OPERATION AND MAINTENANCE CONSIDERATIONS FOR A PASSIVE TREATMENT COMPLEX[1]

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Passive systems require no electricity and use environmentally-friendly materials such as limestone aggregate and spent mushroom compost to provide a cost-effective alternative to conventional chemical treatment of mine drainage. Although requiring significantly lower maintenance compared to conventional systems, passive treatment is not a no-maintenance solution. Between 1999 and 2001, a 6-component (Phase I) and a 22-component (Phase II) passive complex were installed at the Harbison Walker Restoration Area (Ohiopyle State Park, Fayette County, PA) to treat numerous mine discharges associated with an old surface clay and coal mine. In combination, the two facilities are treating over 227 million liters (60 million gallons) of severely degraded mine drainage per year, neutralizing ~227 kg/day (~500 lbs/day) of acidity and preventing over 45 kg/day (100 lbs/day) of metals from entering a High Quality Cold Water Fishery. Because of the significant benefit to the stream, development and implementation of an Operation and Maintenance Plan was imperative to insure long-term, consistent, functioning of this facility. To date, periodic site inspections and monitoring have identified the need for flushing of solids from the treatment media, for revegetation of selected areas, for replacement of damaged pipes, and for removal of debris from spillways and ditches. Water monitoring, an integral part of the O & M Plan, has enabled documentation of the individual and combined effectiveness of each component and advancement of passive treatment technology.

Additional Keywords: operation & maintenance, passive treatment system, AMD, mine drainage

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Introduction

A 120-acre surface clay and coal mine was operated by the Harbison-Walker Refractories Company, a Pittsburgh-based company formed in 1875. Clay mined from the site was processed into firebricks that were used to line industrial furnaces such as those at steel plants. The Lower Kittanning claystone (Kittanning Fm.; Allegheny Gp.) and immediately overlying Lower Kittanning coalbed were mined and/or spoiled at the site. The site was backfilled and portions were revegetated with either grasses and legumes or evergreens.

The site currently lies within Ohiopyle State Park, Stewart Township, Fayette County, PA. The Pennsylvania Department of Conservation and Natural Resources (PA DCNR) acquired the property and assumed the responsibility for perpetual treatment of two (AC and B1) of the seven (AC, B1, B3, 12, 13, 14, trib. "C") known pollutional discharges associated with the site.

A conventional lime treatment facility was operated by the PA DCNR to treat the AC discharge that varied in flow rate from about 76 Liters/minute (20 gpm) to over 757 Liters/minute (200 gpm). The treated flow would enter a series of four to six settling ponds that required periodic cleaning. The large volume of sludge generated was pumped to two, intermediate, upgradient ponds and then pumped into boreholes. From a brief inspection of the ponds, undissolved lime appeared to significantly contribute to the sludge volume. Many of the existing boreholes were reportedly filled to capacity and sludge had been observed oozing from the ground downslope.

In addition, a soda ash briquette hopper and two small settling ponds were used by the PA DCNR to treat the 114 L/min (30-gpm) B1 discharge, which appeared to emanate below the spoil area. Due to setting and available facilities, the B1 and AC treated discharges were often not in compliance with the permit effluent limits, which were 6 to 9 pH, alkalinity to exceed acidity, and 7 mg/L total iron. There were no manganese or aluminum effluent limits. Discharges B3, trib. "C", 12, 13, 14 and other drainage were not being treated.

The receiving stream, Laurel Run, a High-Quality Cold Water Fishery, was impacted by the untreated as well as the conventionally treated mine drainage. This stream flows into Meadow Run, a tributary to the Youghiogheny River. These are popular fishing and recreational streams, which have also been classified as High-Quality Cold Water Fisheries. Because of the degradation to the stream by the previous mining activities, the Commonwealth of Pennsylvania placed Laurel Run on the1998 303(d) list and assigned a high restoration priority.

Passive Treatment System Installation

In 1999 Stream Restoration Incorporated, a non-profit organization, received a grant through the Commonwealth's "Reclaim PA" initiative to install a passive system to treat discharges 12, 13, and 14. That project is referred to as the Harbison Walker Restoration Area Phase I. In 2000 Stream Restoration Incorporated received a PA DEP Growing Greener grant to install a passive system to replace the conventional systems and treat discharges AC, B1, and B3. That project is referred to as the Harbison Walker Restoration Area Phase II.

The passive treatment systems at Phase I and Phase II were designed by BioMost, Inc. and WOPEC. Construction of the two systems was completed by Amerikohl Mining Inc. Spent mushroom compost was used to complement on-site soils for the wetlands substrate. This compost was also placed in a ½-foot thick layer directly overlying the limestone aggregate in the B1B3 Vertical Flow Pond. AASHTO #1 limestone aggregate (specified 90% Calcium Carbonate Equivalent (CCE)) received from New Enterprise Stone & Lime Co., Inc., New Enterprise, PA was placed in the Vertical Flow Ponds and Horizontal Flow Limestone Bed. Rip-rap spillways were lined with 48% CCE aggregate received from Amerikohl Mining, Inc., Ameristone – Jim Mountain, Mill Run, PA. Oversized (4" x 1") basic steel slag from International Mill Service, Weirton, West Virginia was placed in the B1 Slag-Only Vertical Flow Pond and in the lower inlet end cell of both AC Vertical Flow Ponds and the lower northern cell of the B1B3 Vertical Flow Pond.

The Phase I passive treatment system consists of the following components in series:

Component	Description
Anoxic Collection System	154 Tons, AASHTO #57 Sandstone with 200' 4" SDR 35 pipe
Anoxic Limestone Drain	670 Tons Limestone
Settling Pond #1	7,350 SF with baffles
Vertical Flow Pond	600 Tons Limestone overlain by 36 tons of spent mushroom compost with 69 tons of 48% CCE AASHTO #10 and 71 tons of 48% CCE AASHTO #57 limestone
Settling Pond #2	4,500 SF
Wetland	11,000 SF planted with cattails 30 tons of spent mushroom compost with 23 tons of 48% CCE AASHTTO #57 limestone
Horizontal Flow Limestone Bed	500 Tons limestone

The Phase II passive treatment complex (Fig. 1) consists of the following components:

Component	**Description**	
AC Collection System	Pre-existing buried 6" piping with cleanouts combines discharges A & C; Inlet Control Structure to ACVFPN & ACVFPS	
AC Vertical Flow Pond South (ACVFPS)	2,664 Tons Limestone in 7 cells; 336 Tons basic steel slag in one cell; Flow distribution/flushing system (8 cells in 2 tiers); Adjustable risers incorporated in flushing system for alternative operation as Hybrid Flow Pond, not part of original design.	
AC Vertical Flow Pond North *(ACVFPN)*	2,665 Tons Limestone in 7 cells; 336 Tons basic steel slag in one cell; Flow distribution/flushing system (8 cells in 2 tiers); Adjustable risers incorporated in flushing system for alternative operation as Hybrid Flow Pond, not part of original design.	
AC Flush Pond *(ACFP)*	15,400 SF; A 6" crossover pipe and gate valve that allows function as a Settling Pond during hybrid flow of ACVFPN and/or ACVFPS	
AC Settling Pond/Wetland *(ACSPWL)*	11,168 SF; Naturally functioning; High-diversity native vegetation; wildlife habitat	
AC Wetland *(ACWL)*	8,745 SF; Naturally functioning; High-diversity native vegetation; wildlife habitat; A 6" crossover pipe and gate valve allows conveyance of flow to B1WL1 for additional treatment	
B1 Surface/Subsurface Collection System	Anoxic	1,100' of 6", perforated, pipe in 385 T, #57, Sandstone
	Oxic	408', rock-lined ditches
B1 Slag Vertical Flow Pond (B1VFP)	1,003 Tons basic steel slag; Flow distribution/flushing system (1 tier with 4 cells); Adjustable risers incorporated in flushing system for alternative operation as Hybrid Flow Pond, not part of original project	
B1 Flush Pond *(B1FP)*	5,054 SF; The rip-rap lined spillway from the B1FP to the ACWL allows function as SP during hybrid flow of B1VFP	
B1 Settling Pond *(B1SP)*	11,588 SF	
B1 Wetland 1 *(B1WL1)*	16,273 SF; Naturally functioning; High-diversity native vegetation	
B1 (Bioswale) Wetland 2 *(B1WL2)*	1,955 SF; Naturally functioning; High-diversity native vegetation	
B1 (Bioswale) Wetland 3 *(B1WL3)*	915 SF; Naturally functioning; High-diversity native vegetation	
B3A (Open LS Channel) Collection Ditch	831' x 9'; Rip-rap lined, R4, 48%CCE	
B3A Settling Pond *(B3ASP)*	4,019 SF	
B3 (Open LS Channel) Collection Ditch	632' x 9'; Rip-rap lined, R3, 48%CCE	
B3 Settling Pond *(B3SP)*	4,033 SF	
B1B3 Vertical Flow Pond *(B1B3VFP)*	1,300 Tons Limestone in 7 cells; 160 T basic steel slag in one cell ½' layer spent mushroom compost; Flow distribution/flushing system (8 cells in 2 tiers)	
B1B3 Flush Pond *(B1B3FP)*	6,043 SF	
B1B3 Settling Pond/Wetland *(B1B3SPWL)*	10,219 SF; Naturally functioning; High-diversity native vegetation	
B1B3 Horizontal Flow LS Bed *(B1B3HFLB)*	1,014 Tons Limestone	
Diversion Well Collection System	381 SF Stilling Pool with 6" barrel & bar-guard conveys flow to Diversion Well; Excess flow bypass in natural, oversize durable stone to trib. "C"	
Diversion Well	Grated Manhole, 4' diameter; 10' depth; AASHTO #10, 90%CCE, Limestone (45 T on-site)	

Notes: all piping SCH40 PVC unless otherwise indicated; all limestone aggregate specified 90% CCE, AASHTO #1 unless noted; SF stands for Square Feet

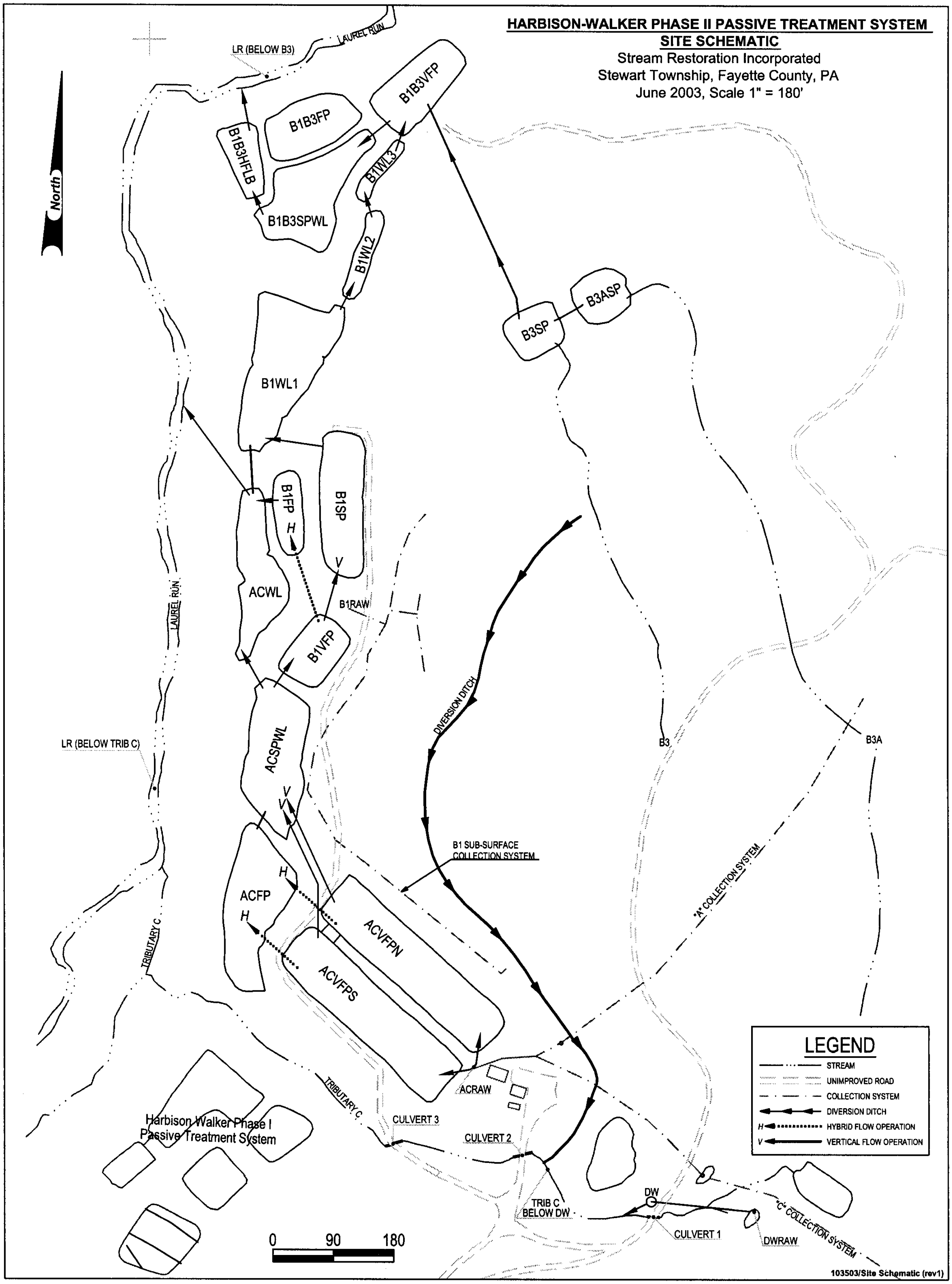

Figure 1. Schematic Diagram of the Harbison Walker Restoration Area

Environmental Results

The Harbison Walker Phase I and Phase II passive treatment systems have been functional since December 1999 and January 2001, respectively. Results must still be considered initial when considering the 25-year design life of the systems.

Water quality improvement was immediate upon system installation and has continued throughout the last several years. Flow rates have varied substantially at the Phase II site. In addition, formerly untreated discharges, encountered during excavation for the complex, have been included in the treatment systems. Water monitoring has included the raw untreated water, passive treatment components, and Laurel Run, upstream and downstream of the system.

Table 1 identifies these initial water quality characteristics through each component of the discharge from the influent to the effluent. Table 2 compares the raw (untreated) mine discharge quality with the final (treated) effluent of the system. The effectiveness of the Phase II passive system is illustrated by Figures 2 and 3.

Table I. Comparison Of Water Quality Through the Harbison Walker Phase II Treatment System

Component	pH	Alkalinity	Acidity	Iron	Manganese	Aluminum
AC (Raw)	3.5	0	456	2	41	58
ACVFPN	6.1	63	14	0	20	10
ACVFPS	6.0	91	33	0	16	16
ACSPWL	6.1	28	11	0	17	4
ACWL	5.2	6	39	2	16	4
B1VFP	10.0	108	0	1	1	0
B1 (Raw)	3.1	0	230	57	32	8
B1SP	3.4	0	179	51	15	3
B1WL1	3.2	0	162	30	16	4
B1WL2/B1WL3	3.3	0	148	25	14	4
B3 (Raw)	4.3	0	47	0	7	6
B3SP	6.1	19	12	1	5	3
B1B3VFP	6.6	46	0	5	10	1
B1B3SPWL	6.6	27	0	3	10	0
B1B3HFLB	7.1	70	0	0	3	0

Average values rounded; Number of samples (n) per component varies from 6 to 11; Alkalinity, acidity, and total metals expressed in mg/L; Lab. pH not averaged from H-ion concentrations; Table attempts to follow flow through system (See Figure 1); Shaded rows are influents to the system; The values, although characteristic of the site drainage, vary based on flow rate and maintenance issues.

Table II. Comparison of the Influents and Final Effluent of the Phase II Passive System

Sampling Point	lab pH	alkalinity	acidity	Fe	Mn	Al
Raw AC	3.5	0	456	1.5	40.6	57.5
Raw B1	4.0	54	186	56.3	26.1	6.1
Raw B3	4.3	0	47	0.1	6.8	6.3
Treated AC, B1, B3, unnamed seeps	7.1	70	0	0.1	3.4	0.1

Average values; Number of samples (n) per component varies from 6 to 11; Alkalinity, acidity, and total metals concentrations in mg/L; pH not calculated from average H-ion concentrations; Treated AC, B1, B3, unnamed seeps represents the quality of the final effluent when all encountered discharges are combined.

Table III. Comparison of Influents and Final Effluent Loadings of the Phase II Passive System

Sampling Point	Alkalinity		Acidity		Iron		Manganese		Aluminum	
	Kg/ day	Lbs/ day	Kg/ day	Lbs/ day	Kg/ day	Lbs/ day	Kg/ day	Lbs/ day	Kg/ day	Lbs/ day
Raw AC	0	0	187.1	412.4	0.5	1.1	17.0	37.4	23.2	51.2
Raw B1	1.8	4.0	32.3	71.3	12.5	27.5	2.0	4.5	0.4	0.9
Raw B3	0	0	2.4	5.4	0.04	0.1	0.3	0.6	0.2	0.5
Final Effluent	13.5	29.8	0	0	0.04	0.1	0.04	0.1	0.04	0.1

Average loadings in kg/day and lbs/day;

The final effluent, when all encountered discharges are combined, can be characterized as net alkaline with low concentrations of dissolved iron, aluminum, and manganese. Total metal concentrations are less than the standard surface mine permit effluent limits. The average manganese concentration is skewed by the first three samples, which contained elevated levels. Within 6 months of operation, manganese concentrations in the B1B3HFLB discharge were less than 0.5 mg/L. It is believed that this phenomenon is due to the establishment of microorganisms and/or development of autocatalytic processes associated with the precipitation of manganese (Rose et al., 2003). The passive system as a whole is decreasing manganese concentrations below that predicted for an alternatively proposed active treatment plant. The Phase I and Phase II passive treatment systems combined are treating approximately 227 million liters (60 million gallons) of mine drainage per year and, on average, are neutralizing about 227 kg/day (500 lbs/day) of acidity and preventing over 45 kg/day (100 lbs/day) of metals from entering Laurel Run.

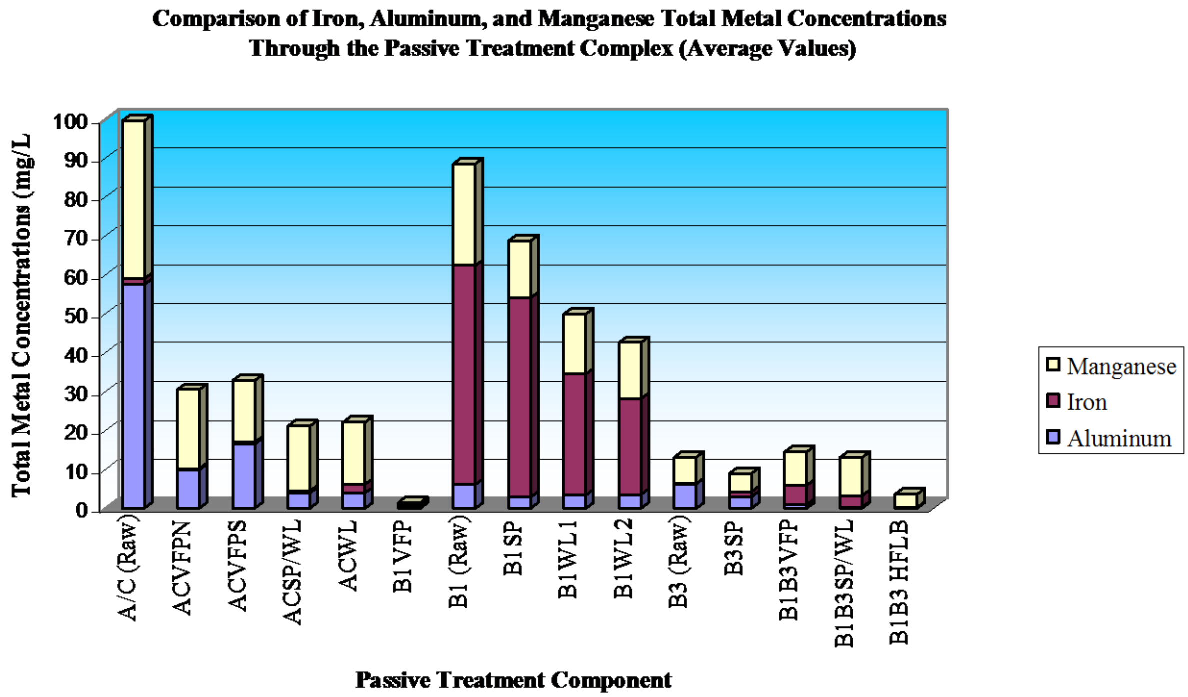

Figure 2. Comparison of Metal Concentrations Through the Passive System

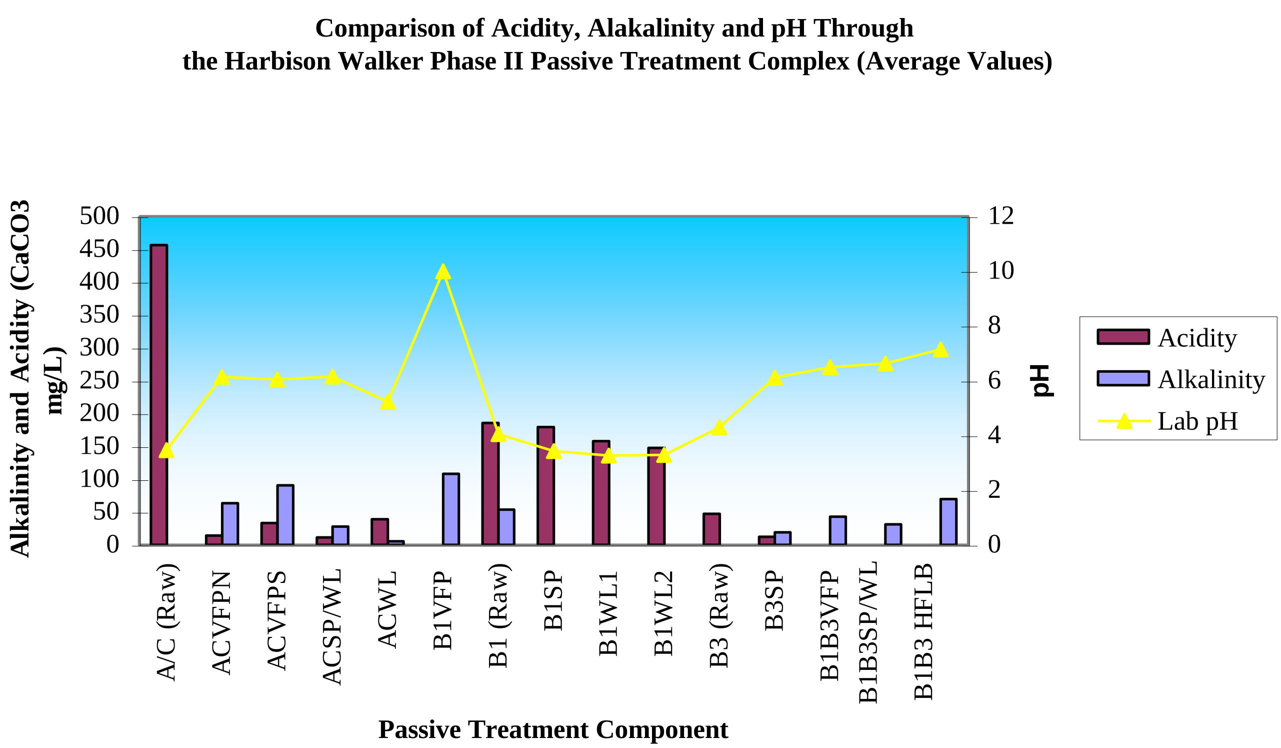

Figure 3. Comparison of Acidity, Alkalinity, and pH Through the Passive System

Operation and Maintenance

The Phase I and Phase II passive systems were designed based on the best available knowledge and technology at the time to provide efficient treatment with minimal operation and maintenance when compared to conventional chemical treatment systems. In order, however, for any passive system to continue to provide long-term treatment of mine drainage, periodic monitoring and inspection of the site is critical in order to determine if/when maintenance, retrofitting, and/or recharging of the treatment media is necessary.

The following is an overview of the major tasks/elements included in the written Operation and Maintenance plan for the Phase II site.

Inspections

One of the most important tasks to maintain the integrity of a passive treatment system is to inspect the site at regular intervals and preferably after major precipitation events or other natural/manmade occurrences that may affect the performance or integrity of the structures. The frequency of inspections is site dependant. An aerobic wetland treating a net-alkaline iron discharge may only need to be inspected annually while a more complex system with vertical flow ponds may require quarterly or even monthly monitoring. As the system ages, review of the monitoring data may allow the inspection frequency to be adjusted.

Site inspectors should have an understanding of, and the ability to perform, basic routine duties, such as evaluating channels, spillways, vegetation and passive treatment components as well as water sampling, measuring flows, and flushing. The inspection report should include the date, the inspector’s name, the organization, observations on the physical condition of the site, any maintenance performed or needed, field data collected, and the start/end time.

Numerous site features should be evaluated. For instance, the overall condition of the vegetation should be rated, as vegetation (i.e. groundcover) is extremely important to provide wildlife habitat and to prevent erosion. Sediment entering the passive treatment components can cause plugging or loss of capacity. All diversion ditches, collection channels, and spillways should also be inspected and kept free of obstructions/debris such as tree limbs, leaves, sediment, trash, etc., to insure proper water handling. Channels/ditches should be cleaned when capacity is reduced by one half.

All passive treatment system components such as vertical flow ponds, settling ponds, flush ponds, wetlands, collection systems, etc., that intercept and convey water need to be inspected for erosion, berm (slope) stability, vegetation, siltation, leaks, etc. Water inlets should be observed during each inspection and kept free from debris, sediment, leaves, and other foreign objects. All flow control structures including pipes should be maintained to assure unrestricted flow. All valves should be monitored to insure full operation (i.e. are able to be completely opened & closed) with no leakage. Other areas of concern include significant changes in water level, water discharging from the emergency spillway, proper water level for plants in the wetlands, and signs of vandalism. Any problem should be corrected as soon as practicable to continue the efficient operation of the system.

Wildlife Utilization

One of the functions of the constructed wetlands is to provide wildlife habitat for desired species. Animal tracks, visual observations of wildlife utilizing the site, or damage caused by wildlife should be noted. If during inspections, signs of damage are noted, such as from muskrats in wetlands, vertical flow ponds, and settling ponds, appropriate steps should be taken to continue the function of the passive system and general site restoration. When possible, the system should be designed or retrofitted to minimize damage by wildlife. For example use of chain link fence buried within the berms of the components will prevent muskrats from burrowing completely through the structure. Also, planting with a variety of species as opposed to a monoculture will minimize damage caused by insects, animals, and disease. This is especially true for wetlands. Significant damage needs to be corrected by repairing berms, removing invasive plants and animals, and replanting. Trapping may become necessary; however, the appropriate governing agency should be contacted to ensure compliance with regulations.

Field Water Monitoring and Sample Collection

In order to assess the efficiency and performance of the system, monitoring of each component should be completed to provide a description of the water quality through the passive treatment complex. The monitoring point locations should be identified on an inspection field sheet, site schematic, and “As-Built” plans. If feasible, water samples can be taken and analyzed using standard chemical testing procedures. Parameters to be analyzed will depend upon the quality of the discharge as well as the end use of the data. In addition to typical mining parameters such as pH, alkalinity, acidity, specific conductance, sulfates, total suspended solids, dissolved oxygen, and total and dissolved metals such as iron, manganese, aluminum, and calcium are also valuable. Field tests should also be completed including flow (as feasible), pH, temperature, and alkalinity. If laboratory analyses are not to be completed, at a minimum, the following field tests should be performed: flow rate, pH, alkalinity, and dissolved iron, where indicated.

In order to facilitate data management and provide a resource to watershed groups, governmental agencies, and researchers, entering data into an online database can enable timely review. The website "Datashed" at www.datashed.org is an example of such a database that was created by Stream Restoration Incorporated (non-profit). "Datashed" is a user-friendly, interactive, GIS enabled database with dynamically updated graphs and reports. The data can be viewed and downloaded from the web, although only those with approved passwords can upload data. A website, such as "Datashed", can also provide downloadable operation and maintenance plans, site schematics, driving directions and monitoring reports. In addition, the website can be programmed to email predefined responsible parties when entered data indicates a potential problem with the system.

Annual Wetland Plant Diversity Assessment

As part of the periodic O&M inspections, it is recommended that an annual wetland plant diversity assessment be completed. The primary purpose is to assess the diversity of plant species within the constructed treatment wetlands in order to determine if species diversity is increasing or decreasing. Species diversity is believed to increase the health, productivity, and treatment capability of the wetland. In addition, increased plant species diversity should result in an increase in wildlife diversity. A secondary purpose is to identify and remove unwanted invasive plants.

Maintenance

One of the primary reasons for conducting inspections and water monitoring of passive treatment systems is to identify maintenance issues and if possible to address those issues during the inspection. If construction equipment is needed, corrective actions should be scheduled as soon as possible. Redundancies included in the system design such as parallel treatment components so that maintenance can be performed without interruption of treatment is recommended.

Preferential Flow Paths and Short-Circuiting

Water traveling through a component whether a wetland, anoxic limestone drain, or vertical flow pond tends to develop preferential flow paths. For example, dissolution of limestone aggregate may create mini pseudo-karst-like pathways and retention of solids may reduce hydraulic conductivity in the treatment media. Over time, short-circuiting and decreased treatment may result. Flushing has been used to address these issues. In wetlands, channeling may also cause significant short-circuiting reducing treatment efficiency. Earthen berms can be incorporated into the design and hay bales can be use to redirect flow into underutilized sections. To discourage short-circuiting in settling ponds, baffles are often used.

Flushing

Some passive treatment components have a flushing mechanism. The purpose of flushing is to remove solids that have accumulated within the component in order to maintain proper hydraulic conductivity within the treatment media as well as to discourage development of preferential flow paths. However, there is some empirical evidence in certain situations that flushing can create or encourage preferential flow paths through the treatment media. The frequency of flushing needed is variable from system to system. Some may need to be flushed annually, others quarterly, and some monthly. The variability would seem to be related to differences in water quality and flow. Periodically, the flushing schedule should be evaluated and adjusted to reflect water quality and quantity changes and system performance. Prior to flushing, the water elevation in the flush/settling pond should be checked to assure sufficient storage capacity. Backflushing by attaching a small pump to the piping system may be conducted to enhance the effectiveness of the flushing event. Care must be taken so as not to exceed the pressure rating of the pipe.

Miscellaneous Piping

Depending upon size and design, passive treatment systems can contain miles of buried piping that are critical to the proper functioning of the system. To insure the continuous treatment of the mine drainage, inlet and outlet structures should be regularly inspected and any problems noted and corrected as soon as possible. These pipes will need to be cleaned when the capacity is reduced by 25 percent. Pipes can be cleaned with pipe clean-out rods, industrial snake clean-out tools, backflushing, or other reasonable methods.

Removal and disposal of accumulated precipitate or sediment

Precipitates from chemical reactions and other solids will be retained within flush ponds, settling/wetlands ponds, Vertical Flow Ponds, etc. Assessments should be made periodically to determine the amount of accumulated sludge. Sludge should be removed when storage is reduced by one half or the accumulated sludge is significantly reducing efficiency. Opportunities may be available to utilize the sludge for metal recovery or the sludge may be allowed to drain/dewater for disposal. Disposal procedures will be determined based on federal and state regulations.

Maintenance and Enhancements at the Harbison Walker Phase II Site

The need for the above described Operation and Maintenance Plan was identified through limited, post-construction, inspection and water monitoring. During these efforts, various maintenance issues as well as enhancements/upgrades to the system were identified and corrected and/or completed. These activities have included flushing of Vertical Flow Ponds, revegetation of selected areas, replacement of damaged pipes with berm reconstruction, removal of debris from spillways and ditches, and upgrades to the system.

AC Vertical Flow Ponds

Initially, the AC Vertical Flow Pond North (ACVFPN) and AC Vertical Flow Pond South (ACVFPS) provided exceptional treatment. After a year of operation, however, monitoring and other field investigations documented that the effluent quality was becoming variable. (Raw pH ~3.3 with the effluent varying from ~4.2 to 5.7 pH) Based on observations during dye testing, the problem appeared to be related to the development of preferential flow paths that resulted in short-circuiting. Additional dye tests as well as backflushing indicated that the short-circuiting was caused, at least in part, by broken pipes. The ponds were drained, portions of the treatment media removed, and the broken sections of pipe replaced and the effluent quality improved. (Effluent pH increased to 6.4 with ~70 mg/L field alkalinity)

Although replacement of the broken pipes improved performance, preferential flow paths had already been established within the treatment media and within about two months field pH was occasionally ~5. By donation of time and of resources by project participants, the ACVFPN and ACVFPS were retrofitted as Hybrid Flow Ponds (patent pending) in order to encourage a more horizontal flow component during normal operation and a more vertical flow component during flushing, helping to interrupt established flow paths. Field tests again noted the pH to be ~6.4 and the alkalinity to be ~70 mg/L. Continued monitoring has also indicated that this system which is treating very acidic water with high concentrations of aluminum (~100 mg/L) needed to be flushed more frequently than on a quarterly basis.

<u>AC Wetland</u>

During construction of the AC Wetland (ACWL), seeps containing high (129 mg/L) concentrations of dissolved iron were encountered. Because of this degraded seepage and/or when design flows for the AC system are exceeded, additional treatment was desirable (field pH <6) and an alternate, valve-controlled, primary spillway was installed for the ACWL in order to discharge into the B1B3 passive system. Even with the added flow, the final effluent from the B1B3 passive system has been circum-neutral, net-alkaline water with dissolved iron, manganese, and aluminum concentrations less than 1 mg/L. For additional alkalinity, the B1 Vertical Flow Pond (B1VFP) was modified to provide an alternative mode of operation as a Hybrid Flow Pond with the treated discharge conveyed to the ACWL via the riprap-lined B1 Flush Pond (B1FP) emergency spillway. Because of this upgrade, the final effluent pH, without discharging into the B1B3 passive system, has been ~6.

Conclusion

With donated services from a committed public-private partnership effort, field monitoring has been conducted and maintenance/upgrades have been completed. Long-term data collection and evaluation are needed to more definitively address operation and maintenance to insure long-term functionality of the system and to encourage the continued development of passive technology. Based on available data and field observations, however, passive treatment is not a no-maintenance solution to mine drainage. The amount of maintenance required varies from component to component and system to system and is dependant on such factors as water quality, flow, and system complexity. Development and implementation of individual, comprehensive operation and maintenance plans that include online data management are necessary to help identify issues that can be corrected in a timely manner to ensure long-term or sustainable treatment of mine drainage.

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