Electrical Resistivity Imaging of Preferential Flow through Surface Mine Valley Fills with Comparison to Other Land Forms

B.M. Greer, Civil and Environmental Engineering
E.T. Hester, Civil and Environmental Engineering
T.M. Burbey, Geological Sciences
C.E. Zipper, Crop and Soil Environmental Sciences

Abstract: Surface coal mining has caused significant land-use change in central Appalachia in the past few decades. This landscape altering process has been shown to affect water quality s in the mining-influenced headwater streams of this biodiverse ecoregion. Among pollutants of concern is total dissolved solids (TDS) which is usually measured via its surrogate parameter, specific conductance (SC). The SC of valley fill effluent is a function of fill construction methods, materials, and age; yet hydrologic studies that relate these variables to water quality are sparse due to the difficulty of implementing traditional hydrologic measurements in fill material. We tested the effectiveness of electrical resistivity imaging (ERI) to monitor subsurface hydrologic flow paths in valley fills. ERI is a non-invasive geophysical inverse technique that maps spatiotemporal changes in resistivity of the subsurface. When a resistance or conductive change is induced in the system, ERI can reveal both geologic structure and hydrologic flows. We paired ERI with artificial rainfall experiments to track highly conductive infiltrated water as it moved through the valley fill. The subsurface structure of two other landforms were also imaged to confirm variations between forms. Results indicate that ERI can be used to identify the subsurface geologic structure as well as track the advancing wetting front and preferential flow paths. We observed that the upper portion of a fill develops a profile that more closely resembles soil with smaller particle sizes, while the deeper profile has higher heterogeneity, with large rocks and void spaces. The sprinkling experiments revealed that water tends to pond on the surface of compacted areas until it reaches preferential flowpaths, where it infiltrates quickly and migrates deeply or laterally. We observed water moving from the surface down to a 20 meter depth in one hour and 15 minutes, and to a depth of 10 meters in just 45 minutes. We also observed lateral preferential flow downslope within 5 meters of the surface, likely due to transmissive zones between end-dumped layers. Finally, when compared to other landscapes we were able to see that a filled highwall slope has larger rocks near the surface than the valley fill, but a similar degree of heterogeneity throughout; while the natural slope has less heterogeneity at depth as is expected in consolidated bedrock. ERI applications can improve understanding of how various fill construction techniques influence subsurface water movement, and in turn aid in the development of valley fill construction methods that will reduce environmental impacts.

References and Related Publications:

Evans, D.M., Zipper, C.E., Hester, E.T., Schoenholtz, S.H. 2015. Hydrologic effects of surface coal mining in Appalachia (U.S.). Journal of the American Water Resources Association 51: 1436–1452.

Greer B.M. 2015. Electrical Resistivity Imaging of Preferential Flow through Surface Mine Valley Fills with Comparison to Other Land Forms. M.S. Thesis, Civil and Environmental Engineering, Virginia Tech.

Acknowledgments: The authors thank Wells Fargo and Company for funding this study through the Clean Technology and Innovation Grant.