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Class I Injection Well Update: The Use of Deep Wells for Wastewater Management at ISL/ISR Facilities

Uranium Recovery Workshop

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Objectives

- Introduction
- ISR Use of Injection Wells for Disposal
- Regulatory Overview
- Technology Overview
- Critical Feasibility/Siting Concerns
  (technical & regulatory)
- Current Regulatory Issues
- Summary and Questions

Deepwells/Injection Wells
Why Are ISR Operators Interested?

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- Control of fluids in ISR mine units requires the management of significant fluid volume derived from:
  - mining and processing
  - bleed
    (overproduction for gradient control)
  - restoration
    (sweep, bleed, and treatment reject stream)
- Required to achieve the limited environmental footprint widely considered to be an advantage of properly mining with ISR technology

Deepwells/Injection Wells
Why Are ISR Operators Interested?

- Can provide a valuable alternative to evaporation ponds and other disposal approaches
- Is a cost-effective wastewater management option with proper siting and planning
- Is protective of human health and the environment when properly sited and constructed/operated according to current regulations

Regulatory Timeline

- **1930s** — Early State programs to regulate ground water discharges
- **1960s** — States actively involved in ground water pollution issues
- **1972** — CWA
- **1974** — SDWA
- **1980** — First Federal UIC regulations
- **(Policy)** — Continued Evolution

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UIC Program

- The mission of the UIC program is to protect underground sources of drinking water from contamination by regulating the construction and operation of injection wells

Structure of the Program: UIC Regulations

- 40 CFR Part 144 - Requirements
- 40 CFR Part 146 – State Program Requirements
- 40 CFR Part 146 – Criteria and Standards
- 40 CFR Part 147 - State UIC Programs
- 40 CFR Part 148 - Hazardous Waste Injection Restrictions

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Classes of Wells

- Five classes of wells are addressed in UIC regulations
- Greater or lesser potential for drinking water endangerment depending on their depth, injectate, and geologic setting
- Categorized based on common design and operating characteristics

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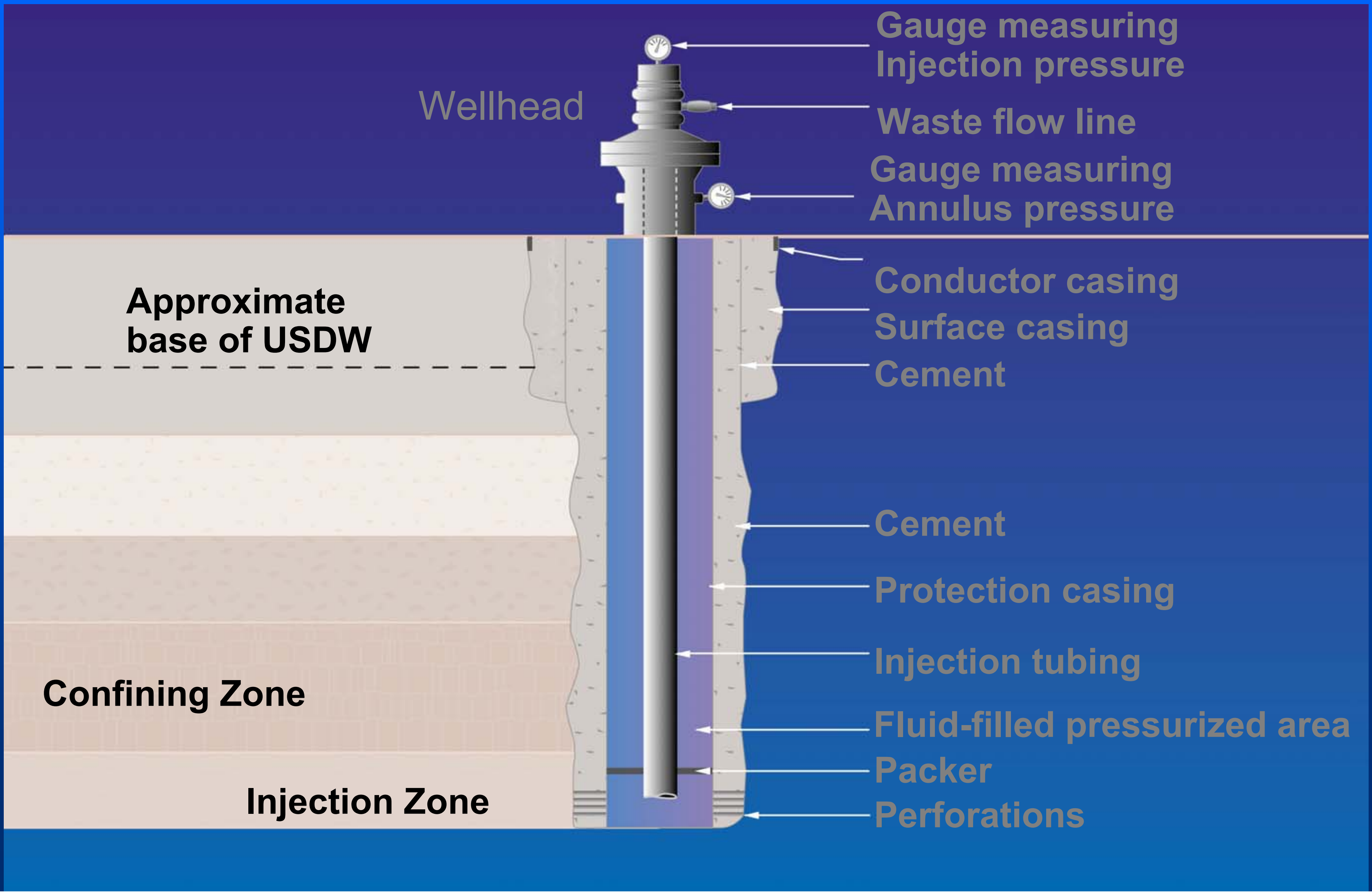
Well Classes Defined

- ***Class I wells*** inject hazardous and non-hazardous wastes into formations that are ***below*** the lowermost USDW (within ¼ mile of the injector).
- ***Class II wells*** inject non-hazardous fluids associated with oil and natural gas production into formations that do not have to be ***below*** the base of USDWs.
- ***Class III wells*** inject steam, water, or other fluids into mineral formations that dissolve the minerals to be pumped to the surface for mineral extraction. Generally, the fluid is treated and re-injected into the same formation.
- ***Class IV wells*** inject hazardous or radioactive wastes ***into*** or ***above*** formations that are USDWs within ¼ mile of an injector. These wells are banned under the UIC program. 144.6.d.3 only prohibits the injection of hazardous waste into exempted USDW aquifers.
- ***Class V wells*** use injection practices that are not included in the other classes. Many are "low-tech" holes in the ground. Others are sophisticated and are regulated like Class I wells.

Class I Wells

- Extensive permitting requirements
- No-migration demonstration for hazardous well operations
- Continuous monitoring (except municipal)
- Internal and external MIT (every five years for most Class I-non-hazardous)
- Frequent reporting
- Used in approximately 20 states

Class I Well Construction



Class V Wells

- Class V: All injection wells that do not meet the definitions of Classes I, II, III, or IV
- Used for disposal of CBM water in Wyoming
- 2008 policy for ISR disposal in Wyoming, latest clarification suggests pre-treatment is needed
- Various unique wells throughout the country (experimental/Region 6, solids injection/Region 9, continuous liquid injection above fracture pressure/BOR in Region 8)
- Many are shallow and low-tech
- Most inject into or above USDWs
- Must not endanger drinking water

SDWA (Safe Drinking Water Act) – Basic UIC Concepts

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- Requires EPA to promulgate regulations to protect drinking water sources from contamination through underground injection
- Defines:
  - Underground injection
  - Endangerment of drinking water sources
- Designed to be implemented by States

Define Aquifer and USDW

- **Aquifer: G**eologic formation that is capable of yielding a significant amount of water to a well or spring
- **Underground source of drinking water (USDW):** An aquifer or portion of an aquifer that
  - a (1) Supplies any public water system *or*
  - a (2) contains a quantity of ground water sufficient to supply a public water system, *and*
  - a (2) i Currently supplies drinking water for human consumption, *or*
  - a (2) ii Contains fewer than 10,000 mg/L total dissolved solids *and*
  - b is not an exempted aquifer

Aquifer Exemption

- EPA can exempt certain USDWs from SDWA protection for the purpose of injection
- Criteria:
  - Does not currently serve as a source of drinking water, and
  - Cannot serve as a source of drinking water because:
    - Is mineral, hydrocarbon, or energy producing or
    - Is at a depth or location that makes recovery impractical (technologically or economically) or
    - Contains "contaminants" that make it impractical to make the water fit for consumption
  - Or it contains TDS of 3,000 to 10,000 mg/L and is not reasonably expected to serve a public water system

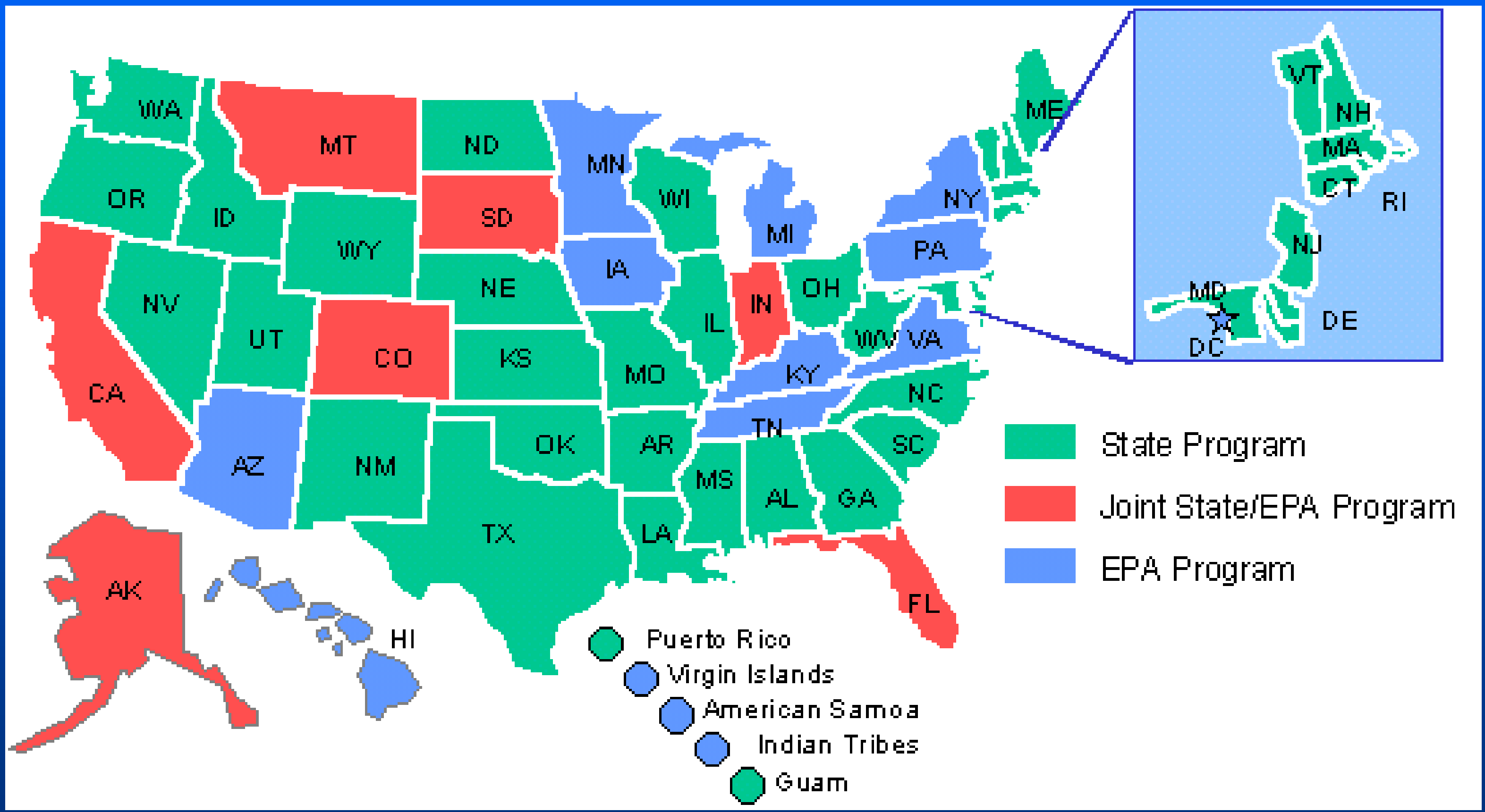
Why an Exemption?

- All USDWs to be protected except exempted aquifers (40 CFR 146.4 b)
- If injection to occur into formation that technically meets definition, but practically is not a potential drinking water source, exemption process available
- In Wyoming classification as Class V or Class VI groundwater serves this purpose, but EPA is exercising “review and response” authority over WDEQ decisions

Structure of UIC Program: State Primacy Requirements

- Must promulgate requirements that are at least as stringent as EPA's:
  - Prohibit all types of injection unless authorized by rule or by permit
  - Prevent underground injection that endangers drinking water sources
  - Implement requirements for inspection, monitoring, recordkeeping, and reporting

Structure of the Program: UIC Primacy Delegation



Wyoming UIC Program

- WDEQ has primacy from EPA
- Program implemented under Water Quality Regulations Chapters 8 &13
- >35 existing Class I wells in WY; <10 of those wells are for ISR operations (all in the Powder River Basin)

Texas UIC Program

- TCEQ has primacy from EPA
- Program implemented under TWC Chapters 27, 305 & 331 and THSC 361

- >100 existing Class I wells

  (both hazardous and non-hazardous)
- < 10 Class I wells for ISR operations

Nebraska UIC Program

- NDEQ has primacy from EPA
- Program implemented under Title 122

- One operating Class I well for ISR
  (Crow Butte Resources)
- One additional Class I injector
  (for city water treatment)

How Does Injection Work?

- Porosity – the material property of having void space within a solid (only useful if connected)
- Permeability – the material property that allows liquid or gas to move through the porosity of a rock
- Fluid Compressibility
  - large reservoir volumes
  - thickness and lateral extent
- Confinement

Compressibility

- Water has a compressibility of approximately 3×10^{-6} gal/gal/psi.
- A sealed tank of 1,000,000 gallons would increase in pressure by 1 psi if 3 gallons of water were added.
- For a reservoir with a radius of 5-miles, thickness of 100 feet, and porosity of 10%, it would take only 500,000 gallons to raise the pressure by 1 psi in the entire reservoir. Operating <1 week at 50 gpm.
- Rock in disposal zones can have about the same compressibility as water so the effective volume required to increase pressure is doubled.

Fluid Injection

- Fluid is injected into saturated pores
  - Native fluid is displaced, and
  - Native fluid is compressed and system expands
- Injection reservoirs should be large or infinite-acting systems for long-term injection

Delta p (Δ p)

- Matthews and Russell (1967) show that pressure increase is greatest at the well, but decreases dramatically (log) with distance

$$\Delta p = 162.6 \frac{Q\mu}{kb}\left[\log \frac{kt}{\Phi \mu c r^2} - 3.23\right]$$

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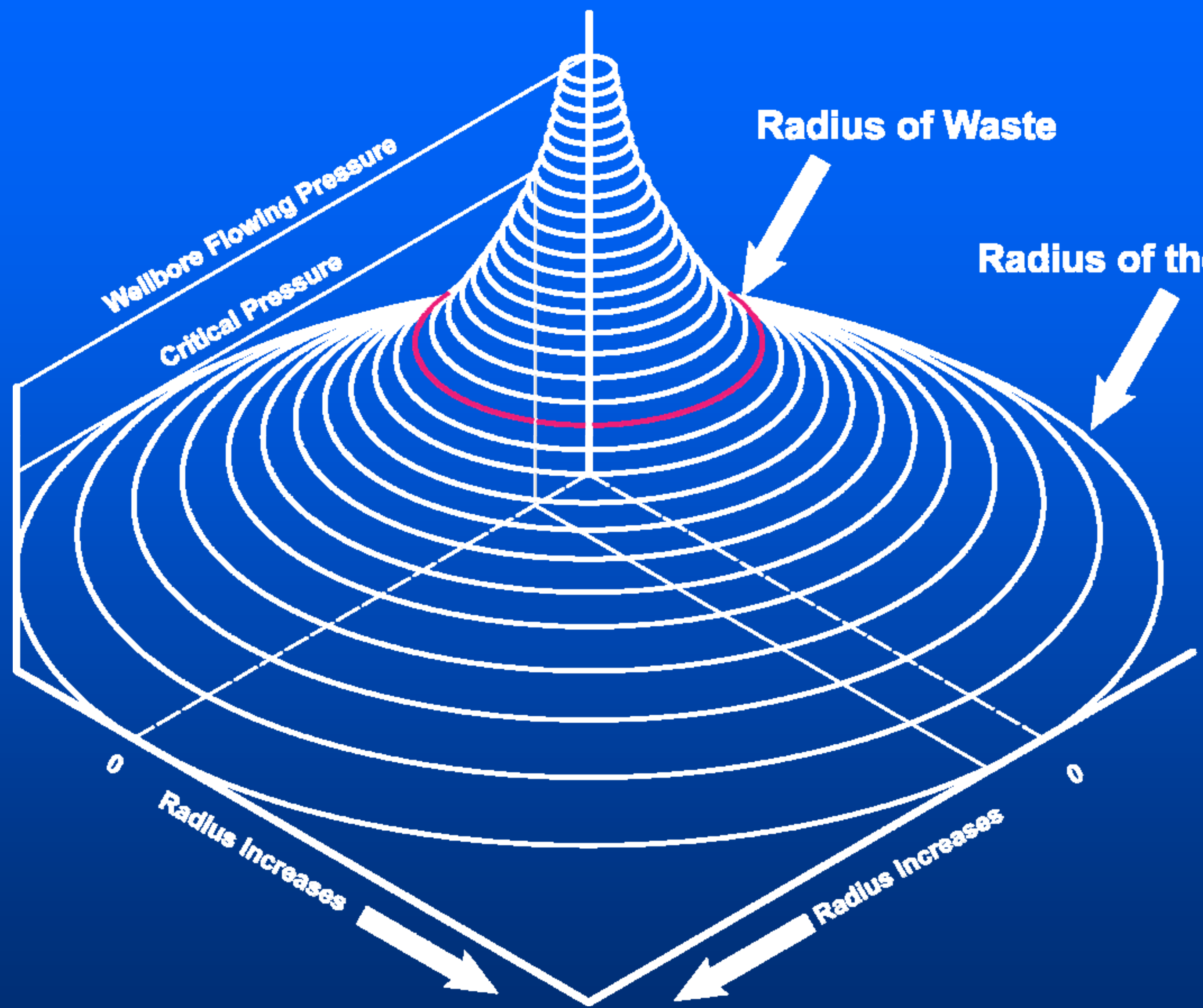
Pressure Front vs. Waste Front

- During injection, the pressure front typically leads the waste front
- Under static conditions the waste front can lead the pressure front
- Both can be reliably projected using a variety of methods depending on the complexity of the well system being modeled.
- Multiple wells in a reservoir can spread the effects, but the effects are additive (theory of superposition)

The Cone of Influence



Class I Well Siting

Critical: injection zone capacity, natural containment, artificial penetrations

Secondary: compatible surface use, access, regulatory environment, public perception

– Class V well requirements dependent on risk posed by depth of injection and type of injectate

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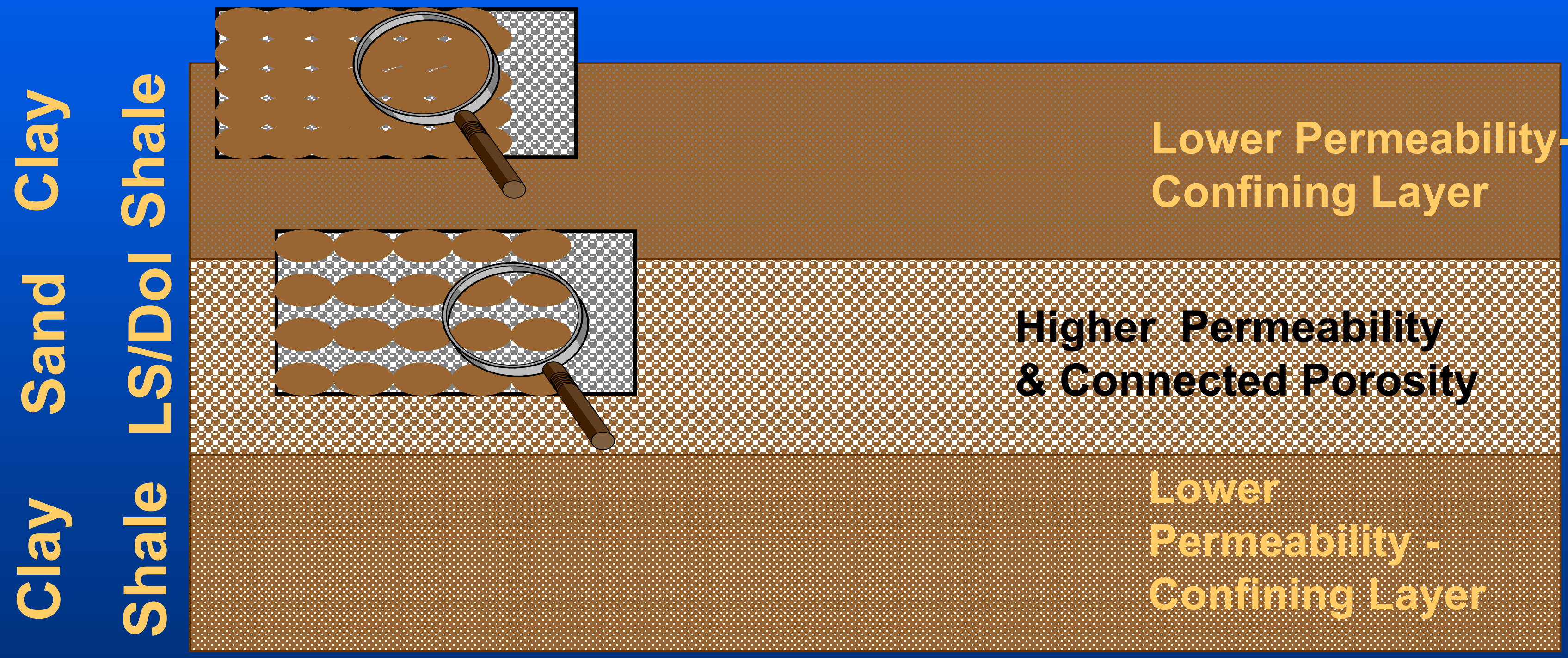
Injection Well Siting



Injection Capacity

- Oil or gas production may not be a good analog due to the economics of limited rates

  (in the oilfield 1 gpm production could currently equate to +/- $0.9 million of revenue per year, Class I disposal can require 10 gpm to >100 gpm)
- Disposed water from ISR can have a higher viscosity than oilfield production

  (temperature and composition critical; water 0.3-1.5 cp, gas 0.005 – 0.05 cp)
- Hydrocarbon reservoir compressibility (1/psi) is typically larger (water $x10^{-6}$, oil $x10^{-3}$ to $x10^{-5}$, gas $x10^{-1}$ to $x10^{-4}$)

Injection Capacity

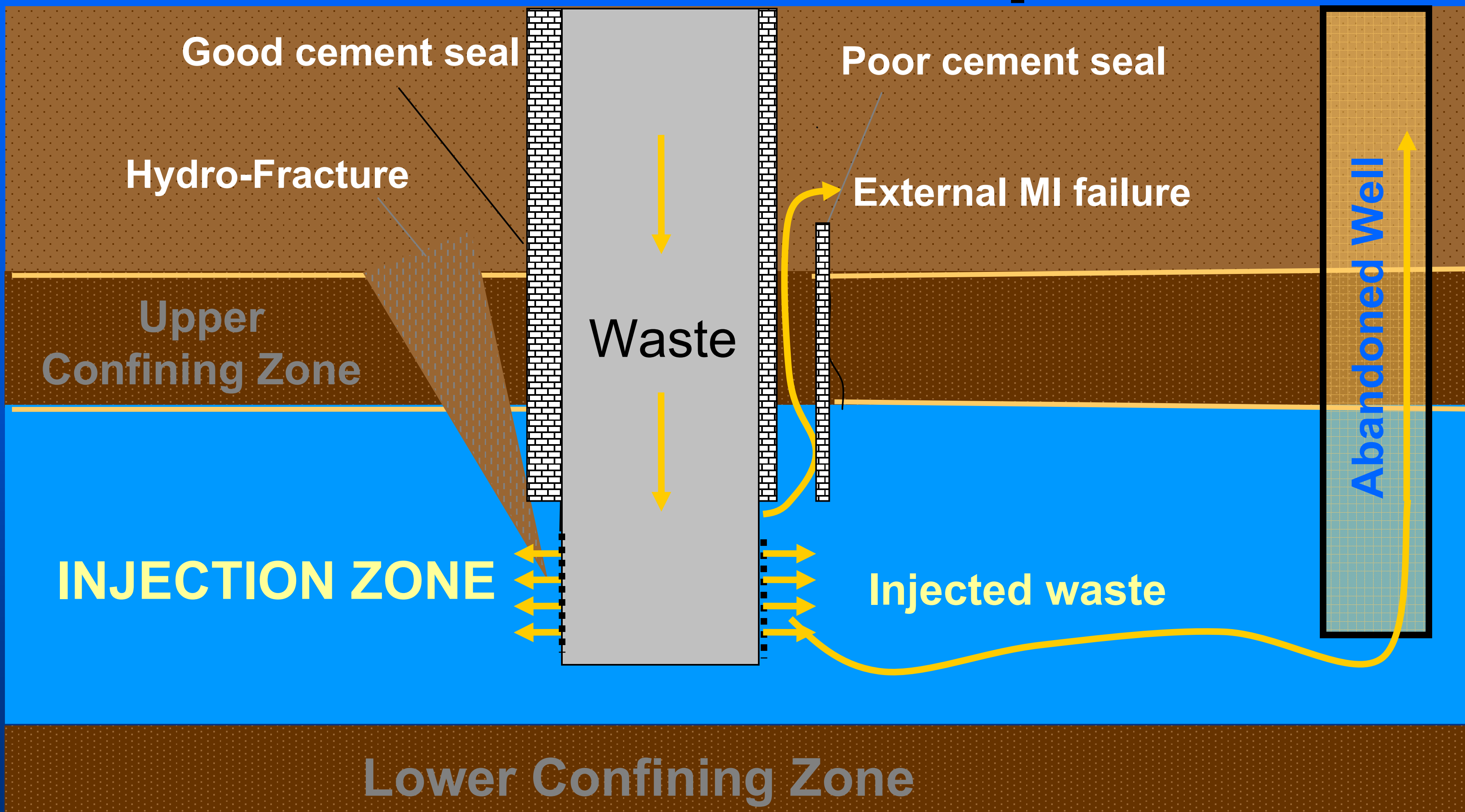
- Hydrocarbon reservoir extent does not have to be a large area to be economic
  (100's vs >10,000 acres per well)
- Hydrocarbon reservoir production may not need to last as long to be economic (years vs decade +)
- Oilfield injection operations may be legal at pressures above formation fracture pressure but is prohibited by federal law in Class I wells
  (reduced capacity & increased treatment required)

Common Target Injection Zones

- Texas: Miocene/Eocene sediments (often Frio/Yegua)
- Wyoming: Cretaceous Teckla-Teapot-Parkman sequence; Lance Formation; Ft. Union Formation; possible Permian and Jurassic sands such as Entrada

  (Wyoming Class V or VI water classifications for native formation fluids with TDS <10,000 mg/l will be needed)
- Midwest: Lower Cretaceous (Dakota), Jurassic (Morrison), Permian (Salt Wash); Cambro-Ordovician section including Arbuckle to Granite Wash

Containment Required



Not to scale

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ISR Wastewater Management - Mining

Most Wastewater Generated During Groundwater Restoration (post-mining)

- Mining (4,000 gpm)
  - 40 gpm bleed at 1%
- Plant Operations
  - Approx. 15 gpm
- Total mining and plant flow <60 gpm

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ISR Wastewater Management - Restoration

- Groundwater sweep (if applied)
  - typical 1-2 pore volumes (150-250 gpm)
- Reverse osmosis (primary)
  - often 4-10 (or more) PV (100-150 gpm)
- Recirculation (40 gpm bleed)
- Stabilization (sampling, no bleed)

Wastewater Management

- Simultaneous operation and restoration will compress the rate of consumptive use
  (however, total volumes may not change significantly)
- Disposal rates will increase with concurrent operation and restoration
- Rate requirements (especially during sweep phase of restoration) could exceed 5x mining flows
- Depending on mine design and regulatory requirements, total wastewater flow may vary from 50 to 350 gpm

Economic Feasibility – Deep Wells

- Initial evaluation prior to permit application
  - Capital - $1.5 to $3.5 million for a “typical” well
  - Amortization of capital (based on an 8,000’ well installation and surface facilities), a 20-year operational life, surface injection pressures of less than 1,000 psi, and an injection rate of 50 to 150 gpm
  - Operating cost range (including power): approximately 0.2 to 0.8 cents/gallon
  - Total project cost range: approximately 0.4 to 1.2 cents/gallon

Critical UIC Issues

- Geology often suitable and regulatory path more clear in Texas and Nebraska
- Many unknowns for New Mexico (only one Class I well for potash)
- Colorado implemented by Region 8
- Wyoming Class I and Class V recently difficult to achieve – work is continuing.

Technical Issues

- Availability of suitable injection horizons (permeability & thickness)
- Rising installation and testing costs for deeper wells (and testing)
- Injection reservoir capacity limitations
- Compliance costs
- Recent access to oilfield equipment at reasonable cost

Regulatory Issues

- Uncertainty about permitting approaches
- Time required for permit approval
- Evolving interpretations of statute and regulation for aquifer exemptions
- Increased attention to water classification (additional testing of deep formations)
- Increased attention to well classification (deep >10,000 ppm unusable waters)

Regulatory Issues

- Efforts needed to educate the public about the technology because of increased public scrutiny
- Evolving waste classification and siting requirements
- Competing water disposal and pore space uses (oilfield disposal, O&G production, CCS - geologic CO2 sequestration)
- Possible future costs to address Wyoming pore space ownership issues

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Summary and Questions

- To meet demand for domestic production of this critical resource, accelerated uranium ISR mining and restoration schedules are needed.

- Deep well injection to manage ISR wastewater will be a critical part of an environmentally pro-active ISR uranium industry in the U. S.

- Discussion and/or Questions?

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