Pit 431 Passive Treatment System Autopsy and Recommendations, Glasgow, Cambria County

Technical report provided by Hedin Environmental through the Trout Unlimited Technical Assistance Program Project TUTAG-21 (Glasgow II)

June 2007

Executive Summary
The former C&K Pit 431 passive treatment system near Glasgow, PA has declined in effectiveness, though VFP 1 and the wetlands are still removing a large amount of acidity and metals from this very acidic discharge into Muddy Run. In particular, VFP 2 appeared almost completely plugged. This TAG project was conducted to test backflushing as a means of opening permeability, and to excavate VFP 2 to ascertain the cause of low flow and the condition of the limestone and compost layers. A major problem at VFP 2 is a layer of Fe and Al precipitate several inches thick over the compost, plus compacted and cemented compost and locally cemented limestone. The limestone and compost layers are undersized, and the underdrains are of substandard quality.

It is recommended that the VFP's be renovated with improved material in a better design. Also, the Mn-removal limestone bed should be converted into an additional VFP. Costs for this renovation are assembled.

Background
In October 2005, the Clearfield Creek Watershed Association (CCWA) requested assistance to assess the performance of the Pit 431 treatment system near Glasgow, PA (Cambria County) and to recommend improvements. The passive treatment system had been constructed by C&K Coal Co., but abandoned when the company declared bankruptcy and none of the bonds were made available for the site. Although VFP 1 and the wetlands were removing considerable acidity, VFP 2 was overflowing and accomplishing little treatment. At that time recommendations were made to determine the causes of poor performance and remedy them. Details of the investigation and recommendations can be found in the project final report (TUTAG-9). One of the primary recommendations of the TUTAG-9 report was to investigate plugging of the VFPs. As a result, the CCWA requested technical assistance to perform a system autopsy, perform minor improvements, and formulate recommendations and cost estimates for further improvements.

The layout of the system is shown on Figure 1 (attached). The TUTAG-9 report found that the system was experiencing permeability issues. In particular, VFP 2 was plugged and discharging through its emergency overflow. VFP 1 showed signs of plugging but to a lesser extent. Previous sampling by CCWA established that VFP1 was removing acidity at rates similar to other functional VFPs.

This project investigated the plugging of VFP 1 and VFP 2. Both ponds were backflushed and trenches were excavated into the substrate of VFP 2. Norman G. Diehl Contracting of Glen Hope, PA provided equipment and labor for the investigations. The work was performed under the joint direction of Art Rose of Clearfield Creek Watershed Association and Neil Wolfe of Hedin Environmental.

Autopsy Findings

VFP 2 was plugged and could not be drained by gravity to allow for excavation of the substrate so the standing water was siphoned and pumped out. Only a few gallons per minute would flow from the flushing system. There was approximately 5 to 6 feet of water above the compost (Photo 1). This represents approximately three feet of head loss due to plugging (estimated from the apparent difference in elevation between the primary outlet pipe and the overflow pipe).

Backflushing

VFP 1 was backflushed with a 10 HP 2 inch pump. Water was pumped first into the west outlet. A riser pipe was installed on the east outlet during pumping to prevent short circuiting through the limestone. Pumping produced bubbles through the compost at the assumed location of the outlet header pipe and at one other nearby location. These bubbles appear to represent the escape of air entrained within the pump. Pumping produced only 1-2 inches of head increase at the east outlet, indicating that the pipes and perforations are relatively open. Minor turbidity was noted in the pond, but in very limited areas (Photo 2). The process was repeated for the east outlet with similar results. It appears that very few solids were dislodged by the backflushing.

The minimal impact observed during the backflushing of VFP 1 led to the decision to use a larger pump for the backflushing of the severely plugged VFP 2. A 16 HP 4 inch pump was attached to the outlet of VFP 2 for backflushing. As in VFP 1, pumping caused some bubbling through the compost layer near the assumed header location. Several minutes after the backflushing began it was noticed that water was upwelling through the berm approximately 6 inches above the VFP water line (Photo 3). The upwelling occurred directly opposite the valved outlet on the VFPs west side. The valve was opened and the pipe flowed full, stopping the upwelling flow through the berm. Interestingly, opening the valve caused a small release of bubbles through the compost on the opposite side of the pond. A conclusion that can be drawn from this upwelling is that the permeability of the VFP substrate is less than that of saturated earth of the berm. No evidence of outflow was noted in the main part of the pond, even though the water was relatively shallow at this time. Obviously the substrate is severely plugged.
The minimal evidence for flushing of precipitates from the underdrain vicinity indicates that backflushing will not appreciably improve the performance of these systems.

Excavations in VFP 2

Two trenches were excavated into and through the substrate of VFP 2 (Figure 1). The first trench was dug parallel to the presumed location of the underdrain header at the north end of VFP 2 (Photo 1). The second trench was excavated approximately 40 feet to the south of and parallel to the first.

Sludge
A layer of sludge of varying thickness and composition was observed on top of the compost (Photo 9). Sludge thickness was greatest near the influent (south) end of the VFP where the sludge was up to two feet thick. Sludge thickness was ~4 inches at the mid point of the VFP and 2-3 inches at the northern end. A prominent gray layer in the sludge was found to be consistent over the entire surface of the VFP (Photo 9). It is believed that this gray layer is Al hydroxide. At the influent end of the VFP the sludge was found to have multiple gray layers as well as numerous layers of varying colors (Photo 10). Most of the sludge layer appears to be Fe hydroxide that precipitated in the pond or in tail-end of the preceding wetland. A minor part of this sludge may be fine detrital clay from the inflow channel. Solids samples were collected of the sludge and forwarded to ACT Labs (Toronto, Canada) for elemental analysis. The results are attached. Interpretation of the results will be performed by Dr. Rose at a later date.

This sludge is considered to be a major cause of the impermeability problem. The material forms a complete cover over the compost, and is uniformly colloidal in nature. The layer appears very impermeable.

Compost
The compost was predominantly very dark brown to black in color but some areas were reddish brown (Photo 8). The reddish brown compost seemed to have a different texture than the black compost. The compost was solid enough to support a person's weight and when broken by the excavator it could be picked up in cantaloupe sized chunks. The thickness averaged 6 to 10 inches but varied considerably, with at least one much thinner area. Very little pore space remained in the compost.

The black compost is interpreted to contain considerable FeS precipitate filling the pore space. In other areas some brown Fe hydroxide fills pores. The combination of pore fillings and compaction has resulted in a dense layer of low permeability.

Underdrain Plumbing
VPF 2 has only a single outflow pipe, and a single flushing pipe and valve.
Two perforated laterals were located in trench 1 with a spacing of 21 feet. One of these laterals was near and parallel to the eastern side of the VFP while the second was approximately in the center of the VFP. It is assumed that at least one more lateral exists along the western edge of the VFP but it was not uncovered in order to prevent damage. The design had called for 5 laterals so two more may exist, but were not detected because the trench was not extended more than a few inches into the limestone in many places. The pipe itself was thin walled 4 inch corrugated PVC with two rows of 0.5 inch perforations at approximately the four and eight o'clock positions (Photo 4). Perforations were spaced 5 inches apart. The exact specification of the pipe is unknown but it was

unusually thin for this application. The thin walls of the pipe provided little feedback to the equipment operator and as a result the two laterals that were uncovered were broken. The pipe and the perforations were generally open and did not appear to be an impediment to flow.

Limestone

The limestone appeared to be 2b sized aggregate (all smaller than 1 inch diameter particles) as shown in Photo 5. This is an unusually small aggregate size for a VFP and likely contributed to the plugging problems. The thickness of the limestone layer varied from 6.5 inches to 1 foot. Aggregate thickness above the eastern lateral was only 2.5 inches (Photo 6).

Staining of the limestone and solids deposition in the void spaces varied based upon distance from the underdrain plumbing. Aggregate within 3-4 feet of the perforated laterals was cemented with solids ranging in color from reddish orange to orange to white (Photo 7). The solids immediately above the pipe seemed to be where the reddish orange solids were concentrated. White solids were observed sporadically at and near the limestone-compost contact. Preliminary data indicates these are mostly Al hydroxide or similar material. Cementation of the limestone in the vicinity of the perforated laterals was such that digging the aggregate with a shovel was very difficult.

Limestone found mid-way between the perforated laterals was fairly clean and appeared to be in good condition (Photo 7). Here the aggregate had only a thin coating of whitish solids and could be easily dug into with a shovel. It appears that the zone of influence of each lateral was limited to 5-6 feet on either side with very little AMD flowing through the aggregate outside this zone (Photo 7).

Geometry of VFP

The inside slopes of VFP 2 ranged from 4:1 to 5:1. This is much flatter than the 2:1 slopes commonly used for VFPs. As a result of the flat slopes, the internal volume of the pond (and therefore the substrate volume) is substantially less than in traditional VFPs. In addition, the limestone layer and to a lesser extent the compost layer did not extend completely across the pond floor. In trench 1, the width of the limestone layer was only 36 feet, compared to about 85 feet at the water surface. In trench 2, the limestone bed was about 48 feet wide. The compost layer extended a few feet further, but was also markedly less wide than the potential size.

Manganese Removal Bed Excavations

Two trenches were dug into the limestone of the manganese removal bed to determine the condition of the limestone at various depths. Limestone exposed at the surface was iron stained from recent flows of incompletely treated water (Photo 11). The top foot of limestone was cemented with a black coating that was comparable to charcoal (Photo 12). This is believed to be manganese minerals. Coating of the limestone with these minerals has cemented the top layer of the aggregate and severely limited its permeability. A basketball sized chunk of cemented limestone remained intact even when lifted (Photo 13). Limestone below this black zone was in fairly good condition with little coating (Photo 14). Solids samples were collected and forwarded to ACT Labs (Toronto, Canada) for elemental analysis. The results are attached. Interpretation of the results will be performed by Dr. Rose at a later date.

In an effort to improve residence time in the manganese bed, three trenches were dug through the cemented layer of aggregate perpendicular to the flow direction, and the excavated limestone was piled into a low berm. The trench gives the water an opportunity to flow into the deeper, uncoated stone.

Recommendations

The investigation revealed that VFP2 is very seriously plugged. Its current condition combined with its poor construction makes its "reactivation" impractical. VFP2 should be rebuilt. The renovations should consider the following features:

- All of the surface sludge, compost and limestone should be removed and disposed of. Consideration should be given to the disposal method. It seems best to combine the compost and limestone into a mixture so that if the compost is oxidized and produces acidity, the limestone will be present to neutralize it.
- The pond should be re-excavated to create inside slopes that are 2.0 or 2.5 to 1. This will provide room for more limestone and compost and it will lessen the "dead" space that is present along the banks of the current VFPs
- The VFP should be reconstructed with larger aggregate (AASHTO #1 is recommended) and covered with organic substrate that is amended with limestone sand or fines (3:1 substrate to limestone mixture by volume is recommended)
- The VFP should be reconstructed with a better quality and better designed underdrain system

The Mn oxidation bed serves little purpose because the water it receives is not alkaline and is not contaminated only with Mn; it is acidic and contains Al and Fe. The bed could be reconstructed into a third VFP. The reconstruction would involve the following features:

- The existing limestone is cemented with solids. It should be removed and disposed of on site by burial.
- The sides of the bed should be built up so that the VFP can provide up to eight feet of head and water storage.
- Limestone and organic substrate with the same specifications as VFP2 should be installed.

Currently the system receives high flows of AMD during wet weather. Consideration should be given to the installation of a flow control structure ahead of VFP1. A design similar to what is used at the Anna S site on Babb Creek or the Rock Run site on Chest Creek should be considered. These HDPE boxes receive the full flow of collected AMD and divert limited amounts of the flow to specific treatment units. Excess flows are diverted around the VFPs.

A flow control structure would allow the flow configuration of the system to be reconsidered. Currently the system operates in a strictly linear manner. All the AMD flows through VFP1, then through VFP2, and then through the Mn bed. Between the VFPs and Mn bed, the water flows in channels that are densely vegetated wetlands. Figure 1 shows this flow configuration.

An alternative approach would treat the VFPs as somewhat parallel systems. The flow would be split at the control box into 4 flows as shown in Figure 2. Three of the flows would each be piped to one of the three VFPs and the fourth flow would serve as high flow bypass. Each VFP would receive a raw AMD input as well as effluent from any upstream VFPs. A preliminary recommendation for flow allocations to each VFP is shown in Table 1. These flow allocations are based on average chemistry and assumed areal loading rates of grams alkalinity generation per square meter of VFP per day ($g\ m^{-2}\ d^{-1}$). Due to the variable nature of the discharge loading, some performance based tweaking of these allocations will be required post-construction. For this reason, the flow control box should be designed in such a way that flows can be manipulated easily.

Table 1. Flow allocations

Location	Flow Allocation
VFP 1	25 gpm
VFP 2	25 gpm
VFP 3	20 gpm
Bypass	Any additional flow

Estimated Costs

A rough cost estimate was developed for the major construction items by calculating materials and excavation quantities and multiplying by estimated unit costs. Tables 2, 3, 4 and 5 show the calculations. All costs are in-place costs than includes materials and labor.

Table 2. Flow Management Construction Cost Estimate

Item	Quantity	Units	Unit Cost	Total Cost
Flow Control Box	1	Each	$5,000	$5,000
Distribution Pipe	650	Feet	$18	$11,700
TOTAL				$16,700

Table 3. VFP 1 Construction Cost Estimate

Item	Quantity	Units	Unit Cost	Total Cost

Existing limestone – excavation and on-site disposal	1,741	CY	$10	$17,407
Existing compost – excavation and on-site disposal	567	Cubic Yards	$10	$5,670
New limestone, purchase, delivery, placement	3,200	Tons	$25	$80,000
New Compost, purchase, delivery, placement	670	Cubic Yards	$20	$13,400
New limestone – compost amendment	300	Tons	$25	$7,500
4" Perforated Pipe	1,880	Feet	$4	$7,520
8" Solid Pipe	160	Feet	$18	$2,880
Water Level Control Structure	1	Each	$1,200	$1,200
TOTAL				$135,577

Table 4. VFP 2 Construction Cost Estimate

Item	Quantity	Units	Unit Cost	Total Cost
Existing limestone – excavation and on-site disposal	341	CY	$10	$3,407
Existing compost – excavation and on-site disposal	414	CY	$5	$2,070
Excavation to steepen berms	600	CY	$3	$1,800
New limestone	2,200	Tons	$25	$55,000
New Compost	480	Cubic Yards	$20	$9,600
New limestone – compost amendment	213	Tons	$25	$5,325
4" Perforated Pipe	980	Feet	$4	$3,920
8" Solid Pipe	100	Feet	$18	$1,800

Water Level Control Structure	1	Each	$1,200	$1,200
TOTAL				$84,122

Table 5. Mn Pond conversion to VFP 3 Construction Cost Estimate

Item	Quantity	Units	Unit Cost	Total Cost
Existing limestone – excavation and disposal	2,519	CY	$10	$25,185
Fill material to raise berms	1,200	Cubic Yards	$4	$4,800
New limestone	2,500	Tons	$25	$62,500
New Compost	1,125	Cubic Yards	$20	$22,500
New limestone – compost amendment	375	Tons	$25	$9,375
4" Perforated Pipe	1,150	Feet	$4	$4,600
8" Solid Pipe	160	Feet	$18	$2,880
Water Level Control Structure	1	Each	$1,200	$1,200
TOTAL				$133,040

GRAND TOTAL	$369,440

These cost estimates do not include engineering, permitting or construction oversight costs. It is likely that these items will add 10% to the estimated construction cost to bring the total to **$406,384**.

Summary

Investigations of the condition of the treatment system revealed that VFP 2 is severely plugged and must be reconstructed. Likewise, VFP 1 is showing signs of plugging though to a lesser extent. Both of these VFPs should be rebuilt with new plumbing, limestone and limestone amended compost. In addition, the manganese removal bed serves little purpose if the system is overloaded so it should also be converted to a VFP by raising the berm, adding new limestone and limestone amended compost. A flow control box should be installed to manage and distribute flows to the three VFPs. The total cost to perform these changes is estimated to be $406,384.

Photo 1. Excavating Trench 1. Note water line on berm. Water depth was approximately 5 to 6 feet above the compost.

Photo 2 Minor turbidity in standing water caused by backflush of VFP 1

Photo 3 Turbidity caused by backflush of VFP 2. Note flow of water from berm just above the excavator bucket.

Photo 4. Perforated pipe.


Photo 5. Aggregate


Photo 6. 2.5 inches of aggregate above eastern perforated lateral

Photo 7 Clean aggregate and fouled aggregate

Photo 8. Full thickness of substrate. Note variable compost color.


Photo 9. Sludge layer on top of compost. Note gray layers.


Photo 10. Multi-colored sludge found at south (inlet) end of VFP 2.

Photo 11. Iron staining of surface limestone in Mn bed

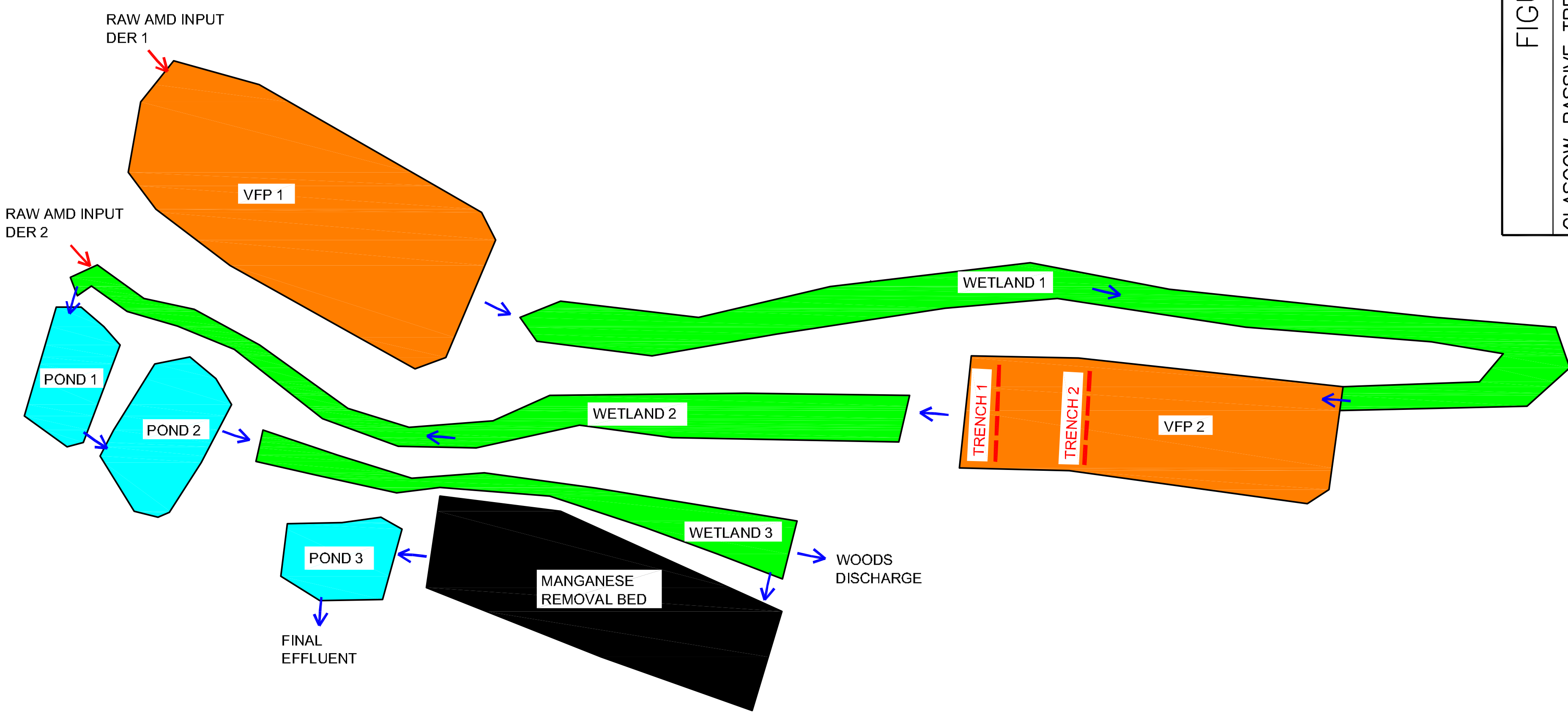
Photo 12. Limestone cemented with black solids stands out as a shelf, unsupported.


Photo 13. Large chunk of cemented aggregate. Wristwatch for scale.

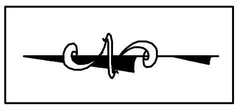

Photo 14. Limestone excavated from the bottom of the Mn bed was in relatively good condition.

FIGURE 1

GLASGOW PASSIVE TREATMENT SYSTEM AUTOPSY
TU-TAG 21
EXISTING CONDITONS AND TRENCH LOCATIONS



MUNICIPALITY: READE TOWNSHIP	COUNTY: CAMBRIA COUNTY, PA
DATE: JUNE 2007	DRAWN BY: NAW
FILE NAME: GLASGOW IR.DWG	SCALE: ~1"=120'

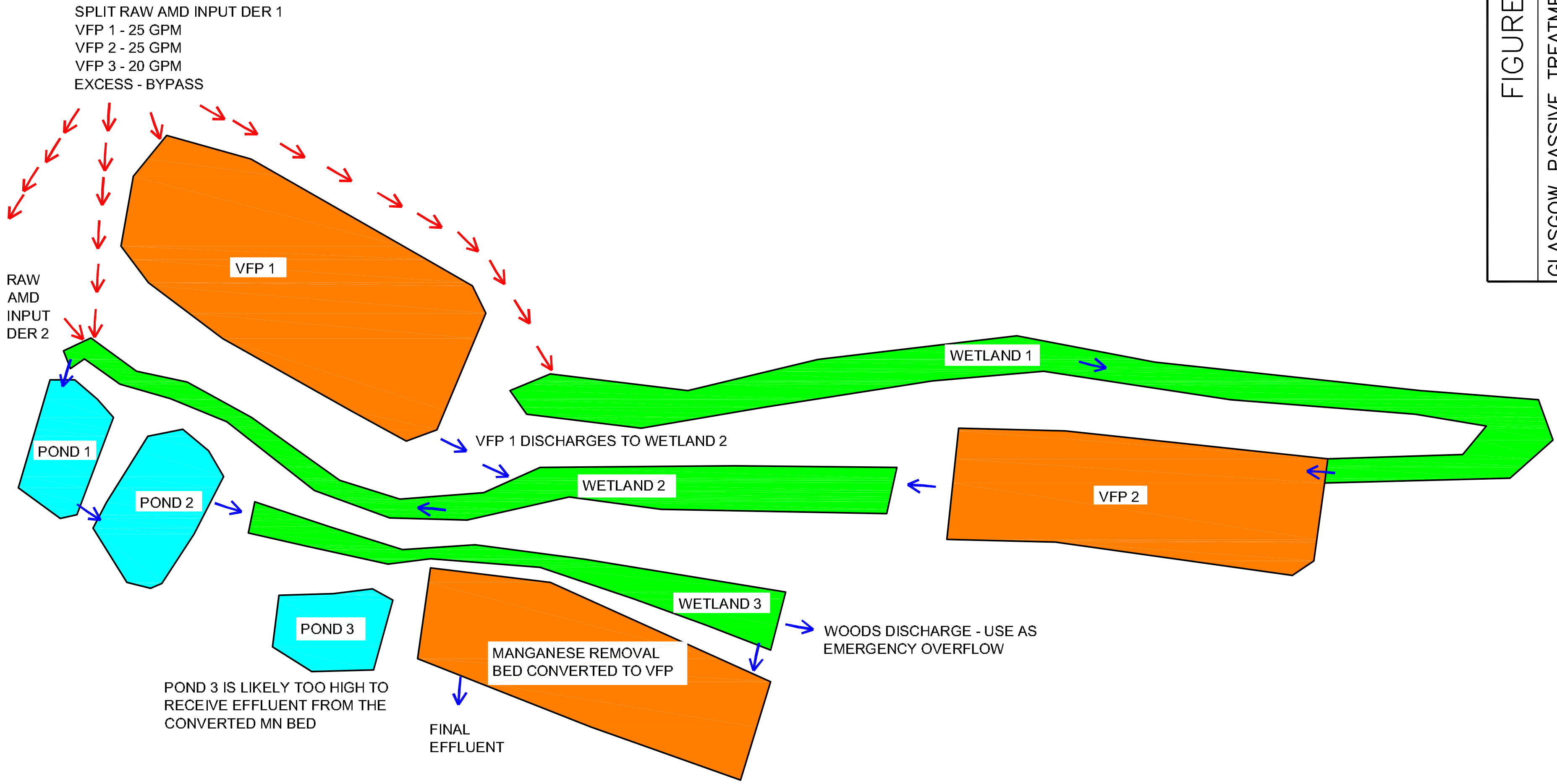


APPROXIMATE NORTH

FIGURE 2

GLASGOW PASSIVE TREATMENT SYSTEM AUTOPSY
TU–TAG 21
REHABILITATION OPTION

FILE NAME: GLASGOW IR.DWG
SCALE: ~1"=120'
DATE: JUNE 2007
DRAWN BY: NAW
MUNICIPALITY: READE TOWNSHIP
COUNTY: CAMBRIA COUNTY, PA



APPROXIMATE NORTH

Final Report
Activation Laboratories

Analyte Symbol	SiO2	Al2O3	Fe2O3(T)	MnO	MgO	CaO	Na2O	K2O	TiO2	P2O5	Ba	Sr	Y	Sc	Zr	Be	V	C-Organ	C-Total
Unit Symbol	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	%
Detection Limit	0.01	0.01	0.01	0.001	0.01	0.01	0.01	0.01	0.001	0.01	2	2	1	1	2	1	5	0.05	0.01
Analysis Method	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	IR	IR
NIST 694 Meas	11.57	1.91	0.74	0.011	0.33	43.28	0.87	0.5	0.114	30.13							1659		
NIST 694 Cert	11.2	1.8	0.79	0.0116	0.33	43.6	0.86	0.51	0.11	30.2							1740		
DNC-1 Meas	47.09	18.29	9.93	0.149	10.21	11.36	1.94	0.17	0.489	0.07	106	142	17	31	37	< 1	160		
DNC-1 Cert	47	18.3	9.93	0.149	10.1	11.3	1.87	0.234	0.48	0.09	114	145	18	31	41	1	148		
BIR-1 Meas	47.6	15.34	11.34	0.171	9.63	13.28	1.82	0.02	0.963	0.03	6	107	15	43	13	< 1	342		
BIR-1 Cert	47.8	15.4	11.3	0.171	9.68	13.2	1.75	0.03	0.96	0.05	7	108	16	44	16	0.58	313		
GBW 07113 Meas	72.35	12.8	3.14	0.141	0.15	0.58	2.5	5.37	0.28	0.05	498	41	48	5	417	4	< 5		
GBW 07113 Cert	72.8	13	3.21	0.14	0.16	0.59	2.57	5.43	0.3	0.05	506	43	43	5	403	4	5		
FK-N Meas	66.57	19.09	0.07	0.002	< 0.01	0.11	2.5	13.09	0.007	0.02	211	39	< 1	< 1	3	1	< 5		
FK-N Cert	65	18.6	0.09	0.005	0.01	0.11	2.58	12.8	0.02	0.024	200	39	0.5	1	13	1	5		
NIST 1633b Meas	49.37	28.53	11.22	0.016	0.79	2.17	0.25	2.31	1.31	0.59	723	1046		41			307		
NIST 1633b Cert	49.2	28.4	11.1	0.02	0.8	2.11	0.27	2.35	1.32	0.53	709	1040		41			296		
LKSD-4 Meas																			18.3
LKSD-4 Cert																			17.7
SY-3 Meas	59.03	11.42	6.45	0.324	2.59	8.3	4.04	4.07	0.146	0.57	438	304	717	8	338	20	54		
SY-3 Cert	59.6	11.8	6.49	0.32	2.67	8.25	4.12	4.23	0.15	0.54	450	302	718	7	320	20	50		
SGR-1 Meas																			25.8
SGR-1 Cert																			27.5
SDO-1 Meas																		8.04	9.88
SDO-1 Cert																		7.7	9.95
W-2a Meas	52.36	15.17	10.86	0.165	6.37	10.96	2.25	0.67	1.091	0.13	175	194	21	35	89	1	283		
W-2a Cert	52.4	15.4	10.7	0.163	6.37	10.9	2.14	0.626	1.06	0.13	182	190	24	36	94	1.3	262		
NIST 696 Meas	4.07	54.29	8.69	0.005	0.01	0.02		0.05	2.637	0.05					1026		401		
NIST 696 Cert	3.79	54.5	8.7	0.004	0.012	0.018		0.009	2.64	0.05					1040		403		
T-H1-MID Orig																		10.5	11.5
T-H1-MID Dup																		11	11.5