Toolbox Available to Treat Flowback and Produced Waters

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The Key to Unlock the Treasure of the Reservoir is . . .
Motivation

World Shale Gas Reserve Estimates

- Proven/Probable
- Possible

- 5,210 TCF
- 2,116 TCF
- 274 TCF
- 548 TCF
- 3,526 TCF
- 2,625 TCF
- 2,547 TCF
- 627 TCF
Water: Challenges

- **Produced Water**
  - 3 barrels produced for every barrel of oil
  - Estimated 220 MM bbls produced daily
  - 98% of drilling & production waste is water

- **Fracturing Demand**
  - +/- 14 MM bbls required for hydraulic fracturing in the US daily
  - 5% - 40% of treatment water returns to the surface as ‘flowback’ after fracturing
Recycling Options

- **Clarification** – removal of suspended solids and some metals and organics
  - Filtration/Separation
  - Chemical Precipitation
  - Ozone

- **Demineralization** – removal of dissolved solids
  - Reverse Osmosis
  - Distillation
  - Crystallizer

Decreasing water quality
Increasing TDS
## Water Variability

<table>
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<tr>
<th>Sample</th>
<th>1</th>
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<td>Ionic Strength</td>
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</table>
Typical Water Treatment Process Flow Diagram

Untreated Water → Primary Treatment → Secondary Treatment → Tertiary Treatment → Treated Water

- Light materials removed in Primary Treatment
- Biological degradation of organic compounds in Secondary Treatment
- Heavy materials removed in Primary Treatment
- Biosludge removed in Secondary Treatment
- Polishing with physical, chemical and/or biological treatments in Tertiary Treatment

- Solids Removal
- Organic Compound Removal
- Polishing Step
Ozone

- Provides an oxidizing agent
- No disinfectant residual
- Fewer byproducts as compared to chlorination
UV Light

- Ultraviolet light treatment kills aerobic and anaerobic (sulfate reducing) bacteria
- Flow rate / light intensity adjusted to maximize control
Electrocoagulation

EC uses electrical current to coagulate suspended colloidal matter.
Reverse Osmosis

Separates by using a semi-permeable membrane which is permeable to water not salts

**PROS**
- Clean water output
- Somewhat mobile
- New development in progress

**CONS**
- High energy costs
- Membrane fouling
- High pressure
- Sensitive to water
- Can be expensive
Distillation

**PROS**
- Clean water output
- Somewhat mobile
- Currently used in the oil industry

**CONS**
- Large capital investment
- Cannot handle all waters efficiently
- High energy costs
AquaPure/Fountain Quail

- Patented unit
- MVR evaporation
- Capacity = 2,000 bpd distilled water
- Treat wide range of wastewater
- High recovery (80-90%)
- Mobile
- Long system life
NOMAD Mobile Water Distillation Unit

Barnett
- 3.5 MMgals water/well
- Started in 2004
- Took 2 yrs to develop learning curve
- Pre-treatment is key
Fountain Quail Recycling Site

Permitted just like a disposal well
Have to material balance all fluids
12’ x 40’ footprint required
Only requires natural gas for power
Which Treatment is Right?

- Determined by End-Use
  - Fracturing
  - Surface Discharge
  - Human Consumption
  - Agriculture
- Existing technologies can be adapted
- Pick from available toolbox
Increased demands on freshwater sources, stricter local legislation on the use of municipal waters in industry, and the unpredictability of drought conditions all conspire to make the use of non-freshwater-based stimulation technologies, as well as the ability to recycle flowback and produced waters an important objective in today’s oilfield. The advantages of using these non-freshwater sources include the reduction or elimination of disposal costs and the environmental benefit gained by recycling non-freshwater sources (as opposed to the large-scale consumption of freshwater required by current technologies). Water produced from the formation (produced water), as well as treatment flowback water, is becoming more costly for disposal due to increasing trucking costs and disposal fees and hence, the demands for water conditioning and reuse have increased dramatically this past decade. Furthermore, the complexity of global water management is significantly magnified when contemplating the local challenges concerned with government regulations, water volumes, water quality, and the like.

Conventional means of waste water regeneration include, for example, water softening, distillation, ion exchange, reverse osmosis (RO), ozonation, and a wide range of filtration technologies. Flowback and produced water vary in composition tremendously depending on several factors, including location of the formation, chemicals used during stimulation, and age of the well. Total Dissolved Solids (TDS) vary tremendously and can reach up to saturation levels (around 300,000 mg/L). In addition, the water can contain a variety of different salts, making one field’s water very different from the next. This variability makes no "one-treatment method" suitable for all waters. For example, during distillation of salt water, the amount of distilled water generated depends on how much salt is in the water; in other words, the overall throughput decreases with increasing salt content. The cost effectiveness decreases with increased salt concentration and is hence not cost effective for produced waters very high in salt.

When deciding between water treatment methods to treat flowback and produced waters, it is important to consider the end use and its specific requirements, as well as composition of the water. With water treatment processes, the cost of treatment chemicals, type of equipment, and maintenance of the equipment, ease of process mobility, personnel, and disposal of treatment waste should all be considered, and as the end use and incoming water quality will vary, the treatment processes have to be selected accordingly.