SECTION VIII: A Follow-Up on the Effects of Mine Subsidence on Streams during the 3rd Act 54 Assessment

VIII.A – Overview

During the 3rd Act 54 assessment period (2003-2008), a total of 55 stream investigations were initiated by the PADEP. At the end of that period, 35 investigations were considered "Unresolved", indicating that the streams had not yet recovered to pre-mining conditions (Iannacchione et al. 2011). Here, the University re-visits the investigations from the 3rd assessment period to determine the status and time to resolution of those unresolved cases. Additionally, the University was tasked with evaluating the status of five streams that were undermined prior to the implementation of TGD 563-2000-655. Unfortunately, streams undermined prior to TGD 563-2000-655 lack sufficient assessments of pre-mining flow and biological integrity to properly measure recovery. Therefore, the University selected five streams that were undermined prior to the implementation of TGD 563-2000-655, were sampled during the 3rd assessment, and were the subject of an unresolved investigation from the 3rd assessment. If the sites have recovered, the Total Biological Score (TBS) is expected to either remain the same or improve from the last assessment. Where appropriate, the TBS for these sites is also compared to control streams as suggested in TGD 563-2000-655.

VIII.B – Stream Investigations from the 3rd Assessment Period

VIII.B.1 – Stream investigation data collection

While BUMIS was not designed to track stream impacts, it is used by PADEP to store basic details on stream investigations including the date of impact, investigation assignment, and the interim and final resolution statuses. The paper files at CDMO can contain additional information, including mitigation plans, flow data, and relevant correspondence. The University utilized these two sources to determine the following for all stream investigations recorded in the 3rd assessment report by Iannacchione et al. 2011: the date the impact occurred, the final resolution status, and the final resolution date. The date the impact occurred was subtracted from the final resolution date to determine the time to resolution in days for each stream investigation.

The University was able to track the outcome of 41 of the 55 stream investigations from the 3rd assessment period using BUMIS. However, 25% of the stream impacts from this period are not identified in the BUMIS database. Nine impacts are documented only in the paper files at CDMO. These impacts have received a formal stream investigation claim number, so it is unclear why they were not entered into BUMIS. An additional five stream impacts were never assigned stream investigation claim numbers and thus could not be tracked in BUMIS or the paper files. The University was only aware of these impacts because they were recorded in an Excel file that was given to the University by PADEP. For these impacts, the University relied on the Excel file to determine the time to resolution and final resolution status. Because the University could not identify the rationale behind omission from BUMIS, omission from the paper files, or inclusion in the afore-mentioned Excel file, it remains unclear if additional impacts occurred that are unaccounted for in any of these places.

VIII.B.2 – Resolution status

Of the 55 stream investigations that were initiated during the 3rd assessment period, 51 had a final resolution by the end of the 4th assessment period (Table VIII-1). The final resolution status can fall into a variety of categories. Three cases were determined by PADEP to be “not due to underground mining”. In these cases, PADEP has ruled that the stream impacts can be attributed to factors such as drought, surrounding land use practices, or other non-mining related issues. For cases with mining-related stream impacts, the majority of streams recovered to pre-mining flow conditions, either on their own or following mitigation work. This includes the thirty-eight cases with a final resolution status of “repaired”, “resolved”, and “stream recovered”. It should be noted that the University and PADEP could not determine the distinction between these three final resolution statuses.

Table VIII-1. Number of stream investigations that were initiated in the 3rd assessment period and their resolution status at the end of the 3rd and 4th assessment periods.

Resolution Status	Number as of 3rd Assessment	Number as of 4th Assessment
Final: Closed due to federal court settlement	0	1
Final: Closed/Info appended to another case	0	1
Final: Compensatory mitigation required	0	7
Final: Not due to underground mining	3	3
Final: Repaired	1	1
Final: Resolved	15	35
Final: Stream recovered	0	2
Final: Withdrawn	1	1
Interim: Not Yet Resolved	35	4
Total	**55**	**55**

A single case was “withdrawn” from consideration by PADEP. ST0434 involved a reported flow loss in the 2I panel of stream 32596 (an unnamed tributary to the North Fork of Dunkard Fork), a stream that was the focus of three other stream investigations during the 3rd assessment period. According to BUMIS, the mining company requested an extension for development of a mitigation plan. The investigation was closed one day later. Because BUMIS does not provide any additional information on this investigation, the reason for the withdrawal is unknown. While the other three stream investigations on stream 32596 were eventually merged into a single case (ST1203), there is no evidence that this case was merged with another investigation.

The final resolution status for one case from the 3rd assessment period clearly indicates that the case was appended to another investigation. ST0701, which tracked flow loss impacts to stream 32719 (an unnamed tributary to Rocky Run) in the F6, F7, and F8 panels of Enlow Fork Mine, is now considered “closed/info appended to another case”. The case was appended to ST1202, which currently remains unresolved (Appendix G2). Biology data suggests that this stream was significantly impacted by mining. A post-mining sample collected by the mine operator in the F7 panel on 4 December 2007 had a TBS of 24. However, flow recovery is the only compliance required for this stream because it was undermined prior to TGD 563-2000-655. Mitigation plans were submitted in the summer 2010 for grouting and bedload removal in the stream. No additional information was available regarding this stream’s current status.

Four investigations initiated in the latter half of the 3rd assessment remain open (Table VIII-2). The investigations in Bailey and Enlow Fork Mines are awaiting final decisions by PADEP hydrologists who will determine if flow conditions have returned to pre-mining levels. Biological recovery has already been documented for the investigation at Bailey Mine. An email from a PADEP biologist dated 22 November 2010 indicates that the TBS for an unnamed tributary to the South Fork of Dunkard Fork was 70.28. This score is well within 16% of 76.3, the TBS for the approved control stream. The investigations in Cumberland Mine required Chapter 105 permits from the U.S. Army Corps of Engineers before mitigation work could begin. According to BUMIS, the permit for both projects was received by CDMO on 27 May 2010. Cumberland Mine permit revision 112 was approved on 26 July 2011 and allows for stream restoration work on stream 41267, an unnamed tributary to Dyers Fork. However, the University could not identify a permit revision that approved restoration work on Stream 41264, another unnamed tributary to Dyers Fork.

Table VIII-2. Unresolved stream investigations initiated in the 3rd assessment period.

Panels	PA WRDS Stream Code[1]	Stream Name	Claim #	Stream Designated Use	Date Problem Occurred	Final Resolution Status
Bailey Mine						
8I	NA	UNT South Fork of Dunkard Fork (SoF-2R)	NOT IN BUMIS	Trout-stocked fishery	6/1/2007	Not yet resolved
Cumberland Mine						
51, 52	41264	UNT Dyers Fork	ST0603	Trout-stocked fishery	5/30/2006	Not yet resolved
50, 51	41267	UNT Dyers Fork	ST0607	Trout-stocked fishery	11/13/2006	Not yet resolved
Enlow Fork Mine						
E13, E14	32724	UNT Rocky Run	ST0710	Trout-stocked fishery	5/1/2007	Not yet resolved

[1] = Zero order tributary

Despite mitigation efforts by the mining companies, PADEP has ruled that some streams have not recovered to pre-mining conditions (Table VIII-1). Below, Section VIII.B.4 provides a discussion of the mining and environmental conditions at these streams.

VIII.B.3 – Time to resolution

The average time to resolution for stream impacts occurring in the 3rd assessment was 1,313 days, or just over 3 ½ years (median: 1,253 days). However, there was significant variation in the time to resolution, reflected in both the large standard deviation of the mean (+/- 761 days, or just over 2 years) and in Figure VIII-1. While a case of flow loss to Dyers Fork in Cumberland

Mine was resolved within just 136 days (the minimum time to resolution), a case of flow loss on stream 32596, an unnamed tributary to the North Fork of Dunkard Fork, took 3,170 days to reach a final resolution (the maximum time to resolution). Of the 10 cases in the 3rd assessment period that took over five years to resolve, eight of these cases involve streams that PADEP ruled have not recovered from mining (Figure VIII-1; one case closed due to federal court settlement, seven cases require compensatory mitigation). With TGD 563-2000-655, it is anticipated that the time to resolution will drop, even for irrecoverable streams, as the TGD clearly states that recovery must occur within 5 years or compensatory mitigation will be required.

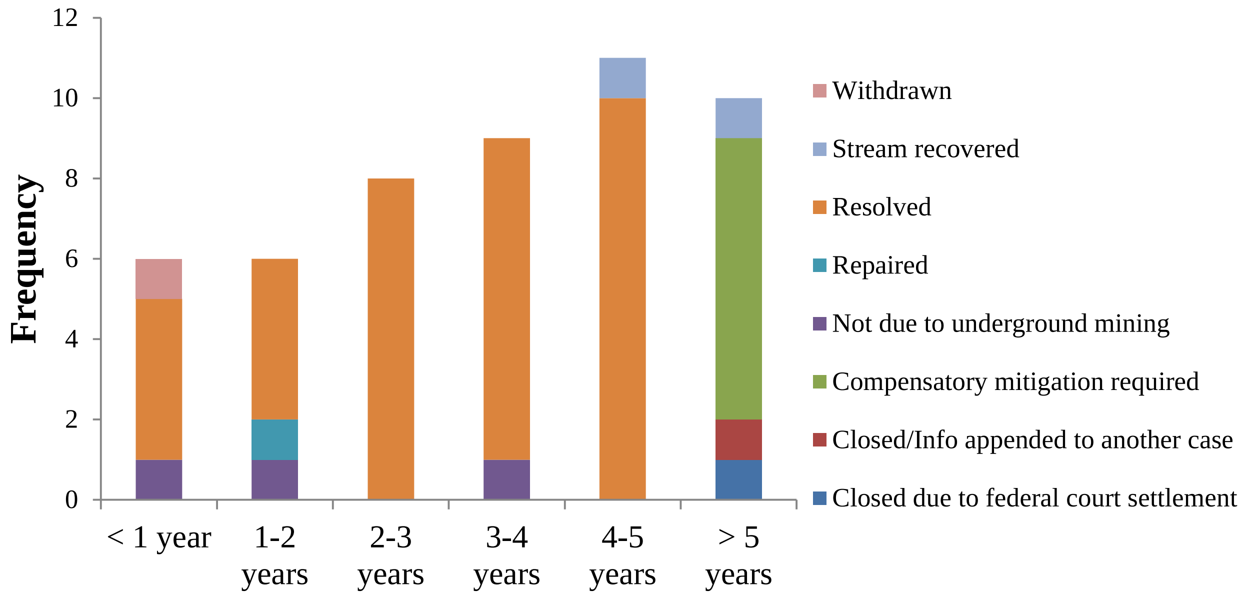

Figure VIII-1. Histogram showing the number of stream investigations that were initiated in the 3rd assessment period according to their time to resolution and final resolution status.

VIII.B.4 – Streams that have not recovered from mining-induced impacts

A single stream investigation was "Closed due to federal court settlement" and seven stream investigations had a final resolution status of "Not recoverable: compensatory mitigation required". In total, eight cases involved streams that have not recovered from mining-induced flow impacts. These eight investigations can be separated into two case studies. The first case study has already been described in some detail in the 3rd assessment report (Iannacchione et al. 2011), but it is briefly re-visited here due to its significance. Stream 39816, an unnamed tributary to Maple Creek, was undermined by the 4 and 5 East panels of High Quality Mine in 2004. Overburden depths for the stream ranged from 255-320 feet in the 4 East panel and 225-255 feet in the 5 East panel (EHB Docket 2004-245-L). Following longwall mining, stream sections overlying these panels experienced flow loss, and despite augmentation and grouting mitigation efforts, PADEP determined that stream flow did not recover to pre-mining conditions. As a result, PADEP issued an order on 12 November 2004 restricting the mine operator to room-and-pillar mining within the 6 East panel to prevent what it predicted would be similar damage to another unnamed tributary to Maple Creek. This order was challenged by the operator and brought before an Environmental Hearing Board (EHB). The EHB ruled in favor of the

PADEP's order (EHB Docket 2004-245-L) and despite an appeal, the Commonwealth Court of Pennsylvania upheld the EHB's ruling (No. 724 C.D. 2007). The PADEP now considers the stream investigation for 39816 "closed due to federal court settlement" (Table VIII-1).

The case from High Quality Mine is interesting for two reasons. First, the mining conditions at High Quality were unique. As the EHB pointed out in its report "…there are no other mines in Pennsylvania where an operator has attempted to longwall coal using modern methods with such shallow cover." (EHB Docket 2004-245-L). Indeed, average overburden depths at other mines currently operating in Pennsylvania are typically at least twice as large as those found in High Quality Mine (see Section III.F.2). There is little doubt that the extremely shallow overburden profiles for the High Quality Mine contributed to the significant stream impacts. Indeed, when the overburden depth is less than 50 times the coal seam thickness plus 100 feet (i.e. $OB < 50t + 100$, where OB = overburden and t = coal seam thickness in feet), it is considered a "rule of thumb" that a stream protection pillar should be left in place to prevent subsidence underneath the stream (Karmis et al. 2012). In streams with such shallow overburdens, the fracture zone that develops above the mine following subsidence can intercept the drainage zone of the stream and result in flow loss (Karmis et al. 2012). At High Quality Mine, the coal seam ranged in height from 7 to 10-ft in the 6 East panel (EHB Docket 2004-245-L). Plugging these values into the rule of Karmis et al. (2012), it can be seen that the overburden depth at High Quality Mine was far less than the 450-600-ft that would be required for full extraction longwall mining. Even the less conservative model by Kendorski (2006; i.e. $OB < 30t + 50$) would require at least 260-350-ft of overburden for full extraction. The second interesting and challenging aspect of the High Quality Mine case is that as the EHB notes, "The absence of sufficient baseline data will make it difficult to determine whether the 4E/5E Stream has ever fully recovered." (EHB Docket 2004-245-L). The streams in High Quality Mine were undermined prior to the passage and implementation of the PADEP's TGD 563-2000-655. As a result, there was insufficient data to fully assess both the extent of the flow loss and the potential for recovery. TGD 563-2000-655 stipulates that mining companies must now submit flow measurements and observations collected over a 24-month period prior to undermining (PADEP 2005). However, TGD 563-2000-655 also notes that such pre-mining flow data may be extrapolated from "control" streams when necessary. It is unclear why a control stream was not utilized in this case. Overall, the stream losses at High Quality Mine were instructive for both the mining industry and the PADEP – not only did this case highlight the limitations to longwall mining but it also emphasized the shortcomings in previous data collection methods.

The second case study in which PADEP ruled that streams have not recovered from longwall mining involves a group of six streams from Bailey Mine (Table VIII-3). Together, these streams were the focus of 13 of the 24 streams investigations from Bailey Mine during the 3rd assessment period (Iannacchione et al. 2011), indicating that they were heavily impacted by mining. Because these streams were undermined before the mine operator came into compliance with TGD 563-2000-655, PADEP determined that recovery should be based on flow only. Two separate consent order and agreements (CO&A) detailed the recovery conditions agreed upon by PADEP and the mine operator for this group of streams. Stream 32596 was the subject of a CO&A that was filed on 19 September 2007 and amended on 24 April 2008 (Docket # 066008 and 076010). The other five streams were included under CO&A Docket # 086003 which was filed on 11 June 2008 and amended on 8 September 2008. The latter CO&A is commonly referred to as the "Bailey Mine Global CO&A". PADEP delivered separate rulings for each CO&A on 27 December 2012.

Table VIII-3. Streams from Bailey Mine that PADEP has determined are not recovered. Panels listed indicate locations of irreparable impacts.

PA WRDS Stream Code[1]	Stream Name	Panels
32598	Polly Hollow	1-4I
32511	UNT to Dunkard Fork	16C
32595	UNT to North Fork of Dunkard Fork	2-5I
NA	Crow's Nest	2-4I
32534	UNT to UNT of Dunkard Fork	9-10H
32596	UNT to North Fork of Dunkard Fork	1-4I

[1] NA = Zero order tributary

For stream 32596, undermining occurred from February 2004 to September 2005 by the 1-4I panels of Bailey Mine. The stream is oriented perpendicular to the longwall panels and was mined in a downstream direction. The streambed is characterized by a large amount of exposed bedrock (26%) as well as cobble, gravel, and silt (ST1203). Overburden depths range from 330-570 feet across the four panels, and are near the lower end of this range across the 3 and 4I panels (ST1203). The thickness of the coal seam being mined in this area is unknown, although a recent permit revision indicates that the mining height in Bailey Mine is generally 6.5-ft (Bailey Mine, Permit Revision 150). Following mining, the stream experienced flow loss impacts. The impacts were particularly severe over the 3I-4I panels, where zero flows (i.e. 0-gpm) were recorded at surface water monitoring station HSW02 from April 2005 to February 2007 (see ST1203). PADEP initiated separate stream investigations for the flow loss impacts over each panel, resulting in four stream investigations for stream 32596 during the 3rd assessment period (Iannacchione et al. 2011). As discussed above, one investigation was withdrawn while the other three were combined into ST1203 during the 4th assessment. To maintain flow at least 10 augmentation discharge points were installed, seven of which were active during the 4th assessment (Table VII-13). Additionally, maps from Consol indicate that approximately 75% of the stream's 5,500-ft had been grouted by December 2008 (Consol Energy Inc. 2009). Grouting has occurred within each panel with varying effectiveness. Due to continued flow loss in the 3I panel, a synthetic stream liner was installed (Table VII-15). In the 4I panel, cement grouting did not repair the flow loss impacts, so the mine operator applied additional grouting using a polyurethane mixture. To evaluate recovery of the stream for the CO&A, PADEP used data from surface water monitoring stations (i.e. volumetric flow rates), augmentation discharges, and precipitation through May 2012. Augmentation was turned off in early 2011 to evaluate natural stream flow conditions. During this augmentation reprieve, only the two most upstream surface water monitoring stations experienced zero flows. These zero flows occurred during the dry season. However, precipitation was well above average during the augmentation reprieve. The period prior to the undermining of stream 32596 was also characterized by above-average precipitation and so, using pre-mining data from the surface water monitoring stations, PADEP determined that “the stream, post-mining, does not flow to the same degree after similar precipitation amounts as it did pre-mining”.

For the streams covered under the Bailey Mine Global CO&A, the mining and mitigation conditions vary. Stream 32511 was actually undermined by the 16C panel in Bailey Mine at the end of the 2nd Act 54 assessment period, between 19 February 2003 and 2 March 2003 (see ST0318). This stream runs in a northeast to southwest direction across the panel. Mining started at the headwaters and progressed in a downstream direction. Overburden depths for this stream segment range from 546-ft at the 16C tailgate to 523-ft at the 16C headgate (see ST0318). After mining, heaving was observed in the stream channel and flow loss occurred. At least 3 augmentation wells have been used to sustain flow (Table VII-13) to this stream during the 4th assessment period. Additionally, “the majority of the 16C panel section of this tributary has been mitigated” (Consol Pennsylvania Coal Company 2010) using grouting techniques. Consol attempted to negotiate with the landowner to purchase the property and perform additional mitigation work; however, these negotiations were described by PADEP as “tentative” (ST1203).

Streams 32595, 32598, and Crow’s Nest are located in the same area of Bailey Mine as stream 32596 and generally share many characteristics with that stream. These streams were undermined between 2004 and 2006. The streams run perpendicular to the panels in many places. All watersheds were mined in a downstream direction. Overburden depths are within the range of those observed at 32596. For example, overburden depths on stream 32595 are 510-ft in the 2I panel, 462-ft in the 3I panel, 390-ft in the 4I panel, and 345-ft in the 5I panel (see ST0519). Following mining, compression heaves and bedrock fracturing resulted in mining-induced flow loss impacts on each of these streams. For stream 32595, at least five augmentation wells were installed to maintain flow across the 2I-5I panels (Table VII-13) and the stream channel was grouted in areas throughout these panels. The Crow’s Nest tributary, which runs across the 4I and 5I panels of Bailey Mine, had at least three augmentation points installed in the 5I panel (Table VII-13). The entire length of the stream within this panel was mitigated using grouting (~1,200-ft). Stream 32598 was undermined and experienced flow loss in the 1-4I panels. Due to landowner access issues in the 2I and 3I panels, mitigation work was only performed in the 1I and 4I panels. As for the un-mitigated 2I/3I panels, PADEP observations from March 2012 indicate that flow loss impacts remain and that mitigation in surrounding panels has not restored flow to these sections (Figure VIII-2).

The mining conditions at stream 32534 differ in several interesting ways from those at the other Bailey Mine Global CO&A streams. First, this stream was undermined later than the others, from December 2006 through August 2007, by the 9H and 10H panels of Bailey Mine. Second, rather than perpendicular, roughly 2/3 of the stream length runs nearly parallel to the panels. The headwaters of stream 32534 begin in the 10H panel and flow in a northeasterly direction, crossing just briefly into the 9H panel. In the 9H panel, the stream orientation changes and the stream flows in a southeasterly direction until it empties into stream 32532. Due to this unique orientation, the stream was not mined from its headwaters to its mouth. Instead, the mid-section was first undermined by the 9H panel, with the headwaters being undermined later by the 10H panel. While this stream differs in orientation and direction of mining, in terms of overburden and natural characteristics it is quite similar to the other Bailey Mine Global CO&A streams.

Overburden depths range from 437-ft to 607-ft and the stream is characterized by large amounts of exposed bedrock. As in stream 32598, landowner access issues prevented mitigation in the 10H panel. In the 9H panel, at least three augmentation wells were installed to maintain flow (Table VII-13) and grouting was used to mitigate bedrock cracks.

Figure VIII-2. Portion of 600-ft no flow section across the 2I/3I panel of Polly Hollow (Stream 32598) in March 2012, approximately seven years after mining. Landowner access issues have prevented mitigation on this stream segment. (Photo courtesy of PADEP)

To determine the recovery status of the Bailey Mine Global CO&A streams, PADEP compared the average percent of non-flowing stream length (hereafter, average percent flow loss) in the wet and dry seasons to data from a set of four control streams (Figure VIII-3). Originally, five control streams were named in the CO&A – streams 32553, 32604, 32606, 32619, and 32620. However, PADEP hydrologists determined that data from control stream 32553, an unnamed tributary to Hewitt Run, were significantly different from that of the other four control streams. Specifically, stream 32553 had larger average percent flow loss relative to the other control streams. As a result of these differences, stream 32553 was excluded from the analysis. For the remaining control streams, the PADEP examined the range of average percent flow loss in the wet and dry seasons (range = minimum average percent flow loss on a control stream - maximum average percent flow loss on a control stream). The average percent flow loss for the streams covered under the Bailey Global CO&A were then compared to this range. If the average percent flow loss fell outside the control stream maximum, then the stream was determined to be impacted.

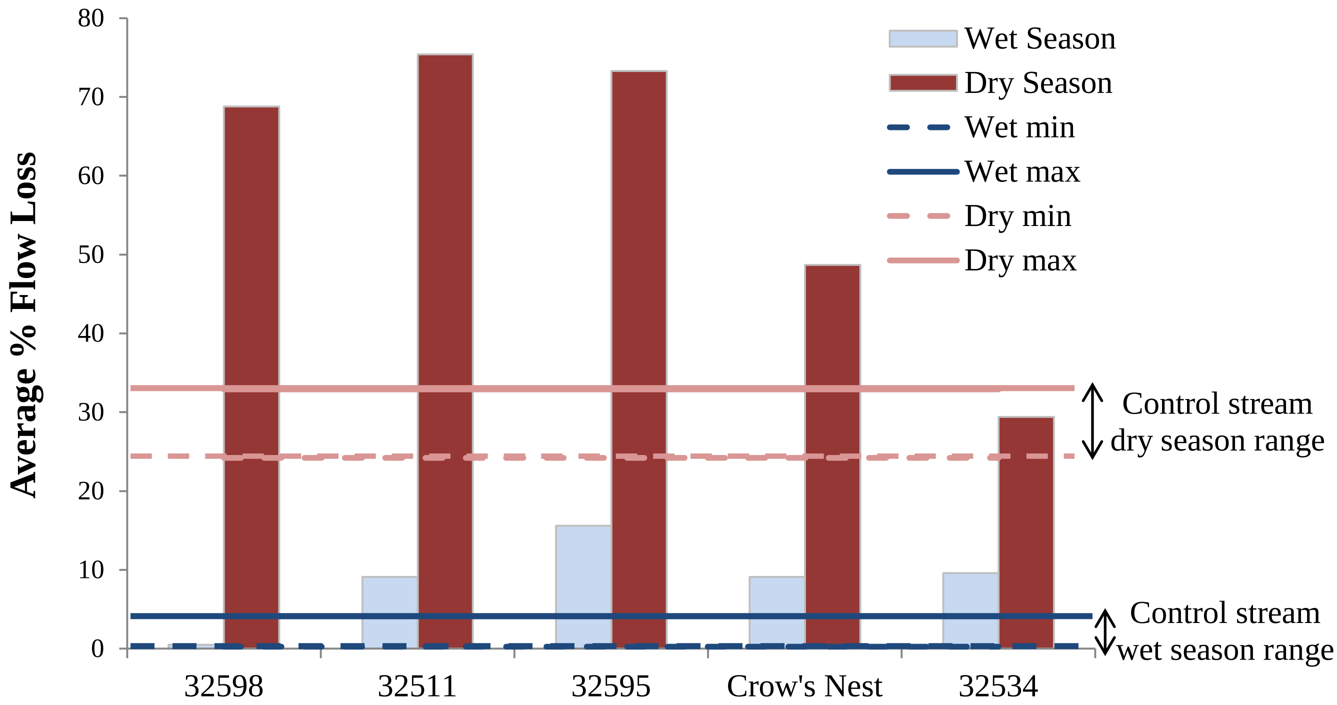

Figure VIII-3. Average percent non-flowing stream lengths in the wet and dry season for streams from the Bailey Mine Global CO&A (bars). Maximum and minimum average percent non-flowing stream lengths for control streams are shown for comparison (lines).

The PADEP determined that during the August 2010-August 2011 period, the average percent flow loss for four of the five undermined streams during the wet season exceeded the range of flow loss in control streams (Figure VIII-3). In fact, the average percent flow loss was two to three times that experienced by control streams. Similar trends were found in the dry season, with four of the five streams again experiencing flow losses outside the control stream range (Figure VIII-3). For streams 32598 and 32511, analysis of data from August 2010-August 2012 revealed the same patterns. On the basis of these data, the PADEP determined that streams 32511, 32598, 32595, Crow's Nest, and 32534 have not recovered from mining-induced flow loss impacts

When comparing the rulings for the two CO&A's in Bailey Mine, two major differences stand out. First, the type of data used to measure flow recovery differs between the two CO&A's. For stream 32596, data on post-mining volumetric flow rates (in gallons per minute) was matched with precipitation and augmentation patterns. For the five streams in the Bailey Mine Global CO&A, the average percent flow loss was compared to the range of average flow loss in multiple control streams (Figure VIII-3). Second, the use of control streams differs between the two CO&A's. For stream 32596, the data from surface water monitoring stations were not compared to control stream data. In contrast, the average percent flow loss for the five Bailey Mine Global CO&A streams was compared to data from four other control streams. The lack of control stream data for stream 32596 may be due to the availability of pre-mining data at the surface water monitoring stations. However, for some of the stations, less than a year's worth of pre-mining data (N = 10 observations) was used in the assessment, which is inadequate for establishing a "normal range of conditions".

Using data from these case studies, the mine operators and PADEP have begun to address a critical question – namely, what factors contribute to extreme mining-induced flow loss impacts? The ability to predict which streams are likely to experience flow loss is critically important, as TGD 563-2000-655 stipulates that "Underground mining operations should be planned and conducted to prevent adverse effects". TGD 563-2000-655 suggests several factors that are likely to be associated with flow loss (PADEP 2005). Consol Energy, Inc. has further classified the factors into two classes - primary and secondary indicators of flow loss (Bailey Mine, Permit Revision 150). They include the following:

PRIMARY FACTORS

1. Drainage/watershed area: Streams with smaller watersheds are more susceptible to flow loss.
2. Streambed lithology: Streams with a larger percentage of exposed bedrock in the stream channel are more susceptible to flow loss.
3. Depth of cover: Streams with shallow overburden depth are more susceptible to flow loss.
4. Percent of watershed mined: Streams with a greater percentage of the watershed mined are more susceptible flow loss.

SECONDARY FACTORS

5. Overburden geology: Streams with a greater percentage of "hard rock" in their overburden are more susceptible to flow loss.
6. Stream orientation: Streams with extensive lengths overlying the tensional zone of the panels are more susceptible to flow loss.
7. Presence of natural fracture zones: Streams with natural fracture zones are more susceptible to flow loss.
8. Mining height: As the mining height (i.e. coal seam thickness) increases, the likelihood of flow loss on above streams also increases.

The University recommends that PADEP and mine operators move beyond these general rules and use data from the case studies above to create more detailed predictions regarding mining-induced flow loss impacts.

VIII.C – Status of Streams Sampled for Biology during 3rd Assessment

Of the five streams that were undermined prior to the implementation of TGD 563-2000-655 but evaluated by the University of Pittsburgh in both the 3rd and 4th assessment periods, two streams have improved in TBS since the 3rd assessment, while three streams have declined (Figure VIII-4). Below, a detailed evaluation of the current status of each of these streams is provided.

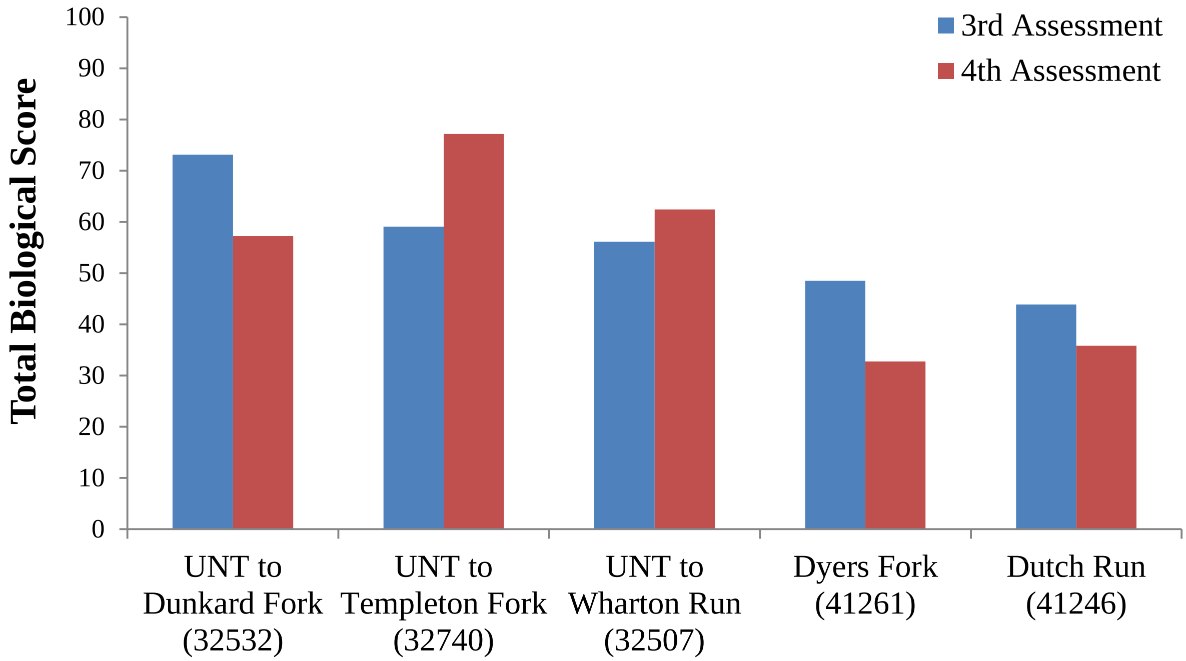

Figure VIII-4. Comparison of Total Biological Scores from the 3rd vs. 4th assessment for five streams undermined prior to compliance with TGD 563-2000-655.

VIII.C.1 – Stream 32532, unnamed tributary to Dunkard Fork

Stream 32532 was undermined by a total of eight panels in Bailey Mine (7H-14H panels). The only portion of the stream that was not undermined is a ~1,000-ft section near the mouth. The stream is a second-order tributary and classified as a warm water fishery. The mining of the 8H panel resulted in significant heaves and subsequent flow loss to the stream across both the 7H and 8H panels in June 2006. The length of flow loss regularly met or exceeded 4,000-ft. According to BUMIS, the mine operator immediately initiated heave removal and grouting in July 2006. On 4 August 2006, CDMO opened a formal stream investigation for this stream (ST0606). In an email dated 22 November 2010, a PADEP biologist indicated that samples collected in the 7H and 8H panels of stream 32532 generated TBS of 83.5 and 72, respectively. According to the email, these scores exceeded the pre-mining TBS of 63, indicating that this section of the stream had recovered biologically (Figure VIII-5). The investigation was closed by PADEP on 1 September 2010.

In the 3rd assessment, the University's macroinvertebrate sample from the 7H/8H gate area scored a 73.1, which is similar to the PADEP's TBS for the 8H panel. During the 4th assessment, the University sampled the same area on 23 April 2013 and this sample had a TBS of just 57.3. This score represents a strong decline from the 3rd assessment and the scores reported by PADEP (Figure VIII-5). Specifically, decreases were observed for four of the five biological metrics, including a loss of six taxa – four of which were Trichoptera (See Appendix D1).

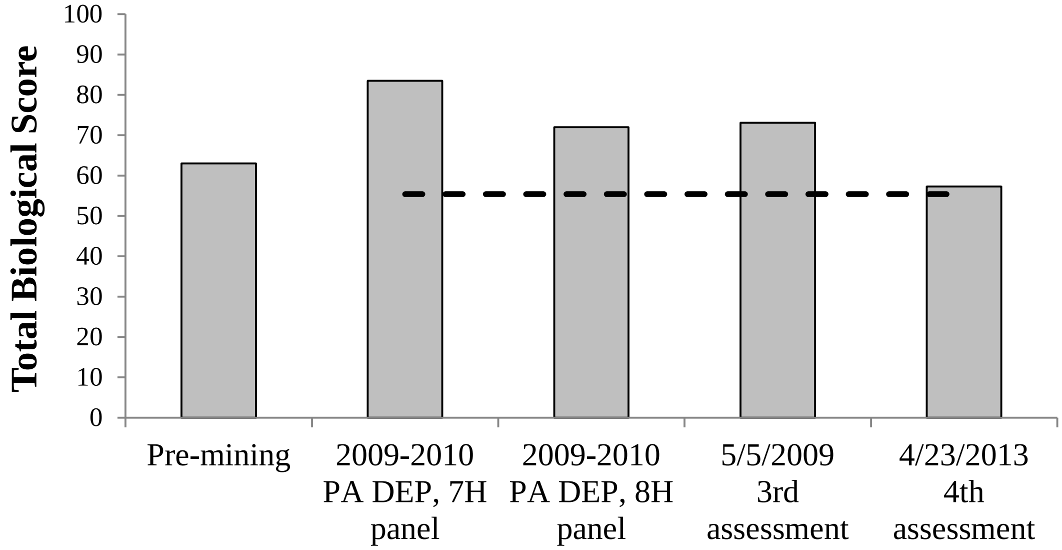

Figure VIII-5. Total Biological Scores for stream 32532, an unnamed tributary to Dunkard Fork, collected by the mine operator, PADEP and the University. Dashed line indicates the minimum Total Biological Score required for stream to be considered recovered.

While it appears that the score for this stream has declined over time, augmentation may be partially responsible for the inflation of TBS during the 2009 and 2010 samplings. Augmentation data from the mine operator shows that this stream received augmentation through January 2011 (Figure VIII-6). While the source of the augmentation may not have been directly within the 7H or 8H panels, augmentation in upstream panels could still influence downstream flow conditions and thus, the macroinvertebrate community. Augmentation was particularly abundant during the falls of 2008 and 2009, just before the spring samplings of 2009 and 2010 (Figure VIII-6). Because many aquatic macroinvertebrates lay their eggs during the late fall (Wallace and Anderson 1996), augmentation during this period may have allowed the egg and larval stages of certain taxa to persist until the spring when the samplings were conducted. Without augmentation, taxa that are sensitive to low flow or flow loss conditions may be unable to survive. It is likely that on-going augmentation prohibited proper evaluation of flow and biological recovery by the PADEP and by the University in the 3rd assessment period. Since this time, the PADEP has created an “augmentation reprieve” period for mine operators during which augmentation is turned off to evaluate natural flow and biology. This new policy should prevent augmentation from affecting measures of recovery on streams mined after TGD 563-2000-655.

Lastly, it is important to note that the University’s score of 57.3 is greater than 88% of the pre-mining TBS of 63. This indicates that despite the lower score when augmentation is not present, the macroinvertebrate community is meeting the pre-mining conditions.

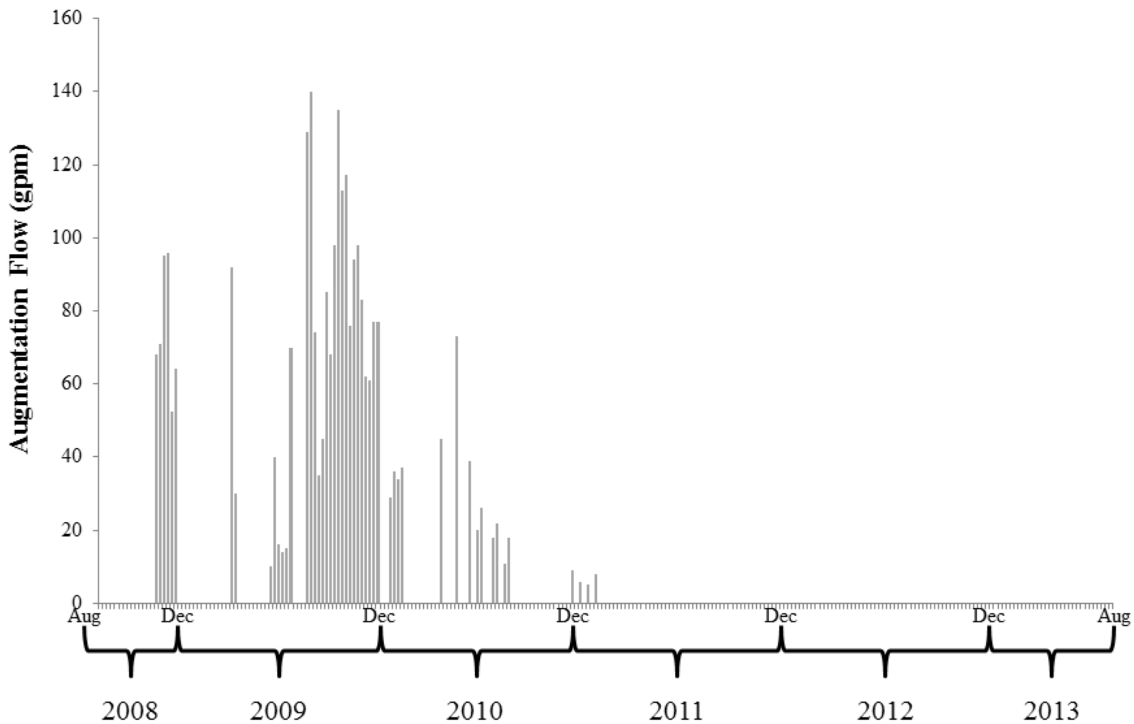

Figure VIII-6. Augmentation flow (in gpm) for stream 32532, an unnamed tributary to Dunkard Fork, during the 4th assessment period (Provided by the mine operator to PADEP). Mining of the 8H panel occurred in June 2006.

VIII.C.2 – Stream 32740, unnamed tributary to Templeton Fork

Stream 32740 is a first order stream with a trout-stocking fishery use designation. This stream was completely undermined by four successive panels (F13-F16) in Enlow Fork Mine during the 3rd assessment. Compression heaves and cracks were noted on 20 September 2006 in the F13 panel by PADEP. Augmentation was used to maintain flow until grouting could begin in the spring of 2007. Despite subsequent heaving and flow loss issues in the F14 panel as well, a formal stream investigation was never opened on this stream during the 3rd assessment period. It was not until 2009 that a stream recovery report (SR0901) was submitted by the mine operator for stream 32740.

The PADEP determined that both flow and biological recovery were required for this stream because the bulk of the undermining occurred after the implementation of TGD 563-2000-655. Pre-mining flow data from 2004 and 2005 indicated that in wet years such as 2004 (Table VIII-4), the stream flowed continuously. In 2005 when precipitation levels were similar to the 30-year average (Table VIII-4), the stream exhibited significant drying from August through October. For example, on 14 August 2005, 52% of the observed stream length was found to be dry (2,967 of 5,679-ft). Despite having two years of pre-mining data for stream 32740, the mine operator contended that the two very wet years of 2003 and 2004 (Table VIII-4) resulted in skewed pre-mining data for both 2004 and 2005. Thus, PADEP approved 40939, an unnamed tributary to Crafts Creek, as a control stream for use in determining both flow and biological recovery.

Table VIII-4. Monthly and yearly precipitation totals for Waynesburg, PA from 2003-2005 as well as the 30-year average (Provided by the mine operator to PADEP).

	30 year average	**2003**	**2004**	**2005**
Jan	2.93	3.33	3.67	6.42
Feb	2.52	5.40	2.40	1.85
Mar	3.51	1.45	3.72	4.04
Apr	3.25	2.40	4.46	2.69
May	4.18	7.17	4.42	3.36
Jun	3.64	7.15	6.33	2.10
Jul	4.01	7.60	4.22	4.41
Aug	3.94	7.66	5.96	3.59
Sept	3.20	3.50	8.33	0.93
Oct	2.48	3.50	4.01	4.16
Nov	3.21	6.70	3.64	3.59
Dec	2.70	2.63	2.53	1.88
Total	**39.57**	**58.49**	**53.69**	**39.02**

To evaluate flow recovery, PADEP reviewed detailed flow data that was submitted by the mine operator on 29 October 2009. The data reveal that the post-mining percentage of non-flowing stream lengths is consistently greater than the pre-mining percentage in all panels (Table VIII-5). However, because the mine operator contended that the pre-mining data were skewed by abnormal precipitation (Table VIII-4), the critical comparison is the post-mining percentage of stream dry vs. the control stream percentage of stream dry. The post-mining percentage of stream dry for stream 32740 is more than twice that of the control stream (38% vs. 16%), suggesting that flow has not recovered in stream 32740. However, PADEP agents determined that this stream had met the requirements for flow recovery and released the case.

In terms of biological recovery, the PADEP sampled this stream in 2009 and found that the TBS for the F13 panel was higher than the score for the control stream (Figure VIII-7). As a result, the PADEP ruled that the stream's biological community had recovered. With both the flow and biological assessments in hand, the stream recovery report was closed on 5 February 2010.

During the 3rd assessment, the University sampled this stream on 29 May 2009, just 3 weeks after the PADEP's sampling effort, and the University's TBS matched PADEP's score (Figure VIII-7). For the 4th assessment, the University re-sampled the same area on 9 May 2013. This sample had a TBS of 77.2, suggesting that the macroinvertebrate community has continued to improve over the past four years. Indeed, four of the five metrics showed strong increases since the last assessment (See Appendix D1). The significant recovery of the biological community over the past several years calls into question the appropriateness of the control stream TBS as an accurate benchmark for measuring recovery of this stream.

Table VIII-5. Flow loss data for stream 32740, an unnamed tributary to Templeton Fork, and control stream 40939, an unnamed tributary to Crafts Creek (Provided by the mine operator to PADEP in October 2009). Bold numbers indicate the key comparison for assessing flow recovery.

Stream	Location	Timing	Average Dry Length, ft	Average Percentage of Monitored Length Dry
32740	Overall	Pre-mining	331	7%
32740	Overall	Post-mining*	1,479	**38%**
32740	F-13 Panel	Pre-mining	128	10%
32740	F-13 Panel	Post-mining	229	17%
32740	F-14 Panel	Pre-mining	31	2%
32740	F-14 Panel	Post-mining	293	19%
32740	F-15 Panel	Pre-mining	148	10%
32740	F-15 Panel	Post-mining	506	33%
32740	F-16 Panel	Pre-mining	20	2%
32740	F-16 Panel	Post-mining	136	10%
40939	Overall	Control*	1,174	**16%**

*For period after mining of F-16 panel

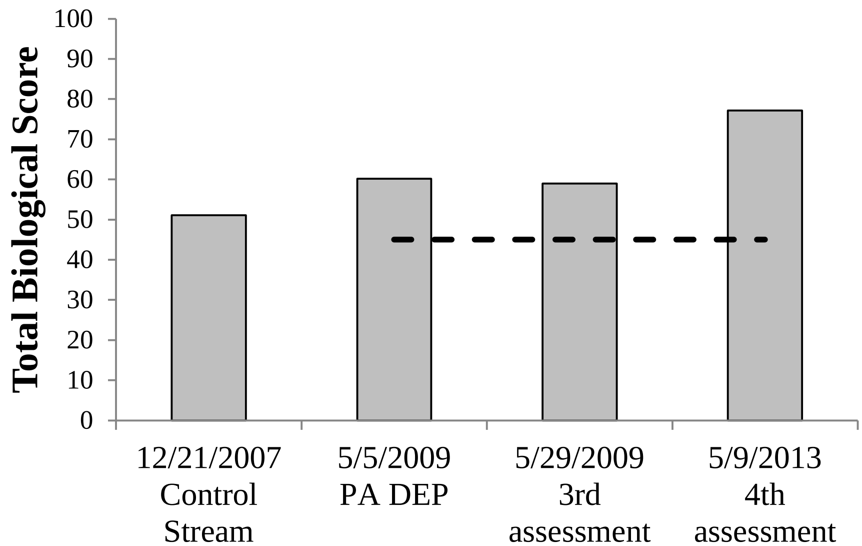

Figure VIII-7. Total Biological Scores for stream 32740, an unnamed tributary to Templeton Fork, collected by the PADEP and the University and compared to the score for control stream 40939, an unnamed tributary to Crafts Creek. Dashed line indicates the minimum Total Biological Score required for stream to be considered recovered.

VIII.C.3 – Stream 32507, unnamed tributary to Wharton Run

This warm water fishery was undermined by the 7H panel of Bailey Mine in 2005. On 24 August 2005, flow loss and fractures were noted by PADEP. These impacts triggered stream investigation ST0511 on 1 September 2005. The PADEP approved a monitoring plan for this stream on 5 May 2006 that would “consist of monthly stream flow measurements, location of flowing and non-flowing segments, and biological sampling on two separate occasions." The mine operator submitted monitoring reports in 2007 and 2010. Two years of pre-mining flow data - from 2003 and 2004 - were present for this stream. However, as with stream 32740, the mine operator contended that the data came from years with unusually large amounts of precipitation (Table VIII-5). In contrast to the investigation on stream 32740, PADEP did not require selection of a control stream for comparison. The University could not determine the reason for the inconsistencies between these two cases.

As stipulated in the monitoring plan, the final 2010 report contained two types of flow data: pre- and post-mining lengths of non-flowing segments (Table VIII-6) and graphs of precipitation vs. pre- and post-mining volumetric surface flow (Figure VIII-8). However, without control stream data for comparison, the datasets provide little insight on flow recovery and if anything, indicate a lack of recovery. For example, the post-mining non-flowing lengths are 58 times those recorded prior to mining (Table VIII-6). Even after grouting, on average ~50% of the stream length remained dry (Table VIII-6).

Table VIII-6. Flow loss data for stream 32507, an unnamed tributary to Wharton Run (Provided by the mine operator to PADEP).

Timing	Average Dry Length, ft	Average Percentage of Monitored Length Dry
Pre-mining	8.1	0.29%
Post-mining	1,629.1	58.43%
Post-grouting	1,377.3	49.40%

These differences in the length of non-flowing segments may be a function of the variation in precipitation over time. Therefore, the mine operator graphed precipitation vs. volumetric flow in an attempt to control for precipitation. Unfortunately, the analysis suffers from two major problems. First, precipitation should be plotted on the x-axis and flow should be plotted on the y-axis because flow varies as a function of precipitation. Second, the most meaningful interpretation of such a graph would be to fit separate regressions to the pre- and post-mining data to determine if the slope of the relationship changes after mining. One would predict that after mining, if precipitation is quickly lost to cracks in the bedrock, then stream flow would be low even after significant precipitation events. This would lead to a lower slope in the post-mining regression. Instead, the mine operator plotted a single regression for both the pre- and post-mining data (Figure VIII-8). While this relationship is largely meaningless, the graph does reveal that volumetric flow rates were reduced nearly 100-fold following mining. The PADEP ruled that flow had recovered despite these extreme inadequacies in the flow data.

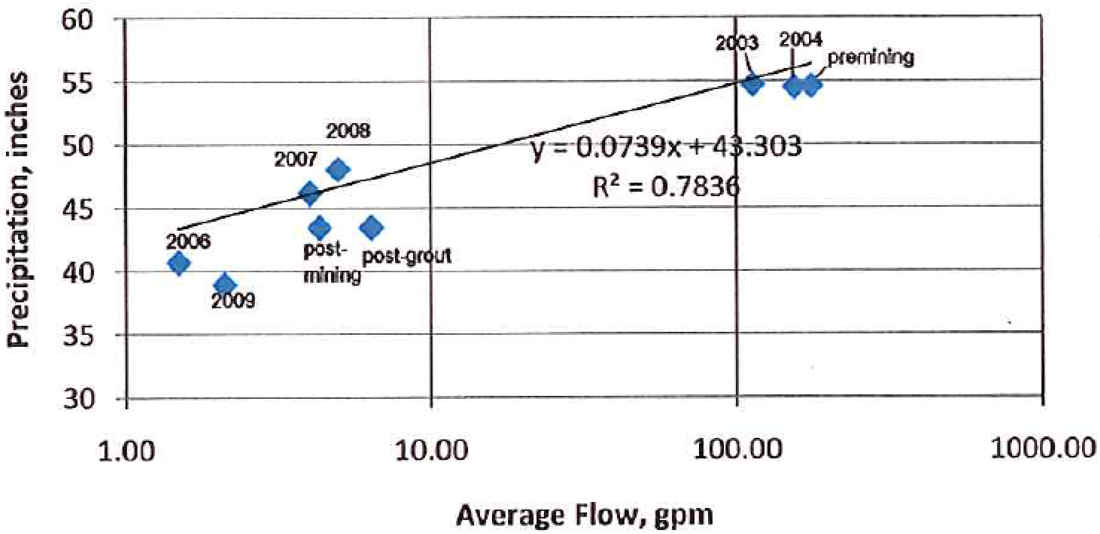

Figure VIII-8. Graph of precipitation vs. volumetric flow rates as recorded at a surface water monitoring station at the mouth of stream 32507, an unnamed tributary to Wharton Run (Provided by the mine operator to PADEP).

In terms of biological recovery, the mine operator's 2010 report contained TGD 563-2000-655 Appendix A sampling that showed the stream was supporting a biologically diverse macroinvertebrate community after mining. Because the stream was undermined prior to the implementation of TGD 563-2000-655, it was not subject to more rigorous biological monitoring. The stream investigation was closed on 19 May 2010.

On 16 April 2013, the University visited the exact location that had been sampled during the 3rd assessment to collect another macroinvertebrate sample. The TBS increased from 56.1 during the 3rd assessment to 62.4 in the 4th assessment (Figure VIII-4). The increase in TBS can be attributed in large part to the presence of six additional taxa in the sample from this period (See Appendix D1).

Despite this increase in TBS, the lack of both pre-mining biological data and a control stream prohibits an assessment of stream biological recovery. Because the 4th assessment score is within 16% of the 3rd assessment post-mining score (PADEP 2005), the diversity of the macroinvertebrate community in stream 32507 appears to be relatively stable following mining.

VIII.C.4 – Stream 41261, Dyers Fork

Dyers Fork is a third order stream with designated uses that include trout-stocked fishery and wildlife water supply. Dyers Fork runs across Cumberland Mine, and during the last assessment period, the downstream half was undermined by panels 51-55. While flow loss has occasionally occurred as a result of mining under Dyers Fork (see ST0323), pooling has become an increasing problem as the mining progresses downstream. The extremely low gradient of this stream (0.015%) and its parallel orientation to the panel in many places make it highly susceptible to subsidence induced pooling (WPI 2012a). The pooling issues have never triggered stream investigations though – this is because the mine operator acknowledged that the pools would result from mining and submitted mitigation plans to the PADEP in advance of mining. Once mining was complete and property access issues were resolved, the mine operator commenced stream restoration work. As a result, gate cuts have been performed throughout Dyers Fork (at gates 46/47, 51/52, 52/53, and 53/54).

During the 3rd assessment, the University sampled the biological community in panel 52 of Dyers Fork on 12 May 2009. The sample scored 48.5 (Note: This TBS differs slightly from that reported in the 3rd assessment. The 3rd assessment score included counts of Coleoptera taxa that are not approved for use with the Total Biological Score metric, according to TGD 563-2000-655 (PADEP 2005)). At the time of sampling, the 51/52 gate cut had been completed, but significant pooling still existed at the tailgate of panel 52. The gate cut across the 52/53 gate (Figure VIII-9) was extremely complex as it required restoration activities under the Route 19 bridge. As a result, the gate cut took place in two distinct phases (see discussion in Section VII.I.2).

Figure VIII-9. Looking downstream toward the Route 19 bridge at the completed gate cut on Dyers Fork at the 52/53 gate in Cumberland Mine on 7 May 2013. (Photo by A. Hale)

Following Phase 1, the mine operator established biological monitoring stations along Dyers Fork, including a site known as DF STA 2 in panel 52. Because the stations lacked appropriate pre-mining data, a station on Garner Run (stream 40643; station GAR 4) was approved by PADEP as a control stream (WPI 2012b). TBS for GAR 4 and DF STA 2 following Phase 1 restoration are shown in Figure VIII-10.

While the mean of the two scores collected by Wallace & Pancher, Inc. (WPI) is higher than the mean of the two control stream scores, the WPI scores were not within 16% of each other, and thus do not satisfy the requirements of TGD 563-2000-655 for recovery.

During the 4th assessment, the University sampled station DF STA 2 to compare findings with those of WPI. The University's sample generated a score of 32.7, which is the lowest TBS on record for this station. It is unclear why this sample scored so much lower than those from WPI. It is possible that the subsequent restoration work during Phase 2 impacted the biological community at this station. However, DF STA 2 is located upstream of the 52/53 gate cut area, and thus the only impacts from the gate cut on this site should have been an improvement in flow conditions. The generally low scores observed on this stream may be due in part to the surrounding land use practices and the low stream gradient. Hay and alfalfa fields surround Dyers Fork and the land use analysis in Section VII.C.2 indicates that this land use type is typically associated with low Total Biological Scores.

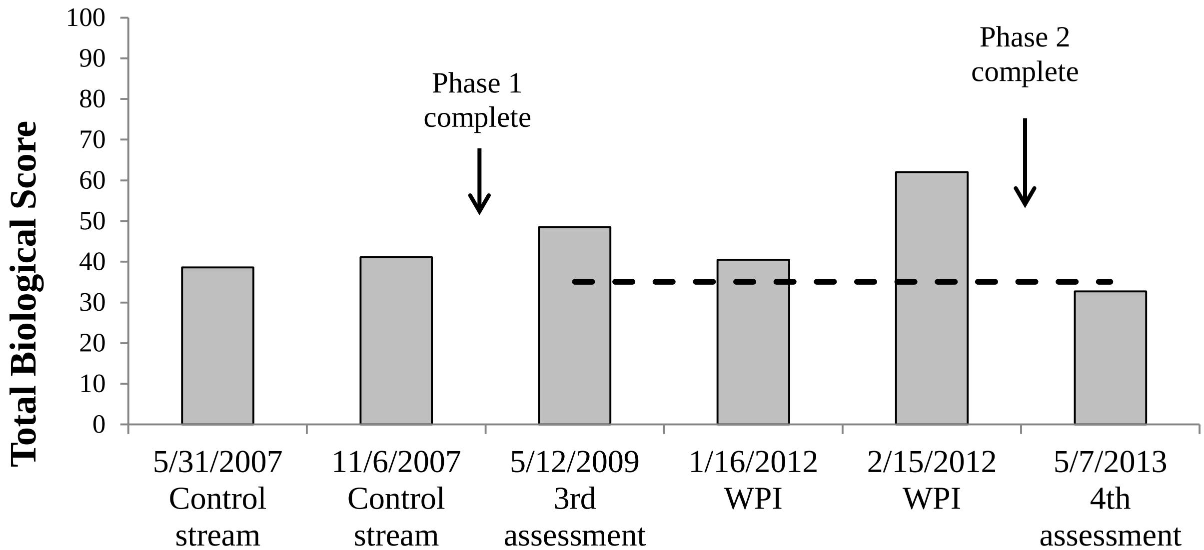

Figure VIII-10. Total Biological Scores for stream 41261, Dyers Fork, in panel 52 collected by Wallace & Pancher, Inc. (WPI) and the University and compared to scores from control stream 40643, Garner Run. Arrows indicate roughly when the two restoration phases were completed. Dashed line indicates the minimum Total Biological Score required for stream to be considered recovered.

Because WPI scores do not meet TGD requirements and the University's 4th assessment score was extremely low, further biological monitoring of Dyers Fork is warranted. While this stream is not currently trout-stocked (WPI 2012a), it is designated as a trout-stocked fishery and this use depends on a healthy macroinvertebrate population.

VIII.C.5 – Stream 41246, Dutch Run

Dutch Run is a second order stream in Cumberland Mine with designated uses as a trout-stocked fishery and wildlife water supply. During the 3rd assessment, the stream was undermined by six successive panels (panels 49-54). Records indicate that every gate road has been cut along this stream to alleviate pooling problems. Like Dyers Fork, stream investigations were not initiated for these stream impacts because the company had predicted the impacts prior to mining and submitted mitigation plans in advance.

During the 3rd assessment, the University sampled the macroinvertebrate community inside panel 53, just south of the 52/53 gate. The area was experiencing pooling at the time of sampling, and generated a TBS of 43.9 (Note: This TBS differs slightly from that reported in the 3rd assessment. The 3rd assessment score included counts of Coleoptera taxa that are not approved for use with the Total Biological Score metric, according to TGD 563-2000-655 (PADEP 2005)). While panel 53 was mined in March 2008, the gate cut for this area (i.e. Restoration Area #7) was not started until January 2012. This was due in part to the addition of a wetland restoration area adjacent to the gate cut (Section X.F). The addition of the wetlands required another permit revision (Cumberland Mine, Permit Revision 105), which was approved by PADEP on 24 January 2011.

When the University re-visited the Dutch Run sampling area on 1 May 2013, the gate cut was completed and the wetlands were in place. However, the wetland plantings had just been installed and as a result, the right stream bank was devoid of mature vegetation (Figure VIII-11). The University's sample generated a TBS of 35.8. The largest difference between the 3rd and 4th assessment samples was found in the taxa richness metric – during the 3rd assessment 20 taxa were collected while the 4th assessment sample only captured 11 taxa (see Appendix D1). It seems probable that these differences are due to the on-going wetland construction project near the sampling site.

Figure VIII-11. Wetlands are being constructed to the right of stream 41246, Dutch Run, in panel 53. (Photo by A. Hale)

While Dutch Run lacked pre-mining data, the PADEP approved a station on Garner Run (stream 40643; station GAR 4) for use as a control stream (WPI 2012b). GAR 4 is the same station that is used as a control for sites on Dyers Fork. Dutch Run's 4th assessment score is greater than 88% of the mean TBS for GAR 4 (mean = 39.85), indicating that despite the reduction in score from the 3rd assessment period, Dutch Run is maintaining a biological community that is comparable to the approved control stream (Figure VIII-12).

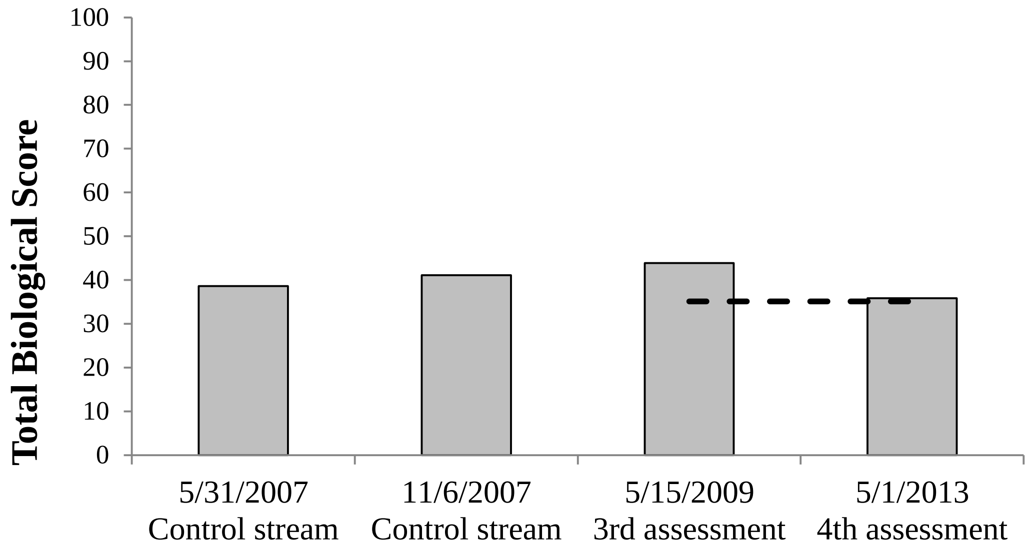

Figure VIII-12. Total Biological Scores for stream 41246, Dutch Run, collected by the University and compared to scores for control stream 40643, Garner Run. Dashed line indicates the minimum Total Biological Score required for stream to be considered recovered.

VIII.D – Summary Points

Of the 55 stream investigations that were initiated in the 3rd Act 54 assessment, 51 reached a final resolution by the end of the 4th assessment period. The average time to resolution for these cases was 1,313 days or just over 3 ½ years.

Four stream investigations from the 3rd Act 54 assessment remain unresolved. These cases have been open for 7-8 years. PADEP is currently reviewing flow data for two of the cases, yet there is little information in BUMIS or the paper files at CDMO regarding the status of flow recovery for the other two cases.

Of the 51 resolved stream investigations, seven cases were ruled by PADEP to be “Not recoverable: compensatory mitigation required”. A single case was “Closed due to federal court settlement”. Overall, these eight cases represent stream impacts that have not recovered following mining-induced flow loss. A number of mitigation techniques were utilized in an attempt to restore flow, including augmentation, cement grouting, polyurethane grouting, and the installation of stream liners. The University examined the mining and natural conditions at these sites in an attempt to arrive at some general characteristics that may act as predictors of severe stream flow loss. In general, the stream segments in these cases are characterized by shallow depths to mining, with impacts occurring in areas with overburdens less than or approximately equal to 500-ft.

The University also re-sampled the biological communities for five streams that were impacted and studied during the 3rd Act 54 assessment. Of these five streams, two showed improvements in TBS from the 3rd assessment while three experienced declines. Despite the decline in TBS for stream 32532, an unnamed tributary to Dunkard Fork, the 4th assessment score was greater than 88% of the pre-mining score. The apparent decline in TBS between the 3rd and 4th assessment periods may be due to the inflation of TBS during the 3rd assessment period when augmentation on this stream was still on-going. Declines in TBS were also observed on Dyers Fork and Dutch Run, two streams which were impacted by pooling impacts in the 3rd assessment. For Dutch Run, the 4th assessment score was greater than 88% of the approved control stream TBS, indicating that despite the decline from the 3rd assessment, the biological community has recovered. For Dyers Fork, the 4th assessment score is less than 88% of the approved control stream score. Further monitoring of this site will be necessary to ensure biological recovery.

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