Geotechnical
Water Resources
Environmental and
Ecological Services

GEI Consultants

Technical Memorandum

Update on Issues for Further Investigation in Regard to the "Pond et al. Study" on Effects of Mountaintop Mining and Valley Fill on Benthic Invertebrate Communities

1.0 Background

Mountaintop mining and valley fill is a mining technique used presently and historically in coal mining in the central Appalachian region of the eastern United States. Excess overburden from the mining operations is deposited in valleys, which often contain ephemeral or intermittent stream systems. To control potential excess sedimentation, sediment ponds are often constructed downstream of the overburden fills. In their review of "appropriate metric systems" Pond et al. (2008b) concluded that mountaintop mining with valley fill techniques are detrimental to the stream ecosystems, based on a relationship between conductivity and "health" of benthic macroinvertebrate communities they developed using two regional multimetric index bioassessment techniques.

GEI Consultants, Inc. (GEI) was retained by the National Mining Association and the West Virginia Coal Association to review Pond et al. (2008b), as well as the underlying draft GLIMPSS index. A previous Technical Memorandum (GEI 2009) identified several areas of concern that should be further investigated in order to validate or qualify the findings of Pond et al. (2008b). This purpose of this memorandum is to update GEI's position on these areas of concern and the proposed plan of study.

To address the concerns raised in GEI (2009), supporting data for Pond et al. (2008b), the WVSCI development study (Gerritsen et al. 2000), and the GLIMPSS development study (Pond et al. 2008a) were requested under the Freedom of Information Act (FOIA). Currently, we have received data showing metric values used in Pond et al. (2008b), as well as some limited habitat and water chemistry values. We have not received the raw data or GPS locations used in Pond et al. (2008b), or any of the data used in Pond et al. (2008a) and Gerritsen et al. (2000). The development of the WVSCI and GLIMPSS MMIs and their use in Pond et al. (2008b) will be analyzed critically once all necessary data are received. Additional field studies are planned by GEI to supplement the analysis of the MMIs and Pond et al. (2008b).

2.0 Progress on Issues Raised by the Study

2.1 General Comments on Data from Pond et al. (2008b)

Data from Pond et al. (2008b) have been received through the FOIA, with a total of 39 metrics calculated. Four additional metrics were available in the appendices of Pond et al. (2008b). As validation of the Pond et al. (2008b) results, two-tailed t-tests were conducted to determine differences between the sites with no mining and the sites with mining. Most of the p-values are similar to the p-values presented in Table 1 of Pond et al. (2008b). Of the habitat and water quality characteristics, only specific conductivity, total Rapid Bioassessment Protocols (RBP) score, percent mining area, and number of fills show statistically significant differences between sites with mining and sites without mining ($p < 0.0038$, Bonferroni corrected). Without correction for multiple tests, pH, embeddedness, and channel alteration would be added to the list ($p < 0.05$.

2.2 Recalculation of individual metrics that comprise the WVSCI and GLIMPSS multimetric indices

As validation of the Pond et al. (2008b) results, the WVSCI and the GLIMPSS scores for the Pond et al. (2008b) data have been recalculated by GEI personnel. While final scores are not exact, WVSCI scores are only <0.33 points and GLIMPSS scores <0.88 points from the scores reported in Pond et al. (2008b), which is likely an effect of rounding.

Interestingly, Ephemeroptera metrics had the lowest values out of the six metrics in the GLIMPSS index for the majority of both the “impacted” and “nonimpacted” sites (Table 1). At 63% of the impacted sites, the lowest scoring metric was % Ephemeroptera minus *Baetis*, with an additional 33% of the sites having the number of Ephemeroptera genera as the lowest scoring metric. At the nonimpacted sites, 38% of the sites had the % Ephemeroptera minus *Baetis* as the lowest scoring metric, and another 8% of the sites had the number of Ephemeroptera genera as the lowest scoring metric (Table 1).

Table 1: Lowest scoring metric in the GLIMPSS index from Pond et al. (2008b).

Lowest Scoring Metric	“Impacted” sites (n=24)	“Nonimpacted” sites (n=13)
% Ephemeroptera minus *Baetis*	15	5
# Ephemeroptera genera	8	1
# Intolerant Taxa (<4)	1	1
% Plecoptera	0	2
% 5 Dominant Taxa	0	3
Total Number of Taxa	0	1

When the WVSCI scores were calculated for these same sites in Pond et al. (2008b), the metric that scored lowest most frequently at the impacted sites was the EPT family richness, while the % 2 dominant taxa was the lowest scoring metric at nonimpacted sites (Table 2). In both cases, nearly 50% of the sites had the lowest value for these metrics.

Table 2: Lowest scoring metric in the WVSCI index from Pond et al. (2008b).

Lowest Scoring Metric	"Impacted" sites (n=17)	"Nonimpacted" sites (n=20)
# Total Taxa (Family)	0	2
EPT Family Richness	8	1
HBI (Family)	0	1
% EPT (Family)	5	5
% Chironomidae (Family)	0	2
% 2 dominant taxa (Family	4	9

Seven of the 37 sites were rated as unimpaired by WVSCI and impaired by GLIMPSS (Table 3). In all cases, the metric % Ephemeroptera minus *Baetis* was the lowest scoring metric in the GLIMPSS index. In all but three of the seven sites, this metric scored more than ten points lower than any other metric, and in two of those three sites, the second lowest scoring metric was the number of Ephemeroptera taxa. Based on this, the inclusion of two Ephemeroptera metrics into the GLIMPSS index appears to be a strong factor in the rating differences between GLIMPSS and the WVSCI, and a dominant driving force for determining which sites are rated as impaired or unimpaired based on GLIMPSS.

Combined, these results may illustrate an "overdependence" on Ephemeroptera-based metrics in the GLIMPSS index.

Additionally, for both the WVSCI and GLIMPSS MMIs, scores are calculated for each metric as a ratio of the measured value to a known reference point (the 5th or 95th percentile of the values for that metric from the reference sites used in development of the MMI) and normalized by multiplication by 100. For these MMIs, the 5th percentile is used for metrics expected to decrease in value as conditions improve, and the 95th percentile is used for metrics expected to increase in value as conditions improve. In addition, when the value for a metric exceeds the 95th percentile (or is under the 5th percentile in appropriate cases), the score is automatically reset to 100 so that a metric or site cannot be rated as "better" than reference condition.

Table 3: Metric scores for sites that were rated as "unimpaired" by WVSCI and as "impaired" by GLIMPSS in Pond et al. (2008b)

		Camp	**Ellis Camp**	**Hardway**	**Hughes**	**Neff**	**Sandlick**	**Whitman**
WVSCI	**Total Family Richness**	72.73	68.18	63.64	68.18	81.82	86.36	50.00
	EPT Family Richness	84.62	76.92	69.23	61.54	76.92	100	53.85
	HBI (Family)	98.11	93.78	90.54	85.41	90.27	95.68	95.68
	% EPT	100	90.71	91.83	69.43	85.67	100	99.66
	% Chironomidae	97.66	88.00	89.52	73.75	85.96	96.61	92.57
	% 2 dominant Families	43.06	52.63	70.97	65.39	60.61	40.08	51.83
TOTAL SCORE		**82.70**	**78.37**	**79.29**	**70.62**	**80.21**	**86.46**	**73.93**
GLIMPSS	**Total generic richness**	53.01	60.24	60.24	55.42	77.11	62.65	43.37
	# taxa TV<4	44.44	48.89	48.89	26.67	53.33	53.33	31.11
	# Ephemeroptera taxa	36.36	45.45	0	9.09	36.36	54.55	36.36
	# Plecoptera taxa	44.44	33.33	44.44	33.33	44.44	66.67	33.33
	# clinger genera	55.81	60.47	51.16	32.56	65.12	74.42	41.86
	HBI (Genus)	77.71	73.61	100	75.06	79.76	77.83	76.14
	% Ephemeroptera – Baetis	13.08	6.54	0	0	22.43	12.21	17.76
	% Orthocladiinae	97.18	89.63	93.15	92.15	90.13	96.15	92.15
	% 5 dominant genera	34.09	24.62	41.67	44.51	46.40	37.12	24.62
TOTAL SCORE		**50.37**	**48.92**	**48.49**	**40.55**	**56.64**	**59.11**	**43.84**

In Pond et al. (2008b), five metrics had values that necessitated resetting the score to 100 in at least one site for GLIMPSS; all of the sites were unmined. For WVSCI, five metrics had values that necessitated resetting the score to 100 in at least one site; not all of the sites were mined. If these metrics had not been reset to 100, each metric score and the final index score for each site would have been higher. We are unsure if this would make any meaningful difference in the final analysis – it remains a point of further study.

2.3 Literature and data search for conductivity effects on benthic macroinvertebrates

Pond et al. (2008b) relied heavily on conductivity measures to corroborate their findings of "stream impairment" using the GLIMPSS index. When GLIMPSS scores were plotted against raw conductivity values for the 37 site in Pond et al. (2008b), a negative relationship can be seen (Figure 1). A GLIMPSS score of 62 is needed to be rated as "unimpaired", and examination of the data indicates that such a score appears to be only feasible for sites with conductivity <500 µS/cm.

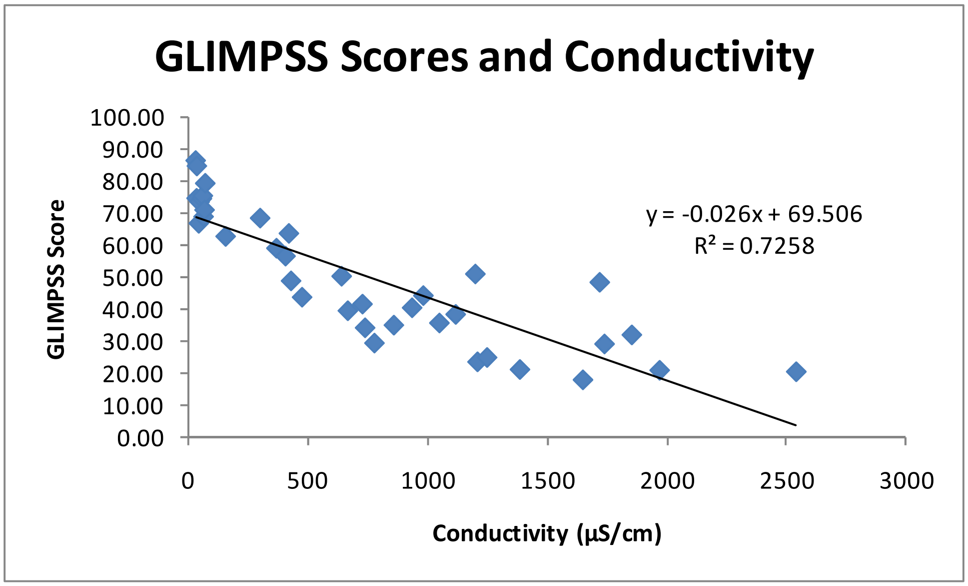

Figure 1: Relationship between GLIMPSS scores and conductivity in Pond et al. (2008b).

A review of the literature produced several studies that support the hypothesis that a relationship exists between conductivity and various parameters of macroinvertebrate populations in streams, particularly with adverse impacts to mayflies (Howard et al. 2000, Chambers and Messenger 2001, Harman et al. 2005, Merricks et al. 2007). However, while much of the literature appears to support a conductivity threshold around 500 µS/cm, results from Kennedy et al. (2004) in the Leading Creek watershed in Ohio indicated that somewhat higher conductivities (up to 1,310 µS/cm) might not cause negative effects.

Most of the other literature sources used the WVSCI and found that conductivity was either negatively correlated with WVSCI scores across the range of conductivity values (Green et al. 2000, Freund and Petty 2007) or had no consistent relationship with the WVSCI scores (Green et al 2000, Armstead 2006, Maggard 2009). All of these studies were conducted with at least some sites in the West Virginia coal mining belt.

The discrepancy in results from the various studies may be because conductivity is often a surrogate measure of other, often complex, water chemistry parameters, and is influenced by numerous organic and inorganic compounds that could vary with location. There appears to be insufficient data in Pond et al. (2008b) to determine if conductivity itself is the route through which impairment of the macroinvertebrate communities is occurring in mined areas or whether other factors affecting the invertebrate populations are also driving the apparent relationship with conductivity. Other studies have raised the same issue and questioned how conductivity may affect the changes in the invertebrate populations – perhaps by altering osmoregulatory efficiency, ion specific toxicity, or some other mechanism (Howard et al.

2000, Chambers and Messenger 2001). If data become available, conductivity relationships in Pond et al. (2008b) should be further investigated to determine if there are other factors that can explain the trend; that is, to determine if conductivity is simply a surrogate for another factor.

2.4 Literature and data search for impoundment effects on benthic macroinvertebrates

There are a number of confounding factors related to valley fill conditions and the patterns observed by Pond et al. (2008b) that may be unrelated to conductivity. For example, the relations between the settling ponds associated with valley fill and resultant changes in stream hydrology, stream chemistry, sediment release, water quality, and food quality could be an important causal agent for the changes in invertebrate community structure.

2.4.1 Distance from Impoundment

In Pond et al. (2008b), minimum distance of a site below an impoundment was 80 m, average distance was 800 m, and maximum distance was 2.2 km. Conductivity values were highest in sites located closer to the impoundment(s) (Figure 2); thus, distance from the impoundment may be the primary factor or a secondary factor along with conductivity that is affecting the macroinvertebrate communities at the sites included in the Pond et al. (2008b) data that was not discussed and should be considered.

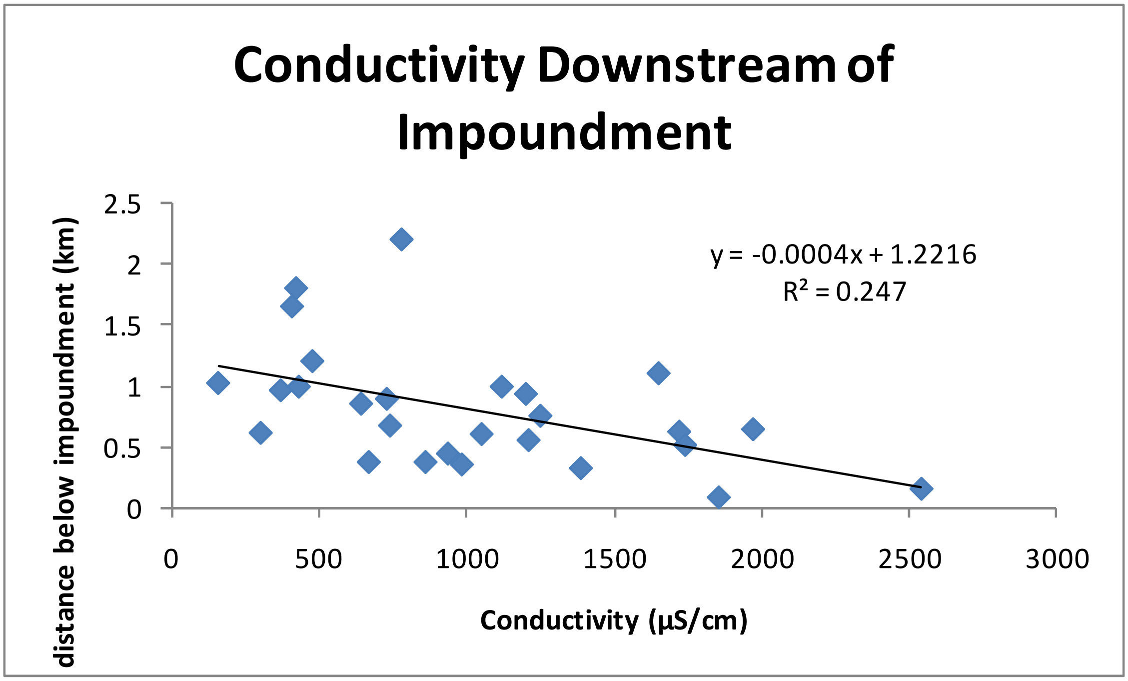

Figure 2: Relationship between conductivity and the distance a site is located downstream of the lowest impoundment in Pond et al. (2008b).

Preliminary evaluation of the literature has resulted in several sources citing changes in trophic groups occurring downstream of lakes and impoundments (Mackay and Waters 1986, Armstead 2006, Maggard 2009). Specifically, filterer-feeding insects (particularly the net-spinning hydropsychid caddisfly and simuliid black fly larvae) tend to be found at higher abundances immediately below surface-release impoundments in comparison to above the impoundment or further downstream. These shifts in trophic groups do not persist downstream as distance from the impoundment increases, since shredder populations increased and filterer-collector populations decreased at sites further downstream from ponds (Merricks et al. 2007).

This shift occurs due to changes in food availability downstream of impoundments, with the surface releases of the settling ponds apparently being rich in components fed on by hydropsychid caddisflies and other filter-feeding organisms (Hartman et al. 2005). As these organisms increase in density in response to the readily available food source, they may competitively displace other organisms, such as mayflies, which tend to be scrapers and collector-gatherers. Brittain and Altveit (1989) reviewed studies that indicated that some species of mayflies increase in abundance in response to enhanced algal and moss growth downstream of impoundments, while the increased periphyton is disadvantageous to other mayflies that prefer clean rock surfaces.

2.4.2 Hydrologic Changes

The sediment ponds and impoundments that accompany mountaintop mining and valley fill practices may also affect the streams by changing their hydrology to retain water and release it more slowly to the stream channels than normal surface flows (Armstead 2006), resulting in streams that behave more like a perennial spring system than an intermittent/ephemeral stream system. Water chemistry and biological communities in such perennial “spring-like” systems are often vastly different from that of intermittent/ephemeral waterbodies and even the more variable downstream systems (Williams 1987). In West Virginia, Green et al. (2000), Armstead (2006), and Maggard (2009) all noted that flows were absent or low at some unimpacted “reference” sites during certain seasons or years while flow was present or greater at the sites downstream of sediment ponds and valley fill activities during the same time period.

GEI intends to further investigate the effects of altered stream hydrology for the study streams by comparing a range of stream conditions similar to those found in the Pond et al. (2008b) study streams to natural spring systems. This comparison would evaluate the potential influence that conversion of the ephemeral/intermittent stream system to a perennial spring-type system might do to alter the community composition in the streams in question.

2.4.3 Sedimentation

There are also possibly negative effects of sedimentation resulting from construction of the valley fill sediment-control dams. Based on the reviewed research, sedimentation resulting from the mountaintop mining, valley fill, and sediment pond construction may not be the major issue, but further examination may indicate whether or not it is a secondary contributing factor to be considered.

2.5 Maintenance of Trophic Function

GEI (2009) briefly examined the results of Pond et al. (2008b) to determine if any differences in the functional structure of the community existed. Many of the percentages of each functional feeding group and habit group were actually relatively similar between mined and unmined streams. Filterer-collectors increased between 8% and 12% from the sites without mining influence to the sites with mining influence. The largest decrease in functional feeding groups was observed with scrapers, which decreased 10% between the sites without mines and the moderate mining activity sites. All other decreases or increases were 7% or less between sites without mining and sites with mining. As for the habit groups, almost all differences between percent composition of each group were small. This suggests that the overall function of the benthic invertebrate communities remained relatively unchanged even though the taxonomic composition changed.

As mentioned above, the published literature we reviewed indicated that impoundments can result in changes in trophic groups downstream, specifically increases in filterer-collectors (Potesta & Associates 2003, Armstead 2006). Potesta & Associates (2003) also reported that while percent Ephemeroptera was significantly lower at the valley-fill sites than at the sites without mining in the watershed in both seasons, total abundances were actually higher. Changes in the biological communities and the water chemistry did not appear to have significant impacts on stream function with respect to downstream segments, and that the reduction in mayflies did not appear to affect the overall function of the streams, as all functional feeding groups were still represented.

Maggard (2009) raised the speculation that “sometimes mine water is better than little or no water” and pointed out that even the two streams with no mountaintop mining or valley fill activity had high conductivities. He also indicated that the reductions in mayflies observed by Pond et al. (2008b) may likely be due to the effects of sediment ponds or changes in vegetation rather than high conductivity.

2.6 Basis for GLIMPSS Index?

Pond et al. (2008b) relied heavily on the results from the recently developed, although still unpublished, multi-metric invertebrate index, GLIMPSS. Pond et al. (2008b) indicated that the GLIMPSS index "performed better" than the previously established WVSCI index. GEI (2009) noted that there are several aspects of the development and use of the GLIMPSS index that should be investigated further. Upon receipt of the original data set used by the GLIMPSS and WVSCI authors, GEI intends to conduct analysis of the data to evaluate those areas highlighted in GEI (2009).

First, we intend to conduct an evaluation of other potential metrics not included in the original 36 tested in GLIMPSS, particularly additional tolerance metrics, habit metrics, and metrics that include Trichoptera, and their potential incorporation into a multimetric index using similar criteria for redundancy, sensitivity, precision, discriminatory ability, etc. Second, we intend to investigate the spatial distribution of sites used in development of the GLIMPSS index to determine if it may be inadvertently geared toward identification of sites affected by mountaintop mining and valley fill rather than general disturbances. This might have been due to overrepresentation of mined sites in the impacted subset rather than the spectrum of anthropogenic influences.

3.0 Summary

In summary, while the findings of Pond et al. (2008b) appear on the surface to strongly indicate a causal agent of conductivity to "impairment" of invertebrate communities, as related to variable valley-fill mine influence – our preliminary review indicates that it is possible that conductivity is acting as the surrogate for other factors that could account for those patterns . It is clear that additional study of these patterns should be conducted to determine if conductivity is potentially providing a "false signal" and if, in fact, there are other reasons for the observed changes in invertebrate community structure.

A preliminary literature review indicated that the presence of impoundments from the sediment ponds and the associated changes in nutrient availability and hydrology that results from these impoundments is a possible factor causing differences observed in the macroinvertebrate communities downstream of mining impacts. In addition, while most studies report that mayfly abundance and richness is decreased downstream from mining, our initial analysis of the Pond et al. (2008b) data indicated that the overall functional feeding group and habit group composition of the invertebrate communities does not differ substantially between sites with and without mining influences other than what would be expected from the effects of the sediment pond impoundments.

Futhermore, once we have received the necessary data, the validity of the GLIMPSS index will be investigated, as the methods used for metric selection and the data incorporated into developing it may have biased the results.

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