Hydraulic Fracturing with Cryogenic Fluids: Boosting Hydrocarbon Production While Conserving Fresh Water Resources

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CURRENT CHALLENGES IN UNCONVENTIONAL FIELD DEVELOPMENT

- Demand growth
- Volumes
- Number of wells
- Water management
- Logistics
- Well performance
- Environmental footprint
- Emissions and GHG’s
- Truck traffic on county roads
- COST!!
DEMAND GROWTH

Montney gas/ average per well YoY

- **Well Count**
  - 2012: 400
  - 2013: 600
  - 2014: 800

- **# Stages**
  - 2012: 10
  - 2013: 15
  - 2014: 20

- **Total Fluid Pumped**
  - 2012: 10,000 m$^3$
  - 2013: 15,000 m$^3$
  - 2014: 20,000 m$^3$

- **Total Proppant Placed**
  - 2012: 1,000 tonnes
  - 2013: 1,500 tonnes
  - 2014: 2,000 tonnes

Source: Canadian Discovery Frac Database
2014 Montney gas/ average per well

- Average # Stages
  - Non-Energized: 16
  - Energized: 17

- Average Water Pumped
  - Non-Energized: 5,000
  - Energized: 10,000

- Average Total Proppant Placed
  - Non-Energized: 1,600
  - Energized: 1,800

Source: Canadian Discovery Frac Database
WATER MANAGEMENT

- Water sourcing and sourcing restrictions
- Water transportation
- Water storage
- Water infrastructure investment
- Disposal and recycling challenges
- Pad sizing
- Hidden costs
NA Water Stress Map

A database of hydraulically fractured wells is overlaid on a map of baseline water stress in the United States and two Canadian provinces for which we have data. This map measures the ratio of water withdrawal to mean annual available supply, and shows where there is high competition for limited water resources among users. Red areas on the baseline water stress map are places where a large portion of available water supply is already being used. The gray areas are dry and undeveloped. Black dots on the map represent wells hydraulically fractured.

ALTERNATIVES TO MANAGE CHALLENGES

- Optimize job size
- Energize your wells

Optimize number of stages
Optimize sand tonnage
Reduce water usage

In 2014 on average, energized fracturing fluids volume were ~50% smaller than water based fracturing fluids volume.

Source: Canadian Discovery Frac Database
REDUCE WATER USAGE

WCSB Estimated Total Water Consumption for Completions YoY

Bubble size is the estimated total water used YoY (in Million m³)

Source: Canadian Discovery Frac Database

Slide 8
FOLLOW PRODUCTIVE INITIATIVES

Nitrogen Usage Growth in WCSB

Estimated N2 use Top Plays YoY

WCSB N2 Estimated Usage YoY

Source: Canadian Discovery Frac Database
REDUCE TRUCK TRAFFIC

Kakwa river water usage

![Water Consumption Graph](chart1)

- Slickwater: 17,500 m³
- N₂ Foam: 1,875 m³

![Truck Traffic Graph](chart2)

- Slickwater: 698
- N₂ Foam: 290

*Slide 10*
REDUCE COST

Binary Foam saves $850K and CO₂ Foam saves $950K over Slickwater

Source: SPE 175948
ENHANCE WELL PERFORMANCE

• Water damage mechanisms:
  • Clay swelling / softening / movement
  • Aqueous phase trapping (high capillary pressure)
  • Proppant embedment
  • Fracture face damage (fluid imbibition)
  • Poor cleanup and water recoveries during flowback
  • Poor proppant transport / conductivity
  • Lower hydrocarbon rates and EUR’s
ADVERSE ROCK – WATER INTERACTION (VIKING ZONE)

Core Immersed in McBride dugout water

Core Immersed in Bridge Creek 3% KCl Water

SOURCE: Baker Hughes
CASE STUDY SHOWING ENHANCED PRODUCTION / REDUCED COST – SPE 175948

- Cryogenic N\textsubscript{2} and CO\textsubscript{2} used in energized fluid systems provide proven, effective technology to stimulate tight sands and shales
- Non-damaging fluid which greatly reduces water volumes, chemicals and proppants
- Reduces real and environmental costs while maximizing NPV

Source: BMO A&D Drill Bits – October 2011
STUDY SCOPE

- >3,500 Hz Montney wells completed to date
- Study criteria:
  - Montney/Doig Gas
  - OGR < 75 stb/mmcf
  - 12 months of production data
  - On Production Date >2010
  - 1,627 wells met the criteria

Fluid systems analyzed

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Acronym</th>
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<tbody>
<tr>
<td>Slickwater</td>
<td>SW</td>
</tr>
<tr>
<td>Energized Slickwater</td>
<td>E-SW</td>
</tr>
<tr>
<td>Other Water Based Fluids</td>
<td>WB</td>
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<tr>
<td>Energized Water Based</td>
<td>E-WB</td>
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<tr>
<td>Oil Based</td>
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<tr>
<td>Energized Oil Based</td>
<td>E-Oil</td>
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<tr>
<td>N₂ Foam</td>
<td>N₂ Foam</td>
</tr>
<tr>
<td>CO₂ Foam</td>
<td>CO₂ Foam</td>
</tr>
<tr>
<td>Binary (N₂+CO₂) Foam</td>
<td>BI Foam</td>
</tr>
</tbody>
</table>

Energized Fluids < 50% CO₂ or N₂
Foams CO₂ / N₂ / Both > 50%

The most comprehensive statistical analysis of the Montney
Binary Foams outperform any other fluid on a 90 day basis!
Flatter slope implies increased variability
Completion cost doesn’t include water disposal cost
Slickwater is consistently the MOST expensive fluid used in the Montney!
WHAT WE LEARNED

- **Reduce Costs by 20%**
  - By using CO₂ in completions, you could cut costs by 20% by having a more effective flowback system and less water used.

- **Reduce Reliance on Fresh Water by 80%**
  - By using CO₂ in completions, you could reduce reliance on fresh water by 80%.

- **Increase Production by 15%**
  - By using CO₂ in completions, you could increase production by 15%. The duration of the well life is extended using CO₂.

- **Lower Truck Traffic up to 50%**
  - By using CO₂ in completions, you could lower truck traffic by 30 – 50%.

Optimize Sand Concentration

CO₂

SPE 175948 • The Full Montney • M.Reynolds

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ferus
RECENT US SUCCESSFUL APPLICATION

• 2015 - first application of CO$_2$ based fracture fluid in the Bakken fm (North Dakota)
• Over 6,000 tons used in a multi-stage fractured HZ completion
• Stay tuned for results
LOGISTICAL CHALLENGES

- Large volume hydraulic fracturing jobs
  - Supply constraints
  - Truck traffic
  - Site layout challenges
  - Sub-optimal product delivery
  - Over-sizing of fracture treatments
  - Cost
OPTIMIZE LOGISTICS

• Proximal Supply
  - Substantially reduced plant gate price
  - Significantly reduced transportation
  - Scheduling flexibility; reduced standby
  - Reduced exposure to weather & road bans
OPTIMIZE LOGISTICS

• Demand Planning
  - 24/7 Real-Time Dispatch Services
  - Coordinate storage, trucks and product deliveries
  - Optimize delivery times through real-time interaction

• Reliable Transportation
  - Triple drive axle tractors allowing for larger capacity
  - Typically use tandem tractors requiring two trailers

• On-Location Storage

• On-Site Service - Field supervisors
INTEGRATED SOLUTIONS

• Holistic approach to solve the problem
• Technical services
  • Optimize job size
  • Improve fracturing fluid design
• Partner with experts
  • Supply
  • Logistics
  • Transportation
• Reduced costs
• Reduce environmental Impact
• Enhanced well productivity and economics
Questions?

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