Managed aquifer recharge utilizing riverbank filtration and groundwater transfer and injection for sustainable groundwater-irrigated agroecosystems in the Mississippi Delta

by

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Groundwater Protection Council
Annual Forum and Underground Injection Control Conference
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Partnerships

USDA ARS – Research lead and funding

U.S. Army Corps of Engineers – Design and construction

- Delta Council
- Delta Farmers Advocating Resource Management
- Mississippi Department of Environmental Quality
- Mississippi Farm Bureau Federation
- Mississippi Soil and Water Conservation Commission
- USDA Natural Resources Conservation Service
- U.S. Geological Survey
- Yazoo Mississippi Delta Joint Water Management District

Why Sustainable Aquifer Management?

- *Sustainable groundwater* is a prerequisite for *sustainable development*
- *Managed Aquifer Recharge (MAR)* technology can support sustainable management of aquifers

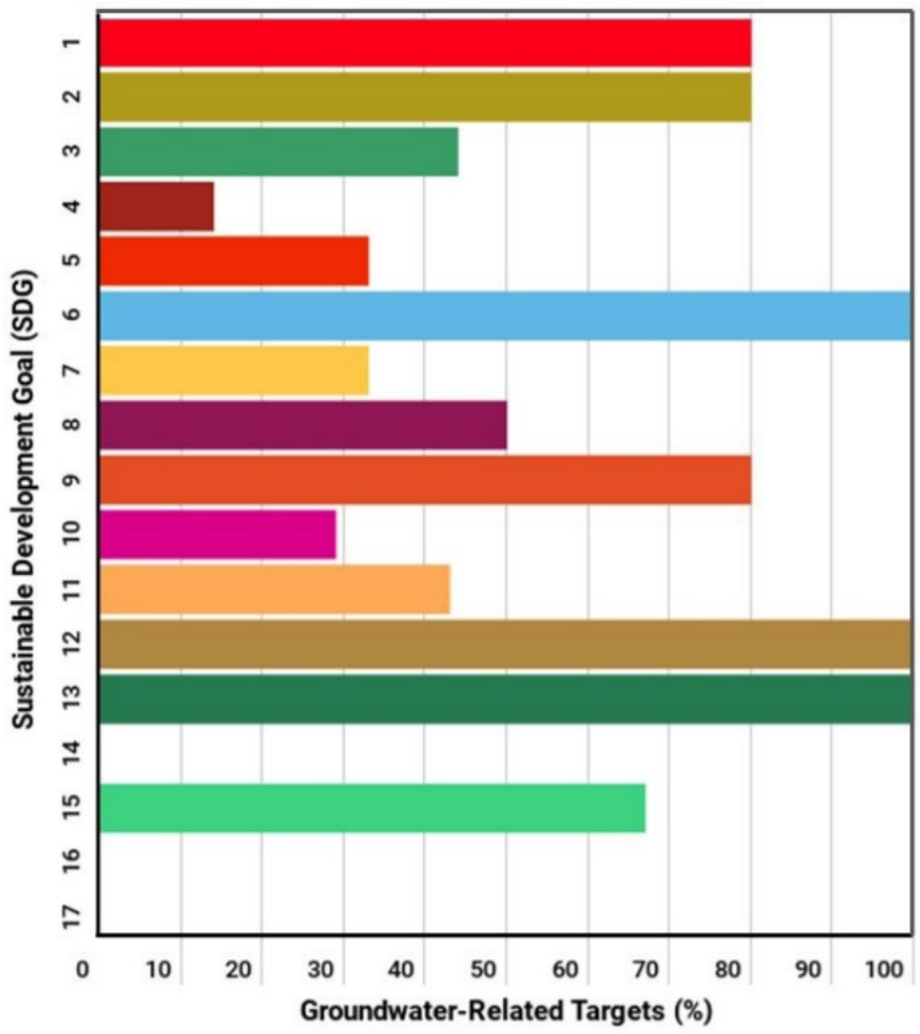

Figure 1. Percentage of groundwater-related targets per SDG

SOURCE: Guppy, L., Uyttendaele, P., Villholth, K. G., Smakhtin, V. 2018. *Groundwater and Sustainable Development Goals: Analysis Of Interlinkages*. UNU-INWEH Report Series, Issue 04. United Nations University Institute for Water, Environment and Health, Hamilton, Canada.

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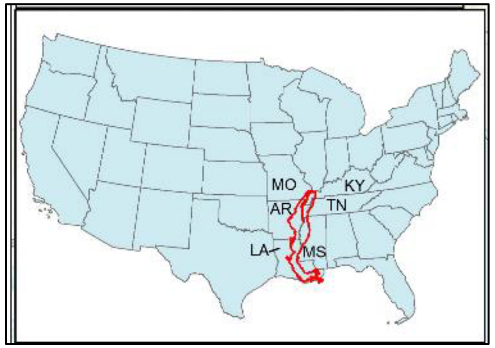
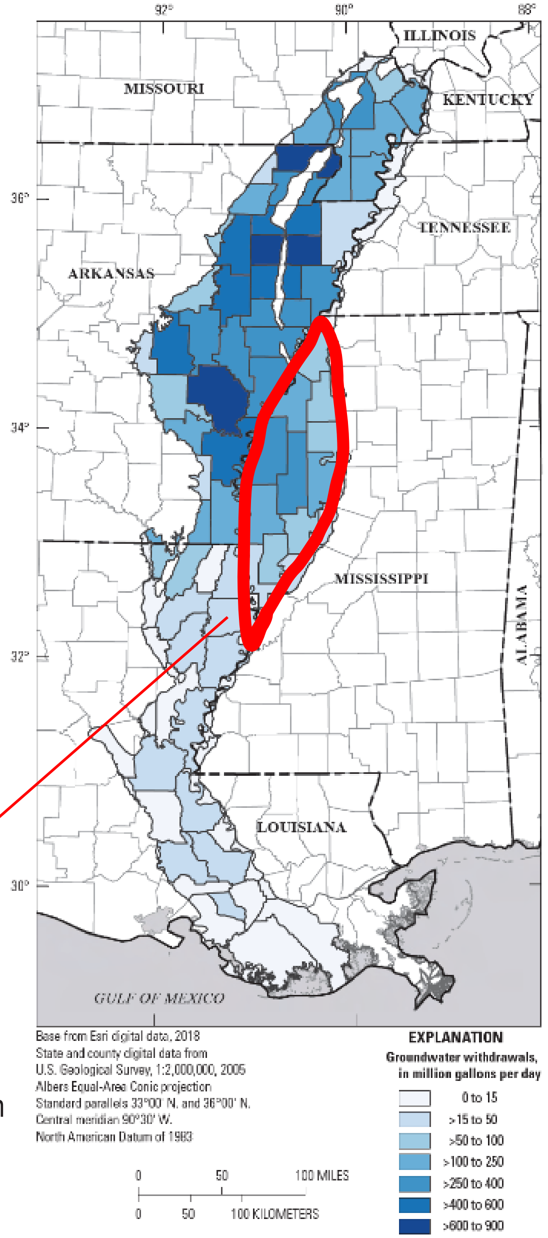
Second highest GW withdrawals in the United States

- The *Mississippi River Valley alluvial aquifer (MRVAA)* had the second highest groundwater withdrawals of any principal aquifer in the U.S. of *12.1 Bgal/day*
- In the humid southeastern U.S, we get a lot of rain – still can have *imbalances* between aquifer inflows (recharge) and natural outflows and pumpage



Groundwater withdrawals for the year 2015

Mississippi Delta



SOURCE: Lovelace, J.K., Nielsen, M.G., Read, A.L., Murphy, C.J., and Maupin, M.A., 2020, Estimated groundwater withdrawals from principal aquifers in the United States, 2015 (ver. 1.2, October 2020): U.S. Geological Survey Circular 1464

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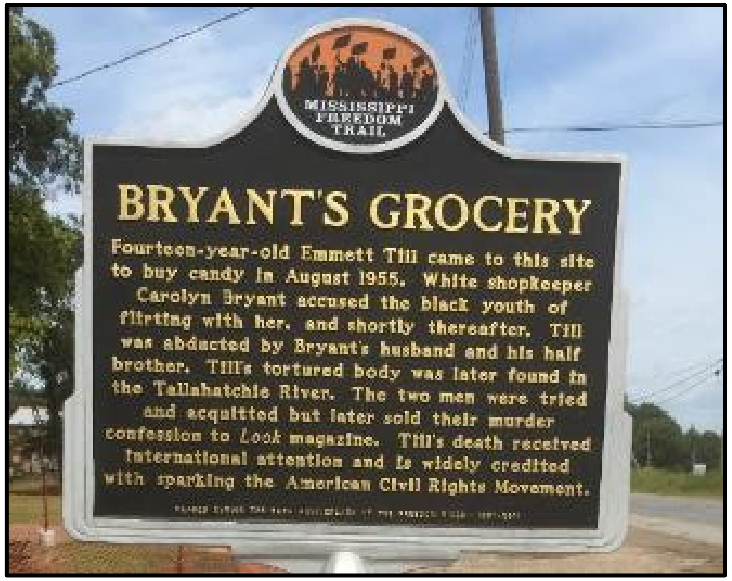
THE MISSISSIPPI DELTA…

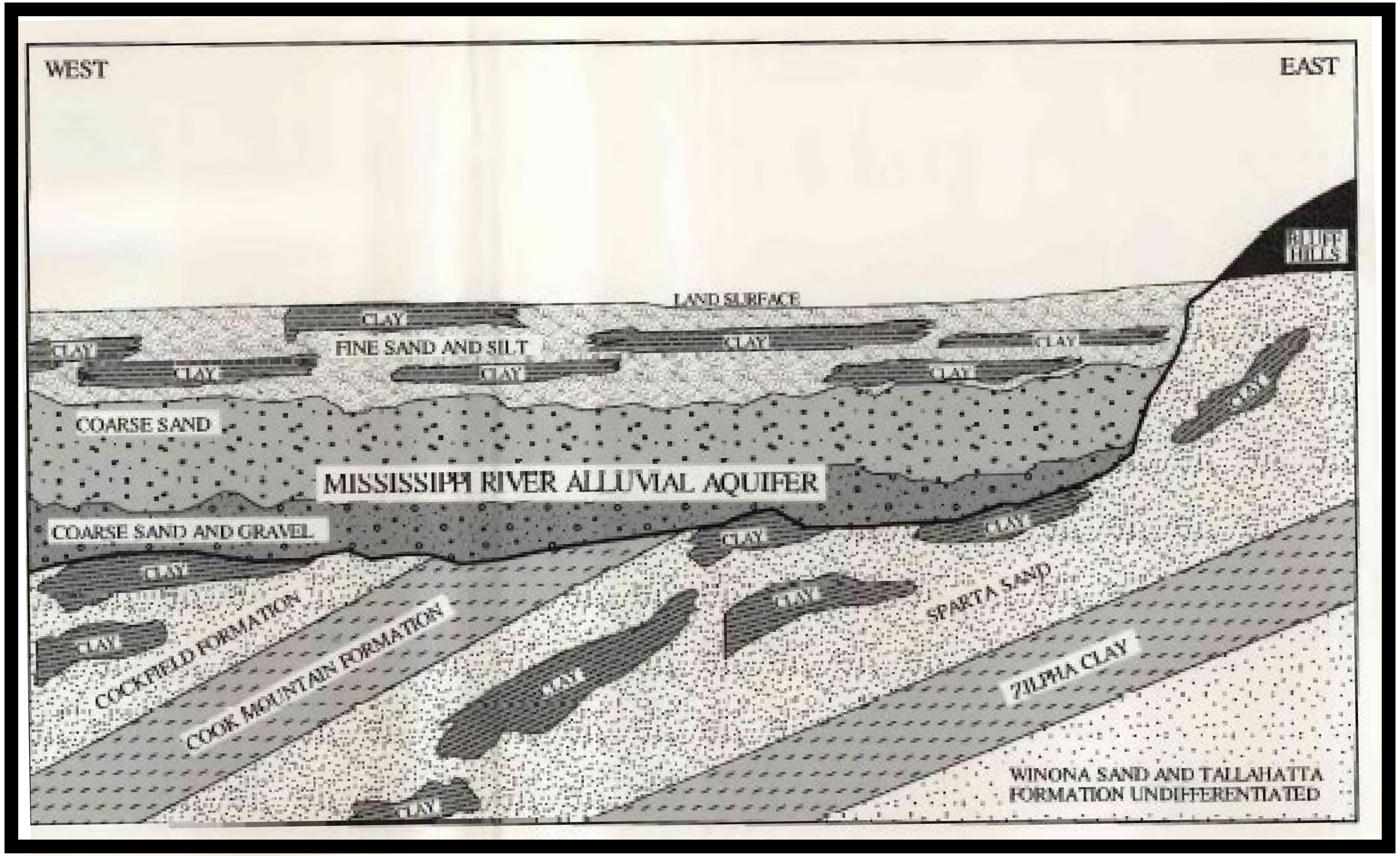


Source: https://www.bbking.com/gallery/

- Birthplace of the blues and other uniquely American musical genres
- Extreme hardship due to the history and enduring legacy of slavery, sharecropping, segregation, and racism and the unpredictability of the Mississippi River itself
- Major producer of food, fuel, and fiber products, yet many communities are suffering from pervasive and long-term economic depression
- Increased water security thorough sustainable management of the MRVAA would support a sustainable agroecosystem and economic opportunity in the Delta

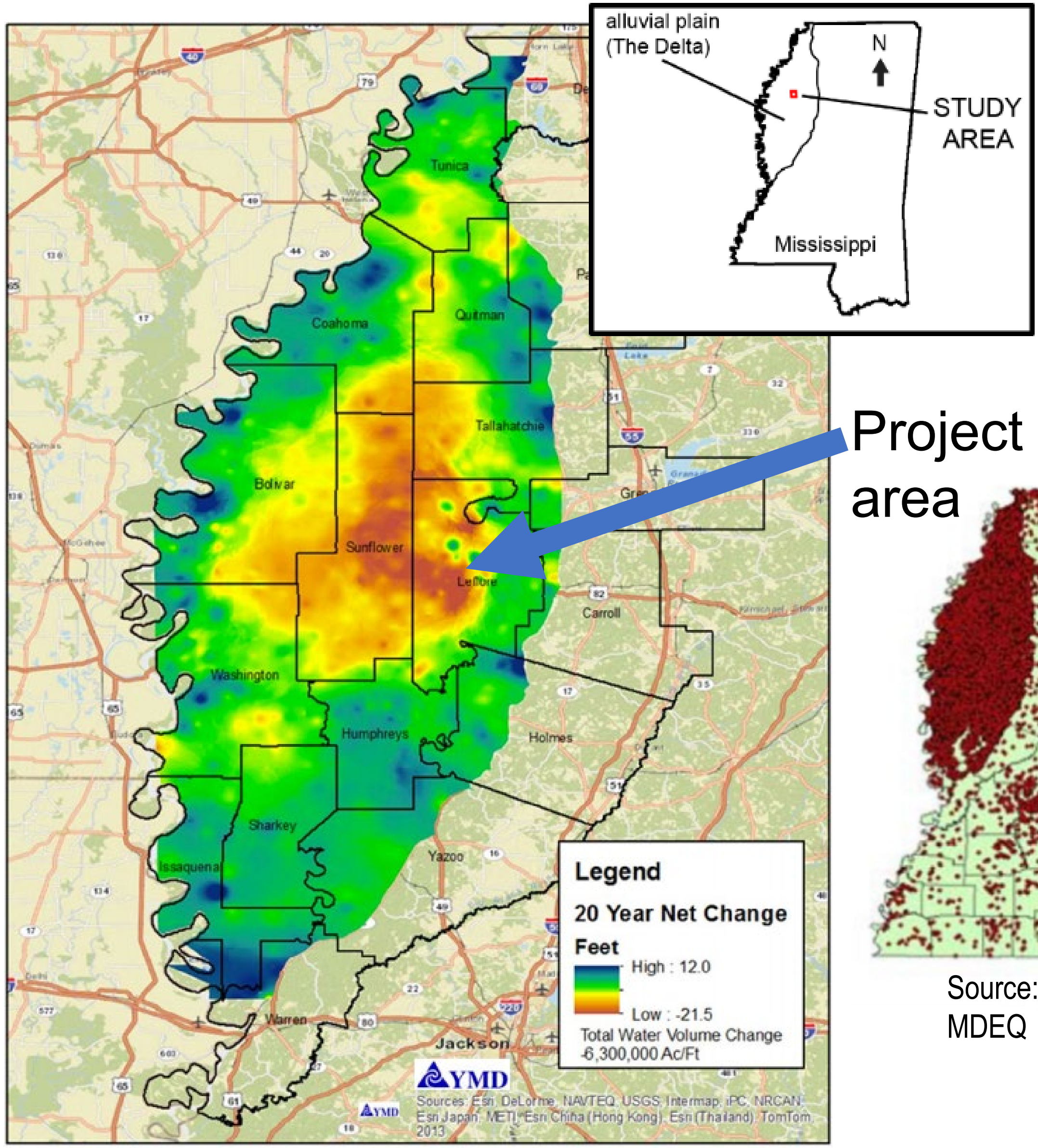
Complex hydrogeology of MRVAA

- Surficial aquifer system, 20 to 200 ft thick
- Semi-confined by surficial layer of silt and clay
- Permeable zones consist of coarse sand and gravels

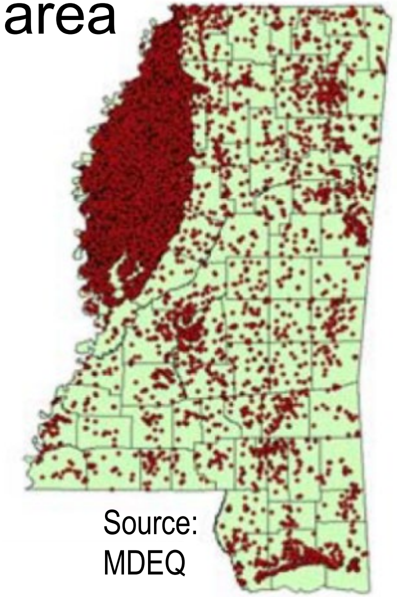


Source: Arthur, J.K., 1994, Thickness of the upper and lower confining units of the Mississippi River alluvial aquifer in northwestern Mississippi: USGS WRIR 94-4172

Mississippi Delta – A groundwater-irrigated agroecosystem under stress



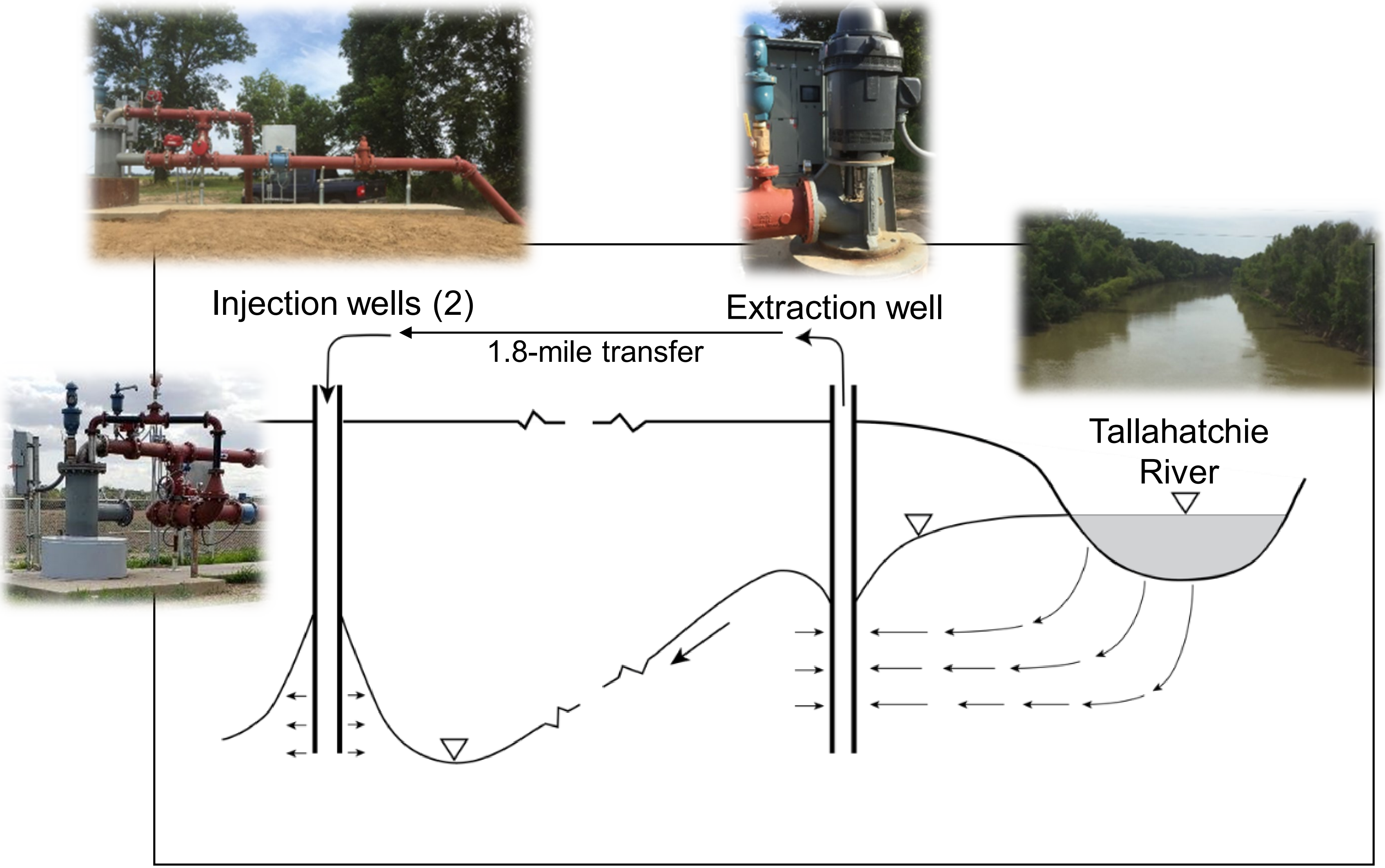
Source: YMD Joint Water Management District, 2014 Water Level Survey



Source:
MDEQ

- 3,000 → 21,000 irrigation wells from 1980's to today
- 3.3 Million ac-ft of GW loss within the cone of depression from 1987 to 2009
- *Aquifer injection and storage* identified as a MAR technology to potentially reverse groundwater depletion

Groundwater Transfer and Injection Pilot Project



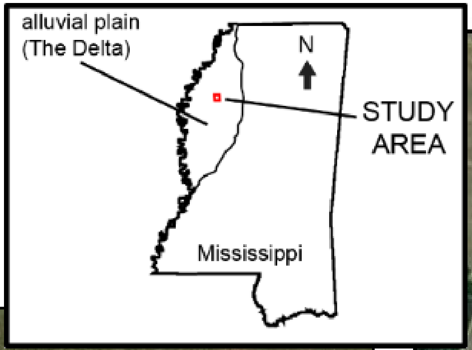
1) ***Extract*** groundwater of improved quality via riverbank filtration
2) ***Transfer*** water to area of greater groundwater depletion
3) ***Inject*** water into aquifer storage
4) Withdraw groundwater as needed using ***existing infrastructure***

Project objectives

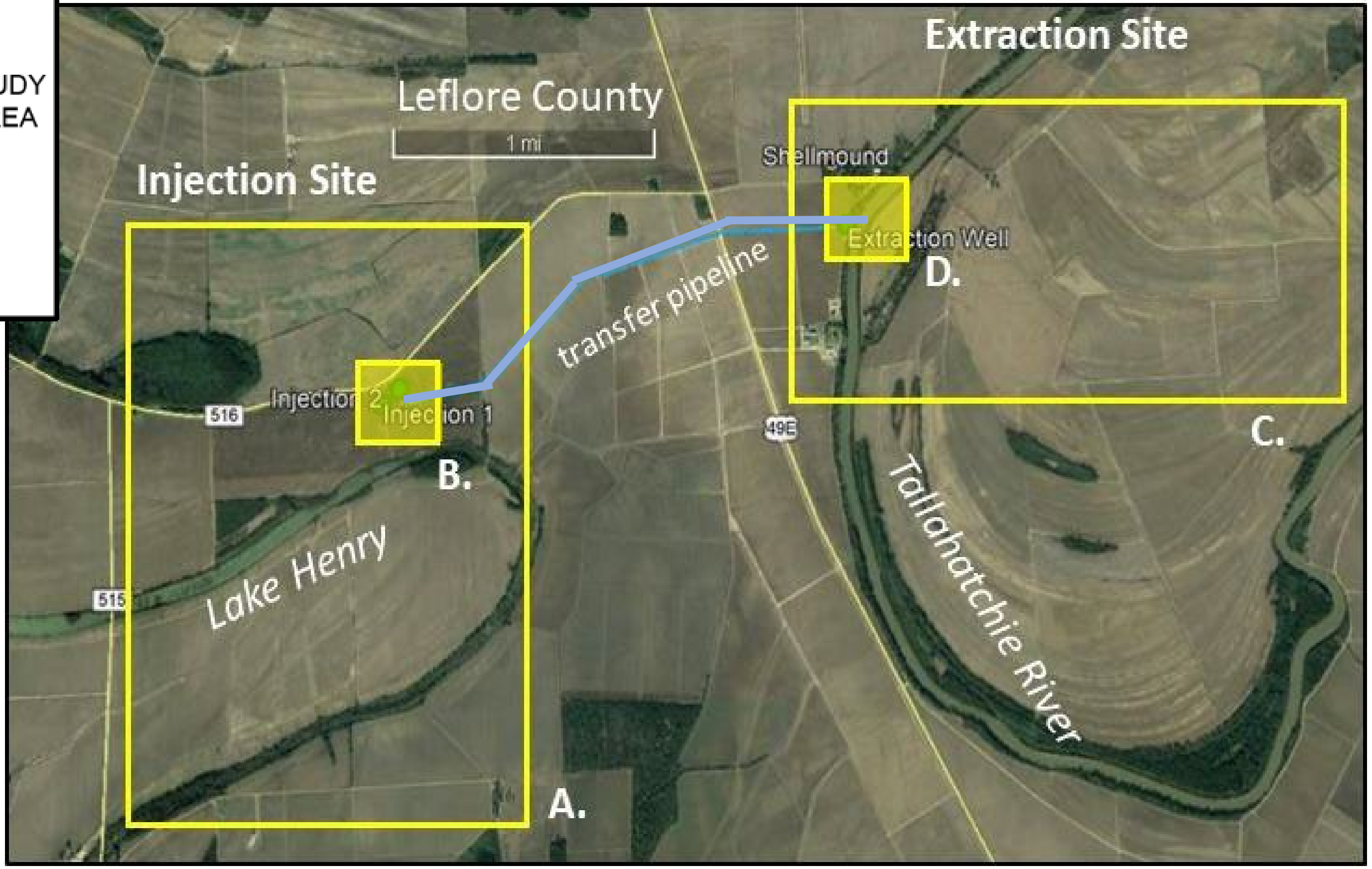
- Pilot facility to *assess feasibility*
- Identify *sustainable injection* rate and *O&M requirements*
- Is this a viable path toward *sustainability* in the region?

Extensive soybean and corn fields surrounding injection well site (looking south)

System configuration



Backflush discharge
into Lake Henry



Extraction and Injection sites
at Shellmound, Mississippi

System characteristics

- $1.9 million construction costs
- One extraction well with variable frequency drive (up to 1,500 gpm)
- Two injection wells, each with permitted capacity 750 gpm
- 16-inch diameter wells
  - Extraction well: 63–113 ft depth of withdrawal
  - Injection wells: 80–120 ft depth of injection
- Submersible pumps in both injection wells for backwash (1,200 gpm)

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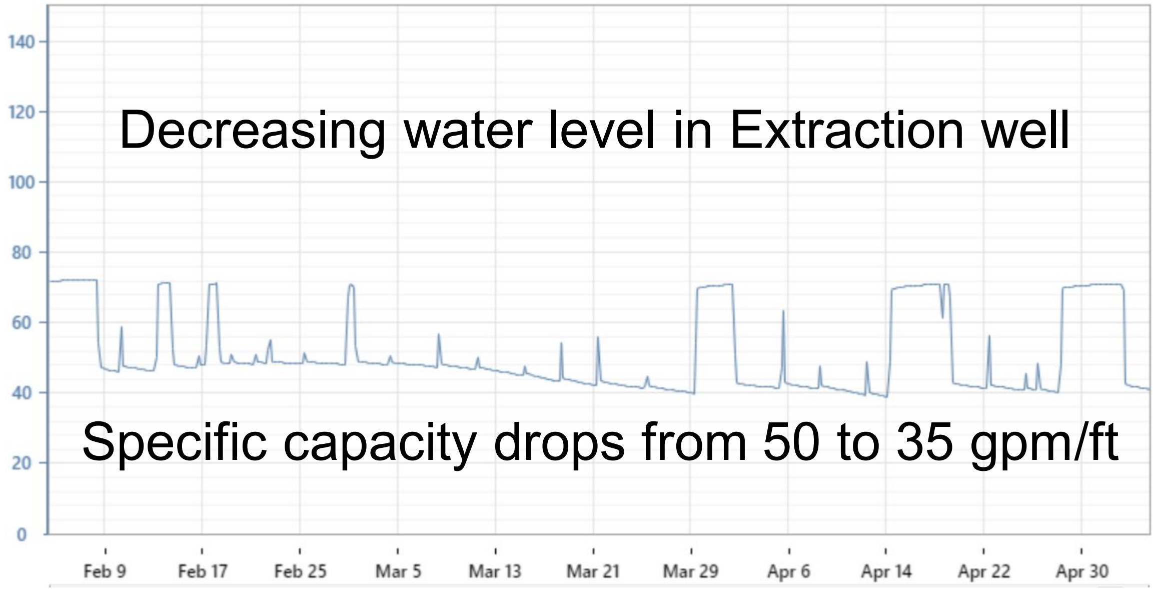
Operational tests

- <u>Initial 3-month test</u>:
  - April 14 – July 12, 2021
  - Injected total of 550 ac-ft
  - Average injection rate 730 gpm/well (total 2.1 MGD; minimum daily mean river flow is 378 MGD)
  - Well clogging, leaks, and rehabilitation

- <u>2nd test period</u>:
  - Started February 8, 2022
  - Injected total of 420 ac-ft (by June 16)
  - Average injection rate 1,150 gpm; alternating wells (600 gpm/well) began May 13
  - Backflush twice per week to minimize well clogging

Some challenges…

- Natural *high iron concentrations*
  - Fouling of sensors by iron precipitation
  - Biofouling of injection wells
  - Discharge of backflush water to Lake Henry exceeds 1 mg/L total iron limit in NPDES permit



- *Sand boils and leakage* of injected water at land surface
- *Sinkhole* at extraction well and decreasing specific capacity possibly due to well sanding

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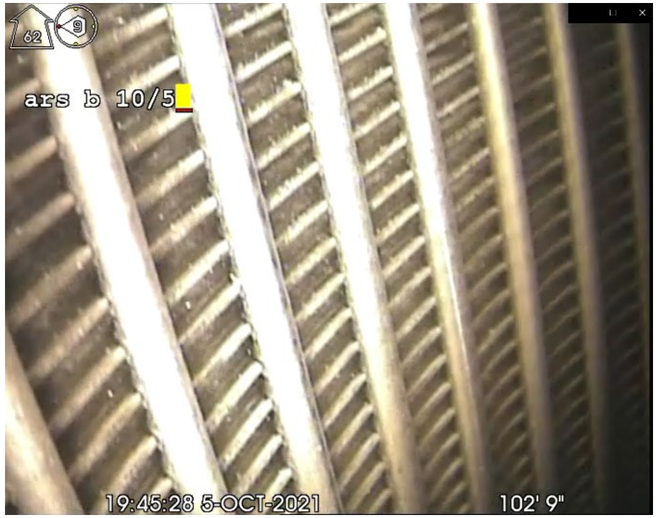
Sand boils and well rehabilitation

- Most-permeable injection zones *clogged* with iron bacteria causing *increased pore-water pressure*
- Exceeded buoyant weight of overburden
- USACE conducted *oxalic acid rehabilitation* of both injection wells Sept. 22–28
- Specific capacity returned to *~90%* of initial value (~40–50 gpm/ft, May 2021); now ~110–120% of initial value

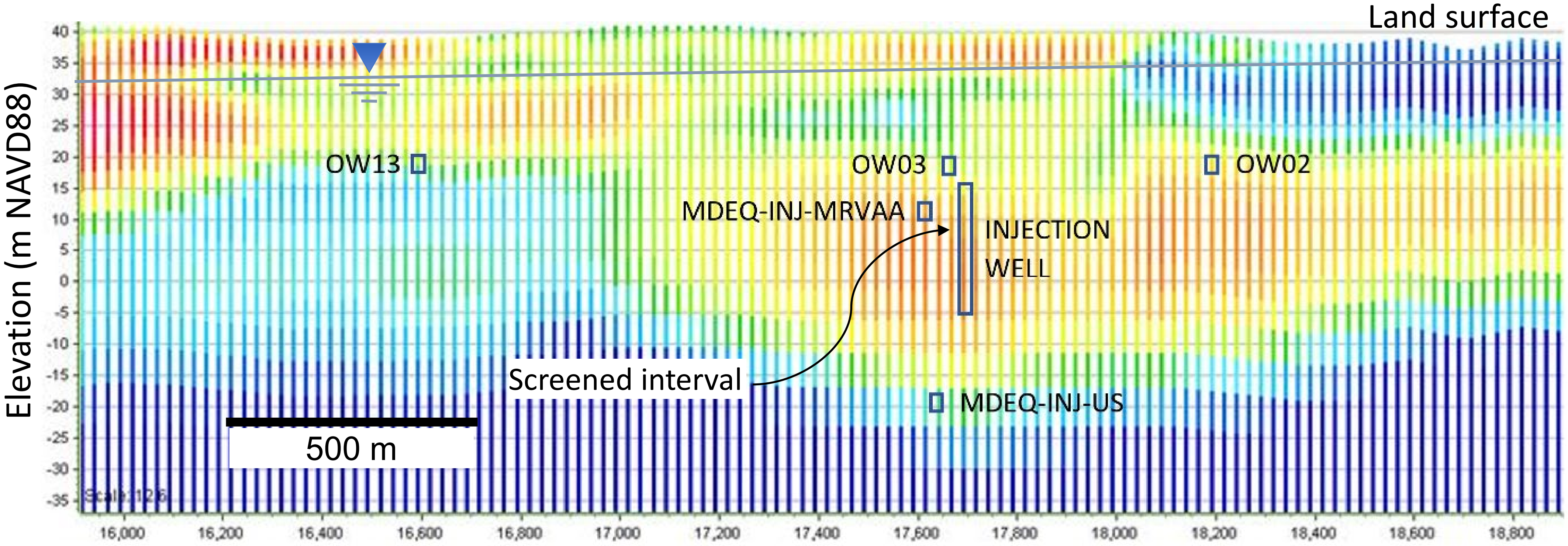
Injection Well B before rehab



Injection Well B after rehab

Airborne electromagnetic geophysical survey shows complex geological heterogeneity

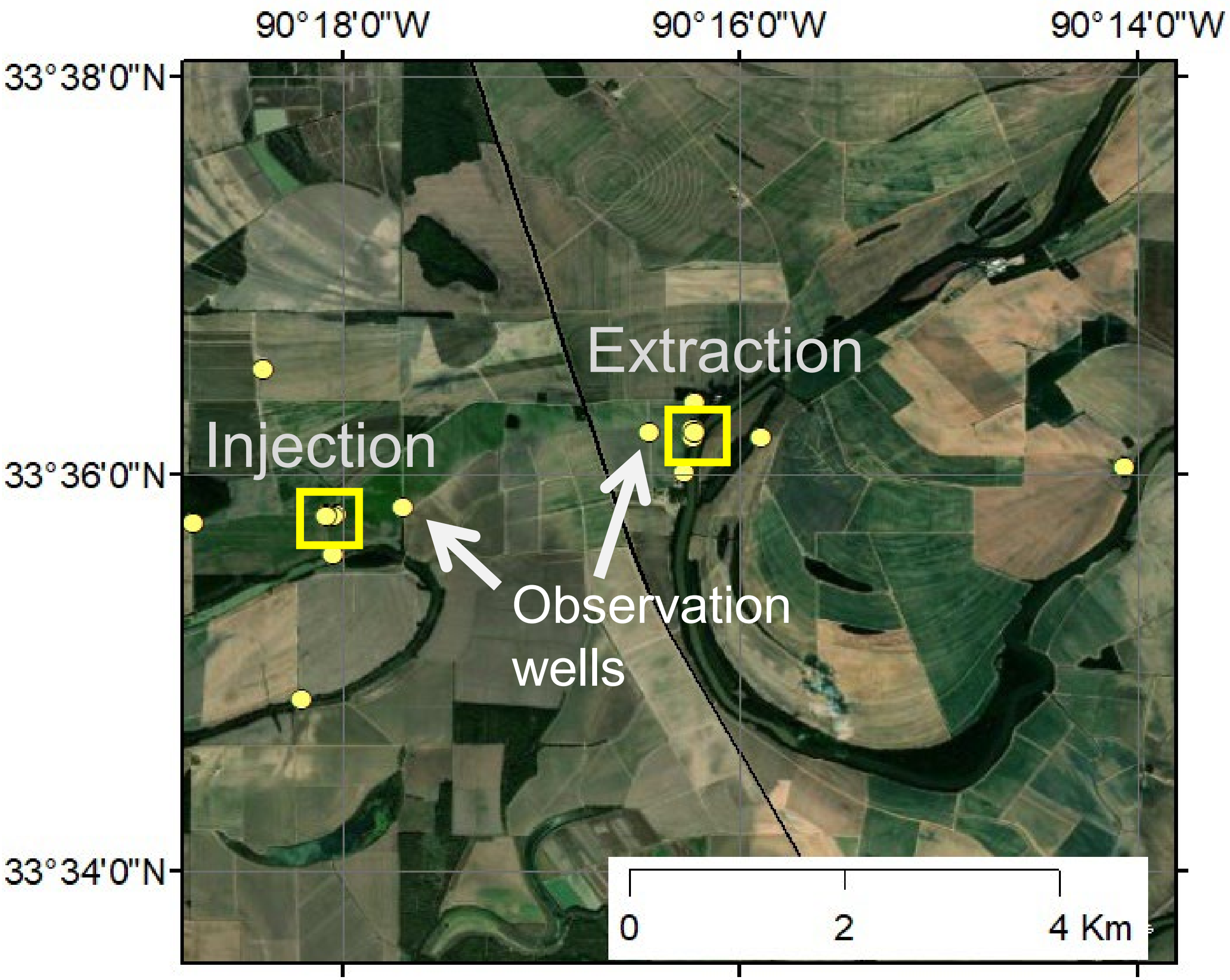
- Variations in lithology likely contributed to soil piping at injection wells (& extraction well)
- Higher resistivity (yellow and warmer colors) are more sandy texture sediments
- Heterogeneity a key control on groundwater flow and quality



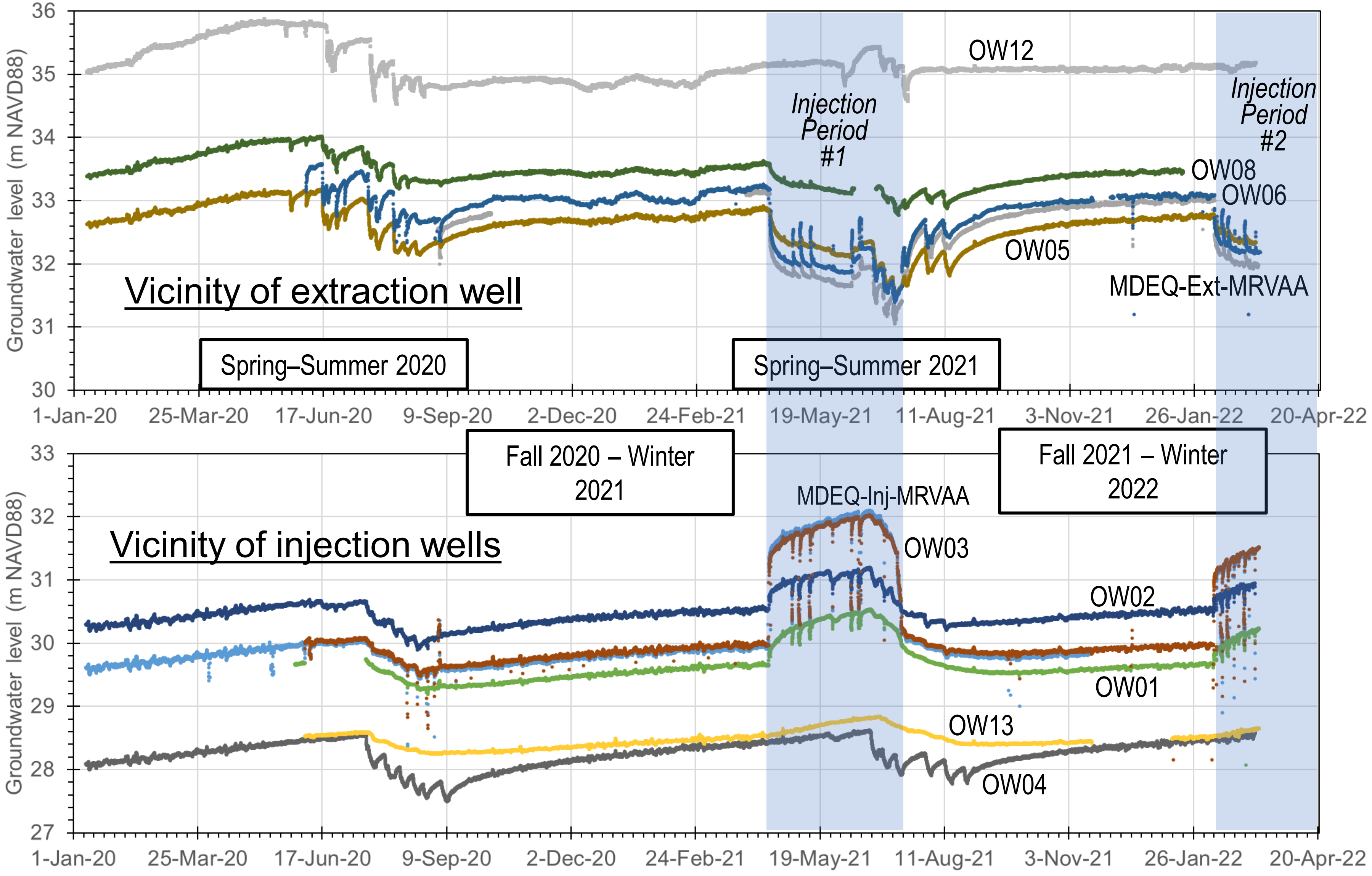
Source: Burton, B.L., Minsley, B.J., Bloss, B.R., Rigby, J.R., Kress, W.H., and Smith, B.D., 2019, Airborne electromagnetic, magnetic, and radiometric survey, Shellmound, Mississippi, March 2018: U.S. Geological Survey data release, https://doi.org/10.5066/P9D4EA9W

Monitoring of water quantity and quality

- 17 Observation wells
- All wells (including extraction and injection wells) *continuous (hourly) groundwater level*
- 6 wells *semi-monthly field water quality* (temperature, specific conductance, pH, DO)
- All wells *monthly lab water quality* by USACE ERDC lab in Vicksburg, MS
- Other water quality sampling: Tallahatchie River, injection well backflush, Lake Henry (backflush impact)

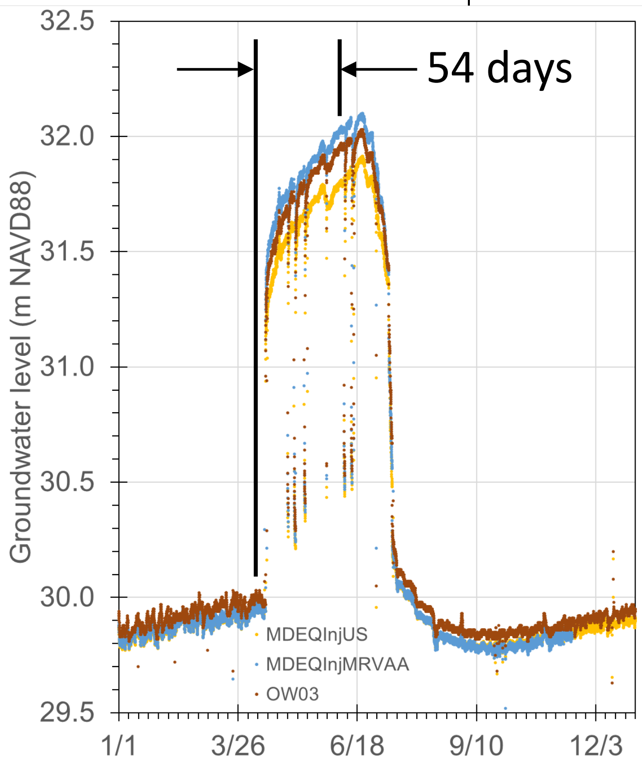


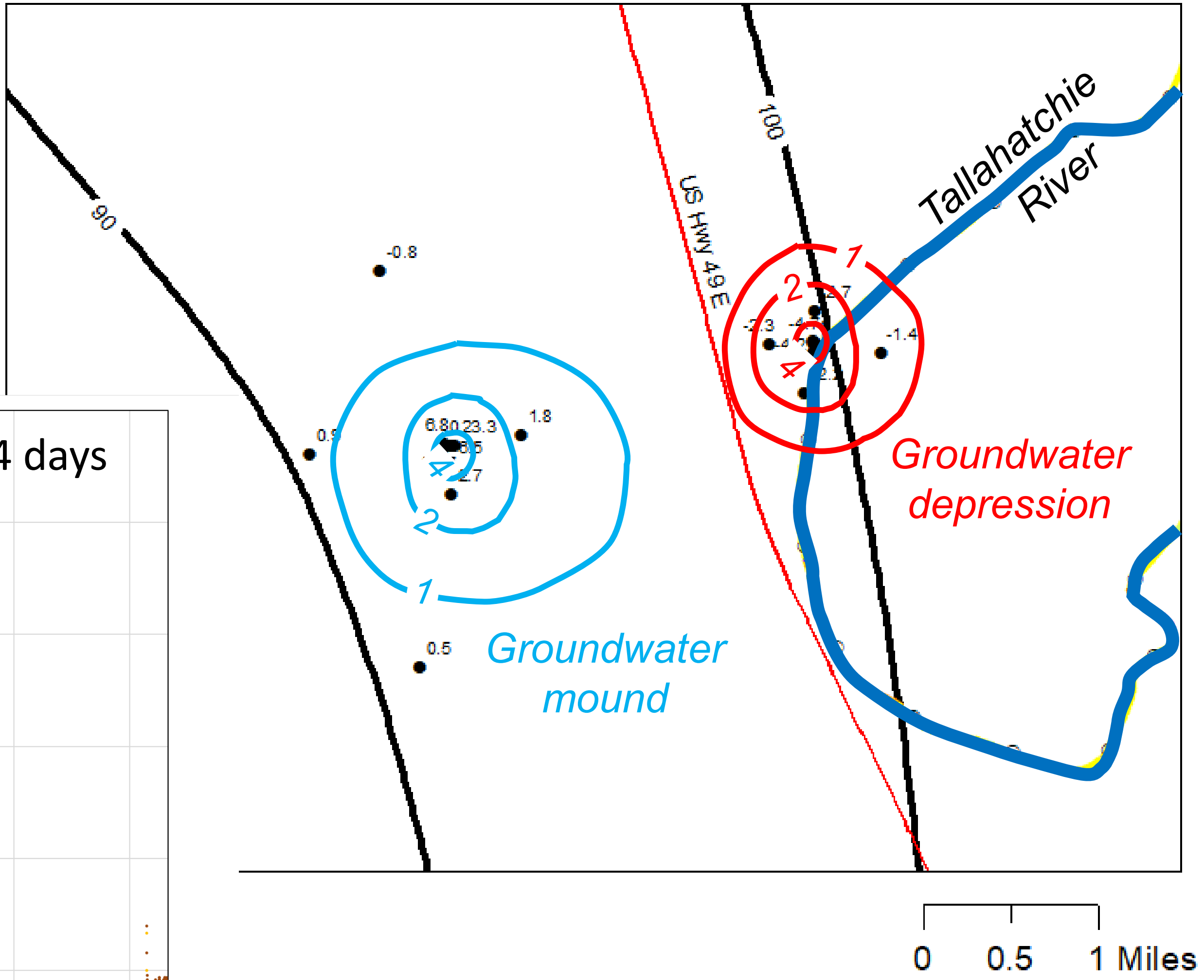
Groundwater levels vary by season, withdrawals, and injection



Water level impacts larger from injection than extraction

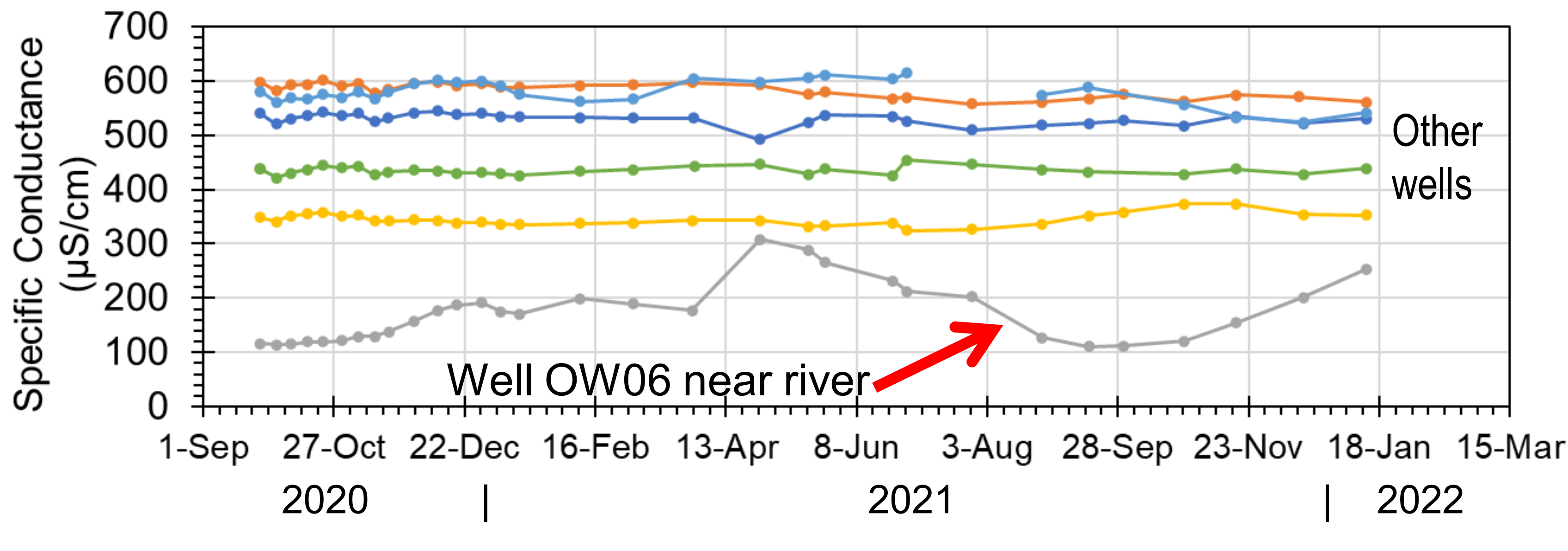
- Water level change 54 days into Injection Period 1 (June 7)
- Groundwater mound up to 7 ft high
- Groundwater depression up to 5 ft deep
- Depression smaller than mound likely due in part to recharge by river water

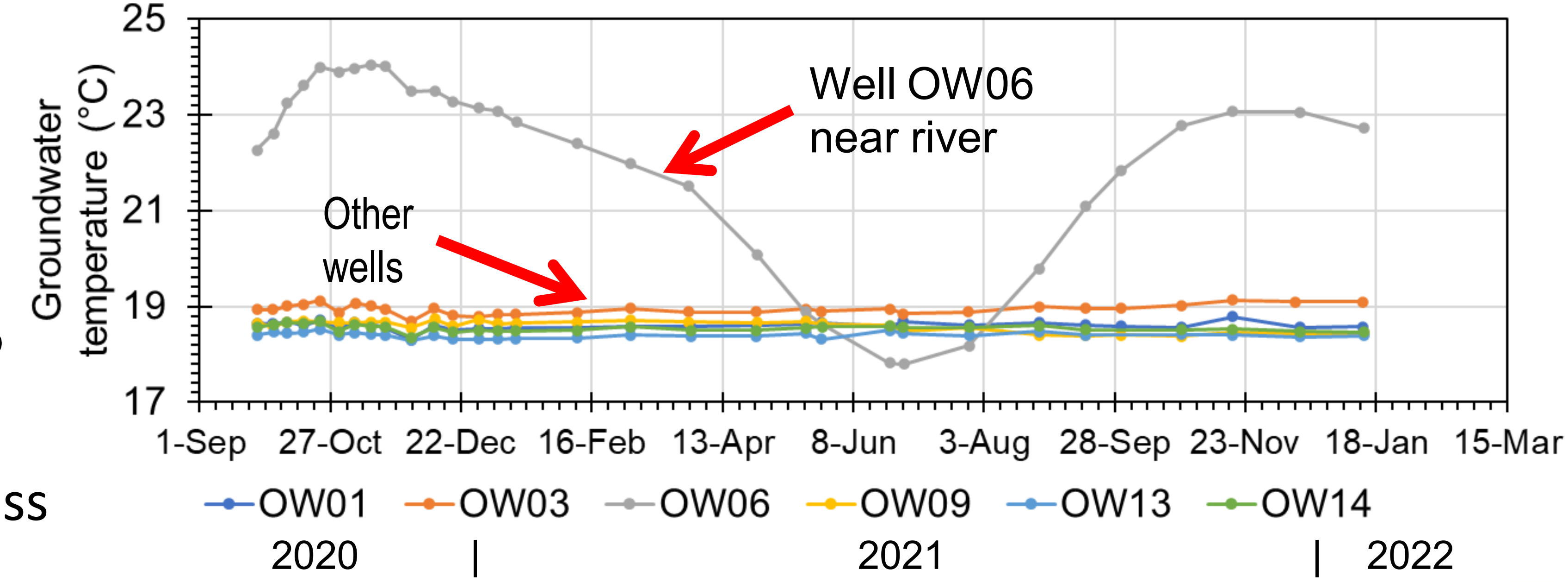




Aquifer recharge by river leakage

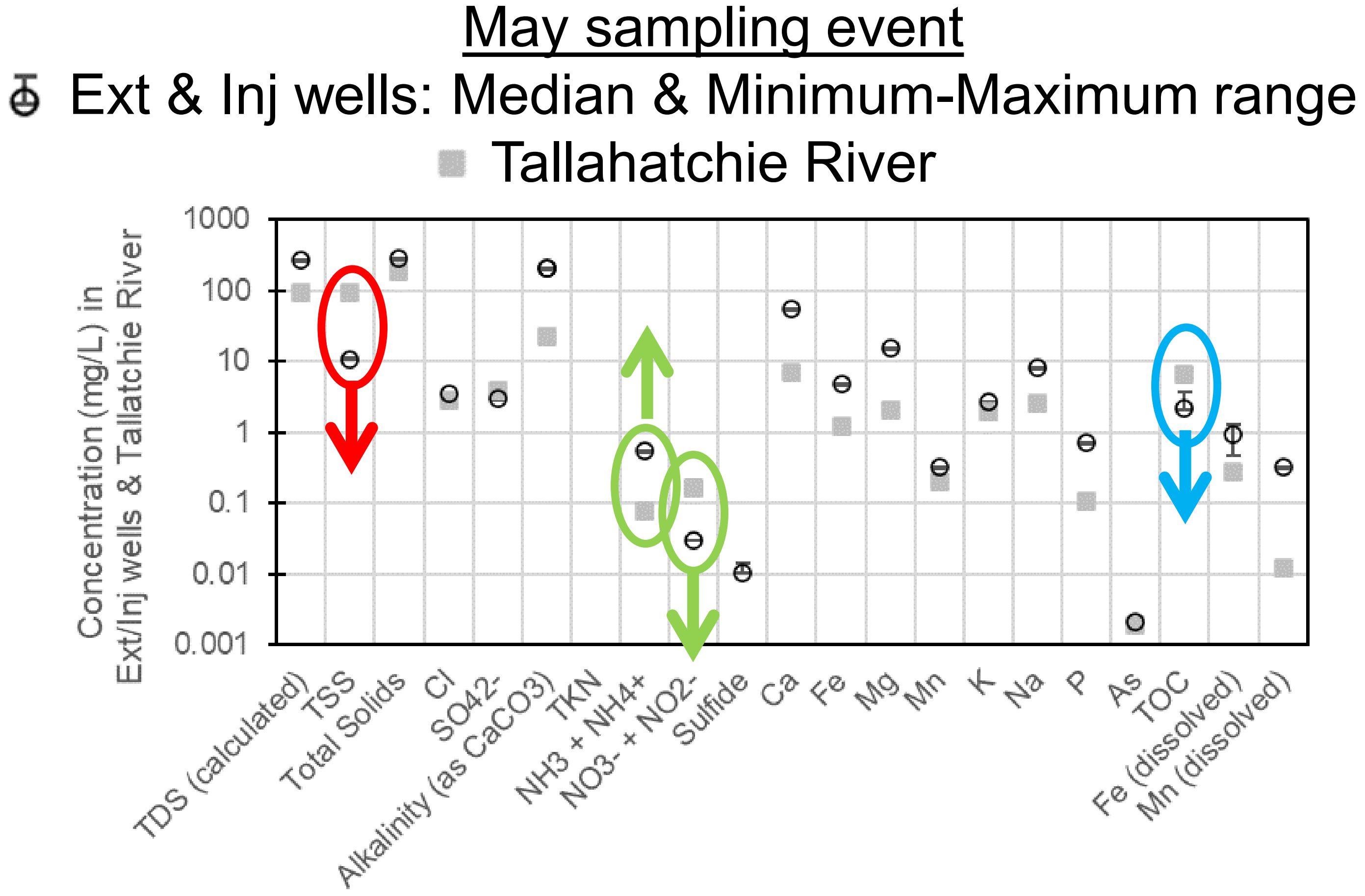
- Water quality field measurements indicate
  - *Lower specific conductance* near the river compared to injection site
  - Strong *seasonal pattern* in groundwater *temperature* at well OW06 nearest river
- Consistent with *leakage* of less mineralized *river water into aquifer*





Water quality changes during riverbank filtration

- River oxic → Groundwater suboxic: DO 6+ (river) and <0.3 mg/L (well)
- 10x decrease in **TSS** concentration – likely filtration
- Loss of **Nitrate** – may be due to denitrification, or increased **NH_4^+** suggests ammonification (DNRA)
- Loss of **TOC** – likely filtration and biogeochemical oxidation
- Increases in nearly all other analytes – mineralization likely caused by rock-water interaction and biogeochemical processes

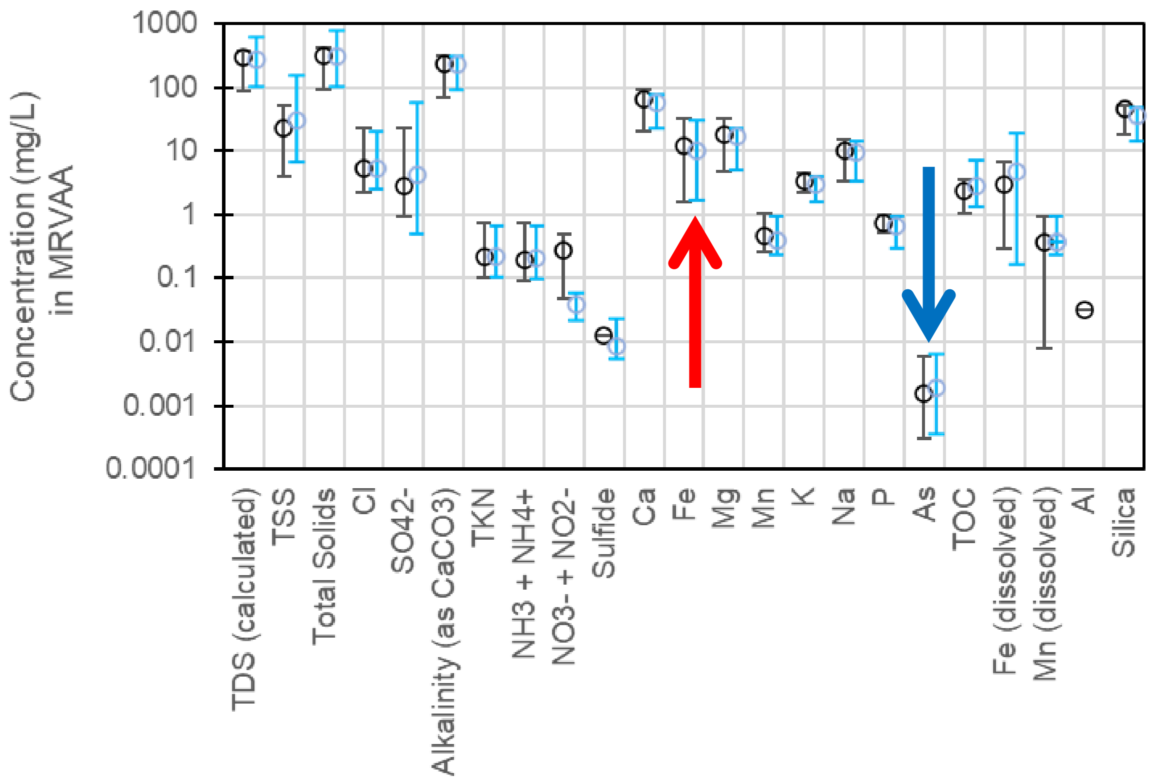


Groundwater quality before and after first injection period

- High **Iron** concentration – naturally occurring – may support bacterial growth and iron mineral formation
- Low **Arsenic** concentration. USEPA drinking water limit 0.01 mg/L
- Overall, small changes in MRVAA water quality *on average*

March and **November** sampling events

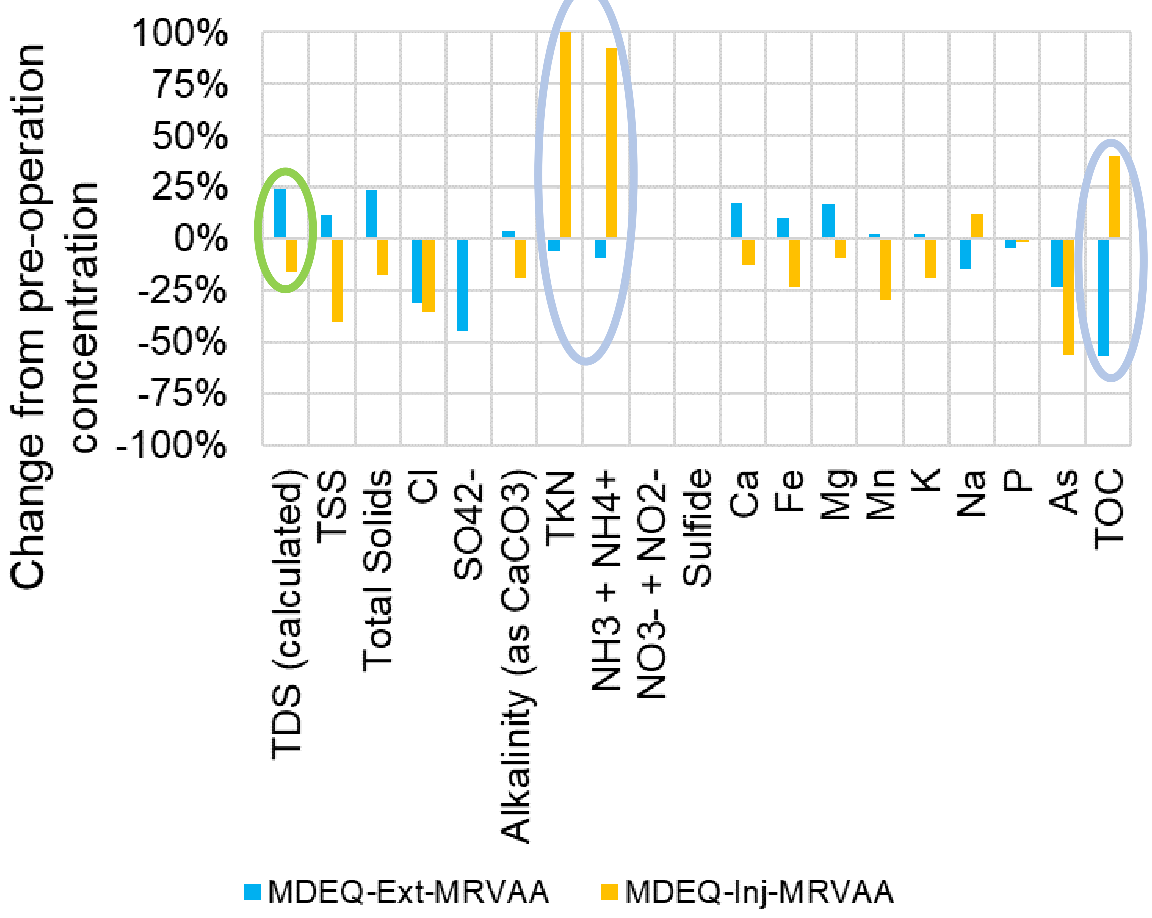
Observation wells: Median & Minimum-Maximum range



Different changes in mineral and nutrient content of groundwater at extraction vs. injection sites

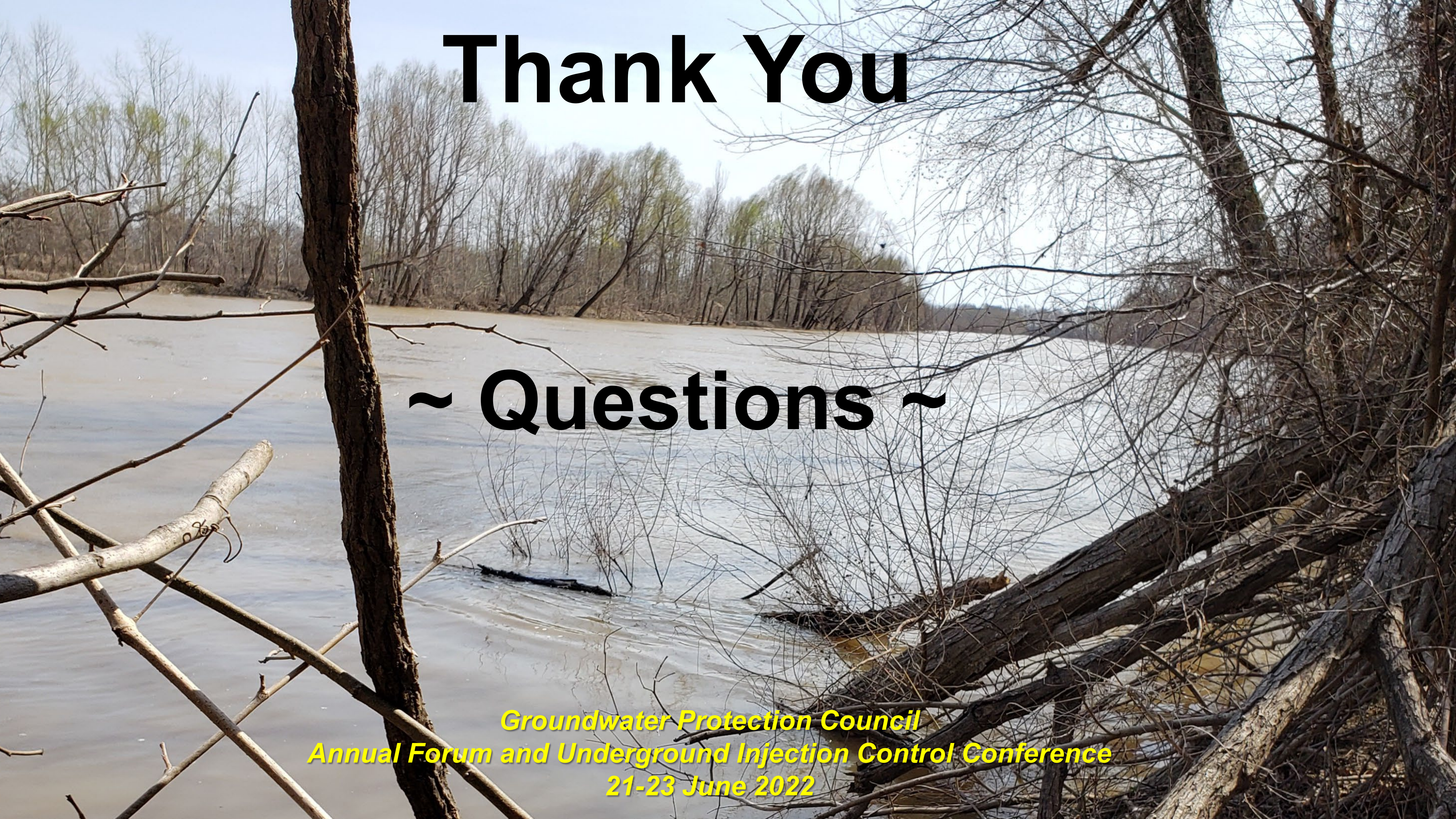
- Change from March (pre-operation) to November 2021
- Compare observation wells nearest the extraction and injection wells and screened at similar depths
  - TDS increases at extraction and decrease at injection
  - Nutrients (TKN, NH_4^+, TOC) decrease at extraction and increase at injection

Extraction and **Injection** observation wells



Current Status and Future Work

- Complete Injection Period #2 for a duration of up 6 months
- Determine best O&M practices for safe ***injection rate*** and ***backflush frequency***
- Assess environmental and hydrological sustainability of the technology
  - Regional modeling – USGS
  - Local-scale modeling, Hydrogeology, and Geochemistry – USDA-ARS and Univ. of Mississippi
- Assess technical and economic feasibility of a larger scale implementation


Thank You
~ Questions ~
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