Arnot No. 2 Mine Discharge 4 Passive Treatment System Investigation

Technical Report Provided by Hedin Environmental through the Trout Unlimited AMD Technical Assistance Program

October 28, 2009

Background

The Arnot No. 2 Mine Discharge 4 Passive Treatment System has a long and complicated history. Constructed in the fall of 1996 the system originally consisted of a vertical flow pond (VFP) that discharged directly into an anoxic limestone drain (ALD). Pulp waste material was used as the organic layer in the VFP rather than the more commonly used spent mushroom compost. The system was plagued with plugging problems so in 1999 the pulp waste material was replaced with a layer of spent mushroom compost amended with wood chips and #2 limestone. VFP plugging problems persisted and the entire contents of the VFP was replaced in 2005. The reconstructed VFP contains 1,600 tons of AASHTO #3 limestone and 900 cubic yards of spent mushroom compost. The ALD continued to show signs of plugging which led to its excavation in July of 2008. The excavation revealed severely plugged pore spaces in the limestone around the influent plumbing. At that time ALD was converted to an oxic limestone bed (limestone ramp) by permanently uncovering the limestone so that future plugging problems can be easily addressed.

In 2009 the Babb Creek Watershed Association requested technical assistance in the form of a system performance assessment through Trout Unlimited's AMD Technical Assistance Program. This report provides the results of the assessment and recommendations for long term reliable treatment.

System Performance

The raw discharge is acidic and contains elevated levels of iron, aluminum and manganese. Metals concentrations are well within the limits that can be reliably treated by properly designed and constructed passive treatment systems. Table 1 shows the average raw discharge water quality.

Table 1. Average characteristics of the Arnot #2 Mine #4 Discharge

	Flow	pH	Acid	Fe	Al	Mn	Sulfate
Arnot #2 Mine #4 Discharge	166	3.4	80	1	6	6	204

Flow is gpm, pH is S.U., all other parameters are mg/L, acidity as $CaCO_3$

Despite the relatively low metals concentrations, permeability has been a persistent problem. Plugging of the VFP has been attributed to various components of the system over time – primarily the organic substrate. However, since the VFP discharges directly into the ALD, it is likely that the limestone in the ALD was the permeability limiting component.

On September 11, 2009 the site was visited by Hedin Environmental staff. Field analyses were made (pH, temperature, alkalinity and flow) and samples were collected for analysis by G&C Laboratory. The sampling results are shown in Table 2 along with historical averages. On this date the VFP was producing weakly net alkaline water (-7 mg/L net acidity) but the limestone ramp provided sufficient alkalinity to produce a final effluent with a net acidity of -95 mg/L.

Table 2. Sampling results for the Arnot passive system, September 11, 2009.

	Flow	pH	Alk	Acid	Fe	Al	Mn	SO4
Arnot #2 Mine #4 Discharge		3.3	0	69	1.5	6.4	4.4	226
VFP Effluent		6.1	45	-7	0.9	4.1	3.8	205
Final Effluent	150	6.8	109	-95	0.1	0.5	0.6	198

Flow is gpm, pH is S.U., acidity, iron, aluminum, manganese and sulfate are mg/L.

The presence of 4 mg/L Al in the alkaline VFP effluent is unusual. The presence of particulate Al was apparent in the field because the VFP effluent was a cloudy white color. Aluminum is highly insoluble at pH between 5 and 9. AMD that flows through alkaline organic substrate and reactive limestone aggregate develops pH 6.5 – 7.0 which causes the Al to precipitate within the substrate. Typically, AMD discharging from a VFP contains less than 0.5 mg/L Al. The presence of the Al in the VFP effluent suggests that the underdrain is collecting water that does not flow through the substrate and limestone (i.e. a short-circuit). It is currently mixing with enough alkaline water (produced by flow through the substrate and limestone) to result in a net alkaline condition.

Using measurements of the VFP taken from aerial photography, the loading rate per unit area was calculated. The VFP has a surface area of 1,227 m^2. On September 11, 2009 the system was receiving 46 (g/m^2)/day acidity. The design standard acidity loading rate per unit area for a VFP is 35-40 (g/m^2)/day so the system was overloaded by 15-24% on that date. Comparing influent and acidity loading it was found that the VFP was producing 56 (g/m^2)/day alkalinity. This is an acceptable rate that indicates that the system is chemically performing as well as would be expected.

Using the same loading per unit area calculations for the historical data shows that the system is overloaded under average flow and acidity conditions (Table 3). The limestone ramp provides sufficient alkalinity to produce net alkaline discharge when the VFP is producing effluent with little net alkalinity. While this arrangement will produce net alkaline effluent under a wide range of loading conditions, it does so at the expense of the VFP. Repeated overloading will shorten the lifespan of the VFP and increase maintenance requirements.

Table 3. Loading calculations for the Arnot VFP

	Flow Rate	Acidity	Acidity Loading per Unit Area
September 11, 2009	150 gpm	69 mg/L	46 (g/m^2)/day
Historical Average	160 gpm	85 mg/L	59 (g/m^2)/day
Historical Maximum	300 gpm	90 mg/L*	120 (g/m^2)/day

**This is the acidity value reported during the maximum observed flow (9/9/04). The maximum observed acidity is 148 mg/L which occurred during very low flow conditions.*

Recommendations

Three recommendations are given that will improve treatment reliability. The recommendations can be implemented individually but should be implemented in the order presented here.

Recommendation 1 – Fix Short Circuiting Flow

The VFP data suggest that acidic water is bypassing the organic substrate and limestone and flowing directly into the underdrain plumbing. The VFP should be carefully inspected to see if this flow path is apparent. Potential short circuiting zones include areas where the organic substrate is absent or very thin. If these areas are identified, they should be covered with 8-12 inches of organic substrate. Small areas may be repaired with a hand rake if sufficient material is available adjacent to the area in need of repair. Pipes that extend through the limestone and substrate can provide flow paths along the outside of the pipe directly to the underdrain. The pipe should be removed or cut and capped below the compost layer if feasible. If removal is not feasible, seep collars should be installed that prevent flow along the pipes.

Recommendation 2 – Flow Management

Flow management to avoid overloading conditions is critical to reliable long term system operation. If there is sufficient head between the mine entry and the VFP, a flow distribution system should be designed and installed. The flow distribution system will limit the amount of flow to the VFP to 150 gpm and bypass any additional flow. Two bypass options should be included with one directing bypass flow to the limestone ramp and the other bypassing the system altogether. It is unclear how much flow the limestone ramp can accept so the flow distribution system must be easily adjustable.

The basic construction of the flow distribution system should be modeled after those installed at Hunters Drift, Anna S, and Mitchell.

Recommendation 3 – Mix and Amend Compost Layer in VFP

The VFP is now four years old and will require maintenance in the next 2-3 years (perhaps sooner due to overloading). Typically compost is mixed after 5 to 7 years of treatment to redistribute exhausted material and prevent short-circuiting. When the time comes to mix the compost it should also be amended with fine limestone (AASHTO #10 or similar). Amending the compost with fine limestone will improve system performance and make the system more resilient to loading fluctuations. The compost should be amended at a rate of one part limestone to three parts compost by volume. This is the rate of compost amendment used at the Anna S passive treatment system which has successfully treated more acidic mine drainage for nearly six years. The existing system contains about 900 yd^3 of compost which will require 400 tons of limestone fines.

Recommendation 4 – Convert Limestone Ramp to VFP

The limestone ramp could easily be converted to a VFP by adding two feet of limestone amended spent mushroom compost to the top of the existing limestone layer. Some limestone may have to be removed to accommodate the compost layer. The existing flush valve should be replaced with a water level control structure that would allow for the water level to be set 2 feet above the compost layer.

Since the dimensions of the limestone ramp are similar to those of the existing VFP, the raw discharge could be split evenly between the two. If 40 (g/m^2)/day acidity is used as a design target, then the maximum flow rate into each VFP would be 112 gpm. The total treatable flow would then be 224 gpm, a 70th percentile flow.

Since flows exceed 224 gpm 30% of the time, the decision must be made whether it is better to overload the system during high flow periods or bypass excess flow to the stream. The September 2009 sampling indicates that the system can produce net alkaline effluent at 150 gpm. This is sufficient to treat the largest observed flow rate (150 gpm to each VFP for a total of 300 gpm). Based on this fact and the lack of a pond to mix the bypassed flow with alkaline VFP effluent, it is recommended that all of the water be directed to the VFP with only emergency bypass provided.

In addition to improving reliability, converting the limestone ramp into a VFP would make maintenance easier. Any time flow is less than 150 gpm (about half the time) one of the VFPs could undergo maintenance while the other fully treats the discharge.