Assessment of Undiscovered Technically Recoverable Oil and Gas Resources of the Bakken Formation, Williston Basin, Montana and North Dakota, 2008

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Version 1.0

Bakken Oil Migration Model

Although all U.S. Bakken oil production is within the Bakken oil window, most Canadian Bakken production resulted from the migration of Bakken oils from the Bakken kitchen (fig. 32). Petroleum geochemistry studies by Osadetz and others (1992), Burrus and others (1996), and Kreis and others (2005; 2006) have shown that oils generated from mature Bakken source rocks migrated into structurally-trapped, porous conventional reservoirs of the middle sandstone member of the Bakken Formation and into reservoirs of the Madison Group (fig. 32). The migration model for Bakken oils from the pod of mature source rock is consistent with the migration model (fig. 33) of LeFever and others (1991) and the hydrologic flow model (fig. 34) of Bachu and Hitchon (1996). A hypothetical conventional assessment unit, the Middle Sandstone Member AU, was defined and assessed external from the area of the oil window and included in the USGS assessment where oils generated within mature Bakken shale source rocks could migrate into conventional traps of the middle sandstone member (fig. 32; also see fig. 38).

Bakken "Oil Window," Bakken Production and Bakken-Sourced Oils, U.S. and Canada

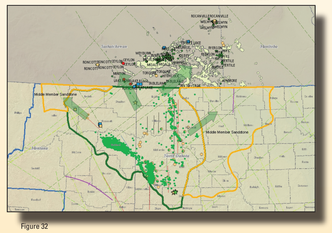


Figure 32

Bakken Oil Migration Model

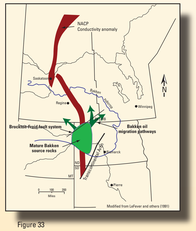


Figure 33

Williston Basin Hydrologic Flow Model

Figure 34

Effective Drainage Area and Cell Size

Critical to the continuous assessment methodology is estimating a distribution of the effective drainage area, or cell size (fig. 35A), for the undiscovered area of each AU (fig. 35*B*). Both horizontal and vertical well performances are considered here because both types of wells are used in the initial and infill development of Bakken resource plays (fig. 36). In this study, Elm Coulee field was used as a model (fig. 37) in conjunction with the recent study by Cox and others (2008) to help develop a drainage distribution scenario for unexplored areas in the Bakken continuous resource plays. For example, an area of about 535 mi² at Elm Coulee contains about 600 Bakken producing wells, of which 3 to 4 percent are vertical. The resulting cell-size distribution used in all Bakken continuous AUs except the Central Basin-Poplar Dome AU was: minimum = 80 acres; maximum = 800 acres; mode = 320 acres; mean = 400 acres.

Hypothetical Vertical Well Drainage Area Distribution

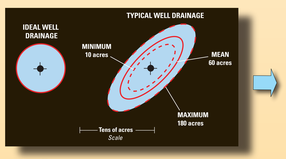


Figure 35A

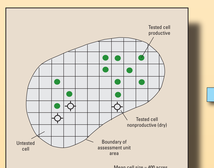


Figure 35*B*

What is the Effective Drainage Area for Bakken Horizontal and Vertical Wells?

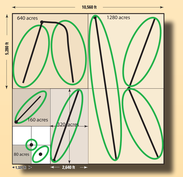


Figure 36

Horizontal and Vertical Well Patterns and Spacings Elm Coulee Field, Montana

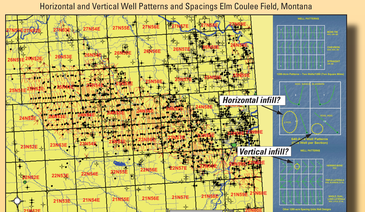


Figure 37

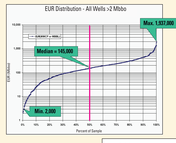
Success and Estimated Ultimate Recovery for Continuous AUs

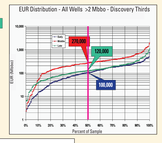
Success is defined in the USGS assessment methodology as a producing well making a minimum EUR of 2,000 bbls oil. Also, more than 450 drill-stem tests (DST) in the Bakken Formation were evaluated to help estimate a historical success ratio; however, the DST records must demonstrate that the test is completed without any mechanical problems within the Bakken Formation before a well was classified as a success or failure. In most Bakken continuous AUs, the future success ratio was higher than the historical success ratio because of a greater chance for success due to advanced drilling and completion techniques and increased knowledge and awareness of Bakken oil potential.

Estimated ultimate recovery (EUR) was generated for each well file recorded in the IHS Energy production (IHS Energy, 2007) file through June 2007, with the producing formation listed as Bakken or Sanish/Bakken. Wells were clipped to the corresponding continuous AUs and a series of EUR distributions were generated. Multiple EUR distributions for each continuous AU were evaluated with distributions generated for three main categories in all wells, only verticals wells, and only horizontals wells (see EUR distribution graphs below). For the Nesson-Little Knife Structural AU, an EUR distribution was also generated for Sanish/Bakken vertical wells (see EUR graphs below, right side). EURs for each continuous AU were also generated as discovery thirds, that is, equal thirds relative to sequential date of completion to aid evaluation relative to time, technology, and exploration strategy. EUR distribution graphs are shown below for the two most explored AUs – the Elm Coulee-Billings Nose AU and the Nesson-Little Knife Structural AU – and a summary of the assessment input and output is listed below each series of graphs. Boundaries and mean EUR for continuous AUs are shown in figure 38; the results of the USGS assessment for the Bakken Formation are shown in table 1.

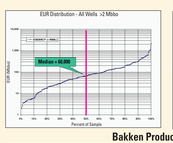
Historical Exploration, Production, and Performance Analysis for Continuous AUs

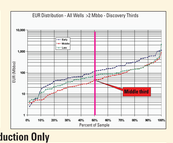
Elm Coulee-Billings Nose AU



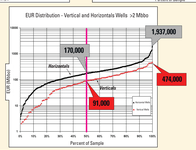


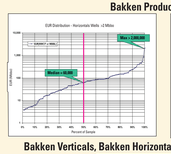
Nesson - Little Knife Structural AU (Bakken and Sanish (Three Forks)/Bakken Production)

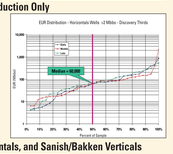




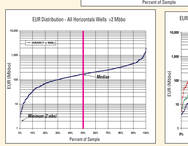
Bakken Production Only

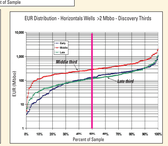


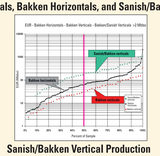




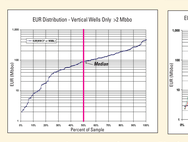
Bakken Verticals, Bakken Horizontals, and Sanish/Bakken Verticals

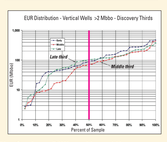


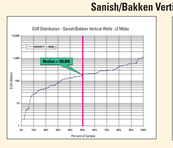


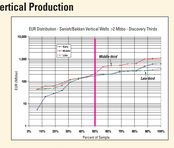


Sanish/Bakken Vertical Production









Assessment Summary: Elm Coulee - Billings Nose AU

Mean area: 1,735,000 acres
Historical success ratio: 95%
Cell size (acres): 80/320/800 (Mean=400)
Mean% area untested: 79%
Mean future success ratio: 89%
Mean% area w/potential: 89%
EUR distribution: 2,000/80,000/2,000,000 bbls
Mean EUR/cell = 137,000 bbls

Mean Technically Recoverable Resource = 410,000,000 bbls

Assessment Summary: Nesson - Little Knife Structural AU

Mean area: 2,321,000 acres
Historical success ratio: 85%
Cell size (acres): 80/320/800 (Mean=400)
Mean% area untested: 96%
Mean future success ratio: 92%
Mean% area w/potential: 88%
EUR distribution: 2,000/90,000/4,000,000 bbls
Mean EUR/cell = 200,000 bbls

Mean Technically Recoverable Resource = 909,000,000 bbls

Conventional Middle Sandstone Member AU

A hypothetical conventional AU, the Middle Sandstone Member AU, was defined external from the area of the Bakken oil generation window (fig. 38) and assumes some potential for migration of oil from the Bakken-source kitchen along structures into structural traps of the middle sandstone member. Assessment of the Middle Sandstone Member AU was performed by analog from the USGS World Energy Assessment 2000 (U.S. Geological Survey World Energy Assessment Team, 2000) and by using the size and numbers of grown discovered fields in the middle sandstone member in the Canadian portion of the Williston Basin. A greater risk was assigned to this AU relative to Canadian discoveries because of the lack of major structural pathways (that is, fault systems), possible updip seals, and position of the AU relative to hydrologic flow and oil migration models as compared to those to the north in Canada.

Assessment Units - Mean EUR (Mbbo)

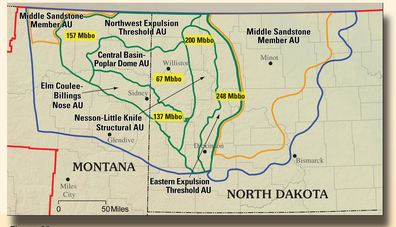


Figure 38

Assessment Results

Table 1. *Bakken Formation, Williston Basin Province assessment results.*
[MMBO, million barrels of oil; BCFG, billion cubic feet of gas. MMBNGL, million barrels of natural gas liquids. Results shown are fully risked estimates. F95 represents a 95 percent chance of at least the amount tabulated; other fractiles are defined similarly. TPS, total petroleum system; AU, assessment unit]

	Total Petroleum System and Assessment Unit	Field Type	*Total Undiscovered Resources*											
			Oil (MMBO)				*Gas (BCFG)*				*NGL (MMBNGL)*			
			F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Continuous Oil Resources	**Bakken-Lodgepole TPS**													
	Elm Coulee-Billings Nose AU	*Oil*	374	410	450	410	118	198	332	208	8	16	29	17
	Central Basin-Poplar Dome AU	*Oil*	394	482	589	485	134	233	403	246	10	18	35	20
	Nesson-Little Knife Structural AU	*Oil*	818	908	1,007	909	260	438	738	461	19	34	64	37
	Eastern Expulsion Threshold AU	*Oil*	864	971	1,091	973	278	469	791	493	20	37	68	39
	Northwest Expulsion Threshold AU	*Oil*	613	851	1,182	868	224	411	754	440	16	32	64	35
	Total Continuous Resources					**3,645**				**1,848**				**148**
Conventional Oil Resources	Middle Sandstone Member AU	*Oil*	1	4	8	4	1	1	3	2	0	0	0	0
	Total Conventional Resources					**4**				**2**				**0**
	Total Undiscovered Oil Resources					**3,649**				**1,850**				**148**

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