LONG-TERM DOWNSTREAM IMPACTS OF SURFACE MINING AND VALLEY FILL CONSTRUCTION TO BENTHIC MACROINVERTEBRATES AND WATER QUALITY[1]

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Abstract. Argus Energy (formerly Pen Coal Corporation) has been conducting spring and fall seasonal monitoring of water chemistry and benthic macroinvertebrates since 1995 on the Trough Fork watershed to determine the long-term downstream impacts of mining operations.

Conductivity, TDS, and sulfates have remained relatively low at the upstream site since 1995 with the exception of October data since 2000. Although there was a noticeable increase in these parameters at the downstream site during active mining from October 1997, April levels have appeared to stabilize at levels about 3 times pre-mining levels. October levels have continued to Aspike@ since 2000 at both the upstream and downstream sites.

Total individuals collected have been lower at the downstream site since October 2000, whereas prior to October 2000, total individuals had been higher at the downstream for 8 of the previous 10 sampling events. Although sporadic prior to October 1999, total taxa, EPT taxa, and percent mayflies has remained lower at the downstream site since April 2000.

Pre-mining and early active mining upstream and downstream communities consisted of relatively equal proportions of sensitive, facultative, and tolerant individuals. Extremely large proportions of tolerant individuals were noted during the droughts of October 1998 and April 1999 at both sites. Since October 2002, the downstream site has become more facultative, and less sensitive.

WV-SCI scores have ranged from pre-mining scores of 73 and 79, to lows of 47 and 41 during the drought years, to highs of 91 and 89 for the upstream and downstream sites, respectively. Usually, the downstream site has scored less than the upstream site in 10 out of 16 sampling seasons. Regression data does not show any trends correlating WV-SCI score to conductivity, TDS, sulfates, or aluminum at either the upstream or downstream sites utilizing data over 6 2 years. Some correlation between these parameters and mayfly abundance appear to exist.

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Background

As part of the AWater Quality Improvement Plan@, Argus Energy began an extensive benthic macroinvertebrate monitoring program in both affected and proposed mining watersheds during the Fall of 1995. The Trough Fork watershed was undisturbed at that time, but mining was projected for the area, therefore Trough Fork was included in that monitoring program. This monitoring has continued each spring and fall since that time. Active mining beginning with pond construction started in Vance Branch during January 1996 with initial valley fill construction taking place during February 1996. Reclamation activities and active surface mining were wrapped up in both Vance Branch and Pigpen Branch during the Summer of 1999. However, an underground mine at the head of Pigpen Branch began operating in the Summer of 2001. There are currently four valley fills of varying sizes in the Trough Fork watershed. One is located in a watershed greater than 250 acres, one is in a watershed just less than 250 acres, and the last two fills are in watersheds between 25 and 50 acres.

Since 1995, Argus Energy has continued to increase the number of monitoring points, and has added intensive macroinvertebrate and fish evaluations at many of their locations. Also, benthic macroinvertebrate biomass data has been examined for these two long-term monitoring points on Trough Fork. Currently, Argus Energy is monitoring about 38 sites on 11 streams, bi-yearly for benthic macroinvertebrates and water chemistry, and has sampled several sediment control structures for benthic macroinvertebrates, water chemistry, and amphibians. The purpose of this paper is to present some of this long-term data collected at two locations on Trough Fork from the pre-mining status, through active mining and valley fill construction years, and into the post-mining years.

Surface Impacts

Trough Fork is located in Wayne County, West Virginia, and is a third-order stream at the areas sampled (Fig. 1). Two stations have been sampled on Trough Fork since Fall 1995. The farthest upstream station (BM-005) is located on Trough Fork downstream of the confluence with Tomblin Branch. This station is located upstream from all mining-related surface disturbances on Trough

Fork. The farthest downstream station (BM-006) is located on Trough Fork downstream from the

Figure 1. Trough Fork showing Upstream and Downstream sampling stations. Argus Energy-WV, LLC.

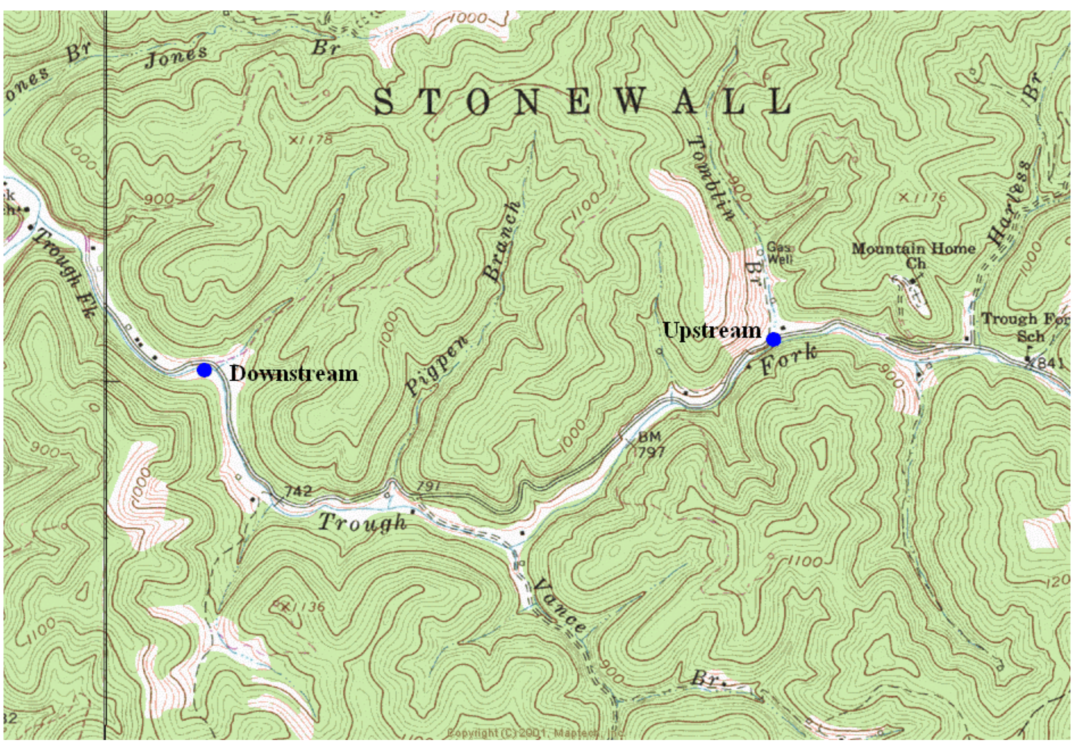

Figure 2. Trough Fork showing Upstream and Downstream sampling stations and tributaries

Pigpen Branch and Vance Branch. Argus Energy-WV, LLC.

confluence with Sugarcamp Branch (Fig. 2). There are currently four valley fills in place in the Trough Fork watershed between the upstream station and the downstream station. Trough Fork has a watershed size of approximately 2,882 acres, and is a major tributary of Kiah Creek which joins the East Fork of Twelvepole Creek to form East Lynn Lake near Kiahsville, West Virginia. Currently permitted activities will impact approximately 580 acres, or 20% of the Trough Fork watershed. Trough Fork has approximately 16,200 linear feet of perennial stream with approximately 44,400 linear feet of intermittent tributaries (based on USGS topographic mapping). The mining activities by Argus Energy will directly impact approximately 19,800 linear feet of these tributaries either by direct mineral removal, or by valley fill construction. This equates to about 44% of the intermittent tributaries of Trough Fork.

The post-mining configuration of the reclaimed mine sites will consist of six valley fills of various sizes, eighteen sediment ponds, approximately 40,000 linear feet of sediment and diversion channels, and approximately 575 acres of re-graded land. This land will then be re-vegetated with various grasses, legumes, shrubs, and trees to enhance wildlife. This scenario will replace the pre-mining site which originally consisted of 580 acres of unmanaged forestland and 19,800 linear feet of intermittent streams.

Methods of Investigation

A modified EPA Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers (EPA 841-B-99-002) as well as methods outlined in AInterim Chemical/Biological Monitoring Protocol For Coal Mining Permit Applications@ (January 19, 2000, US EPA, Region III) were followed in the collection of the benthic macroinvertebrate specimens, water chemistry, and habitat evaluations. Measurements for flow, physical water quality, and chemical water quality were collected in the fall (October) and the spring (April) from 1995 at each station. Benthic macroinvertebrate samples were also conducted, and the physical habitat of each station was evaluated. The individual methodologies are briefly described below.

Physical Water Quality

Physical water quality was analyzed on-site at each station. Water temperature, Dissolved Oxygen (DO), pH, and conductivity were measured with a Hydrolab[J] Minisonde multi-parameter probe. Flow was measured with a Marsh-McBirney[J] Model 2000 portable flow meter. Stream widths, depths, and velocities were measured, and the resulting average discharge was reported for each station.

Water Chemistry

Water chemistry samples were collected at each station and returned to R.E.I. Consultants, Incorporated for processing. Parameters analyzed included acidity, alkalinity, total hardness, nitrate/nitrite, chloride, sulfate, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), fecal coliforms, total phosphorus, dissolved organic carbon, total aluminum, dissolved aluminum, antimony, arsenic, beryllium, cadmium, calcium, chromium, copper, total iron, dissolved iron, lead, total manganese, dissolved manganese, magnesium, mercury, nickel, potassium, selenium, silver, sodium, thallium, and zinc.

Habitat

Habitat was assessed and rated on ten parameters in three categories using a modified version of the EPA=s Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers (EPA 841-B-99-002).

Benthic Macroinvertebrate Collection

A modified EPA Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers (EPA 841-B-99-002) as well as methods outlined in AInterim Chemical/Biological Monitoring Protocol For Coal Mining Permit Applications@ (January 19, 2000, US EPA, Region III) were followed in the collection of the benthic macroinvertebrate specimens. At each station, macroinvertebrate collections were made via a 0.1 m^2 Surber sampler and a 0.25 m^2 AD-Frame@ kick-net sampler. Both samplers were fitted with a 500-Φm mesh size net. Three quantitative replicates samples were collected in a riffle area by Surber sampling. Four semi-quantitative AD-Frame@ kick-net samples were composited from a riffle/run area to equal 1-m^2 sampling area. Samples were placed in 1-liter plastic containers, preserved in 35% formalin, and returned to the laboratory for processing.

Samples were then picked under microscope, and detrital material was discarded only after a second check to insure that no macroinvertebrates had been missed. All macroinvertebrates were identified to lowest practical taxonomic level and enumerated. Several benthic macroinvertebrate metrics were calculated at each station. These included: total abundance, taxa richness, modified Hilsenhoff Biotic Index (mHBI), ratio of scraper and filtering collector functional feeding groups, ratio of Ephemeroptera, Plecoptera, Trichoptera (EPT) and Chironomidae abundances, percent contribution of mayflies, percent contribution of dominant family, EPT Index, proportion of shredder functional feeding group, Simpson=s Diversity Index, Shannon-Wiener Diversity Index, Shannon-Wiener Evenness, and the West Virginia Stream Condition Index (WV-SCI; US-EPA, 2000) as shown below.

Range	**Rank**
78 to 100	AVery Good@
68 to 78	AGood@
45 to 68	AFair@
22 to 45	APoor@
0 to 22	AVery Poor@

Results

Water Chemistry

From Tables 1A and 1B, and especially from Fig. 3 - 5, it is obvious that chemical constituents such as Total Dissolved Solids (TDS), sulfates, and conductivity remained low and very similar between seasons at the Upstream site until October 2000, when Aspikes@ began to appear during the October sampling events. Similarly, these Aspikes@ were noted at that time for the Downstream station when October chemical constituent levels were dramatically higher than the April levels. It is also easy to detect that levels were low at the Downstream site prior to mining activity, but then started to increase once mining began in 1996. Also from these figures, it is apparent that levels have steadily increased within like seasons since April 2000. This is most noticeable with TDS and sulfates (Fig. 4 and 5). No dramatic changes in stream flows has been observed at either the Upstream or

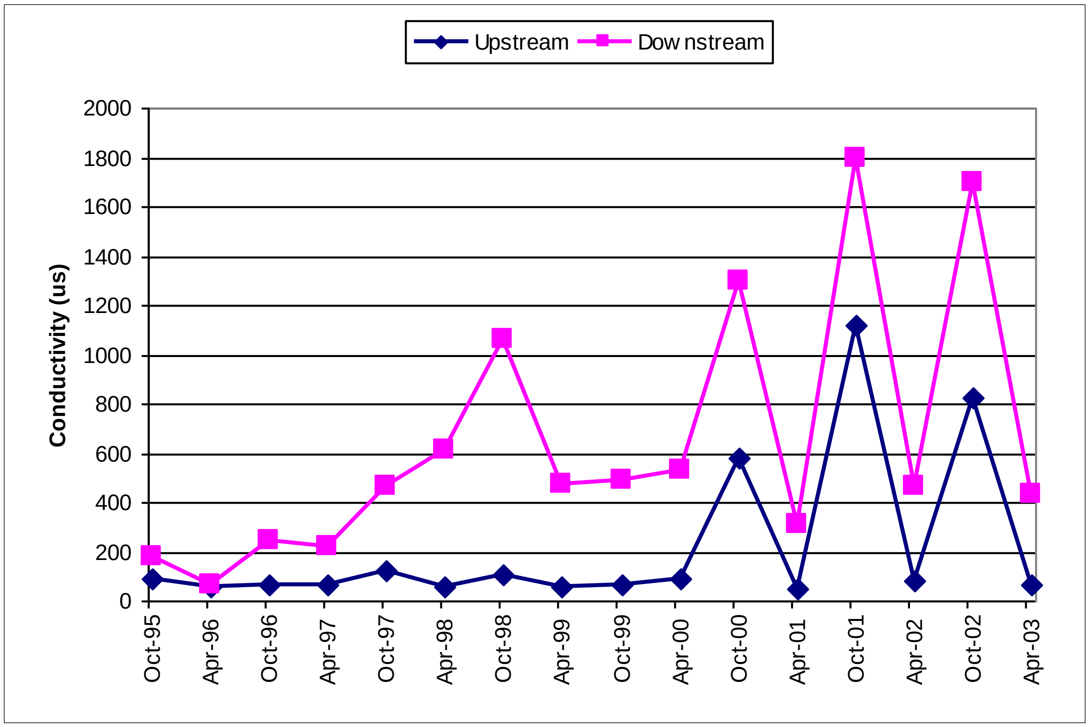

Figure 3. Conductivity of Upstream and Downstream stations on Trough Fork, October 1995 through April 2003. Argus Energy-WV, LLC.

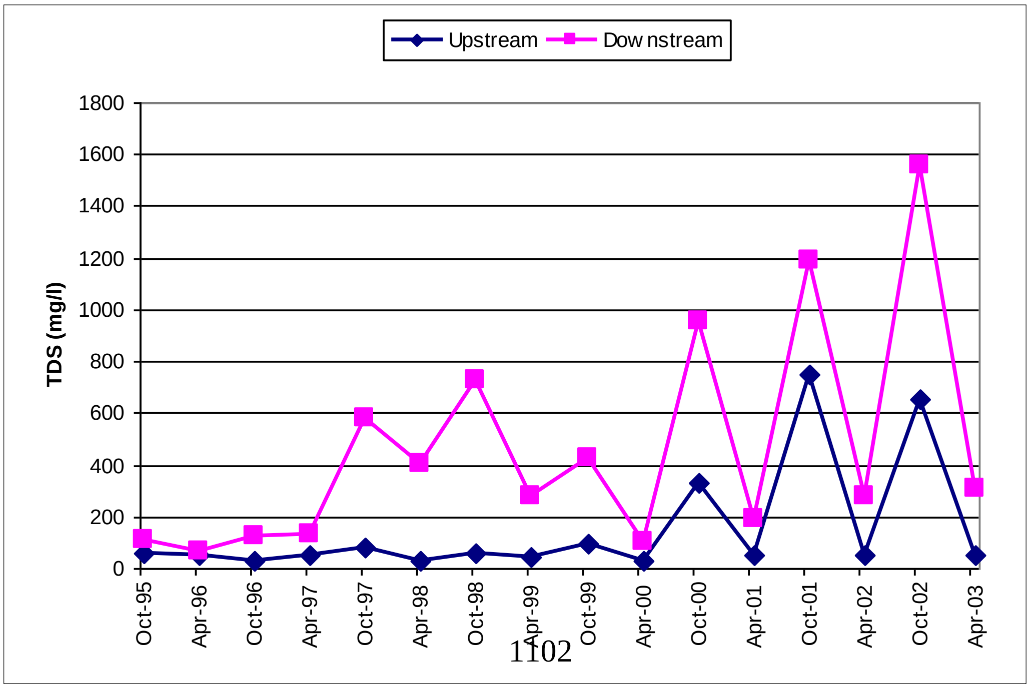

Figure 4. Total Dissolved Solids (TDS) of Upstream and Downstream stations on Trough Fork, October 1995 through April 2003. Argus Energy-WV, LLC.

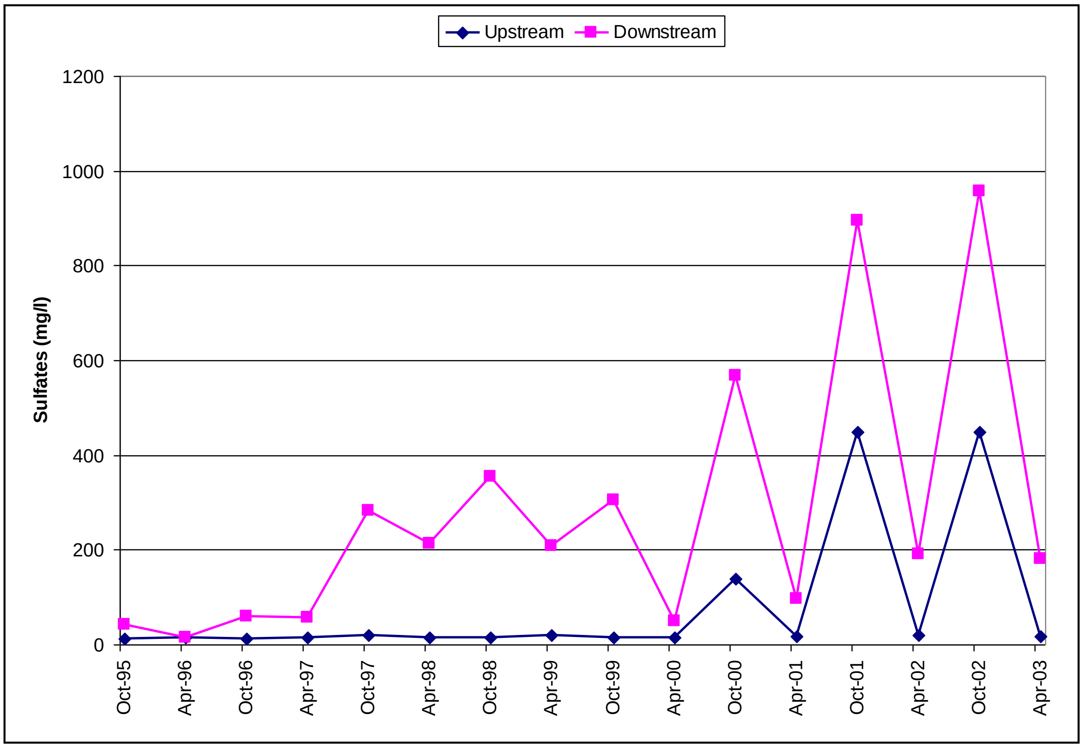

Figure 5. Sulfates of Upstream and Downstream stations on Trough Fork, October 1995 through April 2003. Argus Energy-WV, LLC.

Downstream stations since 1995, but flows appear to be somewhat greater at the Downstream site now than during pre-mining dates. Two tributaries of Trough Fork, Pigpen Branch and Vance Branch (Fig. 2), which enter Trough Fork between the Upstream and Downstream stations, used to be fairly intermittent in flow prior to mining activities in their watersheds, but have become perennial in their lower reaches. They are now significant contributors to the flow of Trough Fork, and because they have elevated levels of constituents such as conductivity, TDS, and sulfates, these levels show up at the Downstream Trough Fork site, especially when the flow of Trough Fork itself is low. Not surprisingly, flows are considerably higher during the April sampling events compared to the October events. This may be the primary explanation for the dramatic Aspikes@ in certain chemical parameters. With the lower October stream flows, a concentrating effect of the chemical constituents occurs, and higher levels are seen. With the higher spring flows, a diluting effect transpires, thereby causing the chemical parameter levels to be lower.

In general, except for the October spikes, levels of many water quality parameters have remained relatively unchanged at the Upstream site since pre-mining samples were collected in October 1995. However, at the Downstream station, several parameters have increased since pre-mining in October 1995 (Tables 1A and 1B). These include conductivity, TDS, hardness, alkalinity, sulfates, sodium, calcium, and magnesium. The parameters which have exhibited dramatic increases at the Downstream site are conductivity (176 Φs in October 1995 to 1695 Φs in October 2002; 64 Φs in April 1996 to 435 Φs in April 2003), TDS (107 mg/l in October 1995 to 1560 mg/l in October 2002; 64 mg/l in April 1996 to 308 mg/l in April 2003); hardness (67 mg/l in October 1995 to 945 mg/l in October 2002; 22 mg/l in April 1996 to 186 mg/l in April 2003), sulfates (41 mg/l in October 1995 to 957 mg/l in October 2002; 15 mg/l in April 1996 to 180 mg/l in April 2003), sodium (5 mg/l in October 1995 to 30 mg/l in October 2002; 1 mg/l in April 1996 to 5 mg/l in April 2003), calcium (14 mg/l in October 1995 to 224 mg/l in October 2002; 4 mg/l in April 1996 to 44 mg/l in April 2003), and magnesium (8 mg/l in October 1995 to 94 mg/l in October 2002; 3 mg/l in April 1996 to 19 mg/l in April 2003). Many other chemical analytes have remained fairly consistent over the years at the Downstream site, including alkalinity, chlorides, nitrates/nitrites, TSS, pH, acidity, and iron. Only those which have

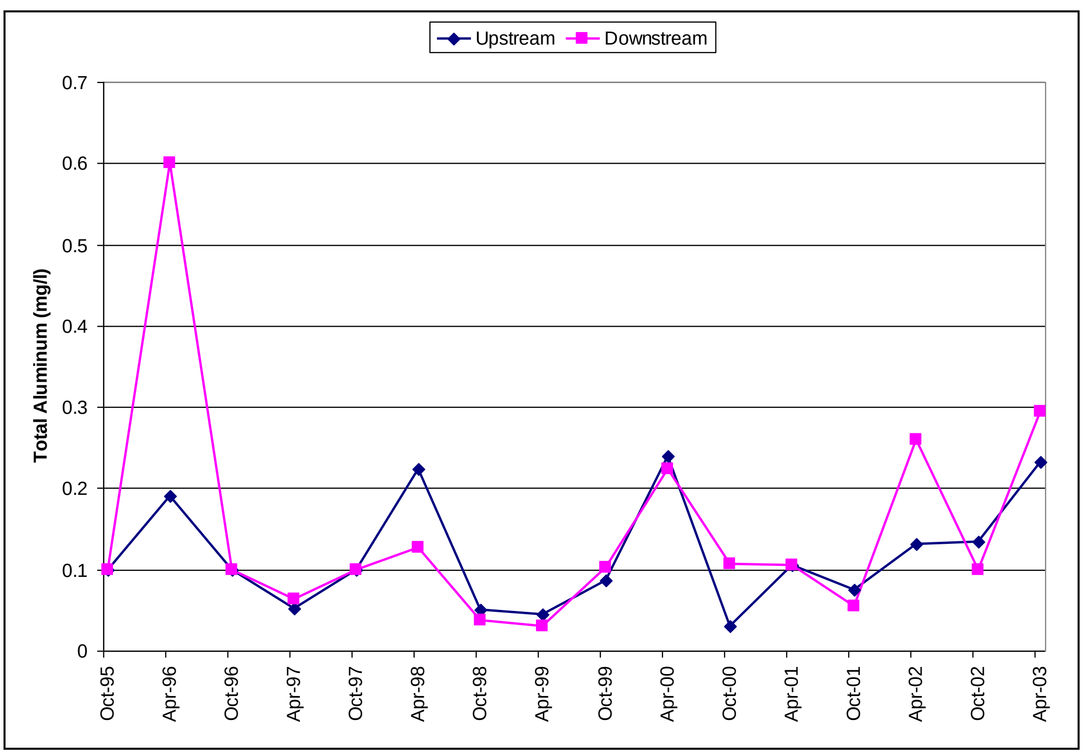

Figure 6. Total aluminum of Upstream and Downstream stations on Trough Fork, October 1995 through April 2003. Argus Energy-WV, LLC.

TABLE 1A. Selected water quality parameters taken at the Upstream Trough Fork station from October 1995 through April 2003. Argus Energy-WV, LLC.

UPSTREAM TROUGH FORK

	Apr03	Oct02	Apr02	Oct01	Apr01	Oct00	Apr00	Oct99	Apr99	Oct98	Apr98	Oct97	Apr97	Oct96	Apr96	Oct95
Conductivity (Φs)	68	825	78	1122	49	583	90	69	59	105	54	124	67	65	58	93
TDS (mg/l)	52	653	55	746	52	332	33	99	43	61	31	79	49	32	54	60
Sulfates (mg/l)	18	448	19	449	18	138	15	16	19	14	15	20	16	13	14	12
Total Aluminum (mg/l)	0.232	0.134	0.132	0.075	0.105	0.030	0.240	0.086	0.045	0.051	0.224	0.100	0.052	0.100	0.190	0.100

TABLE 1B. Selected water quality parameters taken at the Downstream Trough Fork station from October 1995 through April 2003. Argus Energy-WV, LLC.

DOWNSTREAM TROUGH FORK

	Apr03	Oct02	Apr02	Oct01	Apr01	Oct00	Apr00	Oct99	Apr99	Oct98	Apr98	Oct97	Apr97	Oct96	Apr96	Oct95
Conductivity (Φs)	435	1695	469	1792	309	1302	530	489	470	1061	611	469	221	242	64	176
TDS (mg/l)	308	1560	282	1190	193	957	103	424	281	727	407	577	129	122	64	107
Sulfates (mg/l)	180	957	191	895	96	569	49	305	208	354	214	282	56	60	15	41
Total Aluminum (mg/l)	0.295	0.099	0.260	0.055	0.105	0.107	0.224	0.103	0.030	0.038	0.127	0.100	0.064	0.100	0.600	0.100

shown noticeable trends have been included in this report. Aluminum has remained fairly consistent, but in contrast to other parameters, have had its highest levels, or Aspikes@, occurring in April rather than in October for both the Upstream and Downstream station (Fig. 6).

An important note is that levels of most water quality parameters have dramatically decreased with the October 2003 data, but because the benthic macroinvertebrate data had not been analyzed by the time of this writing, it has been left out of the figures and tables. Nevertheless, water chemistry at the Downstream station during the October 2003 sampling is as follows: conductivity 1363 Φs, TDS 981 mg/l, hardness 695 mg/l, sulfates 590 mg/l, sodium 19 mg/l, calcium 157 mg/l, and magnesium 74 mg/l. However, much of the reason these levels may be lower may be because of the large amounts of precipitation this area has received during the Fall 2003.

Habitat

Habitat has been assessed and rated on ten parameters in three categories using a modified version of the EPA=s Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers (EPA 841-B-99-002) since this project was initiated in 1995. Because of the length of this report, and primarily because no dramatic changes have occurred with regards to habitat at either of these two stations, the semi-annual habitat scores have not been included in this paper. Only slight changes in substrate proportions, and primarily at the Upstream site due to increased road traffic, have been noticed.

Benthic Macroinvertebrates

From Tables 2A and 2B one can see that the Upstream site contained more individuals on 8 out of 16 sampling events, and contained more taxa on 11 out of 16 sampling events (Fig. 7 and 8). It is interesting to note that the two stations were fairly similar in abundance and diversity during pre-mining of 1995 and through the early mining phase of 1996 - 1997, but have become quite different during the late mining phase and post-mining phase of 2000. During the post-mining era, the Upstream station has contained more individuals and more taxa than the Downstream site. There may have been a decreasing trend in total numbers of individuals collected at both sites from the post-mining era. There, however, does not appear to be a trend in number of taxa collected (Fig. 7 and 8).

Since post-mining, the number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa has been less at the Downstream site compared to the Upstream site. Pre-mining and active mining phases

TABLE 2A. Number of individuals and number of taxa collected at the Upstream Trough Fork station from October 1995 through April 2003. Argus Energy-WV, LLC.

UPSTREAM TROUGH FORK

	Apr03	Oct02	Apr02	Oct01	Apr01	Oct00	Apr00	Oct99	Apr99	Oct98	Apr98	Oct97	Apr97	Oct96	Apr96	Oct95
# Individuals	431	1859	590	2568	1060	4785	543	1462	2050	1009	676	907	398	1519	193	220
# Taxa	23	26	24	28	32	33	30	20	22	21	27	19	24	23	21	20

TABLE 2B. Number of individuals and number of taxa collected at the Downstream Trough Fork station from October 1995 through April 2003. Argus Energy-WV, LLC.

DOWNSTREAM TROUGH FORK

	Apr03	Oct02	Apr02	Oct01	Apr01	Oct00	Apr00	Oct99	Apr99	Oct98	Apr98	Oct97	Apr97	Oct96	Apr96	Oct95
# Individuals	153	821	234	1164	754	2468	2325	2984	5292	2777	1303	308	328	2277	651	496
# Taxa	20	18	15	19	26	15	21	20	23	20	30	15	26	20	26	16

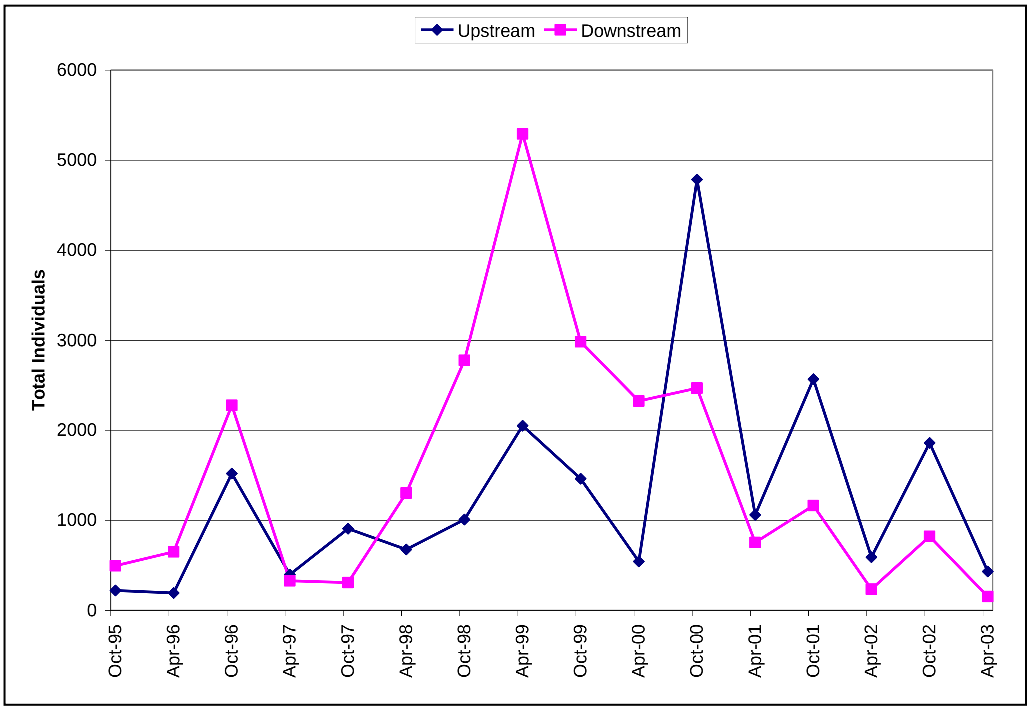

Figure 7. Total Individuals collected at Upstream and Downstream stations on Trough Fork, October 1995 through April 2003. Argus Energy-WV, LLC.

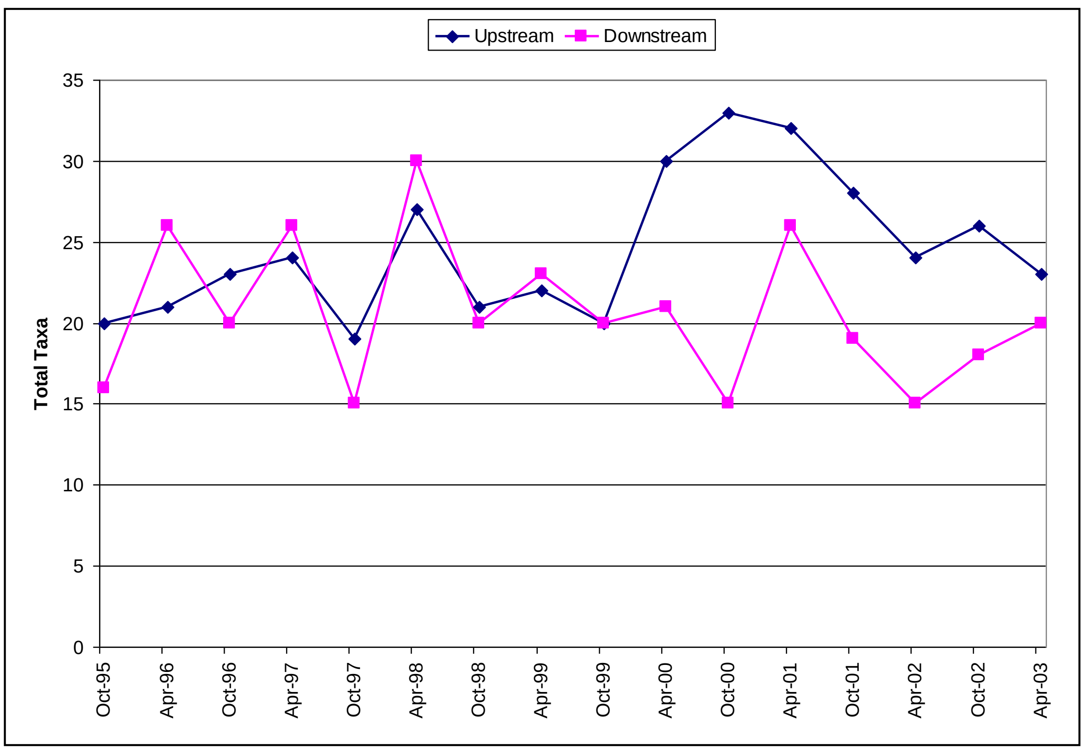

Figure 8. Total Taxa collected at Upstream and Downstream stations on Trough Fork, October

1995 through April 2003. Argus Energy-WV, LLC.

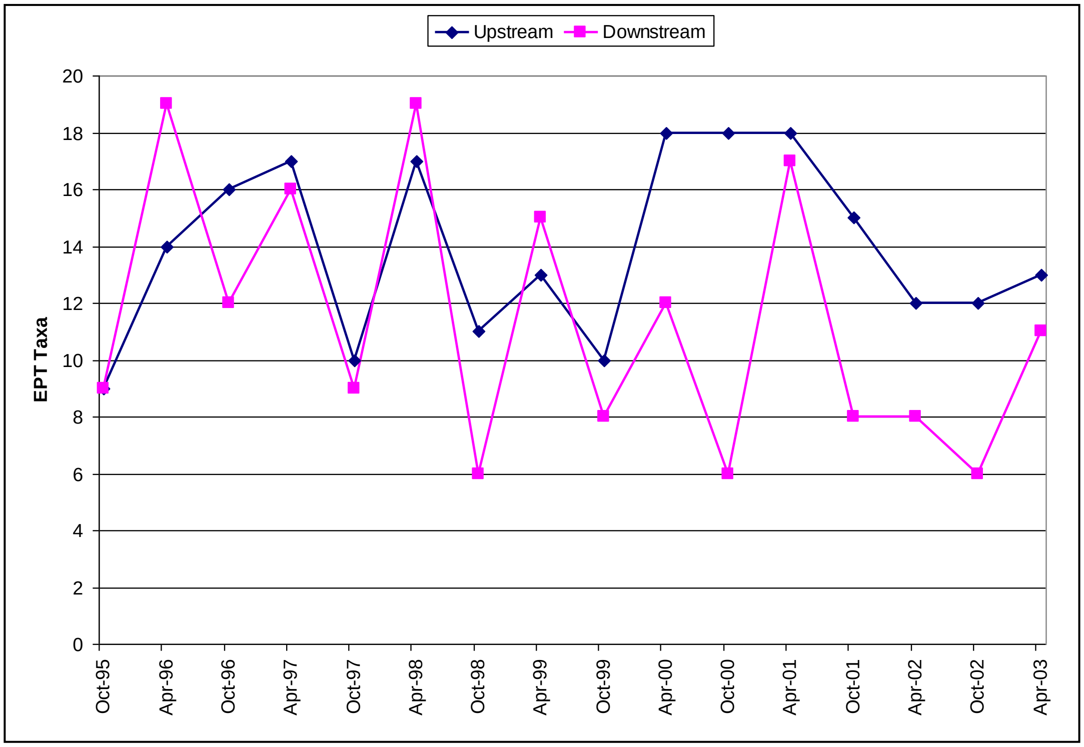

Figure 9. Number of EPT taxa collected at Upstream and Downstream stations on Trough Fork, October 1995 through April 2003. Argus Energy-WV, LLC.

showed a alternation between seasons for highest number of EPT taxa with the spring (April) season having a larger number of EPT taxa, and usually at the Downstream site Fig. 9). One of the most obvious trends has been the decline in the percentages of mayflies within the populations. The Upstream site has contained a greater proportion of mayflies per site in 13 out of 16 sampling events (Tables 3A and 3B; Fig. 10). The very low percentage of mayflies noted at both sites during April 1999 was due to the drought. Other than the poorer water quality conditions (increases in conductivity, TDS, and sulfates in October) at the Upstream site compared to the mid 1990's, there is no explanation for the decrease in mayflies at the Upstream site (Fig. 3 - 5). Percentages of the Dipteran, Chironomidae, have been very sporadic at both sites, and are currently not considerably different than those seen during the pre-mining era (Fig. 11). The high peaks of Chironomidae abundances during the Spring 1999 and Spring 2000 are thought to be related to the drought conditions in which a tolerant insect such as Chironomidae, would have thrived when sensitive insects, such as mayflies, would have done much poorer.

The West Virginia Stream Condition Index (WV-SCI) has ranged from 47 (Afair@) to 91 (Avery good@) at the Upstream station and has ranged from 41 (Apoor@) to 89 (Avery good@) at the Downstream station (Table 5). Scores originally were higher at the Downstream site during pre-mining, have alternated during active mining, and are currently higher at the Downstream site (Fig. 12). No obvious trends are seen in regards to the WV-SCI score over time, but dips in the score were noted during the drought seasons, when percentages of Chironomidae were highest.

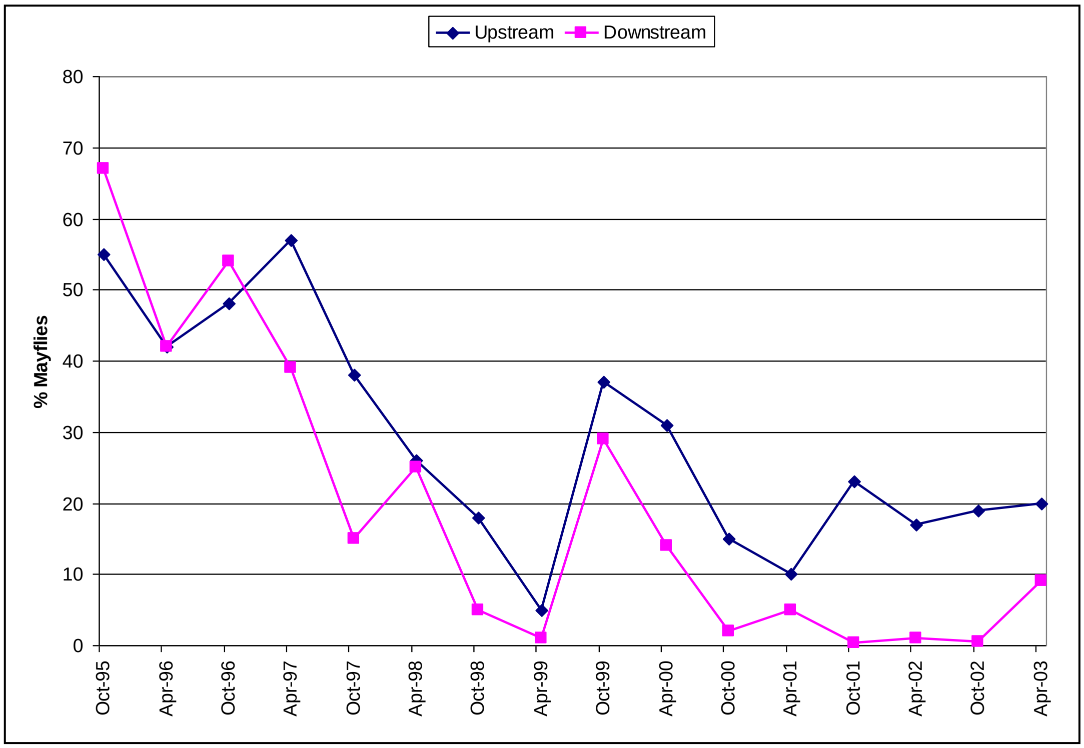

Figure 10. Percent mayflies collected at Upstream and Downstream stations on Trough Fork, October 1995 through April 2003. Argus Energy-WV, LLC.

Benthic macroinvertebrate communities at both sites contained relatively even proportions of sensitive, facultative, and tolerant individuals during the pre-mining and early mining phases (Table 4A and 4B). High percentages of tolerant individuals (Chironomidae and Oligochaeta) were noted at both stations during the drought seasons of Fall 1998 and Spring 1999. The Upstream community is currently fairly similar to the pre-mining era, but the Downstream community is more facultative, and less sensitive than it was during the pre-mining and early mining phase (Fig. 13 and 14).

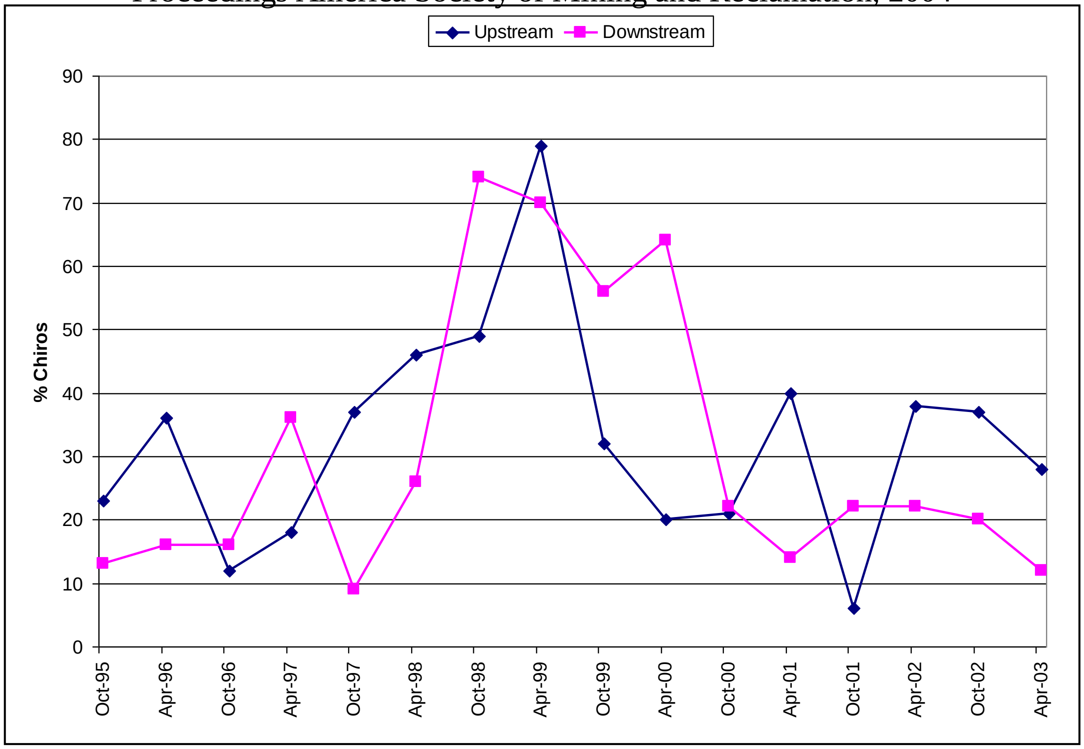

Figure 11. Percent Chironomidae collected at Upstream and Downstream stations on Trough Fork, October 1995 through April 2003. Argus Energy-WV, LLC.

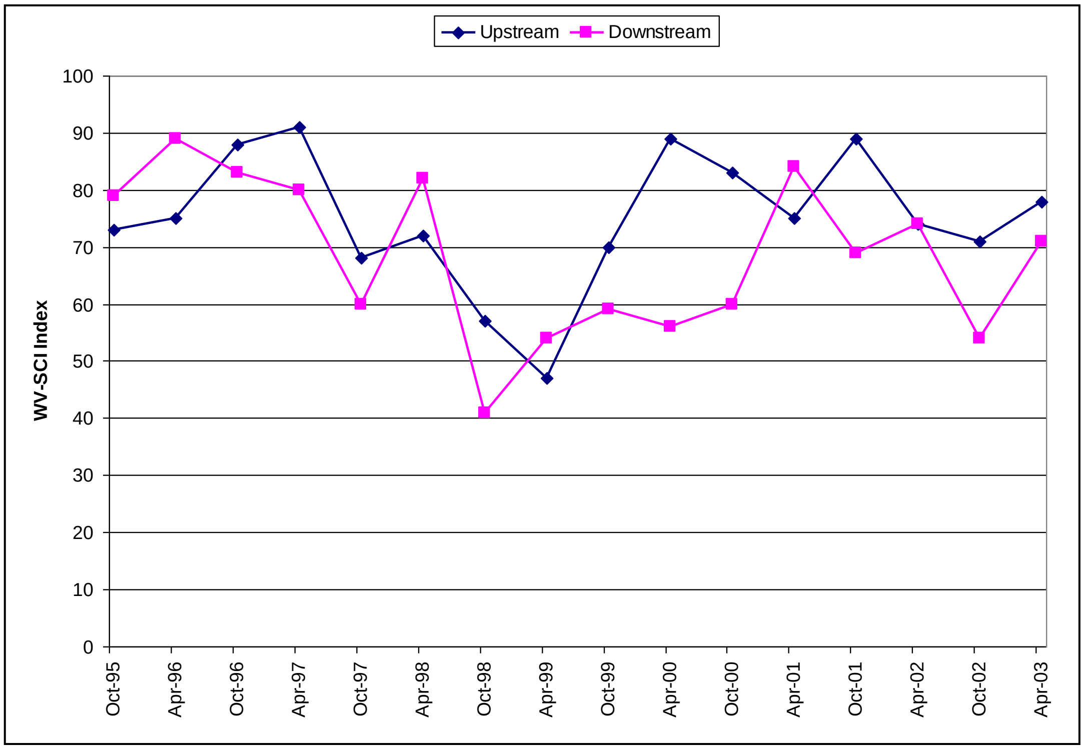

Figure 12. WV-SCI scores from Upstream and Downstream stations on Trough Fork, October 1995 through April 2003. Argus Energy-WV, LLC.

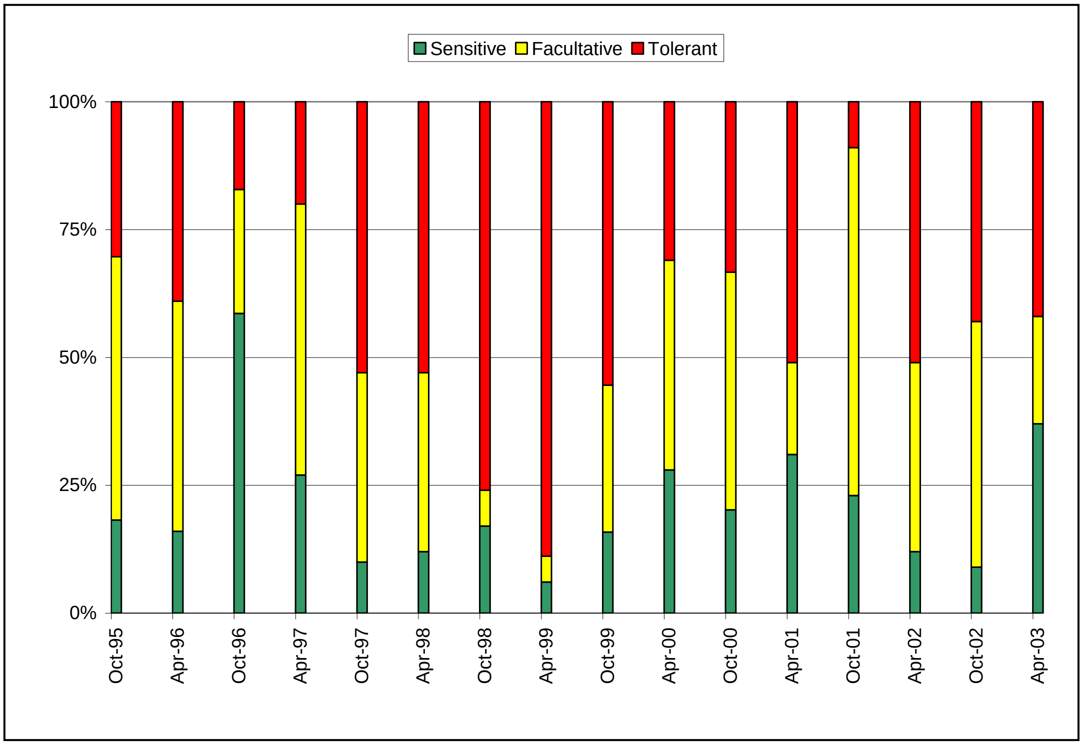

Figure 13. Percent of mayflies collected at Upstream and Downstream stations on Trough Fork, October 1995 through April 2003. Argus Energy-WV, LLC.

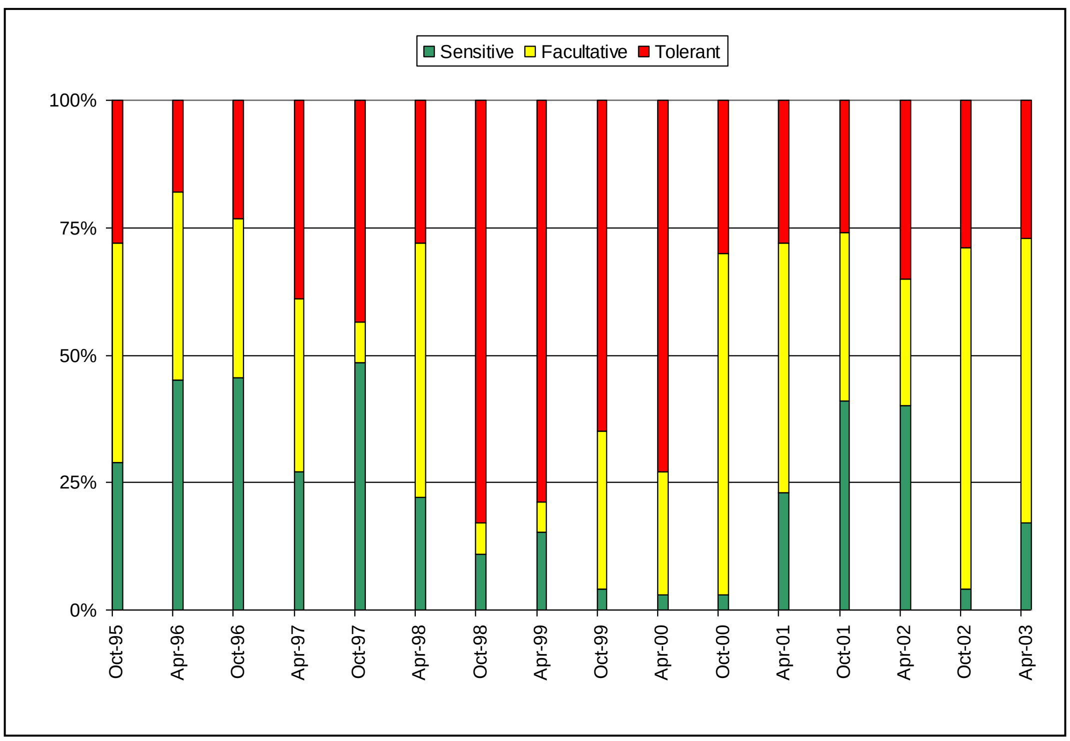

Figure 14. Sensitivities of total individuals collected at Upstream and Downstream stations on Trough Fork, October 1995 through April 2003. Argus Energy-WV, LLC.

TABLE 3A. Number of EPT Taxa, % Mayflies, and % Chironomidae collected at the Upstream Trough Fork station from October 1995 through April 2003. Argus Energy-WV, LLC.

UPSTREAM TROUGH FORK

	Apr03	Oct02	Apr02	Oct01	Apr01	Oct00	Apr00	Oct99	Apr99	Oct98	Apr98	Oct97	Apr97	Oct96	Apr96	Oct95
# EPT Taxa	13	12	12	15	18	18	18	10	13	11	17	10	17	16	14	9
% Mayflies	20	19	17	23	10	15	31	37	5	18	26	38	57	48	42	55
% Chironomidae	28	37	38	6	40	21	20	32	79	49	46	37	18	12	36	23

TABLE 3B. Number of EPT Taxa, % Mayflies, and % Chironomidae collected at the Downstream Trough Fork station from October 1995 through April 2003. Argus Energy-WV, LLC.

DOWNSTREAM TROUGH FORK

	Apr03	Oct02	Apr02	Oct01	Apr01	Oct00	Apr00	Oct99	Apr99	Oct98	Apr98	Oct97	Apr97	Oct96	Apr96	Oct95
# EPT Taxa	11	6	8	8	17	6	12	8	15	6	19	9	16	12	19	9
% Mayflies	9	0.5	1	0.3	5	2	14	29	1	5	25	15	39	54	42	67
% Chironomidae	12	20	22	22	14	22	64	56	70	74	26	9	36	16	16	13

TABLE 4A. Percentages of sensitive, facultative, and tolerant individuals collected at the Upstream Trough Fork station from October 1995 through April 2003. Argus Energy-WV, LLC.

UPSTREAM TROUGH FORK

	Apr03	Oct02	Apr02	Oct01	Apr01	Oct00	Apr00	Oct99	Apr99	Oct98	Apr98	Oct97	Apr97	Oct96	Apr96	Oct95
% Sensitive Ind.	37	9	12	23	31	20	28	16	6	17	12	10	27	58	16	18
% Facultative Ind.	21	48	37	68	18	46	41	29	5	7	35	37	53	24	45	51
% Tolerant Ind.	42	43	51	9	51	33	31	56	88	76	53	53	20	17	39	30

TABLE 4B. Percentages of sensitive, facultative, and tolerant individuals collected at the Downstream Trough Fork station from October 1995 through April 2003. Argus Energy-WV, LLC.

DOWNSTREAM TROUGH FORK

	Apr03	Oct02	Apr02	Oct01	Apr01	Oct00	Apr00	Oct99	Apr99	Oct98	Apr98	Oct97	Apr97	Oct96	Apr96	Oct95
% Sensitive Ind.	17	4	40	41	23	3	3	4	15	11	22	48	27	45	45	29
% Facultative Ind.	56	67	25	33	49	67	24	31	6	6	50	8	34	31	37	43
% Tolerant Ind.	27	29	35	26	28	30	73	65	78	83	28	43	39	23	18	28

TABLE 5. WV-SCI score for both the Upstream and Downstream Trough Fork stations from October 1995 through April 2003. Argus Energy-WV, LLC.

WV-SCI SCORE

	Apr03	Oct02	Apr02	Oct01	Apr01	Oct00	Apr00	Oct99	Apr99	Oct98	Apr98	Oct97	Apr97	Oct96	Apr96	Oct95
Upstream	78	71	74	89	75	83	89	70	47	57	72	68	91	88	75	73
Downstream	71	54	74	69	84	60	56	59	54	41	82	60	80	83	89	79

Since the WV-SCI score is widely used by state regulators, and is an accurate measure of a stream=s biotic condition, it was plotted against a few of the water quality parameters which have shown to have changed over time at these sites. WV-SCI scores were plotted against conductivity (Fig. 15), sulfates (Fig. 16), and total aluminum (Fig. 17). No trends or relationships were obvious. All sampling dates at both the Upstream and Downstream sites were included in these plots. Many other comparative plots were evaluated, but did not present direct relationships. However, a scatter plot of conductivity VS percent mayflies did show some relationship, where as conductivity increased, the percent contribution of mayflies decreased (Fig. 18).

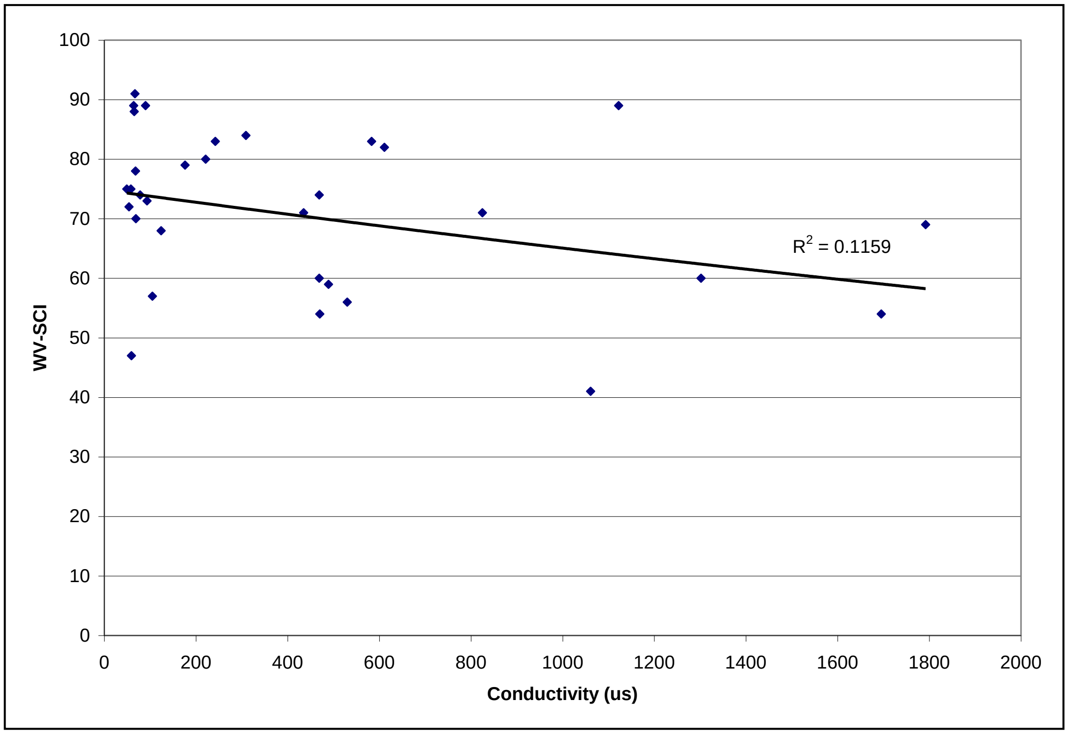

Figure 15. Conductivity VS WV-SCI scores for both Upstream and Downstream stations on Trough Fork, October 1995 through April 2003. Argus Energy-WV, LLC.

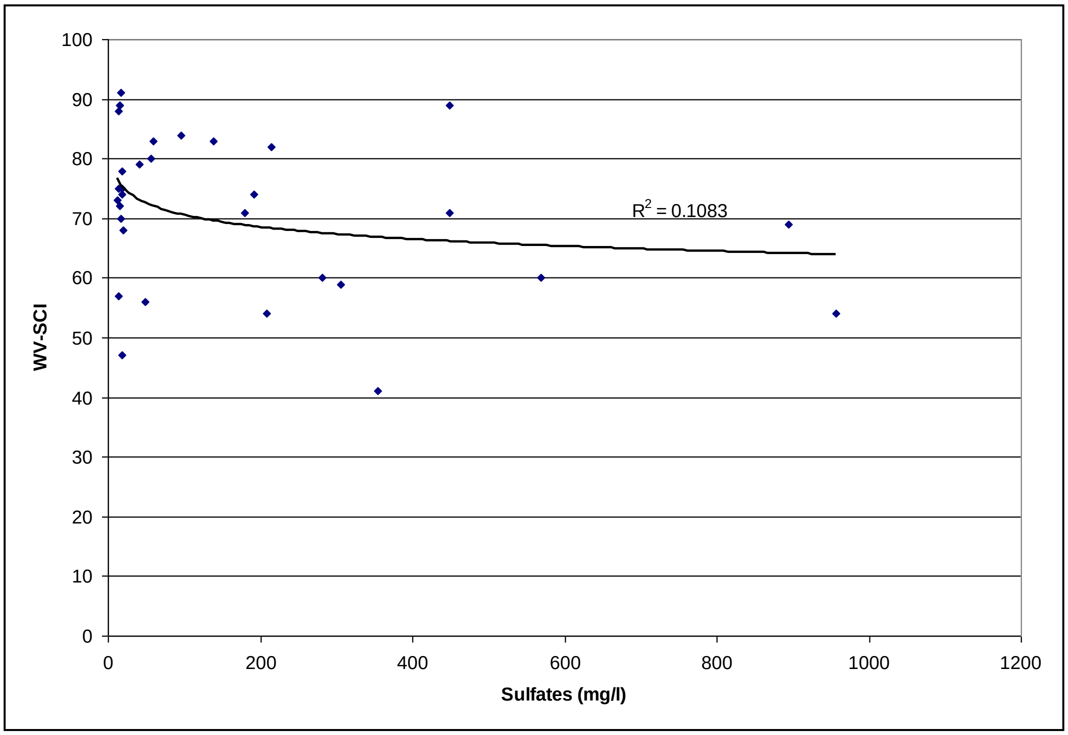

Figure 16. Sulfates VS WV-SCI scores for both Upstream and Downstream stations on Trough Fork, October 1995 through April 2003. Argus Energy-WV, LLC.

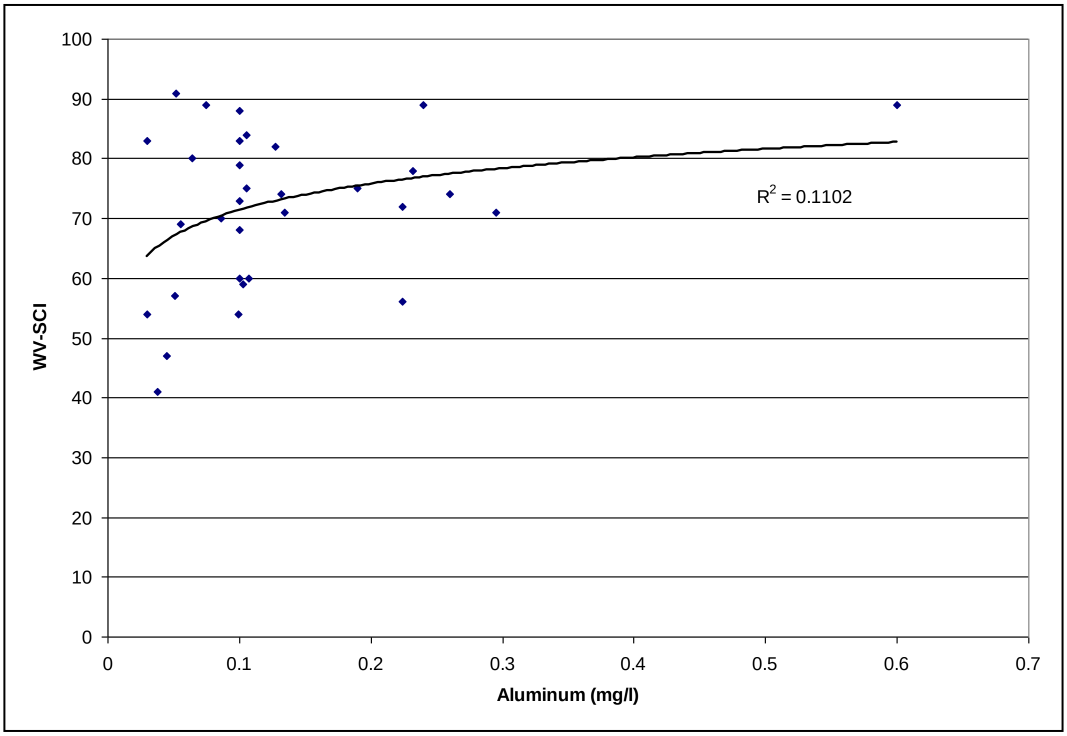

Figure 17. Total Aluminum VS WV-SCI scores for both Upstream and Downstream stations on Trough Fork, October 1995 through April 2003. Argus Energy-WV, LLC.

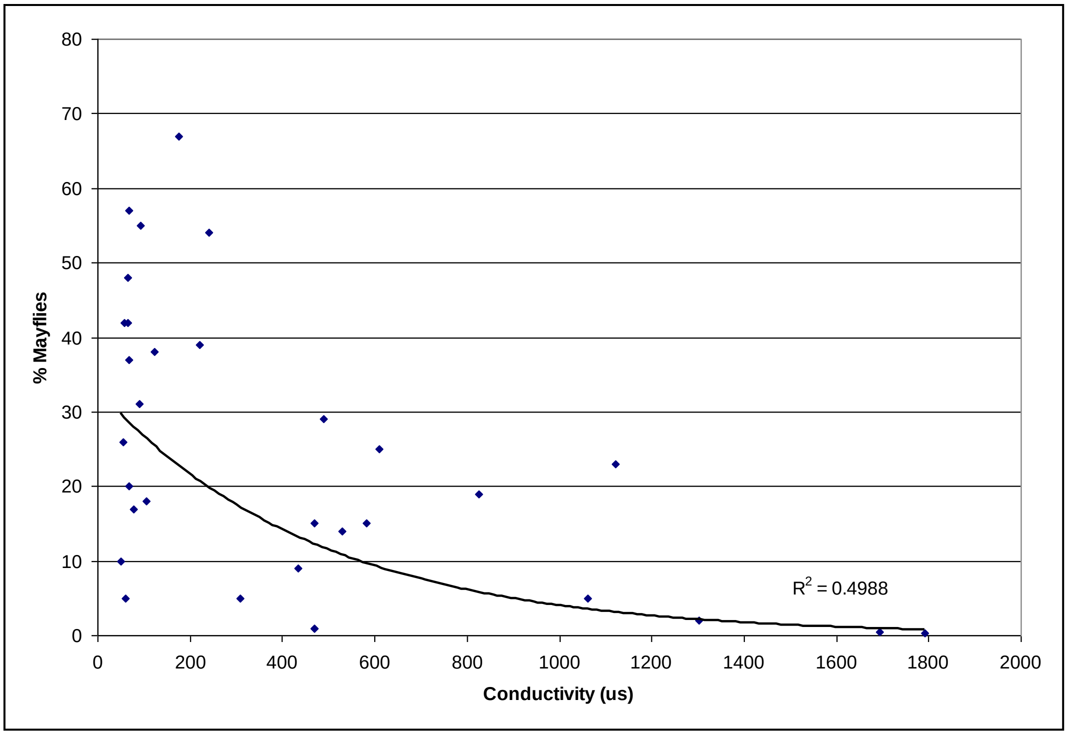

Figure 18. Conductivity VS Percent Mayfiles for both Upstream and Downstream stations on Trough Fork, October 1995 through April 2003. Argus Energy-WV, LLC.

Discussion & Conclusions

One of the most dramatic changes in water quality has been the large increase in sulfate concentrations which are most likely attributed to the oxidation of sulfide bearing overburden exposed during the mining operations. Some water treatments have occurred during these operations to neutralize the acidity produced by the oxidation of pyritic overburden. The treatment chemicals utilized were calcium oxide and sodium hydroxide which most likely contributed to the dramatic increases which were also noticed in the calcium and sodium concentrations at the Downstream site. The increase in magnesium is believed to be attributed to the weathering of magnesium bearing clays. The other increases such as conductivity, TDS, hardness, and alkalinity are directly related to the previously discussed increases in sulfate, calcium, sodium, and magnesium. The increase in alkalinity (which was in the low to mid 20 mg/l at both sites during pre-mining) to levels currently between 65 and 82 mg/l would be desirable as this range should assist in providing a better buffered, and more fertile, aquatic habitat.

A physical change which has been observed has been the slight increase in base flow at the Downstream site compared to the Upstream site. As discussed in the Results section, two tributaries of Trough Fork, located upstream from the Downstream station, have become perennial in their lower reaches due to the placement of valley fills and their sediment ponds. These increases in downstream flow add to the dilution effect of elevated water quality parameters, and provide more available habitat for macroinvertebrates and fish.

As described in the Results section of this paper, the total station abundances or total number of taxa collected are not different from pre-mining conditions (Fig. 7 and 8). These metrics change dramatically depending on season, and have varied considerably over time throughout the course of this study. One undeniable trend has been the decline in the percent of mayflies within both communities populations. The proportion of mayflies has reached very low levels at the Downstream station throughout the active mining and post mining phases, but may be recovering (Fig. 10). With the increases in elevated water quality constituents, the proportions of mayflies have declined. Because water quality has also become somewhat less desirable even at the Upstream site, mayfly percentages have also declined. However, it is probable with any improvements in water quality, will come the improvement in the benthic community. Changes from communities dominated by sensitive and facultative individuals to communities dominated by more facultative and tolerant individuals are a direct result of the lower mayfly proportion.

Besides the declining mayfly populations, and subsequent community sensitivity changes, no other benthic macroinvertebrate trends have been observed. WV-SCI scores once within the Agood@ to Avery good@ ranges, are now within the Afair@ to Agood@ ranges (Fig. 12). Lowest scores for almost all metrics were proven to be directly related to drought conditions which plagued the area during the 1999 and 2000 seasons. It is anticipated that because active surface mining has ceased within the Trough Fork watershed, that water quality will continued to gradually improve. With this improvement should follow improvements in the benthic communities. Argus Energy will continue to monitor the Trough Fork watershed through the completion of mining and reclamation activities to determine the long-term impacts that the mining operation has on the watershed.

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