A COMPARATIVE ANALYSIS OF HYDRAULIC FRACTURING AND UNDERGROUND INJECTION

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Presenter: J. Daniel (Dan) Arthur, P.E., SPEC

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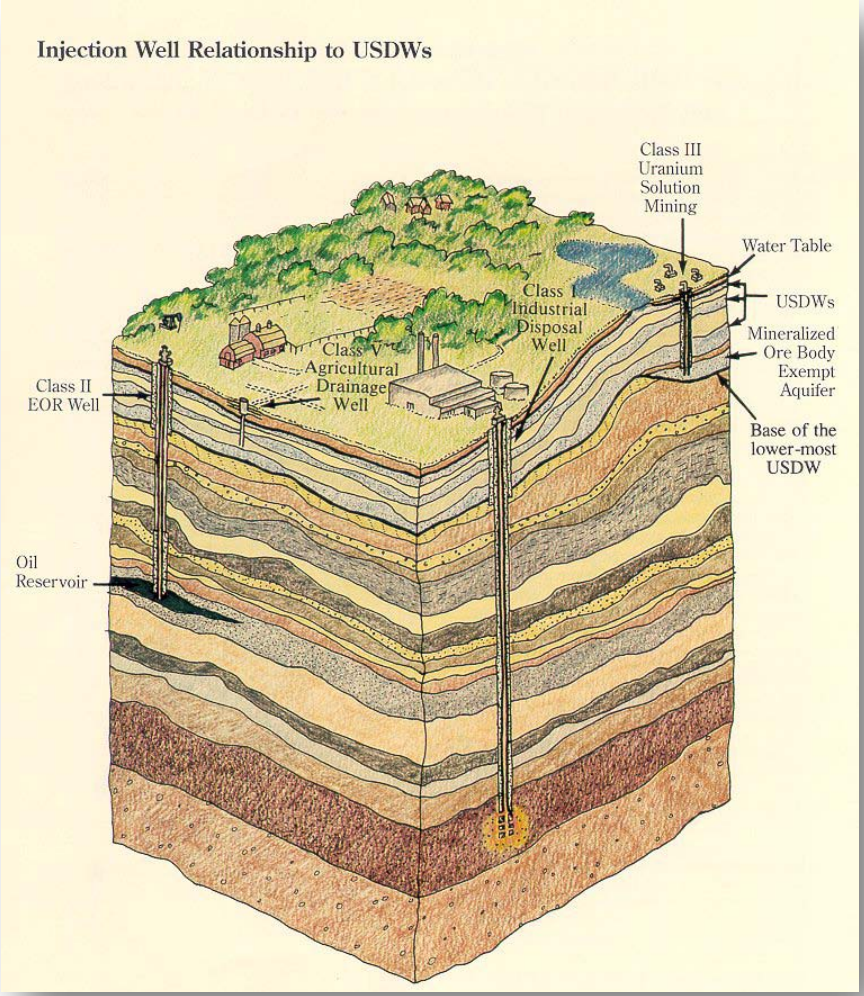
Introduction

- Hydraulic Fracturing is currently being evaluated by EPA for possible regulation under the SDWA as an Underground Injection activity
- There are both similarities and distinct differences between these practices
- This presentation presents some basic comparison information for the two practices



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DESCRIPTION

Underground Injection

- The subsurface emplacement of fluids by well injection; and excludes –
  - (i) the underground injection of natural gas for purposes of storage; and
  - (ii) the underground injection of fluids or propping agents (other than diesel fuels) pursuant to hydraulic fracturing operations related to oil, gas, or geothermal production activities.

Hydraulic Fracturing

- The creation of fractures within a reservoir that contains oil or natural gas to increase flow and maximize production.
- A hydraulic fracture is formed when a fluid is pumped down the well at pressures that exceed the rock strength, causing open fractures to form in the rock.
- The goal is typically to form complex fracture networks within the targeted production zone.

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Regulatory Programs

Underground Injection

- SDWA UIC Program
  - Established to protect usable or potentially usable groundwater aquifers from underground injection activities (i.e., USDWs).
- Program Implementation
  - **Direct Implementation** (DI) – The oversight of a UIC program by an EPA Regional office.
  - **State Primacy** – Granted for all or part of the UIC program, e.g., for certain classes of injection wells.

Hydraulic Fracturing

- Hydraulic Fracturing is most commonly managed by state O&G regulatory agencies
- State O&G regulatory agencies have existing regulations designed to protect groundwater supplies from possible impacts due to O&G activities.
- State environmental agencies may also have a role in regulating activities related to hydraulic fracturing
  - For example, in Arkansas, the AOGC and ADEQ both have roles for gas development and HF.

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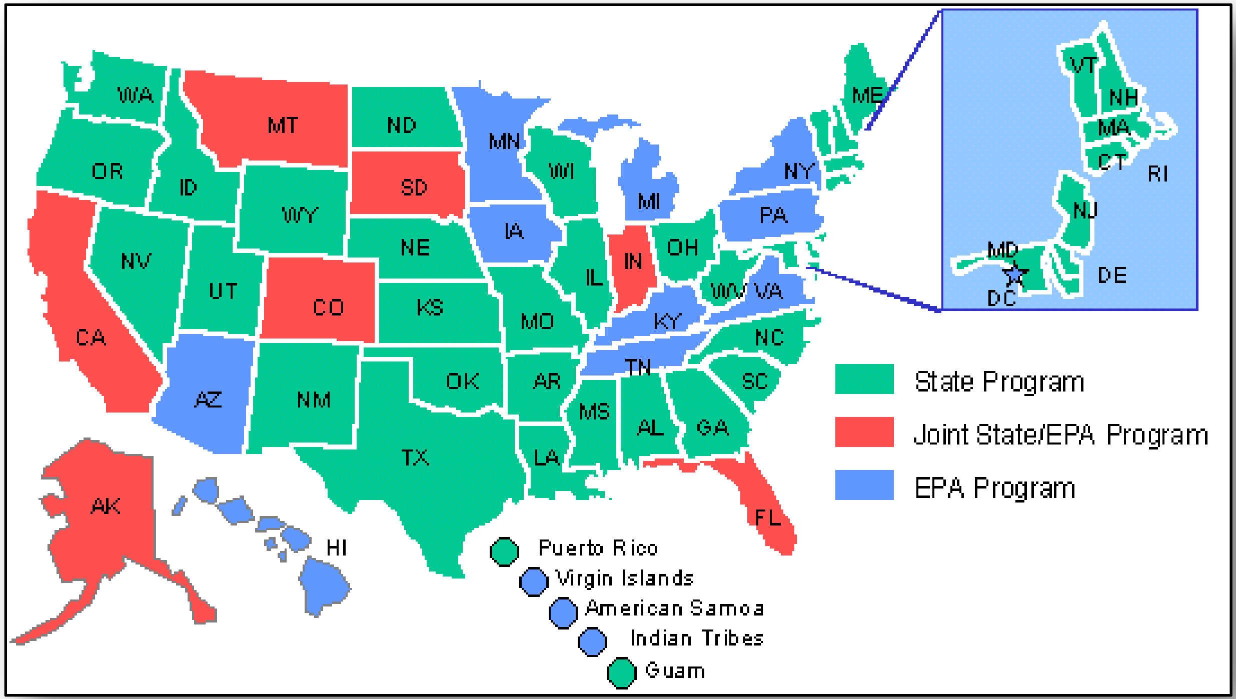
UIC Program Regulators

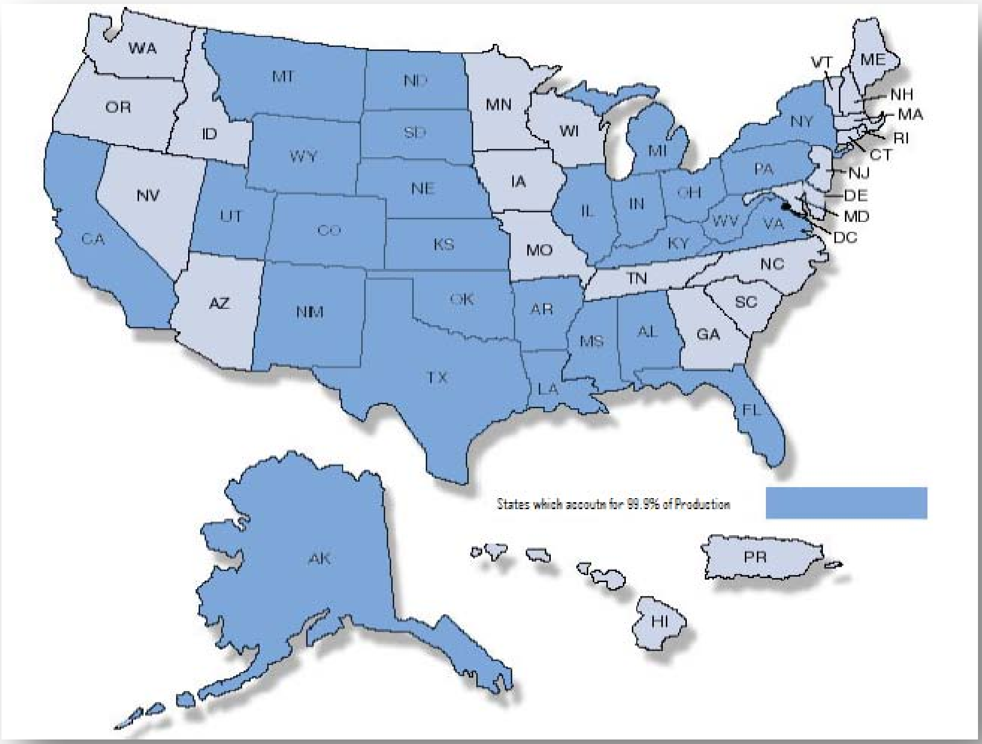
The UIC Program requirements were developed by EPA and designed to be adopted by states, territories, and tribes.



- EPA has delegated primacy for the UIC program for all well classes to 33 states and 3 territories
- EPA shares UIC program responsibilities in 7 states
- 10 states, 2 territories, and all Tribal Nations have the UIC program implemented by EPA

State Oil & Gas Programs

There are 27 states that account for 99.9 percent of the oil and natural gas production in the United States.



- In 2008 there were 33 states that reported oil or natural gas production
- State O&G Programs
  - Prevent waste of oil & gas resources
  - Conserve oil & gas - efficient recovery of the resource
  - Protect the correlative rights of mineral owners

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Program Protection Targets

Underground Injection

- Defined by Regulation, Underground Source of Drinking Water (USDW) –
  - An aquifer that supplies or contains a sufficient quantity of ground water to supply a public water system
  - fewer than 10,000 mg/l total dissolved solids
- Not an exempted aquifer

Hydraulic Fracturing

- Hydraulic fracturing is managed within state oil & gas programs
- It is generally common that states have statute(s) relative to providing a clean and healthful environment within the state
- Protection of water resources (groundwater and surface water) is a priority within every state and a priority of every oil & gas regulatory program

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Applicable Well Types

Underground Injection

- Hazardous Waste Injection
- Industrial Waste Injection
- Municipal Waste Injection
- Enhanced Oil Recovery
- Brine Disposal
- Solution Mining
- Aquifer Storage/Recovery
- Aquifer Recharge
- Other

Hydraulic Fracturing

- Conventional Oil & Gas
- Unconventional Gas
- Unconventional Oil
- CO_2 Sequestration
- Water Supply Wells
- Injection Wells
  - Classes I - V

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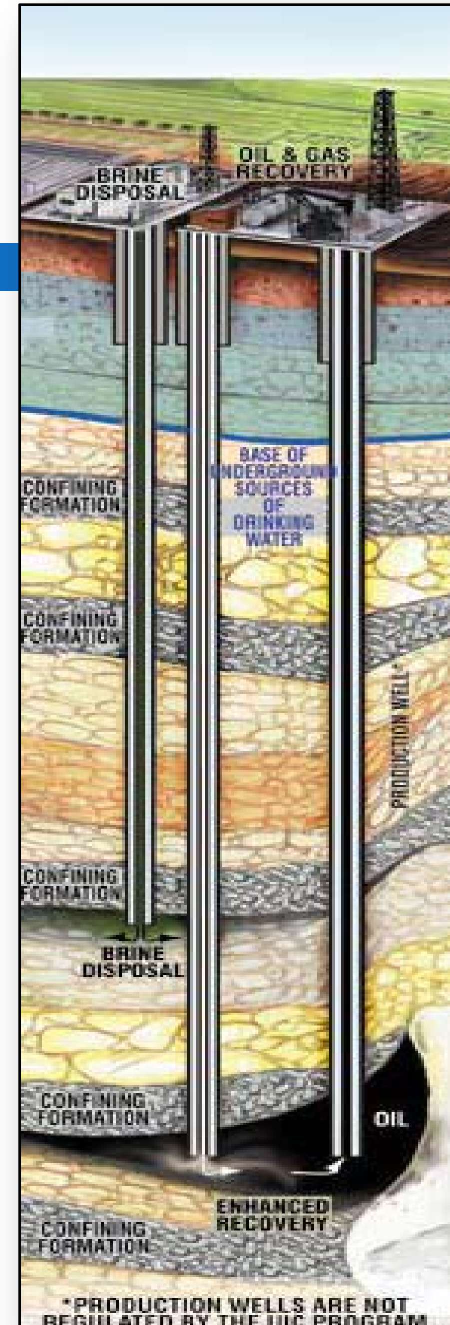
Class II Injection Wells

- Inject fluids associated with oil and natural gas production. Most of the injected fluid is salt water (brine), which is brought to the surface in the process of producing (extracting) oil and gas.
- Inject Beneath the lowermost USDW.
- EPA Inventory lists 143,951 Class II wells in operation in the United States, injecting over 2 billion gallons of brine every day.
- Most oil and gas injection wells are in Texas, California, Oklahoma, and Kansas.



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Permitting

Underground Injection

- Owner/Location/Operator
- Area of Review
- Facility description
- Geological data
- Surrounding land owners
- Plugging & Abandonment Plan
- Specification and source of disposal fluids
- Public records – all other wells/surface water/surface facilities /known faults
- Performance bond/corrective action proposal/contingency & monitoring plans
- Operating plan

Hydraulic Fracturing

- Owner/Location/Operator
- Residential/Municipal well review
- Well site construction/chemical storage
- Geological data/target formation
- Drilling/proposed depth
- Proposed well completion data
- Well construction details
- Proposed fracture schema
- Pits and tanks proposed
- Traffic Plans/Road Use Agreements
- Source water withdrawal permits

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Area Considerations

Underground Injection

- Area of Review Analysis
  - ZOEI
  - Presence of artificial penetration
  - Springs
  - Water wells
  - Wells penetrating the injection zone
- USDW identification
- Confining interval
- Geological considerations

Hydraulic Fracturing

- Pre-Site Assessment
  - Geological considerations
  - Potential interfering wells
  - Area water supply wells
  - Surface and topographical challenges
  - Water sourcing
- Other active production
- Abandoned wells

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Casing and Cementing

Underground Injection

- Surface casing set below lowermost USDW and cemented to surface (generally)
- Well casing and cementing program must prevent fluid movement into or between USDWs
- Injectate confined to permitted injection interval

Hydraulic Fracturing

- Surface casing setting depth typically established by state for purposes of protecting usable quality groundwater from oil and/or gas development activities
- Some states include well casing and cementing programs in permits

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Groundwater Protection

Underground Injection

- Primary goal of the UIC program is the protection of USDWs
- Program is applicable from the wellhead down
- Performance and risk-based measures utilized
  - Prevention of fluid movement into or between USDWs
  - No-migration petition for hazardous waste wells
  - Re-occurring mechanical integrity testing

Hydraulic Fracturing

- The protection of water resources is a primary objective of every state
- State oil and gas regulations
  - Permitting of wells
  - Surface casing requirements
  - Rules adapted based on risk and historical industry performance
  - Orphan well programs
  - SI, TA and abandoned wells
  - Use of tanks and pits
  - Waste handling and spills
  - Etc.

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Well Integrity

Underground Injection

- Most injection wells must demonstrate internal and external mechanical integrity
- For Class II wells, typical internal integrity tests are required once every 5 years
- Some injection wells may be required to have continuous monitoring equipment to assure integrity is maintained

Hydraulic Fracturing

- Operators commonly test wells before perforating to assure the well's integrity is ready for fracturing activities
- Surface equipment and piping is routinely tested
- Testing may not be required, but is done as a best practice
- Continuous monitoring is employed during fracturing

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Pressure Management

Underground Injection

- Injection permits are generally granted with a maximum allowable injection pressure
- It is common for wells to have a P_{Max} determined by the fracture gradient of the top of the injection zone
- Pressures exceeding the injection zone fracture gradient are allowed by rule
- Wells may inject up to the P_{Max} throughout the life of the well

Hydraulic Fracturing

- Surface pressures sufficient to overcome friction and initiate fractures in the production zone are utilized
- High friction factors are common due to facture fluid make-up (e.g., slurry)
- Pressures maintained below pressure ratings of well tubulars and surface equipment (e.g., wellhead)
- Pressures are maintain for duration of fracturing job (e.g., a few hours per stage)

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Operating Procedures

Underground Injection

- Permanent facility typical
- Designed for continuous or batch process
- Continuous monitoring optional for Class II wells (many wells inject on a vacuum)
- Detailed operations depend on well type (e.g., waterflooding vs. SWD)

Hydraulic Fracturing

- Temporary equipment brought on-site for each fracturing
- Fracturing typically done on a stage-by-stage basis
- Number of stages does not necessarily influence the total volume used for a single well
  - Increased number of stages typically means less overall volume per stage
- Continuous monitoring of pressures, rate, density, etc.

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Example Facilities/Equipment

Underground Injection

Hydraulic Fracturing

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Operational Equipment

Underground Injection

Hydraulic Fracturing

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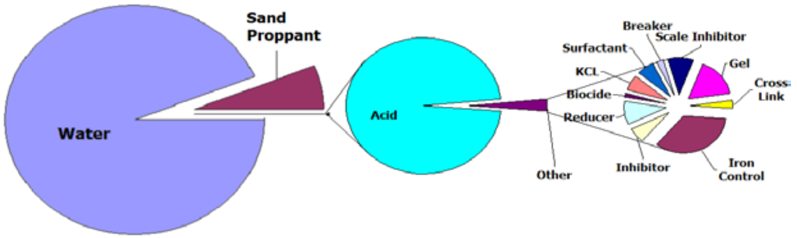
Fluids Disposition



Underground Injection

- Injectate varies depending on well type and permit conditions
- Class II Fluids
  - Fluids brought to surface in conjunction with O&G production
  - Fresh water
  - Exempt waste fluids: Produced fluids, drilling fluids, drill cuttings, rig wash, well completion fluids, workover waste, gas plant dehydration waste, gas plan sweetening waste, spent filters and backwash, packing fluids, produced sand, production tank bottoms, etc.

Hydraulic Fracturing

- Water and proppant
  - Water typically fresh to brackish
  - Proppant is typically sand, but may be resign-coated or ceramic
- Multiple types of fracs
  - Slickwater, foam, etc.
- Chemical additives
  - Additives vary
  - Biocides, corrosion inhibitors, scale inhibitors, clay stabilizers, friction reducer, oxygen scavenger, gel, iron control…

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FLUID CHARACTERIZATION

Underground Injection

- Injection characterization is part of the permitting process
- The extent of characterization is generally dependant on the well class and fluid proposed for injection
- The UIC program allows for some characterization details to be maintained as confidential information

Hydraulic Fracturing

- Primary fluids are disclosed as part of the completion report
- MSD Sheets are made available upon request
- Historically, the make-up of some products are maintained as proprietary and have not been reported
- Recently, multiple states are modifying rules to require full disclosure of fracturing additives

Volume Variations

Underground Injection

- Injection rates/volumes depend on well, formation, and operational objectives
- Common for wells to inject 1,000 to over 20,000 barrels of fluid per day
- Injection and disposal wells may or may not be continuous, but typically operate year-round for multiple years
- Not uncommon for wells to be used for injection for 20+ years

Hydraulic Fracturing

- Fluid volumes depend on the type of HF technique utilized
- HV slickwater fracturing on horizontal wells commonly use 2-5 million gallons of water per well over 10 – 20 stages
- The number of stages is dependant upon the interval to be fractured (a vertical well may use only one stage), thickness of the target zone, lithology of the formation, and other factors

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REPORTING

Underground Injection

- Reporting varies depending on well type
- For Class II wells, annual reporting of monthly average and maximum rate and pressure data is most common
- Depending on permit conditions/requirements, water source information or water analysis may also be required

Hydraulic Fracturing

- Summation of hydraulic fracturing activities have historically be reported on the well completion report
- Some states require service tickets (e.g., Arkansas)
- Several states have been modifying reporting rules, including requiring summary details by fracturing stage

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Financial Responsibility

Underground Injection

- Financial responsibility is a requirement of the UIC program
- Financial responsibility is typically tied to plugging costs of the well
- A plugging plan and cost estimate may be required for permitting
- Blanket bonds are acceptable
- Some individual well bonds

Hydraulic Fracturing

- States require bonding for O&G producing wells
- Bonding requirements vary by state, but are generally tied to plugging liability
- State agencies have a variety of tools relative to enforcement should problems arise

Risk Probability

Underground Injection

- Per a 1989 API and DOE study for basins with "reasonable" likelihood of corrosion, risk probability of injectate reaching a USDW ranged from one in 200,000 to one in 200 million for wells injecting on a continuous basis
- Many states implement the Risk Based Data Management System and are able to assess risk probability on an ongoing basis

Hydraulic Fracturing

- HF events for most well types (including shale gas wells) occur through multiple installed concentric casings over a short duration with considerable vertical separation (thousands of feet) of confining type zones between the production zone and the lowermost USDWs
- Using the same technique as implemented for the 1989 API/DOE study, risks of fracturing fluids reaching a USDW would generally be far less probable than for injection wells

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SUMMARY

- Underground injection and hydraulic fracturing have some distinct similarities
  - Pumping fluid into deep underground formations
  - Surface casing protective of fresh water
  - Confidentiality of some injectate/fracturing fluids
- Underground injection and hydraulic fracturing have some distinct differences
  - Long-term injection versus short-term pumping
  - Concern of corrosion of tubulars over time due to corrosive injectate
  - Fracturing is short-term followed by production opposed to long-term injection
- Fracturing is not limited to unconventional gas wells, but is also done on injection wells, water wells, and other types of wells for a variety of purposes
- DOE/API study found risks of injection fluids reaching a USDW to be remote. Based on operation, similar risks for fracturing would be less.

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Contact and Citing Information

J. Daniel Arthur
1718 S. Cheyenne Avenue
Tulsa, Oklahoma 74119
darthur@all-llc.com

Arthur, J.D., "A Comparative Analysis of Hydraulic Fracturing and Underground Injection", Presented at the GWPC Water/Energy Symposium, Pittsburgh, Pennsylvania, September 25-29, 2010.

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