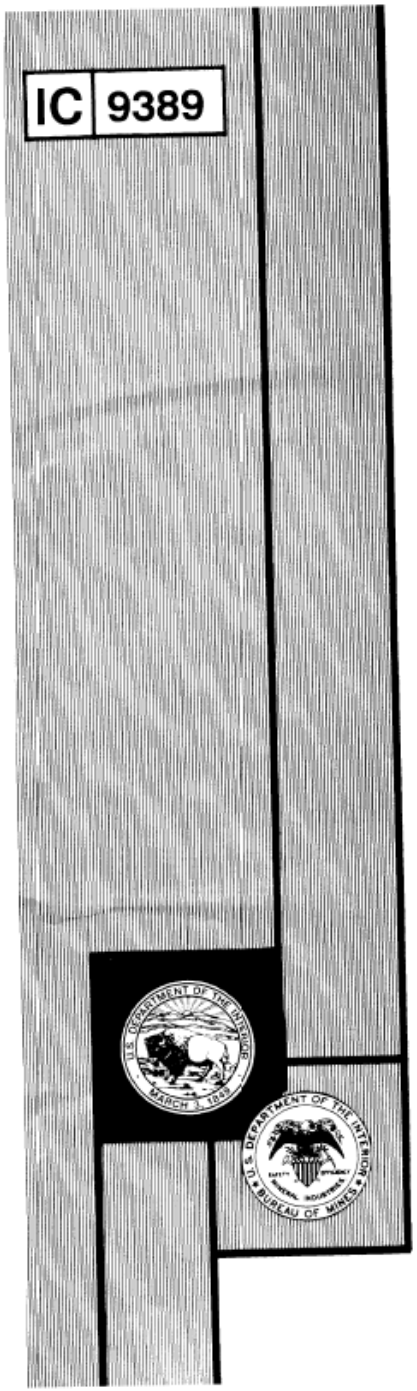


BUREAU OF MINES
INFORMATION CIRCULAR/1994

Passive Treatment of Coal Mine Drainage

By Robert S. Hedin, Robert W. Narin,
and Robert L. P. Kleinmann

UNITED STATES DEPARTMENT OF THE INTERIOR

Effective Passive Treatment of Coal Mine Drainage

Bob Hedin, Ted Weaver, Neil Wolfe, and George Watzlaf

Hedin Environmental

Pittsburgh, PA

Hedin Environmental

- Formed in 1994
- specialize in AMD assessments and passive treatment
- Clients include watershed associations, non-profits, PADEP, mining companies, engineering companies, bonding companies
- 50 installed passive treatment systems based on our designs

Components of an Effective Passive Treatment System

- Proper selection of technology (IC 9389)
- Proper sizing (IC 9389)
- Consideration/mitigation of possible problems
- Proper construction
- Routine maintenance and sampling
- Major maintenance

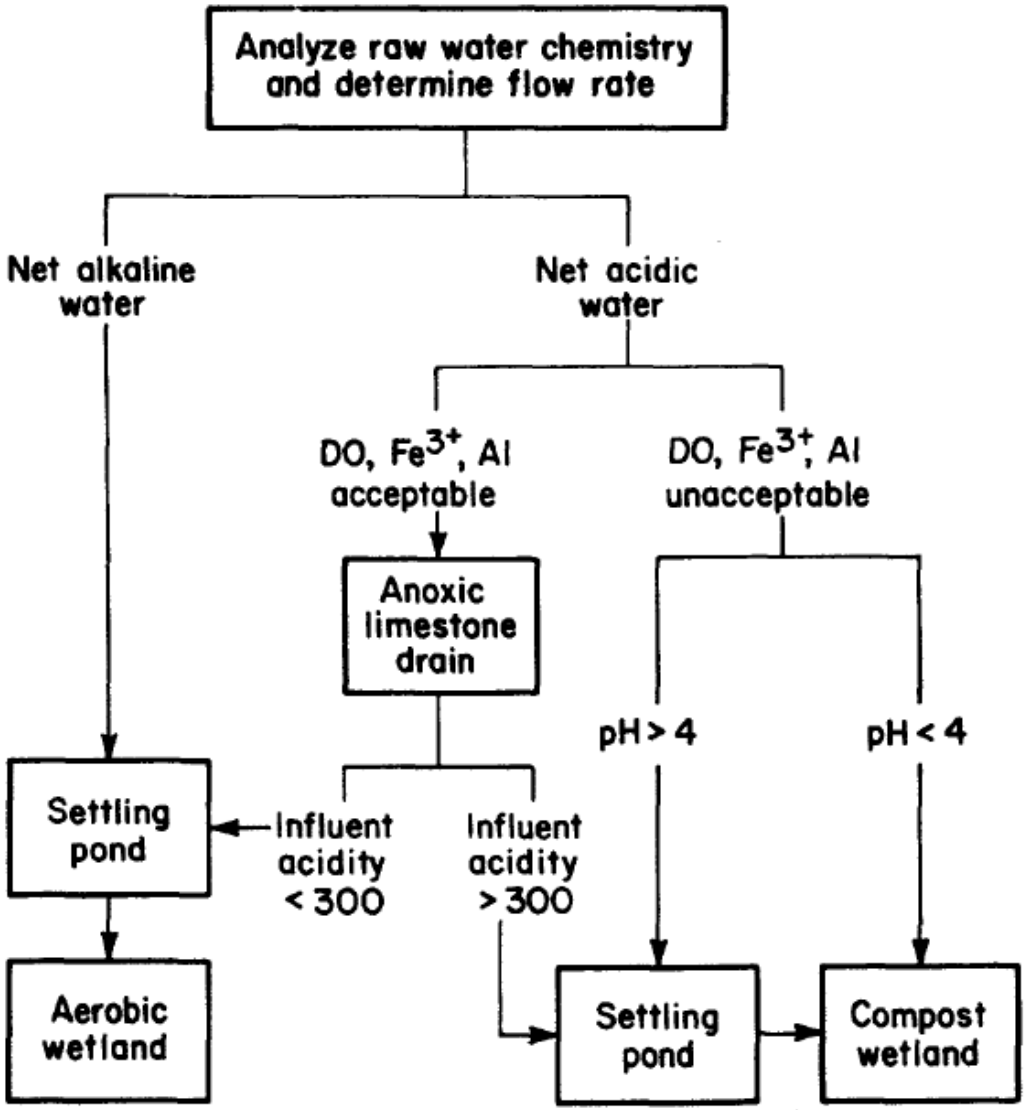
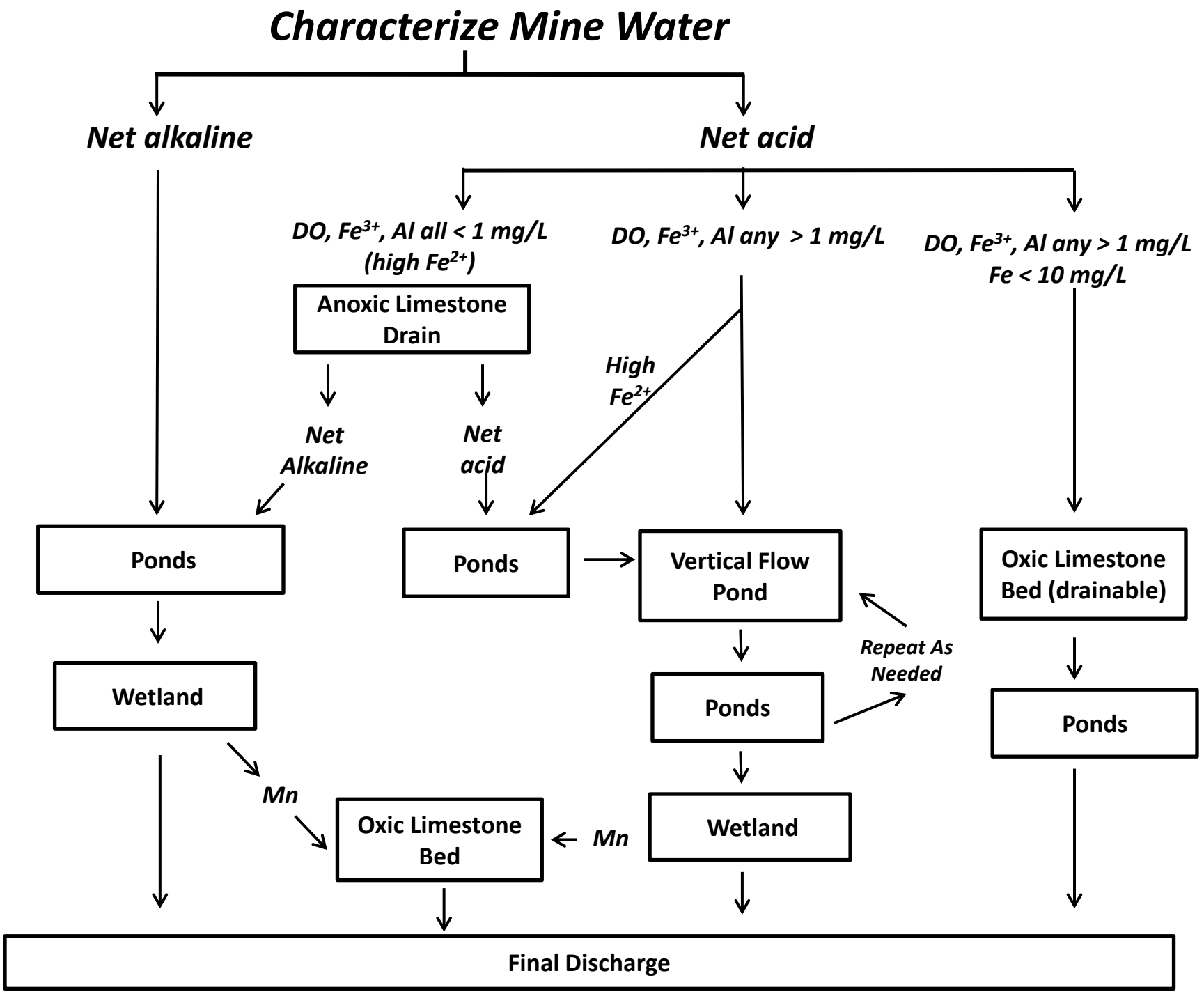


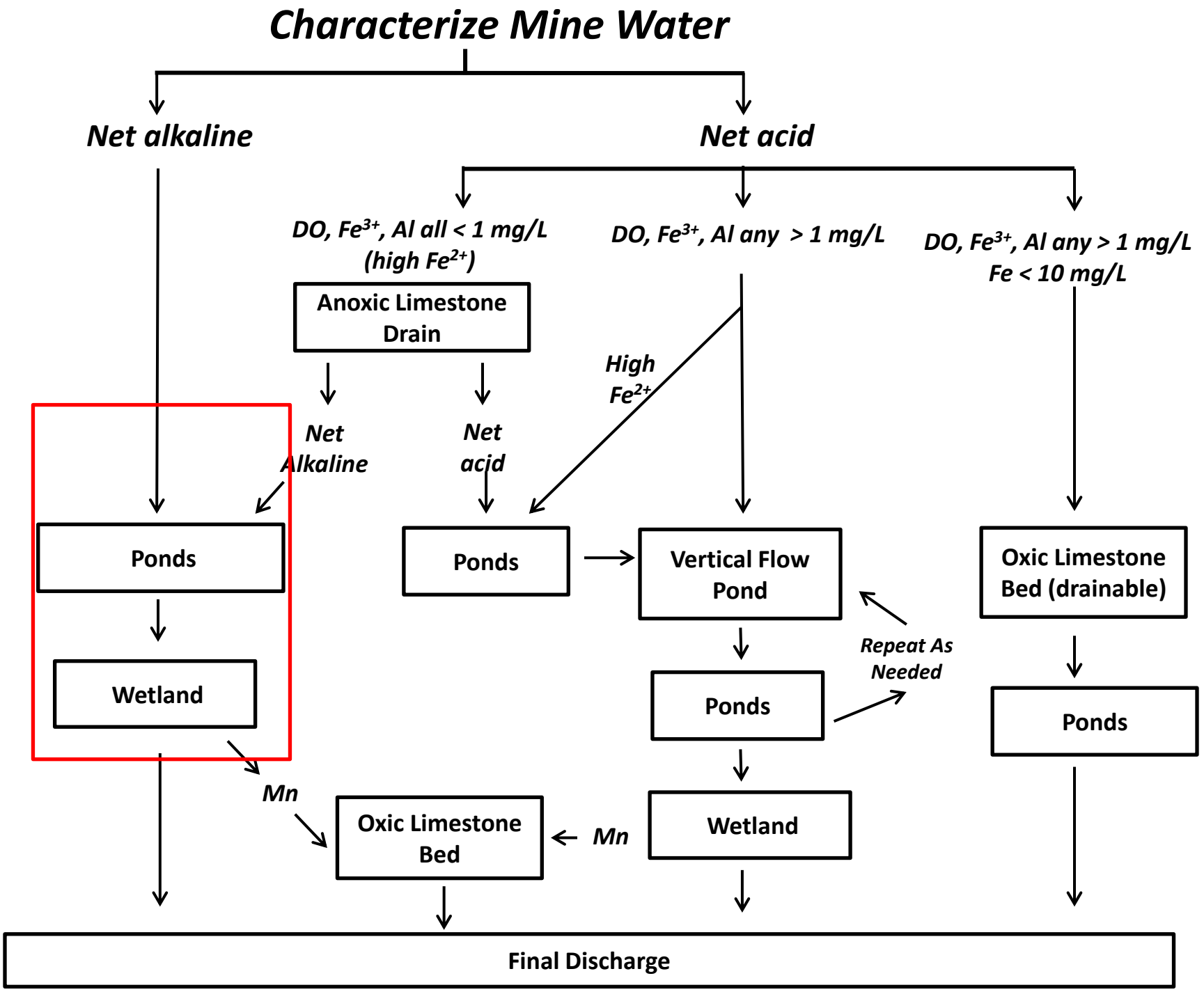
Figure 12.—Flow chart showing chemical determinations necessary for the design of passive treatment systems.


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 Drain
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 Technologies Used by HE

- Ponds
  - oxidize Fe, settle solids, mixing (IC 9389)
- Wetlands
  - polishing , Mn and solids removal; (IC 9389)
- Anoxic limestone drains
  - alkalinity generation (IC 9389)
- Oxic limestone beds (new)
  - alkalinity generation, metal removal, polishing
- Vertical flow ponds (SAPS, Anaerobic Wetlands) (new)
  - alkalinity generation and metal removal

Four Examples of the Reliable Use of these Technologies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DO, Fe3+, Al any > 1 mg/L
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Anoxic Limestone Drain
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

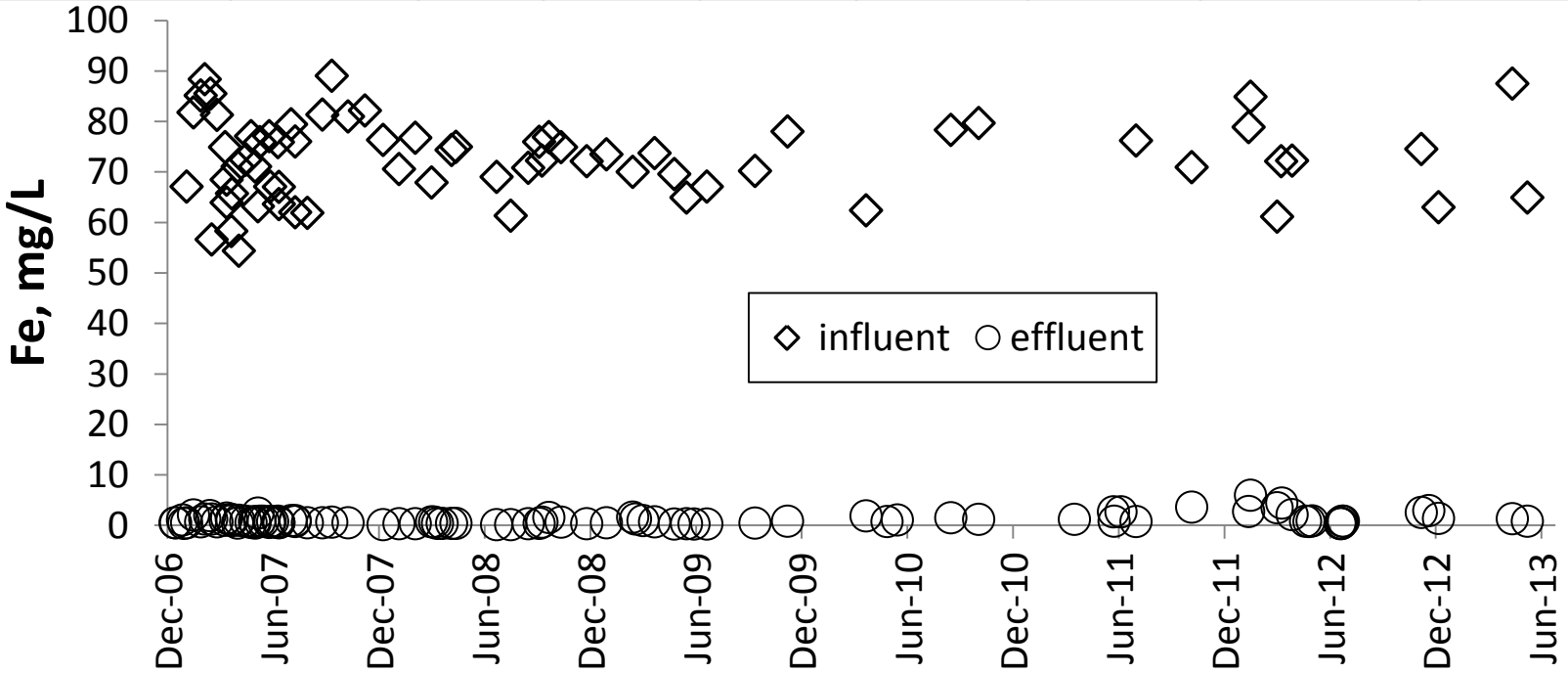
Marchand Mine Passive System

Ponds and Wetlands


Wetland
Wetland
Wetland
Pond F
Pond E
Pond D
Pond C
Pond B
Pond A
Sewickley Creek


$Fe^{2+} + HCO_3^- + O_2 \rightarrow FeOOH + H_2O$

Marchand system, average conditions, 2006 - 2013								
	Flow	**pH**	**Alk**	**Fe^T**	**Mn**	**Al**	**SO_4**	**TSS**
	gpm		----------mg/L----------					
Influent	1,876	6.3	335	72.4	1.2	<0.1	1,136	25
Pond F out		7.1	230	12.4	1.1	<0.1	1,117	16
Effluent		7.8	216	1.0	0.5	<0.1	1,160	<6

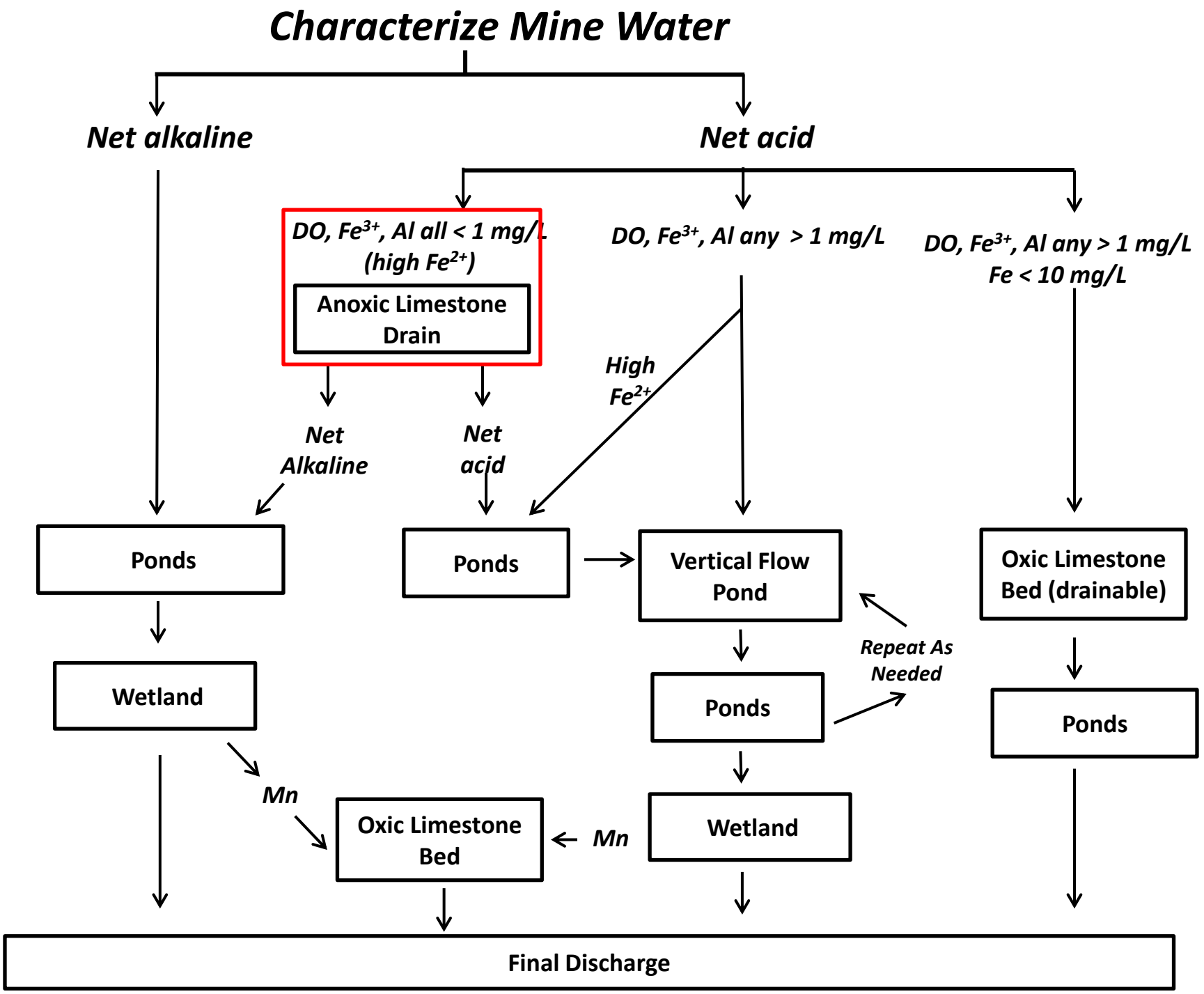


Maintenance of the Marchand System

Fe sludge accumulation

- 575 ton/yr Fe solids
- 575,000 gallons/yr Fe sludge
- 7.5% loss of storage volume per year
- In June 2012 the system's theoretical retention had decreased from 74 hr to 46 hr
- June 2012 sludge in first three ponds was removed


FeOOH recovered
in 2012
Wetland
Wetland
Wetland
Pond F
Pond E
Pond D
Pond C
Pond B
Pond A
Sewickley Creek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Net acid
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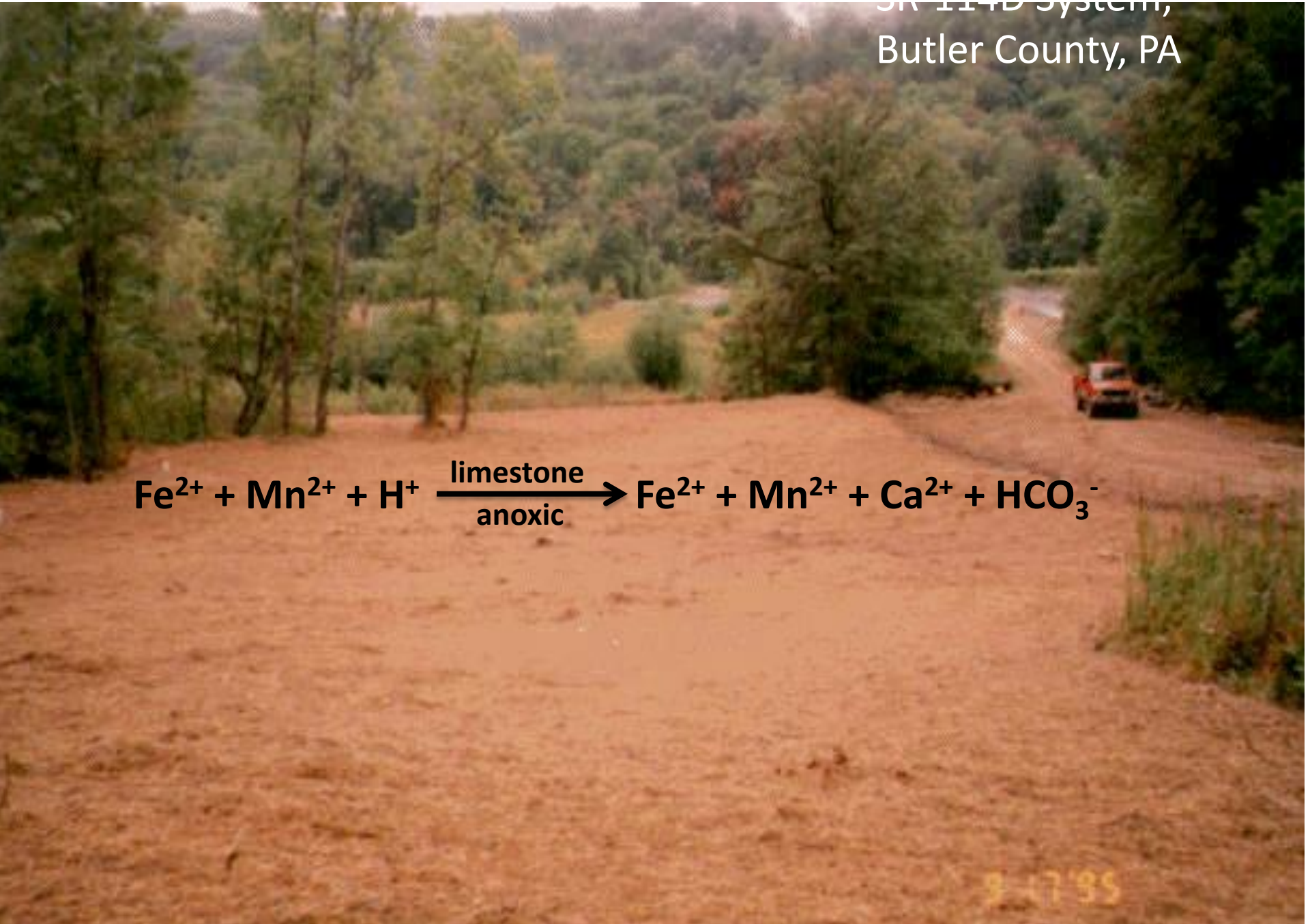
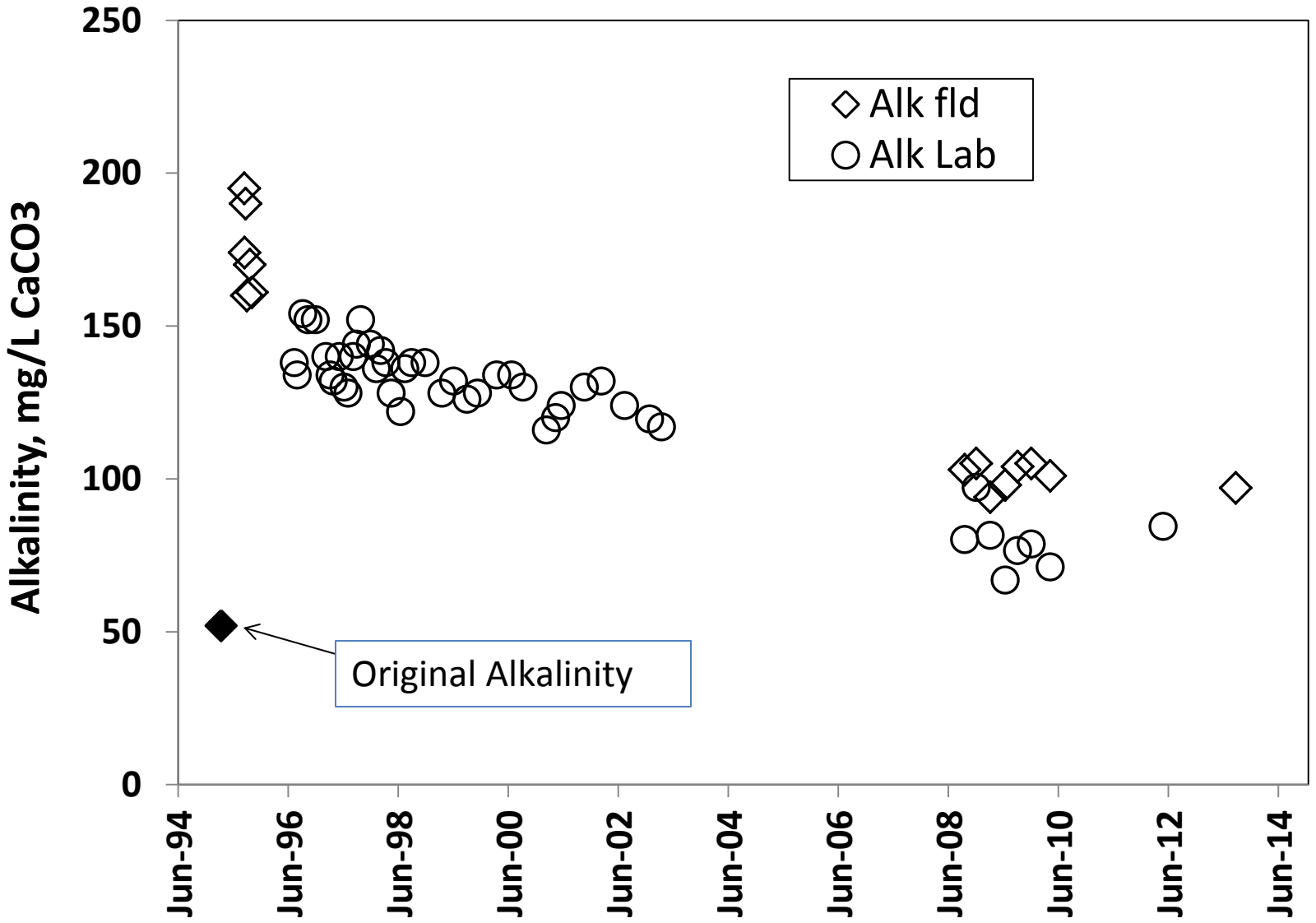
(high Fe2+)
Anoxic Limestone Drain
DO, Fe3+, Al any > 1 mg/L
DO, Fe3+, Al any > 1 mg/L
Fe < 10 mg/L
High Fe2+
Net Alkaline
Net acid
Ponds
Ponds
Vertical Flow Pond
Oxic Limestone Bed (drainable)
Repeat As Needed
Wetland
Ponds
Ponds
Mn
Oxic Limestone Bed
Mn
Wetland
Final Discharge

SR-114D Passive System

Anoxic Limestone Drain


SR-114D System,
Butler County, PA
August 1995
1,300 ton limestone
120 gpm flow with 35 mg/L Fe^{2+}


SR 114B System,
Butler County, PA
$Fe^{2+} + Mn^{2+} + H^{+} \xrightarrow[\text{anoxic}]{\text{limestone}} Fe^{2+} + Mn^{2+} + Ca^{2+} + HCO_3^-$

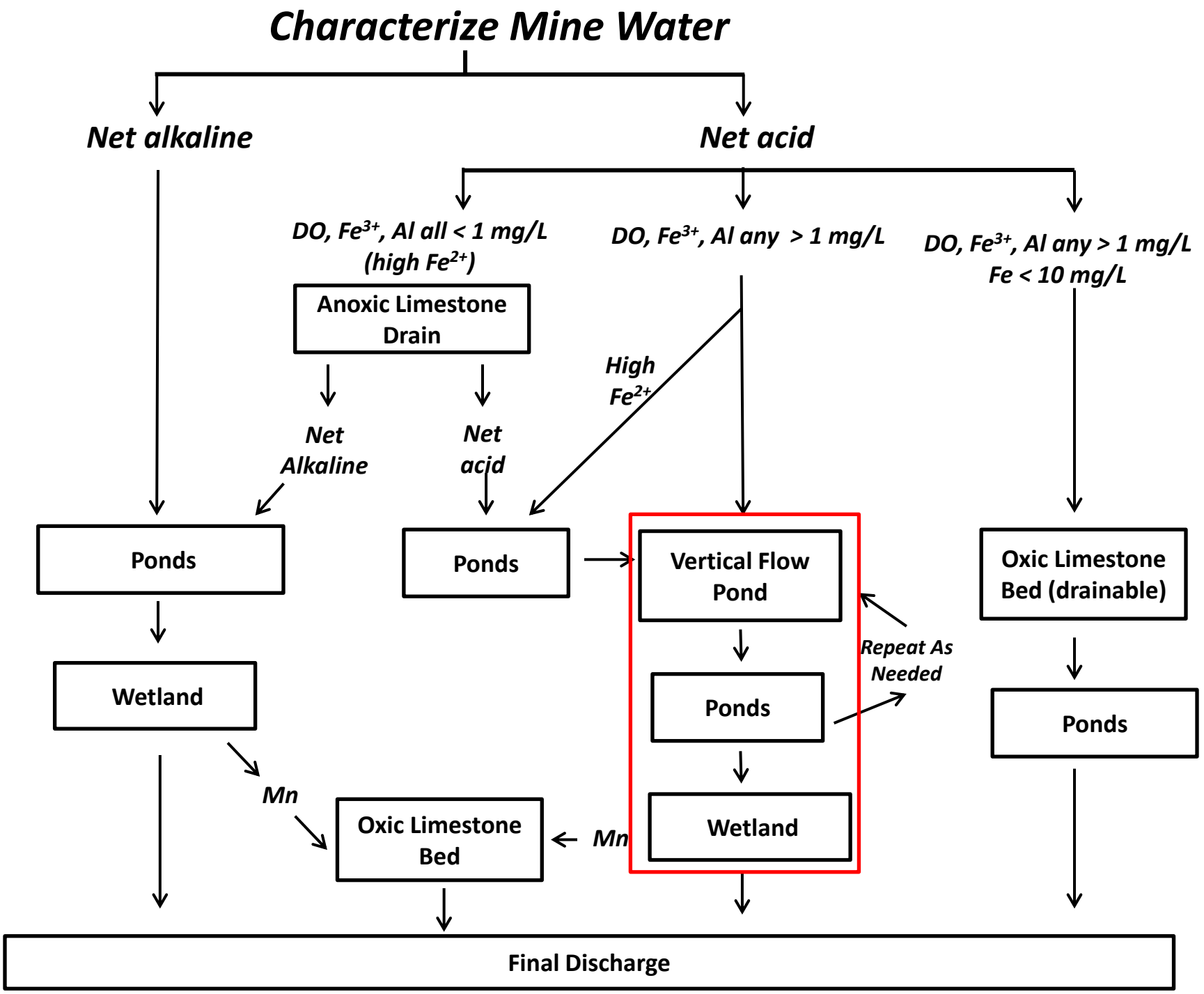

Alkalinity, mg/L CaCO3
250
200
150
100
50
0
Jun-94
Jun-96
Jun-98
Jun-00
Jun-02
Jun-04
Jun-06
Jun-08
Jun-10
Jun-12
Jun-14
Alk fld
Alk Lab
Original Alkalinity

Limestone Dissolution in ALD 1995-2014

- ALD has generated 375 ton $CaCO_3$
- ALD has dissolved 416 tons limestone
- 32% of original 1,300 tons
- Theoretical average retention time has decreased from 10.8 hr to 7.4 hr

SR-114D ALD Maintenance

- No maintenance to date (19 years)
- ALD will need rehabilitated in next 5-10 years
  - Clean remaining limestone
  - Replaced dissolved limestone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Net acid
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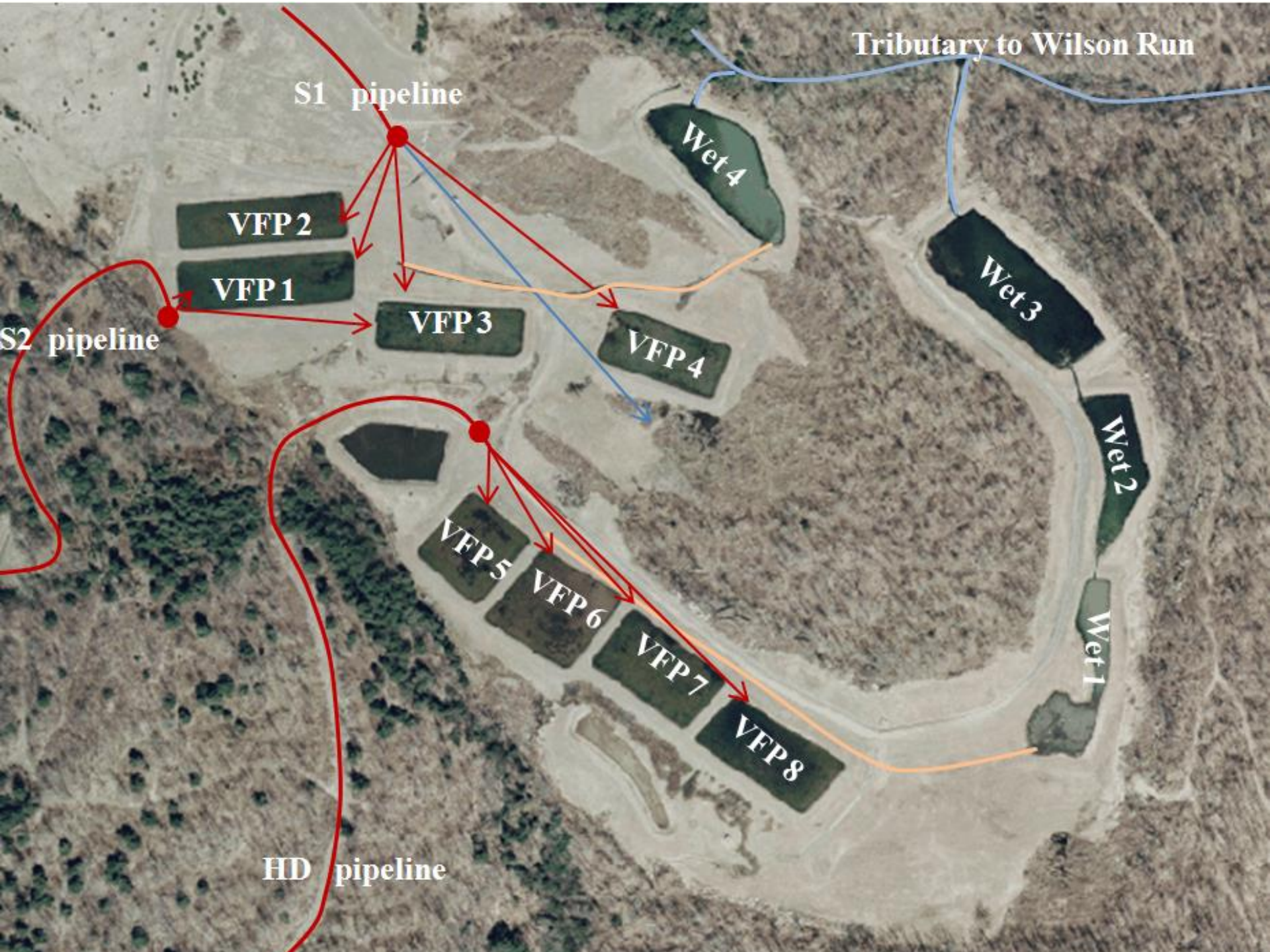
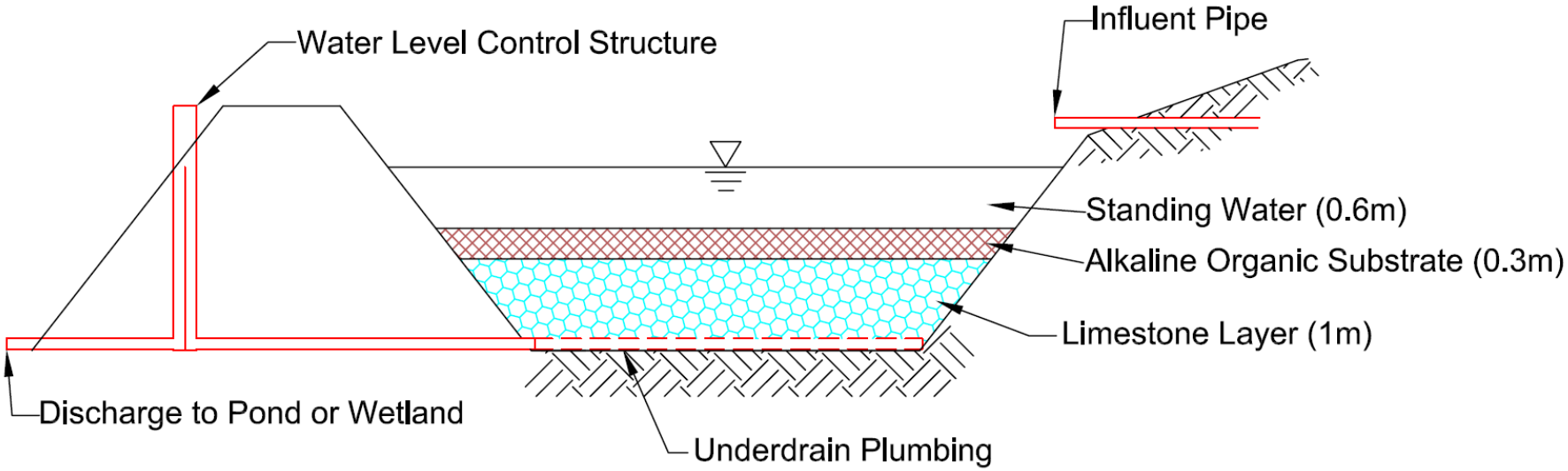
(high Fe2+)
DO, Fe3+, Al any > 1 mg/L
DO, Fe3+, Al any > 1 mg/L
Fe < 10 mg/L
Anoxic Limestone Drain
High Fe2+
Net Alkaline
Net acid
Ponds
Ponds
Vertical Flow Pond
Oxic Limestone Bed (drainable)
Repeat As Needed
Ponds
Ponds
Wetland
Wetland
Mn
Mn
Oxic Limestone Bed
Final Discharge

Anna S Mine
Passive Treatment Complex

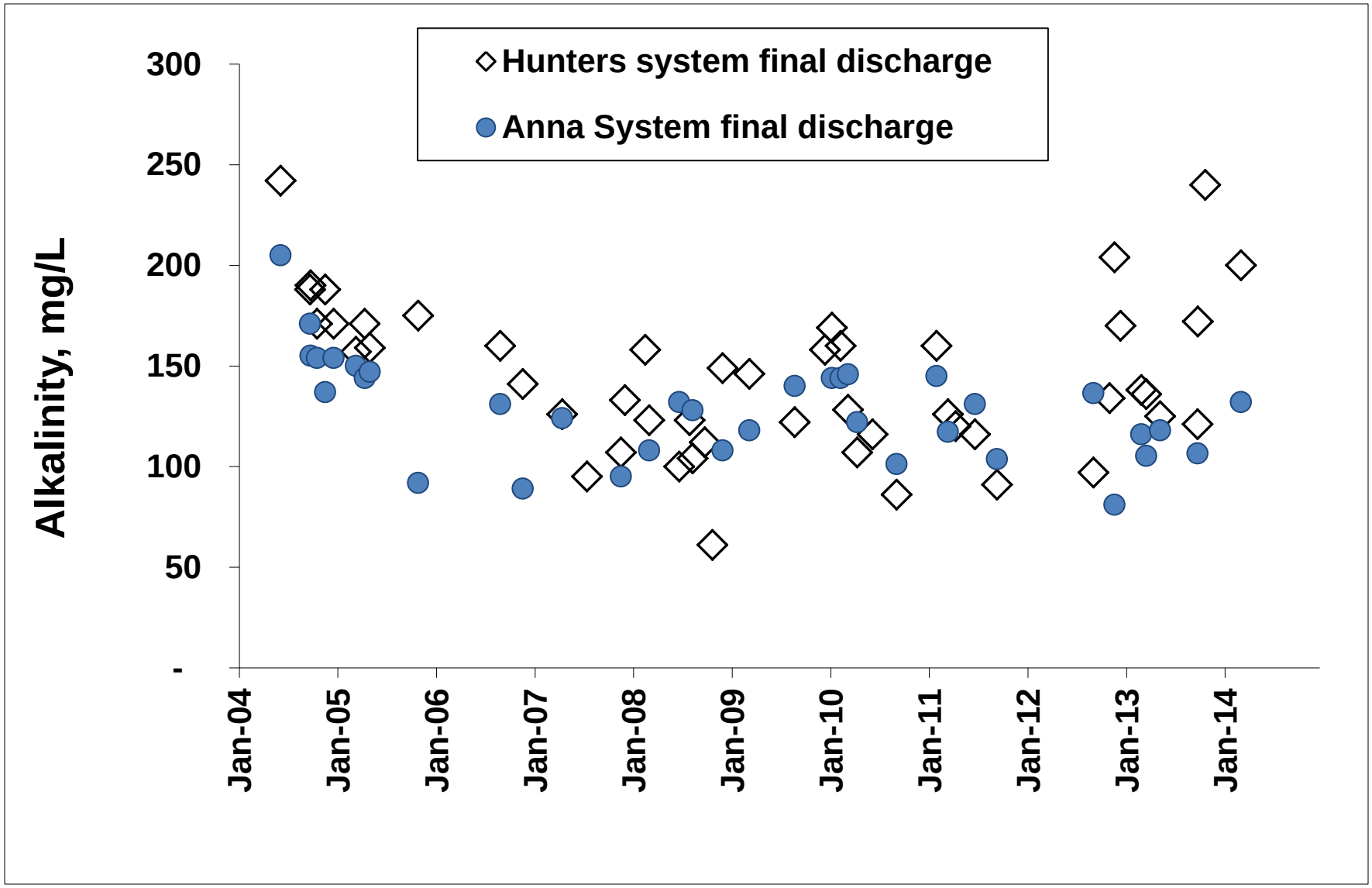
Vertical Flow Ponds


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


Water Level Control Structure
Influent Pipe
Standing Water (0.6m)
Alkaline Organic Substrate (0.3m)
Limestone Layer (1m)
Discharge to Pond or Wetland
Underdrain Plumbing

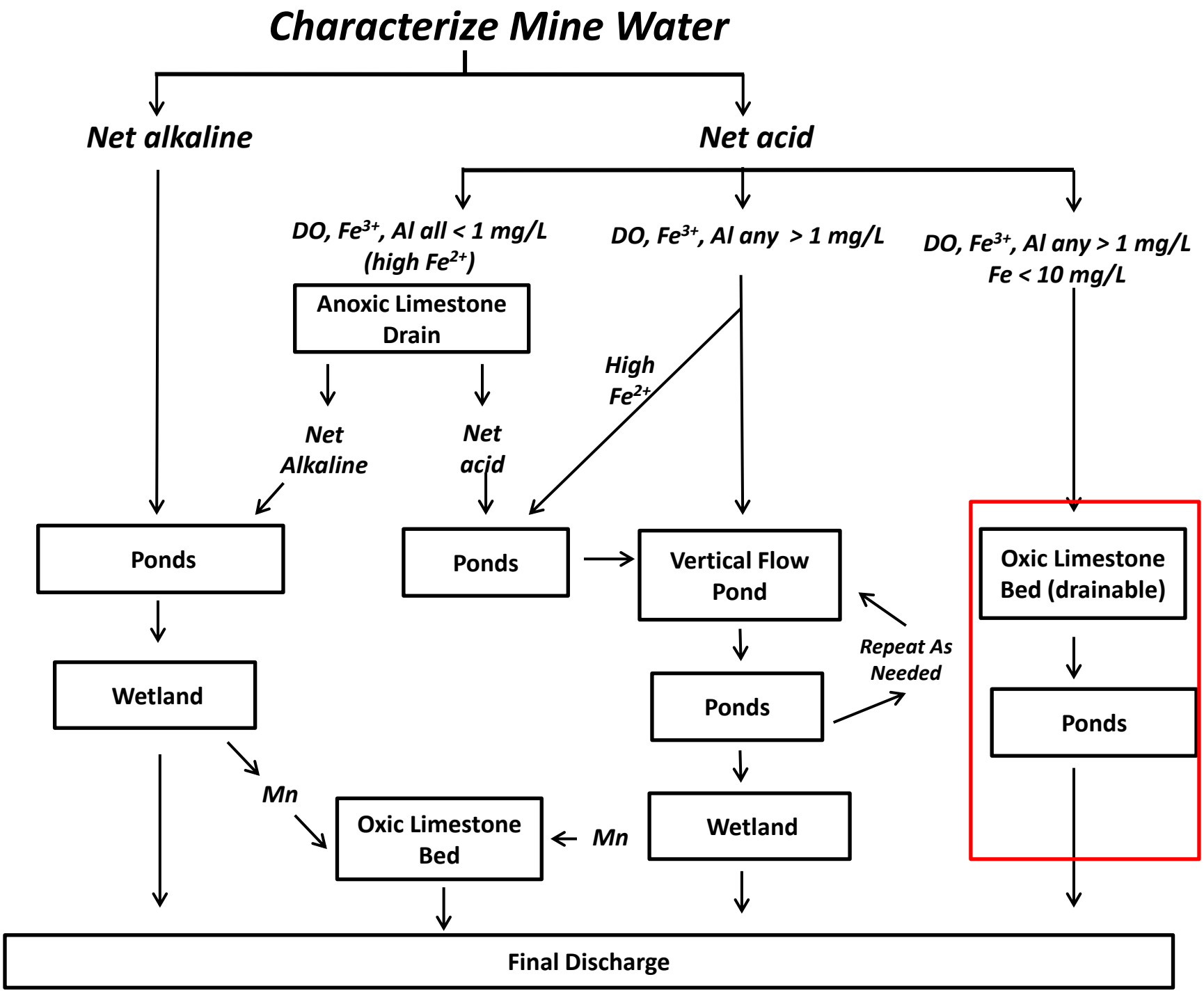
Anna S passive systems, 2004 - 2014

	Flow	pH	Alk	Acid	Fe	Al	Mn	SO_4
	gpm	s.u.	mg/L $CaCO_3$		mg/L	mg/L	mg/L	mg/L
	Anna System							
S1 influent	216	3.1	0	145	7	13	8	356
S2 influent	31	3.8	0	33	<1	2	6	134
VFPs out	na	7.0	150	-114	6	<1	7	323
Final	na	7.4	129	-99	1	<1	4	316
	Hunters Drift System							
HD influent	234	2.8	0	354	35	34	7	556
VFPs out	na	6.8	199	-126	20	<1	5	554
Final	na	7.4	144	-112	<1	<1	2	509


Hunters system final discharge
Anna System final discharge
Alkalinity, mg/L
300
250
200
150
100
50
-
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14

Major Maintenance

- Rehabilitate substrates that contribute to system's effectiveness (alkalinity generation)
- Alkaline Organic Substrate: replenish
- Limestone Underdrain: clean and replenish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Net acid
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(high Fe2+)
DO, Fe3+, Al any > 1 mg/L
DO, Fe3+, Al any > 1 mg/L
Fe < 10 mg/L
Anoxic Limestone Drain
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

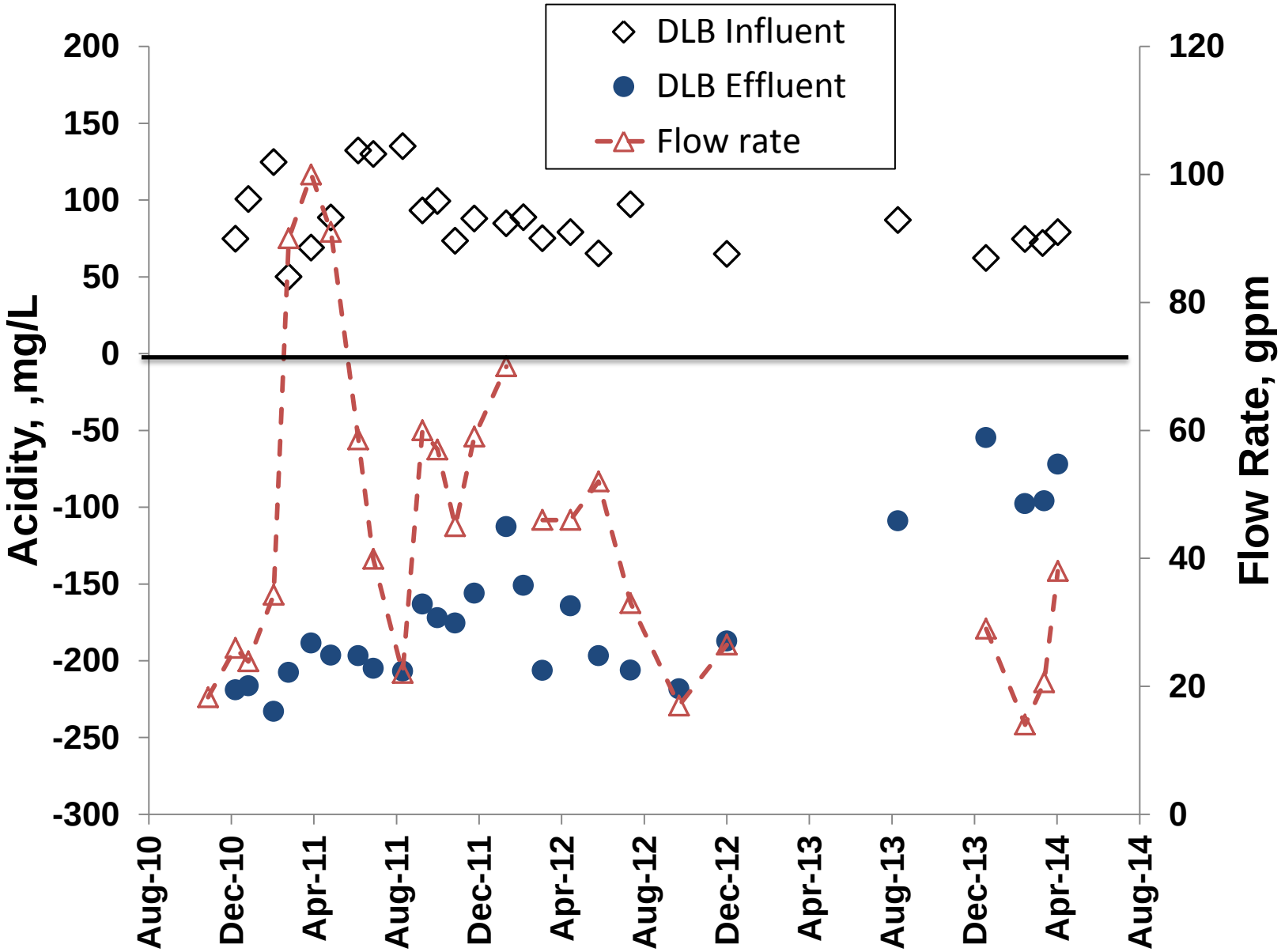
Tangascootack #1 Passive System

Oxic Limestone Bed (drainable)


Water Level Control box
with bottom gate valve
Computer
Solar Panel

Tangascootack #1 system, Nov 2010 – Apr 2014

	Flow	**pH**	**Alk**	**Acid**	**Fe**	**Al**	**Mn**	**SO_4**
Inflow	na	4.0	0	89	0.2	11.1	25.9	927
DLB out	45	7.3	197	-169	0.1	0.2	1.7	968


DLB Influent
DLB Effluent
Flow rate
Acidity, ,mg/L
Flow Rate, gpm
200
150
100
50
0
-50
-100
-150
-200
-250
-300
120
100
80
60
40
20
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

Solids Management

- Routine draining removes portion of solids
- Infrequent cleaning of stone removes remaining solids

Pittsburgh Botanic Garden DLB
solids basin during end of draining

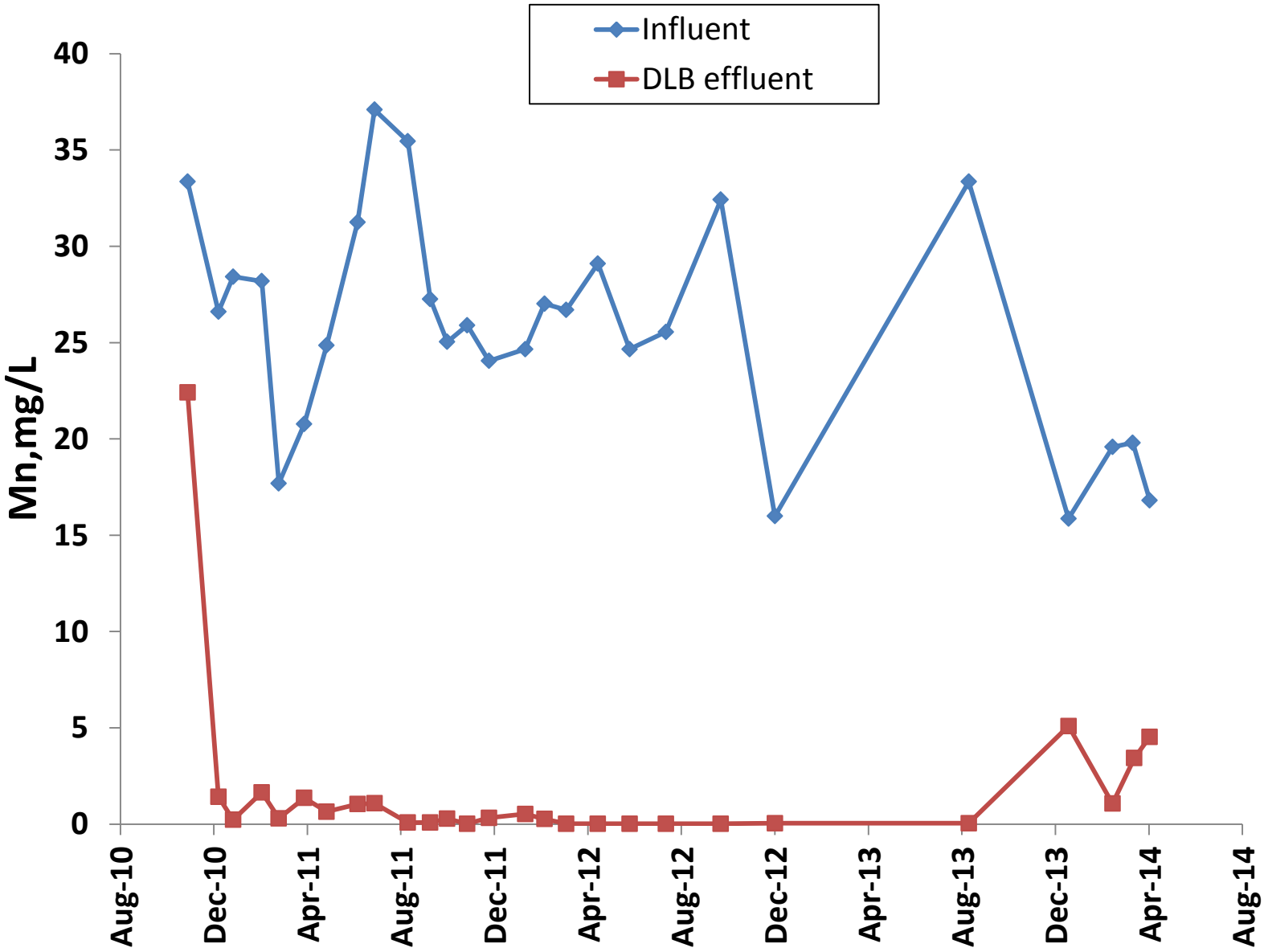
Pittsburgh Botanic Garden DLB
solids basin during end of draining

Major Maintenance

- Clean limestone aggregate every 3-10 years
- Established procedures and costs

Summary

- Highly successful passive treatment of discharge with large range of flow rates and chemical conditions
- Effective treatment obtained year-round
- All systems require O&M, but the needs are modest and with planning can be implemented cost-effectively


Influent
DLB 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

	Al	Fe	Mn	Al	Fe	Mn
Routine						
Influent	13.0	0.5	0.8	13.8	0.44	0.93
Effluent	0.7	0.1	0.2	0.4	0.09	0.14
Retained				13.4	0.35	0.79
Draining						
Removal	12-239	0.6-8.1	0.2-0.8	9.5	0.35	0.10
% removed				71%	99%	13%
% retained				29%	1%	87%

Pittsburgh Botanic Garden DLB
Poured concrete tank
100’ X 20’ X 5’
450 ton limestone
Agri Drain SDS system
Drains empty once/week

Routine conditions		
	In	out
Flow, gpm	na	4-11
pH	3.3	7.6
Acidity	130	-188
Alkalinity	0	221
Al, mg/L	13.0	0.7
Mn, mg/L	0.8	0.2
Fe, mg/L	0.5	<0.1