Harbison Walker--A Hybrid Passive Treatment System
by
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Harbison Walker is an old reclaimed clay mine that is located within the confines of Ohiopyle State Park. This site, although mining was completed years ago, still emits several different types of mine drainage that must be treated prior to entering the receiving stream, Laurel Run. The drainage exists as seeps within and below the mined area, and have the following analysis:

RAW WATER ANALYSIS

Sample Point	pH	Conductance	Acidity	Iron	Manganese	Aluminum	Sulfates
AC Raw Water	3.46	1,880	434	1.65	36.5	56.0	1,437
B1 Raw Water	3.14	1,418	229	60.9	20.18	7.85	749
B3 Raw Water	4.30	574	47.1	0.11	6.74	5.93	400

As exhibited in the chart, parameters of concern are pH/acidity, iron, manganese, and aluminum. Based on the three raw water quality types, an all encompassing hybrid passive treatment system was designed to remediate the quality to current effluent limit requirements that call for a 6-9 pH, an Fe<7, and Alkalinity >Acidity. As you will note on the accompanying drawings, there are essentially three different systems. They are the AC system, B1 system, and the B3 system. As such, within each of the systems, are several treatment components designed, based on flow and quality. These systems all work together to improve water quality so that the final B3 Horizontal Flow Limestone Bed (B3HFLB) discharge has the following median values:

FINAL DISCHARGE WATER ANALYSIS

Sample Point	pH	Conductance	Alkalinity	Iron	Manganese	Aluminum	Sulfates
B3HFLB	6.53	1,145	72.86	0.06	0.44	0.11	629

In order to end up with this type discharge, each individual treatment component had to perform as designed. The components of each system are identified as follows:

System	Component	Comments
AC	Raw Water Source	Seeps collected to make up AC system
ACVFPN	3,000 T. Vertical Flow Pond	Two tiered multi-cell, 7 cells limestone-1 cell slag
ACVFPS	3,000 T. Vertical Flow Pond	Two tiered multi-cell, 7 cells limestone-1 cell slag
ACFP	35,000 Cu. Ft. Flush Pond	Non-Discharging flush pond for ACVFP-S/N-dr. down/spillway
ACSP/WL	6,030 Sq. Ft. Settling P./Wetland	Primary use for particulate settling from Vertical Flow Ponds
ACWL	8,750 Sq. Ft. Wetland	Primary use for final particulate settling and polishing
B1VFP	1,000 T. Slag-Only Vertical Flow Pond	Water from ACSP/WL treated with slag to mix with B1 raw
B1	Raw Water Source	Seeps collected to make up B1 system
B1FP	10,000 Cu. Ft. Flush Pond	Non-Discharging flush pond for B1VFP-dr. down/spillway
B1SP	9,000 Sq. Ft. Settling Pond	Treated Slag alkaline water and B1 raw mix settle in B1SP
B1WL1	16,275 Sq. Ft. Wetland	Primary use for final particulate settling
B1WL2	1,955 Sq. Ft. Wetland	Primary use for final particulate settling
B1WL3	915 Sq. Ft. Wetland	Primary use for final particulate settling
B3	Raw Water Sources (2)	Seeps collected to make up B3 system
B3SP	2-9,000 Cu. Ft. Settling Ponds	Seep water from two limestone and slag diversion ditches
B1B3VFP	1,400 T. Vertical Flow Pond	Two tiered multi-cell, 7 cells limestone-1 cell slag
B1B3SP/WL	9,000 Sq. Ft. Settling P./Wetland	
B1B3FP	18,000 Cu. Ft. Flush Pond	Non-Discharging flush pond for B1B3VFP-dr. down/spillway
B1B3HFLB	1,000 T. Horiz. Flow Limestone Bed	Manganese removal-Alkalinity generator-Final Discharge

The basic flow of water starts with the AC raw water split between 2-3,000 ton vertical flow ponds. The treated effluent from the VFP's flows into a combination settling pond and wetland. At this point, there are two travel paths for the water exiting this structure. Part of the water will travel by a valved pipe into a 1,000 ton slag only VFP, while the remaining water flows into another wetland (ACWL). The ACWL can either be discharged into Laurel Run, or it can be diverted to the B1 Wetland (B1WL1) for additional treatment if required. Backing up a bit, the water entering the Slag only VFP is actually the first stage of treatment for the B1 system. As stated, a portion of the treated water from the ACSP/WL system proceeds through the Slag and emerges with approximately a 10.5 pH and an alkalinity of around 80 mg/l. This water immediately mixes with the B1 Raw Water that has been collected through a series of rock drains. The purpose for this segment of treatment was to provide alkalinity and pH for partial treatment of the B1 Raw Water. The mixed waters proceed to the B1 Settling Pond (B1SP) where some of the iron and/or other metals will precipitate. From here, the B1SP effluent travels through three wetlands designated as B1WL1, B1WL2, and B1WL3. The primary purpose for these wetlands is settling. At this point, the AC and B1 treated waters leave the B1WL3 and combine with the B3 system water after entering the B1B3 Vertical Flow Pond (B1B3VFP). Again, before getting too far ahead, let's back up to the B3 system. The B3 Raw water is collected in two diversion ditches that are lined with limestone and slag. The raw water itself in this area is not so bad that the ditches provide enough alkalinity to liberate most of the aluminum, which is then settled out in two settling ponds (B3SP). From the settling ponds, the water moves through a pipe to the B1B3VFP where it joins the AC and B1 waters. Upon exiting the B1B3VFP, the water quality is as follows:

B1B3VFP

Sample Point	pH	Conductance	Alkalinity	Iron	Manganese	Aluminum	Sulfates
B1B3VFP	6.53	1,140	41.62	4.08	8.02	0.84	672

This water now flows to a combination Settling Pond & Wetland (B1B3SPWL) and enters the B1B3 Horizontal Limestone Bed (the final treatment structure) with a quality as below.

B1B3SPWL

Sample Point	pH	Conductance	Alkalinity	Iron	Manganese	Aluminum	Sulfates
B1B3SPWL	6.67	939	22.06	3.10	10.20	0.26	636

After traveling through the B1B3 Horizontal Flow Limestone Bed, the water discharges into Laurel Run as follows:

B1B3HFLB--FINAL DISCHARGE

Sample Point	pH	Conductance	Alkalinity	Iron	Manganese	Aluminum	Sulfates

B1B3HFLB	**6.53**	**1,145**	**72.86**	**0.06**	**0.44**	**0.11**	**629**

As a final comparison between the raw water versus the final discharge, please note the following:

Sample Point	pH	Conductance	Acid./Alk.	Iron	Manganese	Aluminum	Sulfates
AC Raw Water	**3.46**	**1,880**	**434/0**	**1.65**	**36.5**	**56.0**	**1,437**
B1 Raw Water	**3.14**	**1,418**	**229/0**	**60.9**	**20.18**	**7.85**	**749**
B3 Raw Water	**4.30**	**574**	**47.1/0**	**0.11**	**6.74**	**5.93**	**400**
B1B3HFLB	**6.53**	**1,145**	**0/72.86**	**0.06**	**0.44**	**0.11**	**629**

Harbison Walker is an example of how passive technology has been transforming over the last few years in order to meet more stringent effluent limits associated with TMDL and Anti-Degradation regulations. We want to especially thank the Pennsylvania DEP in allowing us the opportunity to be involved in such a creative process. It is projects such as this which allows us to expand our work and accomplishments in the field of Passive Treatment.

Now that we have walked our way through the different systems, I want to spend some time on some of the things I feel we have learned at Harbison Walker over the last two years.

1--In Real Estate, they say it's "location--location--location". In passive treatment systems it should be "flow distribution--flow distribution--flow distribution". Flow distribution directly relates to retention time, which directly relates to contact time. This particular treatment parameter is what ultimately makes a system succeed or fail. If you stop and think about it, everything involved in water treatment is based on the common parameter of time. If it has to do with settling of particulate matter, it's time. If it's solubilization of a treatment media, it's time. If the treatment process depends on bio-remediation, it's time. I realize that time is not the only treatment parameter, but it provides the basis by which all the other parameters function. Why the sudden revelation? Good question. The final nail in the proverbial coffin came in the form of a dye tracer test that we ran on the AC Vertical Flow Ponds. As the dye entered each of the AC VFP's, some of it chose distinct flow paths towards specific points, while the rest exhibited a minor amount of diffuse flow. We recorded the time that the trace began and within 15-20 minutes, dye began to show in one of the discharge pipes. That was not quite the 12-24 hours we had hoped to find. To make a long story short, it was immediately evident why the AC VFP's were not performing as they should--it was a matter of "TIME". There wasn't enough retention/contact time for the water in either VFP due to the short-circuiting. When you watched the dye, it sort of all begin to make sense. The name of the system describes the very nature of the problem, which is vertical flow. For water to flow vertically downward in the manner we visualize it in this application conditions would have to be perfect. The limestone bed would have to have the exact same density throughout, and the pipe perforations would have to be designed to compensate for line loss and pressure drops across pipe intersections. Since we can all probably agree that this doesn't happen, we can assume there will begin to emerge preferential flow paths through the limestone bed. Any such type of preferential flow entirely defeats our purpose of optimizing contact time. To make it worse, how do we flush these beds? Since gravity still rules, the flushes are vertically downwards. Hmmmm! That's right--the flushing can actually enhance the formation of the preferential flow paths. After standing around and pondering for a while, we decided to change the vertical flow regime of one of the AC VFP's into one utilizing horizontal flow. Since both of the AC VFP's had multi-cell, two tier piping arrangements, we took the ACVFPS and shut off 7 of the eight cells. The eighth cell was located on the bottom and at the discharge end of the pond. Also, the water elevation in the ACVFPS was dropped to just below the surface of the limestone to induce horizontal flow through the pond. We now had a modified horizontal flow system that still had all the pipes of the vertical flow pond. That meant we now had a horizontal flow pond with a vertical flush system. Hmmmm, horizontal flow and vertical flush!! What happened with the effluent quality after we did this? The pH came back up, acidity was replaced with alkalinity, we saw an increased reduction in manganese. The other really interesting aspect of this metamorphism was when some of the crew went back a short time later and flushed the system. Unlike the 15-30 minute flush that we normally experience with flushing VFP's before they are clear, the modified system continued to emit solids for in excess of 3 hours. Ding, ding, ding---are you starting to hear the bell. Anyway, we fell into a modified version of a VFP/HFLB, which performed much better than a VFP alone. What else have we learned?

2--We also learned that the Slag only VFP emitted high pH water with moderate alkalinity, based on our design. Actually, the median concentrations for the B1VFP showed a 10.14 pH, 81 mg/l alkalinity, 0.14 mg/l Fe, 0.31 mg/l Mn, and a 0.18 mg/l aluminum. These were total values. the dissolved values were almost non-detectable. We were shooting for high pH values, but also were hoping for much higher alkalinity. Actually, it shouldn't have been any surprise as to the moderate alkalinity, simply due to the chemistry involved. In the slag VFP we are working with hydroxyl alkalinity rather than carbonate alkalinity as associated with limestone. As such, from all my titration work over the years with calcium oxide (primary pH/alkalinity generator in slag), I should have anticipated the alkalinity results based on the pH. I have found that in active treatment systems, alkalinity remains low to moderate in pH values up to a 10.5 pH. At this point, buffering mechanisms begin to kick in, which requires more and more calcium oxide (or other alkaline amendments) in order to increase the pH. As an example, whereas it might take 0.20 grams to increase the pH from a 3.5 to a 10.5, it may take 0.30 grams more to raise the pH from a 10.50-11. This is where you pick up residual alkalinity when actively treating with hydroxyl type chemicals. Therefore, we have to decide if the increase in calcium oxide consumption justifies the resultant alkalinity for what we are trying to accomplish. Another problem in raising the pH up high enough to generate +200 mg/l alkalinity is the precipitation of magnesium in the 10.5-11 pH range. It is a problem since it adds to the ultimate sludge volume. At some active sites, I have seen people treat for 5-10 mg/l of manganese and end up precipitating 150 mg/l of magnesium due to over-treatment. So, all of these concerns are currently being studied like everything else. One thing is for sure though, slag is an amazing water treatment tool, and should play an important role in future treatment systems relative to site specific conditions.

Have we learned anything else? Of course. We learned that trying to construct passive systems in the wet and/or Winter months can result in problems associated with soil stability and also problems with the VFP piping system with regards to connections. We learned to design multiple individual systems at the same site with cross over pipes for emergency situations or for maintenance purposes. We learned that back flushing the system, when done properly, reveals much more than a dye tracer test. In other words we have learned a great deal and continue to learn on a daily basis due to the all encompassing design of the Harbison Walker systems. We want to thank the State of Pennsylvania one more time for their efforts relative to the grants programs. For without those grants, none of this type work would be possible.

If you have any further questions concerning these systems, please don't hesitate to contact Margaret Dunn or Tim Danehy at (724) 776-0161, or myself (Tiff Hilton) at (304) 645-7633.

HARBISON WALKER PASSIVE TREATMENT SYSTEM
MEDIAN QUALITY VALUES 3/2000-12/2002

Sample Point	pH	Conductance	Alkalinity/Acidity	T. Fe/D. Fe	T. Mn/D. Mn	T. Al/D. Al	Sulfates
AC Raw Water	3.46	1,880	0/434	1.65/----	36.5/36.3	56.0/----	1,437
ACVFPS	5.97	2,058	75.8/6.40	0.38/----	14.2/13.5	12.9/2.24	1,442
ACVFPN	5.70	1,943	70.5/0	0.33/----	24.7/24.0	11.1/1.16	1,475
ACSP/WL	6.41	1,820	19.4/0	0.47/----	15.55/----	3.27/0.29	1,405
ACWL	5.80	1,761	6.22/18.5	1.65/----	16.05/----	1.77/0.71	1,295
B1VFP (SLAG)	10.14	1,836	81.0/0	0.14/----	0.31/0.02	0.18/0.09	1,105
B1 Raw Water	3.14	1,418	0/229	60.9/58.4	20.18/----	7.85/7.37	749
B1SP	3.22	1,432	0/158	45.6/38.6	14.3/13.8	2.93/2.48	873
B1WL1	3.22	1,255	0/150	30.1/28.6	16.1/14.9	3.38/3.24	836
B1WL2	3.25	1,335	0/132	23.4/21.6	14.2/13.8	3.48/3.26	794
B3 Raw Water	4.30	574	0/47.1	0.11/----	6.74/----	5.93/----	400
B3SP	6.54	455	0/18.6	0.37/0.09	3.07/3.06	1.95/0.26	249
B1B3VFP	6.53	1,140	41.62/0	4.08/3.55	8.02/8.00	0.84/0.38	672
B1B3SPWL	6.67	939	22.06/0	3.10/2.30	10.20/9.70	0.26/0.11	636
B1B3HFLB	6.53	1,145	72.86/0	0.06/-----	0.44/----	0.11/0.06	629