SECTION IX: Effects of Mine Subsidence on Wetlands

IX.A – Overview

PADEP tasked the University with assessing the impact of mining related subsidence on wetlands in the Commonwealth. Specifically, the University reports on the acreage of wetlands undermined, the change in wetland acreage following mining, and the acreage of wetland replacements conducted during the 4th assessment period. The University also investigates two major issues that are pertinent to wetland management and restoration – natural variation in wetland size over time and the effectiveness of wetland restoration projects.

IX.B – Data Collection and Analysis

IX.B.1 – Determining Total Acreage of Wetlands Undermined and Change in Wetland Acreage Post-Mining

The University collected data on wetland acreage from the paper files at CDMO. TGD 563-2000-655 requires that permit applications include an inventory of all wetlands above areas of planned longwall mining and room-and-pillar mining where depth of cover is < 100-ft (PADEP 2005). Therefore, the University expected to find extensive wetland inventories in files permitting longwall mine expansions. However, locating such data was a challenge. Many of the areas mined during the 4th assessment period were permitted prior to full compliance with TGD 563-2000-655. While TGD 563-2000-655 was approved in October 2005, full compliance was only required for permit applications received 24 months after TGD 563-2000-655's implementation (i.e. October 2007; PADEP 2005). During this two year window, major expansions were permitted by PADEP, including the Cumberland Mine West Expansion (permitted on 31 July 2007, revision 74) and the Enlow Fork Mine North Expansion (permitted on 18 January 2008, revision 70 – the permit application was received prior to the two year deadline). For these expansions, wetland inventories were only required in areas of surface mining activity (Form 15A). Today, the mine permit application has been revised to reflect TGD 563-2000-655 requirements. Section 8.12 now requires an inventory of all wetlands in areas above underground mining (unless room and pillar depth of cover exceeds 100-ft, as per TGD 563-2000-655).

The University found that the most reliable and complete source of wetland data was located in the permit renewal files for the longwall mines (Appendix J). Mine permits must be renewed every five years, and TGD 563-2000-655 requires that the renewal include an evaluation of wetland gains and losses over the prior five year period (PADEP 2005). Unfortunately, the Act 54 five year assessment period does not perfectly align with the permit renewal timeframe for most longwall mines. As a result, data tables from permit renewals that were submitted prior to August 2013 included data on wetlands that were undermined in the 3rd Act 54 assessment period. They also lacked data on many wetlands that were undermined during the 4th assessment period. Indeed, the data from the Cumberland and Emerald Mine permit renewals is almost exclusively for wetlands undermined during the 3rd assessment period (see maps in Appendix C). For the assessments and analyses below, the University included data on all wetlands that were inventoried in the permit renewals, regardless of whether they were undermined in the 3rd or 4th assessment periods. By using all of the available data, the University provides a complete analysis of mining impacts on wetland acreage. For Cumberland and Emerald Mines, the University supplemented the permit renewal data with data from the ArcGIS files supplied by Alpha Natural Resources, Inc. to the University (Appendix J3 and J4). However, the University kept these data distinct from that reported in the permit renewals. Comparisons across mines are made using only the data in the permit renewals. This allows for comparison of acres undermined and wetland gains/losses during a five year period at each longwall mine.

Blacksville 2 Mine stands out as an exception, as this longwall mine did not submit a permit renewal during the Act 54 assessment period. The Blacksville 2 Mine expansion permit (permitted on 16 March 2009, revision 67) contains data on pre-mining wetland acreage for the expansion area as required by the new mine application. However, without a permit renewal, the University did not have a five-year assessment of wetland acreage undermined or wetland gain/loss for comparison with the other longwall mines. To approximate the wetland acreage undermined in a five year period, the University identified all of the wetlands in the Blacksville 2 expansion and then determined which wetlands were undermined during the 4th Act 54 assessment period. The total acreage of these wetlands was calculated using data from the expansion permit. Thus, the undermined wetland acreage reported for Blacksville 2 Mine actually spans the 4th Act 54 assessment period in contrast to the data from other mines.

Wetland acreage was not assessed at Mine 84 due to the minimal amount of longwall mining that occurred there during the 4th assessment period (~56 acres).

In addition to reporting on wetland acreage, PADEP also requested that the University report on the number of wetlands undermined. However, during identification of wetland locations (Section IX.B.2), the University discovered that many individual wetlands on the maps were being grouped together and identified as a single wetland by the mine operator in the permit renewal data tables. For example, wetland Enlow-53F is listed as a single wetland on the permit renewal data tables for Enlow Fork Mine (Appendix J5), yet maps reveal that this wetland is composed of five separate wetland patches (Figure IX-1). The grouping may have been less problematic if the University could have identified the method behind the wetland grouping. However, it is unclear why Enlow-53F was treated as a group of 5 wetland patches while Enlow-98D was treated a single wetland within that larger group (Figure IX-1). The University also detected wetland grouping in Bailey Mine. Here, 100 pre-mining wetlands were listed in the permit renewal data table but 190 wetland patches were mapped in the field. The University feels that any report on the number of wetlands undermined would be biased and largely inaccurate as a result of the wetland grouping. Therefore, here the University reports only statistics on the acreage of wetlands undermined.

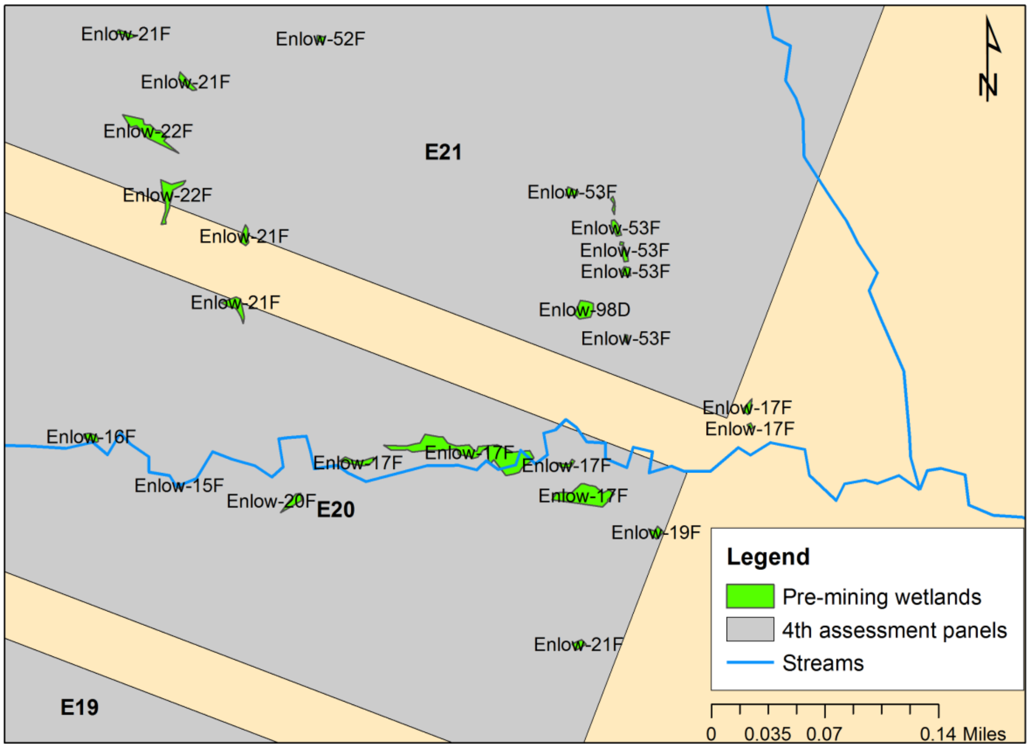

Figure IX-1. Map of Enlow Fork Mine pre-mining wetland delineations. Multiple wetlands are grouped together and identified as a single wetland (e.g. Enlow 53-F). This creates challenges in reporting the number of wetlands undermined using the data from the permit renewals.

IX.B.2 – Identifying Wetland Locations

For a full discussion of the methods used to identify wetland locations, see Section II.C.8. Wetland maps are located in Appendix C.

IX.C – Pre-Mining Wetland Acreage and Type

Across five longwall mines, a total of 236.9 wetland acres were inventoried by mine operators prior to mining. Enlow Fork Mine reported the largest pre-mining wetland acreage, with 150.8 acres of wetlands being identified in the E11-E21 and F10-F19 longwall panels (Table IX-1). However, Cumberland Mine actually had the greatest density of wetlands prior to mining, with 2.92 wetland acres for every 100 acres of proposed longwall mining (Table IX-1). Blacksville 2 and Emerald Mines had similar densities of pre-mining wetlands (~0.60 acres/100 acres of proposed mining), while Bailey Mine had the lowest density with just 0.28 wetland acres for every 100 acres of mining (Table IX-1). The average overburden for these wetlands varied across mines. On average, wetlands at Blacksville 2 Mine had the greatest depth to mining while wetlands at Emerald Mine had < 600-ft of cover (Table IX-1).

Table IX-1. Pre-mining wetland acreage for five longwall mines. Wetlands included in this analysis are located over areas of room-and-pillar or longwall mining. Wetlands outside of mining but within the permit area are not included. Data are from permit renewals and the Blacksville 2 expansion permit.

Mine	**Panels Included in Inventory**	**Acreage Mined by Panels**	**Pre-Mining Wetland Acreage**	**Pre-Mining Wetland Acres/ 100 Acres Mined**	**Average Overburden for Pre-Mining Wetlands**
Bailey	9H-14H; 8I-12I	2,645	7.4	0.3	638.1
Blacksville 2	14-18W; part of 19W	1,263	8.6	0.7	843.2
Cumberland	48-53	2,167	63.2	2.9	617.1
Emerald	B1-B2; part of B4	1,139	6.8	0.6	591.6
Enlow Fork	E11-E21; F10-F19	6,159	150.8	2.4	648.9
Total			236.9		

Comparing these data with the 3rd Act 54 assessment, pre-mining wetland acreage more than doubled (3rd assessment acreage: 93.9; Iannacchione et al. 2011). While this assessment includes data on some wetlands that were undermined during the 3rd assessment (Section IX.B.1), there is very little overlap between the data used in the two Act 54 reports. Using the information on wetland acreage and panel location in Appendix G1 of the 3rd Act 54 report, the University determined that only 16.4 wetland acres could potentially be considered redundant between the two reports. Therefore, it is safe to say that the pre-mining acreage reported to PADEP by the mine operators has doubled over the last five years.

The increase in reported pre-mining acreage is likely a direct result of the changes that were required by TGD 563-2000-655. During the 3rd Act 54 report, wetland data were largely unavailable in the paper files at CDMO. As a result, the 3rd Act 54 report, as well as the 2nd Act 54 report, relied on the National Wetlands Inventory (NWI; U.S. Fish and Wildlife Service 2014b) to determine pre-mining wetland acreage. There are two reasons why the NWI alone is inadequate for inventories of pre-mining wetlands. First, the images used by the NWI to delineate wetlands in Greene and Washington counties are from 1982-1985 (NWI Pennsylvania metadata). Landscape and climatic changes over the past 30 years may have resulted in the loss or gain of wetlands that could not be observed using NWI data. Second, NWI wetlands are identified based on vegetation, visible hydrology, and geography using high altitude imagery (U.S. Fish and Wildlife Service 2014b). Errors in wetland boundaries and classification are inherent in this system. Field work is required to ground-truth the NWI and to identify additional wetlands that may not have been detected.

Today, TGD 563-2000-655 requires that multiple sources - including NWI maps, Natural Resource Conservation soil surveys, aerial imagery, and local mapping - be used to identify areas of potential wetlands (PADEP 2005). Field surveys must follow to identify the precise location and limits of each wetland using the Routine Method described in the Army Corps of Engineers Wetlands Delineation Manual (Environmental Laboratory 1987). During the field surveys, at least one sampling area/test site is established for each wetland (Bailey Mine, Permit Revision 161; Cumberland Mine, Permit Revision 115; WPI 2010; Enlow Fork Mine, Permit Revision

105). At the test site, dominant plant species, hydrologic characteristics, and a soil profile description are recorded. Wetland boundaries are then delineated and recorded using GPS and sketch maps. In addition to providing more precise boundaries, this method also identifies very small wetlands that are often missed in the NWI delineations. This intensive method of identifying wetlands has likely played a significant role in the increase in reported wetland acreage prior to mining.

Approximately 84% of the pre-mining wetland acreage was composed of palustrine emergent (PEM) wetlands (Table IX-2). Palustrine describes the wetland system, and includes all non-tidal wetlands that are dominated by trees, shrubs, persistent emergent vegetation, or emergent mosses or lichens (Cowardin et al. 1979). Emergent describes the wetland class, and refers to wetlands with greater than 30% cover by erect, rooted, herbaceous, hydrophytic vegetation (Cowardin et al. 1979). PEM wetlands are commonly referred to as freshwater marshes, meadows, or fens. The primary function of most of these PEM wetlands is to provide habitat for wetland species, but many PEM wetlands also provide important flood storage during storm events and pollution prevention (based on functional inventories provided in permit renewals).

The emergent vegetation of PEM wetlands can often transition into scrub/shrub vegetation (PSS). Scrub/shrub vegetation is defined as woody vegetation that is less than 20-ft tall, and includes shrubs and small trees. Wetlands with both emergent and shrubby vegetation are considered PEM/PSS, and these wetlands composed 29.07 acres of the pre-mining wetland acreage for the 4th assessment period (Table IX-2). PEM wetlands can also transition into areas with forested vegetation (PFO), or woody vegetation that is more than 20-ft tall. Wetlands composed of both PEM and PFO areas made up 4.14 acres of the pre-mining wetland acreage (Table IX-2). All other wetland types combined made up less than 4 acres of the total pre-mining wetland acreage (Table IX-2).

Table IX-2. Pre-mining wetland acreage by wetland type for five longwall mines. Data are from permit renewals and the Blacksville 2 expansion permit. Wetland types follow the classification system of Cowardin et al. 1979 and are described using the classification codes of the U.S. Fish and Wildlife Service (2014a).

	Wetland Type (acres)							
Mine	PEM	PEM/PFO	PEM/PSS	PEM1	PFO	PFO1/PEM1	PSS	PSS/PFO
Bailey	6.9	0.3	0.1	0.0	0.0	0.0	0.1	0.0
Blacksville 2	6.5	0.2	2.0	0.0	0.0	0.0	0.0	0.0
Cumberland	54.2	1.0	8.1	0.0	0.0	0.0	0.0	0.0
Emerald	6.6	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Enlow Fork	125.8	2.7	18.7	0.1	0.4	0.8	2.0	0.4
TOTAL	199.9	4.1	29.1	0.1	0.4	0.8	2.0	0.4

IX.D – Change in Wetland Acreage Following Mining

Bailey, Emerald, and Enlow Fork Mines each reported net gains in wetland acreage following mining-related subsidence (Table IX-3). The largest gains were reported in Enlow Fork Mine, with the addition of three wetland acres. However, the largest overall change in wetland acreage was a net loss of 4.84 wetland acres in Cumberland Mine (Table IX-3). Wetland mitigation is required to offset these wetland losses. The Cumberland Mine wetland mitigation projects are described below (Section IX.F). As for Blacksville 2 Mine, post-mining wetland surveys were not completed by the end of the Act 54 reporting period, so the net change in wetland acreage for this mine could not be assessed.

Table IX-3. Net change in wetland acreage following mining for five longwall mines. Data are from permit renewals and the Blacksville 2 expansion permit.

Mine	**Pre-Mining Wetland Acreage**	**Post-Mining Wetland Acreage**	**Net Change in Wetland Acreage**
Bailey	7.40	7.97	0.57
Blacksville 2	7.45	No data	No data
Cumberland	63.23	58.39	-4.84
Emerald	6.85	8.98	2.14
Enlow Fork	66.12[1]	69.12	3.01

[1] = Includes only those wetlands for which post-mining surveys have been conducted.

While three of the longwall mines reported net gains in wetland acreage, this does not indicate that the pre-mining wetland acreage was unaffected by subsidence. In fact, large losses in pre-mining wetland acreage (~33-41% pre-mining acres lost; Figure IX-2) were offset by significant gains in new wetland acreage for these three mines (Figure IX-2). Interestingly, Cumberland Mine – the only mine reporting a net loss in wetland acreage – actually had the smallest percent loss of pre-mining wetland acreage (Figure IX-2). The minimal gains in wetland acreage following subsidence were not enough however to offset even these small losses.

The question becomes – is the newly created wetland acreage functionally equivalent to the wetland acreage that was lost as a result of mine subsidence? To address this question, the University investigated changes in wetland acreage by wetland type (Table IX-4). In Cumberland Mine, 24 acres of wetlands that were classified as strictly PEM prior to mining were lost following subsidence (Table IX-4). Many wetlands that were considered strictly PEM prior to mining had developed some scrub/shrub vegetation after mining. The PEM wetland acreage was thus re-classified as PEM/PSS during post-mining surveys. There are two possible explanations for this shift from strictly PEM to PEM/PSS wetland types. First, mine subsidence may have lowered the water table, reducing groundwater discharge to the PEM wetlands. Second, variation in precipitation between the pre- and post-mining surveys may have reduced surface water inputs to the PEM wetland. Either of these mechanisms could have reduced the degree of inundation within the PEM wetlands and allowed for the encroachment of facultative wetland (FACW) woody species, such as black willow (*Salix nigra*). Within the PEM/PSS wetlands, the scrub/shrub vegetation is a relatively minor percentage of the total wetland acreage (median percentage of scrub/shrub vegetation = 11%). Thus, the conversion of PEM wetlands to PEM/PSS has not resulted in a total loss of the functions associated with the original PEM wetlands.

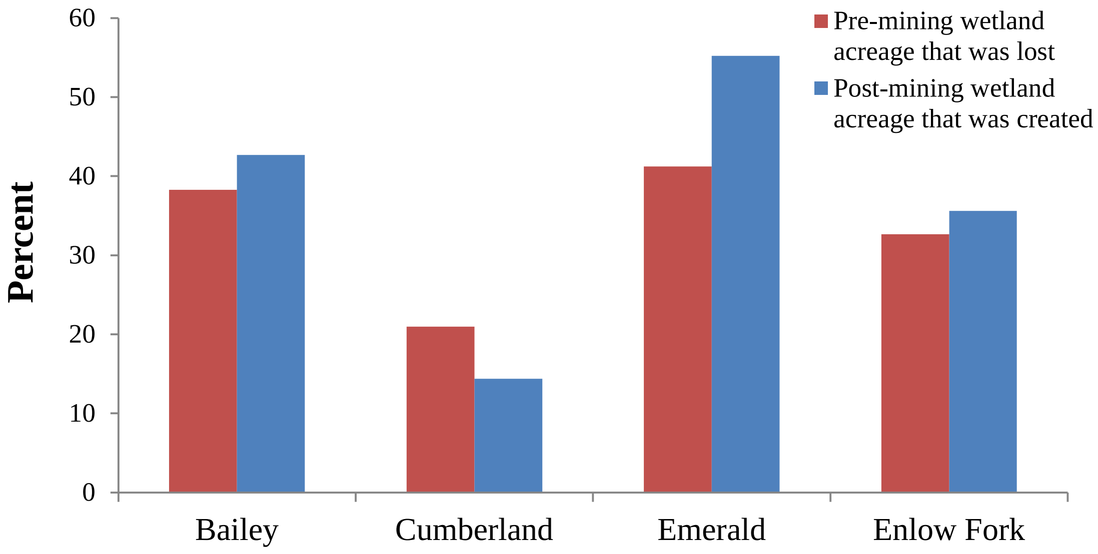

Figure IX-2. Percent of pre-mining wetland acreage that was lost following mine subsidence (red). Percent of post-mining wetland acreage that was created through mine subsidence (blue).

Table IX-4. Change in wetland acreage following mine subsidence by wetland type for five longwall mines. Data are from permit renewals. Blacksville 2 Mine is not included because there is no post-mining data for this mine. Wetland types follow the classification system of Cowardin et al. 1979 and are described using the classification codes of the U.S. Fish and Wildlife Service (2014a).

	Wetland Type (acres)								
Mine	PEM	PEM/PFO	PEM/PSS	PEM1	PFO1/ PEM1	PSS	PSS/PFO	PEM/PSS/ PFO	PEM1B/ PUBHh
Bailey	0.6	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Cumberland	-24.0	-0.1	15.8	0.0	0.0	0.0	0.0	3.4	0.0
Emerald	1.8	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Enlow Fork	8.9	1.0	-3.1	-0.01	-0.3	0.5	-0.1	0.0	0.0
TOTAL	-12.7	0.9	12.9	-0.01	-0.3	0.5	-0.1	3.4	0.2

In contrast, the losses in PEM/PSS wetland acreage at Enlow Fork Mine and PEM/PFO acreage at Bailey Mine may be harder to functionally offset with gains via subsidence (Table IX-4). The gains in PEM wetland acreage at both of these mines (Table IX-4) cannot fully replace the habitats and resources that were available in the more complex PEM/PSS and PEM/PFO wetland types. Eventually, the new PEM wetland acreage may develop into PEM/PSS and/or PEM/PFO, however, the slow growth of woody vegetation means that the conversion process will require years to decades.

Interestingly, Bailey Mine also gained acreage of an entirely new wetland type following mining. Post-mining surveys recorded 0.17 acres of palustrine emergent/palustrine unconsolidated bottom (PEM1B/PUBHh) wetlands along stream 32537, an unnamed tributary to the South Fork of Dunkard Fork. The modifiers on the wetland code for these areas indicate that the wetlands are saturated (B) and/or permanently flooded (H) due to a dike or impoundment (h, U.S. Fish and

Wildlife 2014). The last modifier suggests that the new wetland acreage is not due to mine subsidence and rather is a result of changes in land use.

IX.E – Non-Mining Related Influences on Change in Wetland Size

While the PADEP attributes changes in wetland size to mine subsidence, it is important to recognize that climatic variation can cause natural changes in wetland size. Climate influences the water level in freshwater wetlands, and it is the water level that dictates wetland type and size (Keddy 2000). Wetland water levels are largely a function of the balance between precipitation and evapotranspiration (Mitsch et al. 2009). Because precipitation and temperature vary both seasonally and annually, wetland size can vary across multiple time scales. To assess the degree of natural variation in wetland size, multiple pre-mining delineations would need to be performed on a given wetland. While this approach is not economically feasible for all wetlands that will be undermined, targeting a group of wetlands that are representative of the larger set could be useful in interpreting the impacts of subsidence on wetland size. Currently, mine operators only submit a single pre-mining delineation for each wetland to PADEP. However, ArcGIS data from Alpha Natural Resources, Inc. indicate that multiple pre-mining delineations are performed on at least a subset of wetlands. In panel C-2 of Emerald Mine, pre-mining wetland delineations were conducted along Muddy Creek and two of its unnamed tributaries (streams 41086 and 41084) in September 2004 and July 2009. Eight wetlands were identified in the 2004 delineations. In 2009, nine wetlands were identified. A new wetland had been created, but over half of the existing wetlands had decreased in size (Table IX-5). Overall, the area experienced a net loss of 0.816 wetland acres between the two pre-mining delineations (Table IX-5). These losses may be driven by differences in precipitation between the two delineation periods. The University calculated the total precipitation for 12 months prior to each of the delineations and found that the period prior to the 2004 survey was much wetter than the period leading up to the 2009 survey. There were 16 additional inches of precipitation in the period before the 2004 survey, suggesting that the decreases in wetland size in 2009 may have been related to climatic variation. For those wetlands that showed little change in size between the two delineations, it is possible that their primary source of water input may be groundwater, as water levels in groundwater-fed wetlands tend to fluctuate to a lesser degree than water levels in wetlands fed primarily by precipitation and run-off (Mitsch et al. 2009).

Additional data is clearly needed to fully assess the link between climate and change in wetland size. However, based on the case study in Emerald Mine, the University suggests that climatic variation warrants consideration by PADEP when evaluating the impacts of subsidence on wetland acreage. Multiple pre-mining delineations on a focal group of wetlands may provide PADEP and mine operators with a natural standard deviation in wetland size that can be applied to evaluate post-mining delineations. However, the University recognizes that choosing a representative group of wetlands for monitoring may be a significant challenge.

Table IX-5. Comparison of wetland acreage from two different pre-mining delineations (2004, 2009) for wetlands near Muddy Creek over Emerald Mine C-2 panel. Data are from Alpha Natural Resources, Inc.

Wetland ID	**Pre-mining 2004 Acreage**	**Pre-mining 2009 Acreage**	**Net Change**
CBMC-4	0.470	0.319	-0.151
CBMC-3	0.198	0.015	-0.183
CBMC-2	0.423	0.058	-0.365
CBMC-5	0.055	0.088	0.033
CBMC-5A	0.000	0.020	0.020
CBMC-6	0.143	0.100	-0.043
CBMC-7	0.040	0.006	-0.034
CBMC-8	0.011	0.013	0.002
CBMC-9	0.075	0.085	0.009
TOTAL	**1.416**	**0.600**	**-0.816**

IX.F – Wetland Mitigation during the 4th Assessment

Cumberland Mine was the only longwall mine with a subsidence-related net loss of wetland acreage during the 4th assessment period. Because the net loss was greater than 0.5 acres, (Table IX-3), the permittee was required to perform compensatory mitigation. If the loss had been less than 0.5 acres, the mine operator could have made a monetary contribution to the Pennsylvania Wetland Replacement Project which is administered by PADEP and the National Fish and Wildlife Foundation (PADEP 1996). The money from this fund is used to support projects that restore or create wetlands and riparian buffer zones. All losses greater than 0.5 acres however require wetland replacement.

Guidelines for wetland replacement are described in a PADEP Technical Guidance Document entitled “Design Criteria – Wetland Replacement/Monitoring” (hereafter TGD 363-0300-001; PADEP 1997). In general, PADEP requires a 1:1 replacement ratio in area and wetland type for all impacted wetlands (e.g. if 1.1 acres of PEM wetlands are impacted, then 1.1 acres of PEM wetlands must be constructed). Additionally, the guidance stipulates that the replacement wetlands must be located adjacent to the impact site unless an alternative location is approved. When the impacted wetlands share a “significant nexus” with a navigable waterway, the U.S. Army Corps of Engineers wetland replacement guidelines apply (Rapanos v. United States). Unlike PADEP, the U.S. Army Corps of Engineers’ area replacement ratios can vary with wetland type. In the Pittsburgh district, the Army Corps generally recommends PEM replacement ratios of 1:1, PSS ratios of 2:1, and PFO ratios of 3:1 (U.S. Army Corps of Engineers, pers. comm.), however the agency reserves the right to alter the ratios to meet the requirements of the Final Compensatory Mitigation Rule (U.S. Army Corps of Engineers and U.S. Environmental Protection Agency 2008).

To mitigate the wetland losses at Cumberland Mine, the mine operator proposed projects at two different sites. The first mitigation site is located along Dutch Run near the 52 and 53 gate cut areas. During the gate cuts, re-contouring of the stream banks and channel slope modifications impacted 0.88 acres of wetland DR-27. The wetland mitigation project along Dutch Run was designed to offset the losses to wetland DR-27 and to create wetland “credits” (i.e. acres) that could be applied to other projects that required wetland replacement. A total of 2.22 wetlands acres of various types, including PFO, PSS, PEM and POW (Palustrine Open Water; Table IX-6) were created at this site. The wetland impacts to DR-27 claimed 0.88 credits in the new restoration site, while impacts from another restoration project claimed 0.14 credits. As a result, 1.28 credits or acres were left over for application to the wetland losses that resulted from subsidence.

Table IX-6. Breakdown of wetland cover type at the Dutch Run wetland mitigation site. Wetland types follow the classification system of Cowardin et al. 1979 and are described using the classification codes of the U.S. Fish and Wildlife Service (2014a) except as noted. Data are from Cumberland Mine, Permit Revision 105.

Cover Type	**Acreage**	**% of Total Area**
POW[1]	0.7	32%
PFO	0.37	16%
PSS	0.93	42%
PEM	0.22	10%
TOTAL	**2.22**	**100%**

[1] = Palustrine open water

The Dutch Run wetland replacement enhanced and expanded portions of DR-27 and also added a large open water area (Figure IX-3). The open water zone is located over an area that was classified as PEM wetland acreage prior to mining but was lost as a result of subsidence. The open water zone is fed by both groundwater inputs and a surface water inlet channel from Dutch Run. An outlet channel leads away from the open water zone and back into Dutch Run to maintain proper water levels in this area. The design was approved by PADEP on 24 January 2011. The Dutch Run stream gate cuts were initiated in January 2012 and wetland excavation for the open water zone began in May 2012.

The University surveyed the Dutch Run wetland mitigation site with PADEP agents on 1 May 2013. At that time, the trees and shrubs had just been planted (Figure IX-4a) and some emergent vegetation was present on the edges of the open zone (Figure IX-4b). Several structures were also present in the open water zone, such as hummocks and root wads, which will provide habitat for wetland animals. Unfortunately, the University cannot assess the effectiveness of the Dutch Run wetland mitigation project in this report. Because the wetland plantings were completed just four months before the end of the University’s reporting period, the first monitoring report was not available for us to review. The mine operator is responsible for submitting reports to the PADEP every six months for the first two years following mitigation and annually for the next three years. These reports should contain an inventory of vegetation survival and percent cover, general information on the site conditions, photographs, and plans for correcting any identified problems.

While the Dutch Run mitigation site is replacing 1.28 of the 4.84 wetland acres lost via subsidence in Cumberland Mine, it is unclear if the new wetland at this site will serve the same function as the lost wetland area. The majority of the wetland acres lost via subsidence were of the PEM wetland type (Table IX-4), but just 10% of the Dutch Run site contains PEM wetland cover type (Table IX-6). The bulk of the site (74%) will be composed of PSS wetlands and palustrine open water (POW) wetlands (Table IX-6). It should be noted that POW wetlands were not detected in the pre-mining surveys over Cumberland Mine. Open water wetlands are the easiest to construct and make excellent habitat for waterfowl (Zedler 2000), however, the addition of this novel wetland type does not functionally replace the loss of PEM wetlands. The Dutch Run site does not appear to fulfill the 1:1 wetland type replacement criteria as described in TGD 363-0300-001 (PADEP 1997).

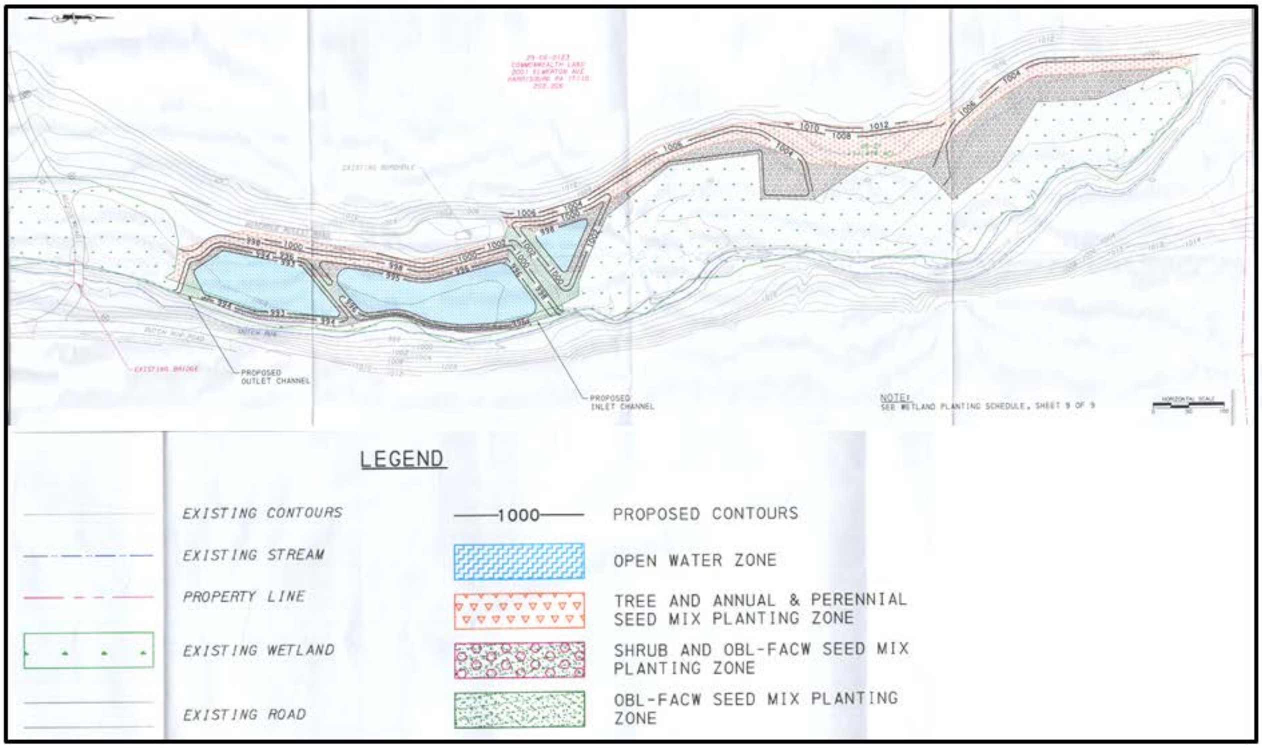

Figure IX-3. Design for the Dutch Run wetland mitigation site. Design is from Cumberland Mine, Permit Revision 105.

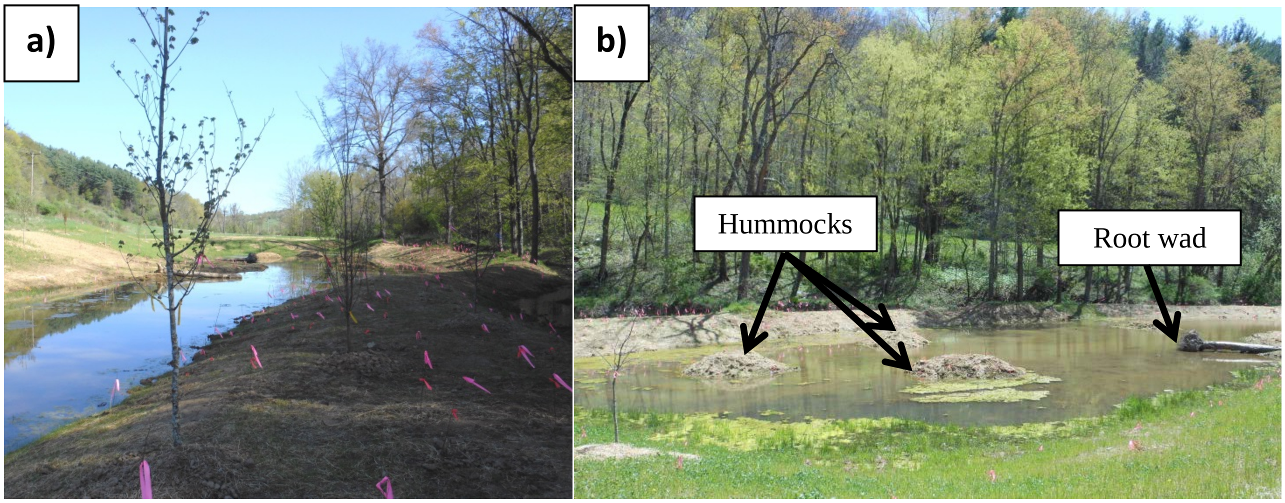

Figure IX-4. Photos from the University survey of the Dutch Run mitigation site in May 2013. a) Trees and shrubs (with pink flags) had just been planted. B) Hummocks and root wads in the open water zone provide habitat for wetland animals.

The remaining 3.56 wetland acres that were lost via subsidence will be mitigated at a second site that is situated along Whiteley Creek over the 56-57 gate area in Cumberland Mine. Work on this mitigation site had not begun by the end of the Act 54 reporting period, but designs indicate that the wetland replacement at this site will create 3.97 acres of wetland (Table IX-7). The original permit for this work was approved by PADEP on 12 January 2012 (Revision 115). However, the permit was approved before post-mining wetland surveys had been conducted at the site. The mine operator performed post-mining wetland surveys in July 2012 and discovered that three new wetlands had been created by subsidence in areas that overlapped that the proposed mitigation site (Wetlands WC-11101, WC-11102, WC-11104; Figure IX-5). Additionally, wetland WC-8, which existed prior to mining and was supposed to abut the proposed mitigation site, increased in size by 0.046 acres (Data from Alpha ArcGIS files). As a result, the mitigation designs had to be modified to accommodate the new wetlands that had been created following subsidence. Revised mitigation plans were submitted to PADEP and approved on 5 December 2012 (Revision 128). However, these plans were revised again on 30 September 2013 (Revision 134) and on 6 November 2013 (Revision 135) for unknown reasons.

Table IX-7. Breakdown of wetland cover type at the Whiteley Creek wetland mitigation site. Wetland types follow the classification system of Cowardin et al. 1979 and are described using the classification codes of the U.S. Fish and Wildlife Service (2014a). Data are from Cumberland Mine, Permit Revision 135.

Cover Type	**Acreage**	**% of Total Area**
PFO	1.09	27%
PSS	0.79	20%
PEM	2.09	53%
TOTAL	**3.97**	**100%**

While the final mitigation plans were submitted outside of the Act 54 4th assessment period, a brief description of the plans is included here. Two gas lines criss-cross the mitigation site

(Figure IX-5) such that the proposed wetlands will be installed in five separate cells. Two inlet channels, one from Whiteley Creek and one from stream 41284 (an unnamed tributary to Whiteley Creek), will provide surface water flow to wetland cells 4 and 5 (Figure IX-5). The wetlands will also receive some groundwater input, as data from five wells drilled at the mitigation site indicate that average groundwater levels are within 0.5-ft of the bottom of the wetland cells (Revision 134). Over half of the wetland acreage is designed to be PEM wetlands (Table IX-7). The PEM areas will be seeded with an obligate wetland seed mix that is dominated by sedge and reed species (Revision 135) and sweetflag (*Acorus calamus*) seed. The PFO and PSS wetland areas will be planted with wetland trees (*Platanus occidentalis*, *Quercus bicolor*, *Nyssa sylvatica*; N = 25/species) and shrubs (*Cornus amomum*, *Cephalanthus occidentalis, Alnus incana*; N = 108/species), respectively.

The Dutch Run and Whiteley Creek mitigation sites are fully replacing the acreage that was lost via subsidence in Cumberland Mine. However, they may not be fully replacing the function of the lost wetland acreage. Between the two sites, 2.31 acres of PEM wetlands will be created. However, subsidence at Cumberland Mine created a net loss of 4.84 wetland acres, most of which were of the PEM wetland type. Overall, there appears to be a net loss of emergent wetland vegetation and its associated functions in Cumberland Mine, despite mitigation at the Dutch Run and Whiteley Creek sites. While the gains in PSS and PFO wetland types are valuable for wildlife, the loss of PEM wetlands could affect plant species diversity, detrital input, and nutrient cycling.

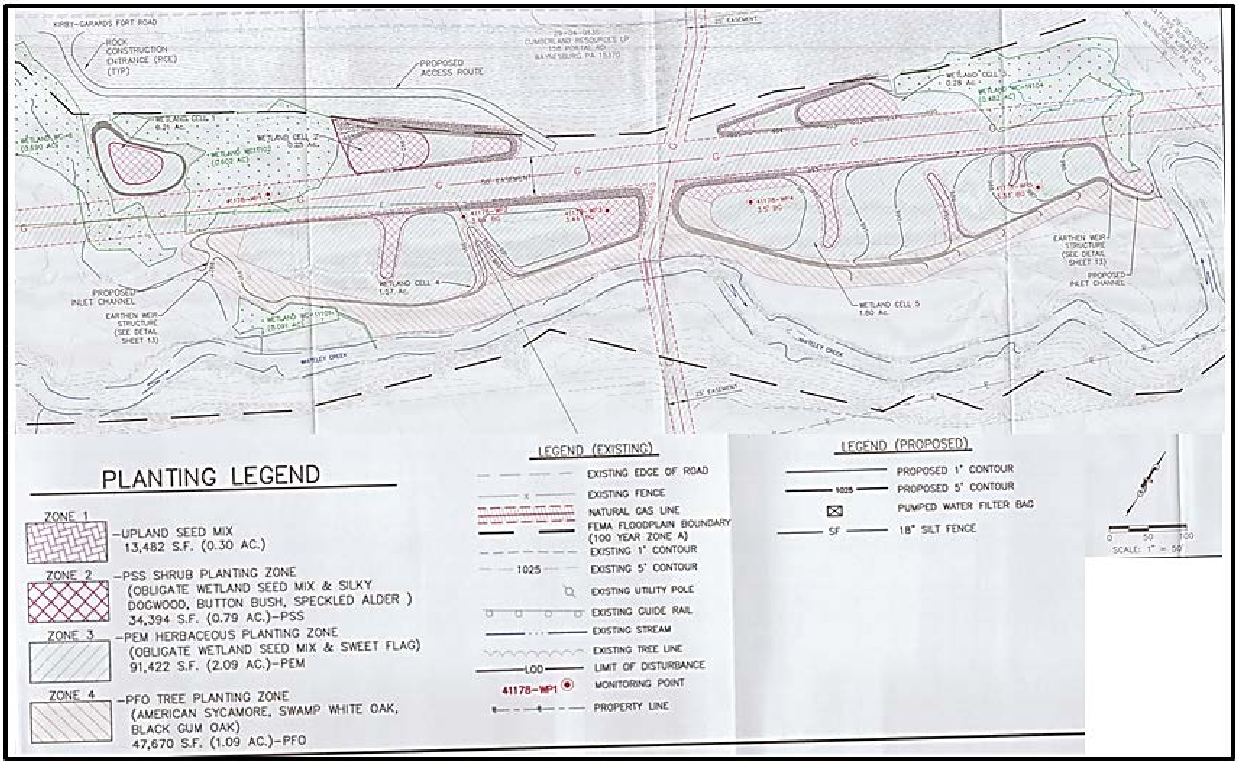

Figure IX-5. Design for the Whiteley Creek wetland mitigation site. Design is from Cumberland Mine, Permit Revision 135. Green stipple represents pre-mining wetlands.

IX.G – Challenges in Ensuring Wetland Mitigation Effectiveness

A general concern with any restoration project, including wetland replacements, is the effectiveness of the mitigation. Monitoring programs that assess the function of wetland mitigation sites are used to determine restoration "success". Monitoring requirements in Pennsylvania TGD 363-0300-001 call for the permittee to monitor wetland mitigation sites for five years following construction (PADEP 1997). Some argue though that it can take closer to 15-20 years to determine the success of mitigation projects involving freshwater marshes, and even longer for other wetland types (Mitsch and Wilson 1996). Unfortunately, there are few published studies tracking the long-term development of wetland restoration projects (Zedler 2000).

In Pennsylvania, at least three past studies have indicated challenges in achieving functional success in wetland mitigation projects. For example, a survey of 69 mitigation wetlands between 1992 and 1995 indicated a mitigation success rate of 68.7% (PADEP 2001). In this survey, wetlands were rated on a simple scale of 1-4 with 1 indicating a "success" (i.e. presence of a wetland on the mitigation site) and all other numbers indicating some type of failure (2 = hydrology present, but poor vegetation, 3 = no hydrology, vegetation is stressed, 4 = not a wetland; PADEP 2001). It should be noted that wetland age was not documented in this study, so it is unclear if lack of function can be attributed to lack of maturity in the mitigated sites. In 2002, a comparative study found that created wetlands in Pennsylvania had reduced organic matter, lower plant species richness and lower total plant cover relative to natural wetlands (Campbell et al. 2002). These authors broadly addressed the contribution of wetland age to these differences by dividing created wetlands into two groups – those created more than 10 years ago and those created less than 10 years ago. While soil characteristics of older created wetlands more closely approximated those of natural wetlands, plant species richness was lowest in the created wetlands that were > 10 years old. In these sites clonal species such as the broad-leaved cattail (*Typha latifolia*) had become dominant. Reference sites also contained large patches of cattail but other plant species were able to co-exist with the cattails at these sites. In a more recent comparative study, wetland mitigation sites in Pennsylvania were found to have a lower functional capacity than natural wetlands (Gebo and Brooks 2012). Functional capacity scores were based on a suite of 10 wetland functions, including functions related to hydrology, biogeochemistry, and biodiversity. Specifically, floodplain mitigation sites, such as those at Dutch Run and Whiteley Creek, exhibited significantly lower short-term surface water storage and retention of inorganic particulates on average than reference sites (Gebo and Brooks 2012). Interestingly, this study found no effect of wetland age or size on the function of mitigation wetlands. Overall, these studies suggest that wetland mitigation projects in Pennsylvania have historically not been completely successful in replacing the function of lost wetland acreage.

Many of the mitigation sites that were evaluated in the studies cited above were constructed in the 1980s and 1990s. Wetland mitigation design has improved substantially since that time to overcome many of the environmental constraints that can stand in the way of an effective wetland replacement. For example, the absence of a seed bank and/or lack of opportunity for seed dispersal posed a significant challenge for early restoration sites that were constructed on areas with degraded seed banks or far away from natural wetlands (Zedler 2000). The construction of the Dutch Run and Whiteley Creek mitigation sites immediately adjacent to existing wetlands ensures that these mitigation sites will receive vegetative propagules.

Similarly, the inclusion of wells on the Whiteley Creek mitigation site to monitor groundwater levels for two years prior to restoration will help inform the establishment of an appropriate hydrologic regime, a factor with which many early wetland restoration projects struggled (Zedler 2000). However, building resilience (i.e. long-term stability, ability to withstand change while retaining similar function) into restoration projects remains a significant challenge (Suding 2011). For instance, initial successes in restored wetlands in Illinois were compromised later due to invasions by non-native species (Matthews and Spyreas 2010). In Pennsylvania, the permittee is only required to monitor the mitigation site for five years (PADEP 1997), so restoration cannot require on-going remediation and intervention to ensure their long-term success. Because the Whiteley Creek mitigation site is on property owned by the mine operator, the site will need to be self-sufficient after the five year monitoring period. In contrast, the Dutch Run mitigation site is on property owned by the Pennsylvania Game Commission. Thus, the state agency will likely be able to provide remediation measures on an as-needed basis if necessary after the five monitoring period. While this is not an ideal solution to the problem of designing wetland resilience, it does ensure that measures are in place to protect the mitigation site over time. As the science of wetland restoration continues to progress, wetland mitigation is expected to continue to improve in terms of effectiveness. Indeed, it is critical that the wetland mitigation projects have a high probability of success because they must replace the wetlands that have already been lost via subsidence.

IX.H – Summary

Because much of the active mining during the 4th assessment occurred in areas that were permitted prior to the deadline for compliance with TGD 563-2000-655, the University could not rely on permit applications for wetland data. Instead, the University found that permit renewals were the most reliable source of wetland data. Permit renewals contain information on pre- and post-mining data for all wetlands undermined during a given five year period.

Relative to the 3rd assessment, reports of pre-mining wetland acreage more than doubled, with five longwall mines reporting a combined total of 235.7 wetland acres prior to mining. This is likely a direct result of TGD 563-2000-655, which requires that multiple sources - including NWI maps, Natural Resource Conservation soil surveys, aerial imagery, and local mapping - be used to identify areas of potential wetlands. Of the five longwall mines, Cumberland Mine had the greatest density of pre-mining wetlands, with 2.92 wetland acres for every 100 acres of planned longwall mining. The majority of all pre-mining wetlands (84%) were classified as palustrine emergent wetlands, meaning that they were freshwater systems dominated by erect, rooted, herbaceous vegetation.

Of the four longwall mines with available post-mining data, three reported net gains in wetland acreage following mining. Despite these net gains, 33-41% of the original wetland acreage was lost after subsidence. The losses of original wetland acreage were offset by the creation of new wetland acreage. The new wetlands were generally palustrine emergent, while the lost wetlands had a mix of emergent and scrub/shrub or forest vegetation. The emergent wetlands may eventually develop woody vegetation, but this could take decades. Currently, the new wetlands do not functionally replace the complexity and resources that were provided by the original wetlands.

Cumberland Mine was the only mine with a net loss of wetlands totaling 4.84 acres. The bulk of these losses occurred in palustrine emergent wetlands. To replace the losses, the mine operator proposed two mitigation sites, one along Dutch Run and the other next to Whiteley Creek. Together, these sites will create 6.19 wetland acres. However, just 2.31 acres of palustrine emergent wetlands will be created. Thus, the mitigation does not provide a 1:1 functional replacement of the lost wetlands. Furthermore, the University could not evaluate the effectiveness of either mitigation project as the Dutch Run site was planted just months before the end of the reporting period and work on the Whiteley Creek site had not even begun. Past studies of wetland mitigation projects in Pennsylvania suggest that mitigation sites have lower functionality relative to natural wetlands. Clearly, close study of the Dutch Run and Whiteley Creek mitigation sites is warranted to ensure that these sites achieve their proposed function and that they are maintained for years to come.

Lastly, it should be noted that evaluation of subsidence-related changes in wetland acreage is complicated by natural variation in wetland size due to seasonal and annual fluctuations in temperature and precipitation. Currently, PADEP requires one pre-mining and one post-mining delineation for each wetland. Multiple delineations on a focal group of wetlands may provide PADEP with a standard deviation for wetland size over time. Such information would allow agents to control for climatic variation while assessing the impacts of subsidence.

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