Characterization Short Cuts in Fractured Rock Aquifers

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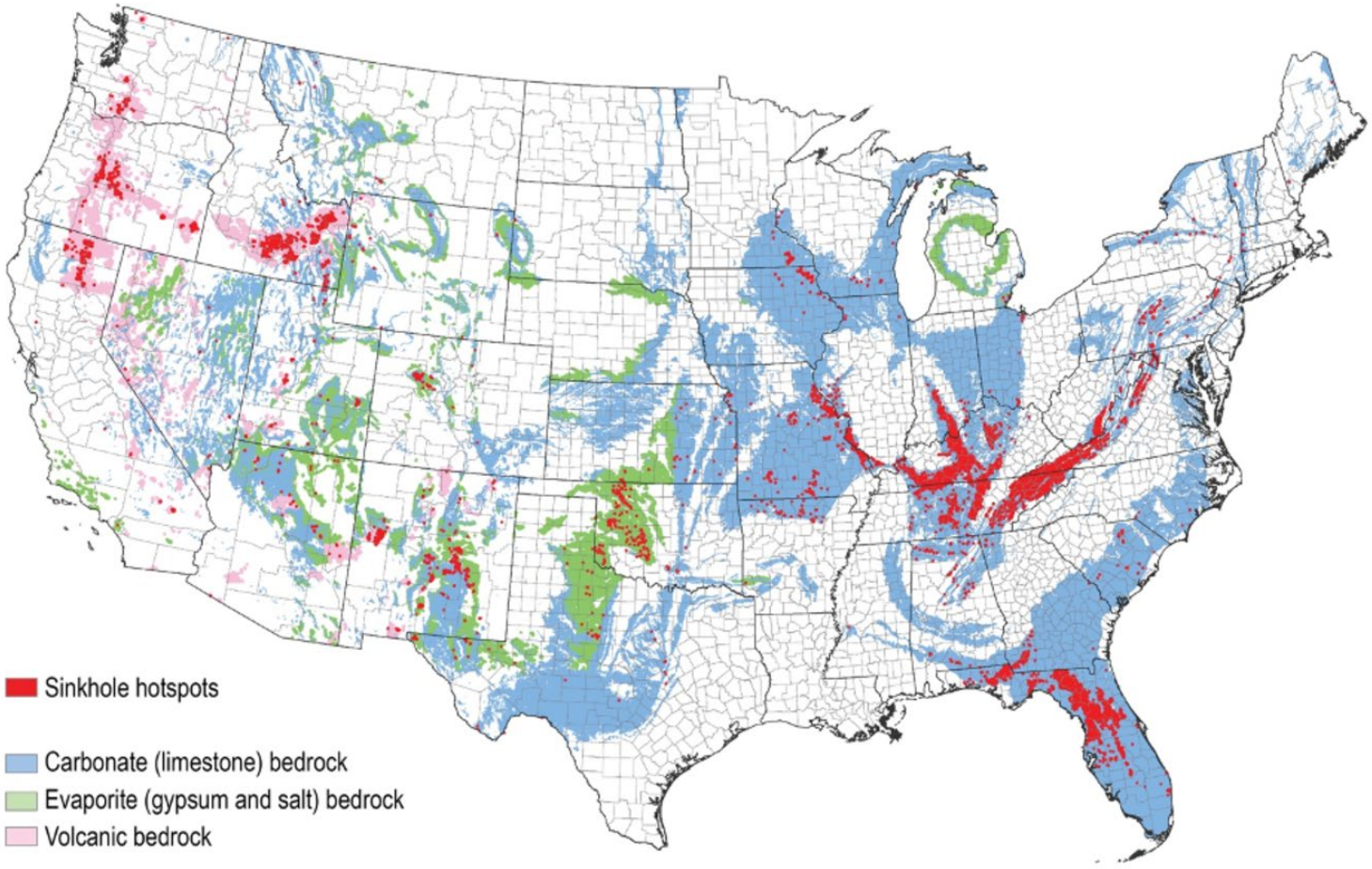
Outline

- Case Study in the Arbuckle-Simpson Aquifer
  - Enhanced Aquifer Recharge (EAR) site in a karst aquifer
  - Early data collection efforts highlighted
  - Evaluating monitoring well placement

- Takeaway: don’t manage sites underlain by fractured rock aquifers with typical approaches

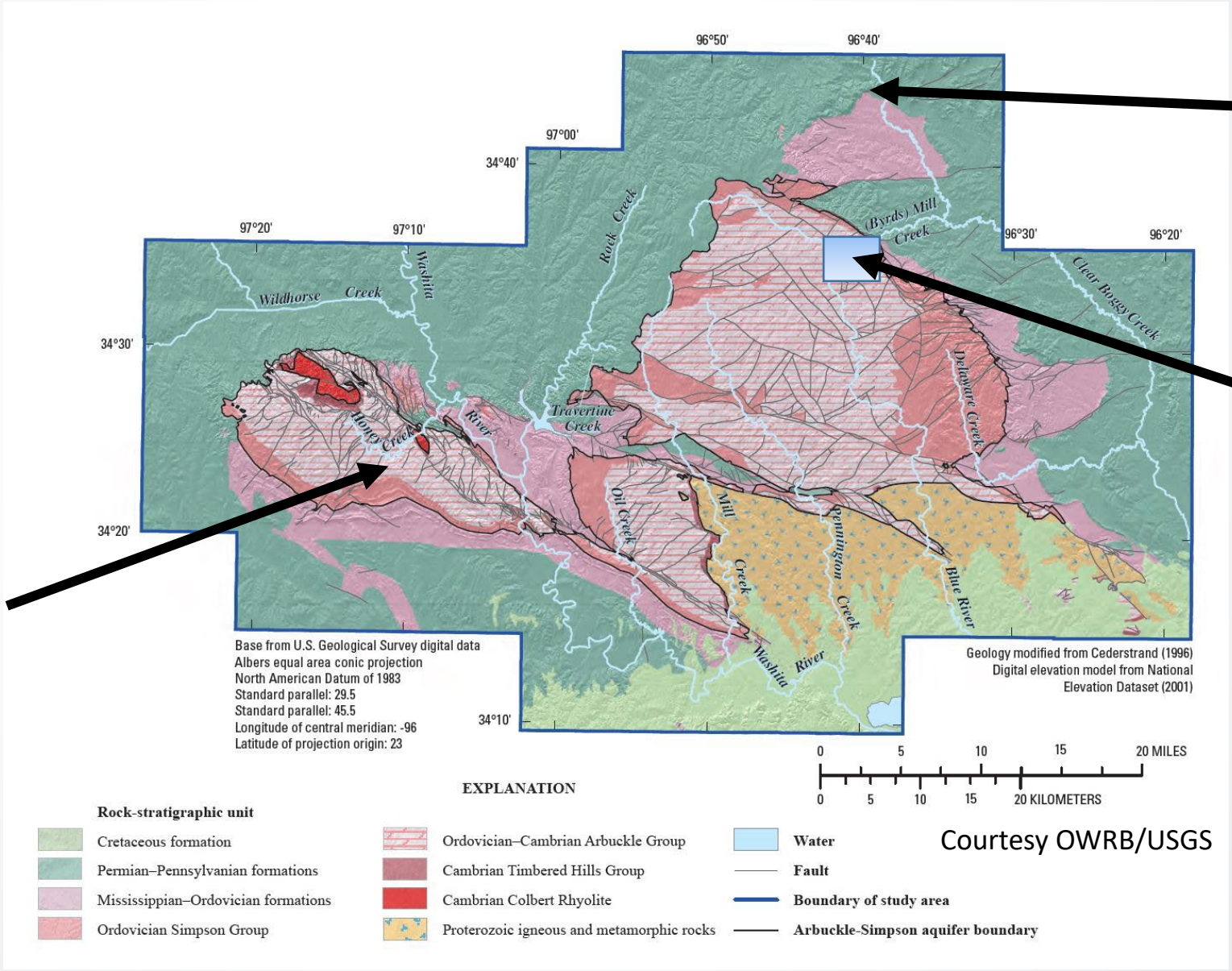
Importance of Karst and Fractured Rock Aquifers

- USGS, 2021
  - 40 % of US groundwater drinking water supplies comes from karst aquifers
  - Groundwater *storage* is in the rock matrix; *transport* is through openings
  - **Karst aquifers are highly heterogeneous and anisotropic**



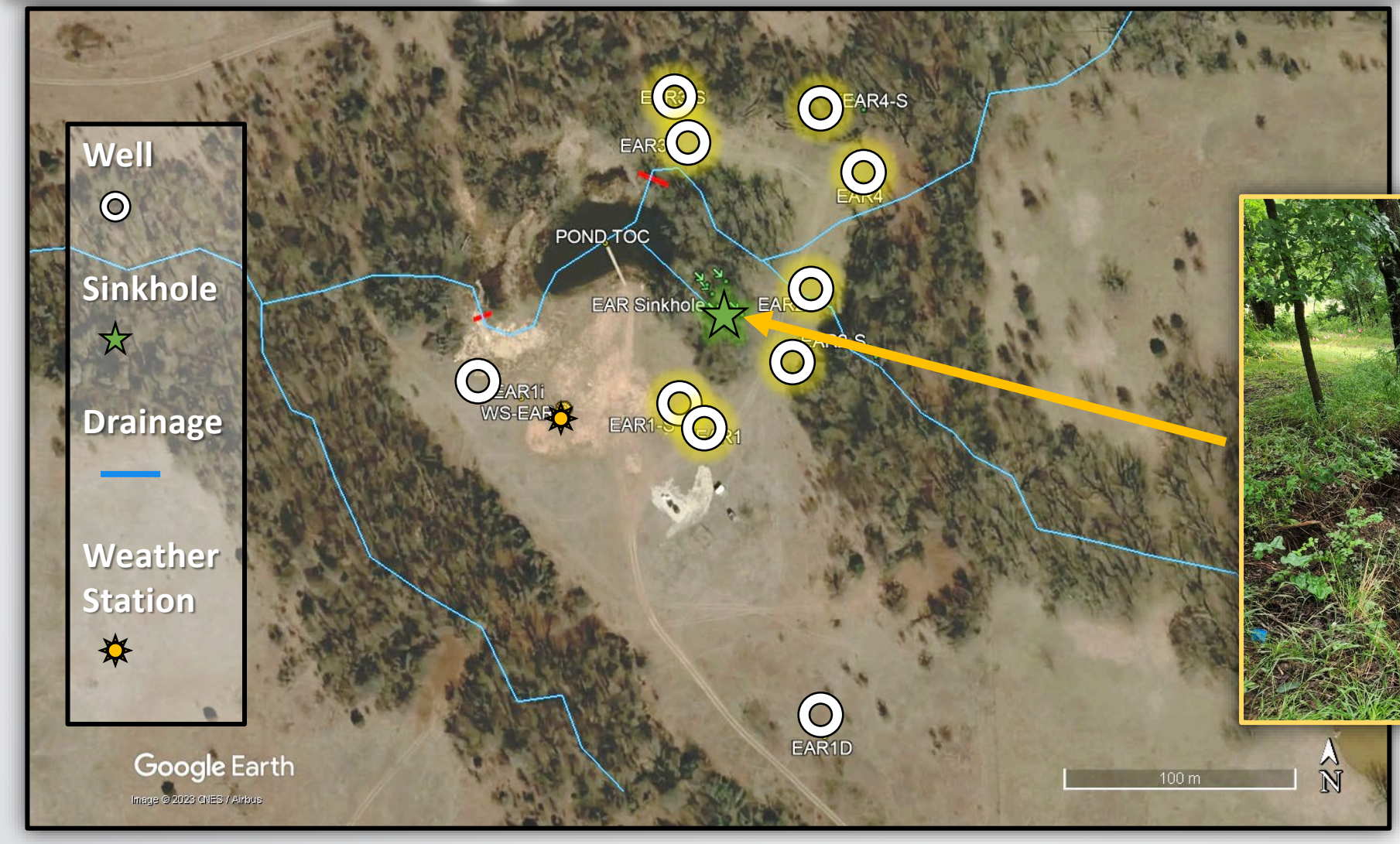
Source: USGS. 2021. Karst Aquifers. https://www.usgs.gov/mission-areas/water-resources/science/karst-aquifers

Arbuckle-Simpson Aquifer



Courtesy OWRB/USGS

Recharge Site



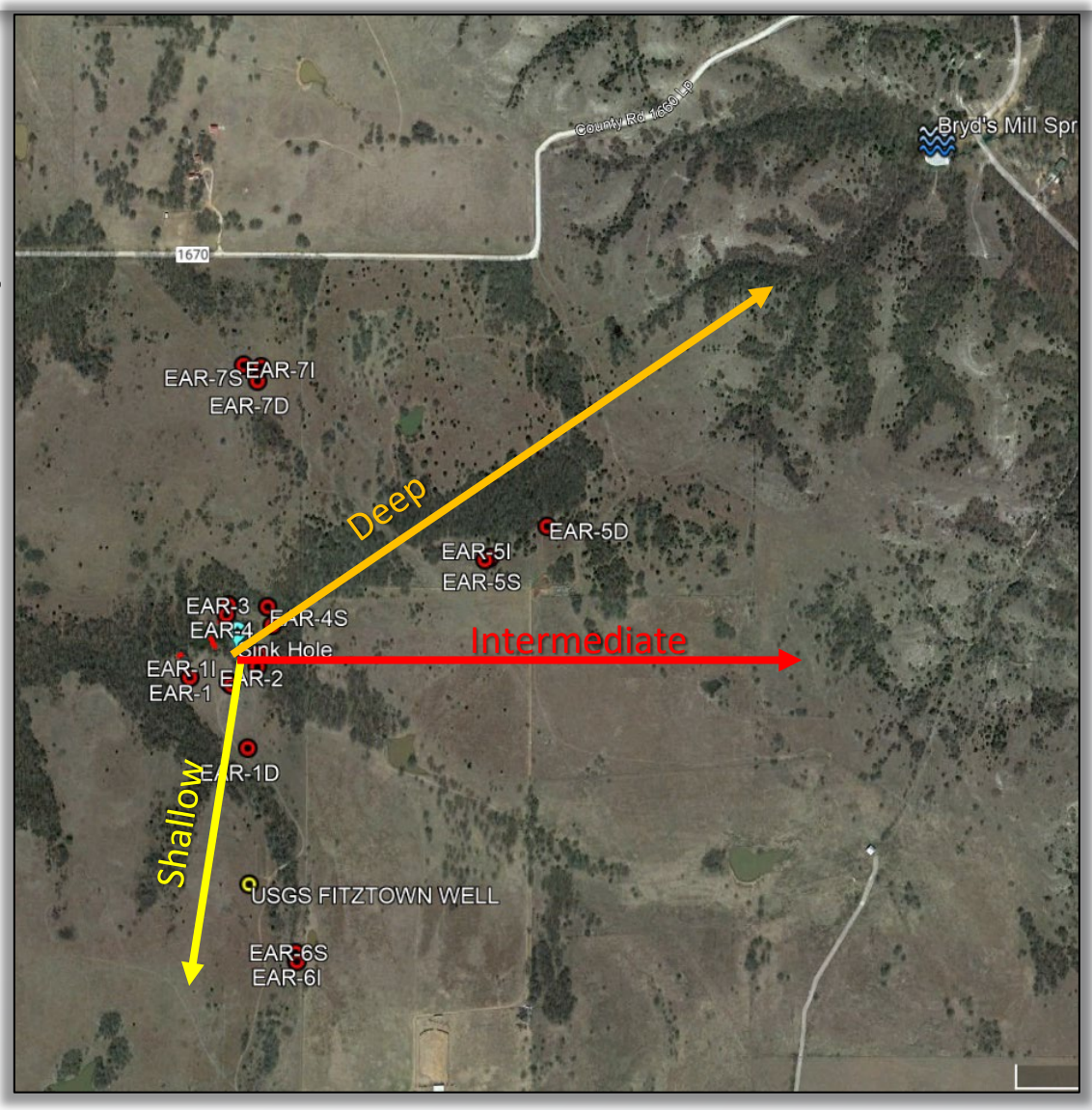
Drainage Area
~ 325 acres

Google Earth Map of EAR site

Potential Groundwater Flow Systems

- USGS suggest that groundwater flows towards Byrds Mill Spring (BMS)
- EPA data suggest at least 3 groundwater flow systems
  - Shallow System < 150 ft
  - Intermediate System ~ 250 ft
  - Deep System ~750 ft

- Water age at BMS < 50 yrs
- Vertical groundwater movement needs to be determined



Google Earth Map of EAR site

Data Collection Activities

- Water Quality
  - Groundwater (wells, springs)
  - Precipitation/runoff (source water)
  - Surface water (pond, Blue River)
  - Soil porewater (vadose zone)
- Hydrology/Geology
  - Infiltration capacity
  - Sinkhole recharge capacity
  - Geophysical data collection
  - Soil and rock core
  - Aquifer testing (slug/packer/pump tests)
- Climatic Data
  - Component variables to compute Evapo-Transpiration (ET) and soil moisture

Groundwater sampling

Picture showing the type of runoff sampler installed at the EAR site.

Overland Flow Balance

Qin – Qout = Δ Pond + Δ Sinkhole + Δ Soil + Precip/Runoff + Evapo-Trans

Inlet Weir

Sinkhole flume

Outlet Weir

Geophysics

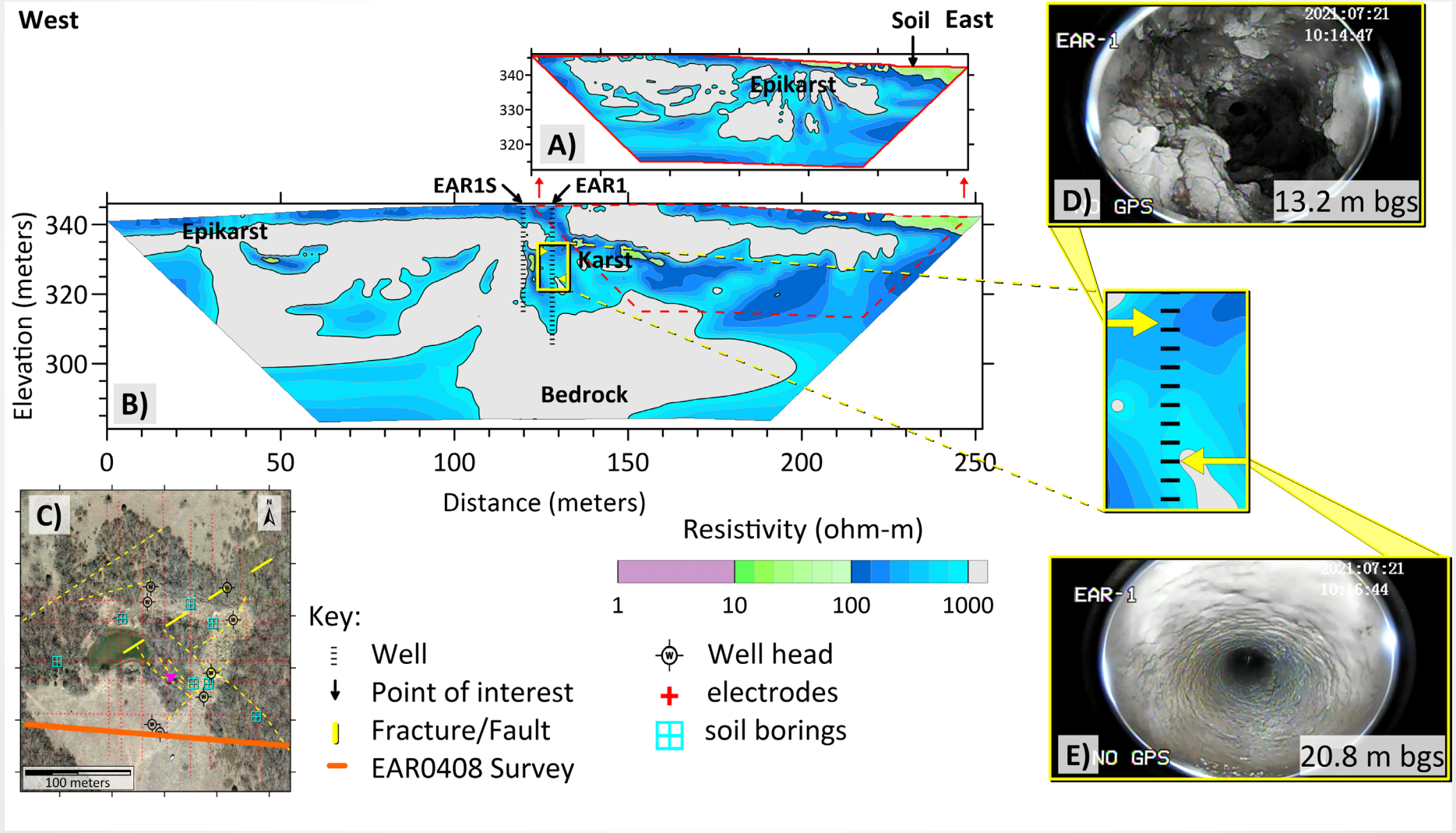
Borehole Logging Tools:

- E-Log (Resistivity, SP, Temperature, Natural Gamma)
- Induction Conductivity
- 3-Arm Caliper
- Acoustic Televiewer, Optical Televiewer
- Full-wave Sonic
- Fluid Sampler
- *Electromagnetic (EM) Borehole Flowmeter*

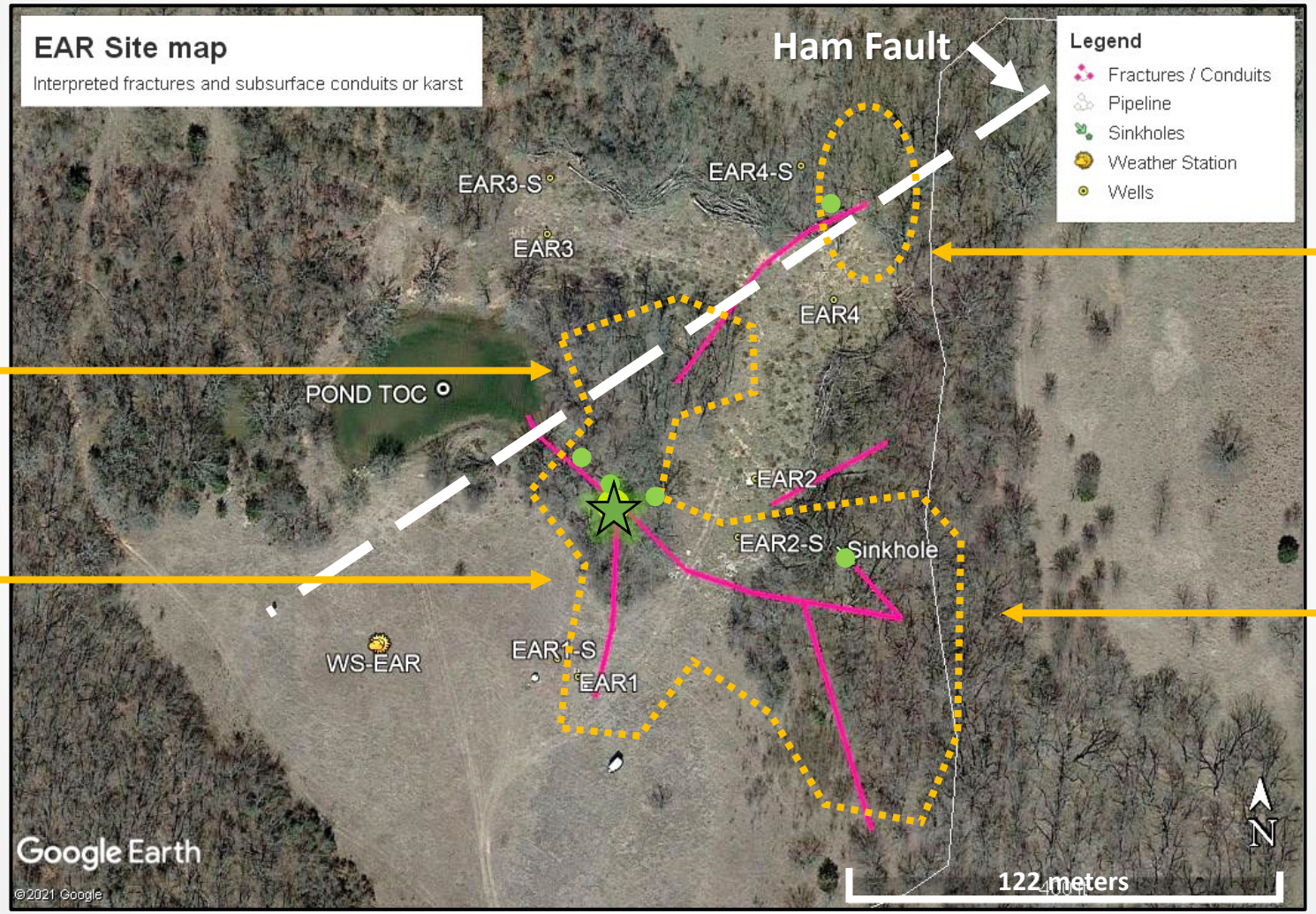
Surface Tools:

- Electrical Resistivity Imaging (ERI)
- *EM profiler*
- *Magnetometer*

ERI Findings ("Plumbing")



ERI Findings



Thick epikarst

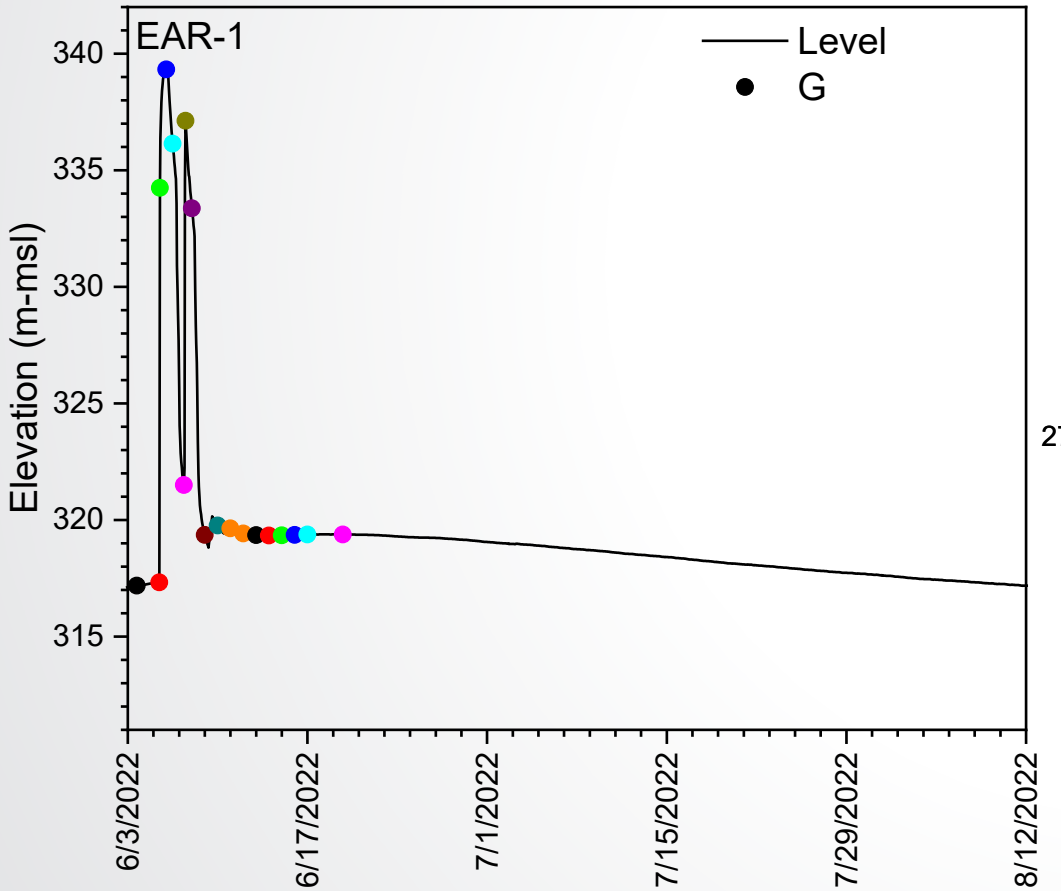
Epikarst

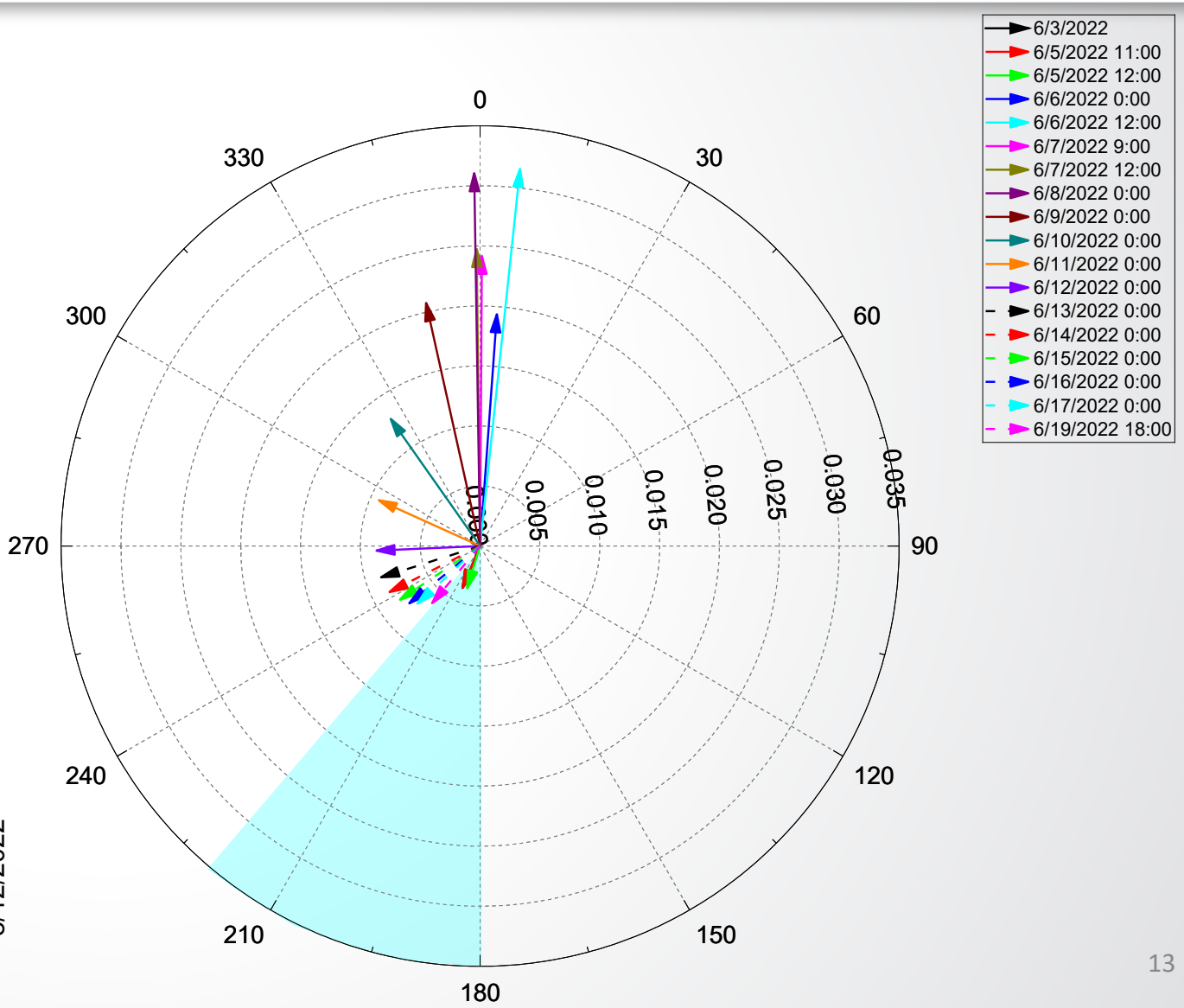
Prominent karst

Thick epikarst

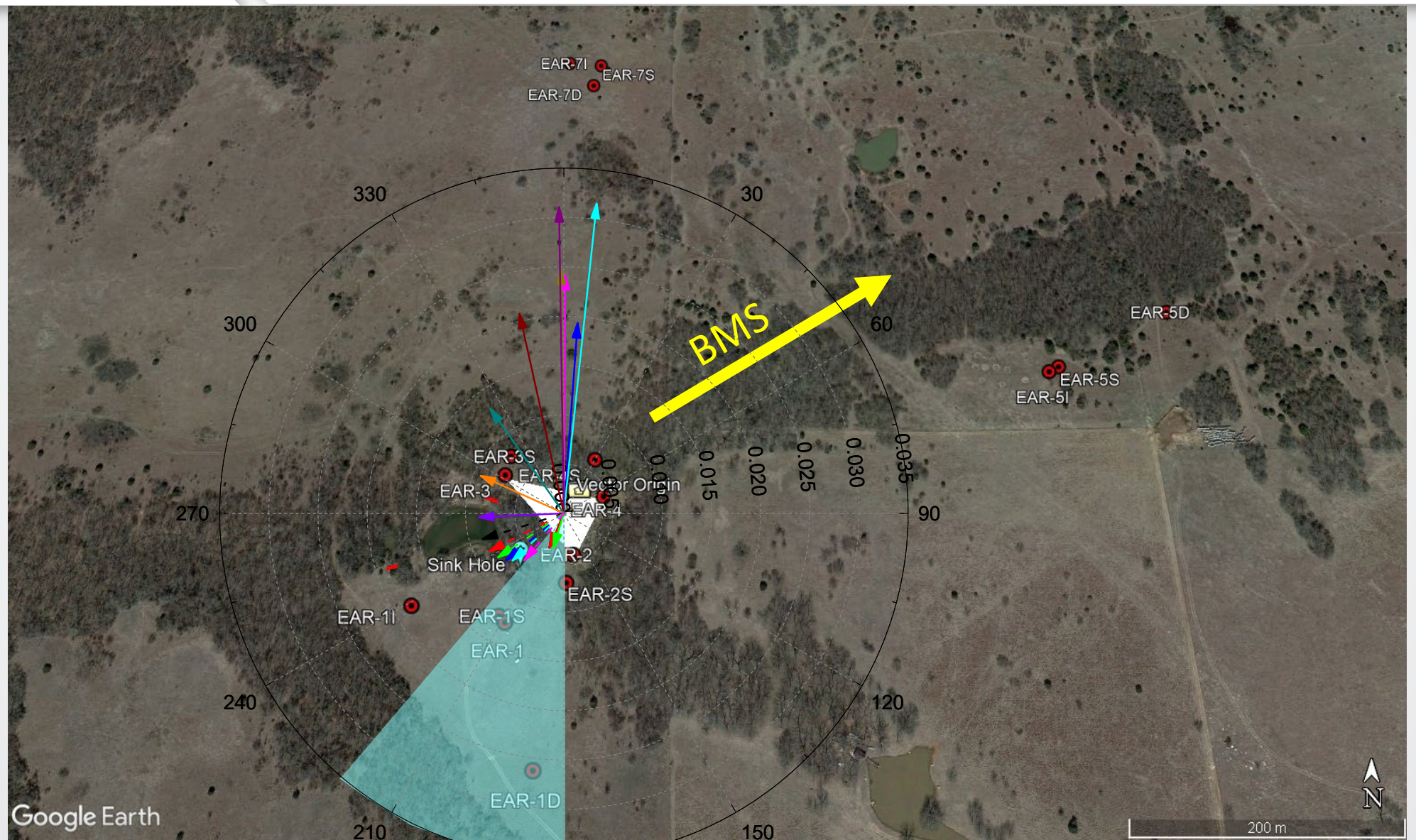
Google Earth Map of EAR site

June 2022 Overland Flow Event





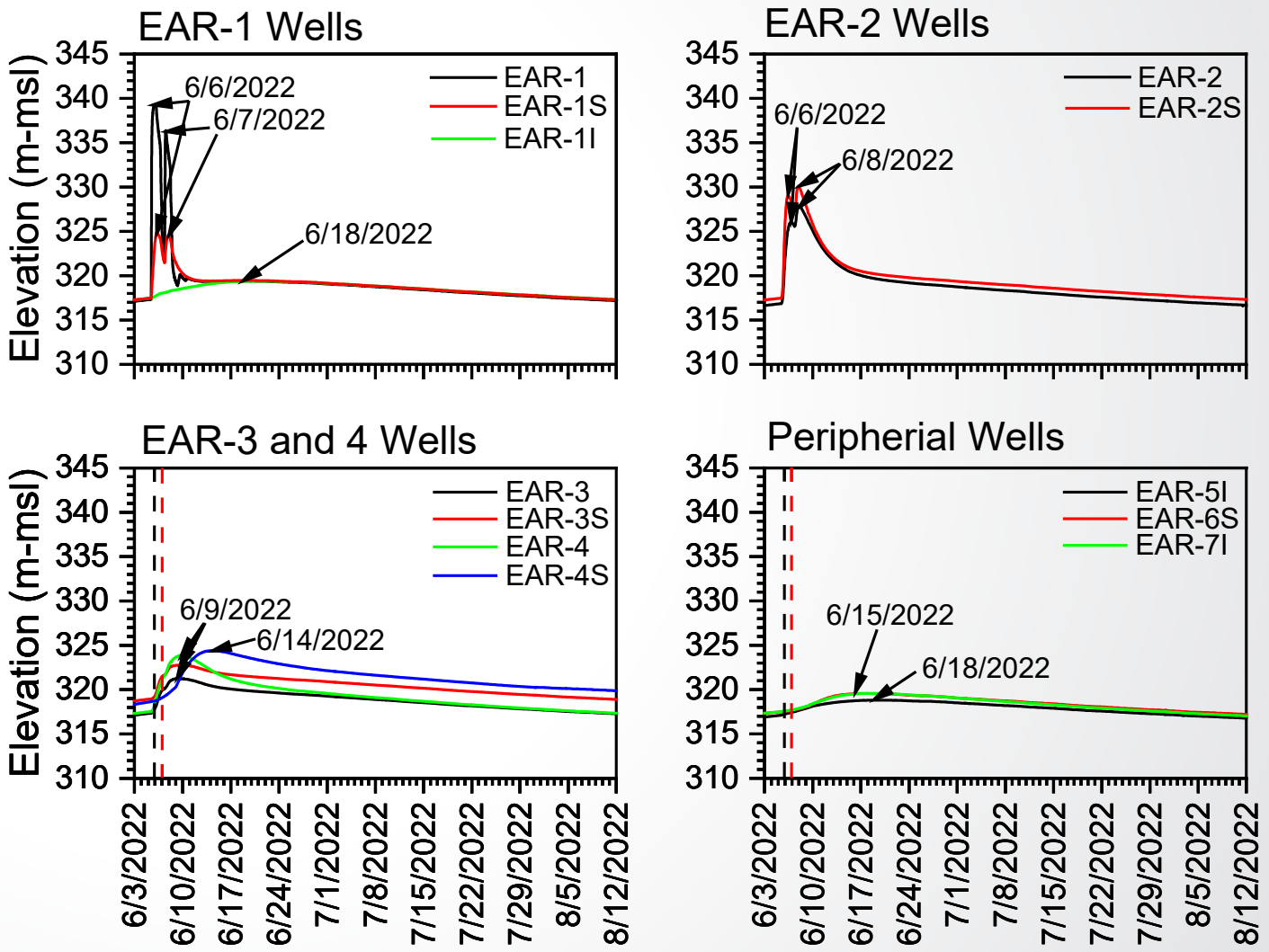
June 2022 Overland Flow Event



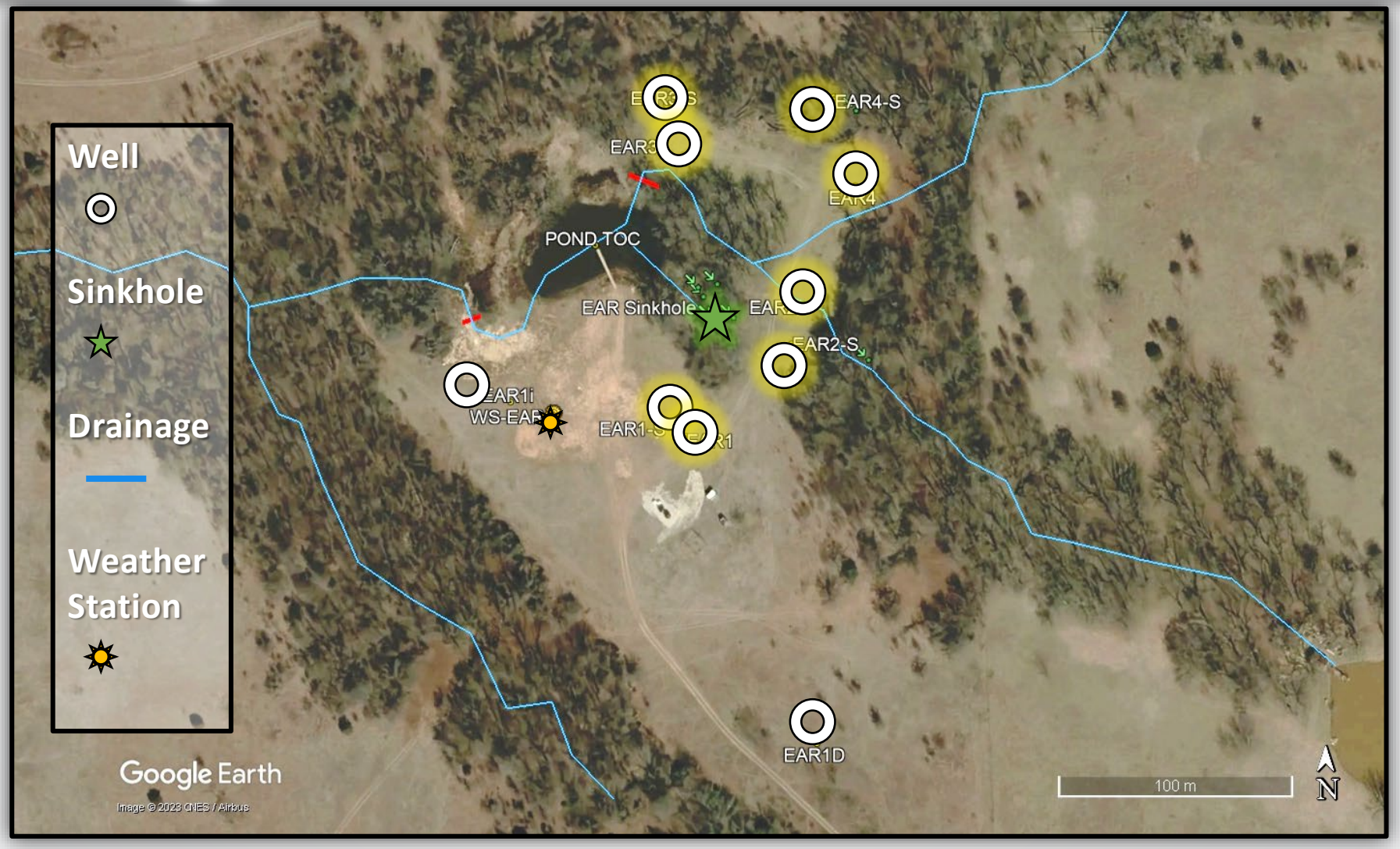
Google Earth Map of EAR site

June 2022 Overland Flow Event

- Water Levels
  - EAR-1, -1S, -2, and 2S show immediate response to sinkhole
  - EAR-1, -1S, -2, and 2S drain until meet overall aquifer rise in water
  - Other site wells near sinkhole show delayed response



Well placement evaluated



Google Earth Map of EAR site

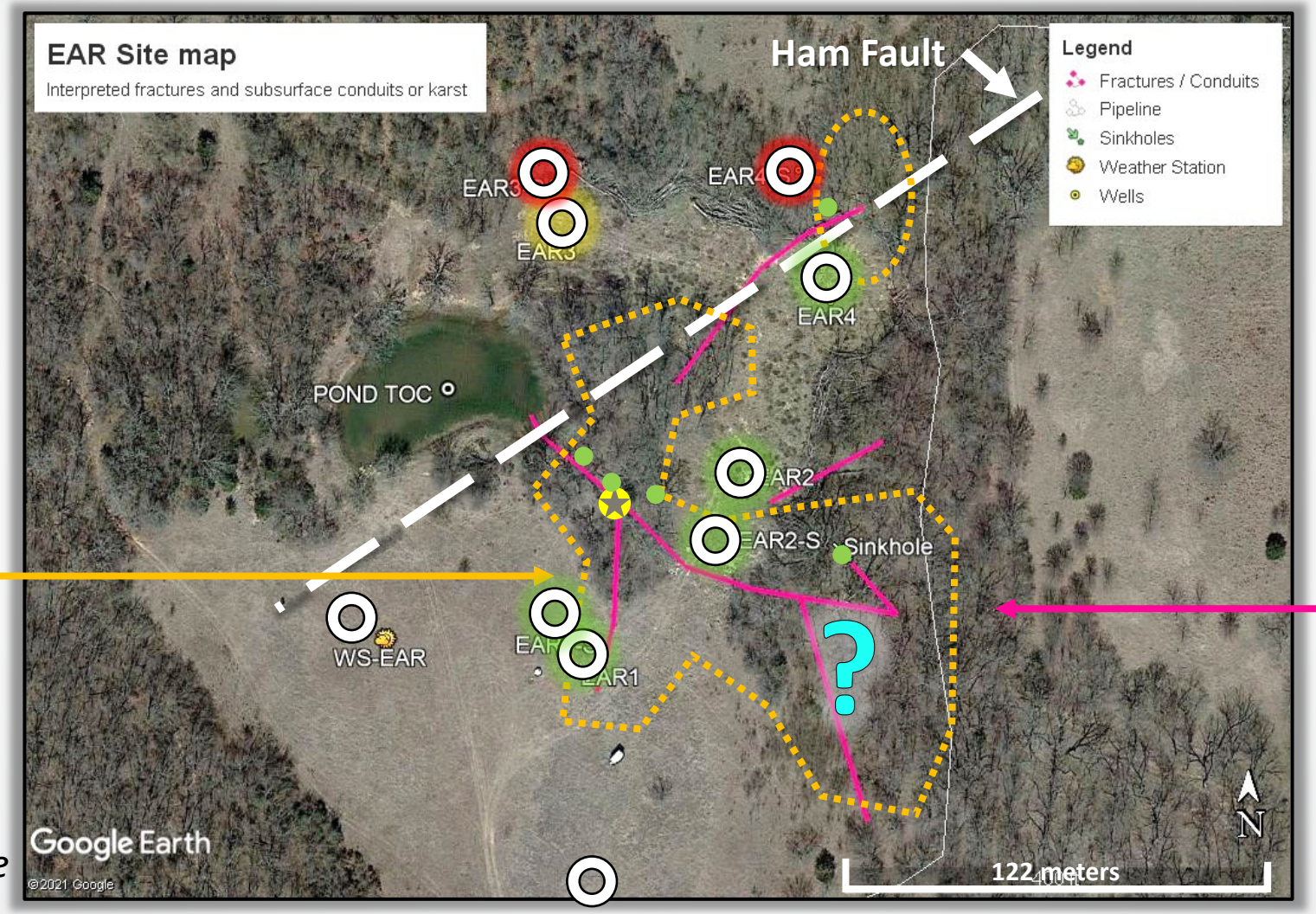
Well placement evaluated

Bad spot

Great spot

Good spot

Evaluating



Karst / epikarst

Fractures

Google Earth Map of EAR site

Summary

- Short cuts
  - Start with geophysical characterization; drill targets for confirmation and make those locations monitoring wells
  - Deploy transducers in each well (effectively capture potentiometric change)
  - Use tracers/pumping tests to test your Conceptual Site Model

- Take home messages
  - Traditional placing of wells (poke and hope) to create a monitoring network can be ineffective
  - Fractured rock aquifers requires additional characterization
    - Surface and borehole geophysics
    - Geologist consultation

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Thank you

Questions?