Crossville Coal Passive Treatment System – Redesign of a Non-Functioning Iron and Manganese Treatment System

Wesley Smith, Adam Ramsey, Rick Mann

Office of Surface Mining Reclamation and Enforcement, Lexington Field Office, 2675 Regency Road Lexington, KY, wsmith@osmre.gov

Abstract

Unanticipated acid mine drainage (AMD) discharges from the Crossville Coal surface mine (Crossville) in Tennessee were initially treated using an anoxic limestone drain (ALD), treatment ponds and manganese removal beds. Failure of the ALD resulted in the manganese removal beds plugging with iron precipitate, which required the discharges to be pumped to additional treatment structures where it was chemically treated to achieve compliance with effluent limits. These treatment measures not only substantially increased treatment costs but resulted in repeated violations of the terms and conditions of Crossville's mining and NPDES permits. Due to Crossville's financial conditions, Crossville was unable to abate the violations, which resulted in the Office of Surface Mining Reclamation and Enforcement (OSMRE), the regulatory authority in Tennessee, forfeiting Crossville's reclamation bonds to complete reclamation. Upon forfeiture, OSMRE took control of the site and redesigned the treatment system, taking advantage of some existing structures with emphasis on a long-term passive treatment solution. The source of the mine drainage is ground and surface water which artesian through the mine spoil and discharge from the interface of the spoil and original solid strata (low wall) of the reclaimed pit. The combination of coal extraction, the steeply dipping geology, and reclamation of the final mining pit allowed surface water that infiltrated the mine spoil and groundwater intersecting the mining area to accumulate in the final mine pit. This scenario resulted in the creation of a large underground reservoir that subjected the overlying mine spoil to constant leaching, thus creating the non-compliant AMD discharges from the site. The characteristics of the AMD discharges include low dissolved oxygen (<1 mg/L), approximately 50 mg/L alkalinity, and iron and manganese concentrations of approximately 30 mg/L and 18 mg/L, respectively. After taking control of the site, OSMRE's goals were to replace the failed passive treatment system with a permanent solution to treat the AMD discharges without the use of chemicals or electricity. The passive treatment system redesign included large ponds, waterfalls, and shallow sinuous ditches to increase dissolved oxygen and release carbon dioxide. The surface runoff flow patterns from the contributing watershed were also redesigned to minimize both surface runoff entering the system and infiltration into the spoils. The existing manganese removal bed was redesigned using AMDTreat, and the limestone replaced, with the used rock being recycled to line newly constructed ditches. Currently the treatment system is operating without chemical treatment or electricity.

Keywords: Passive treatment, manganese, reclamation, forfeiture

History

The Crossville Coal surface mine is located near the central portion of the Cumberland Plateau in Cumberland County, TN. The site was initially permitted under the Tennessee Interim program in 1980. In 1997, the site was permitted by OSMRE. The mine's target coal seam was the Sewanee coal seam, which varied in thickness from 0.5 ft to 40 ft (0.15 m to 12 m). The permit straddles the northeast-trending Sequatchie Valley anticline (Fig. 1). The majority of mining occurred on the northwest limb of this anticline, where the dip is approximately 12° (Fig. 2).

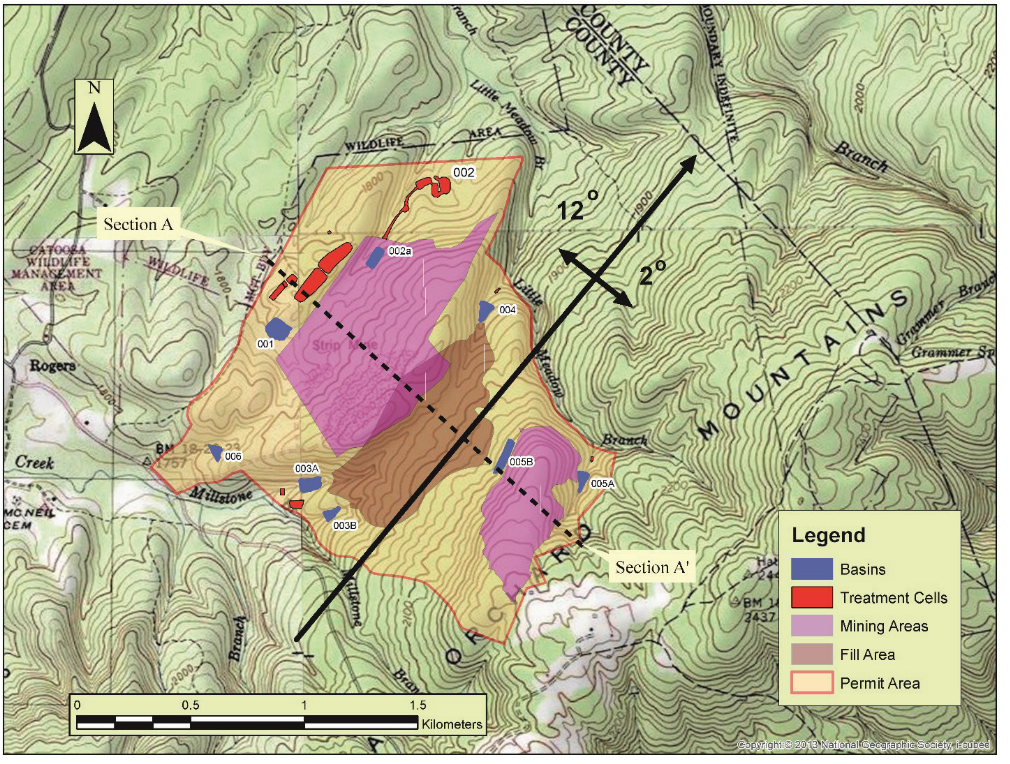

Figure 1 *Site Map showing the Sequatchie Valley Anticline*

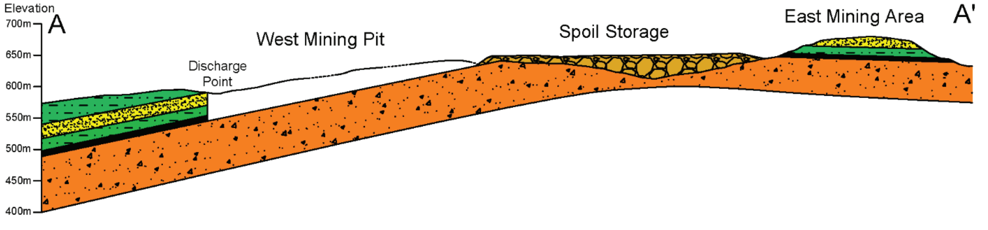

Figure 2 *Cross Section A-A' at Crossville Coal Mine Site*

The Vandever Formation, Newton Sandstone, Whitwell Shale and Sewanee Conglomerate, all Lower Pennsylvanian in age, were disturbed as part of the mining (Fig. 3). Elevated manganese concentrations were first identified at the site in 1999. Larsen et al. (2005) found the primary source of manganese to be siderite concretions and cements in the shale, mudstone and sandstone overburden.

Discharges from the pit were first controlled by pumping the pit water through a "maelstrom oxidizer" in combination with the use of sodium hydroxide until a passive treatment system was completed in 2014. The passive treatment system included an ALD, two settling ponds and a manganese removal bed (Fig. 4). During backfilling operations, a bed of crushed limestone with dimensions of 250 × 150 × 3 ft (76 × 46 × 0.91 m) was placed in the west mining pit, directly beneath a large, lined sediment pond (herein referred to as Pond 002A). A limestone chimney drain was also constructed along the low wall of the pit to transport water from the reclaimed pit to the ALD which was 600 × 8 × 4 ft (183 × 2.4 × 1.2 m) in size. Water discharged from the ALD into a sump, which

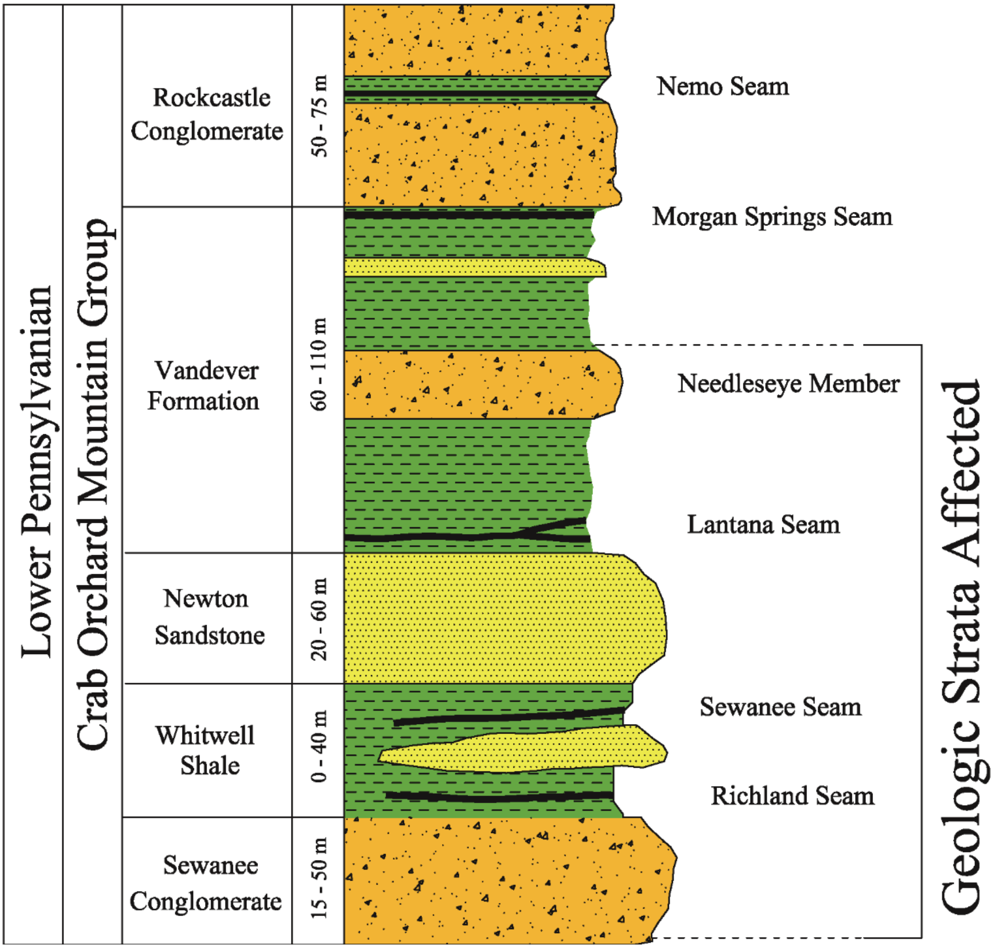

***Figure 3** Geologic Strata at Crossville Coal*

subsequently discharged to two settling ponds in series which were 216 × 86 × 6.3 ft (66 × 26 × 1.9 m) and 176 × 80 × 5.5 ft (54 × 24 × 1.7 m) in size, respectively. Water flowing out the second settling pond flowed to a 200 × 125 × 5.6 ft (61 × 38 × 1.7 m) manganese removal bed.

Although the treatment system was initially successful, within 1 year after installation the system was incapable of meeting effluent limits during high flow events, resulting in the need to pump water to the maelstrom oxidizer where it was treated with sodium hydroxide prior to discharge. In 2021, the reclamation bond was forfeited and OSMRE initiated a redesign of the treatment system. During the OSMRE investigation, water was found to artesian at the surface above where the chimney drain transitioned into the ALD, a likely indicator that the ALD was plugged and no longer capable of transmitting the flow from the pit. In addition, the limestone in the manganese bed was found to be coated with iron precipitate and essentially non-functional, requiring nearly continuous pumping to meet effluent standards. Water sampling of the artesian discharge above the ALD indicated that the water had low dissolved oxygen (< 1 mg/L), approximately 50 mg/L alkalinity, and iron and manganese concentrations of approximately 30 mg/L and 18 mg/L, respectively. This raw water quality has remained consistent over nearly two years of monitoring. OSMRE constructed a weir at the site and installed transducers in previously drilled backfill wells to determine

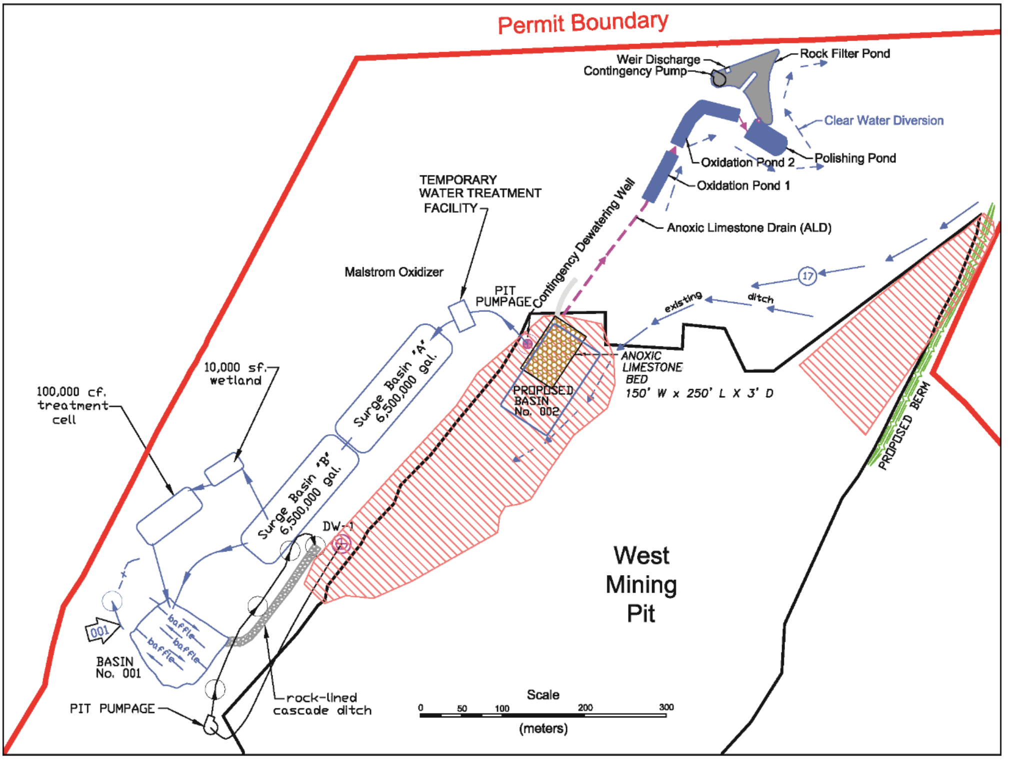

Figure 4 *Original Treatment System Design*

the flow variability and elevation of water in the reclaimed pit. Flow has been measured as high as 1,276 gpm (4,830 L/min), with an average flow of 219 gpm (829 L/min), and a 90th percentile of 468 gpm (1,772 L/min). Much of the variability was due to surface water entering the treatment system, as there was a near instantaneous increase in flow during precipitation events.

Goals of the treatment system redesign included: eliminate pumping, the need for electricity and chemical treatment, minimize maintenance requirements, reduce infiltration, minimize surface water entering the system, increase residence time, and ensure the iron concentration of water entering the manganese beds is < 1 mg/L. The local geology complicated these goals, as the depth to bedrock in many places is a meter or less, therefore, constructing additional ponds, or expanding the footprint of the system was not an option.

As mentioned previously, variability in the flow of water that would need to be treated fluctuated greatly due to surface water entering the system. To minimize the inflow of surface water runoff, several surface water diversions were designed and constructed reducing the effective watershed treatment area from approximately 124 ac (50.18 ha) to 12 ac (4.85 ha). The diversions were designed using the SEDCAD software based upon a 25-year, 24-hour storm event. Based on the soil in which the diversions were constructed, some of the diversions were lined with a 40 mm HPDE liner to reduce infiltration into the mine spoil and some were rock lined to reduce long term erosion and increase stability. From preliminary monitoring data to date, storm flow and duration have been greatly reduced and ongoing monitoring will continue to assist in determining how much of an effect the diversions have had on the base flow.

The chimney drain was excavated and the transition from the drain to the ALD was sealed with bentonite. During this process a portion of the ALD was excavated, and it was confirmed that iron precipitate had plugged the ALD resulting in its failure. The plugged ALD allowed mine water to fill up the reclaimed pit and artesian out of the spoil at the toe of the Pond 002A and discharge over the low wall. Previously, Pond 002A which is 350 × 200 × 13 ft (107 × 61 × 4.0 m) was not included in the mine drainage treatment system, only treating surface water runoff, and discharging into the adjacent tributary. Since Pond 002A was constructed entirely above the reclaimed mine pit, OSMRE made the decision to identify the location of the artesian water discharges, consolidate the discharges to a central location, and route them through the redesigned treatment system. After consolidating these discharges, a new sump was constructed (herein referred to as the raw water sump), positioning the sump's embankment on the solid unmined low wall. By doing so, the sump's embankment would serve a dual purpose of intersecting the chimney drain, forcing the water which previously flowed into the ALD to artesian to the surface and into the newly constructed raw water sump, as well as capturing the water that was previously boiling up and discharging over the low wall. A spillway was constructed to connect the raw water sump to Pond 002A. The spillway of Pond 002A was also reconstructed to discharge into the treatment system rather than the adjacent tributary. This pond was equipped with baffles to increase travel time and allow for an increase in dissolved oxygen and release of carbon dioxide. Between the spillway of Pond 002A and the settling pond, a shallow sinuous ditch with dimesons of 280 × 28 × 1.3 ft (85 × 8.5 × 0.40 m) was constructed over the abandoned ALD. Railroad ties were used to create 28 baffles in the ditch to increase residence time. Baffles were also installed in all ponds to eliminate short circuiting and increase residence time. The majority of iron now precipitates in Pond 002A, which aides in keeping iron precipitate out of the manganese beds.

The size of rock in the existing manganese bed was R-3 rip rap, so it was excavated and replaced with AASHTO #3 stone, with the excavated rock used to line the newly constructed ditches. The second settling pond in series was also converted to an additional manganese bed as AMDTreat indicated that the original bed footprint was insufficient at high flow. Three wells were installed in each manganese bed to measure sludge accumulation and rocks were suspended in each of the wells to monitor for iron precipitate. A header pipe and valves were installed in the second manganese bed to ensure flow distribution. Table 1 illustrates the latest water quality data as the water moves downstream through the treatment system.

Finally, a weir was constructed in the spillway of 002A to allow for additional storage within the impounding structure. The weir was designed with two 6" (15.24 cm) valves that can be adjusted to maintain a baseflow of approximately 200-250 gpm (757–946 L/min). The weir can impound approximately 2.84 ft (0.86 m) or 4.5 ac-ft (5,550.66 m^3) of water if flows increase above the set rate of the valves. This will allow control of the flow of water entering the system, so as to not overload the system and potentially coat the limestone with iron precipitate.

Table 1 *Water Quality Data October 2023 – Upstream to Downstream Features*

Location	pH	Specific Conductance	Total Iron	Total Manganese
		µS/cm	mg/L	mg/L
Raw Water Sump	6.29	1040	25.00	18.10
Pond 02A Spillway	6.53	1001	3.10	17.30
End of Sinuous Ditch	7.02	985	1.38	7.12
Settling Pond Spillway	6.84	1003	0.45	4.76
Mn Bed #1 Spillway	7.18	1050	0.23	<0.04
Outfall	7.61	1059	0.13	<0.04

Conclusions

Monthly expenditures have decreased substantially by eliminating the need for electricity, and all water now discharges through a single outfall. The monthly cost savings as compared to the previous pump and treat system is approximately $50,000 per month. The valve system in the spillway at Pond 002A will ensure flow increases from precipitation events are more evenly distributed. The site will continue to be monitored throughout the seasons to quantify the decrease in flow due to changes in geomorphology.

References

Larsen, D., Mann, R. (2005) Origin of high manganese concentrations in coal mine discharge, eastern Tennessee. Journal of Geochemical Exploration, 86:143-146