DRAFT
[Do not cite or distribute]

MOUNTAINTOP REMOVAL MINING/VALLEY FILL ENVIRONMENTAL IMPACT STATEMENT TECHNICAL STUDY

DRAFT PROJECT REPORT FOR TERRESTRIAL STUDIES

DECEMBER 2000

Terrestrial Plant (spring herbs, woody plants) Populations of Forested and Reclaimed Sites

Principal Investigator:
Steven N. Handel, PhD, Department of Ecology, Evolution, and Natural Resources, Rutgers, The State University of New Jersey

Primary Project Personnel:
Kate Burke, Graduate Program in Plant Ecology, Rutgers University
Jessica DiCicco, Field Technician, Ecology, Evolution, Nat'l Resources, Rutgers University
Amy E. K. Long, Field Researcher, Ecology, Evolution, Nat'l Resources, Rutgers University
Zachary T. Long, Graduate Program in Ecology, Evolution, Nat'l Resources, Rutgers University

Objectives:

The objective of this study was to determine the patterns of terrestrial vegetation on areas affected by mountaintop removal mining and valley fills in the southern Appalachian region, and watersheds closely adjacent to areas that have used this mining technique. Specifically, we wish to know the plant species present, the relative numbers and size of species present, and the pattern of vegetation along transects from toe of slope towards the top of slope or from forest to mined areas. These data will enable us to understand the potential for re-establishment of native vegetation, and the actual change of vegetation since closure of the sites. Together, this will assist in developing potential improvements in the habitat condition of post-mining land.

Importance of the objectives:

It is urgent to know the fate of the mined lands after closure, to determine the potential for re-establishment of surrounding native vegetation, and to see if a different flora becomes established. The soils, seed pool, and local conditions on mined sites may be quite different from the original conditions, and we must understand if mined areas will develop differently from the forested terrestrial communities surrounding the mined sites. These data are also needed to assess the quality of the habitat for animals of the region. If current closure methods are creating different habitat types, this must be known precisely, to be the foundation for regulatory action.

Methods:

Tree and shrub studies - site selection:

In order to assess the progress of invasion of woody species onto disturbed mine lands, sites were selected which had a remnant forest adjacent to the mined area. These areas were considered most relevant because they included a seed source for the mined area, and therefore offered an opportunity for woody species to invade the more open disturbed land. Study of mined lands adjacent to mature forests, of course, maximizes the potential for invasion of species, and potentially weighs the data sets towards higher invasion rates. However, it is necessary to see invasion, and the over-sampling of edge areas gives the investigator a higher potential for determining invasion rates.

Sites across the mining region of southern West Virginia were selected, to represent a wide variety of ages, conditions, and treatments. We visited sites recommended by EPA, WVDEP, FWS, and mining officials and engineers from the mines studied. Knowing that we wished to record re-establishment of woody vegetation on mined lands, mining officials derected us towards the richest sites they knew were available, and our policy was to visit every site recommended. At each specific locale, we picked transect locations typical in density and degree of vegetative cover for this summary. The total number of forested site transects surveyed and reported is 25 and the total number of mined land transects is 30. Ten different mine properties were surveyed, with ages ranging from six to twenty-four years since beginning of reclamation. Emphasis was on surveys of sites that were older, but closed after the 1977 surface mining law (SMCRA) was put in effect. Changes in protocols necessitated bythat law caused important differences in reclamation practise (Vories and Throgmorton, 1999). A complete list of study sites is in the Appendix (Table 1).

Tree and shrub studies – data collection:

First, twelve transects were run, each on a continuous line from types of mined land (i.e. valley fill, mountain-top removal area, backfill, or contour mine) into an adjacent mature remnant forest, apparently unaffected by mining activity. (Many of these forested sites once were logged, and showed vestiges of former rough logging roads. Consequently, these forests, themselves, have been modfied by human activity, and may be expectd to be lower in biodiversity than historic stands [Martin, etal. 1993, chaps. 5, 8]. However, all forested areas contained large, diverse canopy trees with well-developed stands, and unexcavated soil.) The transect line was continuous from mined area to the adjacent remnant forest.

There were an additional 43 transects studied where it was not possible to run continuous transects, as above. In these cases, the forest remnant transect was run perpendicular or adjacent to the mined area transect, as shown in Diagram 1. On valley fill areas, transects were arrayed from top of slope to toe of slope, for the length of the fill. Because of the typically triangular geometry of these fills, fill areas at the toe of slope were usually much closer to surrounding forests. Also, some valley fills have plantings on flat terraces, usually black locust.

Data were collected during the year 2000 growing season only. The presence of woody plants, even small ones, on these sites can represent the reproductive performance of many years. The location of the boundary or edge between forested and mining activity land was recorded for each transect, and is the "0" point on data sets. The point-quarter sampling method was used to survey the woody plant community (Barbour, Burk, et al. 1999). This technique was used as it allowed the investigating team to cover the most ground, the most sites, and collect the most data points in the time frame given. There is a potential to underestimate rare species with this technique, as a census of all plants in an area is not done. However, a species effort curve performed in this lab on the data indicates that minimal, if any, rare species were missed given our large data set that covers thousands of individual plant records. Consequently, the field sampling technique is representative of the woody species on site.

At each sampling point, located at 20 meter intervals along the transect line, the area was divided into four quadrats. In each quadrat the distance from the sample point on the transect line to the nearest woody species was measured and recorded for three different size classes, for a potential of twelve individuals per transect point. The size classes were defined as 0-1 inch ("small"), 1-3 inch ("medium"), and more than 3-inch ("large") diameter, as measured at the base of each stem. For each of these stems the nearest neighbor's distance and species identification were recorded, as well as the distance to the nearest conspecific (individual of the same species). Trees that were obviously part of an implemented planting program were not included in the counts, as these did not naturally arrive on these sites, and are not part of an invasion process. Any offspring produced by planted individuals were included in the data, however. Data were entered on computer databases for further study. Leaves and stems of questionable plants were collected and keyed out using herbarium specimens. Occasionally, specimens could not be keyed to species, because they were barren of flowers or fruits; it was impossible, given the rapid time frame of the study, to return to each site at other times of the year 2000 season to search for reproductive specimens.

Tree and shrub studies –data analysis:

The main objective of this study was to determine the success of woody species in invading the disturbed mining areas. The data were examined in several ways. Transects were categorized as one of six types: continuous forest; forest remnant; valley fill; mountain-top removal area; backfill; or contour mine. Data were displayed within each of these categories, by the three size groupings of plants: small; medium; and large. The density of woody plants of the different size classes was also determined. These densities can be compared in order to evaluate the progress of the woody invasion. Species lists of continuous and mined areas were developed, and comparisons between native forests and mined lands performed. Plant diversity was also estimated using the Shannon-Weiner statistic, which includes measures of number of species and their relative abundances. For example, stands with the same number of plants and the same number of species can be distinguished if one stand has these species is more or less equal proportions; a more diverse stand with this statistic would have these species in more equal numbers.

Herb studies – site selection:

Nineteen forested sites, considered to be either intact forest (11) or engineered forest (8), were chosen to evaluate the herb community, adjacent to the locations where the EPA aquatic biology team was collecting data for this EIS. Sections of watersheds that had been mined (the engineered forest) as well as areas that were distant from mining activity (the intact forest) were selected. Sites are listed in the Appendix (Table 2). This protocol allows comparison and correlation of herb data with the aquatic study, for a more complete understanding of these sites. No sites on the continuous transects used for the tree survey were used for these forest herb data, because these are plants of shady habitats, that were by-and-large missing from these mined sites.

Herb studies – data collection:

The study team visited all sites during April - May, 2000, to map the study sites and sample the herbaceous vegetation. Early season sampling of the herb flora was necessary, as many spring herbs often complete their life history before the summer months, then persist underground until the following year (Schemske, et al., 1978; Bierzychudek, 1982). Transects were sampled every 10 meters, starting at the base of the slope, up hill for an additional 50 meters. It was determined by the investigating team that the herb cover significantly diminished around 40 or 50 meters from base of slope, and data from a broader geographical range could be collected if this was a decided end point. At each sample location, a 5x1m plot across the face of the slope was censused for all herbs. Species identity and stem count for each species were recorded for each 5x1 plot. Samples of species were collected for herbarium records and identification verification.

Herb studies – data analysis:

Data were summarized to determine relative distribution and number of species along the slope, on undisturbed forest slopes compared to forest slopes adjacent to disturbed areas (i.e. mines and wide road cuts). These data were entered in a database for statistical analyses to determine vegetation distribution patterns. Shannon-Weiner Index of Diversity was performed as well as calculations to determine the mean number of stems counted and the mean number of species present in both forest types.

Soil studies:

Nineteen soil samples were collected, nine remnant forest samples and ten mined soil samples. Two points along the point-quarter transect line were randomly selected, one in the mined area and one in the paired remnant forest. The contour mine transects (7 of 30 mine sites, as well as 4 remnant forests that were paired with the contour mines) were omitted because soil treatment was quite different and these data are atypical of the remaining sites of prime interest. At each of these points the area was divided into a grid ten by ten meters, numbered 0 through 9 with each number one meter apart from the next along both axes. Random numbers were used to determine grid location at which a sample of approximately 8 $inches^3$ at the soil surface was taken. Five samples were collected at each site, placed into plastic bags, and brought back to the Rutgers' lab for dehydrogenase activity analysis and for further mechanical analysis by the Rutgers' Soil Testing Laboratory.

DHA analysis is an assessment of the microbial activity in the soil. When triphenyl tetrazolium chloride (TTC) is added to soil, it reacts with dehydrogenases (enzymes) that have been produced by soil microbes. This reaction creates formazan, which is red in color. The concentration of formazan can then be measured using a spectrophotometer. The amount of formazan produced indicates the amount of dehydrogenase enzymes present in the soil. Two ml of 1% TTC and 0.35ml $CaCO_3$ buffer were added to 2.00g soil samples. The samples were mixed, capped, and incubated at 37° for 24 hours. Three replicates of each soil sample were run. After incubation, the contents of each test tube were extracted with 50ml methanol and centrifuged. The supernatant was collected and absorbance was measured in a spectrophotometer (set to 485nm). Results were compared to TPF (triphenyl formazan) standards. By weighing out a sample, drying it at 65˚C for 24 hours, and reweighing it, the moisture content of the samples was also determined. Dehydrogenase activity was calculated using the following equation (Harris and Steer, 1997):

$$\text{Formazan formation } (\mu g/g/24h) = \frac{29.54 \times \text{absorbance} \times \text{volume}}{\text{Dry weight of sample}}$$

Soil samples brought back to Rutgers' Soil Testing Laboratory were tested for pH, salt content, macro- and micronutrient content, gravel content, inorganic nitrogen, soil organic matter, and mechanical analysis. The elements chosen for analysis are those considered critical for plant health, and are also amendable aspects of soil specifications in the reclamation of mined lands.

To assess soil depth, a hole was dug at the center point of the designated grid. Using a standard shovel, soil was removed until digging was no longer exposing soil (i.e. hitting rock too large or solid to dig through) or a depth of 60 centimeters was reached. All depths were recorded and reported.

Results:

Tree and shrub studies:

Presence of trees and shrubs on the study sites:

The 99 species listed in Table 3 were found on the 25 forest transects and 30 mined transects. Table 4 shows the differences in species composition across these two types, ranked from most to least commonly present. The species did not have to be abundant at a particular site to be included, merely present on the site (i.e. whether the species has one or one thousand individuals, it is recorded as "present"). These numbers do not include data that were collected from contour mine sites or their associated remnant forests, which have been treated and reported separately, so the sample size here is 23 forest transects and 25 mined transects. Most of the species found in the majority of forest transects were found on only a few mine transects, with the exception of *Acer rubrum*, *Liriodendron tulipifera*, and *Rubus* spp., which are regularly found as small plants in disturbed areas. There are twenty species occurring on the mined lands that are not found in the forested lands and thirty forest species not found on the mined lands. Of the twenty unique mine species, many of these are typical early successional species *(Acer rubrum, Liriodendron tulipifera, Rubus sp.)* and many others (pines and black locust) are offspring of the trees planted as part of reclamation efforts. Overall, there are ten more species found in the forest than on the reclaimed mined lands.

These data from Table 4 can also be summarized across sites by richness, defined as the number of species found, regardless of abundance. Figure 1 shows that the forested category always contains more species than the sites in the mined category, when listed from most to least rich site. (I.e., the woody species are not growing in as much variety on the mined sites as in the forests.) In other words, the forests have a higher species richness and more biodiversity than the mine sites (Figure1 and Figure 11).

Species-presence data can also be arrayed by individual species, in addition to the site values shown in Table 4 and Figure 1. Tables 2a and 2b illustrate the number and percent of transects studied where each species in the data set was found. Forested sites have a higher percent of transects represented for the large majority of species. These data show that woody species are more generally occurring across the sample universe, not just sequestered in a few unusually rich transects that happened to be included within individual site surveys.

There is special interest in the major tree species of the forest, as these are of possible commercial interest. Figures 3a and 3b display six of the most common hardwood tree species found, by absolute number and percent of all woody stems found (total of 4,140 stems in the data sets, including all size classes). These trees are always more abundant as a proportion of stems on the forested sites. Five of the six are more common by absolute number on the forested sites; only red maple has more individuals on the mined sites, as many seedlings of this species were present.

Woody species found at study sites can also be displayed by type of mining site (Table 5), to see more clearly if there are special determinants associated with species presence. Again, these numbers are based simply on being present at all, not abundance.

Remnant forests have the most species, and mountain top removal sites have the fewest, when grouped in this way. However, only four MTR sites were examined and twenty remnant forests were. If one examines the average number of species by site (see site table in appendix to see number of species per site), MTR's have 6.25 and remnant forests have 17.7 species on average. Table 5 also illustrates that some species (for example *Acer rubrum* and *Liriodendron tulipifera*) are more generalist (i.e. are found on all the site types). Others were found only on mined areas (*Lespedeza bicolor*) or only in forests (*Acer pensylvanicum, Lindera benzoin*).

The distribution of species can also be considered in terms of how abundant, or how frequently the species appeared on the site (Table 6). Most species found in great number in the forests are not found in similar abundance on the mined sites. At the same time, common woody species on the mined sites, typical of early successional stages, are not found as abundantly in the forests.

The forest community is comprised of a greater number of species. It is also a more diverse community than the mine land communities. More uncommon species occur in the forest and there is less dominance by a few common species. That is, the mine sites have a few dominant species making up more of their communities and fewer rare species present (Figures 4a and 4b). These data are the number of woody plants found during the point quarter sampling. The mine plot in Figure 4b is based on percentages, which allows a simpler comparison, as sampling effort was unequal between mine and forest lands. The mine species distribution starts quite low on the y-axis because there were many points, about 1600, where woody stems were not present at all (this very high point is not plotted on this graphic). An absence of any woody plants was rarely found on any of the forest sample points. Having more species that occur more evenly or frequently (i.e. not having a population dominated by only a few species) creates a more diverse environment. For many of the species found, the percent occurrence is high on forest land. Having all the species occur only once or twice, such as on the mine lands, and being dominated by only a few species, creates a less diverse community.

Distribution of trees and shrubs across the study transects:

To spatially study the process of invasion, data are displayed across the transects, where, on figures 5-9, "0" represents the "edge", the sharp boundary between forest and mining area. In these graphics, all alien species were removed from the data sets, as the interest in this study is the reappearance of the native West Virginia plant community. These data (in Figures 5-9) are from the twelve continuous transects described earlier (page 1). There are three MTR, three VF, three BF, and three CM, all with paired forest remnants. The following figures graph the mean stem densities per $25m^2$.

Figures 5a, 5b, and 5c illustrate the stem densities calculated for the small size class, medium size-class, and large size-class, for woody individuals on nine continuous mine and forest transects. A "continuous transect" is a location where only one line was run, going from mine land directly into the remnant forest. Figure 5a shows that the small individuals (1" and smaller diameter at base) are not regenerating on the mined lands as abundantly as they do in the forest. Figure 5b shows that survival of the medium size class individuals (1-3" diameter at base) is decreasing on the mined lands, compared to the small class' performance. (Figure 5c) Large individuals (3" diameter at base) are not present on the mining areas. There is little to no growth into this size class. This is not an unreasonable size class to reach given the age of these mines (range of 6 to 23 years old since reclamation).

The six most common forest tree species have the following age and size projections (under favorable soil conditions): *Acer rubrum* can reproduce as early as 4 years with size at first reproduction of 5-20cm (2-8") diameter at breast height (DBH). *Quercus rubra* is 25 years at first reproduction with size of 60-90cm (23.6-35.4") DBH. *Liriodendron tulipifera* is 15-20 years at first reproduction, DBH of 17-25cm (6.7-9.8"). *Acer saccharum* as early as 22 years, DBH equal to 20 (8")cm. *Fagus grandifolia* reaches substantial seed production at age 40 or with a DBH of 6cm (2.4"). *Magnolia acuminata* starts reproducing at age 30, optimum at age 50, with DBH unreported (Burns and Honkala, 1990, for these data). These age and size estimates are given at breast height, roughly 4' high, for the average adult. The size classes used in this report were determined at the base of the plants, as most of the individuals were not taller than two feet, so tend to overestimate plant performance when compared to the USDA correlations. The reclamation age of many of the mine sites is nearing, or has reached, the reproductive age for several of these trees, but this study's data indicates that the trees have not approached the correlated sizes.

The woody data from mined transects can also be divided into the four mining area categories of interest: Mountain-top Removal, Valley Fill, Backfills, and Contour Mine. Figures 6a, 6b, and 6c illustrate the stem densities calculated for woody individuals in all three size-classes, on three Mountain-top Removal (MTR) sites and the paired remnant forest transects. Figure 6a shows that the small individuals (1" and smaller diameter at base) are not regenerating on the mine lands as they do in the forest. Of the three MTR's surveyed, one was six years old since reclamation and the other two were both 15 years since reclamation. It is expected to see small size-class individuals well before 15 years is reached. The medium individuals (1-3" diameter at base, Figure 6b) are not present on these mined lands, and there are only a few large individuals (3" diameter at base) present on the surveyed, reclaimed mine land (Figure 6c).

Figures 7a, 7b, and 7c illustrate the stem densities calculated for woody individuals in all three size-classes on three Valley Fill (VF) sites, that accompany MTR sites, and the paired remnant forest transects. The remnant forests of two of these transects were located above the fill (Colony Bay: Cazy fill; Hobet Mine: Bragg Fork fill) and the other was located at the bottom of the fill (Leckie Smokeless: Briery Knob). Due to the triangular geometry of Valley Fills (Diagram 1), which (a) allows closer proximity to forest edge, and (b) provides a moisture gradient created by the drainage ravines at the toe of the slope, there was in increase in stem densities with decreasing elevation in the Valley Fill sites. This apparently has increased the presence in this mining area of the small size-class plants. However, the data for the medium and large size classes shows that this trend is decreasing over time. Valley fills remain stressful sites for these seedlings, and slow growth or lack of survival could underlie these low data points. As these sites are ages 14, 17, and 19 years, a higher representation in all three sizes would be expected during successional change.

Figures 8a, 8b, and 8c illustrate the mean stem densities calculated for woody individuals in all three size-classes on three Backfill (BF) sites and the paired remnant forest transects. One Backfill is 12 and the other two are 14 years old since reclamation. Figure 8a shows that the small size-class individuals are regenerating along the forest edge as would be expected, but taper off rapidly beyond 60 meters and are not found further from the edge. An edge effect can also be observed in the medium size-class (Figure 8b) in the first 20 meters that quickly fades until there are no medium individuals found beyond that point in great number. Few large size-class individuals were found on the mined site (Figure 8c).

Figures 9a, 9b, and 9c illustrate the stem densities calculated for woody individuals in all three size-classes, on three Contour Mine (CM) sites and their three paired remnant forest transects. All three of these sites are 10 years since reclamation. The contour mines we visited are much shorter than the other types of mine lands and typically are less compacted upon completion than flat areas, because of less grading activity (Vories and Throgmorton, 1999). Bonferroni T tests ("proc glm" statistical test of SAS version 6.0) were run on the mean densities of the four mine types, by size class. The Contour Mines' plant densities in the small and medium size classes were significantly greater than all three other mine types (Figure 10). Because all four mine types included in this study had so few large individuals, there was no significant difference among any of the mine treatments.

Regeneration of the small size-class individuals on the CM illustrates the edge effect of a forest (Figure 9a). The CM trend of regeneration falls abruptly after 10 meters, and suggests that few woody stems would be present beyond 50 meters (the local limit of this site type). Figure 9b shows a pattern similar to Figure 9a, the smaller individuals are surviving into the next size class. No large individuals occurred within our sampling efforts on these CMs (Figure 9c). However, these sites are only 10 years since reclamation and not many tree species are expected in this size class from seed this quickly (see maturation information in text above).

Finally, one transect studied represents a unique site where it is possible to compare three types of land engineering, all at the same age, to determine what woody plants have naturally recruited into the site. This site was at Peerless Eagle Mine, and its age is estimated between 10 and 15 years. The top third is mountain-top removal, the middle third is a clear-cut forest remnant (apparently cut in preparation for the fill, but never filled to that height, and has since revegetated), and the bottom third is valley fill Figure 11a). Consequently, the soil in the clear-cut area was only minimally disturbed; soil was removed or covered in the other areas. Figure 11b illustrates the lack of plant recruitment into the two engineered areas. During the same time, the central clear-cut area has fully revegetated, probably due to stump sprouts and germination from the undisturbed seed bank (Figure 11a).

Additional perspectives on trees and shrubs:

The Shannon-Weiner Index (H) is a measurement of community diversity, a function of both species number and relative abundance commonly used in vegetation analysis (Barbour, et al., 1999). For small, medium and large plant size classes, the diversity index is significantly higher (paired t test, df = 8, p_{small} = 0.0191, p_{medium} = .0082, p_{large} = .0033) on the forested parts of the transects (Figure 12), indicating greater species diversity than on the mine lands.

Finally, figures 13a, 13b, and 13c compare mine age and average total plant density on each transect site. Data from all remnant forest transects are shown as a mean of values, with standard deviation. These are displayed across the x-axis to allow a visual comparison with the values from the mine lands. However, this does not represent in any way the actual age of the forested sites; this acts as an approximate asymptote to which developing forests in this region might attain. These figures illustrate that mine area age does not positively correlate with increasing stem density (linear regression, r2 = 1, 95% conf. interval). If the densities were increasing over time, we would see an increase in the slope of the regression line for the mines. However, for all three size classes there is no linear relationship, indicating no increase in number of individuals over time. The data for the forest were added to give a visual cue of where the average forest density is for each size class.

General Conclusions for Trees and Shrubs:

There is a lowering of tree and shrub species and an extremely low number of stems of woody plants on all but contour mine sites in this study compared to forests. The few native plants that do invade the mining areas are very close to the edge of the forest and are heavily concentrated in the smallest size class, less than 1 inch diameter at base. The absence of significant numbers of stems larger than even 1 inch suggests that these are very stressful sites and very slow growth or high death rates for small plants are typical conditions. These are very low invasion rates compared to many sites adjacent to mature forests that do not have mining as a land use. As has been noted in many recent studies (e.g. Vories and Throgmorton, 1999), the combination of poor substrate quality and interference by inappropriate grass cover restricts the ability of native communities to return to these extensive land areas. Stands that have regenerated on pre-SMCRA sites often have diverse, productive forests (Rodrique and Burger, 2000), but newer protocols challenge this level of stand development, as is illustrated by these data. Recently, a series of new State of West Virginia regulations have been passed to detail better procedures for re-establishing forest lands on AOC mine sites. These regulations include detailed requirements in soil, cover, and landscape requirements to begin getting productive habitats returning to the land. These new active regulations could be the starting point to address the poor stand development seen on the sites recorded in this study. However, full return of the rich biodiversity of the historical forests of the region would require more intervention than the addition of several dominant species, as is required in the new West Virginia regulations.

Herb studies:

Presence of herbs on the study sites:

The herb communities on the forested sites were generally dense and species-rich, as is typical of this region (Hinkle et al., 1993). Eighty-five herbaceous species have been identified (Table 7a), and more were found on site, which required flowering structures for complete species identification. The presence and composition of the forest herb stratum is critical for forest health, as these herbs maintain soil structure and nutrients, and offer habitat to many animal species.

Three of the nineteen transects were on valley fills, the rest in forests. Presence-absence only of the woodland herbs was recorded at these three sites, so these data are analyzed separately from the remaining data, which follow. Woodland herbs were not expected to be observed in open, sunny fields, as most of the herbs on Table 7a require the shade and moisture of the forest floor. The species that were recorded on the mine sites are on Table 7b.

Of the remaining the sixteen sites, eleven were in mature, intact forests. The remaining five sites were lands that were directly adjacent to mining activities, such as the mine itself, a railroad, or a busy vehicular (haul) road. Table 8 lists herbaceous species found on study sites, ranked by presence from most to least number of sites. The engineered forest sites are contrasted with the intact forest sites to determine the effects of mining activity on adjacent forest herbs. There might not be direct physical destruction of these adjacent forest remnants, but the disturbance of high activity levels (i.e. mining equipment, blasting, fumes and exhaust from train engines and hauling vehicles) as well as sun shafts cutting through to the forest floor from adjacent human-dominated areas surrounding a forest remnant may disrupt the forest community, starting with the herbaceous stratum. Seventeen fewer species are found on sites adjacent to engineered areas than on intact forest sites.

In analyzing species distribution on the slopes, intact sites have more species at any point than engineered sites (Figure 14a). this can be seen with a two-way analysis of variance (ANOVA) (proc GLM, SAS version 6.0) to test for the effects of treatment type, distance from toe of slope, and the interaction of treatment and distance on mean number of species. Significant results were found for treatment type and distance from toe of slope on the species mean (both had a p value = 0.0001), indicating that the number of species were effected by both the distance up the hill and the type of site. There was no significant interaction between environment and distance.

The herb stratum in intact sites also contained more stems in study areas than in engineered sites, along the entire slope (Figure 14b). A two-way ANOVA was performed, testing treatment and distance on mean number of herb stems (treatment p = 0.0016 and distance p = 0.125). Treatment type was found to be significant for number of plants found. There was no significant interaction found for distance from toe of slope on number of stems. There was no significant effect of treatment and distance collectively on number of herb stems counted.

The diversity of the herb stratum follows a similar pattern as described above. Figure 14c shows that the engineered sites had less diversity than the intact sites at all but one point along the slope. ANOVAs show a significant value (p = 0.003) for treatment type, and a marginally significant result (p = .0989) for distance on diversity. Once again, there was no significant relation between treatment and distance.

Tables 9a and 9b record the herbaceous species found at study sites, ranked from most to least abundant (number of stems counted) in engineered and intact sites and by percent abundance, respectively. (The two tables record absolute number and percent of stems on these sites.) Several of the species, which are found most abundantly on the intact forest sites, were not present, or are present in very low numbers, on the disturbed engineered sites. This would indicate that the human activity is effecting the forest ecosystem and changing the community composition. Four of the top ten intact forest herbs are in the top ten of the engineered sites, however, three of the top ten were not present at all on the engineered sites. This might indicate that although some of the heartier species are persisting, some of the more sensitive species are disappearing.

Table 10 records herbaceous species found at study sites, ranked by abundance (number of stems counted) in engineered and intact sites. In this table, values have been standardized by multiplying engineered numbers by 11/5 to even out difference in the number of sites sampled. By equalizing the numbers, we can see the abundance of the species from a more level starting point. (The total number of stems for the engineered and intact forests respectively are 3978 and 8817.) The totals indicate, even when the different number of sites studied is compensated for, that the density of herbaceous stems at the engineered sites was less than half that of the intact forest sites.

General Conclusions for Herbs:

The herb community, important for nutrient status and wildlife values, is much less dense and species-rich when disturbance is adjacent to an intact forest. Part of the reason for the difference in spring herb abundance and diversity could be attributed to mining activity. When mining activity results in covering up the toe of the slope, the most diverse and rich communities are eliminated. The engineered sites studied could have been higher up the original slope than at the intact sites. Also, since the engineered sites have been more disturbed, the quantity of light penetrating the canopy may be increased. This increase in light energy reaching the ground can dry out the soil and make conditions less favorable for the spring herb population. These herbs rarely invade mining lands on the areas studied, so data sets used for woody plants did not include forest herbs because they were seldom, if ever, observed. (Dispersal limits and the need for shady, moist microhabitat are obvious limits to regeneration.) A return to full forest biodiversity of plants is apparently even more challenged on mining areas when herb species are added to a concern.

Soil Sampling:

Table 11 lists the soil depth and percent moisture content recordings from ten mines and their paired remnant forest. Depths were determined by digging holes until either large rock was hit, impeding further digging, or 60cm was reached. The forest is often described as having a very thin layer of soil (e.g. Torbert and Burger, 1996), difficult to be collected before mining operations begin. However, this study's sampling encountered, three times in the forest, 60 cm loose soil depth, with additional soil below that was not sampled. Overall, the forest soils were consistently found to be deeper, moister, and darker in color than the mine soils (Table 11). The mine soil consisted mostly of small rocks, and solid impenetrable rock was hit at generally shallower depths.

Moisture content (Table 11) can account for some of the observed color variation. The darker soils, such as those found in the forest, were much higher in moisture content than the valley fills and backfills. Only two MTR soil samples were collected and they came from the same MTR site (Leckie Smokeless: Briery Knob). This site was very unusual compared to other MTRs visited during this study. The forests to either side of the mined area were flat, like the MTR, and level to the "prairie" site. It appeared that the mining activity was carried out very close to the surface of the ground, therefore disturbing very little of the natural processes. However, the representative showing us the property was not sure of those particulars of the mine's history and the mining company was no longer in business. These two MTR sites had higher moisture content and microbial activity (Figure 15) than expected by the investigators.

The microbial activity is displayed in Figure 15 by land type, with bars marking average values drawn across each group of columns. Overall there was not much difference between remnant forests and back fills. This is consistent with earlier vegetation findings that Back Fills are more promising habitats than the other two mine types. But when comparing the microbial data to the stem density data (Figures 6-8), there seems to be no correlation between the two. Once again, further and more in-depth soil analyses must be performed before any conclusions can be drawn. It is important to analyze the soil column by horizon and time did not permit that type of collection for our team this year.

Table 12 summarizes the Rutgers University Soil Testing Laboratory's findings on the same soil samples used for the DHA analysis. Sample size was small, and it is difficult to observe any trends in the data. The pH values range from 3.6 (a BF and RF) to 7.7 (a VF). There is no observed trend of pH decreasing with age. This should be monitored over time, to see how quickly the rock is breaking down and creating the needed soil layers. Gravel content was not unusual apart from one remnant forest with 53.45% gravel. This was a very thin section of woods, 37m wide, located above the VF and subsequent BF of Briery Knob. Much of the West Virginia woods contained rock outcrops, so this should not be too uncommon. There are large ranges discovered in the soil analysis within the macro- and micronutrients, but it is notable that the N content in the remnant forests (RF) are significantly higher than in the mine lands. This is a critical nutrient whose pool must be enhanced for long-term forest productivity.

Conclusions:

The soil collections from the vegetation analysis sites are too few at present (due to small sampling size) to firmly state an overview of the current conditions of the mine-land soil. Further sampling would be required to complete a detailed analysis. More mine types, greater range of soil age since reclamation, more reclamation schemes, and more in-depth sampling techniques such as soil cores to identify the soil horizons and assess the horizon development need to be examined. Some of this information is in the soil study section of the EIS. Our small scale soil study shows that there is a moisture differs between land types, which must contribute to seedling development and survival, but we cannot say if this is an overriding.

The surface microbial activity does not appear to be unevenly distributed. Backfills did almost as well as the remnant forests. Further testing would be conducted to test the activity level throughout the first few soil horizons. Studies expect to find the most microbial activity at the surface horizons (Harris and Steer, 1997), so it is not surprising to see all four land types sampled here producing similar levels.

Literature Cited:

Barbour, M.G., J.H. Burk, W.D. Pitts, F.S. Gilliam, and M.W. Schwartz. 1999. Terrestrial plant ecology. Third edition. Addison Wesley Longman, Menlo Park.

Bierzychudek, P. 1982. Life histories and demography of shade-tolerant temperate forest herbs: a review. New Phytol. 90:757-776.

Burger, J.A., and J.L. Torbert. 1999. Status of reforestation technology: the Appalachian region. Pages 95-123 in Vories and Throgmorton, op. cit.

Burns, Russell M., and Barbara H. Honkala, tech. coords. 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agricultural Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, D.C.

Core, Earl L. 1966. Vegetation of West Virginia. McClain Printing Co, Parsons, WV.

Gleason, Henry A., and Arthur Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada, 2nd ed. New York Botanical Garden, Bronx, NY.

Harris, J., and D. Steer. 1997. DHA soil microbial activity analysis. Dept. of Environmental Science, University of East London, U.K.

Hinkle, C.R., W.C. McComb, J.M. Safley, Jr., and P.A. Schmalzer. 1993. Mixed mesophytic forests. Pages 203-254 in Martin, W.H., S. G. Boyce, and A.C. Echternacht, editors. Biodiversity of the southeastern United States, upland terrestrial communities. Wiley and Sons, NY.

Newcomb, Lawrence, and Gordon Morrison. 1977. Newcomb's Wildflower Guide. Little, Brown and Co., Boston, MA.

Rodrique, J.A., and J.A. Burger. 2000. Forest productivity and woody species diversity on pre-SMCRA mined land. Proc. Amer. Soc. Surface Mining Reclam., pages 205-223.

Schemske, D.W., M.F. Willson, M.N. Melampy, et al. 1978. Flowering ecology of some spring woodland herbs. Ecology 59:351-366.

Strausbaugh, P. D., and Earl L. Core. 1977. Flora of West Virginia, 2nd ed. Seneca Books. Morgantown, WV.

Torbert, J.L., and J.A. Burger. 1996. Influence of grading intensity on herbaceous ground cover, erosion, and tree establishment in the southern Appalachians. Pages 639-646 in Successes and failures: applying research results to insure reclamation success. ASSMR, and Powell River Project of Virginia Tech Univ.

Venning, Frank D., and Manabu C. Saito. 1984. A Guide to Field Identification: Wildflowers of North America. Golden Press, New York, NY.

Vories, K.C., and D. Throgmorton, editors. 1999. Proceddings of: Enhancement of reforestation at surface coal mines: technical interactive forum. USDI OSM, Alton, IL, and Coal Research Center, SIU, Carbondale IL. 274 p.