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Unlocking Opportunity Kotatua Field "X-2 Sand'; Low-Quality Reservoir and Depleted Reservoir Pressure Through Waterflood

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Abstract. Asset Optimization South team has successfully increased oil production in Kotatua Field by initiating water injection in the "X-2" sand. The "X-2" sand has low permeability and has historically been produced commingled with the Bravo sand, which has higher permeability. The Bravo sand has been waterflooded since 1974, while the "X-2" reservoir has been pressure depleted to the point of negligible. "X-2" pressure rejuvenation started in May 2018 with conversion of 6 commingled injectors and 1 commingled producer converted become single completion and dedicated as a pilot. During the monitoring of the waterflood response, apart from BHP monitoring, the extensive oil fingerprinting analysis was accrued out to determine oil allocation and zonal contribution. After observing the waterflood response, the project was expanded in 2019 by converting 3 more injectors and workover 16 producers to single completion of "X-2' sand. End of 2019 the project has successfully delivered incremental 2,589 BOPD equivalent to 746 MSTB cumulative with a total expenditure of US$ 1.0 MM. It delivered additional reserves 3.7 MMSTB until August 2022.

Keyword(s):" X-2" Sand; Low-Quality Reservoir; Depleted Reservoir Pressure; Waterflood

1. Introduction

The Kotatua field has four major oil reservoirs: "X-2", Bravo A, Bravo B and Bravo C. The "X-2" sand has low permeability relative to the Bravo sands. To improve oil deliverability from the "X-2" sand, hydraulic fracturing was implemented. The first "X-2 sand" hydraulic fracturing job was in 1972 on 1 well, with subsequent commencement of a massive fracturing campaign in 2007-2014 until 95 producer wells had been fractured. The massive campaign unlocked reservoir-wide pressure communication in the tight sand and permitted the reservoir pressure to be depleted to ~350 psi (at depth 4,200 ft). At this low pressure, fracturing jobs were ceased in 2015 as there was insufficient reservoir pressure support to economically deliver production. At this time, the "X-2" recovery factor remained low at 20%, an observation which ultimately triggered initiation of the current "X-2" optimization project and implementation of the pilot water injection.

2. Methods, Procedure and Process

2.1 Reservoir Overview

"X-2" sand is characterized by its composition dominated by silty to very fine sand size with a lot of burrow, lenses, and lamination. The oil saturation is found mostly in burrows and silty lenses. The other important composition creating high porosity character while the permeability very low is the presence of forams. Forams naturally have chambers/voids that can be measured as porosity. Those chambers/ voids are not connected to each other causing low permeability. The value range of permeability is 90 mD.

2.2 G&G Project Assessment

In the beginning of project, map used to determine the Area of Interest (AOI) and wells selection was permeability-thickness (kh), net-sand, permeability, and HPT generated by using krigging 2-D mapping method. Basically krigging 2-D mapping uses average number of each parameter within each well. Based on net-sand thickness and HPT, the AOI will be in the Northern part of Kotatua structure. If permeability map is considered, the AOI will be limited to East side Northern structure because the West side has low permeability. *(Figure 1)*
KH (permeability times thickness) map was then generated to emphasize and understand "X-2" deposition information. Based on KH map, the AOI will be limited to the East area same as that in permeability map. In addition to that, KH map later will be used as a key map in project to define injector and producer position.

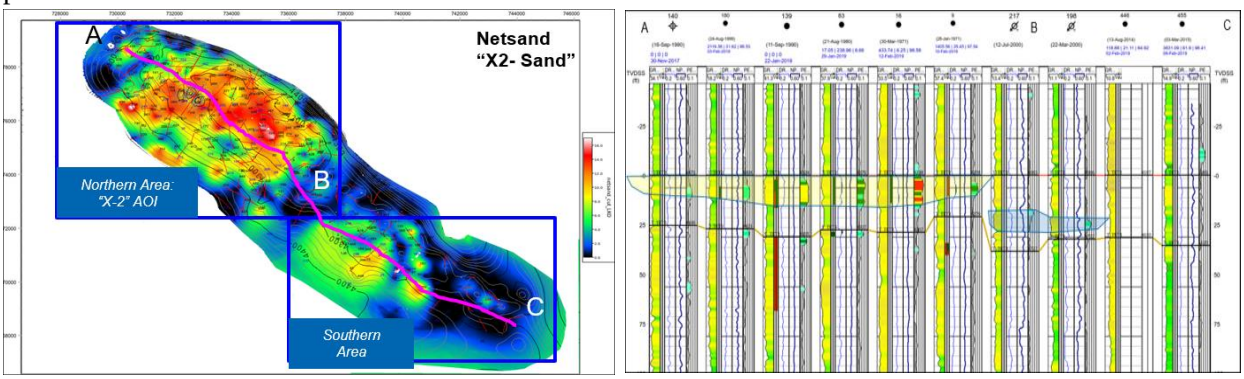

Figure 1. AOI of X-2 sand in Kotatua field(rinie,2018)

2.3 Candidate Selection

Developing alternative on strategy table could help to focus on decision making. There were four categories in strategy table; create alternative scenarios, injection strategy, injection completion type and G&G detail review. As decision from strategy table focus on some consideration; optimized on existing injector well by conducting workover with single completion strategy. Injector well selection will refer to G&G subsurface review that have good correlation to surrounding producer wells.
The injector selection by referred to the map (Figure 2). The dark red color is the highest KH value, meaning the quality and thickness is higher compared to the blue color. Referring to KH map, the best "X-2" sand quality resides in the attic area and the sand distribution was limited only in the Northern part of Kotatua structure. It creates unique stratigraphic trap and confined space. Having those condition, peripheral injection into limited sand was initiated to sweep the oil from the flank to the top structure. Based on cross

section with NW-SE direction, the sand has good continuity with medium to low lateral variation within AOI area. Others evaluation that importance was alignment with surrounding producers that have been fractured, this aimed to effectively boost the production of fractured well. High level stragety for candidate selection describe on (Figure 3)

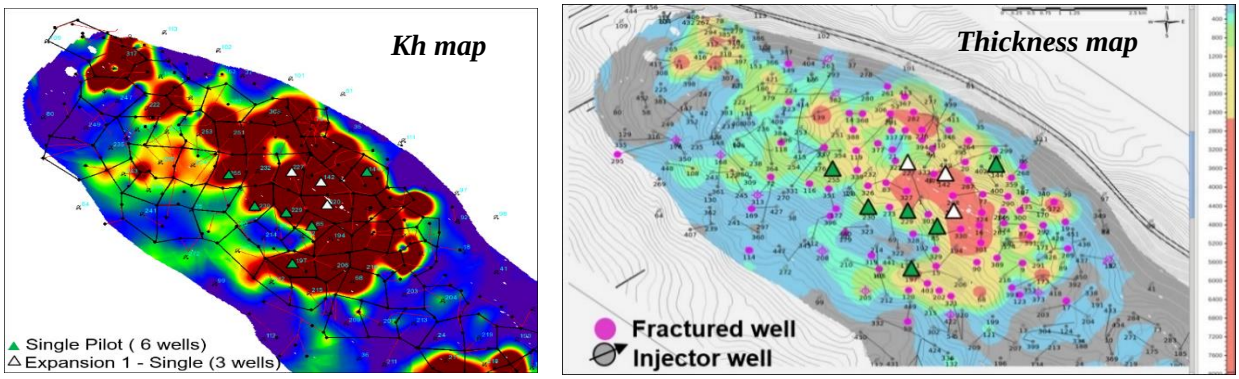

Figure 2. Candidate well location(rinie,2018)

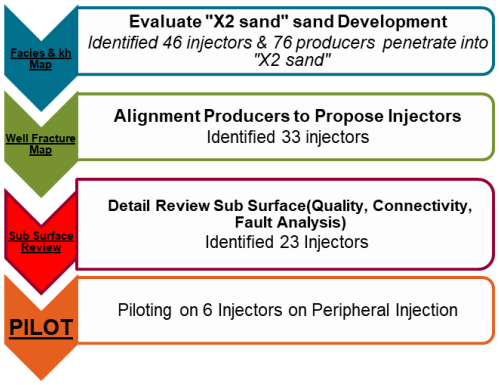

Figure 3. High level strategy candidate selection (yudi,2018)

2.4 Mbal Prediction

IPM-Mbal model was utilized to evaluate water injection and performance in “X-2” Sand of Kotatua field. The objectives were developed simple Mbal single tank model, assess voidage and production-pressure performance. Then provide prediction of pressure and production impact.

2.5 Pilot Execution

The best selected scenario was chosen based on the highest economic value which consist of 6 injector wells. The pilot start executed in April 2018 and online injection in May 2022. On this pilot stage also executed one workover producer well to be single completion on “X-2“sand. This producer well is located on first ring of injector that got response on pressure and WC improvement. Also, this effort trial the effectiveness the injection whether could support producer single completion “X-2” sand keep online.
The completion strategy of injectors and producers “X-2” sand was single completion (Figure 4). The objective to maximize the injection and get optimum sweep oil from injectors to producers.
The injection rate from 6 injectors had variation rate from 300 BWIPD to 1200 BWIPD, so total injection about 4500 BWIPD.

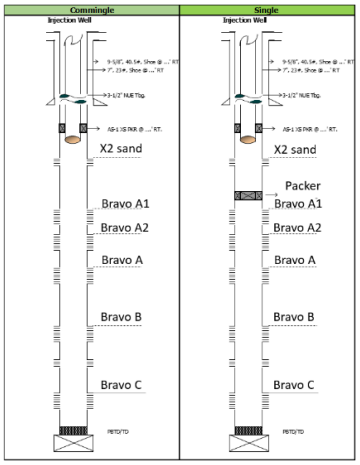

Figure 4. Completion type injector & producer X-2 sand (yudi,2018)

The pilot was successful then expanded by added 3 more injector wells on attic structure AOI "X-2" sand with approach by pattern injection. The expansion stage commences in Q4 2018.

3 Result

3.1 Surveillance

Most of producer wells are producing commingle from two or more sands (X-2 and Bravo). After 3 months injection online, surrounding producer wells were observed that the sonolog data shown inclined. A watercut also got improvement. To ensure the impact of "X-2" sand injection, an extensive surveillance and monitoring program required. A fingerprinting surveillance was performed to identify the zonal contribution between "X-2' versus Bravo sands. The fingerprinting analysis is basically a gas chromatography that has ability to reliably resolve small compositional differences in genetically related oil as shown in (Figure 5). This fingerprinting surveillance was conducted prior injection to understand the contribution of each sand either X-2 sand, or Bravo sand then routinely conducted post injection to understand the injector response. The evidence of X-2 injection response demonstrated any percentage change of fingerprinting result prior and post injection. (Table 1).

3.2 Workover

The injection response observed made unlock opportunity on "X-2" sand, brought back workover activity. It is important to developed flow process review to proposed workover on producer well. First, the wells are in first ring of injector and produced with commingle completion. Second, the "X-2" sand on those producer wells had been fractured. Third, the well is getting response on sonolog data by increased the FAP *(Fluid Above Pump)*. Fourth, the watercut of well is getting improve and confirmed with fingerprint data that show dominant contribution production from "X-2" sand.

Workover to convert completion type from commingle to be single completion on "X-2" sand, this objective is to maximize the performance recovery from displacement effect of injection. Total workover executed of single completion were 16 wells on period Q-4 2018 until Q4-2019. The fracturing job also could be revived by commence on 3 jobs and performed 100% success by delivering oil gain 699 BOPD.

During workover execution, pressure surveillance also conducted by performed Shut in Bottom Hole Pressure (SBHP). The pressure plot from taken SBHP showed that pressure increase from 350 psi to 1000 psi (Figure.6)

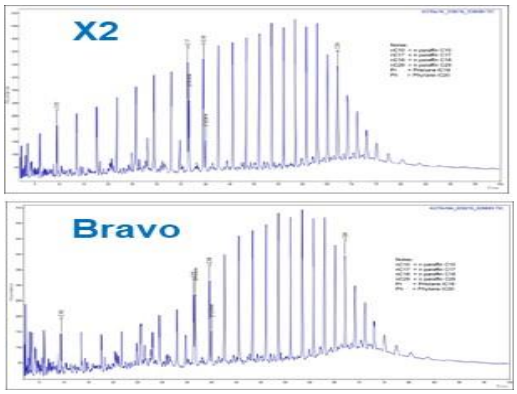

Figure 5. Chromatogram finger printing(rinie,2018)

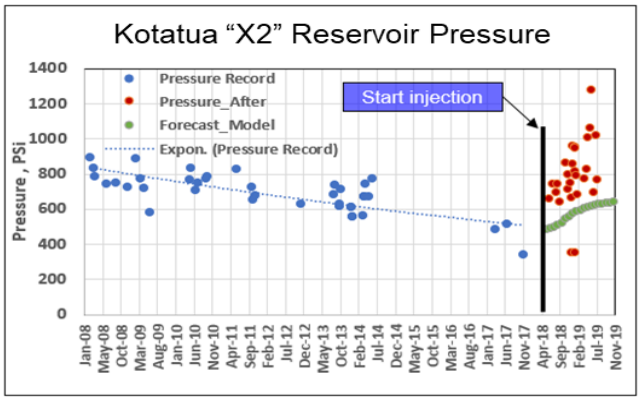

Figure 6. Pressure Plot (yudi,2018)

Table 1. Fingerprinting Result

WELL	Before WF		After WF	
	"X2"	BRAVO	"X2"	BRAVO
KTT326	60%	40%	100%	0%
KTT375	4%	96%	82%	18%
KTT368	0%	100%	56%	44%
KTT359	0%	100%	67%	33%

The project was successful to rejuvenate the "X-2" sand that was temporary abandon for 4 years due to dead faint. The reservoir already pressurized, and workover activity massively performed to increase Kotatua production. As of end 2019, monthly performance of "X-2" injection delivered contribution oil gain 2589 BOPD with daily injection 7050 BWIPD. (Figure 7). Additional cumulative production since commence injection were 746 MBO and improve RF ~ 0,51 %.

By performing "X-2" injection could rest Kotatua Field decline rate from 13,3 % become 11,7 % in 2019. (Figure 8). Until August 2022, this project contirbute to P1 add reserves 3,7 MMBO.

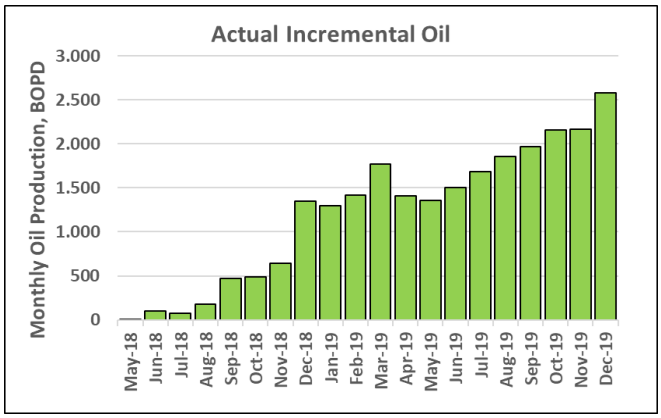

Figure 7. Monthly "X-2" Production (yudi,2019)

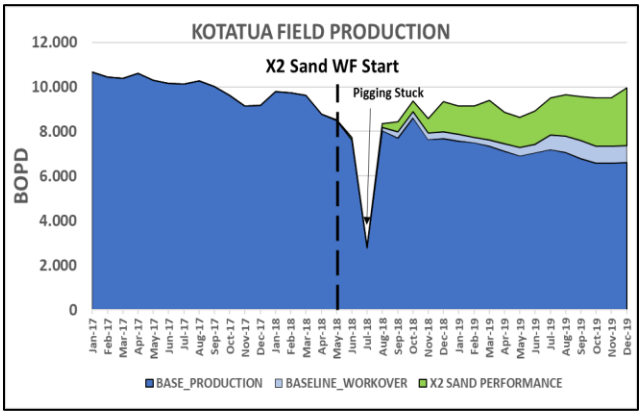

Figure 8. X-2 Production to Kotatua Production (yudi,2019)

4 Conclusion

The project was successful to flood a tight reservoir and delivered huge additional reserves. This part will share about lesson learn, best practices and challenges.

4.1 Lesson Learn:

- Developing focus strategy on reservoir level is the best reservoir management practice
- G&G subsurface evaluation have played strong role in selecting injector candidates
- Routine surveillance in waterflood project is key role to monitor the performance before and after injection

4.2 Best Practices:

- Utilize the Low-rate pump ESP to handle low-rate single completion "X-2" sand
- Implementation of hydrofract (continues breakdown) using rig to improve well injectivity on injector well
- Use of fingerprinting analysis to determine oil allocation pre- and post-waterflood injection

4.3 Challenge

- Low injection rate in low quality reservoirs
- Well injection measurement reliability on surface metering
- Low discharge pressure at Kotatua GS

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Acknowledgments

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