OPERATION, MAINTENANCE & REPLACEMENT PLAN

TANOMA TROMPE AND IMPROVEMENT PROJECT

Tanoma South Passive Treatment System

Evergreen Conservancy

Rayne Township
Indiana County, Pennsylvania
Crooked Creek Watershed

OPERATION & MAINTENANCE PLAN

Tanoma Passive Treatment System

General Description/Location

System Components:	Settling pond with trompe- and electric blower-powered aeration; aerobic wetland cells; renewable energy demonstration components; trompe		
Projected System Life:	30+ years	Latitude/Longitude:	40°41'38"/79°3'2"
Landowners:	Evergreen Conservancy	Tax Map No.:	35-016-100.01
Municipality:	Rayne Twp., PA	7½' Topo:	Clymer
Access:	Rayne Church Road		
Hydrologic Order:	Crooked Creek (CWF)→ Allegheny R.→Ohio R.		
Mine Operator (Permit#):	Clearfield Bituminous Coal Corporation (defunct)		

Raw AMD Characteristics Values: *average* min/median/max

Point	Flow	Lab pH	Acidity	Fe (T)	Mn (T)	Al (T)
RD	*974* 191/200/3031	*6.8* 6.5 /6.8/7.5	*-102* -207/-109/35	*9.1* 5.5/8.6/14.5	*4.2* 0.6/0.8/0.9	*0.4* 0.0/0.0.5/0.5

Data from www.datashed.org *accessed12/07/2017; apparent spurious max Mn omitted.*

General System Overview

Tanoma System During 2015 Construction

The Tanoma system treats raw alkaline mine drainage (AMD) issuing from an abandoned deep mine through three individual boreholes to the system's settling pond and wetlands (all 10 cells are referred to as Ponds 1- 10). A micro-hydroelectric generator, a wind turbine, and solar panels are located on site to run a blower that is connected to a set of bubble disc diffusers in pond 1 as well as supply the site with usable electricity. BioMost Inc. (BMI) installed a second set of three 20-head bubble disc diffusers and a set of six floating air-lift aerators (lifterators) that are powered by three trompes (a trompe is a type of hydraulic air compressor) located at the outlet of the system. The system includes directional and windowed baffle curtains, a check dam, and a flow diverter intended to maximize the effective retention time within the ten treatment cells. The final wetland cell (pond 10) discharges to a pre-cast concrete flow splitter box that directs flow to the three trompes operating in parallel. The splitter box enables the trompes to function effectively throughout a wide range of flow rates. As flow increases, the water level in the box rises, overtops a weir, and then enters the second, and third trompes. Air compressed in the trompes is conveyed via a 4" PVC pipe to the settling pond (pond 1) to provide air to the disc diffusers and lifterators.

Trompe Overview

A trompe is a 17th century technology that uses falling water to compress air and has no moving parts (a/k/a "hydraulic air compressor"). A trompe is generally composed of an inlet pipe, air inducer head, down-pipe, separation chamber, air chamber, up-pipe, and outlet. Water enters the trompe through the inlet pipe. Water is then immediately directed through the air inducer head. The inducer head is typically composed of a tee in which the water enters horizontally, flows around air tubes, and drops vertically into the downpipe. The falling water accelerates and creates low pressure (Venturi effect) that pulls air into the air tubes producing a water and air mixture that flows down the downpipe. The water flowing in downpipe has a greater velocity than the rising velocity of entrained air bubbles, therefore the air is carried by the flowing water until it reaches the separation chamber at the bottom of the trompe. In this chamber the velocity of the air and water mixture slows due to the increased diameter of the pipe that makes up the chamber, this allows for separation of the air from the water. Air rises to the top of the separation chamber and into the air chambers where it is compressed to a pressure equal to the depth to which the air outlet is submerged in water. Note that the maximum pressure that can be reached is controlled by the height of water in the uppipe. The water flows along the bottom of the separation chamber, comes up the uppipe, and discharges through an outlet. A diagram of the trompe component is provided on the attached as-built drawings. Additional information and technical information about trompe technology is available online***: [https://www.osmre.gov/programs/tdt/appliedscience/projects.shtm]***

Operation & Maintenance Items

Routine Inspection/Operation/Maintenance

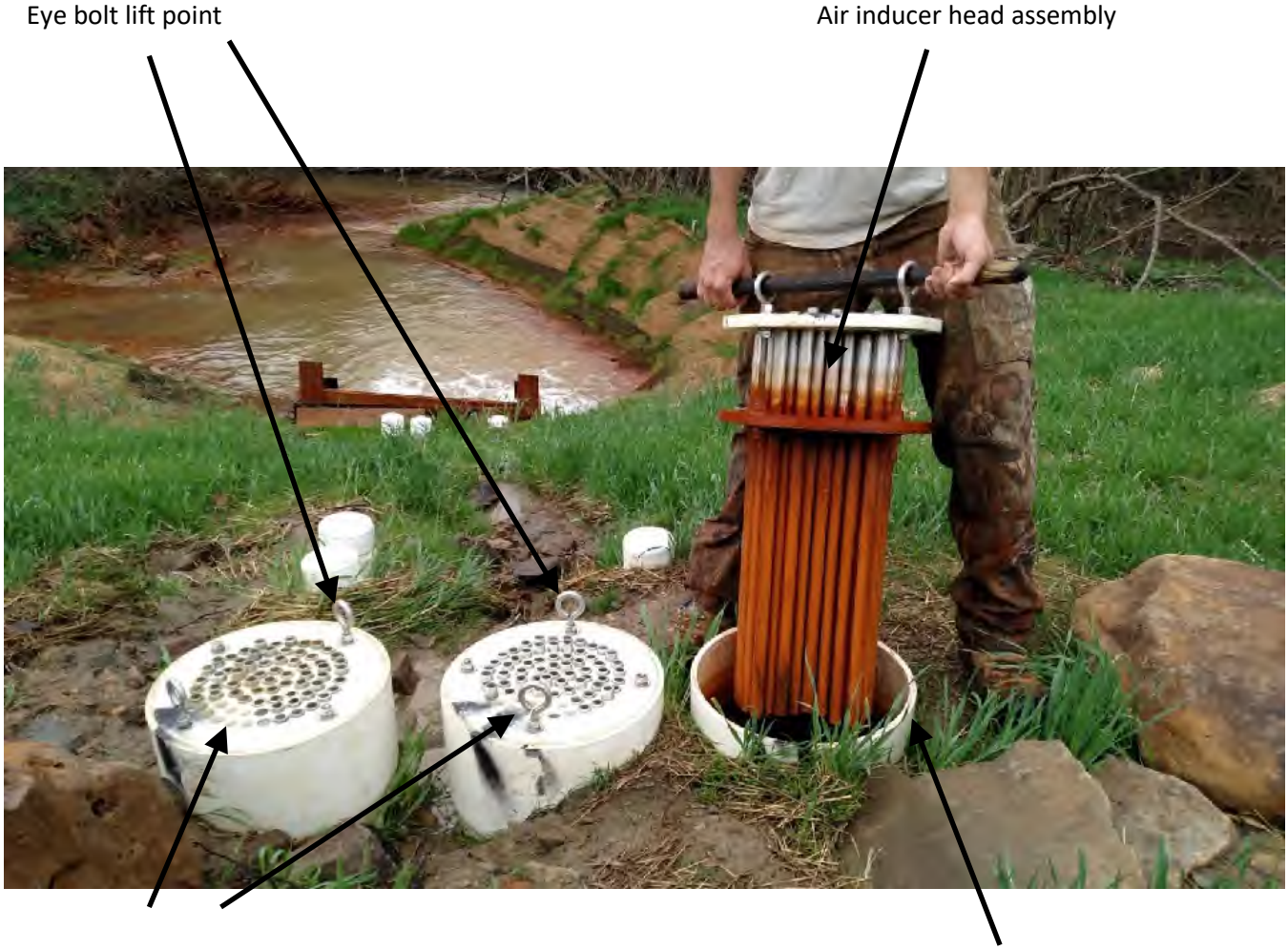
Routine inspections and regular maintenance of the treatment system should be completed on at least a monthly basis. These inspections ensure that the mine drainage flows through all components of the system and that the treatment goals for the final effluent are being met. These efforts are intended to be suitable for completion by one individual.

- Check to ensure that aeration is occurring in pond 1
- Check to ensure the turbine for the micro-hydroelectric generator is spinning freely
- Check the water level in all ten ponds. If water levels appear higher than normal, look for blockage downstream within the system
- To maintain regular flow conditions and to prevent overtopping/bypassing system component(s), remove debris and vegetation if observed in any weirs, pipes or channels. Remove debris and unwanted vegetation as needed
- To assess performance of the passive treatment system, at a minimum, monitor water quality of the system effluent on a monthly basis. This should include iron, flow, and pH. In addition, water samples should be collected for laboratory analysis on a quarterly basis or biannually if feasible
- Flow should be measured at least monthly at the pond 1 weir, the trompe outlet weir, and the pond 10 overflow weir when applicable. All weirs are 4.0'-wide rectangular type, and a lookup table is attached.

Maintenance Items

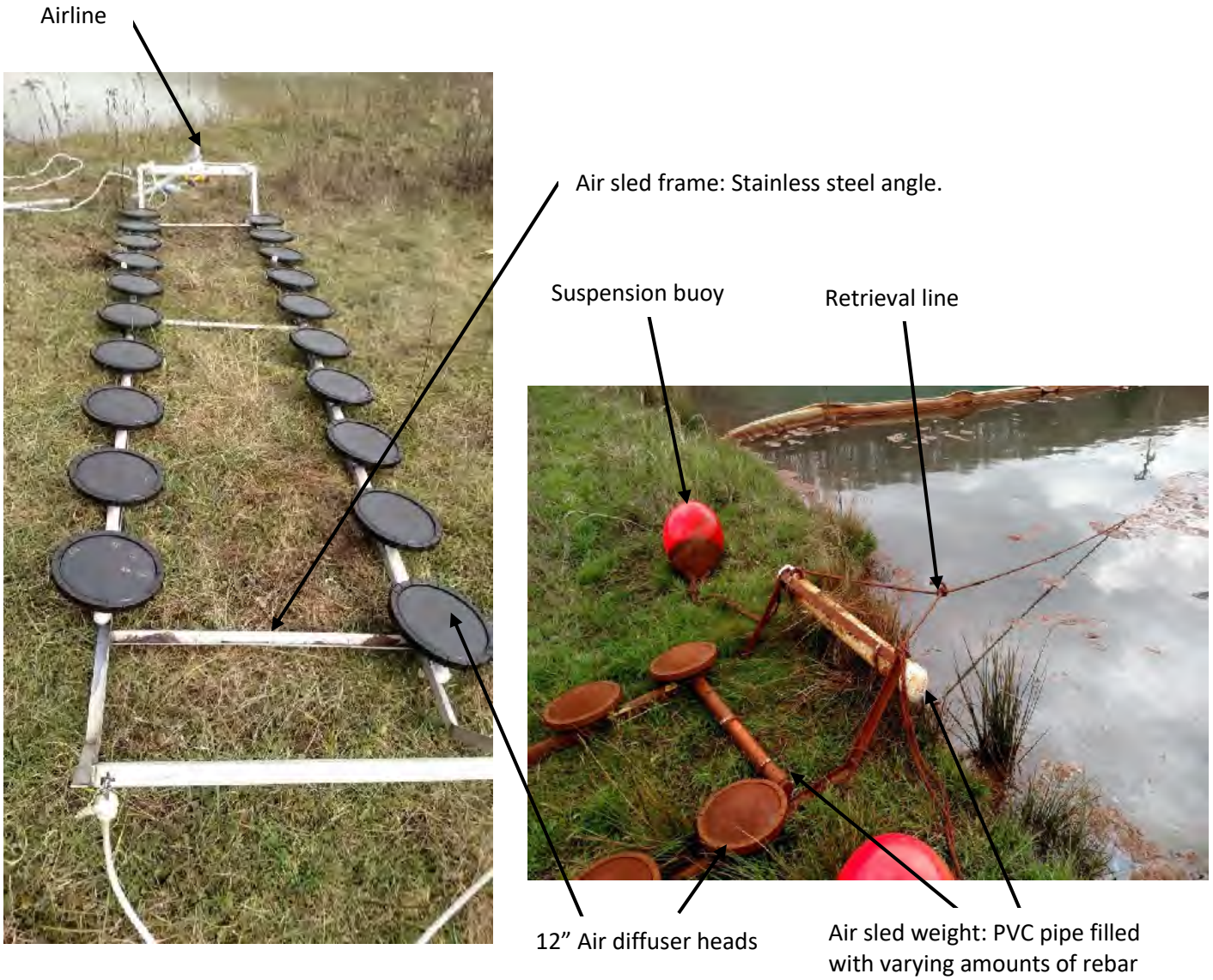
Minor maintenance items are designed to be completed by a single individual utilizing hand tools as needed.

Air Inducer Heads (3): The air inducer heads are composed of an HDPE frame with threaded ½" diameter aluminum air tubes that extend vertically from the top of the tee into the flowing water and terminate at the top of the downpipe. These air tubes enhance the Venturi effect and help the trompe run efficiently. If the air tubes loosen, thread tape or a thread locking compound is suggested to added. Regularly inspect the air inducer heads for loose air tubes or debris caught around the air tubes. Remove any debris which may obstruct flow through the trompe. Inspect the air tubes for armoring and clean any precipitates that may reduce airflow inside the air tubes.



1) Lift air induction head from tee, clean debris or buildup from around air tubes.
2) Tighten any air tubes that may have vibrated loose
3) Inspect air tubes for wear. Replace as needed
4) Clean in/around air tubes as needed
5) Maintain an adequate amount of space to allow safe passage of aquatic life (fish, muskrats, etc.) through the trompe. Air tubes may be added or removed as needed.

Air Diffuser Sleds (3): Use compressed air from trompe to aerate pond 1 via twenty fine-bubble diffuser head (60 diffuser heads total). Check for kinks in the airline, and cracks in the air frame or damage to the bubble disc diffusers. Check for iron precipitation or buildup on the disc diffusers which could reduce air distribution efficiency. If higher-than-usual buildup of air pressure is occurring, consider acid washing disc diffusers (carefully using muriatic acid and a stiff nylon scrub brush) to remove iron precipitation. Use care threading disc diffusers into the air frame. If cross threading occurs, replace as needed.



1) Remove air diffuser sled from pond with retrieval lines (1/2" nylon rope).
2) Remove and clean diffuser heads (replace diffuser heads if damaged/broken)
   Clean diffuser heads with muriatic acid and a nylon scrub brush or synthetic abrasive (i.e. Scotchbrite).
   Expect for the air diffuser heads to need cleaned approximately 2-3 times annually
3) Reposition diffuser head structure in the aeration pool, making sure the buoys allow the air diffuser head assembly to sit level

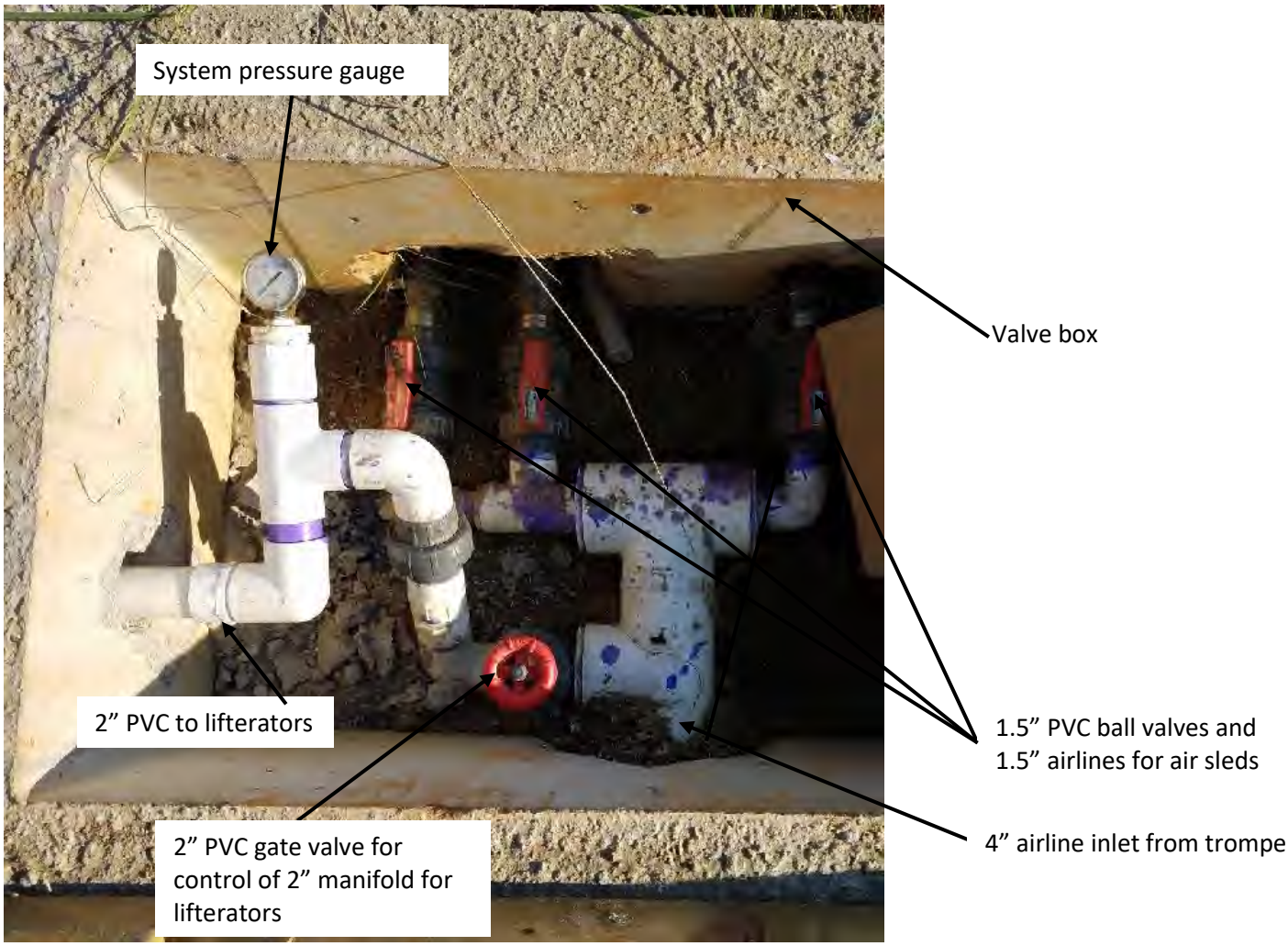
Note: Always take proper safety precautions when handling acids. Eye protection, rubber gloves, and a respirator are recommended.

Lifterators (6): Utilize compressed air from the trompes to create an airlift pump. The air reduces the density of the water in the 6" PVC pipe and the water is "pumped" up the pipe across the surface of an aluminum plate. Aeration occurs with the addition of compressed air at depth, as the water cascades off edge of the plate as well as when being "pumped" up the 6" PVC pipe.

Check for uneven flow circulation due to iron terrace formation. This may add additional weight to the surface of the aluminum distribution discs which may cause uneven flow distribution. Applying weight as a counterbalance or removing precipitates may be necessary to maintain even flow distribution. Iron may also form at the outlet of the airline at the connection point into the lifterator that can cause an air blockage. The blockage can be easily remedied by removing the lifterator from the pond and removing any iron buildup around the airline insertion point. (Diagram #3)

1) Check to see if air is lifting water up the lift pipe
   - If there are bubbles, but no water flow, the bottom of the liftpipe may be occluded by sludge, reposition to try to re-establish water flow (lift action), the lifterator may need to be moved further to center of pond
   - If repositioning does not restore function, pull lifterator out of pond using retrieval line and check and clean airline outlet if needed (note if sludge level rises the pipes may need to be shortened and the airline positioned relative to the new bottom elevation of the liftpipe).
1) Visually inspect to determine if aluminum distribution plate is floating level.
   - If needed, clear material build-up from plate.
3) Inspect airlines for leaks and repair as needed.

Airline and Manifold: There are two 10" diameter air chambers per trompe (six total) that outlet via 4" PVC pipes and feed air into a single 4" SCH40 PVC airline. The 4" airline extends to a manifold in a valve box near pond 1. Air is directed to the three air diffuser sleds and six Lifterators via a valved manifold. Note, prior to working on any airline, open 2" pressure relief valve at trompe. A condensate removal device is installed along the airline near the pavilion. The hydrant outlet of this device should be opened every time someone is onsite to ensure water does not accumulate in the airline and occlude the passage of air. The frequency of draining may vary. A 4" tee-type cleanout is installed along the airline near the shed which allows for visual inspection and cleaning of the air line.



1) Inspect valves to make sure there are no cracks and no leaks
   - Replace any damaged pipe or fittings
2) Check pressure at gage
   - Gage reading should be approximately 2.5 psi (due to submergence in about 6' of water)
3) Adjust valves as needed to allow for equal airflow to all air sleds and lift aerators
   - Method 1: Shut all valves, slowly open each valve incrementally until aeration devices are working
   - Method 2: Open all valves; slowly close each valve incrementally until aeration device are working
   - Note that during lower flow conditions some of the aeration devices may need to be idled

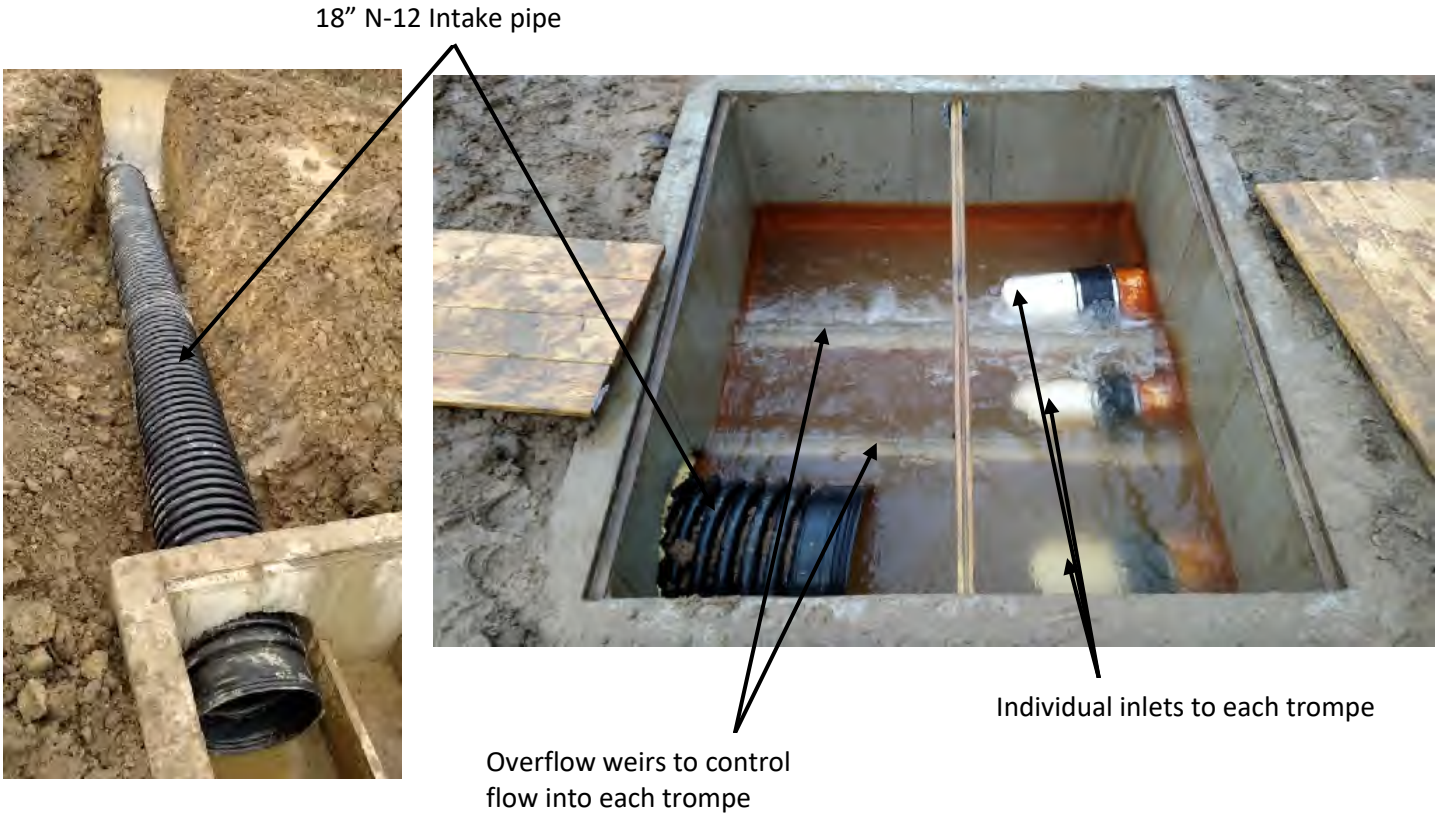
Trompe Piping

1) Inspect trompe piping. If cleaning is needed, remove air inducer head from tee and "snake out" piping of the trompe. A vacuum truck may be necessary if there is material in the trompe that cannot be removed from the trompe by the water velocity alone. If a vacuum truck is needed, the water will need to be systematically shut off to each trompe. This can be completed by removing the tapered inlet (angled pipe stub and Fernco) and temporarily installing a 10" 90° elbow on the inlet of the trompe to direct water to the other two trompes. Note: A "push-type" sewer camera can be useful to determine what type of maintenance is needed.
2) Reinstall air inducer head with same alignment

Baffle Curtains: The baffle curtains extend between two berms and allow for more even flow distribution through the system. The curtains have a plurality of "windows" submerged about 1' below the water surface that allow the flow to move through the curtain at evenly spaced intervals for the entire width of a given pond.

1) Pond baffle curtains should be checked around the anchor points and along the top steel cable
   - Replace any corroded hardware as needed
   - Repair any erosion of the embankment around the anchor point if needed
2) Water backing up on the upstream side of the baffles could be an indicator of vegetation blocking the windows
   - Remove blockage using broom, rake or other device while curtains are in-place using a boat as needed
   - Alternatively: Attach a temporary rope long enough to traverse the pond to one side of curtain, release from anchor from that side and pull curtain across pond and along embankment and clean by hand

Intake pipe and Splitter box: Directs flow from pond 10 and splits among the three trompes. The splitter box has weirs that cause the trompes to flow near full capacity before overflowing to the next trompe operating in parallel.



1) Check to make sure there are no clogs or broken components
   - Clean/repair/replace as needed

Replacement

The trompes and airline should remain viable for decades to come with very little maintenance needed. Eventually the trompe, airline and related piping may need be replaced; at that time, it would likely worthwhile to contact current practitioners in the field of passive aeration to evaluate if any state-of-the-art technology could be used to improve or replace the trompe system. If no better technology is available, replace the trompe and related piping with the materials of the same type and size. A similar approach is applicable to the lifterators and air diffuser sleds.

Trompe Installation

Left: Confirming proper elevations in the excavation before trompe installation
Right: Lowering the 14" diameter trompe separation chamber into the ground

Left: Installing trompe uppipes
Bottom: All three trompes with the uppipes installed, and beginning to bed the trompes in AASHTO #57 aggregate

Right: Airlines (outlet side) are fully bedded in aggregate
Bottom: Airlines plumbed from each of six air chambers into one main airline (prior to bedding in aggregate).

Top: 10" SCH40 PVC pipe connects each chamber of the splitter box with the corresponding trompe. **Bottom:** Inside of the splitter box with an 18" N-12 inlet pipe (from pond 10) and three 10" SCH40 PVC trompe inlet pipes. Water fills to the first chamber before spilling over first weir into the second chamber and subsequently into the third chamber allowing each trompe reach near full capacity and efficiency prior to the following trompe beginning to operate.

Top: Trompe outlet weir box with trompe inlets and splitter box in the background.
Bottom: Up-close of the trompe uppipes plumbed into the bottom of weir outlet box.

4" Airline Installation

Top: Airline along stream.
Bottom left: Airline near shed.
Bottom right: Airline between ponds #3 & 4.

Top: Airline above pond #3 looking downhill as airline extends from shed area.
Bottom: Airline above ponds #2 & #3.

Left: Looking uphill at airline from valve box at pond 1.
Bottom: Looking downhill at airline towards manifold box at pond 1.

North

POND 10

POND 9

POND 8

POND 7

POND 6

POND 5

POND 4

POND 3

POND 2

POND 1

OVERFLOW WEIR
(4.0' WIDE)

TROMPES (3)

18" N-12 TEE SET VERTICALLY

18" N-12 INTAKE PIPE

3-CHAMBER FLOW SPLITTER BOX

TROMPE OUTLET WEIR
(4.0' WIDE)

1,350' 4" SCH40 PRESSURE RATED
PVC AIRLINE (BURIED)

EX. 18" SDR35 PIPE WITH
AGRI DRAIN IN-LINE WATER
LEVEL CONTROL STRUCTURE

WINDOWED BAFFLE CURTAINS

EXISTING UNDERGROUND UTILITIES
(REPRESENTATIVE LOCATION)
GAS LINE (MOUNTAIN V)
WATER LINE (J. MCGINNIS)
ELECTRIC LINE (J. MCGINNIS)

PLASTIC Z-PILING TO
DISTRIBUTE FLOW
(CHECK DAM)

Z-PILING FLOW DIVERTER

EX. PAVILION

CONDENSATE
REMOVAL DEVICE

4" CLEANOUT

MAINTENANCE SHED

THREE 1.5" AIRLINES
AND 2" PIPE TO
LIFTERATOR
MANIFOLD

EX. DUAL 15"
N-12 PIPES

2" LIFTERATOR MANIFOLD

VALVE BOX

POND 1 WEIR (4.0' WIDE)

20-HEAD AIR SLEDS (3)

EX. BAFFLE CURTAINS (4)

LIFTERATORS (6)

CROOKED CREEK

TANOMA RD.

RAYNE CHURCH RD.

1130

1140

1150

1160

1170

LEGEND

- CONTOUR (INDEX)
- CONTOUR (INTERMEDIATE)
- ROAD (PAVED)
- POND
- STREAM

80 40 0 80

SHEET 1 of 2 | AS-BUILT SCHEMATIC

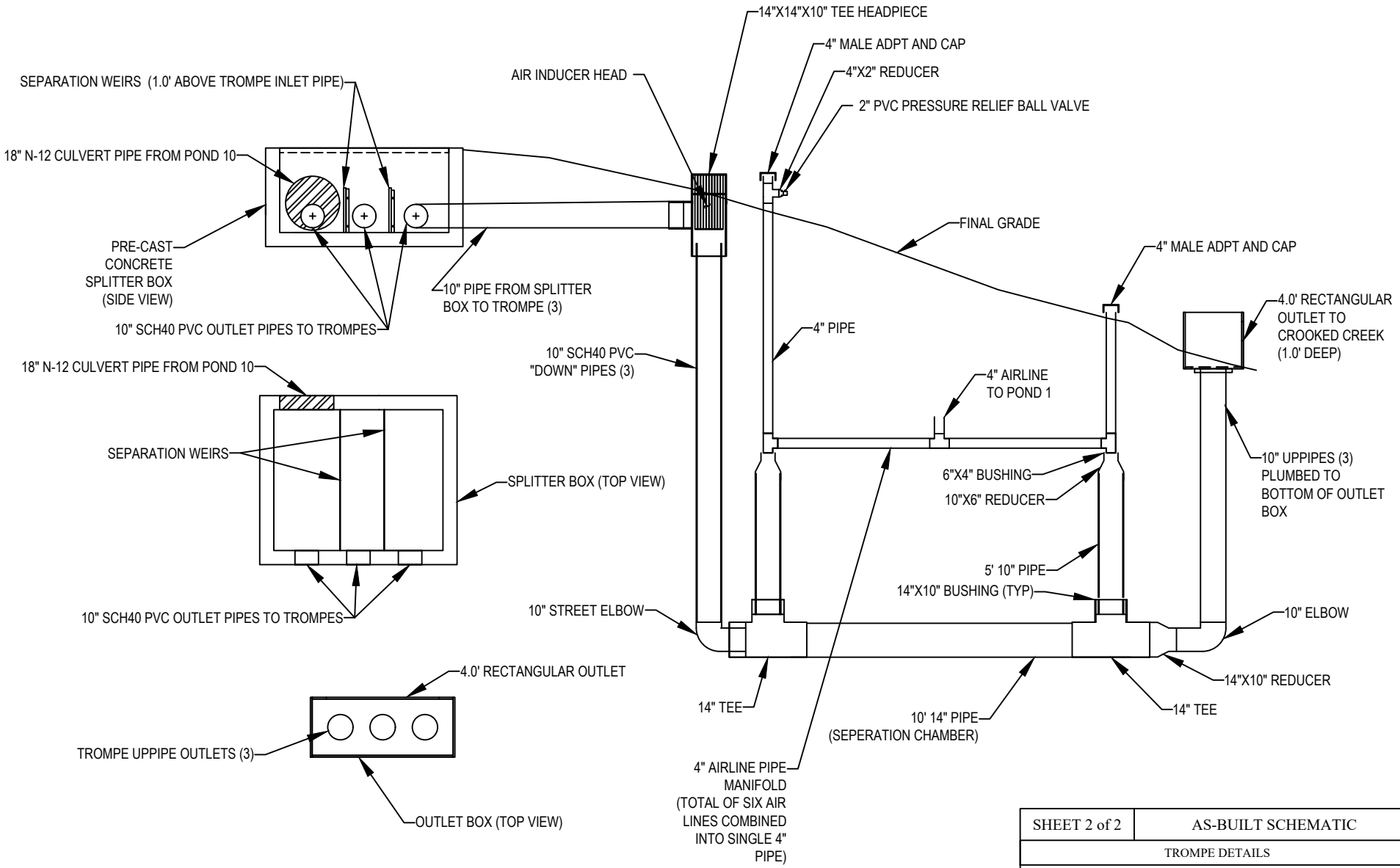
PLAN VIEW

TANOMA TROMPE
and
IMPROVEMENT PROJECT
EVERGREEN CONSERVANCY

Rayne Township
Indiana County, Pennsylvania
Scale: 1" = 80' December 2017

BioMost, Inc., Mars, Pennsylvania
Mining and Reclamation Services

2690-Tanoma/TanomaAB



SHEET 2 of 2	AS-BUILT SCHEMATIC

TROMPE DETAILS

TANOMA TROMPE

and

IMPROVEMENT PROJECT

EVERGREEN CONSERVANCY

Rayne Township
Indiana County, Pennsylvania
Scale: NTS December 2017

BioMost, Inc., Mars, Pennsylvania
Mining and Reclamation Services

100101/2012 Prop/Tanoma

TANOMA

4.0 RECTANGULAR WEIR

(Francis Formula-Pocket Ref)

CFS=(3.33(W-0.2H)H1.5)*448.83

INCHES	INCHES	GPM		INCHES	INCHES	GPM
0.125	0 1/8	6		6.125	6 1/8	2,124
0.250	0 1/4	18		6.250	6 1/4	2,189
0.375	0 3/8	33		6.375	6 3/8	2,253
0.500	0 1/2	51		6.500	6 1/2	2,319
0.625	0 5/8	71		6.625	6 5/8	2,385
0.750	0 3/4	93		6.750	6 3/4	2,451
0.875	0 7/8	117		6.875	6 7/8	2,518
1.000	1	143		7.000	7	2,586
1.125	1 1/8	171		7.125	7 1/8	2,654
1.250	1 1/4	200		7.250	7 1/4	2,723
1.375	1 3/8	231		7.375	7 3/8	2,792
1.500	1 1/2	263		7.500	7 1/2	2,862
1.625	1 5/8	296		7.625	7 5/8	2,932
1.750	1 3/4	331		7.750	7 3/4	3,003
1.875	1 7/8	366		7.875	7 7/8	3,074
2.000	2	403		8.000	8	3,146
2.125	2 1/8	442		8.125	8 1/8	3,218
2.250	2 1/4	481		8.250	8 1/4	3,291
2.375	2 3/8	521		8.375	8 3/8	3,364
2.500	2 1/2	563		8.500	8 1/2	3,438
2.625	2 5/8	605		8.625	8 5/8	3,512
2.750	2 3/4	648		8.750	8 3/4	3,587
2.875	2 7/8	693		8.875	8 7/8	3,662
3.000	3	738		9.000	9	3,737
3.125	3 1/8	784		9.125	9 1/8	3,814
3.250	3 1/4	831		9.250	9 1/4	3,890
3.375	3 3/8	879		9.375	9 3/8	3,967
3.500	3 1/2	928		9.500	9 1/2	4,044
3.625	3 5/8	978		9.625	9 5/8	4,122
3.750	3 3/4	1,028		9.750	9 3/4	4,201
3.875	3 7/8	1,079		9.875	9 7/8	4,279
4.000	4	1,131		10.000	10	4,358
4.125	4 1/8	1,184		10.125	10 1/8	4,438
4.250	4 1/4	1,238		10.250	10 1/4	4,518
4.375	4 3/8	1,292		10.375	10 3/8	4,598
4.500	4 1/2	1,347		10.500	10 1/2	4,679
4.625	4 5/8	1,403		10.625	10 5/8	4,760
4.750	4 3/4	1,459		10.750	10 3/4	4,842
4.875	4 7/8	1,517		10.875	10 7/8	4,924
5.000	5	1,574		11.000	11	5,006
5.125	5 1/8	1,633		11.125	11 1/8	5,089
5.250	5 1/4	1,692		11.250	11 1/4	5,172
5.375	5 3/8	1,752		11.375	11 3/8	5,256
5.500	5 1/2	1,813		11.500	11 1/2	5,340
5.625	5 5/8	1,874		11.625	11 5/8	5,424
5.750	5 3/4	1,935		11.750	11 3/4	5,509
5.875	5 7/8	1,998		11.875	11 7/8	5,594
6.000	6	2,061		12.000	12	5,679

FEET	INCHES	GPM		FEET	INCHES	GPM
0.01	0.12	6		0.51	6.12	2,122
0.02	0.24	17		0.52	6.24	2,183
0.03	0.36	31		0.53	6.36	2,246
0.04	0.48	48		0.54	6.48	2,308
0.05	0.60	67		0.55	6.60	2,371
0.06	0.72	88		0.56	6.72	2,435
0.07	0.84	110		0.57	6.84	2,499
0.08	0.96	135		0.58	6.96	2,564
0.09	1.08	161		0.59	7.08	2,629
0.10	1.20	188		0.60	7.20	2,695
0.11	1.32	217		0.61	7.32	2,761
0.12	1.44	247		0.62	7.44	2,828
0.13	1.56	278		0.63	7.56	2,895
0.14	1.68	311		0.64	7.68	2,963
0.15	1.80	345		0.65	7.80	3,031
0.16	1.92	380		0.66	7.92	3,100
0.17	2.04	415		0.67	8.04	3,169
0.18	2.16	452		0.68	8.16	3,238
0.19	2.28	490		0.69	8.28	3,308
0.20	2.40	529		0.70	8.40	3,379
0.21	2.52	569		0.71	8.52	3,450
0.22	2.64	610		0.72	8.64	3,521
0.23	2.76	652		0.73	8.76	3,593
0.24	2.88	694		0.74	8.88	3,665
0.25	3.00	738		0.75	9.00	3,737
0.26	3.12	782		0.76	9.12	3,810
0.27	3.24	827		0.77	9.24	3,884
0.28	3.36	873		0.78	9.36	3,958
0.29	3.48	920		0.79	9.48	4,032
0.30	3.60	968		0.80	9.60	4,107
0.31	3.72	1,016		0.81	9.72	4,182
0.32	3.84	1,065		0.82	9.84	4,257
0.33	3.96	1,115		0.83	9.96	4,333
0.34	4.08	1,165		0.84	10.08	4,409
0.35	4.20	1,216		0.85	10.20	4,486
0.36	4.32	1,268		0.86	10.32	4,563
0.37	4.44	1,321		0.87	10.44	4,640
0.38	4.56	1,374		0.88	10.56	4,718
0.39	4.68	1,428		0.89	10.68	4,796
0.40	4.80	1,482		0.90	10.80	4,875
0.41	4.92	1,537		0.91	10.92	4,954
0.42	5.04	1,593		0.92	11.04	5,033
0.43	5.16	1,649		0.93	11.16	5,112
0.44	5.28	1,706		0.94	11.28	5,192
0.45	5.40	1,764		0.95	11.40	5,273
0.46	5.52	1,822		0.96	11.52	5,353
0.47	5.64	1,881		0.97	11.64	5,434
0.48	5.76	1,940		0.98	11.76	5,516
0.49	5.88	2,000		0.99	11.88	5,597
0.50	6.00	2,061		1.00	12.00	5,679