Production Enhancement of a Brown Field in the Niger Delta Using Well Intervention Techniques

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Abstract- **OB oil field in the Niger Delta is not producing optimally because of decline in reservoir pressure and low recovery efficiency. The wells have been producing for over 50 years, so the equipments are faulty resulting in premature well abandonment. This work diagnosed the problem of the field, developed a systematic method of production enhancement, and modeled the reservoir, using eclipse 100 to perform multiple sensitivities on some variables to identity conditions for optimum production, and enhance the productivity of the well. The result shows that the mobility ratio of the field is 0.5 therefore water flooding is the best choice for increasing the pressure, also the maximum number of wells required is two production and three injection wells. The distance between injectors and producers is 9110ft. From the design short radius horizontal wells yielded optimum recovery but are discarded because of poor economic viability, hence vertical wells are the best choice for optimal production.**

Keywords: Brown field, Production enhancement, Simulation, Eclipse and Well Reservoir Management, Water Flooding

Symbols and Annotations

CCT	Coiled Tubing Technology
DD	Directional Drilling
Bbl	Barrels
GF	Giant Field
OWC	Oil Water Contact
HCIIP	Hydrocarbon Initially in Place
M	Mobility Ratio
MOV	Movable Oil Volume
K_{rw}	Relative Permeability of Water
K_{ro}	Relative Viscosity of Oil
dp	Increase in Pressure
dl	Increase in Length
A	Area
q	Oil flow rate
k	Permeability
µ	Viscosity
μ_0	Oil Viscosity
μ_w	Viscosity of water

1. INTRODUCTION

Oil companies are experiencing dwindling oil reserve, and the discovery of new oil field is becoming more difficult. For these reasons, both co-operate and private individuals are channeling their interest and resources to enhance production from existing field and optimize mature fields to remain in business.

Principles, and cost reduction measures and utilization of latest technologies are the key to maximizing economic recovery from matured reservoirs [1], [11].

In the early phase of many crude-bearing sands, oil production is prolific, the primary principal expenditure focus on the external part. As a result reservoirs that are not producing much are quickly abandoned for fields that are more productive. High rewards lie in the world of brown fields. The world average recovery factor is between 35% - 37%, which implies that about 63% - 65% reserves still remain untapped.

As a result of new technologies deployed in improving matured field, the world's crude oil condensate reserves increased from 1.654 trillion to 1.656 trillion bbl at year end 2015. Total gas reserves jumped from 30.7 cu ft to 6.95 quadrillion cu ft [2]. About 30 giant fields make up 50 percent of the world's oil reserves and most of them are classified as matured fields. Novel and techniques that is economically viable and sound reservoir management strategies are prerequisite for the development of mature fields.

The technologies to restore brown fields are based on either reservoir or well applications. The determination of the optimum number of wells that can deplete the well is key to the enhancement of brown fields, once it is achieved well development practices like recompletion, stimulation, treatments, optimization of lift, surveillance, new entries and recollection of data are considered, followed by drilling of injectors for pressure maintenance or displacement [3].

A matured field is one that has been producing crude oil for a long time and is experiencing low production rate, low recovery efficiency, premature well abandonment, high volume of produced water and decline in reservoir pressure. In Nigeria since the first discovery of crude oil in commercial quantity in Oloibiri, Bayelsa State in 1956, more oil fields had been discovered apparently reservoirs that had been producing for a long duration are experiencing decline in oil production because of reduction in reservoir pressure. Hence it is pertinent to consider revamping brown fields in Nigeria to recover reasonable crude oil from these reserves to increase the economic fortunes of the country [12].

2 ENHANCING PRODUCTION IN A BROWN FIELD

About 70% of world oil production is from developed oil fields which has being in production for more than 30 years [4]. In some field well mediation are performed to improve oil production rate.

In Oman North field, well mediation project was undertaken in the year 2003 to 2005, which increased the field oil production rate [1]. The activities performed in the field to improve its productivity are outlined below:

a. Well surveillance: Different logs were run, pressure integrity tests for wells and reservoirs were also taken, coiled tubing and wire line units were deployed to determine where, when, and how to mediate.

b. Respectability exercise were undertaken to restore the wells to standard working conditions, which include: tubing patches, and squeeze.

c. Reclamation exercises were carried out to increase the field oil production rate; these include substitution of electrical submersible pumps, Gas lift valves and recapture of blocked holes.

Coiled tubing technology(CTT) has being in use for well maintenance and remedial work since 1960's, CTT is a continuous length of pipe that is stored , wrapped around a large reel, the same way a thick electrical cable is stored and shipped. The low cost and reduced environmental impacts of CTT have contributed to this growth. Directional Drilling (DD) of wells with horizontal distance of over 1,500 feet has been accomplished using coiled tubing. Drill out of blockages in existing wells using positive displacement mud motors mounted to Coiled tubing without the prior removal of production tubing or liners [5],[6]. Coiled tubing is also used in the traditional work over application, as well as in horizontal wells to insert and manipulate flow control equipment that regulates reservoir drainage [7].

DD was applied to increase the recovery factor of fluid dominated deltaic sandstone reservoir characterized by low permeability and underlain by a sandstone aquifer in Pennsylvanian Bartlesville sand.

In the Flatrock Field of Osage County, Oklahoma, the field produced over 30 million barrels of oil with over 1,000 conventional wells. Explosives were used to fracture the old vertical wells used which resulted to increased initial oil production rates to economic levels. However they also developed increased water cut immediately they clocked 12 months of service. To remedy the situation a horizontal well was drilled at a horizontal distance of 1,050 feet. Though oil production rate was not increased, the water cut was reduced from 75 percent to 14 percent [8].

In New Hope Field, Franklin County, Texas, dramatic increase in oil production rate was recorded by Texaco Exploration and Production Inco., when they drilled two horizontal injection wells into the reservoir. The injection wells were placed about 8,000 feet deep lower on the anticline structure of the field than the existing producing wells. This resulted to increased production per producing wells from 100 to 400bl/day, the highest production rate in the history of the field [9].

In Grassy Creek Trail Field, Emery and Carbon Counties, Utah, discovered in 1953 with five vertical wells which produced about 141,000 barrels of oil in 1961 and 1976. A second development program started in 1982 with the application of multiple short lateral borehole completions. Sixteen wells were drilled, but thirteen delivered production of 358,817 barrels of oil in a period of six years, two and half times the amount delivered by the five conventional wells during sixteen years [10].

3. RESERVOIR MODELING AND SIMULATION

Eclipse test was used to simulate the well, perform various affectability examinations to the ideal condition of the well for optimum performance.

3.1 Simulation workflow

The following steps were taken to build the repository model.

a. Analysis of the geographical rock and liquid properties of the depository.
b. Estimation of the oil in place.
c. Using the outcomes from step 1 and 2 to build a three dimensional depository model.
d. History matching of the wells
e. Using the developed reservoir model to test and observe the repository's reaction to changes in choice variables. This enables the determination of the ideal conditions that will improve the efficiency of the well.

3.2 Model description

A critical aspect of the reservoir reproduction is to isolate the waste range of the supply into various cells. The cells are characterized in the x, y, and z bearings as shown in Figure 1. A total of 212 and 91 cells were characterized in I and J bearings respectively. The thickness of the matrix is characterized with 64 layers in 2 bearing. The model comprises of 212, 212 matrix cells with measurements of 327ft x 322ft x 7ft. The oil in place is 162mm barrels.

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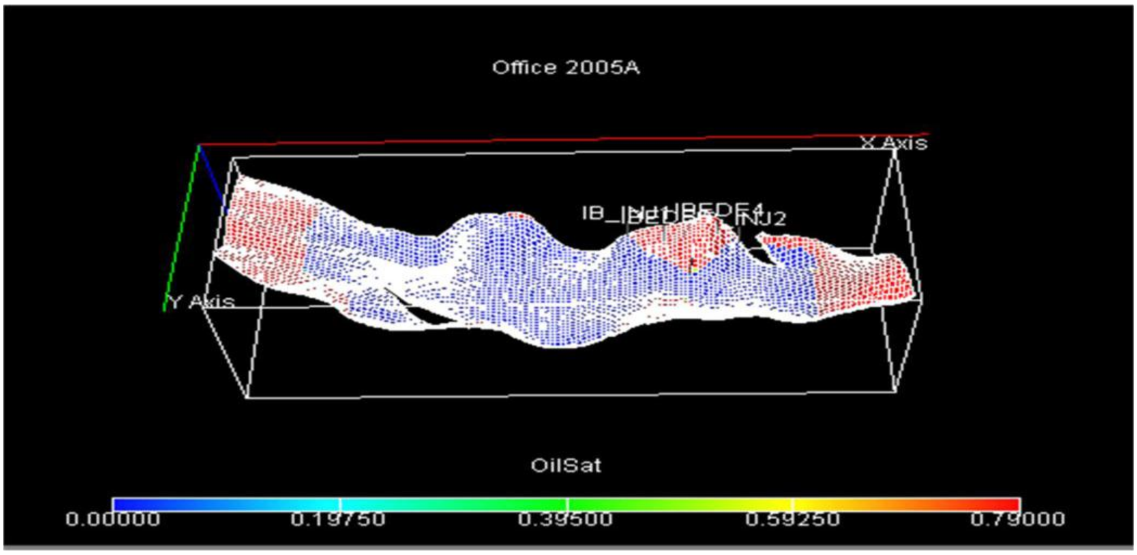

Figure 3.1: Showing Grid Dimension

Table 3.1: Reservoir Properties

Average NTG	Reservoir B1 = 0.4
	Reservoir B3 = 0.7
Average Porosity	B1= 0.18, B3 = 0.19
Initial water saturation	0.3
Oil API	37^0
Oil Viscosity	0.68cp – 1.08cp
Boil/rb	1.3scf/stb
Initial Pressure	4066 psia
Oil Water Contact	B1 = 9305 ft
	B3 = 9377ft
Dip Angle	0.4 deg
Average Pressure	4110 psia
Average Permeability	238 mD
Reservoir Temperature	175 ^{0}F
Water Viscosity	0.36 cp
Initial GOR	650- 750 Scf/stb
Bubble Point Pressure	3820 – 3920 Psi
Gas Oil Contact	9089 – 9134
HCIIP	162 mmbls

4. RESULTS

4.1 Well Count

To determine the ideal number of wells that can deplete the reservoir, a creaming bend was developed. This is essentially a plot of aggregate oil production against aggregate of delivering wells. The creaming bend shows the point at which lessening return happens for a specific number of wells.

The creaming bend for the field (Appendix 1) was produced by plotting one vertical production well after another in various areas in the repository model. The number of wells before the smoothed zone is chosen as the number to initiate production. The bend smoothed when the number of wells is 5. This implies that the number of wells required to deplete the field will not exceed five.

The well positioning process, initiated with 5 vertical production wells and four infusion wells for pressure upkeep and oil dislodging towards the well bores.

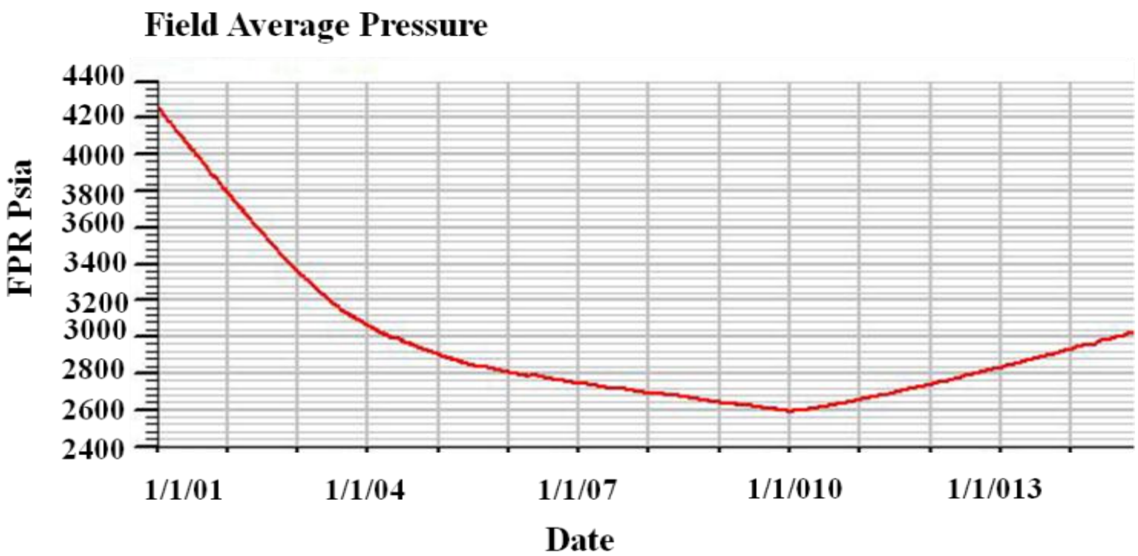

Figure 4.1: Pressure Depletion over Time

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The production wells were set utilizing the systems specified. They were made to cut crosswise over layers that have recoverable measure of oil. Wells were allotted with a steady rate of 6,000bb/day at a bottom-hole press of 2500psi. The outcomes from every run were broken down and well with high water cuts and low production rates were disposed. The quantity of injection wells was reduced for every well killed and production rate of the remaining wells was increased. The procedure was repeated for four, three, two and one vertical well separately. The ideal number of wells that yielded optimum oil recovery rate is two vertical production and 3 infusion wells as shown in Appendix 1.

4.2 Recovery Mechanism for the Development Scheme

From table 3.1, the air point pressure of the field is constrained close to the reservoir pressure, as production is initiated, the slight distinction in the supply and air pocket point pressure results in the freedom of gas, as the pressure falls below the pocked point pressure. This leads to a rapid drop in pressure with time (Figure 4.1). The precarious pressure drop is undesirable because a low repository pressure implies a decrease in oil production rate. Hence, an auxiliary strategy for oil recovery is required to compensate for the quick decrease in pressure.

4.3 Choice of Pressure Maintenance

The choice to conduct water flooding in oil fields is customarily considered when the oil viscosity is low, so that the mobility ratio is less than unity, from Darcy's law:

$$Q = \frac{kA}{\mu}\frac{dp}{dl} \qquad 4.1$$

This condition of low viscosity has similar result as high permeability in stimulating high flow rates thus fast-tracking field improvement by combining the end point relative permeability and by application of Darcy's law:

$$M = \frac{\text{max.Vel.of the displacing phase (water)}}{\text{Max.Vel.Of the displaced phase (oil)}} \qquad 4.2$$

By substituting the parameters of table 1, the mobility ratio (M) = 0.5.

This implies that the oil will travel faster than the water, hence dislodges it in a perfect piston like fashion. This is the most satisfactory form of displacement and denotes that the total volume of moveable oil can be recovered by injection of a corresponding volume of water; consequently the flooding is correspondingly proficient and speedy. Hence water flooding is the best choice for pressure upkeep.

4.4 Optimal Well placement

The strategy employed for situating wells was distinguishing the sweet spots in the supply which yields the highest oil rate. Sweet spots are districts where crude oil is situated in the reservoir.

The second strategy was to position wells on the up plunge (far from the oil water contact (OWC)) of the repository, to forestall water coning as shown in Figure 4.2.

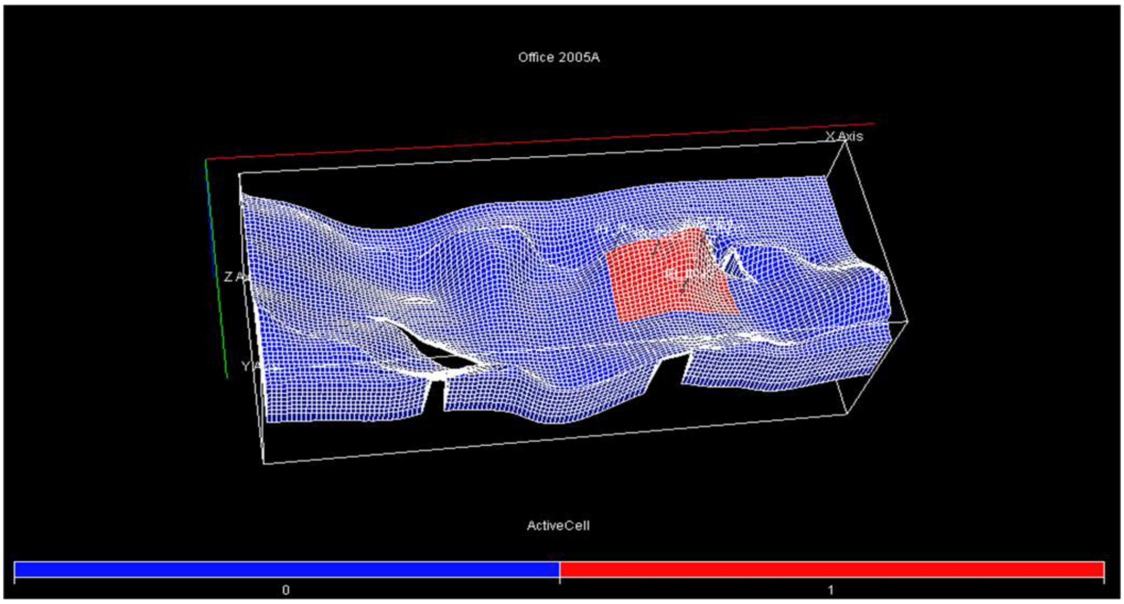

Figure 4.2: Wells Positioned on the up plunge

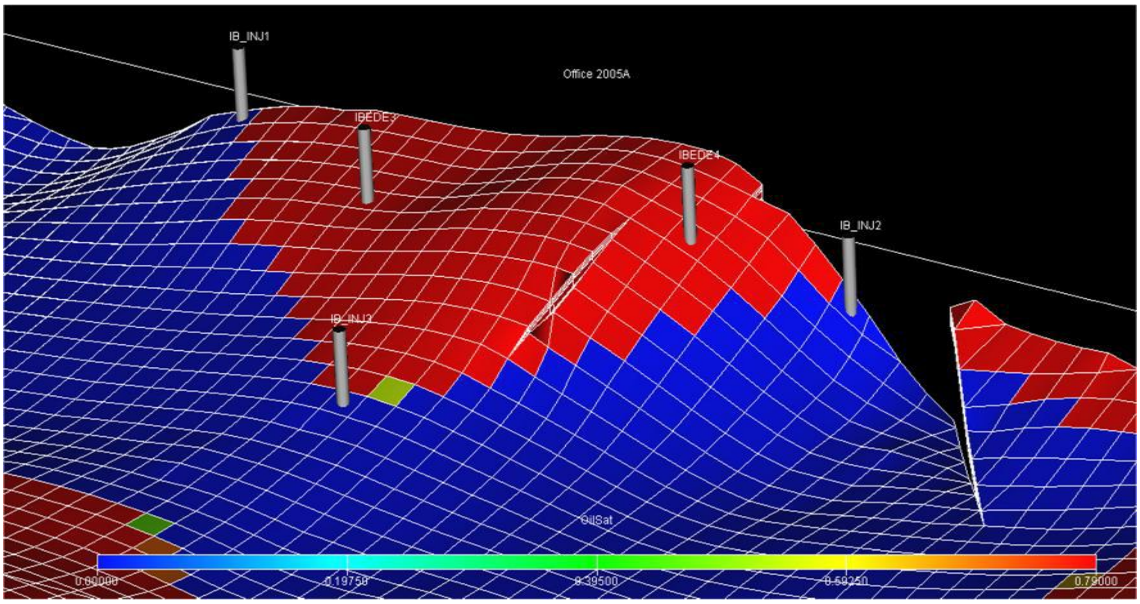

Figure 4: Optimum Well Placement

4.5 Improvement of Volumetric Sweep Efficiency

The injection and production wells were re-aligned to increase the total reservoir volume that is swept by the injected fluid which resulted to increase in volumetric sweep efficiency.

Table 4.1: Injector Well Distance Sweep Efficiency

Distance (ft)	Field displacement efficiency (%)	Cumulative Oil Production
3,000	38	55.985664
5600	40.9	66.396452
9110	43	70.823232

4.5. Determination of Optimal distance between injectors and Producers

From Figure 3, producer IBEDEZ and IBEDE4 yielded the highest oil rate. IBEDE4 has the highest water cut as a result of the closeness of injector 2 to IBEDE4. The wells were repositioned and injectors placed beneath the oil OWC to expand water drive to both makers.

From table 4.1, the highest field displacement efficiency yielded the highest cumulative oil production; hence the injectors were placed at a distance of 911ft from the producers.

5. CONCLUSION

To improve oil production in a brown field with a solution gas drive. Eclipse 100 black oil simulation was used to determine the conditions for optimum oil recovery. The field model with water injectors was developed.

- Short Radius Horizontal wells gave the highest recovery, but were replaced with vertical wells because the drilling expenses were not absorbed by the income generated.
- From the design two production and three injection wells yielded optimum oil production rate.
- The optimum distance between injectors and producers is 9110 ft
- Water flooding was employed to maintain the reservoir pressure because of the field's low mobility ratio of 0.5.

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APPENDIX

Appendix 1: Creaming Curve