Wingfield Pines Passive Treatment System Investigation
Chartiers Creek Watershed, Allegheny County

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

May 3, 2013

Background

The Wingfield Pines passive treatment system is located in Upper St. Clair Township, Allegheny County, PA on property owned by the Allegheny Land Trust (ALT). The system was installed in 2009 to treat approximately 1,500 gpm of alkaline mine water containing 12-20 mg/L iron (Fe). The system provided excellent treatment in 2010, 2011, and 2012 but the effectiveness visibly declined during the 2013 winter. Also during the last three years the system has been affected by excessive algal growth and muskrats. ALT requested that the Trout Unlimited (TU) AMD Technical Assistance Program assess the system's current performance and provide operation and maintenance recommendations that would manage these challenges and maintain good water treatment. The recommendations provided will be implemented, to the extent possible, by an intern during the summer of 2013.

Results of System Inspection and Sampling

On March 28, 2013, Hedin Environmental (HE) and ALT staff walked through the Wingfield Pines treatment system. The system consists of five ponds and a large constructed wetland (Figure 1). The ponds contained orange water which was not unexpected. The constructed wetland also contained orange water and was discharging turbid water which is unusual. During the first three years of operation little turbidity or iron staining was observed at the final effluent. A second very noticeable feature was the absence of emergent plant growth in the wetland. Five months earlier the wetland had been full of a mix of emergent plants. Muskrat activity was apparent from a dozen piles of vegetation that the animals create when they feed. A third item noted by ALT was muskrat burrows and erosion at various places along the walking trails.

After the completion of the site inspection, HE personnel collected water samples from throughout the system and made a thorough inspection of the berms and paths. There results of the water sampling are shown in Table 1. The "Stones" sample was collected from the stepping stones crossing which is one-third through the wetland. The "Bench" sample was collected beside the bench on the boardwalk and is two-thirds through the wetland. The samples were analyzed for total (Fe-T) and dissolved (Fe-D) iron. Dissolved Fe, at neutral pH, represents ferrous iron. The difference between total and dissolved Fe is particulate iron or suspended iron oxide solids.

The system receives alkaline mine water with moderate concentrations of Fe. The flow rate has averaged 1,443 gpm (61 measurements between Nov 2009 and May 2013) and the influent Fe concentration has averaged 15.6 mg/L. Previous measurements of chemistry through the system found that the Fe was totally oxidized after flow through the first cell and that the system's effectiveness depended on the removal of Fe solids, not the oxidation of ferrous Fe.

Table 1. Chemistry of the Wingfield Pines treatment system on March 28, 2013. The flow rate was 1,293 gpm. Analyses by G&C Laboratory (Summerville PA).								
Sample ID	**Field pH**	**Alk**	**Fe-T**	**Fe-D**	**Mn**	**Al**	**SO4**	**TSS**
		-------------------- mg/L ----------------------						
Influent	6.6	na	18.9	4.5	0.3	0.1	3423	23
Pond 2 In	7.4	426	8.4	<0.1	0.3	<0.1	341	14
Pond 3 In	7.5	382	6.5	<0.1	0.3	<0.1	285	10
Pond 4 In	7.5	408	5.7	0.1	0.3	0.2	317	8
Pond 5 In	7.8	400	4.9	<0.1	0.3	0.1	321	10
Wetland In	7.9	422	4.5	<0.1	0.2	<0.1	313	13
Stones	8.1	424	3.8	<0.1	0.2	<0.1	329	5
Bench	8.0	408	3.3	<0.1	0.2	<0.1	326	<5
Effluent	8.2	420	2.8	<0.1	0.12	<0.1	306	6

The results from March 28, 2013 were consistent with previous measurements. There was negligible dissolved Fe detected after the first pond. Half of the Fe was removed in the first pond, which is the largest pond and is also generally free of any algal growth. Flow through the second pond, which is mostly free of algae, removed another 2 mg/L Fe. However, flow through the 3rd, 4th and 5th ponds, which are all heavily vegetated with algae, only decreased Fe by another 2 mg/L. The algae, which was very thick in summer months (Figure 1) had declined substantially but its presence created visually obvious channelized flow through the middle of the 3rd, 4th and 5th ponds.

The wetland, which is as large in surface area as all the ponds combined, only decreased Fe by another 1.7 mg/L. The wetland was largely devoid of emergent vegetation because of herbivory by muskrats. Channelized flow was also visibly apparent. Thick growths of algae along the wetland banks had clear water while a channel of water flowing through the center of the wetland was turbid orange. It appears that dense accumulation of algal biomass along the wetland banks has contributed to the development of flow channels through the middle of the wetland. Without any emergent plant growth, these flow channels provide very little solids removal.

Table 2 shows Fe concentrations at the Wingfield system at various dates since it was constructed in 2009. Most of the time the final effluent is clear and there is less than 0.5 mg/L Fe. Higher concentrations of Fe were measured in December 2009, February 2010, and January/March 2013. It appears that when vegetation declines in winter, due to natural senescence or herbivory, Fe solids are more likely to reach the final effluent. This natural occurrence appears to have been enhanced in 2013 by the development of short-circuiting preferential flow around large accumulations of algal biomass.

A follow-up system inspection occurred on May 3, 2013 under warm spring conditions. Algal growth in the ponds and wetlands was apparent and flow channels through the ponds were becoming blocked by algae. Cattails were beginning to regrow in the wetland. The effluent from Pond 5 had slight turbidity and the flow in the wetland by the bench and at the final effluent was clear.

Table 2. Record of Fe measurements at the Wingfield Pines passive treatment system.			
Date	Influent	Wetland In	Effluent
	-------------- mg/L --------------		
09/08/09	12.3	1.8	0.2
11/01/09	15.1	2.6	0.1
11/28/09	13.6	3.4	0.1
12/18/09	16.2	4.3	1.1
01/31/10	na	na	0.4
02/19/10	14.0	2.9	1.8
03/27/10	13.9	2.2	0.1
12/17/11	na	na	0.5
10/21/12	17.3	2.2	0.1
01/12/13	19.4		4.4
03/28/13	18.9	4.5	2.8

"na" indicates data not available

The inspection of the treatment system and walking paths identified numerous locations where muskrats, slumping, and erosion had created unstable conditions on berms (Figures 2 and 3). Erosion was apparent around most of the grates which created tripping hazards (Figure 4). The final effluent structure had water flowing around both sides because of erosion (Figure 5). The locations of all problem areas were mapped onto a system map (Figure 6).

Maintenance Recommendations

Grates

The grates that cross channels that connect pond 1→ 2, pond 2 →3, pond 4 → 5, and pond 5 to the wetland need maintenance. There is erosion and damage from animal digging on the sides of the grates resulting in a tripping hazard (Figure 4). The holes could be filled with fine gravel which would eliminate the tripping hazard and may lessen future erosion and animal digging. Gravel with a maximum diameter of 1 inch is necessary. AASHTO #9 limestone was tested on one grate and found to be very effective. Approximately 2 cubic yards (2.7 tons) of gravel should be adequate to fix all the grates.

There is a loose rubber lining between the grates and the aluminum caps that prevents corrosion. This lining should remain in place wherever the grating contacts the aluminum caps.

Filling of Muskrat Burrows and Slumping

There is some slumping of the berm separating ponds 4 and 5 (Figure 3). Although the slumping has not compromised the integrity of the berm (and is unlikely to do so), it could be repaired and stabilized with earth and stone. There is erosion at the ends of several troughs that could use similar maintenance. Muskrat burrows are a problem in many areas. The borrows collapse when stepped on and create a tripping hazard. The holes should be collapsed with a shovel and filled in with earth or stones.

The total amount of dirt needed for fixing the berms and muskrat burrows is likely 2-3 CY. One small truckload will be adequate.

Final Effluent Structure Repair

Water is flowing around both sides of the final effluent structure (Figure 5). This needs to be repaired by filling the sides with dirt so that there is no opportunity for water to bypass the discharge structure. Once the fill is in place, large stones should be placed on top to further stabilize the area.

The effluent structure is designed to allow adjustment of the water depth in the wetland by adding/removing boards. The boards that are not being used should be stored in the site storage shed. A chain that was intended to lock in the boards was not effective. The chain can be removed.

Muskgrass Control

As seen from the aerial photograph of the site (figure 1), there is considerable algal growth in the Ponds 3, 4, 5 and in the first third of the wetland. The primary alga present is muskgrass, *Chara spp.*, which is common colonizer of open alkaline waters. The alga gets its name from its musky smell. Muskgrass is a native to Pennsylvania but is invasive and a common nuisance problem in ponds. Information about muskgrass is available in a Penn State bulletin at this link. http://pubs.cas.psu.edu/freepubs/pdfs/xh0034.pdf

The muskgrass colonized the Wingfield Pines treatment system in the second summer (2010) and has been present ever since. For the last three summers muskgrass has completely covered most of the Ponds 4 and 5 and a large portion of the wetland. The heavy growth creates a tremendous filter that effectively removes most of the iron solids in the ponds and definitely contributes to the very good removal of Fe in spring, summer and autumn seasons. Muskgrass declines every winter, and its biomass contributes to the development of preferential flow paths in the wetland. This feature of the muskgrass growth likely contributes to poorer treatment in winter months, especially in 2013.

There is no easy way to eliminate muskgrass. The Penn State bulletin provides chemical control options, but all have fish risks. The Wingfield Pines system is populated with mosquito fish which appear to be providing excellent mosquito control. The loss of these fish is not recommended. Muskgrass can be physically removed. Jeemco Inc., located in New Wilmington PA, operates an aquatic weed harvester that cuts algae and removes it from the pond. The harvested algae are brought to shore where it can be composted or disposed of. The Jeemco service costs $150/hour. Harvesting algae from Westminster College's 16 acre lake typically takes 2 weeks. The Wingfield Pines ponds total about 2 acres. It would probably take three days to mobilize and clean out Ponds 3, 4, and 5. The total cost is estimated at $4,000 – 5,000. ALT would need to have a plan to compost or dispose of the algae. If not properly handled, the muskgrass would probably create an odor problem. It is likely that muskgrass would recolonize the ponds and removal would be necessary again in 2-3 years.

Grass carp have been used as biological controls for muskgrass. Grass carp are native to China and their introduction to Pennsylvania waters is regulated by the PA Fish and Boat Commission. A bulletin about grass carp can be found at this link.
http://fishandboat.com/images/pages/forms/pfbc_tgc002.pdf
Only sterile grass carp can used and the ponds must contain screens that assure that the fish cannot escape. Triploid grass carp can be purchased from certified dealers, the closest being John A. Angelo (181 Rogers Mill Rd., Normalville, PA 15469). It is unknown if grass carp can tolerate water with high iron oxide turbidity or if the Wingfield Pines ponds are too shallow. The successful introduction of grass carp might lessen the muskgrass problem, but it might also create unexpected new biological problems.

With time, the muskgrass will likely decline. Last summer, muskgrass was replaced in portions of the ponds and wetlands with the pondweed, *Potamogeton crispus*. This species is non-native and invasive. The long-term implications of pondweed are unknown. Muskgrass and pondweed both requires unshaded conditions. If the emergent plants can become established in the wetland, the shading they provide will likely eliminate both muskgrass and pondweed.

Elimination of Preferential Flow Paths
As noted above, the heavy growth of muskgrass appears to have contributed to the development of preferential flow paths down the middle of Ponds 3, 4, 5 and in the wetland. It may be advantageous to install flow barriers in the wetland that divert flow out of established channels. ALT should consider placing diverters made of haybales in the wetland. The two recommended locations for haybale diverters are: 1) across the middle of the first wetland section and, 2) across the wetland upstream of the boardwalk. These barriers could be constructed with about 40 rectangular haybales.

Muskrat Damage Control
Muskrat activity is very high in the Wingfield Pines system. Muskrats are small mammals that feed on cattail tubers and the roots of other aquatic vegetation. Their feeding, especially during winter months, can remove much of the emergent plant growth in the wetland. Muskrats construct above water huts and feeding platforms and hidden burrows. Burrows are dug into earthen berms slightly above the water level. These burrows create unstable conditions that are walking hazards and can, in extreme cases, cause berm failure. A Penn State information sheet on muskrats can be found at this link. http://www.extension.org/pages/8829/muskrat-damage-management

The most effective way to lessen muskrat problems is removal by trapping. The most commonly used muskrat traps are Conibear type 110 and other leghold types. The traps are usually placed in swimming channels and kill the animal by snapping (like a mousetrap) or drowning. Muskrats are active from dusk to dawn so it should be easy to remove trapped animals early in the morning. The muskrat trapping season is limited to November 17^{th} to January 6^{th}. The Pennsylvania Game Commission can direct ALT to local trappers who would be available to establish a trapping program at Wingfield Pines. Because the Wingfield Pines site is very good muskrat habitat, they will recolonize the wetland every summer. A sustained trapping program will be necessary to limit muskrat activity in the wetland.

The natural predators of muskrats are mink. Mink are large mammals that average 2 feet long and weigh 2-3 pounds. It is unknown if there are mink in the Chartiers Creek riparian zone around Wingfield Pines. According the PA Game Commission (PGC), mink presence is not likely to solve the muskrat problem as Wingfield. If mink are not already present at Wingfield Pines, their introduction would require special permission from the PGC and, because it is not a common practice, would be difficult.

Muskrat burrowing into berms can be controlled by placing barriers along the water edge. The two most common barriers are chain link fence (placed on the ground) and aggregate. Both are placed in a band that extends at least two feet above and below the water line. Making the Wingfield Pines system “muskrat proof” would be a large effort. The ponds and wetland contain about 5,000 ft of berm that is potentially vulnerable to muskrat burrowing. Assuming that the barrier is made with aggregate that is placed in a band that is 4 ft wide and 6 inches thick, then one ton of aggregate will treat about 10 feet of shoreline. The cost to purchase and place the aggregate is likely about $40/ton and the unit cost is estimated at $4/ft of shoreline. Treatment of all 5,000 ft of exposed berm would cost about $20,000. Not all the berm shoreline is being utilized by muskrats. ALT may want to experimentally apply stone to one high problem area and monitor the effectiveness of eliminating muskrat burrowing.

Figure 1. The Wingfield Pines passive treatment system on August 12, 2012. Water flow from the top of the photo through the ponds and into the wetland on the bottom of the photo. The growth in the ponds and the first wetland section is largely muskgrass, *Chara spp.*. The muskgrass is a very good filter and its effective removal of Fe solids is apparent by the lack of orange color in the wetland.

Figure 2. Muskrat damage of a wetland berm.

Figure 3. Slumping of the berm between pond 4 and 5 on the pond 5 side.

Figure 4. Tripping hazard caused by erosion/animal digging on the sides of the grates.

Figure 5. Erosion around the final effluent structure is allowing water to bypass around.

Figure 6. Problem areas at the Wingfield Pines site. Red circles indicate muskrat damage, blue circles indicate erosion around grates, and black circles berm slumpage or erosion.