Transportation Systems for Oil & Gas Development: Case Study of the Bakken Shale

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Preview

- Bakken shale formation
- Production technologies
- Input requirements/outputs
- Transportation demands
- Mode use and traffic distribution
- Forecasting and modeling concepts
- Highway impacts and planning
- Conclusions/lessons learned
Shale Oil Formations in North Dakota

- 10,000-12,000 feet beneath surface
- Tight rock formation
- Hydraulic fracturing
- Horizontal drilling

North Dakota Oil and Gas Division
Horizontal and Vertical Wells

Lateral: 6,000 to 11,000 feet
Well Spacing

- More vertical wells are needed to access similar sized reservoir area
- Ratio of vertical/horizontal may be 4:1
- E.g., a 640-acre section could be developed with 16 vertical wells (on individual pads) or 4 horizontal wells drilled from a single pad
- North Dakota: typical space unit=1,280 acres
- 8-12 wells per unit based on drilling practices
- Batch drilling may increase density
Production Trends and Potential

- ND produces ≈ 1 million barrels of oil per day (BOPD)
- Production may increase to 1.6 million BOPD
- Dept. of Mineral Resources projects 10-14 billion barrels of *technically recoverable reserves*
- Industry projections are much higher
  - (e.g., Continental Resources) 20+ billion barrels
- In-place oil reserves: 400+ billion barrels
  - Continental Resources: 900 billion barrels
- 60,000 new wells expected to be drilled during next 20-30 years
- See following production charts
North Dakota is second leading state in oil production
Number of Oil Wells: North Dakota

Currently: 10,000+ producing wells
Daily Output per Well: North Dakota
Oil Production Details

- Bakken output per well: 140 BOPD
- Average Initial Production as high as 1,700 BOPD with sharp decline afterward
- Statewide average IP rate = 1,200 BOPD
- Projected Bakken/Three Forks development
  - 1,100 to 2,700 wells per year
    - Expected value (2,000 new wells per year)
- Projected new wells: 40,000 – 70,000 next 30 years
- Production may exceed 1.5 million BOPD in near future
Bakken Well Production Curve
Input Requirements/Outputs

- All Bakken wells are hydraulically fractured
- Requirements:
  - 2-4 million gallons of fresh water
  - 3-5 million pounds of sand and/or ceramics
  - Chemicals, fuel, drilling mud, cement, etc.
- Fracking cost > $2 million per well
- Outputs: oil, saltwater, natural gas
- 1 bbl of saltwater per 2 to 3 bbl of oil
Material, Product, and Equipment Movements

- Inputs railed to transloading sites
- Specialized equipment to and from well site
- Roughly 2,300 drilling-related truck trips per well (next slide)
- Outbound crude oil
  - By truck to pipeline or rail transfer location
  - By small diameter pipeline to trunkline connection
- Natural gas: by gathering pipeline to trunk connection
- Outbound byproducts
  - E.g., salt water mix for disposal by truck or pipeline
# Drilling Related Truck Movements per Bakken Well

<table>
<thead>
<tr>
<th>Input or Product</th>
<th>Loaded Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water (Fresh)</td>
<td>450</td>
</tr>
<tr>
<td>Water (Waste)</td>
<td>225</td>
</tr>
<tr>
<td>Frac Tanks</td>
<td>115</td>
</tr>
<tr>
<td>Sand</td>
<td>100</td>
</tr>
<tr>
<td>Scoria/Gravel</td>
<td>80</td>
</tr>
<tr>
<td>Rig Equipment</td>
<td>65</td>
</tr>
<tr>
<td>Drilling Mud</td>
<td>50</td>
</tr>
<tr>
<td>Cement</td>
<td>20</td>
</tr>
<tr>
<td>Pipe</td>
<td>15</td>
</tr>
<tr>
<td>Other</td>
<td>30</td>
</tr>
</tbody>
</table>

1,150 Loaded Trucks

2,300 Loaded & Empty Trucks
Current Mode Share Crude Oil: Gathering Movement

Movements from Wells to Transfer Locations

North Dakota Pipeline Authority
## Oil Pipeline Network in North Dakota

<table>
<thead>
<tr>
<th>Category</th>
<th>Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil gathering pipeline</td>
<td>10,800</td>
</tr>
<tr>
<td>Crude oil (transmission) pipeline</td>
<td>3,100</td>
</tr>
<tr>
<td>Oil product pipeline</td>
<td>1,070</td>
</tr>
<tr>
<td>All oil pipelines</td>
<td>14,970</td>
</tr>
</tbody>
</table>

Estimates from North Dakota Pipeline Authority. No historical requirement for reporting of gathering pipelines. Thus, gathering pipeline miles estimated from multiple sources.
ND Oil Gathering Network: Northern Bakken Region

North Dakota Pipeline Authority – Feb., 2013
ND Oil Gathering Network: Pre-Boom Legacy Pool

- Mature producing region developed in 1970s
- Most wells have gathering pipeline access
- Compare to recent Bakken development, where trucking dominates
Gathering Mode Distribution Over Time

- Initially, all crude oil is transported by truck to rail or pipeline transfer locations
- When wells are added to a spacing unit, small diameter gathering pipeline may be built from trunk pipeline network
- Projected distribution: ≥ two-thirds of crude oil outbound by gathering pipeline in mature system
- Depends on many factors: added trunk line capacity, rail improvements and capacity, highway improvements and restrictions
Crude Oil Mode Shares
Line Haul

- Current: 70% rail; near-term projection: 90% rail
- Reasons for rail dominance
  - Limited pipeline capacity (sized to historical production: next slide)
  - Challenges/length of time in siting and constructing new pipelines
  - Greater ease of capacity expansion on railroads
  - Lower cost of railroad expansion
  - Rail access to a wider variety of markets → premium prices
ND Crude Oil Pipelines

North Dakota Pipeline Authority – Feb., 2013
Rail Movement Characteristics

- 700-725 bbl per tankcar
- Shipments: multicar units or trainloads (e.g., 100+ cars)
- Current rail share ≈ 1,000 cars per day
- Equivalent to ten 100-car trains/day
- 70%+ rail share → 16-20 trainloads/day of crude oil at peak
Rail Transportation Issues

- Line capacity for other goods
- Service levels and priorities
- Testing, classification, placarding
- Tankcar standards
- Accident exposure (train-miles)
- Risk assessment/routing
- Grade crossings
Highway Transportation Issues

- Forecasting challenge
  - Historical traffic trends are essentially useless
  - Great spatial and temporal variation in traffic (next slide)

- Unprecedented traffic on rural roads typically designed for farm-to-market traffic

- Insufficient base layers and soil support

- Inadequate data on existing road structure

- Rapid deterioration of roads (e.g., US-2, ND-68)

- Mostly narrow two-lane rural roads: capacity and safety issues
Spatial/Temporal Traffic Variations

- Initial drilling phase
  - Drill at least well per spacing unit to hold lease
  - Scramble to acquire and hold leases
- Fill-in period when spacing units are drilled out
- Countervailing demand forces
  - IP rates of old wells are dropping
  - New wells are being added to the same areas
  - Challenges for travel demand forecasting
- Other unknowns: gathering pipeline density
Avg. Projected Truck ADT on County Roads for Three Heavily Impacted Oil Counties (with Control Case)

Slope County (not impacted by oil production) illustrates traditional truck traffic levels
Damage to ND Highway 68 Resulting from Oil-Related Traffic

US 2 Near Ray, ND

- Design Life: 20 years; 900,000 ESALS
- Pavement age = 9; currently > 1.1 million ESALs; ESAL life=14 million
ND 1806 in McKenzie Co., North Dakota

Rapid deterioration in less than 1 year

ND Highway 1806: Sep. 2, 2010

ND Highway 1806 on April 28, 2011
Road System Impacts

- Studies for North Dakota legislature
  - Detailed forecasts of traffic to/from individual spacing units
  - Truck traffic projected annually for 20 years
  - Models calibrated against observed traffic data for base year
  - Estimated truck ADT converted to equivalent single axle loads (ESALs)
  - Paved road condition forecasted year-by-year
  - Improvements identified: reconstruction, widening, resurfacing
  - Unpaved road analysis based on increasing frequencies of blading/graveling, increased gravel costs
## Typical Loads and ESAL Factors for Specialized Vehicles

<table>
<thead>
<tr>
<th>Load Type</th>
<th>Thou. Lbs.</th>
<th>ESALs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractor-Semitrailer</td>
<td>80.0</td>
<td>2.37</td>
</tr>
<tr>
<td>Generator House</td>
<td>160.2</td>
<td>9.49</td>
</tr>
<tr>
<td>Shaker Tank/Pit</td>
<td>142.7</td>
<td>6.40</td>
</tr>
<tr>
<td>Derrick</td>
<td>159.0</td>
<td>8.78</td>
</tr>
<tr>
<td>Mud Pump</td>
<td>165.9</td>
<td>6.18</td>
</tr>
<tr>
<td>Substructure, etc.</td>
<td>160.6</td>
<td>10.18</td>
</tr>
<tr>
<td>Mud Tank</td>
<td>138.8</td>
<td>9.04</td>
</tr>
<tr>
<td>Workover Rigs</td>
<td>105.0</td>
<td>6.06</td>
</tr>
</tbody>
</table>
Investments in Oilfield Access Roads

- Large-scale investment program in North Dakota
  - $2.5 billion state highway program: 2013-2015 biennium
  - Roughly $930 million for county and township roads
  - Current studies include bridge investment needs

- Other critical issues
  - Enforcement resources
  - Safety (including heavy vehicles)
  - Grade crossings
  - Hazmat/emergency response
Conclusions

- Oil-related traffic patterns are dynamic
- Vary spatially and temporally
- A multimodal transportation system is needed
- Different modes may be utilized more/less intensively in different stages of development
- Rural collector/local road system may be heavily impacted
- Road infrastructure may be entirely inadequate and require substantial upfront investment
- Caution must be exercised not to overbuild the road system
Conclusions (cont.)

- Gathering pipeline network may be added over time
- Crude transmission capacity may also be expanded
- New pipeline construction poses challenges
- Rail can be expanded more quickly at less cost, mostly within existing footprint
- Pipeline transport cost are likely to be lower than rail costs in the long run