

Overview of Development History and Future Potential for the Lower Three Forks Formation (3rd bench): Bakken-Three Forks Petroleum System

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Introduction

Following the discoveries of the Elm Coulee (2000) and Parshall (2005-06) Fields, the Bakken-Three Forks play emerged as a primary exploration and development target for the oil and gas industry across the Williston Basin (fig. 1). Western North Dakota contains the core acreage of the play, and since the discovery of the Parshall Field, daily oil production for the state has grown from approximately 90,000 barrels per day (1990-2005) to over 1.4 million barrels per day in 2019. While recent global events have slowed development and production, more than 15,400 horizontal wells have been drilled and completed within the Bakken and Three Forks Formations to date, which have cumulatively produced over 3.3 billion barrels of oil from North Dakota alone (NDOGD, 2019).

North Dakota operators initially targeted the Middle Bakken as the primary reservoir in the Bakken-Three Forks Petroleum System (2004-2008) (fig. 2). The upper Three Forks then developed into a second viable reservoir target during 2008-2010 (fig. 2). Additional viable reservoir targets were identified and tested in the underlying middle and lower Three Forks during 2013-2014 (fig. 2). The history and development of the middle Three Forks was previously reviewed by Nesheim (2020a), which has had more than 250 horizontal wells drilled and completed in that unit.

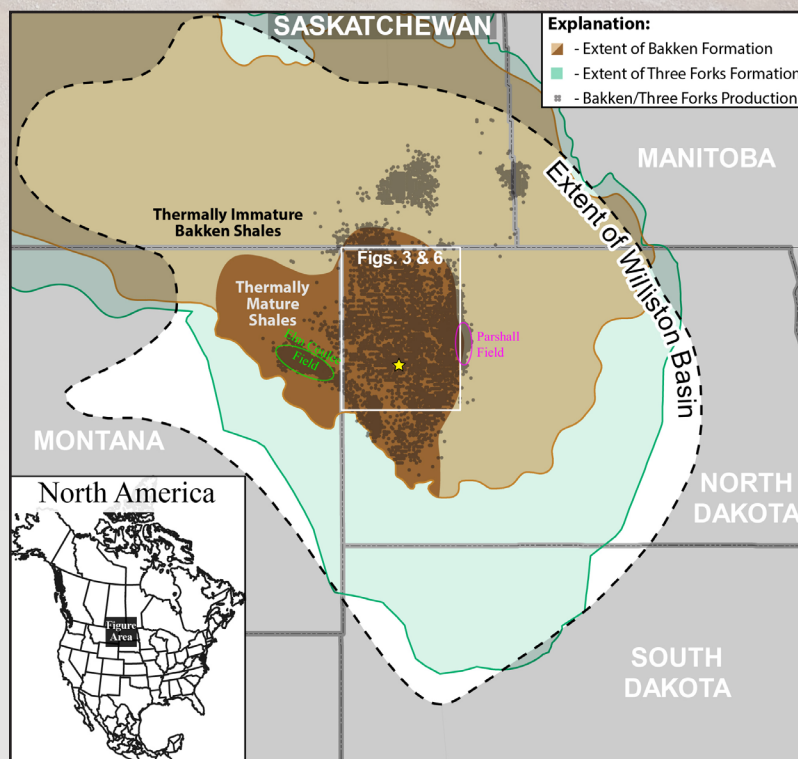


Figure 1. Regional extent and production map of the Bakken and Three Forks Formations in reference to the Williston Basin. The yellow star indicates the figure 2 reference log-core, Denbury's Lundin 11-13SEH (NDIC: 21706, API: 33-053-03829-00-00).

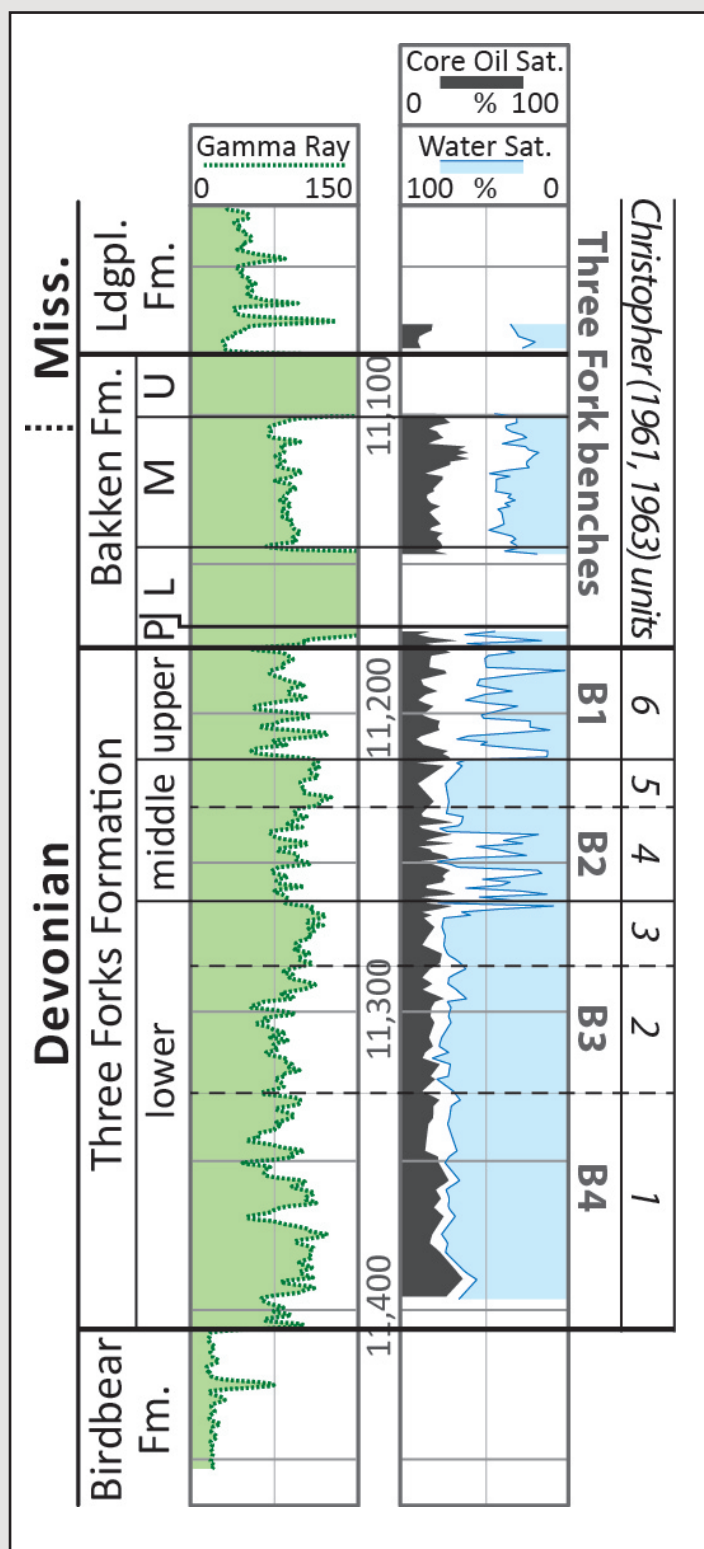


Figure 2. Example gamma-ray log of the Bakken-Three Forks section with core-plug fluid saturation data from Denbury's Lundin 11-13SEH (NDIC: 21706, API: 33-053-03829-00-00). Fm. = Formation; L = Lower Member; Ldgpl. = Lodgepole; M = Middle Member; Miss. = Mississippian; P = Pronghorn Member; U = Upper Member.

Lower Three Forks Discovery, Exploration, and Development

Prior to any drilling or completion activity in the lower Three Forks, operators, led by Continental Resources, initiated a basin-scale coring program to evaluate the entire Three Forks section. The initial two cores that spanned the lower Three Forks were cut in late 2009 by EOG Resources, the Round Prairie 1-17H (NDIC: 18257, API: 33-105-01748-00-00) and Liberty 2-11H (NDIC: 18101, API: 33-061-01027-00-00). After no additional cores of the unit in 2010, ten cores of the lower Three Forks were cut in 2011 followed by thirteen cores in 2012, fourteen cores in 2013, and five cores in 2014. During that span, nearly two dozen different operators cut cores that captured portions to full sections of the lower Three Forks, most notably Continental Resources (9 cores) and Whiting Oil and Gas (7 cores). Elevated oil saturations and fluorescence from several lower Three Forks core samples indicated hydrocarbon charge for the unit within portions of the Williston Basin.

Continental Resources spudded (drilled) the first set of four horizontal wells targeting the lower Three Forks during the final two months of 2012. Of those wells, the first completed and commercially productive was the Stedman 3-24H3 (NDIC: 24493, API: 33-105-02920-00-00), which is located within the Hebron Field of Williams County (fig. 3). The Stedman was completed with a 30-stage hydraulic fracture stimulation which injected nearly 2.9 million pounds of sand and ceramic proppant along with 59,007 barrels of fluid. With a modest initial production (IP) of 240 barrels of oil and 221 million cubic feet of gas, the Stedman has cumulatively produced over 111,000 barrels of oil and 93,000 million cubic feet (MCF) of gas and is still producing to this date.

One of the most productive lower Three Forks horizontal wells has been Oasis Petroleum's Helling Trust Federal 5494 43-22 16T3 (NDIC: 28061, API: 33-061-03051-00-00) located within the Alkali Creek Field in southwestern Mountrail County (fig. 3). Initially drilled in late 2014, the Helling Trust Federal well was completed in early 2015 with a 50-stage hydraulic fracture stimulation which injected almost 3 times as much proppant and fluid as the Stedman 3-24H3 (injected approximately 148,209 barrels of fluid along with 8.9 million pounds of partially resin-coated sand). The Helling Trust Federal yielded an IP of 961 barrels of oil along with 1,204 MCF of gas and went on to total approximately 257,000 barrels of oil during the first 700 days of production. Cumulatively, the Helling Trust Federal has produced 349,916 barrels of oil, 529,263 MCF of gas, and is still actively producing.

There were 10 horizontal wells producing from the lower Three Forks by the end of 2013, and 30 producing wells by the end of 2014. A total of 37 horizontal wells were drilled targeting the lower Three Forks from late 2012 through the end of 2014, a period when oil prices (WTI) ranged from \$85-\$110 per barrel. However, only 6 additional lower Three Forks wells have been drilled and completed since the beginning of 2015 (fig. 4). During this period, WTI oil prices ranged between \$45-\$65 per barrel and oil production from the unit dropped below 40,000 barrels per month, down from a high of over 100,000 barrels (fig. 4).

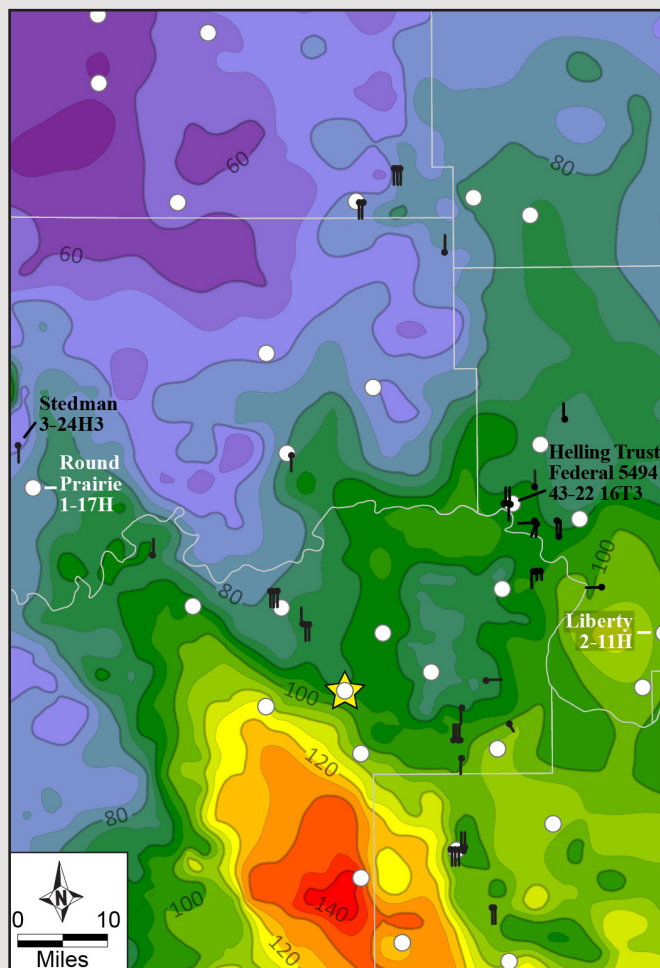


Figure 3. Horizontal lower Three Forks well map underlain by isopach (thickness) contours of the Pronghorn-upper Three Forks-middle Three Forks composite section, which is the stratigraphic interval that separates the lower Three Forks (reservoir) from the Lower Bakken Member (hydrocarbon source) (fig. 2). The vertical separation between the source and reservoir intervals may be a factor in controlling hydrocarbon charge within the lower Three Forks and ultimately well production. The yellow star indicates the Figure 2 reference well log-core, Denbury's Lundin 11-13SEH (NDIC: 21706, API: 33-053-03829-00-00). White circles represent lower Three Forks core locations with white labels indicating the initial two cores cut in the unit. Additional lower Three Forks cores extend beyond the map area.

There has been a total of 43 horizontal wells drilled and completed within the lower Three Forks in western North Dakota that have been identified to date (Nesheim, 2020b) (fig. 3). Most of these lower Three Forks horizontal wells (41) have been drilled within the upper portions of the interval, equivalent to the unit 2 from Christopher (1961, 1963) and the 3rd bench as referred to by industry (fig. 2). The other two wells were drilled within the basal portions of the lower Three Forks, within the interval equivalent to unit 1 from Christopher (1961, 1963) and the industry's 4th bench (fig. 2). Wells drilled and completed within the lower Three Forks have cumulatively produced 5,745,244 barrels of oil and 10,656,888 MCF of gas.*

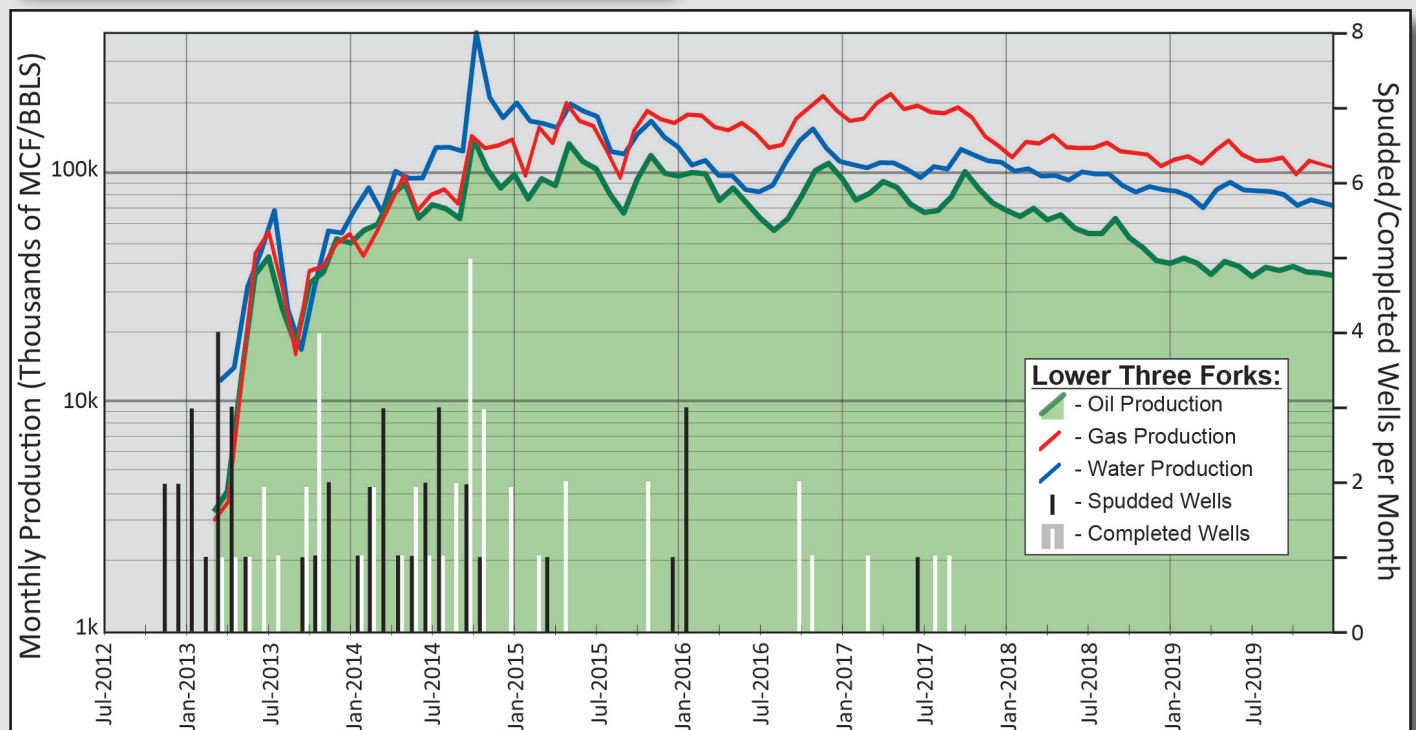


Figure 4. Monthly production diagram for lower Three Forks horizontal wells of western North Dakota with monthly spudded and completed well totals for the unit. Production data is through the end of 2019.

*Production data is through July 2020 and does not include the production from any wells on confidential status.

Current Status

In 2019, 37 lower Three Forks wells had a monthly production average of 39,000 barrels of oil (fig. 4). However, the last lower Three Forks horizontal well was completed in 2017 (fig. 4). Industry typically develops oil plays when new wells can generate enough profit to pay for the initial drilling and completion costs within 3-4 years or less. The initial cost of a two-mile horizontal Bakken-Three Forks well is approximately \$7.5 million. Assuming an average wellhead price of \$50 per barrel, plus factoring in 20% royalty to the mineral right owner(s) and 10% tax to the state (both on gross oil sales), a new horizontal well would have to produce approximately 214,000 barrels of oil to net \$7.5 million. Out of the 43 lower Three Forks horizontal wells drilled and completed to date, only six wells have cumulatively produced 214,000 barrels of oil, three of which reached that mark in two years or less whereas the other three took 4+ years (fig. 5). The average lower Three Forks horizontal well cumulatively produces approximately 113,000 barrels of oil through the 3-year mark and 129,000 barrels through the 4-year mark (fig. 5). At those 3- and 4-year production totals, wellhead oil prices would need to be within the \$80 to \$100 per barrel range to make the average lower Three Forks well economic. However, focusing on the more productive lower Three Forks acreage, operators could yield some economic results at sub-\$80 per barrel prices.

The most productive lower Three Forks acreage, including wells like the Helling Trust Federal, are located within the central

portions of the Williston Basin, including northeastern McKenzie, northwestern Dunn, and southwestern Mountrail Counties (fig. 6). Within the central basin area, lower Three Forks water-cut drops consistently below 60%, and locally below 50% (fig. 6). Water-cut is the percentage of water comprising the total produced fluids. As the water-cut decreases, the percentage of oil produced increases. The sub-60% water-cut area is sizable, but overlaps with most of the top tier Middle Bakken, upper and middle Three Forks acreage. In the relative low oil price environment of the past several years, operators have focused on the best producing reservoirs within the most productive acreage. The best lower Three Forks wells are still less economic than the Middle Bakken, upper and middle Three Forks wells which have sustained the development of the play.

Future Potential

Conservatively, the sub-60% water-cut areas, which overlap with most of the better-producing lower Three Forks horizontal wells, total approximately 710,000 acres (fig. 6). Subdividing that acreage by the standard 1,280-acre spacing units, the standard of the Bakken-Three Forks play, translates into approximately 550 spacing units for the lower Three Forks. Furthermore, using a multiplier of three horizontal wells per spacing unit, there is the potential for over 1,600 horizontal lower Three Forks wells (~3rd bench wells) within the sub-60% water-cut areas. More optimistically, the sub-70% water-cut area spans over 1,600,000

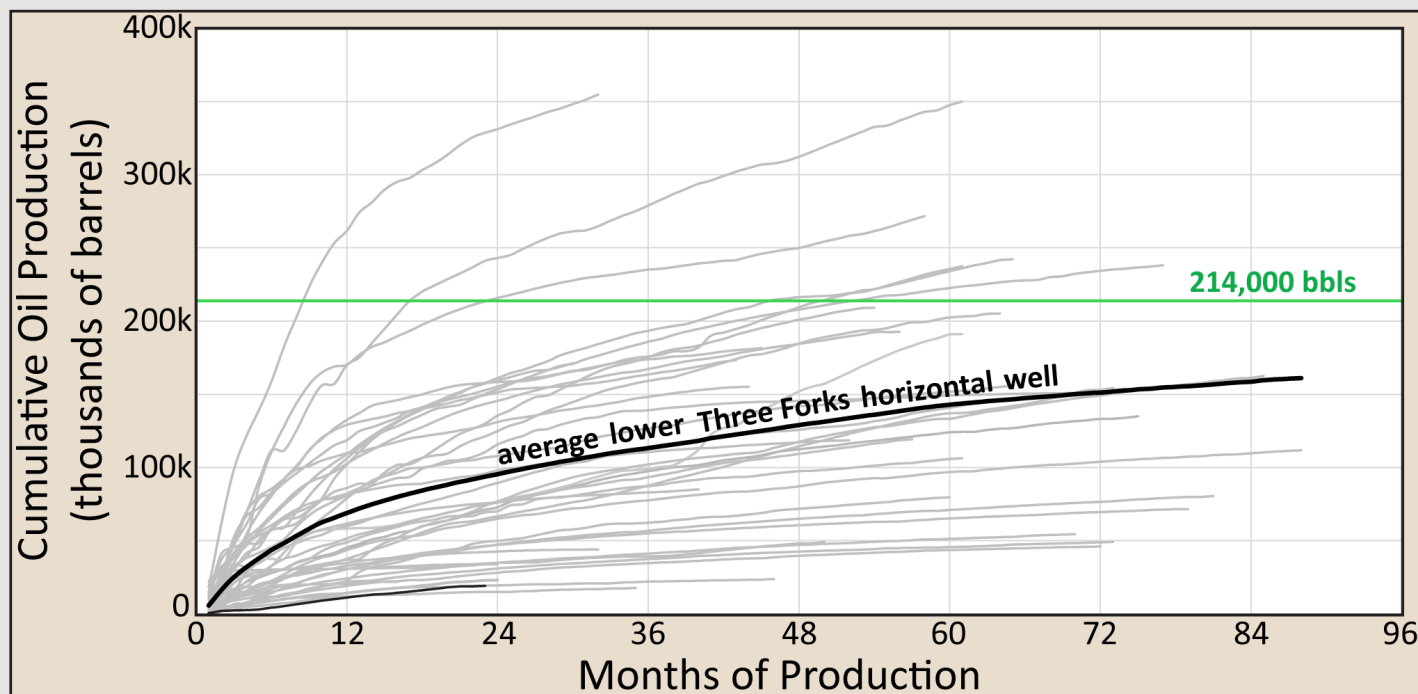


Figure 5. Cumulative oil production plots for lower Three Forks horizontal wells. The thin, light grey lines represent cumulative oil production versus cumulative production months for individual lower Three Forks horizontal wells. The 214,000 barrels of oil mark represents the approximate production threshold at which a horizontal well has generated enough revenue at the \$50 per barrel pricing to cover the initial costs to drill and complete the well.

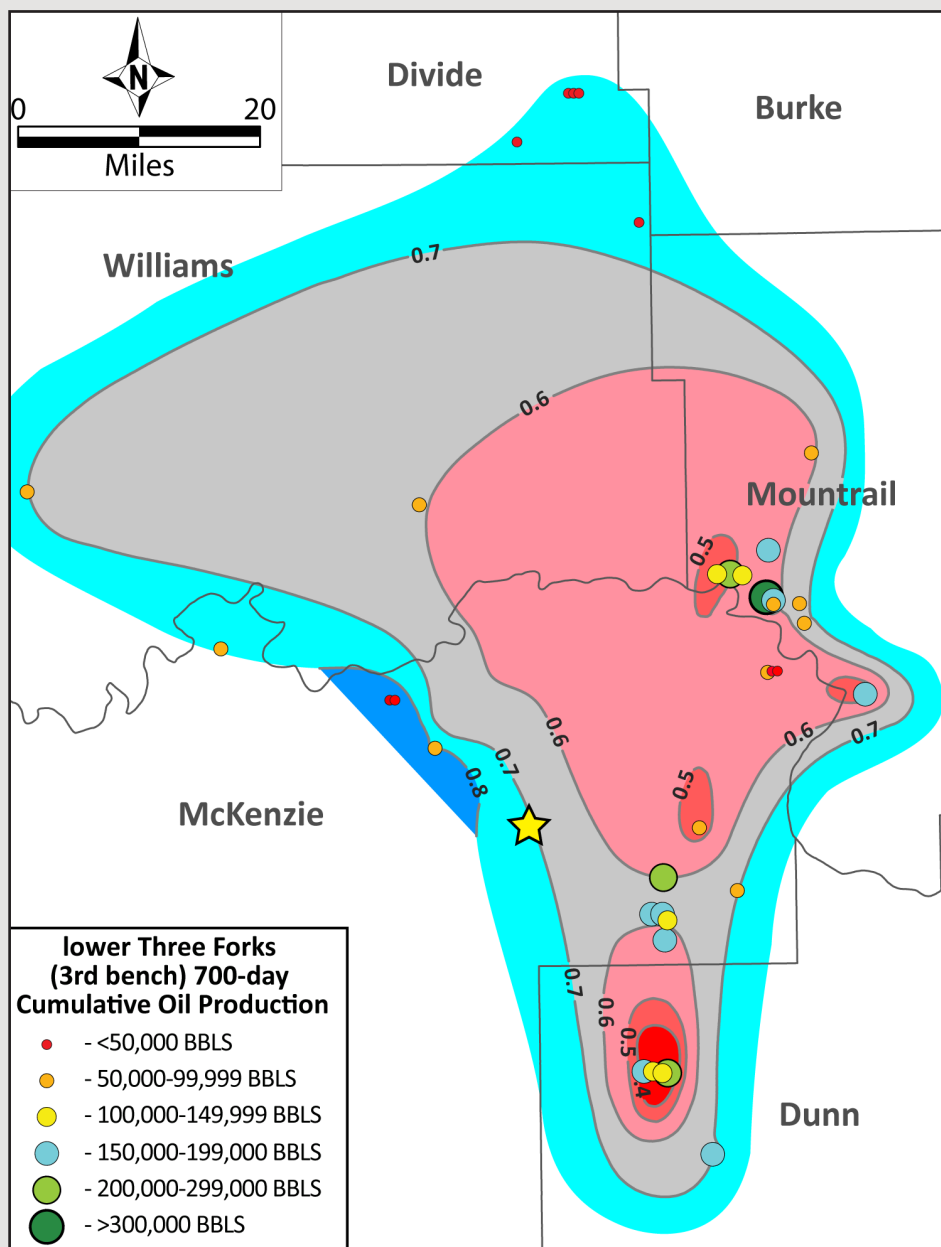


Figure 6. Water-cut contour map for lower Three Forks 3rd bench/unit 2 (Christopher, 1961, 1963) production and 700-day cumulative oil production bubbles from Nesheim (2020c). The yellow star indicates the figure 2 reference well log-core data.

acres, which is more than double that of just the sub-60% water-cut areas (fig. 6). Given all of this, the prospective number of future horizontal lower Three Forks wells could reach upwards of several thousand wells.

Although the lower Three Forks has sat dormant for the past few years, several factors will eventually lead to a revival of activity in the unit. First, operators continue to develop the Middle Bakken and the upper-middle Three Forks within the central basin area, where the lower Three Forks shows the most promise for potential productivity. Eventually the remaining well inventories of the Middle Bakken and the upper-middle Three Forks will decrease to the point where operators will shift some developmental focus to the lower Three Forks. Second, oil prices are always fluctuating through boom-bust cycles, and eventually another oil-price driven boom will occur which will assist

in bringing back activity to the lower Three Forks. Third, technology for drilling and completing unconventional-style horizontal wells continues to improve. Most lower Three Forks wells are now four or more years old, and therefore were not completed with the most up-to-date methodology. Technological advances will also play a role in eventually bringing back lower Three Forks activity. Although the lower Three Forks currently represents a small fraction of the total production from the greater Bakken-Three Forks plays, it will likely contribute to extending the play's lifespan by at least several years of additional drilling inventory, as well as added long-term production.

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