

PROPOSED BIRDTAIL UNIT NO. 4

Application for Enhanced Oil Recovery Waterflood Project

Bakken Formation

Bakken – Three Forks A Pool (62A)

Birdtail Field (MB15), Manitoba

December 5, 2018
Tundra Oil and Gas Limited

INTRODUCTION

Birdtail Units No. 1, No. 2 and No. 3, located in Township 16 Range 27 west of the prime meridian, first produced in September 1996, January 1997 and November 2009, respectively (Figure 1). The main production targets in the units are the Middle Bakken and Three Forks A pools.

For the lands north of Birdtail Unit No. 3, potential exists for incremental production and reserves from a Waterflood EOR project in the Three Forks and Middle Bakken oil reservoirs. The following represents an application by Tundra Oil and Gas Limited (Tundra) to establish Birdtail Unit No. 4 (N/2 of Section 31, LSDs 3-6, 11-13 of Section 32-016-27W1 and S/2 of Section 06-017-27W1) and implement a Secondary Waterflood EOR scheme within the Three Forks and Middle Bakken formations as outlined on Figure 2.

The proposed project area falls within the existing designated 15-62A Bakken-Three Forks A Pool of the Birdtail Oilfield (Figure 3).

SUMMARY

1. The proposed Birdtail Unit No. 4 will include 7 horizontal wells, within 23 Legal Sub Divisions (LSD) of the Middle Bakken/Three Forks producing reservoir. The project is located north of Birdtail Unit No. 3 (Figure 2).
2. Total Net Original Oil in Place (OOIP) in Birdtail Unit No. 4 has been calculated to be **882.2** e³m³ (5,549 Mbbl) for an average of **38.3** net e³m³ (241.2 Mbbl) OOIP per 40 acre LSD.
3. Cumulative production to the end of August 2018 from the 7 wells within the proposed Birdtail Unit No. 4 project area was **31.4** e³m³ (197.5 Mbbl) of oil, and **53.7** e³m³ (337.9 Mbbl) of water, representing a **3.6%** Recovery Factor (RF) of the Net OOIP.
4. Estimated Ultimate Recovery (EUR) of Primary Proved Producing oil reserves in the proposed Birdtail Unit No. 4 project area has been calculated to be **61.3** e³m³ (385.3 Mbbl), with **29.9** e³m³ (188.2 Mbbl) remaining as of the end of August 2018.
5. Ultimate oil recovery of the proposed Birdtail Unit No. 4 OOIP, under the current Primary Production method, is forecasted to be **6.9%**.
6. Figure 4 shows the production from the Birdtail Unit No. 4 peaked in October 2013 at 26.69 m³ (OPD). As of August 2018, production was 10.86 m³ OPD, 33.00 m³ of water per day (WPD) and a 75.2% watercut.
7. In October 2013, production averaged 5.3 m³ OPD per well in Birdtail Unit No. 4. As of August 2018, average per well production has declined to 1.81 m³ OPD. Decline analysis of the group primary production data forecasts total oil to continue declining at an annual rate of approximately **19.1%** in the project area.
8. Estimated Ultimate Recovery (EUR) of proved oil reserves under Secondary WF EOR for the proposed Birdtail Unit No. 4 has been calculated to be **122.1** e³m³ (768.3 Mbbl), with **90.7** e³m³ (570.8 Mbbl) remaining. An incremental **60.8** e³m³ (382.4 Mbbl) of proved oil reserves, or **6.9%**, are forecasted to be recovered under the proposed Unitization and Secondary EOR production vs the existing Primary Production method.
9. Total RF under Secondary WF in the proposed Birdtail Unit No. 4 is estimated to be **13.8%**.
10. Based on waterflood response in Birdtail Units 1, 2 & 3, the Three Forks and Middle Bakken Formations in the proposed project area are believed to be suitable reservoirs for WF EOR operations.
11. Horizontal producers will be converted to future injectors (Figure 5) within the proposed Birdtail Unit No. 4, to complete horizontal to horizontal waterflood patterns with a mix of inter-well spacing.

DISCUSSION

The proposed Birdtail Unit No. 4 project area is located within Townships 16-17, Range 27 W1 of the Birdtail oil field. The proposed Birdtail Unit No. 4 currently consists of 7 horizontal wells within an area covering 23 LSDs (Figure 2). A project area well list complete with recent production statistics is attached as Table 3.

Tundra believes that the waterflood response in Birdtail Units No. 1, 2 and 3 demonstrates potential for incremental production and reserves from a WF EOR project in the subject Middle Bakken and/or Three Forks oil reservoirs in the proposed Birdtail Unit No. 4.

Geology

Stratigraphy

The stratigraphy of the reservoir section in the Birdtail Unit No. 4 area is shown cross section A – A' (Appendix 1). The cross section runs from northwest to southeast through wells offsetting the proposed unit. There are no vertical wells drilled in the proposed unit – it has been developed with horizontal wells. The producing sequence from youngest to oldest is: the Upper Bakken Shale, the Middle Bakken fine grained sand/siltstone, the Lyleton 'B' siltstone, and the Lyleton 'C' silty shale. The sequence is unconformably overlain by the Mississippian Lodgepole formation and unconformably underlain by the Devonian Birdbear Formation.

The main productive zone is considered to be the Middle Bakken Formation. There may be some remnant Lyleton 'B' reservoir that locally, directly underlies the Middle Bakken and contributes a marginal amount of oil to the system.

Sedimentology

The Middle Bakken reservoir consists of fine to coarse grained siltstone to sandstone (often tan colored when oil stained). It can be divided into two units – the upper Middle Bakken and the lower Middle Bakken. The upper Middle Bakken is about 0.5 – 1m thick in the Birdtail Unit No. 4 area and is mainly considered non – reservoir. It is composed of heavily bioturbated grey siltstone with small brachiopod shells and the occasional crinoid and coral fragments. Pyrite nodules are common. The environmental interpretation of the upper Middle Bakken is an offshore transition/lower shoreface.

The lower Middle Bakken consists of finely laminated grey and tan colored siltstone and fine grained sandstone interbeds with occasional bioturbation. Where there is a higher sand content, bioturbation is rare. This is the main reservoir unit of the Middle Bakken. Geological mapping together with horizontal well data suggests that it ranges from 1.0 to 2.5 meters thick in the Birdtail Unit No. 4 area (Appendix 2). The interpretation of the lower Middle Bakken is of a tidally influenced middle to upper shoreface environment. Overall, the Bakken interval is representative of a shallow marine transgressive system.

The upper Lyleton B reservoir unit is at the top and is composed of ripple – cross laminated dolo-siltstones increasingly interbedded with tight greenish/grey dolomitic shales with depth. The upper Lyleton B is interpreted to have been deposited in a brackish bay type environment.

The mid to lower Lyleton B and underlying Lyleton C of the Three Forks Group are often called the 'Torquay' Formation. They are generally brick red, light green, and light brown and are mainly composed of very fine dolomitic siltstones and shales and are considered non – reservoir. The lower Lyleton B and C are interpreted to have been deposited in a sabkha environment.

Structure

Appendix 3 shows the Lyleton Subsea Structure integrated with proprietary seismic data together with data points from horizontal wells. The Lyleton surface is useful for more detailed structure mapping since horizontal wells often encounter the Lyleton providing more data points. The lower Middle Bakken reservoir sits directly on top of the Lyleton making the Lyleton surface particularly useful when evaluating the oil water contact. The Lyleton subsea structure ranges from approximately -35m in the southwest side of the unit and dips to approximately -45m along the east side of the unit. All of the Middle Bakken within Birdtail Unit No. 4 is above the local oil/water contact of approximately -45 to -47m subsea.

Reservoir Continuity

Cross Section A – A' (Appendix 1) and existing production (Table 3) indicate that there is likely very good lateral continuity in the basal Middle Bakken formation within Birdtail Unit No. 4. Vertical reservoir continuity between the Middle Bakken and the underlying Lyleton is likely very poor to non – existent due to the heterolithic depositional environment and the multiple thin shale interbeds.

Reservoir Quality

Six (6) wells offsetting the proposed unit have core analysis in the Middle Bakken formation and have been summarized below:

1. 100/15-25-16-27W1/0, Kmax.h: 142.5 mD.m
2. 100/09-30-016-27W1/0, Kmax.h: 3.50 mD.m *please note this value is anomalously low due to the base of the Middle Bakken core being lost during the coring process so there are no samples from the best, highest permeability reservoir.
3. 100/05-31-016-27W1/0, Kmax.h: 17.7 mD.m
4. 100/02-32-16-27W1/0, Kmax.h: 159.1 mD.m
5. 100/10-36-016-28W1/0, Kmax.h: 94.8 mD.m
6. 100/02-01-017-28W1/0, Kmax.h: 192.4 mD.m

All of the six wells summarized above have Kmax.h values that would be acceptable to enhanced oil recovery. Their values indicate that the lower Middle Bakken has good reservoir in the area. The Kmax.h values have been posted to the map but have not been contoured due to limited data points. (Appendix 4).

The good reservoir interpretation is also supported with relatively high average porosity values as shown in Appendix 5. Tundra has mapped the average porosity of the lower Middle Bakken reservoir that exceeds a Limestone Density porosity cutoff of 15.4%. Average porosity values range from 20.5 to 22.5% throughout the proposed unit.

Fluid Contacts

The oil/water contact locally is considered to be at -45 to -47m subsea and was mapped by integrating proprietary seismic and well control. The oil water contact generally runs north-south along the east side of proposed Birdtail Unit No. 4. Please refer to [Appendix 3](#).

OOIP Estimates

The total volumetric OOIP for the Middle Bakken within the proposed Birdtail Unit No. 4 has been calculated to be **882.2** e³m³ (5,549 Mbbbl) of oil ([Table 4](#)).

The OOIP was calculated LSD by LSD interpolating between vertical wells using the equation

OOIP= [Ah phi (1-Swi)/Boi], where,

OOIP = Original Oil in Place

A =Reservoir Area (m²)

h = Reservoir Thickness (m)

phi = Reservoir Porosity

Swi = Connate Water Saturation – estimated to be 0.36 in the area

Boi = Initial Formation Volume factor – assumed to be 1.003 in the area

Net pay cut-offs for the Middle Bakken applied were: Limestone Density Porosity greater than or equal to 15.4% and a water saturation less than or equal to 60%.

Original Oil in Place (OOIP) calculations and geologic summary were prepared by Bill Ward, P.Geol. (Geology Advisor at Tundra)

Historical Production

A historical group production plot for the proposed Birdtail Unit No. 4 is shown as [Figure 4](#). Oil production commenced from the proposed Unit area in August 2012 and peaked during October 2013 at 26.69 m³ OPD. As of August 2018, production was 10.86 m³ OPD, 33.00 m³ WPD and a 75.2% watercut.

From peak production in October 2013, oil production is declining at an annual rate of approximately **19.1%** under the current Primary Production method.

The remainder of the field's production and decline rates indicate the need for pressure restoration and maintenance. Waterflooding is deemed to be the most efficient means of secondary recovery to introduce energy back into the system and provide areal sweep between wells.

UNITIZATION

Unitization and implementation of a Waterflood EOR project is forecasted to increase overall recovery of OOIP from the proposed project area.

Unit Name

Tundra proposes that the official name of the new Unit shall be Birdtail Unit No. 4.

Unit Operator

Tundra Oil and Gas Limited (Tundra) will be the Operator of record for Birdtail Unit No. 4.

Unitized Zone

The Unitized zone(s) to be waterflooded in Birdtail Unit No. 4 will be the Middle Bakken and Three Forks formations.

Unit Wells

The 7 horizontal wells to be included in the proposed Birdtail Unit No. 4 are outlined in [Table 3](#).

Unit Lands

Birdtail Unit No. 4 will consist of 23 LSDs as follows:

N/2 Section 31 of Township 16, Range 27, W1M
LSDs 3-6, 11-13 of Section 32 of Township 16, Range 27, W1M
S/2 Section 6 of Township 17, Range 27, W1M

The lands included in the 40 acre tracts are outlined in [Table 1](#).

Tract Factors

The proposed Birdtail Unit No. 4 will consist of 23 Tracts based on the 40 acre LSDs containing the existing 7 horizontal wells.

The Tract Factor contribution for each of the LSD's within the proposed Birdtail Unit No. 4 was calculated as follows:

- Gross OOIP by LSD, minus cumulative production to date for the LSD as distributed by the LSD specific Production Allocation (PA) % in the applicable producing horizontal or vertical well (to yield Remaining Gross OOIP)
- Tract Factor by LSD = the product of Remaining Gross OOIP by LSD as a % of total proposed Unit Remaining Gross OOIP

Tract Factor calculations for all individual LSDs based on the above methodology are outlined within **Table 2**.

Working Interest Owners

Table 1 outlines the working interest (WI) for each recommended Tract within the proposed Birdtail Unit No. 4. Tundra Oil and Gas Limited holds a 100% WI ownership in all the proposed Tracts.

Tundra Oil and Gas Limited will have a 100% WI in the proposed Birdtail Unit No. 4.

WATERFLOOD EOR DEVELOPMENT

Technical Studies

The waterflood performance predictions for the proposed Birdtail Unit No. 4 are based on internal engineering assessments. Project area specific reservoir and geological parameters were used to guide the overall Secondary Waterflood recovery factor. Internal reviews included analysis of available open-hole logs, core data, petrophysics, seismic, drilling and completion information, and production information. These parameters were reviewed to develop a suite of geological maps and establish reservoir parameters to support the calculation of the proposed Birdtail Unit No. 4 OOIP (Table 4).

Pre-Production of New Horizontal Injection Wells

Primary production from the original vertical/horizontal producing wells in the proposed Birdtail Unit No. 4 has declined significantly from peak rate indicating a need for secondary pressure support. Two (2) existing producing horizontal wells and two (2) proposed future horizontal wells will be converted to horizontal injection wells as shown in Figure 5, which will result in horizontal to horizontal waterflood patterns with a variable inter-well spacing within Birdtail Unit No. 4.

Through the process of developing similar waterfloods in this area, Tundra has measured a significant variation in reservoir pressure depletion by the existing primary producing wells. Placing new horizontal wells immediately on water injection in areas without significant reservoir pressure depletion has been problematic in similar low permeability formations and has a negative impact on the ultimate total recovery factor of OOIP. Considering the expected reservoir pressures and reservoir lithology described, Tundra believes an initial period of producing all horizontal wells prior to placing them on permanent water injection is essential and all Unit mineral owners will benefit.

Tundra monitors reservoir pressure, fluid production and decline rates in each pattern to determine when producing wells will be converted to water injection

Reserves Recovery Profiles and Production Forecasts

The primary waterflood performance predictions for the proposed Birdtail Unit No. 4 are based on oil production decline curve analysis, and the secondary predictions are based on internal engineering analysis performed by the Tundra reservoir engineering group.

Primary Production Forecast

Cumulative production in the Birdtail Unit No. 4 project area, to the end of August 2018 from 7 wells, was **31.4** e³m³ of oil and **53.7** e³m³ of water for a recovery factor of **3.6%** of the calculated Net OOIP.

Ultimate Primary Proved Producing oil reserves recovery for Birdtail Unit No. 4 has been estimated to be **61.3** e³m³, or a **6.9%** Recovery Factor (RF) of OOIP. Remaining Producing Primary Reserves has been estimated to be **29.9** e³m³ to the end of August 2018.

The expected production decline and forecasted cumulative oil recovery under continued Primary Production is shown in Figures 7 and 8.

Pre-Production Schedule/Timing for Conversion of Horizontal Wells to Water Injection

Tundra will plan an injection conversion schedule to allow for the most expeditious development of the waterflood within the proposed Birdtail Unit No. 4, while maximizing reservoir knowledge. Two (2) producing wells are planned to be converted to water injection in 2019, but ultimately, the final conversion dates and candidates will be chosen based on production performance after unit approval.

Criteria for Conversion to Water Injection Well

Four (4) water injection wells are required for this proposed unit as shown in **Figure 5**.

Tundra will monitor the following parameters to assess the best timing for each individual horizontal well to be converted from primary production to water injection service.

- Measured reservoir pressures at start of and/or through primary production
- Fluid production rates and any changes in decline rate
- Any observed production interference effects with adjacent vertical and horizontal wells
- Pattern mass balance and/or oil recovery factor estimates
- Reservoir pressure relative to bubble point pressure

The above set of parameters allows for the proposed Birdtail Unit No. 4 project to be developed equitably, efficiently, and moves to project to the best condition for the start of waterflood as quickly as possible. It also provides the Unit Operator flexibility to manage the reservoir conditions and response to help ensure maximum ultimate recovery of OOIP.

Secondary EOR Production Forecast

The proposed project oil production profile under Secondary Waterflood has been developed based on the response observed to date in the Birdtail Units No. 1, 2 & 3 WF (**Figure 6**).

Secondary Waterflood plots of the expected oil production forecast over time and the expected oil production vs. cumulative oil are plotted in **Figures 9 and 10**, respectively. Total Secondary EUR for the proposed Birdtail Unit No. 4 is estimated to be **122.1** e³m³ with **90.7** e³m³ remaining representing a total secondary recovery factor of **13.8 %** for the proposed Unit area. An incremental **60.8** e³m³ of oil, or an incremental **6.9%** recovery factor, are forecasted to be recovered under the proposed Unitization and Secondary EOR production scheme vs. the existing Primary Production method.

Estimated Fracture Pressure

Completion data from the producing wells within the project area indicate an actual fracture pressure gradient range of 18.0 to 21.0 kPa/m true vertical depth (TVD). Tundra expects the fracture gradient encountered during completion of the proposed horizontal injection well will be somewhat lower than these values due to expected reservoir pressure depletion.

WATERFLOOD OPERATING STRATEGY

Water Source

Injection water for the proposed Birdtail Unit No. 4 will be supplied from the Lodgepole source water well at 100/02-32-016-27W1. Lodgepole water from the 100/02-32 source well is pumped to the main Birdtail Unit Water Plant at 8-30-16-27W1, filtered, and pumped up to injection system pressure. A diagram of the Birdtail water injection system and new pipeline connection to the proposed Birdtail Unit No. 4 project area injection wells is shown as **Figure 12**.

Produced water is not currently used for any water injection in the Tundra operated Birdtail Units and there are no current plans to use produced water as a source supply for Birdtail Unit No. 4.

Currently all produced waters are inherently a mixture of Three Forks and Bakken native sources. This mixture of produced waters has been extensively tested for compatibility with 100/02-32 source Lodgepole water, by a highly qualified third party. All potential mixture ratios between the two waters, under a range of temperatures, have been simulated and evaluated for scaling and precipitate formation tendencies. Testing of multiple scale inhibitors has also been conducted and minimum inhibition concentration requirements for the source water volume determined. At present, continuous scale inhibitor application is maintained into the source water stream out of the Birdtail injection water facility (Birdtail Units No. 1 & 2). Review and monitoring of the source water scale inhibition system is also part of an existing routine maintenance program.

Injection Wells

New water injection wells for the proposed Birdtail Unit No. 4 will be drilled and configured downhole for injection as shown in **Figure 11**. The horizontal injection wells will be stimulated by multiple hydraulic fracture treatments to obtain suitable injection. Tundra has extensive experience with horizontal fracturing in the area, and all jobs are rigorously programmed and monitored during execution. This helps ensure optimum placement of each fracture stage to prevent, or minimize, the potential for out-of-zone fracture growth and thereby limit the potential for future out-of-zone injection.

The new water injection wells will be placed on injection after approval to inject. Wellhead injection pressures will be maintained below the least value of either:

- the area specific known and calculated fracture gradient, or
- the licensed surface injection Maximum Allowable Pressure (MOP)

Tundra has a thorough understanding of area fracture gradients. A management program will be utilized to set and routinely review injection target rates and pressures vs. surface MOP and the known area formation fracture pressures.

All new water injection wells are surface equipped with injection volume metering and rate/pressure control. An operating procedure for monitoring water injection volumes and meter balancing will also be utilized to monitor the entire system measurement and integrity on a daily basis.

The proposed Birdtail Unit No. 4 horizontal water injection well rate is forecasted to average **10 – 30 m³** WPD, based on expected reservoir permeability and pressure.

Reservoir Pressure

The initial reservoir pressure for wells drilled in the Middle Bakken in the proposed Birdtail Unit No. 4 is shown in **Figure 13**. The estimated reservoir pressure for the proposed unit area is in the range of 4000 - 4600 kPa.

Reservoir Pressure Management during Waterflood

Tundra expects it will take 2-4 years to re-pressurize the reservoir due to cumulative primary production voidage and pressure depletion. Initial monthly Voidage Replacement Ratio (VRR) is expected to be approximately 1.25 to 2.00 within the patterns during the fill up period. As the cumulative VRR approaches 1, target reservoir operating pressure for waterflood operations will be 75-90% of original reservoir pressure.

Waterflood Surveillance and Optimization

Birdtail Unit No. 4 EOR response and waterflood surveillance will consist of the following:

- Regular production well rate and WCT testing
- Daily water injection rate and pressure monitoring vs target
- Water injection rate/pressure/time vs. cumulative injection plot
- Reservoir pressure surveys as required to establish pressure trends
- Pattern VRR
- Potential use of chemical tracers to track water injector/producer responses
- Use of some or all of: Water Oil Ratio (WOR) trends, Log WOR vs Cum Oil, Hydrocarbon Pore Volumes Injected, Conformance Plots

The above surveillance methods will provide an ever increasing understanding of reservoir performance, and provide data to continually control and optimize the Birdtail Unit No. 4 waterflood operation. Controlling the waterflood operation will significantly reduce or eliminate the potential for out-of-zone injection, undesired channeling or water breakthrough, or out-of-Unit migration. The monitoring and surveillance will also provide early indicators of any such issues so that waterflood operations may be altered to maximize ultimate secondary reserves recovery from the proposed Birdtail Unit No. 4.

On Going Reservoir Pressure Surveys

Any pressures taken during the operation of the proposed unit will be reported within the Annual Progress Reports for Birdtail Unit No. 4 as per Section 73 of the Drilling and Production Regulation.

Economic Limits

Under the current Primary recovery method, existing wells within the proposed Birdtail Unit No. 4 will be deemed uneconomic when the net oil rate and net oil price revenue stream becomes less than the current producing operating costs. With any positive oil production response under the proposed Secondary

recovery method, the economic limit will be significantly pushed out into the future. The actual economic cut off point will then again be a function of net oil price, the magnitude and duration of production rate response to the waterflood, and then current operating costs. Waterflood projects generally become uneconomic to operate when Water Oil Ratios (WOR's) exceed 100.

WATER INJECTION FACILITIES

The Birdtail Unit No. 4 waterflood operation will utilize the Tundra operated well 100/02-32-016-274W1, sourced from the Lodgepole, and water plant (WP) facilities located at the Birdtail 8-30-16-27W1 battery (Figure 9).

A complete description of all planned system design and operational practices to prevent corrosion related failures is shown in Appendix 6. All surface facilities and wellheads will have cathodic protection, and all injection flowlines will be made of fiberglass to prevent corrosion. Injectors will have a packer set above the Middle Bakken and Three Forks formations, and the annulus between the tubing and casing will be filled with inhibited fluid. Refer to Appendix 6 for additional corrosion control details.

NOTIFICATION OF MINERAL AND SURFACE RIGHTS OWNERS

Tundra is in the process of notifying all mineral rights and surface rights owners of this proposed EOR project and formation of Birdtail Unit No. 4. Copies of the notices and proof of service, to all surface and mineral rights owners will be forwarded to the Petroleum Branch when available to complete the Birdtail Unit No. 4 Application.

Birdtail Unit No. 4 Unitization, and execution of the formal Birdtail Unit No. 4 Agreement by affected Mineral Owners, is expected during Q1 2019. Copies of same will be forwarded to the Petroleum Branch, when available, to complete the Birdtail Unit No. 4 Application.

Should the Petroleum Branch have further questions or require more information, please contact Angel Duran at 403.910.1673 or by email at angel.duran@tundraoilandgas.com.

TUNDRA OIL & GAS LIMITED

Original Signed by Angel Duran, December 5, 2018, in Calgary, AB