Current NETL Water Management R&D Efforts

Drilling Engineering Association Quarterly Forum

Bill Pike, LTI/NETL
Outline

• Introduction to NETL
• Shale/Water Issues Overview
• Updates on Selected Research Projects
MISSION
Advancing energy options to fuel our economy, strengthen our security, and improve our environment

National Energy Technology Laboratory

Oregon
Pennsylvania
West Virginia
Strategic Center for Natural Gas and Oil
Advancing Technologies Supporting Development of Domestic Unconventional Resources

Tens of billions of barrels of residual oil recoverable via CO₂ enhanced oil recovery in mature fields in 22 states

Potentially thousands of trillion cubic feet of natural gas from methane hydrate in Alaska and the Gulf of Mexico

Hundreds of trillion cubic feet of natural gas in shales and tight gas sands across the country

Shales photo courtesy of Statoil
NETL-SCNGO Oil and Gas R&D Program

Fundamental Research → Feasibility Studies → Prototype Development → Field Demonstration → Commercialization

Technology Timeline

Section 999 Complementary Program
- Extreme Drilling
- Unconventional Oil and EOR
- Environmental
- Resource Assessment
- Tech Transfer

Traditional Program
- Unconventional Fossil Energy Resources
- Environmental Impacts (Gas)
- Methane Hydrates

Section 999 Consortium Program
- Ultra-deepwater
- Unconventional Res.
- Small Producer

CDPs

SBIRs

SCNGO Integration

Unconventional Fossil Energy Resources
Environmental Impacts (Gas)
Methane Hydrates
Ultra-deepwater
Unconventional Res.
Small Producer

SCNGO Oil and Gas R&D Program

SBIRs

CDPs

NETL-SCNGO Oil and Gas R&D Program
Shale Gas/Water Issues

- **Supply**
  - Surface and subsurface options vary from play to play
  - Reuse of fracture flowback becoming more common in some plays

- **Management/Handling**
  - Solutions have evolved to meet play-specific challenges ranging from topography to geochemistry
  - Mix of economic and regulatory drivers

- **Treatment/Disposal**
  - Options vary from play to play
  - Subsurface disposal often remains least expensive option
  - Treatment and reuse becoming more effective choice in some plays for economic, logistical, and PR reasons
Marcellus (PA, WV)

- **Source**
  - Ample supply of surface water
  - Operators have developed systems of impoundments fed by ponds connected by network of piping to supply well pads
  - Drilling use 80,000 gal water/well (nearly all recycled); fracturing use 4-5 million gal/well
  - Industry has reported >85% of frac flow back being recycled

- **Disposal**
  - Frac flowback volume low (~12 to 25% over 30 days)
  - PA geology unfavorable to deep well injection
  - Truck to Ohio or WV for injection or to PA brine treatment plants operating under discharge limits

- **Current mix of dilution, reuse, and disposal seems to be working**
Flowback Water Composition

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<th>Sample</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
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Source: Halliburton presentation to OCC, March 2010
Treatment Plants and Disposal Wells in Marcellus Play
Future Need for Water Treatment Options

- Currently PA producing ~650,000+ barrels per month of water requiring treatment and/or disposal

- At expected rates of development, this volume will grow as wells are brought online and volume of high TDS produced water (not flowback water) increases
  - Estimated minimum of 200% increase in four years
  - Estimated maximum of 3600% increase in ten years

- Mix of treatment and disposal well options will be required to match individual economic/operating situations

- Disposal via municipal water treatment plants may not be an option
TDS Removal: Applicability vs. Cost

Source: Kimball, R., 2010, CDM presentation at U.S.-China Oil and gas Forum
Current Water Treatment R&D Project Focus

- **Solids Removal**: Settling, Filtration, Flotation, Hydroclone
- **Oil & Grease Removal**: Settling, Hydroclone, Flotation, Extraction, Adsorption, Oxidation
- **Soluble Organics Removal**: Bioprocesses
- **Divalent Cation Removal**: Ion Exchange, Precipitation, Nanofiltration
- **Salinity Removal**: Thermal Distillation, Reverse Osmosis, Membrane Distillation
- **Crystallization**

Institutions:
- Altela
- WVU/FilterSure
- Texas A&M
- GE Global Research – SCNGO
- GE Global Research - RPSEA
Objective: Demonstrate that the patented AltelaRain technology can be successfully deployed in a cost-effective manner to treat Marcellus Shale produced and flowback water, and that it can operate within state and federal regulatory requirements.

Integrated Water Treatment Technology for Sustainable Water Resource Management in the Marcellus Shale

Altela, Inc

- Accomplishments:
  - Determined AltelaRain® technology meets PA regulatory requirements
  - AltelaRain® 4000 water desalination system tested at well site in Indiana Co., Pa. During nine months of continuous operation, unit successfully converted 77% of each barrel treated to pure distilled water.
  - Avg. cost per barrel was ~20% lower than conventional disposal cost and wastewater truck traffic was significantly reduced. Distilled water produced at the site suitable for fracturing or discharge to surface.
  - Based on DOE demo project results, Altela redesigned system. Four AltelaRain® 600 modules have been sold and installed in Williamsport, Pa. to treat approximately 100,000 gpd of produced and flowback water.
Objective: Design a low-cost, mobile process to treat the low-total dissolved solids (TDS) portion of the flowback water from hydraulic fracturing operations in order to reduce the cost of shale gas production.

Accomplishments:

- Developed parametric tool to evaluate economics of any flowback water recovery process relative to conventional disposal for four products:
  - Clarification (particulates, free oil/grease, iron, and biota removed)
  - Clarification plus softening (removal of Ba, Sr, Ca, Mg)
  - Above, plus desalination to < 20,000 ppm from 40,000 ppm TDS
  - Above, plus desalination to < 500 ppm

- Determined applicability of low TDS approach for each shale play:
  - Fayetteville & Woodford, ~100%, flowback generally <40,000 ppm
  - Barnett, by selectively directing the flowback during first 5 days of operation, ~30-40% of the flowback may qualify as low-TDS
  - Marcellus, <10% of flowback amenable to low-TDS recovery. However, 20-40% of flowback may qualify as low-TDS at certain locations with isolation of flowback during first 3~5 days.
Accomplishments (continued):

- Conducted bench-scale evaluations of various mechanical, chemical, and membrane treatment options and identified process technologies and operating conditions needed to reach output water specifications.

- Successfully removed inorganic compounds that could physically precipitate inside membrane modules and contaminants that could foul membrane surfaces.

- Based upon bench-scale experimental data, developed detailed conceptual flowsheets for treatment processes for each of the four output products and evaluated each process for technical performance, costs, and mobility for a 50-gpm flowback feed, mobile system.

- Developed system performance and cost models for commercial feasibility determination.
Objective: Develop process to treat frac flowback water, using a wastewater pretreatment process that removes undesirable salts and metals and results in 1) reusable water and 2) salt product that meets road salt specifications.

Accomplishments:

- Defined frac water composition and flow rate specifications for fixed and mobile treatment systems.
- Ruled out ion exchange as softening technique for high-hardness frac water based on required regeneration chemicals and rinse water.
- Developed Aspen/OLI model for chemical treatment of frac water. Calculated material balances for lime softening and sulfate precipitation.
- Defined feed composition range for stationary frac water treatment plant operating in Northeast Pennsylvania.
- Identified NORM and TENORM disposal options and costs (ongoing).
- Simulated thermal brine concentrator and crystallizer performance and demonstrated foaming issue with Marcellus frac water evaporation.
Accomplishments (continued):

- Demonstrated effectiveness of sulfate precipitation for NORM removal from frac water and established costs.
- Measured effectiveness of radium removal from frac water using RSC (Radium Specific Complexer) resin. Demonstrated sensitivity of resin capacity to barium concentration and evaluated cost of radium removal by sulfate precipitation vs. ion exchange using resin.
- Screened and tested adsorbents for radium removal and compared performance to RSC resin
- Demonstrating that ion exchange is not cost-effective to soften high hardness frac water
- Initiated cost analysis for pretreatment by nanofiltration and chemical treatment (underway)
Pilot Test of Pretreatment Options to Allow Re-Use of Frac Flowback and Produced Brine for Gas Shale Development

Texas A&M University

- **Objective:** Identify a reliable and cost-effective pre-treatment methodology for use in processes employed to treat and re-use field-produced brine and fracture flowback waters. Demonstrate technology in field operations using a trailer-mounted unit that will remove constituents in high salinity flowback water.

- **Timing:** Oct. 2009 – Sept. 2011
Pilot Test of Pretreatment Options to Allow Re-Use of Frac Flowback and Produced Brine for Gas Shale Development

Texas A&M University

Accomplishments:

- Identified pretreatment technologies and validated performance of the pre-filtration process train (cost, efficiency, product water quality)
- Developed a “chemicals free” methodology for removing contaminants from highly saline oil field produced brine
- Developed a preliminary engineering model to project capital and operating costs
- Constructed and tested a mobile field laboratory outfitted with each of the process train components
- Carried out field site assessments and identified most promising types of technology for pretreating hypersaline brine
- Shakedown test: Cerrito Prieto Ranch, Webb Co. Texas, (Eagle Ford)
Zero Discharge Water Management for Shale Development
West Virginia Water Research Institute, WVU, ShipShaper LLC, FilterSure, Inc.

• **Objective:** Develop and demonstrate a process for treating hydraulic fracturing water returns from Marcellus wells that will allow an increased recycle rate while decreasing makeup water and disposal requirements.
  - Test mobile, on site treatment options
  - Evaluate volumes, chemistries and disposal options for byproducts
  - As filtration is optimized, employ laboratory studies to evaluate filter systems and electocoagulation at bench scale
  - Test with “real” frac water at the scale of 2 to 6 gpm
  - Field test mobile systems upscaled to 150 gpm

• **Timing:** Oct. 2009 – May 2012
## WVU/FilterSure Prototype Performance

### 2GPM Filter Unit

<table>
<thead>
<tr>
<th>Measured Water Chemistry</th>
<th>Actual Frac Return Water (mg/L)</th>
<th>2GPM prototype Mobile Treatment Unit (mg/L)</th>
<th>% Reduction</th>
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<tbody>
<tr>
<td>TDS</td>
<td>112,000</td>
<td>81,400</td>
<td>27</td>
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<tr>
<td>SO₄</td>
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<td>Cl</td>
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<tr>
<td>Sr</td>
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WVU/Filtersure Prototype Testing
Planned Laboratory Test

- Conduct laboratory scale tests at WVU’s NRCCE Facility using 6 GPM Process Development Unit (PDU)
  - Flow 20 BBL of actual frac return water at a rate of 6 GPM
  - Samples taken Pre-test, During Test and Post test in timed intervals
  - Water samples collected at defined time intervals throughout test cycle for TSS, PSD, and chemical analysis
  - Pressure, and effluent conductivity and turbidity measured during testing
  - Media samples collected at different depths and analyzed post-test
  - Solids will be flushed and analyzed
  - Effluent samples will be analyzed for TSS, TDS, PSD, metals, chlorides, conductivity and turbidity

- Final results will be used to optimize filter media, establish backwash frequency and establish new baseline chemistry.
Mobile Treatment Unit Constructed for Planned Field Test

**Planned Field Test**

- Two Filter Units running in parallel to treat 5,000 bbl/day (Rate 150GPM)
- Media selected to reject greater than 20 micron sized solids
- Focus on Sulfate reduction – current test show 76% reduction in SO$_4$
Summary

• Water supply, management, treatment and disposal issues vary depending on location

• Operators are treating water prior to reuse in ways that meet their individual needs

• Volumes of high TDS produced water in the Marcellus play will continue to grow despite efforts to reuse fracture flowback water

• A robust range of water treatment and disposal options will help to accelerate and optimize development of the natural gas resource

• DOE investment in R&D supports the development of new technologies
SCNGO Water-Energy Research

**Demand Growth**
- Large fracture stimulations for shale plays
- Growth in demand for power generation
- Potential long-term demand from oil shale

**Increased Output**
- Shale hydraulic fracture flowback
- Mature oil fields with high water cuts
- Increased drilling & fracturing activity
- Increased competition for water supply
- Tighter regulations for disposal
- Opposition to treatment and disposal

**Tighter Constraints**
- Effective treatment technologies
- Low-volume fracturing technologies
- Produced water volume reduction technologies
- Demand-reducing processes
- Science-based regulations
NETL Shale Research Portfolio

Produced Water and Fracture Flowback Water Treatment

Water Resources Mgmt.

Environmental Impact Mitigation and Decision-making

Productivity improvement and Recovery Optimization

Reservoir/Resource Characterization

Current Projects

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4

2

12

9