

Understanding the Middle Bakken*

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Abstract

Since the initial Bakken discovery well in 1957, over 8000 Bakken and 1600 Three Forks wells have been drilled across North Dakota, Montana, and Saskatchewan. Over the past decade we have seen a rapid uptick in the geologic understanding of the Bakken and Three Forks, coupled with increasingly effective, and efficient, customization of drilling and completions. We illustrate how the emergence of geologic data coverage has driven industry understanding of play nuances. Regional structural, thickness, and geochemistry maps highlight early play characterization and identification of the eastern "line of death" and unique characteristics of the Sanish and Parshall fields. Lithofacies classification of vertical well log suites illustrate the insights gained from delineation wells that framed interpretation of the complex play stratigraphy. More recently, sufficient well coverage has emerged to consistently map oil saturation/water cut across the basin; supported by more detailed depth and character mapping using the extensive gamma-ray coverage. Keeping pace with burgeoning geologic understanding, well completion techniques have been tested and tuned - from single to 40 and 50 stages - with sand volumes ranging well above 10 million pounds and accompanying fluids beyond 150,000 barrels. Currently, multi-lateral co-development of Bakken and two-to-four Three Forks formations are becoming standard operating procedure. "Frac hits" have emerged as the key development optimization focus as well spacings approach 500 feet in common formations and 250 feet in staggered multi-level patterns. While overlapping zones of stimulation can have beneficial effects, delayed infills are proving to be very problematic with unclear economic tradeoffs of increased, though contested well production, often offset with dramatic production decline in adjacent, active wells. Oilfield analytics provide a unique perspective of the ongoing efforts to "right size" drilling and completions engineering for rock and fluid characteristics in the Bakken and Three Forks reservoirs. Dynamic well spacing,

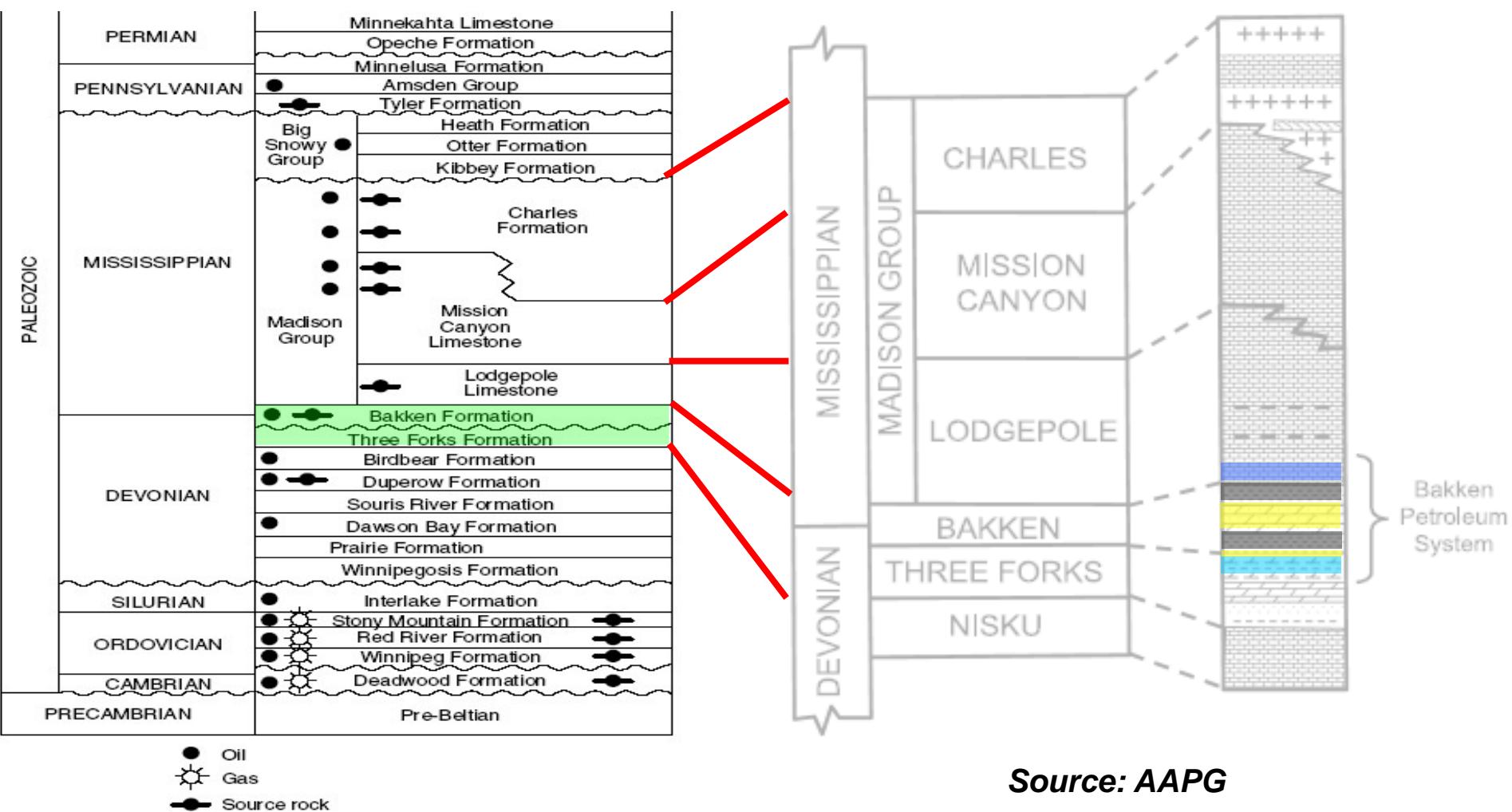
vertical and lateral geometry, drilling and completions parameters, and geologic character can all be quantified; providing a common basis for using analytic techniques to predict well performance. The results of these analyses are improved understanding of geologic prospectivity, independent of engineering, as well as indications of optimized engineering techniques for different geologic scenarios.

UNDERSTANDING THE MIDDLE BAKKEN

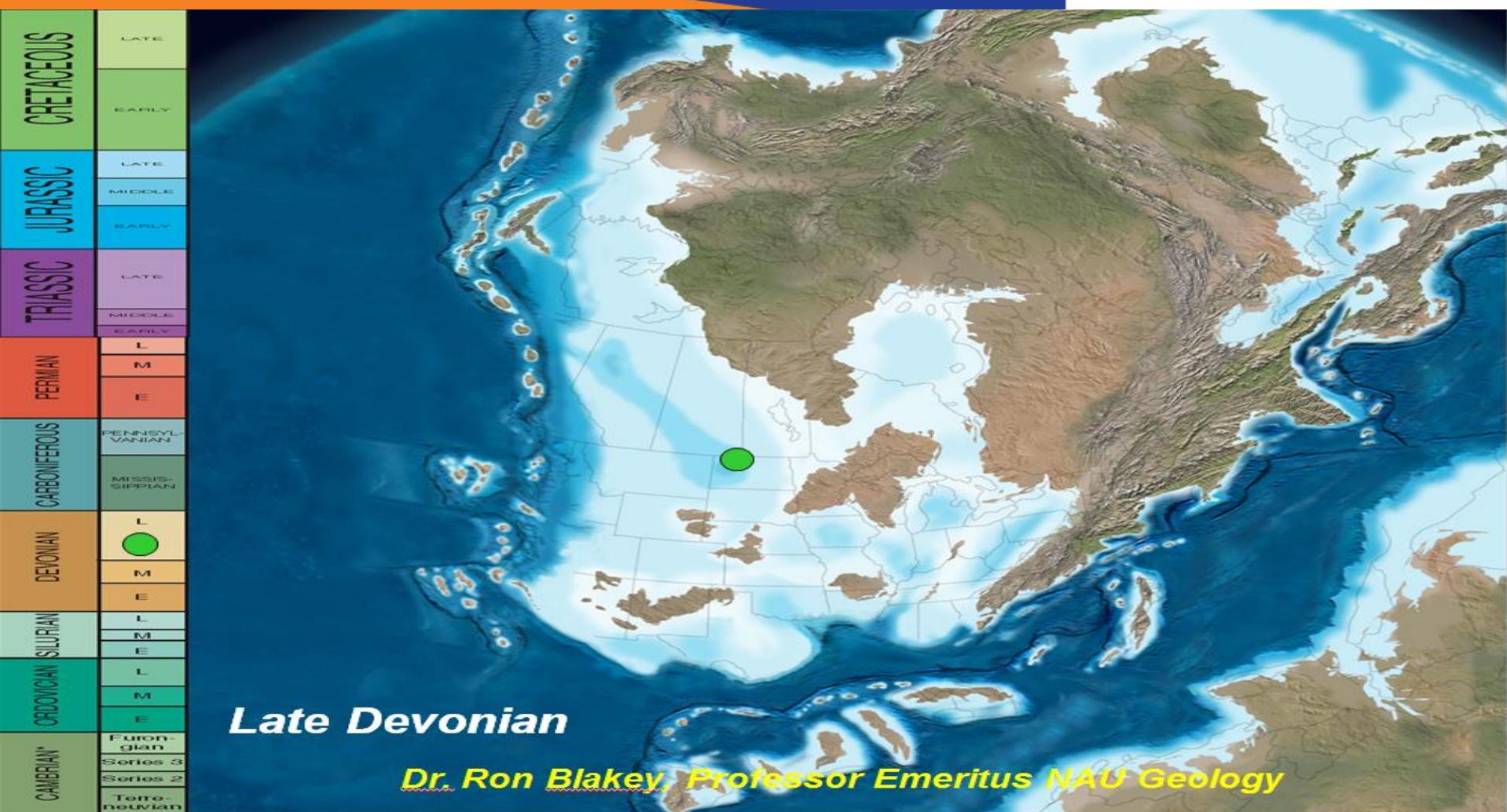


GROUND TRUTH

Bakken/Three Forks Stratigraphy



Paleo – Bakken/Three Forks

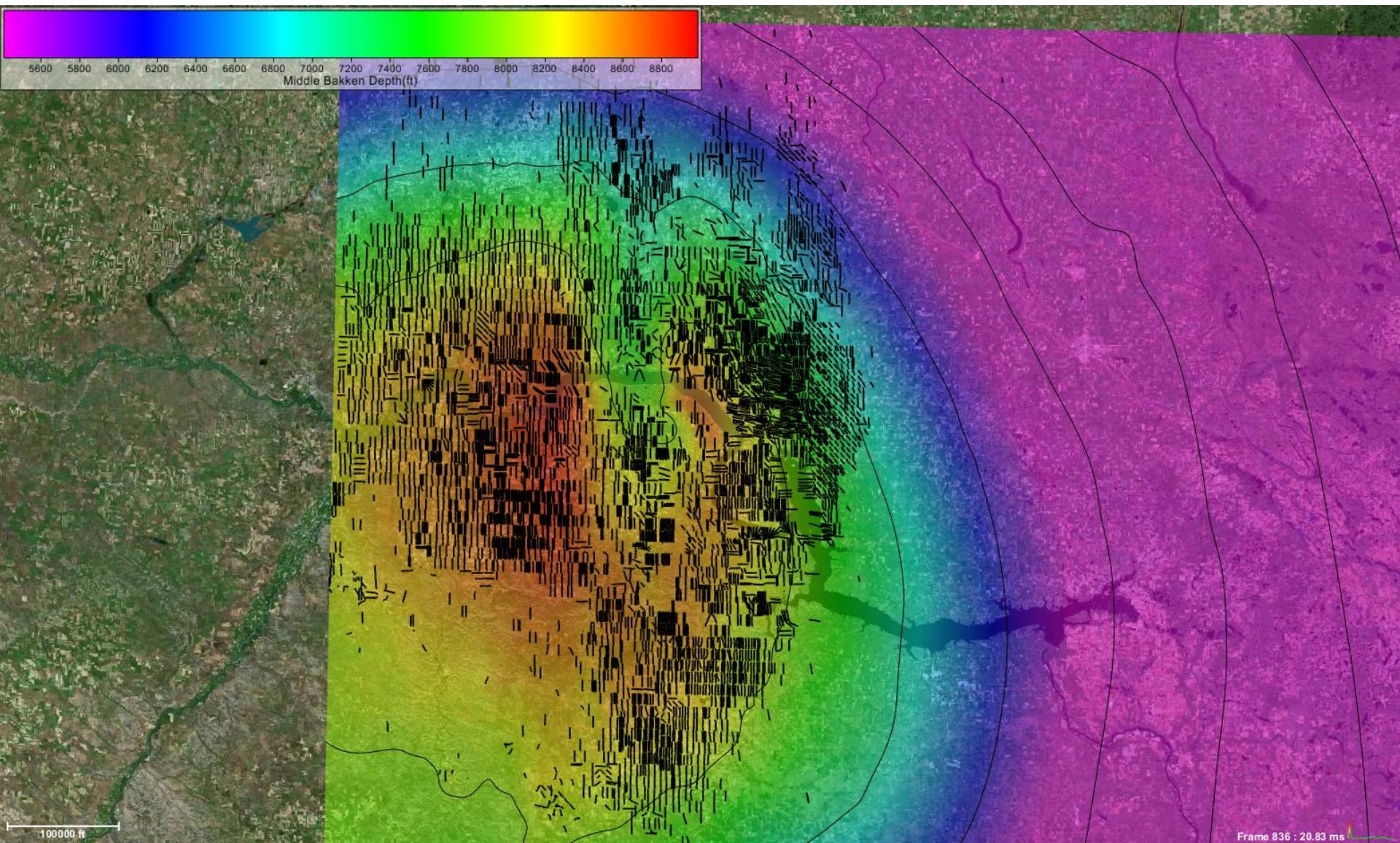


Study Objectives

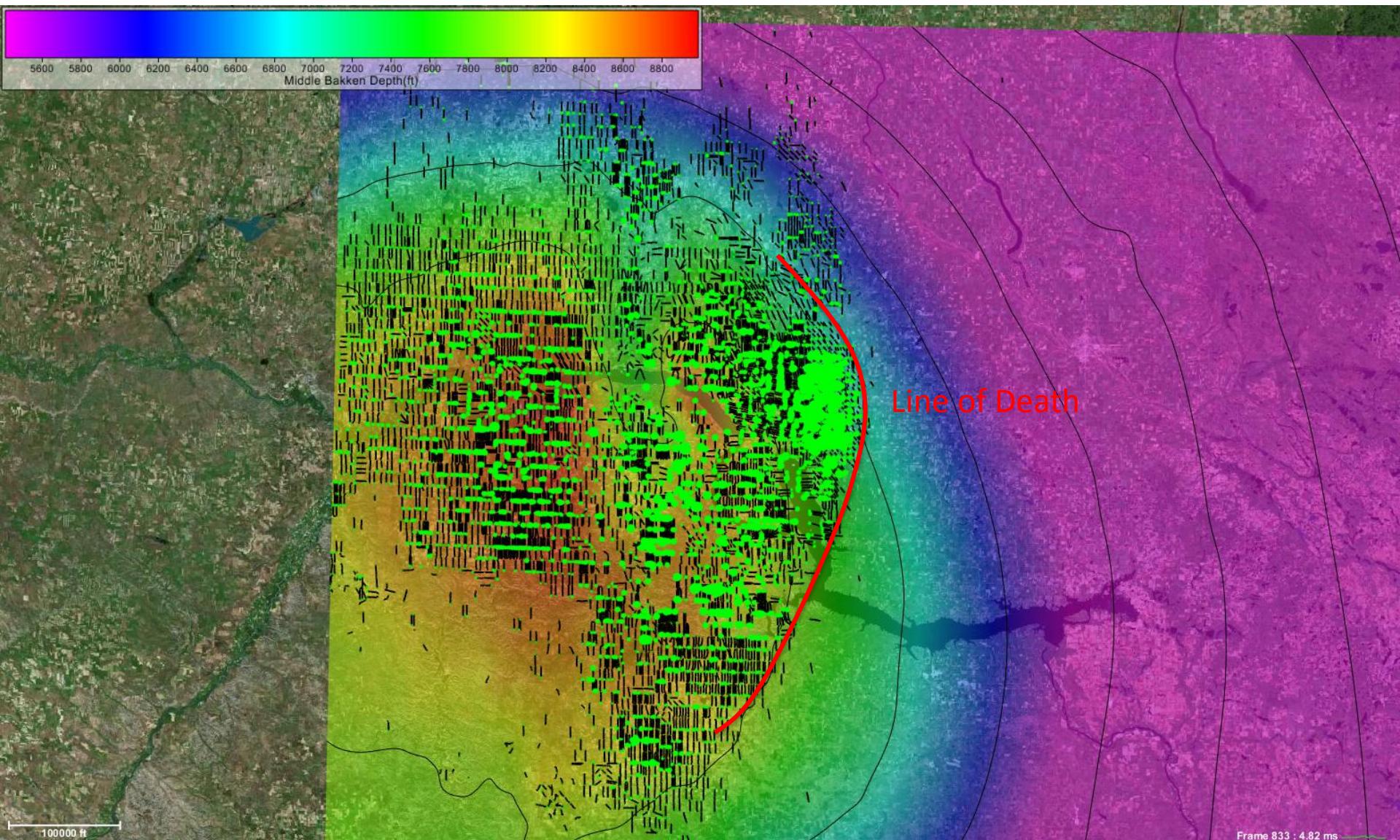


- Identify key geologic drivers of Middle Bakken production and the degree to which they impact performance
 - Depth
 - Thickness
 - Thermal Maturity
 - TMAX
 - Water Cut
- Benchmark engineering impact on performance for variable geology

Middle Bakken Depth vs. 3 Month Oil/ft

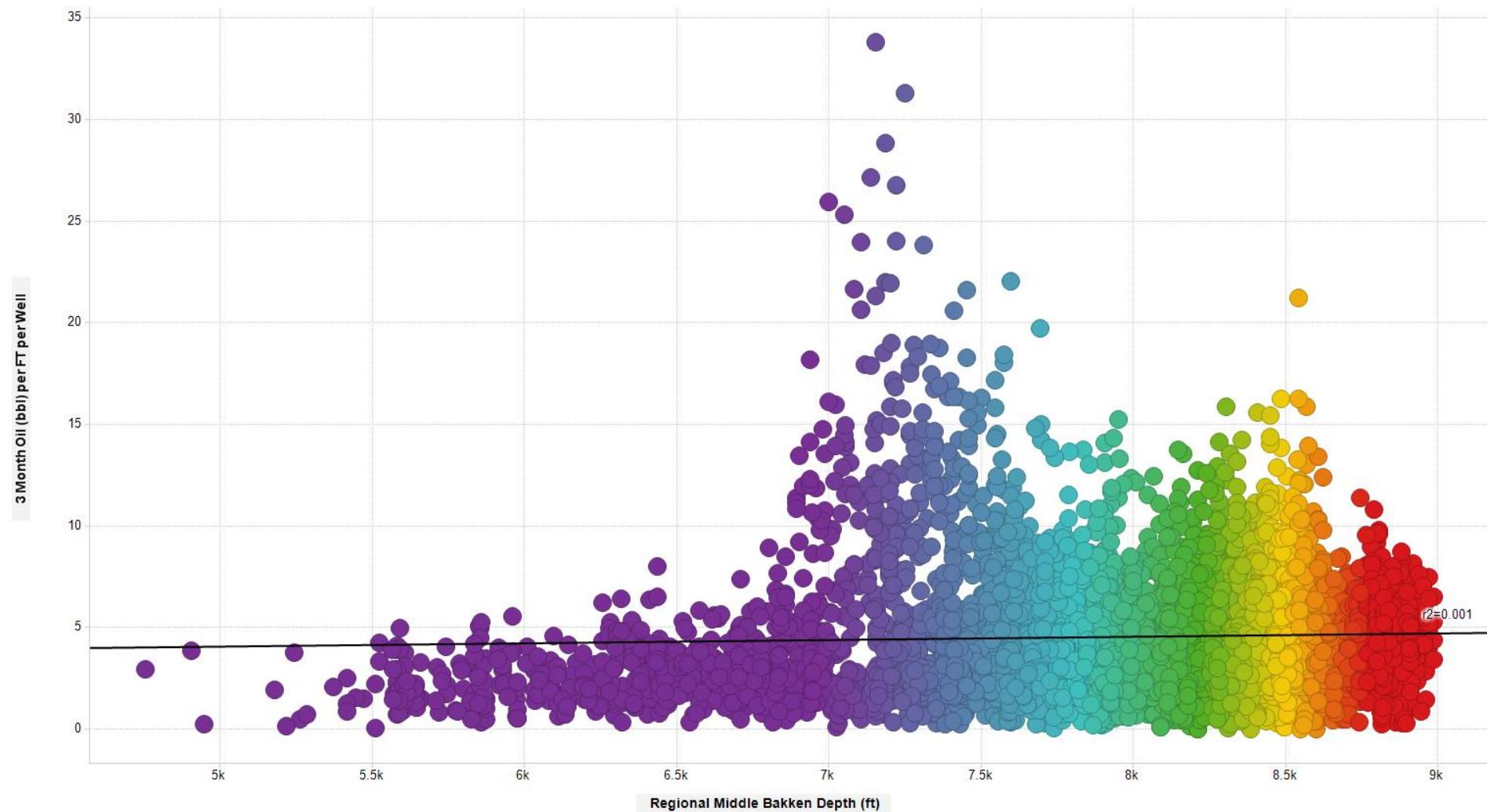


Middle Bakken Depth vs. 3 Month Oil/ft



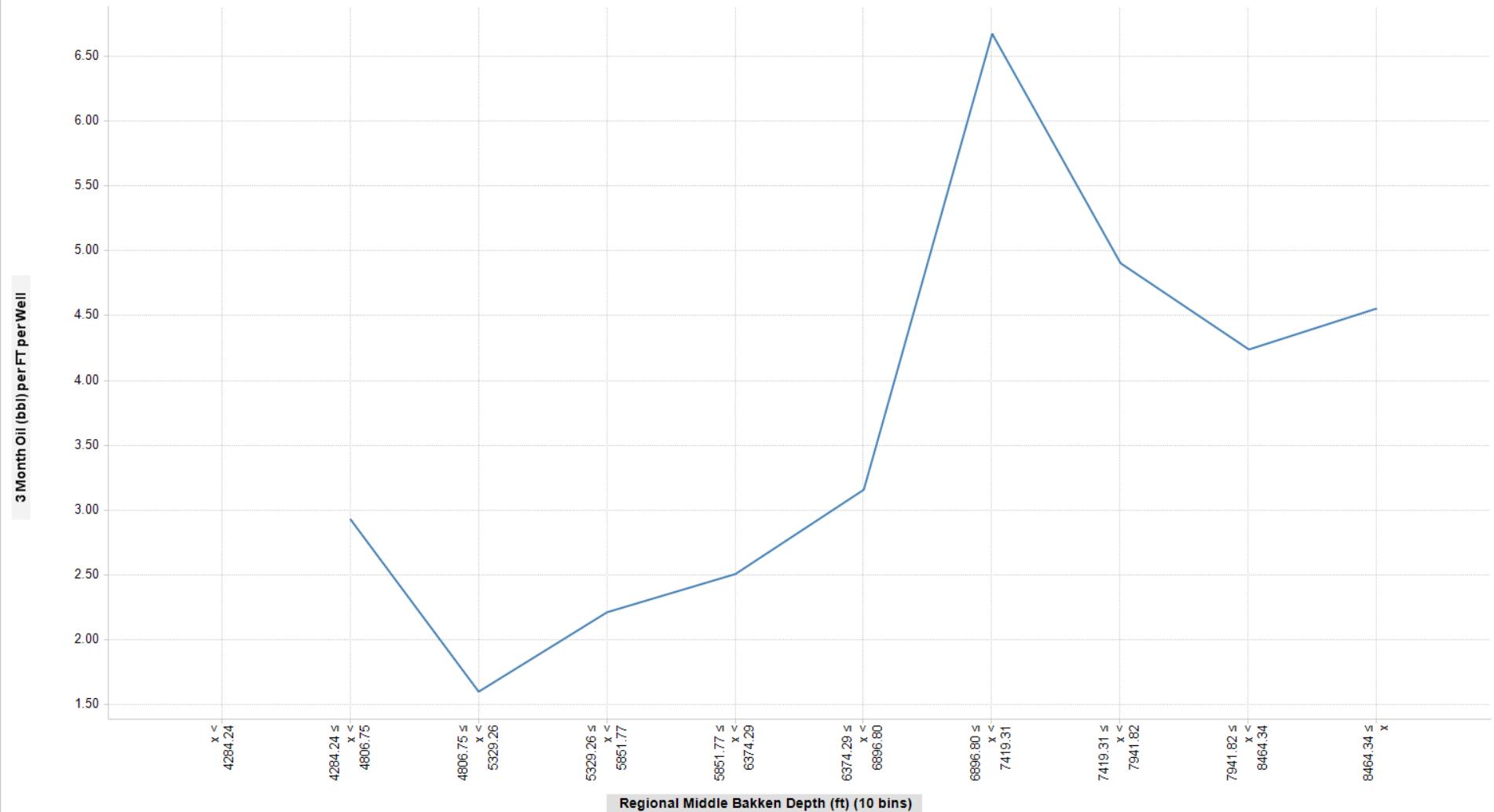
Middle Bakken Depth vs. 3 Month Oil/ft

3 Month Oil (bbl) per FT per Well vs. Regional Middle Bakken Depth (ft)

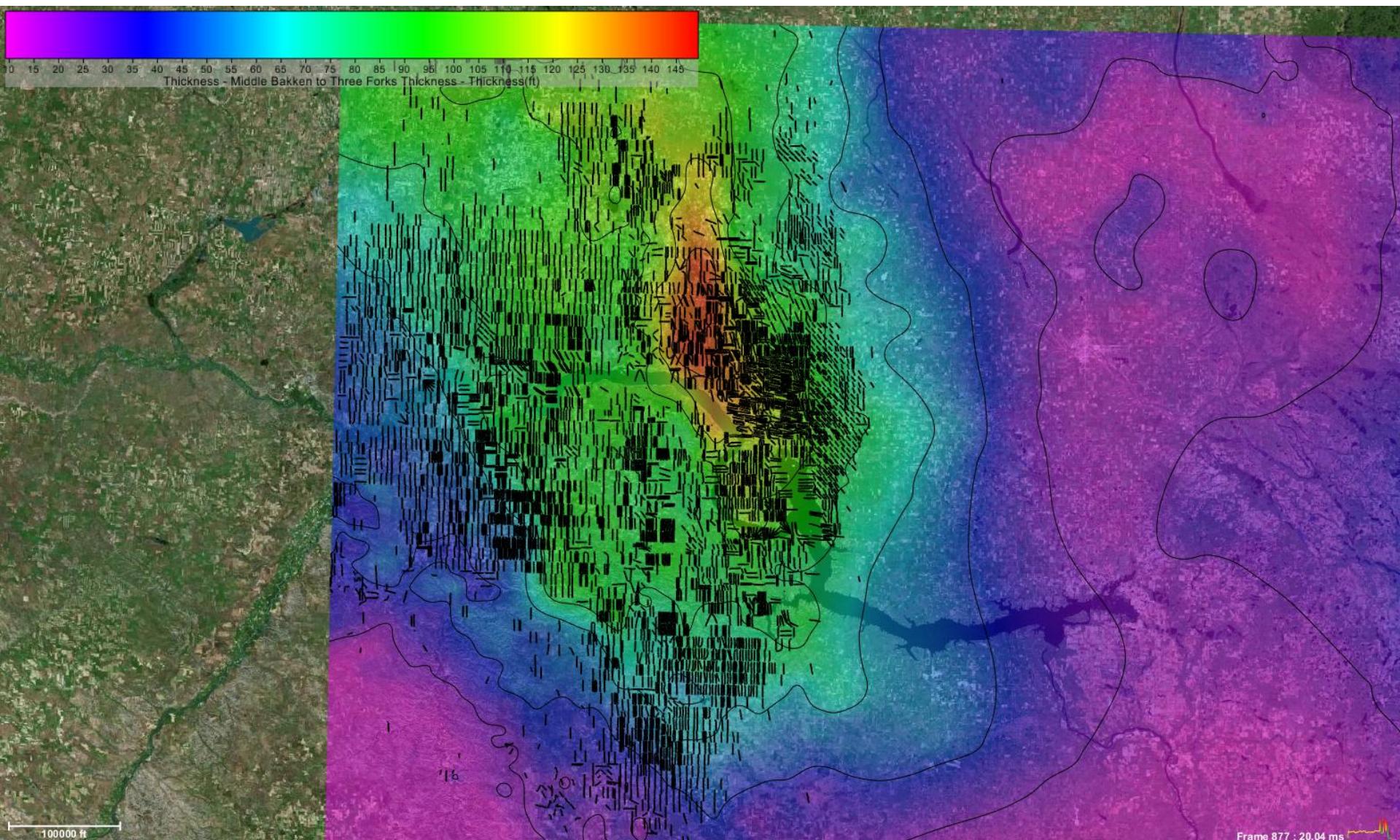


Middle Bakken Depth vs. 3 Month Oil/ft

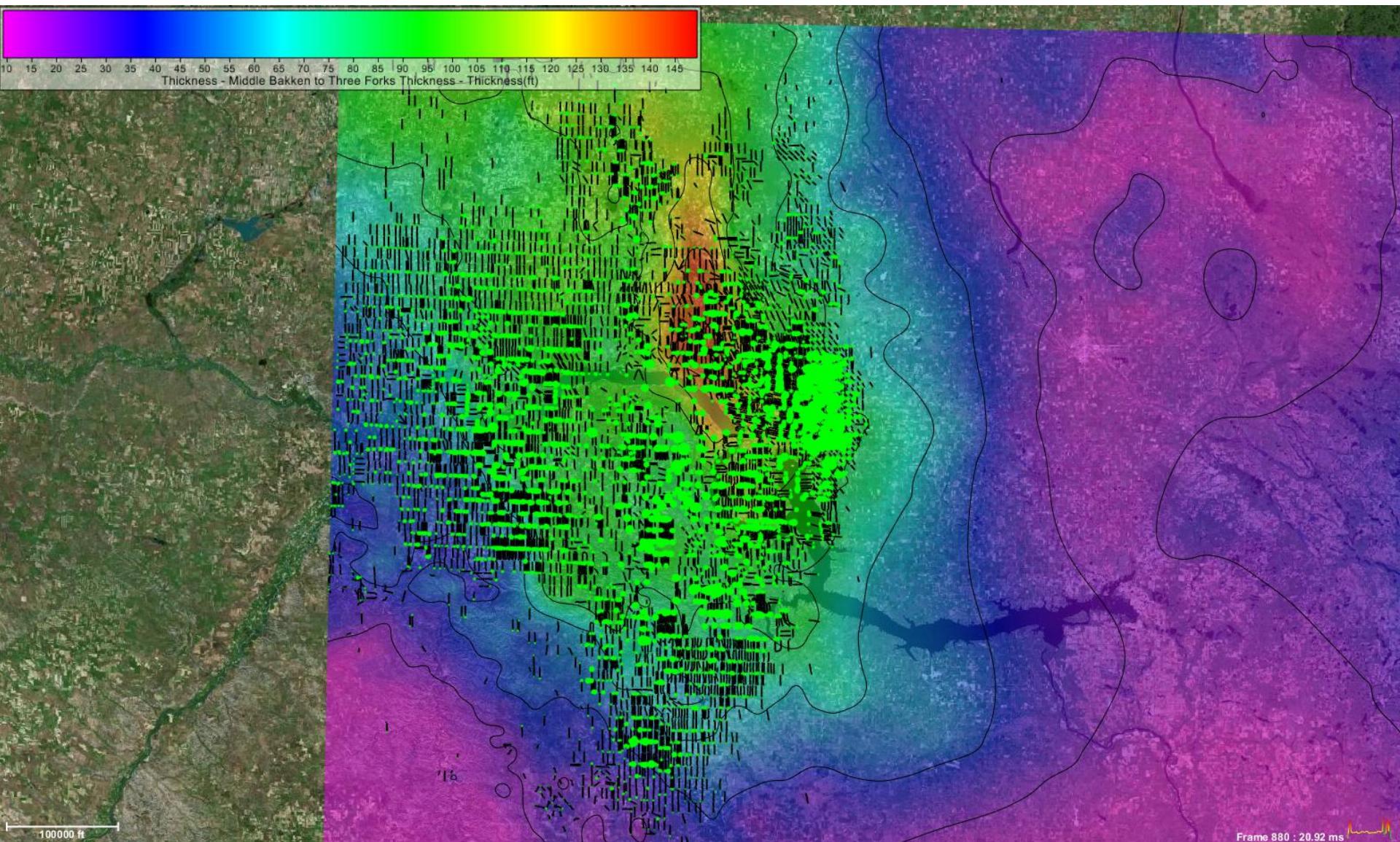
3 Month Oil (bbl) per FT per Well vs. Regional Middle Bakken Depth (ft)



Middle Bakken to Three Forks Thickness vs. 3 Month Oil/ft

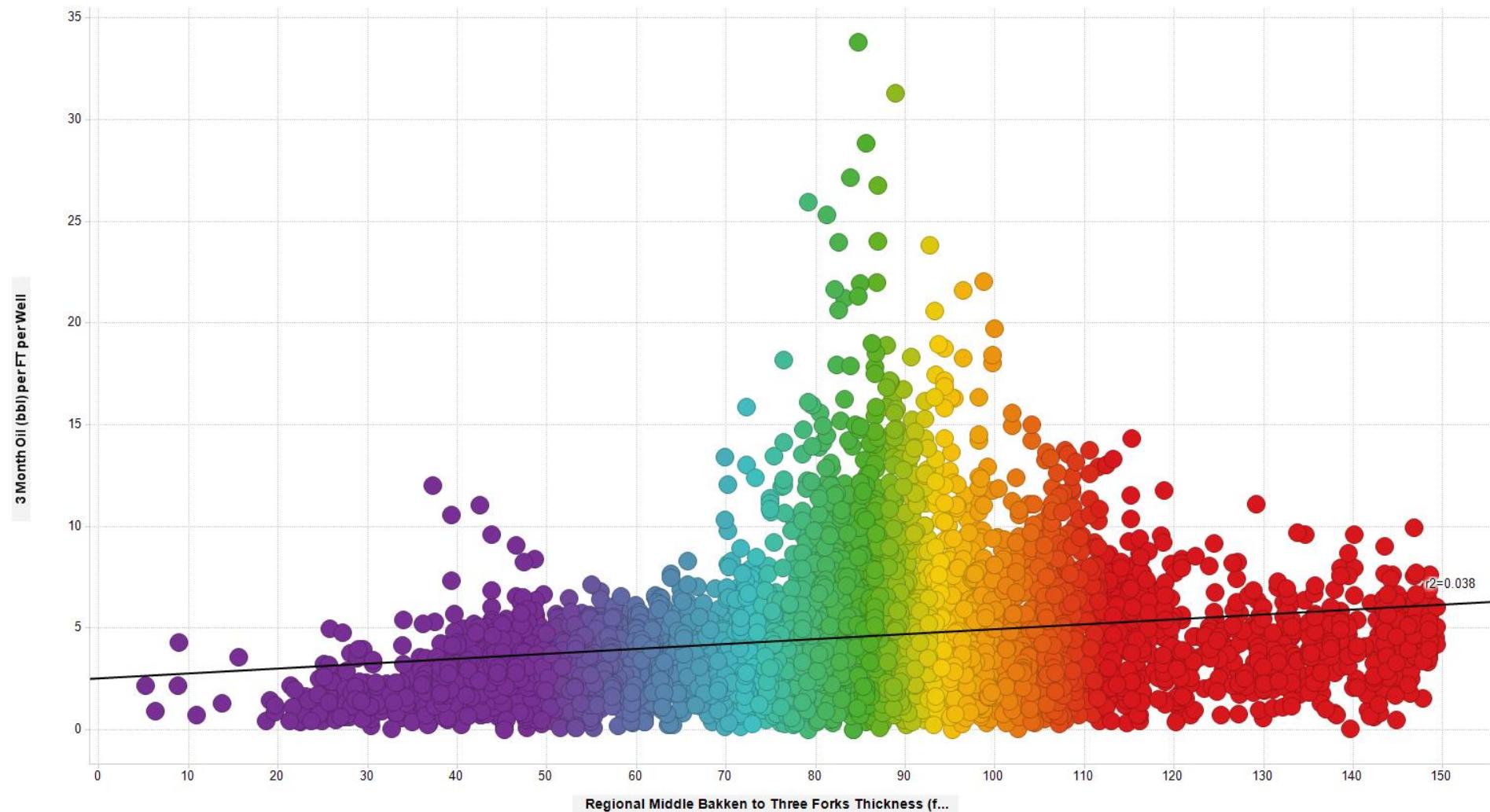


Middle Bakken to Three Forks Thickness vs. 3 Month Oil/ft



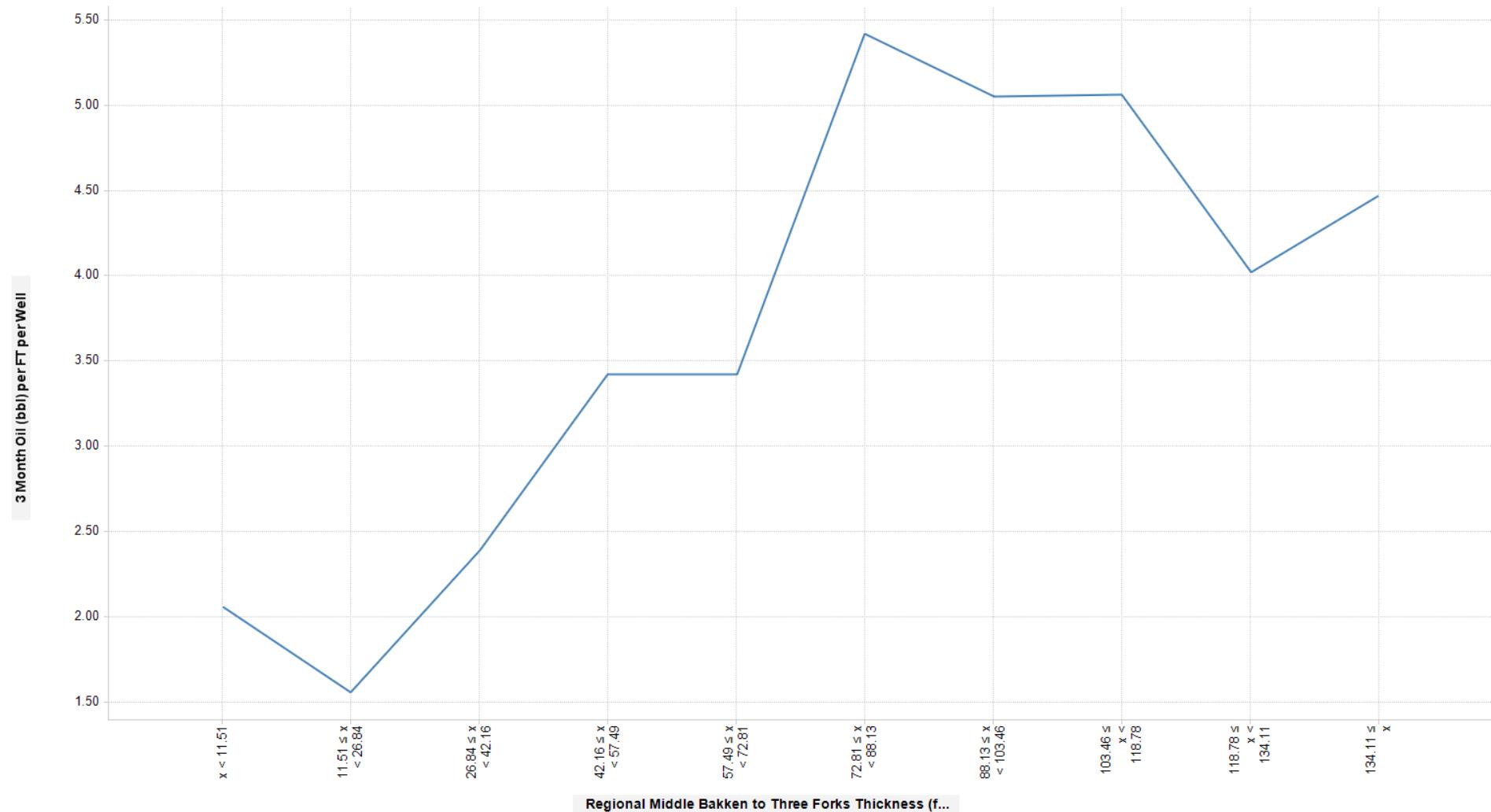
Middle Bakken to Three Forks Thickness vs. 3 Month Oil/ft

3 Month Oil (bbl) per FT per Well vs. Regional Middle Bakken to Three Forks Thickness (ft)

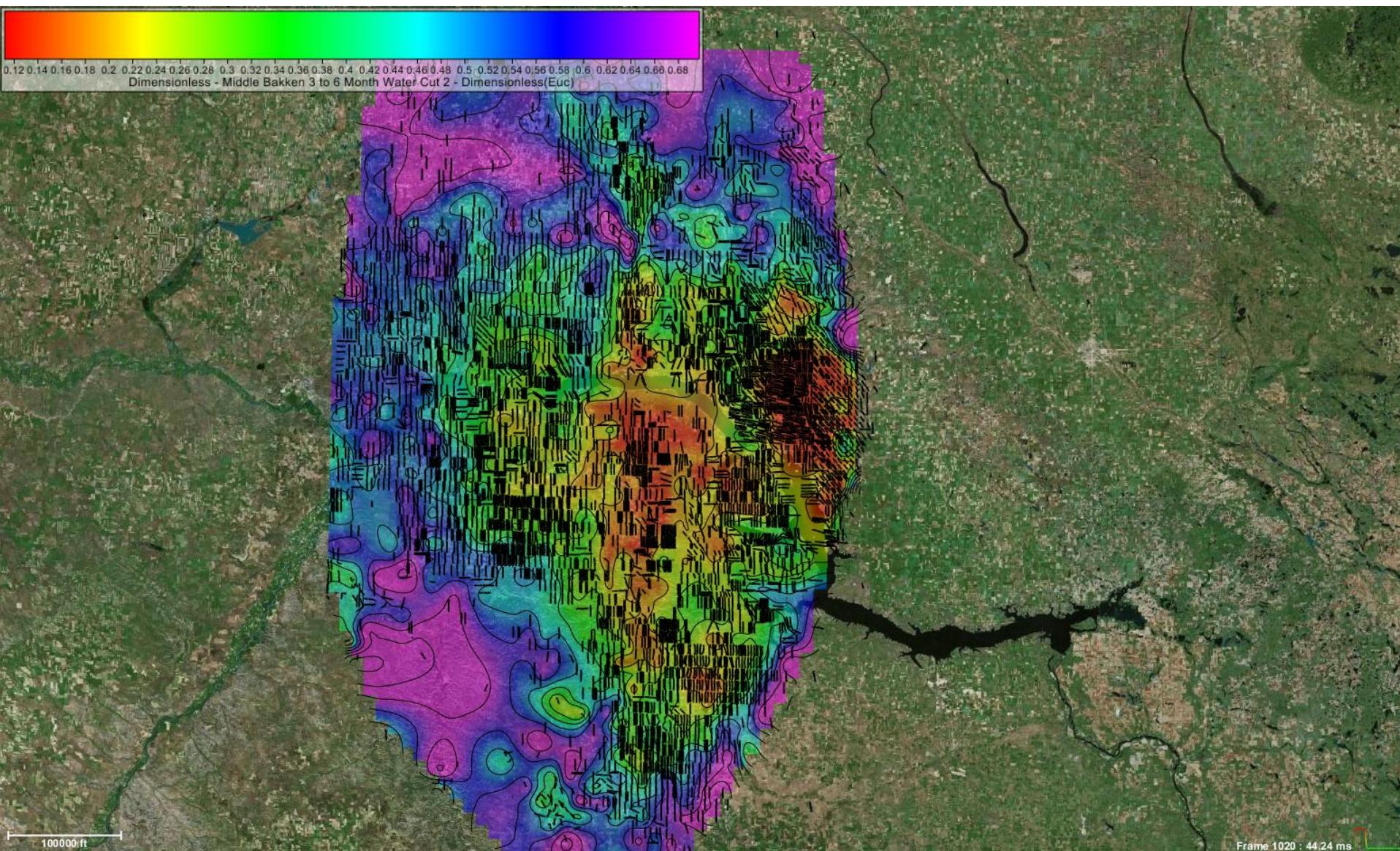


Middle Bakken to Three Forks Thickness vs. 3 Month Oil/ft

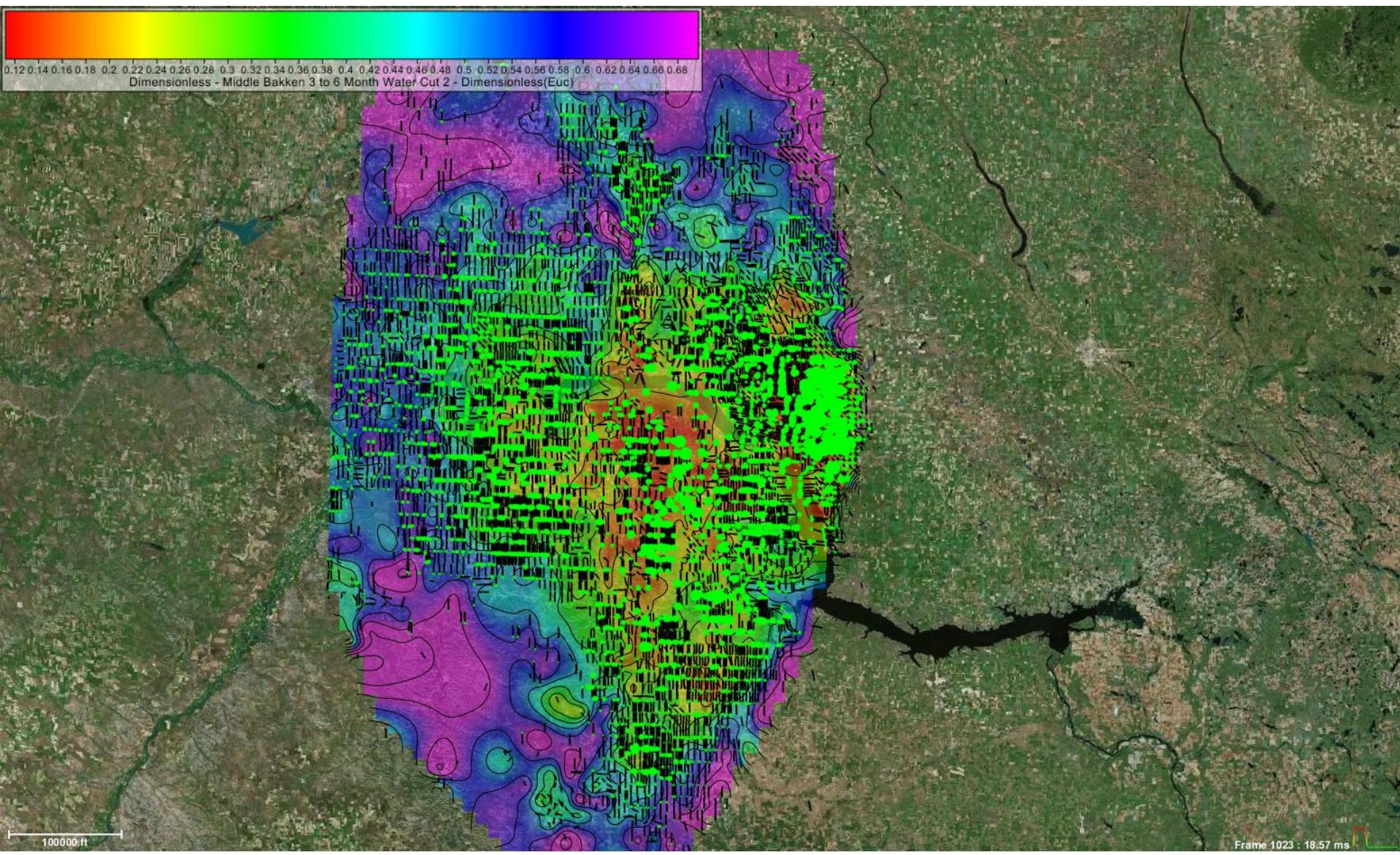
3 Month Oil (bbl) per FT per Well vs. Regional Middle Bakken to Three Forks Thickness (ft)



Regional Middle Bakken Water Cut vs. 3 Month Oil/ft

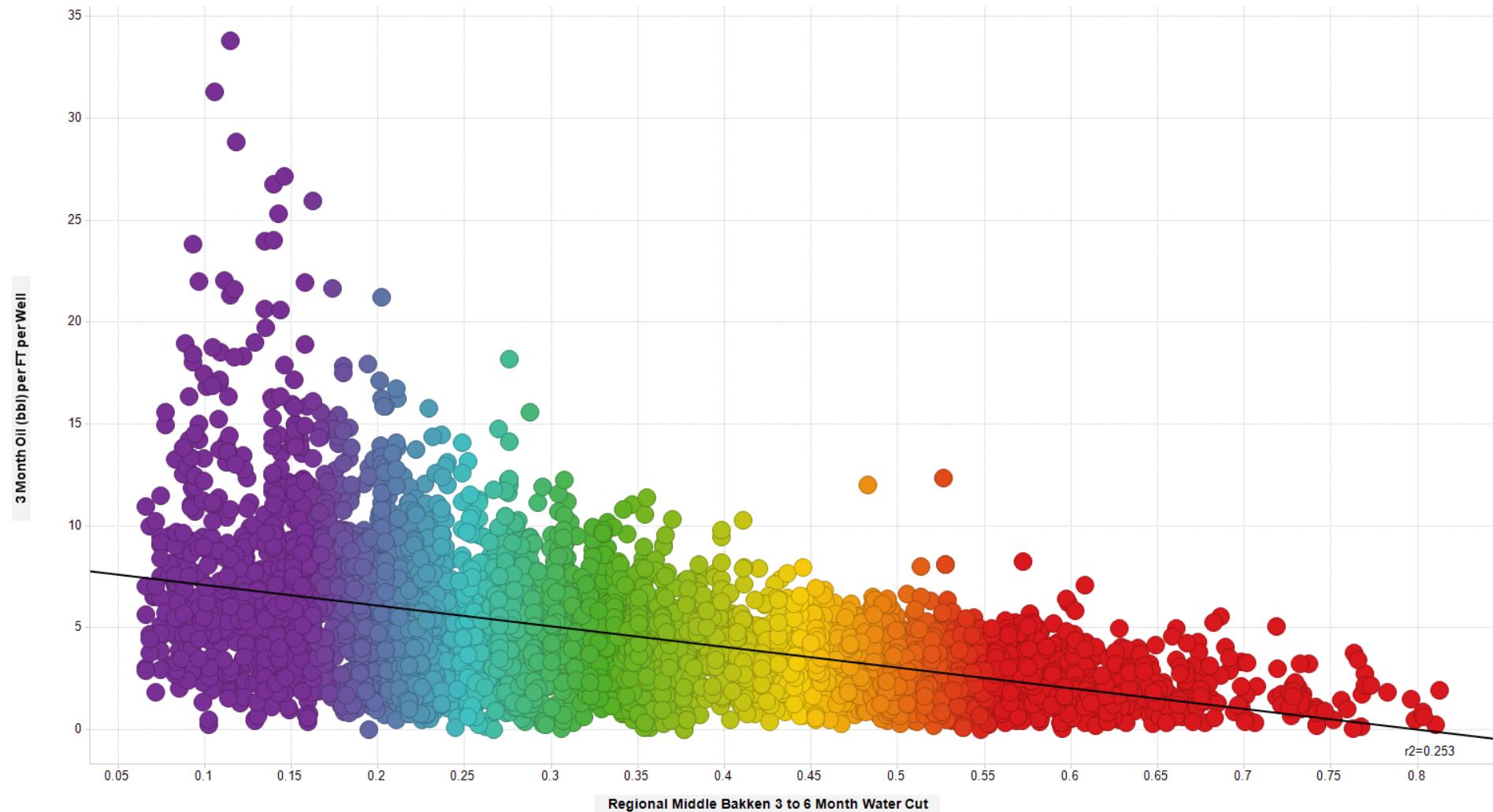


Regional Middle Bakken Water Cut vs. 3 Month Oil/ft



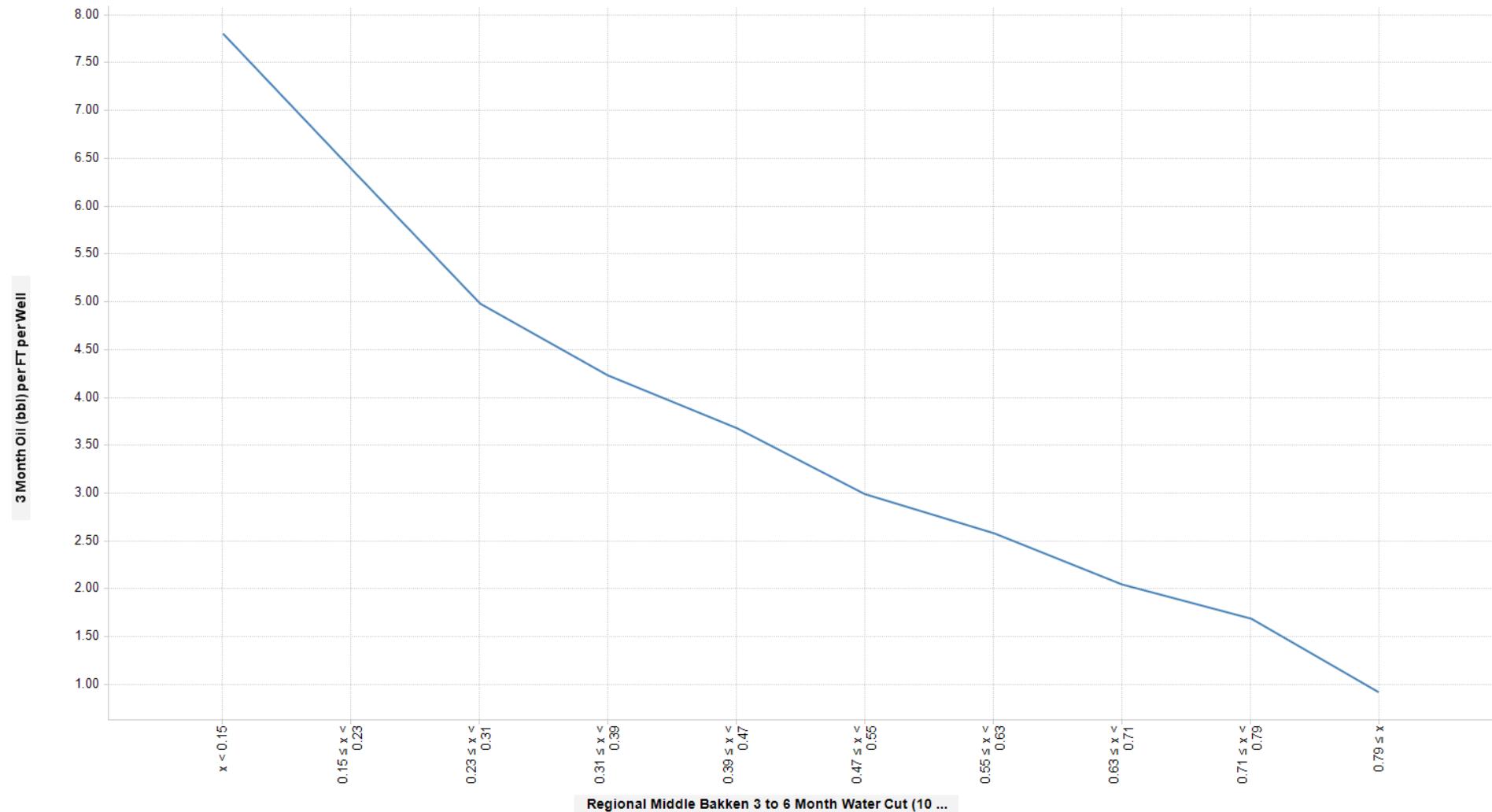
Regional Middle Bakken Water Cut vs. 3 Month Oil/ft

3 Month Oil (bbl) per FT per Well vs. Regional Middle Bakken 3 to 6 Month Water Cut

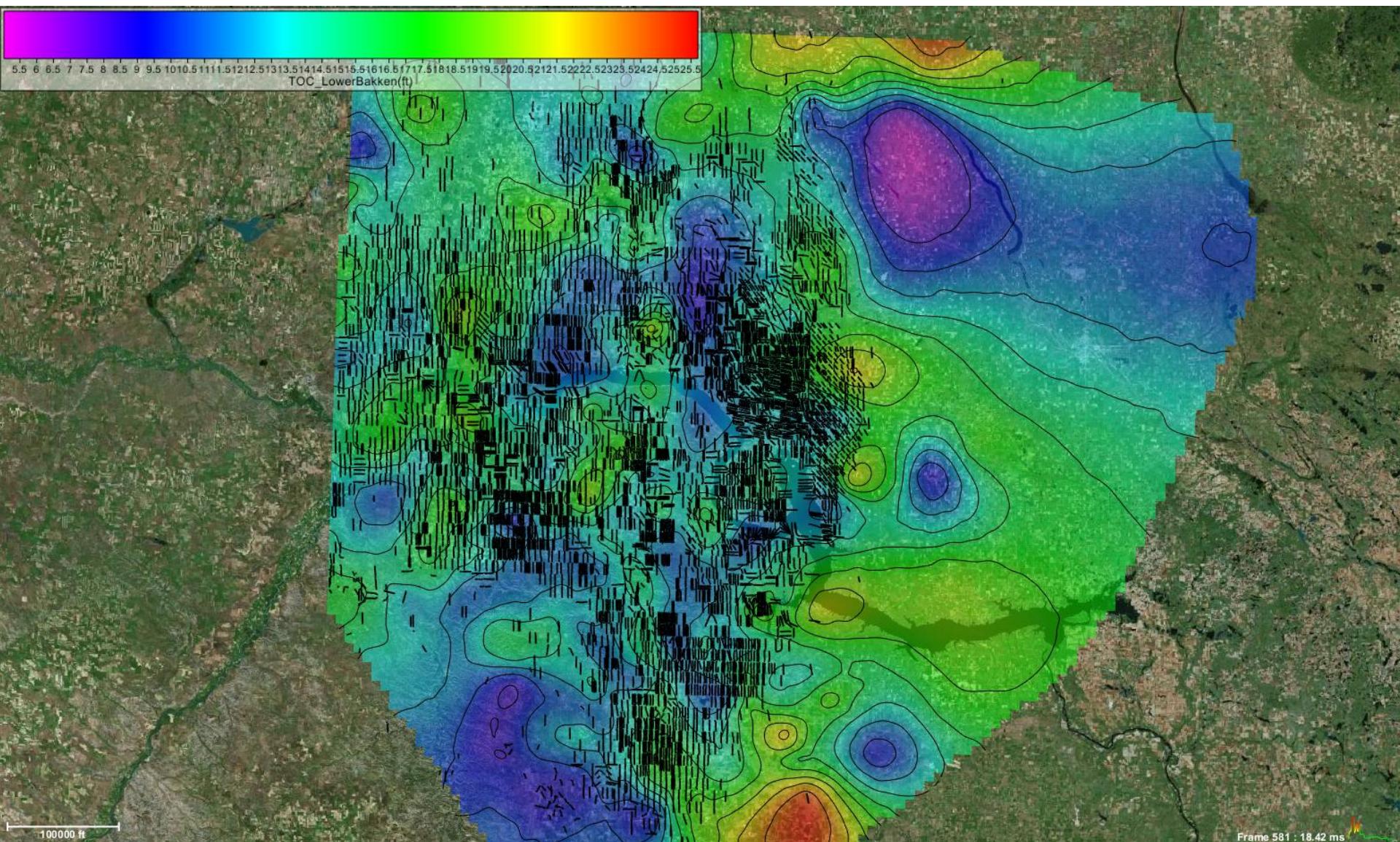


Regional Middle Bakken 3 to 6 Month Water Cut vs. 3 Month Oil/ft

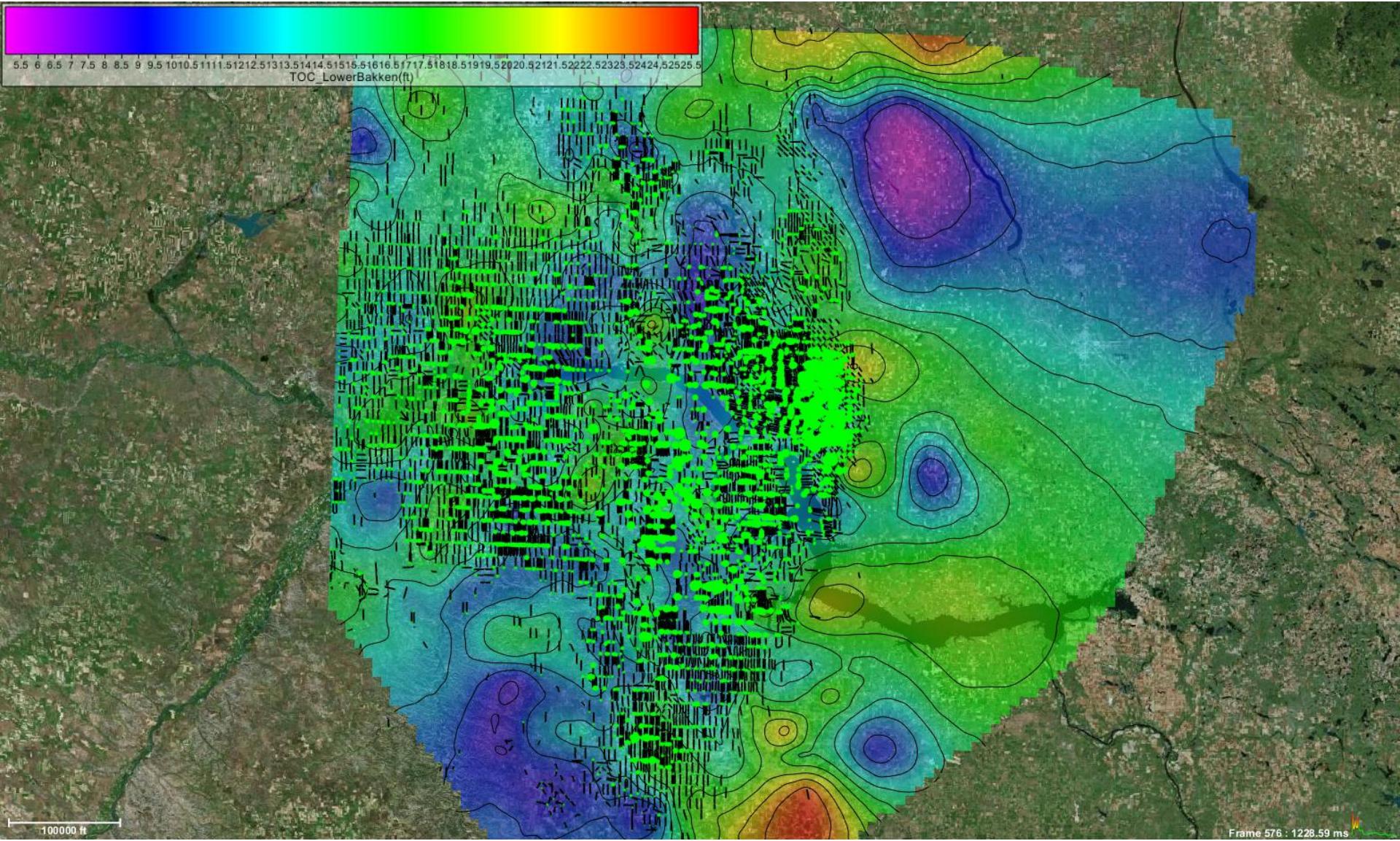
3 Month Oil (bbl) per FT per Well vs. Regional Middle Bakken 3 to 6 Month Water Cut



Lower Bakken TOC vs. 3 Month Oil/ft

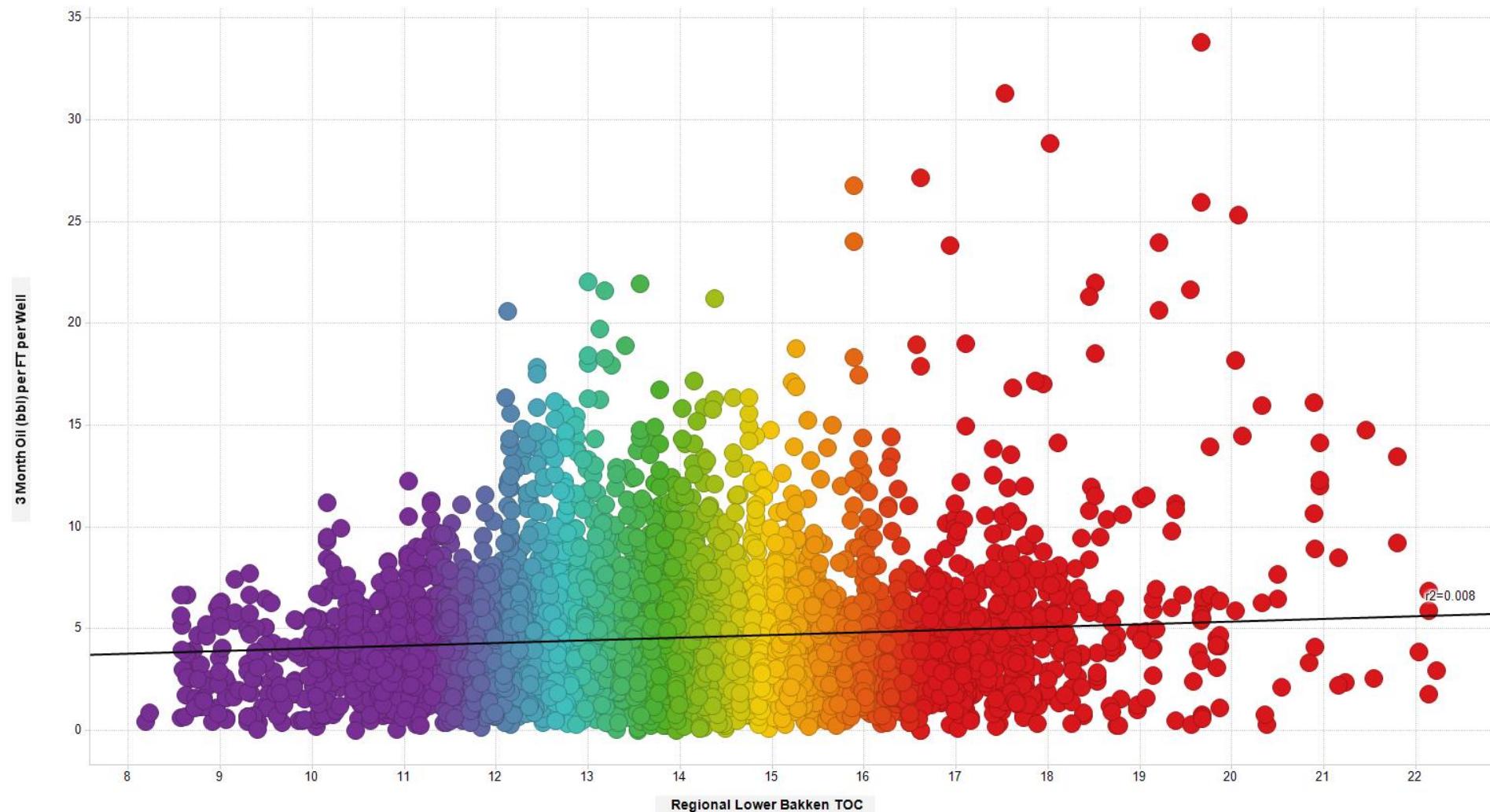


Lower Bakken TOC vs. 3 Month Oil/ft



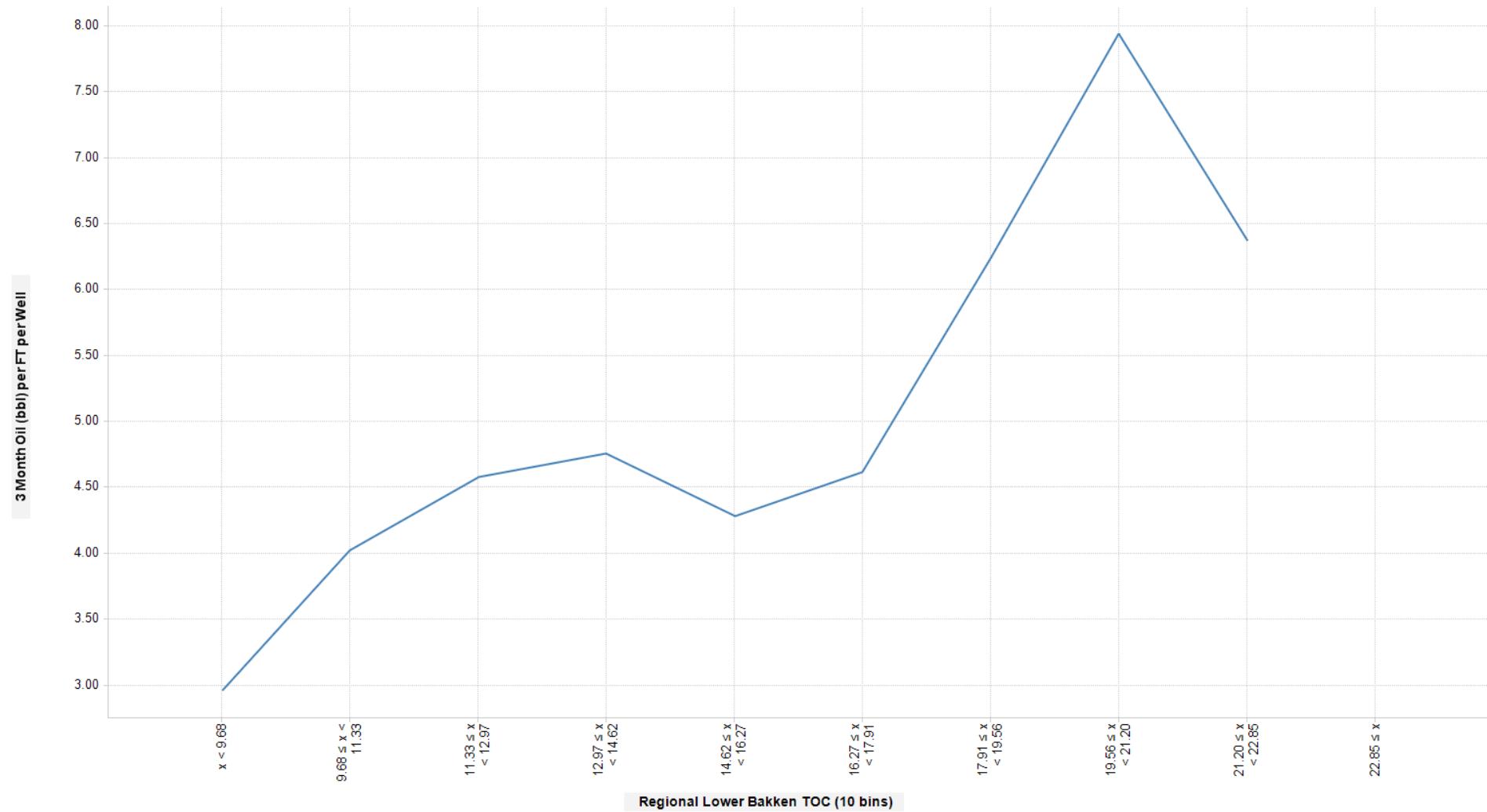
Lower Bakken TOC vs. 3 Month Oil/ft

3 Month Oil (bbl) per FT per Well vs. Regional Lower Bakken TOC

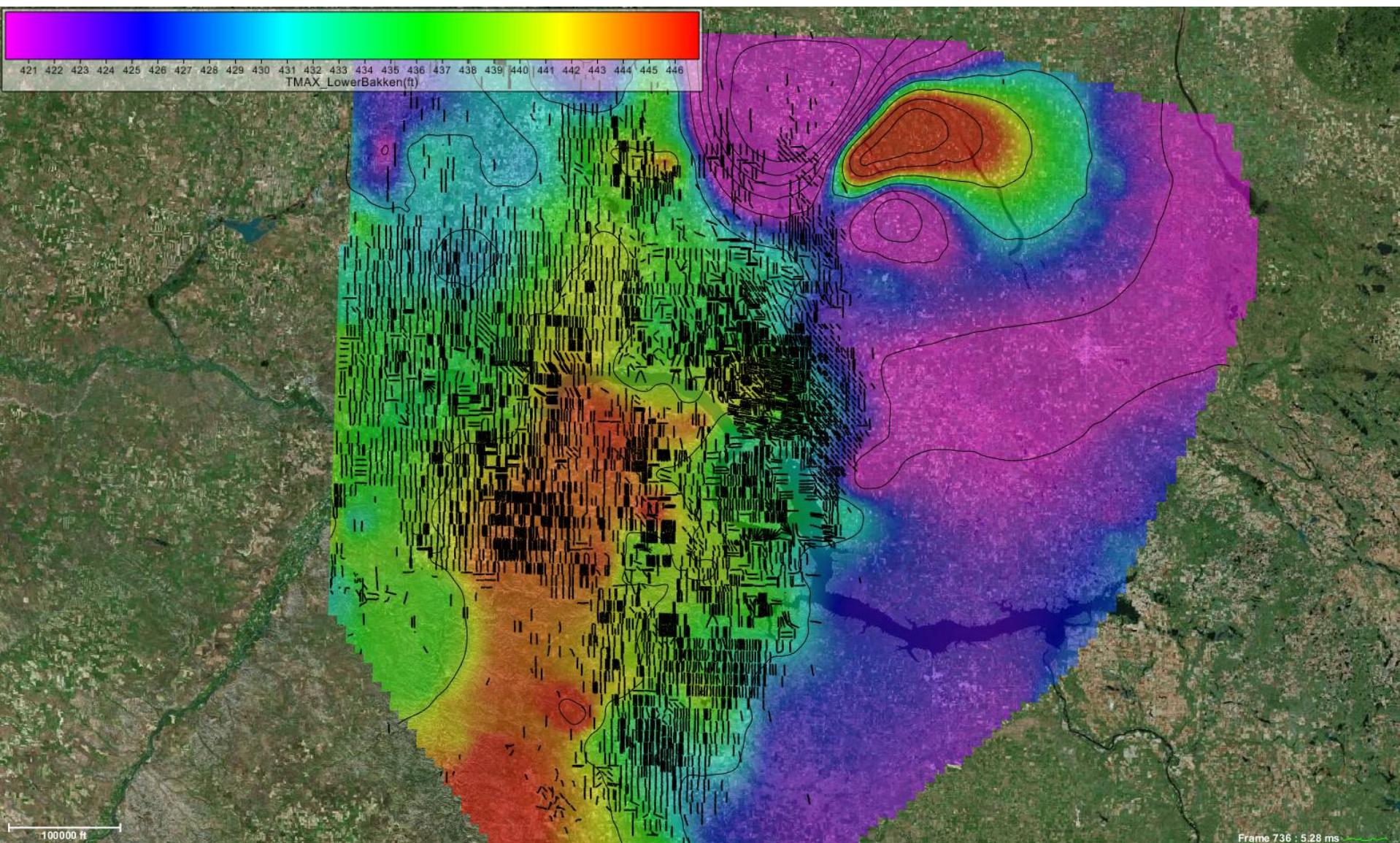


Lower Bakken TOC vs. 3 Month Oil/ft

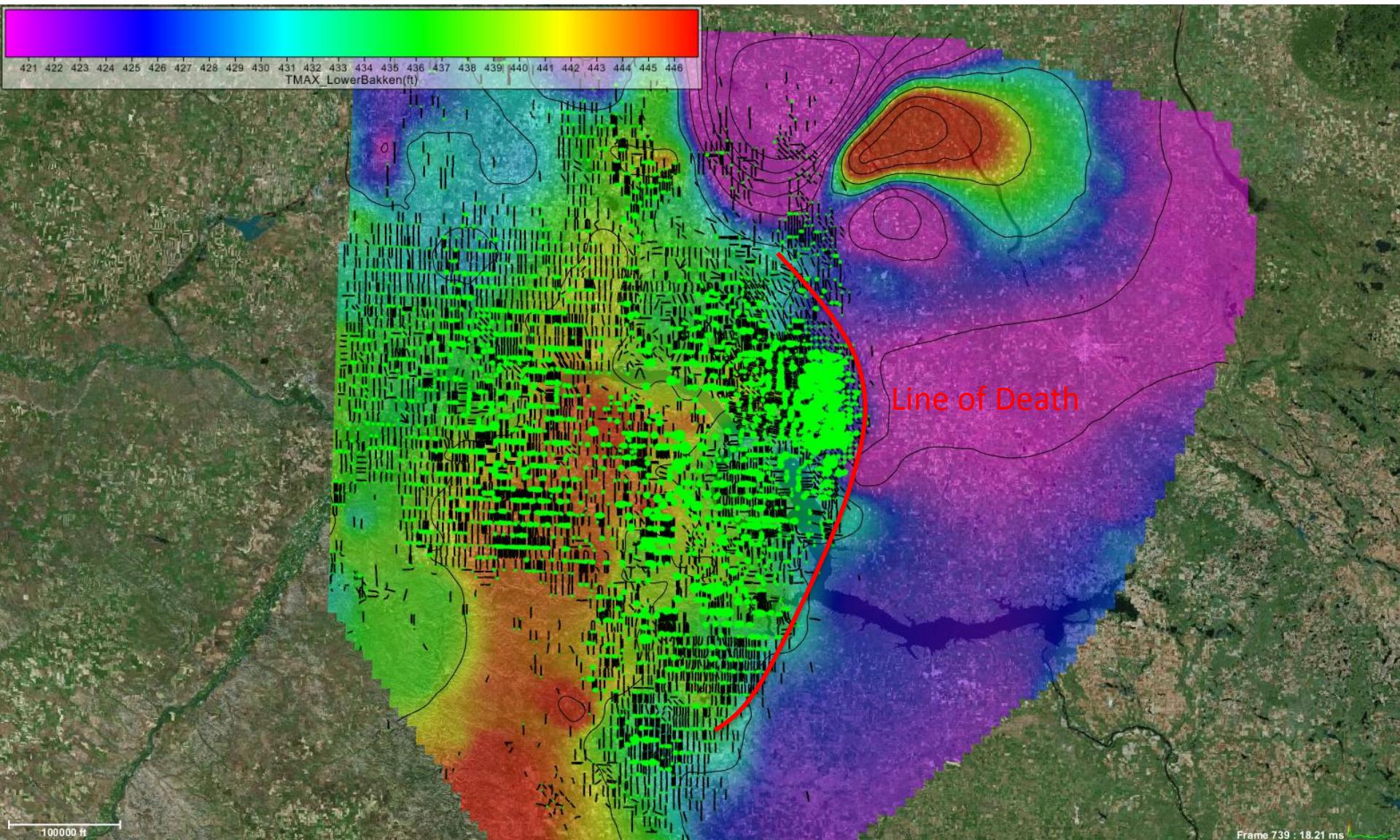
3 Month Oil (bbl) per FT per Well vs. Regional Lower Bakken TOC



Lower Bakken TMax vs. 3 Month Oil/ft

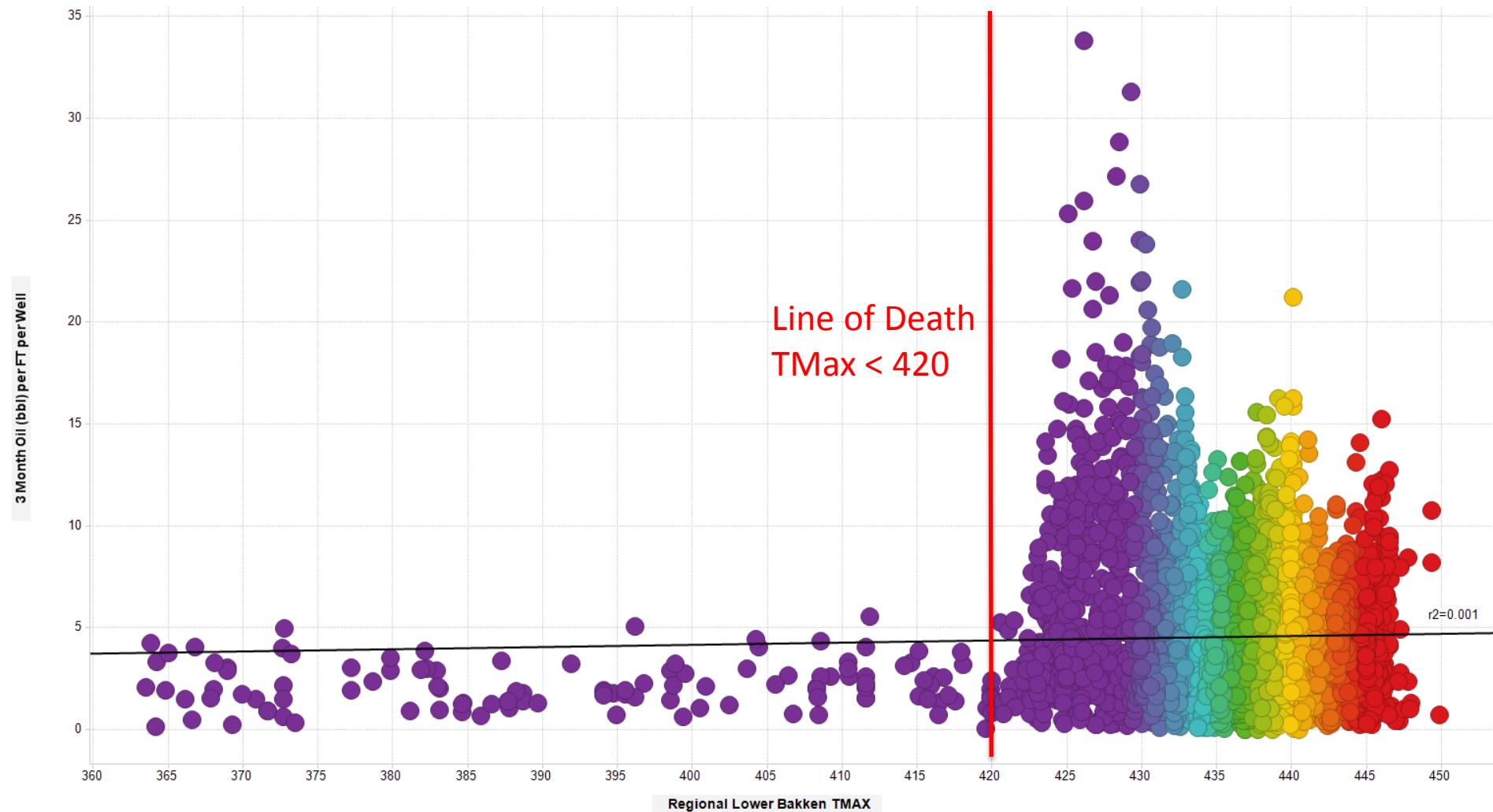


Lower Bakken TMax vs. 3 Month Oil/ft



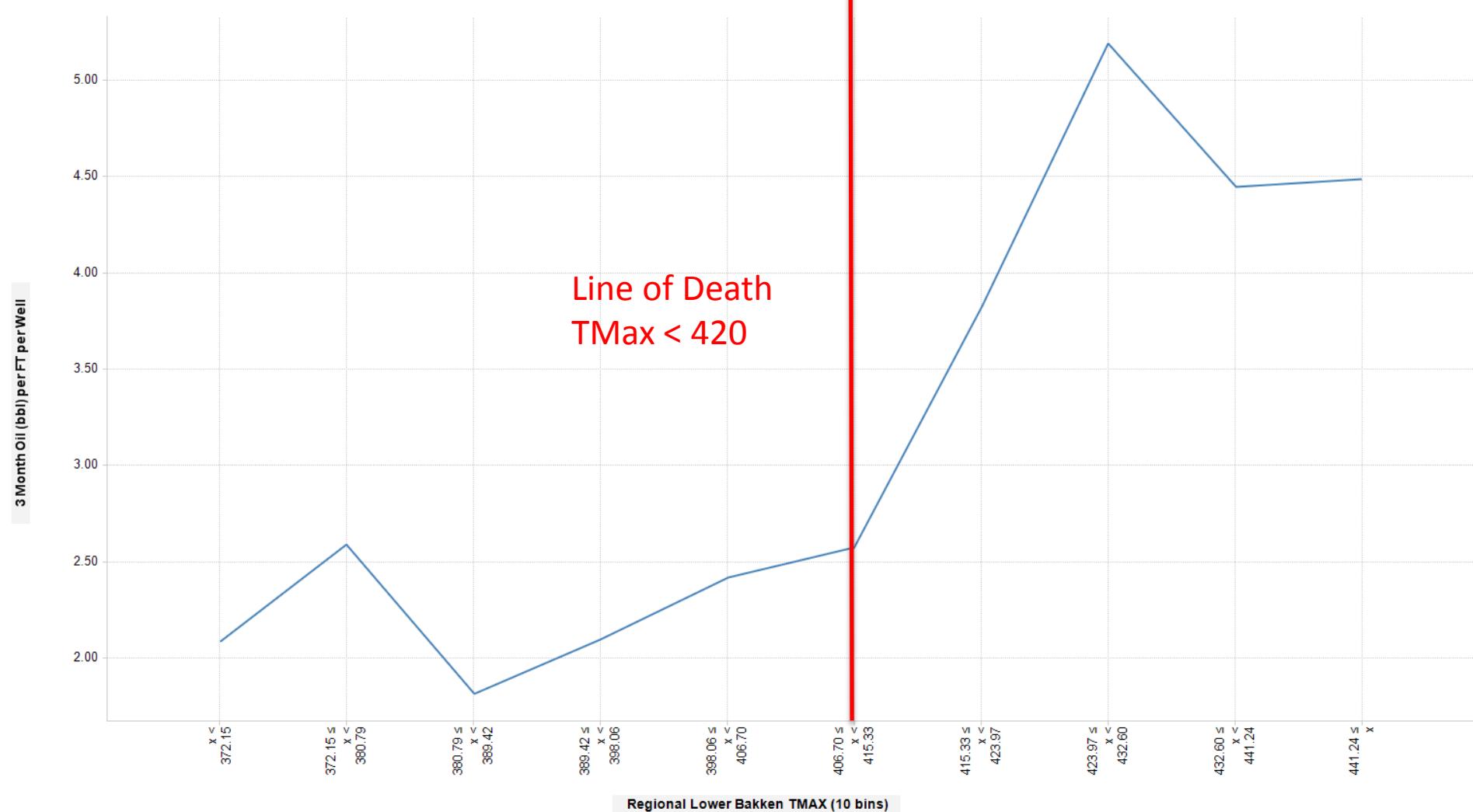
Lower Bakken TMax vs. 3 Month Oil/ft

3 Month Oil (bbl) per FT per Well vs. Regional Lower Bakken TMAX



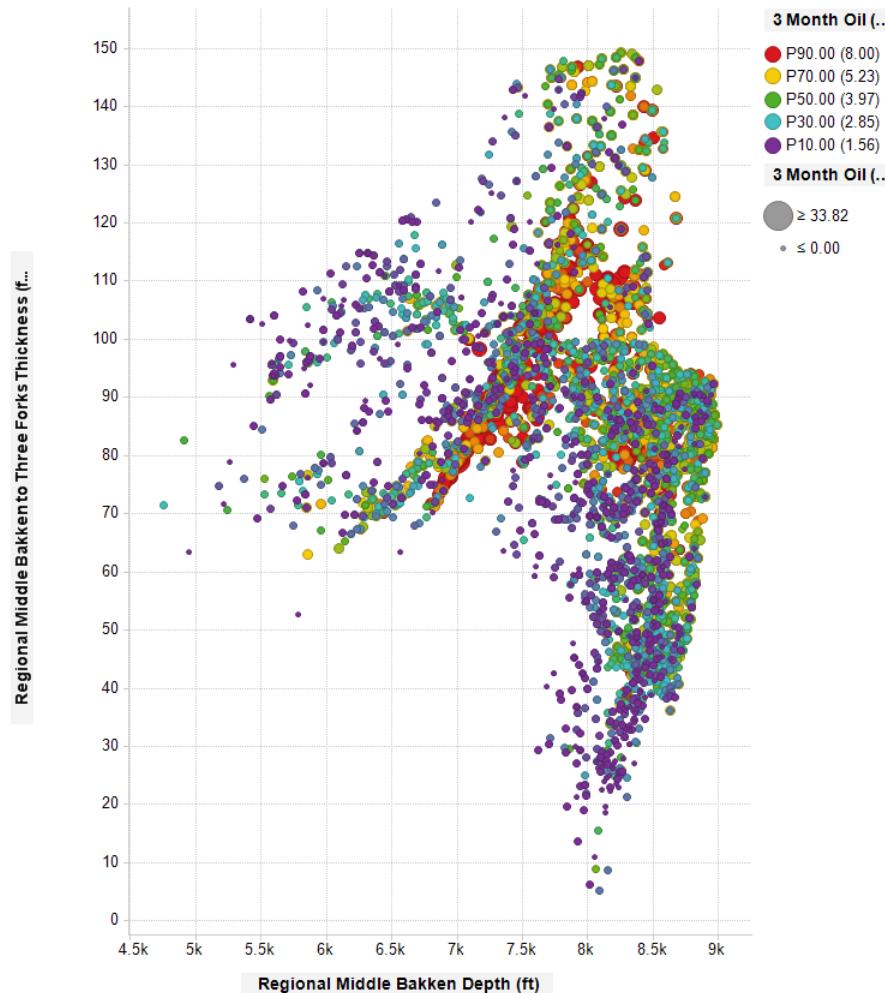
Lower Bakken TMax vs. 3 Month Oil/ft

3 Month Oil (bbl) per FT per Well vs. Regional Lower Bakken TMAX

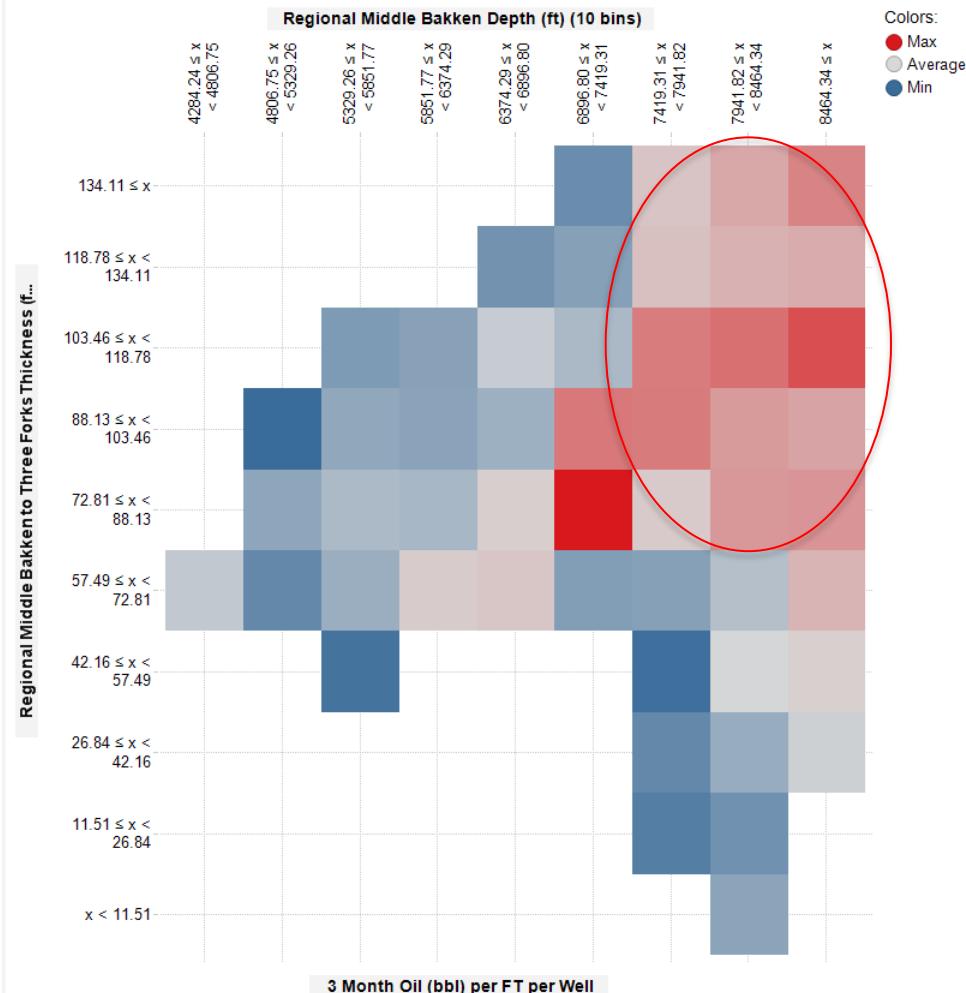


Middle Bakken Depth vs. Middle Bakken to Three Forks Thickness by 3 Month Oil/ft

Regional Middle Bakken to Three Forks Thickness (ft) v...

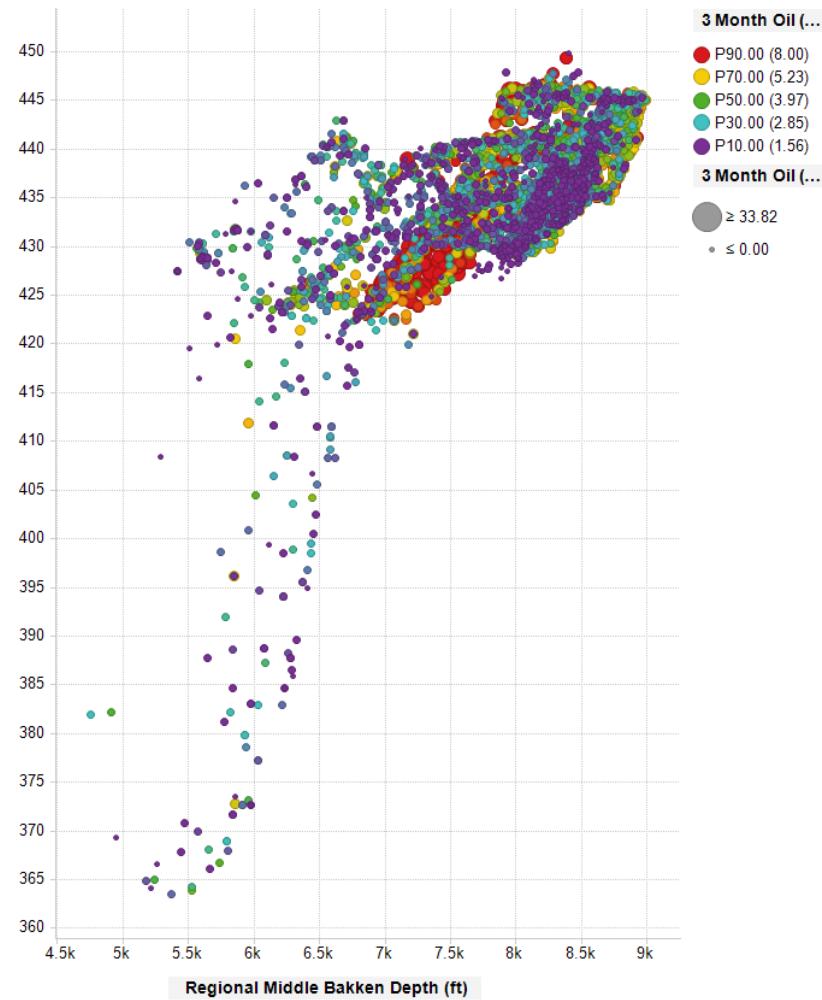


Regional Middle Bakken to Three Forks Thickness (ft) (10 bins) v...

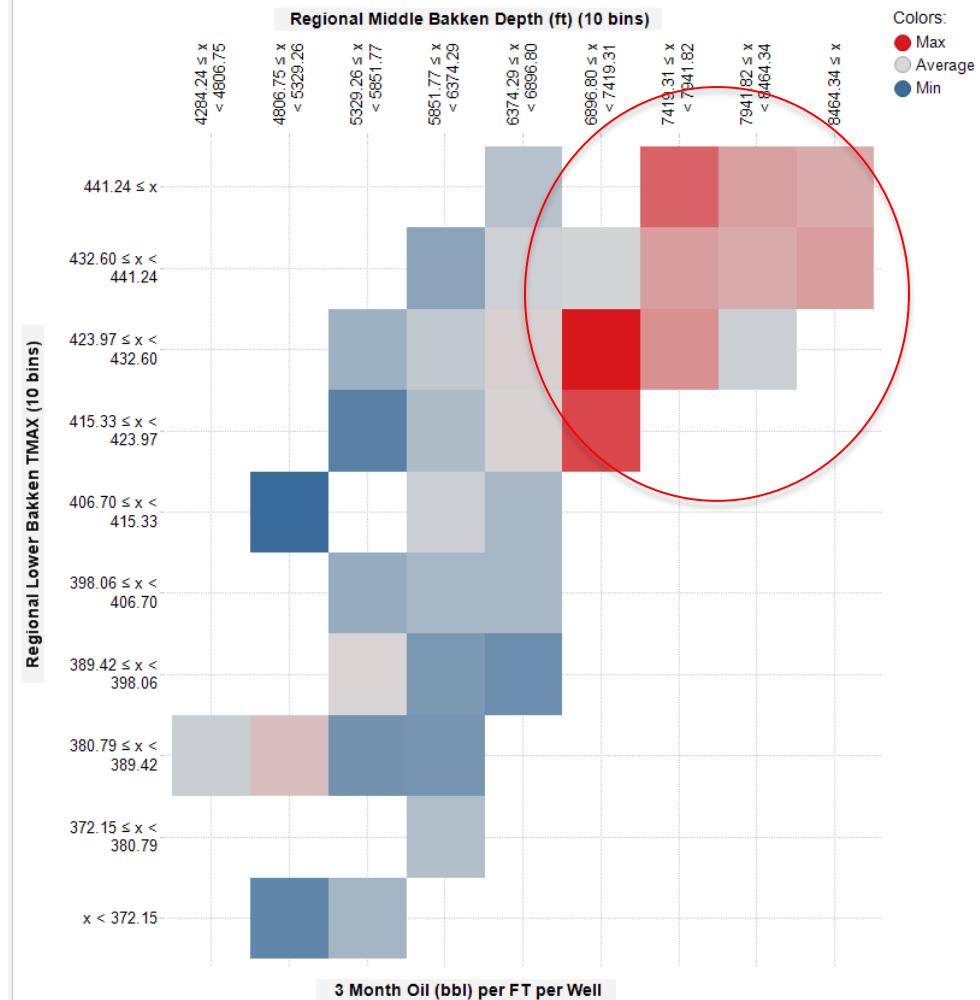


Middle Bakken Depth vs. Lower Bakken Tmax by 3 Month Oil/ft

| Regional Lower Bakken TMAX vs. Regional Middle Bakke...

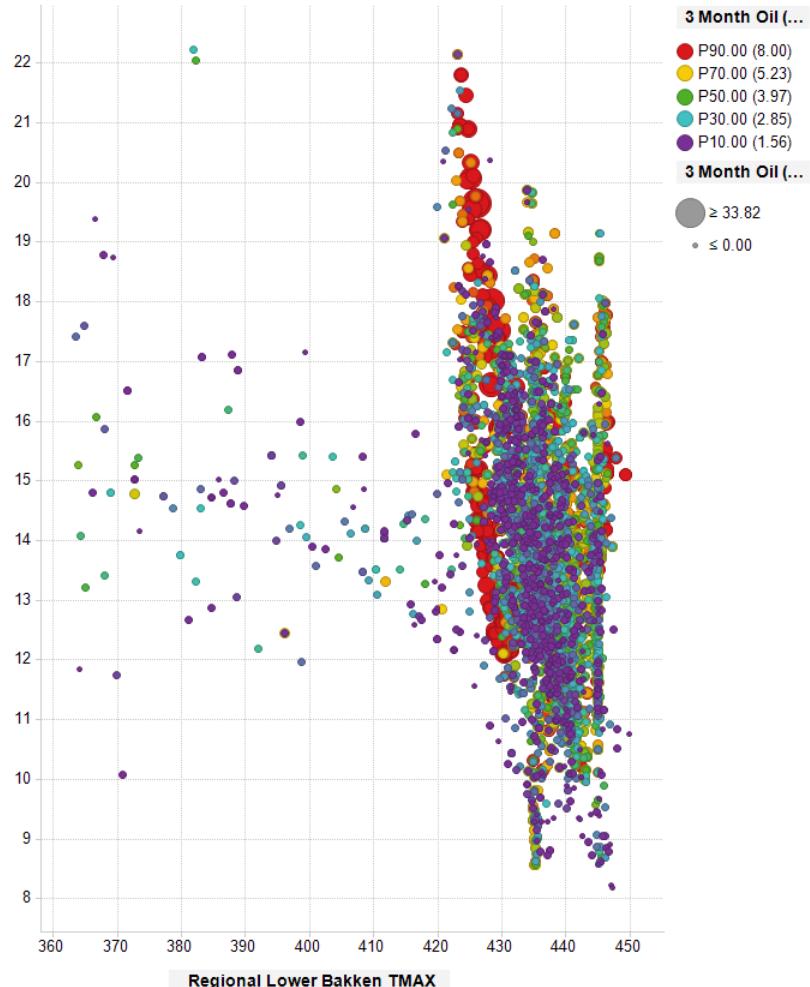


| Regional Lower Bakken TMAX (10 bins) vs. Regional Middle Bakke...

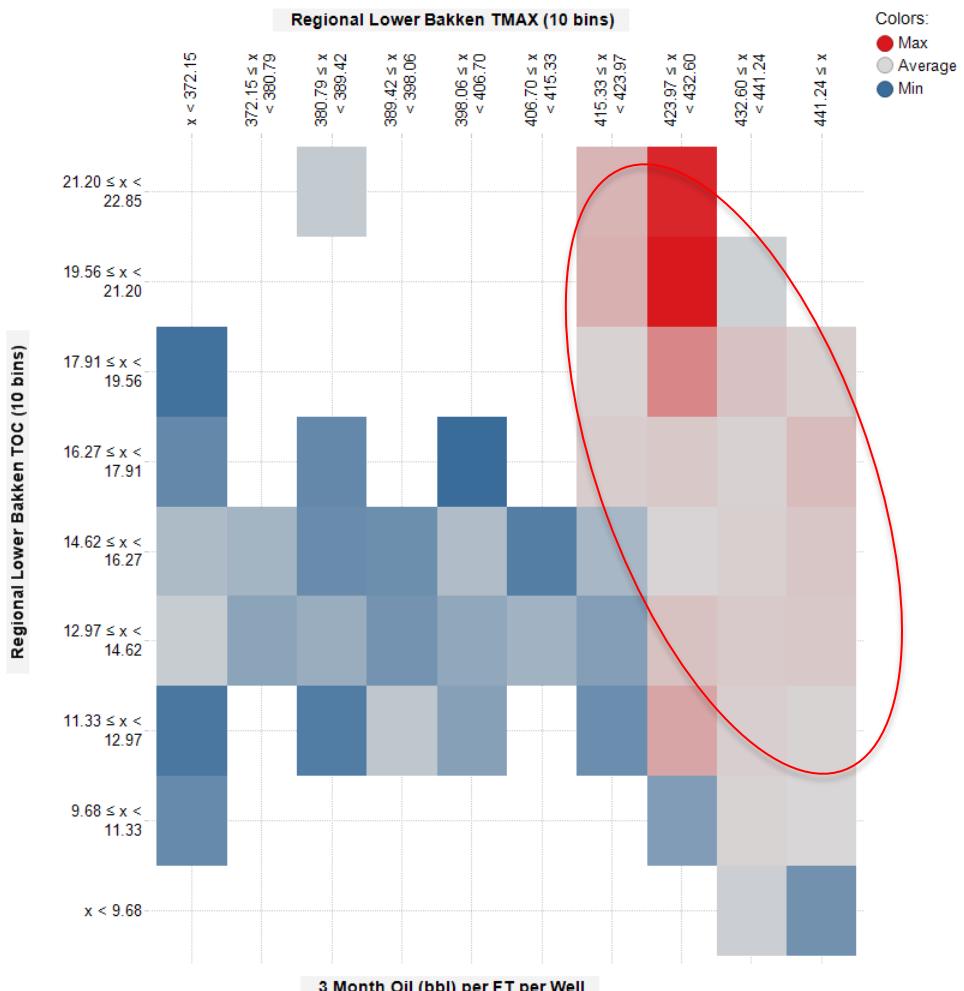


Lower Bakken TMax vs. Lower Bakken TOC by 3 Month Oil/ft

| Regional Lower Bakken TOC vs. Regional Lower Bakke...

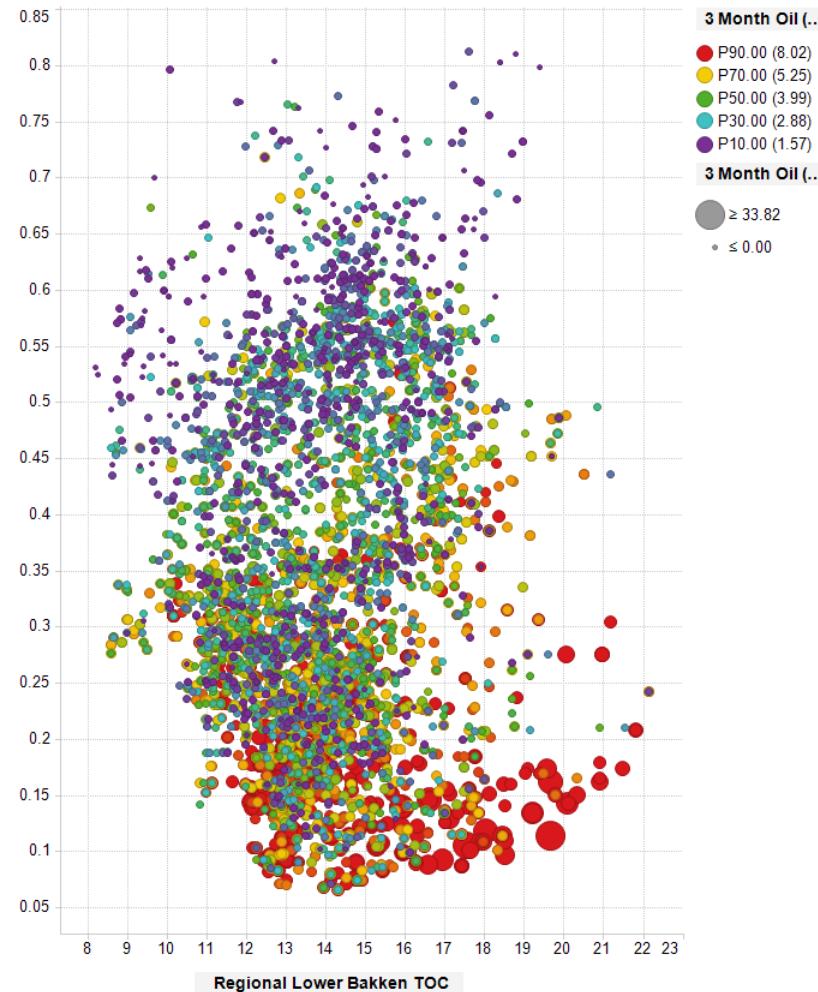


| Regional Lower Bakken TOC (10 bins) vs. Regional Lower Bakke...

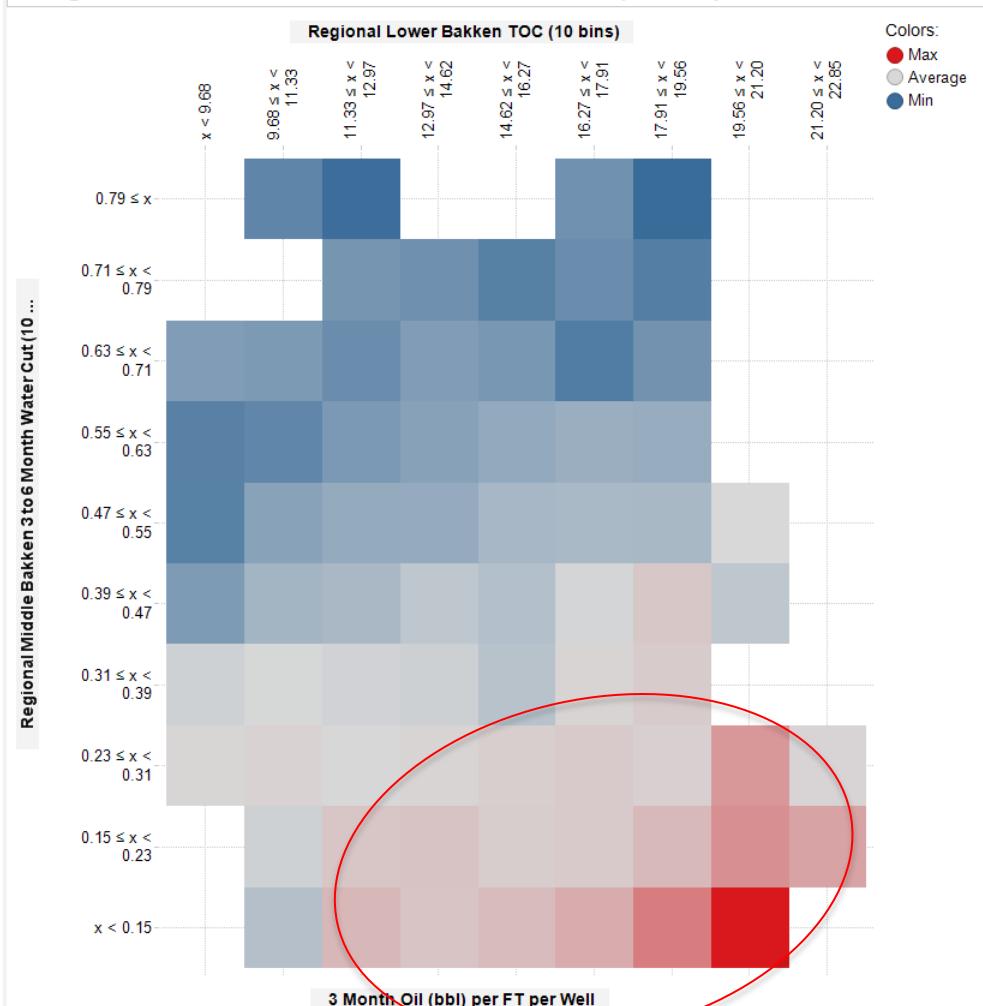


Lower Bakken TOC vs. Middle Bakken 3 to 6 Month Water Cut by 3 Month Oil/ft

Regional Middle Bakken 3 to 6 Month Water Cut vs. Region...



Regional Middle Bakken 3 to 6 Month Water Cut (10 bins) v...

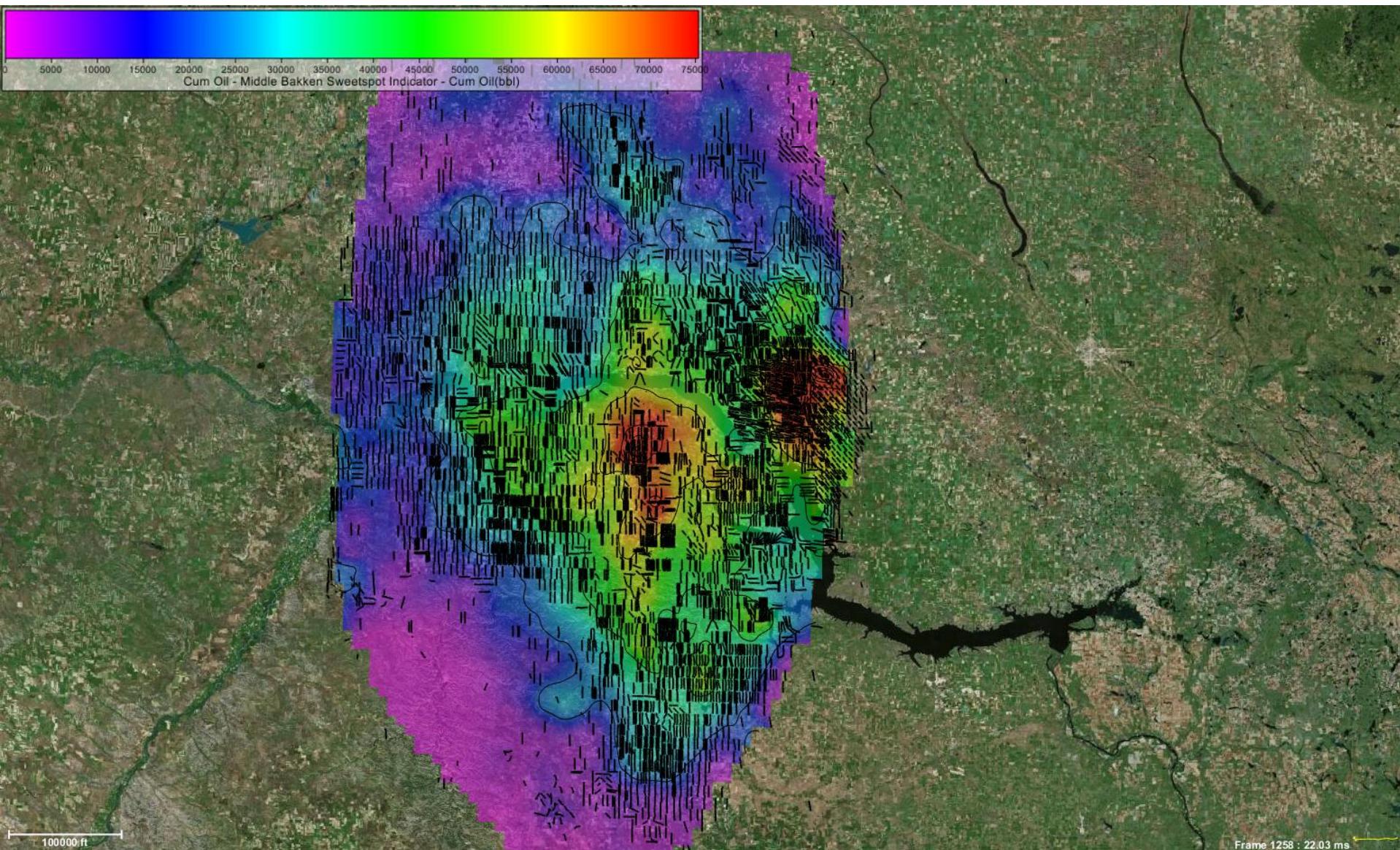


WHERE ARE THE SWEETSPOTS?

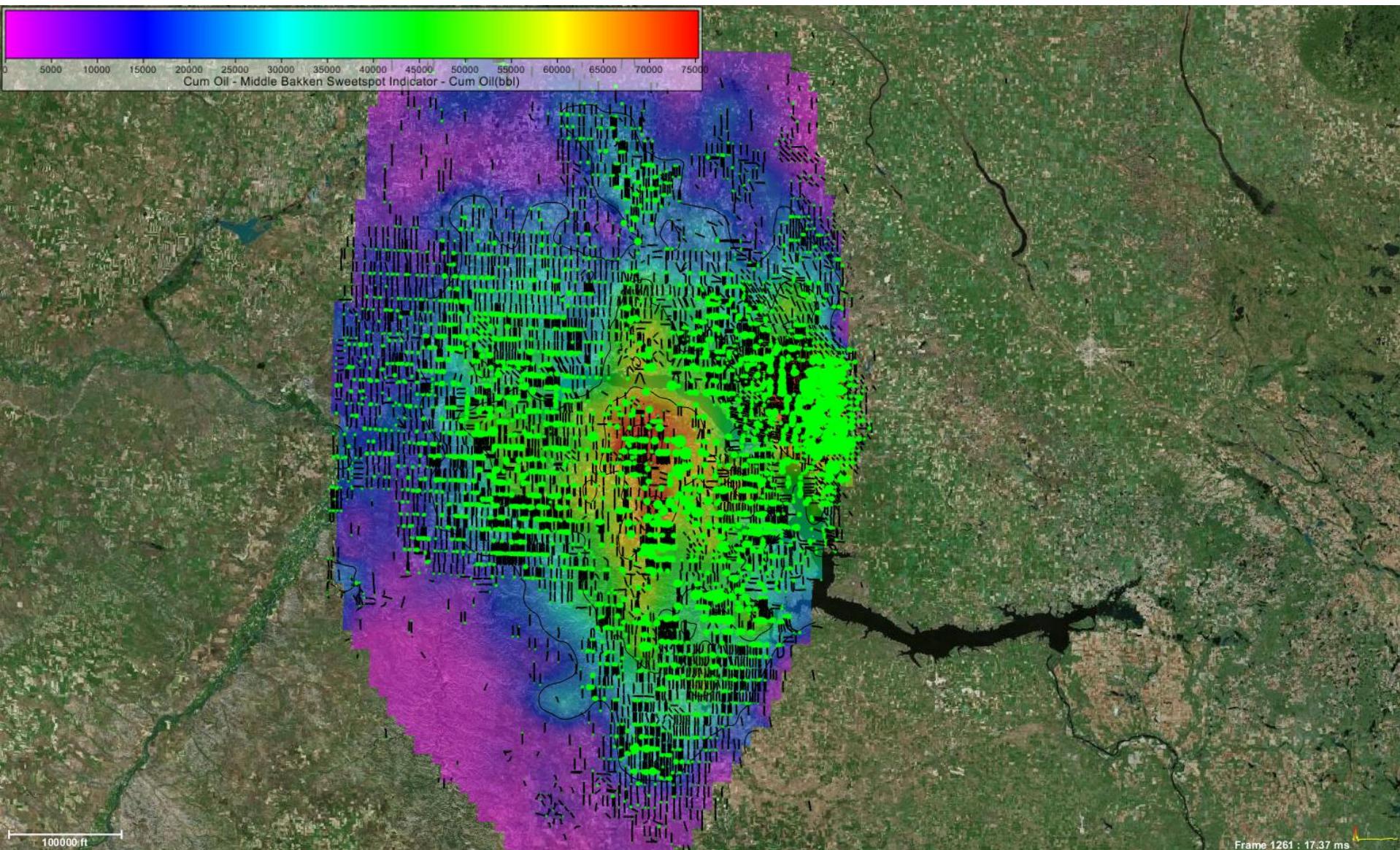


GROUND TRUTH

Middle Bakken Sweetspot Indicator



Middle Bakken Sweetspot Indicator



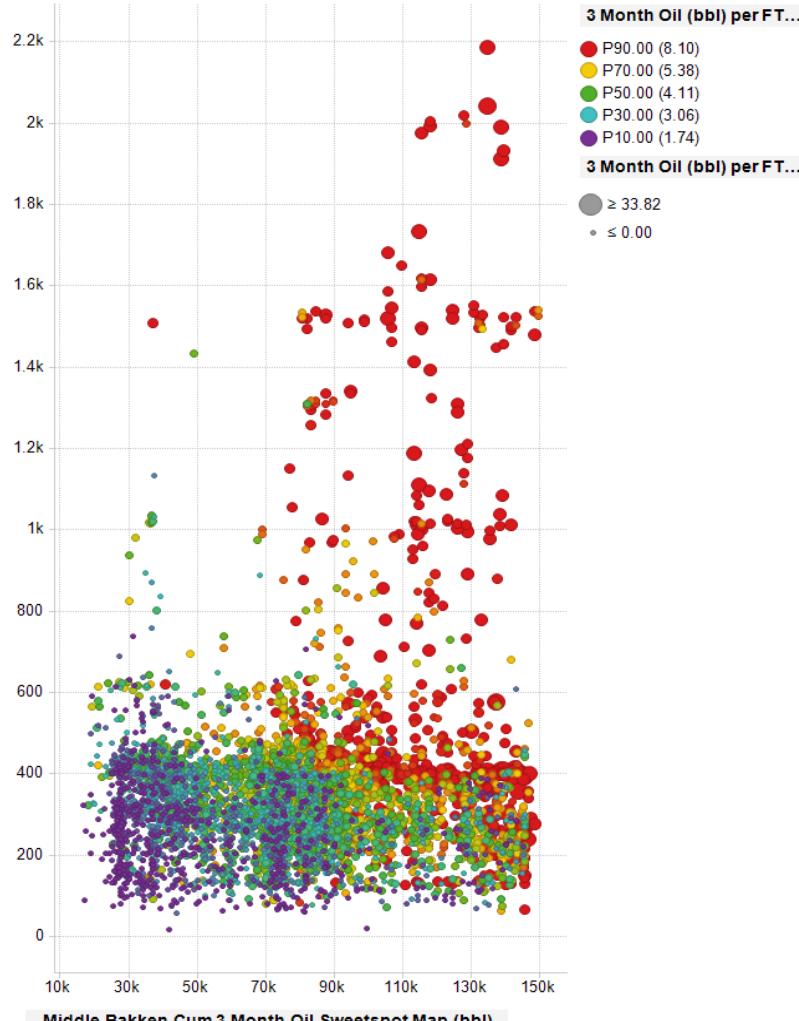
RIGHT SIZING ENGINEERING FOR GEOLOGY



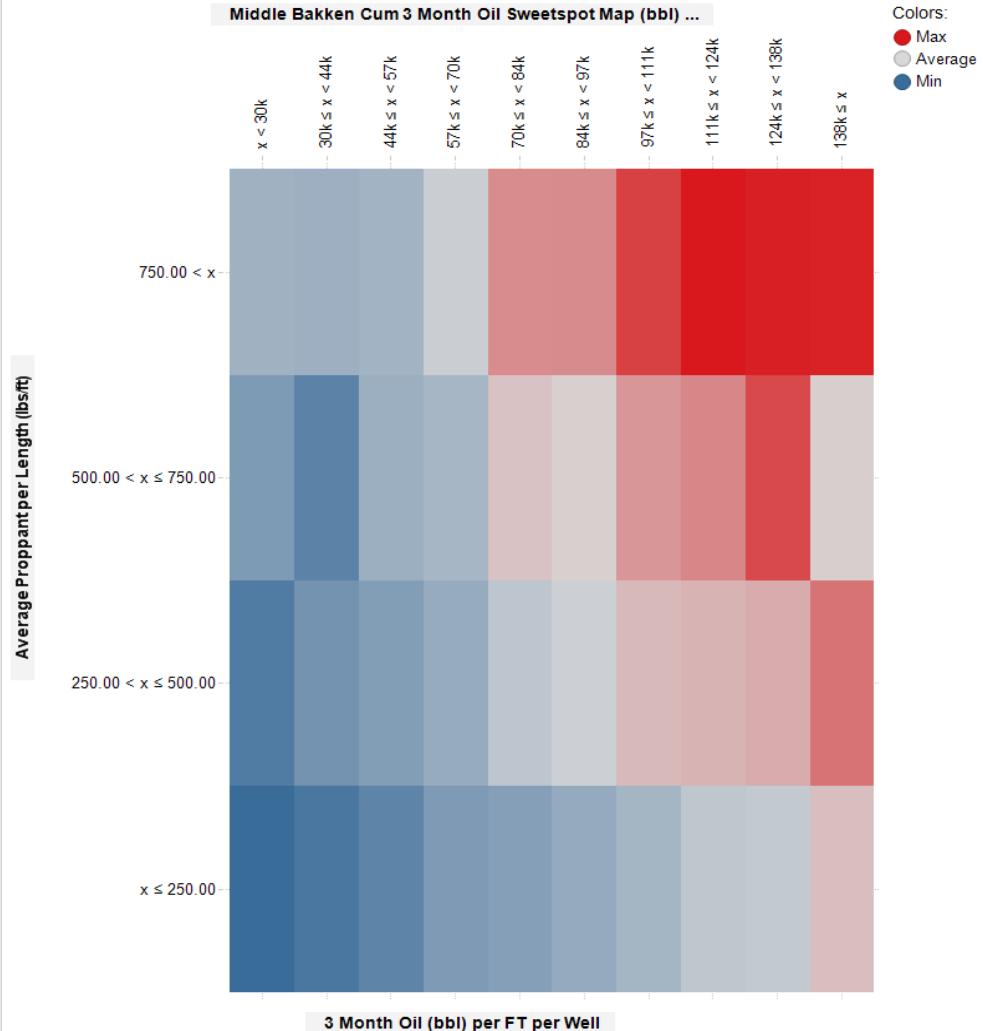
GROUND TRUTH

Middle Bakken Sweetspot Indicator vs. Proppant/ft by 3 Month Oil/ft

Average Proppant per Length (lbs/ft) vs. Middle Bakken Cum 3 Month Oil (bbl) per FT per Well

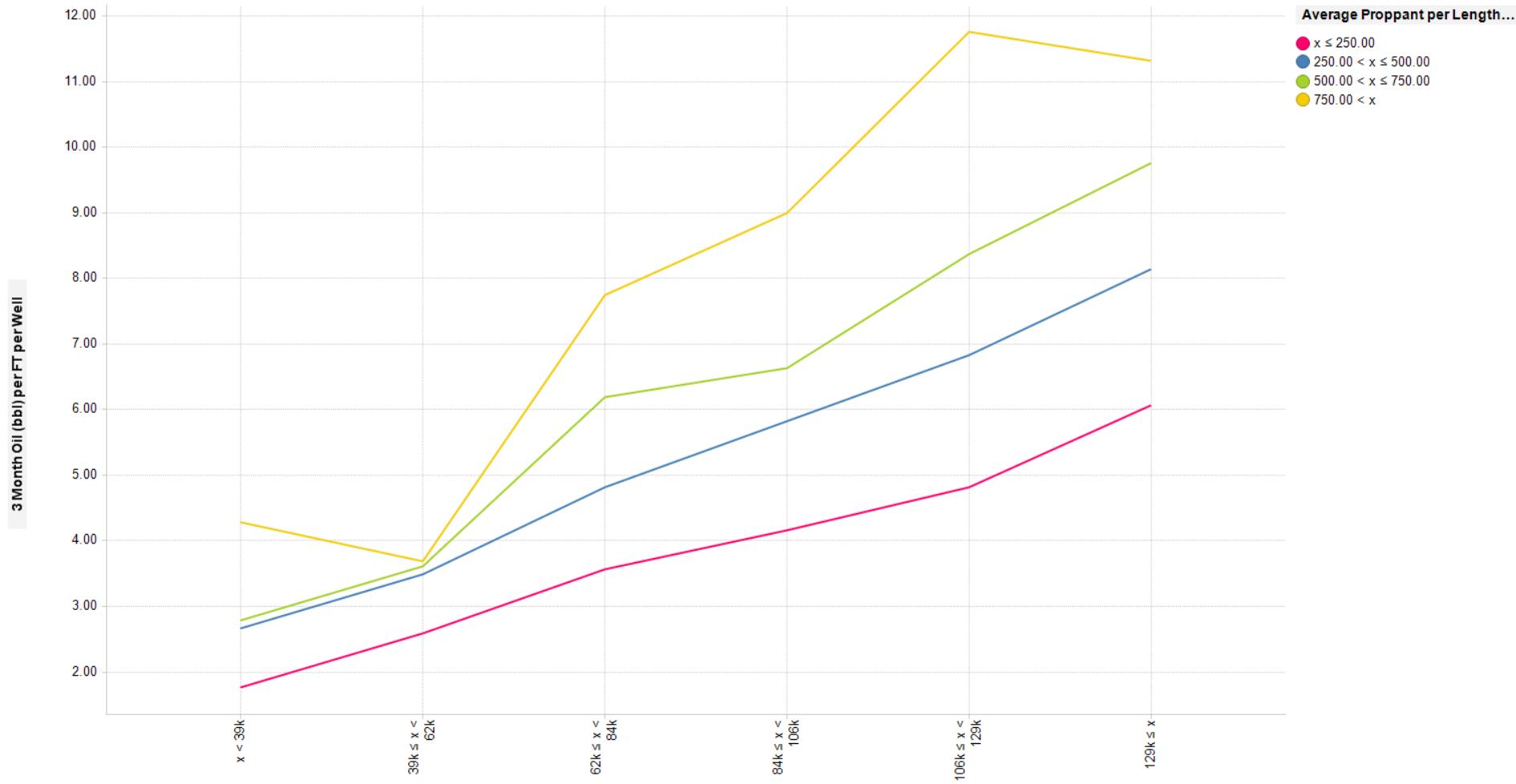


Average Proppant per Length (lbs/ft) vs. Middle Bakken Cum 3 Month Oil (bbl) per FT per Well



Middle Bakken Sweetspot Indicator vs. 3 Month Oil/ft by Proppant/ft

3 Month Oil (bbl) per FT per Well vs. Middle Bakken Cum 3 Month Oil Sweetspot Map (bbl)



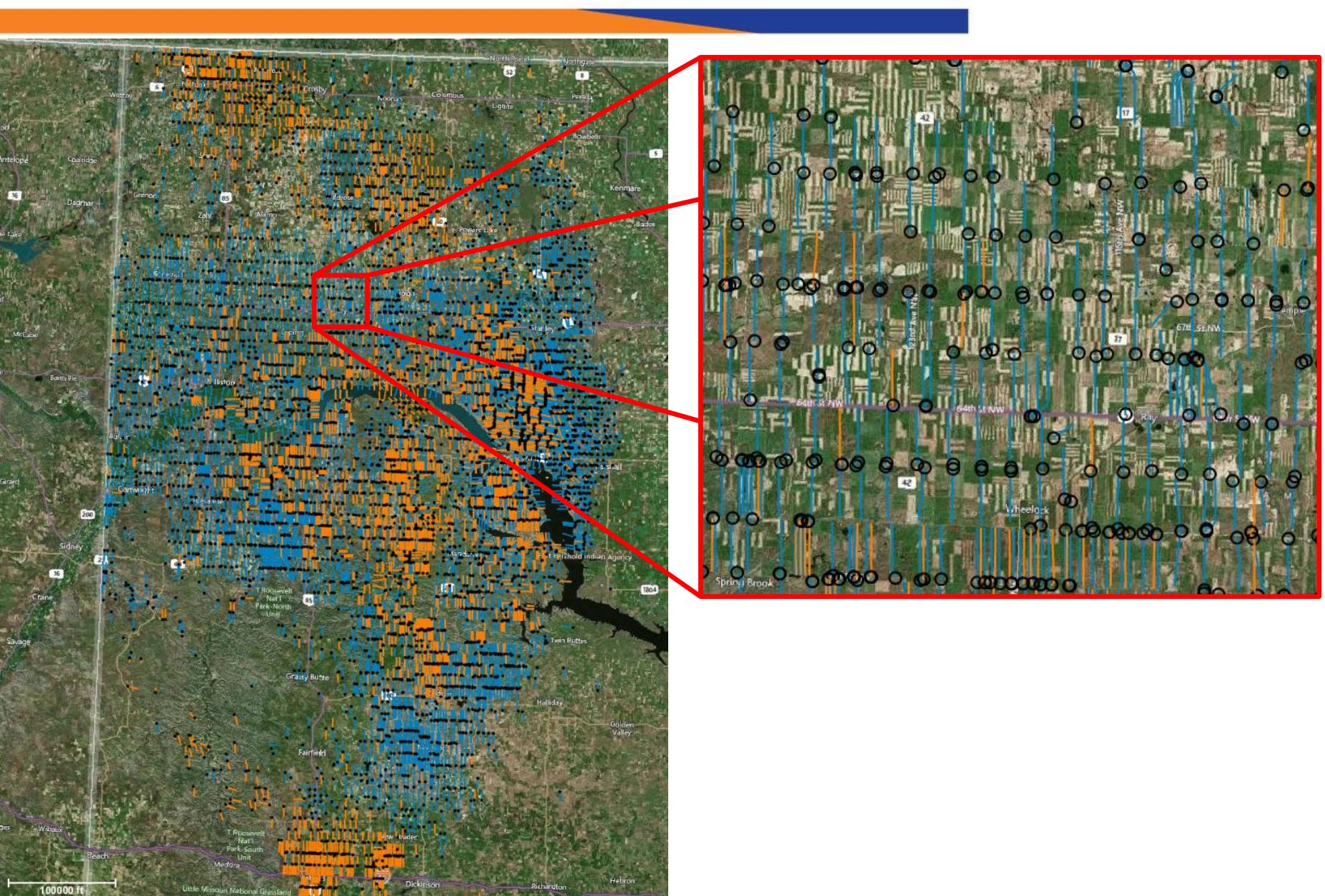
Middle Bakken Cum 3 Month Oil Sweetspot Map (bbl) ...

WELL SPACING IMPACT

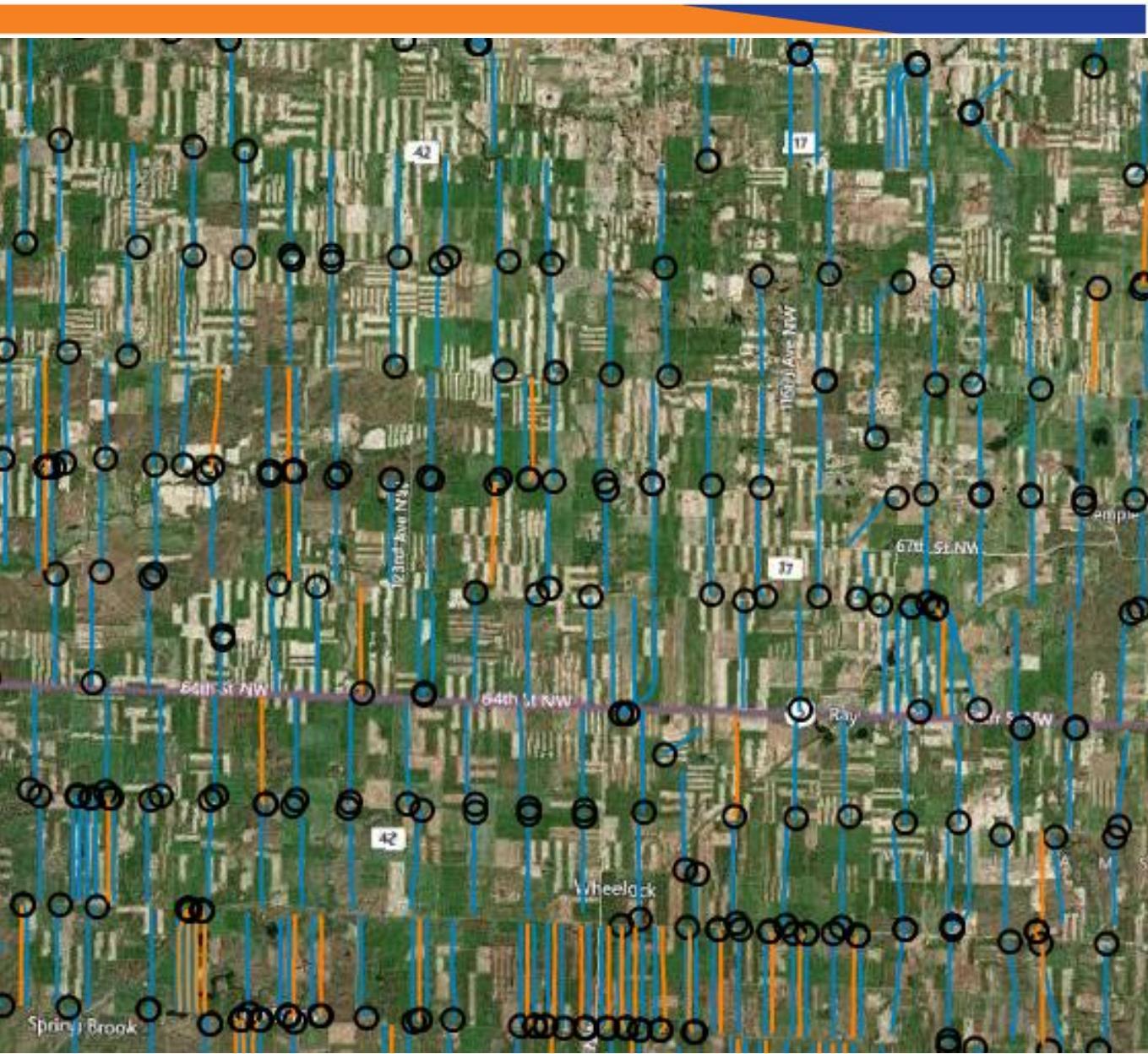


GROUND TRUTH

Well Spacing Analysis Example

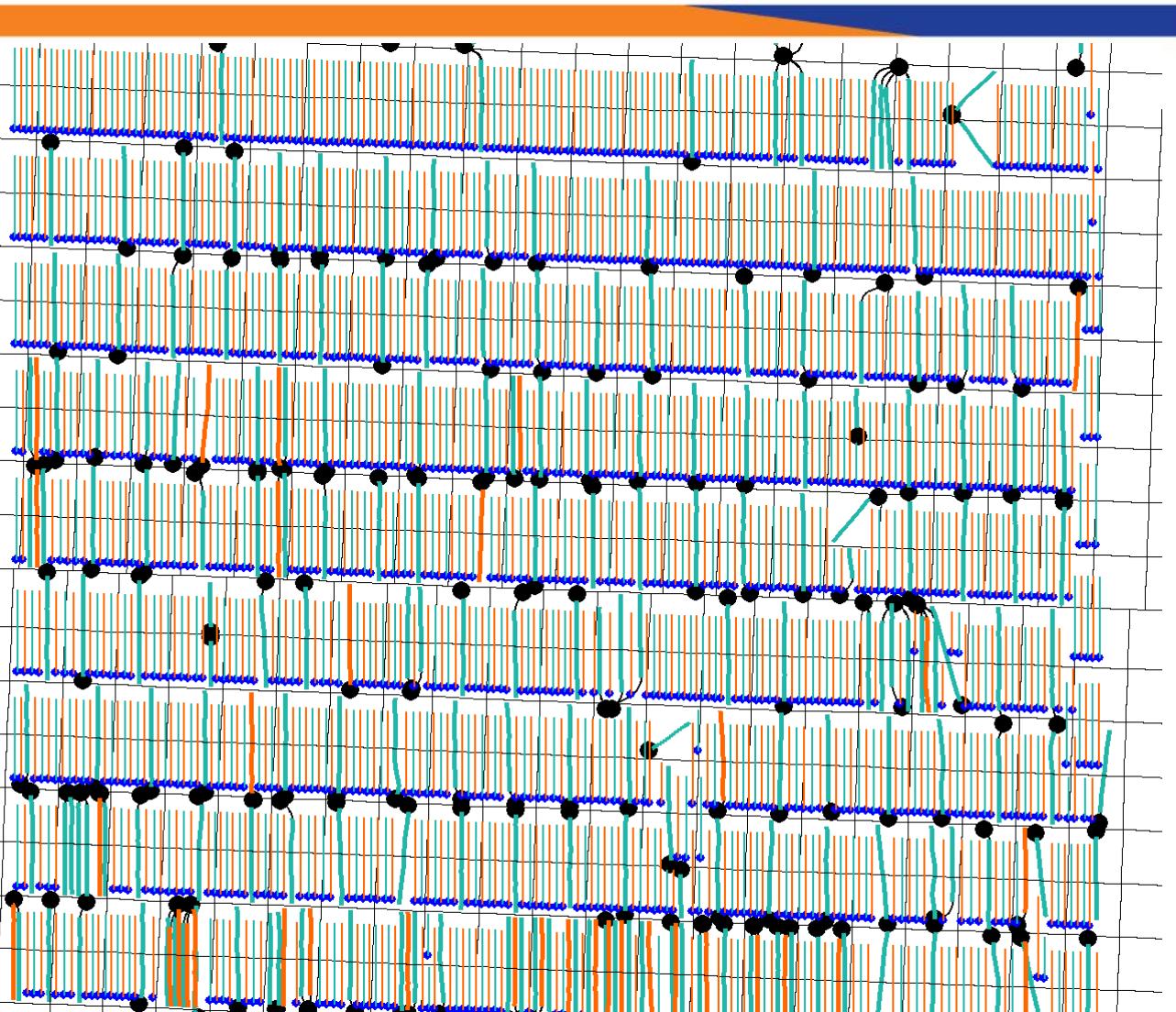


Well Spacing Analysis Example



How many prospective well locations are there?

1200ft Middle Bakken to Middle Bakken Spacing



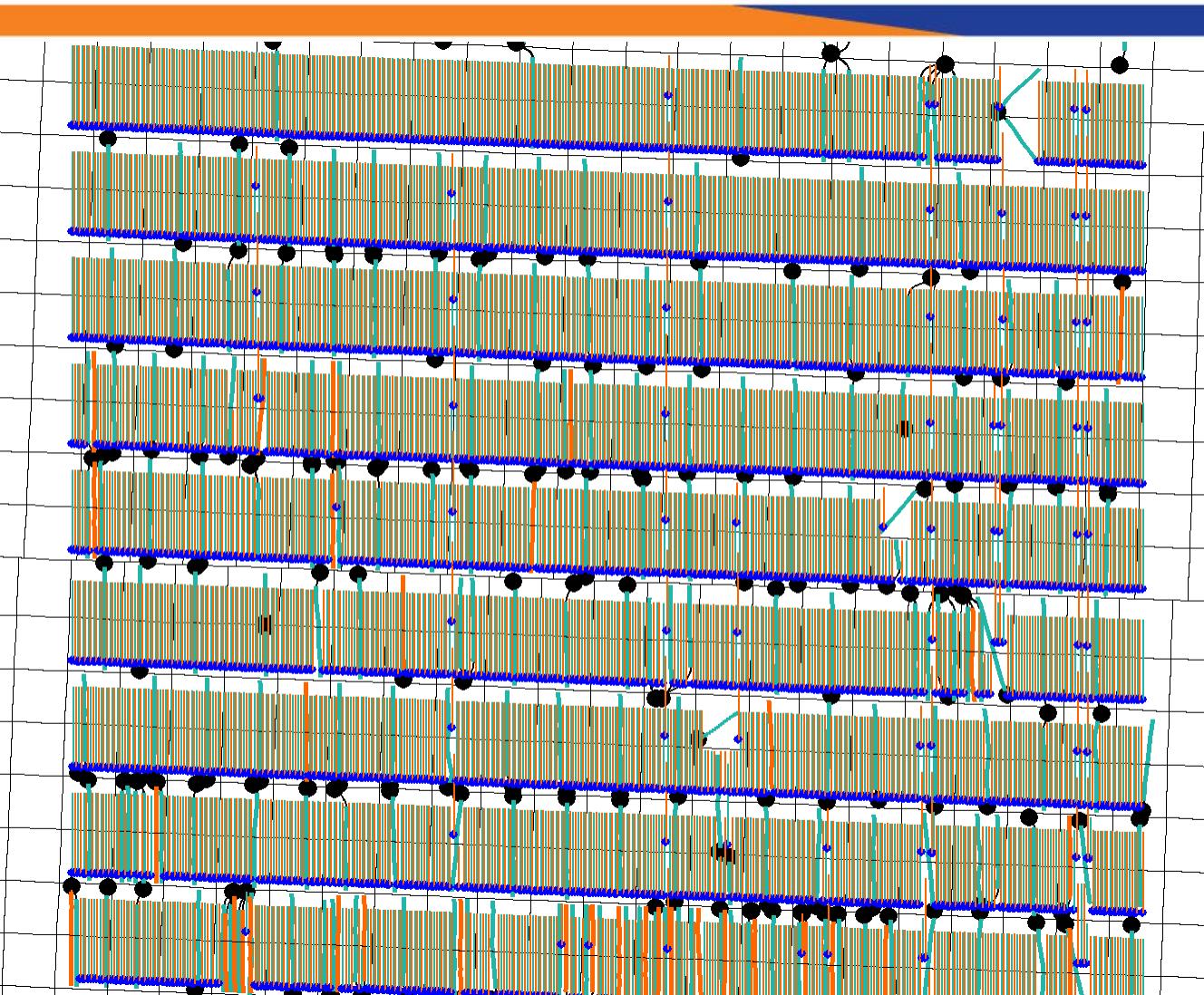
New Locations
= 1179

New Middle Bakken
= 517

New Three Forks
= 662

Estimated Total D&C
Cost (\$8M/well)
= \$9.4B

500ft Middle Bakken to Middle Bakken Spacing



New Locations
= 3379

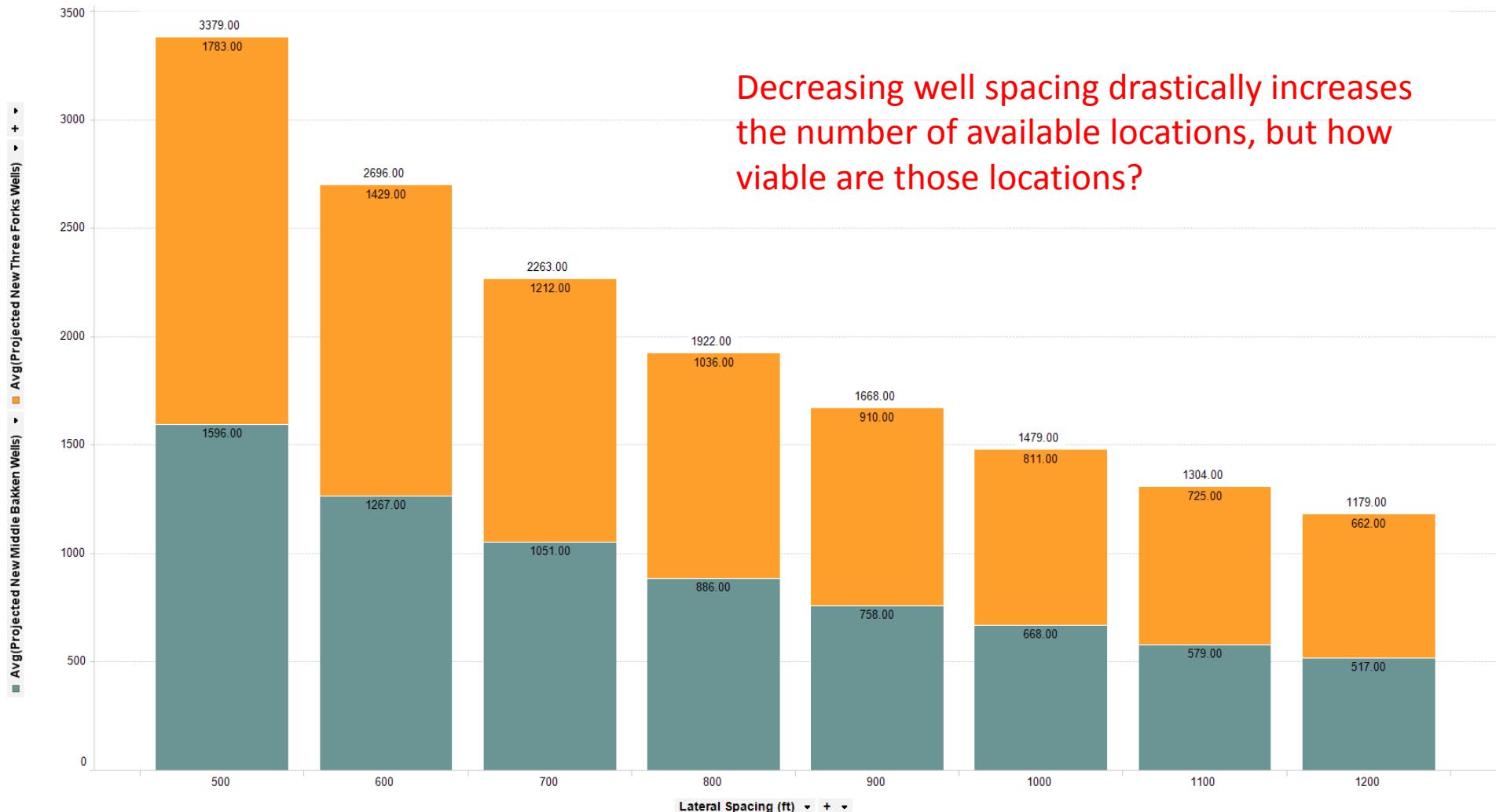
New Middle Bakken
= 1596

New Three Forks
= 1783

Estimated Total D&C
Cost (\$8M/well)
= \$27.0B

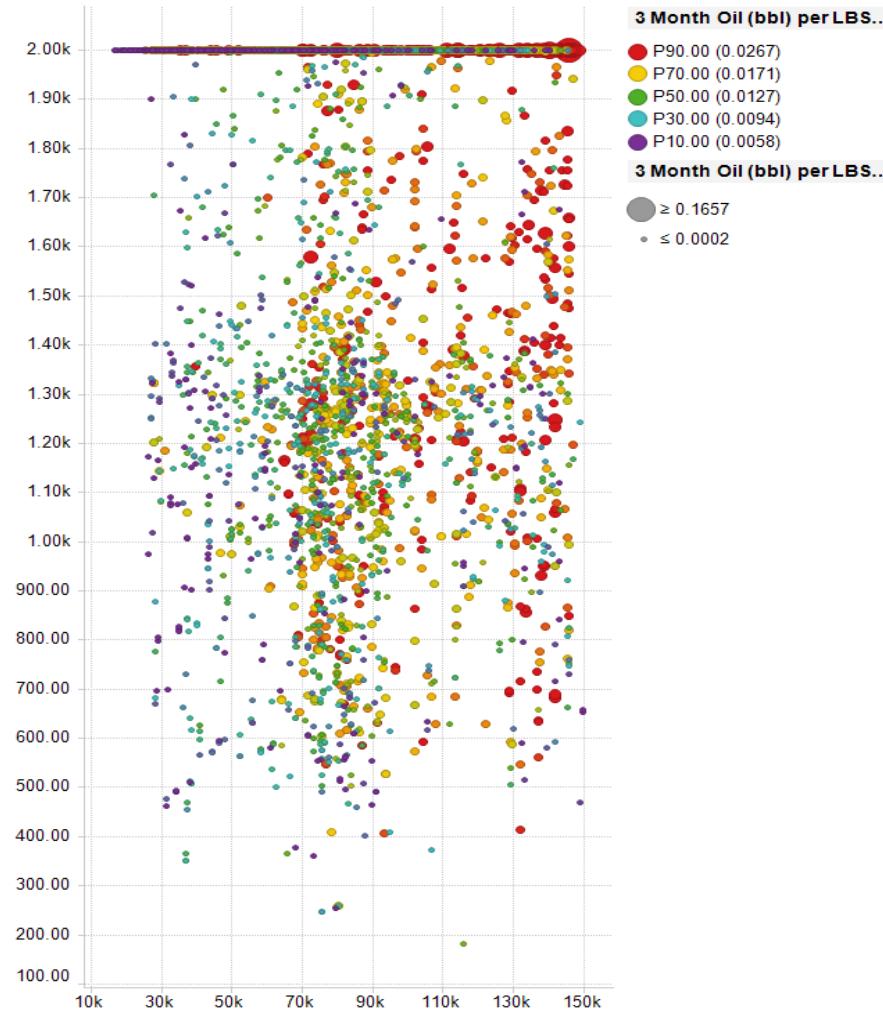
Projected Total New Well Locations vs. Lateral Spacing

Decreasing well spacing drastically increases
the number of available locations, but how
viable are those locations?

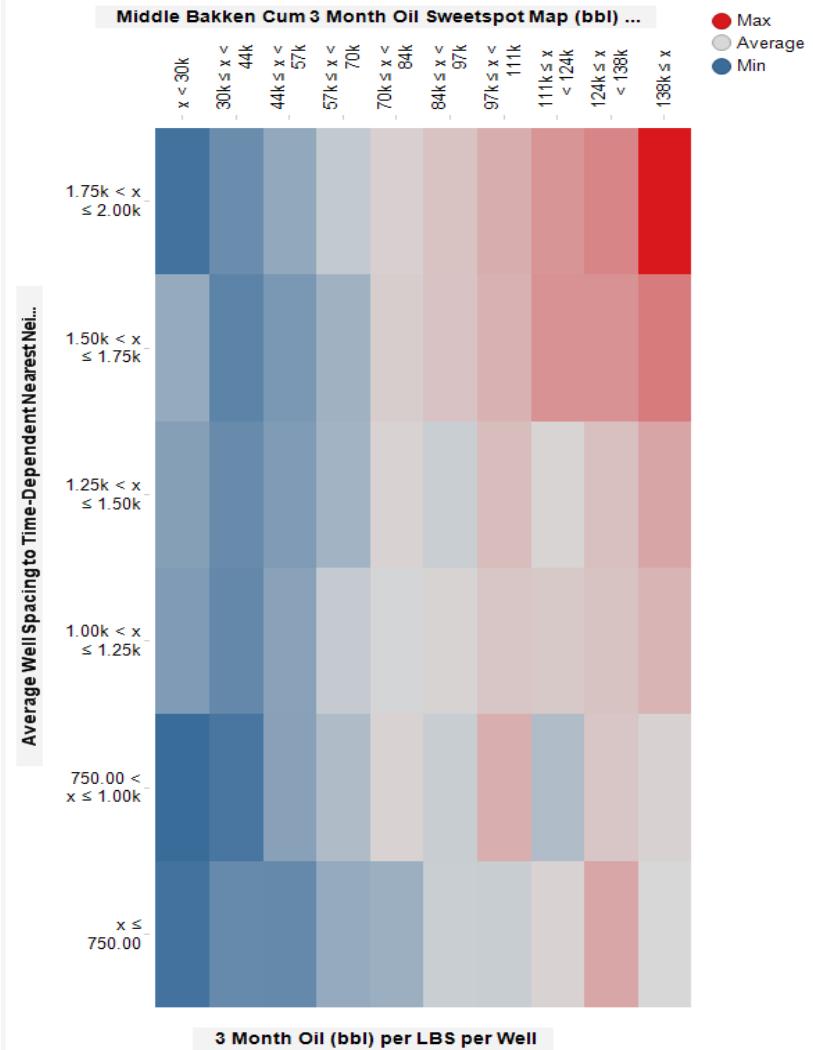


Middle Bakken Sweetspot Indicator vs. Time-Dependent Well Spacing by 3 Month Oil/ft

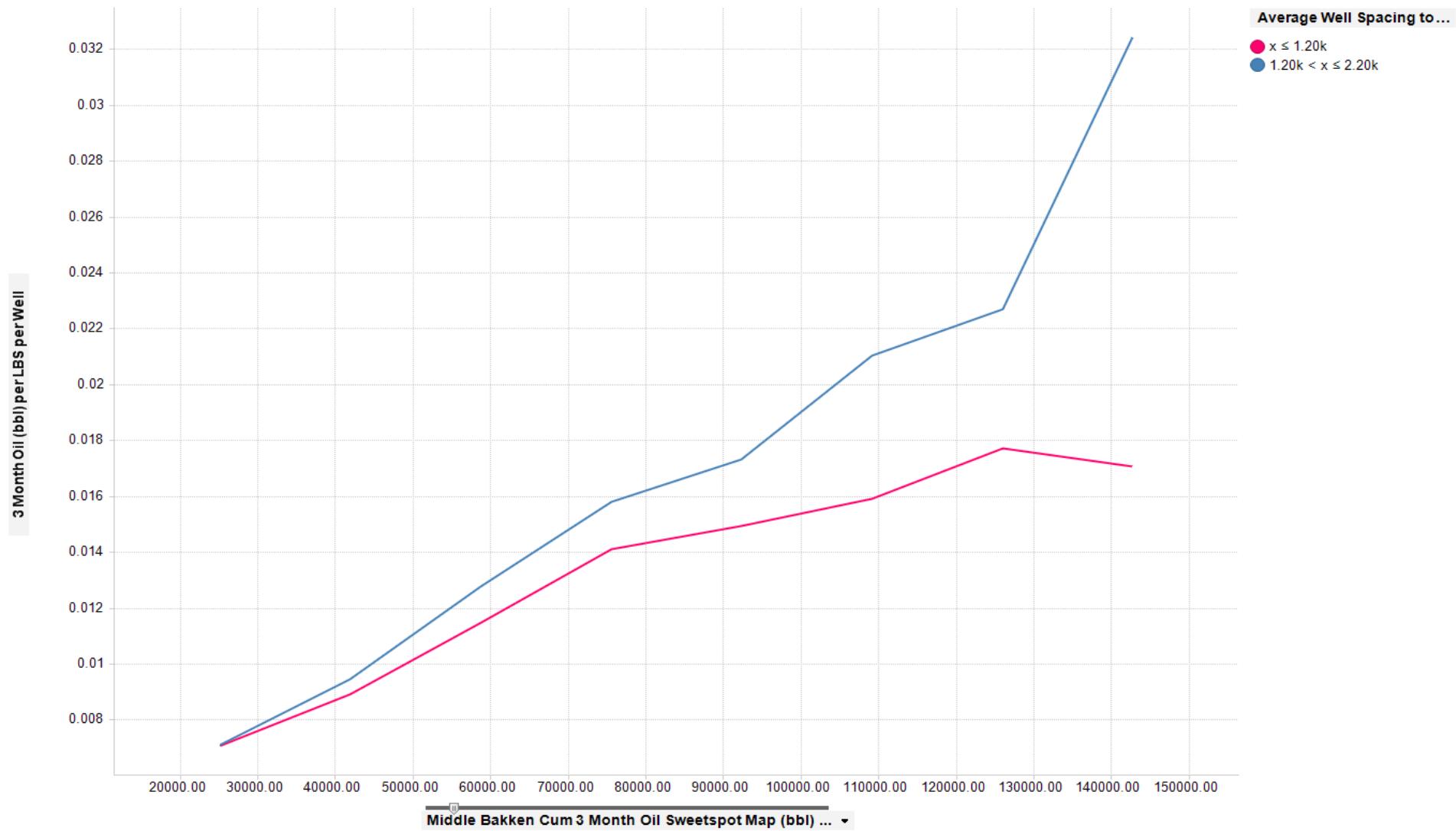
Average Well Spacing to Time-Dependent Nearest Neig...



Average Well Spacing to Time-Dependent Nearest Neig...

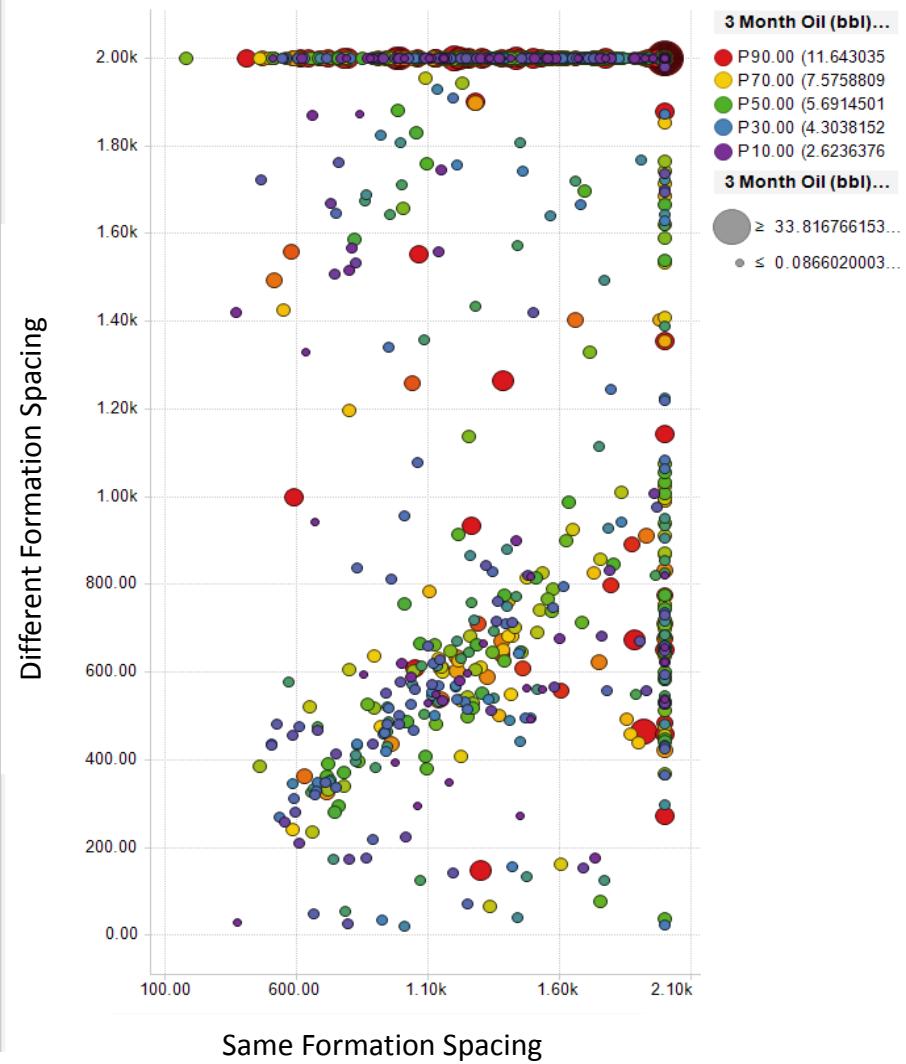


Middle Bakken Sweetspot Indicator vs. 3 Month Oil/lbs by Well Spacing

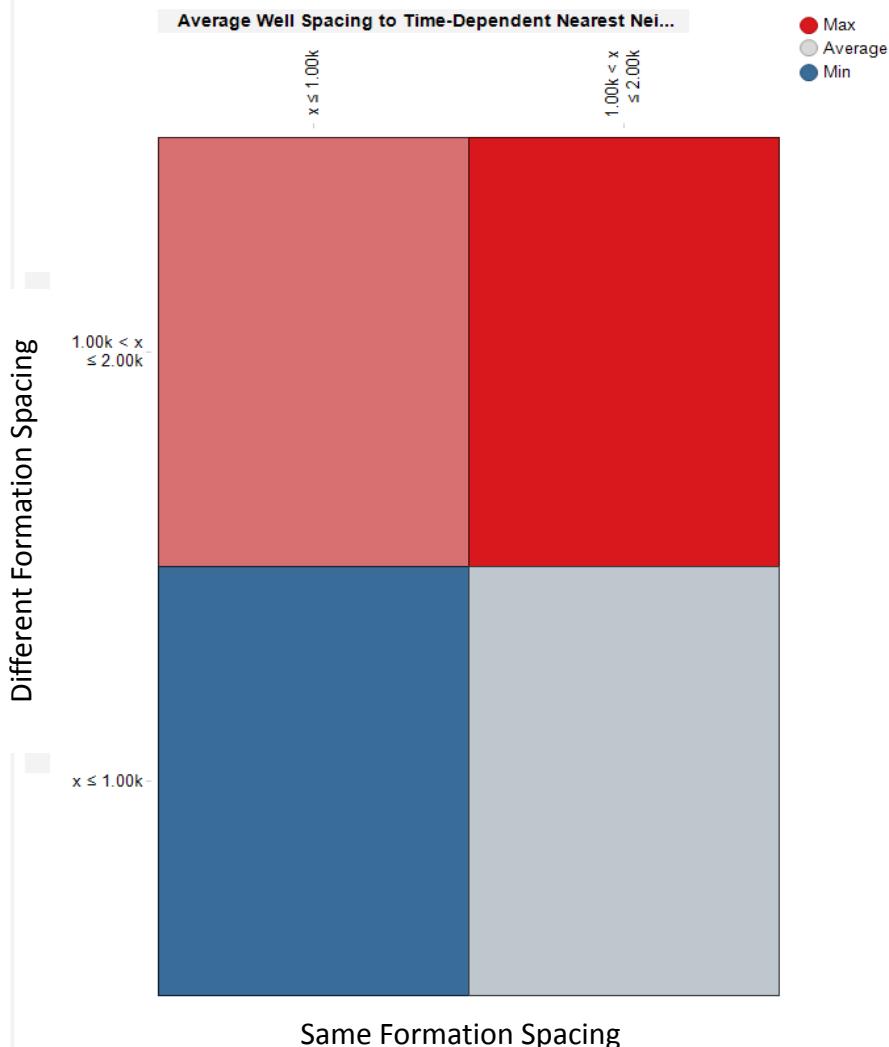


Core Area: Same Formation Spacing vs. Different Formation Spacing by 3 Month Oil/ft

Average Well Spacing to Time-Dependent Nearest Ne...



Spacing Attribute Comparison Heat Map



Conclusions



- Oil Sweetspot defined by:
 - Middle Bakken Depth (>7,000')
 - Middle Bakken to Three Forks Thickness (>70')
 - TMax (>420)
 - TOC (>18)
 - Water Cut (<40%)
- Wells with > 750lbs of proppant/ft show better performance in all ranges of geologic quality
- Decreasing same formation to less than 1,000' spacing can result in a ~33% decrease in production
- Three Forks wells next to Middle Bakken might have negative impact on Middle Bakken well production in core region