badway Branch	WVBST-78-G		52.12	115	8.00	428	94		<0.05	0.684	3000
6/24/1998	Newson Branch	WVBST-78-H		23.80	137	8.10	618	120		<0.05	0.269	4700
6/24/1998	Moorecamp Branch	WVBST-78-I		66.46	142	8.30	706	250		<0.05	0.165	2
6/23/1998	Left Fork/Davy Branch	WVBST-85-A		63.61	124	8.10	342	60		0.169	0.518	>20000
6/23/1998	Left Fork/Davy Branch	WVBST-85-A	0.8	87.54	163	7.90	316	52		0.189	0.683	0
6/17/1998	Shannon Branch	WVBST-94		80.51	116	7.40	149	41		<0.05	0.0715	270
6/17/1998	Upper Shannon Branch	WVBST-95		28.56	127	7.70	241	50		<0.05	0.05	3800
6/17/1998	Puncheoncamp Branch	WVBST-98-A		61.72	131	7.30	107	23		0.53	0.206	120
9/24/2003	Tug Fork River	WVBST	71.9	71.53	146	8.15	646	177	18	0.52	0.93	116
9/17/2003	Clear Fork	WVBST-76	0.1	65.60	147	8.35	432					30
5/15/2003	Jenny Branch	WVBST-87	1.9	91.62	135	6.34	56	11.4	11	0.12	0.25	200

TABLE 3. Tug Fork 3 Subwatershed

Date	Stream Name	ANCode	Mile Point	WVSCI	RBP	pH	Sp Cond (umhos/cm)	Sulfate (mg/L)	TSS (mg/L)	Total Al (mg/L)	Total Fe (mg/L)	Fecal (col./ 100mL)
7/8/1998	Tug Fork River	WVBST	47.4	73.01	163	8.30	605	140		0.0561	0.214	160
6/16/1998	Sulphur Creek	WVBST-41		32.86	127	7.40	325					180
6/16/1998	Thacker Creek	WVBST-42		37.79	140	4.50	640	270		3.26	0.05	310
6/16/1998	Scissorsville Branch	WVBST-42-A		57.34	129	7.30	895	430		0.924	0.625	22
6/16/1998	Mauchinville Branch	WVBST-42-B		44.16	139	4.80	653	280		1.75	0.153	5
6/16/1998	Grapevine Creek	WVBST-43		52.43	142	7.30	712	310		1.18	0.297	5600
6/16/1998	Lick Fork	WVBST-43-A		47.44	142	3.70	708	300		4.32	0.05	<5
7/7/1998	Bull Creek	WVBST-57	0.6	64.73	107	8.40	263	65		<0.05	0.152	2500
7/7/1998	Left Fork/Bull Creek	WVBST-57-B		37.75	113	8.80	290					<10
9/17/2003	Beech Creek	WVBST-46	0.1	68.31	146	7.18	1070	476	5	0.05	0.14	6200
9/23/2003	Ben Creek	WVBST-52	0.2	52.72	141	8.27	943	334	5	0.07	0.21	118

TABLE 4. Tug Fork 4 Subwatershed

Date	Stream Name	ANCode	Mile Point	WVSCI	RBP	pH	Sp Cond (umhos/cm)	Sulfate (mg/L)	TSS (mg/L)	Total Al (mg/L)	Total Fe (mg/L)	Fecal (col./ 100mL)
6/17/1998	Miller Creek	WVBST-27	2.5	67.88	135	7.40	157	32		0.838	1.58	180
6/17/1998	Mill Fork	WVBST-27-C		77.16	160	7.90	231	56		0.291	0.699	99
6/23/1998	Buffalo Creek	WVBST-31	1	62.58	117	7.50	344	120		0.4	0.6	9400
6/15/1998	South Fork/Buffalo Creek	WVBST-31-B		71.95	137	7.50	194					810
6/15/1998	Sugartree Creek	WVBST-32		59.33	132	7.20	260	85		0.297	1.62	490
6/17/1998	Williamson Creek	WVBST-33		43.48	103	7.30	289	99		0.0706	0.133	28000
6/22/1998	Sycamore Creek	WVBST-34		67.18	143	8.10	530	120		<0.05	0.123	240
6/15/1998	Lick Creek	WVBST-35		53.28	156	7.80	478					570
6/22/1998	Dick Williamson Branch	WVBST-36		33.17	108	7.50	994	440		<0.05	0.097	5800
7/1/1998	Sprouse Creek	WVBST-38		51.96	65	8.10	1315	470		0.42	0.59	18
5/7/2003	Lick Creek	WVBST-35	2.2	64.64	139	7.87	1039	486	6	0.17	0.35	86

TABLE 5. Tug Fork 5 Subwatershed												
Date	Stream Name	ANCode	Mile Point	WVSCI	RBP	pH	Sp Cond (umhos/cm)	Sulfate (mg/L)	TSS (mg/L)	Total Al (mg/L)	Total Fe (mg/L)	Fecal (col./ 100mL)
6/25/1998	PowderMill Branch	WVBST-3		38.16	74	7.10	684	11		0.0587	1.72	800
6/30/1998	Painter Branch	WVBST-10-0.5A		78.06	116	7.40	68					700
7/7/1998	Bull Creek	WVBST-14		69.53	104	7.80	307					2800
6/24/1998	Right Fork/Bull Creek	WVBST-14-B		72.66	128	7.80	104					3500
6/30/1998	Silver Creek	WVBST-16		59.36	99	7.80	144					1400
6/30/1998	Jennie Creek	WVBST-17	2.7	53.80	130	7.60	170	16		0.15	0.6	760
7/7/1998	Marrowbone Creek	WVBST-19	0.9	60.80	95	7.90	583	150		<0.05	0.579	480
7/6/1998	Marrowbone Creek	WVBST-19	8	78.27	105	8.10	583	220		0.26	0.18	470
9/22/2003	Lost Creek	WVBST-7	1.7	51.55	98	6.65	123					4600
9/16/2003	Jennie Creek	WVBST-17	0.7	54.94	95	7.42	441	50.5	5	0.07	1.56	370
9/17/2003	Marrowbone Creek	WVBST-19	3.1	44.01	143	8.11	783	270	<3	0.02	0.19	44

Miller Creek

NO BENTHIC MACROINVERTEBRATE SAMPLES WERE COLLECTED

TABLE 6. Clear Fork Subwatershed												
Date	Stream Name	ANCode	Mile Point	WVSCI	RBP	pH	Sp Cond (umhos/cm)	Sulfate (mg/L)	TSS (mg/L)	Total Al (mg/L)	Total Fe (mg/L)	Fecal (col./ 100mL)
7/1/1998	Clear Fork	WVBST-76	10.2	40.16	128	8.10	396	91		<0.05	0.234	3600
6/24/1998	Clear Fork	WVBST-76	5.6	63.64	153	8.00	350	70		<0.05	0.469	860
6/24/1998	Daycamp Branch	WVBST-76-E		82.24	153	7.70	183	26		0.296	0.714	45

TABLE 7 Mate Creek Subwatershed												
Date	Stream Name	ANCode	Mile Point	WVSCI	RBP	pH	Sp Cond (umhos/cm)	Sulfate (mg/L)	TSS (mg/L)	Total Al (mg/L)	Total Fe (mg/L)	Fecal (col./ 100mL)
6/15/1998	Mate Creek	WVBST-40		36.08	121	7.90	542	240		<0.05	0.14	1500
7/1/1998	Rutherfork Branch	WVBST-40-B		49.65	117	5.20	790	360		1.5	2.3	135
6/16/1998	Mitchell Branch	WVBST-40-C		32.93	139	7.90	894	300		0.304	0.377	1400
6/15/1998	Chafin Branch	WVBST-40-D		46.31	117	6.60	764	370		<0.05	0.159	120
6/15/1998	Double Camp Fork	WVBST-40-H		65.44	114	7.60	347					580
9/24/2003	Mate Creek	WVBST-40	3.5	59.54	136	7.86	942	360	3	0.15	0.2	60

TABLE 8. Panther Creek Subwatershed												
Date	Stream Name	ANCode	Mile Point	WVSCI	RBP	pH	Sp Cond (umhos/cm)	Sulfate (mg/L)	TSS (mg/L)	Total Al (mg/L)	Total Fe (mg/L)	Fecal (col./ 100mL)
7/7/1998	Panther Creek	WVBST-60		50.17	134	7.90	220	22		<0.05	0.169	3000
7/7/1998	Panther Creek	WVBST-60		61.71	140			23		<0.05	0.147	6000
7/7/1998	Greenbrier Fork	WVBST-60-A	2	30.98	124	7.40	277	13		2.41	3.46	110000
6/17/1998	Cub Branch	WVBST-60-D		88.64	117	7.50	68	11		0.132	0.357	520
7/7/1998	George Branch	WVBST-60-E		84.82	160	7.50	43	6		0.0954	0.329	45
7/7/1998	Crane Creek	WVBST-60-F		87.66	157	7.30	83	14		<0.05	0.153	12
6/17/1998	Hurricane Branch	WVBST-60-G	0.9	89.75	178	7.20	46	9		<0.05	0.115	55
7/8/1998	White Oak Branch	WVBST-60-I-1		91.28	168	7.30	42	6		0.552	0.808	100
9/23/2003	Panther Creek	WVBST-60	2.8	70.49	155	7.88	303					240
5/28/2003	Slaunch Fork	WVBST-60-I	2.3	61.87	166	7.44	113	11.5	3	0.1	0.17	<2

TABLE 9. Dry Fork Subwatershed

Date	Stream Name	ANCode	Mile Point	WVSCI	RBP	pH	Sp Cond (umhos/cm)	Sulfate (mg/L)	TSS (mg/L)	Total Al (mg/L)	Total Fe (mg/L)	Fecal (col./ 100mL)
7/7/1998	Dry Fork	WVBST-70	1.3	66.06	143	8.40	601	81		<0.05	0.126	150
7/6/1998	Dry Fork	WVBST-70	18.4	55.89	141	8.10	675	100		<0.05	0.05	470
7/7/1998	Dry Fork	WVBST-70	7.4	65.42	140	8.60	582	88		<0.05	0.0976	32
7/2/1998	Mile Branch	WVBST-70-C		80.28	126	7.80	230					39000
7/2/1998	Grapevine Branch	WVBST-70-F		53.27	118	7.60	124	24		<0.05	0.138	3000
7/2/1998	Beartown Branch	WVBST-70-I		70.59	138	7.50	322	94		0.713	0.166	
7/9/1998	Bradshaw Creek	WVBST-70-M	1.8	55.13	122	7.80	165	25	41	1.64	1.74	
7/9/1998	Groundhog Branch	WVBST-70-M-1		32.15	128	7.80	143					38000
7/8/1998	Wolfpen Branch	WVBST-70-M-3		60.33	124	7.60	108					>20000
7/6/1998	Little Slate Creek	WVBST-70-N	4.5	89.87	158	7.30	71	9		<0.05	0.185	68
7/8/1998	Little Slate Creek	WVBST-70-N	0	33.67	95	7.80	196	44	633	15.4	16.7	<20000
7/8/1998	Little Slate Creek	WVBST-70-N	2.7	88.45	139	7.50	137	20	55	2.39	3.12	3600
7/8/1998	Atwell Branch	WVBST-70-O		69.8	105	8.00	240	51	169	6.75	7.06	>20000
7/9/1998	Bartley Creek	WVBST-70-Q		66.1	147	8.20	279	49	50	0.263	0.35	3000
7/1/1998	Clear Fork	WVBST-70-T-2		28.8	143	7.10	718					1400
7/6/1998	Big Branch	WVBST-70-U-1		86.2	159	7.10	61	9		<0.05	0.477	27
6/30/1998	Jacob Fork	WVBST-70-W	0.8	68.48	145	7.70	502	120		<0.05	0.162	160
7/1/1998	Jacob Fork	WVBST-70-W	7.8	58.55	130	8.10	588	150		<0.05	0.0922	2800
7/2/1998	Mountain Fork	WVBST-70-W-1-A	0.8	57.59	139	7.80	268	62		0.0895	0.328	120
7/1/1998	Vall Creek	WVBST-70-Z	0	78.09	137	7.70	135	24		<0.05	0.127	3200
7/1/1998	Vall Creek	WVBST-70-Z	2.3	87.66	157	7.50	39	5		<0.05	0.226	150
5/13/2003	Dry Fork	WVBST-70	19.3	53.5	146	8.40	705	116	3	0.06	0.18	39
9/17/2003	Dry Fork	WVBST-70	0.2	66.49	159	8.34	694	95.7	4	0.08	0.21	86
9/16/2003	Dry Fork	WVBST-70	35.4	55.67	131	7.73	768	74.6	12	0.097	0.36	500
9/17/2003	Bradshaw Creek	WVBST-70-M	0.1	66.76	146	8.37	343					1850
9/17/2003	Little Slate Creek	WVBST-70-N	1.5	65.16	122	7.98	278					1250
9/16/2003	War Creek	WVBST-70-U	0.1	74.41	121	8.10	246					250
9/16/2003	Big Creek	WVBST-70-W-1	0.2	66.92	153	7.69	512	147	3	0.09	0.34	118
9/16/2003	Big Creek	WVBST-70-W-1	0.2	68.25	144			145	5	0.097	0.28	98

TABLE 10. Elkhorn Creek Subwatershed

Date	Stream Name	ANCode	Mile Point	WVSCI	RBP	pH	Sp Cond (umhos/cm)	Sulfate (mg/L)	TSS (mg/L)	Total Al (mg/L)	Total Fe (mg/L)	Fecal (col./ 100mL)
6/22/1998	Elkhorn Creek	WVBST-99	16.4	59.38	147	7.80	336	59		<0.05	0.268	1300
6/22/1998	North Fork/Elkhorn Creek	WVBST-99-L	0	50.58	138	8.30	448	90		<0.05	0.277	>20000
6/16/1998	North Fork/Elkhorn Creek	WVBST-99-L	6.2	35.47	150	7.60	247	35		<0.05	0.0886	5600
6/22/1998	Buzzard Branch	WVBST-99-L-1		63.76	130	8.00	608	140		<0.05	0.05	4600
9/16/2003	Elkhorn Creek	WVBST-99	2.5	55.56	145	7.89	598					2000
9/17/2003	Elkhorn Creek	WVBST-99	16.6	56.48	158	8.30	499					11000
9/17/2003	Laurel Branch	WVBST-99-E	0	23.15	112	8.73	385		3			>12000
9/15/2003	North Fork/Elkhorn Creek	WVBST-99-L	0.3	51.87	111	8.23	521					>12000
6/5/2003	Windmill Gap Branch	WVBST-99-L-4	1.7	82.93	123	7.68	309	68.7	80	0.65	0.82	

TABLE 11. Pigeon Creek Subwatershed

Date	Stream Name	ANCode	Mile Point	WVSCI	RBP	pH	Sp Cond (umhos/cm)	Sulfate (mg/L)	TSS (mg/L)	Total Al (mg/L)	Total Fe (mg/L)	Fecal (col./ 100mL)
7/6/1998	Pigeon Creek	WVBST-24	0	53.15	131	8.10	595	140		0.32	0.62	600
6/22/1998	Pigeon Creek	WVBST-24	9	52.06	98	8.30	523	110		<0.05	0.328	1300
6/23/1998	Pigeon Creek	WVBST-24	29.3	35.62	120	8.40	934	220		1.21	1.66	6400
6/23/1998	Pigeon Creek	WVBST-24	31.8	89.75	119	7.30	156	29		<0.05	0.0852	17
6/24/1998	Spruce Fork	WVBST-24-E-2	0.1	49.74	106	8.10	719	200		0.178	0.579	230
6/22/1998	Simmons Fork	WVBST-24-K-8		34.65	89	7.90	227	40		<0.05	0.156	800
6/16/1998	Elk Creek	WVBST-24-N		48.89	147	7.80	187	37		0.121	0.431	460
6/16/1998	Millstone Branch	WVBST-24-O		71.27	147	7.10	55	13		<0.05	0.0761	3000
6/16/1998	Pigeonroost Creek	WVBST-24-P		83.43	147	7.20	57					22000
6/16/1998	Spring Branch	WVBST-24-Q-7		60.50	160	7.50	729	270		0.119	0.145	66
9/16/2003	Pigeon Creek	WVBST-24	2.5	64.98	135	8.31	818	228	<3	0.07	0.24	1950
5/7/2003	Pigeon Creek	WVBST-24	13.5	46.9	121	8.25	696	171	4	0.23	0.41	1050
9/22/2003	Pigeon Creek	WVBST-24	16.8	54.55	142	8.47	974	223	5	0.2	0.24	230
9/16/2003	Pigeon Creek	WVBST-24	21.8	55.96	139	8.52	1273	256	<3	0.21	0.29	76
9/16/2003	Pigeon Creek	WVBST-24	21.8	58.66	140	8.52	1273	266	4	0.196	0.29	60
9/17/2003	Laurel Fork/Pigeon Creek	WVBST-24-E	1.8	59.29	138	8.20	657	254	<3	<0.02	0.16	74
9/17/2003	Trace Fork	WVBST-24-K	0.5	41.14	111	8.32	1154	417	<3	<0.02	0.24	190
9/17/2003	Elk Creek	WVBST-24-N	0.6	53.65	139	8.63	777	137	3	<0.02	0.15	1900
9/23/2003	Rockhouse Fork	WVBST-24-Q	0.5	47.93	136	7.88	717	240	<3	0.18	1.03	260

Jacobs Fork, a trout stream in McDowell County in the Tug Fork watershed.

TABLE 12-A. Tug Fork watershed dissolved Al samples.

Date	Stream Name	ANCode	Mile Point	Diss Al (mg/L)
9/24/2003	Tug Fork River	WVBST	71.9	0.03
9/16/2003	Jennie Creek	WVBST-17	0.7	<0.02
9/17/2003	Marrowbone Creek	WVBST-19	3.1	<0.02
5/7/2003	Pigeon Creek	WVBST-24	13.5	0.1
9/16/2003	Pigeon Creek	WVBST-24	21.8	0.16
9/22/2003	Pigeon Creek	WVBST-24	16.8	0.15
9/16/2003	Pigeon Creek	WVBST-24	2.5	0.03
9/17/2003	Laurel Fork/Pigeon Creek	WVBST-24-E	1.8	<0.02
9/17/2003	Trace Fork	WVBST-24-K	0.5	<0.02
9/17/2003	Elk Creek	WVBST-24-N	0.6	<0.02
9/23/2003	Rockhouse Fork	WVBST-24-Q	0.5	0.08
5/7/2003	Lick Creek	WVBST-35	2.2	<0.02

TABLE 12-B. Tug Fork watershed dissolved Al samples.

Date	Stream Name	ANCode	Mile Point	Diss Al (mg/L)
9/24/2003	Mate Creek	WVBST-40	3.5	0.1
9/17/2003	Beech Creek	WVBST-46	0.1	<0.02
9/23/2003	Ben Creek	WVBST-52	0.2	<0.02
5/28/2003	Slaunch Fork	WVBST-60-I	2.3	<0.02
9/17/2003	Dry Fork	WVBST-70	0.2	<0.02
9/16/2003	Dry Fork	WVBST-70	35.4	<0.02
5/13/2003	Dry Fork	WVBST-70	19.3	<0.02
9/16/2003	Big Creek	WVBST-70-W-1	0.2	0.02
5/15/2003	Jenny Branch	WVBST-87	1.9	<0.02
6/5/2003	Windmill Gap Branch	WVBST-99-L-4	1.7	<0.02
5/14/2003	Right Fork/Sandlick Creek	WVBST-109-A	0.3	<0.02
5/14/2003	Laurel Branch	WVBST-115-F	1.2	<0.02