



West Virginia Mine Drainage Task Force Symposium &
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Nature-Based Solutions for Mine Water Challenges: Linking Mining Reclamation, Environmental Remediation, Ecological Restoration, and Sustainable Resource Extraction

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GALLOGLY COLLEGE OF ENGINEERING
SCHOOL OF CIVIL ENGINEERING
AND ENVIRONMENTAL SCIENCE
The UNIVERSITY of OKLAHOMA



The land on which the University of Oklahoma resides was the traditional home of the “Hasinai” Caddo Nation and “Kirikir?i:s” Wichita and Affiliated Tribes and served as a hunting ground, trade exchange point, and migration route for the Apache, Comanche, Kiowa and Osage Nations.

Today, 39 Nations dwell in the state of Oklahoma as a result of settler and colonial policies.

The University recognizes the historical connection our university has with Indigenous communities We acknowledge, honor and respect the diverse Indigenous peoples connected to this land. We fully recognize, support and advocate for the sovereign rights of all of Oklahoma’s 39 Tribal Nations.

The Wedding at Cana (Paolo Veronese, 1563) The Louvre, Paris



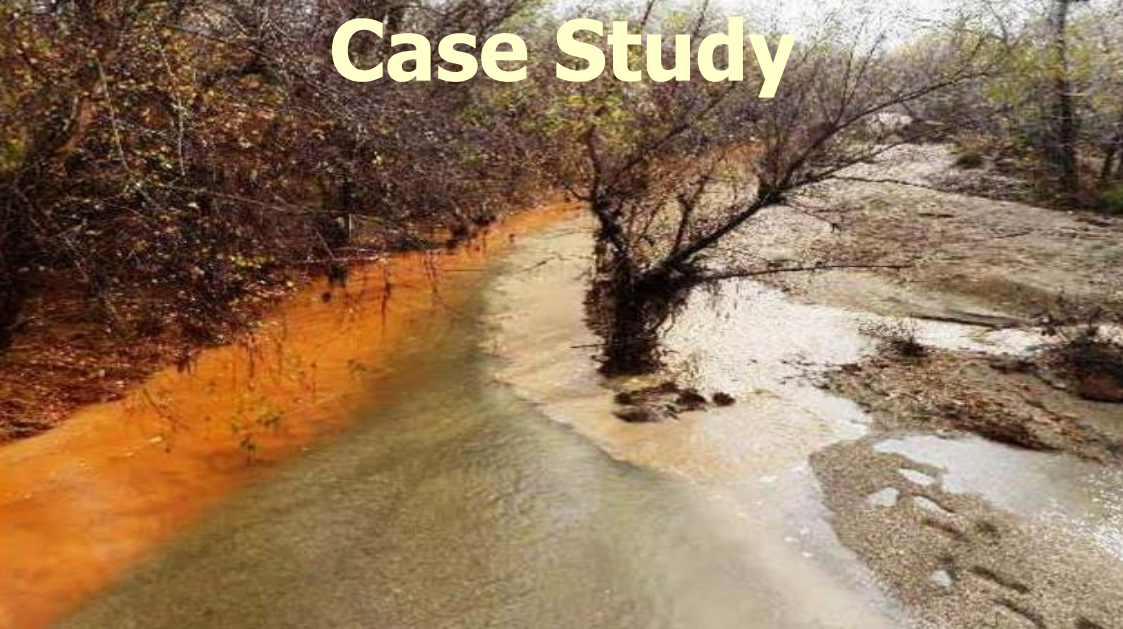
A Holistic Perspective



Mining Applications



Case Study



Conclusions





A Holistic Perspective

Mayer Ranch passive treatment system outflow
Tar Creek Superfund Site, Oklahoma



**Mining
Reclamation**

*Recovery of mined lands
and waters to a regulatory
approved post-mining use*

*Actions taken to address
release of hazardous
materials likely affecting
human health and the
environment*



**Mining
Reclamation**



**Environmental
Remediation**



**Mining
Reclamation**



**Environmental
Remediation**



**Ecological
Restoration**

Assisting in recovery of degraded, damaged or destroyed ecosystems

*Sustainable
withdrawal of
materials from
the environment
for human use*



**Resource
Recovery**

**Mining
Reclamation**

**Environmental
Remediation**

**Ecological
Restoration**

Nature-Based Solutions



**Resource
Recovery**

**Mining
Reclamation**

**Environmental
Remediation**

**Ecological
Restoration**

We Live in a Multi-Hazard World



Miami, OK floods (2007)



Norman, OK tornado (2023)



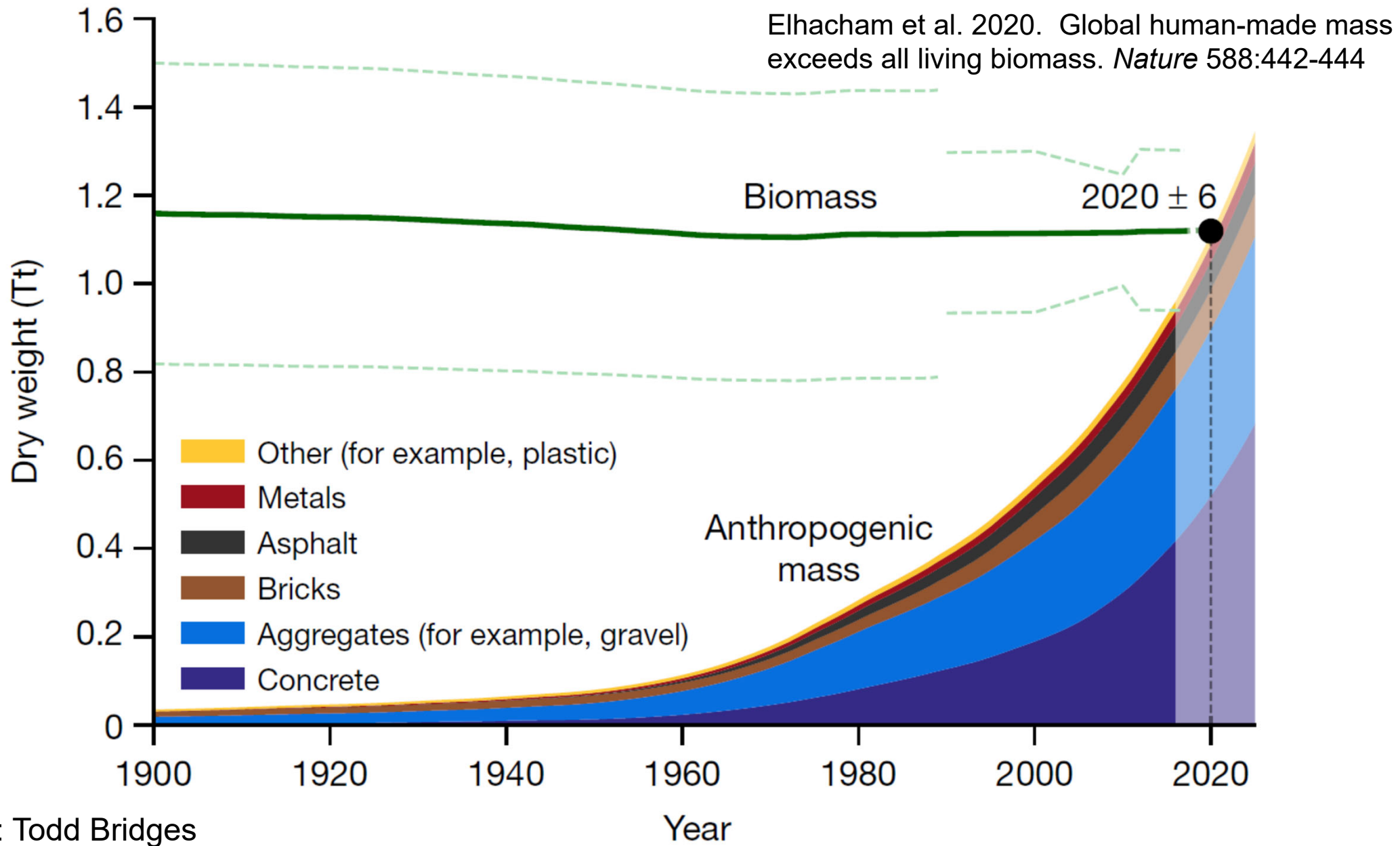
COVID-19 pandemic



San Luis Reservoir, CA (2021)



Maui fires, HI (2023)

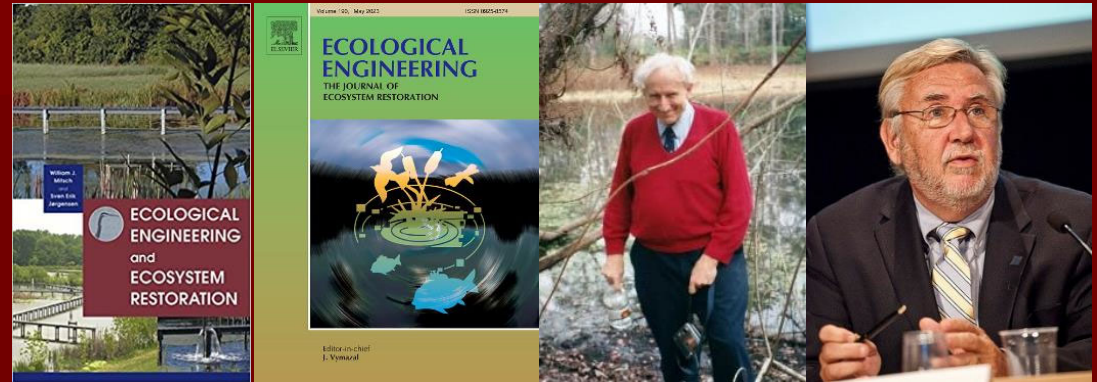


Source: Todd Bridges

Working with Mother Nature, not against her

■ Ecological engineering

- The design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both (Mitsch and Jorgenson 2004)



H.T. Odum

W.J. Mitsch

■ Engineering With Nature

- The intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits through collaboration (Bridges 2018)



T.S. Bridges

Working with Mother Nature, not against her

■ Nature-based solutions

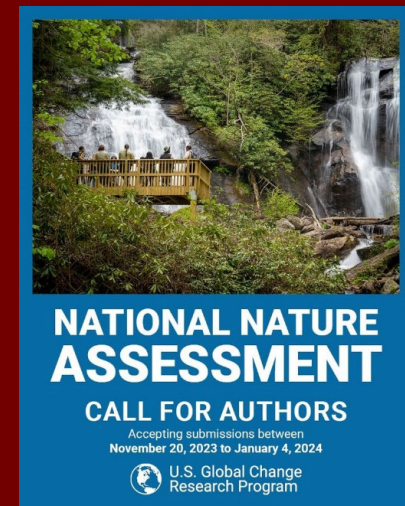
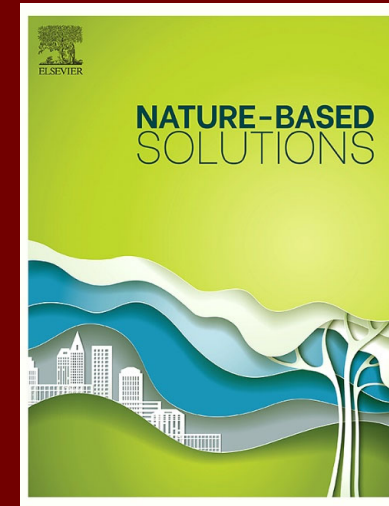
- Actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature (IUCN 2023)


■ Natural infrastructure

- Use of preserved, restored, or enhanced elements or combinations of vegetation and associated biology, land, water and naturally occurring ecological processes to meet targeted infrastructure outcomes (CCME 2018)

■ Natural and nature-based features

- Landscape features to produce flood risk management benefits; may be natural (produced purely by natural processes) or nature-based (produced by a combination of natural processes and human engineering (Bridges et al. 2021)



An aerial photograph of a massive open-pit mine. The mine is characterized by numerous terraced levels and steep, dark slopes. A prominent feature is a large, irregularly shaped pond in the center, which has a distinct greenish tint. The surrounding landscape is rugged and shows signs of extensive excavation. The sky is overcast, and the overall scene conveys the scale and industrial nature of the mining operation.

Mining Applications

Mina Invierno, Isla Riesco, Chile

There is nothing new under the sun!

- IMWA members were pioneers!
- Mine water “NBS” for four decades
- Passive treatment is ecological engineering
- PTS are NBS

- So why care about this new buzzword?



US Bureau of Mines personnel at an early passive treatment system, Friendship Hill National Historic Site, Pennsylvania

1. Success must be holistic and sustainable

- Environmentally effective
- Cost effective
- CERCLA and NRDAR*
 - Remediation and restoration as distinct
 - Remediation to decrease risk
 - Restoration to “baseline condition”
- NBS = comprehensive answers

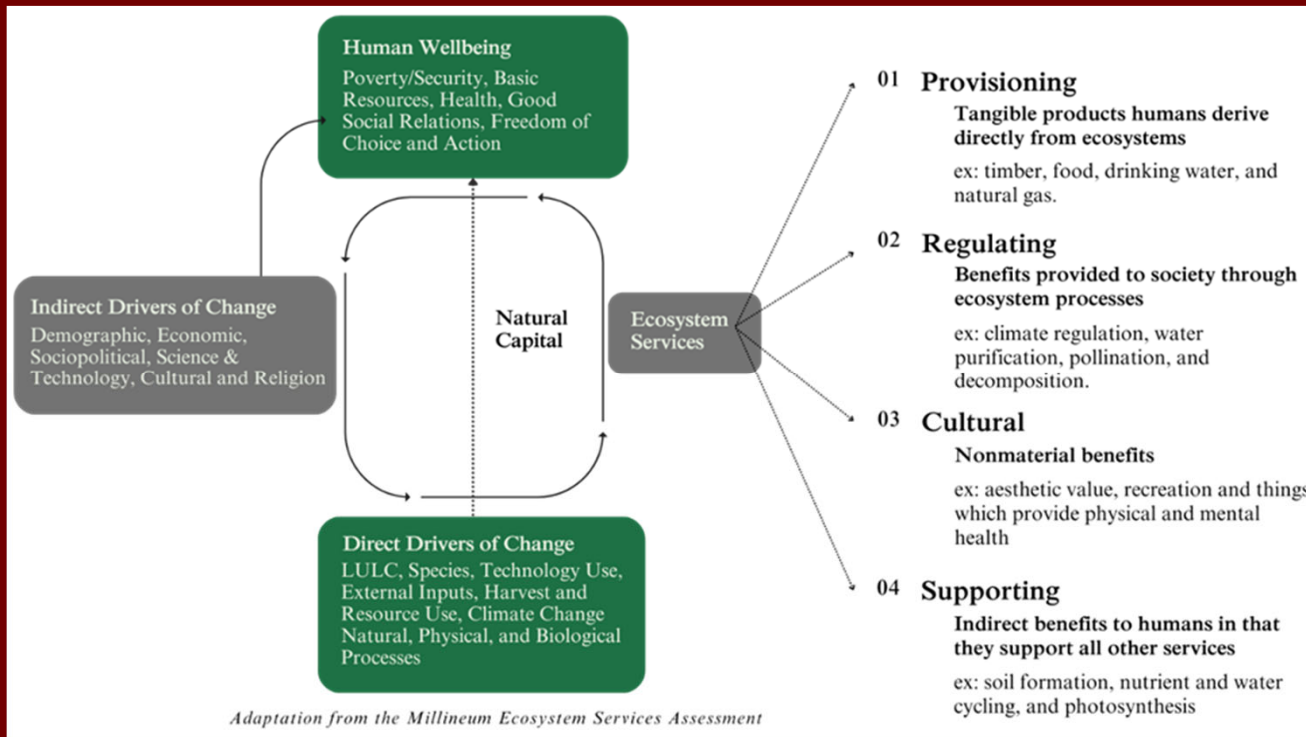
*Comprehensive Environmental Response, Compensation, and Liability Act (Superfund) and Natural Resources Damage Assessment and Restoration



Signage in the Silver Valley, Idaho

2. Provision of co-benefits

■ NBS provide ecosystem services



3. Closing the loop

- NBS promote resource recovery
 - Iron oxyhydroxides
 - Sulfides or other residues
- Tailings and wastes
 - Strategic minerals
 - Critical minerals
 - Rare earth elements



4. Re\$ource\$

Unprecedented global availability

■ United States

- Bipartisan Infrastructure Bill
- Inflation Reduction Act
- Executive Order 14072
- Engineering With Nature Program
- National Nature Assessment
- DOE Critical Minerals opportunities

Executive Order 14072

Section 4: *Deploying Nature-Based Solutions to Tackle Climate Change and Enhance Resilience*



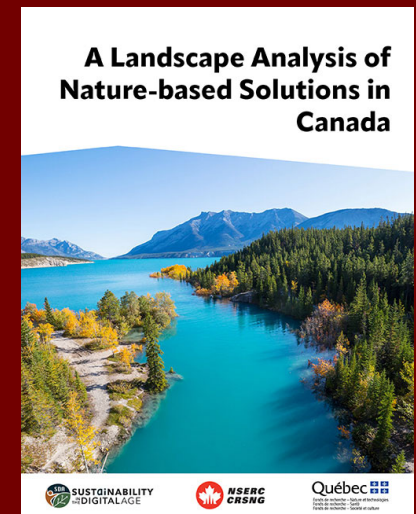
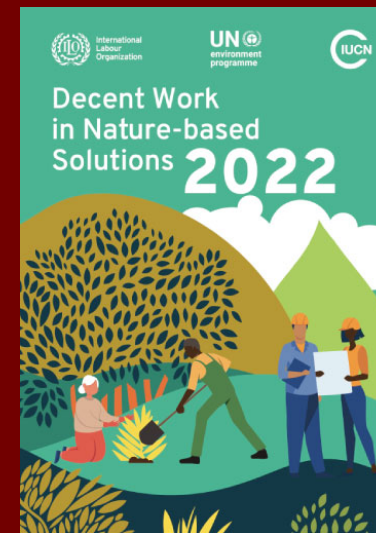
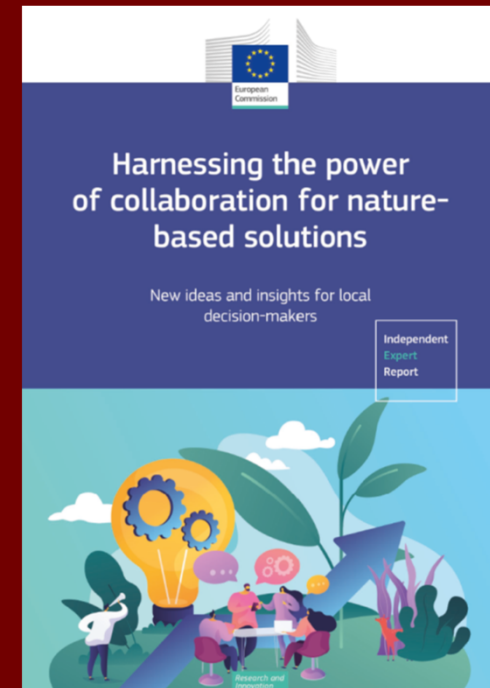
One Hundred Seventeenth Congress
of the
United States of America
AT THE FIRST SESSION
*Began and held at the City of Washington on Sunday,
the third day of January, two thousand and twenty-one*
An Act
To authorize funds for Federal-aid highways, highway safety programs, and transit programs, and for other purposes.
Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,
SECTION 1. SHORT TITLE; TABLE OF CONTENTS.
(a) SHORT TITLE.—This Act may be cited as the “Infrastructure Investment and Jobs Act”.



4. Re\$ource\$

Unprecedented global availability

- United Nations
- European Union
- United Kingdom
- Australia
- Canada



Nature-Based Solutions

- Applicable to both active and legacy mine sites
- Restore functioning ecological systems
- Provide multiple co-benefits
- Close the resource recovery loop
- Resources available



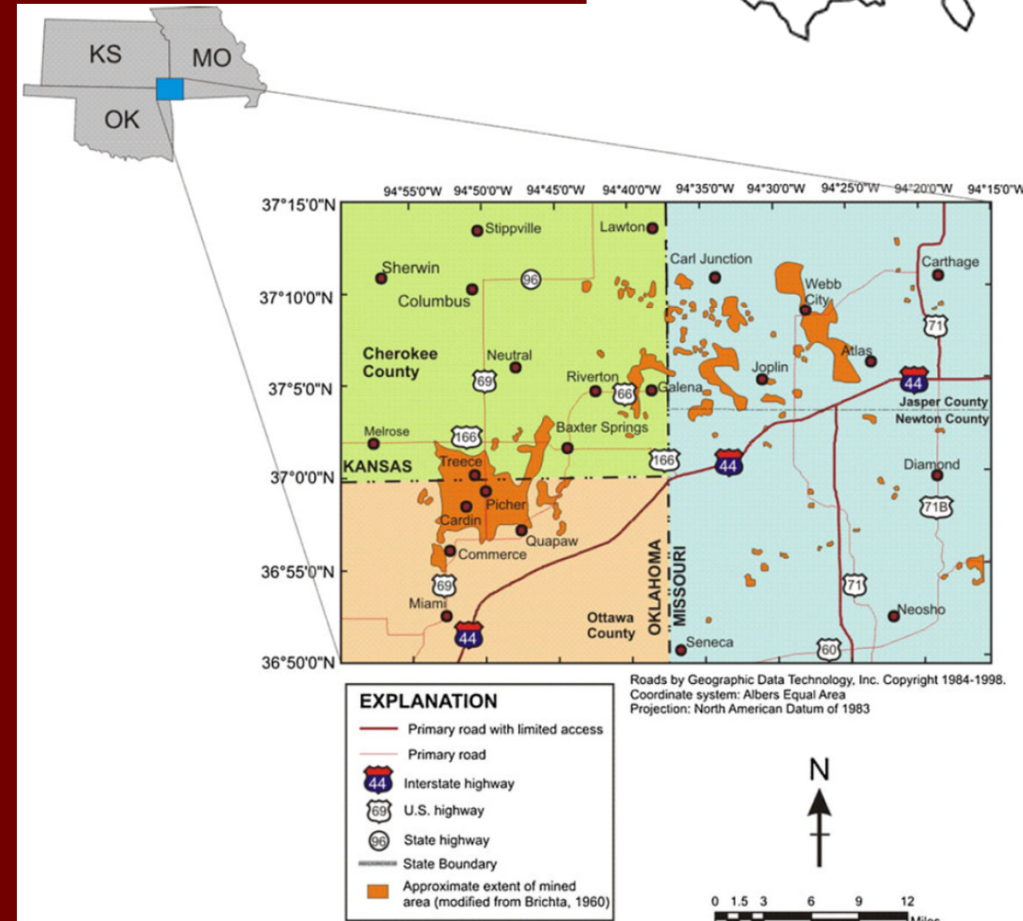
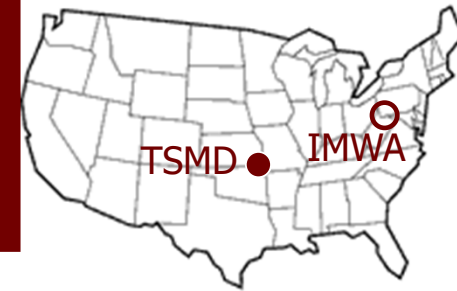


Case Study

Tar Creek, Tri-State Mining District, Oklahoma

Tri-State Mining District – Picher Field

- >3000 km² mined, 1830s ≈ 1970
- Mississippian sulfides (PbS, ZnS)
 - 164x10⁶ mtons crude ore
 - 1.7x10⁶ mtons Pb concentrates
 - 9x10⁶ mtons Zn concentrates
- Quapaw Nation OK treaty lands
- 100 million m³ mine pool
- 10,000 ha disturbed land
- Tar Creek Superfund Site (1983)



Extensive underground workings



Massive surface operations



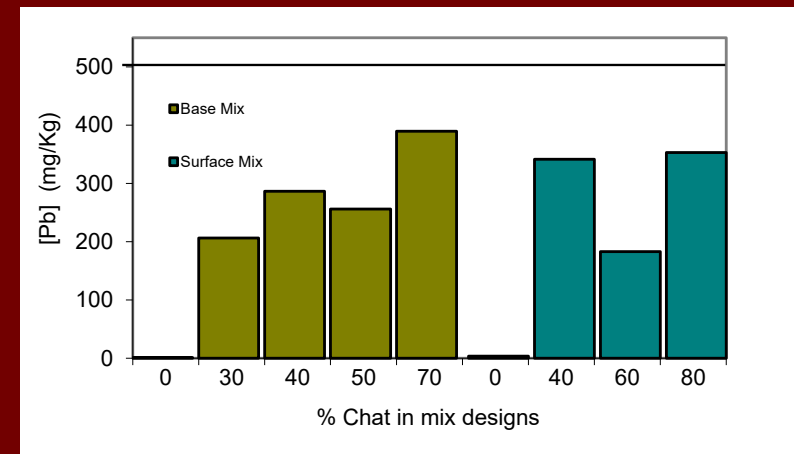
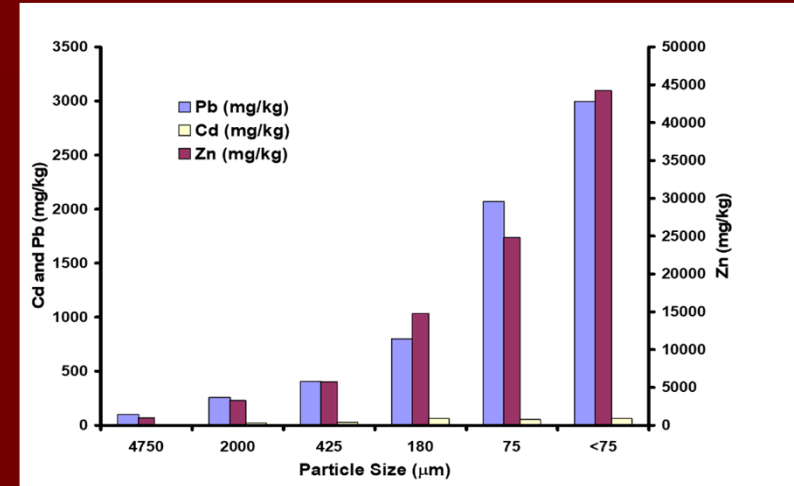
Tar Creek Watershed, Ottawa County, OK – In need of nature-based solutions!

No comprehensive nature-based solutions approach, but several innovative research and demonstration projects.



Beneficial reuse of "chat"

- Favorable properties as aggregate
- Must be encapsulated





Land reclamation

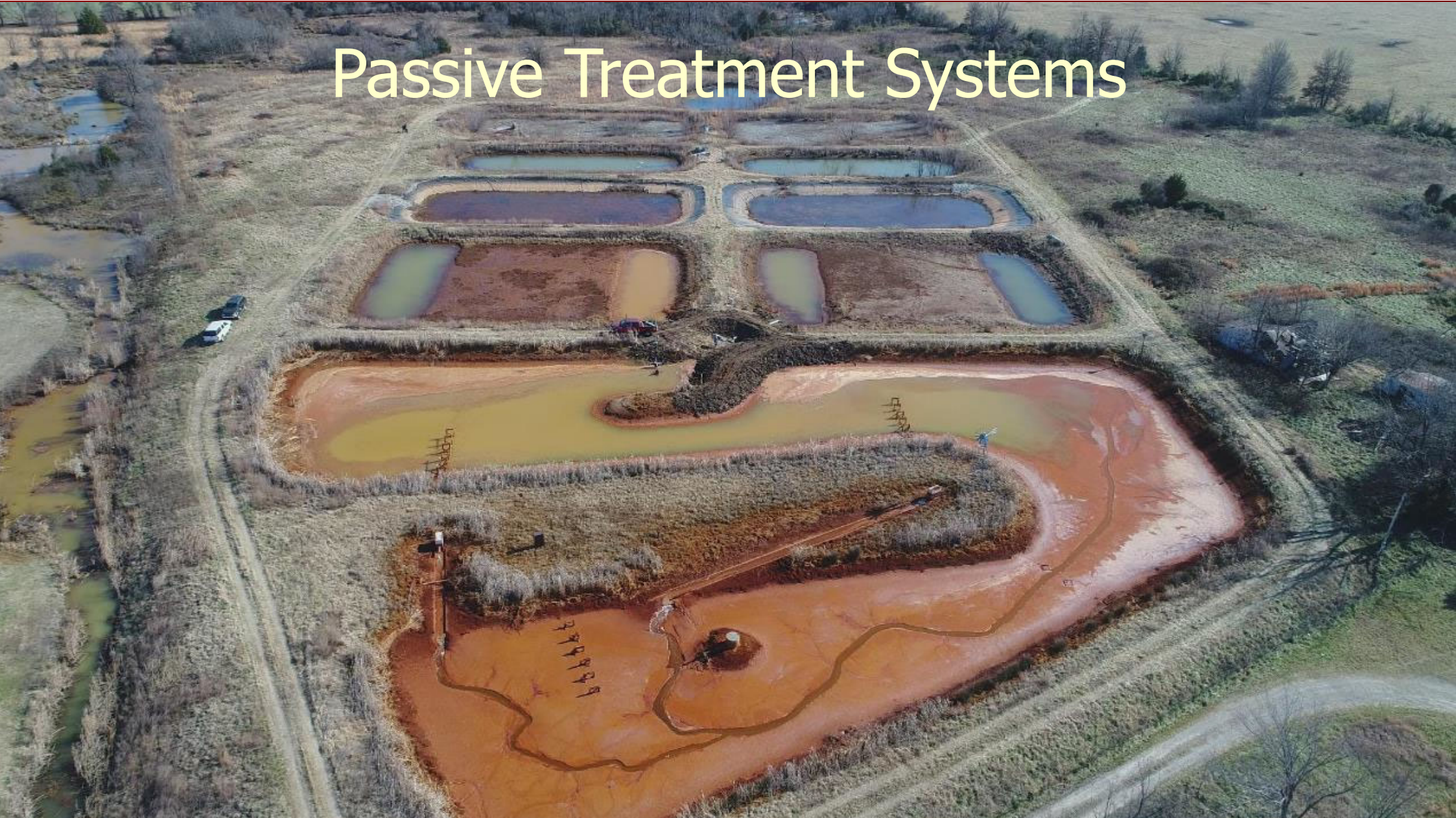


- Currently a tribally-led clean up
- *First-ever tribally led remedial response cooperative agreement (2013)*
- Now contracted for all state and federal lead projects
- 6.5×10^6 mtons source materials
- Recognize utility of NBS approach for remediation and restoration

Incorporation of Traditional Ecological Knowledge

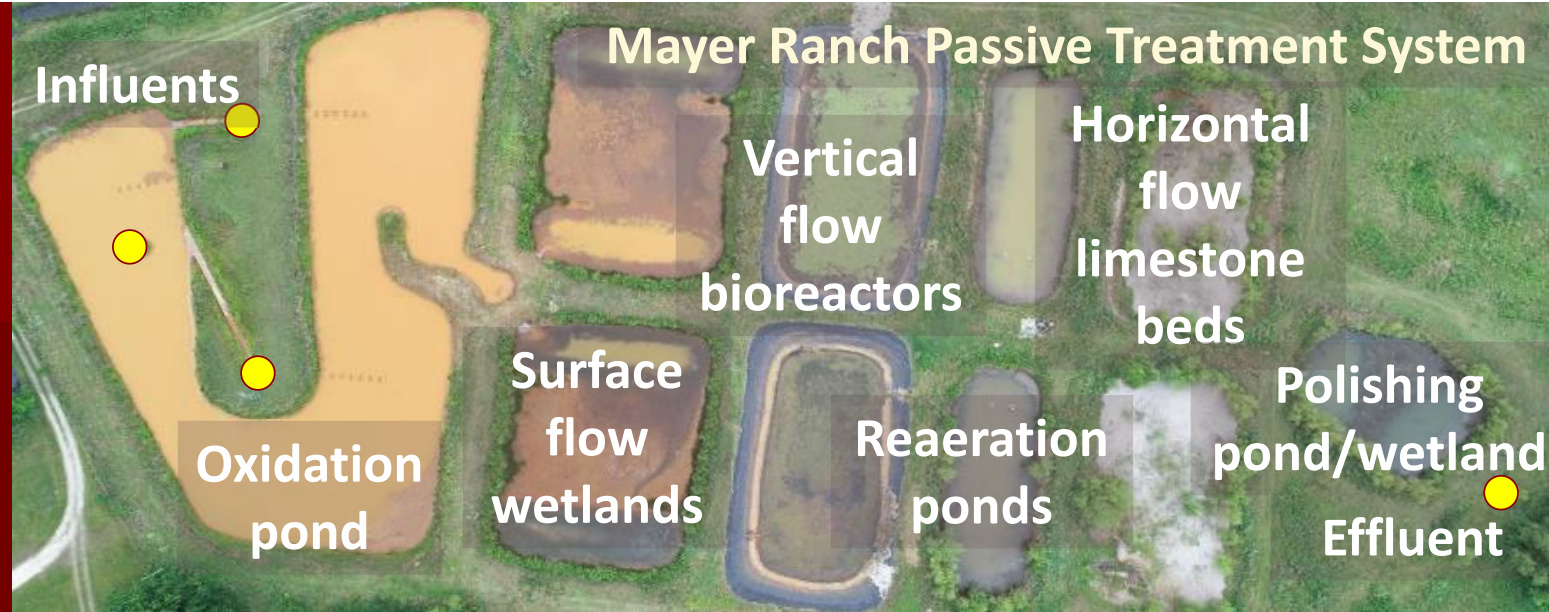


Passive Treatment Systems



○ Mayer Ranch

- USEPA CWA 104(b)(3) funding
- Online 11/2008
- 10 process units
- Flow = 420 lpm
- Area = 2.25 ha



Water quality changes

	In	Out
pH	5.97	7.06
Fe (mg/L)	160	0.33
Zn (mg/L)	6.91	0.14
Pb (mg/L)	0.093	<PQL
Cd (mg/L)	0.015	<PQL

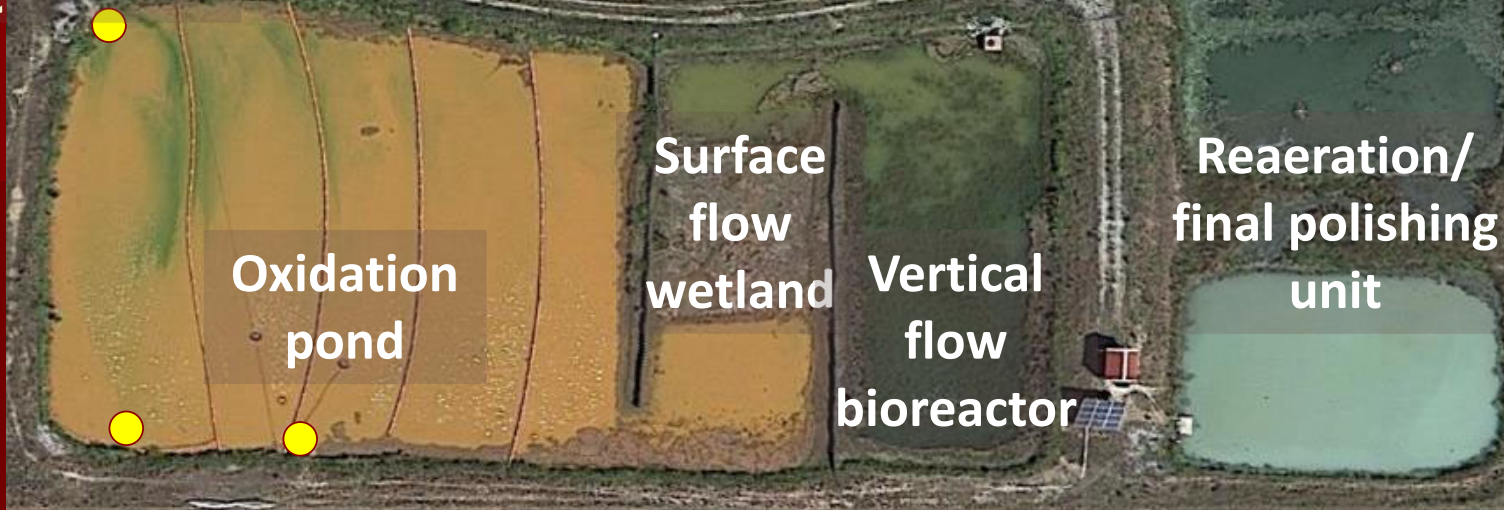
Mass retention

	Annual (kg)	15-Years (kg)
Fe	36500	547500
Zn	1550	23250
Pb	20	300
Cd	3.3	50

Southeast Commerce Passive Treatment System

Influent

Effluent



- Southeast Commerce
 - OSEE/DEQ funding
 - Online 02/2017
 - 4 process units
 - Flow = 600 lpm
 - Area = 1 ha

Water quality changes

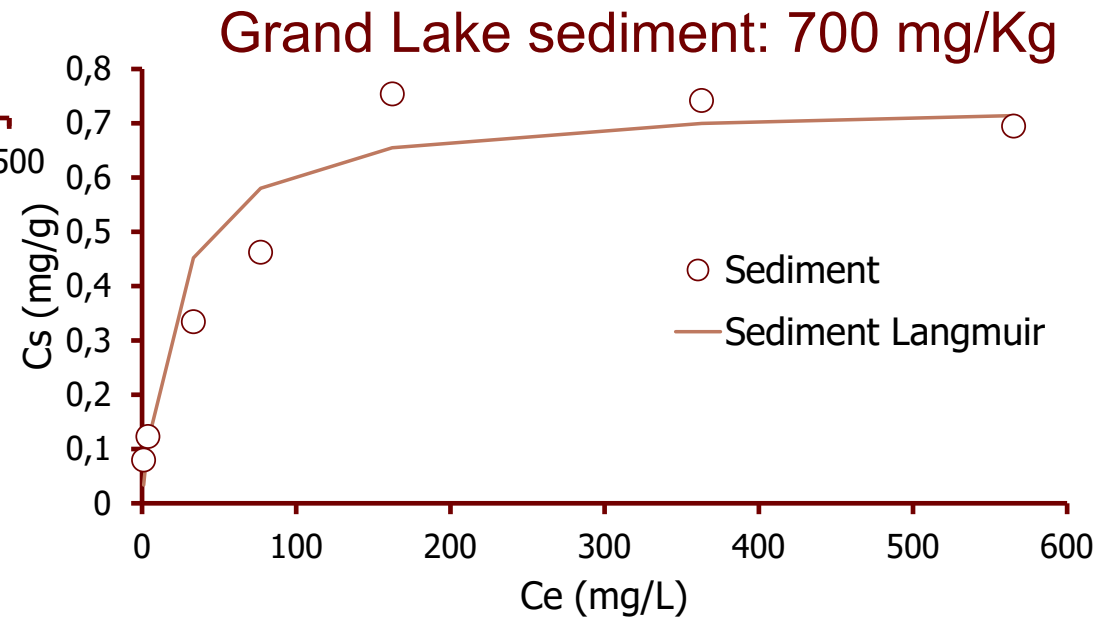
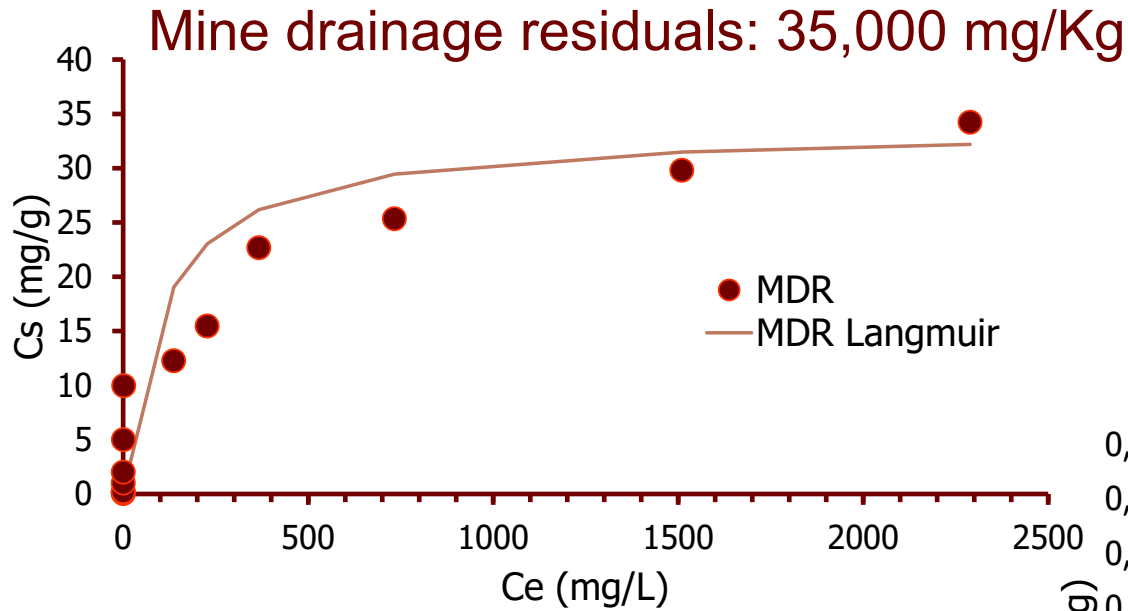
	In	Out
pH	5.94	6.83
Fe (mg/L)	140	0.79
Zn (mg/L)	6.54	0.07
Pb (mg/L)	0.279	<PQL
Cd (mg/L)	0.195	<PQL

Mass retention

	Annual (kg)	7-Years (kg)
Fe	34700	243000
Zn	1575	11000
Pb	64	450
Cd	5	35

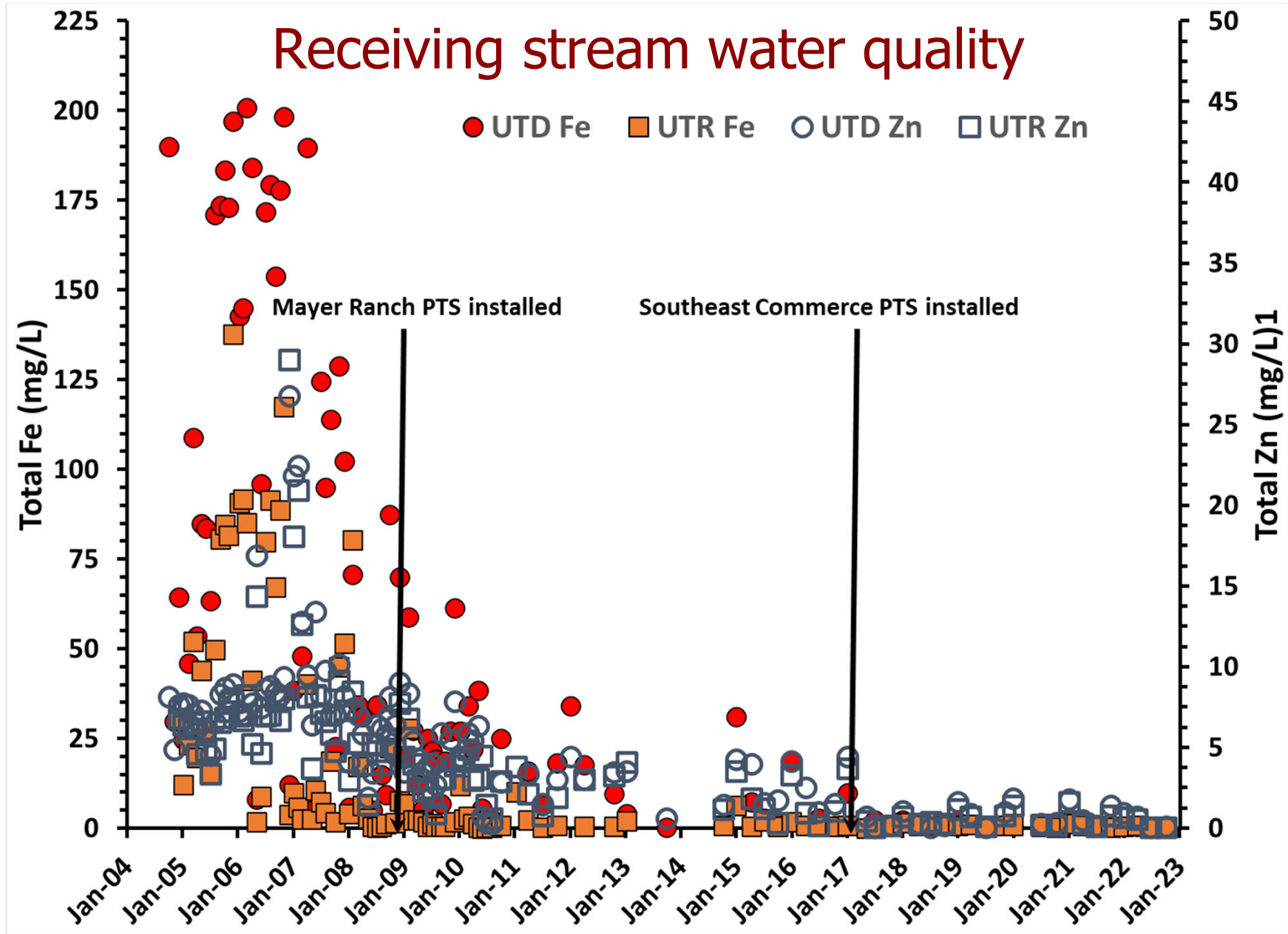


Langmuir Phosphorus Sorption Isotherms



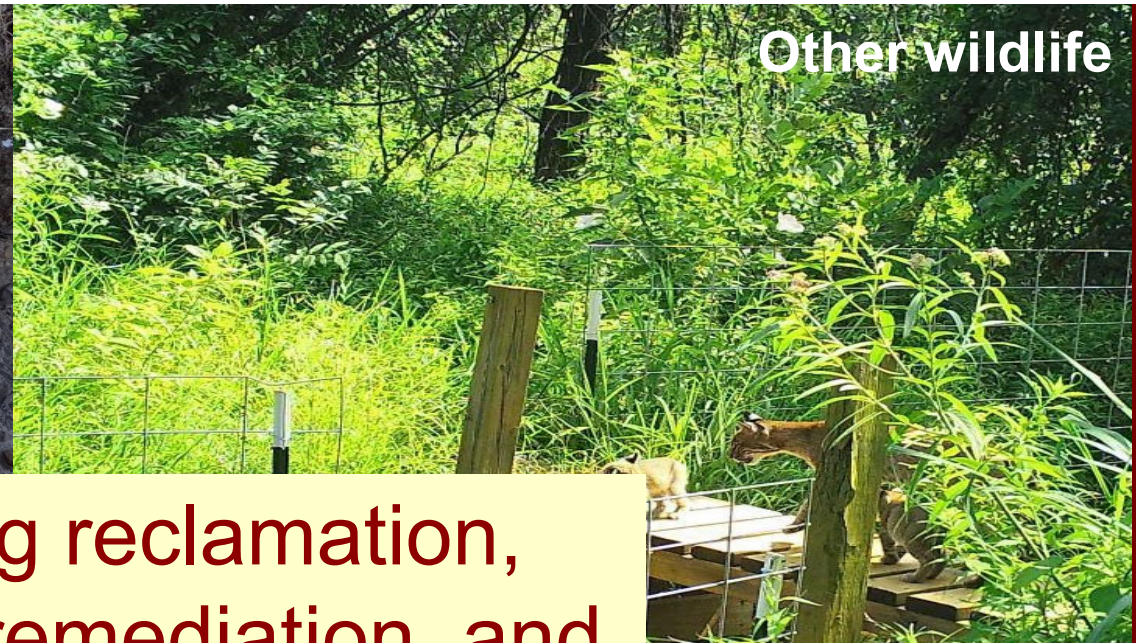
**Substantial potential as
P-sorption material**

Receiving stream water quality





Fish community recovery



Other wildlife

Linking mining reclamation, environmental remediation, and ecological restoration



North American b



atter (2022)

A photograph of a wetland landscape. In the foreground, there is a pond with several large green lily pads. The water is calm and reflects the surrounding vegetation. In the middle ground, there is a dense field of tall grasses and reeds. In the background, there is a thick forest of green trees under a cloudy sky. The overall scene is a natural, undisturbed wetland environment.

Conclusions

The Nature Conservancy's Bohler Seeps and Sandhills Preserve, Oklahoma

Conclusions

- THINK BIG!
- Holistic and flexible nature-based solutions approach
- Provides efficient model to reach multiple objectives and deliver numerous co-benefits
- System-based comprehension of interconnected hydrological, biogeochemical, ecological, and other processes
- Sustainable paradigm to address complex and interrelated 21st century challenges



CREW

Center for Restoration of
Ecosystems and Watersheds
The University of Oklahoma

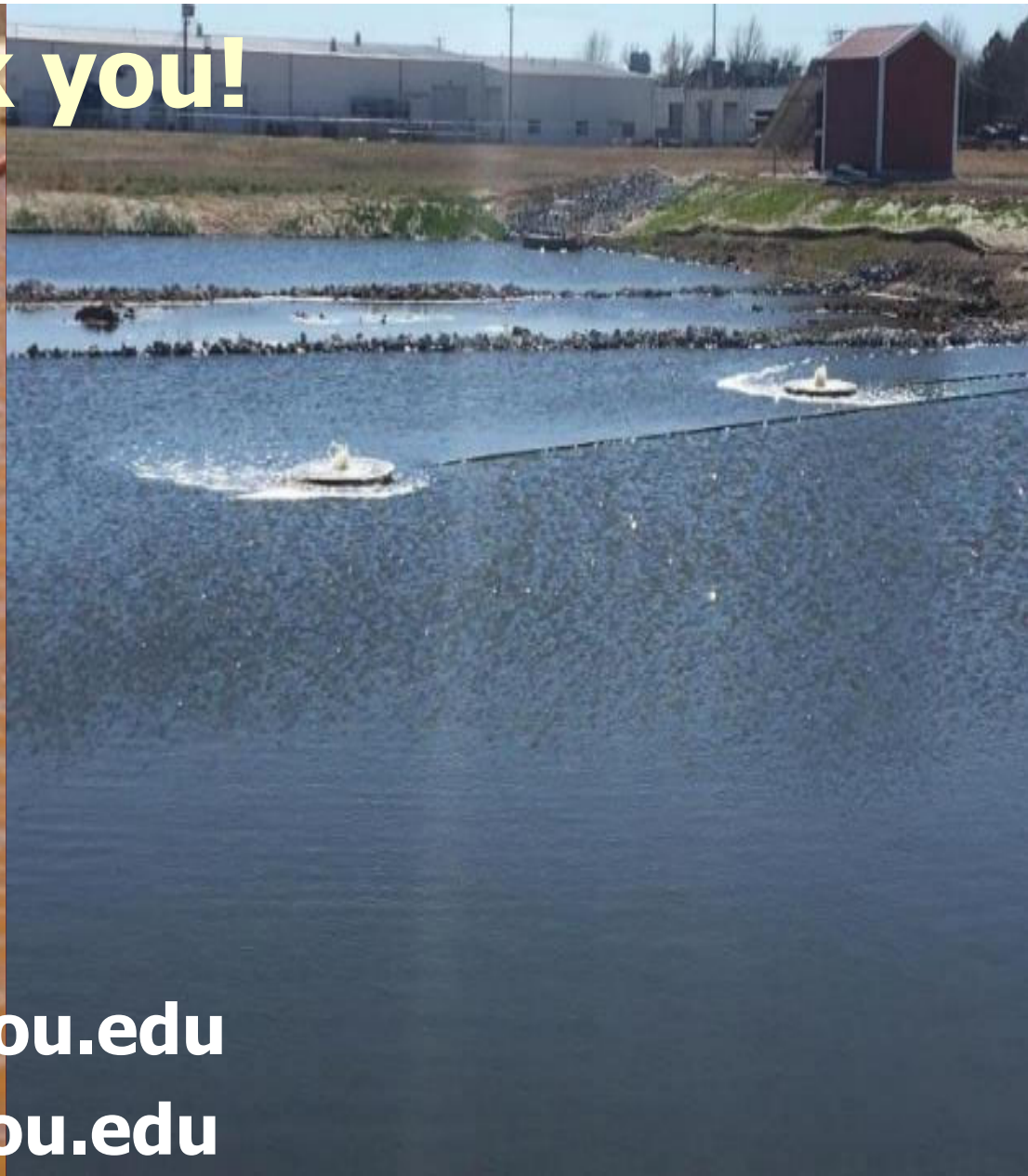


CREW Partners

- Our private landowners
 - Mayer, Pritchard, Martin, Corbus families
- Our major funding partners
 - USEPA Water Quality Division
 - USGS Toxic Substances Hydrology Program
 - Grand River Dam Authority
 - ODEQ Land Protection Division
 - Oklahoma Secretary of Energy and Environment
 - USACE Engineering With Nature
 - Many other funding partners
- Our research collaborators
 - OU CREW, CEES and Biology
 - Quapaw Nation of Oklahoma
 - LEAD Agency
 - Cities of Commerce and Norman
 - Northeastern Oklahoma A&M College
 - Central Oklahoma Master Conservancy District
 - CH2M-Hill team and subcontractors
 - BioMost Inc. and Riverman Engineering



Thank you!



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