Treatment of Acidic Coal Mine Drainage with Vertical Flow Ponds and Drainable Limestone Beds

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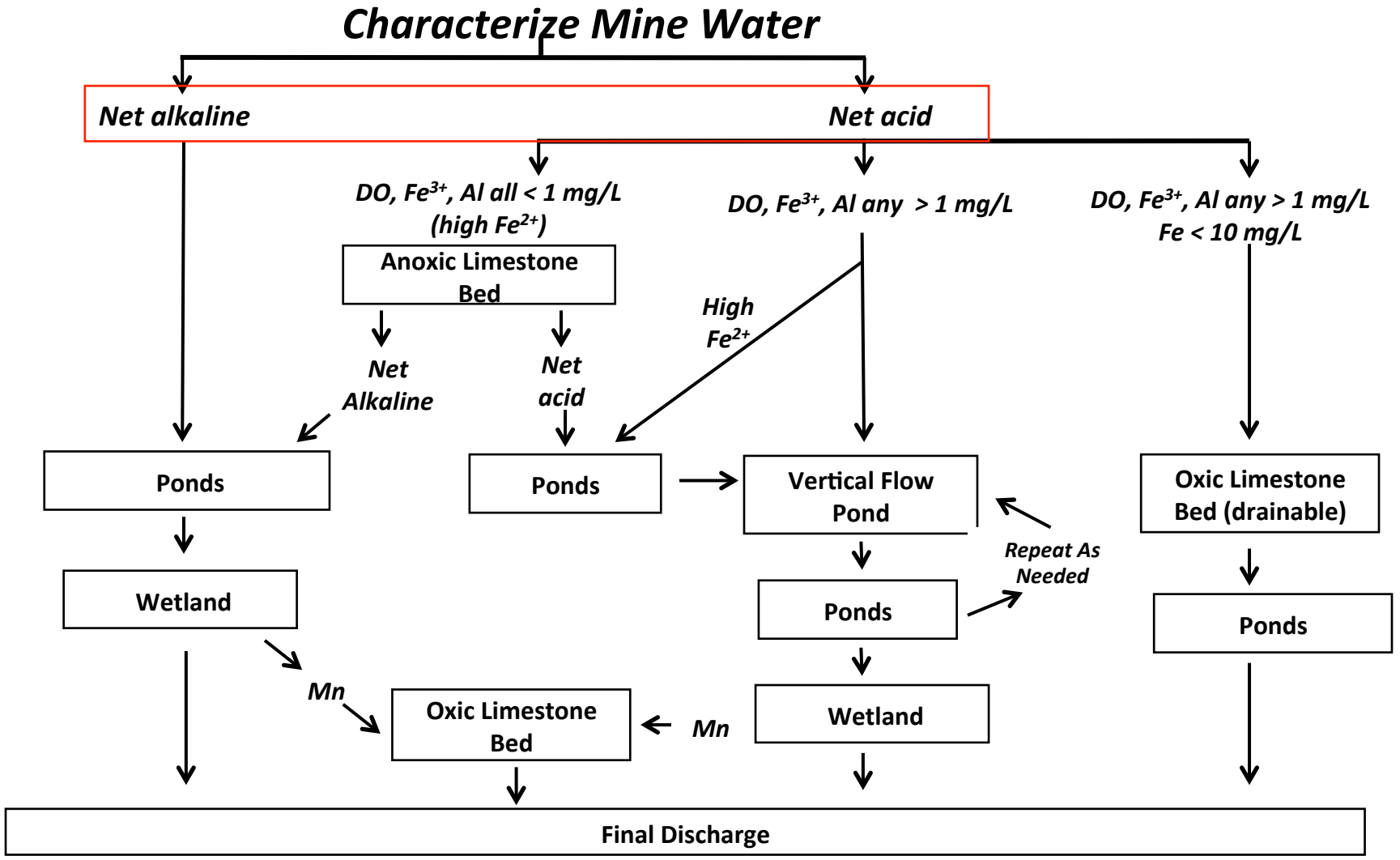
Common Passive Treatment Technologies Used in the Eastern US Coal Fields

- Ponds
  - oxidize Fe, settle solids, mixing
- Constructed Wetlands
  - polishing ,Mn and solids removal
- Anoxic limestone beds
  - alkalinity generation
- Oxic limestone beds
  - alkalinity generation, metal removal, polishing
- Vertical flow ponds
  - alkalinity generation and metal removal

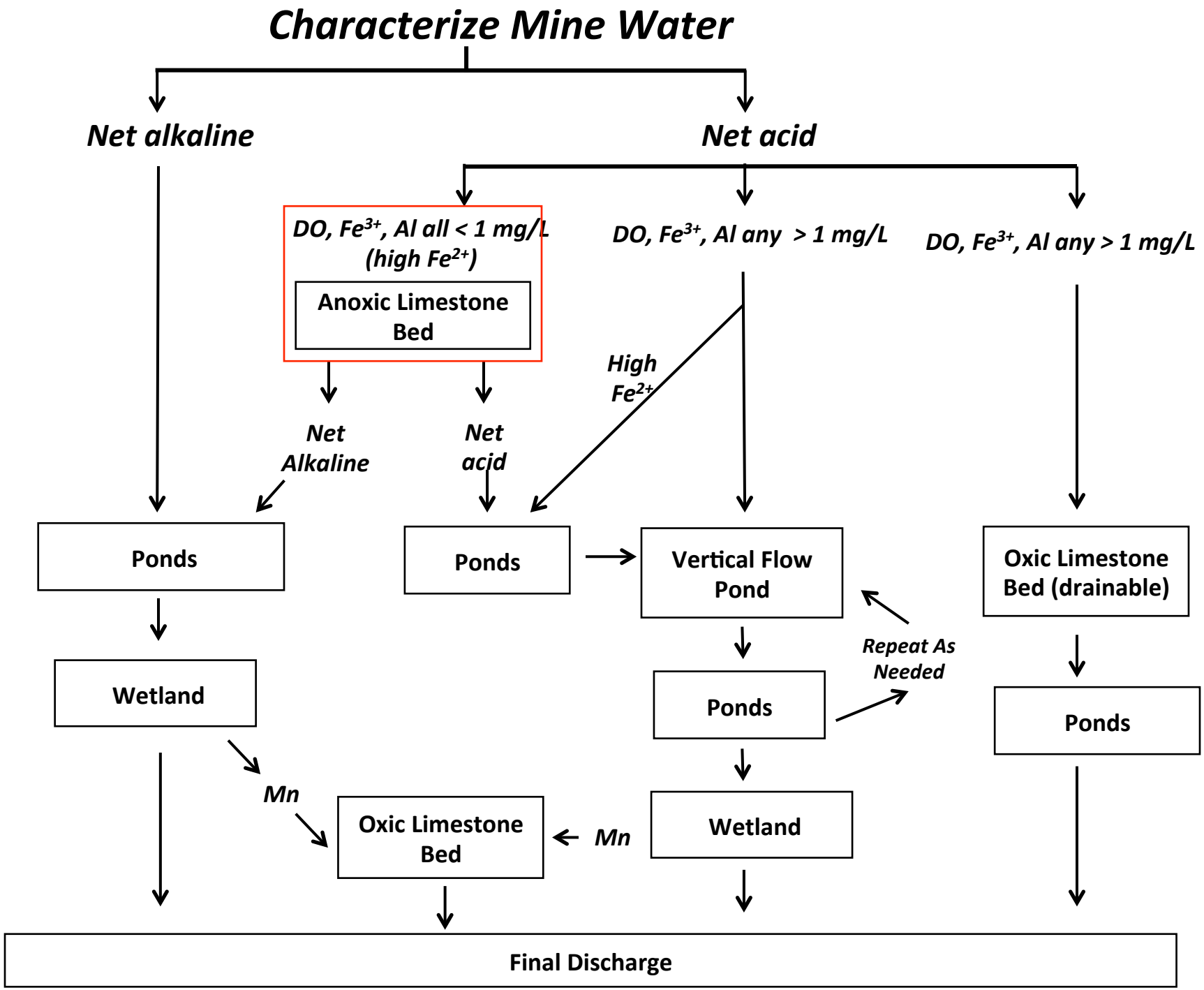
Technology is based on chemistry,

Sizing is based on loadings


Characterize Mine Water
Net alkaline
Net acid
DO, Fe3+, Al all < 1 mg/L
(high Fe2+)
DO, Fe3+, Al any > 1 mg/L
DO, Fe3+, Al any > 1 mg/L
Fe < 10 mg/L
Anoxic Limestone Bed
High Fe2+
Net Alkaline
Net acid
Ponds
Ponds
Vertical Flow Pond
Oxic Limestone Bed (drainable)
Repeat As Needed
Wetland
Ponds
Ponds
Mn
Oxic Limestone Bed
Mn
Wetland
Final Discharge

Passive Treatment of Net Acid Coal Mine Drainage

- Neutralize acidity and generate alkalinity
  1. Calcite dissolution
  2. Bacterial processes in organic substrate
- Remove metal contaminants
  1. Al, Fe, Mn, others
  2. Primary removal as oxide and hydroxide solids
  3. Secondary removal as sulfides and carbonates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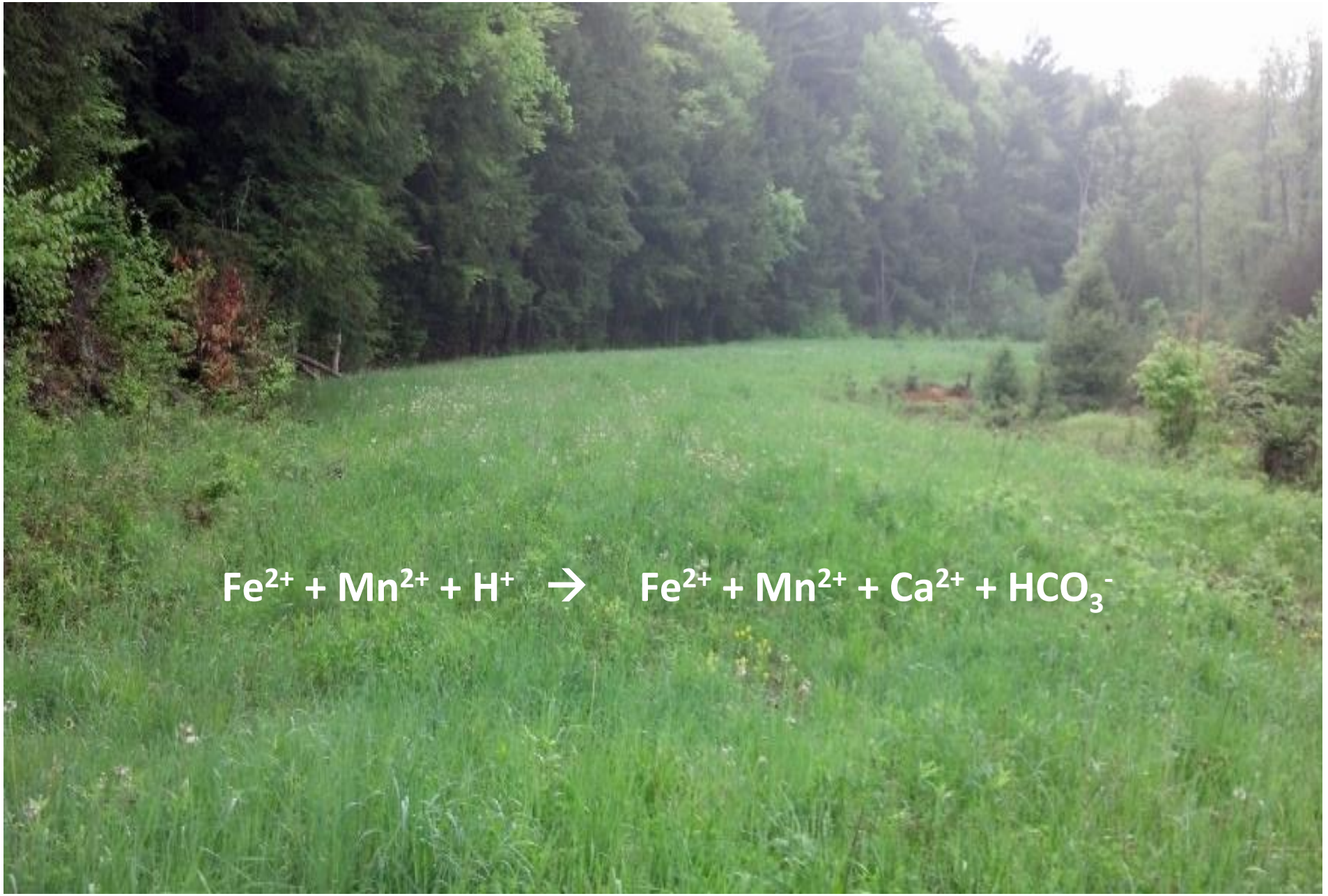
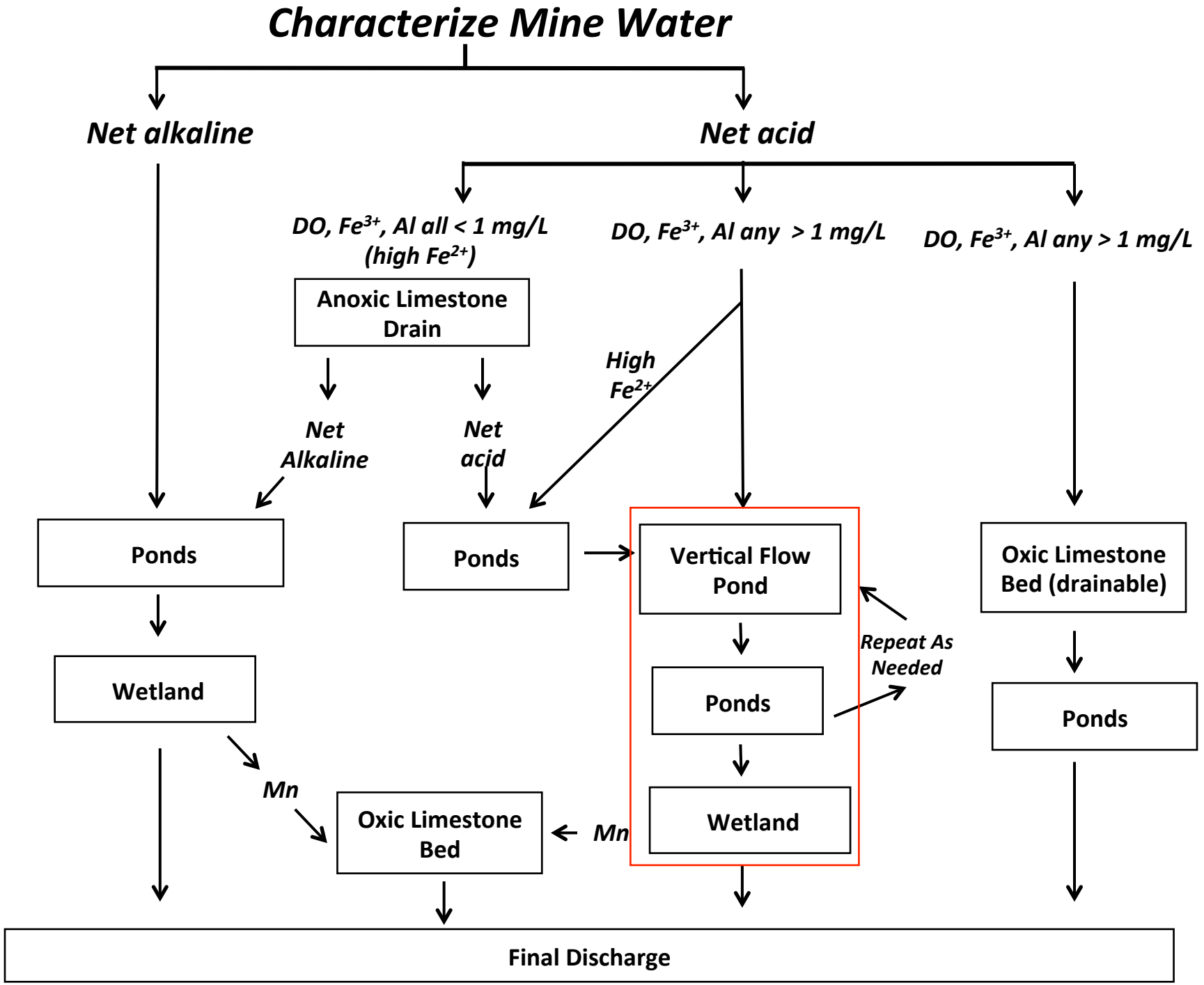

$Fe^{2+} + Mn^{2+} + H^{+} \rightarrow Fe^{2+} + Mn^{2+} + Ca^{2+} + HCO_3^-$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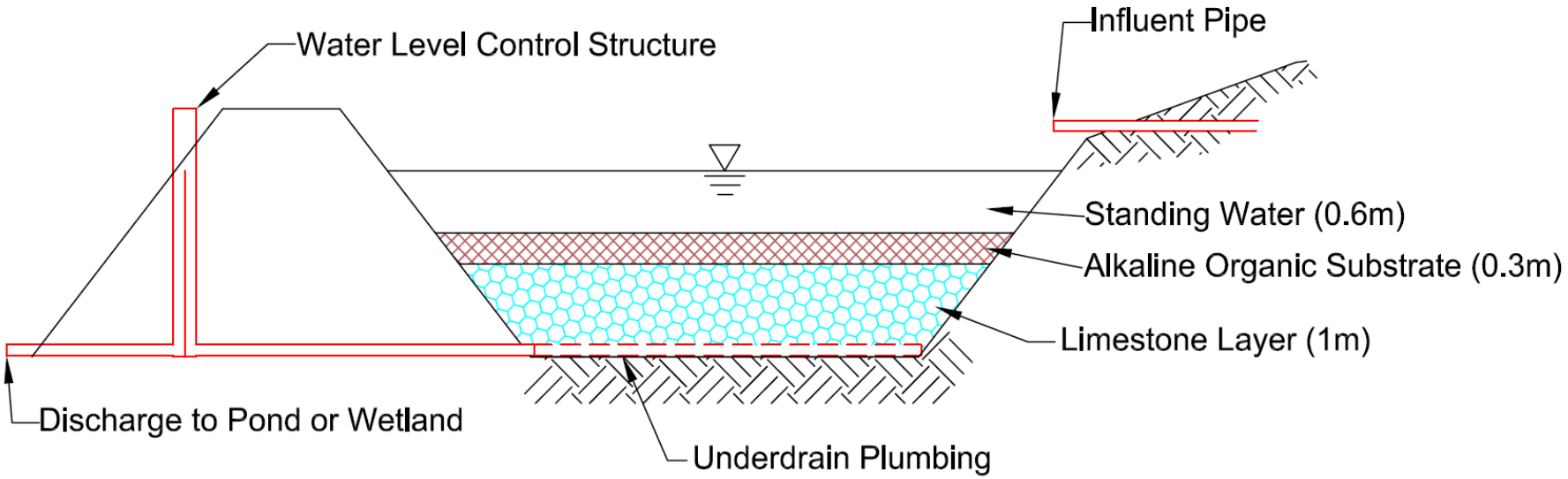
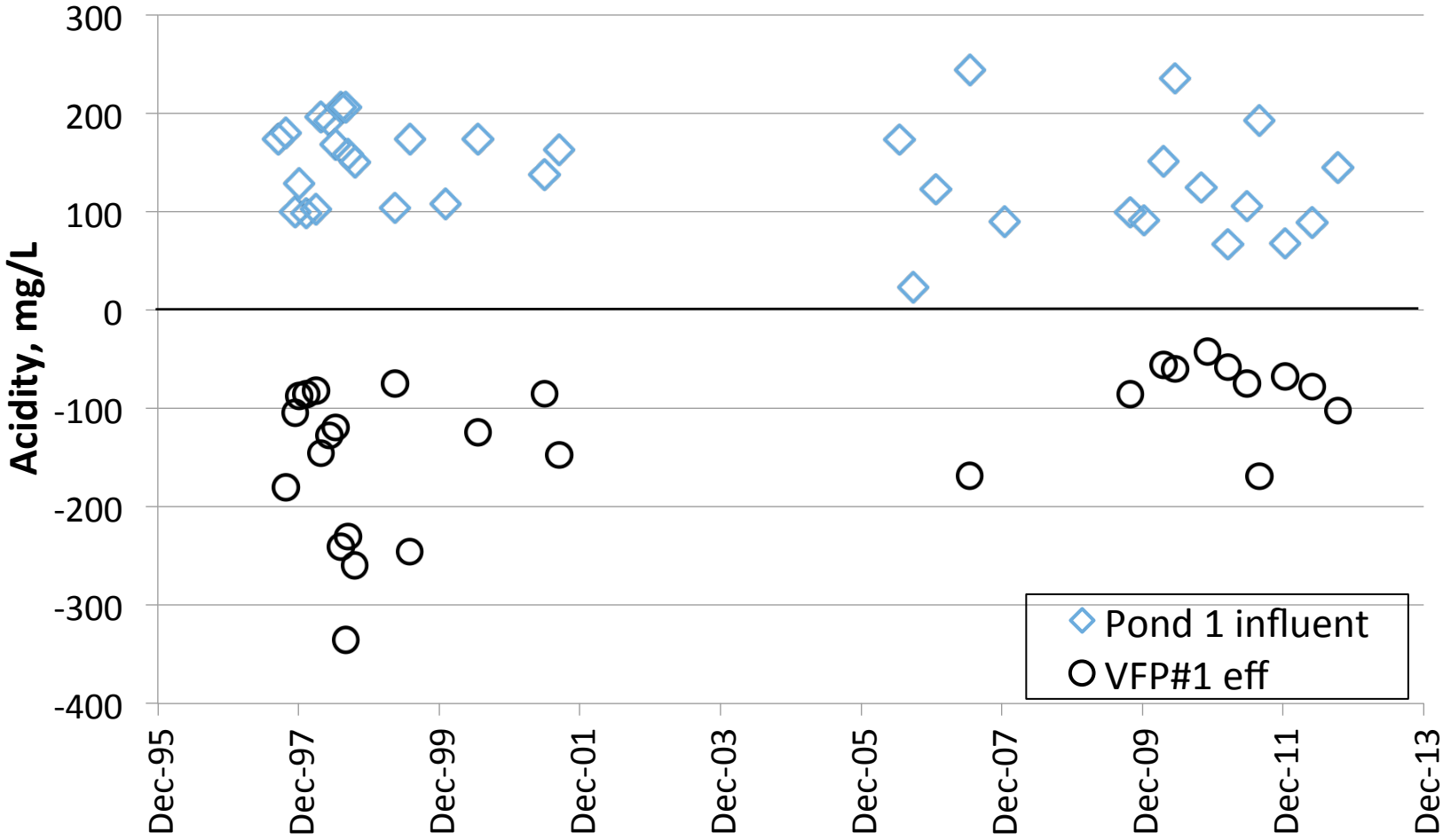
Vertical Flow Pond (VFP, SAPS, RAPS, APS)



Delta Maust Passive System (Somerset County, PA)

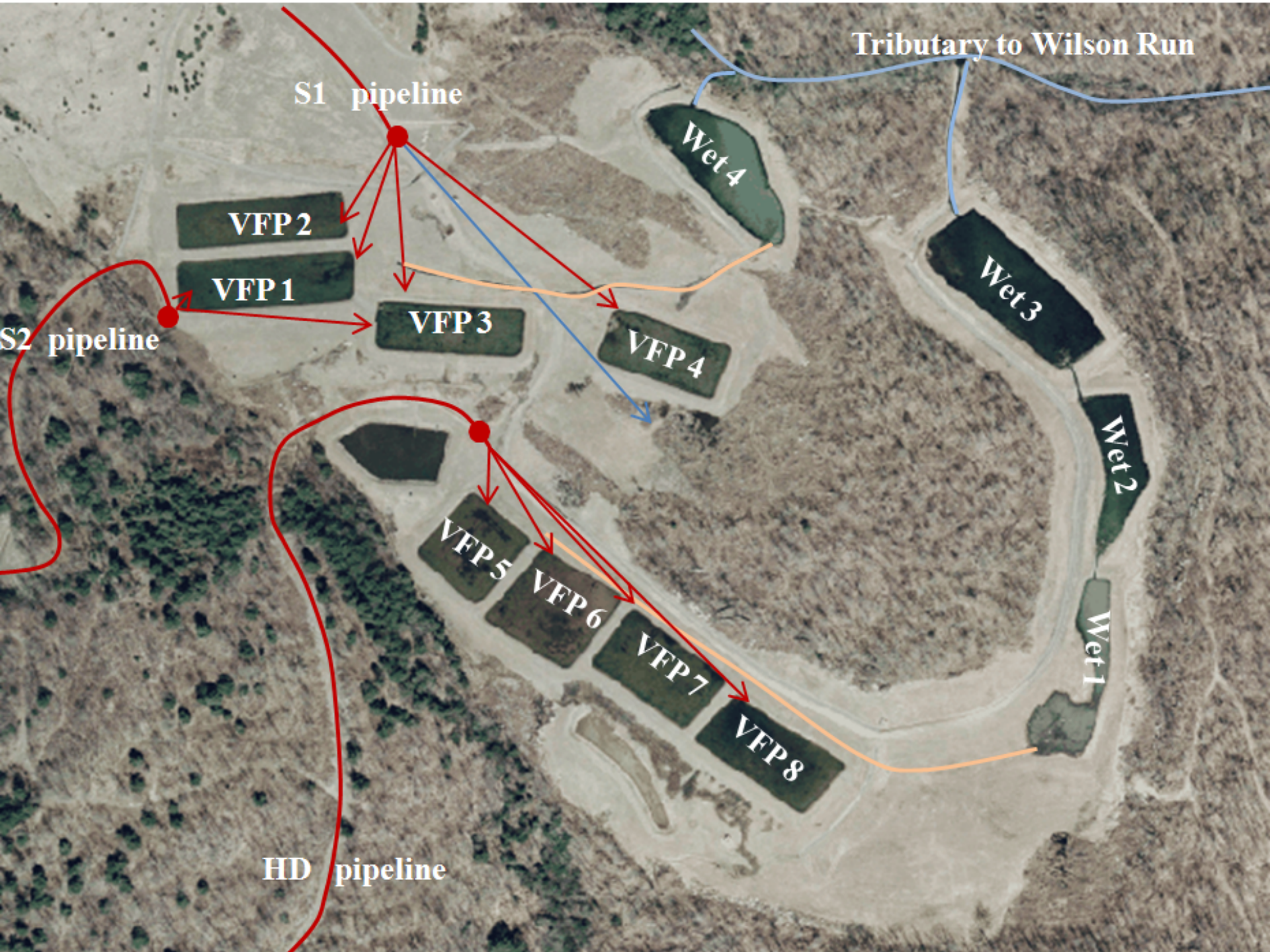
- Bond forfeiture project
- Design: pond, VFP#1, wetland, VFP#2, wetland
- VFP#1 construction
  - 24 inch depth of spent mushroom compost mixed 2:1 with limestone fines
  - 18 inches AASHTO#3 limestone aggregate
  - PVC pipe underdrain
  - 25,000 ft^2 (2,325 m^2)
- Installed in 1997

Delta Maust Passive Treatment System, 1997 - 2012								
	Flow	pH	Alk	Acid	Fe	Al	Mn	SO_4
Influent	20	3.2	0	141	30.2	2.3	13.9	553
VFP#1 out		7.1	152	-130	1.1	0.3	10.3	474



Anna S Mine Passive Treatment Complex (Tioga County, PA)

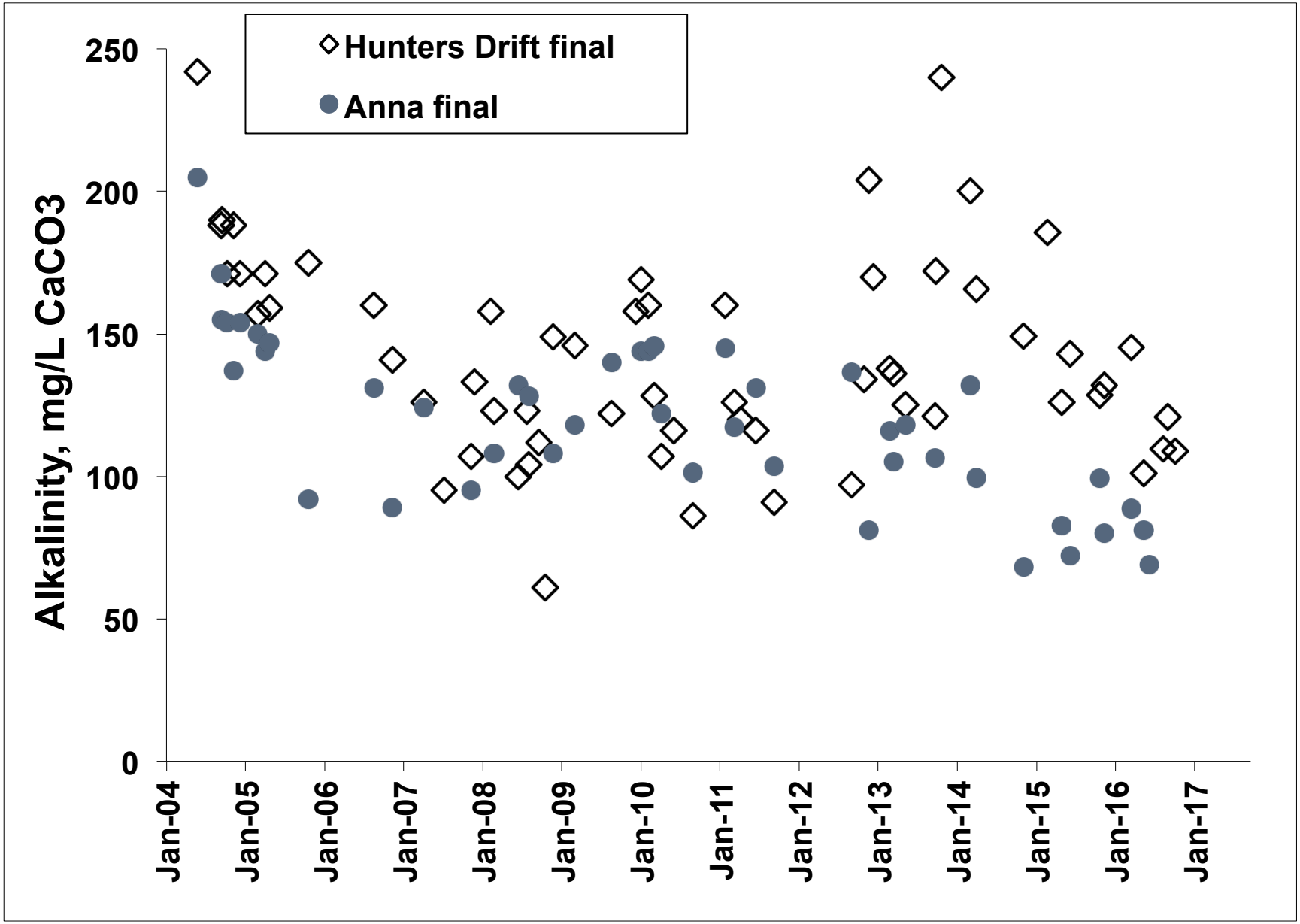
- Abandoned Mine Land project
- Two independent systems

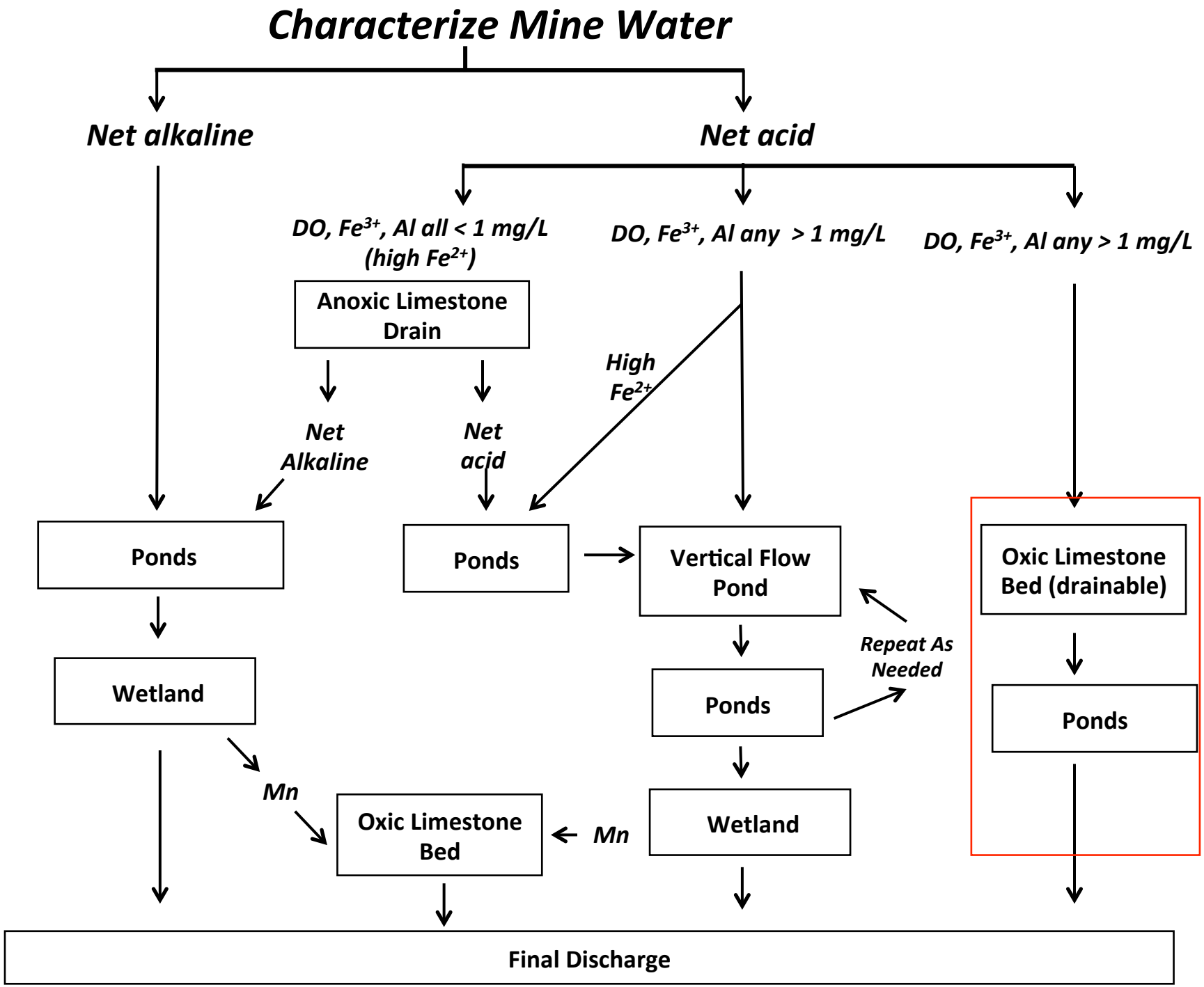

Tributary to Wilson Run
S1 pipeline
S2 pipeline
HD pipeline
VFP 1
VFP 2
VFP 3
VFP 4
VFP 5
VFP 6
VFP 7
VFP 8
Wet 1
Wet 2
Wet 3
Wet 4


2 ft standing water
1 ft compost amended with limestone
3 ft limestone aggregate
PVC pipe underdrain

Anna S passive systems, 2004 - 2016

Point (n)	Flow	pH	Alk	Acid	Fe	Al	Mn	SO_4
	gpm	s.u.	mg/L $CaCO_3$		mg/L	mg/L	mg/L	mg/L
Hunters Drift System								
HD in (47)	225	2.8	0	347	35.4	32.7	6.4	551
VFPs out (25)		6.9	185	-129	19.8	0.6	6.6	552
HD final (61)	na	7.5	142	-112	0.4	0.3	2.0	493
Anna System								
S1 in (34)	204	3.1	0	138	6.9	12.3	7.8	342
S2 in (29)	27	3.8	0	32	1.7	5.7	1.8	130
Final (45)	na	7.5	119	-99	0.8	0.3	3.2	302


Hunters Drift final
Anna final
Alkalinity, mg/L CaCO3
250
200
150
100
50
0
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17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Mn
Wetland
Final Discharge

Treatment of AMD Containing Al and Fe^{3+} with Oxic Limestone Beds

Research project funded by Pennsylvania Department of Environmental Protection

Two types of solids: attached scale and suspended in interstitial water

Scale on aggregate

Suspended solids in pore water

Key Findings of Flushing Study

- Two types of solids: attached scale and suspended in interstitial water
- Draining bed empty once/week removes suspended solids and maintains permeability

Agri Drain Smart Drainage System
(solar powered computer controlled gate valve)

Pittsburgh Botanic Garden DLB during draining

Key Findings of Flushing Study

- Two types of solids: attached scale and suspended in interstitial water
- Draining bed empty once/week removes suspended solids and maintains permeability
- Al and Fe scale can be easily cleaned; treatment restored

Key Findings of Flushing Study

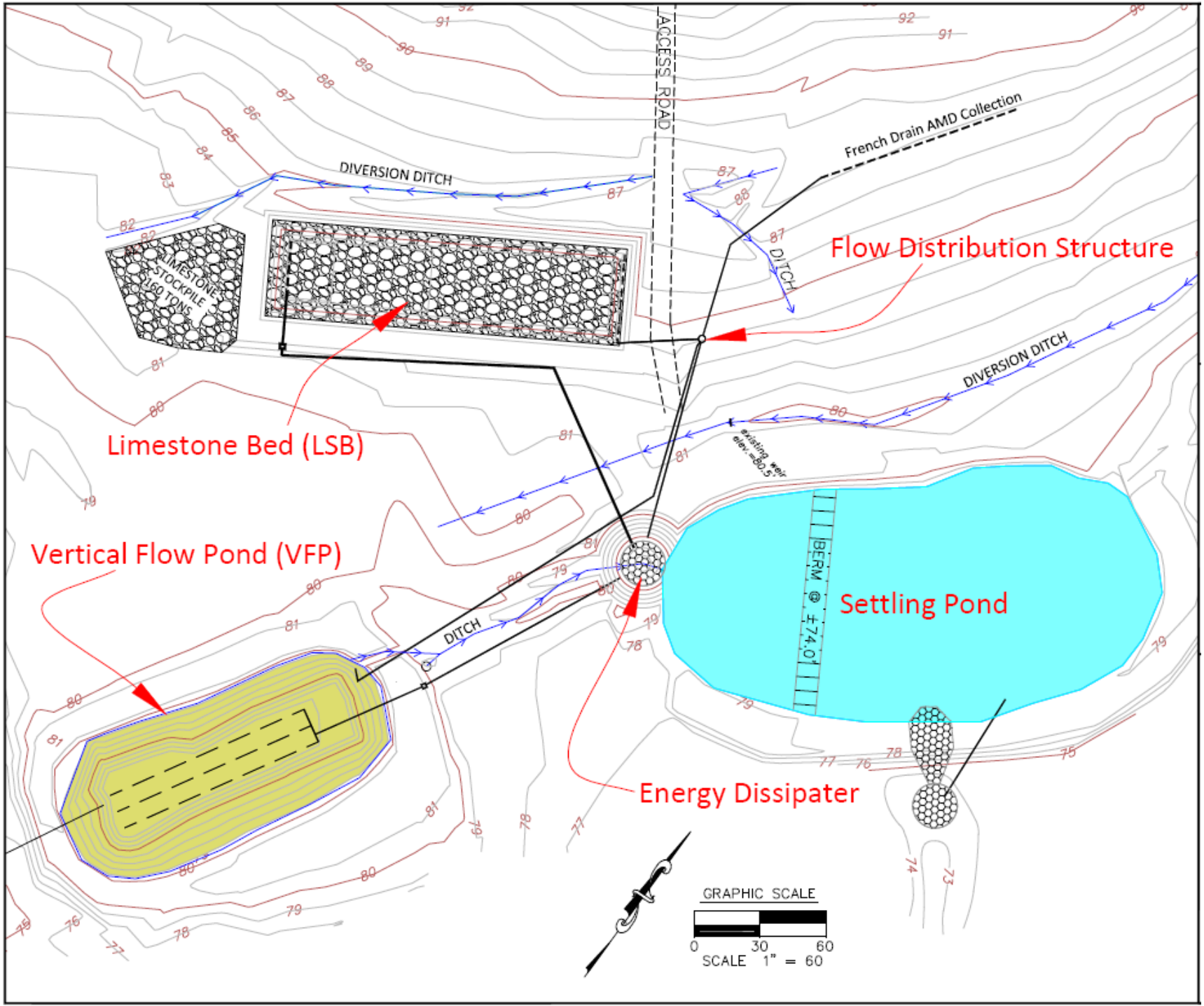
- Two types of solids: attached scale and suspended in interstitial water
- Draining bed empty once/week removes suspended solids and maintains permeability
- Al and Fe scale can be easily cleaned; treatment restored
- Prolonged retention time improves alkalinity generation
- Mn removal feasible
- Sustainable treatment is possible

Mitchell West Box, 2008 – 2016 (regular draining; no cleaning)

Point (n)	**Flow**	**pH**	**Alk**	**Acid**	**Fe**	**Al**	**Mn**	**SO_4**
	gpm	**s.u.**	**mg/L $CaCO_3$**		**mg/L**	**mg/L**	**mg/L**	**mg/L**
Influent (36)	na	3.0	0	209	7.2	22.1	12.5	545
Effluent (39)	1.1	6.8	62	-55	0.5	3.7 (0.4)	3.1	510

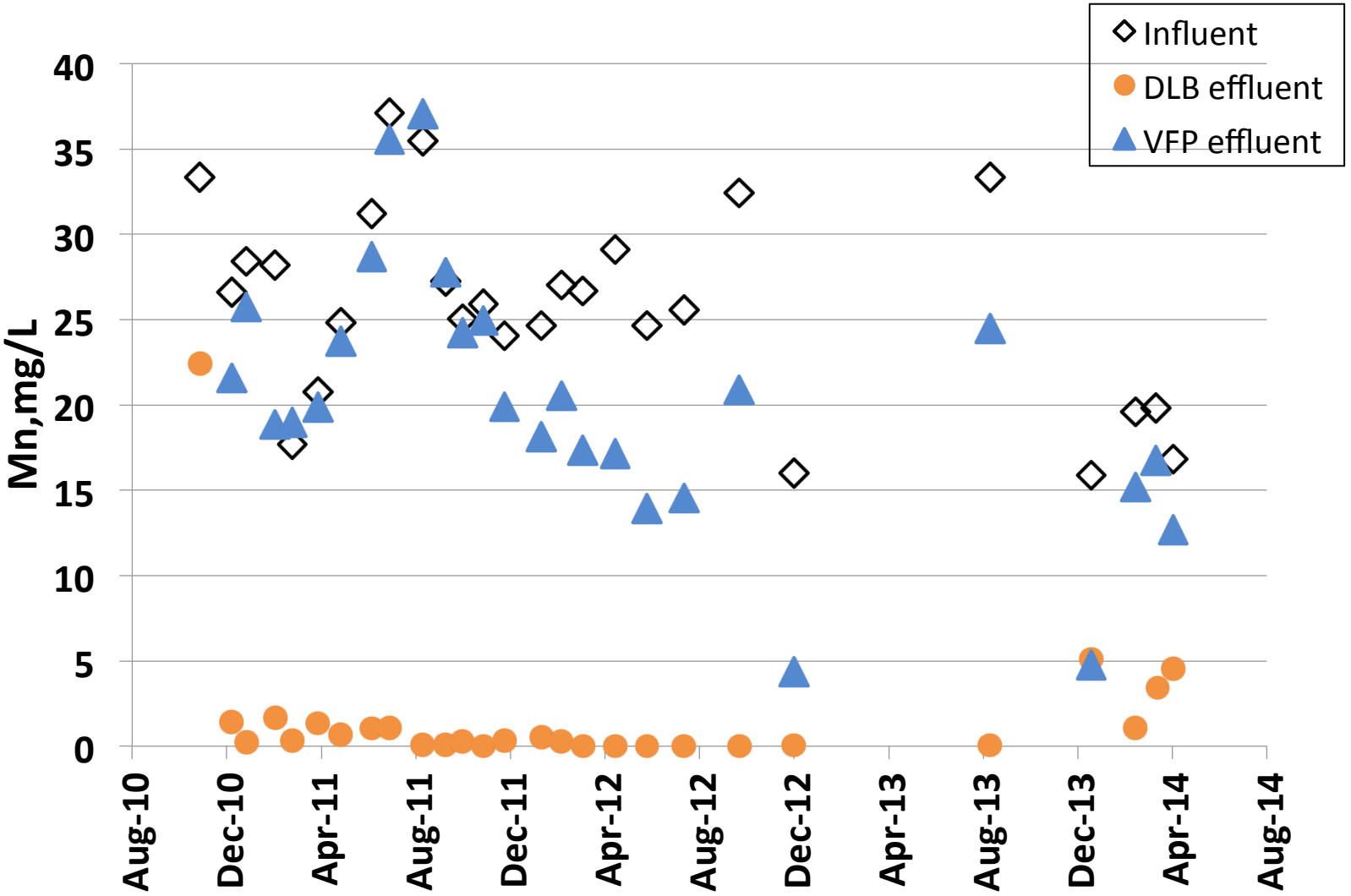
Tangascootac #1 Passive system (Clinton County, PA)

- Abandoned Mine Land project
- Side-by-side treatment with VFP and DLB
- Flow control and distribution
- Vertical Flow Pond
  - 735 tons LS aggregate and 223 CY organic substrate
- Drainable Limestone Bed
  - 1,000 tons LS aggregate
  - AgriDrain SDS


ACCESS ROAD
French Drain AMD Collection
DIVERSION DITCH
Flow Distribution Structure
LIMESTONE STOCKPILE 1160 TONS
DITCH
DIVERSION DITCH
Limestone Bed (LSB)
existing weir elev. 80.5'
Vertical Flow Pond (VFP)
BERM @ ±74.0'
Settling Pond
DITCH
Energy Dissipater
GRAPHIC SCALE
0 30 60
SCALE 1" = 60

Scootac system, Dec 2010 – Apr 2014

	Flow	pH	Alk	Acid	Al	Mn	Fe	SO_4
	gpm		*mg/L $CaCO_3$*		*mg/L*			
Raw	86	4.0	0	89	11.1	25.9	0.2	927
Vertical Flow Pond	40	7.0	157	-127	0.1	20.3	0.6	927
Drainable LS Bed	45	7.3	192	-169	0.2	1.7	0.1	968
Polishing Pond	na	7.1	160	-133	0.3	8.8	0.5	917


Influent
DLB effluent
VFP effluent
Mn,mg/L
40
35
30
25
20
15
10
5
0
Aug-10
Dec-10
Apr-11
Aug-11
Dec-11
Apr-12
Aug-12
Dec-12
Apr-13
Aug-13
Dec-13
Apr-14
Aug-14

VFP vs DLB

	Vertical Flow Pond	Drainable Limestone Bed
Footprint		Smaller
Cost, capital		Lower
Cost, O&M	Lower	
Major maintenance interval	7-15 years	3-7 years
DOC/BOD production	Yes	No
Al removal	Yes	Yes
Fe Removal	Partial	Yes (oxic)
Mn removal	No	Yes
Metals other than Fe, Al, Mn	Oxides and sulfides	Oxides and sorption


Questions?