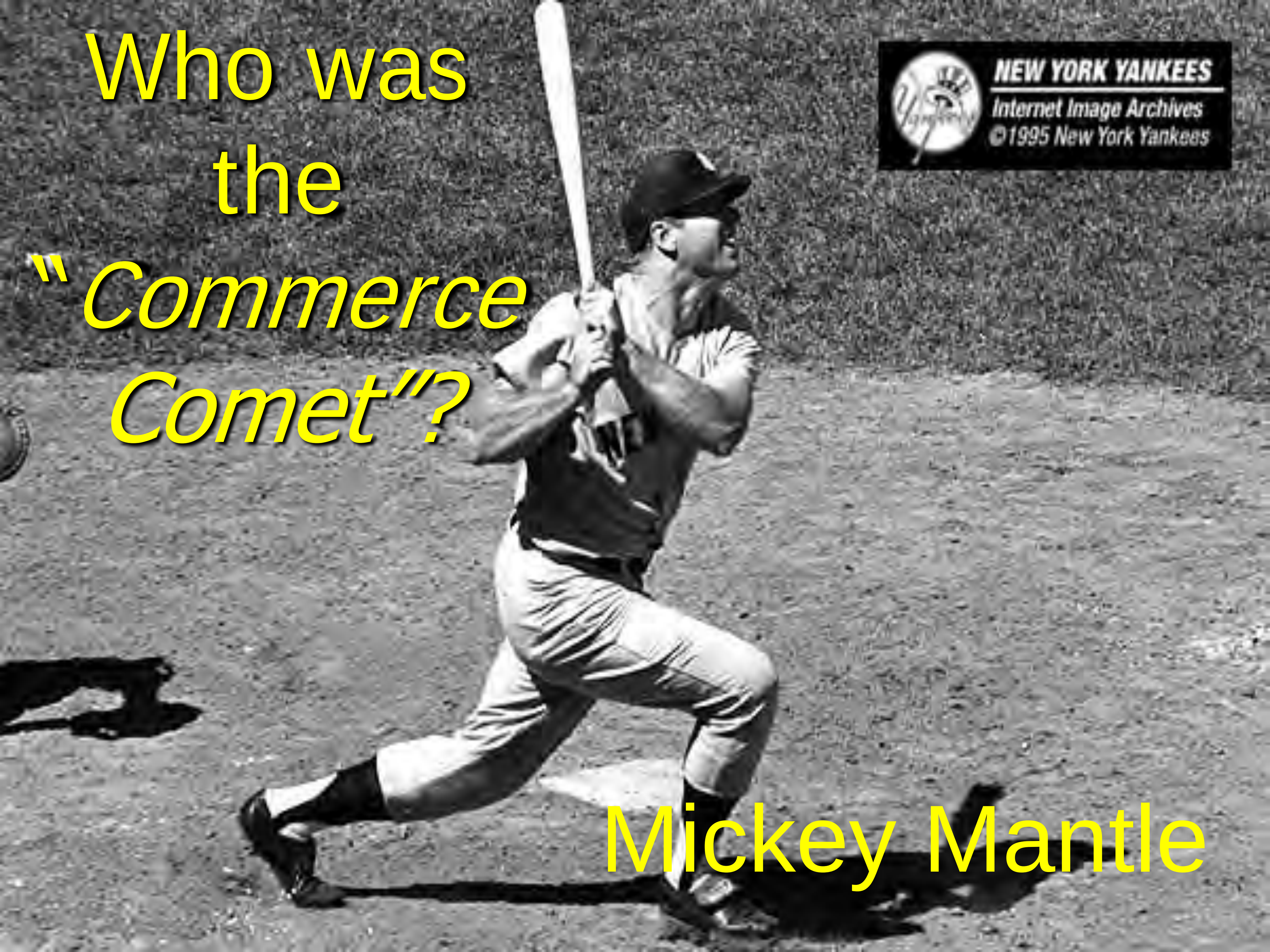
Reversing the Irreversible? Passive Treatment of Mine Waters at the Tar Creek Superfund Site

R.W. Nairn, K.A. Strevett, J.A. LaBar

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


Who was the "*Commerce Comet*"?
NEW YORK YANKEES
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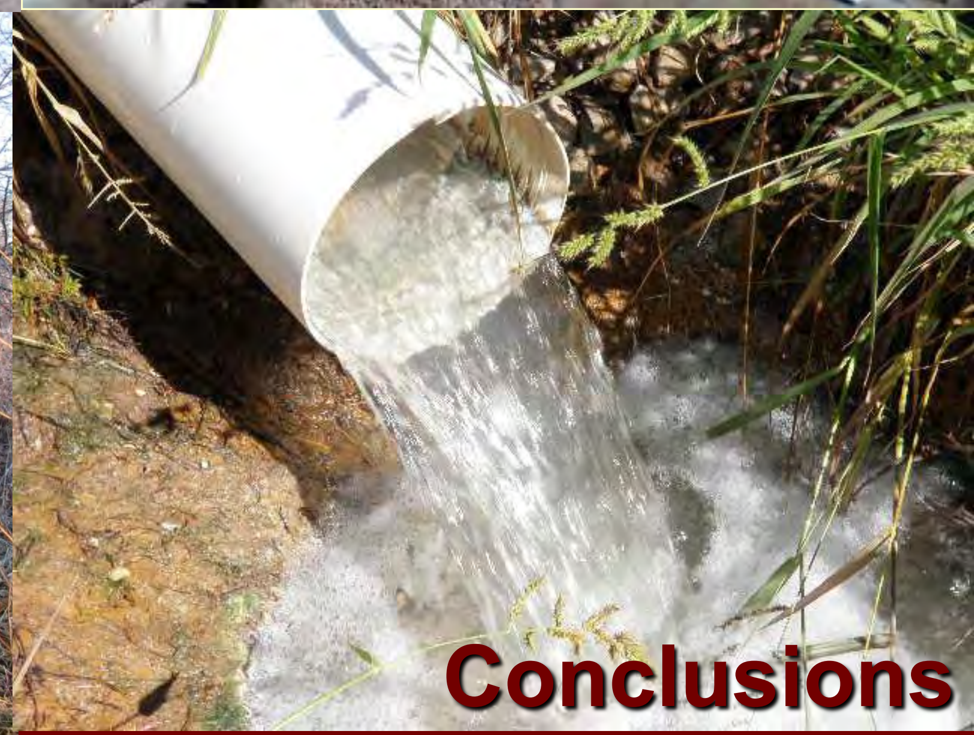
Mickey Mantle


Study Site/Problem

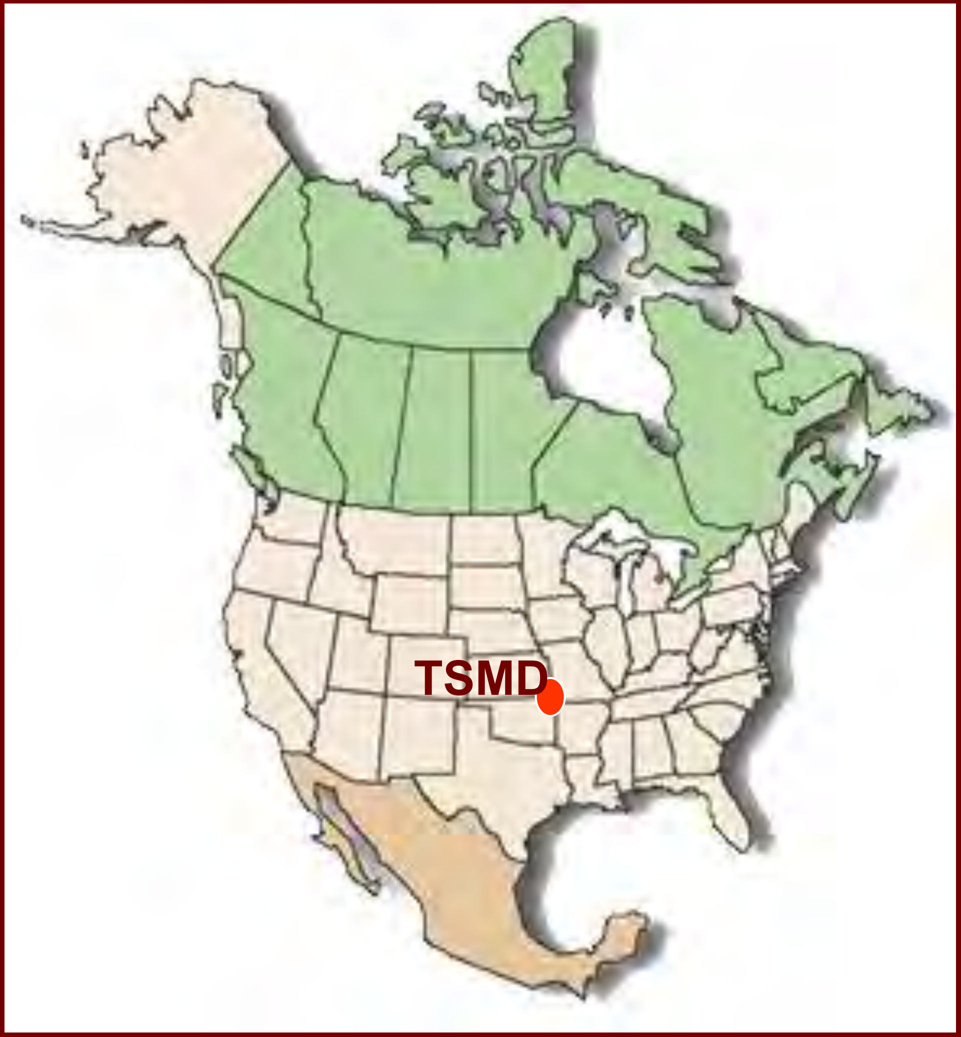
Design/Construction

System Evaluation

Conclusions

Study Site/Problem

Tri-State Lead-Zinc Mining District

- >3000 km^2 mining area ~1838-1971
- Mississippi Valley Type deposits
  - – PbS and ZnS
- 2º concentrations
  - – FeS_2, $CuFeS_2$, Cu_3AsS_4, and $BaSO_4$
- Cherty limestone host rock



Tri-State Lead-Zinc Mining District

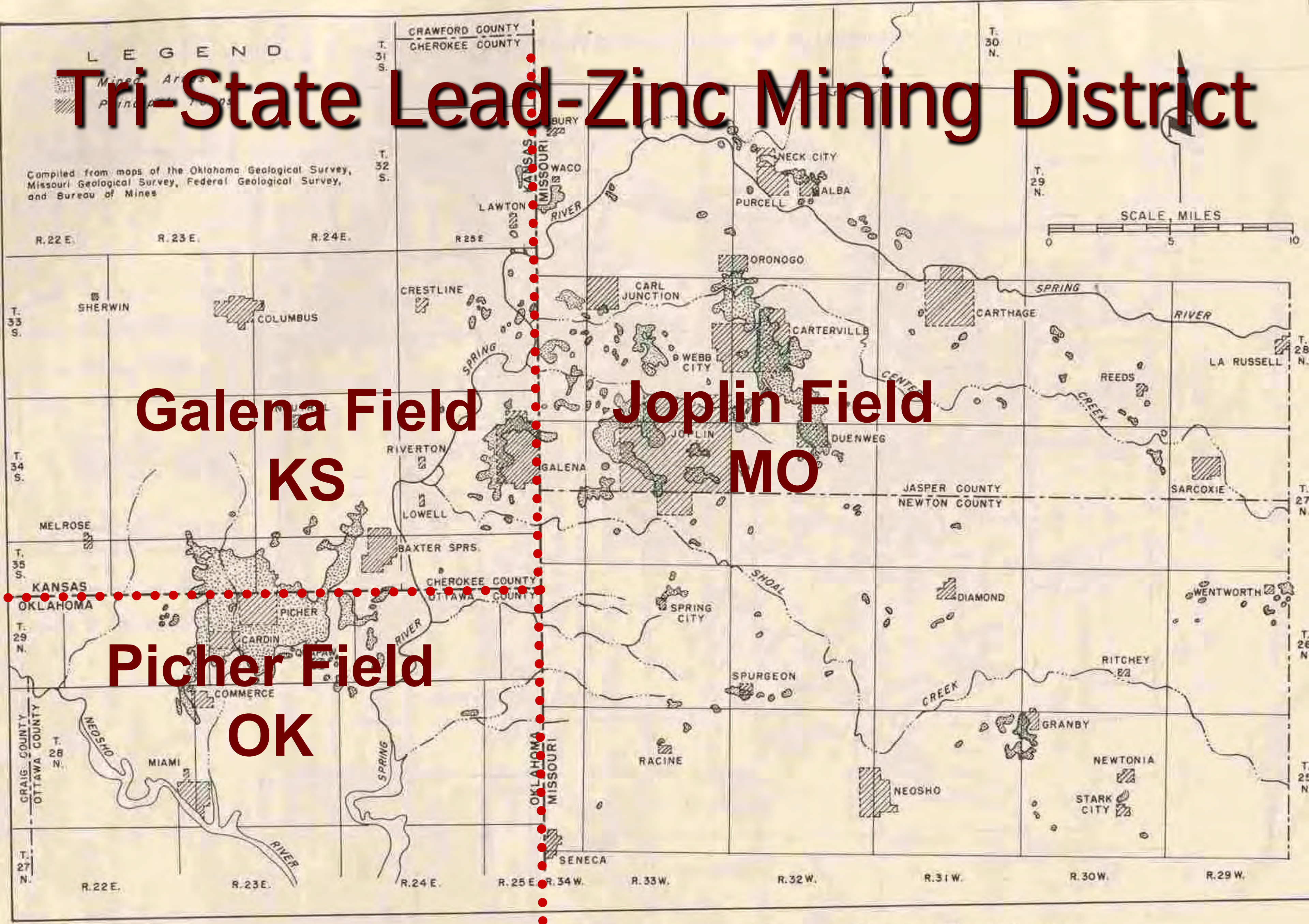
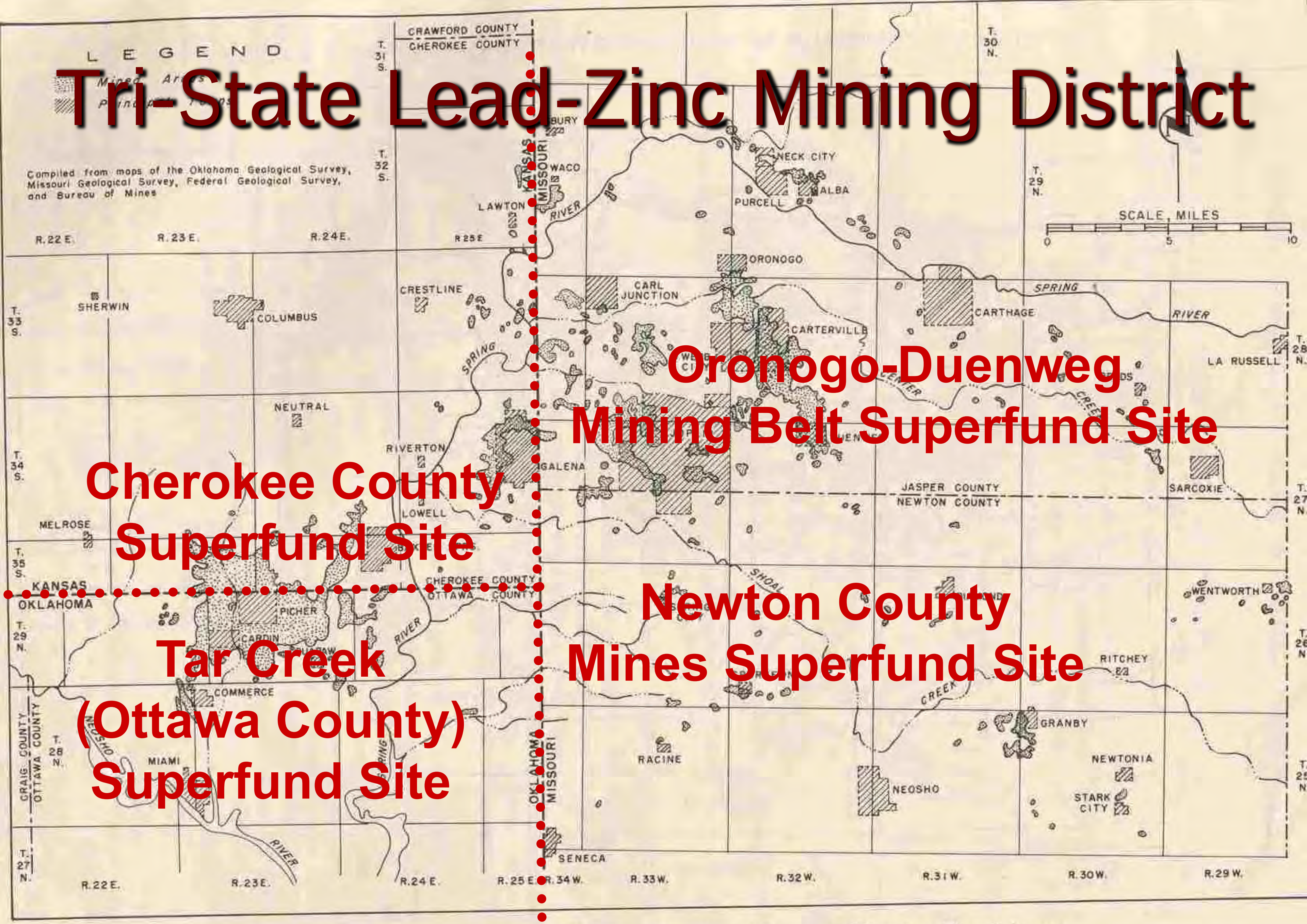


FIGURE 1. - Principal Part of Tri-State Zinc-Lead District, Showing Mined Areas.

Tri-State Lead-Zinc Mining District



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Tar Creek Superfund Site

- National Priorities List (1983)
- 105 km^2, includes 6 communities
- Elevated Fe, Zn, Cd, Pb in water, chat, soils and biota
- Eight Native American Tribes

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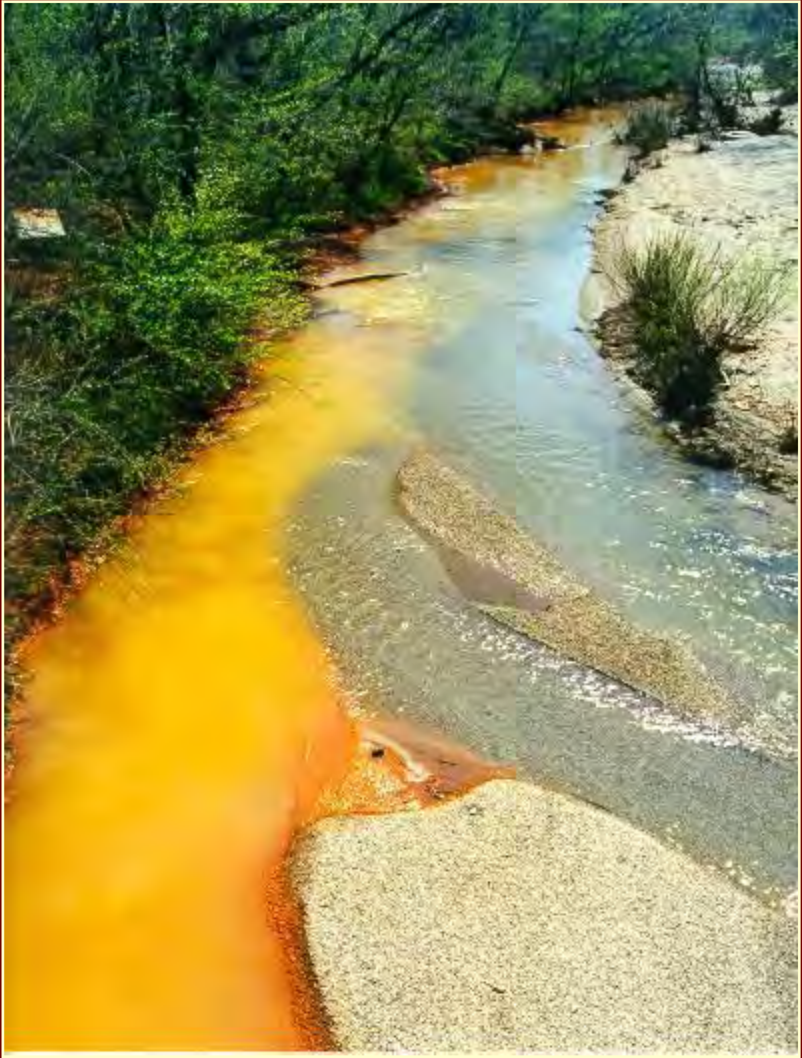


Tar Creek Surface and Ground Water Decision

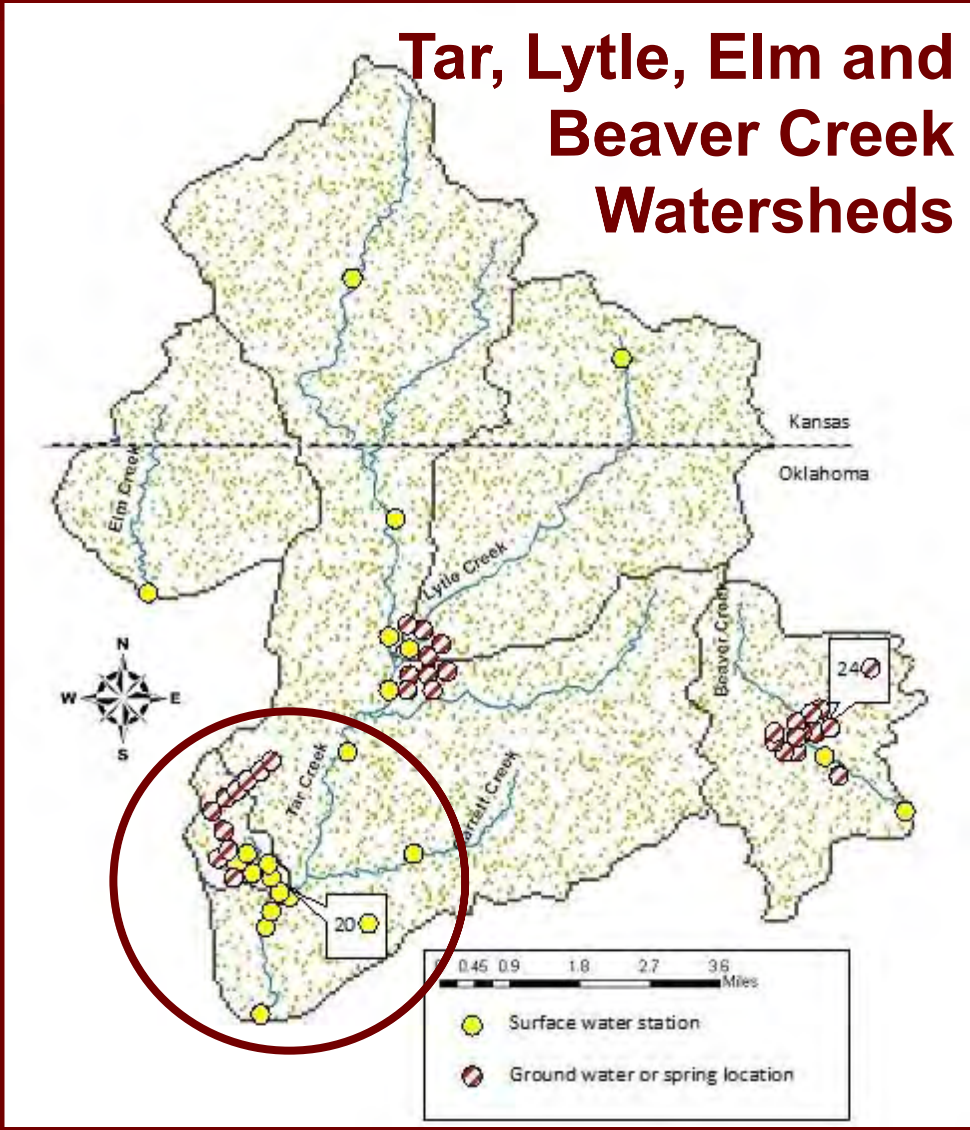
- USEPA (1984) concluded that:

  *"impacts to (surface waters) are due to **irreversible man-made damages** resulting from past mining operations at the site"*

- Waters still do not meet even the reduced designated beneficial uses (1994, 2000, 2005, 2010)

Meeting the Challenge

- Comprehensive watershed monitoring
- Significant artesian discharges
  - Net alkaline
  - Fe, Zn, Pb, Cd, As
- Focus on *point of discharge* treatment



Mayer Ranch Study Site

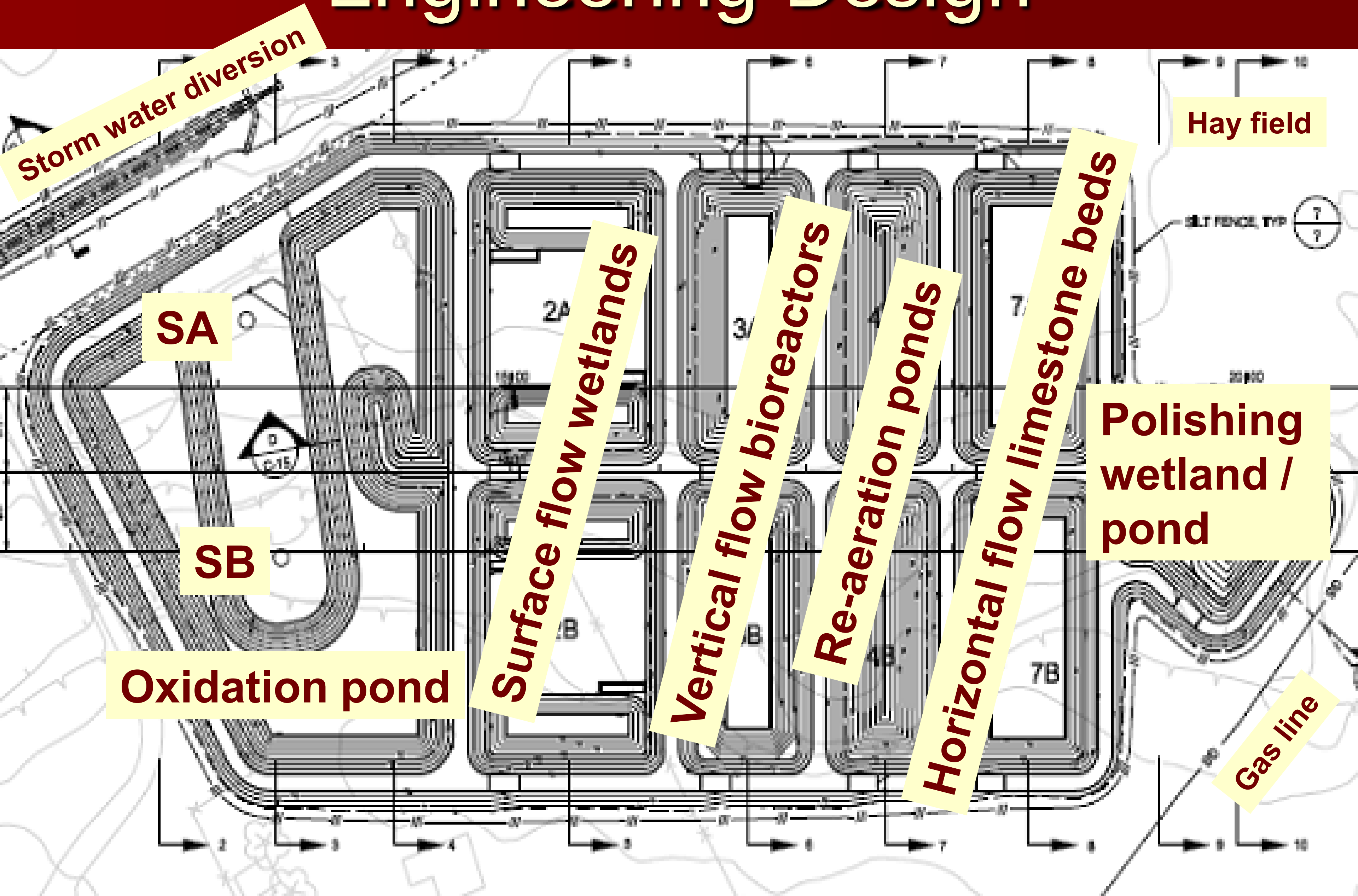
- Artesian discharges from abandoned boreholes
- 570-950 L/min
- Represent ~ 20% contaminant mass load in watershed

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


Design/Construction

Engineering Design



Passive Treatment System Construction

- Began sampling water quality and quantity in fall 1998
- Construction July-November 2008
- More than 50 graduate and undergraduate students involved in research at this site
- Students from at least 12 institutions

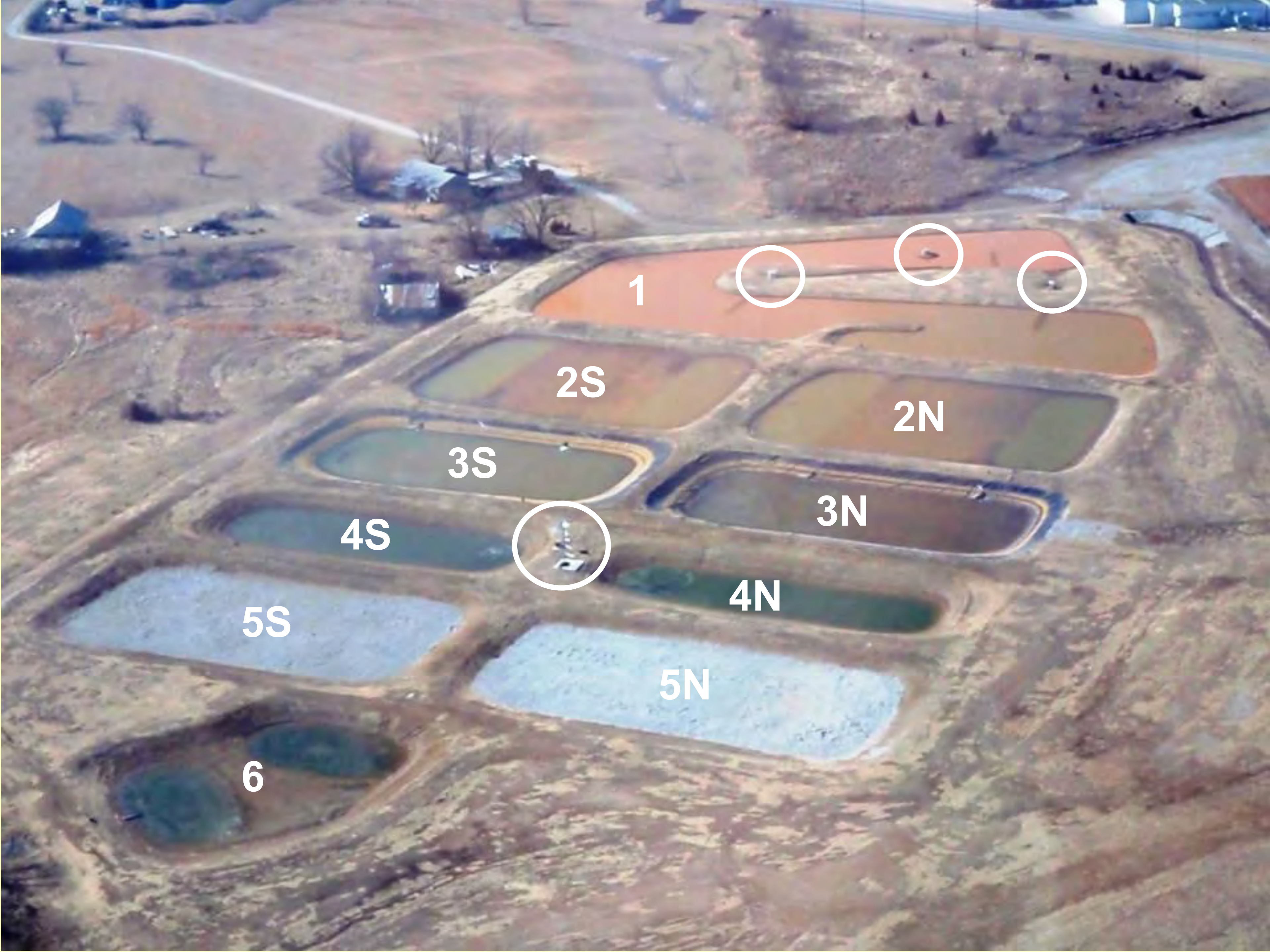
K&J Portable Toilets


NATIONAL
480
BOART
LONGYEAR
BOART LONGYEAR
480


C EP6025

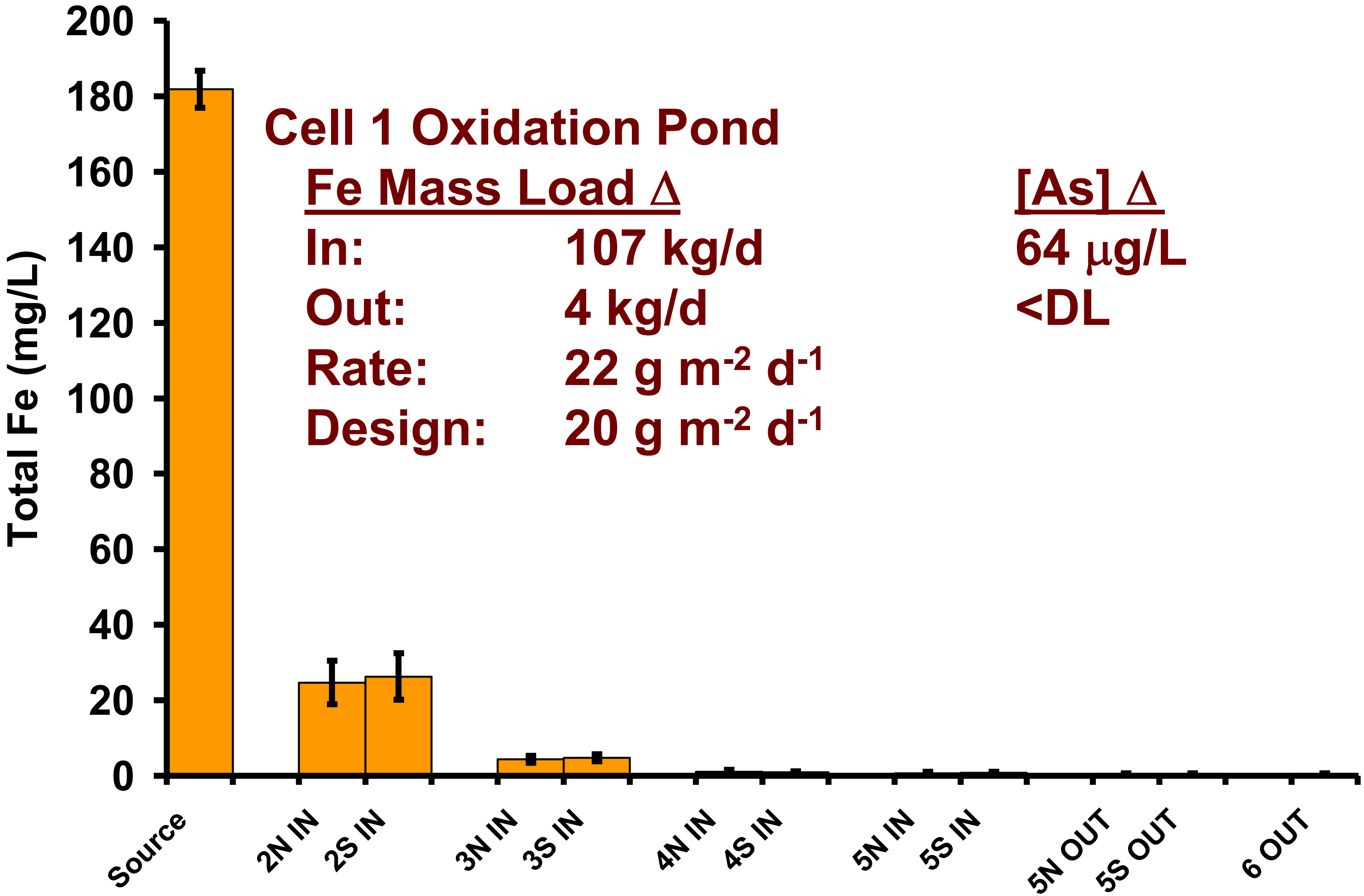

Seep D


45% hard wood chips
10% manufactured limestone sand
45% spent mushroom substrate


1
2S
2N
3S
3N
4S
4N
5S
5N
6

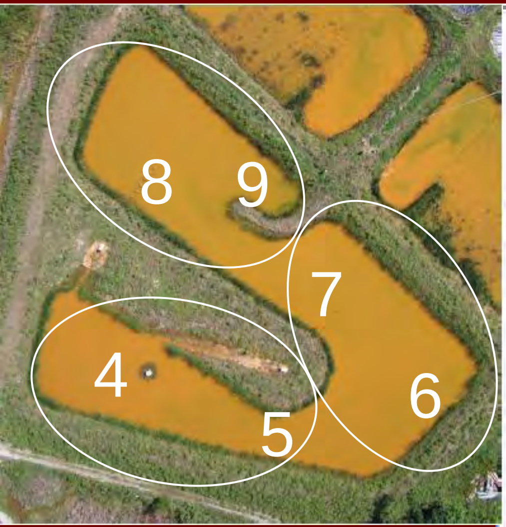

System Evaluation

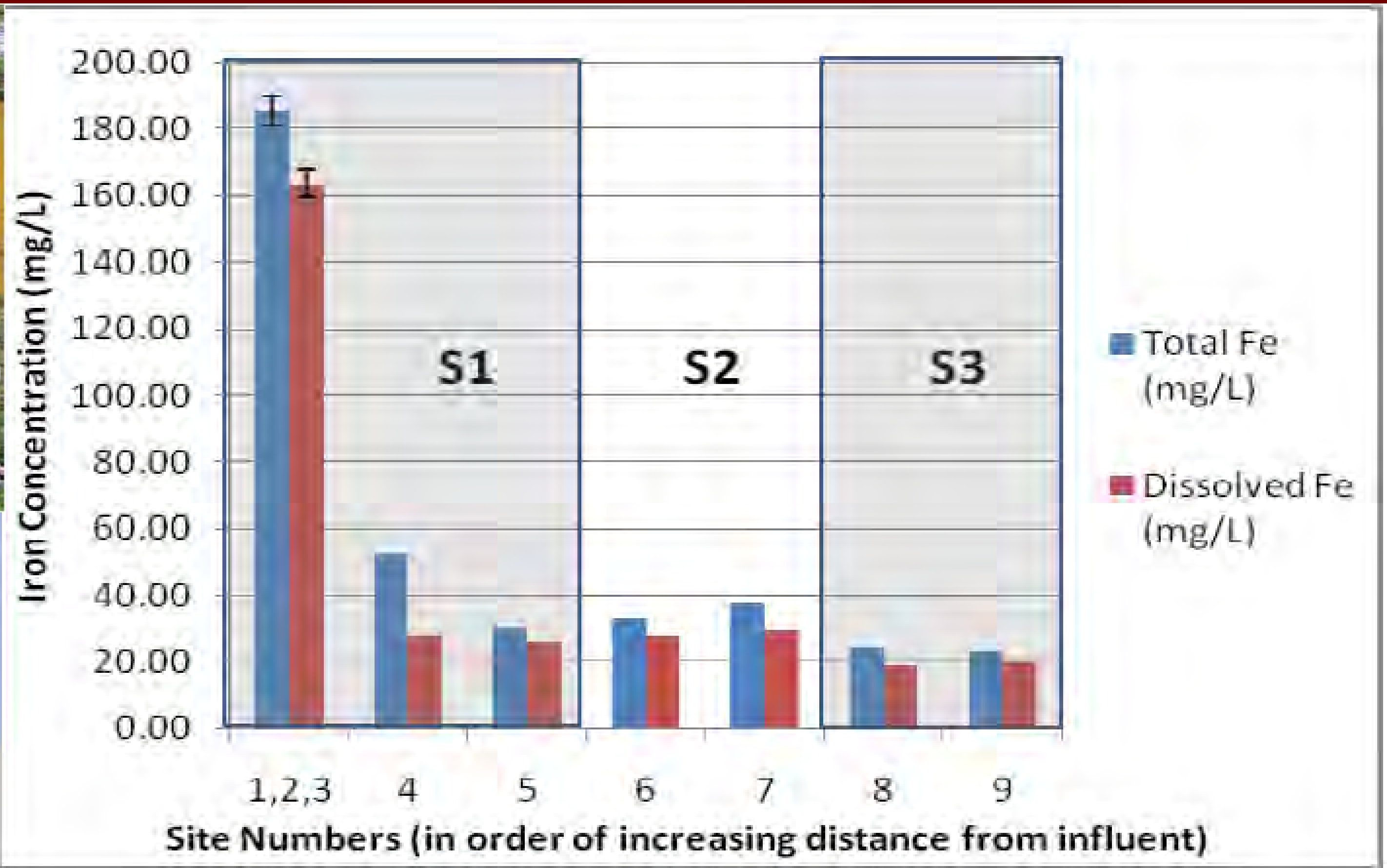
Iron Removal



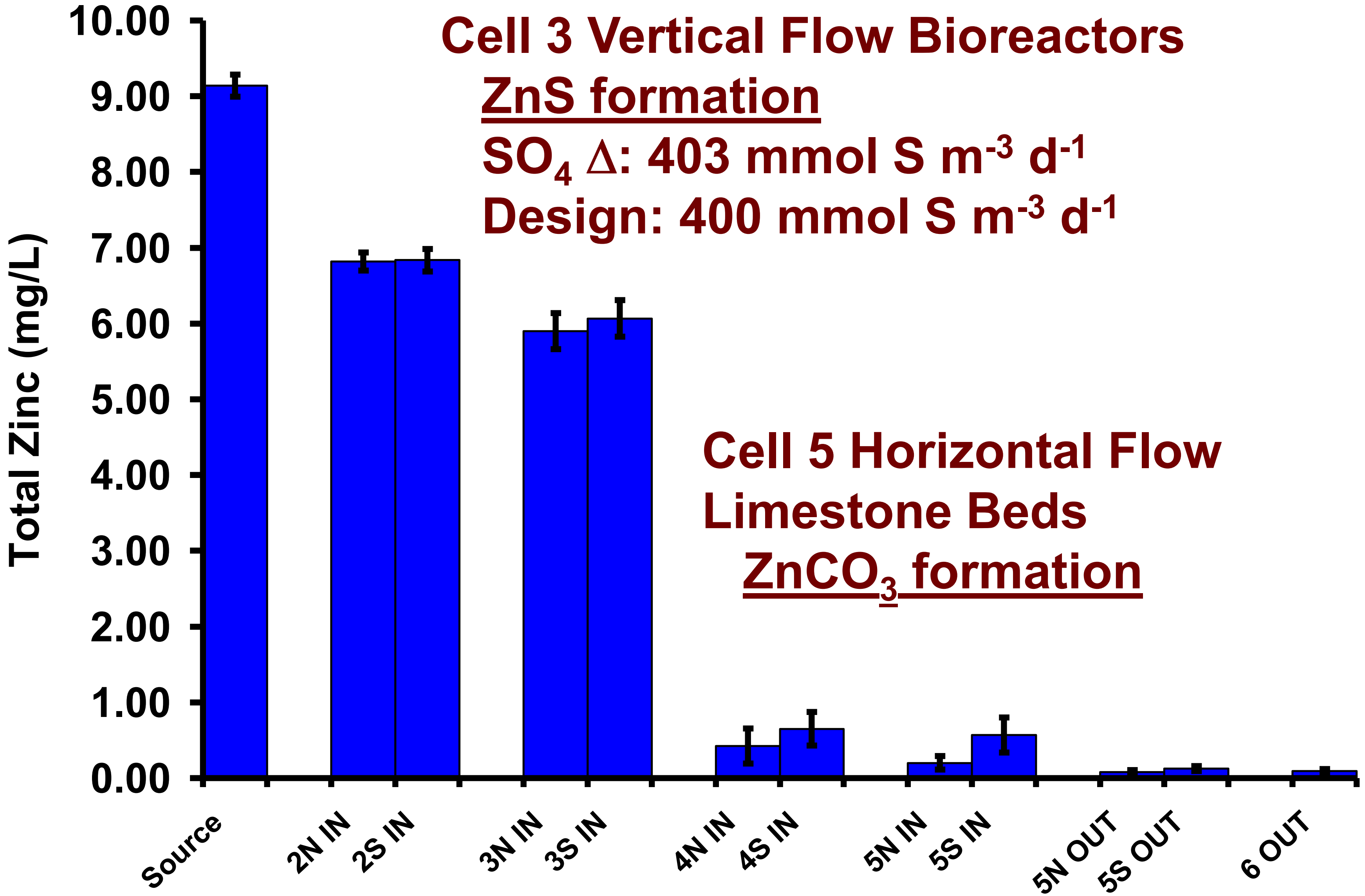
Cell 1 Iron Removal (Oxenford et al 2010)

- Rapid initial oxidation, hydrolysis, settling
- Oxidation limiting overall removal



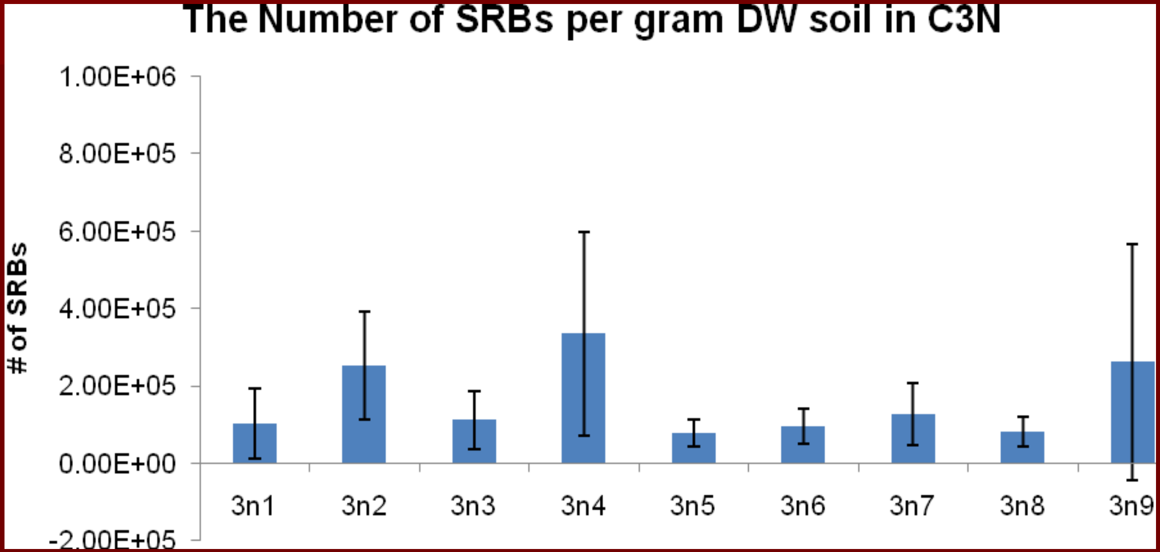


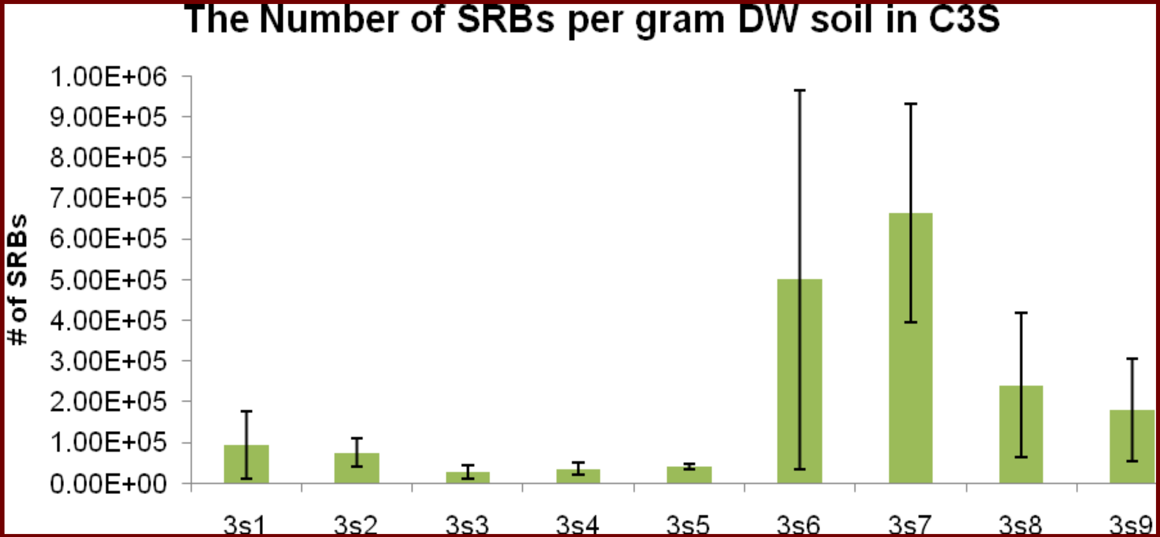
Zinc Removal



Cells 3N/3S Sulfate Reduction
(Choi et al 2010)

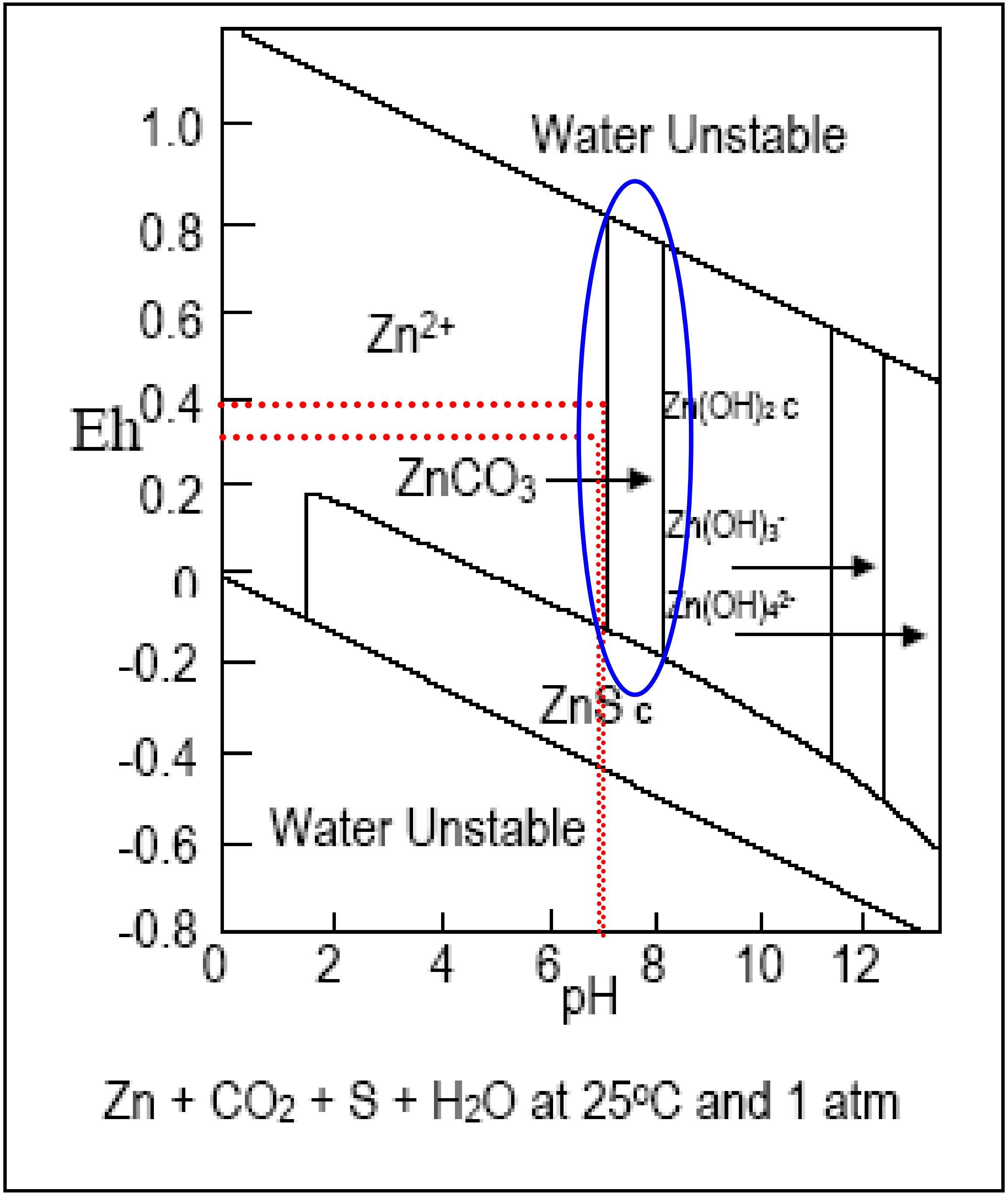
- 27 samples/cell
- DGGE & QPCR
- [DNA]
  - Differ ($p<0.05$) from original
- [SRB]
  - No difference between cells
  - SRB 0.1% of all organisms





$ZnCO_3$ Formation

- HFLB designed for specific Eh-pH conditions
- Eh: 0.31-0.43
- pH: 6.90-7.17
- Mean dissolved Zn Δ nil



Mean Water Quality Changes

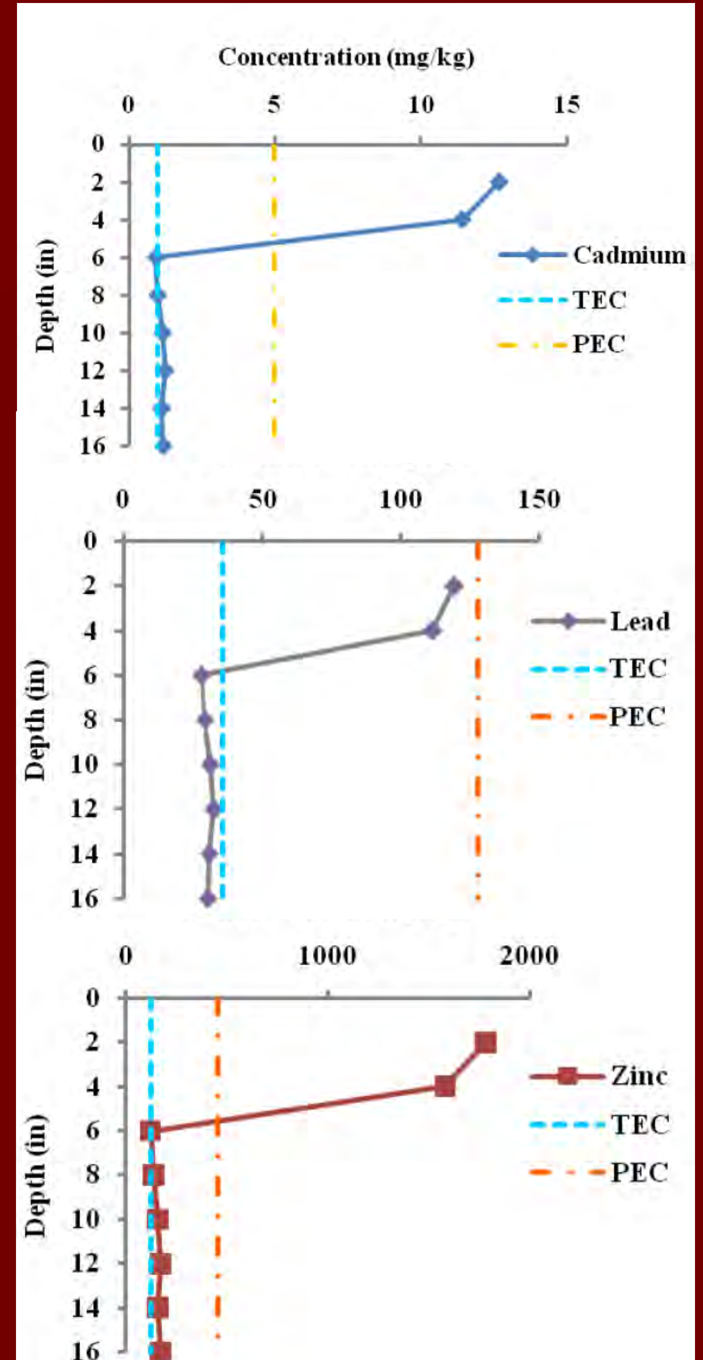
	In	Out (dissolved)
pH	5.95	7.11
Tot. Alk. (mg/L)	393	224
Net Alk. (mg/L)	29	224
Fe (mg/L)	192	0.44 (0.15)
Zn (mg/L)	11	0.45 (0.37)
Ni (mg/L)	0.97	0.16 (0.16)
Cd (μg/L)	17	<DL
Pb (μg/L)	60	<DL
As (μg/L)	64	<DL
SO_4^{-2} (mg/L)	2239	2057

On-Site Mass Retention

	Mass retained (kg/year)
Fe	57000
Zn	3300
Ni	300
Cd	5
Pb	17
As	18

Grand Lake O' the Cherokees Sediments

- Premier recreational reservoir
- Surficial sediments contaminated



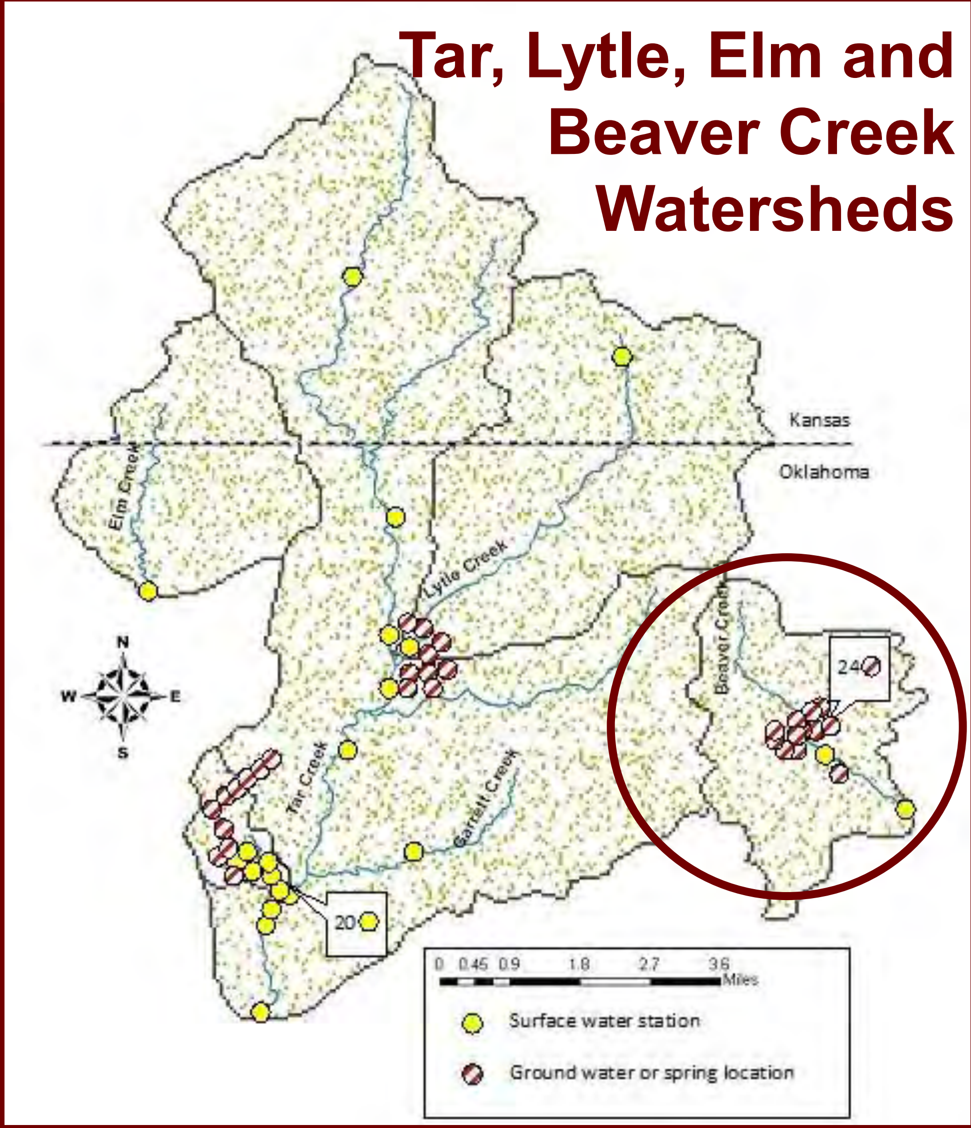
Ongoing Research at Mayer Ranch

- Oxidation, hydrolysis, settling kinetics
- Substrate pore water chemistry
- Microbial community activity
- Ecological structure & function
- Hydrologic tracer studies
- Receiving stream biogeochemistry, fish and macroinvertebrate communities
- Accumulated solids/substrates beneficial reuse
- Evaluation of potential for bioaccumulation

Applicability Elsewhere

- Beaver Creek
- Significant artesian discharges
  - Net alkaline
  - Fe, Zn, Pb, Cd, As
- Culturally significant water body for the Quapaw Tribe

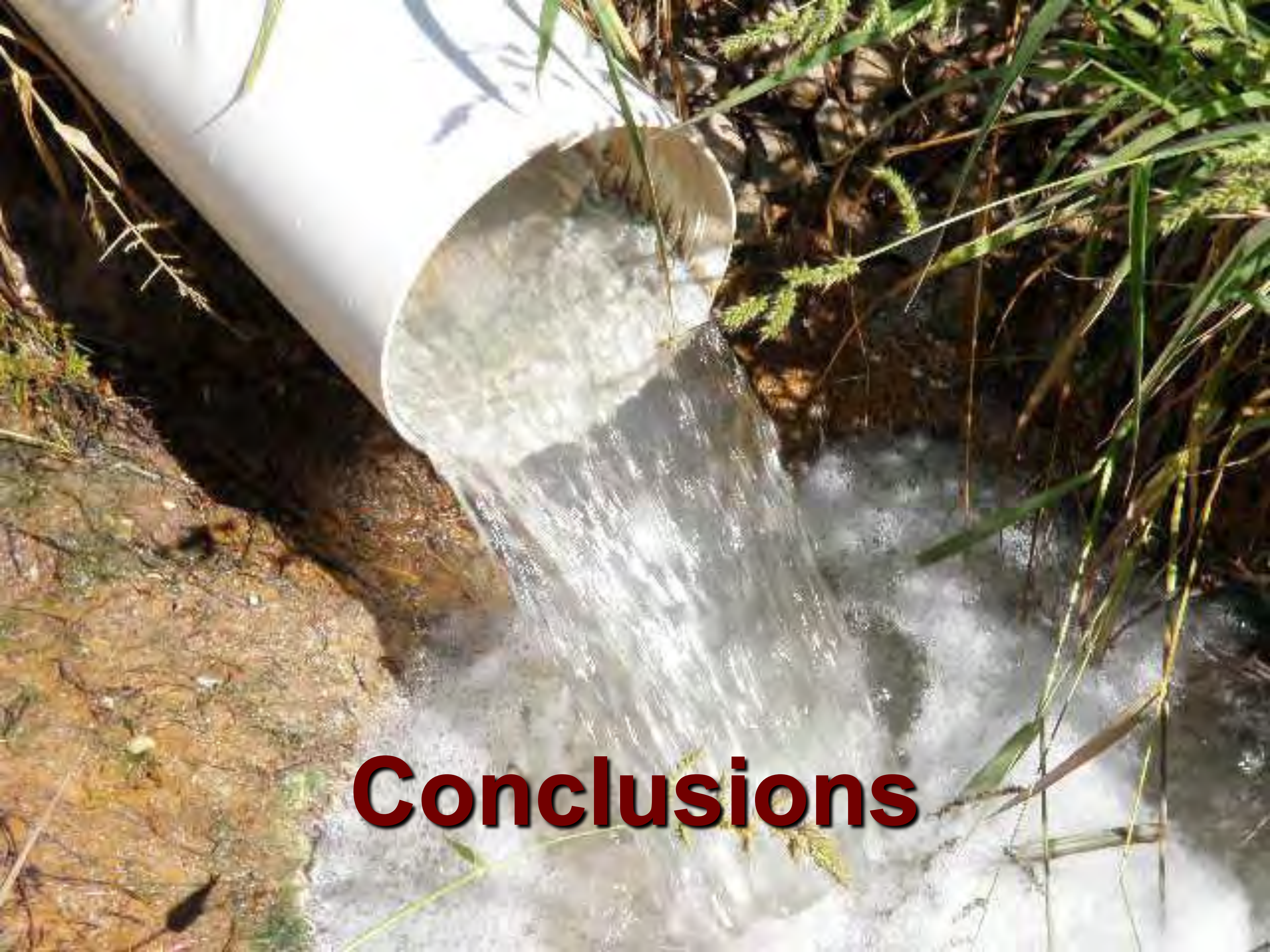
Tar, Lytle, Elm and Beaver Creek Watersheds



Applicability Elsewhere

- Potosi, Bolivia
- Head of the Spanish Silver Train
  - – 500 years of mining
  - – 40,000 tonnes Ag produced
- High desert environment (>14,000 feet)
- Mine waters used for irrigation

"I am rich Potosí, treasure of the world, the king of all mountains, and envy of all kings"



Conclusions

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- Successful implementation of first full-scale mine water treatment system in the Tri-State Mining District
- System represents state-of-the-art ecological engineering field research site
- Technology transferable to other mine water discharges

Concluion

- Tar Creek Superfund Site
  - Estimated ~50 year remedial timeline
  - Total remedial costs ~$330M
- Tri-State Mining District
  - Four Superfund sites in three states
  - Total remedial costs $400M+
- *Waters "irreversibly damaged" not addressed*

Concluion

- Mayer Ranch passive treatment system
  - Capital costs: $1.2M
  - Total costs: ~ $4M
  - Design life: 25 years ($20K/yr O&M)
- Comprehensive watershed-scale passive treatment
  - ~$10-20M
  - ~2-4% of total estimated remedial costs

Acknowledgements

- George and Maxine Mayer and family
- Red Pritchard and family
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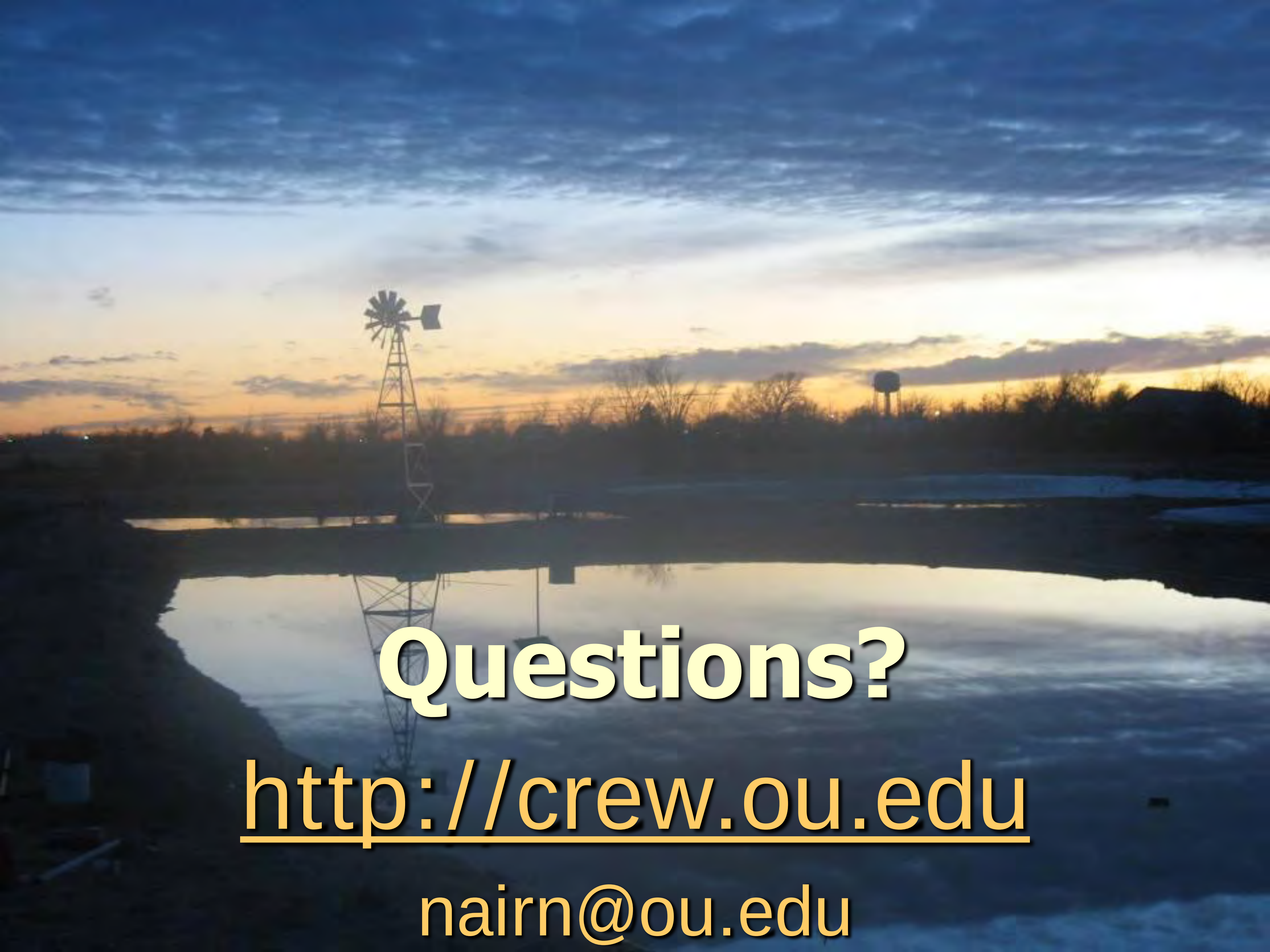
- Quapaw Tribe of Oklahoma
- ODEQ Land Protection Division
- CH2M-Hill team and subcontractors
- USEPA Water Division (Agreement X7-97682001-0)
- USGS Toxic Substances Hydrology Program (Agreement DOI-USG 04HQAG0131)



Questions?

http://crew.ou.edu

nairn@ou.edu