Successive Alkalinity Producing Systems (SAPS) & Aluminator Evaluations

Case Study 3

Background

Project Name: REM Orcutt/Smail, Little Mill Creek Restoration Project

Location: Union Township, Jefferson County, Pennsylvania
U.S.G.S. Quadrangle - Corsica, PA
Latitude 41° 12'27.3", Longitude 79° 11'2.2"
(*see* Figure R1)

Funding: Bond Forfeiture - Handled through the Pennsylvania Department of Environmental Protection & Bonding Company

Design: Initial 1992 Design - Damariscotta; 2002 Redesign – NRCS (conceptual – Damariscotta)

Design Water Data Characterization (surface mine discharge):

REM (Northern Discharge)

flow[1]	pH[2]	alkalinity[3]	acidity[3]	iron[4]	aluminum[5]	manganese[4]	sulfate[4]
35	3.5	0	1000	425	5	110	1,600

---

[1]gpm; [2]s.u.; [3]$CaCO_3$ equivalent; [4]total, mg/L; [5]estimated

REM (Southern Discharge)

flow[1]	pH[2]	alkalinity[3]	acidity[3]	iron[4]	aluminum[5]	manganese[4]	sulfate[4]
28	4.9	7.0	200	50	<5	50	800

---

[1]gpm; [2]s.u.; [3]$CaCO_3$ equivalent; [4]total, mg/L; [5]estimated

Treatment Approach: Anoxic Limestone Drains (ALD) and Successive Alkalinity Producing System (SAPS).

Construction: February/March 1992
Design Modified (SAPS/Aluminator© piping/water collection system was modified): 2002

Damariscotta
Little Mill Creek Watershed Rehabilitation Project
(No. 3 SAPS & Anoxic Limestone drain)

Original Design (February/March 1992)

The REM Orcutt/Smail acid mine drainage discharges emanate from small abandoned "punch mines" and are recharged by surface mines. These small mines were developed in the early 1900s and surface mining took place in the 1970s and 1980s. The discharges enter an unnamed tributary to Little Mill Creek and were the treatment responsibility of the coal operator until his bankruptcy and subsequent bond forfeiture. The Pennsylvania Department of Environmental Protection (then Department of Environmental Resources) worked with the bonding company to develop passive treatment at this location. Damariscotta developed the initial passive treatment system at this location which entailed anoxic limestone drains, prototype SAPS systems, settling basins, and aerobic wetlands. The attached design drawings and aerial photograph (Appendix 3) show the treatment system location and layout.

This system has two discharges (referred to as the "northern" and "southern" discharges) that are combined part way through the treatment system. An anoxic drain 25'X100'X4', containing approximately 550 tons of No. 57 limestone, was developed on the somewhat smaller, "southern", discharge. An anoxic limestone drain was also developed on the "northern" discharge that was roughly 40'X100'X4' and contained approximately 900 ton of limestone. A perforated collection pipe (***one*** pipe approximately 20 feet long – not a piping bed typically placed in drains today) was placed at the discharge end of the system and angled upward for discharge and to prevent air from entering the anoxic drain. Aerobic wetlands and settling basins were established immediately following each of these drains that encompassed approximately 0.1 acres, (7,380 ft^3) for the southern discharge, prior to combining with the flow from the northern discharge; and 0.17 acres (5,100 ft^3) for the northern flow prior to combining with the southern flow. Both flows were then combined in a prototype SAPS system similar to the designs used at the Filson and Howe Bridge sites. This SAPS system was 50'X75' on the bottom with 2:1 inslopes, approximately 3' of No. 57 limestone, and 0.5' of spent mushroom compost. The collection pipe (4" perforated, corrugated-flexible piping) system was placed directly on 0.5' of limestone on the bottom of the SAPS unit. The collection pipes were placed on approximately 5' centers and serpentined for the length of the unit. One roll (250') of this collection pipe was placed in the SAPS unit and was connected to a solid collection pipe at the discharge end of the unit. The discharge structure was a 4" diameter, solid SDR 26 pipe that angled upwards from the bottom elevation of the pond to a discharge invert equal to the design pool elevation of the SAPS. This pipe discharged into an aerobic wetland cell (number 2 of the 5 aerobic cells present); a flush (drain) pipe was also established that had the outlet placed in the aerobic wetland cell number 3 (of 5). The flow (combined) from the first SAPS unit was discharged into the second (of five total) aerobic wetland cell, were it proceeded through the next three aerobic units (No.'s 3, 4, & 5) before entering the last SAPS (and treatment cell) in the entire system. This SAPS was constructed in a similar fashion to the first SAPS system; however, the size of the system was approximately 50'X100'(bottom dimensions) and two pipes were placed in this system instead of one. The two, primary, discharge pipes were angled upwards to control the elevation within the SAPS system; and the flush (drain) pipes were placed to discharge into the unnamed tributary to Little Mill Creek (*see* Figure R2, for a general schematic of the system layout).

Modified Design (2002)

The REM Orcutt/Smail systems performed as designed initially; however, it did not meet effluent criteria numbers (primarily pH – which was less than 6, iron and acidity which were both greater than allowable by law) and was considered a "failure" by the Knox Department of Environmental Protection. In contrast, it was considered a success by scientists that had been trying to treat acid mine drainage passively (specifically the United States Bureau of Mines and West Virginia University). The primary reason for the excitement was the fact that this system, in the early years following implementation, was consistently removing 80-90% of the acidity load (with concomitant metal removal). To date this was the most degraded acid mine drainage that was treated effectively, with a passive treatment system. The PA DEP abandoned the system after it became apparent to them that the system would not meet effluent criteria required for acid mine drainage discharges. The system continued to decline in effectiveness, due to the lack of operation and maintenance, until very little "treatment" occurred within the system.

The redesign of this system took place in 2002, with the actual construction planned for 2003. This redesign, like those at Filson, was an attempt to address the inherent flaws and outdated technology that were in the original design. The redesign addressed updating of the piping systems in the SAPS, adding additional SAPS units, and/or expanding the SAPS that are there, and adding additional settling basins. A copy of the redesign, as envisioned by the NRCS is included in Appendix 3.

Findings

For the REM Northern Discharge; the aluminum and manganese components of the mine drainage to be treated, as shown in the background section, account for roughly 23% of the total acid load. The aluminum and iron were relatively minor design concerns of the project. Iron treatment needs were the primary focus, at approximately 77% of the total acid load. Manganese and iron were the only two metals of concern in the REM Southern Discharge, both contributing roughly 50%(each) of the total acid component of this flow.

The primary focus of treatment at this location was to remove the iron to effluent standards (3.5 mg/L), increase pH to between 6-9, and maintain net alkalinity.

Damariscotta was provided with water quality analyses for sampling events from May 1992 through June 2002. Scatter plots of pH, acidity, alkalinity, and aluminum are provided in Figures R3 through R6 (for the combined final discharge). A consistent trend in the effluent quality of the system is evident in these figures, with declines in treatment effectiveness happening relatively quickly (less than one–year) and then stabilizing for key indicating parameters.

Similar to the Filson sites, no measurement of the source water chemistry was made after the original construction, as the source was incorporated into the bottom of the Anoxic Limestone Drains (ALDs) and no collection point was physically available for sampling. Thus, the first sampling location was the effluent pipe of the ALDs, for both the Northern and Southern discharges. The final effluent did not vary dramatically for any of the data for the first several months; after which the pH values started to decline as did the alkalinity values, while the metals and acidity increased proportionally. The pH values were typically 5.5 or higher leaving the ALDs and near 5.5 discharging the treatment system for the first few months (greater than 6 in the first month or two). After approximately 6 months the final discharge dropped in pH to near or below pre-treatment values (less than 3.5). The first SAPS system that collected the combined flows from both the Northern and Southern discharges, did not operate as expected due to the design of the outlet discharge structure that was required (by the state regulatory agency) to have an invert elevation at the same elevation as the surface water in the SAPS. Without the ability to adjust this outfall to compensate for head differences, the surface water merely discharged via the emergency spillway receiving no treatment from the limestone/compost layer of the SAPS. The same thing happened with the final SAPS. Enough alkalinity was introduced through the ALDs on the Northern and Southern discharges that iron oxidation was facilitated, even though the SAPS failed to operate as designed, which resulted in pH values that were suppressed below the values of the source waters. Alkalinity followed a similar trend to that of pH, with values staying relatively elevated at the ALD discharge, up to five/six years after installation but falling quickly after that; primarily due to the failure of SAPS systems.

Acidity values and metal followed this same trend, with the REM Orcutt/Smail effluent carrying some measurable acidity, and metals (i.e. iron) over the first years of operation, while over time these values increased, nearing original source values. This type of trend is common in systems that receive little or, in this case, no operation and maintenance attention. The modifications to this system are an attempt to try and return the water quality to the values that were obtained immediately after the systems were constructed in 1992.

This system was designed to meet the state of Pennsylvania's and the Federal government's mining effluent criteria (and did so on occasion, initially), and to remove as much acidity (and associated metals) loading as possible to help recover the biota in the Mill Creek watershed (which Little Mill Creek is a part of). However, overtime the overall system efficiency declined to the point where little or no treatment occurred. Some of this was due to design, while the remainder was related to lack of care of the system. Thus, while there were many reasons for the overall effectiveness of this system, they can be reduced to basically two that are primary, interrelated issues and are outlined as follows: 1) preliminary design of this type of system; and 2) regulatory oversight of initial design and budgeting concerns.

Preliminary Design

The designs that were utilized for this system were prototype and as such, in retrospect, had several design "flaws", that limited the systems ability to treat *this type* of water to the level required by the Pennsylvania Department of Environmental Protection and the Federal government's standards. We know today that given an appropriate design that this system would most likely have met the effluent standards required by law, and done so consistently. The technology that was employed, at that time, was technologically appropriate and overall sound. Time, however, has shown that the modification of the original/basic design would have allowed for greater efficiency and longevity. The "flaws", that have become clear over time are: 1) the lack of a more complete piping system (black flexible piping (250 feet per SAPS unit) was utilized in this system, similar to that used in both Howe Bridge and Filson) – greater zone of influence; 2) establishment of an Aluminator type system on the "northern" discharge, instead of an Anoxic Limestone Drain (although the anoxic drain at this location lasted over five years with approximately 5 mg/L of aluminum in the source water); and 3) slightly larger SAPS systems (although this was limited by funding).

Regulatory oversight of initial design and budgeting concerns

An additional part of the problem, associated with the initial design of the REM site came from regulatory oversight and budgeting constraints. Primarily the oversight was restrictive due to the fact that this agency did not have the staff that was familiar with this type of passive treatment technology and was skeptical of the ability of this type of system to function given the water chemistry (some of these concerns were legitimate, others were not). This was developmentally restrictive, from the standpoint that new design approaches were not "allowed" because the reviewing engineer was unfamiliar with the approach/technology. Thus design features were compromised, which ultimately turned out to be detrimental to the system's ability to function. An example of this was the requirement to establishment the discharge pipe in the SAPS system to the *exact* elevation of the surface water level in the SAPS, with no allowance for head differences

Damariscotta
Little Mill Creek Watershed Rehabilitation Project
(No. 3 SAPS & Anoxic Limestone Drain)

(i.e. the ability to adjust the discharge piping to compensate for head differences). This design feature alone limited the operation effectiveness of the SAPS to about six months.

The budgeting constraints, however, were the largest factors in limiting this system's ability to function properly. The initial design estimate of $130,000 was reduced to slightly under $70,000, which limited the amount of materials, size, and *any* continued operation and maintenance of the system. This constraint, in retrospect, has illuminated the fact that the SAPS and ALDs systems were undersized and that problems encountered in the field (e.g. lack of a suitable bottom to place stone on - in the final SAPS systems) were not dealt with appropriately because the funds were not present to do so. When the system did not meet the criteria required by the PA DEP the system was abandoned. With no operation and maintenance funds allocated the system declined in efficiency to the point that very little treatment occurred (over the last ten years). This was despite the fact that at peak operation efficiency this system removed more acid load from the Mill Creek Watershed than five other passive systems that were established in the watershed that met effluent criteria (although these systems were not required to do so).

Over the last several years, the Mill Creek Coalition pursed funding through the Natural Resource Conservation Service (NRCS) located in Clarion, PA and Headwater Charitable Trust to upgrade and modify the design to compensate for some of the original design problems. The design was redone in 2002, conceptually by Damariscotta for the NRCS. The regional engineer for the NRCS utilized our conceptual design for a basis of the modifications/upgrades and finalized the design in early 2003, for implementation in 2003. Upon review of the design, several features were identified that would limit the new system's ability to function at peak levels that include: 1) improper pipe sizing and placement in both ALDs and SAPS; 2) improperly sized settling basins; 3) routing of untreated water around systems treatment components, and then placing this water back into the system at a downstream point; 4) fix discharge outlets in SAPS units; and 5) improper material quantities and depths. While these types of shortcomings have been illuminated to the NRCS, some of these were not changed in the final design and will likely result in the revised system's inability to operate at maximum efficiency.

This case study is used to illustrate that when an improper design is implemented that will ultimately not operate at maximum design effectiveness ("fail"), speculation can be thrown on the treatment system components rather than on the improper design. All most all of the cases of "failed" passive treatment systems, that we have examined, were the result of situations similar to this. The overall approach to passive treatment systems in the form of ALD, SAPS, Aerobic Wetlands, Settling Basins, and Aluminators has lead many to believe that these types of approaches are simple and that little design knowledge (science behind the approach), beyond the basics is necessary; and that standard engineering principles can be applied to implement effective systems. This coupled with the fact that any type of standard design approach, for passive treatment systems, does not exist has led consumers to the erroneous conclusion that certain types of passive treatment are not effective.

Damariscotta
Little Mill Creek Watershed Rehabilitation Project
(No. 3 SAPS & Anoxic Limestone Drain)