Investigation of the Arbuckle

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Kansas Water Authority

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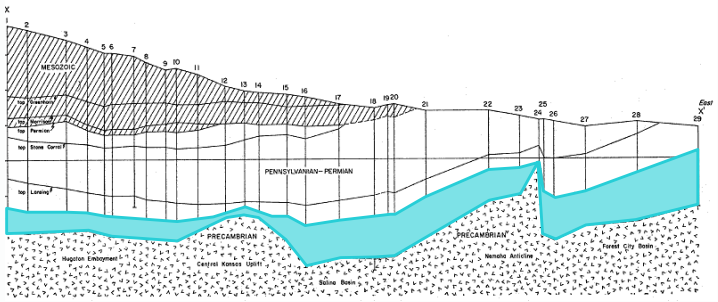
Goodland, KS

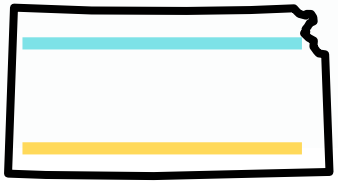
Why are we concerned about the Arbuckle? Why now?

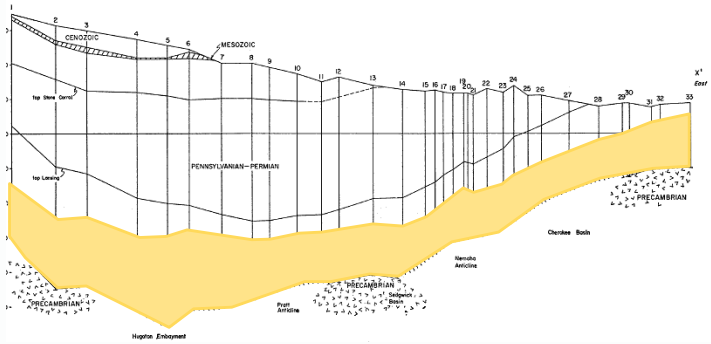
- 30 years ago Arbuckle seemed like the perfect geologic interval
  - prolific producer of oil
  - infinite pore space for disposal
  - deep below ground surface with multiple sealing intervals above
  - endless fresh water supply
- Today the Arbuckle shows multiple symptoms of decreased capacity
  - origin of unprecedented seismicity trigger
  - increasing potential source of contamination of fresh water aquifers
  - potential for artesian flow in the near future
  - requires overpressure to access limited remaining capacity
  - restricted use for disposal of low density fluids
- Could have significant economic and environmental impact on Kansas
  - over a billion $ annually related to use of Arbuckle
    - Industry taxes, jobs, local economic impact, support community, future expansion

What is the Arbuckle Group?

- Thick sequence of sedimentary rocks
  - directly above basement (granite) rocks
  - highly permeable in intervals
  - vital to many industries in Kansas
- There is a lot we don't know
  - large number of unmapped faults
  - highly variable zones/areas
    - karst, highly localized dissolution
    - some zones more favorable for disposal
    - knowing could help place new wells
  - water chemistry (in situ and disposal fluids)
  - fluid flow
- Why so much variability in characteristics and properties of the Arbuckle across the State?
- Clear need for regional framework for building localized understanding to optimally use

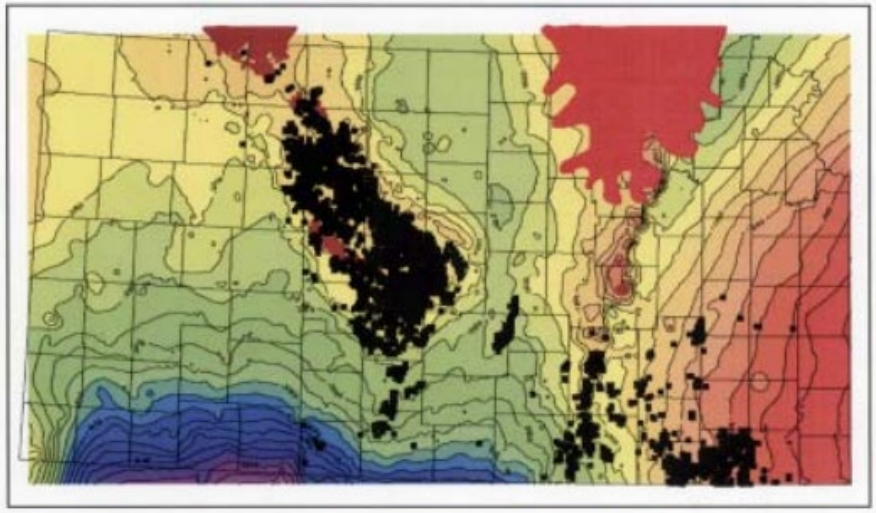






Uses of the Arbuckle Group

- Oil and gas (KCC)
  - ***production***
  - oilfield brine disposal
- Industrial waste disposal (KDHE)
  - hazardous and non-hazardous
  - oil refining
  - product storage
  - chemical manufacturing
  - food production
- Drinking water (KDHE)
  - municipal water treatment
  - freshwater source
- CO_2 sequestration (EPA)



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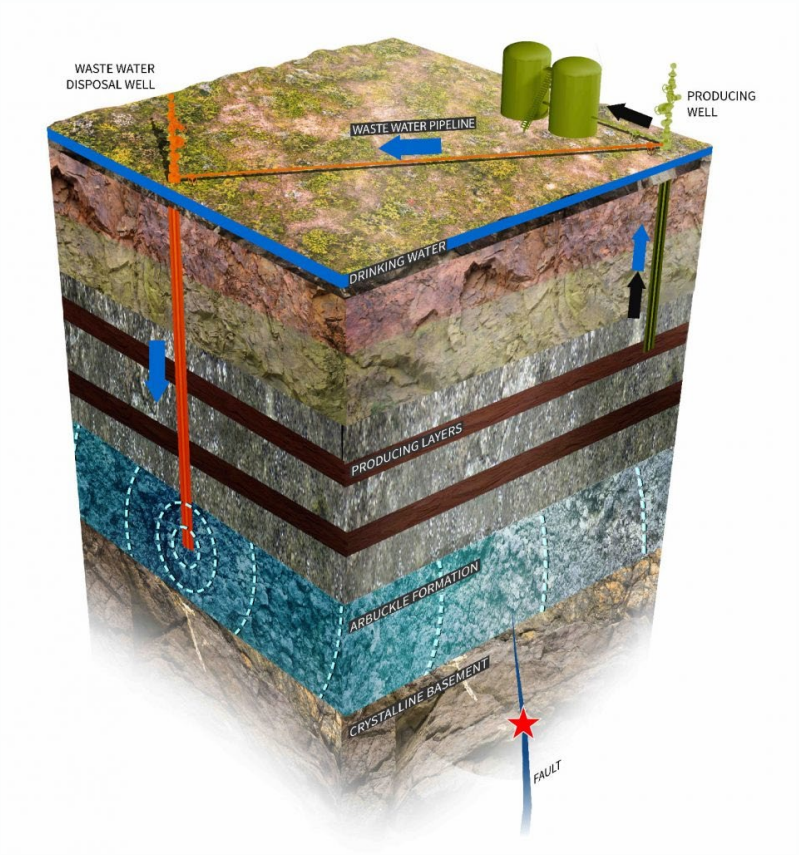

credit: Stanford University

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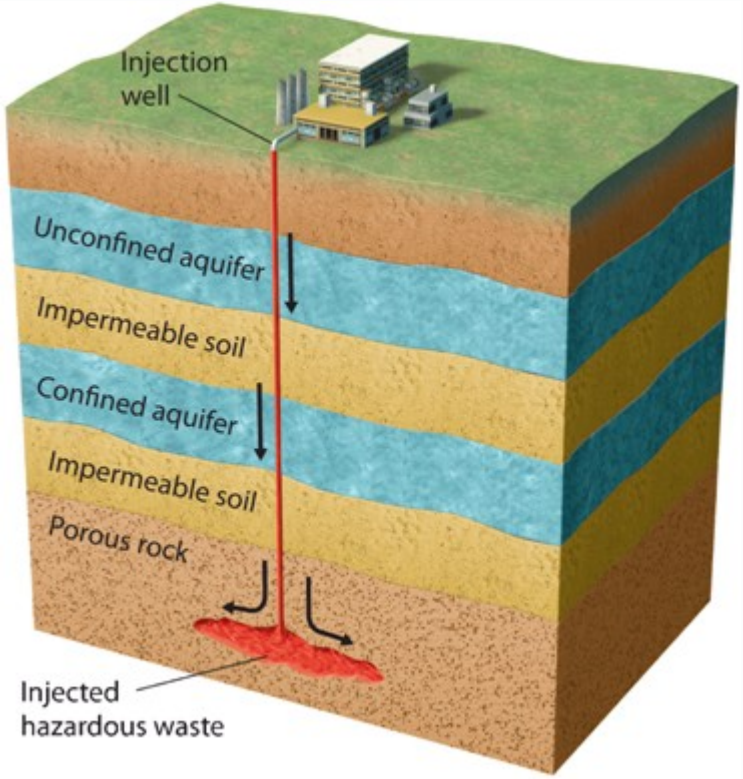

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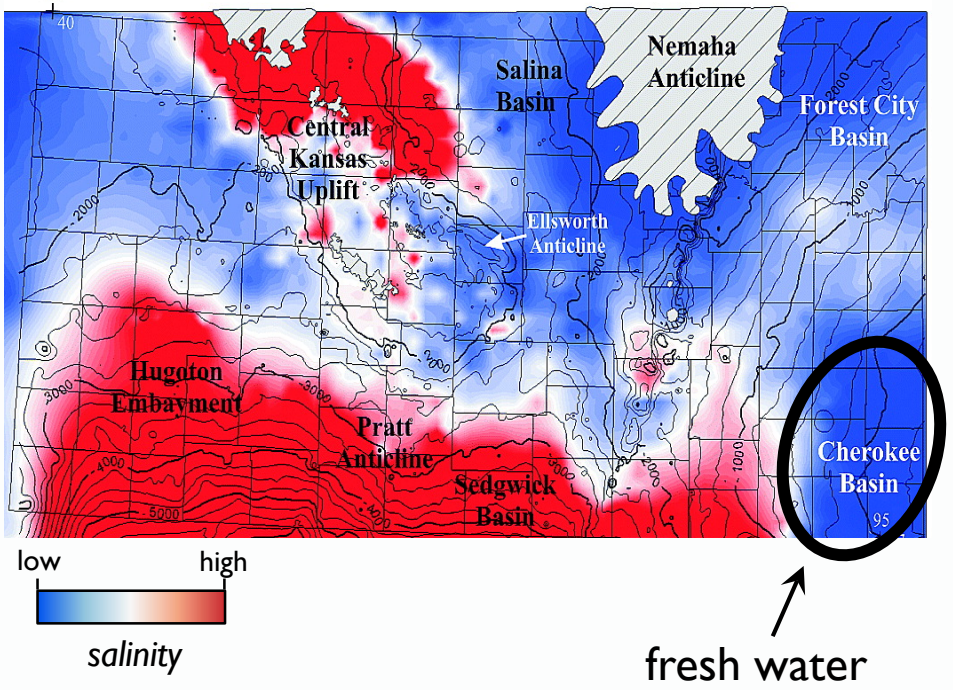

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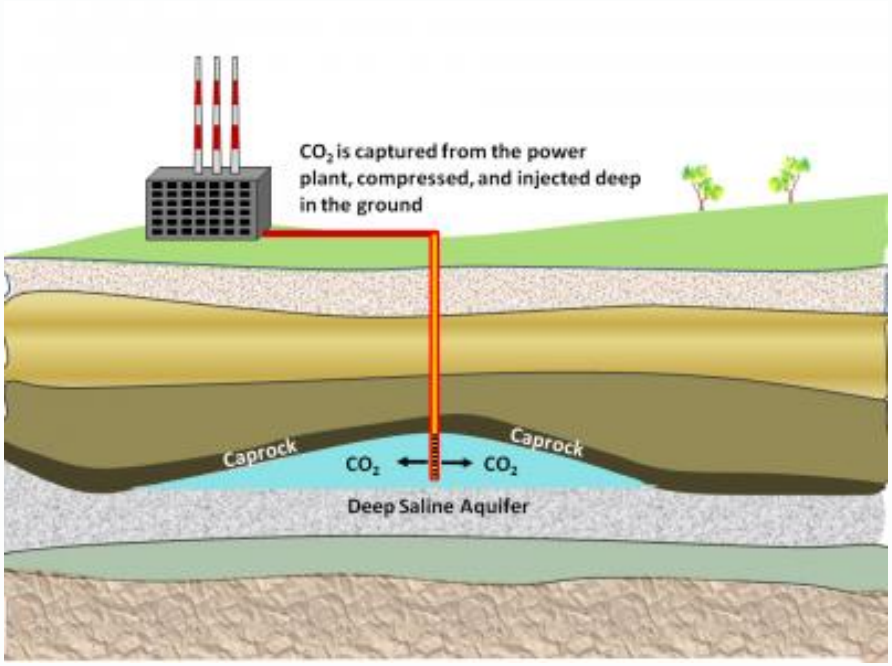


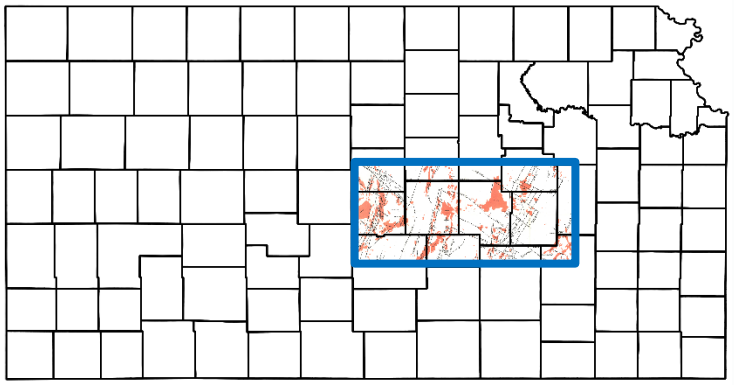
credit: Ron Falta, Clemson University

What do we need to know?

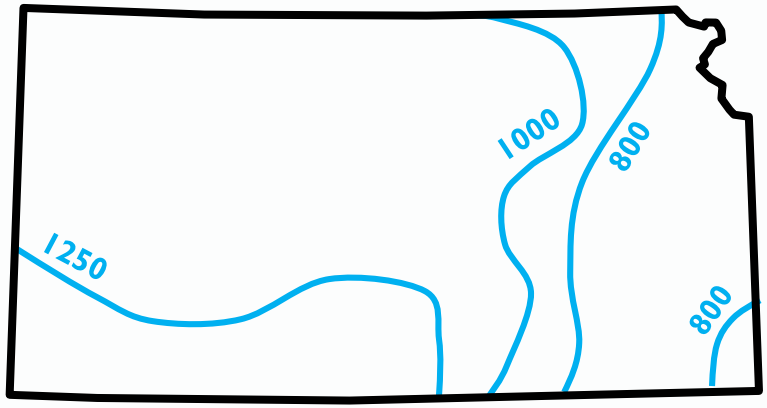
- Measurement-based products
  - Comprehensive structural mapping
  - High-resolution pressure/fluid-level mapping
  - Detailed water chemistry and fluid-flow modeling
  - Characterize to help policy makers, regulators, commercial users, industrial producers, municipalities make informed decisions
- Ramifications of not obtaining an enhanced understanding
  - impaired or loss of ability to inject
  - continued seismicity
  - widespread environmental and aquifer damage
  - impact to State industries, economy

Current Data is Limited

structural map



potentiometric surface map

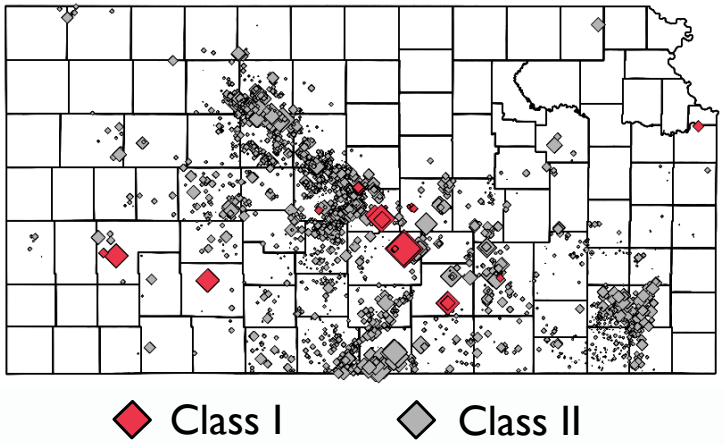


- Past KGS research
  - Structure mapping
    - Merriam and Smith (1961)
    - Berendsen and Blair (1986)
  - Lithology, stratigraphy, geomorphology
    - Cole, 1975 (KGS)
    - Carr et al. (1994)
    - Franseen et al. (1999, 2004)
- Fluid level mapping (USGS, 1993)
- Generally based on sparse data points

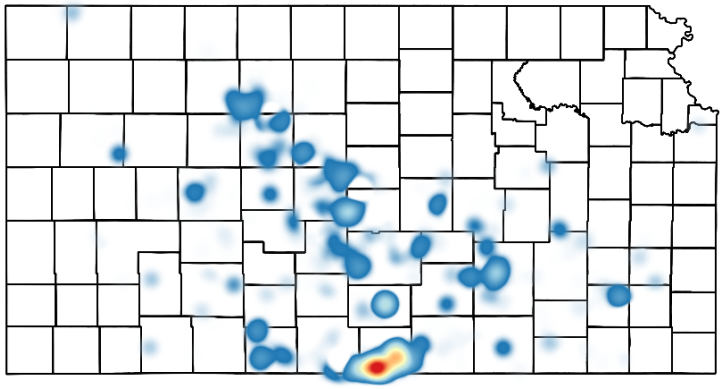
Arbuckle Disposal

- Class I wells: 49
  - industrial and municipal waste
  - gravity feed
  - monitored and tested
- Class II wells: > 2,000
  - oilfield brine (extracted during production)
  - pressurized
  - less monitoring/testing
- Oil and gas development in south-central Kansas
  - 2011 to 2015
  - tenfold increase (Harper Co)

Arbuckle disposal wells

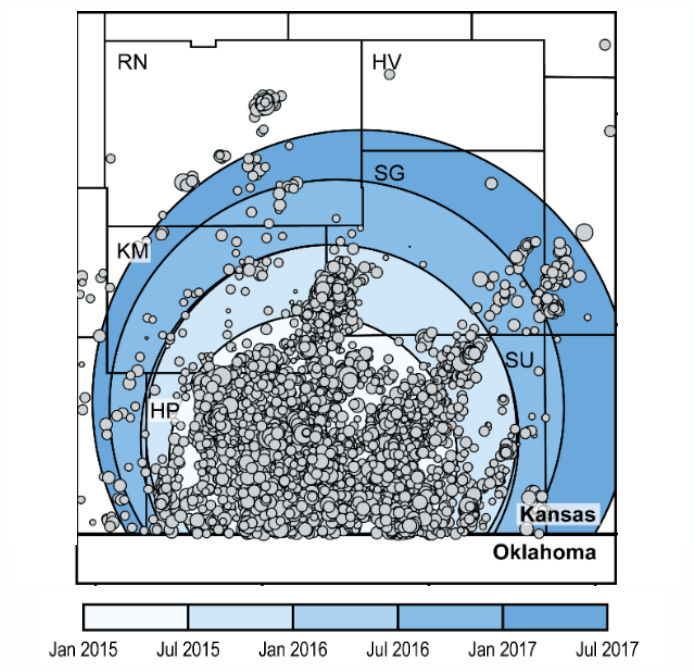


change in disposal volume

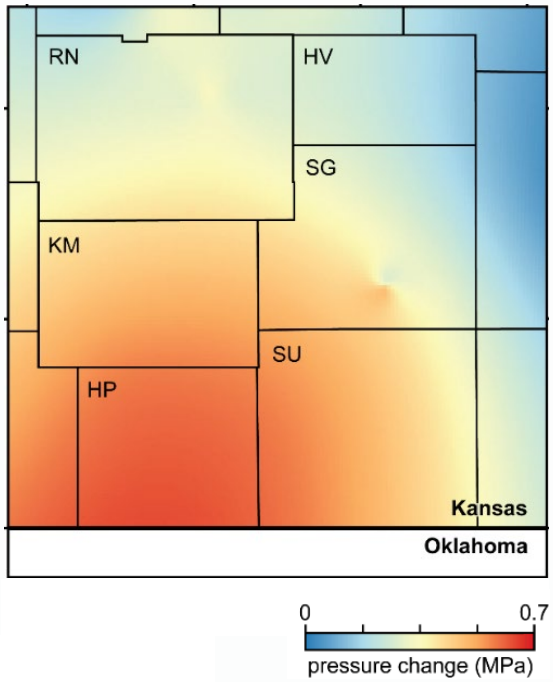


Symptoms of a Problem

progression of earthquakes



Arbuckle Group pressure



elevated pressure implies increased fluid level

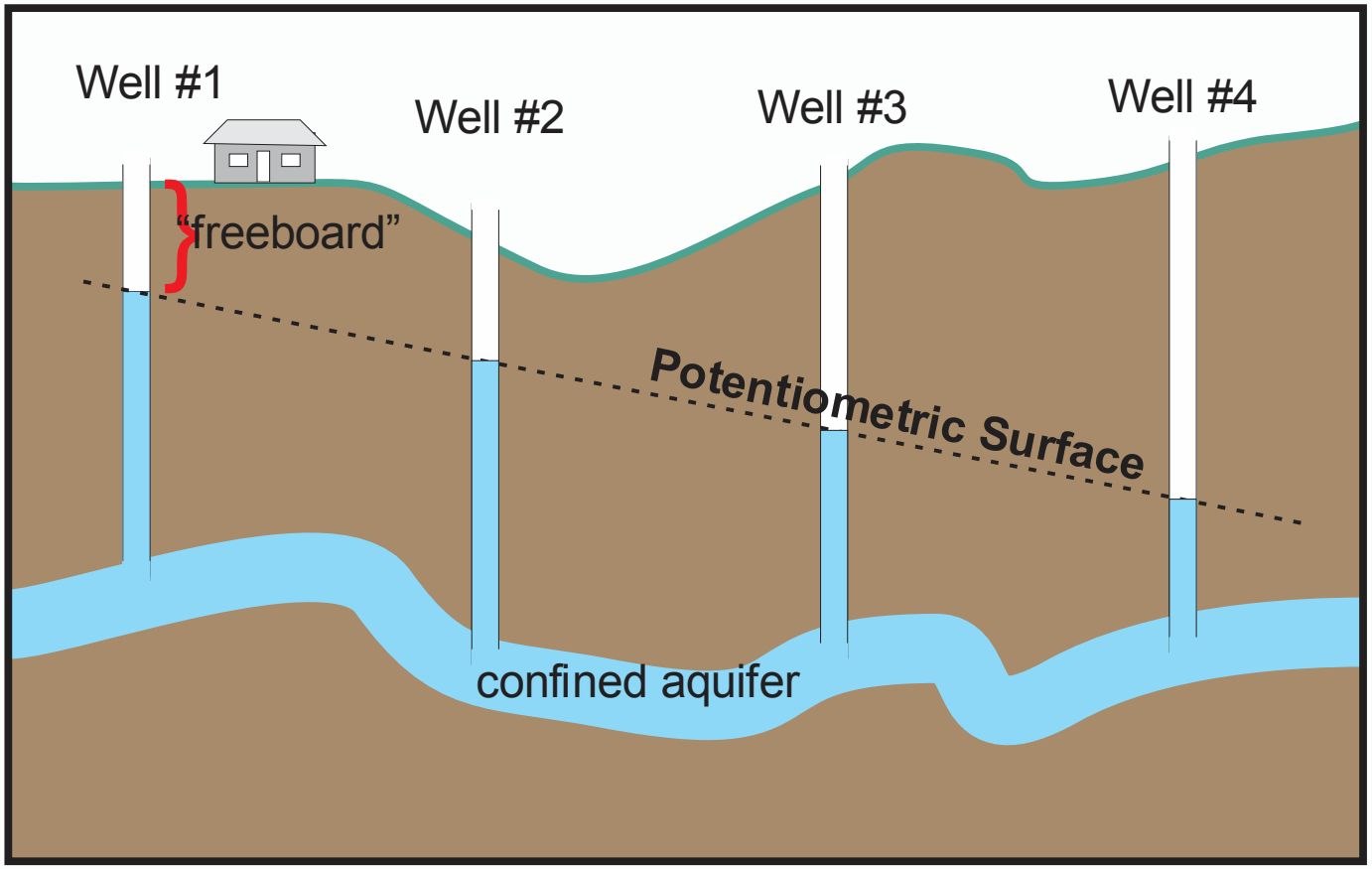
Arbuckle Usage Statistics

- Input–Output
  - *Oil extracted since early 1900s:* 2 billion barrels
  - *Fluid injected the past 10 years:* 7 billion barrels (3.5x historic production)
  - *Fluid injected last year:* 160 x volume of oil extracted

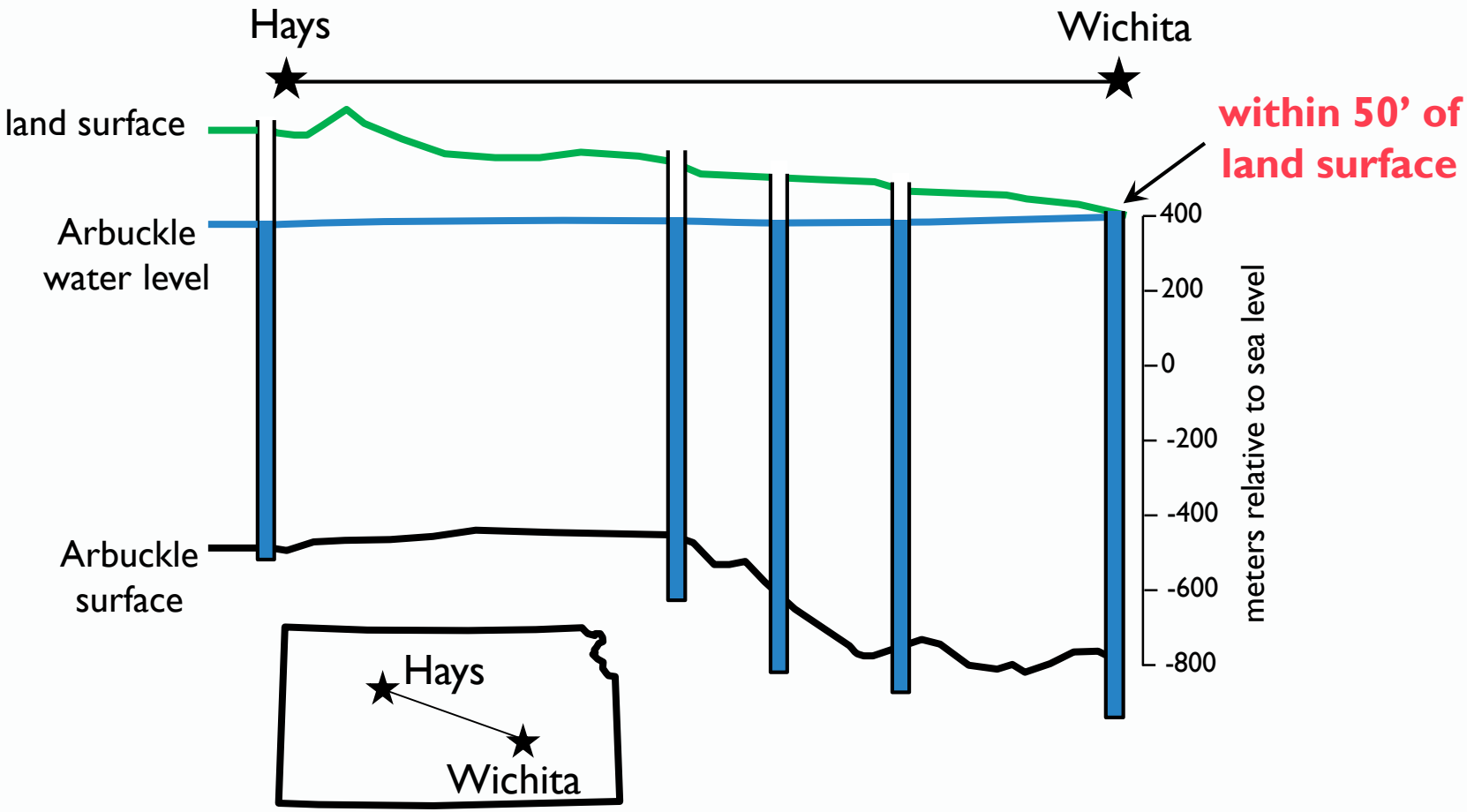
- Pressure and fluid level
  - Likely higher now than ever before
  - Elevated risk for seismicity
  - Likely future groundwater contamination associated with fluid level rise

- We need more data to better understand:
  - scope of the problem
  - how to inject sustainably
  - avoid potential problems

Potentiometric Surface



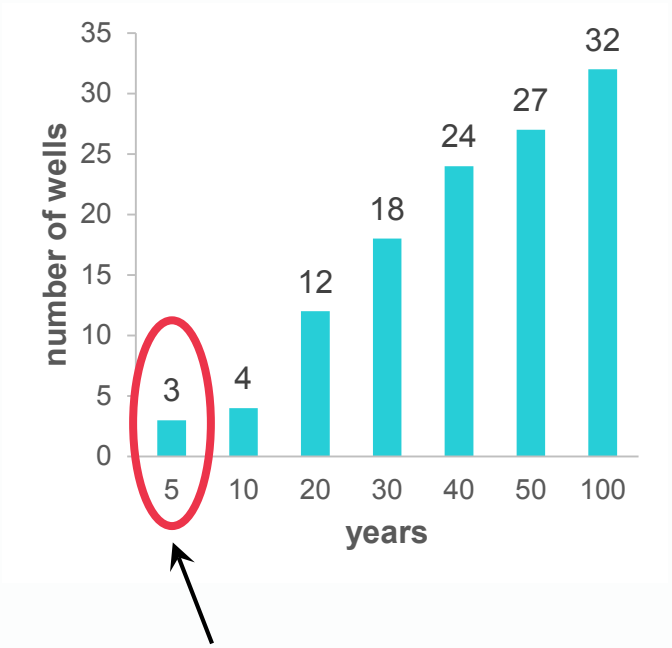
Arbuckle Fluid Levels



Implications and Hypothetical Scenarios

- Loss of gravity feed
  1. ***Existing facilities***
     - could lose use of disposal wells
     - would require cost-prohibitive measures
  2. Hypothetical facility
     - freshwater can't enter Arbuckle
     - sits in wellbore
- Drinking water contamination
  - fluid level above water source
  - inadequately plugged wells
  - *reality of leaks:* sinkholes
- The possibility is real within 20 years or less

projected lifetime of 40 Class I wells



3 wells within five years

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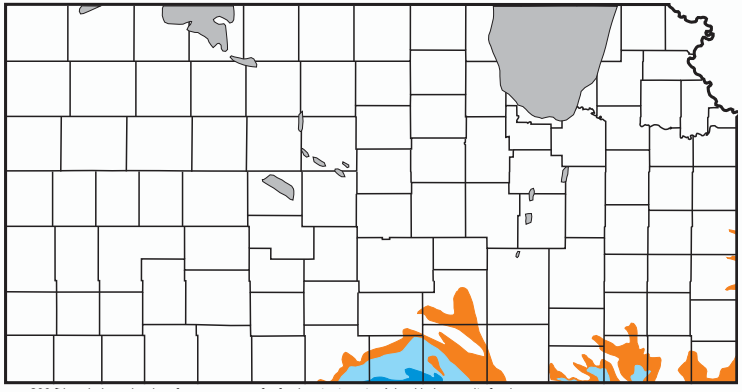
map represents ability to dispose of freshwater-density fluid



Loss of gravity feed

At risk for losing gravity feed

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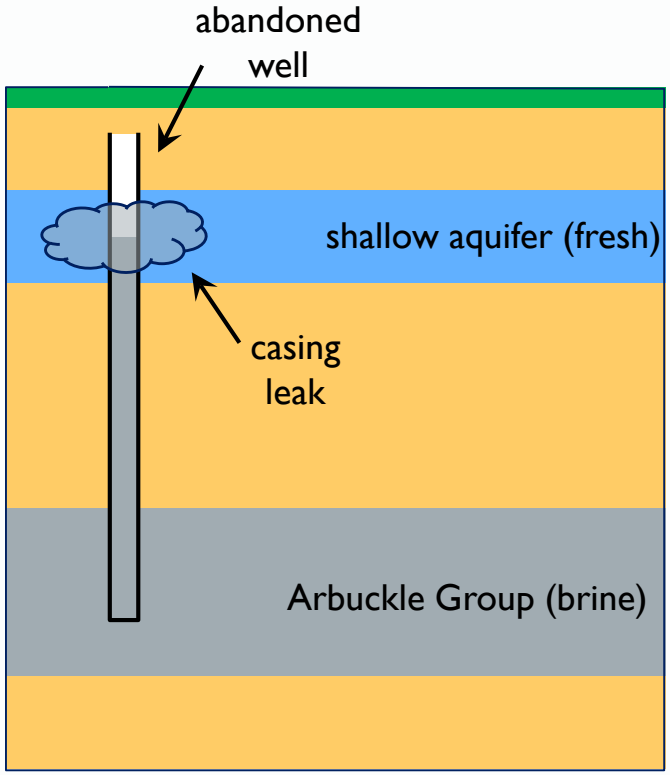

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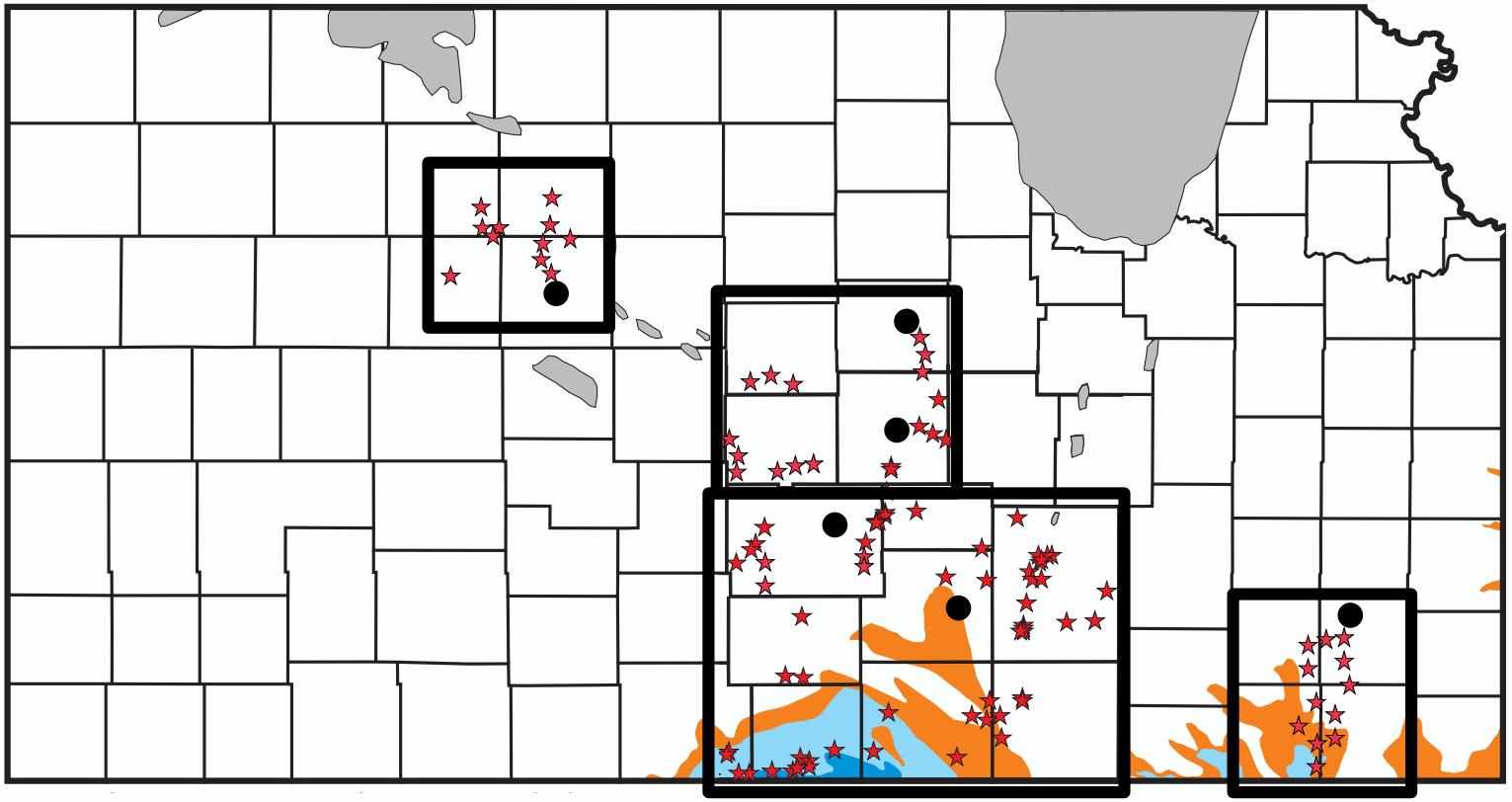
Macksville sinkhole

Focus Areas and Resulting Products

- Objective: informed disposal for sustainable use of the Arbuckle
  1. Fault mapping and rock property variability
     - *Product:* High-resolution fault maps, relative permeability of Arbuckle zones (karsting, fractures, etc.)
  2. Determine sustainable injection rates/volumes
     - *Product:* establish better link between formation pressure, injection volumes/rates, fluid level rise, and percolation rates
  3. Potentiometric surface mapping (new measurements in 120 wells)
     - *Product:* more detailed piezometric surface to identify problem areas for disposal, and shallow aquifers at risk for contamination
- Product users: policy makers, regulators, commercial users, industrial producers, municipalities

Proposed Research Areas



★ Arbuckle wells for new measurements

● Major city

Products, Budget and Timeline

year	deliverables	budget
1	Locate 120 wells of opportunity and highest interest seismic data Get permissions and acquire initial well data Locate and secure seismic data, interpret seismic data Identify areas with potential for contamination and rate concern	$826,000, includes: ▪ data acquisition (40 wells) ▪ seismic data purchase ▪ salaries, travel, supplies
2	Progress maps with partial raw data entry—working maps Get permissions and acquire more well data, Continue securing and interpret seismic data	$826,000, includes: ▪ data acquisition (40 wells) ▪ seismic data purchase ▪ salaries, travel
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4	**Enhanced Arbuckle maps** ▪ faults, structure ▪ irregular zones (karst, fractures, etc) ▪ rock properties (well logs)	$214,000, includes: ▪ salaries ▪ supplies
5	**Arbuckle fluid properties maps (flow, chem, SFL, P, etc)** ▪ flow rate ▪ gradient ▪ fluid relative to potable water supplies	$214,000, includes: ▪ salaries ▪ supplies