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Implementing Most Recent Technology using Nanoparticles as Enhanced Oil Recovery Technique at Pattern-13, Block D2, Layer Z600 at Rantau Field, NAD

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Implementing Most Recent Technology using Nanoparticles as Enhanced Oil Recovery Technique at Pattern-13, Block D2, Layer Z600 at Rantau Field, NAD.

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Abstract

Enhanced Oil Recovery (EOR) is purposed to improve additional recoverable reserve and recovery factor by injecting material such as chemical, surfactant, microbial, steam, gas and recent technol- ogy such as nanoparticle material / Nano flooding. *Nano flooding using nanoparticle material* is one of the most recent EOR technique. Nanoparticles has size less than 10^{-8} meters or 0.1 μm and its size is much smaller than common reservoir rock pore throat (1-20 μm). Hence it can propagate through deep reservoir throat and displace remaining oil that cannot be displace during primary and secondary process (water flooding). Its dominant mechanism to displace remaining oil in the reser- voir are wettability alteration by reducing contact angle between oil drop and surface rock in the aqueous system to be more water-wet system.

EOR is also part of task force plan from President of Indonesia to increase Indonesian oil production immediately. The application of Nano flooding requires shorter time than any matured EOR tech- niques and it called fast-tracing method because its all simplicity in laboratory test activities and more cost efficient with much lower required volume and minor upgrading surface facilities, from study to field trial. The first field trial is going to be implemented at Rantau Field in structure Z600 Block D2 at Pattern-13. This pattern consists of one injector and 3 monitoring wells. The *Original Oil in Place* (OOIP) at Pattern 13 is about 2.092 MMSTB. Secondary process using water flooding has been conducted since 1997. However, the cumulative production is still low ~0.140 MMSTB or only achieved recovery factor (RF) less than 7% and Nano flooding is proposed to improve oil re- covery immediately.

This paper describes opportunity and challenges, lesson learned from current project and its imple- mentation design of Nano flooding project. The study and field trial implementation are going to be the first trial of Nano flooding in Indonesia. Nano flooding technique has achieved success stories in Canada and China as field trials. Once field trial at Pattern-13 succeed, the full-scale, including other fields can be highly potential to be implemented to increase Indonesian oil production.

Keywords: *Nanoparticle material, Enhance Oil Recovery, Wettability alteration*

Introduction

Many oil fields worldwide have reached the stage where the total production rate is declining. In Indonesia, there is still a significant upside potential for unrecovered oil and gas, with many Indonesia fields ready for enhanced oil recovery (EOR). Increased oil recovery (IOR/EOR) is urgent and highly prioritized by Indonesian Minis- tries due to the serious economic impact the low oil recovery has on the Indonesian Economy. Based on data from SKK Migas in 2016, the op- portunity for EOR in Indonesia is about 4.6 billion barrels of oil from 136 fields. Making its mark as a new and advanced EOR technology, the applcation of Nanotechnology in enhanced oil recovery (Nano-EOR) comes with several recognized benefits for fast-tracking EOR implementation.

There are some challenges from technical, fiscal, and regulation aspects. One of technical aspect that Indonesia is facing is long lead time in study and preparation from screening to implementation. In addition, the high cost with low oil price situation makes some matured EOR methods become unfeasible. With these challenges, the oil and gas industry are facing, with focus on fast-tracking and cost-efficient. It is considered the best time to introduce Nano-EOR in Indonesia now.

Benefit of Nano – EOR

Among EOR methods, Chemical (Surfactant) may have the highest risk (Lake et al., Oil Field Review, 1992) due to large capital investments to develop new CEOR facilities, the most difficult design decision (wrt. Reservoir P&T, salinity, clay, slug, etc) and being strongly affected by reservoir heterogeneities. The main reasons for Nano-EOR being considered as a fast-tracking and cost-efficient recovery method, may be summarized as:

1. Cost Efficient

Displacement mechanism of using Nano-EOR will occur inside the pore-throat of the rocks therefore only small quantities/ concentration are required and hence cost reduction on Capex and Opex. The benefits of applying Nano-EOR can be attributed to the particles physical capabilities. “Nano” refers to one billionth (10^{-9}) in size in science terms and Nano fluids are suspensions of nanoparticles in base fluids. The two physical characteristics of nanoparticles (NPs) that make them particularly beneficial for enhanced oil re- covery processes is their size and physical- chemistry properties. Their extremely small size gives it the capability to easily flow through reservoir rock pore throat (which is mostly identified in micron size) and they have the ability to manipulate their physical-chemistry (such as changing from hydrophilic to hydrophobic with silanization). This is important to cost efficiently displace and maximize the remaining oil.

2. Fast Tracking EOR Method

Less complexity in Lab-test compares with CEOR, makes Nano-EOR faster on testing and front-end activities. Unlike surfactant that created micro emulsion, our nanoparticles are strongly soluble in water (hydrophilic) and does not create micro emulsion and degradable at high temperature (<130^o C) that makes the activities in the laboratory not as complicated as CEOR. Hence, Nano-EOR doesn’t have any problem with post-production or separation process with produced oil. Nano-EOR has an optimum concentration and the injection strategy that should be observed in the laboratory.

3. Fast Track & Cost Efficient

Minor surface facility modification compares to CEOR (SPE-174656-MS), hence it can reduce capex cost and implementation time. In short, all these market available EOR methods are facing the needs.

4. Fast Track EOR Method

Wider range of application, more suitable fields than CEOR, makes Nano-EOR more generic, robust and faster. Worldwide research results show that Nano-EOR has a potential for sand-stones and carbonates with the recovery efficiency up to ~40% of the OOIP at core-scale (Sun et al, 2017). It is also suitable from low to high permeability, light to heavy oil and low to high salinity with various initial rock wettability based on research.

Nano-EOR has been tried in some fields in Canada and China in recent years. It was surprisingly achieving success with can increased production rate up to 88%. The screening criteria is created based on implemented project basis (Figure 1)

Fast Tracking of Nano - EOR

Increased oil recovery is urgent and highly prioritized by Indonesian Ministries due to the serious Economic impact of the low oil recovery on the Indonesian Economy. A Fast Tracking EOR is hence requested by the Indonesian Ministries. The EOR methods need to be economical at low oil prices and to be sustainable. There are signif- icant potentials for increased production from present Indonesian fields as compared to best practice fields World Wide.

The Nano-EOR technology will further build an Indonesian Competency Organization by employing and training Indonesian talents to ensure execution of major part of work is carried out Indonesia and by Indonesian, and that the efforts, knowledge and competency become sustaina- ble. The personnel have extensive experience in, and master all commercial oil recovery meth- ods. Only a few EOR methods are considered commercial viable at less $50 /barrel i.e. Low Sa- linity, Water alternating Gas (WAG) and Nano- EOR.

That technology will actively pursue and contribute in such a way that Indonesia take the lead in Nano EOR. That is further proposing Nano EOR in close interaction with Water Injection as a very suitable recovery method to achieve Cost Efficiency and Fast Tracking EOR. Indonesia have an outstanding Pioneer with International recognized competency within Nano EOR and many low recovery fields suitable for Nano EOR.

If standardization and efficiency in the implementation and operation phase can be achieved, the cost efficiency potential can be realized in full. That technology intent to standardize e.g. approach and equipment, will seek to accelerate plans and activities when experience is gathered, and will run activities in parallel were appropriate. Decision for commercial will be taken as early as possible during the Field Testing, and not necessarily wait until the Field test is com- pleted.

It is planned that the Nano EOR activities at the different fields shall effectively be managed and supported by one team of experts and operational personnel, have good experience in building and developing competency teams and Project organization for effective execution of Projects, additional facilities, extensive facilities upgrade/ modification and high raw material cost issues. Through the introducing of Nano-EOR, these existing challenges with conventional EOR can be resolved or avoided, at a lower cost. As a trial, Rantau structure will be trialed the first of Nano-EOR Flooding implementation.

Objective and Target.

The objective of the Nano EOR Study and Field Test Program is to establish a sufficiently robust technical basis with acceptable risk, for an immediate, wide and accelerated commercializa- tion of Nano EOR in close interaction with water Injection in Indonesia. The objective is to further verify the cost efficiency and economical poten- tials of Nano EOR application in some typical reservoir conditions at Indonesia. The Field Test results shall also be the basis for the finalization of the Nano EOR business model between Pertamina EP and supported company. The target is to increase the recovery factor by 5-10 %, and to extend the field life by 3-5 years.

Propose Nano EOR Flooding at 2018- 2020

The Field Test Program shall be designed to fully support the Fast Track Nano EOR projects for immediate commercialization.

The Field Test will be carried out in a systematic and prioritized way according to requirements, commitment and agreement from Pertamina EP, SKKMigas and ESDM. It shall cover estimate 3 others fields with WF implementation (even pilot) and high potential for increased recovery Fields which are more suitable for Nano EOR shall be prioritized i.e. likely success with (P>70%), and fields with high potentials with regards to increase recovery and with high OOIP. Fields with particular challenges shall be avoided in the first phase of the tests.

The Projects shall be proactively managed by modern Risk Management principles and systems, and all Stakeholders are requested to regularly take part in Risk Work Shops to ensure transparency of the critical activities and to clearly identify the responsible organization and persons. Risk Mitigating actions with deadline and responsible organization identified shall hence be transparent and distributed to all Stakeholders and Parties regularly i.e. monthly.

Rantau structure of Field Test.

Conducted assessment and found that the
reservoir in Rantau Field, Layer Z600, Block D2, Pattern 13 (Figure 2) is suitable for a Nano Field Test. Some issues and the mitigations that will help to improve success to this field test:

Reservoir fluid and rock properties are suitable for Nano-EOR, Recovery factor in Pattern 13 is relatively low for about 6%, hence there is still huge potential for incremental oil production. Rantau structure, in general, has a complex reservoir structure caused by fault. Communication between injector and all relevant production wells has been detected, some have a good response such as Well P346. All wells in Pattern 13 are targeted only for single layer, Z600 (no comingle wells). Hence, monitoring of the Nano- EOR impact will be easier.

The reservoir is relatively shallow, which makes well interventions and stimulations etc. significantly cheaper to carry out if needed. Water quality is good with in agreement with relative plugging index value.

The reservoir responded well to water injection initiated in 2014 (response time approximately 3 months after starting up).

Field test start-up will take place in good timing relative to water injection initiation. Water Injection rates is unstable. We preferred stable injection rate for Nano EOR.

Please make sure water injection rate is stable for 1 or 2 weeks prior to start injecting
Nano-EOR. Sand problem is found in the nearby wells due to unconsolidated sandstone. Therefore, there is risk on sand production on the wells in Pattern 13. We suggested to do evaluation in well status prior to start Nano-EOR. No or limited native core for lab. Studies hence we suggest using analog cores for Lab studies with similar properties and mineralogy Quality control of surveillance data (production and pressure data at injecting and monitoring wells. Detail timeline for Nano-EOR Field Trial can be looked in Figure 3.

Rantau structure overview for Nano EOR.

Rantau field, located at 110 Km northwest
Medan, was discovered by BPM Shell in 1929 and has been produced with 597 different oil wells. It consists of several layered reservoir with highly faulted structure. Peak production was reached at 32 thousand barrels oil per day in 1969. Zone interest for application of Nano EOR at Z600, with OOIP Z 600: 128.9 MMSTB, NP (cum prod)
: 3.3 MMSTB, and current status is full scale wa- ter flood through irregular pattern. Rantau Field, in general, has complex reservoir structure due to fault. Figure 4. Rantau structure production History **Error! Reference source not found.**show the production history of Rantau structure.

Full scale water flood show a promising impact on oil recovery. Rantau structure has complex reservoir structure caused by fault existence across reservoir. Major and minor faults separate each layer into several blocks. 5 (five) blocks candidate for selected block/pattern, have been reviewed, and pattern/block selected based on low RF, high potential reserve and WF implementation. Figure 5, map of Rantau map with pattern/block that will select as Nano EOR.

Focused block for this screening will be in block D2 and pattern 13. Based on geological model, Z600 seem to be homogenous with no large var- iation on both porosity and permeability distribution with average value of 18% and 85 mD. Block D2 with OOIP (MSTB) 13.872, NP (MSTB)
4.658, RF 33.6%. And Pattern 13 with OOIP
(MSTB) 2.092, NP (MSTB) 114.3, and RF 5.5%.
So, for Block D2, pattern 13, with lower factor due to still low RF and high potential for Nano EOR.

Remark, that Nano EOR have been implemented at reservoir with good reservoir quality and homogeneous, good injector-producer response, has injection facilities are already existed with capacity 20.000 BWPD.

Phases in Nanoflooding Project

There are 3 main phases in Nanoflooding Project based on its purposes:

1. Phase 0: Data Gathering

Data Gathering is the systematic approach to gathering and measuring information from a variety of sources to get a complete and accurate picture of an area of interest. Data collection enables a person or organization to answer relevant questions, evaluate outcomes and make predictions about future probabilities and trends.

Regardless of the field of study or preference for defining data (quantitative or qualitative), accurate data collection is essential to maintaining the integrity of research. Both the selection of appropriate data collection instruments (existing, modified, or newly developed) and clearly delineated instructions for their correct use reduce the likelihood of errors occurring.

A formal data collection process is necessary as it ensures that the data gathered are both defined and accurate and that subsequent decisions based on arguments embodied in the findings are valid. The process provides both a baseline from which to measure and in certain cases an indication of what to improve.

2. Phase 1: EOR Process Identification and Processing.

The purpose of this phase is to evaluate fluid and rock properties, structure map, reservoir connectivity, well log studies, core analysis, core/cutting evaluation, mineralogy, surveillance data, well testing, existing production and injection data. From there, we can understand reservoir behav- ior, driving mechanism and evaluate reservoir deliverability. Understanding reservoir means we can mitigate major geological and reservoir risks and establish action plan.

3. Phase 2: Nano-EOR Field Trial and Implementation.

Before we implement the Nano-EOR Field Trial, first we need to define objective of field test, selection of surveillance method suitable for field condition. Assessing existing data and intelligent data surveillance of subsurface is one of many way to increase certainty of Nano-EOR injection.

After implement Nano-EOR Field Trial, monitoring and surveillance are needed to supervise respond of well monitoring and injection. Operation support, Monitoring & Surveillance Evaluation, Way forward and Suggestions based on field test result are main key to achieve success of Nano-EOR Field Trial.

Laboratory Procedures and Guidelines.

The objective of Laboratory Procedures and Guidelines is for it to be used as a guideline for evaluation, development and implementation of quality systems and standards for Nano-EOR Field Trial. Once laboratory quality standards have been developed, an implementation plan then needs to be drawn up with short-, medium- and long-term objectives and activities, implementing partners identified, and the necessary budgetary support provided.

In Nano-EOR Field Trial, we conduct 3 main ac- tivities for laboratory test (Figure 6). Those 3 main activities are:

1. Fluid and Material Characterization Test

In this sub-laboratory test, we perform Reservoir Fluid Analysis, Nanosphere Analysis, and Porous Media Analysis. Equipments that used for this test are standard laboratory equipments for Reservoir Fluid Analysis and Particle Size Ana- lyzer (PSA) for 10 nM material size or less. Data that will acquired from this test are Oil Properties, Water Properties, pH of Nano-particles, and dis- tribution of nano-particles. Duration for this test is about 3-7 days

2. Fluid-Fluid Interaction Test

In this sub-laboratory test, we perform Nanofluid Formulation & Selection and Compatibility test between nanofluid and water injection. Equipments that used for this test are standard blend- ing equipment for Nanofluid Formulation & Se- lection and basic compatibility test equipment for compatibility test. Data that will acquired from this test are nanofluid viscosity-concentration test, nanofluid characteristic at reservoir condi- tion and rheology change in water injection. Du- ration for this sub-test respectively are 5-7 days and 4-8 weeks for each test.

3. Fluid-Rock Interaction/ Coreflood Experiments

In this sub-laboratory test, we perform Spontaneous Imbibition Test, Forced Imbibition Test, and Optimization Test for Nano EOR flooding. Equipments that use for this test are standard equipment, Amott-Cell, and standard core flood equipment respectively. Data that will acquired from this test are contact angle measurement, water saturating process, oil displacement, dis- placement efficiency and filtration ratio. Duration for this test are 5-10 days, 10-30 days, and 30- 60 days respectively.

Economical calculation and production estimating due to Nano EOR Flooding.

With OOIP from pattern 12, is 2.092 MMBBL, Cumulative prod (Np) 0.1046 MMBBL, and RF 5%. With assume ultimate RF 35%, or 0.7323 MMBBL. With cumulative production of primary and secondary recovery 40%.

With reference from past experience at china or Canada field trial that Nano EOR injection can increase production 3-6% from recovery, so effect of Nano EOR can produce 0.05361 MMBBL oil. It can be seen difference rate and cumulative oil between injected with Nano-EOR and with as- sumption oil price at UsD 70 / BBL, production cost of Rantau Structure is approximately UsD 25 / BBL, it can get UsD 2.4 MM revenue with Nano technology. As economical, the Nano EOR injection can be result benefit to increase and ad- ditional production, and start with small pattern reservoir.

Conclusion.

1. Nano EOR implementation, hopefully can be increase 3-6 % from remaining recovery base on previous experience.
2. Pattern 13, Block D, layer Z600, will be se- lected as Nano EOR injected, due to fast re- sponse during water injection, and still low RF (5%).
3. This project is as study and field test, before implemented full scale injection.
4. This project, still on plan to be execute on 2018, and the progress still on laboratories test, and preparation for mechanical site prep- aration for injection.

Appendix.

1. Rantau Structure daily production report, Layer Z400, 500 and 600 WF, 2015.
2. Nano Flooding technology, many papers technology conference, from 2016.

List of Figures

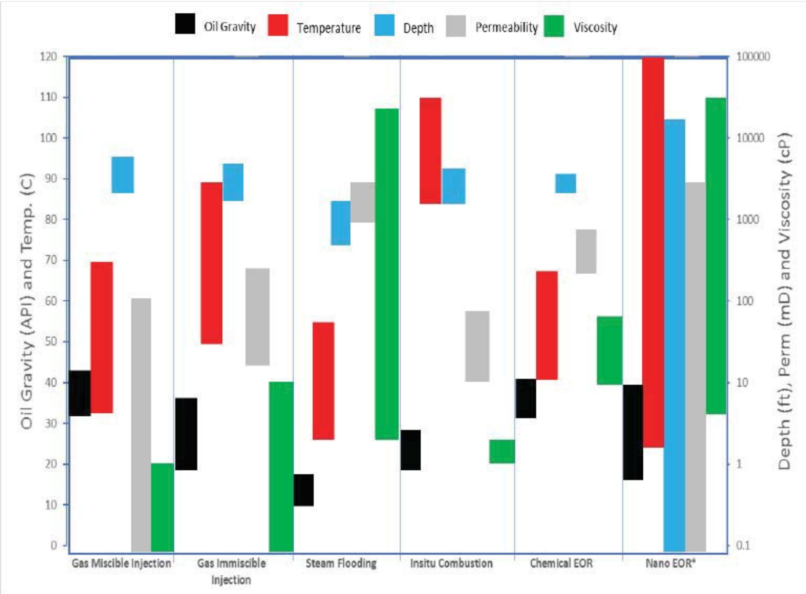


Figure 1. EOR Methods Screening Criteria based on EOR Successful Project and Nano-EOR. (SPE -130726-MS)

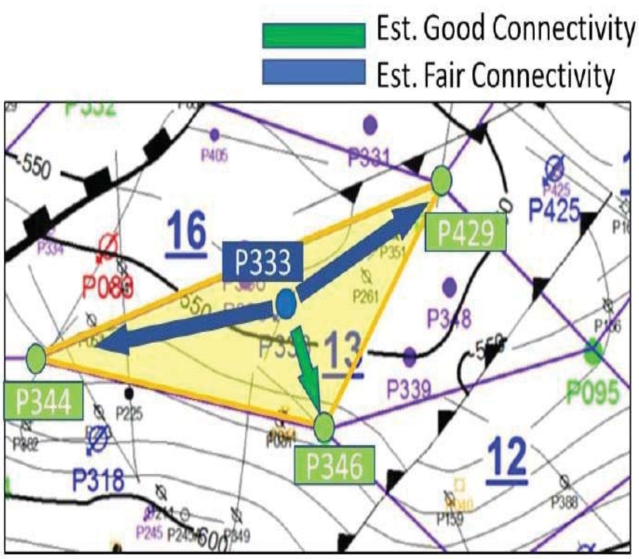


Figure 2. Rantau Structure, Pattern 13, Layer Z600, Block D2

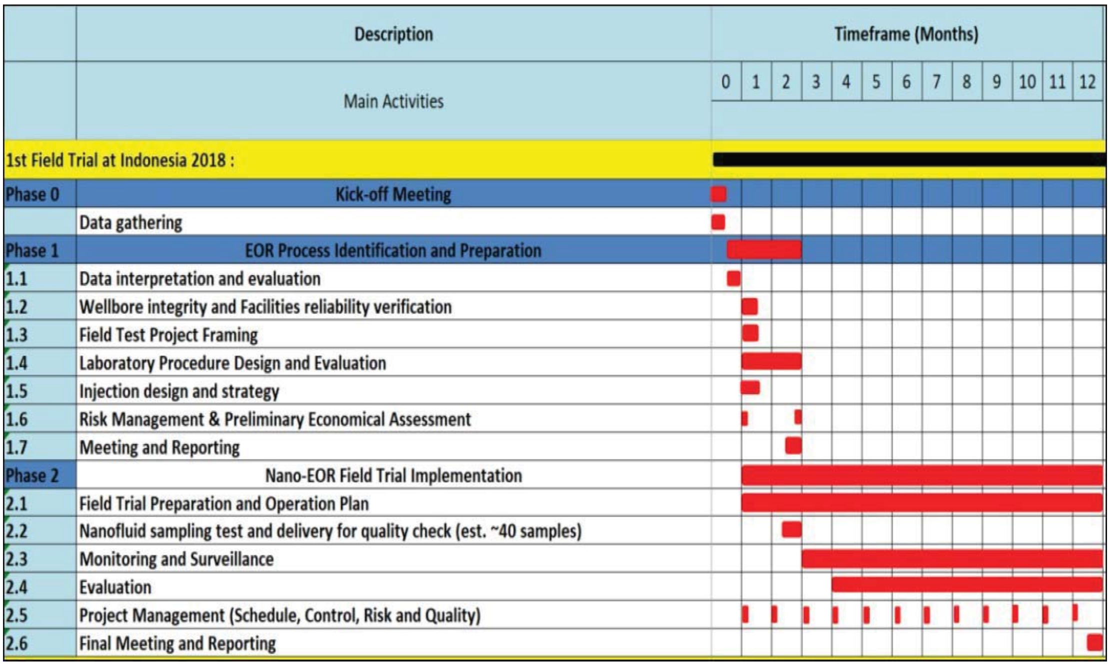


Figure 3. Timeline for Rantau Pattern 13 – First Nano-EOR Field study and Single Field Test

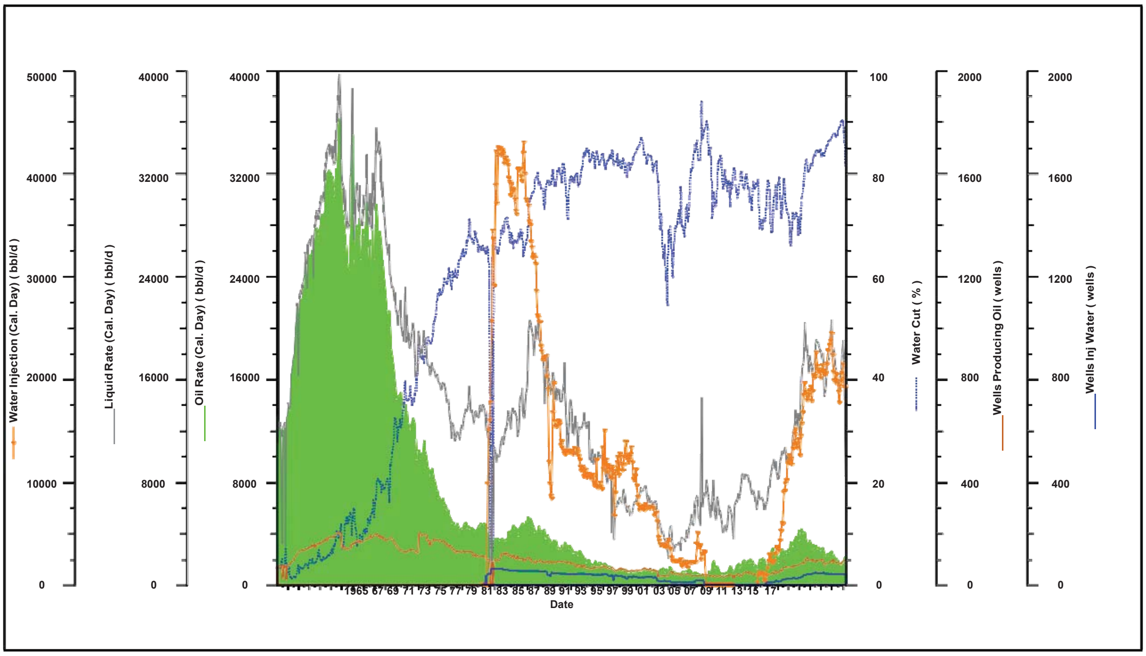
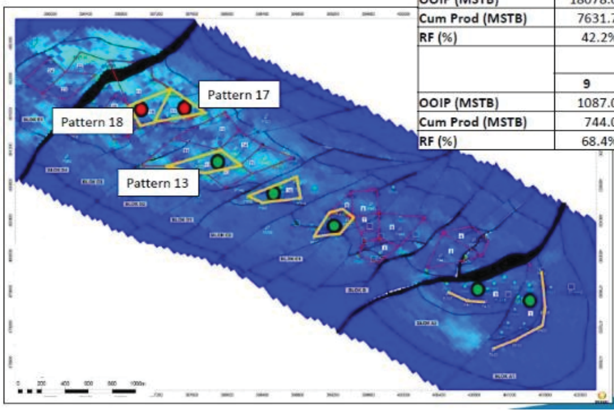


Figure 4. Rantau structure production History



	Block				
	C1	C2	D2	D3	D4
OOIP (MSTB)	18078.0	9911.0	13872.0	10329.0	17155.0
Cum Prod (MSTB)	7631.7	3144.3	4658.2	2845.2	3280.7
RF (%)	42.2%	31.7%	33.6%	27.5%	19.1%
	Pattern				
	9	10	13	17	18
OOIP (MSTB)	1087.0	2497.0	2092.0	1971.0	1463.0
Cum Prod (MSTB)	744.0	851.2	114.3	414.4	1.8
RF (%)	68.4%	34.1%	5.5%	21.0%	0.1%

- Proposed another pattern with lower recovery factor if applicable
- Block D still has low RF → high potential for Nano EOR

Figure 5. Map of Rantau structure with Patterns/ blocks selection.

	Description	Timeframe (Months)												
	Main Activities	0	1	2	3	4	5	6	7	8	9	10	11	12
Phase 2	Nano-EOR Field Trial Implementation													
2.1	Laboratory Test (To be done by Pertamina UTC)													
2.1.1	Fluid and Material Characterization a. Reservoir Fluid Analysis: Oil (Properties), Production and Injection Water (TDS and Ionic composition) b. Nanosphere: Size distribution (Particle Size analyzer) and elemental analysis (SEM+EDX) c. Porous Media: Core (Cleaning, Properties measurement and Aging (if required))													
2.1.2	Fluid-fluid Interaction a.Nanofluid formulation and selection (Dispersed in injected water with max. 3 different concentrations) b. Compatibility tests (Stability of nanofluid for 2 weeks at reservoir temperature, dynamic IFT measurements with 3 different temperature (room, 35 and 45 C)													
2.1.3	Fluid-rock Interaction/Coreflood experiments a. Spontaneous Imbibition (Core preparation of drainage and imbibiton: oil recovery experiments: Core with Injected Brine and max. 3 different nanofluids): Total 4 Cores b. Forced Imbibition: Coreflooding with injected water until oil production (Sor) and then starts injection Nanofluids (Max. 3 different concentration of nanofluids and 2 coreflooding each concentration). Total Max. 6 Cores c. Process Optimization: Select injection strategies to maximize oil recovery. Total Max. 4 Coreflooding													

Figure 6. Timeline for Nano-EOR Laboratorium Test.

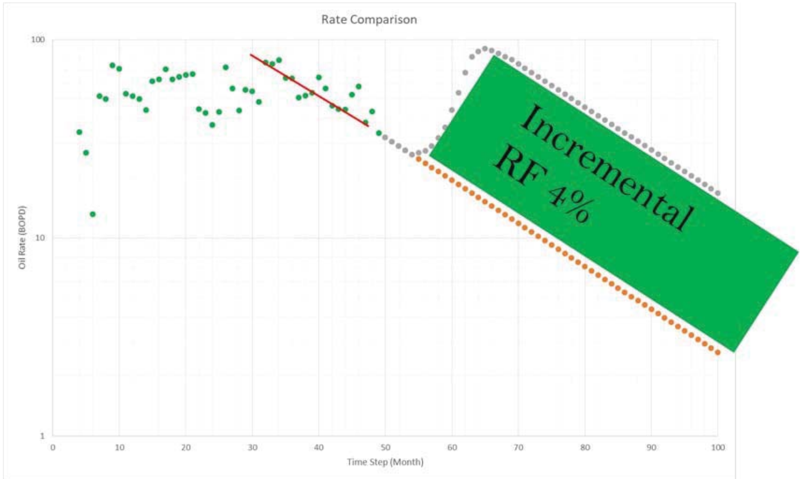


Figure 7. Oil Rate comparison between Injected Nano-EOR and without it.

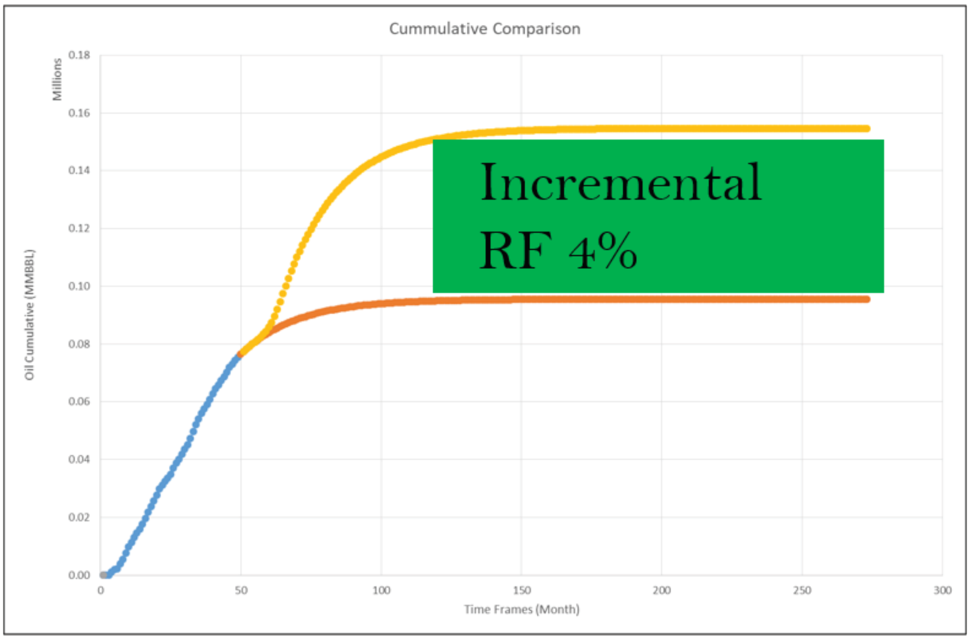


Figure 8. Oil Cumulative comparison between Injected Nano-EOR and without it.