Innovation and Adaptation of the Oil and Gas Industry Throughout Bakken Development

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Critical Challenges. Practical Solutions.

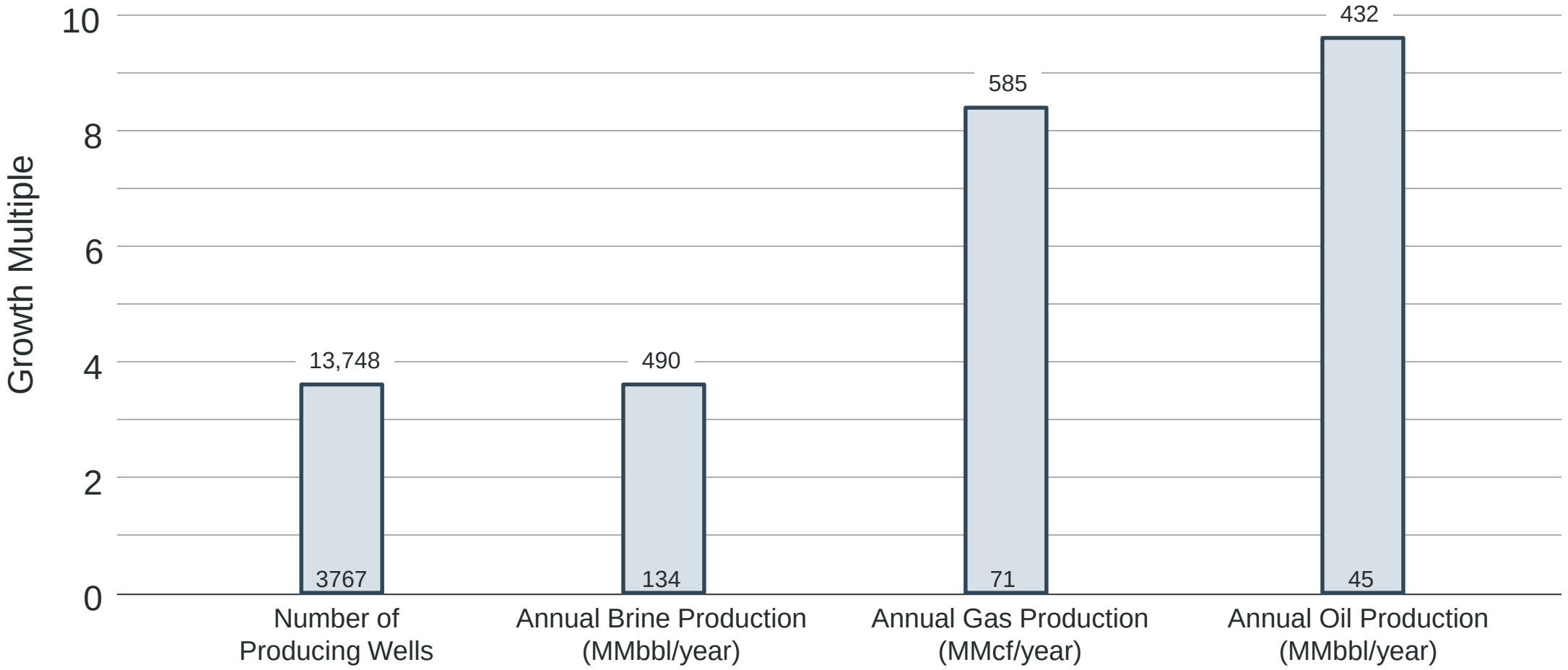
Goal

Highlight a few specific areas where the oil and gas industry, including regulators, have innovated and adapted to develop the Bakken Formation from 2007 through 2016.

Outline

- Background/statistics
- Well pads
- Well drilling and completion
- Well production
- Flaring
- Liquids gathering pipelines
- Spills

Background: Bakken Development by the Numbers 2007–2015



Notes: bbl = barrel
cf = cubic feet
MM = million

Well Pads

- Early Bakken development
  - Single well and associated infrastructure
  - Minimum footprint for truck loading and workover rig

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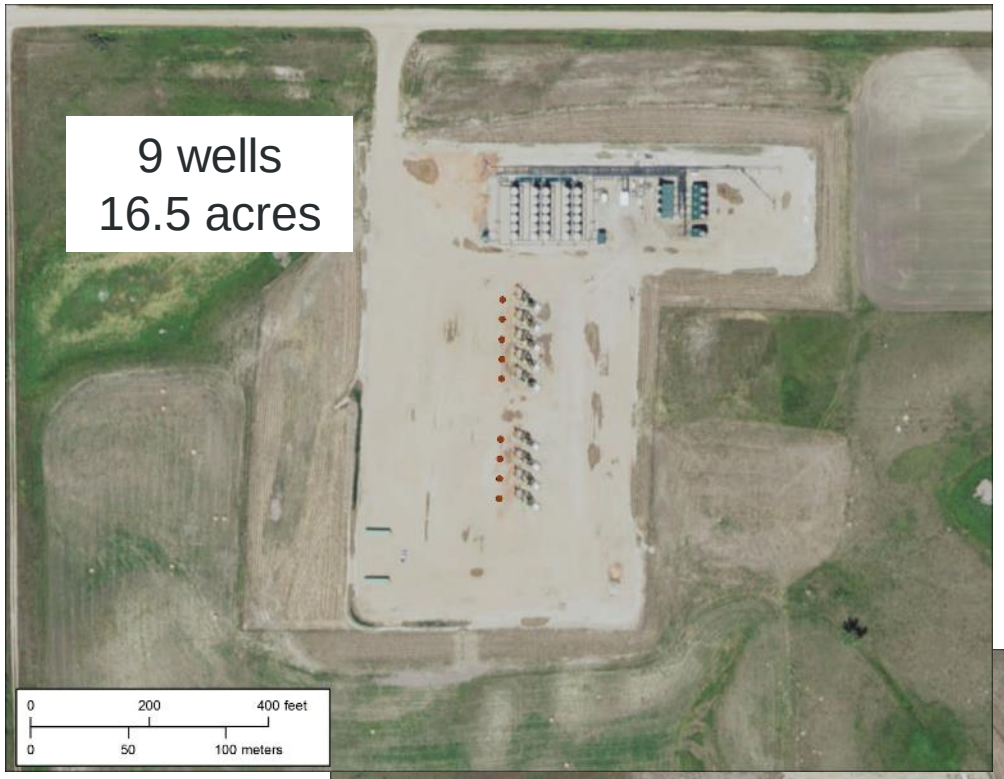
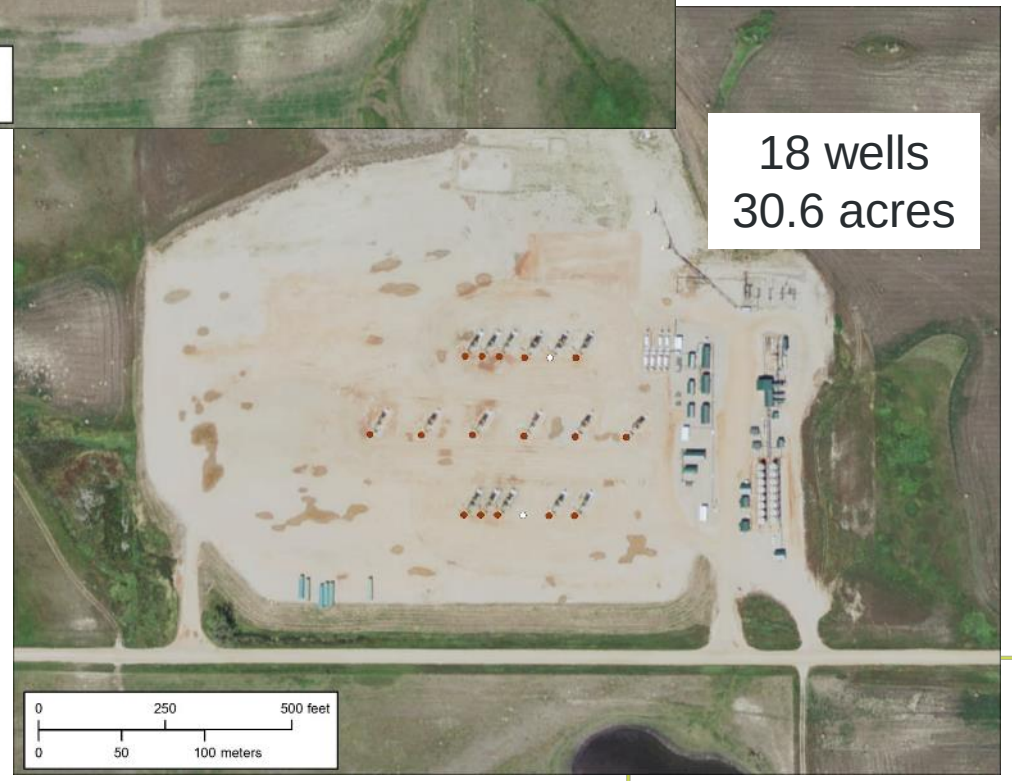
Well Pads (cont'd)

- Later Bakken development
  - Multiwell pad
    - ♦ Reduced footprint
    - ♦ Aggregation of infrastructure
  - Uniform permitting of spacing units
  - Energy corridors
  - Industry continues to pursue operational efficiencies by planning logistics for several multiwell locations (i.e., oil & gas production complex)





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Well Drilling and Completions

	2007–2008	2015–2016
Drilling Time	32 days	18 days
Wells Drilled	8–10 wells/year/rig	22–25 wells/year/rig
Lateral Length	5000–10,000 feet	10,000 feet and greater
Fracture Stages	One stage	30–50 stages
Fracture Fluid Volume	15,000 bbl/well	140,000 bbl/well
Proppant Used	1 million lb/well	6 million lb/well
Fracture Fluid Makeup	Potable water	Potable, surface, saline waters
Lateral Spacing (same zone)	1320 feet	660 feet*
Heel/toe Setback	200 feet	<200 feet**

* Continental Resources' Hawkinson project
** Multicompany modeling effort

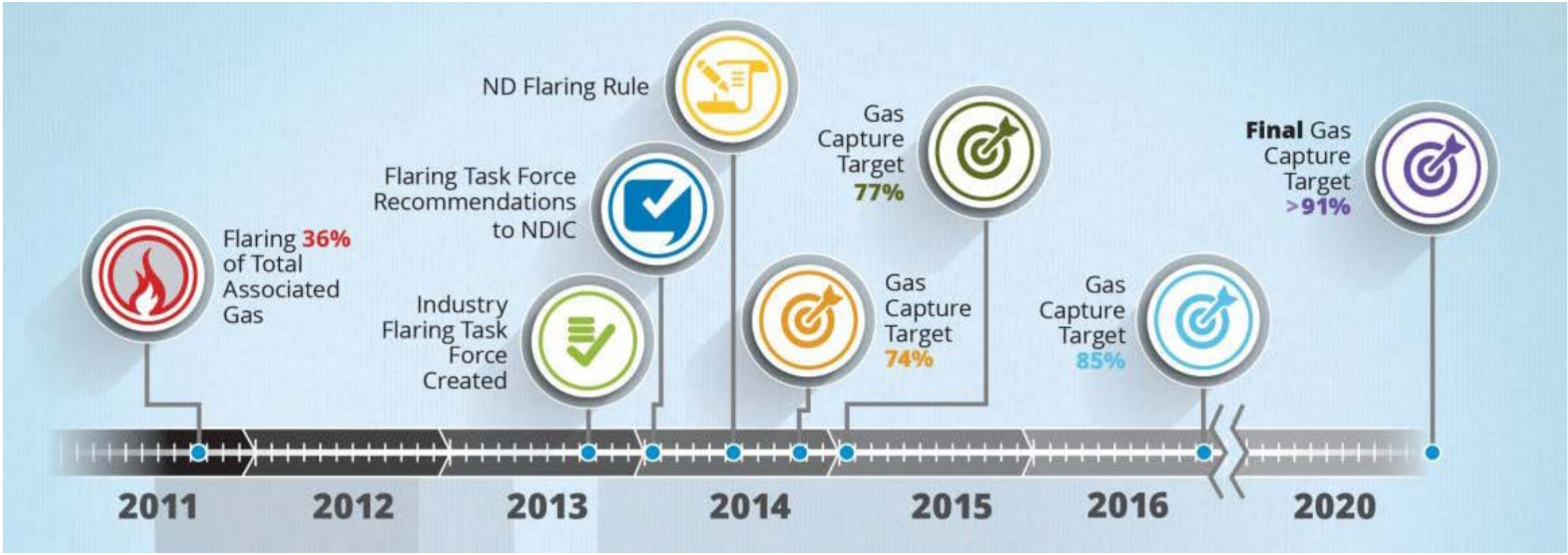
Notes: bbl = barrels
lb = pounds

Well Production

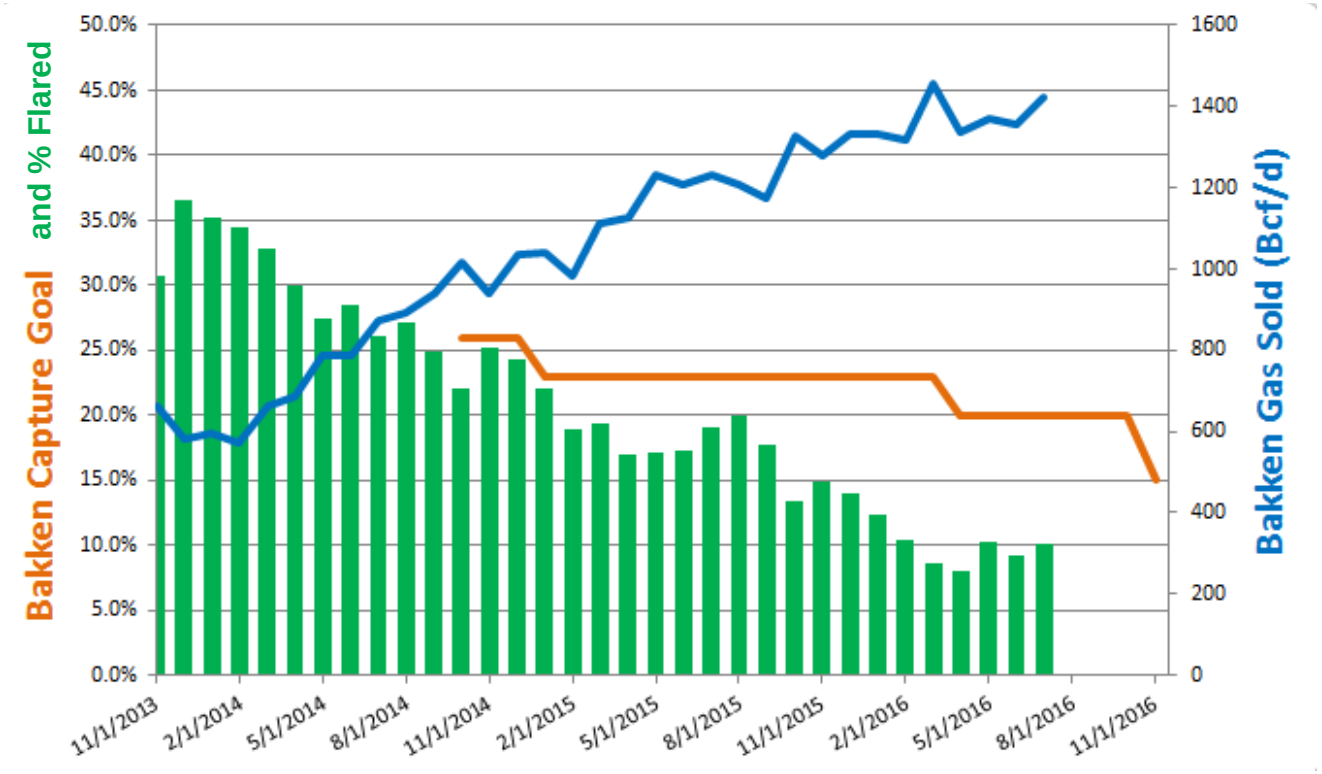
	2007–2008	2015–2016
Daily Production – Oil	150,000 bbl/day	1,000,000 bbl/day
Initial Production (IP) – Oil	533 bbl	1260 bbl
Initial Production (IP) – Gas	329 Mcf	1615 Mcf
Initial Production (IP) – Water	431 bbl	1565 bbl
Estimated Ultimate Recovery (EUR)–Oil	100–500 MBOE	500–1000 MBOE

Notes: bbl = barrel
Mcf = thousand cubic feet
MBOE = thousand barrels of oil equivalent

Flaring: Chronology of Flaring Reduction Efforts



Flaring – Meeting the Targets

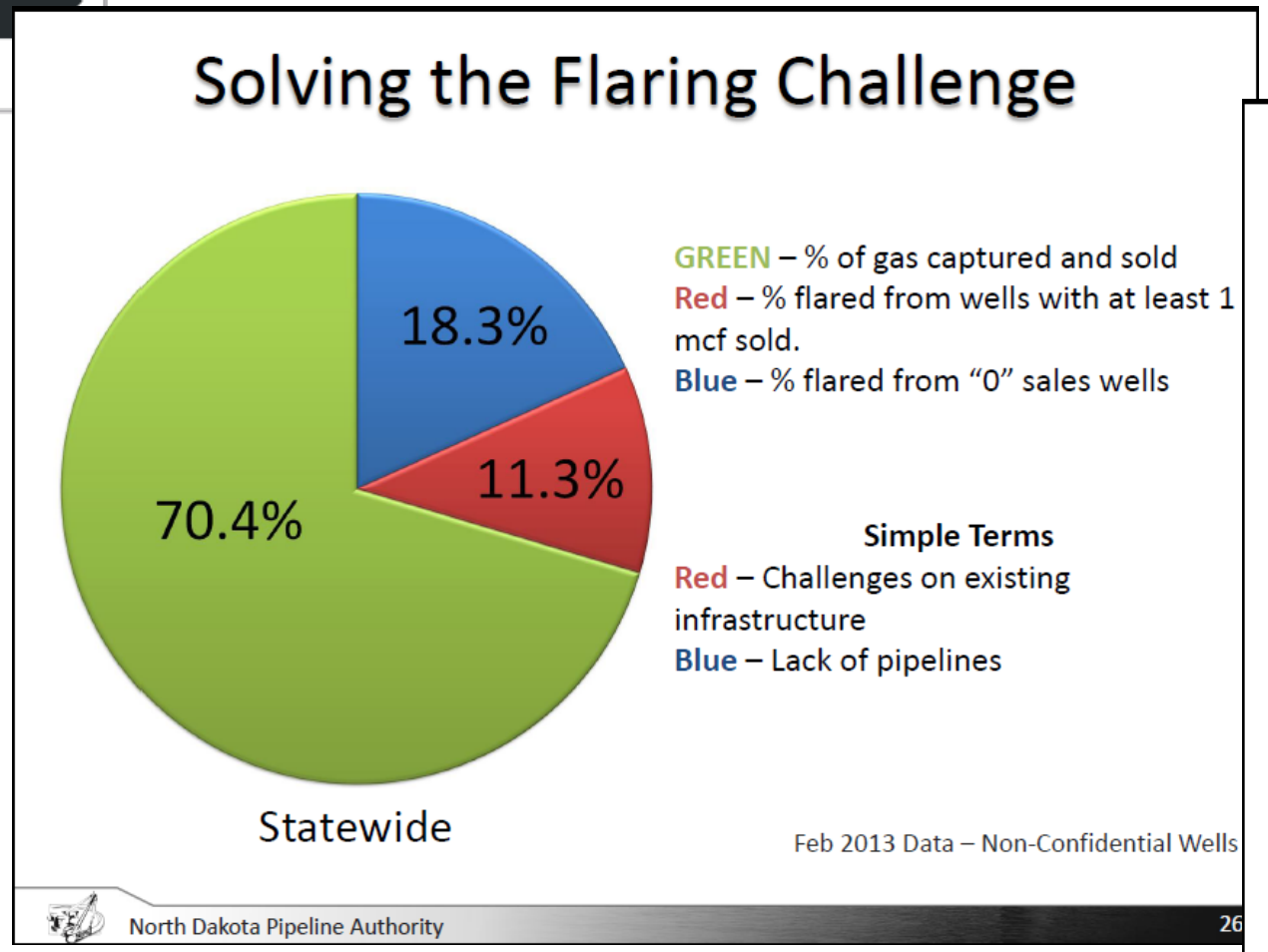


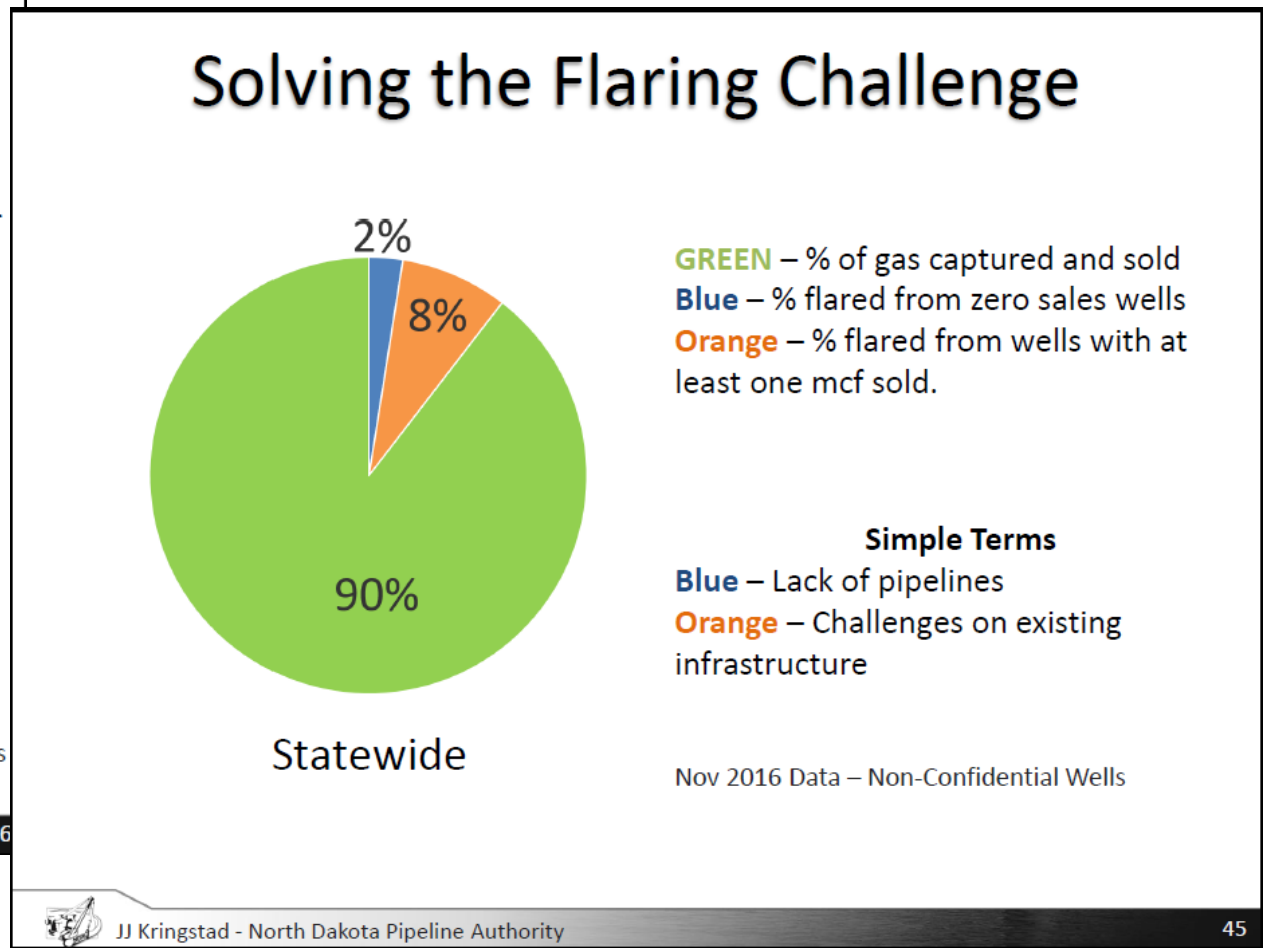
- Infrastructure investment through 2016
  - $13.6 billion
  - 1250 miles of pipe
- Number of gas plants is up 2.5 times
  - 8 plants in 2007 to 20 plants in 2015
- Gas-processing capacity is up over 7 times
  - 222 MMcfd in 2007 to 1599 MMcfd in 2015
- Producers, midstream operators and state worked together to accomplish flare reduction

Source: NDPC Flaring Task Force

Notes: Bcf/d = billion cubic feet per day
MMcfd = million cubic feet per day

February 2013 vs. November 2016

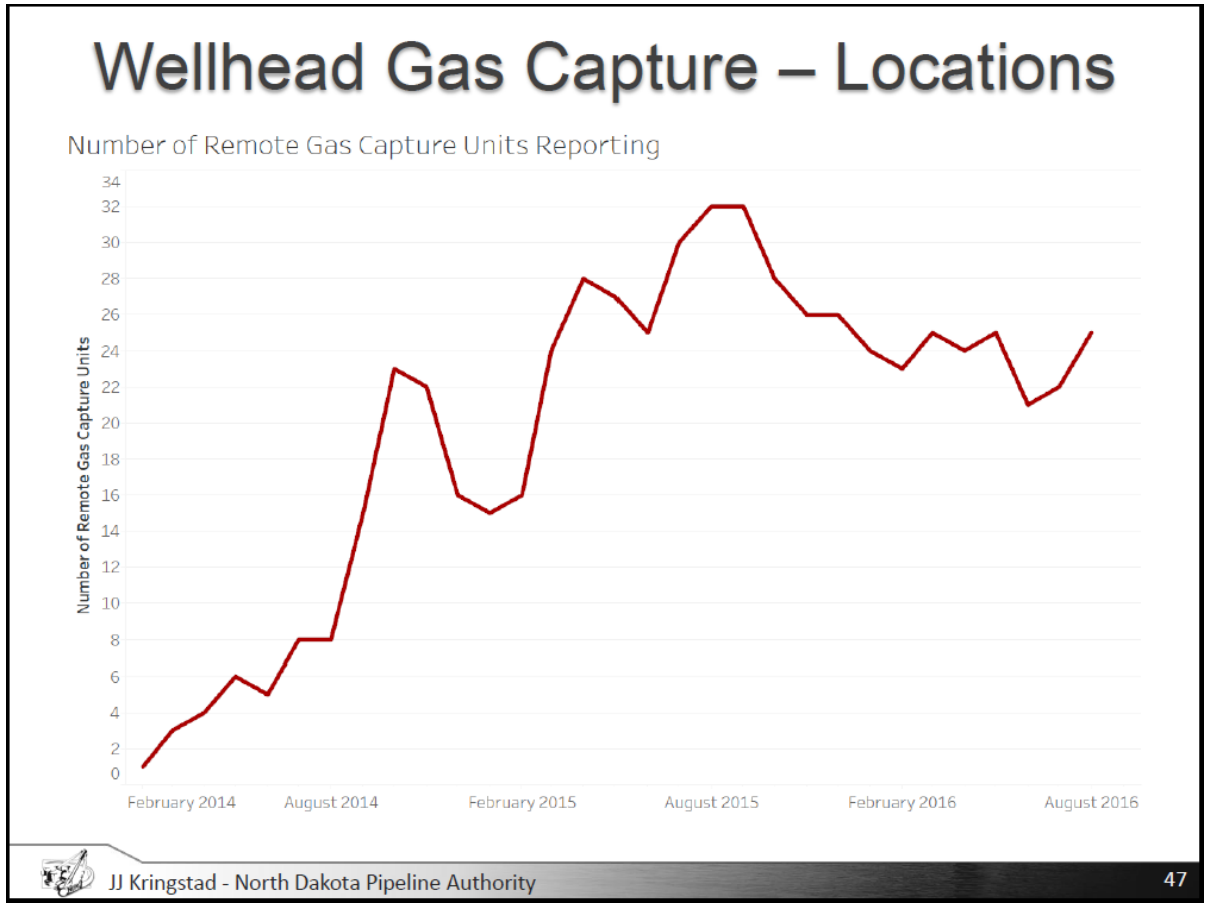




Slides courtesy North Dakota Pipeline Authority
https://northdakotapipelines.com/presentations/

Alternative to Gas-Gathering Infrastructure

- Where pipeline constraints prevent full gas capture, mobile gas use technologies have helped reduce flaring.
- Technologies:
  - Gas-fired generators providing site power
  - Portable gas-processing plants remove NGLs (propane, butane, pentane)
  - Gas compression and liquefaction (CNG, LNG)
- Currently 25 locations using remote capture technology.



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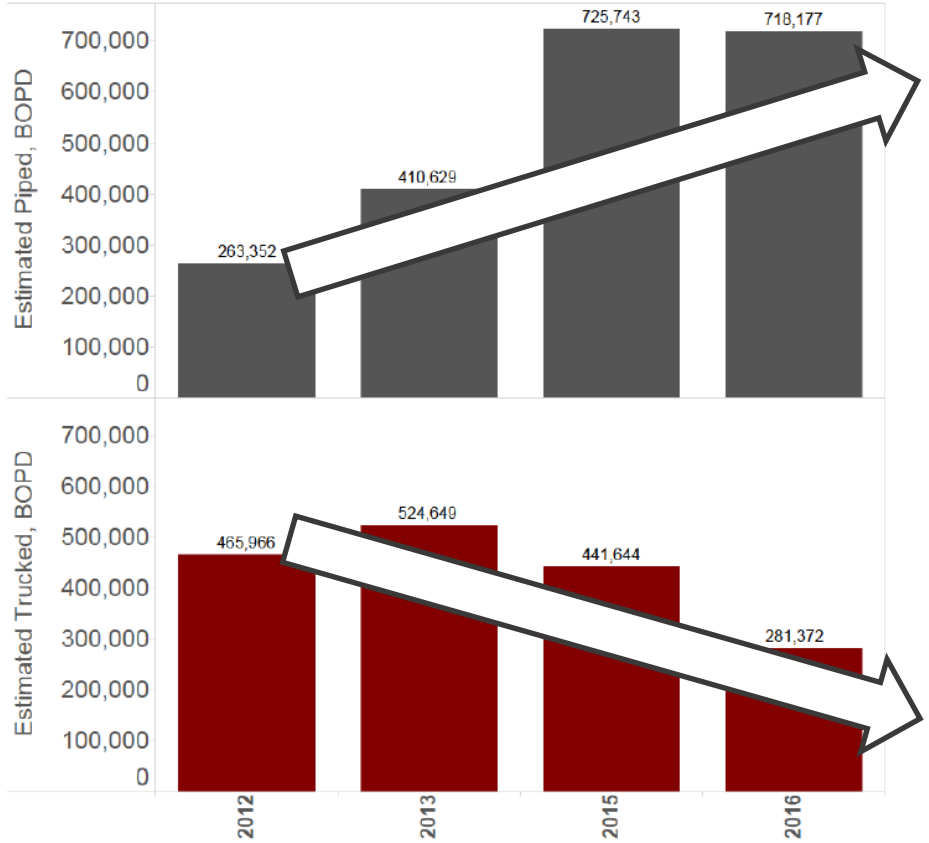
Liquids Gathering Pipelines

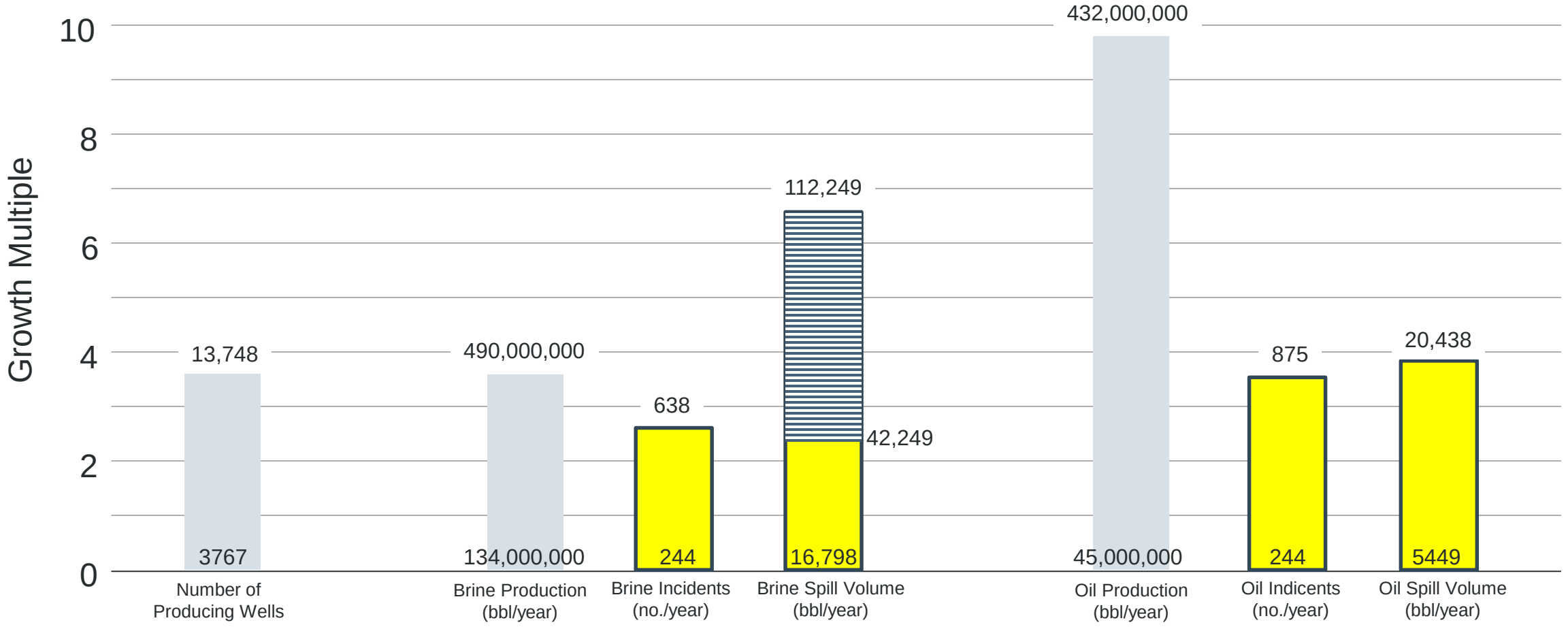


- Prior to 2016, gathering pipelines were largely unregulated
- In 2016, North Dakota studied the installation and operation of liquids gathering pipelines
  - Active engagement of pipeline operators, manufacturers, and regulators
- Today we have a robust set of regulations governing liquids gathering pipelines
  - Industry continues to investigate ways to improve pipeline operations

Slide courtesy North Dakota Pipeline Authority
https://northdakotapipelines.com/presentations/

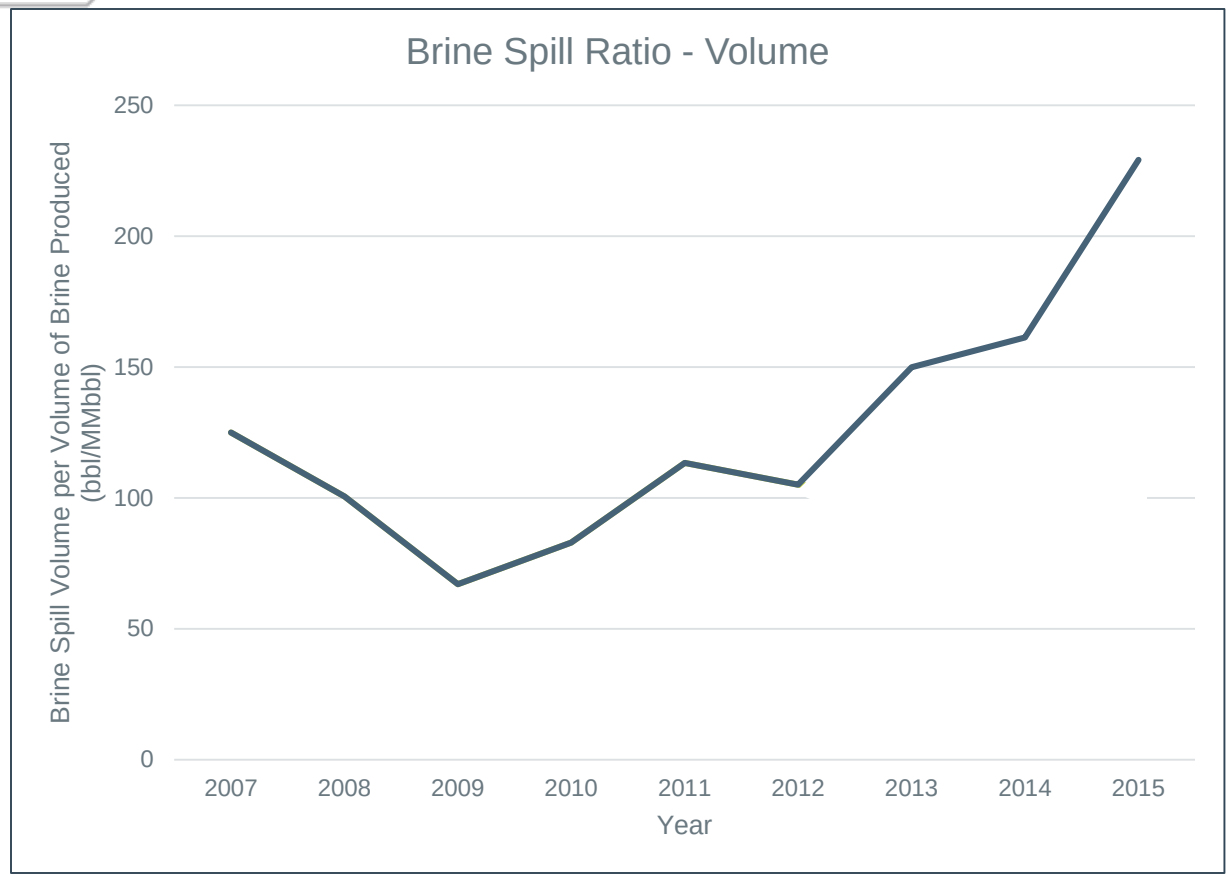
Notes: BOPD = barrels oil per day

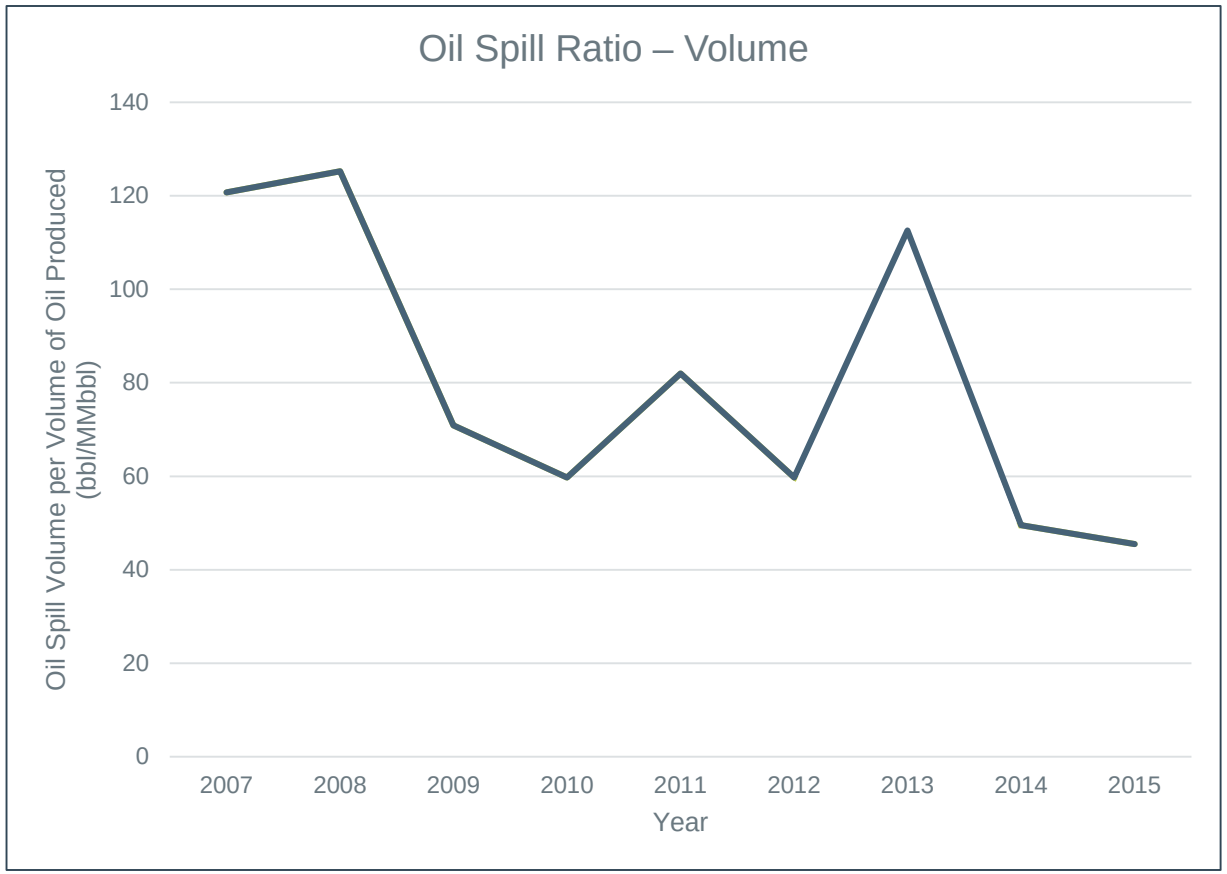
Spills Statistics (2007 vs. 2015)



Notes: bbl = barrel

Spills Analysis (2007–2015)





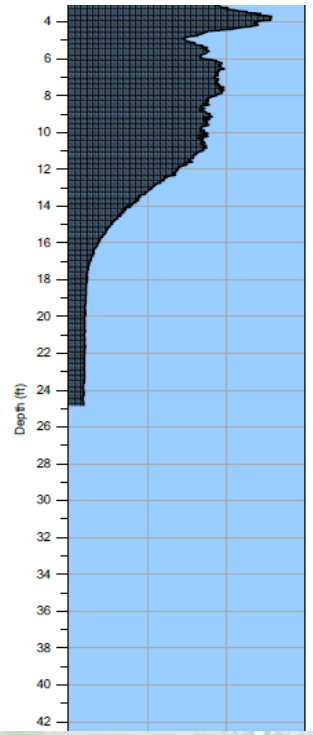
Notes: bbl = barrel
MMbbl = million barrels

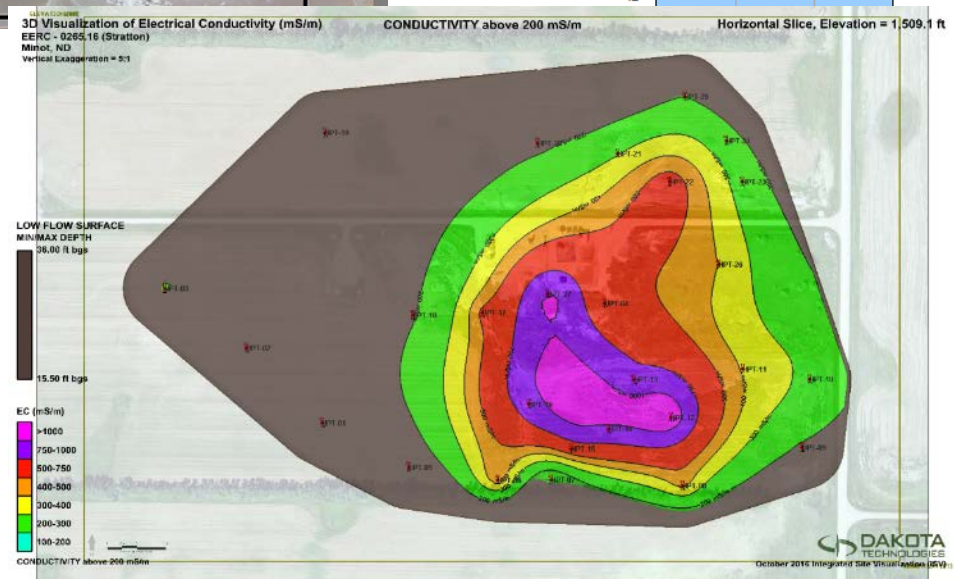
Spill Remediation Innovations

- Increased attention to pipeline construction, pipeline monitoring, and operations to reduce the occurrence and severity of leaks and spills.
- Use of novel techniques and tools to remediate oil and brine releases:
  - Electrokinetics
  - Crystallization inhibitors
  - Real-time EC measurement

Source: Aaron Daigh - NDSU

Source: Dustin Anderson





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