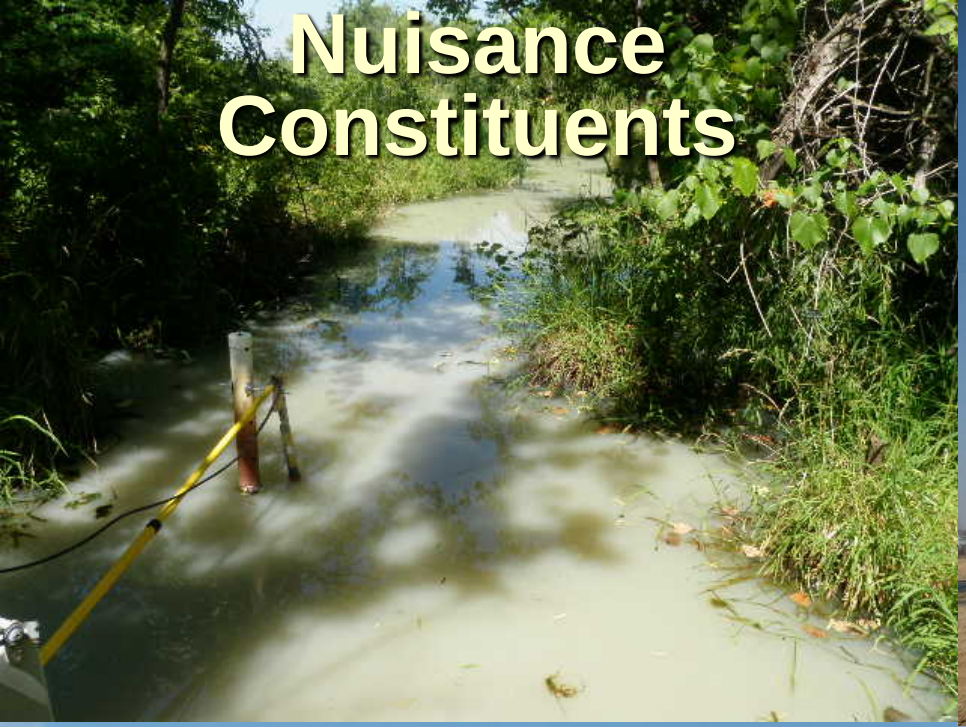
Off-the-Grid Aeration to Address Nuisance Constituent Production in Passive Treatment Systems

R.W. Nairn and K.A. Strevett

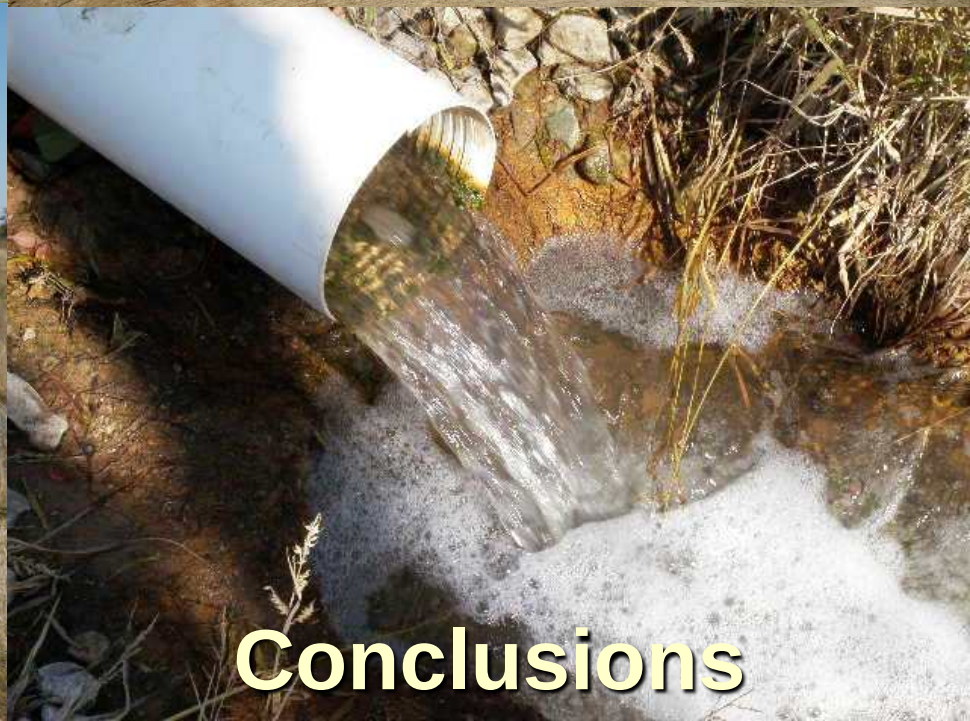
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science
The University of Oklahoma, Norman, OK

OSMRE Applied Science Program
Cooperative Agreement S11AC20000


Nuisance
Constituents


Re-aeration Options


Performance


Conclusions

Nuisance Constituents

Nuisance Constituents

What do we consider a nuisance?

- Excessive concentrations of atypical, non-mine drainage related constituents
- Produced by predominately anaerobic, biologically-based process units
  - Vertical flow bioreactors (VFBRs)
- Are we simply trading one water quality problem for another?

Common Nuisance Constituents

- Elevated nutrient concentrations
  - Nitrogen
  - Phosphorus

- Oxygen demanding substances

$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + CO_2$

- Sulfide at ecotoxic levels

$2CH_2O + SO_4^{-2} \rightarrow H_2S + 2HCO_3^-$

Typical Performance Data

Mayer Ranch Passive Treatment System, Tar Creek Superfund Site, Ottawa County, OK

Targeted Contaminants of Concern Mass Retention

	----------Mass Loadings (g/d)----------				
	As*	Cd*	Fe	Pb*	Zn
Total inflow	57	10	105,000	73	6,770
System outflow	7.3	0.25	479	12	88
Retention	51	9.94	105,000	61	6,690

*Effluent concentrations below detection limit; 1/2 value of practical quantification limit used for mass balance calculations

Data from S. Yepez MS thesis 2012

Typical Performance Data

Mayer Ranch Passive Treatment System, Tar Creek Superfund Site, Ottawa County, OK

Major Nutrients Mass Retention

	TP (g/d)			TN (g/d)		
	Fall	Spring	Summer	Fall	Spring	Summer
Influent	1,180	1,890	1,060	491	565	456
OX	-1,160	-1,830	-1,010	-344	-163	-286
SF	-10	-19	-33	-49	40	-78
VF	38	46	62	54	-123	77
RA	-7	-24	11	77	-127	20
LB	-19	-11	52	31	-16	50
PW	-26	-13	-2	-64	55	30
Effluent	21	72	283	195	232	509
Export	-1,160	-1,810	-777	-296	-333	53

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Total Sulfide Mass Retention

	Total Sulfide (g/d)		
	Fall	Spring	Summer
Influent	---	---	---
OX	---	---	---
SF	---	---	---
VF	1,460	1,670	6,020
RA	-1,380	-1,620	-2,430
LB	-83	-53	-214
PW	---	---	-5,860
Effluent	---	---	1,000
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Data from S. Yepez MS thesis 2012

Typical Performance Data

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Data from S. Yepez MS thesis 2012

Typical Performance Data

Mayer Ranch Passive Treatment System, Tar Creek Superfund Site, Ottawa County, OK

Oxygen Demand Mass Retention

	----------$CBOD_5$ (g/d)--------			----------COD (g/d)----------		
	Fall	Spring	Summer	Fall	Spring	Summer
Influent	9,030	4,160	5,020	25,600	21,200	14,800
OX	-8,310	-3,070	-3,550	-19,900	-14,700	-8,970
SF	-351	-678	-1,250	-1,420	-874	-2,860
VF	638	945	4,690	786	-4,470	7,870
RA	244	-737	-2,690	-157	1,290	-3,140
LB	1,270	107	-785	-629	-308	-1,630
PW	293	315	-1,500	-314	2,160	-2,470
Effluent	5,340	1,770	1,400	8,170	6,380	9,620
Export	-3,690	-2,390	-3,630	-17,400	-14,800	-5,130

Data from S. Yepez MS thesis 2012

Typical Performance Data

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Effluent Criteria

	System Effluent (mg/L)	Effluent Criteria (mg/L)	Source
TN	1.01 ± 0.26	0.36 (lakes) 0.69 (streams)	EPA, 2000
TP	0.59 ± 0.14	0.020 (lakes) 0.037 (streams)	EPA, 2000
Sulfide	<0.5 - 3.4	0.002 as H_2S	EPA, 1986
$CBOD_5$	2.3 - 8.5	25	EPA, 1984
COD	8 - 21	NA	NA

Re-aeration Options

Common Aeration Techniques

- Utilize elevation changes/head pressure differences
- Physically entrain air via turbulent flow
- Well-studied for iron oxidation
- Much less so for VFBR effluent re-aeration


11/25/2011

What to do when elevation changes are minimal?

Hartshorne Study Site

- Abandoned Rock Island underground coal mine
- Constructed late 2005
  - Vertical anoxic limestone drain
  - Two VFBRs
  - Three oxidation ponds
  - Polishing wetland
- Flows: <1 to 75 LPM
- Cooperative effort by OSMRE, OCC and OU

Hartshorne Water Quality

	Minimum	Maximum	Median	n
pH	5.25	5.84	5.36	18
SC (mS/cm)	2960	17100	11800	18
T. Alk. (mg/L)	95	214	117	18
Fe (mg/L)	215	1311	765	15
Mn (mg/L)	14	29	18	15
Na (mg/L)	1400	3437	1893	4
Cl (mg/L)	197	381	225	9
SO_4^{-2} (mg/L)	5456	13620	7842	12

Hartshorne Re-aeration

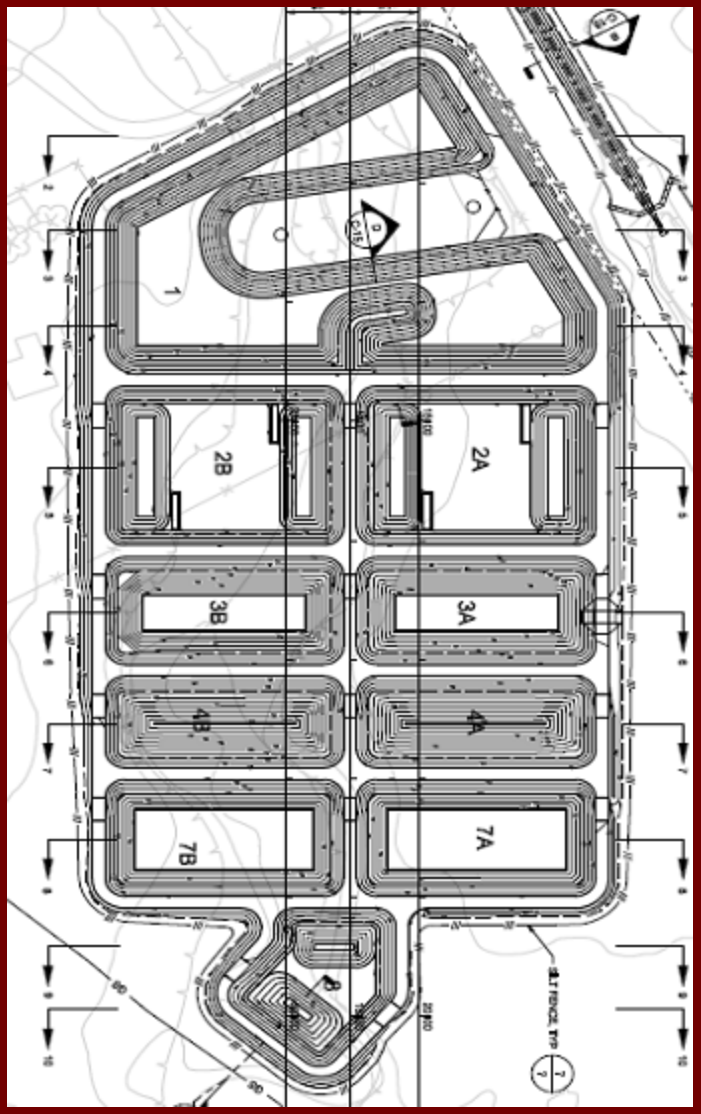
- Windmill aeration in initial oxidation pond
  - Examining iron removal rates
- Solar aeration in re-aeration pond after first VFBR
- No side-by-side comparison

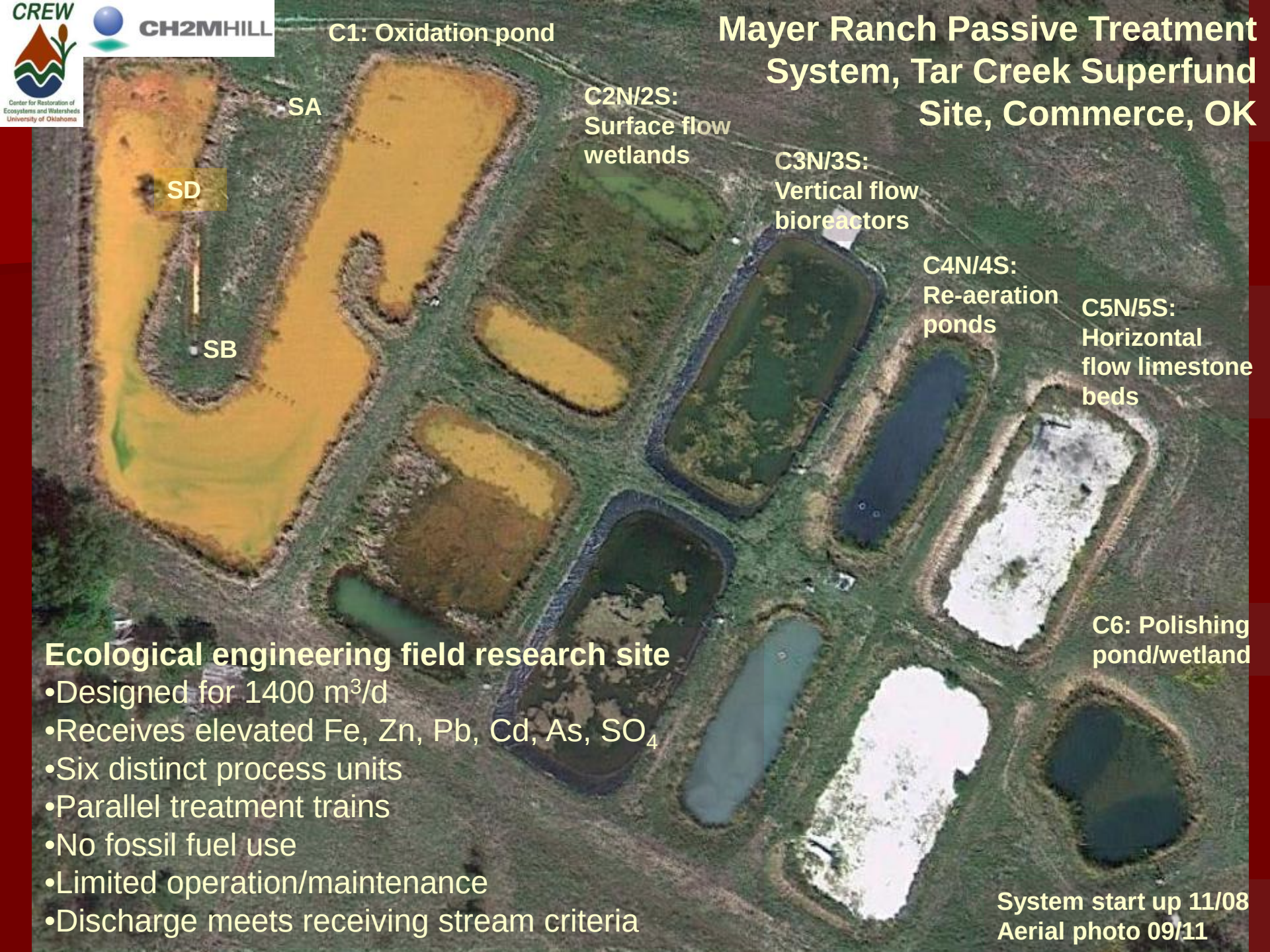
Hartshorne VFBR Re-aeration

- Pennington EKBS-15 Solar Aerator
- 15 W Solar Panel
- 14.5 v output
- 12 v marine battery
- PEC 45 pump (0.6 amp-hour)
- Single rubber diaphragm bubble diffuser
- Cost: $2300

Mayer Ranch Study Site

- Abandoned Tri-State Lead-Zinc Mining District
- Constructed 2008
  - 10 process units
  - Parallel trains
- Design flow: 1000 LPM
- USEPA and USGS funding




CREW
Center for Restoration of Ecosystems and Watersheds
University of Oklahoma
CH2MHILL
Mayer Ranch Passive Treatment System, Tar Creek Superfund Site, Commerce, OK
C1: Oxidation pond
SA
SD
SB
C2N/2S: Surface flow wetlands
C3N/3S: Vertical flow bioreactors
C4N/4S: Re-aeration ponds
C5N/5S: Horizontal flow limestone beds
C6: Polishing pond/wetland
Ecological engineering field research site
•Designed for 1400 m3/d
•Receives elevated Fe, Zn, Pb, Cd, As, SO4
•Six distinct process units
•Parallel treatment trains
•No fossil fuel use
•Limited operation/maintenance
•Discharge meets receiving stream criteria
System start up 11/08
Aerial photo 09/11

Mayer Ranch Water Quality

pH	5.95 ± 0.06
Alk. (net)	393 ±18 (29) mg/L
Fe	192 ± 3 mg/L
Zn	11 ± 0.07 mg/L
Ni	0.97 ± 0.02 mg/L
Cd	17 ± 4 μg/L
Pb	60 ± 13 μg/L
As	64 ± 2 μg/L
SO_4^{-2}	2239 ± 26 mg/L

Mayer Ranch VFBR Re-aeration

- North - windmill aeration
- South - solar aeration
- Allows side-by-side comparison

Mayer Ranch VFBR Re-aeration: Windmill

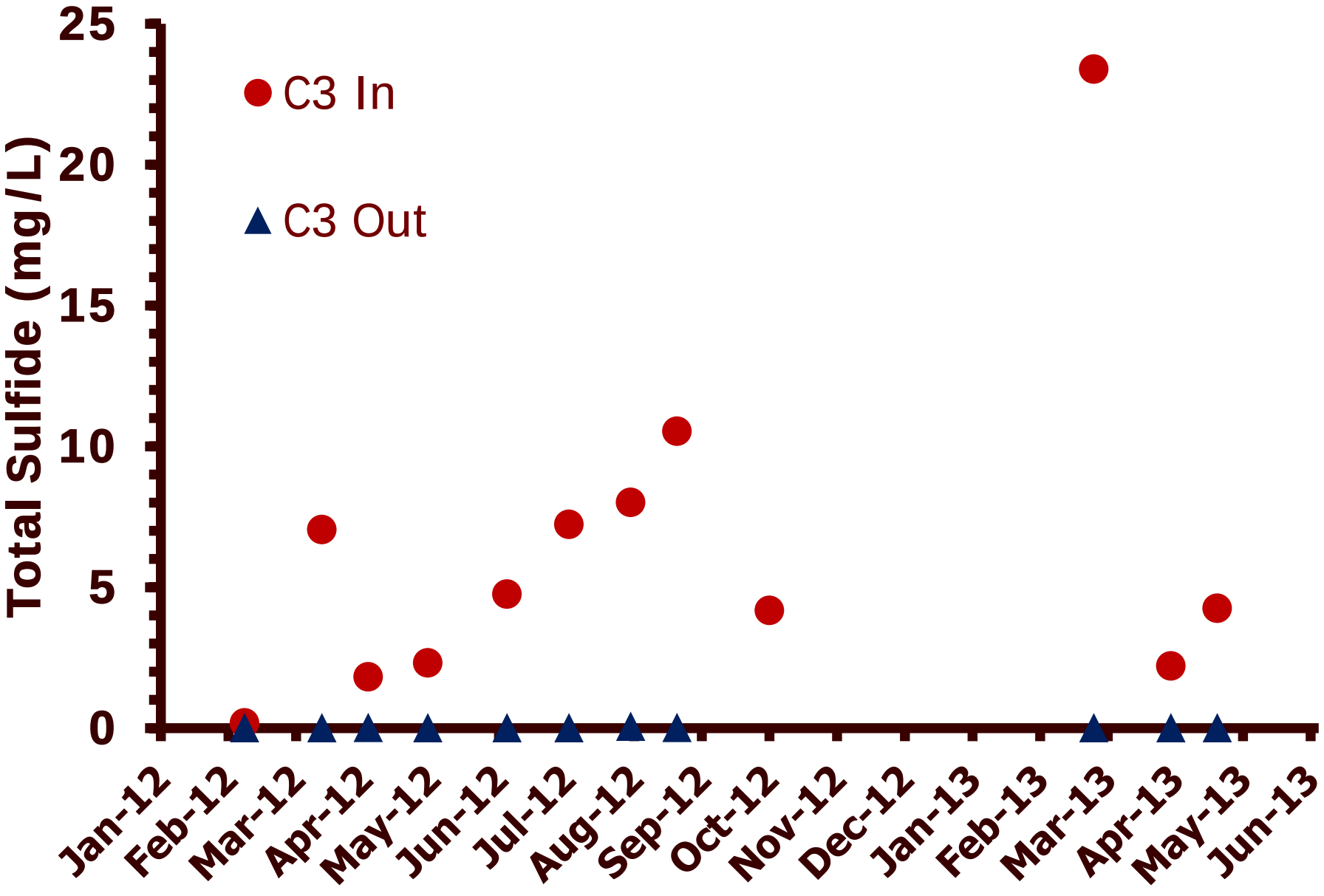
- Superior Windmill Aeration System
- 20-foot tower
- 70” upwind turbine
- Jet Stream direct drive compressor
- 30 psi produced
- 90 cfh at 9 mph
- Operates at 3.9 mph
- Dual rubber diaphragm bubble diffusers
- Cost: $2100

Mayer Ranch VFBR Re-aeration: Solar panel

- Keeton Industries SB-1 Solear Lake Bed Aeration System
- 120 W Solar panel
- High volume compressor
- 30-amp charge control center
- 210 amp-hour deep cycle solar battery
- 12/24 volt smart box convertor
- Dual rubber diaphragm bubble diffusers
- Cost: $5200


Performance

Hartshorne Sulfide



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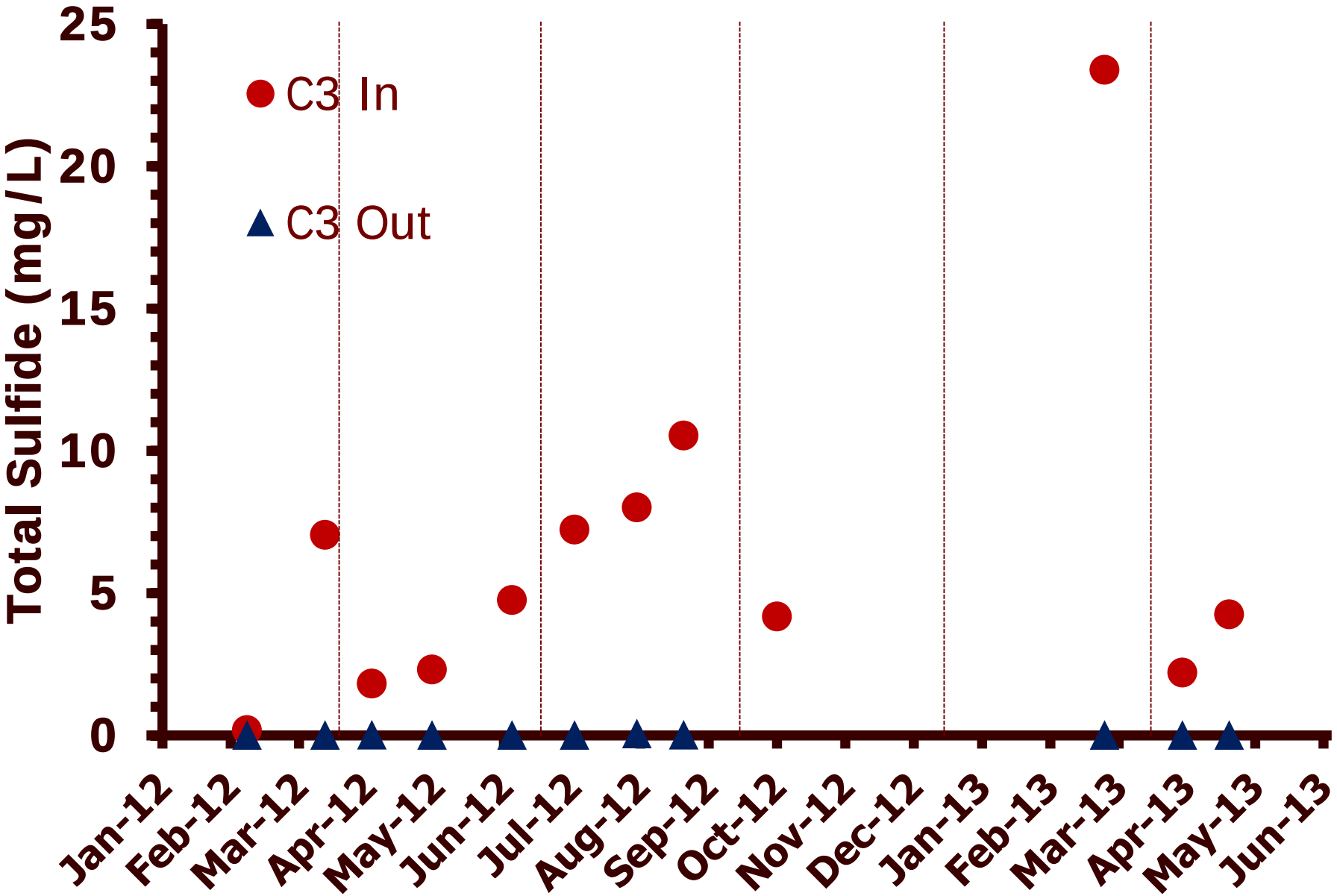

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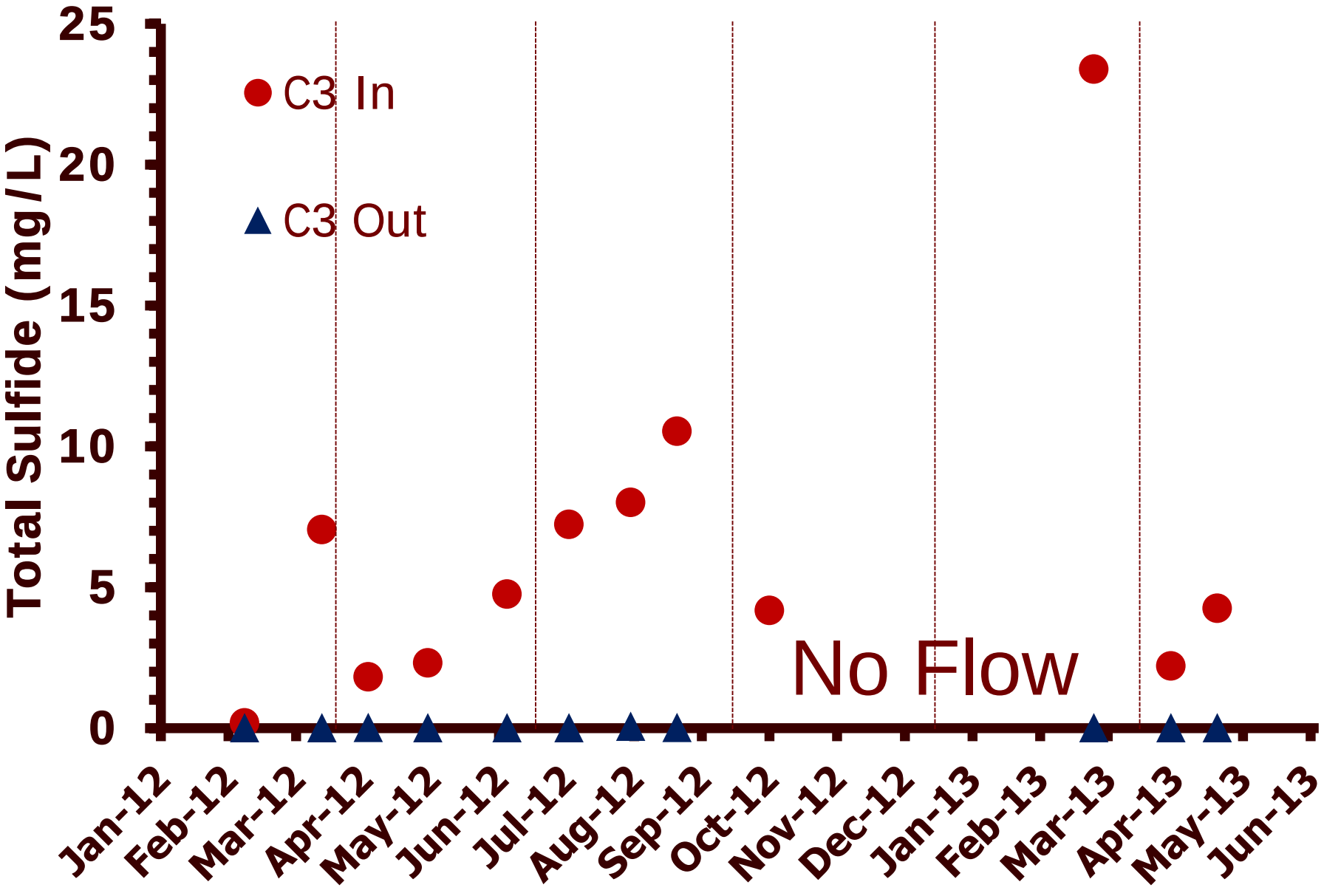
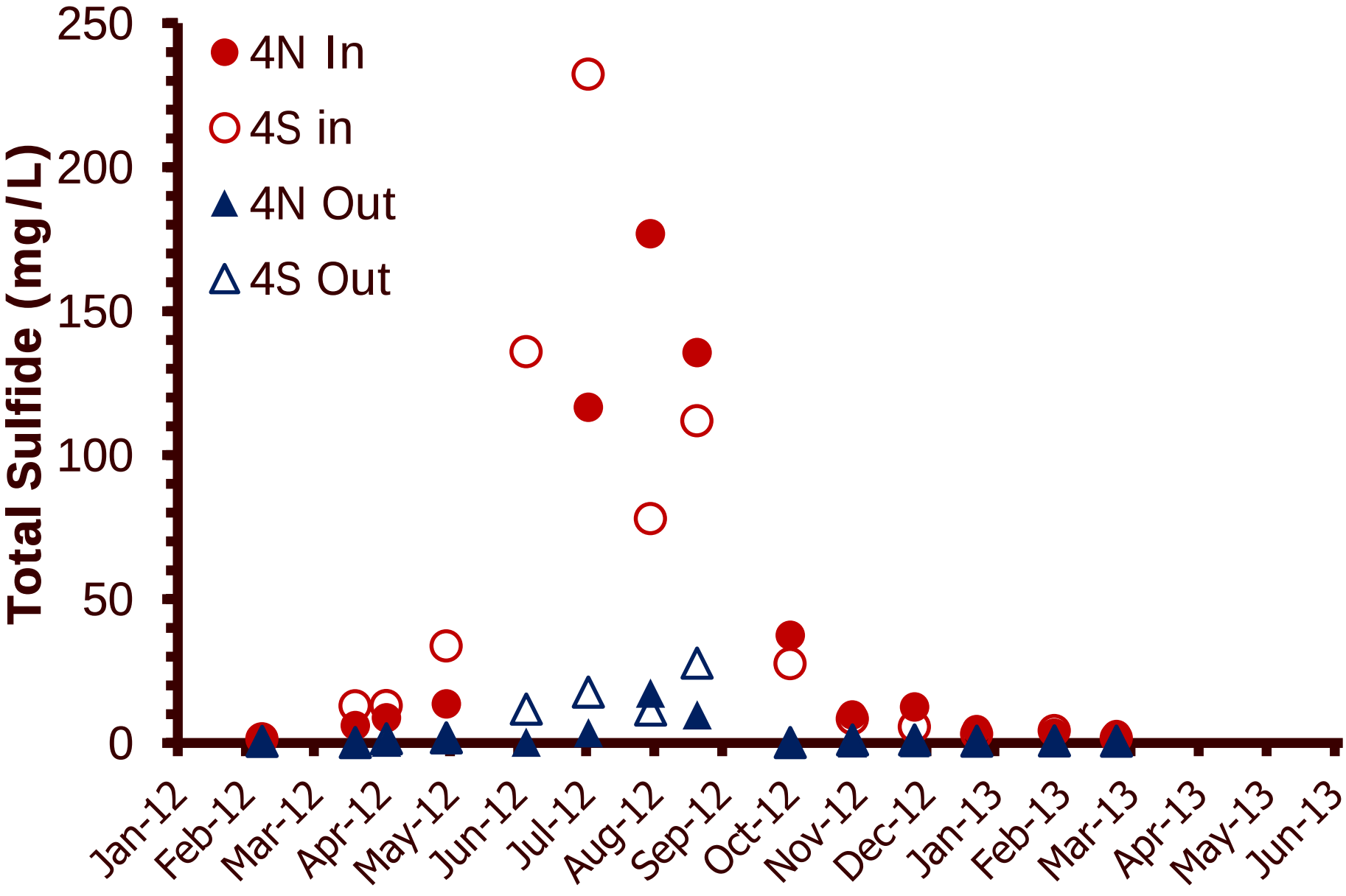
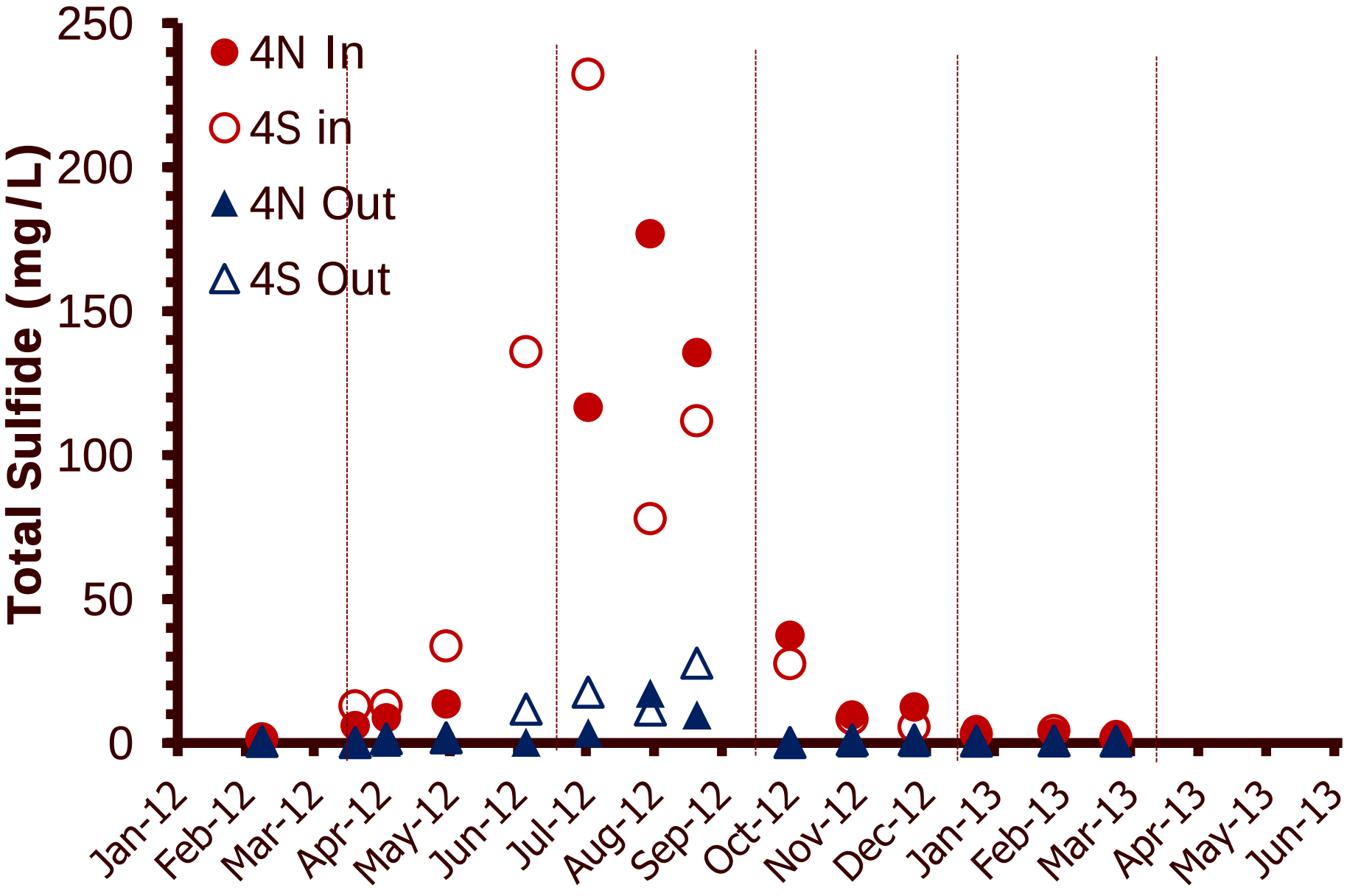


Mayer Ranch Sulfide



Mayer Ranch Sulfide



Mayer Ranch Dissolved Oxygen

Cells 4N & 4S Re-Aeration Ponds

Wind: 6.4 g m^{-3} day^{-1}

Solar: 5.6 g m^{-3} day^{-1}

DO % saturation

110
100
90
80
70
60
50
40
30
20
10
0

Source
C2N IN
C2S IN
C3N IN
C3S IN
C4N IN
C4S IN
C5N IN
C5S IN
C5N OUT
C5S OUT
C6 OUT

Nutrients and Oxygen Demand

- Nutrient concentrations elevated in VFBR effluents
  - Nitrogen and phosphorus show seasonality
  - Blue-green algae blooms documented in final units
- Biochemical and chemical oxygen demand levels not of substantial concern

Conclusions

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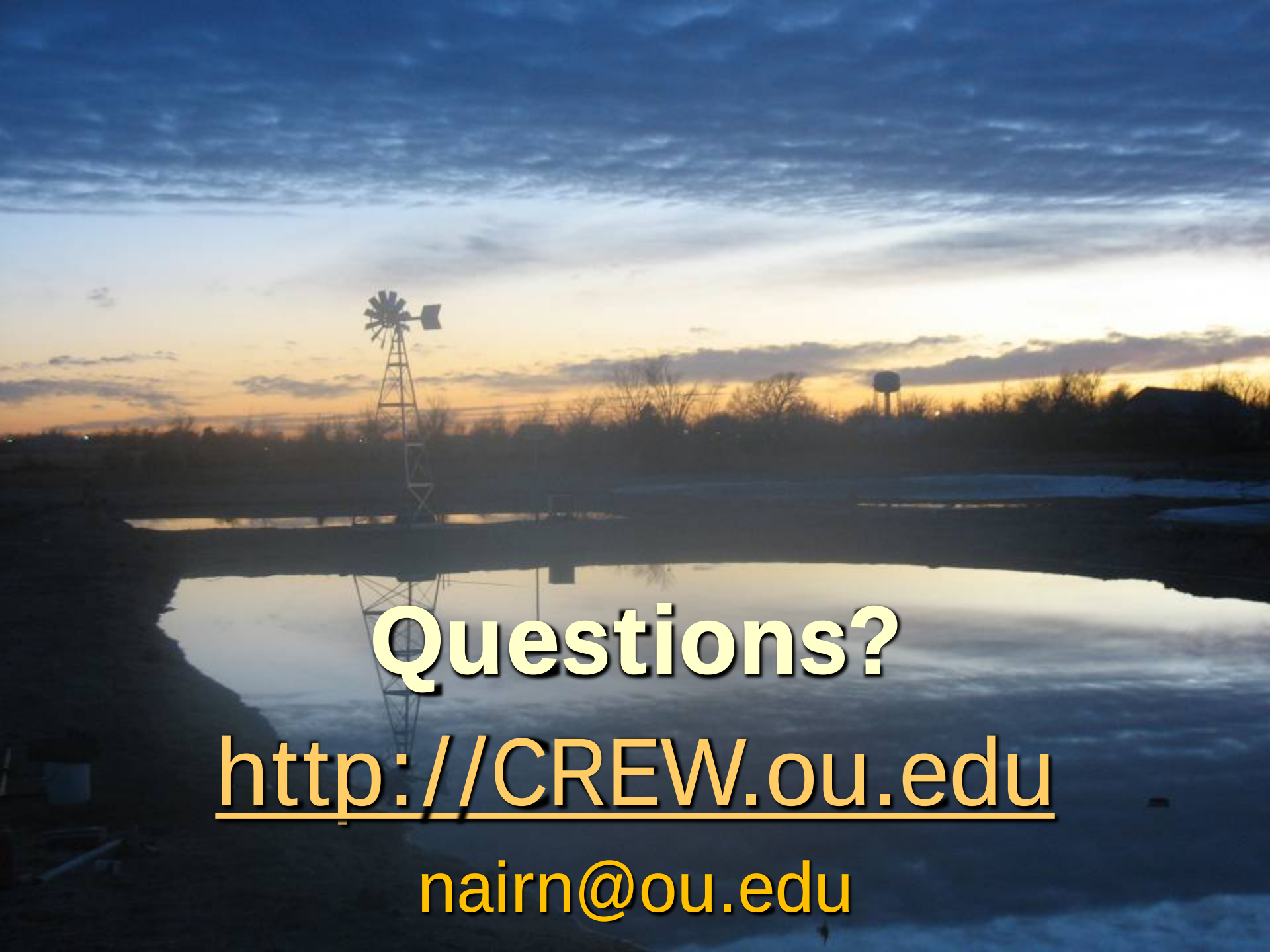
- Non-mine drainage water quality constituents should be included in monitoring schemes and system performance evaluations
- Off-the-grid solar- and wind-powered aeration systems can effectively address these constituents

Conclusions

- Comparative evaluation of performance is ongoing
  - Direct drive wind-powered re-aeration impacted by time of day and time of year
  - Solar-powered units can operate 20 hours/day and store energy in battery for operation on cloudy days
- Operation and maintenance appear to be minimal


Questions?
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