Mud Motor vs Rotary Steerable System Risked Economics Calculator

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Speaker Information

- Stu Keller
- Drilling Engineering Consultant
- Occidental Oil and Gas Corporation
Introduction

- Oxy Worldwide Drilling & Completions Central Drilling Group
- 3+ years with Oxy; 30 years with ExxonMobil; all in Drilling & Completions
- Purdue University B.S. Engineering Science
- Based in Houston
- Specialized in
  - BHA & Tubular Design
Occidental Oil and Gas

Permian Basin Is The Core Domestic Asset

EOR Business
- YTD ‘16 Production - 144 MBOEPD
- 1 million net acres
- 1.9 Billion BOE remaining in reserves and resources

Resources (Unconventional)
- YTD ‘16 Production - 125 MBOEPD
- 1.4 million net acres
- 8,500 identified well locations

Midstream
- 12 processing plants
- ~2,900 miles of pipeline
  - CO₂ pipelines
  - Oil infrastructure and pipelines
  - Marketing business

Infrastructure difficult to duplicate

* Based on 4Q15 metrics
Oxy Has Significantly Decreased Permian Horizontal Well Costs and Drilling Days Since 2014

Permian Resources – Manufacturing Mode

Delaware Wolfcamp A 4,500’ HZ
- 2014: $10.9M, $5.6M drilling, $5.3M completion
- Current: $6.3M, $3.4M drilling, $2.9M completion
- Best: $5.4M, $2.7M drilling, $2.7M completion

East Midland Wolfcamp A 7,500’ HZ
- 2014: $9.2M, $5.5M drilling, $3.7M completion
- Current: $6.1M, $3.8M drilling, $2.3M completion
- Best: $5.3M, $3.4M drilling, $1.9M completion

Drilling Days:
- Delaware Wolfcamp A 4,500’ HZ: 2014: 43 days, 1Q15: 37 days, 2Q15: 20 days, 3Q15: 19 days, 4Q15: 17 days, 1Q16: 13 days, Best: 11 days
- East Midland Wolfcamp A 7,500’ HZ: 2014: 46 days, 1Q15: 31 days, 2Q15: 20 days, 3Q15: 18 days, 4Q15: 17 days, 1Q16: 16 days, Best: 11 days
Oxy Positive Displacement Motor (PDM) vs Rotary Steerable System (RSS) Economics Calculator - Overview

- Calculates Risked Cost of PDM, RSS, RSS+PDM
- Includes probability of trip, probability of LIH, fishing economics
- Sensitivities to ROPs
Oxy PDM vs RSS Risked Economics Calculator Has Three Main Components

**GENERAL DATA INPUT**

- **Survey Type**
  - Oxy PDM
  - RSS
  - RSS+PDM

**DIRECTIONAL TOOL INPUT**

- **Drilling Risk**
  - PDM: 70%
  - RSS: 100%
  - RSS+PDM: 100%

- **Sliding / Steering**
  - PDM: 30%
  - RSS: 0%
  - RSS+PDM: 0%

- **Sliding / Stepping**
  - PDM: 20%
  - RSS: 0%
  - RSS+PDM: 0%

- **Denting / Diverting**
  - PDM: 0.1
  - RSS: 1.0
  - RSS+PDM: 1.0

- **Runouts**
  - PDM: 20
  - RSS: 0
  - RSS+PDM: 0

- **Contractual rates**
  - PDM: $12,000 / day
  - RSS: $35,000 / day
  - RSS+PDM: $43,000 / day

- **Equipment cost**
  - PDM: $100,000
  - RSS: $500,000
  - RSS+PDM: $500,000

- **Risk Analysis**
  - Trip risk: 12%
  - Total trip risk: 36%
  - Probability of failure: 2%
  - Tool failure risk: 1%
  - Fishing daily charges: $5,000 / day
  - Sidetrack fixed costs: $100,000
  - Sidetrack operations: $100,000

- **Sensitivity Analysis**
  - Minimum ROP: 25.0
  - Maximum ROP: 125.0

**RESULTS**

**DAILY PERFORMANCE**

- **Average on-bottom ROP**
  - PDM: 18
  - RSS: 18
  - RSS+PDM: 18

- **Footage / Day**
  - PDM: 6.0
  - RSS: 6.0
  - RSS+PDM: 6.0

- **Drilling time**
  - PDM: 6.0
  - RSS: 6.0
  - RSS+PDM: 6.0

- **Rig time**
  - PDM: 5.0
  - RSS: 5.0
  - RSS+PDM: 5.0

- **Circulating time**
  - PDM: 3.0
  - RSS: 3.0
  - RSS+PDM: 3.0

- **Denting / Diverting**
  - PDM: 0.1
  - RSS: 1.0
  - RSS+PDM: 1.0

- **Subtotal**
  - PDM: 24.0
  - RSS: 24.0
  - RSS+PDM: 24.0

**SECTION SUMMARY**

- **Rotating**
  - PDM: 6.0
  - RSS: 6.0
  - RSS+PDM: 6.0

- **Sliding / Steaming**
  - PDM: 6.0
  - RSS: 6.0
  - RSS+PDM: 6.0

- **Subtotal Drilling**
  - PDM: 12.0
  - RSS: 12.0
  - RSS+PDM: 12.0

- **Sidetrack time**
  - PDM: 3.0
  - RSS: 3.0
  - RSS+PDM: 3.0

**Non-risked cost**

- **Rig cost**
  - PDM: $348,062
  - RSS: $216,364
  - RSS+PDM: $216,364

- **Directional tool cost**
  - PDM: $140,000
  - RSS: $100,000
  - RSS+PDM: $100,000

- **Standby cost**
  - PDM: $40,000
  - RSS: $40,000
  - RSS+PDM: $40,000

- **Other total charges**
  - PDM: $50,000
  - RSS: $50,000
  - RSS+PDM: $50,000

- **Total non-risked cost**
  - PDM: $528,062
  - RSS: $416,364
  - RSS+PDM: $416,364

**Risked Cost**

- **Tripping risk cost**
  - PDM: $20,000
  - RSS: $10,000
  - RSS+PDM: $10,000

- **Sidetrack length**
  - PDM: $560,000
  - RSS: $560,000
  - RSS+PDM: $560,000

- **Fishing daily total**
  - PDM: $560,000
  - RSS: $560,000
  - RSS+PDM: $560,000

- **Optimum Fishing Time**
  - PDM: 2.4
  - RSS: 2.4
  - RSS+PDM: 2.4

- **Total risked cost**
  - PDM: $782,062
  - RSS: $616,364
  - RSS+PDM: $616,364

**Total Risked Cost**

- PDM: $782,062
- RSS: $616,364
- RSS+PDM: $616,364

**Total Risked Cost / ft**

- PDM: $262
- RSS: $192
- RSS+PDM: $192
### Notes

- Blue fields are input; white calculated
- Calculations are for a single section
- By default ROPs are on-bottom (flat times: survey, connection, orienting, trip time entered separately)
- Contract mode (drop down) can be $/day, $/hr, or $/ft
- Flat times and risk data are optional
- Data shown are hypothetical
### Results

#### Notes

- Average on bottom ROP accounts for sliding ROP with motor
- Lowest total section time may not correspond with lowest cost/ft
- Key results are non-risked and total risked cost/ft
- For this example, motor has lowest total risked cost (75 $/ft) but RSS has lowest non-risked cost (64 $/ft)
Sensitivity

Notes

• Sensitivity is to on-bottom ROPs
• Dashed lines correspond to specified input data
• Both non-risked and total risked cost/ft shown
• In this example, for expected performance, motor expected to have least risked cost/ft
• RSS ROP would need to increase from 90 to 140 ft/hr to match motor risked cost/ft
Risk Costs are Unique Feature

Notes
- Program calculates fishing time based on either fixed historical success rate or optimum fishing time (OFT) equation (based on SPE 22380; drop down select box)
- Success rate fishing time = \( \text{success rate} \times \frac{\text{sidetrack cost}}{\text{daily fishing cost}} \)
- Probability of successful fishing = \( \text{fishing time} \times \frac{\text{daily fishing cost}}{\text{sidetrack cost}} \)
### Probabilistic Version

#### Probabilistic Analysis Data Input

<table>
<thead>
<tr>
<th>Time / survey</th>
<th>Minimum</th>
<th>Most Likely</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDM, RSS, RSS+PDM</td>
<td>4.0</td>
<td>5.0</td>
<td>6.0 min</td>
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<tr>
<td>RSS, PDM, RSS+PDM</td>
<td>6.0</td>
<td>7.0</td>
<td>8.0 min</td>
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<tr>
<td>RSS, PDM, RSS+PDM</td>
<td>8.0</td>
<td>9.0</td>
<td>11.0 hrs/day</td>
</tr>
<tr>
<td>RSS, PDM, RSS+PDM</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1 hrs/day</td>
</tr>
</tbody>
</table>

#### Drilling - PDM

| PDM Rotating | 60% | 70% | 71% |
| PDM ROP | 100.0 | 110.0 | ft/hr |
| PDM Sliding ROP | 27.0 | 30.0 | 33.0 ft/hr |

#### Drilling - RSS

| RSS Rotating | 58% | 99% | 100% |
| RSS ROP | 90.0 | 90.0 | 99.0 ft/hr |
| RSS Sliding ROP | 81.0 | 81.0 | 81.0 ft/hr |

#### Drilling - RSS+PDM

| RSS+PDM Rotating | 58% | 99% | 100% |
| RSS+PDM ROP | 90.0 | 100.0 | 110.0 ft/hr |
| RSS+PDM Sliding ROP | 90.0 | 100.0 | 110.0 ft/hr |

#### Probability of LHI (Risk)

<table>
<thead>
<tr>
<th>PDM</th>
<th>RSS</th>
<th>RSS+PDM</th>
</tr>
</thead>
<tbody>
<tr>
<td>9%</td>
<td>10%</td>
<td>11%</td>
</tr>
<tr>
<td>9%</td>
<td>10%</td>
<td>11%</td>
</tr>
</tbody>
</table>

#### Sidetrack

| ST fixed costs | $149,000 | $150,000 | $151,000 |
| ST flat time | 47.0 | 48.0 | 49.0 hrs |

### Results

#### Daily Performance

<table>
<thead>
<tr>
<th></th>
<th>PDM</th>
<th>RSS</th>
<th>RSS+PDM</th>
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</thead>
<tbody>
<tr>
<td>Average on-bottom ROP</td>
<td>10.9</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Footage / day</td>
<td>1119</td>
<td>1800</td>
<td>1800</td>
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<tr>
<td>Drilling time</td>
<td>19.0</td>
<td>18.33</td>
<td>18.0</td>
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<tr>
<td>Survey time</td>
<td>1.04</td>
<td>1.55</td>
<td>1.57</td>
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<tr>
<td>Connection time</td>
<td>1.49</td>
<td>2.14</td>
<td>2.15</td>
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<tr>
<td>Circulating time</td>
<td>2.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Orienting / downlinking</td>
<td>0.50</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Subtotal</td>
<td>24.00</td>
<td>24.00</td>
<td>24.00</td>
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#### Section Summary

<table>
<thead>
<tr>
<th></th>
<th>PDM</th>
<th>RSS</th>
<th>RSS+PDM</th>
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</thead>
<tbody>
<tr>
<td>Rotating time</td>
<td>13.5</td>
<td>71.4</td>
<td>64.3</td>
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<td>Sliding / Steering time</td>
<td>66.0</td>
<td>0.8</td>
<td>0.7</td>
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<td>Subtotal Drilling time</td>
<td>120.5</td>
<td>72.2</td>
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<td>Survey time</td>
<td>6.0</td>
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<td>6.0</td>
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<tr>
<td>Connection time</td>
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<td>8.4</td>
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<tr>
<td>Circulating time</td>
<td>11.2</td>
<td>3.9</td>
<td>3.6</td>
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<td>Orienting / downlinking</td>
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<td>3.9</td>
<td>3.6</td>
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<td>Tripping time</td>
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<tr>
<td>Other time</td>
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<td>0.0</td>
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<tr>
<td>Subtotal flat time</td>
<td>31.4</td>
<td>24.7</td>
<td>24.3</td>
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<tr>
<td>Total time</td>
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<td>101.0</td>
<td>27.1</td>
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<tr>
<td>Total section time</td>
<td>5.9</td>
<td>4.0</td>
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<tr>
<td>Cost</td>
<td>$354,681</td>
<td>$274,364</td>
<td>$222,667</td>
</tr>
<tr>
<td>Directional tool cost</td>
<td>$72,000</td>
<td>$175,000</td>
<td>$180,000</td>
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<tr>
<td>Standby cost</td>
<td>-</td>
<td>$40,000</td>
<td>$40,000</td>
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<tr>
<td>Other daily charges</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Non-Risked Cost</td>
<td>$426,681</td>
<td>$457,364</td>
<td>$442,667</td>
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<td>Non-Risked Cost / ft</td>
<td>$66</td>
<td>$70</td>
<td>$68</td>
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<td>Non-Risked cost</td>
<td>$366,930</td>
<td>$416,693</td>
<td>$315,580</td>
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<td>Fishing daily total cost</td>
<td>$65,000</td>
<td>$65,000</td>
<td>$65,000</td>
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<td>Optimum Fishing Time</td>
<td>1.7</td>
<td>2.4</td>
<td>2.4</td>
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<td>Risk Cost</td>
<td>$53,413</td>
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<td>Total Risked Cost</td>
<td>$480,094</td>
<td>$618,470</td>
<td>$614,548</td>
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<tr>
<td>Total Risked Cost / ft</td>
<td>$75</td>
<td>$89</td>
<td>$95</td>
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Conclusions & Acknowledgements

Conclusions

- A risked-based economics calculator can be useful for selecting the most cost-effective directional drilling system.
- Accurate data on expected ROPs, flat times, and risk are needed for the tool to be most useful.

Acknowledgements

- Diego Tellez of Oxy played a key role in developing this tool
- Thanks to Oxy management for allowing this presentation
Thank You