

## PROPERTIES OF CONSTRUCTED SOILS ALONG FOUR-LANE HIGHWAYS IN WEST VIRGINIA<sup>1</sup>

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**Abstract.** Four-lane highways have been constructed in West Virginia since the 1960's. During the early construction periods of four-lane highways, geologic information was not assessed, nor was the effect of the disturbance of these geologic materials on soil quality established prior to construction activities. Due to the mountainous topography of the Central Appalachian region, the construction of four-lane highways requires large, expansive cut and fill areas that may contain acid or alkaline producing materials. The disturbance and mixing of these materials with the original soil produces "new" soil that differs considerably from the surrounding native soil. In order to evaluate highway substrate conditions and the development processes of these new soils, study areas along sections of highways have been selected for comparison based on differences in age and geologic parent materials. The long-term goal of this research is to improve selective soil handling of earth excavated during highway construction similar to that of mine overburden materials. Cut, fill and on-grade areas within sections of Interstates 68, 79, and 81 and Corridor H (U.S. Route 33 and State Route 55) have been randomly selected as sampling sites. Soil pits located at 10-m increments along transects perpendicular to these four-lane highways have been sampled at 0-10 cm and 10-20 cm depths and described according to USDA methods. Surface samples also were taken near the edge of the highway. Field pH values of all sites ranged from 5 to 8. Preliminary analysis of the data suggests that thin A horizons develop within 1 to 2 years in rapidly weathering surface materials. In these young soils, little development is observed beneath a weakly developed A horizon, commonly creating an A-C1-C2 or A-AC-C horizon sequence. Soils of intermediate ages (9-12 yrs) were similar to young soils, although at some sites a more developed soil profile was occasionally observed (A-Bw-C1-C2). The most developed soil profiles were observed on sites where soils had been constructed 25 to 43 years ago. At these locations, multiple B horizon sequences were common creating A-Bw1-Bw2-C or A-Bw-BC-C horizons.

**Additional Key Words:** Soil quality, soil development, disturbed soils, minesoils, soil genesis.

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## **Introduction**

Highway construction disturbs long linear strips that cross a variety of soil and geologic materials. Therefore, soil placement and handling problems are unique. Many completely different micro sites may be generated over short distances. Some areas along highway corridors remain bare of vegetation, even after periods of greater than 25 years have passed since construction. With prior knowledge of these potential problem areas, engineers and planners would be able to develop alternative methods of soil and rock handling. For instance, analysis of soils and geologic materials in advance of highway construction, similar to that required for surface coal mining operations, would assist in the prediction of problem areas for the establishment of vegetation for effective sediment and erosion control.

Because soils along highway corridors are disturbed in a similar way as surface coal mining, these two different activities are comparable. Disturbed soils have distinctly different morphological features when compared to contiguous native soils. Disturbed soil properties are the result of various blasting and soil/rock handling and placement procedures employed as well as the consequent natural soil formation functions of time, topography, parent material, biological activity, and climate. These disturbed soils are in theory quite “young” in the sense that time has not fully acted upon them, and they have not yet reached a state of equilibrium with the environment. However, several studies have noted that surface horizonation is evident in as little as three years post disturbance creating an A-C horizon sequence (Ciolkosz et al., 1985; Daniels and Amos, 1981; Shafer, 1980; Sencindiver and Ammons, 2000; Thurman and Sencindiver, 1986). This trend is credited to the acceleration of the soil physical and chemical processes performed by air, water and plant roots acting upon consolidated rock at the surface or near surface of disturbed soils (Sencindiver and Ammons, 2000). Seventeen of 29 pedons described in Pennsylvania minesoils, aged 1 to 29 years had AC or Bw subsurface horizons (Ciolkosz et al., 1985). Haering et al. (1993) observed Bw horizons in minesoils constructed from coal overburden strata consisting of siltstone, but in material containing more than 25% sandstone, only A, AC and C horizons were evident. The importance of soil texture to chemical and physical properties, such as nutrient and water behavior is well documented. Sobek et al. (1978) observed that minesoil properties were closer to their parent material properties than natural soils were to their parent material properties. The texture of soils disturbed by mining

operations and road construction is directly related to the geologic materials disturbed and may be sandy, if derived of sandstone, or silty, if derived of siltstone.

Successful reclamation along highways is dependent upon a thorough knowledge of the individual soil and site properties that must be stabilized and a prediction of how the soils will behave over time (Booze-Daniels et al., 2000). Soils on cut areas will be thinner than the native soils; therefore, vegetation will have a smaller volume of soil from which to absorb water and nutrients. Soils on fill areas may be thicker than soils on cut and on-grade areas, so effective plant rooting should not be restricted by unbroken parent material or underlying rock. Compacted zones may perch water tables during wet weather conditions causing saturation and anaerobic conditions within the rooting zone. In a study of older mine soils (5-20 years old) at the Powell River Project watershed in southwest Virginia, compaction was the most significant soil factor limiting successful long-term revegetation (Daniels and Zipper, 1997). Severely compacted mine soils, especially those with less than 60 cm of effective rooting depth, cannot hold enough plant available water to sustain plant communities through extended periods of drought (Daniels and Zipper, 1997).

Current interest by the West Virginia Division of Highways (DOH) in the use of native plant species for site stabilization has led to a parallel study of the anthropogenic substrates. This study seeks to evaluate existing soil conditions along highway corridors and develop new methods to enhance soil quality on highway cut, fill and on-grade areas. The first objective was to evaluate and compare soil properties on highway cut, fill and on-grade sites located adjacent to Interstate Highways 68, 79 and 81 in West Virginia. The ongoing construction of Corridor H along U.S. Route 33 and State Route 55 presents a unique opportunity to study development of soils affected by highway construction over time. Therefore, the second objective was to evaluate soil development on five fill areas adjacent to Corridor H, and to compare soil properties to age and geology.

### **Methods and Materials**

#### **Procedures for Selecting Sampling Sites**

Sampling sites were selected along Interstate Highways 68, 79, and 81, and Corridor H (U.S. Route 33 and State Route 55) in West Virginia. Before field work began, the following criteria were established for selecting highway sampling sites:

1. Slope steepness should be no more than 70%.
2. Cut and fill areas must extend at least 20 m perpendicular to the highway from the point at which vegetation begins (described as the site boundary) to allow for 10-m and 20-m sampling points (on-grade areas must extend at least 10 m).
3. Bridges, culverts or any other type of drainage structure should not interrupt transects.
4. There must be ample parking space at the site for safety of the workers.

Highways were first subdivided based on gross geologic differences. It was determined that geology for the entire length of Interstate 68 was uniform. Interstate 79 was originally divided into two sections, but fieldwork indicated that soils were similar between the two sections. Therefore, only the northern section was included in this paper. For Interstate 81, two geologic sections were originally identified. The longer section was predominantly limestone whereas a shorter section on the northern end consisted mostly of shale. However, no acceptable sampling sites were identified within the shale section. Therefore, only the limestone section was evaluated.

Each highway was visually surveyed, for all cut, fill and on-grade sites apparently meeting the criteria described above. Potential sites were listed according to type and were randomized using Microsoft Excel spreadsheet with RAND and RANK functions. Sampling sites were selected by visiting the first site on each randomized list. If the site met the selection criteria, then the site was chosen for sampling. If the site did not meet all of the selection criteria, then the next site on the list was visited. This selection process continued until one fill, one cut and one on-grade site in each section met all the selection criteria.

In order to represent variability across Corridor H, subdivisions based on age and apparent variation in gross geologic parent materials were established. Once segments of uniform age and geology were identified, each segment was surveyed visually, and one fill area from each of the four sections was randomly selected using the same process explained above.

All field work was conducted in 2002 and 2003. Therefore, the interstate sites were 28 to 42 years of age at the time of sampling, and the Corridor H sites were 1 to 27 years old.

Sampling Methods

The basic sampling design was similar for all sites (Fig. 1). A centerline transect extending perpendicular to the highway was established at the approximate center of all cut, fill and on-grade sites. Two adjacent transects were established parallel to the centerline, each extending 20 m (except on-grade areas which extended 10 m). Transects originated where the vegetation began adjacent to the highway. This point was established as the site boundary. There were 10 m between the centerline and each adjacent transect creating a 20-m belt across each site. The first sampling point on each transect was 10 m from the site boundary (Row A). A second sampling point on each transect was 20 m from the boundary (Row B). At each sampling point, a soil profile was described to a depth of 50 cm or to bedrock, whichever was shallower, according to standard soil survey methods (Soil Survey Division Staff, 1993). Samples were collected from 0-10 cm and 10-20 cm depths from each pit described. Samples also were collected at the site boundary. At these locations, samples from the 0-10 cm depth were collected and no field descriptions were written. Distance from the edge of the road to the boundary of the study area and GPS coordinates were recorded for all sites.

All samples collected were analyzed for chemical and physical properties. However, for this paper, only field data for all sites are presented.

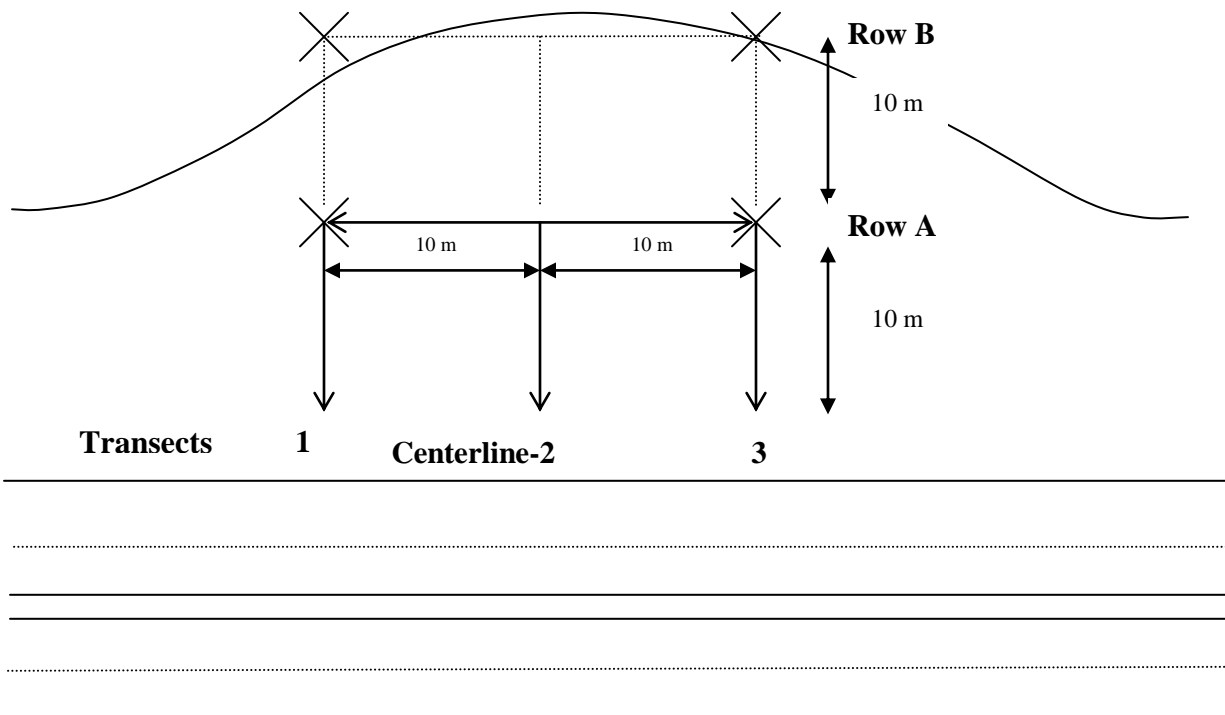


Figure 1. Experimental sampling design for highway sampling sites.

### Site Descriptions for Interstates 68, 79, and 81

Interstate 68. The 48.3-km (30-mile) section of Interstate 68 originates at the intersection of Interstate 79 in Monongalia County, West Virginia and extends west to the West Virginia/Maryland state line. This section of highway was originally constructed from 1973-1974 (28-29 years old at sampling date). It is primarily underlain by Pennsylvanian sandstones of the Conemaugh Series, including Mahoning, Connellsville and Freeport sandstones intermixed with thin bands of coal, shale and limestone.

Interstate 79. The 96.6-km (60-mile) section of Interstate 79 included in this study extends from the West Virginia/Pennsylvania line south to milepost 100. Original construction occurred from 1967-1972 (30-35 years old at sampling date). This section represents a mix of Pennsylvanian sandstones, siltstones, shales, and limestones, consisting of Connellsville sandstone, Clarksburg limestone, Pittsburgh and Little Clarksburg coal seams, and various thin bands of shale within the Conemaugh Series.

Interstate 81. The 40.2-km (25-mile) section of Interstate 81 spans all of Berkeley County, West Virginia in a general northeast/southwest direction. Original construction occurred from 1961-1966 (37-42 years old at sampling date). This section represents mainly Ordovician aged limestone geology. However, shale is exposed on the northern end of the highway, and thin bands of shale are present at various locations.

### Site Descriptions for Corridor H

Five fill sites along Corridor H were evaluated based on differences in age and geology (Fig. 2). Sections 1 and 2 were located within the Conemaugh-Monongahela formations, but they had an age difference of approximately 12 to 16 years between construction periods. The age of section 3 was similar to section 2, but the geologic formation differed. Section 3 was within the Allegheny-Kanawha formations. Sites within sections 4 and 5 were influenced by Devonian shales, although there were some differences in specific geologic groups. These sites were only 1 to 2 years old at the time of sampling.



Section 1. Section 1 is a 16.1-km (10-mile) section of U.S. Route 33 in Lewis County. Original construction took place from 1975-1979 (23-27 years old at sampling date). Pennsylvanian sandstones of the Conemaugh Series, including Mahoning, Connellsville and Freeport sandstones primarily underlie this section of highway; the sandstones are intermixed with thin bands of coal, shale and limestone.

Section 2. Section 2 is a 9.7-km (6-mile) span of U.S. Route 33 in Upshur County. Original construction of this section took place in 1991 (11 years old at sampling date). Pennsylvanian sandstones of the Conemaugh-Monongahela geologic groups primarily underlie this section of highway as well. The geology of this section is similar to section 1, but constructed soils are younger.

Section 3. Section 3 is a 24.1-km (15-mile) span of U.S. Route 33 through Upshur, Barbour and Randolph counties. Original construction of this section took place in 1994 (8 years old at sampling date). Pennsylvanian sandstones including the Allegheny-Kanawha groups primarily underlie this section of highway. The geology of this section is approximately 50% sandstone with shale, siltstone and coal.

Section 4. Section 4 is a 9.7-km (6-mile) span of U.S. Route 33 in Randolph County. Original construction took place between 2000 and 2002 (1-2 years old at sampling date). Devonian shale including Chemung (marine deposition of gray shale with layers of siltstone, sandstone and conglomerate), Brallier (olive gray dark shale with siltstone and sandstone lenses) and Harrel (noncalcareous black shale) underlie this section of highway.

Section 5. Section 5 is a 11.3-km (7-mile) span of State Route 55 in Hardy County, near Baker, West Virginia. Original construction took place between 2000 and 2002 (1-2 years old at sampling date). Devonian shale including the Chemung, Hampshire (red and green nonmarine shale with sandstone beds), Harrel and Brallier geologic groups underlie this section of highway.



## **Results and Discussion**

The information given in Tables 1 through 3 describe the range of conditions observed in all three pits described at 10-m and 20-m distances from the boundary for each cut, fill and on-grade site sampled on Interstates 68, 79 and 81. The horizon sequence given for each location describes the conditions observed along the centerline transect of each site. Some variability is typically observed among pits within a row. However, points along the centerline transect sufficiently represent the rows because pits described across a row are parallel to the highway, and slope, stratification of materials, and other site specific conditions are generally uniform at these locations.

### **Interstate 68**

**Fill.** The A horizon thickness ranged from 6 to 8 cm, and both moderate granular and subangular blocky structure were observed. The texture of the A horizon was silt loam with 45-60% sandstone, siltstone and shale fragments. The solum thickness ranged from 15 to 50+ cm. B horizons included Bw and BC. The structure of the Bw horizon was moderate subangular blocky, and texture was silt loam with 45-70% sandstone, siltstone and shale fragments. The BC horizon was similar to the Bw, but with slightly weaker, coarser structure. The dominant texture for the BC horizon was silt loam with 50-75% sandstone, siltstone and shale fragments, however silty clay loam texture was described for the BC horizon at one pit. Manganese concentrations and mixed soil materials were observed throughout B horizons. The texture of the C horizon was silty clay loam with 50-75% sandstone, siltstone and shale fragments. The slope was 60-65%. Field pH was 6.5-7.5.

**Cut.** The A horizon thickness ranged from 5 to 8 cm, and the dominant structure was moderate granular. Granular structure in combination with moderate or weak subangular blocky structure was described in the A horizon at some pits. The texture of the A horizon was silt loam with 5-15% sandstone fragments. The solum thickness ranged from 8-32 cm. Differences in the solum thickness were due to shallow sandstone bedrock that was encountered at depths that ranged from 11-48 cm. Transition horizons were present beneath the A horizon, and horizon sequences among pits were variable. The AB horizon had weak granular and moderate subangular blocky

Table 1. Ranges of some physical properties at 10-m and 20-m locations on fill, cut and on-grade sites on Interstate 68 in West Virginia.

Sites <sup>1</sup>	Depth <sup>2</sup> of A Horizon cm	Depth <sup>2,3</sup> of Solum cm	Horizon <sup>4</sup> Sequence	Texture <sup>5</sup>	Rock <sup>6</sup> fragments % Type	Slope %
<u>Fill</u>						
10 m	8	36-50+	A-Bw-BC-C	sil-sicl	60-75 ss, sis, sh	60-65
20 m	6-7	15-28	A-Bw-BC-C	sil-sicl	45-50 ss, sis, sh	60-65
<u>Cut</u>						
10 m	6-8	8-32	A-AB-Bw-R	sil-sicl-cl	15-40 ss, carb	15-25
20 m	5-7	11-20	A-AC-C-R	sil-sicl-cl	5-25 ss, carb	45-50
<u>On-grade</u>						
10 m	5-8	14-16	A-Bw-C-R	sil-l	25-35 ss	0-10

<sup>1</sup> Sites were sampled at 10 m and 20 m locations from the site boundary.

<sup>2</sup> The range of depths observed in the A horizons and the solum includes three soil profiles.

<sup>3</sup> The solum includes all horizons except C, Cr, and R.

<sup>4</sup> Horizon sequence is given for pits described on the centerline transect.

<sup>5</sup> sil=silt loam, sicl=silty clay loam, cl=clay loam, l=loam.

<sup>6</sup> % rock fragments by volume (> 2 mm); ss=sandstone, sis=siltstone, sh=shale, carb-carbolithic .

structure, while the AC horizon expressed granular structure and weak subangular blocky structure. The texture for the transition horizons was silty clay loam. The dominant structure for the Bw horizon was moderate subangular blocky, but weak subangular blocky was described at some sampling points. The texture for these horizons was silt loam, silty clay loam or clay loam with 5-40% sandstone fragments. The texture of the C horizon was silt loam, silty clay loam or clay loam with 10-40 % sandstone fragments. The cut was a benched type and the slope (15-50%) was not uniform between sampling rows. Manganese concentrations and black coatings on

rock fragments were observed throughout many of the pits described. Carbolithic fragments also were observed in some pits. Field pH was 5.5-6.5.

Table 2. Ranges of some physical properties at 10-m and 20-m locations on fill, cut and on-grade sites on Interstate 79 in West Virginia.

	Depth <sup>2</sup> of A Horizon cm	Depth <sup>2,3</sup> of Solum cm	Horizon <sup>4</sup> Sequence	Texture <sup>5</sup>	Rock <sup>6</sup> fragments % Type	Slope %
<u>Fill</u>						
10 m	6	25-26	A-Bw-BC-C	sil-sicl	5-45 ss, sh, ls	65
20 m	7	21-27	A-Bw-C	sil-sicl	10-45 ss, sh, ls	65-70
<u>Cut</u>						
10 m	5-8	11-15	A-Bw-C1-C2	sil-sicl	5-45 sis, ss, sh, carb	25-55
20 m	6-8	8-26	A-Bw-R	sil-sicl	5-45 sis, ss, sh, carb	30-45
<u>On-grade</u>						
10 m	6-7	6-29	A-Cr-R	sil-sicl	30-75 sis, sh	0-5

<sup>1</sup> Sites were sampled at 10 m and 20 m locations from the site boundary.

<sup>2</sup> The range of depths observed in the A horizons and the solum includes three soil profiles.

<sup>3</sup> The solum includes all horizons except C, Cr, and R.

<sup>4</sup> Horizon sequence is given for pits described on the centerline transect.

<sup>5</sup> sil=silt loam, sicl=silty clay loam, cl=clay loam.

<sup>6</sup> % rock fragments by volume (> 2 mm); ss=sandstone, sh=shale, ls=limestone, carb=carbolithic.

On-grade. The dominant texture of all horizons was silt loam, but a few horizons were loam. The solum thickness ranged from 14 to 16 cm. Sandstone bedrock was encountered at depths ranging from 22 to 30 cm. The A-horizon thickness ranged from 5 to 8 cm, with a moderate

Table 3. Ranges of some physical properties at 10 m and 20 m locations of fill, cut and on-grade sites on Interstate 81 in West Virginia.

Sites <sup>1</sup>	Depth <sup>2</sup> of A Horizon cm	Depth <sup>2,3</sup> of Solum cm	Horizon <sup>4</sup> Sequence	Texture <sup>5</sup>	Rock <sup>6</sup> fragments % Type	Slope %
<u>Fill</u>						
10 m	6	50+	A-Bw1-Bw2-BC	sil-sicl	5-65 ls, sh	30
20 m	6	15-50	A-Bw-C1-C2	sil-sicl	5-100 ls, sh	25-30
<u>Cut</u>						
10 m	5-6	15-50+	A-Bw-BC-R	sil-sicl	5-85 ls	0-5
20 m	6-7	13-50+	A-Bw-R	sil-sicl	5-85 ls	35
<u>On-grade</u>						
10 m	7-9	30-45	A-Bw1-Bw2-C	sil-sicl-sic	5-80 ls, sh	0-5

<sup>1</sup> Sites were sampled at 10 m and 20 m locations from the site boundary.

<sup>2</sup> The range of depths observed in the A horizons and the solum includes three soil profiles.

<sup>3</sup> The solum includes all horizons except C, Cr, and R.

<sup>4</sup> Horizon sequence is given for pits described on the centerline transect.

<sup>5</sup> sil=silt loam, sicl=silty clay loam, sic=silty clay.

<sup>6</sup> % rock fragments by volume (> 2 mm); ls=limestone, sh=shale

granular structure. The A horizon contained 25% sandstone fragments, the Bw horizon had 35% sandstone fragments, and the C horizon had 25% sandstone fragments. The Bw horizon had weak subangular blocky structure. Mixed soil materials in the B horizons and manganese coatings on rock fragments were described throughout the profiles of some pits at this site. The slope was 0-10%. Field pH was 6.5-7.5.

Summary. The age of the soils developing along Interstate 68 ranged from 28 to 29 years. Sandstone geology dominated the parent materials of the soils developing at these sites. The A

horizon thickness was uniform over the cut, fill and on-grade sites, ranging from 5 to 8 cm thick. The thickness of the solum over all sites ranged from 8 to 50+ cm and was thickest on the fill site. The expression of multiple B-horizons was observed on the fill site and in some areas on the cut site. Silt loam and silty clay loam textures were dominant, although loam texture was observed in some horizons on the on-grade site, and clay loam was observed in a few horizons on the cut sites. Rock fragments ranged from 5 to 75%, and were highest at the fill site. Rock fragment content was lower in surface horizons than subsurface horizons at all sites. Clay content was lower in the A horizons than in subsoil horizons. Apparently, there has been enough time for clay to move from the A horizon to lower horizons. However, no clay films were evident in the B horizons. Therefore, we concluded that Bt horizons have not yet formed. Field pH ranged from 5.5-7.0 and was more acidic on the cut site where thin bands of coal were exposed and closer to neutral on the fill and on-grade sites where no coal was observed.

#### Interstate 79

Fill. The A horizon thickness ranged from 6 to 7 cm. The dominant structure of the A horizon was moderate subangular blocky, but moderate granular structure was described in combination with subangular blocky at the 10-m locations. The texture of the A horizon was silt loam with 5-10% sandstone, shale and limestone fragments. The solum thickness ranged from 21 to 27 cm. Multiple B horizons were observed in pits described at the 10-m locations. The structure of the Bw horizon was moderate subangular blocky. The BC was similar but expressed weaker and coarser structure. The dominant texture of the B horizons was silt loam with 5-25% sandstone, shale and limestone fragments. The dominant texture for the C horizons was silt loam with 35-45% sandstone, shale and limestone fragments. Manganese concentrations and mixed soil materials were common throughout the soil profile. The slope was 65-70%. Field pH was 8.0.

Cut. The A horizon thickness ranged from 5 to 8 cm. The structure of the A horizon included both weak subangular blocky and moderate granular. Stronger subangular blocky structure was described in some horizons. The texture of the A horizon was silt loam or silty clay loam with 5% siltstone fragments. The solum thickness ranged from 8 to 26 cm. Where bedrock was encountered at shallow depths on this benched cut, the solum was thin. A transition BA horizon with moderate subangular blocky and granular structure was described at one sampling location.

The texture of this horizon was silty clay loam with 25% siltstone, sandstone and shale fragments. Structure of the Bw horizon was moderate subangular blocky, and texture was silty clay loam with 10-15% siltstone, sandstone and shale fragments. The dominant texture of the C horizon was silty clay loam with 25-45% siltstone fragments. Multiple C horizons were differentiated by increasing clay and rock fragment content. Carbolithic fragments were described throughout the soil profile at some pits on this site. The slope range was 25-55%, and field pH was 5.5-6.0.

On-grade. The A horizon thickness ranged from 6 to 7 cm. The structure of the A horizon was moderate granular and moderate subangular blocky. The dominant texture of the A horizon was silt loam with 30-75% siltstone, sandstone and shale fragments. The solum thickness ranged from 6 to 29 cm. The soils with thin sola were those located where bedrock was present at shallow depths. A Bw horizon with weak subangular blocky structure was described in one pit. The texture of this horizon was silty clay loam with 45% limestone and siltstone fragments. The Cr horizon was soft, yellow to tan siltstone. The slope range was 0-5 %. Field pH was 8.0.

Summary. Age of the soils along Interstate 79 ranged from 30 to 35 years. Dominant lithologic units were siltstone, sandstone and shale. The A horizon thickness was uniform over cut, fill and on-grade sites, ranging from 5 to 8 cm. The solum thickness of all sites ranged from 8 to 27 cm and was thickest on the fill site. Bw horizons were described at all sites, and multiple B horizons were observed on the fill site. Textures for all horizons were silt loam or silty clay loam with 5-75% siltstone, sandstone and shale fragments. Rock fragment content was the lowest in the surface horizons compared to other horizons at all sites. Rock fragment content was highest in the on-grade site, compared to the cut and fill sites. Field pH ranged from 5.5 to 8.0 and was more acidic on the cut site and closer to neutral or alkaline on the fill and on-grade sites.

#### Interstate 81

Fill. Thickness of the A horizon at all sampling points was 6 cm. Moderate subangular blocky and granular structure was described in this horizon. The texture was silt loam with 5% limestone and shale fragments. The thickness of the solum ranged from 15 to 50+ cm. Multiple B horizons were observed at this site and included Bw1, Bw2 and BC horizons. Moderate

subangular blocky structure was described for the Bw horizons, with weaker, coarser structure described for the BC horizons. The texture of the Bw horizons was silt loam or silty clay loam with 5-45% limestone and shale fragments. The texture of the BC horizons was silty clay loam with 20-65% limestone and shale fragments. Multiple C horizons were described at some of the 20-m locations. C horizons were differentiated by rock fragment content. Texture of C horizons was silty clay loam with 65-100% limestone and shale fragments. The slope ranged from 25 to 30%. Field pH was 7.0-8.0.

Cut. Thickness of the A horizon ranged from 5 to 7 cm. Structure of the A horizon was moderate granular and subangular blocky, and texture was silt loam with 5-25% limestone fragments. Thickness of the solum ranged from 13 to 50+ cm. Bw, Bw1, Bw2, BC and B/A horizons were represented at this site. B/A horizons were described at two of the three 10-m locations. Structure of the B/A horizons was moderate subangular blocky and granular, and texture was silt loam or silty clay loam with 35% limestone fragments. Structure of the Bw horizons was moderate subangular blocky. The dominant texture of the Bw horizons was silt loam with 5-10 % limestone fragments. Texture of the C horizon was silt loam or silty clay loam with 85 % limestone fragments. The slope ranged from 5 to 35 %. Field pH was 7.0-8.0.

On-grade. Thickness of the A horizon ranged from 7 to 9 cm. The dominant structure of the A horizon was moderate granular and subangular blocky, and texture was silt loam with 5% limestone and shale fragments. The thickness of the solum ranged from 30-45 cm. Bw, Bw1, Bw2 and Bw3 horizons were represented at this site. The dominant structure of the Bw horizons was moderate subangular and angular blocky. Structural grade was described as weaker and coarser in Bw3 horizons. Platy structure was described in discrete areas. Texture of the Bw horizons was silty clay loam or silty clay with 10-35 % limestone and shale fragments. Texture of the C horizon was silty clay loam or silty clay with 15-80% limestone and shale fragments. Slope range was 0-5%. Field pH was 7.0-8.0.

Summary. Age of the soils for these sites ranged from 37 to 42 years. Limestone geology dominated all the sites. Thickness of the A horizon was uniform over cut, fill and on-grade sites ranging from 6 to 8 cm, and the solum thickness ranged from 13 to 50+ cm among all sites. The

expression of multiple B horizons was observed at all sites. Silt loam and silty clay loam textures dominated with 5-100% limestone and shale fragments. Rock fragment content was the lowest in the surface horizons. Field pH ranged from 7.0 to 8.0.

### Summary of Interstate Sites

Thicknesses of A horizons at all sites were similar (5-9 cm). In general, solum depth was greater on the fill sites along each highway, but the most developed soils on fills, cuts and on-grade sites were observed along Interstate 81. Multiple B horizons were commonly described at these sites, and the solum depth commonly exceeded 50 cm. These A-horizon and solum thicknesses are consistent with minesoils of similar ages (Ciolkosz et al., 1985; Thomas et al., 2000).

Although most textures described along all three highways were silt loam and silty clay loam, more sand was observed at sites along Interstate 68 than along other highways. Some loam and clay loam textures were described at some points along this highway. Also, more clay was apparent at sites along Interstate 81 than at other sites, with the description of some silty clay textures. Field observations also indicated that some of the silty clay loam textures were close to silty clay. Differences in textures were expected. Most of the native soils mapped along Interstate 68 in Monongalia County, West Virginia have loam textures (Wright et al., 1982), and sandstone formations were prominent. Limestone is the predominant lithologic unit in Berkeley County, and most soils mapped along Interstate 81 have silt loam surface textures and clayey B horizons (Bell, 2002).

In general, rock fragment content was lower in surface horizons than in subsurface horizons at all sites. Several sites had 75% or more rock fragments in the subsurface horizons. These high amounts of rock fragments and the differences between surface and subsurface horizons are consistent with minesoil properties (Ciolkosz et al., 1985; Daniels and Amos, 1981; Sencindiver and Ammons, 2000).

Field pH had a general relationship to the geology of each site. Values tended to be highest where limestone was present and lowest where carbolic materials were observed.

In addition to geology or parent material, other factors affecting soil profile development are climate, vegetation, topography, and time (Buol et al., 1997). Average annual temperature and precipitation at Martinsburg, near Interstate 81, and Morgantown, where Interstates 68 and 79



intersect, are similar (Bell, 2002; Wright et al., 1982). Average temperature is 11.8°C at Martinsburg and 11.4°C at Morgantown. Average precipitation at Martinsburg is 95 cm and at Morgantown it is 100 cm. All sites were vegetated, although species varied (data not presented). Topography, parent material and time varied among sites. The slopes of cut and fill sites on Interstate 81 were generally less steep than the slopes of sites on other interstates. Because of the surrounding gentle topography along Interstate 81, construction of this highway required shallower cuts and fills to level the road surface. Also, ages of the soils developing along the interstate highways increased from Interstate 68 (28-29 years) to Interstate 79 (30-35 years) to Interstate 81 (37-42 years). So, soils along Interstate 81 were the oldest, and they had the least erosion potential because of slope. Therefore, the soils along Interstate 81 would be expected to exhibit more soil development than soils along Interstates 68 and 79.

### Corridor H

The information given in Table 4 describes the range of conditions observed in all three pits described at 10-m and 20-m distances from the boundary for each fill area sampled on Corridor H. The horizon sequence given for each location describes the conditions observed along the centerline transect of each site.

26-year-old-site. This site is located within section 1 (Fig. 2). The thickness of the A horizon ranged from 6 to 7 cm. The dominant structure of the A horizon was moderate granular and subangular blocky, however weaker structure was described in discrete locations. Texture of the A horizon was silt loam with 5% sandstone, siltstone, shale fragments. Thickness of the solum ranged from 7 to 50+ cm. The most common subsoil horizon described at this site was an AC horizon. The structure of the AC horizon was weak granular and subangular blocky. The dominant texture of the AC horizon was silt loam with 5-25% sandstone, siltstone and shale fragments. A slight increase in clay relative to the A-horizon was observed in the AC horizon. A Bw horizon was described at only one site. It had moderate subangular blocky structure, silt loam texture, and 5-25% sandstone, siltstone and shale fragments. C horizons had silty clay loam textures with 15-50% rock fragments. Buried horizons beneath fill material were described at discrete locations. These horizons were described as Bwb or Btb horizons with moderate subangular blocky and platy structure. The Bwb had silt loam texture, and the Btb had silty clay

Table 4. Ranges of some physical properties at 10 m and 20 m locations of 5 fill sites on Corridor-H in West Virginia.

Sites <sup>1</sup>	Depth <sup>2</sup> of A Horizon cm	Depth <sup>2,3</sup> of Solum cm	Horizon <sup>4</sup> Sequence	Texture <sup>5</sup>	Rock <sup>6</sup> fragments % Type	Slope %
<u>Section 1</u>						
<u>26-year-old site</u>						
10 m	6-7	7-14	A-AC-C	sil-sicl-cl	5-50 ss, sis, sh, carb	15-20
20 m	7	17-50+	A-Bw1-Bw2	sil-sicl	0-45 ss, sis, sh	5-10
<u>Section 2</u>						
<u>11-year-old site</u>						
10 m	6-10	6-10	A-C1-C2-C3	sil-sicl-cl	5-45 ss, sis, sh, carb	55
20 m	7	7	A-C	sil-sicl	10-45 ss, sh	55-60
<u>Section 3</u>						
<u>8-year-old site</u>						
10 m	4-6	6-18	A-C	sil-sicl	5-45 ss, sis, sh, carb	50-55
20 m	4-5	12-18	A-AC-C1-C2	sil-sicl-sic	5-50 ss, sis, sh, carb	45-50
<u>Section 4</u>						
<u>1-2-year-old site</u>						
10 m	--	--	C/A-C1-C2	sil-sicl-cl	50-100 sh, ss, sis	65-70
20 m	--	--	C/A-C1-C2	sicl	50-100 sh, ss	60-70
<u>Section 5</u>						
<u>1-2-year-old site</u>						
10 m	4-5	4-5	A-C	sil-sicl-cl	25-80 ss, sis, sh	25
20 m	3-4	3-4	A-C	sil-sicl-cl	35-90 ss, sh	15-20

<sup>1</sup> Sites were sampled at 10 m and 20 m locations from the site boundary.

<sup>2</sup> The range of depths observed in the A-horizons and the solum includes three profiles.

<sup>3</sup> The solum includes all horizons except C, Cr, and R.

<sup>4</sup> Horizon sequence is given for pits described on the centerline transect.

<sup>5</sup> sil=silt loam, sicl=silty clay loam, sic=silty clay, cl=clay loam, sic=silty clay.

<sup>6</sup> % rock fragments by volume (> 2 mm); ss=sandstone, sis=siltstone, sh=shale, carb=carbolic.

loam texture. Rock fragments were absent in these horizons. Carbolithic fragments were described throughout some pits on the site. Slope ranged from 10 to 20%. Field pH ranged from 4.0 to 7.5.

11-year-old site. This site is located within section 2 (Fig. 2). Thickness of the A horizon ranged from 6 to 10 cm. The dominant structure for the A horizon was weak granular, and texture was silt loam with 5-15 % sandstone, siltstone and shale fragments. No AC or B horizons were described at this site, however multiple C horizons were present and included C, C1, C2, and C3 horizons. The dominant texture of the C horizons was silty clay loam with 25-45% sandstone, siltstone and shale fragments. Clay loam texture was described in the C3 horizon of one pit. Carbolithic fragments were described throughout some pits. Slope ranged from 55 to 60%. Field pH ranged from 5.5 to 8.0.

8-year-old site. This site is located within section 3 (Fig. 2). The A horizon thickness ranged from 4 to 6 cm. Structure of the A horizon was moderate granular, and texture was silt loam with 5% sandstone fragments. Solum thickness ranged from 6 to 18 cm. One AC horizon was described at this site. Its structure was weak granular and subangular blocky, and texture was silt loam with 15% sandstone, siltstone and carbolithic fragments. Bw horizons were common at this site, but not present on the centerline transect. The structure of the Bw horizons was weak subangular blocky. The dominant texture was silt loam with 10-15% sandstone, siltstone and shale fragments. C horizons were silty clay loam and contained 15-50% rock fragments. Carbolithic fragments were described throughout some of the pits described at this site. Slope ranged from 45 to 55%. Field pH ranged from 5.5 to 7.0.

1-2-year-old site. This site is located within section 4 (Fig. 2). The surface horizon was a C/A horizon ranging from 10 to 30 cm thick. This horizon was structureless, massive with pockets of weak granular and subangular blocky structure comprising less than 50% of the total volume of the layer. The dominant texture of the C/A horizon was silty clay loam with 50-60% shale, siltstone and sandstone fragments. Multiple C horizons were described beneath the surface horizon. The dominant textures of the C horizons were silt loam or silty clay loam with 50-100% gray marine shale, sandstone and siltstone fragments. Large bridging voids (20-30 cm

diameter) were described at this site. Slope ranged from 60 to 70%. Field pH ranged from 4.5 to 8.0.

1-2-year-old site. This site is located within section 5 (Fig. 2). Thickness of the A horizon ranged from 3 to 5 cm. Structure was weak granular, described in combination with weak subangular blocky in half of the pits described. Texture of the A horizon was silt loam with 25-80% shale, siltstone and sandstone fragments. The C horizon consisted of 60-90% red and green shale and sandstone fragments. Slope ranged from 20 to 30%. Field pH ranged from 5.5 to 7.0.

#### Summary of Corridor H Sites

Thickness of A horizons ranged from 3 to 10 cm on all sites. These thicknesses are similar to minesoils (Ciolkosz et al., 1985; Haering et al., 1993; Thomas et al., 2000). In general the younger sites had thinner A horizons than the older sites, but A horizons were not as thick on the oldest sites as reported for some minesoils (Thomas et al., 2000). The 1-2 year-old site at section 5 had A horizons of 3 to 5 cm thick with weak structure. This rapid development of A horizons has been observed in minesoils (Ciolkosz et al., 1985; Daniels and Amos 1981; Schafer 1980; Thurman and Sencindiver 1986, Haering et al., 1993). However, distinct A horizons had not yet formed on the other 1-2 year-old site (section 4). The description of C/A horizons indicated that A horizons were in the process of developing on this site.

Solum thickness varied from 3 to 50+ cm. No solum was described in the 1-2 year-old site at section 4, and the solum equaled the thickness of the A horizon on the 1-2 year-old site at section 5 because only A and C horizons were described. Similar horizon designations have been reported for young minesoils (Ciolkosz et al., 1985; Haering et al., 1993; Thomas et al., 2000). Also, no AC or Bw horizons were observed on the 11-year-old site (section 2). AC horizons have been described in some minesoils of the same age (Thomas et al., 2000), but not in others of the same or similar age (Daniels and Amos, 1981; Thomas et al., 2000). The sola thicknesses of the 8-year-old and the 26-year-old sites were similar to sola observed by researchers who evaluated minesoils of similar ages (Ciolkosz et al., 1985; Daniels and Amos, 1981; Thomas et al., 2000). Five of the six sampling points on both the 8-year-old site and the 26-year-old site exhibited AC or Bw horizons. However, these horizons were relatively thin on the 8-year-old site, with the base of the deepest ones being only 18 cm. Some of the sola

observed on the 26-year-old site were deeper than 50 cm. Also, some of these older soils had multiple B horizons, and grade of structure was stronger in the 26-year-old site, relative to the 11-year-old site. Therefore, some of the older soils had cambic horizons (Soil Survey Staff, 1998).

Textures were similar for all the fills because the types of rock fragments observed at each site were similar (Table 4). Also, rock fragment content was very similar among the sites, but tended to be higher in the younger soils, especially the 1-2 year-old sites.

Although field pH values ranged from 4.0 to 8.0 across all sites, most sampling points had a pH of 5.5 to 7.5. The pH values tended to be lower where carbolithic materials were observed in sections 1, 2, and 3, and in section 4 where soils were developing in the dark-colored Devonian shales. Native soils developed from Devonian parent materials tend to be acid (Estepp, 1989; Pyle et al., 1982).

Another factor affecting soil formation is slope steepness. Slope steepness was similar for sections 2, 3, and 4. Less steep slopes were observed in sections 1 and 6. The gentle slopes in these two sections would promote more rapid soil development than in similar aged materials on steeper slopes.

### **Summary**

This survey of constructed soils along highways has demonstrated that the properties of these anthropogenic substrates are like minesoils in that the soil formation processes of time, parent material, climate, vegetation and topography, act on highway soils in a similar manner. Soils developing on highway fills are very similar to soils developing on fills on reclaimed mined lands. Constructed soils on highway cut and on-grade areas commonly encounter bedrock at shallow depths. Therefore, soils on these sites are generally thin, and effective plant rooting may be restricted. Other factors such as surface and subsurface horizonation, rock fragment content, compaction, and the presence of bridging voids or carbolithic fragments are similar between the two anthropogenic substrates.

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