SECTION VIII: Effects of Mining on Streams

VIII.A – Overview

The PA DEP tasked the University with assessing the impacts of underground bituminous coal mining on the flow and biological health of streams that overlay the active mines during the 3rd assessment period. The impacts of underground bituminous coal mining on streams can arise either from contamination or from subsidence. During the 3rd assessment period they occurred almost exclusively from subsidence. Subsidence can occur with any kind of underground bituminous coal mining, but is an expected outcome with longwall mining. The few examples of subsidence associated with room-and-pillar mining were documented in Sections V.E and VII.D.8 and were found to rarely lead to stream flow problems.

The predominance of longwall mining and the low prevalence of subsidence-associated flow problems with room-and-pillar mining together resulted in nearly all stream flow reports being associated with longwall mining during the 3rd reporting period. The typical subsidence basin has its greatest depth toward the center of the mined panel, rising to the historical surface height at the edges of the panel. For streams, this can create five kinds of problems:

- First, stream water pools in the lowest part of the subsidence basin, flooding previously dry land.
- Second, the unmined areas between panels are now higher than grade and act as dams, preventing stream flow across them. As the subsidence basin is formed, considerable deformation stress is placed on the underlying rock layers as they bend to conform to the shape of the subsidence basin. Some rock layers lack sufficient plasticity and fracture at points of greatest stress.
- The third kind of stream problem results from the compression ruptures discussed in Section VII.C.4. Stresses are concentrated in the valley bottoms causing the rock layers forming the base of the streams to rupture. These compression ruptures can block water flow and, in some cases, the flow can propagate to the base of the fracture zone many feet below the surface.
- The fourth kind of problem results from tension cracks (similar to those shown in Section IV.E and VII.C.1), either through the direct loss of surface flow into deeper layers of rock through the fissures, or through loss of the groundwater that feeds the surface flow.
- The fifth has to do with variation of flow altering the biological properties of the streams, changing sediment load, oxygen content and habitat availability and quality. This can result in non-attainment of the designated use, either through direct stresses on the fish species, or by altering food and habitat availability.

In general, these five causes of stream impacts are referred to in the PA DEP reports as incidents of pooling or flow loss, regardless of the precise cause.

If the PA DEP determines that stream flow has been diminished as a result of undermining, the mining company is required to restore flow to its pre-mining condition. Initially, mining companies may augment flow with water pumped from wells or trucked in from remote sources (Figure VIII-1). This is a temporary solution.

Figure VIII-1 - An augmentation line supplying temporary flow to stream 32508 over Bailey Mine (Photograph from PA DEP files).

For more permanent and long-term solutions, the PA DEP requires that the mining company submit a mitigation plan for approval. At the end of this assessment period, it was noted that mining companies were now required to submit these mitigation plans along with their mining permit applications so that work can proceed as quickly as possible in cases where impacts occur. Using simulations and modeling, mining companies predict which streams have a chance to be impacted by underground mining and can thus design detailed mitigation plans prior to subsidence. This may facilitate a faster resolution time for stream impacts. Appendix E2 provides examples of stream mitigation efforts and associated flow observations made by the University on these same streams.

The change in vertical subsidence as discussed in Section IV.D.2 often causes both pooling in the low areas over the longwall panel and loss of flow in the high areas over the gate roads. In such cases, mitigation involves cutting a new channel in the high areas between subsided panels (often referred to a gate cutting), along with stream bank restoration in the channeled areas. This often restores normal flow. Cutting new channels is also often effective when compression ruptures block normal stream flow.

Tension fractures or cracks can result in loss of flow because the surface water retreated to subsurface aquifers through the newly created fractures. When sufficient clay overlays the fractured bedrock, the clay often works down into the fracture and the water loss self-seals. When the fractures do not self-seal, the mining company must resort to grouting. Grouting involves drilling boreholes in the fractured rock layer and injecting one of a number of substances, typically clay, cement-based mixtures, epoxies or urethanes (Figure VIII-2) into the holes. In rare instances, when repeated grouting does not seal the fractures, the substrate may be temporarily removed and an impermeable membrane, referred to as a liner, is constructed over the stream channel. The substrate material is then re-deposited into the stream bed and the stream bank vegetation is restored.

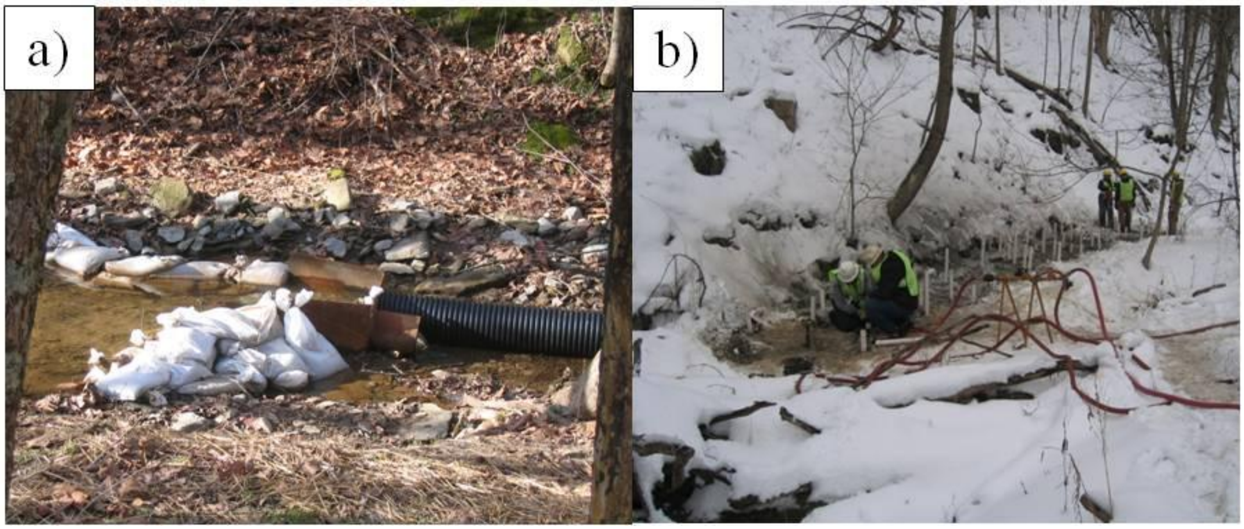

Figure VIII-2 - *Grouting operation procedures. First, a) stream flow must be collected and diverted around the area where grouting will occur - shown at stream 32532 in Bailey Mine and then b) boreholes are drilled and clay pumped into fractures - shown at stream 32740 in Enlow Fork Mine (Photographs from PA DEP files).*

While restoring flow to pre-mining conditions is often sufficient to regain the biological health of a stream, additional measures may be taken to ensure sufficient re-colonization of the stream by aquatic taxa. Mining companies may create various habitats within the stream channel by using log vanes, j-hooks, root wads, and other methods to promote the re-establishment of macroinvertebrate and fish populations. These artificial habitats provide the aquatic taxa with breeding grounds and places to hide from predators, which are necessary for sufficient recovery of the aquatic community as a whole. When mitigation techniques are successful, a period of monitoring follows. If the monitoring indicates the stream is within the 88-percentile of the pre-mining or control stream TBS, the PA DEP designates the problem as resolved.

The goals of the University were to:

1. Determine the total length of undermined streams, categorized by mining method and mine.
2. Report on the resolution status at the end of the 3rd assessment period for all PA DEP stream investigations associated with underground bituminous coal mining.
3. Report the number of stream investigations per mile of undermined stream, by mining method and mine, and categorized by their resolution status (Withdrawn, Resolved, or Unresolved) at the end of the 3rd assessment period.
4. Conduct independent stream surveys of flow and biological health for a subsample of the undermined streams, to determine the extent to which reported flow problems had

resulted in decreased biological health and the extent to which stream biological health had recovered following mitigation.

VIII.B – Data Collection

VIII.B.1 – Definition of 'Stream' and Identification of Individual Streams

Under PA Code, Title 25, Environmental Protection, Chapter 93, Water Quality Standards, a lotic ecosystem (i.e. flowing body of water) must meet specific criteria to be designated a stream. A stream must support at least two recognizable taxonomic groups in the macroinvertebrate community. These taxa must be sufficiently large to be seen without the aid of a microscope and they must spend a "living part of their life cycle" in an aquatic habitat. Other lotic bodies that do not meet these requirements are not streams and therefore do not fall under the scope of this report.

Furthermore, the PA DEP, working with the U.S. Geological Survey (USGS), created a Water Resources Data System (WRDS) for PA streams. Each named stream has a 5-digit numeric identification code referred to as a WRDS number. The PA Gazetteer of Streams (PADER, 1989) provides a complete list of these numbers. They are also available in USGS digital watershed coverage (Hoffman & Kernan, 1996). All streams with WRDS numbers that overlay the regions undermined (see below) were included in the inventory.

VIII.B.2 – Definition of Designated Stream Use

The PA DEP has assigned designated uses to streams, based on use designations defined in the PA Code section 93.3 (http://www.pacode.com/secure/data/025/chapter93/s93.3.html), indicating the type of fishery supported by the stream: Trout Stocked, Warm Water, High Quality (HQ) Trout Stocked, HQ Warm Water, and HQ Cold Water, and Exceptional Value. The designated uses of all undermined streams were recorded in UGISdb.

VIII.B.3 – Compilation of Undermined Stream Inventory

An inventory of the undermined streams was requested by the PA DEP, classified by mining method and mine name (Table VIII-1). This was accomplished by cross-referencing data in BUMIS with the 6-month mining maps. The 200-ft buffer was extended from the edge of the areas mined and all streams within these mined areas and buffers were inventoried. This information was joined to UGISdb (Section II) and details related to topographic characteristics and other relevant information were added. The identities of undermined streams were compiled, their undermined lengths were determined, and an inventory was created using Excel spreadsheets, by mine, mining method, and designated use.

Table VIII-1 – Lengths of Undermined Streams by Mine and Mining Method.

Mine Name	Mining Method						Total
	Room-and-Pillar		Longwall		Pillar Recovery		
	Length, mi	# of Segments*	Length, mi	# of Segments	Length, mi	# of Segments	
4 West	1.8	5					1.8
Agustus	0.5	1					0.5
Bailey	5.8	38	11.4	28			17.2
Blacksville No.2	2.7	20	7.5	18			10.2
Cherry Tree	0.2	3					0.2
Clementine No.1	3.8	13					3.8
Crawdad No.1	0.5	2					0.5
Cumberland	4.9	38	11	24			15.9
Darmac No.2	0.4	5					0.4
Dora No.8	0.9	5					0.9
Dutch Run	1.3	12					1.3
Eighty-Four	1.5	10	5.2	16			6.7
Emerald	3.3	27	8.4	23			11.7
Enlow Fork	5.5	39	19.9	43			25.4
Genesis No.17	0.4	2					0.4
Gillhouser Run	0.2	2					0.2
High Quality	0.2	3	0.4	2			0.6
Keystone East	1.3	4					1.3
Little Toby	0.6	3					0.6
Logansport	1.8	8					1.8
Madison	0.6	2					0.6
Miller	0.1	2					0.1
Nolo	1.9	5					1.9
Ondo	1.6	5					1.6
Parkwood	0.4	3					0.4
Penfield	0.2	3					0.2
Penn View	0.2	3					0.2
Quecreek No.1	2.2	6					2.2
Rossmoyne No.1	0.3	2					0.3
Roytown	0.3	3					0.3
Shoemaker	0.1	3	0.01	1			0.1
Stitt	0.8	2					0.8
Titus	0.2	2			0.01	1	0.2
TJS No.5	0.1	2					0.1
Toms Run	0.2	1					0.2
Tracy Lynne	1.7	7					1.7
Twin Rocks	0.9	4					0.9
Windber No.78	0.3	4					0.3
Total							113.7

* Segments - The part of a stream extending between designated tributary junctions

Nearly two-thirds of all undermined streams were associated with longwall mining and the remainders were undermined by room and pillar in the 3rd assessment period (Table VIII-2).

Table VIII-2 - Lengths of undermined streams sorted by mining method.

Mining Method	Length Undermined, mi
Longwall	63.9
Room and Pillar	49.8
Pillar Recovery	0
Total	113.7

VIII.B.4 – Compilation of Stream Investigation Reports

A stream investigation report was initiated in BUMIS, and in accompanying paper files at the CDMO, when a property owner, mining company, or PA DEP subsidence agents reported an incidence of flow loss or pooling. The PA DEP assigned each reported effect a claim number according to the year in which the report was filed and the order in which they were received. For example, the 12th reported problem in the year 2005 was assigned the number ST0512. Using a query tool, the University determined the total number of reported effects in BUMIS that occurred during the assessment time period. The date that the reported effect occurred and date of its final resolution are recorded in BUMIS.

The final resolution status has two possible outcomes: 1) Not Due to Underground Mining or 2) Resolved. If the PA DEP hydrologists, subsidence agents, and biologists determine that the reported effect is a result of surrounding land use, drought, or other factors unrelated to underground bituminous mining, the final resolution is Not Due to Underground Mining. During the current reporting period, 55 stream investigations occurred with 18 Resolved, 2 Not Due to Underground Mining, and 35 Not Yet Resolved (Table VIII-3).

Table VIII-3 - Status of all stream investigations at the end of the reporting period.

Resolution Status	Number
Final: Resolved	18
Final: Not Due to Underground Mining	2
Interim: Not Yet Resolved	35
Total	55

The Not Yet Resolved category was used when the investigation determined that the reported effects were indeed a result of underground mining. The mining company was required to submit mitigation and/or monitoring plan(s) to the PA DEP. The current requirement is that these mitigation plans must be submitted with the mining permit request. After approval of the mitigation and monitoring plans, the mining company must update the PA DEP on the progress and status of the stream(s). The PA DEP monitors the stream(s) closely during this time. Using flow and biology comparisons to either control streams or to pre-mining data from the same stream, the PA DEP makes the final determination if an effect is reported, and when, and if, the stream recovered. The investigation is then closed and the reported effect is Resolved. At the end of the assessment time period, not all reported effects had a final resolution status and for those streams where the investigation was still in progress, the final resolution status was listed as Not Yet Resolved. Figure VIII-3 shows the distribution of stream investigations sorted by mine and resolution status.

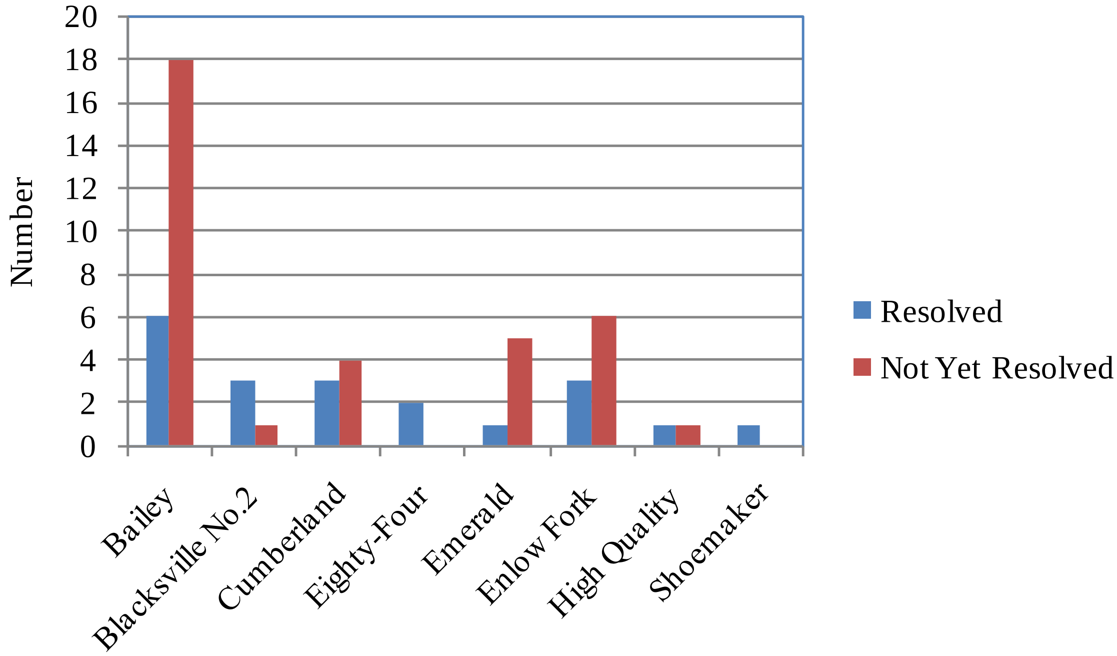

Figure VIII-3 – Distribution of stream investigations sorted by mine and resolution category.

BUMIS also contains the longwall panels where the effect occurred and the type of impact that occurred. In addition to searching BUMIS and the stream investigation files submitted by DEP hydrological and water pollution specialists at CDMO, the University also examined records associated with stream problem located at CDMO. When incomplete records were found, they were recorded as Not Yet Resolved. In 2007, PA DEP discontinued the use of stream investigation files if the mining company did not dispute a report of stream flow problems. Thus for the latter part of 2007 and all of 2008, there was much less information available for analysis.

An Excel spreadsheet was created to track reported stream effects by investigation number, mine type, dates of occurrence and/or resolution, type of effect, final resolution status, and actions taken by the PA DEP and mine operators. All information from BUMIS, from PA DEP staff-supplied spreadsheets, and from the paper files at CDMO was joined to UGISdb, and the relevant information was added.

VIII.B.5 – PA DEP Methodology for Assessing Impacts on Stream Flow

Stream impacts due to longwall mining conducted during the 3rd assessment period were of two types:

- impacts on flow, and
- impacts on the biological health of the stream.

During the third assessment period there was a major change in the methods for assessing flow and biological impacts. These are defined in PA DEP Bureau of Mining and Reclamation Technical Guidance Document (TGD-655) 563-2000-655 (PA DEP, 2005). On October 8, 2005, TGD-655 became the official guidance document. The PA DEP phased in the new stream protection requirements with the industry, over the next 12 – 18 months. This period allowed for the implementation of new ways in collecting biological data and increasing the frequency of stream flow measurements over areas of longwall panels. Thus, the flow data that exists for most of the streams undermined during the current reporting period does not meet the requirements of the TGD-655.

Prior to the TGD-655, potential impacts on flow were assessed following a period of little or no rain, so that the observed flow represented the ordinarily sustained flow through a combination of surface runoff and groundwater input, and was not simply a pulse of runoff following a rain event. The length of dry or pooling segments of a stream was calculated by using a handheld GPS unit to locate and measure the observed impact. (See Appendix D - Flow Observations Conducted by PA DEP Subsidence Agents / Biologists).

The reported impacts on flow for the eight longwall mines, for which full data are available, are summarized in Appendix E1. Averaged across the mines, for every mile of stream undermined, there were 0.63 reports of stream flow problems reported, i.e. roughly a 50-50 chance of a problem per mile of stream during the 3rd assessment period. By the end of the 3rd assessment period, of the 55 total reported effects in Appendix E1, 35 or 64-pct remained Not Yet Resolved (Table VIII-3).

Table VIII-4 - Stream investigations per mile of undermined stream sorted by mine.

Mine Name	Stream Undermined, mi	Total Investigations	Investigations per mile Undermined	Not Yet Resolved Investigations	Not Yet Resolved Investigations per mile Undermined
Bailey	17.2	24	1.4	18	1.0
Blacksville No.2	10.2	4	0.4	1	0.1
Cumberland	15.9	7	0.4	5	0.3
Eighty-Four	6.7	2	0.3	0	0.0
Emerald	11.8	6	0.5	6	0.5
Enlow Fork	25.4	9	0.4	6	0.2
High Quality	0.6	2	0.3	1	1.6
Shoemaker	0.1	1	10	0	0.0
Total / Average	87.9	55	0.63	37	0.42

For those stream problems that were Resolved, the time to resolution was determined (Appendix E1). The average time from original report filing to resolution was 688 days, with a standard deviation of 451 days and a median of 551. The minimum days to resolution for the 20 Resolved stream investigation cases was 136 and the maximum was 1,688.

Determinations of the extent of disruption to flow can be very difficult. Many of the streams in question are first and second order streams that exhibit highly variable flow with stretches in which flow typically ceases during the driest months. The time since a rain event and the long-term precipitation input can have substantial effects on the length and temporal duration of dry segments. Very little of the monitoring data presented by mining companies or the PA DEP allows definitive objective conclusions to be drawn. The PA DEP based its conclusions about the extent of the flow problems and involvement of mining-based subsidence and bedrock fracture on the best available evidence. That evidence included an impressive familiarity with the streams in the area, the coincidence of apparent decreases in flow with the period immediately following undermining, and the appearance of tension cracks, compression ruptures and pooling associated with the observed changes in flow. It was the opinion of the University that the conclusions drawn by the PA DEP about the effects of subsidence on stream flow were in general sound and well-reasoned. However, repeated pre- and post-mining monitoring in a way that would allow statistical comparisons could help preclude conflict and protracted legal proceedings. Indeed, the 2005 TGD-655 calls for the following:

- Weekly measurements six months prior to undermining,
- Daily measurements two weeks prior to undermining and continuing until the potential for impacts due to subsidence has passed, and
- Weekly measurement six months post undermining.

One example of such thorough data collection is shown in Table VIII-5 for Mount Phoebe Run, a stream above panels LW-49 and LW-50 of the Cumberland Mine. In the future, these detailed monitoring plans may allow for more robust accounts of flow impacts on undermined streams.

PA DEP has already used this detailed flow data to determine if future longwall panels will jeopardize flow in the undermined streams. An example of this was provided by the 4-East and 5-East panels in High Quality Mine. An unnamed tributary to Maple Creek ran across these panels and the PA DEP collected extensive pre-, during, and post-mining flow data from 2004 to 2007 (Table VIII-6). The flow data revealed that segments of the stream that were deemed perennial prior to mining were intermittent post-mining. Despite temporary augmentation which restored flow, the stream would go dry whenever the augmentation was turned off. When the mining company proposed to undermine a similar stream segment with the 6-East panel, the request went before an Environmental Hearing Board (The Board). The Board determined that "It is scientifically appropriate to consider the effect of mining on the 5-East watershed as a predictor of what would happen to the 6-East watershed if the 6-East Panel were longwall mined because the surface and subsurface characteristics and features of the two contiguous watersheds are very similar." (EHB Docket No. 2004-245-L). Based in large part on this data, the Board concluded that "the Department was correct in concluding that UMCO's longwalling would have permanently dewatered the previously perennial flow of the 6-East Stream." (EHB Docket No. 2004-245-L). The EHB ruling allowed High Quality to remove Panel 6-East as long as the area below the stream was mined using room-and pillar methods. Longwall mining was permitted in areas prior to and after the stream.

Table VIII-5 - Flow data (in gallons per minute) for Mount Phoebe Run in Cumberland Mine. Multiple monitoring stations are present and data is collected at least once a month. Additional data exists through February 28, 2006, however, only the following dates are shown as an example (Data from PA DEP stream investigation file ST0517).

Date	SW 47	MT T2	MT 2	MT T3	MT 3	MT T6	SW 29	MT T7	MT 5	MT 6	MT T8	MT 7	MT 8	MT 9	S 22
Oct.28, 2004	64	16	105	20	146	19	205	26	199	221	47	301	326	340	400
Nov.2, 2004	56			17	125		174	21	186	191	26		254	276	290
Nov.9, 2004	11	1	16	4	30	14	60	3	70	72	6	106	127	131	150
Nov.16, 2004	16			6	26		50	2	60	62	2	71	80	81	80
Nov.24, 2004	109	40	190	41	269	60	502	40	551	549	40	606	649	681	70
Dec.3, 2004	46			15	104		204	25	250	270	35	307	401	450	431
Dec.9, 2004	60	25	114	23	190	40	322	26	341	332	41	380	409	422	470
Dec.13, 2004	103			32	240		398	41	470	460	80		714	739	806
Dec.20, 2004	11	8	17	6	31	11	81	10	105	120	15	180	256	262	302
Dec.27, 2004	50			16	104		201	24	240	260	40		325	390	421
Jan.13, 2005	165	81	285	60	355	111	704	45	608	541	84	941	1,124	1,259	1,354
Jan.20, 2005	475			57	496	73	675	46	630	413	52		851	888	919
Jan.26, 2005	245		362	60	248	48	383	23	507	405	22	590	566	657	704
Feb.7, 2005	301	107	386	5	388	10	516	65	499	410	42	395	387	562	419
Feb.23, 2005	107	60	167	14	261	21	375	43	261	345	24	456	348	529	650
Mar.3, 2005	205			48	410	49	588	46	591	647	58	833	1,213	1,323	1,126
Mar.14, 2005	436	146	465	45	353	52	466	86	788	772	42	1,220	951	876	933

Table VIII-6 - Extensive flow data collected for an unnamed tributary to Maple Creek in High Quality Mine. Additional data exists through 2007, however, only the following dates are shown as an example.

DATE	Upstream Augmentation, gpm	4-East Panel Weir, gpm	Weir at 4-5 Gate, gpm	5-East Panel Weir, gpm
December 12, 2004	~ 60-70	40.4	44.8	44.8
December 23, 2004	~ 8-10	9.8	16.5	28.6
December 27, 2004	38	28.6	28.6	25.2
January 19, 2005	OFF	44.8	91.2	washed out
January 21, 2005	> 10	19.1	54.6	washed out
January 26, 2005	OFF			
February 1, 2005	OFF	0	~ 1	~ 3-4*
February 3, 2005	OFF	0	2	~ 3-4*
February 22, 2005	OFF	19.1		
February 28, 2005	OFF	16.5	36	40
March 7, 2005	OFF	22	65.6	65.6
March 17, 2005	OFF	14.1	22.7	36.2
March 22, 2005	OFF	5	14	14*
April 1, 2005	OFF		70	115
April 5, 2005	OFF	44.8	85.6	115
April 12, 2005	OFF	11	25.8	37.8
April 14, 2005	OFF	5.7	18.6	23.3*
April 18, 2005	OFF	1.7	8	8*
April 19, 2005	OFF	0.8	4.6	5.7*
April 20, 2005	OFF	< 0.1	1.2	3.8*
April 21, 2005	OFF	0	2.3	3.8*
April 25, 2005	OFF	0	Needs repaired	1.7*
April 26, 2005	OFF	0	3.8	0.84*
April 27, 2005	OFF	0	3.8	1.7*
April 28, 2005	OFF	0	1.7	0.5*
May 2, 2005	OFF	0	1.2	0.3*
May 4, 2005	OFF	0	1.2	0
May 5, 2005	OFF	0	0.15	0
May 6, 2005	OFF	0		0
May 9, 2005	OFF	0	0	0
May 10, 2005	OFF	0	0	0
May 11, 2005	OFF	0	0	0
May 13, 2005	OFF	0	0	0
May 16, 2005	OFF	0	0	0
May 17, 2005	OFF	0	0	0

* indicates flow that was below the mandated 25 gallons per minute.

Detailed flow data was crucial in the determination of impacts on streams and will be an important component of data collection for mining companies in the future.

VIII.B.6 – PA DEP Methodology for Assessing Impacts on Stream Biology

Prior to 2005, no specific biological assessment methods were required by law. Several variations of the EPA Rapid Bioassessment Protocols (http://www.epa.gov/owow/monitoring/rbp/ch07main.html) were used. As a result, most streams undermined prior to 2008 did not have biological data collected using TGD-655 methods. When applying for a permit revision or renewal, mining companies are now required to submit baseline, pre-mining stream assessments using the TGD-655 methodologies for streams with the potential for flow loss or pooling. While these methods were designed for low gradient streams, they have been successfully applied to both low and high gradient streams.

The TGD-655 provides precise and explicit methods for sampling stream macroinvertebrates and for calculating six scores:

- Taxa richness,
- Trichoptera richness,
- Percent of all taxa that are Ephemeroptera, Plecoptera and Trichoptera (% EPT),
- Percent taxa that are pollution/stress intolerant,
- Filterer-Collector + Predator Taxa Richness (FC+PR Richness), and
- Total Biological Score.

The Total Biological Score (TBS) is the average of the five preceding metrics in this list, after normalizing each to a 95th percentile statewide score. Any normalized score that exceeds 100 is set to 100. Normalized values of any of these measures in the range of 70 or higher indicate healthy streams with high biological use. These streams support healthy and productive fisheries. Macroinvertebrate scores are a good indicator of both ecological health and a productive fishery that is likely to attain its designated use.

Lack of existing data made most undermined streams, pre- and post-mining within-stream comparisons impossible. However, the University was able to use TGD-655 protocols to assess biological health of streams and compare the scores to a control stream when control stream data was available. The streams surveyed by the University are listed in Appendix D and the calculated macroinvertebrate TBS are provided

In a draft protocol document provided by the PA DEP, (PA DEP, 2005b) some guidance is provided for interpreting TBS. The aquatic life use attainment status is determined by comparing a stream segment survey's TBS to a bioregion-specific use attainment benchmark score. If the TBS of the surveyed stream segment is less than the benchmark score, the reach is not attaining aquatic life use. The suggested aquatic life use attainment benchmark scores for Bio-region 1, which includes the SW Appalachian Plateau where all the longwall mining in the Commonwealth occurred in the 3rd assessment period, is 50.1. This represents the lower 5th percentile of the distribution of TBS obtained from18 reference streams. Any stream not meeting the benchmark score was therefore at the extreme low end of TBS scores for streams in Bioregion 1. The benchmark was therefore a reasonable value for indicating streams that lost substantial biological function. It should be noted that the PA DEP provided this benchmark in a draft document and it represents good science; however, it should not be construed as PA DEP policy. The University provided this analysis because it is scientifically and statistically a well grounded comparative measure with a clear interpretive value.

In the presence of pollution or stress, all of the above measures are expected to decline. Thus a second means of interpreting the TBS was to compare pre- and post-mining TBS, or post-mining TBS with a designated non-undermined control stream. A score that was lower than 88-pct of the value of the pre-mining or control stream was deemed to have been impacted, according to the TGD-655.

VIII.B.7 – Choice of Streams Assessed by the University

Although a full assessment of the effects of underground mining on stream biology requires extensive pre-mining and extensive post-mining macroinvertebrate sampling, sampling at that level of intensity was not within the scope of work negotiated with the PA DEP. The University therefore set sampling priorities on the basis of two criteria.

VIII.B.7.a – Re-surveyed Streams from the 2nd Assessment Period

First, the PA DEP requested the University to re-survey a list of streams that remained problematic at the end of the 2nd assessment period. The University surveyed five streams for TBS and seven for flow. Many of the streams were not sampled due to access issues. Detailed reports of the University survey results are found in Appendix D. A summary of the results for the re-surveyed streams is presented in Appendix F1. For those re-surveyed streams for which macroinvertebrate data could be collected, the average TBS was 48.8. This mean score was below the bioregion 1 benchmark of 50.1. However, the standard deviation of the mean score is 6.2, thus overlapping the benchmark. The average TBS therefore indicated that on average the streams impacted in the 2nd assessment period were near, to slightly below, the benchmark for minimal biological attainment in Bioregion 1.

Because these streams were undermined well before the current TGD-655 was put in place in 2005, pre-mining TBS were not available for these streams. However, for six streams, measures of Taxa Richness and %EPT were available from pre-mining or post-mining surveys or both for comparison with the University's surveys. These are shown in Table VIII-7. In only one case was pre-mining data available, Laurel Run from the Emerald Mine. Unfortunately, this stream had ceased to flow when the University team attempted a survey. Of the remaining five streams for which post-mining biological metrics were available, all appear to be either holding constant since the post-mining surveys or increasing in biological diversity and function.

Table VIII-7 - Comparison of 3rd Assessment Period Stream Survey Metrics to Pre- and Post-mining Scores for Streams Impacted during the 2nd Assessment Period

WRDS Stream Code	Stream Name	Pre-mining Taxa Richness	Pre-mining % EPT	Post-mining Taxa Richness	Post-mining % EPT	Act 54 Taxa Richness[a]	Act 54-% EPT[a]
Bailey Mine							
32511	UT to Dunkard Fork	N/A	N/A	14	7	23	39
32600	Kent Run	N/A	N/A	9.5	47.4	17	59
Blacksville No.2 Mine							
41813	Roberts Run	N/A	N/A	14.7	35	16	25
Emerald Mine							
40432	Laurel Run	30	39	11[b]	Panel 8 – 64 Panel 9 - 5[b]	Dry	Dry
Enlow Fork Mine							
32708	Templeton Fork	N/A	N/A	18	31	26	27
32712	Rocky Run	N/A	N/A	11	27	11	18

[a] – Values represent observed values only and are not adjusted.
[b] – Post-mining data taken in June 2004.

VIII.B.7.b –Surveyed Streams from the 3rd Assessment Period

Second, the University surveyed a set of streams for which problems had been reported during the 3rd assessment period. In consultation with PA DEP, the University determined that the best approach was to obtain good sampling for a larger set of streams from one large mine, followed by a small number of samples from other mines. The Bailey Mine was among the most active during the 3rd assessment period and had the largest number of stream reported effects associated with it. In addition, a control stream was previously identified and macroinvertebrate data was collected. Therefore, the Bailey Mine was chosen for intensive sampling. A total of 17 streams were surveyed for macroinvertebrates (Appendix F2). Six surveyed streams were undermined by the Bailey Mine. The remainder was spread over the five next-largest longwall mines.

The average TBS in these streams was 46.1 with a standard deviation of 7.2. It is important to note that the TBSs were extremely variable. The scores ranged from a low of 13.3 to a high of 73.1. Overall, these streams were on average just below biological attainment. Bailey and Blacksville No.2 streams were also compared to the TBS obtained by PA DEP for their control streams, which had TBS of 76.3 and 62.6, respectively (Table VIII-8). The TGD-655 considers biological health to be unchanged from or restored to pre-mining levels if the scores are above 88-pct of the control stream value. These values were 67.1 and 55.1 for Bailey and Blacksville No.2, respectively. The mean of the six Bailey streams' TBS was more than two standard errors below the TBS for the control stream (mean = 50.5, std err = 7.9). Four of the six surveyed Bailey mine streams fell below the cutoff indicating adverse effects and failure to attain pre-mining levels, based on comparison to the control stream. The single surveyed stream from the Blacksville No.2 mine had a TBS above the critical 88-pct of its control stream's TBS. It was not considered adversely affected. Fully half of the streams surveyed fell below the Bioregion 1 cutoff for biological attainment. However, this cannot be attributed solely to mining effects, since there was no baseline comparison and multiple land use practices in the watershed can result low TBSs. During the course of the University's surveys, cattle and horses were observed watering in many of the streams. This not only caused changes in stream chemistry, but also increased sedimentation loads. In Appendix D, the surrounding land use around each stream surveyed for TBS is described in order to acknowledge that scores may have been impacted by agricultural practices.

Table VIII-8 - Comparison of 3rd Assessment Period Stream Survey Scores to Control Stream Scores.

WRDS Stream Code	Stream Name	Total Biological Score	Control Stream WRDS	Control Stream Total Biological Score	Score below which the stream is adversely affected	Adversely Affected
Bailey Mine						
32507	UT to Wharton Run	56.1	32542	76.3	67.1	Y
32530	Headley Hollow	68.8	32542	76.3	67.1	N
32532	UT to Dunkard Fork	73.1	32542	76.3	67.1	N
32596	UT N Fork of Dunkard Fork	27.2	32542	76.3	67.1	Y
32598	Polly Hollow	29.4	32542	76.3	67.1	Y
N/A	UT to Dunkard Fork	48.3	32542	76.3	67.1	Y
Blacksville No.2 Mine						
41728	Bulldog Run	58.0	41819	62.6*	55.1	N

* indicates that the TBS is an average of scores collected across multiple dates.

VIII.C – Summary

During the 3rd assessment period, nearly 114 miles of stream were undermined. For every two miles of stream undermined, there was an investigation of stream flow diminution or pooling, on average. By the end of the 3rd assessment period approximately one-third of these investigations had been resolved. Stream flow varies across seasons, across years, and even within seasons as a result of the vagaries of weather.

On average, a final resolution required 688 days. About half of the streams surveyed for macroinvertebrate diversity and composition had TBS below a PA DEP draft recommended cutoff for biological attainment for the SW PA Bioregion 1, indicating that one or more sources of perturbation have negatively influenced the TBS. Various land use practices, including underground mining, were likely sources of perturbation. Because most of the TBS scores obtained could not be compared to a pre-mining or control stream TBS, ascertaining the effect of mining per se was not possible. Although control streams for biological comparisons were designated for most, but not all, active longwall mines by the PA DEP, biological data was made available to the University for only two of these, Bailey and Blacksville No.2 Mines. The six stream surveys conducted for the Bailey Mine were statistically compared to that mine's control stream value. For the six Bailey Mine streams, the mean post-mining TBS was highly significantly below the control stream score (i.e. more than two standard deviation of the mean below the control TBS), indicating that recovery had not on average been attained. Two of these six streams were within the 12-pct difference of the control stream established by the TGD-655 as indicating recovery or maintenance of pre-mining biological health and have therefore substantially recovered. The other four were far from attainment. Comparison based on more limited biological data of post-mining Taxa Richness and %EPT scores with new surveys by the University indicated that there had been a mix of no improvement to substantial improvement since the post-mining surveys. There is substantial heterogeneity among streams, with about half the streams meeting PA DEP criteria for attainment of pre-mining biological scores.

The use of a single control stream, while understandable from a cost and time perspective, may not adequately represent the diversity of stream characteristics in the undermined area. It would be very useful to have pre-mining data for the undermined streams. More recent mining permits and permit revisions reflected a change in approach by the mining companies that was much more pro-active regarding the potential for mining-induced stream flow problems. The most recent permits, filed since the end of the 3rd assessment period, contained considerably more biological data for the streams to be undermined and this data was largely obtained following the TGD-655 protocols.