PRELIMINARY CASE STUDY OF

MIDDLE THREE FORKS CO-DEVELOPMENT INFLUENCE UPON UPPER THREE FORKS WELL PERFORMANCE

Within The Bakken-Three Forks Petroleum System

BY TIMOTHY O. NESHEIM

INTRODUCTION

Exploration and development of the Bakken Petroleum system as a modern unconventional oil play (horizontal drilling coupled with hydraulic fracture well completions) began in the mid-2000s within western North Dakota (Nordeng et al., 2010). While initial exploration and development focused on the Middle Bakken reservoir, the upper Three Forks evolved into a second primary reservoir during the late 2000s (fig. 1) (Gaswirth and Marra, 2015; Nesheim 2019). To date, more than 17,500 wells have been drilled and completed within the Middle Bakken and upper Three Forks Formations (USGS, 2021).

Horizontal drilling in the middle Three Forks began in late 2012 followed by initial well completions and production in early 2013 (Nesheim, 2020a). By the end of 2020, more than 250 horizontal middle Three Forks wells had been drilled and completed with combined cumulative production of more than 57 million barrels of oil and 120 billion cubic feet of gas (fig. 1 and 2) (Nesheim, 2020a). Middle Three Forks hydrocarbon charge appears concentrated within the central, deepest portions of the Williston Basin where the Lower Bakken shale is both relatively thick (≥20 feet) and at its highest levels of thermal maturity, generating enough hydrocarbon volume to migrate downwards to charge not only the upper Three Forks but the underlying middle Three Forks as well (Nesheim, 2019).

While hundreds of productive horizontal wells have been drilled and completed within the middle Three Forks, questions remain regarding the development of the unit. One important set of related questions: how does middle Three Forks horizontal well development influence

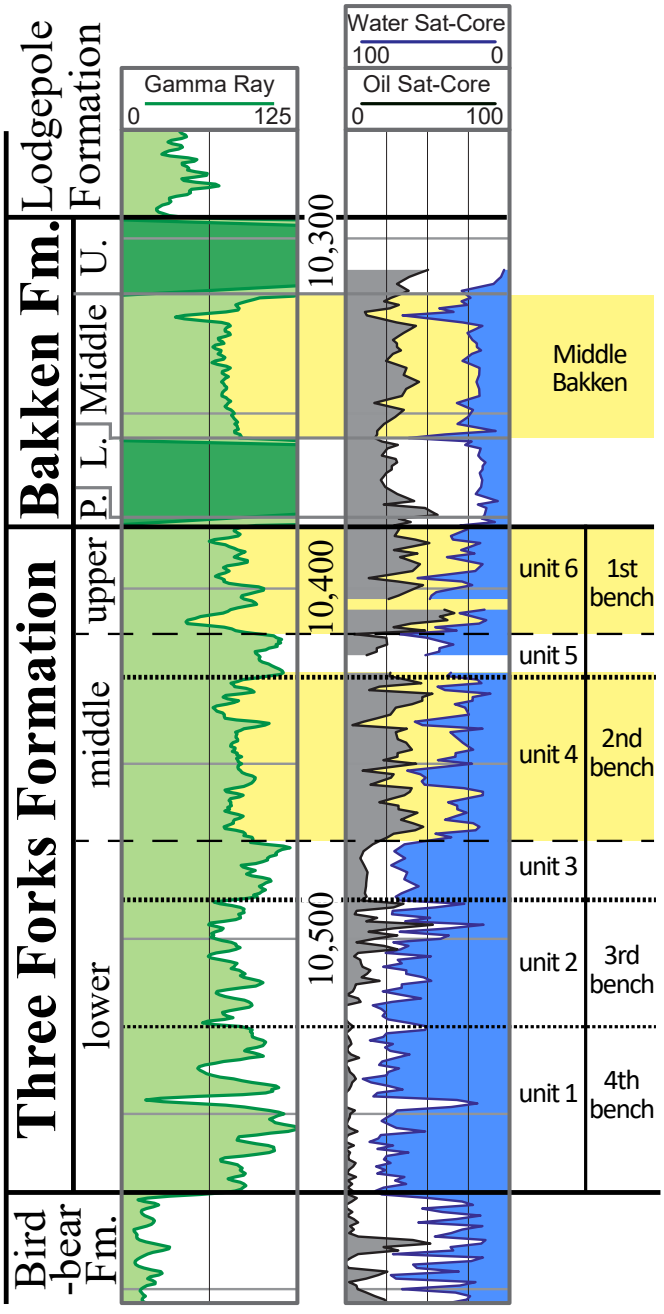

FIGURE 1.
Gamma-ray wireline log example of the Bakken-Three Forks section with core-plug oil and water saturation data from Enerplus Resource's Hognose 152-94-18B-19H-TF (NDIC: 26990; API: 33-053-05475-00-00). Upper-middle-lower Three Forks stratigraphic nomenclature system is from Bottjer et al. (2011), and the 6-unit subdivision system is from Christopher (1961; 1963).

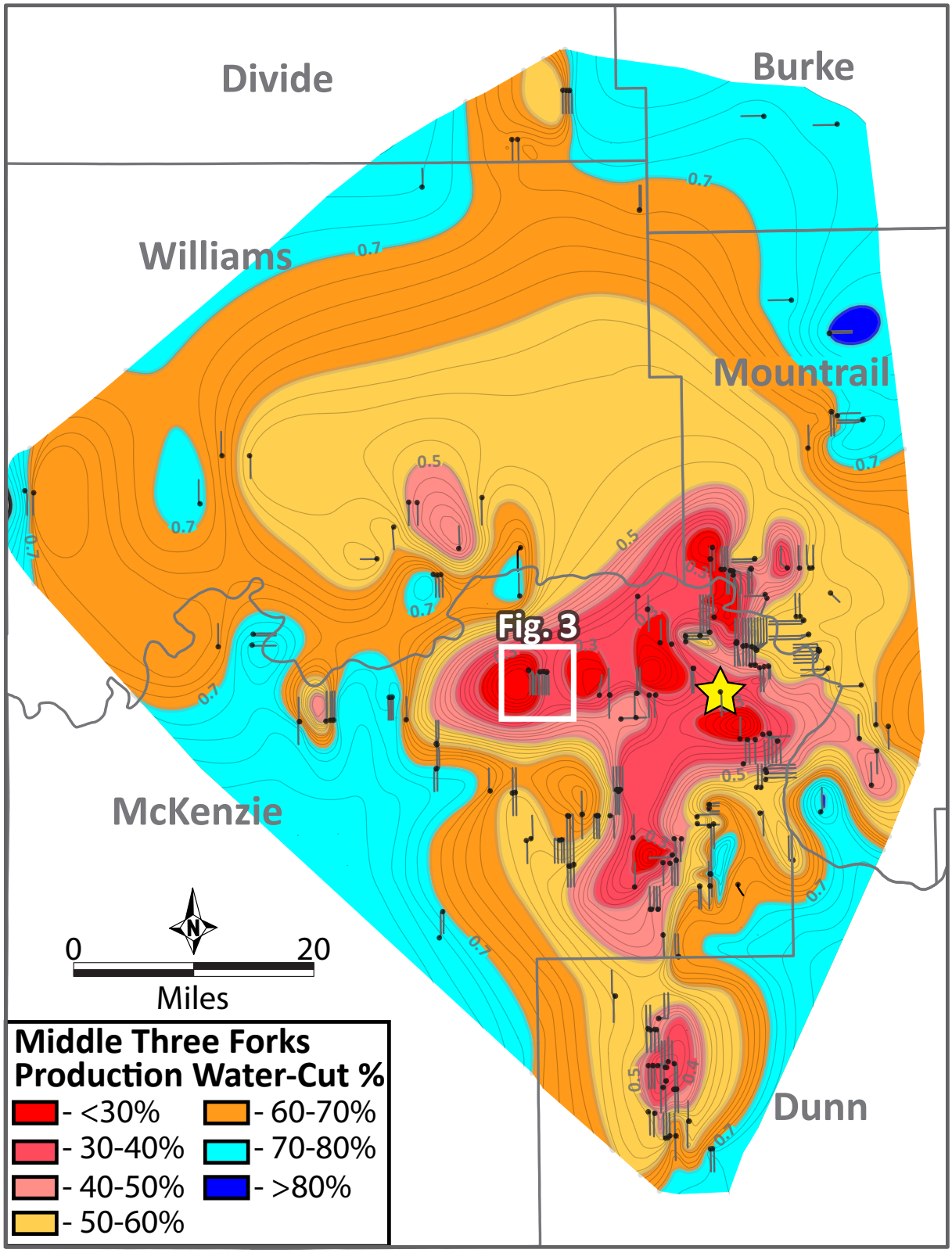

FIGURE 2. Contour map depicting calculated middle Three Forks water-cut from horizontal well production. Water-cut contours are in 0.01 fractional increments. Black dots and lines represent surface locations and corresponding horizontal boreholes for middle Three Forks wells. The white outline depicts the Figure 3 map area and the yellow star depicts the location of the Figure 1 well location. Modified from Nesheim (2020b).

production from horizontal wells drilled and completed within the overlying upper Three Forks? How much oil and gas production from middle Three Forks horizontal wells comes from the overlying upper Three Forks reservoir? When the middle Three Forks is co-developed within the upper Three Forks, are the co-developed upper Three Forks wells less productive than when the middle Three Forks is not co-developed?

In order to evaluate the effect of middle Three Forks co-development on upper Three Forks production, a preliminary case study was completed comparing upper Three Forks production in adjacent areas both with and without middle Three Forks co-development. The Twin Valley Field area (figs. 2 and 3) was selected for this case study for several reasons: 1) location within the area of middle Three Forks hydrocarbon charge (Nesheim, 2019),

2) co-development of the Middle Bakken, upper Three Forks, and middle Three Forks reservoirs with approximately 3-4 wells per target horizon per 1280-acre spacing unit, and 3) field area is removed from any major documented structure (e.g. Nesson anticline). If middle Three Forks co-development has a negative effect on upper Three Forks production, then upper Three Forks wells should be more productive in spacing units without middle Three Forks development.

METHODS

Well log information and drilling records were reviewed to determine the primary landing zone of each horizontal well within the study area (Fig. 3). Production records of all horizontal upper Three Forks wells were compiled and plotted with cumulative oil production versus number of productive months to evaluate upper Three Forks well production between the area of middle Three Forks co-development versus areas without middle Three Forks co-development (fig 4).

RESULTS

A total of 10 upper Three Forks horizontal wells were identified within the Twin Valley field with the following criteria: ~2-mile laterals, 12+ months of production, and located in spacing units containing co-development of the underlying middle Three Forks (fig. 3 and 4). An additional 17 upper Three Forks horizontal wells with ~2-mile laterals and 12+ months of production were identified within adjacent/nearby spacing units that have not had middle Three Forks co-development to date. All of these upper Three Forks wells were completed during 2013-2019, when multi-stage hydraulic fracturing was a common practice by operators in the Bakken-Three Forks play.

Cumulative production totals of the upper Three Forks wells range from approximately 160k - >700k barrels of oil (fig. 4). Overall, production from the upper Three Forks wells in spacing units with middle Three Forks co-development is generally equal to or exceeding production from upper Three Forks wells in spacing units without any middle Three Forks development (fig. 4). At the 3-year (36 months) and 5-year (60 months) marks, upper Three Forks wells with co-middle Three Forks well developed average 416k and 465k barrels of cumulative oil production per well while the adjacent upper Three Forks wells without middle Three Forks development averaged 202k and 251k barrels (fig. 4). So not only are the upper Three Forks wells with middle Three Forks co-development not any less productive, but instead have been more productive than the adjacent upper Three Forks wells. Furthermore, middle Three Forks horizontal wells within the Twin Valley field have outperformed many of the proximal, adjacent upper Three Forks wells without co-development. Middle Three Forks wells in the study area have averaged 341k and 399k barrels of cumulative oil production at the 3-year and 5-year marks (fig. 4). Based upon these preliminary results, middle Three Forks co-development does not appear to have negatively influenced upper Three Forks well performance within the Twin Valley field area.

DISCUSSION

Additional factors beyond the co-development of the middle Three Forks likely contribute to some degree upon the variation in upper Three Forks well production across the study area. While the study area is relatively small, minor geological variations including reservoir

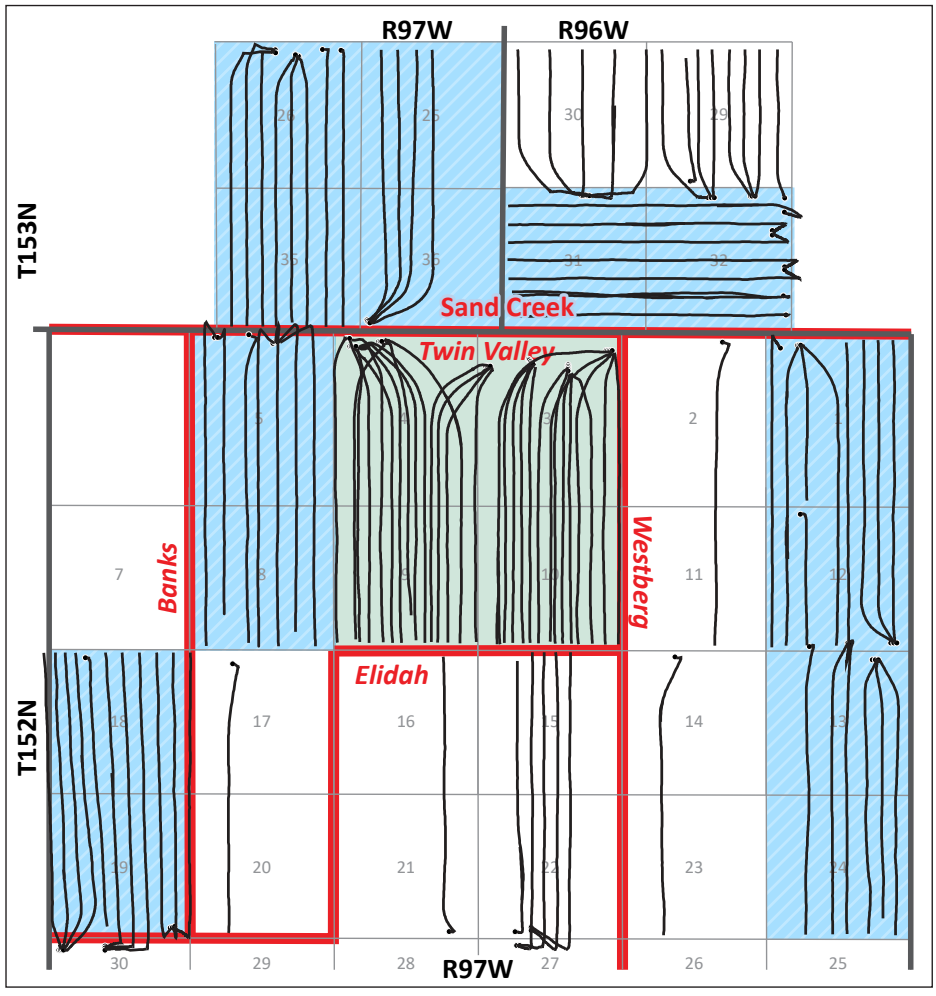

FIGURE 3.
Twin Valley field area with section, township, and range location information. Black lines depict horizontal wells drilled within the Bakken or Three Forks Formations. Red lines and labels are oil and gas field outlines and names. The field area is depicted on Figure 2. Green shaded areas depict 1280-acre spacing units with co-development of upper and middle Three Forks reservoir. Blue shaded areas with white diagonal lines depict 1280-acre spacing units with only upper Three Forks reservoir development (no middle Three Forks co-development).

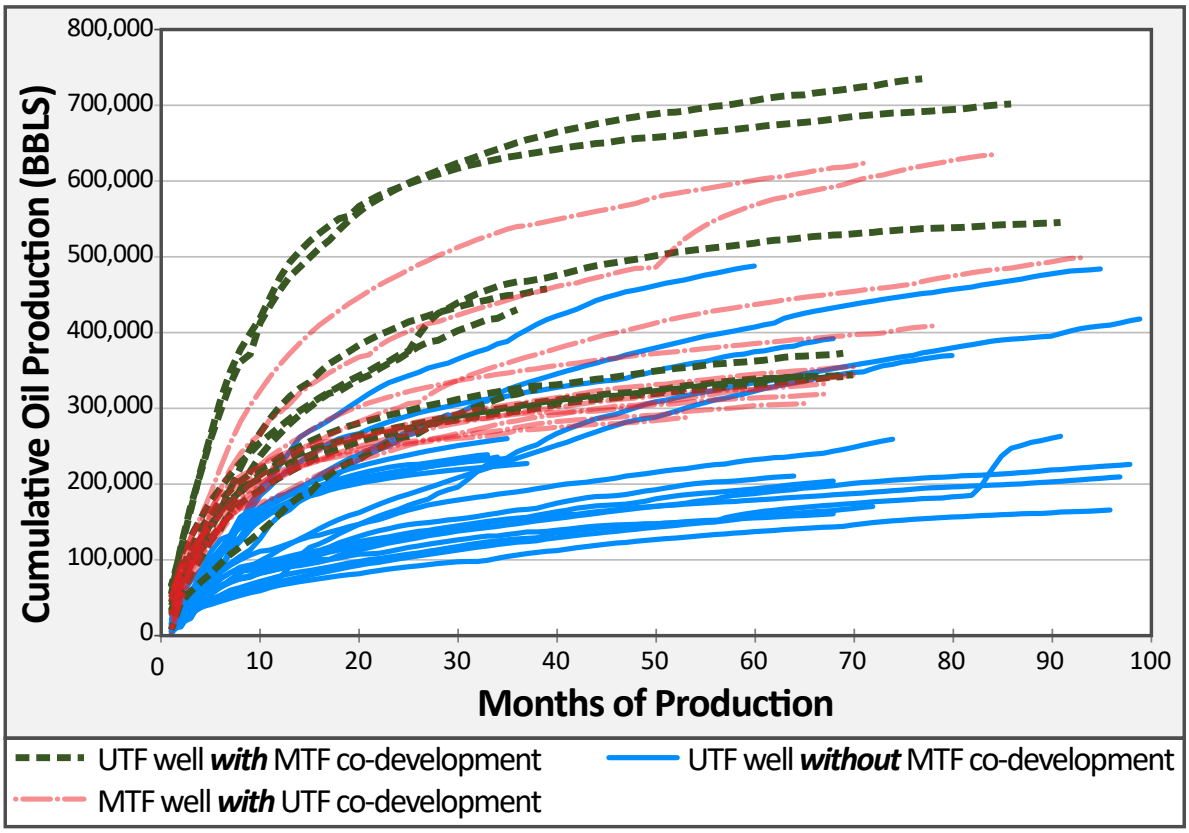

FIGURE 4. Cumulative oil production curves for upper and middle Three Forks horizontal wells from the Figure 3 field area with 12+ months of production data.

quality and structure (faulting and fracturing) may occur that influence production. Furthermore, variations in drilling (horizontal borehole positioning within the target interval) as well as completion style (e.g. number and type of hydraulic fracture stimulation stages) likely occur between the wells that influences short and long-term well performance. Examining these additional variables may lead to more insights into the best practices in drilling and completing wells in both the upper and middle Three Forks.

Looking at the current distribution of the 250+ productive middle Three Forks horizontal wells with relatively low water cut (<50%), 100s to 1,000s of potential infill development wells may be warranted within the unit (fig. 2). Still, a more expansive and detailed study of the middle Three Forks is needed, including a more detailed understanding of the middle Three Forks co-development influence/effect on upper Three Forks well performance.

REFERENCES

Bottjer, R. J., Sterling, R., Grau, A., and Dea, P., 2011, Stratigraphic relationships and reservoir quality at the Three Forks-Bakken unconformity, Williston Basin, North Dakota, in J. W. Robinson, J. A. LeFever, and S. B. Gaswirth eds., The Bakken-Three Forks petroleum system in the Williston Basin: Rocky Mountain Association of Geologists Guidebook, p. 173-228.

Christopher, J. E., 1961, Transitional Devonian-Mississippian Formation of southern Saskatchewan. Regina, Saskatchewan, Canada, Saskatchewan Mineral Resources Geological Report 66, 103 pp.

Christopher, J. E., 1963, Lithological and geochemical aspects of the Upper Devonian Torquay Formation, Saskatchewan: Journal of Sedimentary Petrology, v. 33, p. 5-13.

Gaswirth, S.B. and K.R. Marra, 2015, U.S. Geological Survey 2013 assessment of undiscovered resources in the Bakken and Three Forks Formations of the U.S. Williston Basin Province: AAPG Bulletin, v. 99, no. 4, p. 639-660.

Nesheim, T.O., 2019, Examination of downward hydrocarbon charge within the Bakken-Three Forks petroleum system – Williston Basin, North America: Marine and Petroleum Geology, v. 104, p. 346-360.

Nesheim, T.O., 2020a, History of exploration and development in the middle Three Forks (2nd bench): North Dakota Department of Mineral Resources, Geo News, vol. 47, no. 2, p. 18-20. https://www.dmr.nd.gov/ndgs/documents/newsletter/2020Summer/History_of_Exploration_and_Development_in_the_Middle_Three%20Forks_(2nd%20bench).pdf

Nesheim, T.O., 2020b, Evaluation of Water-Cuts from Middle and Lower Three Forks Production (2nd and 3rd benches): Western North Dakota: North Dakota Geological Survey, Geological Investigations No. 245, 18 p.

Nordeng, S.H., LeFever, J.A., Anderson, F.J., Bingle-Davis, M., and Johnson, E.H., 2010, An Examination of the Factors that Impact Oil Production from the Middle Member of the Bakken Formation in Mountrail County, North Dakota: North Dakota Geological Survey, Report of Investigations No. 109, 89 p.

United States Geological Survey (USGS), 2021, Assessment of Undiscovered Continuous Oil Resources in the Bakken and Three Forks Formations of the Williston Basin Province, North Dakota and Montana: Fact Sheet 2021–3058, https://www.usgs.gov/energy-and-minerals/energy-resources-program/