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# Identification of Mined Areas that may Contribute to Water Quality Degradation at Hobet Coal Mine, West Virginia

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# Identification of Mined Areas That May Contribute to Water Quality Degradation at Hobet Coal Mine, West Virginia

Brian P. Murphy[1]*

**ABSTRACT**—Operational from 1974–2015, the Hobet Coal Mine is one of the largest surface coal mines in the United States. Mining has impacted nearly every aspect of the geography of this region, especially the streams and rivers that are now contaminated with heavy metals, including selenium and iron. Using an erosion model, I identified specific regions that may be subject to high erosion risk in the Rich Hollow basin of the Hobet Coal Mine in West Virginia. This basin is a 444-acre watershed located on the eastern side of the mining complex, and tests positive for high amounts of iron. Data on stream contamination were correlated with the sub-basins that drain into the contaminated regions of the rivers and stream. The erosion model allowed for the identification of areas of particular basins that may have a higher chance of contributing heavy metal contaminants. While full remediation will not be possible, geospatial analysis can be utilized to develop strategies that can assist in the mitigation of some of the worst long-term effects of this type of mining.

**KEYWORDS**—*GIS, coal, erosion, RUSLE, iron, Hobet Mine, mountaintop removal, valley fill, West Virginia, overland flow*

**INTRODUCTION**—The Hobet Coal Mine in West Virginia was an active mining site for 41 years and one of the largest surface coal mines in the United States (FIG 1). The impacts of this particular mine are especially pronounced because of the sheer scale of alteration to the landscape caused by mountaintop removal (MTR) to retrieve the coal and valley fill (VF) mining techniques to dispose of the mining debris. In order to reach the coal located in shallow seams below these Central Appalachian Mountain peaks, up to 650 vertical feet of earth was demolished (Bernhardt and Palmer 2011). Explosives and massive machines were used, such as the 20-story tall dragline excavator, which can weigh up to eight million pounds and remove up to 110 cubic yards of earth with one scoop of its bucket (Fox 1999). The earth that did not contain coal was packed into the adjacent valleys, creating valley fills up to one mile long and 1000 feet wide (Hendryx and Holland 2016). What remains in the wake of this coal extraction is a scarred landscape consisting of artificially flattened plateaus devoid of the forests that once covered the land.

This mining has impacted nearly every aspect of the geography of the region. The soil has been compacted from heavy machinery, reducing permeability and increasing the overland flow of water (Griffith et. al 2012). Compacted soils have contributed to high mortality rates of native hardwood trees that are planted in an attempt to remediate the area. The hydrologic system of the mined area is radically altered, especially by the creation of VFs. In particular, the creation of VFs buries the headwaters of the watershed, influencing downstream biotic and chemical conditions. These streams are critical for transporting tree litter downstream, which drives the aquatic food web (Bernhardt and Palmer 2011). Many toxic chemicals

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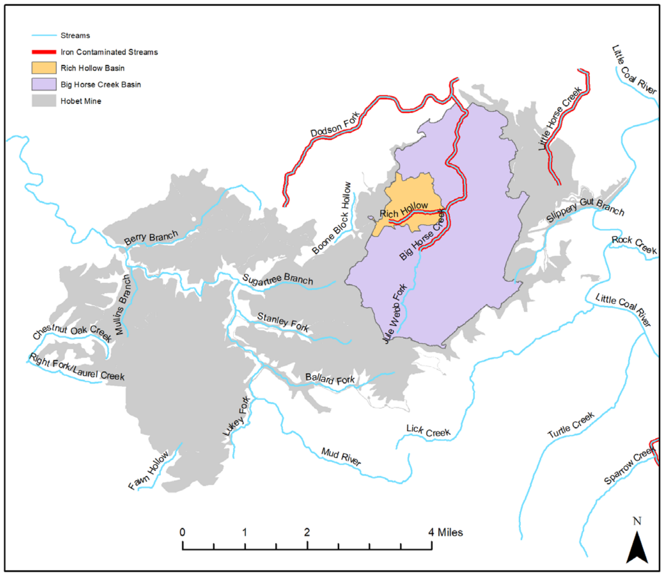

**FIGURE 1.** Location of the Rich Hollow basin in relation to Big Horse Creek basin. These basins are comprised of areas that were mined in the 1990s.

frequently found alongside coal are released by the mining. Due to oxidation in the presence of water and air, some minerals become new compounds that have higher toxicity. These compounds accumulate in the water and in living things ("bioaccumulate") in the food web where they can cause population collapses of native fish species (Arnold 2014). Some compounds such as pyrite oxidize to generate sulfuric acid and iron hydroxides that drastically lower the pH of the water, sometimes below the threshold of what aquatic communities can withstand. Acids also lead to rapid weathering of rocks and soil which contributes to additional metals into the water system. Another major heavy metal contaminant present at the Hobet mine is selenium, frequently found in and around coal streams. Although it is an essential macronutrient, selenium is very toxic in higher amounts and can bioaccumulate in the local community, resulting in many issues including developmental deformities in fish that can be lethal and potentially cause population collapse (Arnold 2014). These changes caused by mountaintop removal put the Central Appalachian Mountain ecoregion in peril. This biodiversity hotspot is considered to be the most biologically diverse freshwater ecosystem in North America and contains 10% of global salamander and freshwater mussel diversity (Bernhardt and Palmer 2011). Not only do these practices devastate the flora and fauna of the region, but they also inflict an enormous negative impact on humans living in the surrounding communities. In 1999, approximately 450,000 West Virginians (25% of the population) were without drinkable water due to contamination and disruption of aquifers and wells from mining (Fox 1999).

According to data obtained from the West Virginia Department of Environmental Protection, the streams and rivers surrounding the Hobet mine site are contaminated with a variety of heavy metals, most notably selenium and iron. Heavy metal contaminants are usually introduced into the water system by sediment particles (Hudson-Edwards 2003; Yenilmez et. al 2011). The main driver of sedimentation of water systems is overland flow, where water travels over the surface of the land, detaching soil particles from the parent material and transporting them into the stream (Liu et al. 2012). Models that factor in the highest possible rates of erosion can reveal areas that are contributing the most sediment into the stream system. Although areas at high risk for erosion cannot be assumed to be the only contributors of heavy metals into the stream system, they are a good place to conduct further analysis.

Annual rates of erosion can be determined by the use of models such as physical models, based on recreating exact mathematical conditions, and empirical models, based on observations and recorded data (Demirci and Karaburun 2011). Empirical models for estimating soil erosion have less stringent data requirements than physical models, making them more attractive for modeling sites that have less data. The Revised Universal Soil Loss Equation (RUSLE) method is the most commonly used soil erosion model in the world because it can provide estimates of the spatial distribution of soil loss. It does so by analyzing land use, conservation practices, soil type, precipitation, and topography to estimate the effects of precipitation and overland flow on erosion (Demirci and Karaburun 2011).

One area in particular that is a good place to start analyzing the Hobet Mine is the Rich Hollow basin, located in the northeast portion of the Hobet Mine Complex (FIG 1). This hollow is contaminated with high levels of iron, and feeds into the larger stream, Big Horse Creek, which also has tested positive for iron contamination (West Virginia Department of Environmental Protection 2018). This area was mined in the 1990s but the ground still continues to leach heavy metals into the stream system. The damage to the environment inflicted by the exploitive practice of MTR and VF is so dramatic that it is not reversible. By removing forest habitat, destroying the landscape, and polluting the streams, MTR is contributing to the defacing of Earth and to the devastation of local biological and human communities. The legacy of MTR will remain in these communities for generations and will affect the environment for millennia (Lechner et al. 2017). While full remediation will not be possible, geospatial analysis can be utilized to develop strategies that can assist in the mitigation of some of the worst long-term effects of this type of mining. Analyzing the amount of erosion can help identify areas that are more prone to contributing contaminants into the water system.

**METHODS**—*Hydrology*. This analysis was performed in ArcMap© 10.5.1. Several types of raster and vector data were utilized. The majority of these data was obtained from the West Virginia Department of Environmental Protection (WVDEP) data download, including LiDAR, polyline, and polygon data (West Virginia Department of Environmental Protection 2018). National Agriculture Imagery Program (NAIP) imagery from the United States Department of Agriculture (USDA) was used for land use classification that identified mined areas. The vector data obtained from WVDEP included polyline data identifying the stream network, as well as what types of heavy metals were contaminating each stream, and polygon data of valley fill locations and areas permitted for mining. First, a digital elevation model (DEM) was created from a LiDAR point cloud. This DEM was resampled from 0.5 meter resolution to 6 meter resolution in order to reduce the computational resources required. Next, a hydrologic model was created based on the DEM. The components of the hydrologic model included a DEM that has had its sinks filled, a flow accumulation raster, a flow direction raster, and a stream network raster as well as a stream polyline network. From the flow direction raster, sub-basins were identified. The streams that were found to contain dangerous levels of contaminants were corresponded with the higher resolution stream polyline output from the hydrologic model. From here the sections of the rivers that had been contaminated were corresponded with the basin that drains into it. This was done by creating a pour point at the pixel of the flow accumulation raster right before the stream in question drained into a higher order stream. A watershed function was run to identify all of the streams that flow into the pour point, creating a basin. The resulting raster was then converted to a polygon.

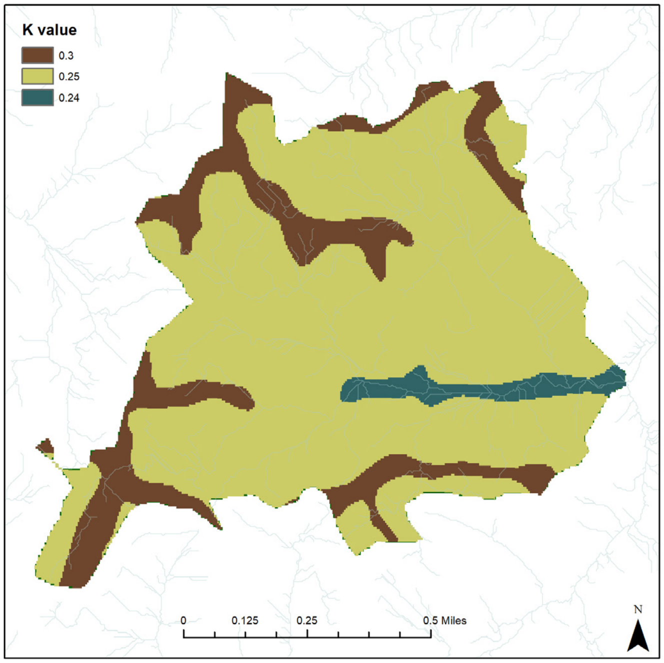

FIGURE 2. Soil erodibility factor (K) of the Rich Hollow basin. Larger values (brown) indicate areas that are comprised of soils that are more susceptible to erosion and small values (blue) indicate areas that are less susceptible to erosion

*Erosion*. Upon the identification of problematic basins, erosion modeling was performed in order to detect which subregions of the problematic basins were at greatest risk of erosion and were contributing contaminated soil to the stream system. The RUSLE model was used to estimate the spatial distribution of soil erosion at the Hobet Coal Mine. This equation is:

$$A = R \times K \times LS \times C \times P \tag{1}$$

$A$ is the estimated average annual soil loss in tons per acre per year; $R$ is the rainfall and runoff erosivity factor; $K$ is the soil erodibility factor; $L$ is the slope length factor; $S$ is the slope steepness factor; $C$ is the land cover and land management factor; $P$ is the support practice factor. Each factor was calculated using the raster calculator. To determine the $R$ (rainfall and runoff erosivity) factor for 2011, when the LiDAR measurements used to create the DEM were taken, the EPA's Rainfall Erosivity Factor Calculator for Small Construction Sites was used (EPA 2018). The $K$ (soil erodibility) factor was determined based on

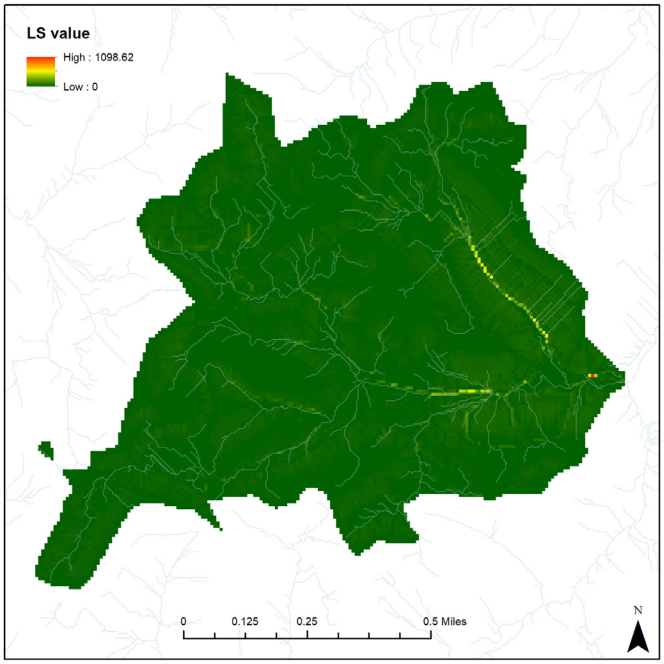

FIGURE 3. The product of slope length (*L*) and slope steepness (*S*) factor values of the Rich Hollow Basin. Larger values (yellow and red) indicate terrain that is more susceptible to erosion.

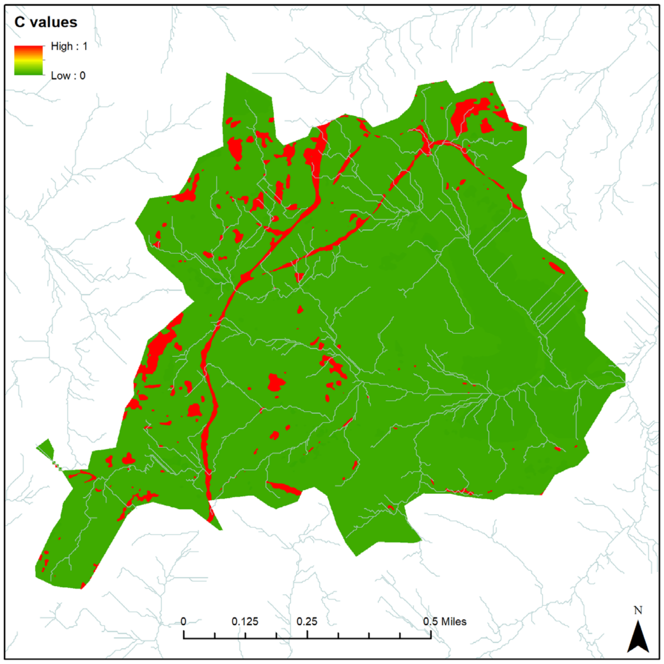

FIGURE 4. The land cover (*C*) factor of the Rich Hollow basin. Aerial imagery was classified into forest, grassland, and exposed soil. High values (red) indicate exposed soil that is significantly more susceptible to erosion.

literature values and published soil surveys including the USDA's Web Soil Survey (USDA 2018; FIG 2). The slope length (*L*) and slope steepness (*S*) factors were calculated using the formula:

$$\text{LS} = \text{Power(“richhollow\_flowaccumulation.tif”*CellSize}/22.1,\ 0.4)\ *\ \text{Power}\ (\text{Sin(“richhollow\_slope.tif”}*0.01745)/0.09,\ 1.4)*1.4 \tag{2}$$

Flow accumulation is the raster layer calculated in the hydrology component of this paper, cell size is the spatial resolution of the DEM, and the slope is a raster image calculated by running the slope tool on the DEM (FIG 3). The *C* (land cover and land management) factor was determined by running a supervised classification to identify land cover, with a particular focus on identifying exposed soil, grassland, and forest (FIG 4). These classes were reclassified according to literature values (Kim 2014). Finally, the *P* factor (support practice) was estimated to be one because there were no agricultural erosion suppression practices being used at this site (Demirci and Karaburun 2011).

The resulting raster images for each factor were multiplied together using the raster calculator, resulting in a raster image that depicts the spatial distribution of erosion potential in the units of tons of soil lost per hectare per year. This raster was then classified based on a previous study using the RUSLE method conducted by Demirci and Karaburun (2012) on the severity of erosion potential with 1 t/ha/yr classified as low erosion and 10 t/ha/yr classified as severe erosion. The low erosion rate is classified as 1 t/ha/yr because any greater erosion rate would take 50–100 yr to reverse (Kouli et. al 2008). These results were then depicted on a map, with a spatial resolution of 6 m, which shows areas of high erosion potential with the stream layers calculated from the hydrological model. Zonal statistics were then calculated to find the mean erosion rate of the total area as well as the valley fills.

**RESULTS**—The RUSLE model was able to generate

TABLE 1. Comparison of erosion rates on valley fills versus the entire area

| Site | Erosion Rate (t/ha/yr) | Area (acres) |
|---|---|---|
| Total Rich Hollow Basin | 7.48 ± 67.28 | 444.29 |
| Just Valley Fills | 5.22 ± 56.17 | 241.23 |

a raster image of erosion potential in the Rich Hollow basin (FIG 5). The areas that showed the highest susceptibility to erosion were the areas that were exposed soil. Fortunately, a large portion of this area had a land cover class other than exposed soil, greatly reducing its erosion potential. The average rate of erosion over this entire watershed was 7.48 t/ha/yr, which is considered high. The average rate of erosion for just the valley filled areas is much less with a rate of 5.22 t/ac/yr, a moderate erosion rate. A t-test was used to compare the erosion rates of the entire watershed and just the valley filled areas, and the resulting *P* value of 0.657 indicated that there was not a statistically significant difference between erosion potential of these areas. There were pockets of high erosion in certain areas that had a large influence on the average erosion rate. These pockets were especially prominent at the headwaters of the hollow, where the primary land class was exposed soil. Within these pockets, there were some pixels that had extremely high values, in some cases 1000 t/ac/yr and above. These are the sites that are most likely to be contributing heavy metal contaminants to Rich Hollow.

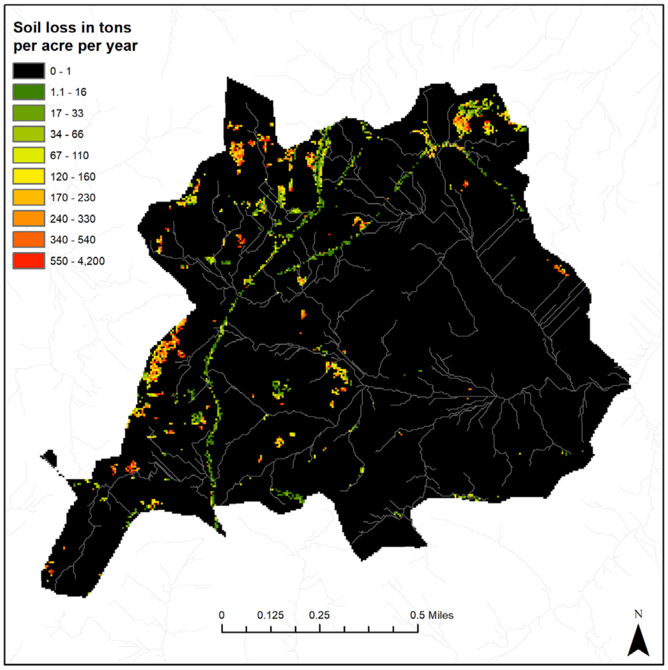

FIGURE 5. Soil loss in the Rich Hollow basin represented in t/ac/yr as calculated using the RUSLE method. Low values (black) represent areas of low erosion potential, while areas that are above 10 t/ha/yr (green) represent areas of high erosion potential. The highest values (orange and red) represent areas of extreme erosion potential.

**DISCUSSION**—This analysis was able to identify areas that are likely contributing to heavy metal contamination of the stream. This methodology is not a replacement for on-site measurements and analysis, but rather a tool for environmental restorationists to improve their efficiency and effectiveness. One of the most notable findings of this research was that the majority of the erosion at this site is not occurring on the valley fills. The biggest contributions of erosion are from small pockets of bare earth located at the headwaters of the stream. Even though these pockets are some of the furthest regions from where Rich Hollow drains into Big Horse Creek, they have the highest erosion potential.

These results could be supported by future research on site. Further sampling could be conducted to find the concentrations of contaminants on a finer hydrologic scale. By incorporating contaminant concentrations into a hydrologic model, the amounts of contaminant contribution from each erosion prone area can be calculated. This could be combined with the results of this study to more accurately locate point sources where the contaminants are originating. Further hydrologic modeling with network analysis could be used to assess the cumulative impact of multiple contaminated streams.

One potential issue encountered during the analysis was that the data were not all obtained at the same time. Because this mine site was changing so frequently from its inception in 1974 to 2015 when it was shut down, data obtained only a few years apart may have significant discrepancies. The area that would be most prone to this issue would be the western portion of the mine which experienced the most topographic change towards the end of the mine's lifespan. This may not have been a very significant issue within the Rich Hollow watershed because it was mined in the late 1980s.

In addition, this study did not take into account wind erosion because it has less of a direct impact on sedimentation delivery than overland flow. It would be valuable to account for this in future research because wind erosion contributes to the spread of dust. This has a direct impact on the communities surrounding the site, as well as any biological or human communities downwind.

**CONCLUSION**—By using the RUSLE erosion prediction method alongside hydrological analysis, scientists can estimate regions that are disproportionately adding heavy metal contaminants to the stream system in the Hobet Coal Mine in southern West Virginia. The primary factor that contributes to erosion at the Hobet mine complex is bare earth which is either exposed because of mining or from roads. Knowing where areas of high erosion risk are located can help ecological restorationists identify problem areas of the mining site that can be targeted for further study or remediation. This can also help them determine the appropriate restoration techniques for preventing polluted water from entering the stream system. Understanding the connections between different biotic and abiotic factors with GIS models can help humans minimize the long-term impacts of extremely destructive practices such as mountaintop removal coal mining.

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