Successful Oilfield Water Management
5 Unique Case Studies

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Charting a Logical Path

Saltwater

- Lower cost (minimal treatment).
- Difficult logistics (storage + transport)

Freshwater

- Higher cost (thermal distillation).
- Lower risk – store and transport freshwater.

1. SALTWATER
   - (BASIC) TSS/POLYMER REMOVAL ONLY
   - (CUSTOM) REDUCE HARDNESS, SCALING INDEX, ETC.

2. FRESHWATER
   - IS THE COST WARRANTED?
   - LOGISTICS.

RE-USE ZLD
Case Study A

**Background:**
- Early on everyone used freshwater for fracs.
- Disposal was limited (until Ellenburger used for disposal).
- Devon has a large acreage position held by production.
- FQWM had to become very efficient to compete with low cost Ellenburger disposal.

**Objectives:**
1. Move recycling (disposal + freshwater) close to drilling activity.
2. Frac with freshwater (minimal storage & transport issues).
3. Reduce disposal volume.
4. Tie in nearby well flowback & PW using poly pipe.
Fountain Quail Mobile NOMAD Recycling Facility.

• Over 900 million gallons of flowback + PW recycled back to distilled water.
• Move recycling with Devon’s drilling program.

Barnett

3 Hydraulic Fracture Stimulations using distilled & fresh water
Case Study B

Background:

- Customer has 17 wells tied into central SWD. Dispose of 5,000-7,000 bpd.
- Freshwater is limited and costly. Customer prefers fracking with and handling freshwater.
- Heavy brine (9.5-10#) has value to operator and others in the region.
- Early flowback hauled long distance to disposal.

Objectives:

1. Use PW as source water to create freshwater using NOMADs. Become independent of groundwater.
2. Reduce SWD volume & extend SWD life.
3. Re-use NOMAD concentrate brine (9.5#) for drilling & completions.
4. Treat high-solids flowback near source.
Evaporation rate is very high (dry, windy).
Nature concentrates NOMAD waste brine to 10# at no cost.
Recycling Center – Hub for Water

**PAST:** Disposal OR Recycling

**FUTURE:** Disposal AND Recycling

Flowback

Produced Water

Other Treatable Water Streams

Recycling Facility

Segregate, skim oil, remove solids, treat water.

Maximize Recovery of Value-Add Products

- Oil ($$$)
- Distilled Water (re-use for fracs)
- Clean Heavy Brine (re-use for drilling)
- Solids + any untreatedable water for disposal.

Optimize & Protect SWD Capacity
## Case Study C

### Background:
- The Eagle Ford is in “drill-to-hold” mode.
- Producers need a very mobile solution and can re-use saltwater in nearby fracs.
- Customer objective was to clean flowback and PW for re-use (high capacity, low cost).
- Remove TSS, iron and polymers.

### Objectives:
1. Test flowback (early, middle and late) and PW removal efficiencies at the well site level.
2. Set-up in 12 hours and be ready for flowback.
Case Study C

High capacity (10,000bpd).
Solids removed prior to re-use.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Metric</th>
<th>Influent to ROVER (Feed)</th>
<th>Effluent from ROVER</th>
<th>Removal</th>
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<tbody>
<tr>
<td>Alkalinity</td>
<td>mg/L CaCO₃</td>
<td>406</td>
<td>206</td>
<td>49%</td>
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<tr>
<td>Iron (Fe)</td>
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<tr>
<td>Manganese (Mn)</td>
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<td>Total Hardness (Ca+Mg)</td>
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<tr>
<td>Silica (SiO₂)</td>
<td>mg/L</td>
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<td>27</td>
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<tr>
<td>Total Suspended Solids (TSS)</td>
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<td>NTU</td>
<td>&gt;100</td>
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<td>pH</td>
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<td>6.8</td>
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</tr>
<tr>
<td>Total Dissolved Solids (TDS)</td>
<td>mg/L</td>
<td>32,835</td>
<td>34,610</td>
<td>n/a</td>
</tr>
</tbody>
</table>
Case Study D

Background:
- Wells are drilled in “Rows”. All flowback along each row is hard-pipe connected to tanks for re-use.
- Upon completion of a Row, the PW from that Row is connected to the next for re-use.
- The flowback and PW can easily be cleaned with the ROVER prior to re-use (TSS/polymer).

Study Objectives:
1. Remove TSS from incoming flowback and PW prior to re-use.
2. Prevents expensive clean-up when moving tanks from old Row to new Row.
3. Improve frac performance (reduce scaling index). *Difficult to quantify value.*
Case Study D

ROW 1

100% Re-Use for Well #2

Flowback from Well #1

Complete ROW, Re-Using Flowback

ROW 2

Move Tanks When ROW Complete
Case Study D

Q: Should TSS, Fe & Polymer be removed prior to re-use?

Flowback from Well #1

PW from ROW 1

100% Re-Use for Well #2

Flow-Back + PW

Make-Up
Case Study D

- Water formed good floc using FQWM standard treatments.
- Turbidity dropped from 600 NTU to 5 NTU.
- Proposed ROVER Treatment cost: $0.79/bbl.

Customer opted to continue “as-is” and re-use the water without treatment. They recognize that high solids has potential negative impacts for production, but they cannot quantify whether improved water quality will affect production.

Re-use without treatment can be a valid water management strategy.
Case Study E

Saltwater #2 – RO Brackish, Wise County, TX

Background:
Customer challenged us with this problem:
- They have an area in northern Wise County with limited freshwater.
- There are saltwater wells available.
- They prefer to have a large freshwater pond and use freshwater if possible.
- Is it economic to try to go to freshwater?

Study Outcome:
1. Budget cost: $0.50/bbl for RO.
2. RO recovery increased by blending up to 2,000mg/L TDS into the “freshwater” pit.
3. The RO reject is sent to NOMAD treatment and is handled along with flowback and PW.
Case Study E

Saltwater Well

147gpm

RO System

Bypass (up to 2,000mg/L)

99gpm

114gpm

RO Permeate

15gpm

RO Reject

33gpm

Saltwater Well

Flowback & PW

Lined Open-Top Tank

15,000 bbl

77% RO recovery if you factor in the bypass.

Fresh Water Supply (un-lined)

200,000 - 400,000 bbl

< 2,000 mg/L TDS

Distilled Water

2 NOMAD Site

10# Brine

SWD
Flexibility

1. ROVER Mobile Clarifier (10,000bbl/d capacity)
2. NOMAD Mobile Plant (2,000bbl/d capacity)
3. Central Plant (60,000bbl/d capacity)

- TSS Removal
- TSS + TDS Removal
New Trends

• Pit covers (prevent evaporation).
• Combine Recycling & Disposal (not Recycling OR Disposal).
• More use of brackish water and saltwater – be careful about hydrogeology.
• Have a common sense discussion with parties involved:
  • Landowners are often writing leases stating that E+Ps must buy groundwater from them.
• Incentivize, not mandate recycling (i.e.: TWRA).
  www.txwra.org
What is Needed?

   - Ask the right questions & keep it simple (saltwater or freshwater).

2. Range of Solutions.
   - Look for a proven track record. Talk to the customers.
   - Technology must be based on real science backed up with real results.

3. Flexibility.
   - Solution must be adaptable to the changing needs of the industry.

   - Share results and experiences (good and bad). We can learn as much, or more, from what has not worked.