Swamp Area Passive Treatment System
Kettle Creek Watershed, Clinton County, PA

A Technical Report
for
Trout Unlimited and the Kettle Creek Watershed Association

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March 2013

Swamp AMD Chemistry

The Swamp acid mine drainage (AMD) is highly acidic and contaminated with high concentrations of Fe, Al, and Mn. Table 1 shows average, median, 75th, and 90th percentile conditions between 2004 and 2012. (Reclamation of the surface mine that produces the Swamp AMD took place in 2004 and for that reason only post-reclamation water quality data were used for design.) The monitoring station is downstream of a large seepage zone and receives surface runoff. The data set contains many low flows, measured during drought conditions, and high flows, measured during wet weather when runoff was contributing. Figures 1a, 1b, and 1c show concentrations of acidity, Al, and Fe at various flow rates. Acidity and Al concentrations do not vary substantially with flows between 10 and 200 gpm. Iron shows a relationship with flow. Fe concentrations are commonly greater than 100 mg/L when flow are less than 20 gpm, but are seldom above 50 mg/L when flows are greater than 50 gpm.

Table 1. Characteristics of Swamp AMD at Pipeline, 2004 – 2012
(31 flow measurements; 23 chemical measurements)

	Flow	**pH**	**Acid**	**Fe**	**Mn**	**Al**	**SO_4**	**Acid ld**
	gpm		**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**kg/d**
Average	77	3.0	430	74.3	25.1	35.6	1171	165
50%	33	3.0	418	49.9	21.2	32.0	1090	67
75%	79	2.9	520	87.3	33.0	46.1	1495	260
90%	176	2.8	626	156.0	44.2	54.8	1816	324

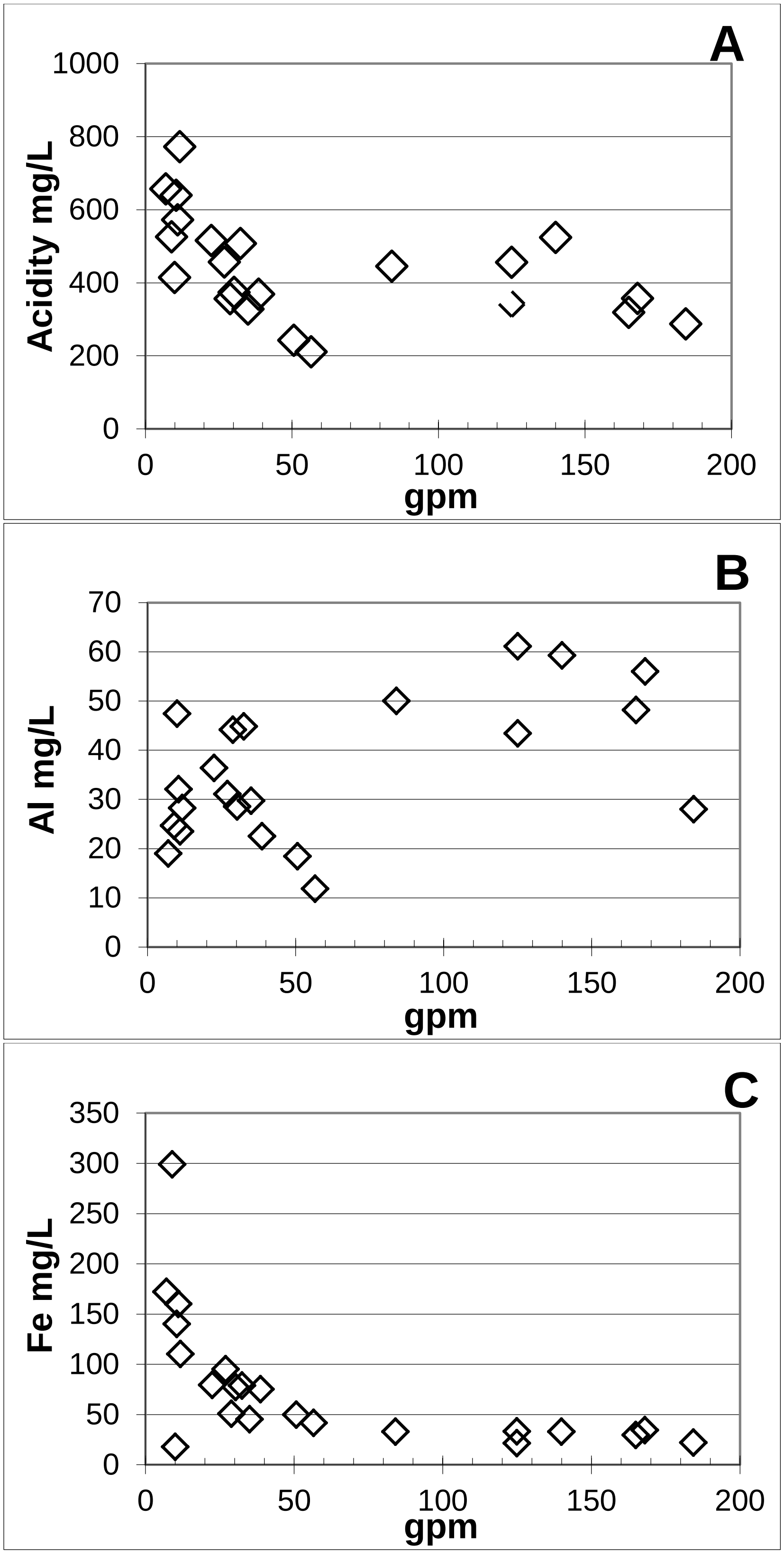

Figure 1. Concentrations of Acidity (A), Aluminum (B), and Iron (C) for the Swamp untreated AMD, 2004 – 2012. The samples were collected and flows were measured at the pipeline weir.

System Design

The system's design changed between the original proposal and the final construction. The location of the system changed when a soil investigation discovered shallow bedrock and groundwater in the original proposed location. The investigation found better conditions (deeper soils and less groundwater) at a site to the west. A system design was developed for this site. The final design contains more treatment capacity than the original plan. The system contains three vertical flow ponds that have a total size 30% larger than originally proposed. The design also includes a drainable limestone bed (DLB) that will neutralize water bypassed around the VFPs during high flows. This was not included in the original proposal. Treated water flows from the VFPs and DLB into a two constructed wetlands where final removal of Fe, Mn, and dissolved organic compounds occurs. The installed wetlands were larger than proposed in the original plan. The installed treatment units and their functions are shown in Table 2.

Table 2. Components of the Swamp Passive Treatment System

Unit name	Purpose	Size
Intake	Screen debris; limit flow rate into system to 300 gpm	
Pond 1	Fe removal; sediment settling; flow equalization	6,000 ft^2
FDS	Manage flows to VFP 1, Pond 2 and DLB	
VFP1	Acidity neutralization and metal removal; 40 gpm maximum flow	16,300 ft^2
Pond 2	Mix VFP1 effluent and Pond 1 overflow; common input to VFP2 and VFP3	10,500 ft^2
VFP 2A	Acidity neutralization and metal removal	23,300 ft^2
VFP 2B	Acidity neutralization and metal removal	22,300 ft^2
DLB	Acidity neutralization and metal removal; only functions during high flows	900 tons
Wetland 1	Fe, Mn, and DOC removal; wildlife habitat	30,000 ft^2
Wetland 2	Fe, Mn, and DOC removal; wildlife habitat	23,200 ft^2

The treatment design was based on the performance of the Anna S Mine Complex passive treatment system in Babb Creek watershed. The Anna S complex, which contains eight VFPs, has been successfully treating AMD that is chemically similar to the Swamp inflow for eight years. The Swamp system has several innovative features. Because of the high concentrations of Fe that occur under low flows (Figure 1C), there were concerns that passing the AMD through one VFP would not generate enough alkalinity to neutralize all the Fe. This concern was addressed by adding a smaller VFP in front of the two primary VFPs. The flow to VFP1 is limited to 40 gpm. At flows less than 40 gpm, which is when Fe concentrations are highest, the mine water flows through VFP1, is aerated in Pond2 and then flows through VFP2A or VFP2B. This "double" treatment should generate enough alkalinity to neutralize all the Fe. At higher flow conditions, much of the water bypasses VFP1 and only is treated by a single VFP (either VPF2A or VFP2B). In these higher flow cases, Fe concentrations are much lower and a single VFP treatment is adequate. A second innovative feature is addition of a DLB to treat flows higher than are considered suitable for the VFPs. The DLB is a new technology that has proven very effective for mine waters with high concentrations of Al. This is the first time that a DLB was included as auxiliary treatment in a passive system.

Construction

The construction contractor, Smith Excavating and Construction began work in July 2011 by installing the intake structure. In August 2011 construction began on the treatment system. During construction the elevation of the wetland was adjusted based on available fill material. The wetland was divided into two separate cells by lowering the downslope half approximately 3 feet. A rock lined channel was installed to connect the two wetlands. Groundwater and poor soil conditions were encountered in several ponds. Water was pumped into VFP 2B and Pond 2 to test for watertightness in November 2011. The water level fell rapidly in both ponds indicating an unacceptable amount of leakage. Following a construction stoppage during winter, synthetic liners were installed in Pond 1, Pond 2, VFP 1, VFP 2A and VFP 2B. Materials were installed in the lined VFPs and the system was completed in October 2012. The construction timeline is summarized in Table 3.

Table 3 Construction Timeline

Date	**Description**
July 2011	Intake Structure installed. Early installation allowed for the performance of this critical component to be observed for an extended time.
August 2011	Construction of treatment system begins, about half of earthwork completed
September 2011	Groundwater seeps and poor soil conditions encountered in some excavations. Historic heavy rains halt construction.
October 2011	Water pumped into ponds to determine water tightness – all ponds fail test.
November 2011	Work begins on plan to make ponds water tight, some grading work resumes.
December 2011	Work stopped for winter.
April 2012	Solicit quotes from pond liner companies.
May 2012	Select Equipment Transport LLC to install liners.
July 2012	Liner installation complete. Construction work resumes.
August 2012	First discharge from system from partially completed system. VFP 2B is only VFP online, VFP 1 and VFP 2A are still under construction.
October 2012	System is complete and all components are discharging. Intake screen is cleaned and modified to prevent clogging due to iron accumulation.
November 2012	First round of effluent samples collected

System Performance

The system came online in late October 2012 and has been sampled three times. The system has effectively treated the AMD. Table 4 shows the chemistry of influent and final effluent samples on the three days. The final effluent was strongly alkaline and contained less than 1 mg/L Fe and Al. Mn was decreased, but was still present in the effluent.

Table 4. Influent and effluent chemistry for the Swamp passive treatment system. The system first discharged in late October 2012.									
Point	**Date**	**Flow**	**pH**	**Alk**	**Acid**	**Fe**	**Mn**	**Al**	**SO4**
		gpm		**mg/L $CaCO_3$**		**mg/L**	**mg/L**	**mg/L**	**mg/L**
Influent	11/7/12		3.0	0	540	47.7	25.6	81.2	1,182
Effluent	11/7/12		7.9	432	-289	0.9	2.3	1.1	757
Influent	1/31/13	>500	3.6	0	102	6.0	5.0	13.2	180
Effluent	1/31/13		7.7	147	-121	0.9	6.2	0.3	660
Influent	2/25/13	39	3.1	0	350	54.2	26.3	27.8	1,133
Effluent	2/25/13	48	7.8	164	-146	0.6	10.7	0.1	943

Twomile Run was sampled in November 2012 and February 2013 (Table 5). Sampling occurred upstream of the treatment system, at the bridge above the inflow of Middle Branch, and upstream of the inflow of Huling Branch. Upstream of the system inflow there is no AMD. Between the treatment system and Middle Branch there should be very little AMD. Between Middle Branch and Huling Branch there are inputs of AMD from Robbins Hollow, an artesian discharge, and contaminated groundwater. The stations were sampled in 2004-2005 before the system was installed. The upstream sample was not polluted with AMD. The two downstream stations had low pH and elevated metal concentrations. Since the system was installed, Twomile above Middle Branch has been alkaline with low Fe and Al. The downstream location was alkaline in November and slightly acidic in February. Restoration of the downstream section of Twomile Run (above Huling Branch) requires treatment of the remaining Robbins Hollow AMD (underway) and reclamation of mine sites in the Huling Branch watershed that contribute contaminated baseflow directly to Twomile Run. In the short term, water quality will fluctuate in Twomile Run as acid minerals that have accumulated in the streambed as a result of decades of AMD exposure are exposed by erosion and dissolved. It is expected that much of this residual acidity will flush out of the stream by late 2013.

Sampling in November and February also included nutrients and total organic carbon (TOC). These parameters were of interest because vertical flow ponds contain a large amount of organic matter which leaches nutrients and organic compounds. When the system was only several weeks old, it discharged high concentrations of ammonia and total organic carbon. Dilution and flow downstream decreased these compounds substantially, but they were still higher at the downstream station than upstream. In February, after three months of operation, the system effluent had 95% less N compounds and 90% less TOC than in November. The instream values in February were similar upstream and downstream in February. Data are shown in Table 6.

Table 5. Chemistry of Twomile Run above the Swamp system (up), above Middle Branch (mid), and above Huling Branch (down). The system first discharged in late October 2012.									
Point	**Date**	**Flow**	**pH**	**Alk**	**Acid**	**Fe**	**Mn**	**Al**	**SO4**
		gpm			**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
TMR above AMD	2004-05		6.3	6	4	0.1	<0.1	0.5	8
TMR above MB	2004-05		4.7	1	18	0.9	2.2	2.5	73
TMR above HB	2004-05		4.1	0	38	0.3	4.1	3.9	186
TMR above AMD	11/7/12		6.1	5	-1	<0.1	<0.1	<0.1	7
TMR above MB	11/7/12		6.6	24	-18	0.2	0.9	1.1	69
TMR above HB	11/7/12		6.2	9	-2	0.4	1.2	1.1	78
TMR above AMD	2/25/13		6.4	4	1	<0.1	<0.1	0.2	10
TMR above MB	2/25/13	847	6.5	8	-1	<0.1	1.5	0.8	72
TMR above HB	2/25/13	1483	5.1	2	7	0.4	2.1	1.1	97

Table 6. Concentrations of nutrients and total organic carbon (TOC) for the Swamp passive treatment system. The system first discharged in late October 2012.						
Point	**Date**	**NH_4**	**Nitrate**	**Nitrite**	**P**	**TOC**
		---------------- mg/L ----------------				
Effluent	11/7/12	24.6	<0.5	<0.01	6.4	132.8
TMR above AMD	11/7/12	<0.1	<0.5	<0.01	<0.1	1.1
TMR above MB	11/7/12	1.3	<0.5	0.01	0.4	9.0
TMR above HB	11/7/12	0.7	<0.5	<0.01	0.2	4.8
Effluent	2/25/13	0.25	0.78	0.01		14.3
TMR above AMD	2/25/13	<0.10	<0.50	<0.01		1.7
TMR above MB	2/25/13	<0.10	<0.50	<0.01		2.4
TMR above HB	2/25/13	<0.10	<0.50	<0.01		2.2