Enhanced Aquifer Recharge (EAR) Project

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6th Annual Oka' Institute Sustainability Conference

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Enhanced Aquifer Recharge Project Contributors

- **Randall Ross, Doug Beak, Jon Fields, Russell Neill, Justin Groves (USEPA)**
- **Tyler Tandy (ORAU)**
- **Todd Halihan (OSU/AESTUS)**
- **Guy Sewell (ECU/City of Ada)**
- **Wayne Kellogg (CN, Retired), Kris Patton (CN)**
- **Robert Keys and others (AEI)**
- **Shana Mashburn and others (USGS)**

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ASR – EAR: Similar But Different

- EAR - rural landscape application of aquifer storage and recovery (ASR).
- Goal - *enhance spring and base flow*, by capturing overland flow *during significant rainfall* events, and creating conditions that facilitate infiltration.
- May allow for water to be stored during time of excess to increase availability during times of scarcity.

- **Research Objective – Evaluate impact of surface water (overland flow) recharge via natural karst features on groundwater *quality* and *quantity* using traditional and innovative hydrogeological, surface and borehole geophysical and geochemical methods.**

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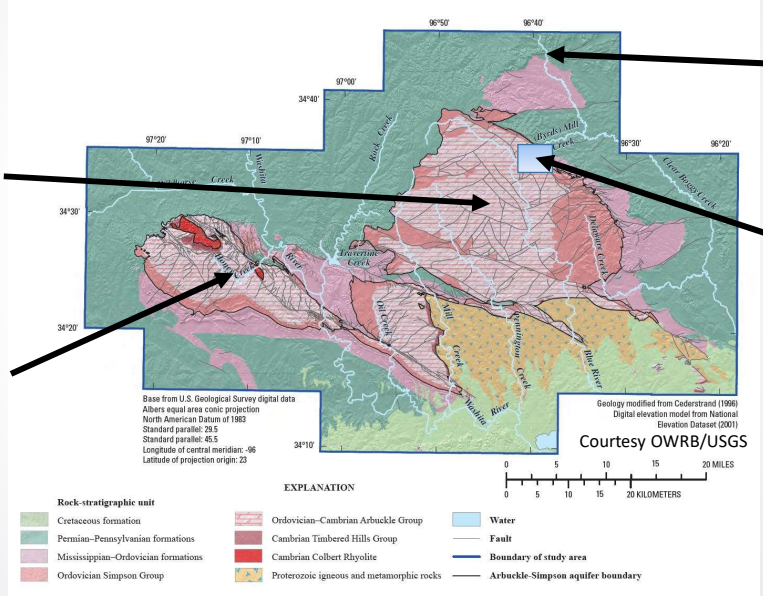
Arbuckle-Simpson Aquifer Geology

Ada (GCRD)

Hunton Anticline

EAR Study Area

Arbuckle Mountains



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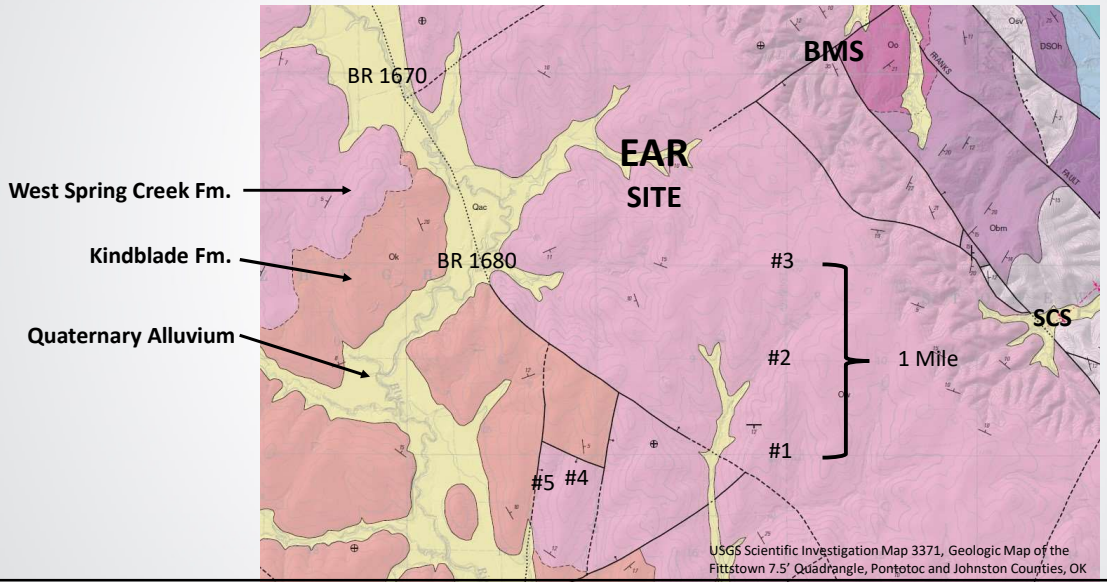
EAR Area Geology



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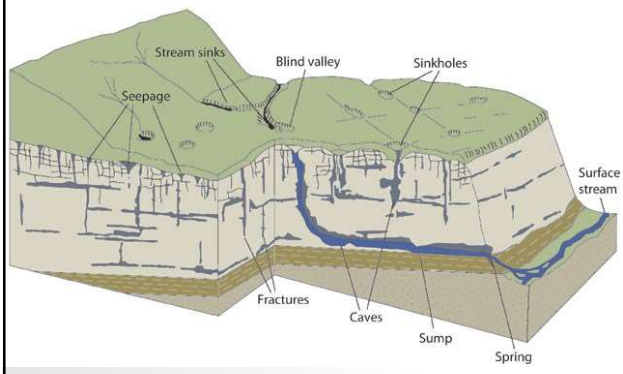
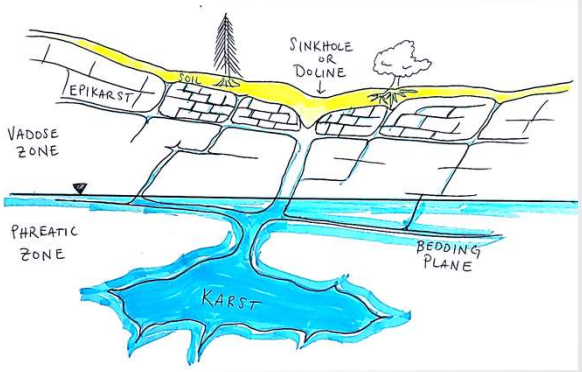
Karst Hydrogeology



Source: Wisconsin Geological and Natural History Survey, 2021



Source: Jon Fields, 2021

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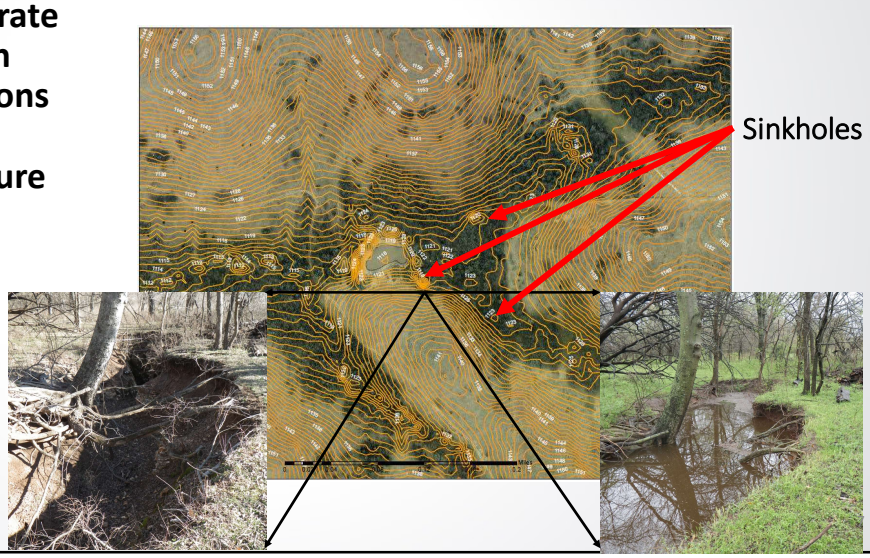
LIDAR Contour Map with Visible Sinkholes

- **Estimated recharge rate ~1400 gpm based on volumetric calculations and water level declines (e.g., pressure transducer data).**



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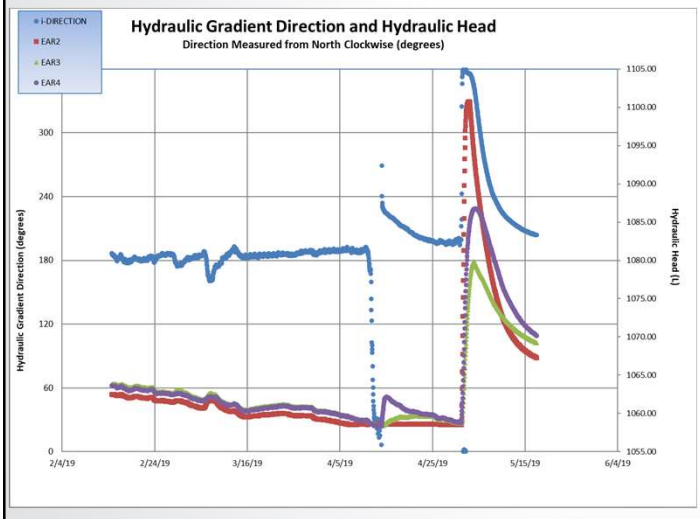
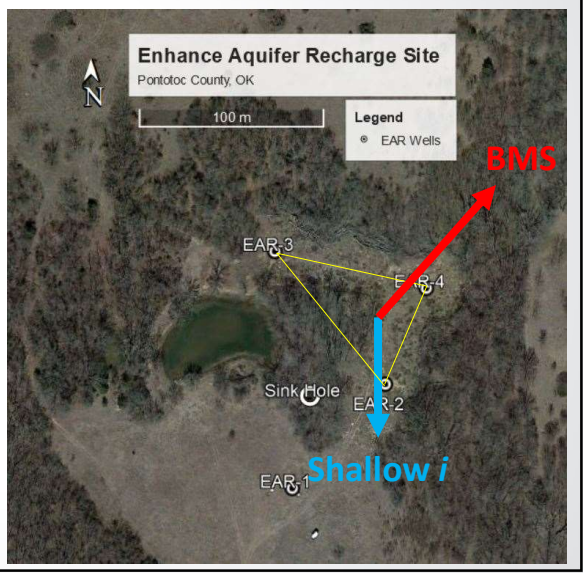
EAR Pilot Study Hydrology





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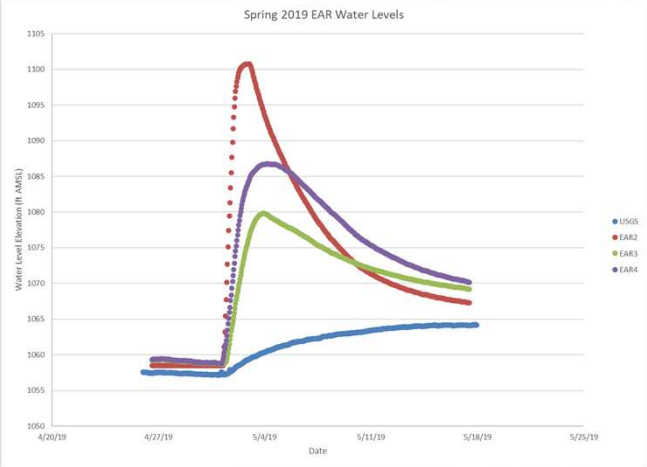
Site Conceptual Model (CSM)

- **Overland flow recharge via karst features temporarily stored in epikarst**
- **Flow through vadose zone via karst features and fractures**
- **Shallow groundwater recharges deeper aquifer**



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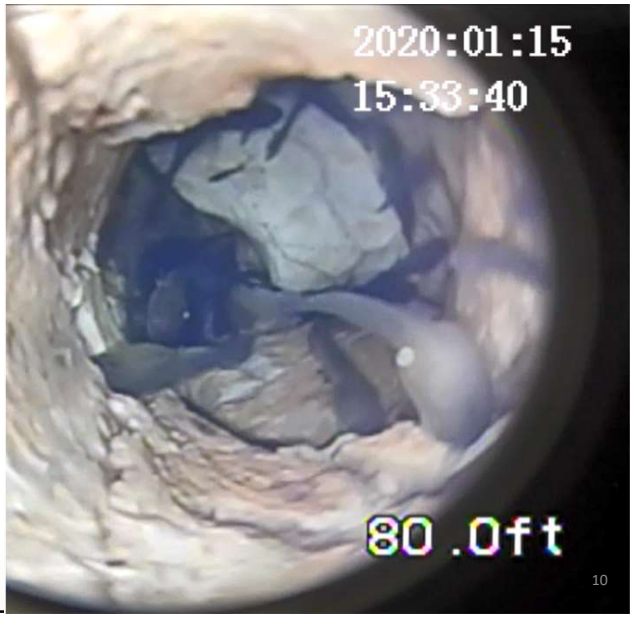
General Observations

- **Hydraulic gradient in shallow groundwater ~180 degrees.**
- **Rapid water level response to overland flow events.**
- **Direct connection between sinkhole and EAR-1 (i.e., fish & tadpoles).**



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EAR Site Characterization and Monitoring Network

- Blue River Stream Gages (USGS)
- Far & Far Field ERI survey
- Weather Stations & Precip collectors
- GW/SW sampling
- SW autosamplers
- Deep & intermediate wells (Q4FY21)
- Weirs (Q4FY21)

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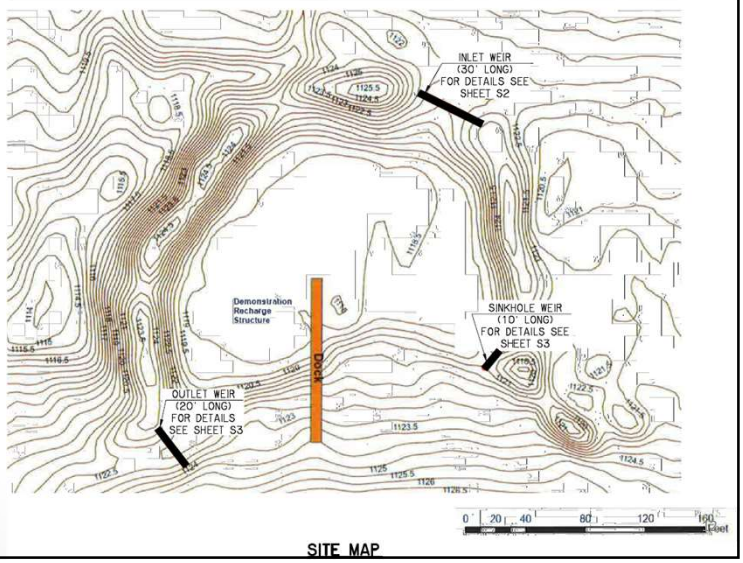
Measuring Overland Flow Input

- City of Ada to install 3 weirs
  - Inlet (Qin)
  - Spillway (Qout)
  - Sinkhole (Qrecharge)



SITE MAP

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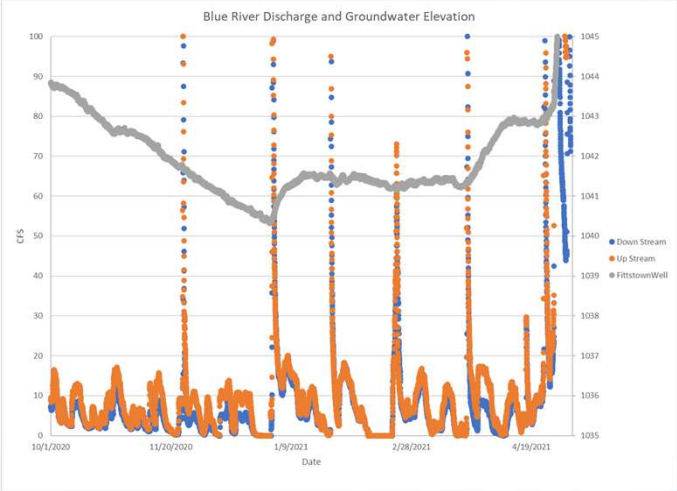
USGS Blue River Gages and Fittstown Well

- **Blue River – losing reach between CR1670 and CR1680 (i.e., downstream discharge less than upstream discharge).**
- **Results in groundwater recharge.**



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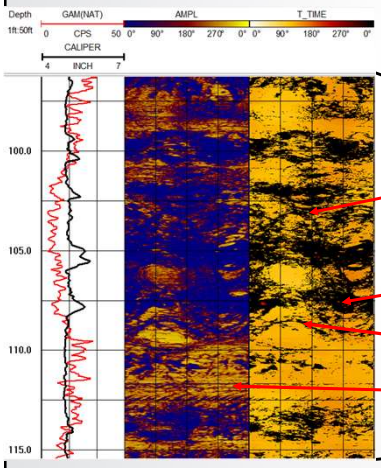
EAR Site Geophysical Logs



Fracture Trace

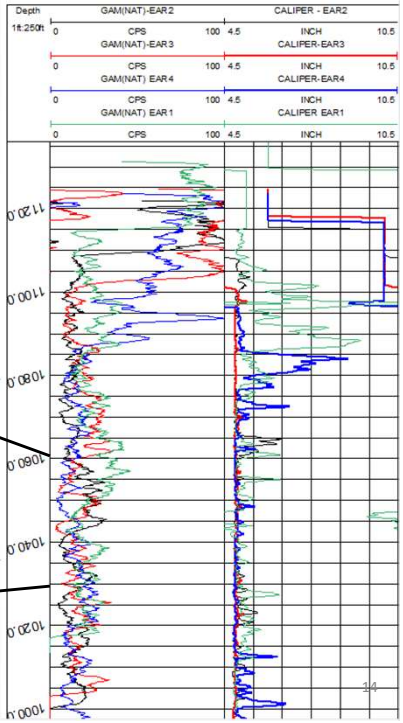
Dissolution Feature

Fracture Trace

Drill Bit Grooves (Competent Rock)

High Water Level

Low Water Level



EAR-2 Acoustic Televiewer (ATV), Caliper & Natural Gamma Logs

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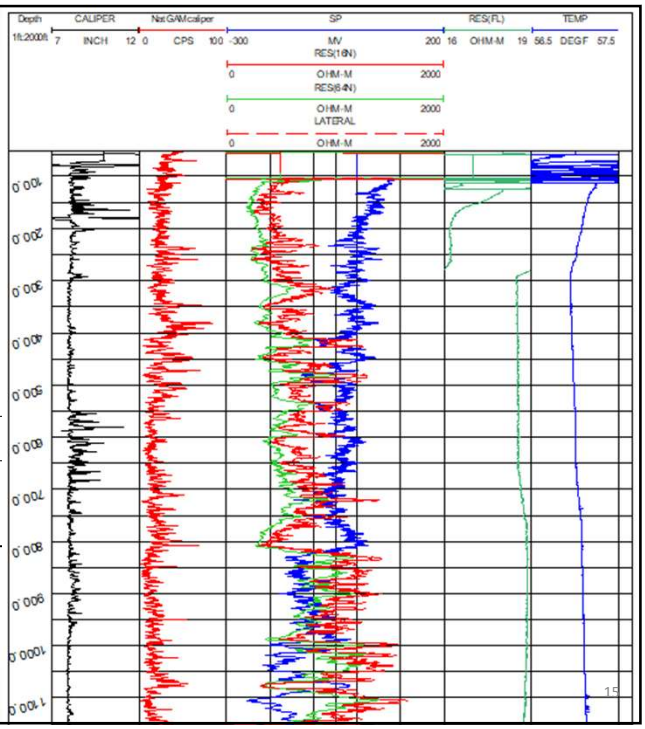
Ada #4 Municipal Well Geophysical Log

West Spring Creek Fm.

Brown Zone

Kindblade Fm.



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Electrical Resistivity Imaging (ERI) and Transient ERI Surveys

- ERI Data Density
  - 5:1 ratio (Length:Depth)
  - 28 surveys
  - ~2,600 data points / survey
  - >72,000 total data points
- Transient ERI
  - Stationary electrodes
  - Repeated measurements

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"Standard" ERI Application

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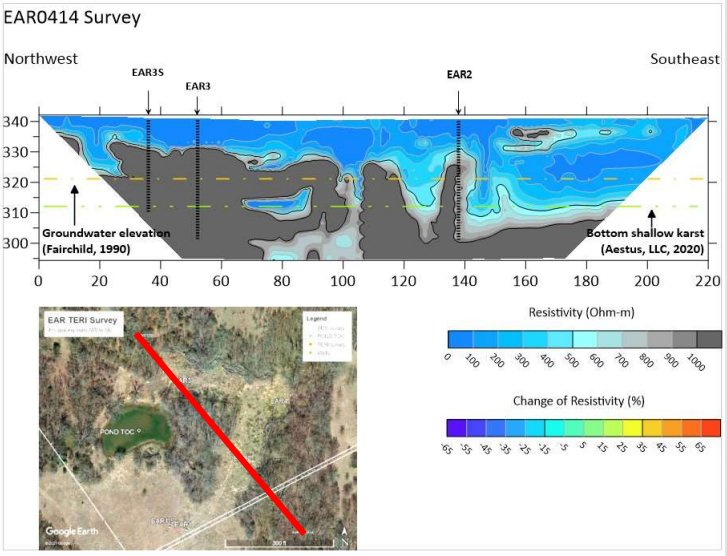
ERI on 4/27/2021



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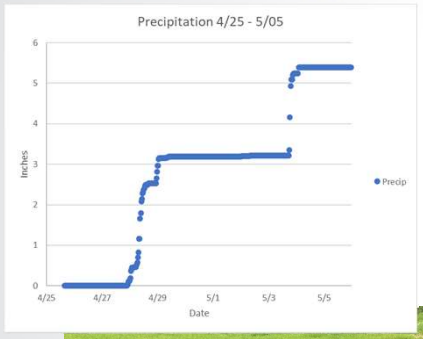
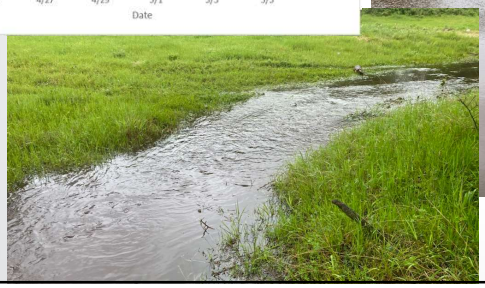
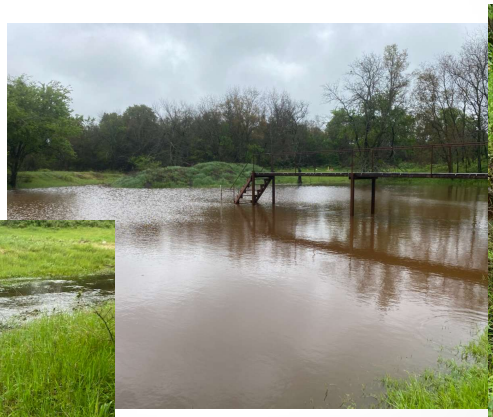
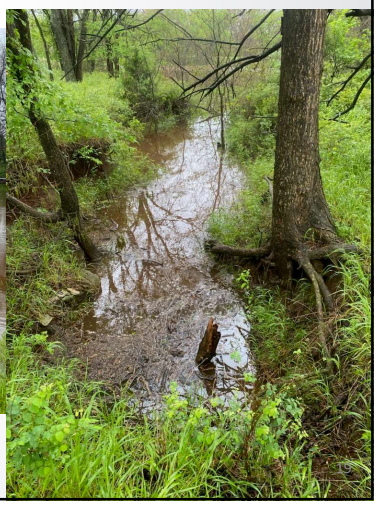
April 28, 2021









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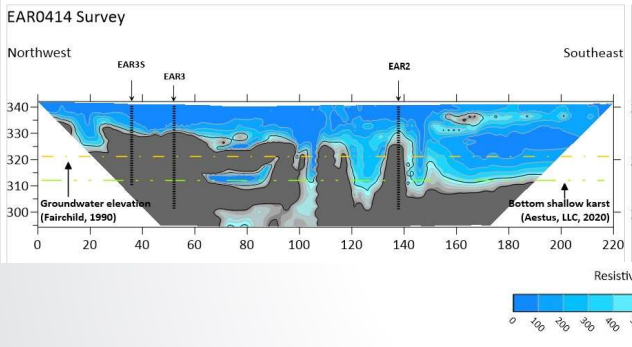
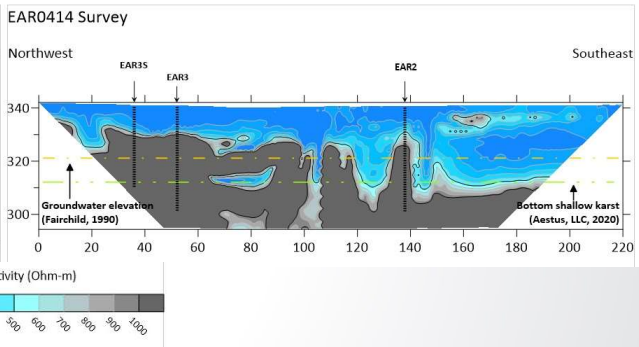
ERI on 4/30 & 5/03





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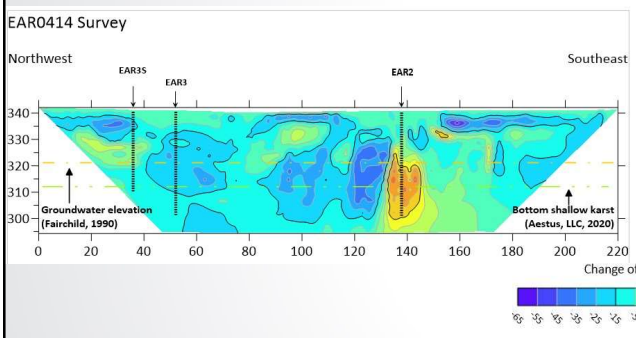
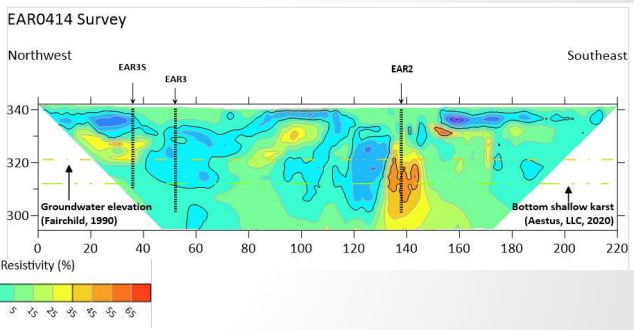
TERI - % Change in Resistivity

4/27 to 4/30



4/27 to 5/03



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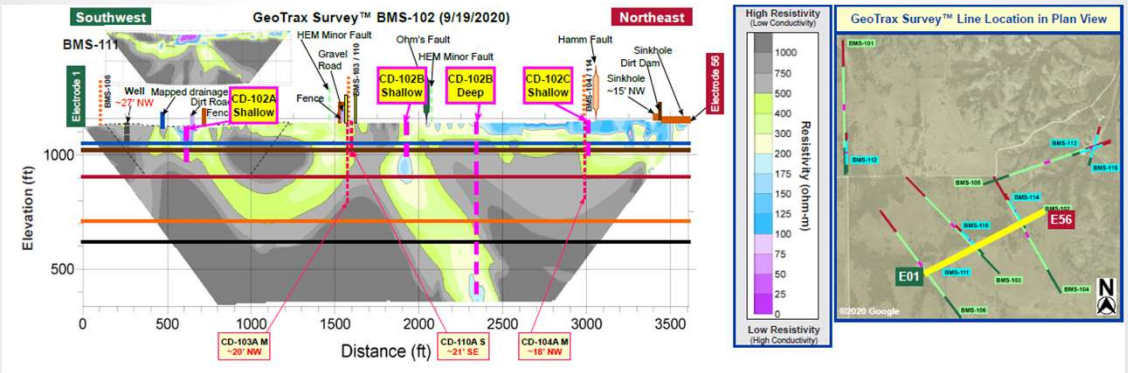
Deep ERI Survey



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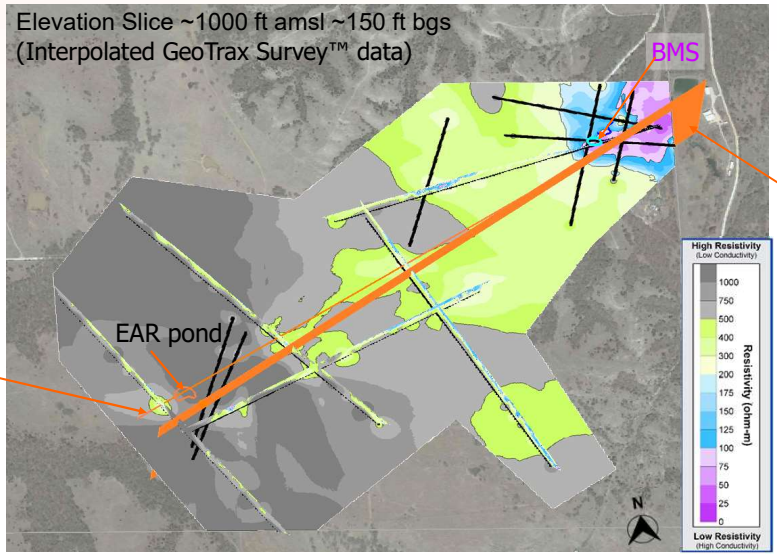
Executive Summary: Interim Stage EAR Sinkhole Connection to BMS



Shallow conduit from GeoTrax Survey™ data

Extension of mapped Hamm fault

From Halihan, 2021

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Sampling Types and Parameters Measured

- Types of samples to be collected
  - Groundwater
    - Wells and Springs
  - Surface Water (SW)
    - Rivers and pond
  - Precipitation
  - Soil Porewater (Vadose Zone)
  - Climate data



- Parameters to be analyzed
  - Field parameters
    - T, SPC, TDS, DO, pH, ORP, turbidity, Alkalinity, Total Hardness, Fe^{2+}, Sulfide
  - Major anions and cations
    - Ca, Mg, K, Na, Cl, sulfate, bicarbonate, carbonate
  - Nutrients
    - Nitrate, ammonia, phosphate, TN, TP, DOC, TOC
  - Trace elements
    - F, I, Ag, Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Li, Mn, Mo, Ni, Pb, Sb, Se, Si, Sr, Th, Tl, U, V, Zn
  - Rare Earth Elements (REEs)
    - Ce, Dy, Er, Eu, Gd, Ho, La, Lu, Nd, Pr, Sm, Tb, Tm, Yb
  - Isotopes
    - Water isotopes ($\delta^{18}O$ & $\delta^{2}H$), Strontium Isotopes
  - Volatile organic compounds

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EAR Tracer Study

Comparison of Fluorescent Magnetic Nano-Particles, with Traditional and Non-Traditional Tracers Methods, in Fractured Rock Aquifers.

BUREAU OF INDIAN AFFAIRS, FY 2020 FUNDING REQUEST
WATER MANAGEMENT PLANNING & PRE-DEVELOPMENT (N3420), EASTERN OKLAHOMA REGION

Chickasaw Nation, ECU and OSU

- Evaluate impacts of recharge on groundwater quality (i.e., connections between EAR Sinkhole and nearby wells and springs)
- Caution - public water supply
- Can use aquifer chemistry to advantage
  - Chloride, Cl- ~4 mg/L: MCL 250 mg/L
- Particle tracking to understand transport properties

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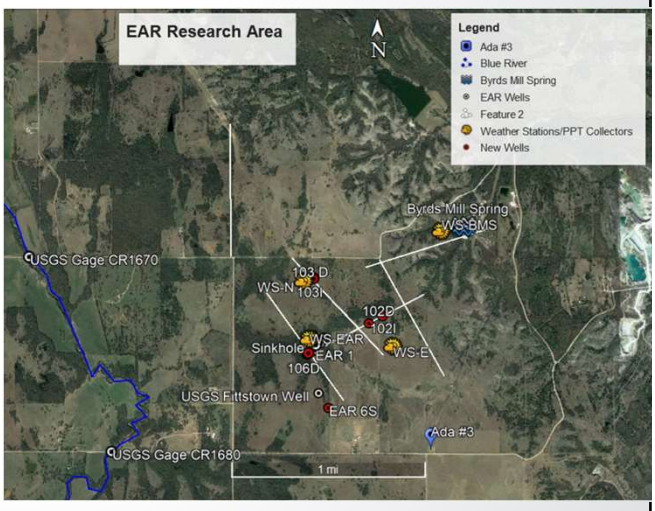
Tasks To Be Completed

- **Install and log deep wells (10/2021).**
- **Install additional surface water autosamplers (BMS, SCS).**
- **Expand TERI and ERI survey network near and far field.**
- **Incorporate microbial sampling.**
- **Continue GW/SW sampling.**
- **Install pore water samplers.**
- **Assist OSU/ECU with tracer studies.**



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In the mystery of groundwater lies the salvation of civilization

Gustavee

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