2012/2013 Powell River Project Annual Report

Predicting TDS Release from SW Virginia Soil-Overburden Sequences

Dan Johnson, W. Lee Daniels and Zenah Orndorff
Cooperators: Carl Zipper and Matt Eick
Dept of Crop and Soil Environmental Sciences, Virginia Tech
www.landrehab.org

Executive Summary

Release of total dissolved solids (TDS) from Appalachian coal mine spoils to headwater streams has emerged as a significant concern for the coal mining industry, its regulatory agencies, and non-governmental organizations. The overall objective of this project is to develop a new set of techniques to reliably predict the amount, ionic composition, and temporal pattern of TDS release from a range of spoil and overlying soil materials from regional coal surface mines. This project was initiated in 2010 with sole support from Powell River Project. Between 2011 and 2013, we received significant parallel funding for this program from the Appalachian Research Initiative for Environmental Science (ARIES) to support our collaboration with the University of Kentucky and West Virginia University to broaden the scope to the central Appalachian region while continuing to focus on SW Virginia in more detail. Therefore, we are utilizing Powell River Project (PRP) funds to focus specifically on the determination of TDS release potentials of soil-saprolite-hard rock sequences in SW Virginia and adjacent counties in eastern Kentucky and southern West Virginia. This information will better allow operators to determine the thickness and availability of low TDS forming strata for use in new and innovative mining and reclamation plans designed to limit TDS release to local streams.

For the PRP portion of this study, we are sampling 20-30 different locations in representative SW Virginia strata where we can clearly sample a relatively intact section of weathered surficial soils, underlying oxidized and partially weathered (brown) rock strata, continuing down into unweathered gray strata with depth. Samples are being analyzed for size consist, approximate mineralogy, acid-base accounting parameters, Fe-oxide content, abrasion pH/hydrolysis and total elemental analysis. We are also investigating net TDS release from ground/crushed spoil fractions equilibrated with varying soil:water and soi:H_2O_2 ratios to develop TDS release indices. The amount and temporal pattern of TDS release for each material will then be related to the chemical and mineralogical analyses described above to determine which field vs. laboratory determined spoil properties are the best predictor(s) of TDS release potentials.

To date, we have sampled seven locations (with 24 complete weathering sequences) from surface soils down to underlying spoils and preliminary results are presented here. In the field, the interface between weathered and oxidized surficial materials and deeper unweathered strata has been clearly delineated by changes in pH and electrical conductance (EC), but not always clearly separable by color. The break between soft/saprolitic bedrock and hard competent rock is also commonly associated with significant increases in EC and presumably TDS leaching potentials. Finally, it is interesting to note that the separation between oxidized/brown strata above vs. harder reduced/gray strata below is often marked (or controlled) by thin shale/mudrock strata or coal seams.

Background

This report is a continuation of our research over the past decade focusing on TDS release from surface coal mining overburden in central Appalachia. TDS release from surface coal mining overburden continues to be a major topic of public and regulatory concern, giving rise to the need for further research in the area.

Over the past two years we have collaborated with the Virginia Center for Coal and Energy Research and major regional coal producers (Alpha, Arch, Patriot, TECO and others) in the development of a large multi-state research consortium, as the Appalachian Research Initiative for Environmental Science (ARIES; http://www.energy.vt.edu/ARIES). The overall program and detailed scope of work continue to evolve, but our TDS prediction research program was expanded greatly (with ARIES funding) to include significant cooperation with the University of Kentucky (UK - Richard Warner and Chris Barton) and West Virginia University (WVU - Jeff Skousen and Louis McDonald). The expanded program involves a much larger sample set and more detailed analyses than we were capable of addressing with PRP funding. However, the ARIES monies allocated to Virginia Tech are budgeted to support column leaching testing on a much larger (e.g. 40 to 50 spoils) regional sample set, to develop scaling factors for field application of the column data, and to develop a regional GIS + spoil testing data base for future statistical analyses and modeling efforts.

For the past two years, we have utilized the funds provided by PRP to continue our focused and detailed efforts on sampling combined weathered:unweathered soil:spoil sequences in SW Virginia along with analytical testing of those materials and improved TDS prediction methods specific to our strata. That being said, the ARIES funded collaborations with UK and WVU have enable us to "farm out" our Virginia spoil samples (> 20) for much more comprehensive lab testing procedures than would have been possible under our original PRP proposal and will also allow us to correlate results with a much wider range of strata from the adjoining region. Thus, the methods and results detailed below remain specific to the work that we are conducting with PRP funds and do not reflect the larger ARIES project per se.

2011 to 2014 Specific Objectives

1. Measure the net TDS elution potential of a range of materials originating from the Pottsville Group in SW Virginia and analyze the difference between (a) fresh relatively unweathered materials at depth; and (B) well-weathered surficial materials.

2. Determine which indicator has a stronger correlation with TDS elution potential in select mine spoils: (a) Previous long-term exposure to the earth's surface, leading to reduction in soluble salts from the long-term leaching effects of percolating water; or (b) variations in the elemental composition of varying geologic strata.

3. Investigate the nature of the boundary between high and low TDS strata in order to determine if: (a) An abrupt boundary exists at some confining layer, such as a shale; or (b) the boundary is more diffuse, being more related to distance from the earth's surface; or (c) no discernible boundary exists; variations occur with variations in parent material.

4. Determine if a relationship exists between TDS elution potentials and field description traits such as: HCl "fizz" reaction, H_2O_2 reaction and/or Munsell color (e.g. gray vs. brown colors).

Methods and Procedures

A range of weathering x depth samples is being collected from the dominant coal bearing formations of the Pottsville Group throughout SW Virginia. Several samples may also be taken from adjoining areas of Kentucky and West Virginia. Sampling locations are chosen where a clear association between the surface weathered soil horizons and underlying partially weathered rock horizons can be confirmed and the materials are accessible. It is assumed that many of the surficial soils sampled are comprised of colluvium (gravity slope deposits), but that it is locally derived. Ideally, we will sample 3 to 4 replicate sequences from each of the 20-30 primary locations to offer some level of replication and to allow for study of variance within local strata. For the purpose of this study, a "location" is comprised of similar soil to overburden weathering sequences within several hundred meters of one another. First of all, detailed soil and saprolite to rock morphological descriptions are made including textures, structure/rock fabric, weathering features, nature of layer contacts, etc. Samples are being collected from each distinct soil horizon or rock layer/zone (see Fig. 1) beginning from the soil surface and extending to some depth (15 to >50 m) below the surface where visual evidence of weathering and oxidation are not present. Samples are handled as either "soil" horizons or "rock" layers, each being treated differently. Soil samples are passed through a 2mm sieve for subsequent physical and chemical analysis. Rock samples are crushed and sieved until all material also passes through a 2mm sieve. Samples will be further ground as called for by specific tests. After preparation, samples are being analyzed for a range of physical and chemical parameters that we assume may assist in prediction of TDS loadings.

Our overall results will be used to help determine which spoil materials will be relatively low with respect to TDS production for use in final reclamation of backfills and valley fill areas where significant contact with groundwater is anticipated. We also will generate field guidance for depth of cut or removal of these materials vs. easily measureable or observable field criteria. All samples are being analyzed for the following parameters:

Complete USDA-NRCS morphological description for soil horizons
Saturated paste electrical conductance (EC) and pH
Saturated paste EC and pH following hydrogen peroxide oxidation
Exchangeable cations
Dilute acid extractable nutrients and metals
Extractable Fe and Mn oxides
Total-S and S-forms if S $\geq$ 0.2%
Calcium carbonate equivalence (CCE)
% Rock fragments
Particle size analysis

These parameters will be compared to field description traits such as color, depth, cementation, etc., to determine if any relationship exists between quickly identifiable field characteristics and long term TDS elution potential.

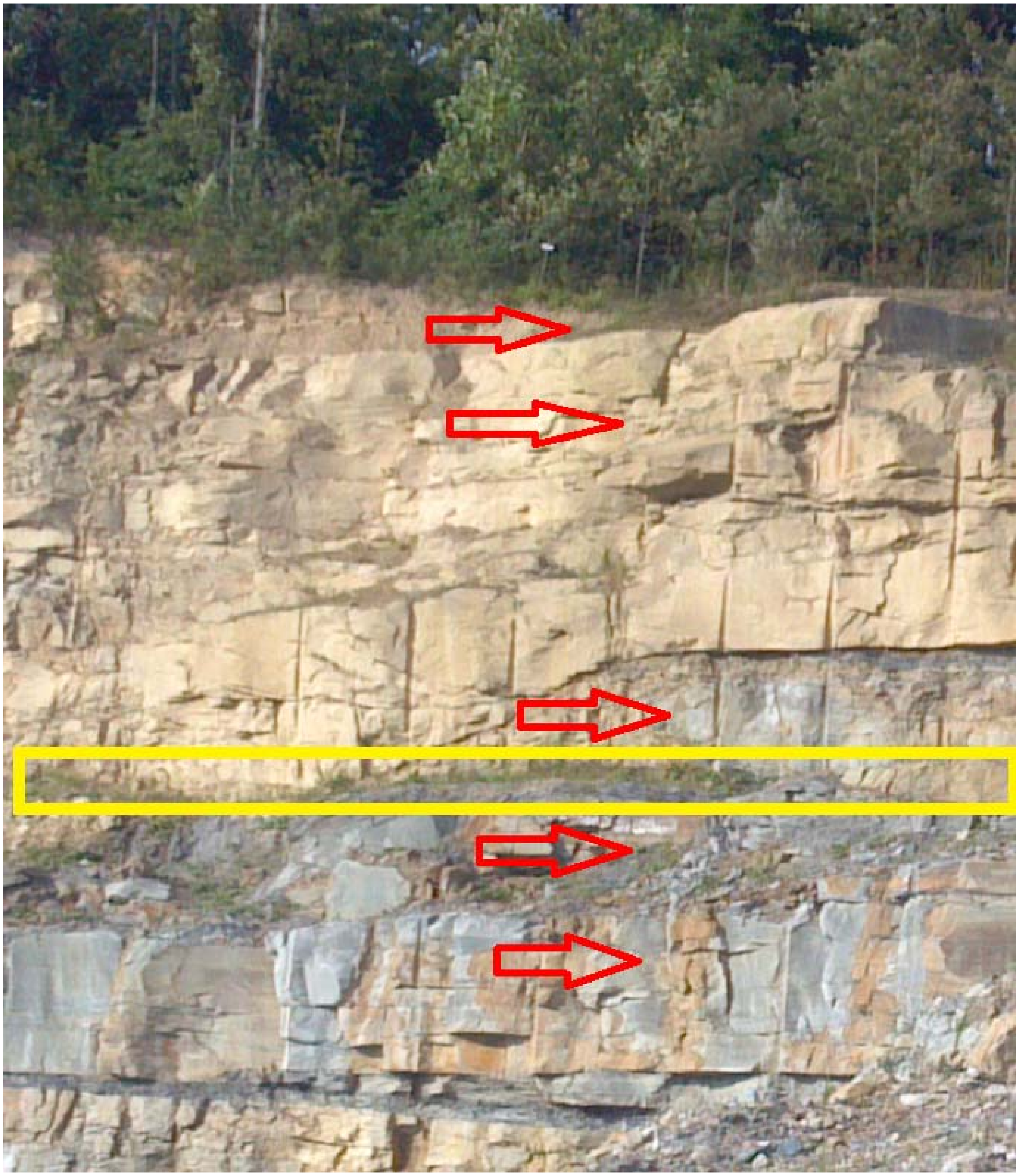

Figure 1 – An example profile illustrating the field sampling scheme employed. Each distinct layer (red arrows) is collected and described. Special notice of the boundary between brown and gray materials (yellow box) is also taken, in an effort to better characterize the transition between these materials. Of the 24 samples to date, this boundary is often a tight shale layer or thin coal seam.

Results to Date

Bulk Soil/Spoil Properties

Twenty four weathering sequences at seven different locations have been sampled to date, with a total of 150 individual samples collected. When time and access has allowed, multiple weathering sequences have been collected in each area. Each of the multiple sequences collected in one area originated from different elevations, changes in the source strata of the material, as well as which coal seam the material is associated with. Replications have also been gathered at three locations. These replications originate from the same elevation/source strata and have been collected from locations within approximately several hundred meters of each other. Three replications from one site are presented in Table 1. Most samples have been processed and tested for saturated paste EC and pH, 1:1 water EC and pH, 1:1 hydrogen peroxide pH, and total S. All samples have been described using field methods (e.g. Munsell color, texture, coarse fragments, rock type, HCl fizz test, peroxide fizz test, etc.). The approximate mineralogy of select samples has been determined from thin sections.

Electrical Conductivity (EC)

Currently, we are using saturated paste EC as a preliminary indicator for initial TDS potential and EC generally increases with depth below the surface. Typically, materials within four meters of the surface produce low EC values (Fig. 2). Low EC materials extended deeper than four meters at several of the sampled locations, which is influenced largely by the local geology, site landscape position and other factors. At most sample locations, EC values increase strongly below the first cemented, unweathered shale seam encountered.

In general, shales were found to have higher EC than sandstones and soil layers, but some sandstones also produced high EC values. Unweathered coal materials were found to have the highest (by far) conductivity values, but this is not unexpected and has been well documented before. Soil B horizons (subsoil layers) were found to have the lowest EC on average, while R layers (hard bedrock) had the highest.

Interestingly, A horizons (topsoil layers) produce higher EC than subsoils, presumably due to their increased organic matter and associated soluble element concentrations via biocycling. However, most A horizons in the area are generally less than 10 cm thick, which is not a substantial volume considering most surface mines remove tens of meters of material.

Table 1- Morphological and field test indicators for three replications of a soil to spoil weathering sequence collected within several hundred meters of each other. Depths indicate lower boundaries of layers. "A" and "Bw" indicate soft material, while "R" designates bedrock layers. Field moist Munsell colors are indicated by hue, value, and chroma. Some local variability can be observed, but EC and pH generally increase with depth. Note sudden increase in pH at bedrock contact. Electrical conductance (EC; mmhos/cm) values also increase abruptly below the first intact shale or coal layer.

Layer Type	*Depth (m)*	*Rock Type*	*Below Shale Seam?*	*Hue*	*Value*	*Chroma*	*pH*	*EC*
A	0.02	Soil	no	7.5YR	2.5	2	**4.52**	**0.25**
Bw	1.5	Soil	no	10YR	5	6	**5.64**	**0.11**
R1	3.5	SS	no	7.5YR	5	8	**7.92**	**0.22**
R2	3.9	coal	yes	10YR	2	1	**4.38**	**0.25**
A	0.04	Soil	no	10YR	2	1	**4.93**	**0.34**
Bw	1.25	Soil	no	10YR	5	6	**4.82**	**0.14**
R1	3.25	SS	no	7.5YR	4	6	**5.86**	**0.13**
R2	3.75	SS	no	7.5YR	4	6	**6.48**	**0.10**
R3	3.75	Shale	yes	7.5YR	3	1	**4.42**	**0.92**
A	0.03	Soil	no	10YR	2	1	**4.54**	**0.28**
Bw	1.35	Soil	no	10YR	5	6	**5.08**	**0.12**
R1	9	SS	no	7.5YR	4	6	**6.44**	**0.08**
R2	9.75	Shale	yes	10YR	3	1	**7.04**	**0.66**
R3	9.75	SS	yes	10YR	6	1	**7.94**	**1.05**

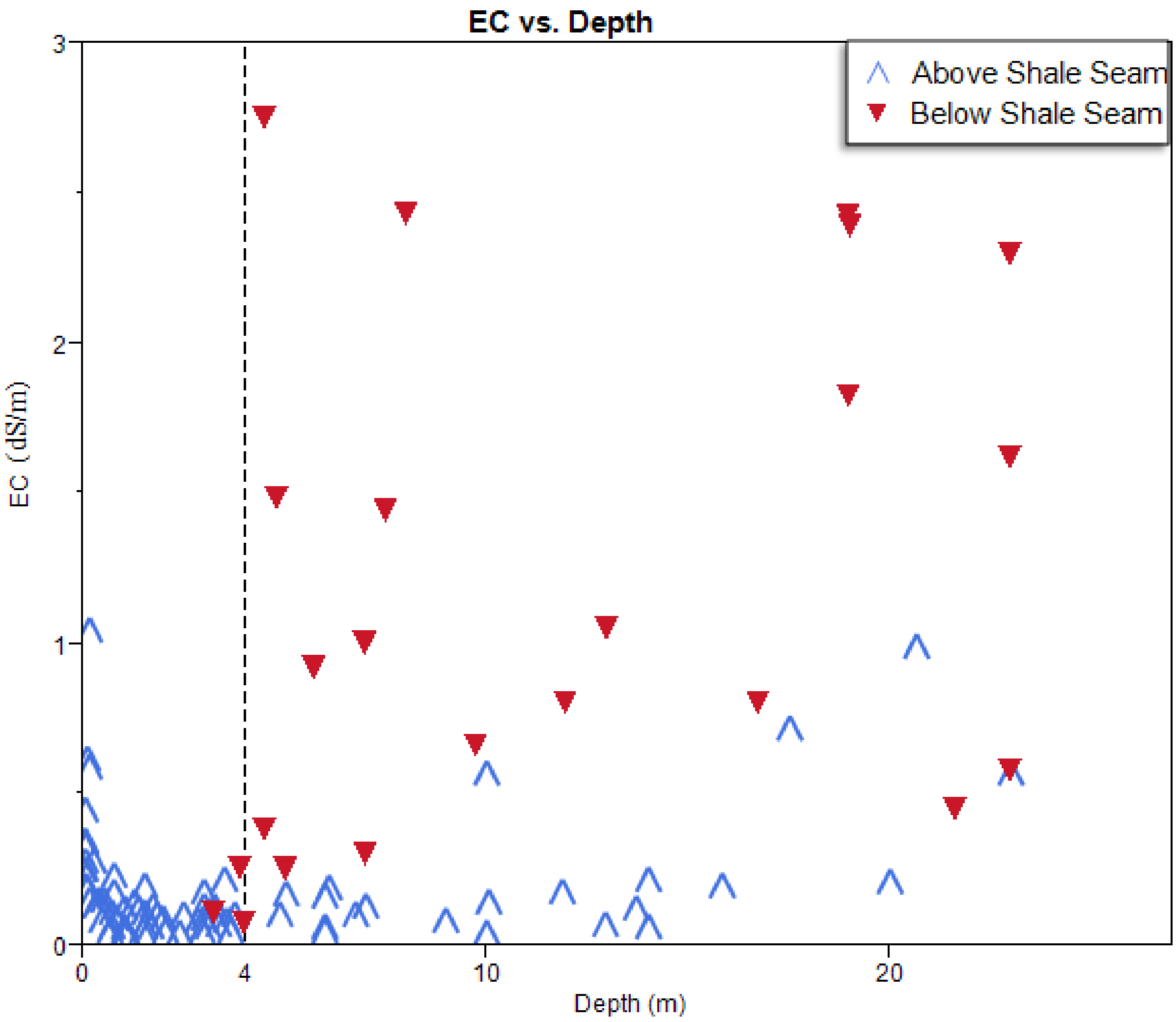

Figure 2 – Saturated paste EC versus depth in meters for 105 samples, which are denoted as being collected above or below the first occurring unweathered shale seam. Topsoil layers (far left of chart, at ~0.1 m) generate significantly higher conductivity values than the associated subsoil layers below. The probability of encountering higher EC materials increases sharply at a depth of around four meters and/or below the first unweathered shale seam.

Color can be an accurate field predictor of EC, but must be used with caution. Generally, grayish (Munsell chroma 1) materials produced higher EC values than brownish materials (Munsell chroma >1), but a few brown materials returned quite high EC values. Further investigation is needed to determine the cause of this phenomenon. We hope that some of our more specialized lab analyses (e.g., thin section mineralogy) will reveal what is different about these few samples. Interestingly, layers noted as containing visible fossils produced drastically higher conductivity values than similar layers without fossils. Various fossil types have been noted, including shells, roots, leaves, stems, bark, and even tree trunks; these have all had the same effect of increasing EC values and as such layers containing fossils should be handled separately and isolated, where feasible. Other field indicators (e.g. HCl and peroxide fizz tests) are currently being analyzed to determine their usefulness in identifying high EC materials.

Weathering Boundary

The boundary between weathered and unweathered materials is very complex and is influenced by a large number of factors. The study location is in a humid climate with high rainfall, which drives most of the weathering reactions. It makes sense that at some depth, materials would begin to be unaffected by the surficial weathering reactions taking place, but this depth has proven to be highly variable from site-to-site. At a number of sites (see last year’s report), we have noted a significant increase in EC between the lowermost saprolitic material and hard rock contact (R layers). The occurrence of a shallow, intact, cemented shale layer at many sites largely appears to control the depth of weathering by preventing further downward movement of water and oxygen into the weathering soil:rock profile. Most sites were observed to abruptly change from brownish to grayish colors directly below shallow occurring shale layers. Lab analysis revealed that this change is coupled with a sharp increase in EC (and often pH). Shale layers which have undergone significant weathering (e.g. fractured, lost cementation) lose this restrictive effect on water and oxygen and allow weathering to penetrate through the layer. Sites lacking a near surface shale layer tend to have more diffuse transitions from the weathered zones into unweathered materials and deeper weathering overall.

Future Plans and Deliverables

More samples are needed to fill in the data set and improve our statistical power. Sampling will continue into summer of 2014 as we gain access to more sites; hopefully rounding out the total number of sites to near 30. Lab analyses will move into some of the slower, more complicated tests such as CCE and extractable Fe+Mn oxides, but should be completed late in 2014. Final data analysis and reporting for the project will be completed by early summer 2015. Preliminary results from this research were presented at the June, 2013, American Society of Mining and Reclamation conference in Laramie, WY, and are available online at: http://www.asmr.us/Meetings/2013/Wednesday%20S-12/12-1%20Johnson.mp4. A wide array of publications is expected, including additional conference presentations and journal articles along with Dan Johnson's underlying PhD dissertation.