Upper Latrobe Passive Treatment System

Final Report and Operation and Maintenance Plan

Prepared for Loyalhanna Watershed Association, June 2010

Background

The Upper Latrobe system passively treats Fe-contaminated water that flows from a borehole into an abandoned underground coal mine. The borehole was drilled in for the purpose of releasing water at a site where passive treatment was feasible. Once the system is functional, efforts to cap or plug untreated flows from the mine will be pursued. The treatment system is on land donated to the Loyalhanna Watershed Association (LWA) by the Latrobe Foundation. Funds to design and construct the system were provided by the Pennsylvania Department of Environmental Protection Growing Greener Program through a grant to LWA. The system was designed by Iron Oxide Recovery, Inc. (IOR) who also managed the day-to-day project activities and prepared this Operation and Maintenance (O&M) Plan. LWA is responsible for the long-term O&M of the treatment system.

Discharge Flow and Chemistry

Table 1 shows the chemical characteristics of the discharge before the system was installed. A listing of all data collected from the borehole attached to the end of this report. The data were collected by LWA and IOR. The discharge is net alkaline water contaminated with 45-50 mg/L Fe. Manganese and Al concentrations are low. The chemistry does not vary substantially. The 90th percentile Fe concentration is only 7 mg/L higher than the median concentration, 45 mg/L Fe. For perspective, most permitted mine drainage treatment systems have an effluent limit of 3 mg/L Fe. The receiving stream, Loyalhanna Creek, is classified as a warm water fishery and has an in-stream Fe limit of 1.5 mg/L.

Table 1. Characteristics of the Upper Latrobe borehole discharge, 2004-2008.

	pH	Alk	Acid	Fe	Mn	Al	SO4
		mg/L as $CaCO_3$		-----------mg/L----------			
Average	6.4	140	-31	45.5	3.4	<0.5	438
Median	6.4	144	-26	45.2	3.4	<0.5	445
90th percentile	6.3	123	-1	52.5	3.7	<0.5	516
# of samples	42	44	41	44	42	42	42

The alkaline chemistry is typical of deep mine discharges from the Pittsburgh coal seam in this area. Discharges from the same deep mine complex are currently treated at the St Vincent College Monastery Run passive treatment complex. The alkaline Fe-contaminated water is well suited for passive treatment with aerobic ponds and wetlands.

Flows were measured at a V-notch weir placed in a channel below the borehole discharge. A valve which controls the flow from the borehole was completely opened in February 2009.

Seven measurements between February and April 2009 ranged from 411 – 450 gpm. The highest flow, 450 gpm, was measured five times suggesting that flow is restricted by the borehole or valve to this value. At the 450 gpm and 45 mg/L Fe, (average, Table 1) the borehole produces 246 lb/day Fe (112 kg/day).

How the System Works

The system treats the iron contamination through oxidation and settling processes. Ferrous iron (Fe^{2+}) is oxidized to ferric iron (Fe^{3+}) which hydrolizes to form particulate iron oxide. These solids settle in the ponds and wetland. At Fe concentrations less than 40 mg/L, solids settling is slower than ferrous iron oxidation. While aeration and oxidation are necessary components of the treatment, the ability of the system produce an effluent with low (< 1 mg/L) Fe depends on the solids settling efficiency.

The system layout is shown on Map 1. The mine water flows through three ponds and a single large constructed wetland. The borehole discharge was split into two flows that are piped to Ponds 1 and 2 (arranged in parallel). Water enters the two ponds via horizontal fountains that aerate and distribute the flow. Water is transferred between the ponds and constructed wetland in multiple troughs that distribute the water and lessen preferential flow paths. The ponds are intended to fully oxidize the iron and settle a majority of the iron solids. The shallow vegetated wetland is intended to act as a filter and remove residual iron solids. The end of the constructed wetland blends into a small pond that will lessen plugging of the discharge pipe with vegetation and also provide fish habitat.

System Design

The system was designed for a 500 gpm flow containing 53 mg/L Fe (90th percentile). The design assumed that the settling ponds would lower the Fe to about 12 mg/L at an average rate of 20 grams Fe per m^2 per day. These assumptions calculated 60,000 ft^2 of ponds (at water surface). The installed system includes three ponds with a total surface area of 62,000 ft^2. Multiple ponds were incorporated so that during major maintenance periods, the system would continue to treat water effectively. The design assumed that the wetland would lower the Fe from 12 mg/L to <1 mg/L at an average rate of 4 grams Fe per m^2 per day. These assumptions calculated 87,000 ft^2 of wetland. The installed construction wetland has a surface area of 88,000 ft^2.

Table 2. Design assumptions and installed surface areas

	Flow	Fe^{tot}	Fe^{dis}	Fe^{part}	Fe removal	Surface area, ft^2	
	gpm	**mg/L**	**mg/L**	**mg/L**	**g/m^2/day**	**calculated**	**actual**
Borehole	500	53	53	<1	Na	na	na
Pond 3 out	500	12	<1	12	20	60,000	62,000
Wetland out	500	<1	<1	<1	4	87,000	88,000

Mine Water Piping The borehole is located in the berm between Ponds 1 and 2 (Figure A). All mine water piping is 6 in diameter schedule 40 PVC. Water is collected downgradient of the borehole valve and split into three flows. The primary flow paths are to Ponds 1 and 2. A bypass pipe allows water to be piped directly to the end of the constructed wetland. The bypass was utilized during construction and is not expected to be used again. The pipes leading to Ponds 1 and 2 have gate valves that are contained in locked metal sleeves. By manipulating the valves it is possible to operate the system is several manners as described below.

- *Routine operations*: borehole valve fully open, Pond 1 gate valve open, Pond 2 gate valve open, Bypass valve closed
- *Pond 1 Major Maintenance*: borehole valve fully open, Pond 1 gate valve closed, Pond 2 gate valve open, Bypass valve closed
- *Pond 2 Major Maintenance*: borehole valve fully open, Pond 1 gate valve open, Pond 2 gate valve closed, Bypass valve closed
- *Pond 3 Major Maintenance*: borehole valve closed

It is not known how long the borehole valve can be closed before water begins to discharge at other points in the area. It is not recommended to close it for more than one week. If work is necessary in Pond 3 that requires more than one week, it is possible to bypass water through Pond 3 to the wetland using the troughs and temporary piping.

Horizontal Fountains Raw mine water enters Ponds 1 and 2 through horizontal fountains constructed from 8 in schedule 40 PVC pipe laid horizontally on an aggregate base. Water discharges from the pipes through 3/8 in holes spaced every foot. The end of each pipe has a 90^o upturned elbow that acts as the overflow and also creates a gas trap that prevents air from getting into the pipe.

Ponds All three ponds are 4 ft deep at the design water level. The ponds were constructed with 60 mil coarse texture HDPE liners. Each pond has a circular sump constructed from HDPE culvert pipe that is 4 ft wide by 2 ft deep (below the pond bottom) filled with 6 in of concrete. Fiberglass rods are imbedded the sumps to show locations when water level is lowered by 2 feet. The sumps were welded into the pond liners.

Troughs Water is transferred between ponds and the wetland through troughs. The troughs are constructed of vinyl plastic and are each 12 in wide by 9 in deep. Ponds 1 and 2 each have five discharge troughs. Pond 3 has seven effluent troughs. The troughs were bolted onto a poured concrete foundation and secured with concrete poured over the trough wingwalls.

Constructed Wetland The wetland has 4-8 inch water depth at the design water level. The wetland blends into a 4 ft deep ponded area at the end of the system. The wetland was constructed with a CETCO Bentomat ST clay liner that extends into the pond. The liner was covered with one foot of topsoil and planted with a variety of wetland species by Ecological Restoration. The outside banks of the wetland were lined with chain link fencing to discourage muskrat tunneling.

Sludge Basin An 18,000 ft^2 sludge basin was installed to be used for sludge storage. The basin is not lined.

<u>Excess Cut</u> The project produced approximately 14,000 CY of excess cut that was used in the construction of Cardinal Park by the Latrobe Unity Parks and Recreation Department and also stored on Latrobe Foundation property for use in later projects.

Project Construction

The project was bid in August 2009. Eight bids were received that ranged from $286,000 to $801,000 with an average value of $454,000. The lowest bid was received from CM Construction (Saltsburg, PA) who was contracted by LWA to install the project. Construction began in September 2009 and was completed in June 2010.

Several change orders occurred during the system's construction. The final construction cost was $316,000. Table 3 shows the final project construction budget.

Table 3. Final budget for CM Construction.

Item	Description	Total
A	Mobilization and Demobilization	$ 16,800
B	Erosion and Sediment Control	$ 9,500
C	Access road installation	$ 33,577
D	Clear/grub	$ 25,000
E	Remove excess cut	$ 14,000
F	Pond earthwork	$ 16,000
G	Pond liners	$ 49,000
H	Piping and valves	$ 10,600
I	Wetland earthwork	$ 8,500
J	Wetland liner	$ 50,250
K	Wetland planting	$ 45,000
L	Sludge basin	$ 6,000
M	Site seed/mulch	$ 6,500
CO2	Additional wetland liner	$ 17,657
CO3	iron sludge removal	$ 1,500
CO4	extra lime	$ 2,980
CO5	Sludge sumps in ponds	$ 5,500
CO6	Muskrat fencing and WLC box	$ 2,200
Total		$ 320,564

Operation and Maintenance Plan

Routine Operation and Maintenance

The primary goal of routine Operation and Maintenance (O&M) efforts is to maintain flow through the installed system. The important aspects of the system's hydraulics include the following features.

- The horizontal fountains should distribute water into Ponds 1 and 2 through multiple spraying streams of water.
- The troughs that carry water between the ponds and wetland should be free of obstructions and should carry similar flows of water.
- The AgriDrain water level control structure at the end of the wetland produces the final effluent. It should be free of obstructions.

Monthly inspections are recommended. The inspection should include a walk through the system with attention to the system's general operation and potential problem areas. The inspector should be able to correct easy problems such as trough blockage (iron sludge, leaves and sticks).

Several minor maintenance items should be done every year by the operator. The water level control box at the end of the system may accumulate dirt, iron, and debris. Once a year the box should be cleaned out and the top panels should be removed, wiped cleaned, and replaced. The panels are removed with a tool that is stored onsite. The small holes in the horizontal fountains (Ponds 1 & 2) should be cleaned if there are signs of blockage. A small brush (test tube cleaner) will do the job. Water should be left running during the cleaning so that the blockage is washed out of the pipes. All gate valves should be operated (opened and closed repeatedly) once a year to make sure they work properly.

An inspection form has been developed that prompts the inspector to record useful observations. The inspection form is attached.

Major Maintenance

<u>Unexpected Major Maintenance</u> Major maintenance involves non-routine efforts that cannot be accomplished by the site inspector. Examples would be the removal of trees that have fallen into the ponds or wetland, removal of beaver dams, repairs to the influent fountain pipes, repairs of the troughs, and removal of excessive vegetation in the wetland. The system is located in the Loyalhanna Creek flood plain and it is likely that the system will be occasionally inundated by major flooding events. Repairs may be necessary after such an event. Major maintenance efforts that correct one-time problems (all the above) can be funded through the Western PA Coalition for Abandoned Mine Reclamation Quick Response Emergency Repair program.

<u>Planned Major Maintenance: Sludge Removal</u>

The ponds will accumulate 1-2 inches of iron sludge per year. Sludge removal should be considered after 10 years when the pond capacity (and retention time) has decreased by ~30%. The bottom of the each pond contains a sump (4-ft diameter, 1.5 ft deep round HDPE culvert pipe with concrete bottoms) that should facilitate the removal of iron with a sludge pump. Sludge should be pumped to the sludge basin where it will naturally dewater and eventually (months) be dry enough to remove with an excavator. Leaving the sludge in the pond indefinitely should not cause any problems.

The system is designed to allow the primary sludge accumulating ponds (1 and 2) to be isolated during sludge recovery operations. The sludge removal process would include the following steps.

1. inspect the sludge basin and clear as necessary to prepare for sludge storage (cut/remove vegetation and debris)
2. turn off the flow to the pond being cleaned with the appropriate gate valve
    a. all the water will then flow through the alternate ponds and constructed wetland
    b. if the final effluent water quality is not acceptable, decrease the borehole flow using the screw valve
3. after a day, the water and sludge will separate; pump the clear water off
4. locate the sludge sump and position the pump intake in the sump
5. pump sludge from the sump into the sludge basin; in order to get sludge to flow to the sump, it may be necessary to operate a second pump that would spray and fluidize the sludge
6. leave sludge in the basin to naturally dewater
7. monitor the sludge condition to determine when it is suitable for excavation and loading into a truck (about 45% solids)

The ponds contain a 60 mil HDPE liner. This liner should be able to support operators and light vehicles. Heavy equipment should not maneuver within the ponds without the placement of liner protection.

The cost to remove the sludge may be offset by its value as a raw iron oxide product. (Uses of iron sludge for pigment and ion-exchange media have been demonstrated.) LWA should contact IOR or the PADEP regarding sludge removal feasibility after 7-8 years of system operation. PADEP has established an O&M fund to support major maintenance efforts at mine water treatment sites. If the sludge's value does not support its removal at no-cost, then LWA should explore a sludge removal funding request to PADEP.

System Replacement

The system does not contain any exhaustible components or reagents that need to be replaced. As long as the system hydraulics and the storage capacities of the ponds and wetland are maintained, there should be no need to replace the treatment system.

System Monitoring

The system's performance should be measured by sampling the influent and effluent once a quarter (every three months). The sampling points are:

- system influent collected from one of the horizontal fountain overflow pipes
- composite sample from the Pond 3 effluent troughs
- system effluent collected from water level control box effluent pipe

Flow can be measured in the water level control box from the depth of water over the top board. In practice, it is easier to measure the depth from the top edge of the box down to the water. Table 4 shows flows for such measurements that are based on the positions of boards in place on July 1, 2007 (22.5 inches below the top of the box). If the boards are modified, the table will need to be adjusted.

Standard mine drainage analyses include pH, alkalinity, acidity, conductivity, sulfate, total suspended solids, Fe, Mn, and Al. Metals (Fe, Mn, and Al) are typically measured on a sample preserved in the field with nitric acid. The remaining parameters are measured on a sample collected without preservation. If the iron samples cannot be acidified in the field, then the samples should be delivered to the laboratory as soon as possible (same day) for acidification at the lab. (Local labs routinely provide pre-acidified bottles for collection of the acid samples.) During sampling, care should be taken to avoid disturbing and mobilizing soil or iron solids in the sampling area.

The most important parameters for the Upper Latrobe system are pH and Fe. These parameters can be measured with a meter (pH) and Fe can often be measured by a laboratory for only $7-10. The quality of the final discharge can be assessed visually. If the water discharging through the water level control box is clear, then Fe concentrations are likely less than 1 mg/L. Visual assessments should be made on water that is collected in a clear plastic container. Always record a visual assessment of the final effluent, even when samples are collected for laboratory analysis.

Attachments to the O&M Plan

- Figure 1, map of system showing O&M points
- Inspection and Monitoring form
- Flow rate chart

Table 4. Flows rate estimates for water at the Water Level Control Box

Depth to weir (top board), 22.5 inches (measured in rail)		
Depth over weir, in	**depth to water, in***	**Flow, gpm**
0.00	**22.5**	**0**
1.97	**20.5**	**112**
2.17	**20.3**	**128**
2.36	**20.1**	**143**
2.56	**19.9**	**160**
2.76	**19.7**	**176**
2.95	**19.5**	**193**
3.15	**19.4**	**209**
3.35	**19.2**	**226**
3.54	**19.0**	**243**
3.74	**18.8**	**260**
3.94	**18.6**	**284**
4.13	**18.4**	**303**
4.33	**18.2**	**323**
4.53	**18.0**	**343**
4.72	**17.8**	**364**
4.92	**17.6**	**385**
5.12	**17.4**	**406**
5.31	**17.2**	**428**
5.51	**17.0**	**450**
5.71	**16.8**	**472**
5.91	**16.6**	**494**
6.10	**16.4**	**517**
6.30	**16.2**	**540**
6.69	**15.8**	**587**
6.89	**15.6**	**610**
7.28	**15.2**	**659**
7.48	**15.0**	**683**
7.68	**14.8**	**708**
7.87	**14.6**	**733**
*** measured from top edge of box down to water surface in box corner**		

Date ______________________________ **Inspector** ______________________________
Weather (today, recently)____

Item	**"yes" or comment (put long comments on back of sheet)**
Access road to gate (good condition?)	
Gate (closed and locked?)	
Access road to site (good condition?)	
Parking Area (good condition?)	
Pond 1 influent fountain, holes discharging?	
Pond 1 influent fountain overflow elbow flowing?	
Pond 2 influent fountain, holes discharging?	
Pond 2 influent fountain overflow elbow flowing?	
Pond 1 effluent troughs, operating?	
Pond 2 effluent troughs, operating?	
Bore hole valve boxes secured and locked?	
Is iron sludge problematic? Where and how?	
Pond 3 effluent troughs, operating?	
Pond liners, irregularities?	
Wetland, flow irregularities?	
Wetland, water depth 3-6" throughout?	
Wetland, plant vigor?	
Wetland, muskrat or beaver damage?	
Wetland, other problem	
Wetland pond, irregularities?	
Water Level Control box, irregularities?	
Discharge to Loyalhanna Ck, irregularities?	
Is discharge staining Loyalhanna Creek?	
Trees or debris that needs to be cleared?	
Other Observations	

Flow Rate: Distance down in WLC box to water _______ inches (measure to ¼ inch)

Water Sample information

Point	**pH**	**Temp**	**Acid bottle #**	**Raw bottle #**	**Sample appearance***
Fountain (Pond 1 or 2)					
Pond 1 or 2 trough					
Pond 3 trough					
Wetland effluent					
Other					
Other					

* clear; turbid with iron (orange); turbid with mud (brown); other (describe)

ADD MISCELLANEOUS OBSERVATIONS TO BACK OF SHEET

Appendix: Chemical characteristics of the Borehole Discharge

Location	Date	Collector	Flow (gpm)	pH	Alkalinity (mg/L)	Hot Acidity (mg/L)	Total Iron (mg/L)	Manganese (mg/L)	Aluminum (mg/L)	Sulfate (mg/L)	Weather Conditions/ Comments
Borehole	12/17/04			6.3	132	16	48.0	3.4	<.5	524	
Borehole	03/31/05	CW,JH		6.3	138	1	46.9	3.4	<.5	554	
Borehole	05/09/05	JH,CW,VP	348	6.3	140	-9	47.6	3.5	<.5	518	
Borehole	6/30/2005	CW, VP		6.5	154	11	59.0	3.5	0.5	303	
Borehole	11/8/2005	SH, AL		6.3	148	-8	44.4	3.2	<.5	503	
Borehole	12/29/2005	SH, AL		6.3	147	-13	52.7	4.0	<.5	470	

Borehole	1/17/2006	SH, AL	136	6.4	146	-11	45.2	3.4	<.5	518	
Borehole	2/13/2006	SH, AL	96	6.4	143	-11	51.6	3.8	<.5	423	
Borehole	3/21/2006	AL		6.4	138	-26	51.3	3.7	<.5	436	
Borehole	4/24/2006	SH, CJ	160	6.3	144	-5	42.9	3.1	<.5	461	
Borehole	5/30/2006	SH, CJ	151	6.2	143	-31	47.0	3.5	<.5	454	Sunny - Humid
Borehole	6/28/2006	SH, CJ	151	6.2	123	-27	46.1	3.3	<.5	462	Partly Cloudy - Heavy rain days before
Borehole	7/20/2006	SH, CJ	203	6.3	105	-21	46.1	3.5	<.5	456	Sunny - Humid
Borehole	8/24/2006	SH, CJ	150	6.3	125	-30	52.4	3.8	<.5	415	
Borehole	9/25/2006	SH, CJ	150	6.6	115	-26	41.9	3.1	<.5	422	Partly Cloudy
Borehole	10/31/2006	SH, CJ	28	6.3	122	-20	50.0	3.4	<.5	461	Partly Cloudy

Borehole	11/15/ 2006	SH, CJ	120	6.3	134	-24	54.4	3.7	<.5	453	Partly Sunny
Borehole	12/13/ 2006	SH, CJ	57	6.4	144	-15	57.7	3.3	<.5	396	Partly Sunny
Borehole	1/22/2 007	SH, CJ	53	6.3	127	-30	51.3	3.4	<.5	480	Hazy, Snow
Borehole	2/22/2 007	SH, CJ	45	6.4	157	-26	50.0	3.6	<.5	408	Hazy, Snow/Sleet
Borehole	5/23/2 007	SH, CJ	46	6.3	154	-15	45.2	3.5	<.5	478	Sunny - Humid
Borehole	6/26/2 007	SH, CJ	81	6.4	145	-36	47.7	3.3	<.5	439	Sunny - Humid
Borehole	7/24/2 007	DEP	70	6.4	146	8	41.3	3.0	<.5	419	Sunny - Dry
Borehole	7/26/2 007	SH, CJ	96	6.1	80	-42	44.7	3.6	<.5	424	Sunny - no recent rain
Borehole	8/29/2 007	SH, CJ	88	6.5	124	-1	40.3	3.1	<.5	534	Sunny - high rainfall in August
Borehole	9/26/2 007	SH, CJ	80	6.3	154	-3	37.6	3.0	<.5	460	Sunny - no recent rain

Borehole	10/24/2007	SH, CJ	89	6.3	161	-19	46.1	3.5	<.5	485	Flow very low, light rain, lower 50's
Borehole	11/28/2007	SH, CJ	270	6.5	146	-68	43.0	3.4	<.5	457	Several days of rain, mid 30's, sunny
Borehole	12/17/2007	CJ, MD	271	6.4	157	-61	44.6	3.4	<.5	442	Several days of rain, mid 20's, snow
Borehole	1/28/2008	CJ, DB	210	6.5	149	-68	42.4	3.2	<.5	454	Snow, sunny, mid 40's
Borehole	2/25/2008	CJ, MD	240	6.5	157	-63	43.3	3.4	<.5	408	Recent snow, low 40's
Borehole	3/18/2008	HEDIN	170	6.6	157		52.5				
Borehole	3/24/2008	CJ, MD	141	6.4	160	-60	39.9	3.3	<.5	396	Cloudy, low 40's
Borehole	4/21/2008	CJ, JJ	103	6.4	143	-64	36.2	3.1	<.5	362	Cloudy, 60's recent rain
Borehole	5/19/2008	CJ, AB	154	6.4	135	-48	38.0	3.3	<.5	449	Cloudy, recent rain, mid 50's
Borehole	6/25/2008	CJ, AB	103	6.4	152	-58	38.9	3.4	<.5	409	Sunny, upper 70's

Borehole	7/28/2008	CJ, AB	92	6.4	136	-67	37.6	3.1	<.5	456	Sunny, high 70's
Borehole	8/27/2008	CJ, SH	ns	6.4	143	-63	40.3	3.2	<.5	424	Sunny, 70's, no rain in several weeks
Borehole	9/5/2008	D-G	300	6.1	137		42.6				
Borehole	9/29/2008	CJ, SH	ns	6.4	151	-69	39.5	3.2	<.5	393	Sunny, 60's
Borehole	10/17/2008	IOR		6.4	141	-49	47.8	3.0	0.1	387	
Borehole	10/29/2008	SH, CJ	ns	6.5	149	-47	38.6	3.1	<.5	184	Snow flurries, 30's
Borehole	11/6/2008	IOR				-62	47.9	3.1	0.1	366	
Borehole	12/18/2008	SH, CJ	ns	6.4	158		40.4	3.4	<.5	441	Upper 30's, recent rain and snow
Borehole	2/5/2009	IOR	450								Valve fully open
Borehole	2/17/2009	IOR	450								Valve fully open

Borehole	2/27/2009	IOR	450								Valve fully open
Borehole	3/10/2009	IOR	450								Valve fully open
Borehole	3/20/2009	IOR	450								Valve fully open
Borehole	4/2/2009	IOR	430								Valve fully open
Borehole	4/16/2009	IOR	411								Valve fully open
Borehole	7/21/2009	IOR	392								Valve fully open