Constructing Mine Spoil Fills to Reduce TDS in Discharged Waters

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Introduction

The Appalachian coal industry is facing regulatory challenges. New methods are being developed for constructing post-mining landforms with the intent of reducing environmental impacts. This project seeks to develop post-mine landform construction methods that can be applied by the coal industry to achieve improved environmental outcomes.

Valley fill (VF) construction often occurs on Appalachian coal surface mines. Although issues concerning sustainable landform construction are especially acute on mining operations with VFs, the mine spoil fill construction practices being demonstrated by this project have potential for application by surface mining operations throughout Appalachia on conventional backfills, VFs, and other landforms.

Project Goals

This project is developing, demonstrating, and assessing effectiveness of mine spoil fill and landform construction practices intended to reduce the generation of total dissolved solids (TDS) while achieving other environmental and regulatory goals. The mining "best practices" being developed and demonstrated through this research are intended to:

- Reduce TDS levels in water discharge, relative to fills constructed using conventional techniques.
- Produce surface-water flows that more closely approximate pre-mining hydrology compared to those produced by conventional fills.
- Establish soils and vegetative cover that will develop into forested ecosystems resembling those which occur on nearby non-mined areas.
- Control costs to extent possible and in a manner that allows profitable mining operations.

Here, we describe an application of mine spoil fill design and construction methods intended to achieve the above goals. We are referring to such a design as a low-TDS or experimental valley fill. The project is ongoing so this report contains only preliminary results. Hence, we report only the specific conductance (SC) of discharged waters, although other parameters are also being measured.

Methods

In early 2010, discussion of methods for constructing low-TDS mine spoil fills were initiated with a cooperating mining firm. A project site was located. The area, although previously mined prior to the Surface Mining Control and Reclamation Act (SMCRA), was primarily wooded and contained a free-flowing stream with specific conductance (SC) levels that were generally in the 300 to 400 µS/cm range. The watershed in question contained pre-SMCRA mining areas, pre-SMCRA spoils that had been disposed but had become well vegetated, and unmined areas with forest vegetation.

Mine Spoil Assessment for TDS Generation Potential: Techniques developed to characterize mine spoils for their TDS generation potentials **(**Orndorff et al. 2015; Daniels et al. 2016) were applied to develop a mining plan. Prior to VF construction in 2011, the cooperating mining firm was requested to provide the researchers with access to a drill core, and with guidance concerning what they expect to be a typical shot sequence. The drill core was segmented and sampled such that the material intended for each layer of the shot sequence was characterized for TDS generation potentials separately. Rock samples from the drill core for each lift were placed in columns and leached sequentially with simulated rainwater. This process was intended to simulate exposure to environmental waters in the field. Waters produced by the sequential leachings were tested for their overall quality and TDS components. Test results were used to develop mine-spoil handling and management plans.

Fill Design and Construction: We worked with the mining firm to develop a valley fill construction plan that was intended to achieve project goals. We developed guidance to aid that process (summarized by Table 1). We worked with the mining firms to develop a VF design and construction procedure while considering the nature of the mining site and the materials available.

Environmental Monitoring: Experimental and conventional fills are being monitored to enable comparisons of water discharges from experimental fills to those of other fills constructed in similar geologic strata using conventional methods and to pre-mining background data. Primary monitoring parameters include electrical conductivity (EC) and stream discharge (Table 2). Specific conductance (SC = EC corrected for temperature) works well as a proxy for TDS because the conductivity of a solution is directly related to the concentration of dissolved salts and water temperature. Unlike TDS, SC can be measured quickly and easily in the field.

We monitor SC in streams using automatic loggers that record SC measurements at 15 minute intervals. We monitor stream discharge using automated water-level loggers installed in flumes based on methods developed by Dr. Richard Warner (University of Kentucky) and implemented with his advice. During monthly field visits we clean the SC and water-level loggers and flumes. In the field, SC loggers are calibrated with a handheld conductivity meter and water-level loggers are calibrated based on manual depth measurements in the flume. Water samples are also collected monthly for laboratory analysis of major ions prevalent in the Appalachian Plateau region, including sulfate, bicarbonate, calcium, magnesium, sodium, potassium, and chloride, along with selected trace metals. Field notes are recorded and photographs are obtained to track the fill construction process.

To ensure data quality, data points known or suspected as erroneous are flagged and excluded from further analyses. Causes for erroneous data have included malfunctioning equipment, cessation of streamflow, burying of meters with sediments, ice accumulation, and high water flows that exceed flume capacity.

Construction Progress: This manuscript describes project results through mid-2016. As of this writing, the valley fill remains under construction; and the mining firm is actively placing spoil materials into the fill. Our observation during site visitations indicate that spoil materials are being placed in the valley fill in accord with the mining and valley fill construction plan.

Table 1. Summary of spoil management and placement methods (recommended, planned, and employed) for construction of experimental mine spoil fills.

Design Factor	Practice
Landform Design	Minimize flat and near-level areas with potential to enable rainfall infiltration to bulk fill†; and/or construct compact subsurface spoils beneath such areas as needed to channelize or direct infiltrating waters so as to minimize hydrologic interactions with high total-dissolved-solids (TDS)-generating spoils.
Spoil Characterization	Obtain drill cores prior to mining; obtain rock samples from those drill cores and test those strata to determine TDS generation potentials.
Water Drainage	Construct drains using durable low-TDS rock materials. Provide a rock filter or geotextile to protect the drain. Intercept major groundwater flows that enter the mining excavation and valley fill (VF) area; direct these flows into constructed drains, ensuring gravity-directed flow to spoil exits. This practice is intended to (a) minimize interactions of groundwater flows with TDS-generating spoil materials, and (b) provide source waters for dilution of any higher-TDS waters that may be produced by the fill via rainfall infiltration.
Mine Spoil Selection for Bulk Fill	Select low to medium-TDS spoil materials for placement in VFs. Identify high-TDS spoil materials for "high and dry" placement and isolation away from hydrologic flows.
Mine Spoil Placement for Bulk Fill	Loose dump selected spoils to construct bulk fill. This technique for valley fill construction was selected due to the availability of relatively low-TDS spoil materials in quantities adequate to construct the mine-spoil fill at this location.
Bulk Fill Surface	Compact surface (crown) of bulk fill materials, to the extent that is practical and feasible to achieve a low-permeable barrier prior to application of surface-soil materials.
Mine Soil Construction	Cover compacted zone with salvaged soil (to include rooting materials and seed bank) where possible, with low-TDS weathered spoils where soil salvage is not possible, or with a mixture of weathered spoils and salvaged soils.
Contributing Area Management	Minimize open spoil areas by mining and reclaiming in rapid sequence. Ensure that groundwater flows are captured and channelized in low-TDS drainage structures; and that rainwater infiltration into bulk fill is minimized throughout the mining area.
Reclamation / Revegetation	Use the Forestry Reclamation Approach (FRA) where compatible with post-mining land use goals.
Surface Water Management	Ensure that all surface-water drains are pitched, lined, or underlain by compacted spoils as needed to ensure minimal infiltration. Minimize impoundments on mine spoil fills; if above-fill impoundments are necessary, install lining or compact underlying spoils as needed to ensure against water loss from pond bottoms into bulk fill.

† The term "bulk fill" is intended to refer to the mass of spoils placed within the VF. The bulk fill does not include surface materials intended to provide plant rooting, water infiltration, and near-surface hydrologic flows.

Table 2. Current (through 8/2016) data collection and instrumentation at the experimental and conventional valley fill sites. Water samples for major ion analysis are collected monthly while other listed parameters are recorded by data loggers at 15 minute intervals.

Monitoring parameter	Experimental Valley Fill	Conventional Valley Fill
Status	Fill construction began 4/27/2015. Active filling continues to date. Fill lifts not yet evident.	Completed 2007. Conventional reclamation with grass cover.
Conductivity & water temp.	7/11/2012–4/3/2015. Reinstalled 7/24/2015	Since 8/14/2012
Stream stage and discharge	12/15/2012–4/3/2015. Reinstalled 11/11/2015	Since 12/15/2012
Barometric pressure	- - - - - - - - - - - - - - - - - Since 7/2012 - - - - - - - - - - - - - - - - -	
Water chemistry: major ions and trace metals	Since 9/4/2012	Since 9/4/2012
Precipitation	- - - - - - - - - - - - - - - - - Since 7/2012 - - - - - - - - - - - - - - - - -	

Results

Mine spoils from mining lifts (layers) 1 and 3 were pre-selected to be placed in the experimental VF based on our laboratory analyses of SC and TDS components from drill core samples (Figure 1). We began monitoring SC in the stream at the experimental VF site in July 2012. In mid-2014 the VF construction process was initiated with logging and soil removal in the VF footprint. Bulk spoil disposal in the VF began in April 2015 and continues to date (Figure 2).

Specific conductance downstream of the experimental VF has increased gradually since VF construction started (Figure 2), and currently exceeds the levels measured in column leachates for layers 1 and 3 (Figure 1). However, SC of the experimental VF discharge remains well below that of the conventional VF (Figure 2). SC increases did not begin until after rock disturbance began (i.e., there was no discernible SC increase during logging and soil removal). SC drops rapidly (within a few hours) after rainfall, but quickly (usually within 1 day) rebounds to baseline after rainfall stops (downward spikes in Figure 2).

The experimental fill remains under construction. Therefore, long-term (and post-closure) effects of experimental fill construction techniques are not known.

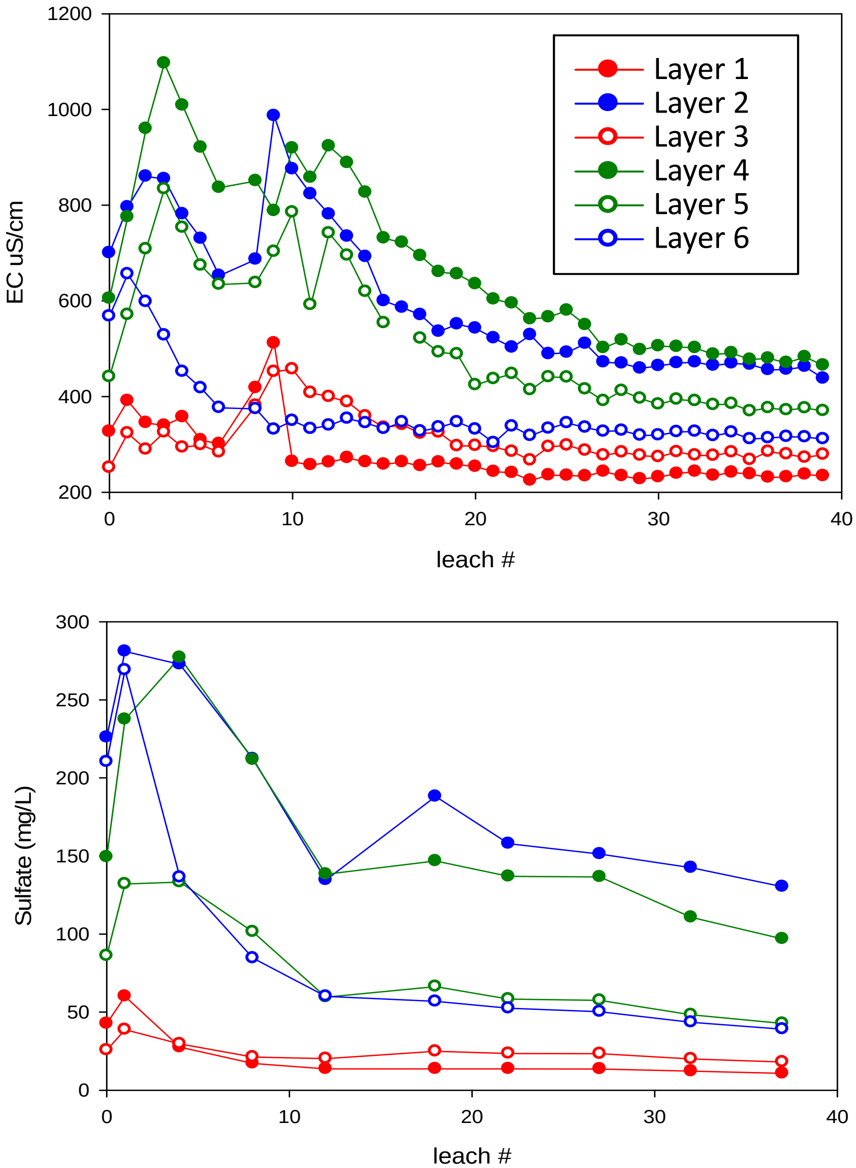

Figure 1. Data generated by the mine spoil testing procedure and used to design the experimental valley fill. Mine spoils from different stratigraphic layers, segmented according to the mining firm's planned shot sequence, are tested for production of conductivity (above), sulfate (below) and other constituents with successive leachings. Layers 1 and 3 were selected for placement in the experimental valley fill.

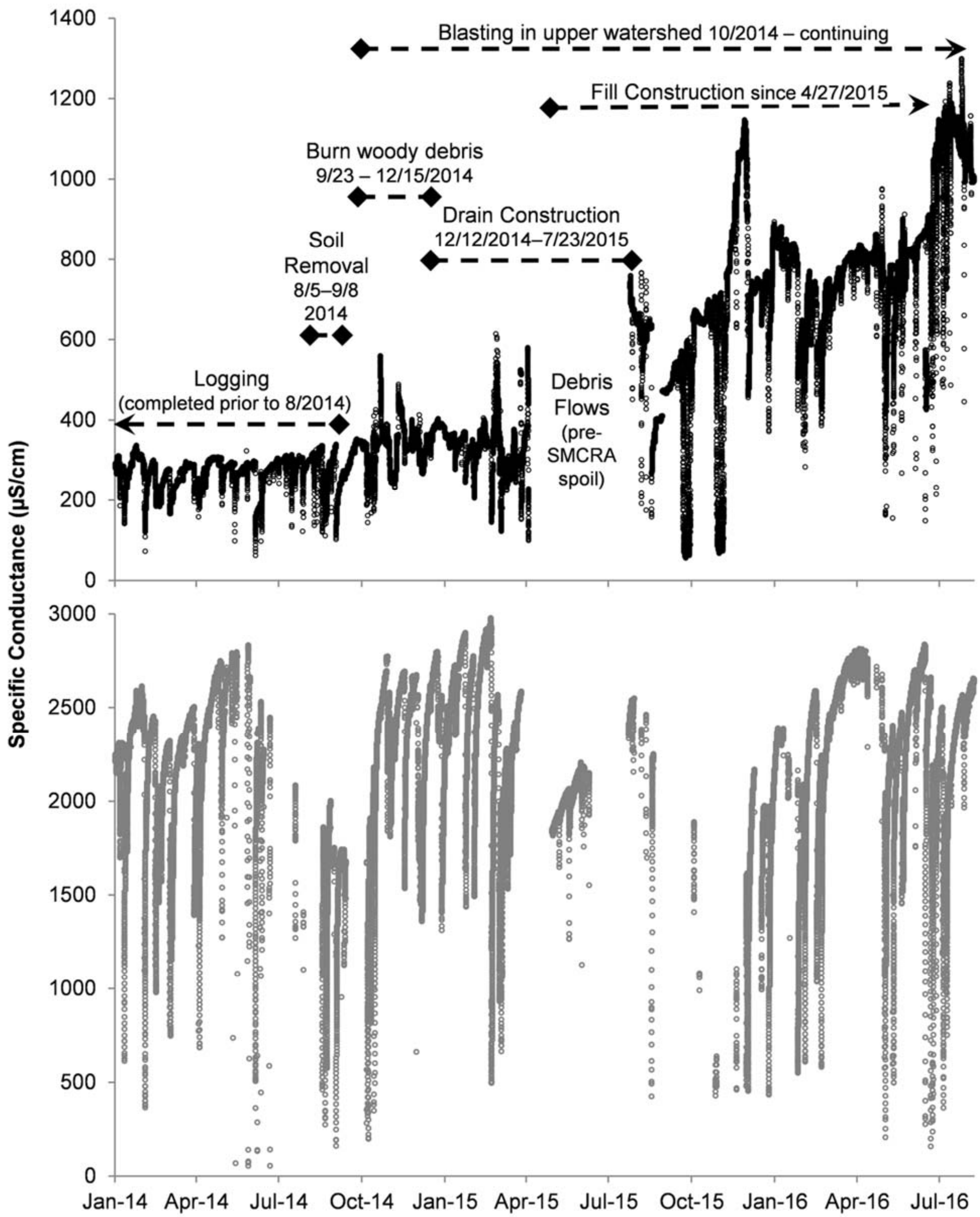

Figure 2. Specific conductance data for the experimental (top) and conventional (bottom) valley fill streams, and construction timeline for the experimental valley fill. Note that the Y-axis scales differ between the top and bottom graphs. Placement of rock materials in the experimental fill is continuing as of this writing.

Summary

The experimental valley fill remains under construction as of this writing. We expect to continue monitoring the experimental valley fill as construction continues. Observations to date indicate:

1. Strategic spoil management can reduce the SC of waters emerging from mine spoil fills during construction (relative to results of conventional practices).
2. Leaching columns appear to predict spoils' relative TDS production potentials. Capability to predict field SC is under evaluation.
3. Effectiveness of fill closure procedures in reducing SC of VF drainage is not yet known.

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