

# Impacts of Reclamation and Remining on Watersheds of Pre-Law Legacy Coal Mines

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## ABSTRACT

Since the passage of modern day US coal mining laws over 35 years ago, remining has played an important role in watershed restoration. However this restoration activity has not been well documented, including the impacts of CCP reclamation when used in combination with remining. Studying the impact remining has had on a watershed basis is important and can serve as valuable background information for regulators involved in the permitting activity as well as the general public.

During remining operations, acid-forming materials are removed with the extraction of coal, pollution abatement best management practices (BMPs) are implemented under applicable regulatory requirements, and the abandoned mined land is reclaimed. During remining, many of the problems associated with abandoned mined lands, such as dangerous highwalls, can be corrected without the use of public funds. Furthermore the implementation of appropriate BMPs during remining can be effective at improving the water quality of pre-existing discharges. The use of CCPs, particularly fly ash and FGD materials, in the reclamation of the remined lands offers the opportunity to alleviate problems associated with pre-law legacy mines.

Using Geographic Information Systems (ArcGIS) to digitally model the trajectory of remining operations in the Duck Creek Watershed, we present an overview of the impact of remining and reclamation (including the use of CCPs) at the watershed level. In this study, we have chosen the Duck Creek Watershed for which historical data from 1970s is available. This watershed study provides valuable information to current regulators of active mine operations who examine remining applications submitted by coal mining industry. The BMPs utilized by these coal remining operations are described along with the impacts on the watershed.

## BACKGROUND AND OBJECTIVES

The passage of the Surface Mining Control and Reclamation Act (SMCRA) in 1977 paved the way for improved reclamation standards and oversight of active mining throughout the Appalachian coal bearing region. Not only did the act regulate the reclamation of active mining, but it also laid the groundwork for improved reclamation standards for remining sites as well. Despite the stringent nature of SMCRA, The Ohio Strip Mine laws were granted primacy due to the fact that they exceeded the standards set in place by SMCRA. Ohio Strip Mine Laws vary over time, beginning with A Law Permits established in 1966 and continuing into 1973. These permits required only a regrading of spoil with no acid mine discharge regulations for reclamation. A permits, and all mining that took place before their initiation, are commonly referred to as “pre-law mining”. Modern Law Mining consists of B, C and D permits. These permits span 1973 to the present, and require the full return of the land to approximate original contour, the mitigation of acid mine drainage, and the revegetation of surface lands for use as pasture, recreation, or forest use.<sup>1</sup> Taken together, these historic federal and state regulations mirror many Best Management Practices in use by coal operators today.<sup>2</sup> Because remining must be performed on significantly degraded abandoned mine sites, many unique challenges to the fulfillment of these objectives exist.

Remining takes place on previously disturbed mine sites that have been abandoned prior to the enacting of modern coal mining laws. The process of remining involves the extraction of economically viable coal reserves from strip mine sites and the subsequent reclamation of these abandoned sites following mine operations. Sites that have been abandoned prior to 1977 (Passage of SMCRA) often exhibit poor water quality conditions and dangerous physical characteristics. Dangerous highwalls and pits are common, and a risk to local populations and recreationists is present. The main objective of Ohio’s remining program is to improve water quality conditions with the implementation of Best Management Practices during and after remining operations.<sup>2</sup>

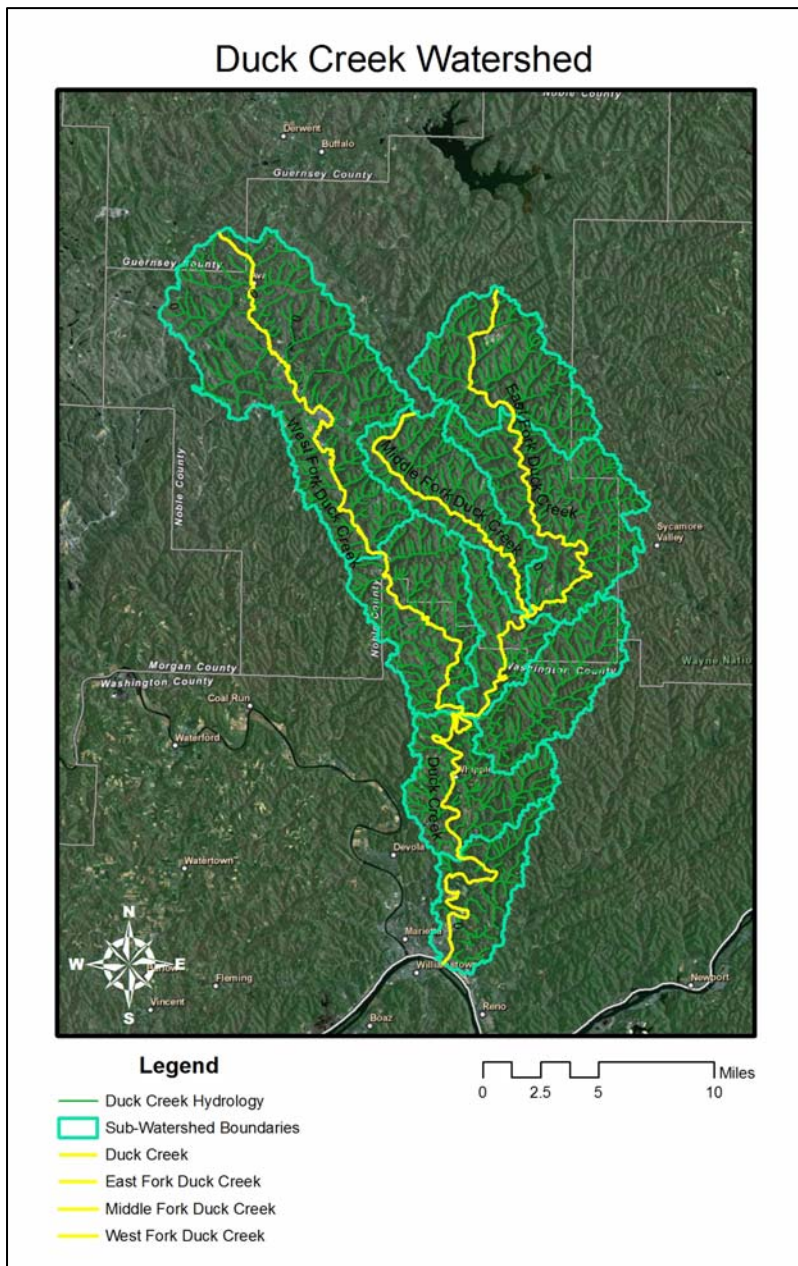
In order to facilitate remining, the Rahall Amendments to the Clean Water Act in 1987 enabled mine operators to apply for modified effluent permits.<sup>3</sup> These permits gave regulators the ability to modify water quality reclamation standards to a level above baseline conditions for sites which demonstrate degraded pre-existing water quality conditions. Unfortunately, operators have largely failed to take advantage of these incentives. A study by Mike Smith of the Pennsylvania Department of Environmental Protection claims that by 1999, 12 years after the passage of the Rahall Amendment, only 330 remining permits had been issued, with 300 of them in the state of Pennsylvania.<sup>4</sup> Today, there have been increases in remining, with at least 13 remining

permits issued since 1980 in the Duck Creek Watershed alone; yet only two of those included modified effluent benchmarks for water quality. This is due in part to further incentives for re-mining which have been developed including the AML Enhancement Rule in 2003, which allowed operators to use federal AML funding for re-mining reclamation; and the Energy Policy Act of 1992 which further removed regulatory burdens imposed due to unforeseen obstacles inherent in the mining of degraded abandoned mine lands.<sup>3</sup> For example, if an operator accidentally uncovered an unknown underground mine shaft in the process of re-mining, and a release of acid mine drainage followed this event, the operator would be spared liability for this increase in pollution load. The Energy Policy Act of 1992 also reduced the revegetation liability from 5 to 2 years in Ohio.<sup>3</sup>

Despite these incentives to engage in the re-mining of abandoned strip mine sites, operators have still shown hesitancy to take on these projects relative to the vast opportunities available across the coal bearing region of SE Ohio.

## CHOICE OF WATERSHED

The 1974 Land Reborn study was commissioned by the Board on Unreclaimed Strip Mined Lands to evaluate the condition of 79 watersheds in the coal bearing region of SE Ohio.<sup>5</sup> The study was initiated in order to establish the reclamation priority of these watersheds to mitigate the effects of acid mine drainage through the use of Federal AML reclamation funding. The study classified each watershed as either low, medium, or high priority based on pollution loadings in rivers, creeks, and streams; the prevalence of abandoned mine lands; and the feasibility of proper reclamation and restoration of the watershed.<sup>6</sup> Of all 79 watersheds, the Duck Creek Watershed (composed of two sub watersheds, 25 and 33) was determined to be the highest priority watershed for reclamation in the state.<sup>6</sup> In 1974, loadings at the mouth of Duck Creek exceeded 38,000 lbs./day of acid, 700 lbs./day of iron, and 100,000 lbs./day of sulfates. In light of this study, a reevaluation of the watershed since 1974 is critical to establishing the progress in Duck Creek since Land Reborn.<sup>5</sup>



While the Duck Creek Watershed is the focus of this initial study, it should be noted that within the scope of the project work plan, Duck Creek is only the first case study in what we expect will be a series of studies evaluating the implementation of remining in Eastern Ohio. The Land Reborn Study serves as an invaluable resource as new watersheds are selected based on the severity of surface mining associated pollution discharges, the progress of remining in the region, and the availability and access to abandoned mine lands that could be possible candidate sites for remining operations. Consideration is also given to the location of nearby CCP producing coal fired power plants, which could aid in the use of coal byproducts in remining reclamation.<sup>7</sup>

Figure 1: Map of Duck Creek Watershed

To summarize, the study has been divided into 2 phases. First, focusing on the Duck Creek Watershed and second, refining the methodology associated with the Duck Creek case study and using the same methodology to evaluate impacts of remining on other watersheds including environmental, economic, and social impacts on the surrounding communities.

## PHASE ONE: DUCK CREEK WATERSHED CASE STUDY

Duck Creek empties into the Ohio River at its mouth near the city of Marietta. The Creek is composed of the West Fork, The East Fork, and the Middle Fork converging in Lower Salem, OH; 24 miles north of Marietta. The creek drains an area of 287 sq. miles in Washington, Noble, Guernsey, and Monroe counties. For the purpose of the study, the watershed has been divided into 9 distinct subwatersheds using the NRCS 14 digit subwatershed shapefile in our study GIS (Geographic Information System). The 9 subwatersheds are as follows:

Sub-watershed #1 – Duck Creek from Stanleyville to Ohio River (11855.7 Acres)

Sub-watershed #2 – Duck Creek from confluence of East Fork and West Fork to Stanleyville (15817.7 acres)

Sub-watershed #3 – West Fork Duck Creek from Dexter City to above East Fork (19870.6 acres)

Sub-watershed #4 – West Fork Duck Creek headwaters to Dexter City (48219.5 acres)

Sub-watershed #5 – Paw Paw Creek (14996.4 acres)

Sub-watershed #6 – East Fork Duck Creek below Middle Fork to above West Fork (except Paw Paw Creek) (9176.4 acres)

Sub-watershed #7 – Middle Fork Duck Creek (16982.7 acres)

Sub-watershed #8 – East Fork Duck Creek below Elk Fork to above Middle Fork (23783.6 acres)

Sub-watershed #9 – East Fork Duck Creek headwaters to below Elk Fork (20249.7 acres)

Subwatershed #3 has been evaluated first with respect to water quality, with 5 more watersheds containing abandoned mine lands remaining for water quality analysis. A full analysis has been made on the status of mined land features in the Duck Creek drainage area.

### **Land Cover Analysis**

Abandoned mine lands in Duck Creek are ubiquitous, and often what remains of them on the land are polluted pit ponds and dangerous highwalls. These highwalls often rise to heights of over 80 feet above their base. Highwalls and pits pose a persistent risk to local populations. Following decades of neglect, often these sites are obscured by thick plant cover. Off Road Vehicles and dirt bike enthusiasts are especially vulnerable to



Figure 2: Typical unreclaimed dangerous highwall/acid pit.

falls or injuries in regions of extensive strip mining. Reclaiming has the capacity to eliminate these dangerous land features and create valuable wildlife, recreational, and pasture spaces.

Since 1977 and the passage of SMCRA, 380 acres of affected mine areas have been reclaimed in the Duck Creek Watershed. This includes active reclaiming operations; B, C, and D permit reclaiming (see Ohio Mine Permit History below), and phase 3 unreleased D permits undergoing reclamation. Using

Geographic Information Systems to isolate reclaiming features, it was determined that 90 acres of abandoned mine lands were reclaimed by reclaiming under C permits, 154 acres reclaimed by reclaiming under D permits, and 136 acres reclaimed through active reclaiming operations, but still in phase 3 final reclamation phase.<sup>8</sup> Table 1 below summarizes these statistics. A comprehensive analysis of the GIS processes used to generate this data is described later in this paper.

Table 1: Status of abandoned highwalls/pits present in 1975 aerial imagery

<i>Permit Designation</i>	<i>Reclamation Status</i>	<i>HW/HWP Length</i>	<i>DH/DHP Area</i>	<i>Total Features</i>
*A Permit	Unreclaimed	32,197 ft.	20 acres	6
*A Permit	Partial Reclamation	311,742 ft.	441 acres	57
*A Permit	Reclaimed	65,008 ft.	139 acres	16
**C Permit	Reclaimed	44,676 ft.	90 acres	16
D Permit	Partial Reclamation	9,393 ft.	25 acres	3
**D Permit	Reclaimed	77,701 ft.	154 acres	21
Pre-Law	Unreclaimed	470,768 ft.	922 acres	152
Permit Unreleased	Partial Reclamation	63,289 ft.	170 acres	22
**Permit Unreleased	In Phase 3 Reclamation*	89,287 ft.	136 acres	19

\* pre-modern law (partial reclamation standards enforced)

\*\* represents reclaiming permits in the Duck Creek Watershed

## Water Quality Analysis

As part of the first phase of this study, an analysis of water quality before and after remining was undertaken at permitted sites. Using water quality data from selected remining permits obtained from the Ohio Department of Mineral Resource Management, an assessment of pre-mining and post-mining levels of metal loadings (aluminum,

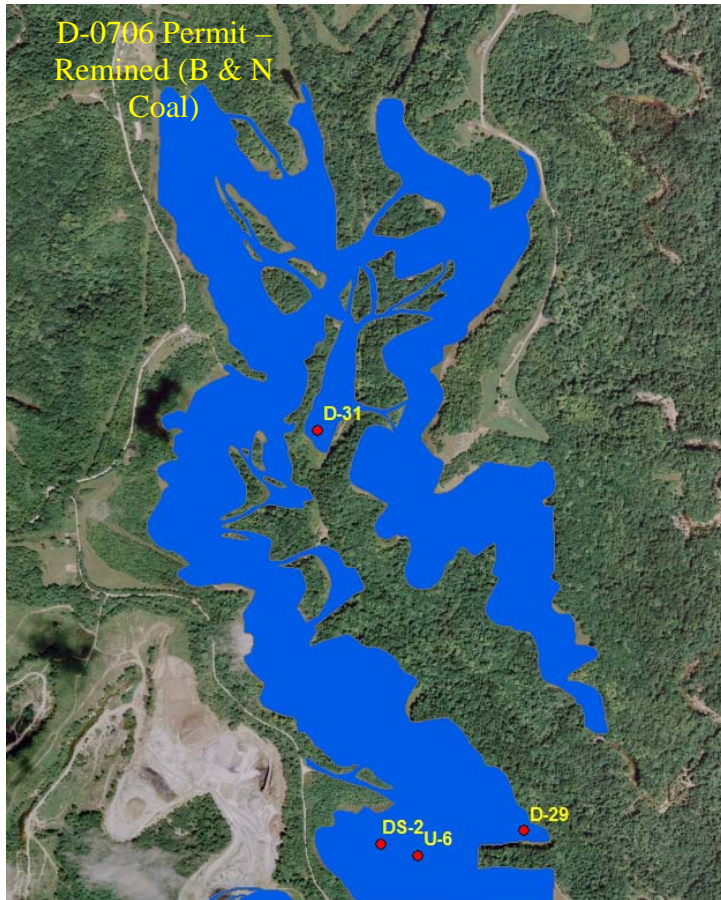


Figure 3: D-0706 Permit (B&N Coal)

manganese, iron), acidity, alkalinity, total suspended solids, and sulfate levels were compared in order to assess the changes in water quality due to remining. As a test of this method, a comparison of DMRM Permit number D-0706 remined by B&N Coal was used to extract water quality at four locations in the permit area and compare water quality before and after mining took place. Ohio D permits require 12 months of pre and post monitoring, providing an excellent template by which to establish the affects of remining in this specific subwatershed.<sup>8</sup> Pre-monitoring for the D-0706 Permit began in 1988 and Post-Monitoring is still ongoing.<sup>8</sup> The location of the permit can be seen in Figure 3.

### Data analysis methods

demonstrated in the 2002 paper, *Effectiveness of Pennsylvania's remining program in abating abandoned mine drainage: water quality impacts*<sup>10</sup>, aids in a micro/permit level analysis of changes in certain water quality parameters of interest in specific mine sites. Analysis of D-0706 shows decreases in acidity and increased pH stability, while a modified effluent permit in the same watershed (D-2218) shows decreases in acidity, pH stabilization, and reductions in sulfates and specific conductance.<sup>8</sup>

Following an analysis of all remining permits in Duck Creek a macro level approach is appropriate to evaluate the improvements in watershed water quality by comparisons between stream loadings from the 1974 Land Reborn study and the OEPA TMDL report for the Duck Creek Watershed.<sup>9</sup> 1974 Baseline conditions have been evaluated and are

present in the GIS Water Quality Analysis portion of the paper.

Limitations to this study do exist. Unfortunately, perfectly coordinated testing sites are difficult to find across a 40 year time period. Because of this, watershed characteristics must be evaluated precisely where possible, and biological data from the 2002 OEPA TMDL study must be used to establish the presence of habitable conditions for wildlife and fish.<sup>9</sup> Another limitation exists in that flow data is not available for older data retrieved from the 1974 Land Reborn Report and B, C, and D-Permit monitoring data.<sup>6, 1</sup>

## GEOGRAPHIC INFORMATION SYSTEM IMPLEMENTATION

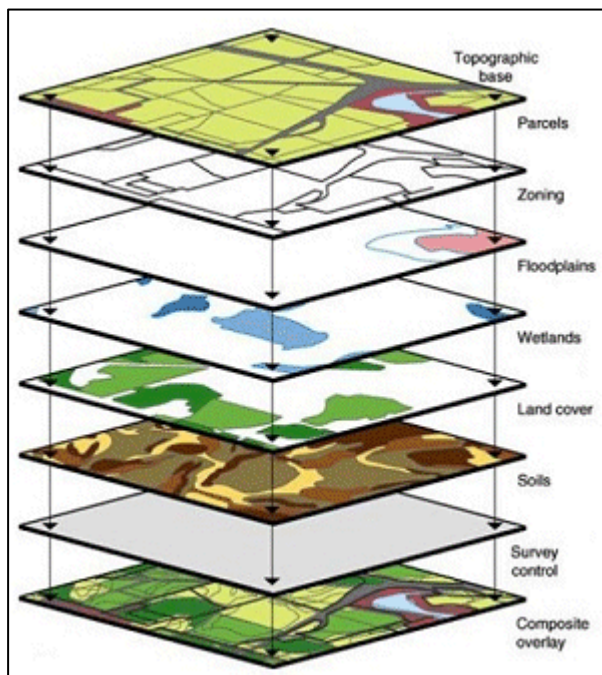


Figure 4: GIS Data Modeling

ArcGIS is a software application that allows users to organize layers of data spatially for the purposes of data modeling, analysis, processing, and display. In evaluating changes in “on the ground” surface mine features, the use of geographic information systems has allowed us to reference all our data spatially to a consistent projected coordinate system. In order to facilitate the calculation of the total length, area, and number of abandoned mine features affected by re-mining, spatial georeferencing was performed on 5 aerial images circa 1975 (ODOT). These images show the historic status of all areas within the Duck Creek watershed, and allow the user to locate highwalls and highwall pits present in 1975. These highwalls and pits are then

digitized and saved as a feature class within the Duck Creek Study geo-database. When digitizing, ODNR AMLIS (Abandoned Mine Land Inventory System) topography maps are used to confirm the locations of possible mine lands.<sup>1</sup> Affected area is calculated from the peak of the spoil pile to the edge of the highwall in order to achieve a consistent method for calculating affected mine area.

Once recorded, each feature is represented by a “tuple” or record within the database. Fields are then created to store attributes such as reclamation status, area, highwall length, and permit association. Once the feature database’s relational structure has been modeled, the analysis phase can begin. By referencing the aerial imagery to 2009 satellite imagery, we can compare the highwall features present in 1975 to the current

conditions on the ground. Each feature within the abandoned mine land database is given a classification based on reclamation progress. These classifications are as follows: 1 = unreclaimed, 2= partially reclaimed, and 3 = full reclamation. Complete accuracy is difficult to accomplish due to the fact that forest regrowth often occurs on abandoned mine lands, obscuring important features used to aid in classification.

Once reclamation status is established, spatial data detailing the extent of Ohio mine permits is obtained through the Division of Mineral Resources Management for use in the GIS.<sup>1</sup> These permits are used to establish the permit designation of each abandoned highwall feature present in 1975. If the permit designation for a fully reclaimed mine site is B, C, or D, then Modern Mine Law applied the reclamation standards to a previously abandoned (pre-1975) surface mine site, and re-mining has occurred.

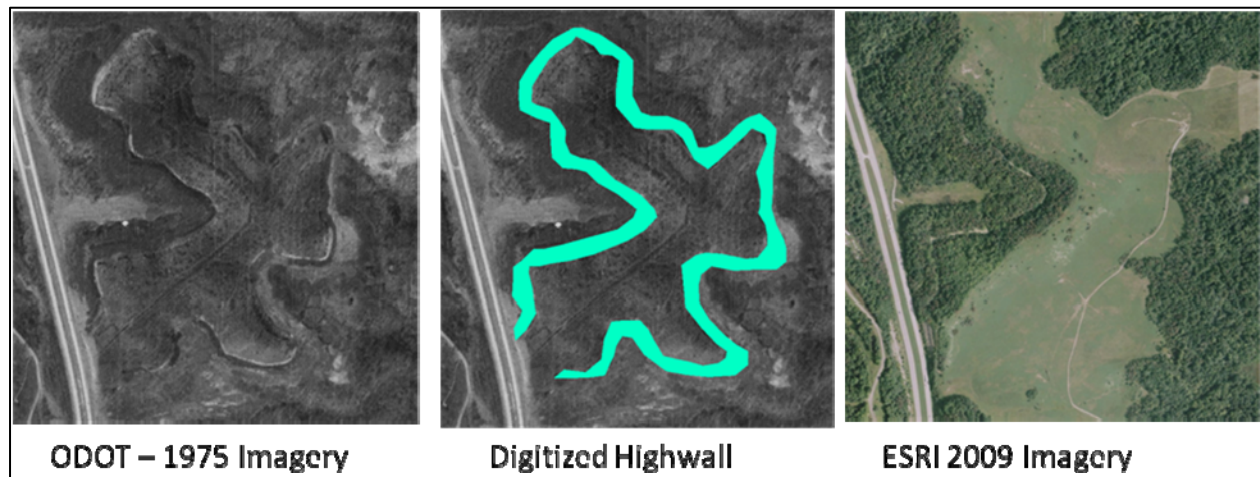


Figure 5: Dangerous Highwall GIS Digitization Process

Because modern laws took effect starting in 1973 with the implementation of Ohio B Mine Law, and because no B permit reclamation occurred within the Duck Creek Watershed between the years 1973 and 1975, it can be ascertained that the abandoned mine features present in 1975 constitute the entirety of possible re-mining sites.

#### *Area Analysis*

Prior to 1975, 2270 acres of abandoned surface mine lands existed within the Duck Creek Watershed. Since 1975, 567 acres have been reclaimed, with 380 reclaimed by re-mining. The remaining 187 acres were reclaimed through the use of federal AML project money. 1020 acres remains completely unreclaimed, and the remaining acreage is only partially reclaimed (usually due to A permit spoil regrading and tree regrowth).

345 total highwall features were digitized, often with more than one feature composing a mine site.

### *Highwall Length Analysis*

The elimination of abandoned highwall length is another benefit of reining. By 1975, there were 239 miles of abandoned highwall present in the Duck Creek Watershed. Since 1975, 55 miles of highwall have been eliminated due to reining. 105 miles of dangerous highwalls remain to be eliminated in Duck Creek.

### **GIS Water Quality Analysis**

Geographic Information Systems allows for this study to achieve a complete centralization of relevant data as we continue to evaluate water quality and physical changes in the Duck Creek Watershed. Within ArcGIS, many complex analysis tools are available with which to analyze changes in water quality at small and large scales. For Duck Creek, several feature classes have been developed in which water quality testing locations have been digitized and supplied with relevant data. Parameters include total acidity, total alkalinity, pH, manganese, iron, sulfates, and specific conductance. In ArcCatalog, a supplemental software package designed by ESRI, new feature classes can be created and supplied with field and feature data. Once the framework has been created in ArcCatalog, layers can be imported to the ArcGIS table of contents for viewing and analysis operations within ArcMap.

### *Pre 1973 Water Quality Analysis*

The Land Reborn study provided valuable pollution loading data for Duck Creek, and the data they recovered serves as a baseline for our mine site pollution analysis.<sup>6</sup>

Table 2: Duck Creek Acid Loadings – 1973<sup>6</sup>

Duck Creek Loadings (1973)	West Fork of Duck Creek	East and Middle Forks	Combined Loadings
Acid (lbs/day)	7660	30010	37670

Baseline pollution loads for the entire Duck Creek system must be compared to current pollution loads taken at the same locations and time of the year for accuracy. Comprehensive data is difficult to acquire in the watershed, especially data that correlates monitoring sites over time to make comparisons and statistical analysis. That being said, broad improvements in biological indicators have been demonstrated by the Ohio EPA's TMDL study of Duck Creek.<sup>9</sup> Furthermore, when one scales down the

analysis to the mine site level, comparisons can be made between pre and post mining water quality monitoring data required of operators by state permitting agencies.

*Pre and Post Mining Water Quality Analysis*

Permit number D-0706 is an appropriate case study with which to demonstrate this technique. Looking at the parameters of pH and acidity, 3 out of 4 testing sites in D-0706 show improvements in water quality when compared with pre-mining data measure during high stream flow in winter and spring.<sup>8</sup> (see table below)

Table 3: D-0706 Water Quality Comparison

Permit D-0706	Discharge Points					
	U-6		DS-2		D-29	
Remining	Pre	Post	Pre	Post	Pre	Post
Date	3/11/89	3/23/06	3/11/89	3/23/06	3/11/89	3/23/06
Ph	5.5	7.7	5.1	7.8	4.2	7.1
Acidity (mg/L CaCO3)	158	8.2	52	4.1	153	5.4

Pre-mining data from remined sites is useful for comparison with post mining data even within a smaller time range. Pre-mining data demonstrates the pre-existing water quality from the sites abandoned prior to the enactment of SMCRA and modern OH strip mine laws, and in some ways is a snapshot of what mine conditions were like in pre-law times. Several pre and post mining WQ datasets have been retrieved from remining permits thanks to the help of the Ohio Department of Natural Resource, B&N Coal, and the Ohio State Historic Preservation Office. Rahall modified water quality sampling usually takes place in 1 month intervals continuously for 12 months.<sup>3</sup> Non Rahall remining permits only require seasonal sampling approximately 4 times per year. Preliminary investigations of water quality pre and post mining show marked improvements post remining.

## REMINING BEST MANAGEMENT PRACTICES

Because mine sites abandoned prior to modern mine legislation are severely degraded, permitting agencies (ODNR, OEPA) have relaxed regulations on remining reclamation. Non numeric permits are issued in an effort to allow operators to reclaim sites based on the fulfillment of a series of best management practices.<sup>2</sup> Evaluation of BMP fulfillment is difficult, but a number of indicators can be used by inspectors and regulators to determine whether full reclamation has been achieved. The following criteria are commonly evaluated when determining the success or failure of the implementation of BMPs:

Regrading is required to control runoff from precipitation and other surface waters. Regrading also implies a return to the approximate original contour of land prior to mining and the restoration of pre mining drainage conditions.<sup>2</sup> Diversion ditches should also be installed to reroute runoff away from disturbed areas. Caps and seals should be used to protect the watershed from possible runoff associated with fill materials or coal combustion byproducts.<sup>2</sup> Best Management Practices require that revegetation be implemented on the surface of the mine site to allow native species to recover and to create stability on the slopes to prevent erosion and restore hydrologic balance.<sup>2</sup> When BMPs are implemented successfully, remining sites often experience an ecological lift.

## COAL COMBUSTION BYPRODUCTS

Coal Combustion By-Products such as FGD, Fixated FGD, FGD Gypsum, and fly ash are the result of emissions control systems installed in coal fired power plants. These control systems involve the use of “scrubbers” that remove sulfur and oxides from the plants flue gas stream.<sup>7</sup> These materials are used frequently in wallboard, reclamation, agricultural fertilizer, and cement production.<sup>7</sup> The use of CCPs in reclaiming mine sites, and specifically remining sites has shown itself to be an efficient and cost effective process.

### **Coal Combustion Byproducts in Remining**

Remining often takes place on sites located in close proximity to abandoned underground mines or adjacent to acid mine drainage discharge locations in the area. Coal Combustion By-Products such as Flue Gas Desulfurization By-Products are useful materials for creating seals with which to mitigate and reduce the flow of acid mine drainage through these discharge points following the completion of reclamation.

### **Broken Aro Demonstration Site**

The Broken Aro Mine site was a remining operation initiated 7 miles west of Coshocton, Ohio.<sup>10</sup> The operation sought to extract remaining economically viable coal reserves

while simultaneously mitigating the potential damage from acidic water located in underground mine operations begun circa 1910. Project researchers had the following to say about the placement of the FGD seal:

“Installation of the FGD seal began concurrent with the continued remining effort in June 1997. A series of open pits were excavated to recover remaining coal in the remining operation. The construction of the seal started adjacent to the exposed highwall with the excavation of a keyway trench which was five feet wide and one foot deep in the pit floor. The FGD material was delivered to the site as needed with a moisture content of about 75%. It must be placed and compacted within ten days of production to achieve optimum performance.”<sup>11</sup>

Further analysis of the effectiveness of the FGD seal at the Broken Aro site indicate that pollution loads discharged into the nearby stream have decreased by 97.5%.<sup>11</sup> The use of CCP fills in the reclamation of remining sites increases the cost effectiveness of an already efficient practice. Federal AML reclamation of abandoned mine lands has been shown to cost between \$8K and \$11K dollars an acre. If previously mined and unreclaimed mined lands in the Duck Creek Watershed had been reclaimed using AML funds, a total cost of between \$3.04M and \$4.180M could have been incurred by the state.<sup>8</sup> Not only will taxpayers be able to save money used for AML reclamation projects, but the use of CCP fills allows the coal operators to save on reclamation costs as well.

## REMINING PERMITTING OPTIONS

Coal operators have a diversity of options when it comes to applying for remining permits. In 1987, the Rahall Amendment to the U.S. Clean Water Act allowed for a recalibration of water quality requirements following the reclamation of remined sites.<sup>3</sup> This requires a modification to the baseline requirements by monitoring water quality for 12 months prior to mining to determine these new standards.<sup>3</sup> These modified effluent permits allow operators to proceed with mining without having to worry about being held responsible for previously degraded mine site conditions.

The Rahall amendment also paved the way for the implementation of non-numeric permits which base the release of bond on the fulfillment of certain Best Management Practices rather than an adherence to water quality benchmarks for reclamation. These permits may be issued when the pre-monitoring of abandoned mine discharge is difficult to accomplish due to the infeasibility of baseline assessment. “(e.g., the discharge exists as diffuse ground water flow, is inaccessible, or too large).”<sup>3</sup> The operator is required to demonstrate a clear “ecological lift” to the area, but this is usually evaluated in terms of water quality parameters and aquatic life indicators.

The Nationwide 49 Permit developed by the U.S. Army Corp of Engineers enables operators to remine abandoned mine lands as long as they can “demonstrate to the Corps that the overall project, including the reclamation activity and any new mining, will

result in a net increase in aquatic resource functions.”<sup>12</sup> A requirement exists such that operators cannot pursue a re-mining initiative if the area designated for mining includes over 40% virgin area.<sup>12</sup> That is to say that the majority of a NWP 49 permit must take place on previously mined lands. The reasoning behind this requirement is unclear. The “60%” rule greatly reduces the viability of re-mining when one considers that the smaller amounts of remaining coal reserves would be far more attractive to operators if they could be supplemented with larger areas of un-mined lands.<sup>12</sup>

Re-mining could be facilitated through Rahall non-numeric permits if the BMPs used to determine an increase in “ecological lift” could include eliminating dangerous highwalls, pits and spoil piles, restoring the area to original contour, or using reforestation to re-vegetate soil as opposed to simply grass cover.

## CONCLUSIONS

Re-mining in the Duck Creek Watershed has been effective as a tool to minimize environmental risks to local communities, protect local people from dangerous landforms, and spare the expense of utilizing federal funds for the reclamation of abandoned mine sites. GIS analysis shows that the length and area of abandoned mine highwalls and surface mines has decreased substantially due to re-mining over the last 35 years; however, much work is left to be done. Preliminary results indicate that water quality is improving as a result of re-mining as well.

Regulators and permitting agencies should re-evaluate the performance of re-mining as a technique for extracting economically viable coal reserves without disturbing virgin lands. They should perform this re-evaluation with the knowledge that re-mining has been demonstrated in multiple studies to have affected positive results on the ecological conditions of the Duck Creek Watershed and other watersheds throughout the Appalachian coal bearing region. Further analysis is needed to demonstrate the effectiveness of re-mining statewide, and discussions with all stakeholders must take place to facilitate the continuing dialogue over ways in which to provide incentives for operators to re-mine and improve the permitting process.

## ACKNOWLEDGMENTS

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