Ecological Engineering by Humans and Beavers: How Small Ponds and Wetlands Can Improve Watershed Water Quality

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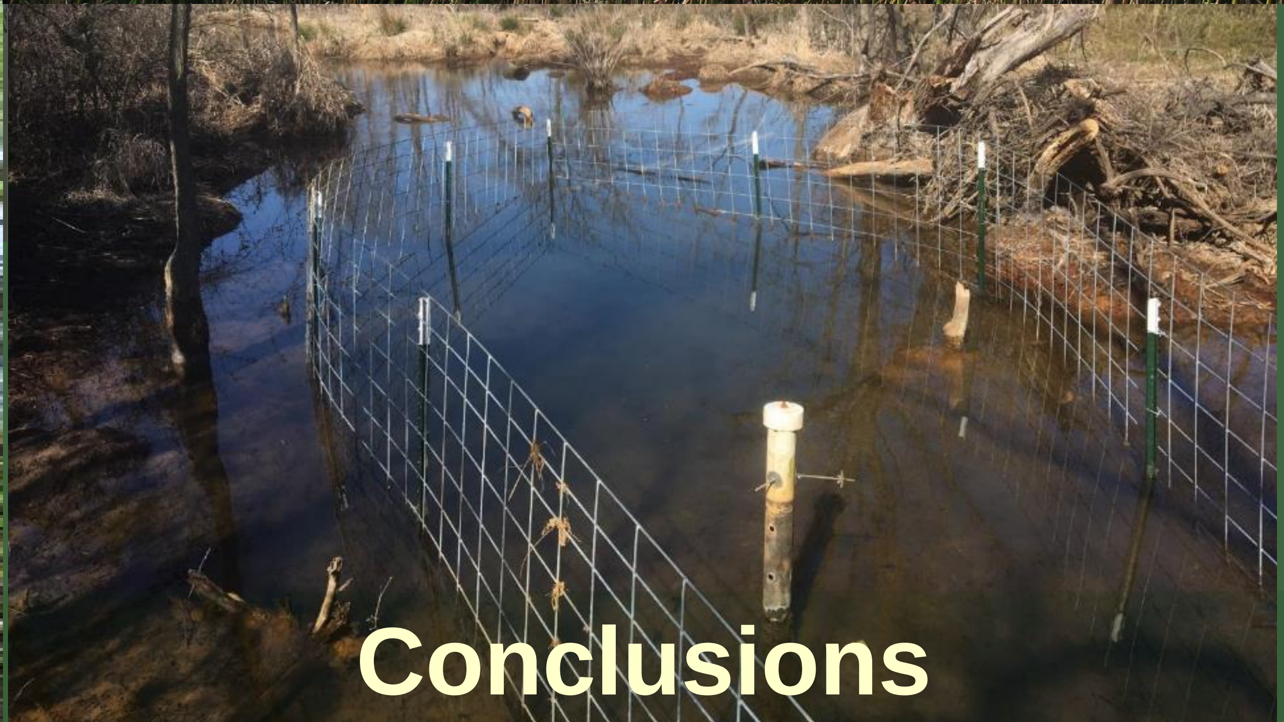
Natural Infrastructure


Human Ecological
Engineering


Beaver Ecological
Engineering


Conclusions


Natural Infrastructure

Natural Infrastructure

- Natural capital
- Green infrastructure
- Nature’s services
- Ecosystem services

PROVISIONING SERVICES

Products obtained from ecosystems

- Energy
- Seafood
- Biomedial
- Transportation
- National defense

REGULATING SERVICES

Benefits obtained from the regulation of ecosystem processes

- Flood prevention
- Climate regulation
- Erosion control
- Control of pests and pathogens

CULTURAL SERVICES

Nonmaterial benefits obtained from ecosystems

- Educational
- Recreational
- Heritage
- Spiritual

SUPPORTING SERVICES

Services necessary for the production of all other ecosystem services

- Biological diversity maintenance
- Nutrient recycling
- Primary productivity

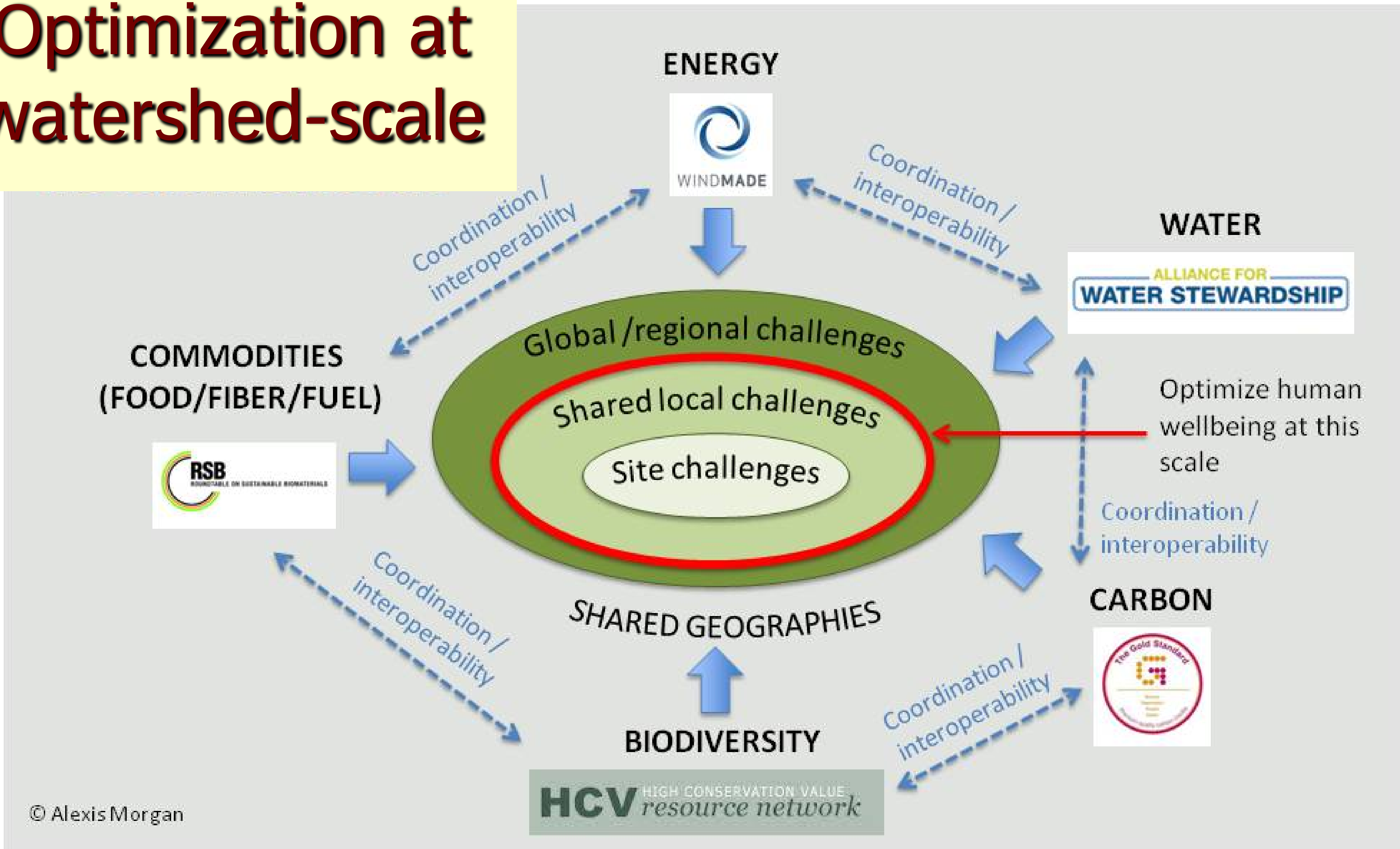
source: *Final Recommendations of the Interagency Ocean Policy Taskforce, 2010*

Natural Infrastructure

- **Conservation of intact natural ecosystems**
  - – Taxa richness and diversity
  - – Biogeochemical functions
- **Creation and restoration of ecologically engineered ecosystems**
  - – Often specific to solving anthropocentric problems

North Texas Municipal Water District
East Fork Raw Water Supply Project and
John Bunker Sands Wetlands Center

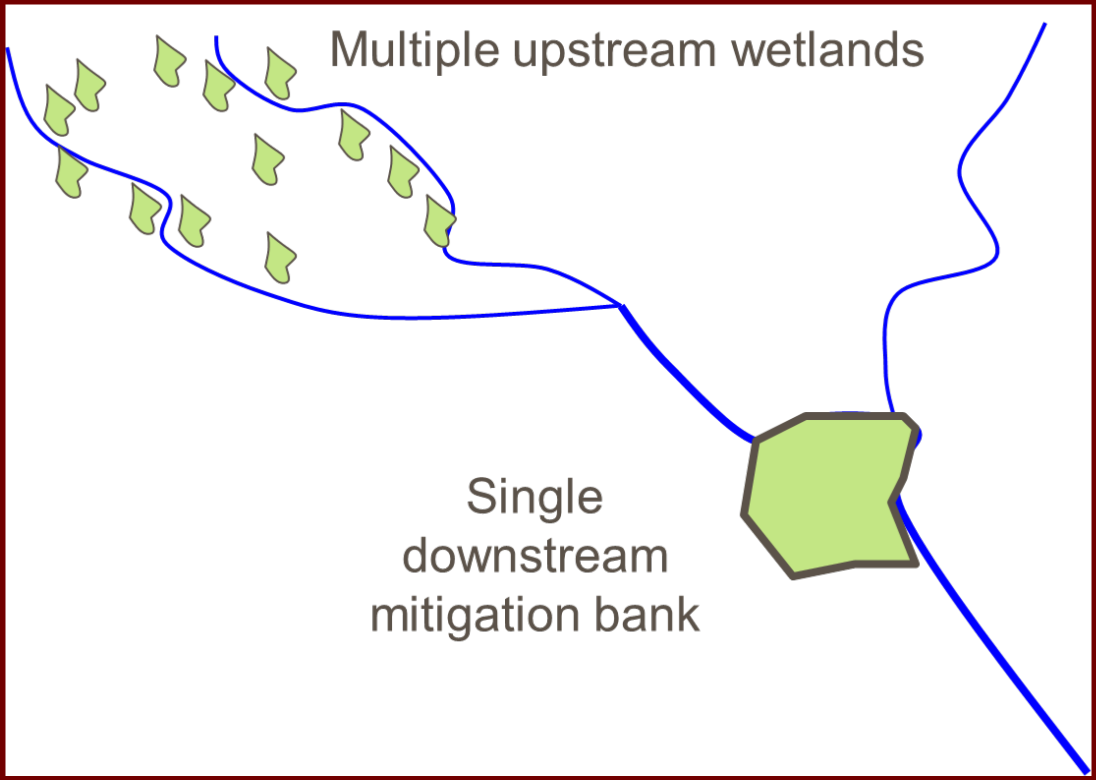
Optimization at watershed-scale



https://www.2degreesnetwork.com

Optimizing water quality improvement ecosystem services at the watershed-scale

- **Landscape position**
  - Relation to surface and ground water sources
  - Lateral position to streams and as buffer zones
  - Watershed position dependent on specific objectives



- **Drastically disturbed watersheds**

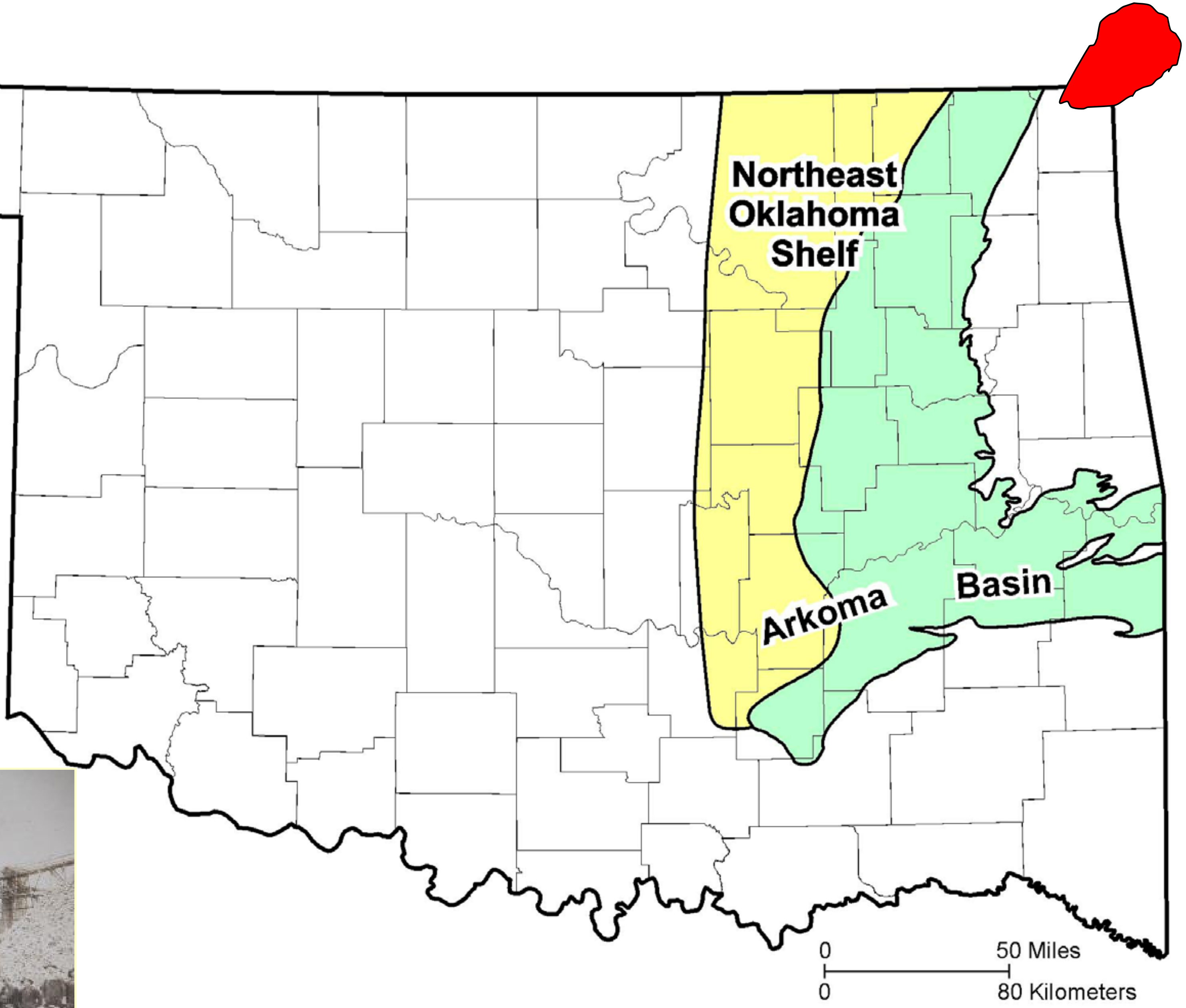
Mountaintop removal/valley fill surface coal mine, southern West Virginia

Abandoned lead-zinc mines, Ottawa County, Oklahoma

Commercial coal belt

Noncommercial coal-bearing region

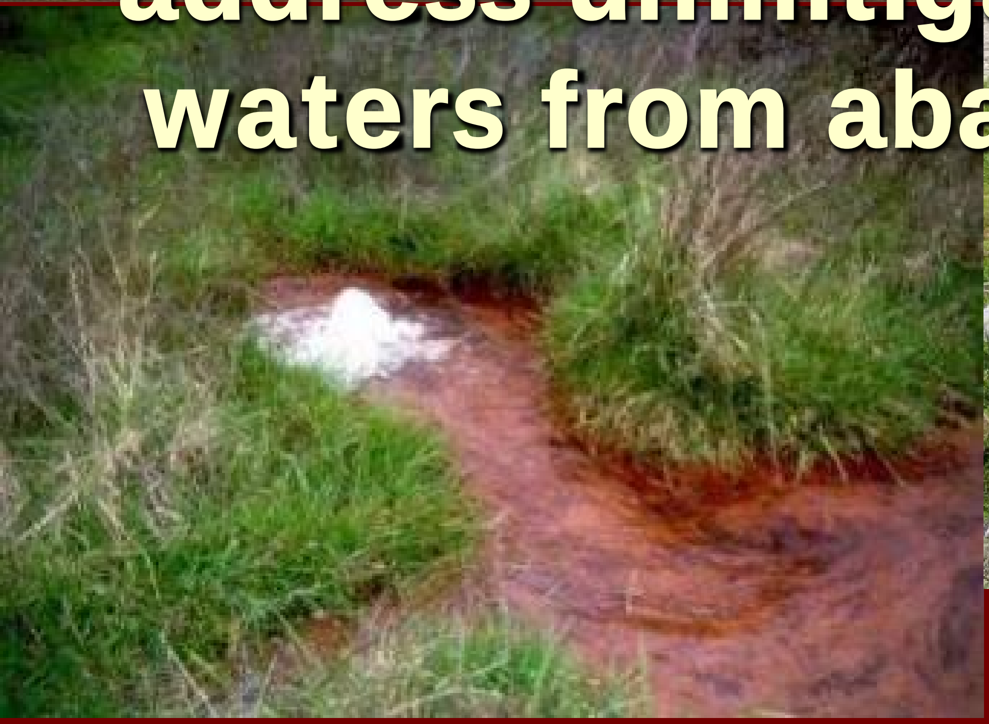
Tri-State Lead-Zinc Mining District




Human Ecological Engineering

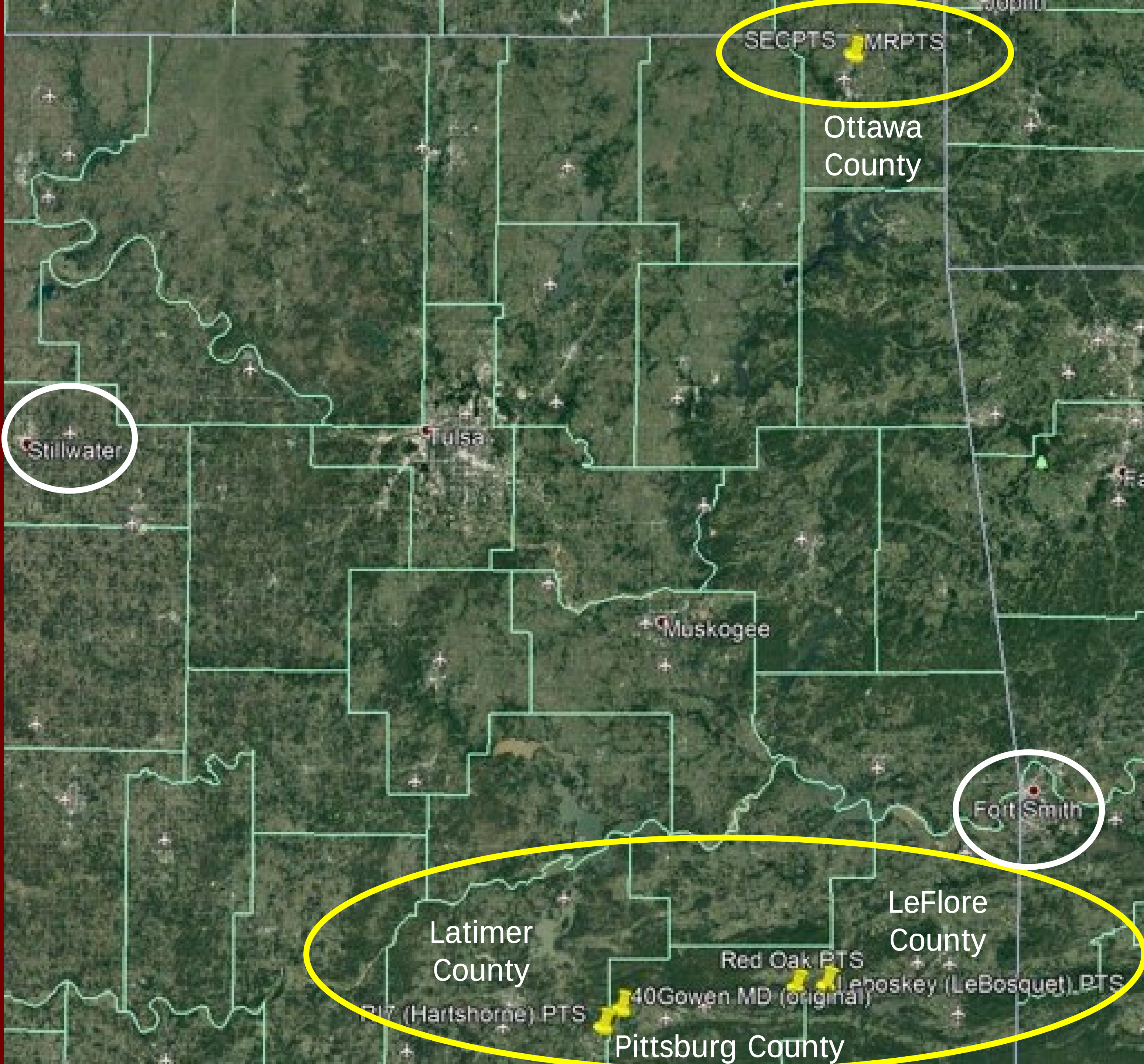


Design and construction of ecosystems to address unmitigated flows of contaminated waters from abandoned mining operations



Mine Water Pollution

- Ecotoxic metals
  - Fe
  - Al
  - Mn
  - Zn
  - Pb
  - Cd
  - Ni
  - As
- Sulfate
- Acidity



Passive Treatment Systems

- Oxidation ponds
- Surface flow wetlands
- Vertical flow bioreactors
- Polishing wetlands

MRPTS oxidation cell under construction, fall 2008

MRPTS oxidation cell during managed drawdown, winter 2017

SECPTS oxidation cell directional baffle curtains, early 2017

SECPTS oxidation cell solar-powered aerators, early 2017

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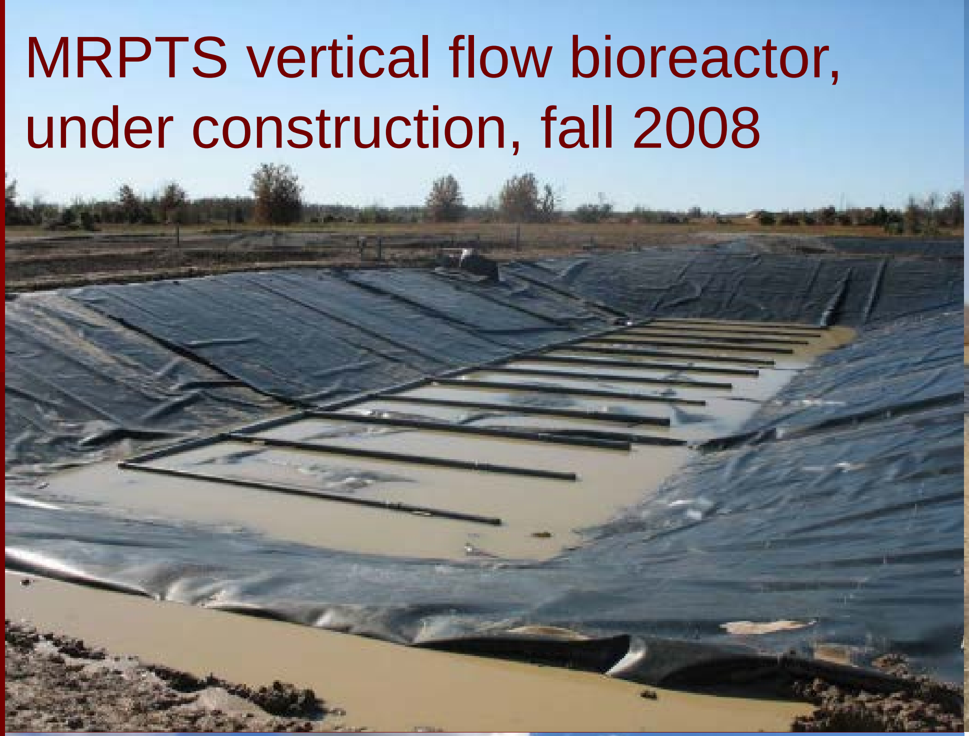
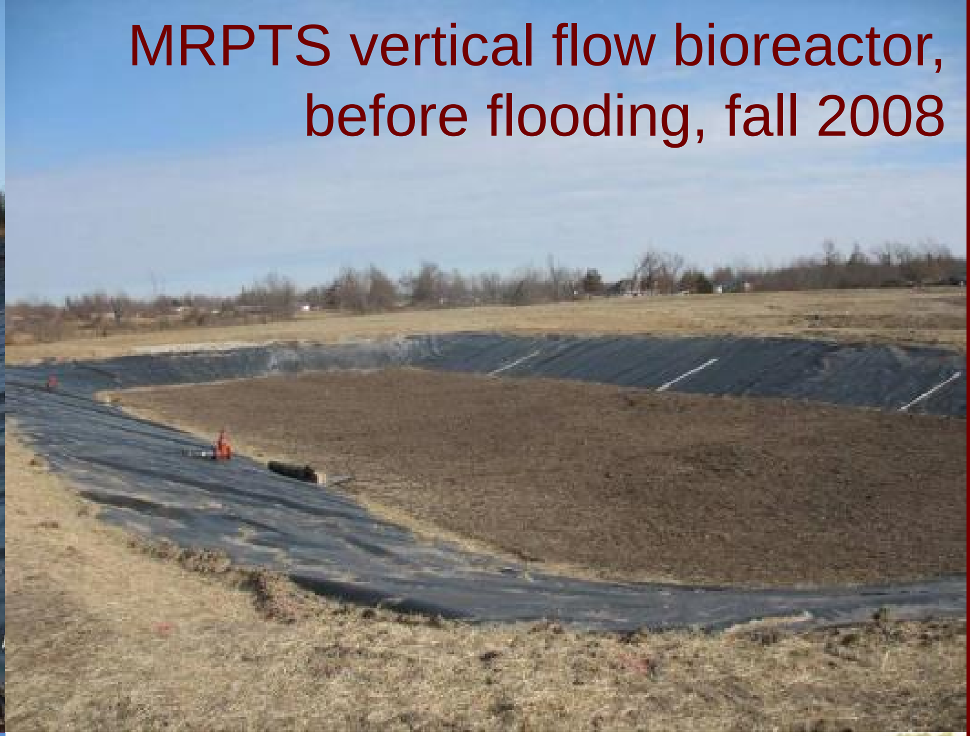
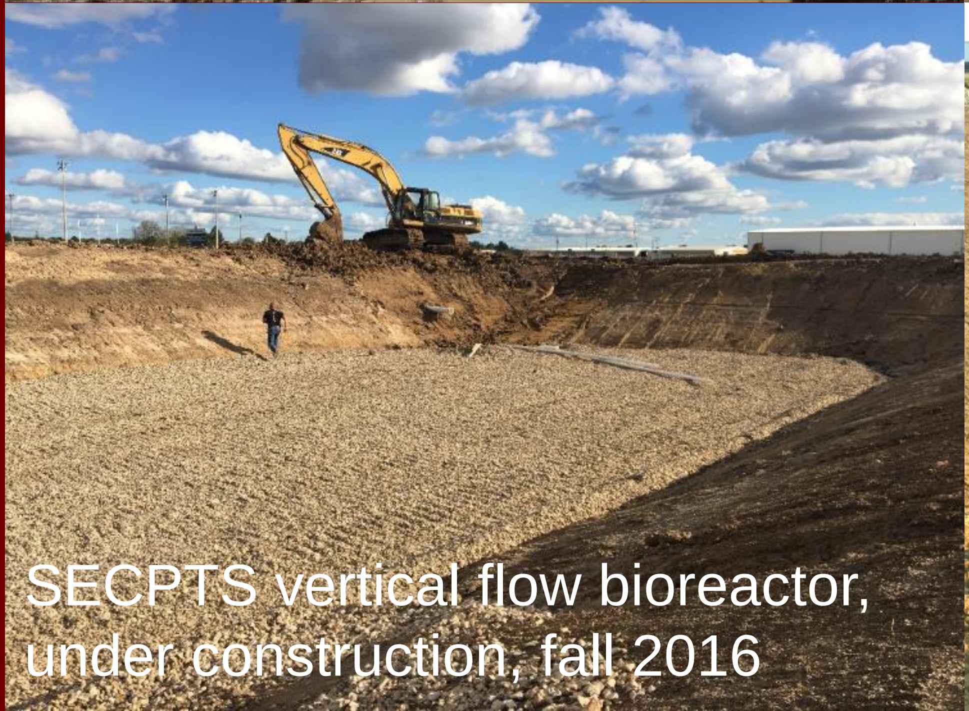


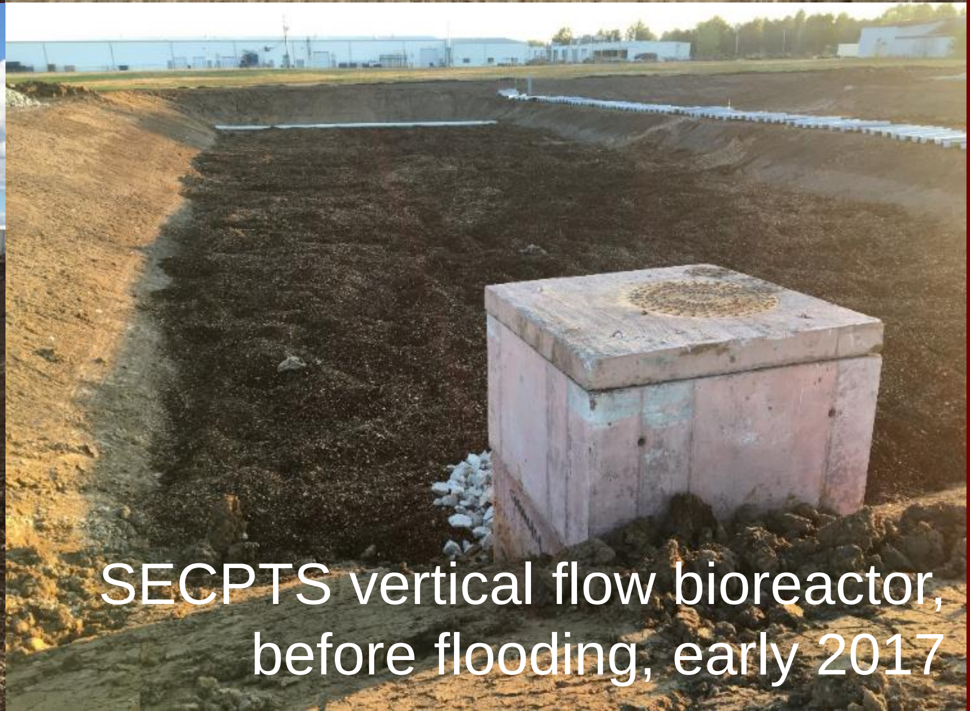
MRPTS vertical flow bioreactor, under construction, fall 2008



MRPTS vertical flow bioreactor, before flooding, fall 2008



SECPTS vertical flow bioreactor, under construction, fall 2016



SECPTS vertical flow bioreactor, before flooding, early 2017


Polishing pond/wetland
Horizontal flow limestone beds
Reaeration basins
Vertical flow bioreactors
Surface flow wetland
Oxidation pond
Mayer Ranch Passive Treatment System

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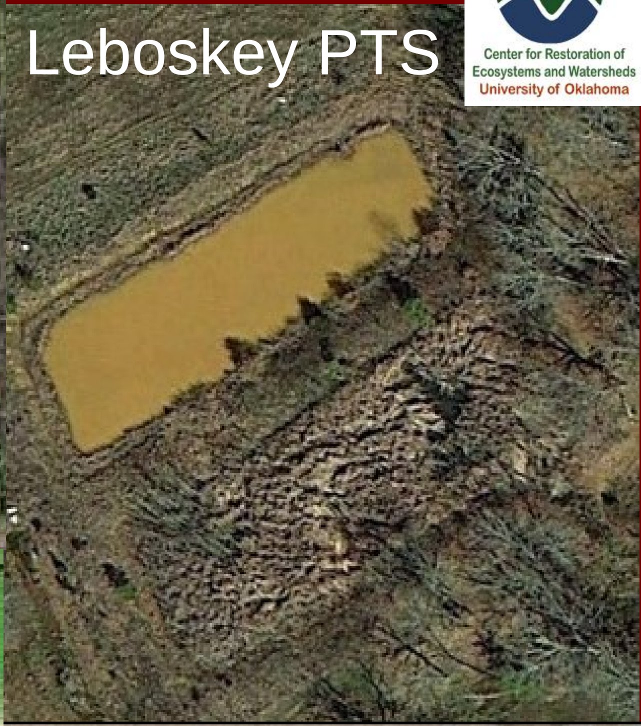
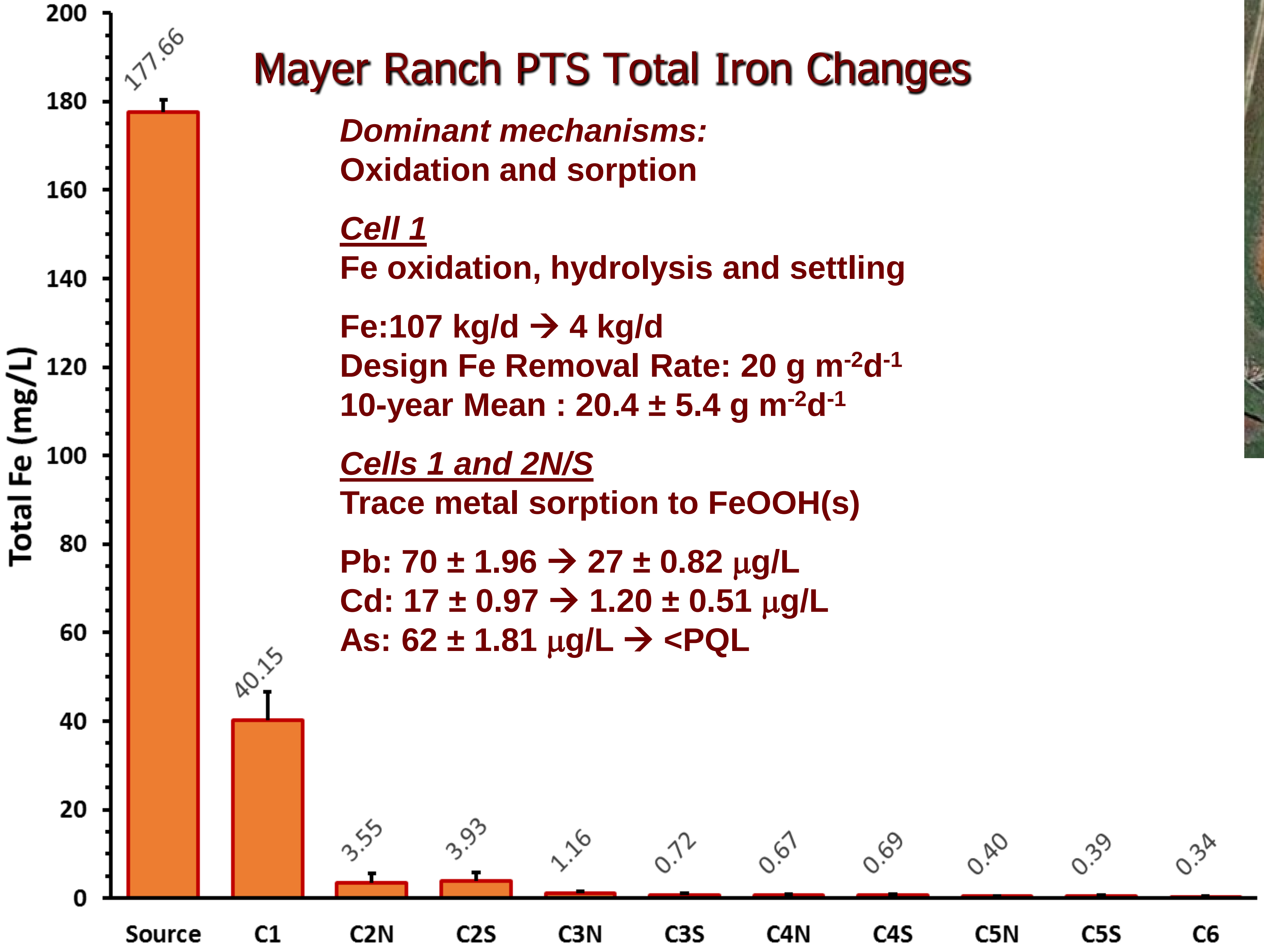


CREW Passive Treatment Systems

	Watershed placement	Water quality target	# units	Receiving watershed (acres)	PTS (acres)
Gowen	Headwaters	pH, Fe, Al, Mn	4	Pit Creek (307)	0.40
Red Oak	Headwaters	pH, Fe, Mn	5	Oak Ridge Creek (1747)	1.10
Hartshorne	Headwaters	pH, Fe, Mn	12	Unnamed tributary to Brushy Creek (70)	2.05
Leboskey	Headwaters	pH, Fe	2	Cedar Creek (301)	0.55
Mayer Ranch	Headwaters	Fe, Zn, Pb, Cd, As, Ni	10	Unnamed tributary to Tar Creek (845)	5.50
Southeast Commerce	Headwaters	Fe, Zn, Pb, Cd, As, Ni	4	Unnamed tributary to Tar Creek (845)	2.20

Mayer Ranch PTS Total Iron Changes



Dominant mechanisms:
Oxidation and sorption

<u>Cell 1</u>
Fe oxidation, hydrolysis and settling

Fe:107 kg/d → 4 kg/d
Design Fe Removal Rate: 20 g $m^{-2}d^{-1}$
10-year Mean : 20.4 ± 5.4 g $m^{-2}d^{-1}$

<u>Cells 1 and 2N/S</u>
Trace metal sorption to FeOOH(s)

Pb: 70 ± 1.96 → 27 ± 0.82 μg/L
Cd: 17 ± 0.97 → 1.20 ± 0.51 μg/L
As: 62 ± 1.81 μg/L → <PQL

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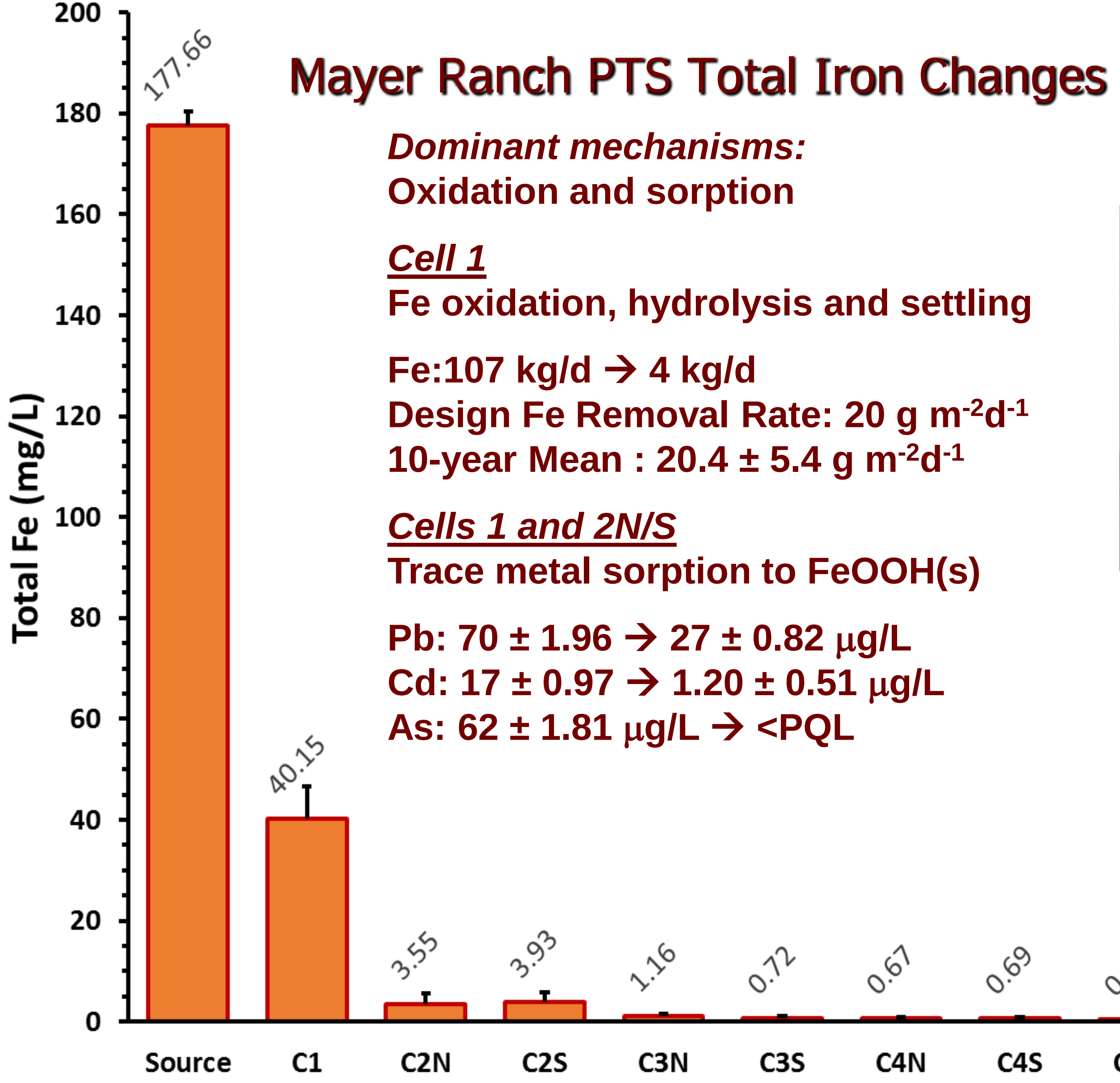

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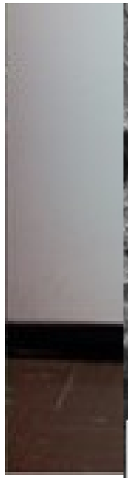
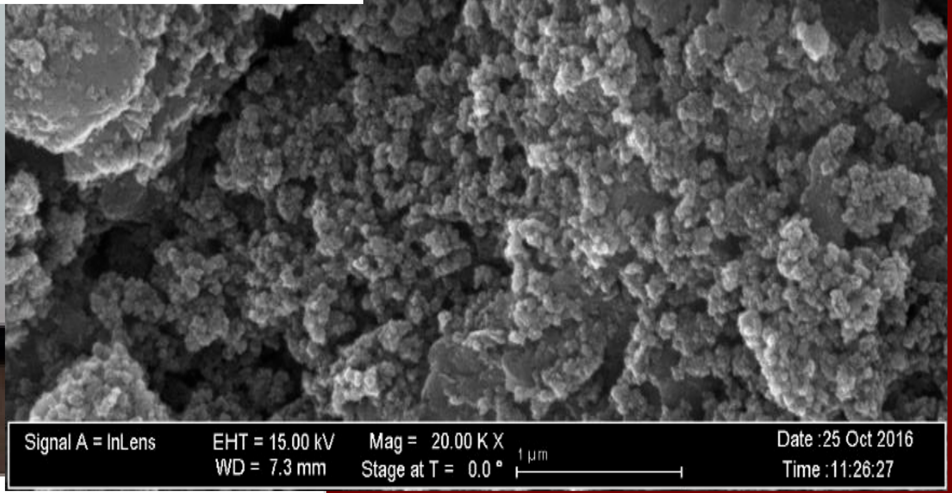
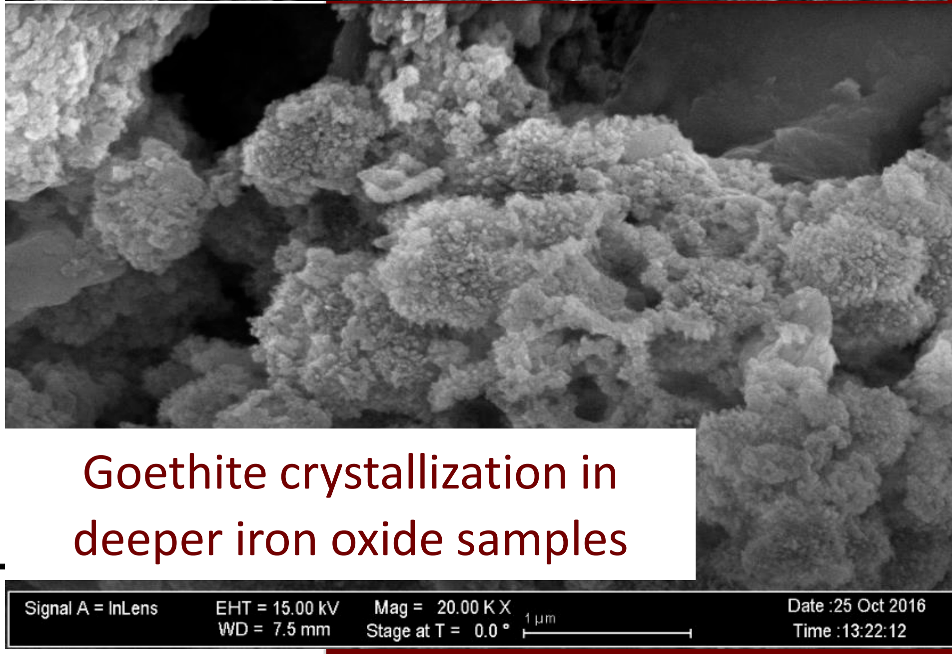
Amorphous ferrihydrite typical of Cell 1 and Cell 2N/2S surface samples

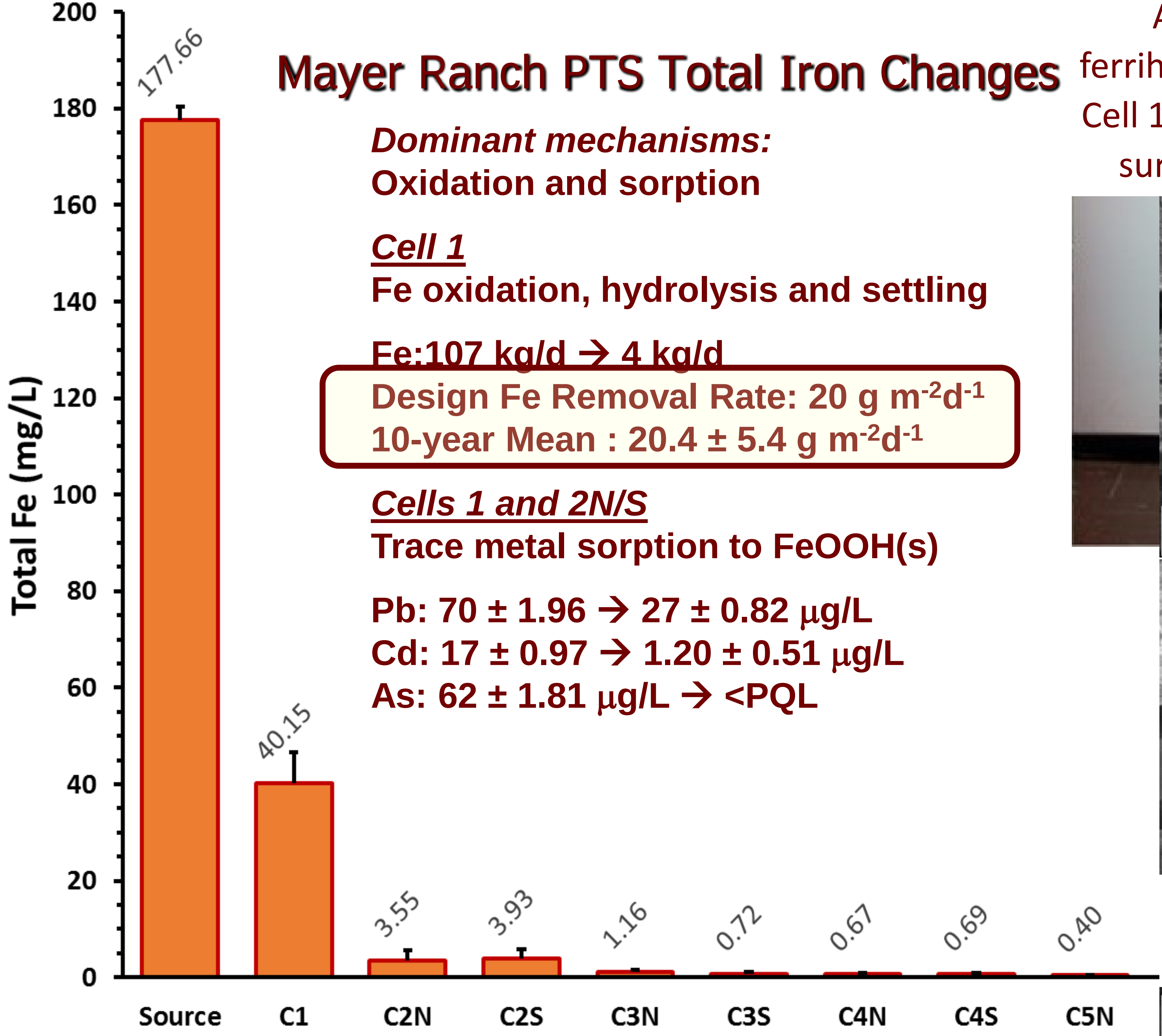






Goethite crystallization in deeper iron oxide samples

Mayer Ranch PTS Total Iron Changes



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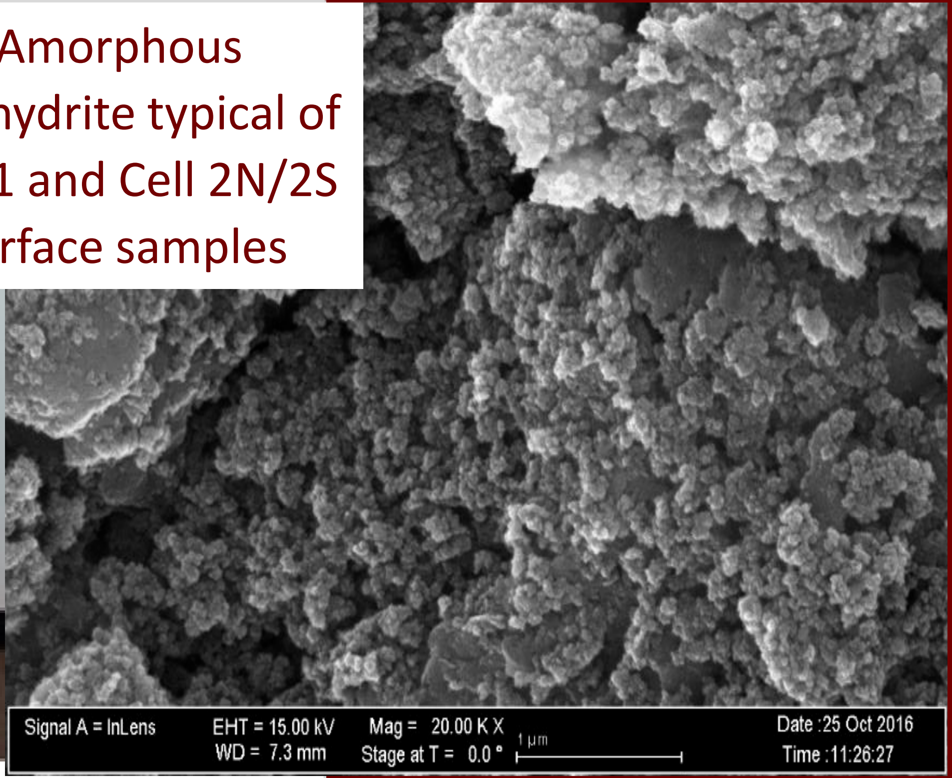
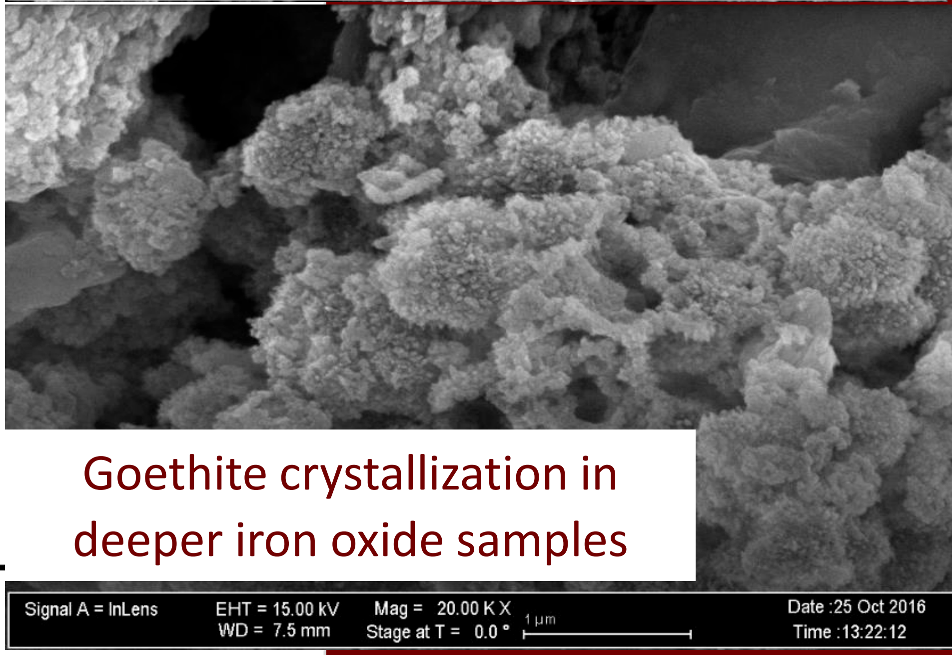
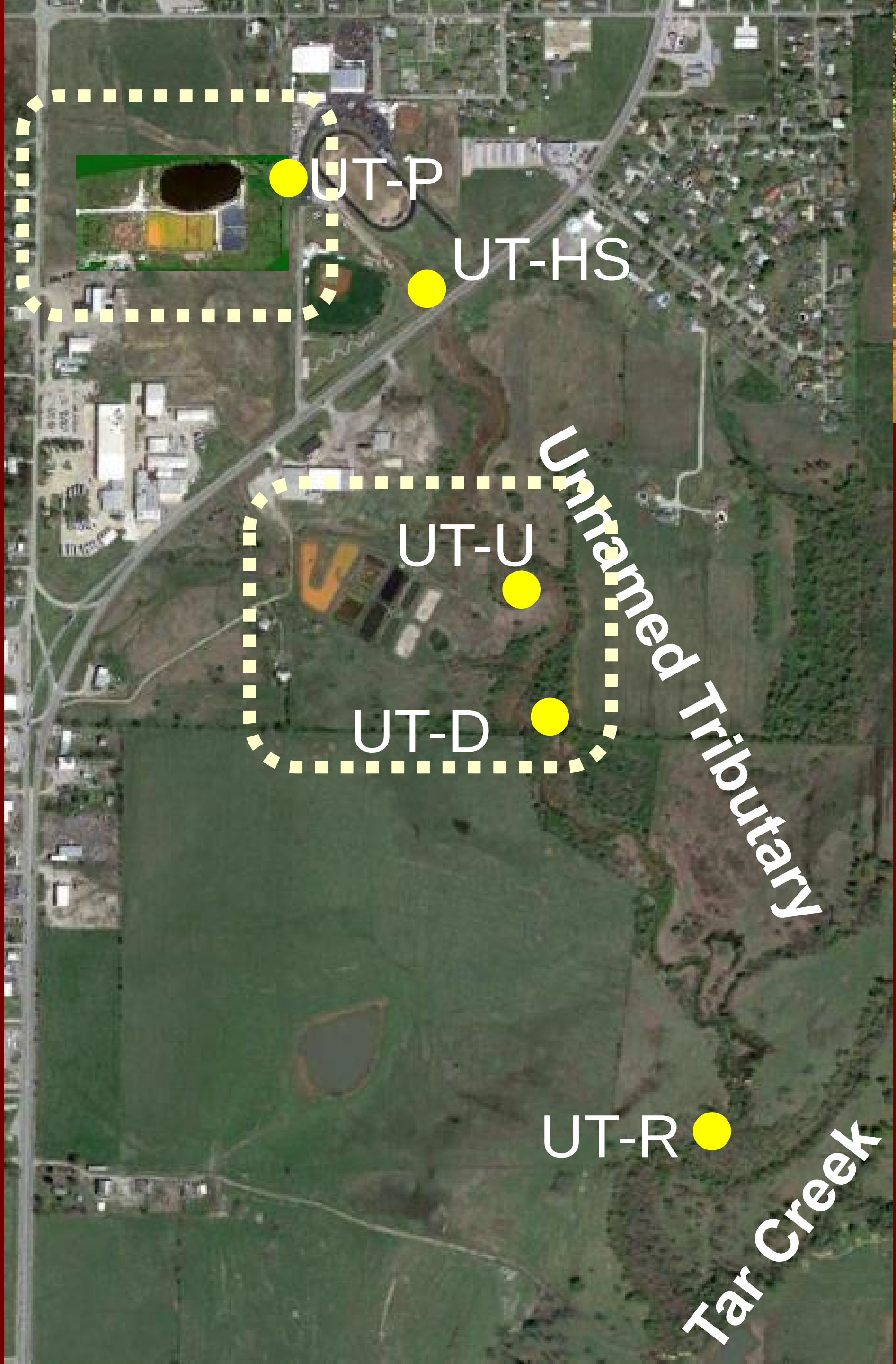




Goethite crystallization in deeper iron oxide samples

Receiving Stream Recovery

- Long-term water quality data collection (15+ years)
- Long-term fish community analysis (12+ years)
- Documented changes in water quality and ecological community



Unnamed Tributary fish data

		Catch per unit effort (CPUE)	
Scientific name	Common name	2005-07	2009-16
Gambusia affinis	Western mosquitofish	39.24	187.60
Lepomis cyanellus	Green sunfish	0.81	16.80
Lepomis macrochirus	Bluegill	1.00	3.00
Lepomis megalotis	Longear sunfish	0.02	6.80
Notemigonus crysoleucas	Golden shiner	0.17	0.60
Lepomis gulosus	Warmouth	0.07	1.0
Lepomis microlophus	Redear sunfish	0	18.00
Lepomis sp.	Sunfish hybrid	0	2.5
Labidesthes sicculus	Brook silversides	0	2.0
Etheostoma gracile	Slough darter	0	0.80
Ameiurus melas	Black bullhead	0	0.40
Fundulus notatus	Blackstriped topminnow	0	0.40
Pomoxis annularis	White crappie	0	0.30
Micropterus salmoides	Largemouth bass	0	0.20
	Species richness	6	14

- Single seine haul at UT-HS in October 2018, where no fish were found until late 2017
- No in-stream habitat restoration, just improvement of source water quality

Human Ecological Engineering

- Effective treatment at source
- Small (<1 acre) ponds in series
- All systems improved target water quality parameters to in-stream criteria
- >10 years continued operation

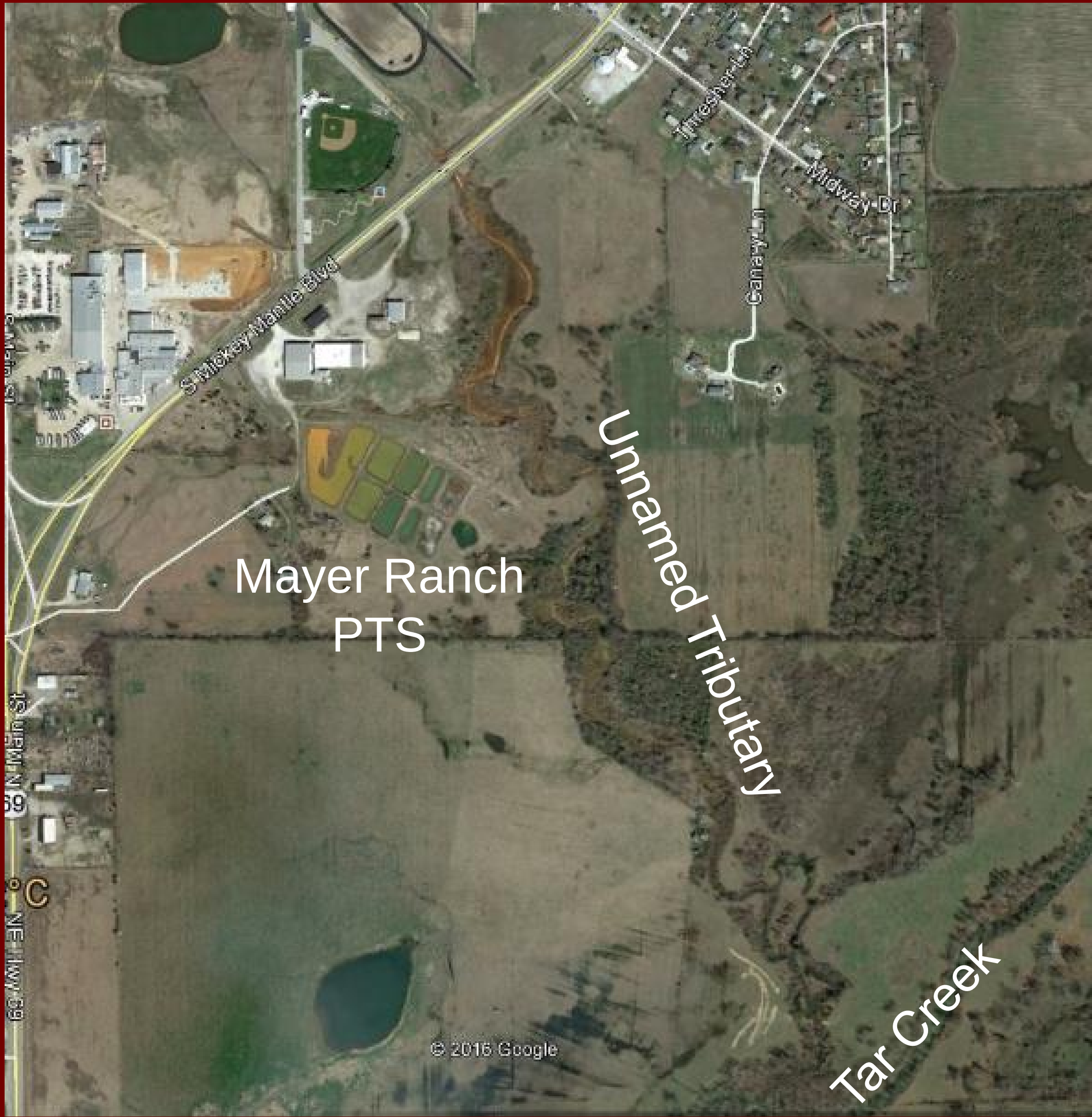
Beaver Ecological Engineering

Our friend, the beaver

- Ecosystem engineers
  - Alter riparian area and forms extensive wetlands
  - Increase plant and animal species richness
  - Definitive impacts on watershed hydrology
- Water quality impacts
  - Largely inconclusive, mainly regarding nutrients
- *Castor canadensis* life cycle
  - 10 year life expectancy; sexual maturity in 1.5 to 2 years
  - Average 5 kits per birth at 100 day gestation period
    - <3% mortality rate for first 2 years

Beaver in the Unnamed Tributary

- 1.32 mi^2 watershed, just over 1 mile stream length
- Water quality monitoring since 2004
- MRPTS implemented 2008
- Beaver recolonization first noted 2013



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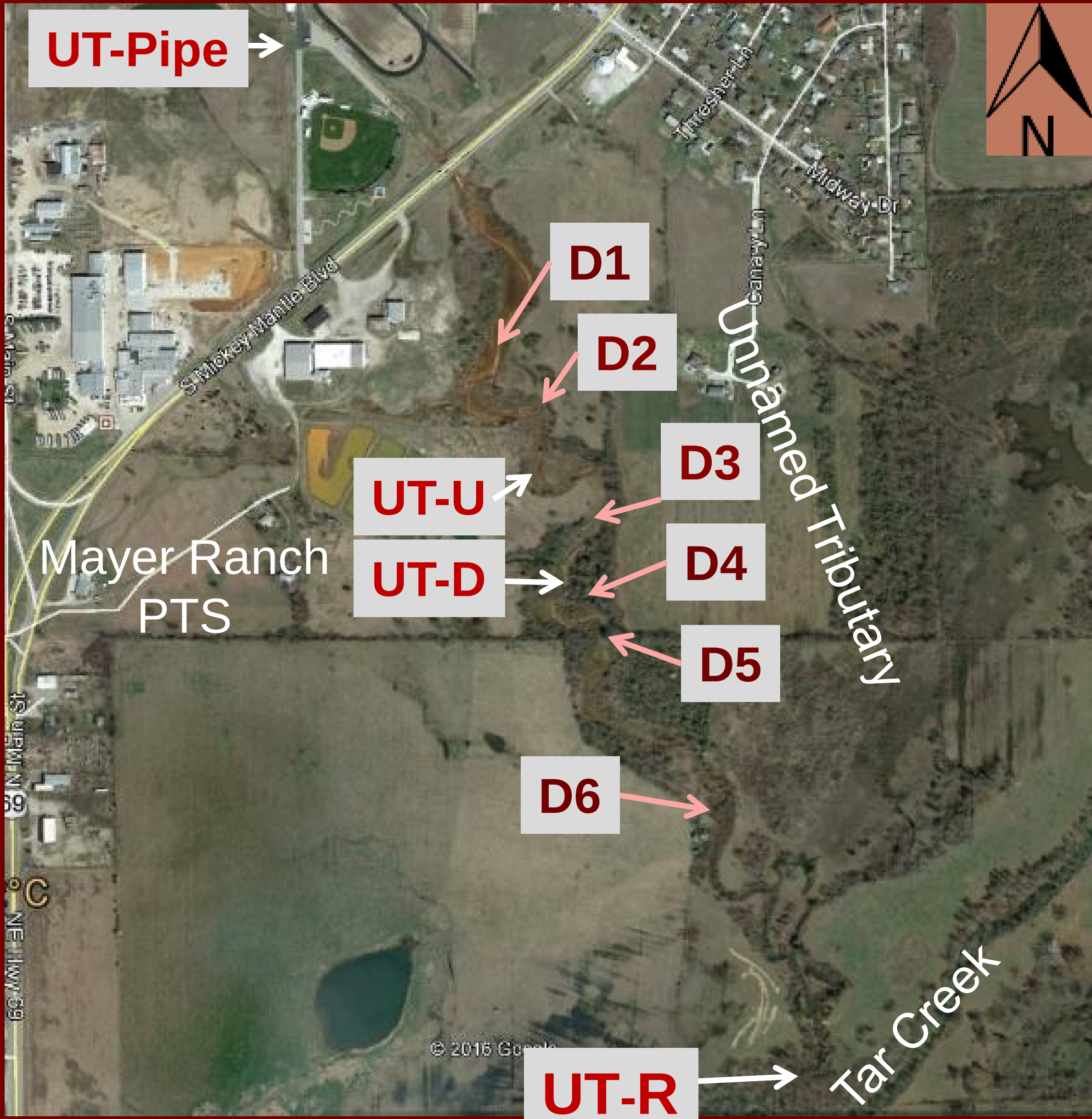
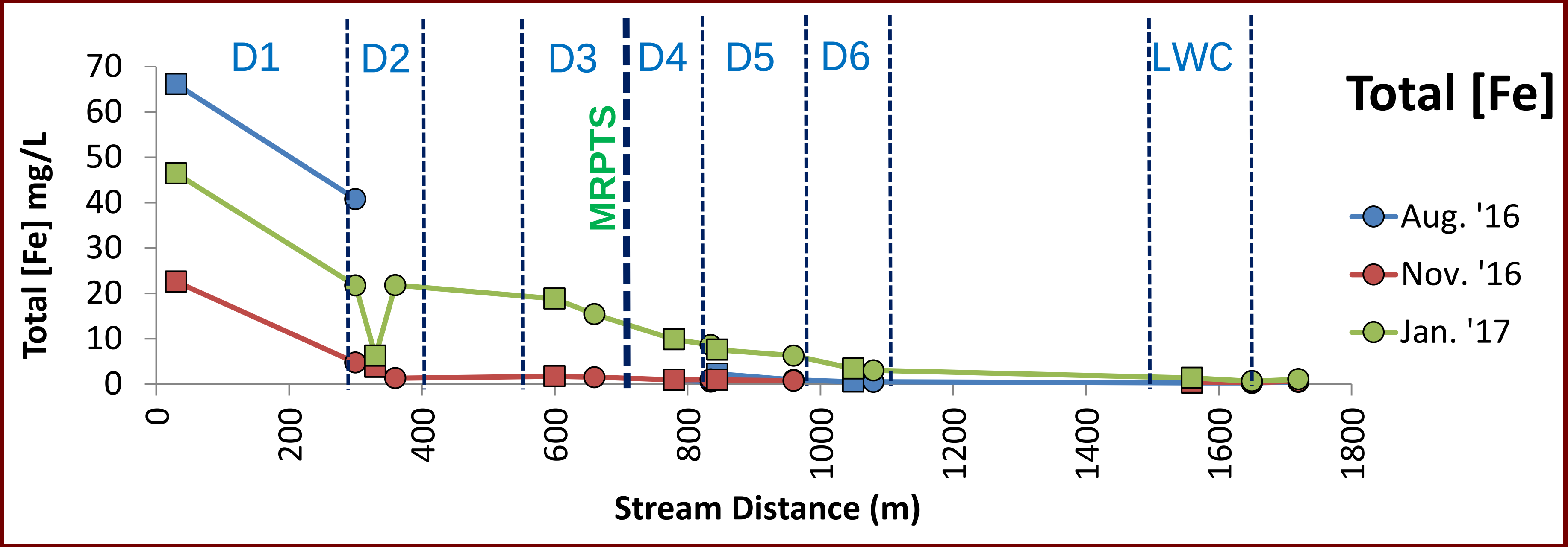
- Beaver recolonization first noted 2013
- Study conducted before SECPTS (online 2017)



Beaver ponds impact water quality

- **Presence of beaver dams decreased [Fe], [Cd], and [Zn] in a mine drainage impacted stream**



Beaver pond Fe removal rate: 4.6 g $m^{-2}d^{-1}$

Beaver Ecological Engineering

- Effective treatment in-stream
- Small (<1 acre) ponds in series
- All systems improved target water quality parameters
- And they provide these ecosystem services for free!

MR-Weir 1998


MR-Weir 2014


SA
SB
MR-W

Beaver maintenance of v-notch weir

Conclusions

Conclusions

- Small ponds and wetlands demonstrably improved water quality in small, drastically disturbed watersheds
- Ecotoxic metal retention rates were not dissimilar in human- and beaver-ecologically engineered ecosystems
- Small ponds and wetlands provided natural infrastructure and resultant quantifiable ecosystem services

CREW Partners for Clean Water

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Mayer, Pritchard, Martin, Corbus, Battles, Burger, Whitlock, Jones and Hulsey families

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