Introduction to Deep Well Injection as a Disposal Option

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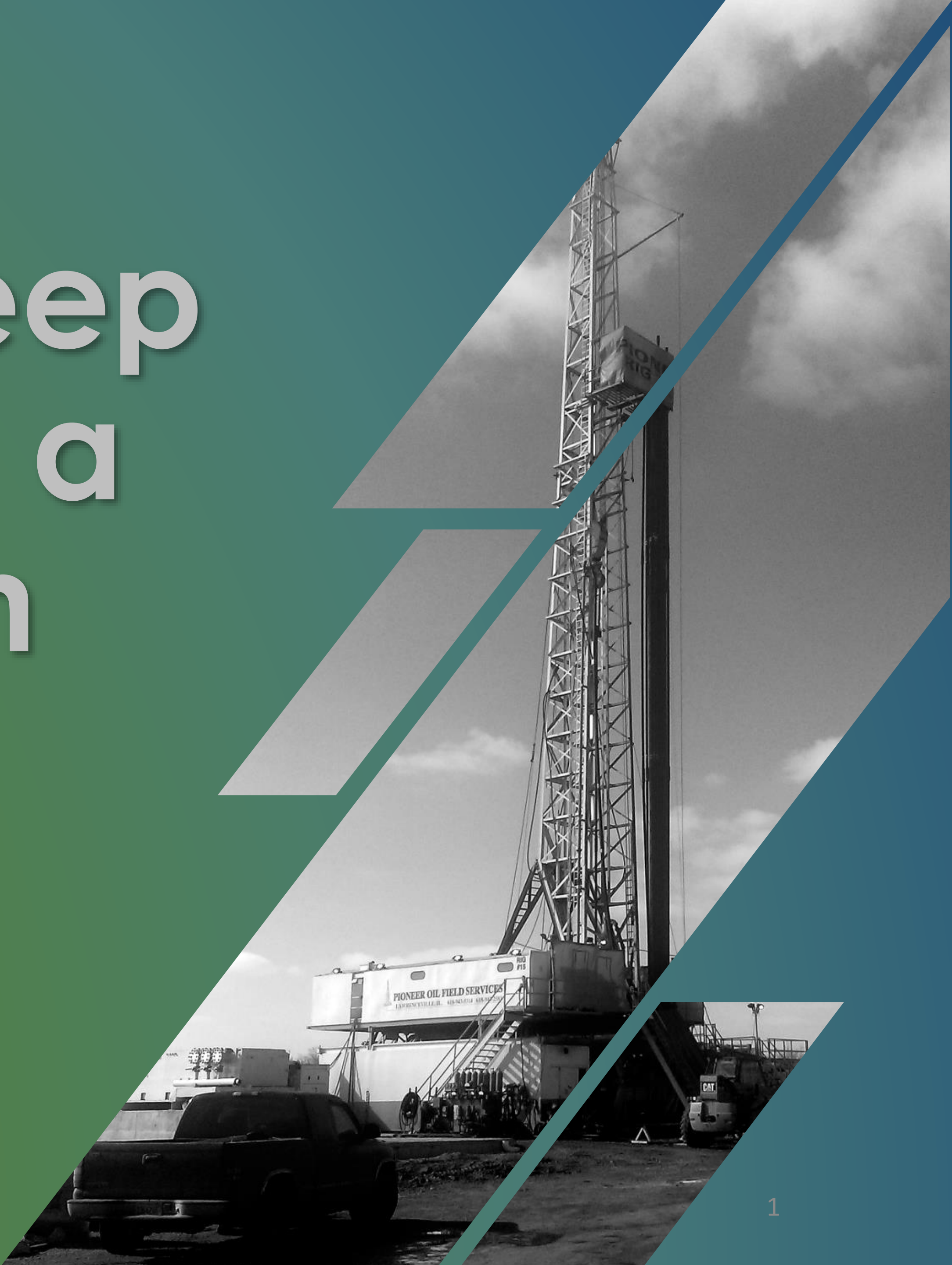
AEF Convention



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Injection Wells: What We'll Cover

1 Background and Use Cases

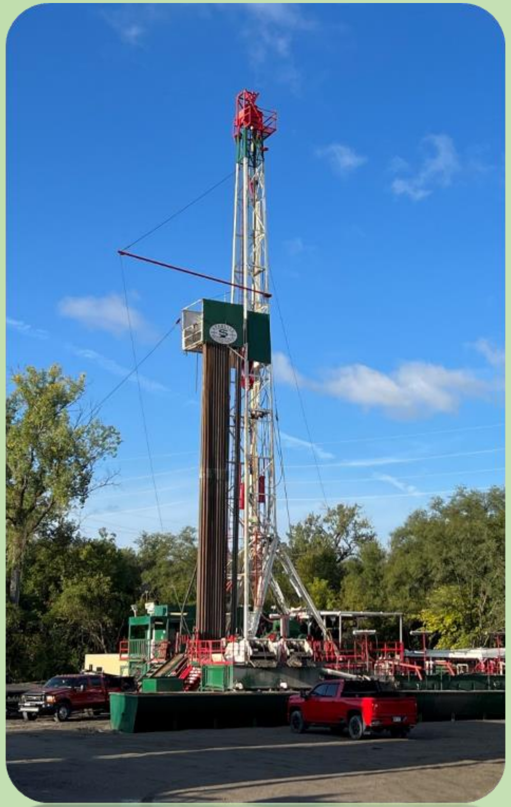
- When is an injection well a good option to consider?

2 Research, Design, Monitoring

- How are environmentally safe injection wells built?

3 State-Specific Considerations

- What would an injection well project look like in Arkansas?



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Background and Use Cases

- **How are injection wells classified?**
- **What circumstances would make an injection well a good disposal option?**

Definition

- **Underground Injection: the technology of placing fluids underground through wells**
  - Underground rock formations contain voids and pore space of varying size and connectivity
  - Varying capacity for fluid storage and flow
- Encompasses multiple types of projects…

History

1930s: First injection wells – oil companies converting production wells

1940s: Steel industry disposal wells

1950s: Manufacturing disposal wells

1960s: Municipal wastewater disposal wells

1970s: EPA granted the authority to regulate underground injection (part of the Safe Drinking Water Act)

1980s: EPA develops UIC (Underground Injection Control) program

2000s: Hydraulic fracturing excluded from UIC regulations in 2005; Carbon sequestration applications emerge

EPA Classifications

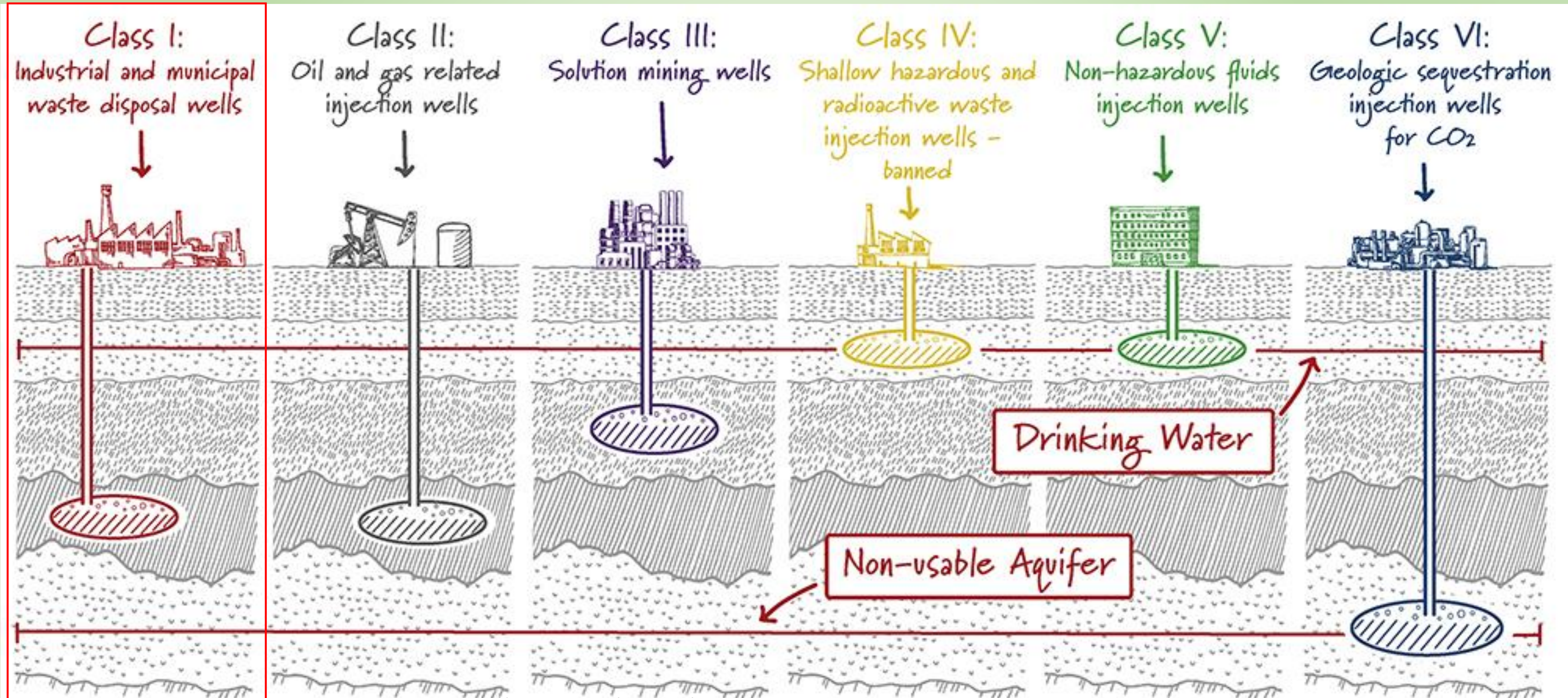
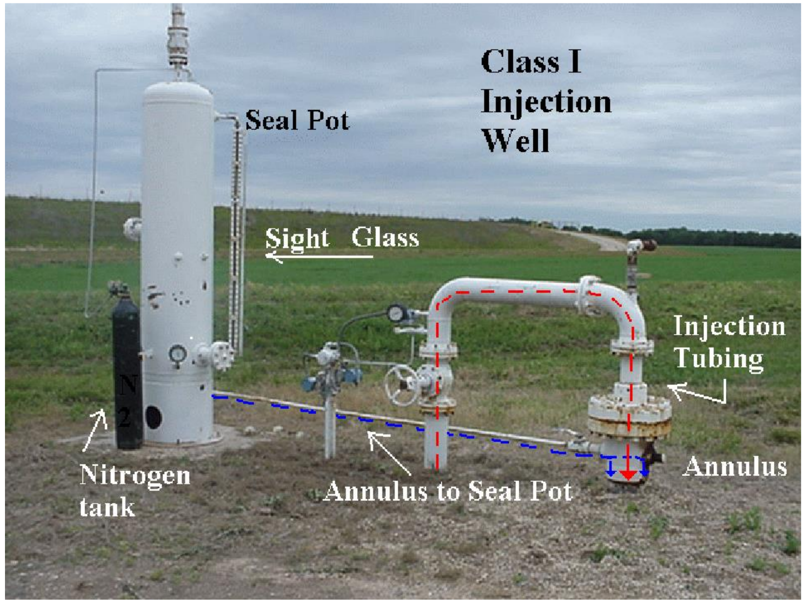


Image source: https://clearpath.org/our-take/the-permitting-program-crucial-for-carbon-captures-success/

DEEP WELL INJECTION

Class I	Wells that inject hazardous and non-hazardous waste beneath the lowermost formation containing an underground source of drinking water (USDW) within ¼ mile of the well bore.

Injection Wells – EPA Classifications



Class I – Deep Well Injection

- Hazardous and nonhazardous wastewater
- 800+ permits nationwide
- Industry w/wastewater - landfill leachate, municipal water treatment, power plants…
- Timeline for hypothetical Illinois well, feasibility to operation: ~20-38 mos
- Cost for hypothetical Illinois well: $8-14.75M

Class VI – Carbon Sequestration

- Carbon dioxide
- 7 permits nationwide (~40 applications)
- Industry w/ captured emissions - refineries, power plants…
- From feasibility to operation ~12-48 mos
- Cost ~ $10-40M

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Example: $7 Million Zero-Discharge Facility

- Illinois site
- Completed 2019
- ROI: 9 months
- Rate: 10 million gallons/year
- Asset life design: 30 years
- Unit costs: <$0.05/gallon

YR 1
- Studies: feasibility, siting, water balance
- $30K

YR1
- Permitting
- $160K

YR2
- Drill and complete well
- $3M

YR2
- Complete pretreatment and pumping
- $4M

Use Cases – Class I

Security/Permanence
- Protects surface and drinking water
- Constant amid changing regs and POTWs

Compliance
- Zero discharge
- Strict surface water discharge regs

If More Cost Effective than Alternatives
- Treatment
- Shipping/Hauling

E.G. Leachate, contaminated groundwater, industrial wastewater, municipal wastewater

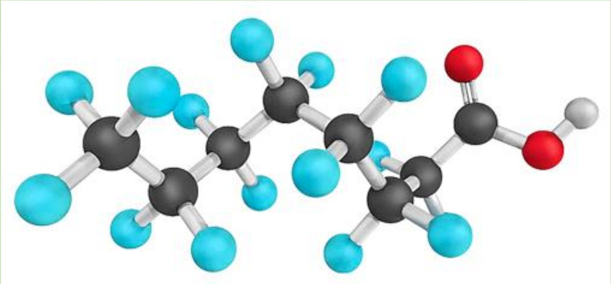
Use Cases – Class VI

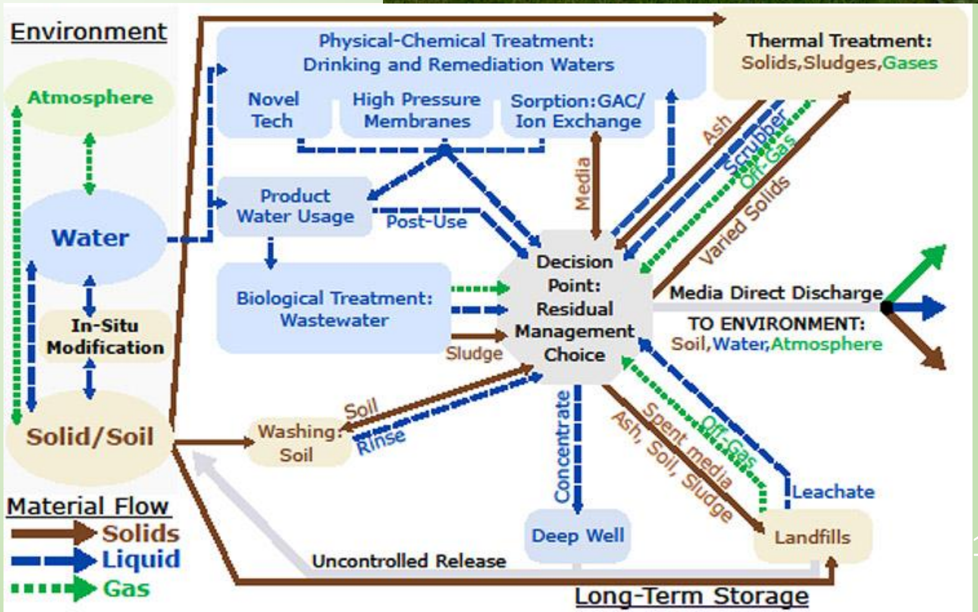
- Carbon Sequestration Incentives
- Grant opportunities
- High-CO2 Effluent Streams
- Carbon Capture and Storage

…For this presentation, focusing on Class I wells

Evolving Regulations - PFAS

- **Per- and Polyfluoroalkyl Substances**
- Difficult to break down/treat; residuals still challenging
- EPA working to create guidelines:
  - "…proactively prevent PFAS from entering air, land, and water at levels that can adversely impact human health and the environment"
- **EPA identifies Class I injection wells as a favorable PFAS management option** (March 2024 Interim Guidance on the Destruction and Disposal of PFAS)

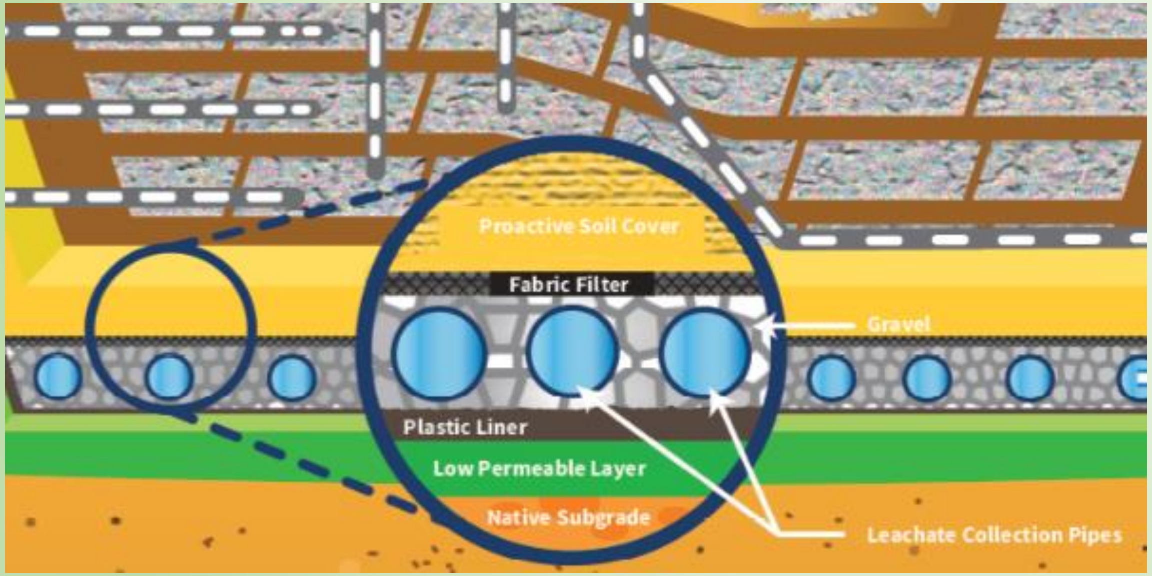




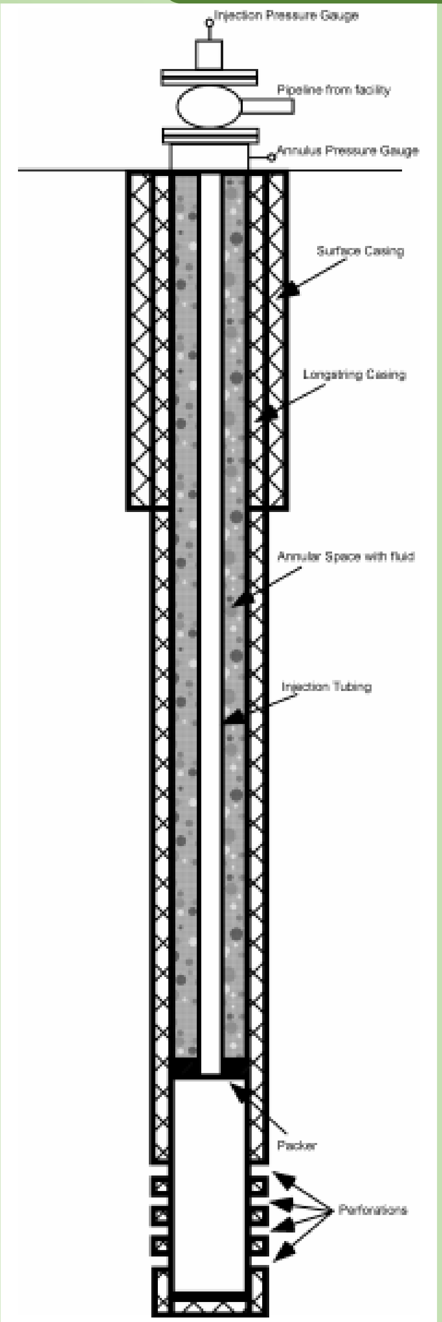
2 Research, Design, Monitoring

- What conditions make a site suitable for an injection well?
- How is an injection well constructed?
- Which factors are tested/monitored during a well's lifetime to confirm it is operating as intended?

- Siting Requirements (**Geology**)
- Multilayered Environmental Safeguards (**Redundancy**)
- Site selection for **>20 year asset life**



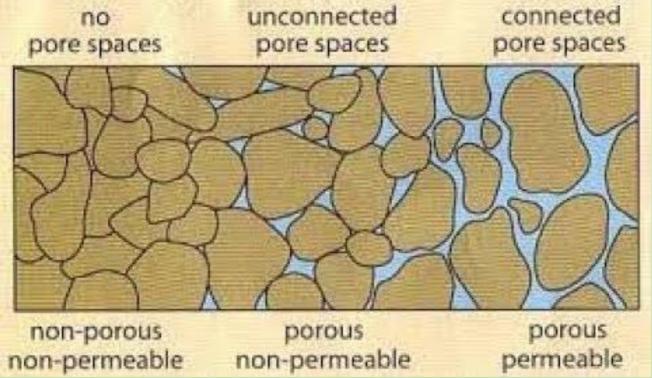
Factors that modern disposal methods consider to stay effective and environmentally safe

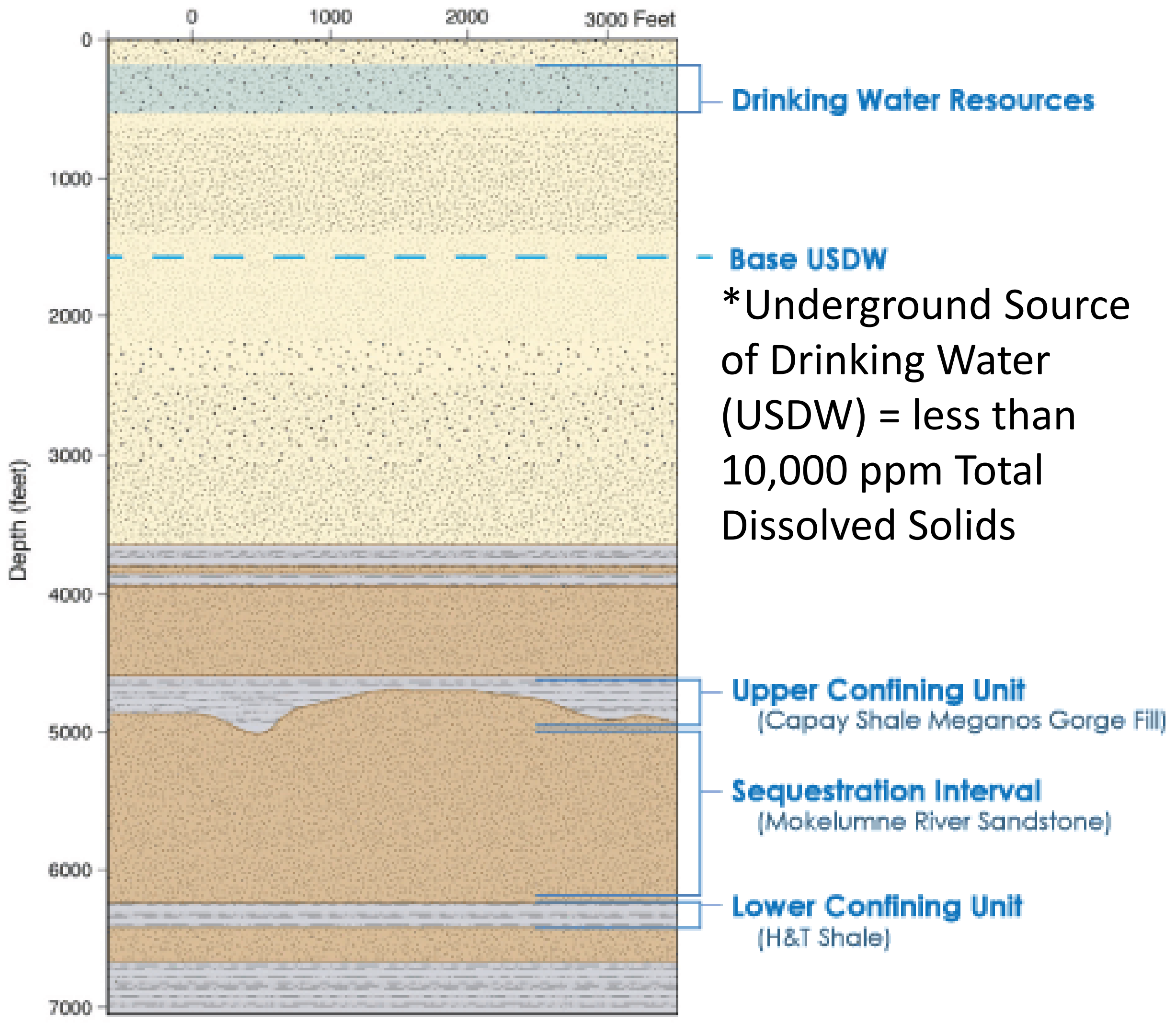


Siting an Injection Well

Suitable Geology: Thickness, Porosity and Permeability

- **Injection Interval**
  - Formations with capacity to accept wastewater volumes
  - **Thick formations** with **<u>high permeability</u>**
- **Confining Units**
  - Formations to **prevent upward migration of fluid into protected aquifers**
  - **Thick formations** with **<u>low permeability</u>**



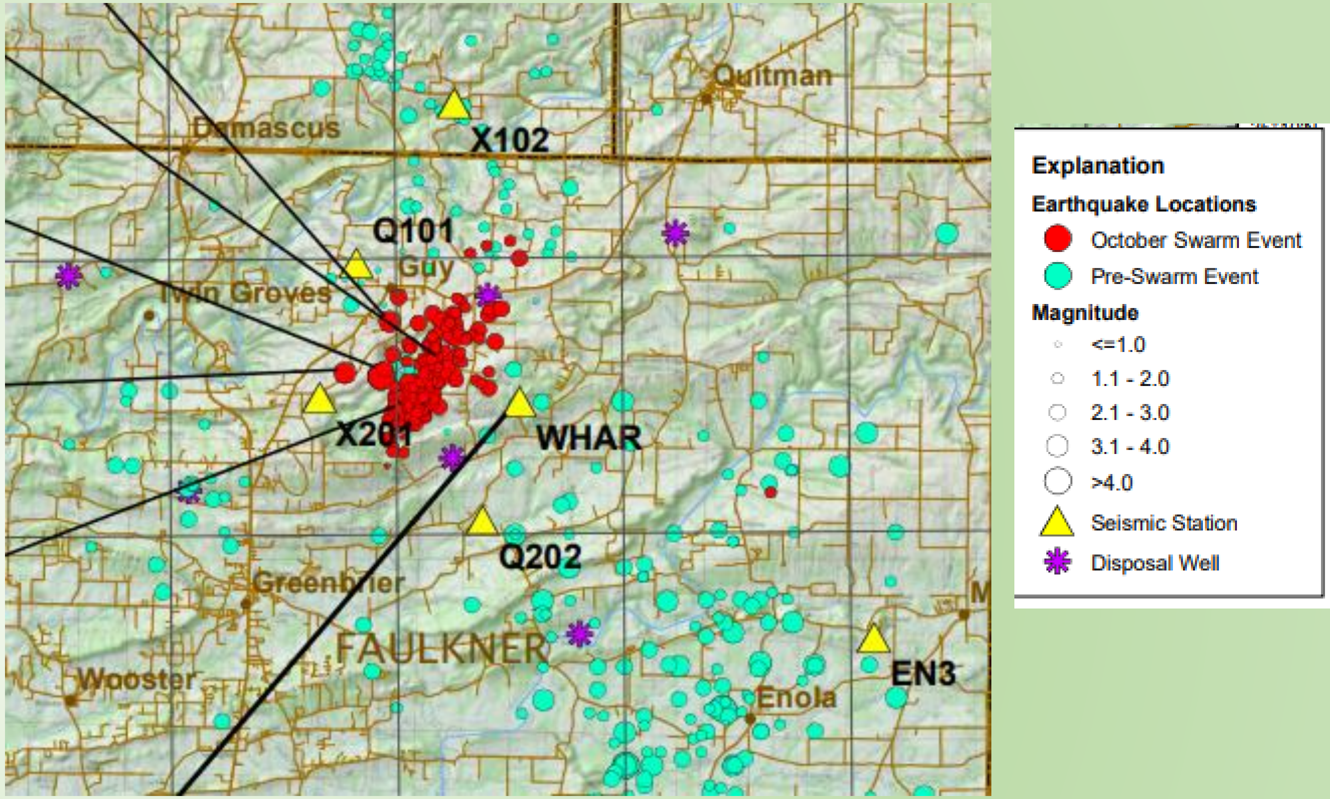


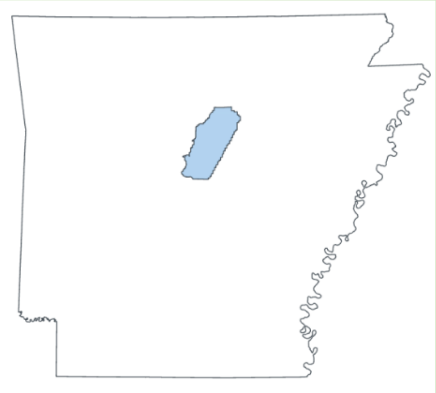
*Underground Source of Drinking Water (USDW) = less than 10,000 ppm Total Dissolved Solids

Siting an Injection Well

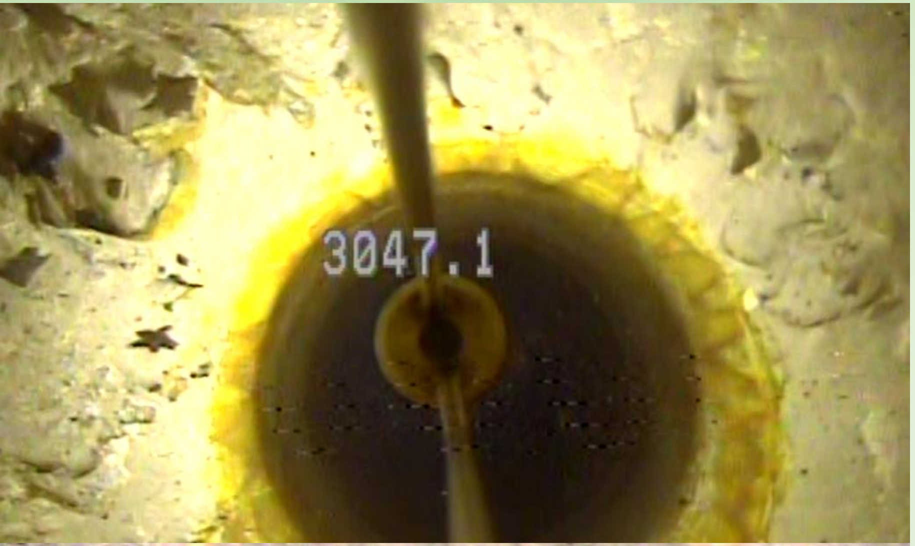
Suitable Geology: Pressures

- **Fluid interactions: Existing and Injected**
  - Injection pressure should be maintained below a calculated maximum to prevent fracturing or fracture propagation
- **Faults and Seismicity**
  - Evaluate location regarding known faults and potential for injection rate and pressure to induce seismic activity
- ****Current moratorium on Class II injection wells resulted from induced seismicity - Earthquake Swarm in 2010**





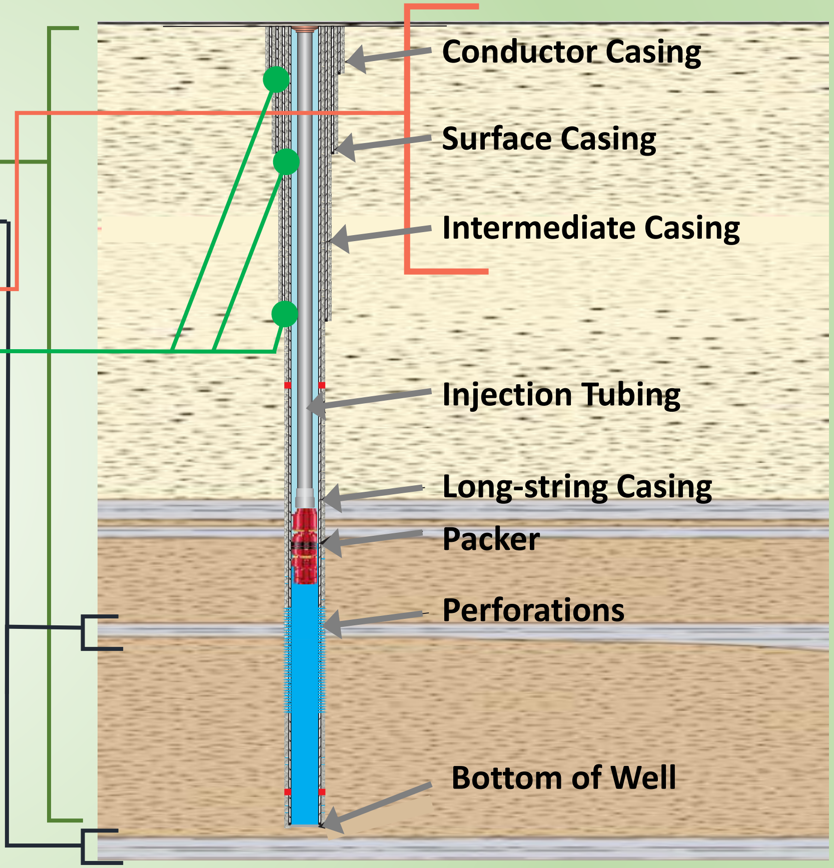
Know Your Waste Stream

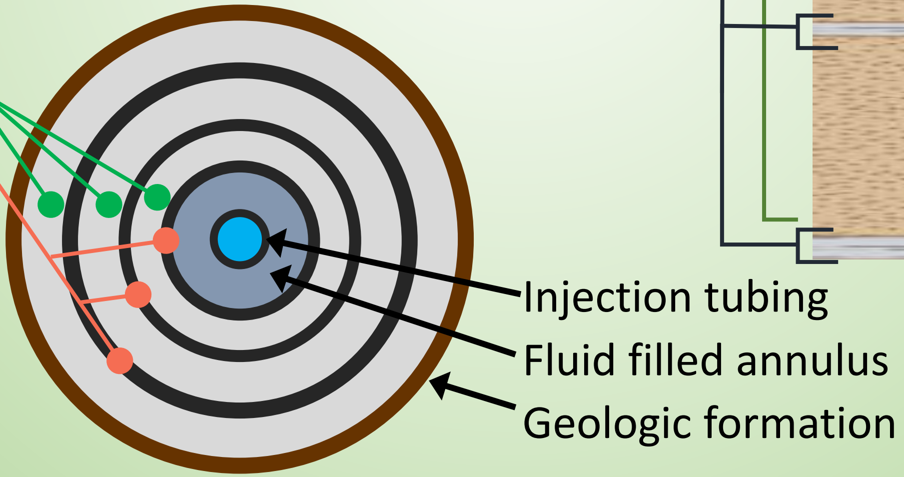


- How will waste stream chemistry interact with formation fluid chemistry?
- Accounting for chemical makeup → maintaining well integrity and keeping costs in line

Well Construction - Subsurface

- **Vertical separation**
- Nearly impermeable **geologic seals**
- **Redundant casing** strings
- **Cement** between casing strings & borehole





Well Construction – Surface Design Factors

- Pump sizing (if gravity injection impossible)
  - 200-2000 gpm rate; 0-2000 psi pressure (dependent on reservoir characteristics)
- Pre-treatment
  - Filtration
  - Disinfection
  - Mass removal

Testing and Monitoring

- Periodic Testing:
  - Annulus pressure test
  - Measure pressure buildup in injection zones
  - Radioactive tracer test
  - Log testing for movement of fluid along borehole
  - Casing inspection logs
  - Annual Mechanical Integrity Tests
- Continuous monitoring: well pressures and flows
  - Injection tubing pressure
  - Annulus pressure
  - Flow rate
  - Injection volume
  - pH of injected fluids

3

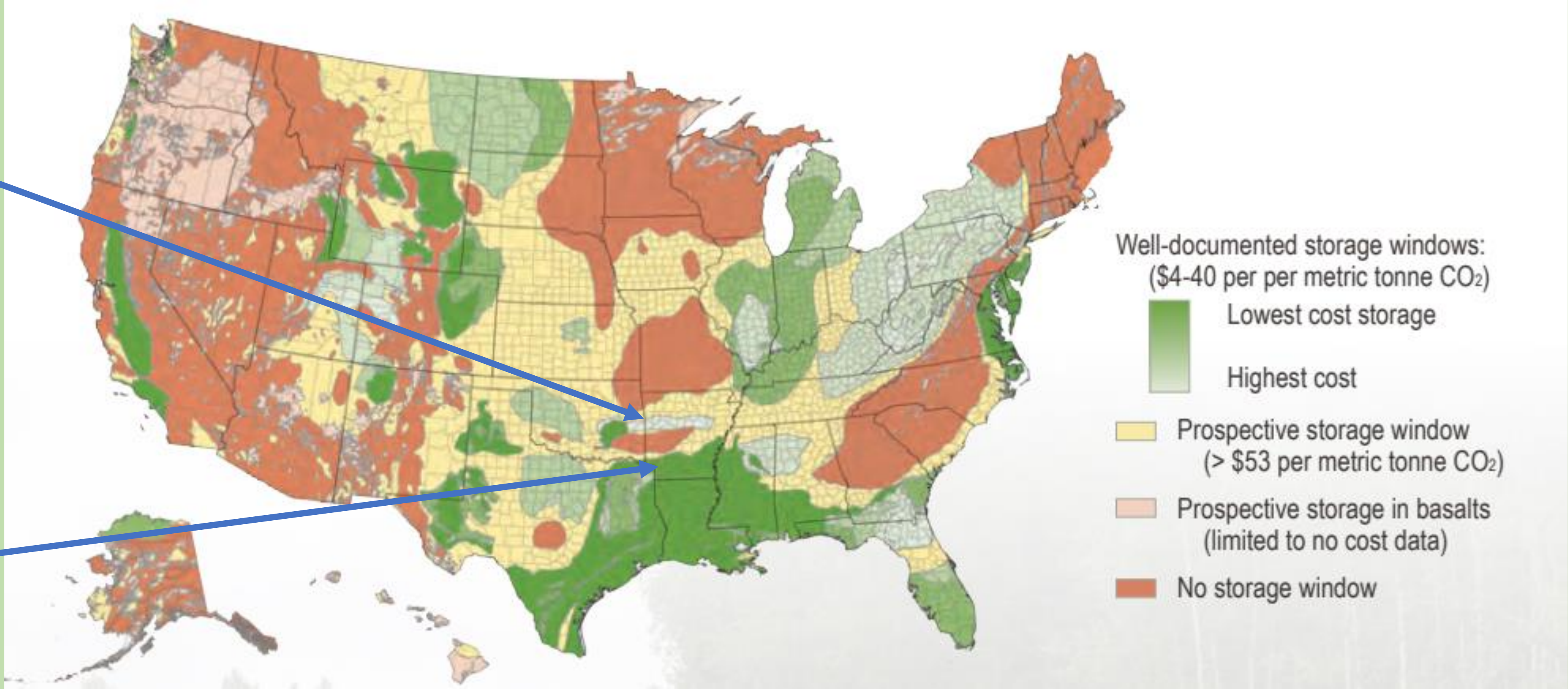
State-Specific Considerations

- **What formations in Arkansas have the potential for suitable injection interval geology?**
- **What steps take an injection well project from initiation to completion?**

Potential Storage Areas – Not a Guarantee of Suitability!

Arkoma Basin

Gulf Coast

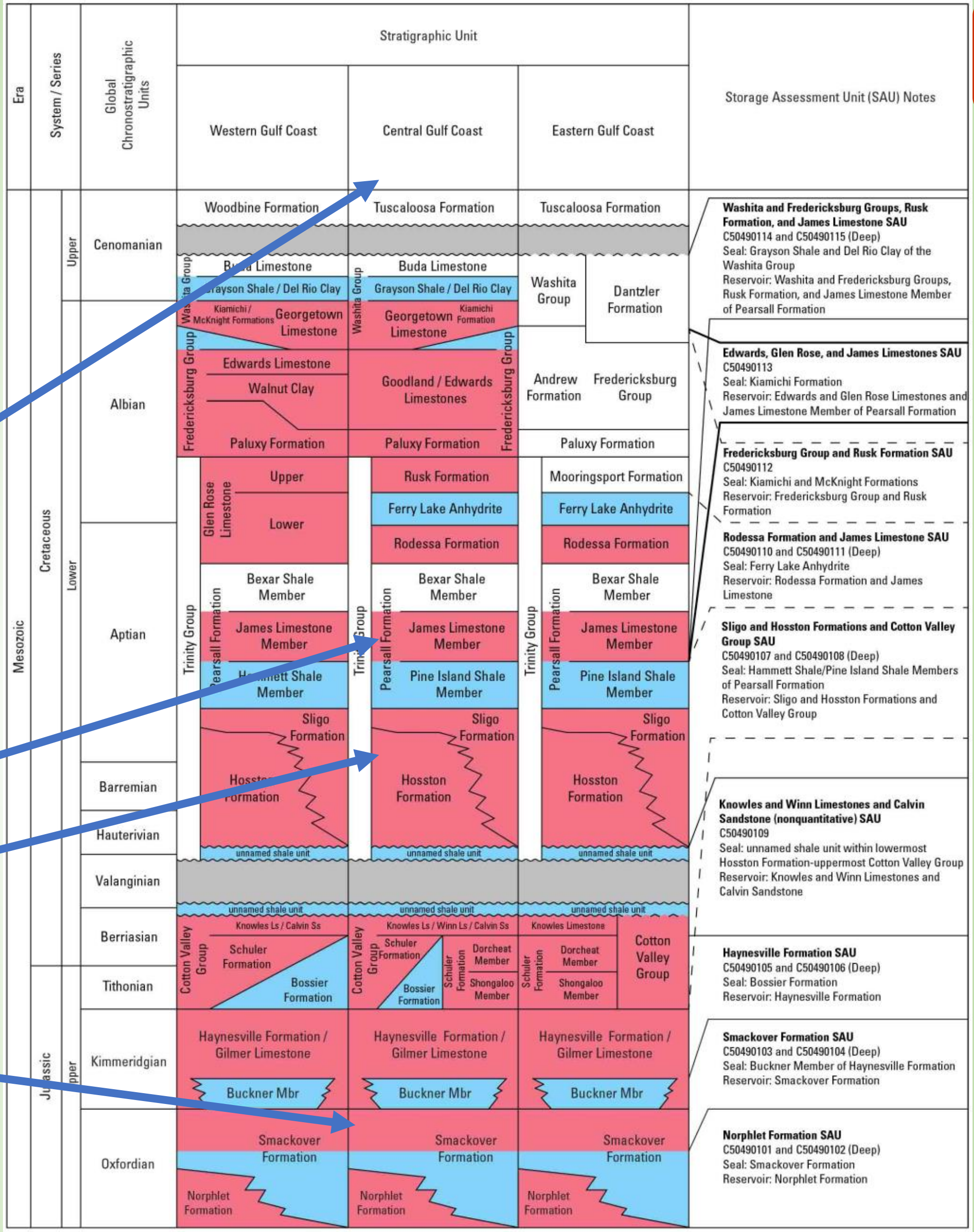


Roads 2 Removal – Carbon dioxide sequestration (even more stringent regs)

Only guarantee of suitability is an Approved Permit Application!

Gulf Coast Stratigraphy

ERA	SYSTEM	SERIES	GROUP	FORMATION	AGE (Ma) [1]
CENOZOIC	Quaternary	Holocene	Alluvium		0.01 - Present
		Pleistocene	Terraces		1.81-0.01
	Tertiary	Eocene	Jackson	Redfield	39.1-33.7
				White Bluff	
			Claiborne	Cockfield	52.3-39.1
				Cook Mountain	
				Sparta	
				Cane River	
			Wilcox	Wilcox	59.1-52.3
		Paleocene	Midway	Midway	61.5-59.1
MESOZOIC	Upper Cretaceous	Gulfian	Navarro	Arkadelphia	71-68
				Nacatoch	
				Saratoga	
			Taylor	Marlbrook	[illegible]-71
				Annona	
				Ozan	
			Austin	Brownstown	87-82
				Tokio	
			Tuscaloosa	Upper Tuscaloosa	98-87
				Middle Tuscaloosa	
				Lower Tuscaloosa	
	Lower Cretaceous	Comanchean	Washita and Fredericksburg	Kiamichi	107-99
				Goodland	
				Paluxy	
			Trinity	Mooringsport	109-107
				Ferry Lake Anhydrite	112-1[illegible]
				Rodessa	114-112
				James	116-114
				Pine Island	118-116
		Coahuila	Nuevo Leon	Sligo	[illegible]32-118
				Hosston (Travis Peak)	
	Jurassic	Upper Jurassic	Cotton Valley	Schuler	150-137
				Bossier	
			Louark	Haynesville (Buckner Member)	154-150
				Smackover	159-154
				Norphlet	161-159
		Middle Jurassic		Louann Salt	175-163
				Werner	176-175
	Triassic	Late Triassic		Eagle Mills	210-195
PALEOZOIC	Cambrian-Permian	Late Cambrian-Permian	Undifferentiated Paleozoic		500-251



Stratigraphic column displaying the east-west distribution of the Upper Jurassic and Cretaceous geologic units within the U.S. Gulf Coast study area. Storage assessment units consist of a reservoir (red) and regional seal (blue). Wavy lines indicate unconformable contacts, and gray areas represent unconformities. Adapted from Nehring (1991), Salvador and Quezada-Muñeton (1991), Goldhammer and Johnson (2001), Witrock and others (2003), Sweezey and Sullivan (2004), Mancini and Puckett (2005), Warwick and others (2007), Mancini and others (2008b), Valentine and Dennen (2012), and Walker and others (2012).

Formations with Active Class I UIC Permits: Hosston, James, Smackover, Tokio

USGS CO2 Sequestration Map – Gulf Coast

AGS, Subsurface Stratigraphic Chart of South Arkansas

Arkansas UIC Program

- ADEQ has primacy over Class I injection wells; conducts bimonthly inspections
- 7 *active* Class I injection well permits as of October 2024 – ADEQ database
- Active injection intervals range from 2500 to 8700 feet below ground surface
- Review timelines and costs vary from project to project

3

Components of a Project: Initiation to End-of-Life

Study & Permit Application

- Feasibility Study
  - Begin conversation with regulators
  - Specific cost estimate
- Site Characterization
- Area of Review
- Well Design
- Operations and Monitoring, Plugging and Abandonment Plans
- Financial Assurance
- ADEQ Submittal

Pre-Treatment Design

- Begin during Regulatory Review
- Pre-treatment design
- Refine pre-treatment cost estimates

IF NECESSARY

Planning and Procurement

- Begin during Public Notice Period
- Refine construction cost estimates
- Construction planning
- Subcontractor selection
- Procurement

Construction

- Site Preparation
- Injection Well Construction
- Testing
- Commissioning
- Application to Operate
- Public Notice & Hearing
- Receive Permit to Operate

Operation and Maintenance

- System Start-up & Commissioning
- Compliance Testing, Monitoring and Reporting
- Financial Assurance
- Plugging and Abandonment

Public Notice and Reaction

- Two public notice periods required for Class I wells
  - When permit application submitted
  - When the Department informally decides whether to approve or deny the permit
- **Communication** with the public necessary to demonstrate environmental safety, defuse existing negative associations

In Conclusion…

- Injection wells: Disposal option for fluid waste streams that **protects surface water and underground drinking water**
- Technical Design Elements Key to Safety: **Geology**, **Chemistry**, **Testing and Monitoring**
- ADEQ UIC program regulates Class I injection wells and **state specific permitting process**

Thank you!
Any questions?

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