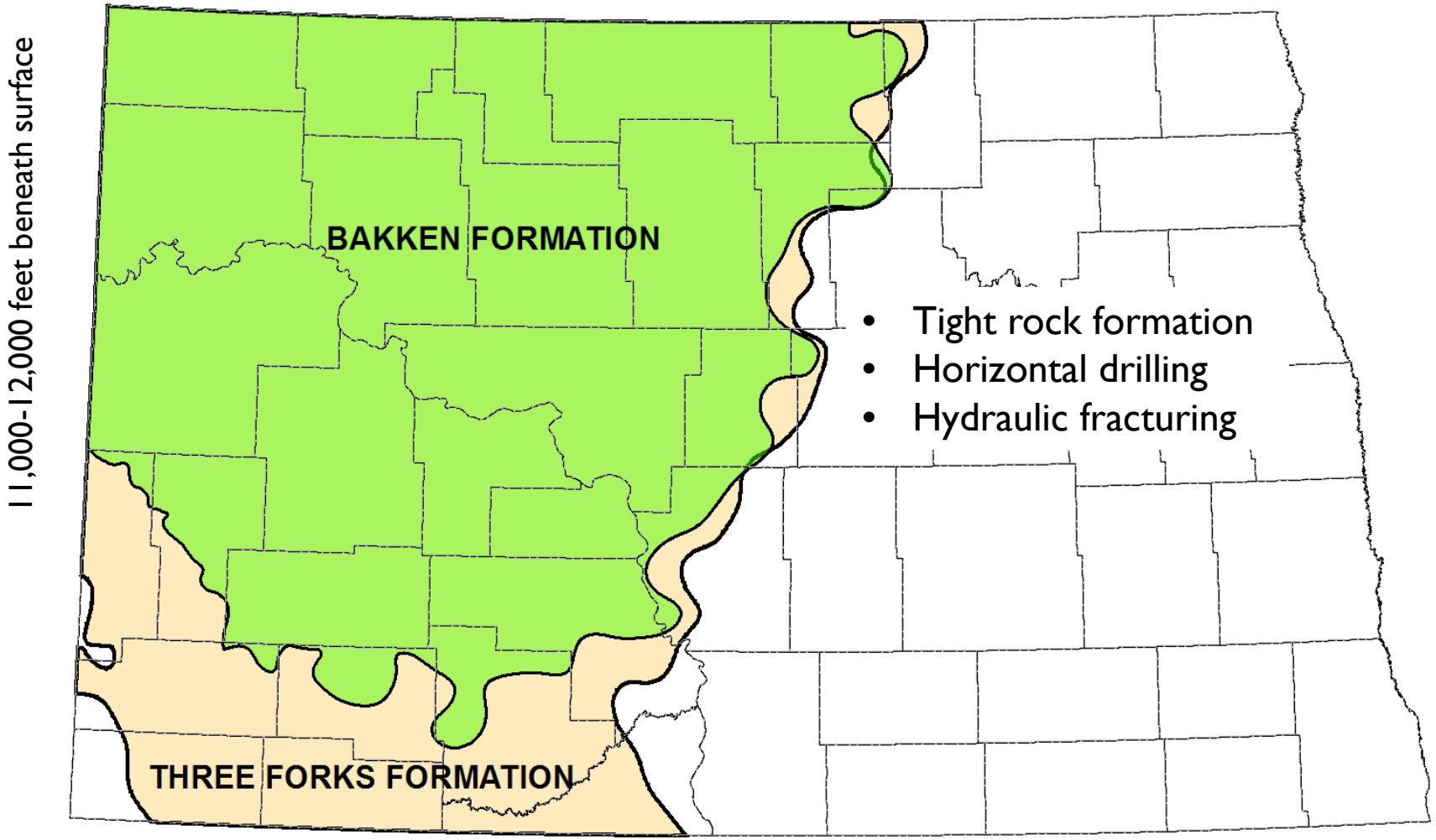
NDSU UPPER GREAT PLAINS TRANSPORTATION INSTITUTE

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

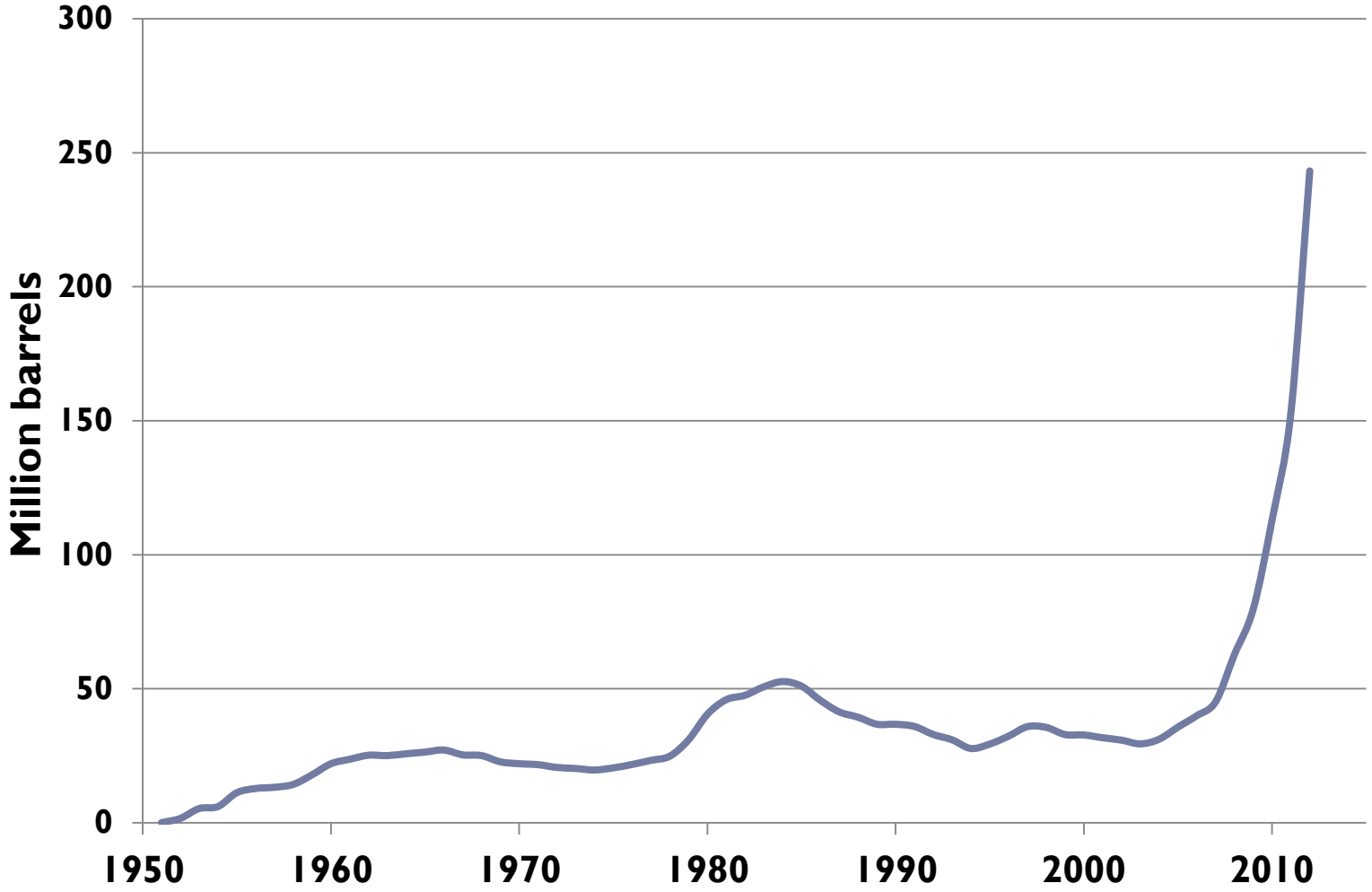
93nd Annual Meeting of
the Transportation Research Board

Denver Tolliver

Shale Oil Formations in North Dakota

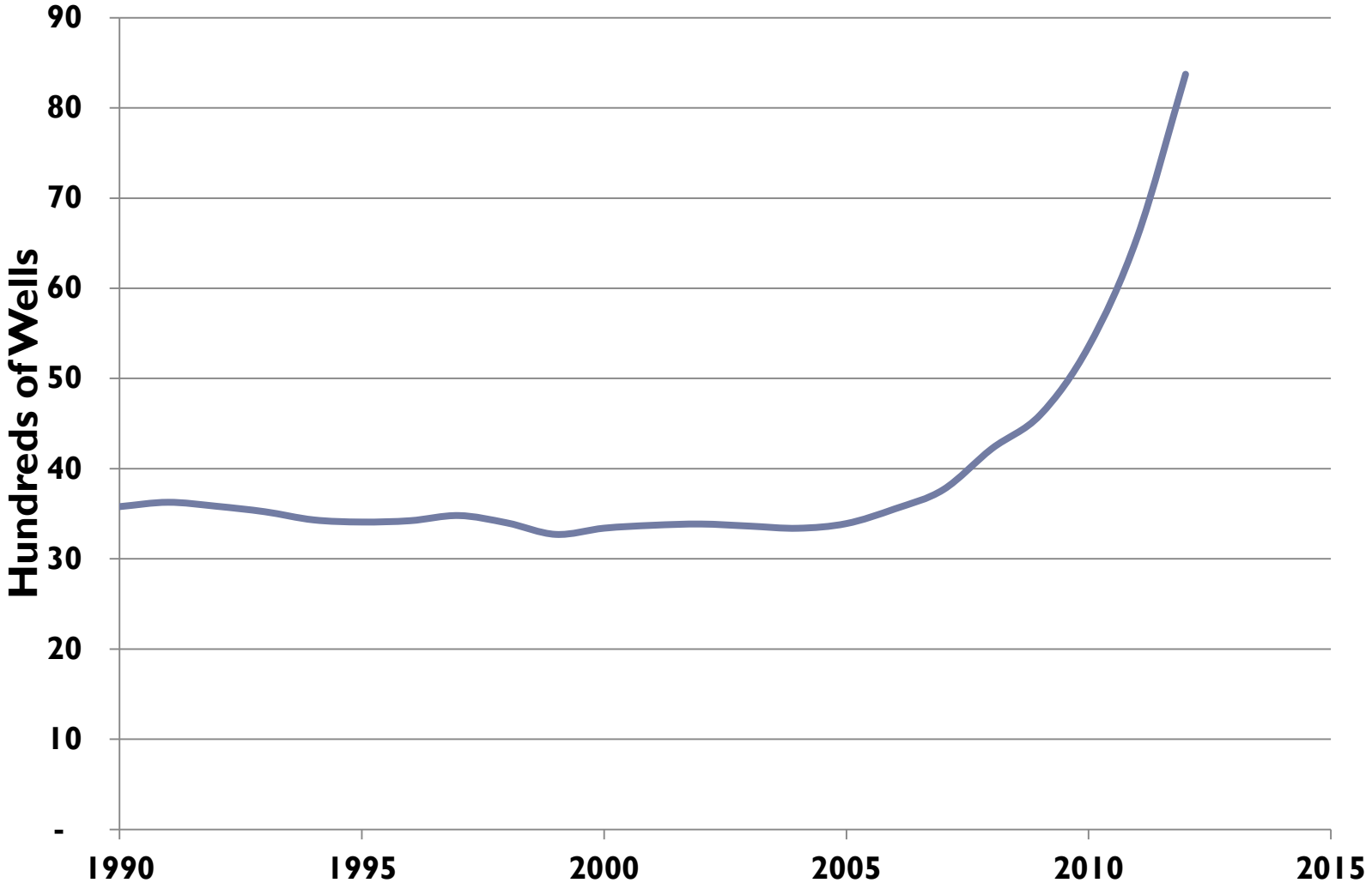


Annual Oil Production: North Dakota

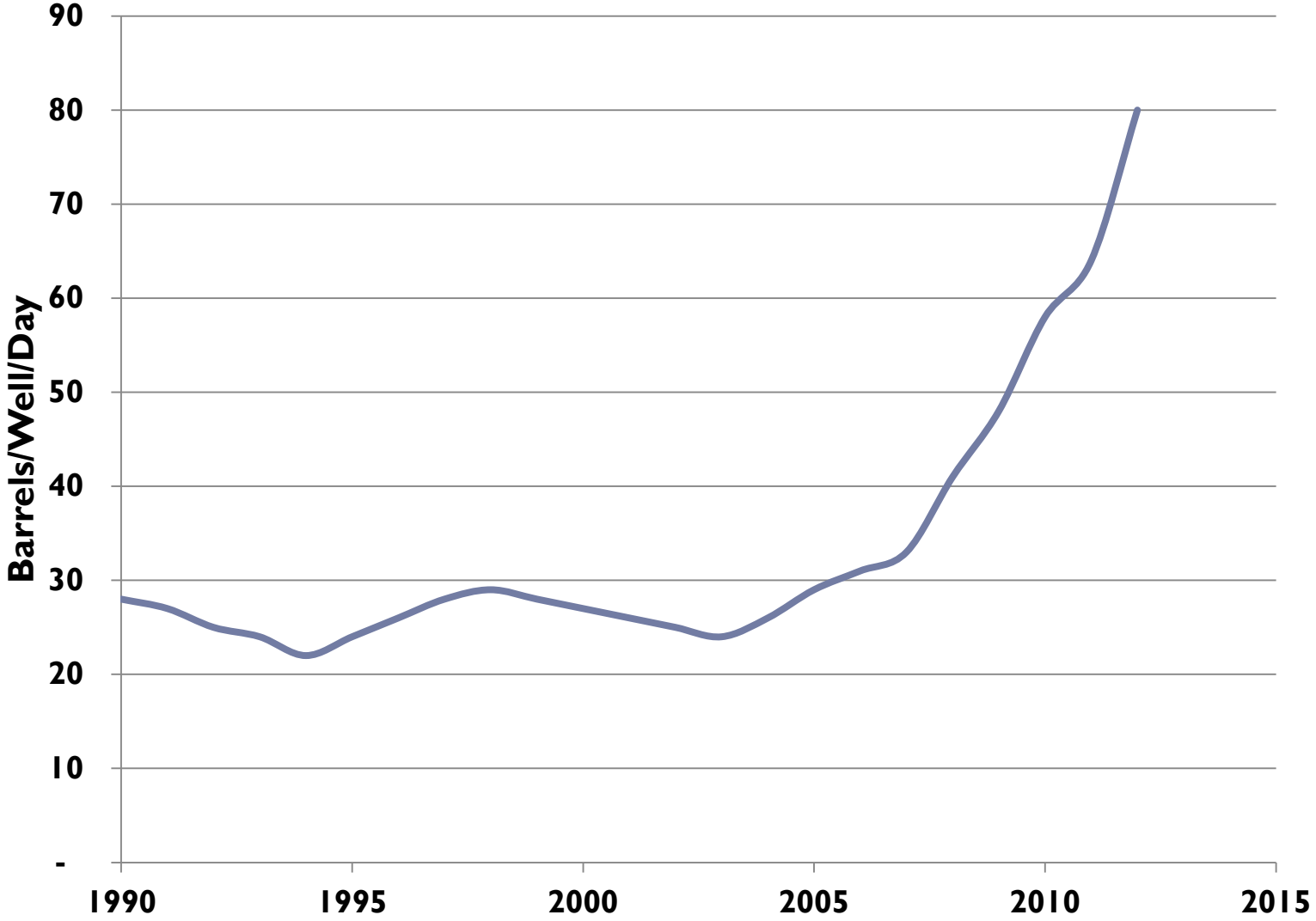


- *North Dakota second leading state in oil production*

Number of Oil Wells: North Dakota



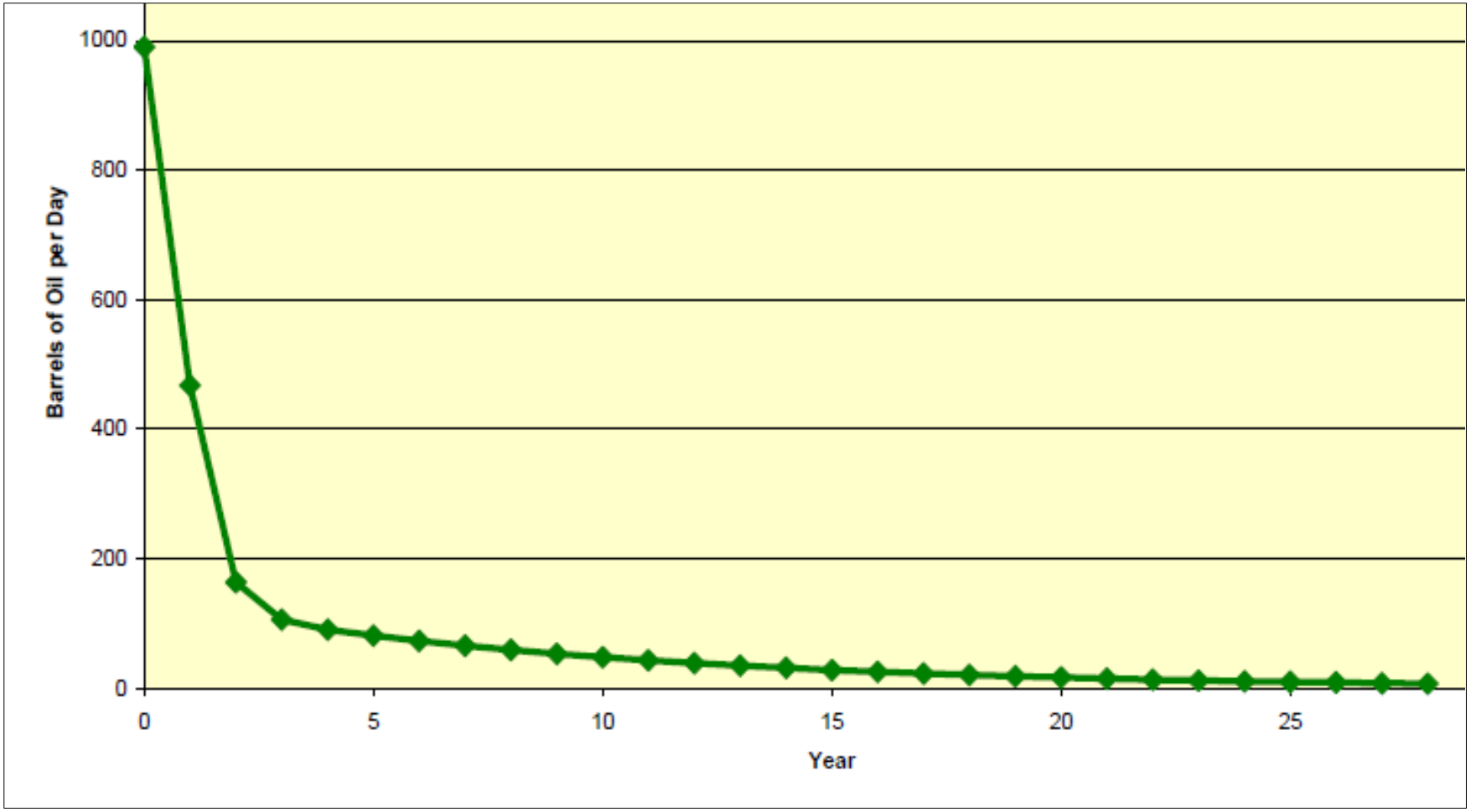
Daily Output per Well: North Dakota



Oil Production Specifics

- ND oil production (fall/2013): 930,000 barrels/day
  - 93% Bakken/Three Forks wells; 7% legacy conventional pools
- Producing wells ≈ 9,800 (60% Bakken/Three Forks)
- Bakken output per well: 140 barrels/day
- Average Initial Production up to 1,700 barrels/day with sharp decline following, statewide average 1,200
- 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
- Daily production may exceed 1.5 million barrels

Bakken Well Production Curve



North Dakota Industrial Commission, Oil and Gas Division, 2012 (Figure 10: *Typical Bakken Well Production Curve*)

Materials and Product Flows

- Inputs to well site for hydraulic fracturing and production
- Specialized equipment to and from well site
- Roughly 2,300 drilling-related truck trips per well
- Outbound crude oil
  - By truck to pipeline or rail transfer location
  - By small diameter pipeline to trunk line 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

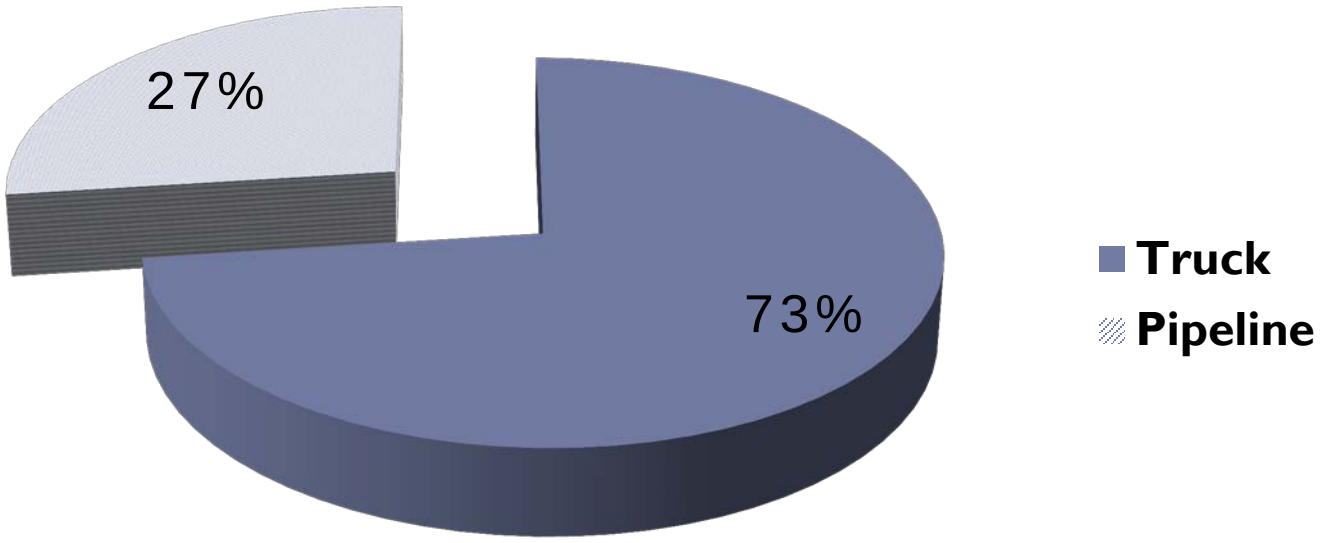
Input or Product	Loaded Trucks
Water (Fresh)	450
Water (Waste)	225
Frac Tanks	115
Sand	100
Scoria/Gravel	80
Rig Equipment	65
Drilling Mud	50
Cement	20
Pipe	15
Other	30

1,150 Loaded Trucks

2,300 Loaded & Empty Trucks

Current Mode Share Crude Oil:
Gathering Movement

Movements from Wells to Transfer Locations



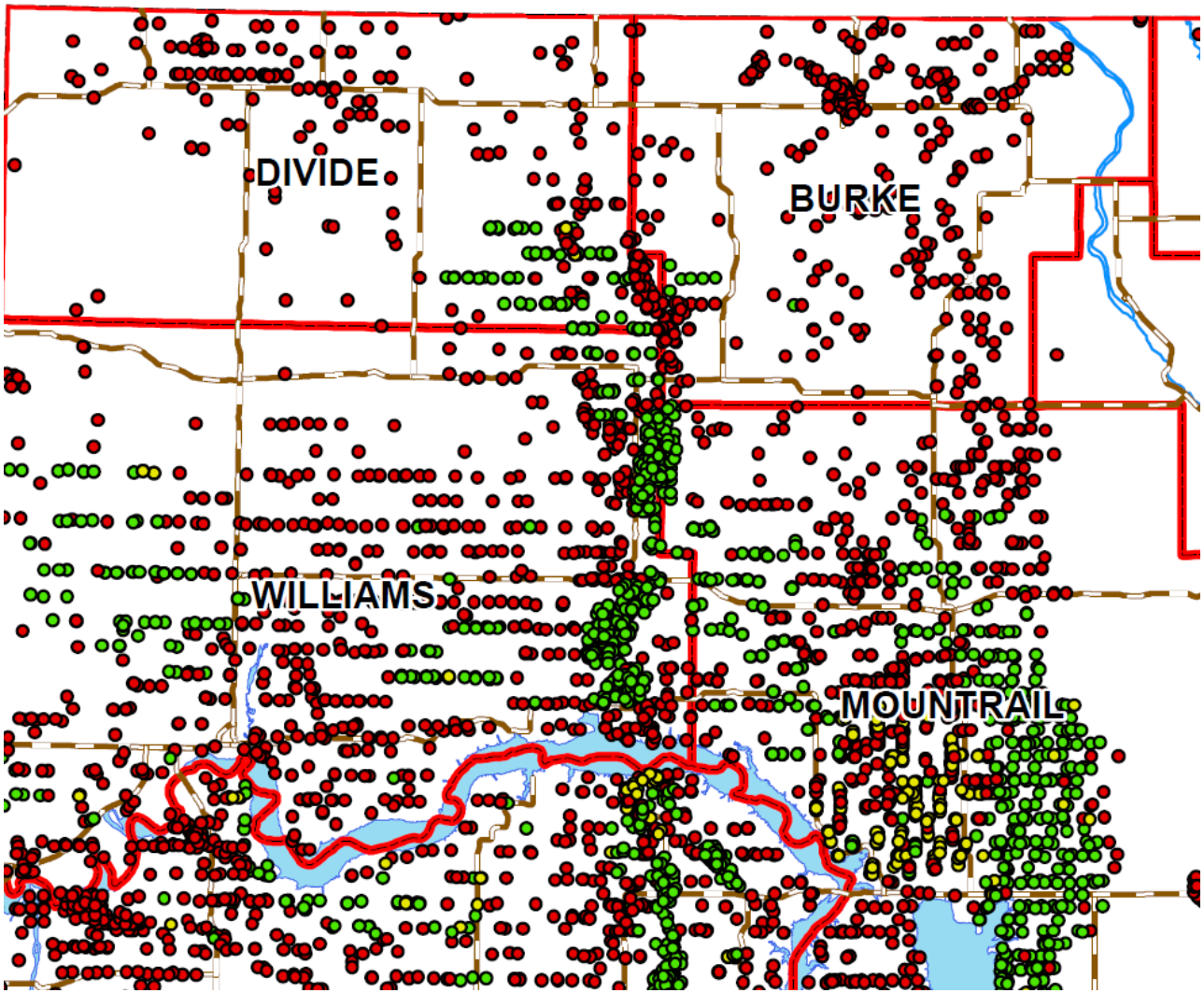
Pipeline Network in North Dakota

Category	*Miles*
Oil gathering pipeline	10,800
Crude oil (transmission) pipeline	3,100
Oil product pipeline	1,070
All oil pipelines	14,970

Estimates from North Dakota Pipeline Authority. No historical requirement for reporting of gathering pipelines. Thus, gathering pipeline miles estimated from multiple sources.

ND Gathering Oil Transportation Network:

Northern Bakken Region



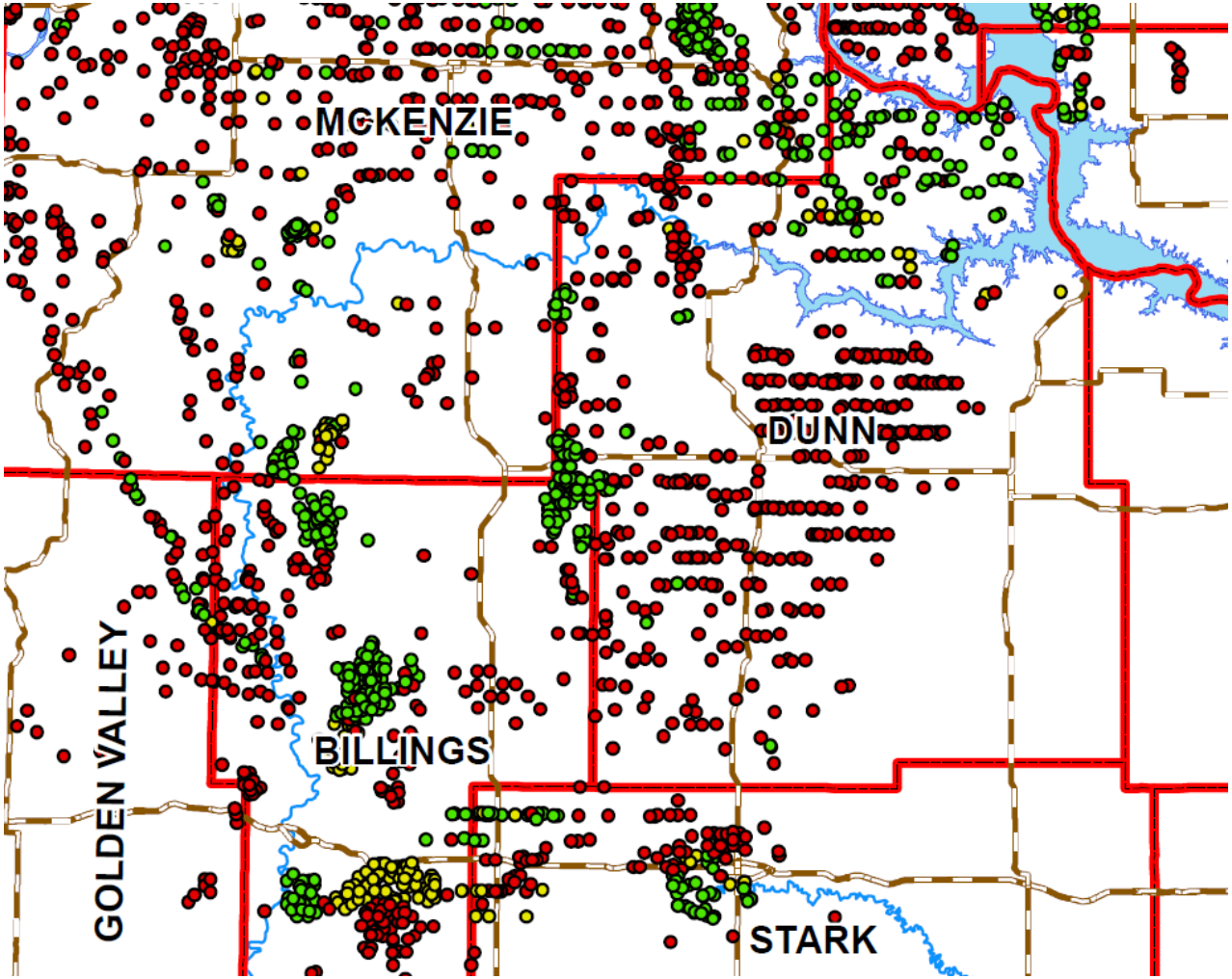
Truck
Pipeline
Both

Note: mature area (green dots) in center

Parshall gathering pipeline network

ND Gathering Oil Transportation Network:

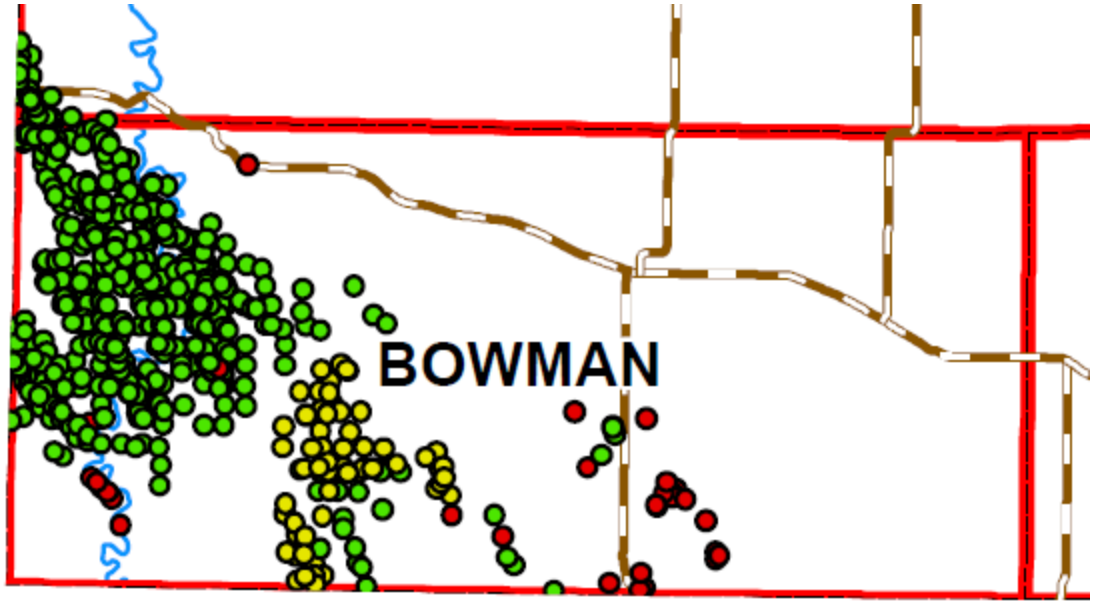
Southern Bakken Region



Truck
Pipeline
Both

ND Gathering Oil Transportation Network:
Pre-Bakken Legacy Pool

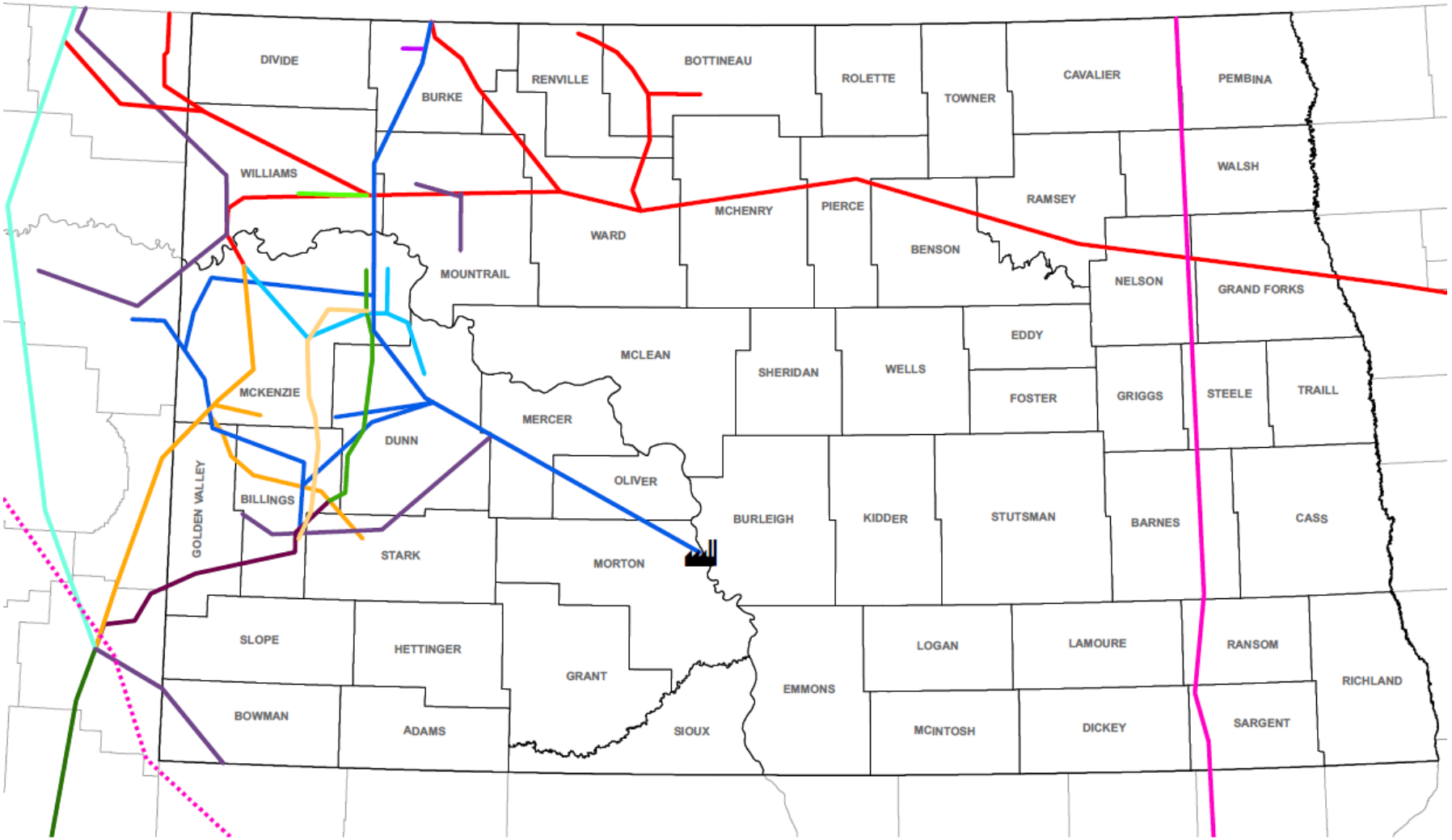
- Mature producing region developed in 1970s
- Most wells have gathering pipeline access
- Compare to recent Bakken development, where trucking dominates



Gathering Mode Distribution Over Time

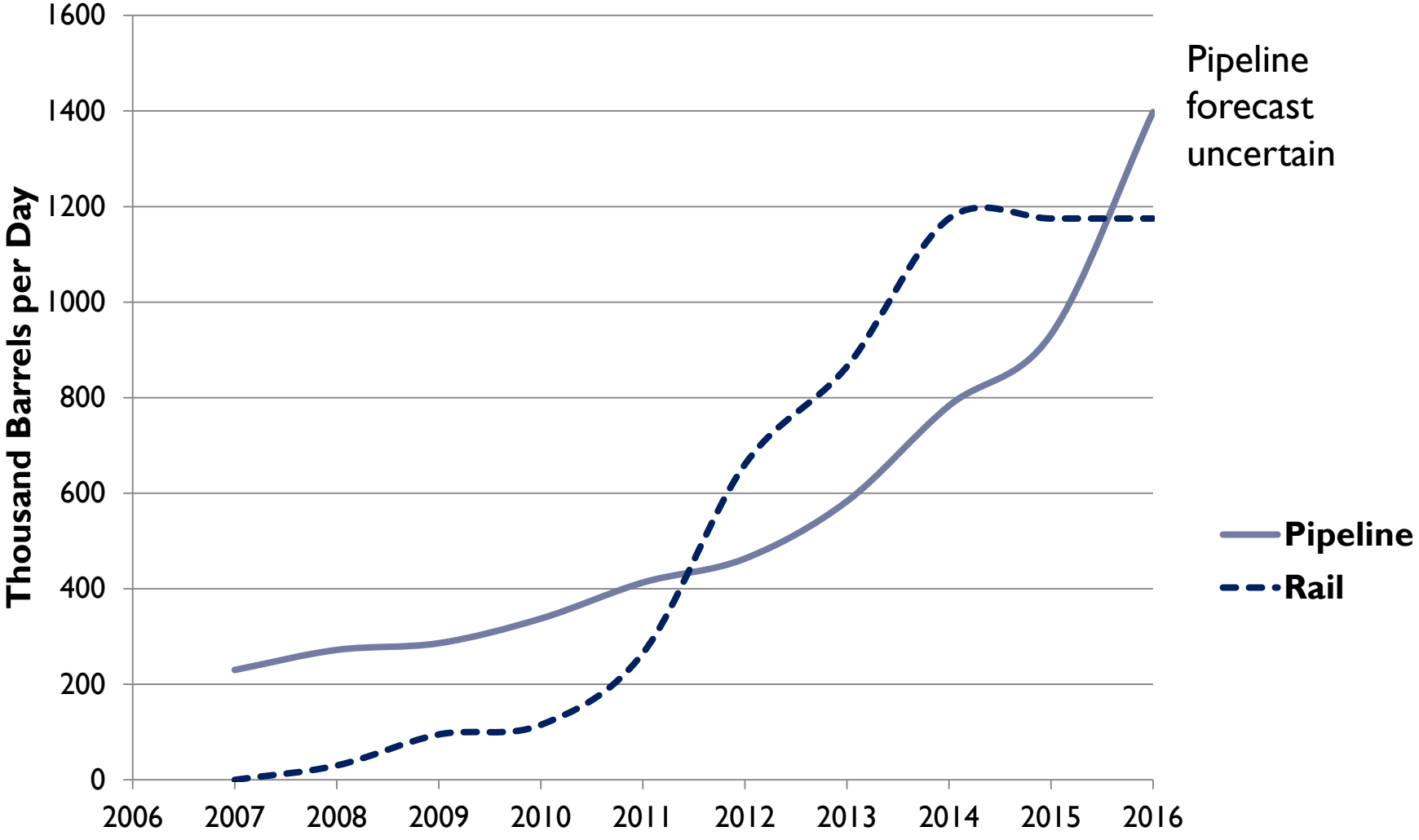
- Initially, all crude oil is transported by truck to rail or pipeline transfer locations
- When more wells are added to a spacing unit, small diameter gathering pipeline may be built to trunk pipeline network
- Projected distribution: ≥ two-thirds of crude oil outbound by gathering pipeline in mature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

ND Crude Oil Pipelines



North Dakota Pipeline Authority – Feb., 2013

System Capacities (Input not Throughput)



North Dakota Pipeline Authority

Crude Oil Mode Shares: Line Haul

- Current: 69% rail
- Near-term projection: 90% rail
- Reasons for rail dominance
  - Limited pipeline capacity (sized to historical production)
  - Challenges/length of time in siting and constructing new pipelines
  - Greater ease in capacity expansion of railroads
  - Lower cost of rail expansion
  - Rail access to a wider variety of markets → premium prices

Rail Movement Specifics

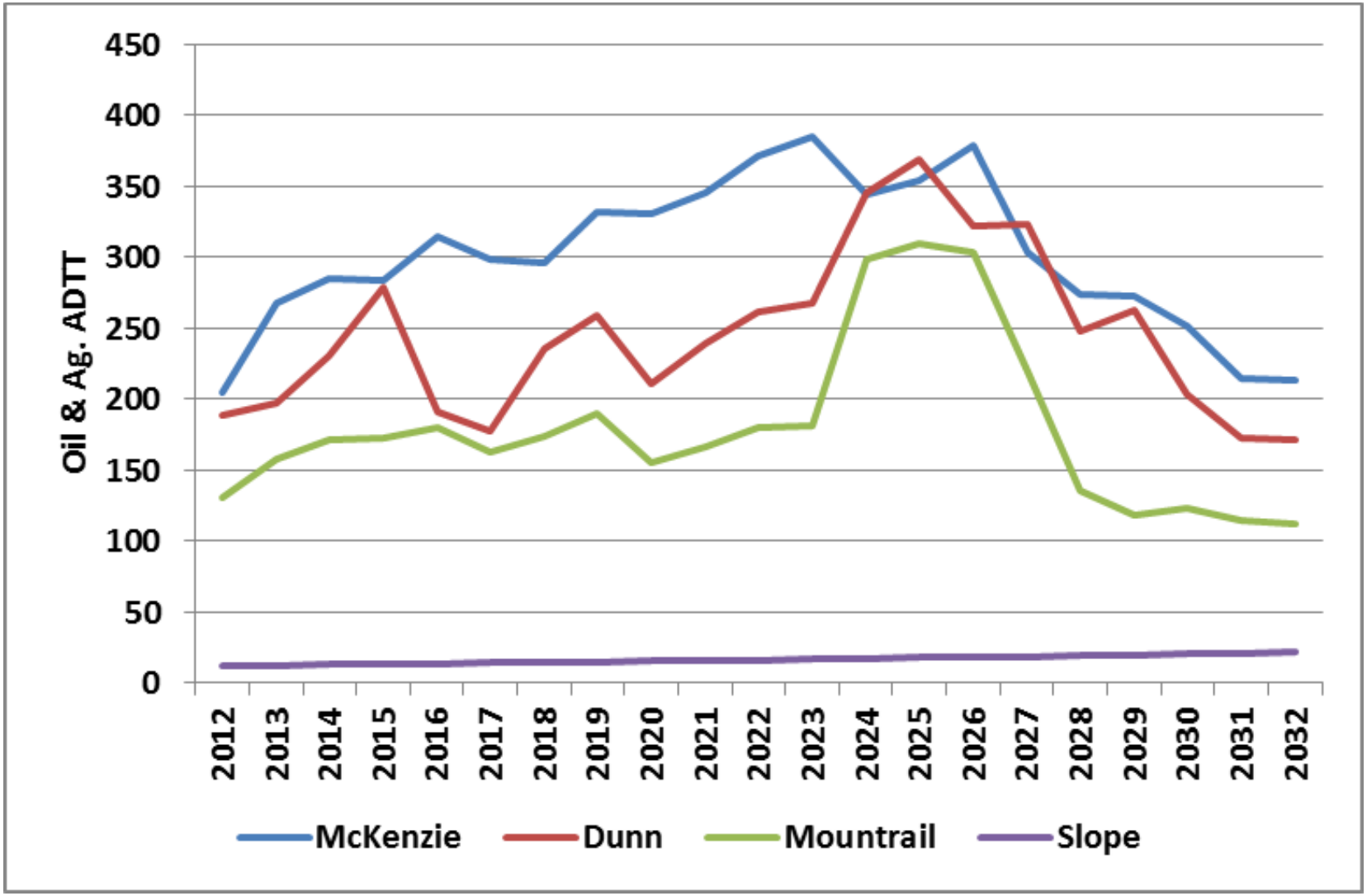
- Shipments in multicar units or trainloads (e.g., 100+ cars)
- Current share in ND ≈ 1,000 railcars per day
- Equivalent to 10 100-car trains/day
- If railroads maintain 70%+ share, could have 16-20 trainloads per day of crude oil at peak
- *Questions/potential issues*

- Line capacity: other goods
- Transload capacity
- Service levels and priorities
- Classification/placarding
- Tankcar standards
- Accident exposure (train-miles)
- Grade crossings
- Risk assessment/routing

Road System Impacts

- All jurisdictions impacted, including county, township, and tribal roads
- Studies for ND legislature
  - Detailed forecasts of traffic to/from individual spacing units
  - Truck traffic estimated annually for next 20 years
  - Models calibrated against observed traffic data for base year
  - Estimated truck ADT converted to equivalent single axle loads
  - Paved road condition forecasted year-by-year
  - Improvements identified: reconstruction, widening, resurfacing
  - Unpaved roads analysis based on increasing frequencies of blading and graveling, increased gravel costs
  - Higher routine maintenance for both paved and unpaved roads

Projected Truck ADT for Three Heavily Impacted Counties (with Control Case)



Damage to ND Highway 68 Resulting from Oil-Related Traffic

NDDOT. *Impact of Oil Development on State Highways*, May, 2006.

US 2 Near Ray, ND

- Design Life – 20 years
  - 900,000 ESALS
- Currently over 1,100,00
  - Pavement age = 9 years
  - Life ESALS=14,000,000

ND 1806 in McKenzie County, ND

ND Highway 1806 on September 2, 2010

NDDOT
North Dakota
Department of Transportation

ND Highway 1806 on April 28, 2011 - After 7 months of traffic

Roads in North Dakota

- Large-scale investment program
  - $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
  - Two-lane capacity
  - 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