Class I Injection Wells: Technological Opportunities for Improved Performance

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Class I injection wells

• Advantages
  - Permanent removal of liquid wastes from biosphere
  - Small surface footprint

• Requirements:
  - Must have sufficient capacity to accept facility’s liquid waste flows (well injection rates and reservoir size)
  - Must meet regulatory requirements – no endangerment of drinking water sources
  - Must maintain mechanical integrity
  - Must operate reliably over planned life of the facility (> 30 years)
Challenges and Opportunities

• Optimize: “to make something as good or as effective as possible”

• Environmental protection: assure no adverse impacts
  - No migration of injected water into USDW aquifers
  - Avoid induced seismicity

• Maximize performance
  - Achieve target injection rates/volumes with minimum possible injection pressure.

• Maximize reliability
  - Maintain mechanical integrity
  - Maintain injectivity (minimization of clogging)
  - Allow for effective rehabilitation

• Cost-effectiveness: Economical in terms of the performance achieved for the money spent
Injection Well Clogging

- Injection well design and operation are more complex than that of production wells as water is being forced into the formation.
- Well and aquifer clogging is typically the primary operational challenge for injection well systems.
  - Chemical clogging
  - Biological clogging
  - Physical clogging
Types of Class I Injection wells

• **High-capacity, low-pressure wells**
  - Capacity => 1 Mgd
  - Wellhead pressure < 100 psi
  - Injection zone moderate to extremely high transmissivity strata (commonly carbonate)
  - Example: South Florida

• **Low- to moderate capacity, high-pressure wells**
  - Capacity < 0.5 Mgd
  - Wellhead pressure > 1000 psi
  - Injection zone low transmissivity strata (commonly siliciclastic)
  - Examples: Texas, Colorado, California
Florida

• Greatest use of injection wells for municipal wastewater and desalination
• Concentrate disposal occurs in South Florida using the “Boulder Zone” of the Lower Floridan Aquifer System
• Boulder zone - fractured dolomites located 2,600 to 3,500 ft; 800 to 1,060 m bgs

Open-hole completions
Florida

- Single well can accept large flows of liquid wastes, commonly greater than 10 MGD (> 38,000 m³/d), with minimal pressure increase.
- Upwards migration is a concern for low density fluids (municipal wastewater) and not a problem for higher density fluids (RO desalination concentrate)
- Clogging generally not an issue
- Ideal conditions for deep injection wells

Other Florida RO concentrate disposal injection well types:
- Class I – Avon Park High-Permeability Zone (Tampa Bay region)
High-pressure injection wells
Colorado and California

Examples: City of Sterling and East Cherry Creek Valley, Colorado

Oilfield type wells
• Perforated completions
• High operational injection pressures
  (Injection pressures => 7,000 Kpa, 1,000 psi)
• Susceptible to clogging due to low injection zone transmissivity
• Injection zone selection and optimization of completion important
Confinement analysis- Quantitative log analysis and modeling
Goal: maximize information value from data normally collected in injection well programs

Conventional logs
Core porosity versus hydraulic conductivity transform applied to sonic porosity.
Density-dependent solute-transport modeling
Turkey Point, Miami-Dade County, Florida

100 year simulation was required by NRC
Includes 40-year planned plant operation, 20-year extension, 40 years post operation
Sensitivity analysis performed to address parametric uncertainty
Aquifer characterization opportunities: Advanced borehole geophysical logging

- Nuclear magnetic resonance
- Formation MicroImager
- Elemental capture spectroscopy

- Location of transmissive injection strata
- Confinement analysis
Wireline formation testers

Modular dynamic tester (MDT™)
- Single probe – measures P and collects water sample
- Dual/multiple probe configuration – sink probe withdraws fluid, pressure is measured in one or more probes.
- Dual packer mode to withdrawal water = small version of drill stem test.

Cased Hole Dynamics Tester (CHDT™)
- Measurement of pressure and formation sampling
- Drill through casing and cement; no explosives
- Combinable with MDT modules
- Drill and plug up to 6 holes and collect 6 samples per trip
- Seal/plug to differential pressure of 10,000 psi
- 5 ½ to 9 ½ inch casings.
Coiled tubing technology

Major advantages
- Speed and economy
- Small footprint
- Short rig-up time

Main applications = workovers
- Clean out light debris (standard and reverse circulation)
  - Dispense chemicals
  - Remove scale
  - Fracturing and acidizing
  - Logging
  - Perforating

CT Drilling
- Side tracks

Schlumberger CT Express – two trailers and thee people, rig-up time less than 30 m.
Coiled tubing drilling

• Sidetrack drilled to restore capacity of a clogged injection well

• Much quicker and less expensive than mobilizing a drilling rig.
Directionally drilled Class I wells: Kansas

- Slant well design
- Uncemented liner
- Goal to maximize completion interval within injection zone
Extreme directionally drilled injection wells

Groundwater model was developed to simulate pressures and movement of injected waters
Completion

• Key design issue is determining completion type and optimizing completion method

• Issues include maximizing efficiency, reducing clogging potential/rate, and facilitating rehabilitation (workovers)
Perforated completions

- Perforation is the result of a high-velocity jet from a shaped charge that penetrates casing, cement, and formation.
Perforated completions

- Perforation program can make a large difference in injection well performance!
- Underbalance needed to clear holes and remove crushed material.
- Goal is maximum dynamic underbalance, which facilitates perforation cleanup.
Numerous factors need to be considered!
Opportunities

- Targeted application of technology can yield great value
- Corollary: Technically less sophisticated approaches can produce bad results

IWGs had a target capacity of 350 gpm but through the use of advanced formation evaluation techniques and completion workflows the well capacity was increased to 2,000 gpm.
Management of clogging

Numerous factors can cause clogging and reductions in injectivity
• Geochemical incompatibility
• Clay swelling and dispersion (water sensitivity)
• Air and gas entrainment or generation
• Biological processes
• Physical clogging from suspended sediments
• Temperature and salinity viscosity effects

Prediction and Preventions
• Geochemical modeling (site specific water chemistry, mineralogy, P and T conditions)
• Laboratory testing (core flow tests)
• Pretreatment (filtration and chemical adjustments)
• Optimize design so that well can accommodate some loss of performance and can be rehabilitated.
Conclusions

• Injection well systems are more complex than production wells because water is forced into the formation and they are much more susceptible to loss of performance (injectivity) due to clogging.

• There are many technologies available that can cost effectively improve system performance, reliability, and O&M costs.

• Key to optimization is not to do things as they have always been done, but rather to look for incremental ways of doing things better.

• Oilfield technology and experience can be highly valuable when one considers that there are 180,000 Class II wells versus 650 Class I wells in the United States.
Questions?