Integrating Production Analysis as a Plan of Pattern Selection for Chemical

by Dedy Kristanto

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Integrating Production Analysis as a Plan of Pattern Selection for Chemical Flood Pilot Project in Limau Block, Pertamina EP

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Abstract

Limau Block, operated by Pertamina EP lies in South Sumatera basin, located 90 km Western part of Prabumulih. Consisted of eight fields, the first well was drilled in April 1951. The production reached a peak of 49,000 BOPD. The reservoir was divided into 22 layers mainly due to faulting. The pilot water flood operation was initiated in April 1991 by injecting water. Currently, Limau block is a mature oil field. By April 2009 production had declined to 10,000 BOPD. It is estimated that more than 80% primary reserves have already been produced and recovery factor has reached 36 %. Most of the reservoirs have been intensively produced over the life of the field and only a few of them are still producing today at low rate due to depletion.

EOR department tried to identify reservoir with remaining production potential that are candidates for Pilot Chemical Flooding Project, which will be the first Chemical Flood Project for Pertamina EP. The chemical selection is ongoing progress. It has become much more of a challenge for the team consisting of integrated Geophysics, Geology, Reservoir, Production, Process Facility, Project Management and Economic Evaluation.

This paper presents the result of Production Part as integrated analysis for Chemical Flooding. The analysis, which was performed by integrated analysis of production and injection, tracer test, well history and surface data, has identified inter well communication between injection well and production well. It shows that the most prospective candidate for Chemical Flood pilot project was S layer in Q-51 field, the pilot project was planned for inverted five (5) spot patterns and predicted breakthrough time was 90 days, it was also predicted a tertiary peak of 3,100 BOPD. Currently, Q-51 field, which had reached a primary peak of 20,600 BOPD and secondary peak of 2,000 BOPD, is injecting 36,820 BWPD through seven (7) peripheral injection wells and producing 31,031 BFPD through 13 production wells. This analysis is useful result as a part of countercheck for Geology and Reservoir Modeling regarding to the plan of Chemical Flooding Pilot Project.

Introduction

Production oil increase successfully with secondary recovery as well as tertiary recovery depend on reservoir reserves, reservoir heterogentiy, field maturity and reservoir performance (field). In secondary recovery phase or tertiary recovery phase are required field integration study to increase production capacity or to drainage oil reserves more than currently. Limau Field has specific reservoir characteristic. Characteristic in Limau Field dominated with sandstone and separated with many fault, with the result that required integration study to determine connectivity or relationship one layer to another layer accorcing vertical direction and horizontal direction. Once of method or technology to determine connectivity and relation one layer to another layer (vertical or horizontal direction) it's Tracer Test method and Shale Gauge Ratio (SGR) calculation method. This methods have purpose to identify reservoir characterictic before the application of Enhanced Oil Recovery (EOR) phase to reservoir. Base on Tracer method and SGR calculation we can get information result concerning about reservoir compartement and flow path to identify fluid flow inside reservoir which influency by reservoir heterogenity distribution and fault compartement.

Geological Review

Limau Field Structure is located in South Sumatera Basin it's about ± 90 km in the direction of West Prabumulih city. Limau Field Anticlinorium type Structure classifier (**Fig. 1**.) with continuity West to East direction and separated

with active fault relatively South to North direction separated with eight (8) Block with twenty two (22) layers. Limau Field startigraphy intepretation have five (5) horizons that is Top Batu Raja Formation, Top Talang Akar Formation, Top Talang Akar 1 Formation (S Layer and W Layer). The concern of Field study and analysis that is Block Q-51 with S Layer it is a take a part Limau Field. The sand correlation of S Layer Block Q-51 of Limau Field is shown in **Fig. 2**.

Field Production History

The first drilling in Limau Filed was on April 1951, until now have 315 productions well. In Block Q-51 S Layer produced with 14 wells. Pilot water flood project was carried on April 1991 can produced 10.000 BOPD it is estimates that more 80% primary reserves have already been produced and recovery factor has reached 36%. The production history of Block Q-51 S Layer is shown in **Fig. 3**. In **Fig. 4** shows the production decline analysis of Block Q-51 S Layer of Limau Field. Based on the **Fig. 4**, it is shown that Block Q-51 S Layer has EUR is 1257.25 Mbbl and Remaining Reserves (RR) is 175.21 Mbbl. From **Fig. 4**, also shows that the S layer still could be developed indicated by the two parallel line of decline line prediction interpolated through the economic limit rate.

Fig 5 shows the Chan's diagnostic plot, which describe that in the Block Q-51 S Layer of Limau Field there is a problem with water coning (normal displacement with high WOR) indicated by the higher WOR and WOR' in the end of production period. **Fig. 6** is shows the Fetkovich Type Curve Block Q-51 S Layer of Limau Field. Based on plot between oil production vs time in **Fig. 6**, it is shows that the Block Q-51 S Layer has the EUR is 1252.6 Mbbl and Remaining Reserves is 170.56 Mbbl, beside that also has the results of permeability (k) is 27 mD, skin factor (S) is -3, and drainage area is 462 acre.

Furthermore, based on the production history and the potensial of Block Q-51 S Layer of Limau Field, then the development plan of chemical flooding then was set up to increase production after water injection. For that purpose, the integration studies of Geophysics, Geology, Reservoir characterisation, Production analysis, Process Facility, Project Management and Economic Evaluation, Fault Sealing Analysis (FSA) and Tracer Test Survey has been done.

Fault Seal Analysis, Water Injection and Tracer Test Survey

Fault sealling analysis in Limau Field was carried out using Fault Sealling Analysis method (FSA) by Yielding et. al. (1997), this method use lithology variation (stratigraphy) and Fault attribute like Throw and move distance to identify sealling potential, and potential sealling analysis was carried out using of Shale Gauge Ratio Analysis (SGR). This method use material granulated proportion enter in to fault gauge source from wall rocks, SGR calculation result calibrated using tracer test result. Produce result for Shale Gauge Ratio (SGR) is interval SGR value. SGR calculation using algoritm, this method calculated by Yielding (**Fig. 7**. and **Fig. 8**), that algoritma we can know fluid flow capacity in to fault (leak/seal). Equation of SGR algoritma is as follows:

$$\mathbf{SGR = \sum(Vsh \,.\, \Delta z) / T \times 100\%}$$

where:

Vsh = Value of shale volume in lithology
Δz = Lithology or layer thickness
T = Throw

Shale Gauge Ratio (SGR) value is becomes parameter to determine that fault is leaking or sealling, with the result that if SGR value more and more higher that indicated fault is sealling (close).

Water injection was used in Block Q-51 S Layer of Limau Field to improve oil recovery and increased production. In oil reservoir, reservoir pressure depletion as long as oil produced from reservoir. Pressure decline until under bubble point pressere can make gas liberated (light component). Bubble gas makes new phase and flow in to production well if saturation phase pass by saturation equilibrium value. Effect for gas produced is makes decrease reservoir energy (pressure) to produced oil, with the result that for naturally recovery is decrease. Generally if reservoir pressure decline due to uncontrol can affect reduction recovery. The result of water injection analysis in Block Q-51 S Layer of Limau Field is shown in **Fig. 9**.

Reservoir pressure decline can gradually according if produced from well produced in reservoir balance with water influx from aquifer. Water play a part in contributed to reservoir fill recharge to replace oil produced into produced well, beside that water play role for reservoir pressure support. Based on that reason many company use water flood method (water injection) to keep reservoir pressure performance still high as pressure maintenance.

Water injection method in Secondary recovery phase, is purpose to get residual oil in reservoir which can't recovery when primary recovery. Water injection method in principle is injected the fluid into reservoir did not to maintenance reservoir pressure but to sweep residual oil in that reservoir. Secondary recovery phase, injection operation use "Dispersed Water Injection" method, where water injected to oil zone horizontally enter in the direction to well produced base on injection and production pattern. Water flood methode is on of secondary recovery phase where water injected to push oil and produced goes to production well after economic limit from primary recovery.

Water injection in this paper (see **Fig. 9**) is purpose to increase recovery from sweep residual oil. Principlelly water injected to well injection and oil produced to production well. Generally injection well can use existing in the Field or

can convert from production well if production well is not prospect again to produced, if required injection well and need new well that study must decide the location where can sweep residual oil optimally from reservoir. Isopermeability map can be used to decide where new injection well location, and to reduce breaktrough time.

Another factor to increase oil recovery from the reservoir is makes injection and production well pattern. To make injection and production pattern consideration many parameters must identified, such as:

- Reservoir or formation heterogenity
- Reservoir structure
- Position and location of existing well
- Economic factor

Injection and production pattern that usually used generally in the field are:

- Direct line drive
- Staggered line drive
- Four spot
- Five spot
- Seven spot

Tracer its chemical component, that can be soluble in fluid with smal concentration without any effect for physical fluid properties and physical rock properties and also can be used as a detected tool. Solubility Tracer ratio in hydrocarbon is between water phase and hydrocarbon phase, tracer molecul can movement between water phase and hydrocarbon phase because Tracer molecules have more partition concentration (absorb in to rock). Tracer result in this paper is result from application Tracer method in the Limau Field by Pertamina EP.

Analysis

Tracer test analysis method principely is injected Tracer component to well injection and record tracer test from monitor well (see **Fig. 10**). Application of Tracer Test in the Limau field is use one (1) injection Tracer well that is well L5A-64 and seven (7) monitor wells, that are L5A-131, L5A-156, L5A-79, L5A-222, L5A-93, L5A-117 and L5A-51. The same well in Limau Field separated with fault that is L5A-156, L5A-79, L5A-222 and L5A-51 (see **Fig. 10**). Base on the Tracer result analysis, we can know fault type in Limau Field is sealling, partially sealling or leaking, starting that result we have purpose to decide where fault is sealing partially sealling and leaking. Base on Tracer record result with time breaktrough 90 days (see **Fig. 11** and **Table 1**.) connectivity analysis base on Tracer test, have a result that all monitor well in Limau Field, specially for separated by fault getting respon from injection well, with the result that Fault type in S Layer Block Q-51 is indicated Leaking Fault Type. Sealling capacity based on SGR analysis compared with Pressure data and Tracer Test gave the results as follows:

SGR $\leq$ 0.2 : leaking
SGR 20-60 % : partially sealing
SGR $\geq$ 60 % : sealing

Fault Analysis in Limau Field generally have high sealling capacity, indicated that fault type is leaking. Base on Tracer test result shown that connectivity from injector well with monitor (production) well, that separated with fault after found out treacer record, leaking fault type and connectivity between injection well with monitor (production) well and compared with SGR analysis. Tracer result and SGR analysis result is shown in **Fig. 12**. Based on the tracer and SGR results, and then is used to plan the application of chemical flooding in Limau Field S Layer Block Q-51 to increase oil recovery.

Apllication of chemical flooding to increase oil recover or production in Limau Field required the integration study between Geophysics, Geology, Reservoir, Production, Process Facility, Project Management and Economic Evaluation, Fault sealling Analysis and Tracer test method, based on study results we can know reservoir characterictic, reservoir heterogenity and connectivity between layer horizontal direction and vertical direction, Accompanying Limau field geology, which have anticlinorium type, separated become many blocks. Look up many datas and Limau Field geolgy, wanted for many study, to know connectivity. Method to observe and analysis connectivity between Block or Layer according integration it is Shale Gauge Ratio (SGR) analysis and Tracer test analysis Method. Out of SGR analysis result give analysis fault in Limau Field which separated block have leaking type (connected) indicated from SGR analysis give Result valus 0 - 0.2 %. To give evidence that Fault is leaking we can analysis with Tracer Test. Priciplely Tracer Tests it is Injected Tracer to Injection well and monitor to well monitor in same block or another block where separated with fault. Well injection will be used to injected in Limau Field that is L5A-64 and 7 (seven) monitor well thht is L5A-131, L5A-156, L5A-79, L5A-222, L5A-93, L5A-117, L5A-51. In Limau Field there is have well, where located separated fault, that is L5A-156, L5A-79, and L5A-51. Base on Breaktrough time record vs Tracer concentration (Tracer test) as shown in **Table 1** and **Fig. 11**, obtained average results for all monitor well have 90 days time breaktrough, base on record data fault type in Limau Field it is Leaking type. This analysis appropiated with SGR analysis method give indicated taht faults separated in Limau Field it is Leaking type. With existence results data and analysis Limau field is recommended to chemical flood injection application. Looking position and well coordinate in Limau Filed especially for S Layer in Block Q-51, support for injection pattern to sweep efficeincy and to increased production. Based on the integration studies it shows that the most prospective candidate for chemical flood pilot project was S layer in Q-51 field, the pilot project was planned for inverted five (5) spot patterns and predicted breakthrough time was 90 days, it was also predicted a tertiary peak of 3,100 BOPD. Currently, Q-51 field, which had reached a

primary peak of 20,600 BOPD and secondary peak of 2,000 BOPD, is injecting 36,820 BWPD through seven (7) peripheral injection wells and producing 31,031 BFPD through 13 production wells, where the result of injection pattern is shown in **Fig. 13**.

Conclusions

1. Based on the production history shows that Block Q-51 S Layer of Limau Block is still potential to be developed using chemical flooding.
2. Based on the Tracer Test Survey compared with SGR analysis method it is obtained that the interval value 0 - 0.2 % which representation of indicated Fault type in Limau Field S Layer Block Q-51 is leaking Fault Type.
3. Connectivity between layers can be detected using Tracer Test method, and the result from Tracer Test analysis can be compared with the integration study for identification of reservoir heterogenity and reservoir characteristic.
4. Injection time breaktrough result for Block Q-51 S Layer of Limau Field from the Tracer Test is 90 days.
5. Factors have to be considered in designing the injection production pattern are reservoir heterogeneity, reservoir structure, position and location of existing well, and economic.
6. The injection pattern for sweep optimalization can use convert well of suspended well to injection well.
7. The 5 (five) and seven (7) peripheral injection well patterns can be applicated in Block Q-51 S Layer of Limau Field.

Nomenclature

EOR : Enhanced Oil Recovery
EUR : Estimate Ultimate Recovery
RR : Remaining Reserves
RF : Recovery Factor
k : Permeability
S : Skin Factor
FSA : Fault Seal Analysis
SGR : Shale Gauge Ratio
Vsh : Value of shale volume in lithology
Δz : Tickness of the layer
T : Throw

Acknowledgments

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TABLE 1- TIME BREAKTHROUGH BLOCK Q-51 S LAYER OF LIMAU FIELD

Date	L5A-51	L5A-74	L5A-79	L5A-117	L5A-131	L5A-156	L5A-193	L5A-222
	Concentration (pCi/cc)	Concentration (pCi/cc)	Concentration (pCi/cc)	Concentration (pCi/cc)	Concentration (pCi/cc)	Concentration (pCi/cc)	Concentration (pCi/cc)	Concentration (pCi/cc)
17-Oct-95	0	0	0	0	0	0	0	0
12-Dec-95	0	0.09	0.03	0	0	0	0	0
5-Mar-96	0	0.04	0.015	0.04	0.07	0.05	0.06	0.02
19-Mar-96	0.18	0.2	0.05	0.16	0.25	0.21	0.15	0.15
16-Apr-96	0.82	1.1	0.95	1.95	2.1	1.6	1.04	1.07
14-May-96	0.808	1.05	0.825	1.7	0.26	0.84	0.78	0.85
11-Jun-96	0.07	0.08	0.26	0.1	0.09	0.09	0.14	0.2
9-Jul-96	0	0.09	0	0.03	0.04	0.04	0.05	0.04
8-Aug-96	0.02	0.02	0	0.01	0.02	0	0.04	0.042
3-Sep-96	0	0.02	0.02	0.01	0	0	0.01	0

Fig. 1- Geological Map of Limau Field and Anticlinorium Pendopo-Limau

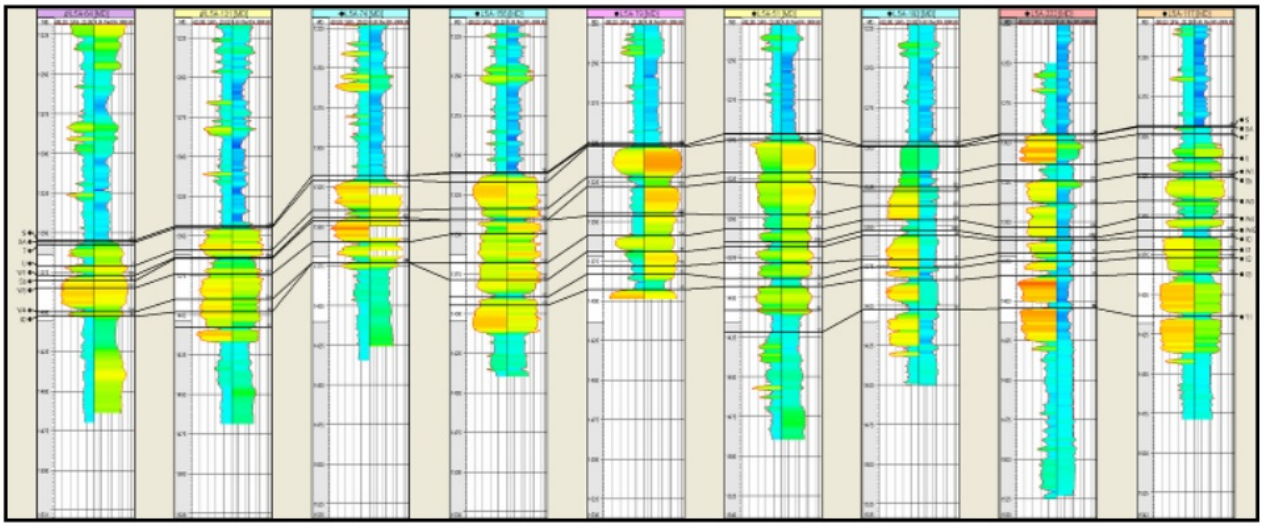

Fig 2- Sand Correlation Block Q-51 S Layer of Limau Field

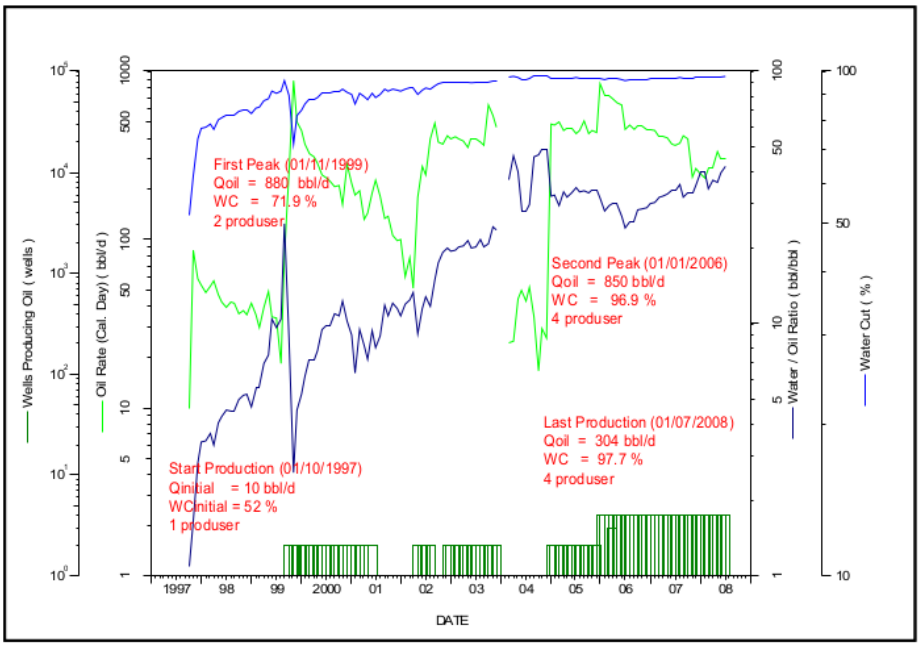

Fig. 3- Production History Block Q-51 S Layer of Limau Field

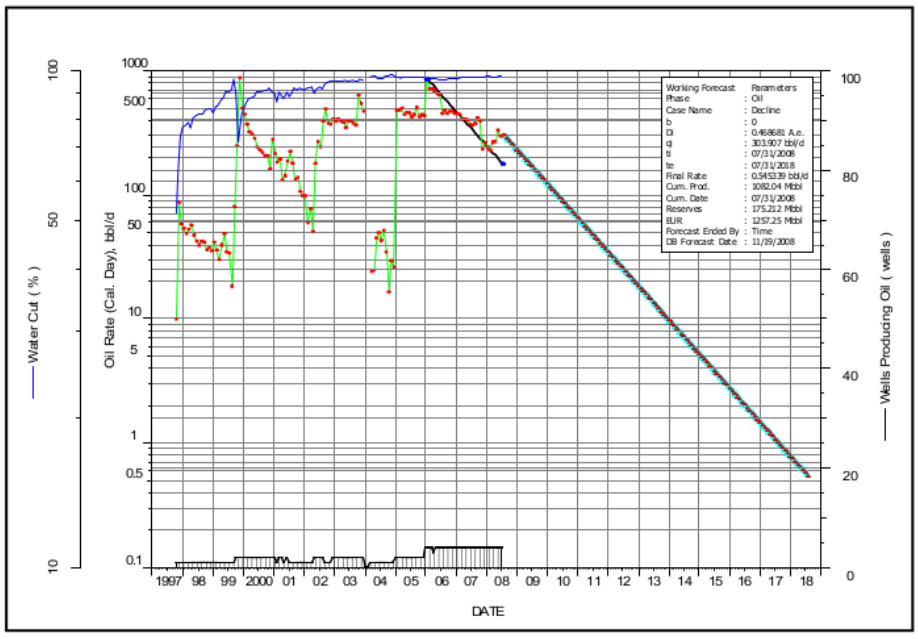

Fig. 4- Production Decline Block Q-51 S Layer of Limau Field

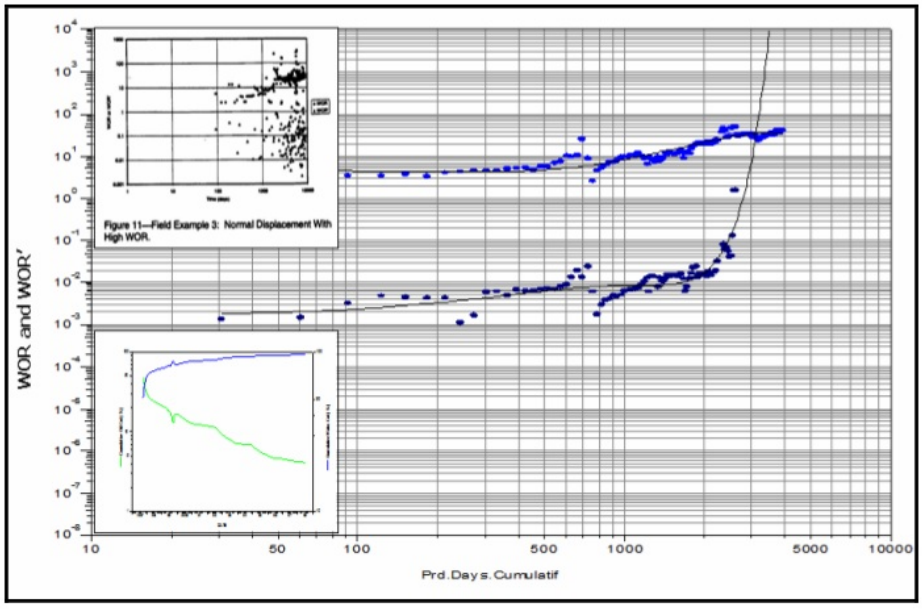

Fig. 5- Chan's Diagnostic Block Q-51 S Layer of Limau Field

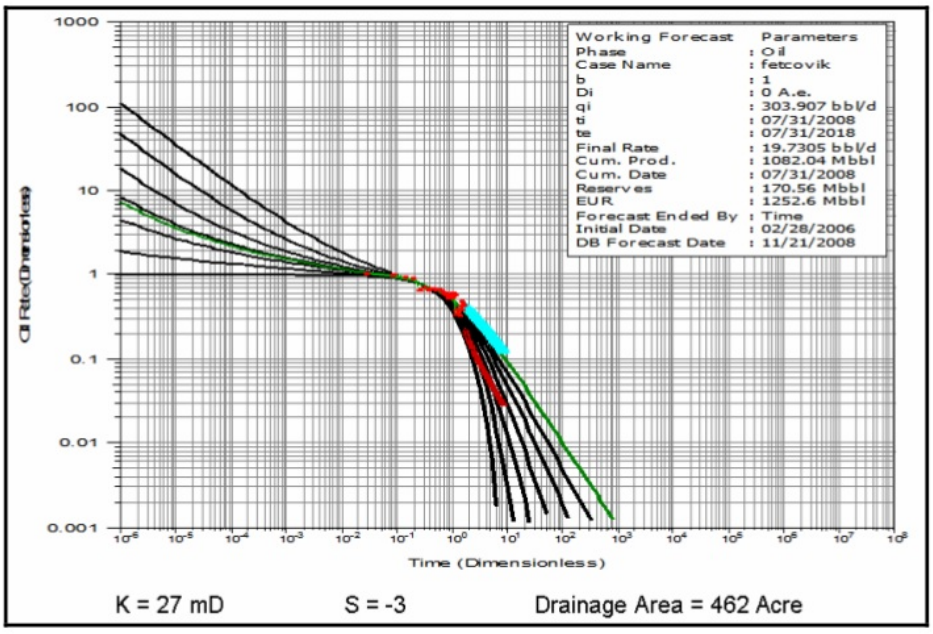

Fig. 6- Fetkovich Type Curve Block Q-51 S Layer of Limau Field

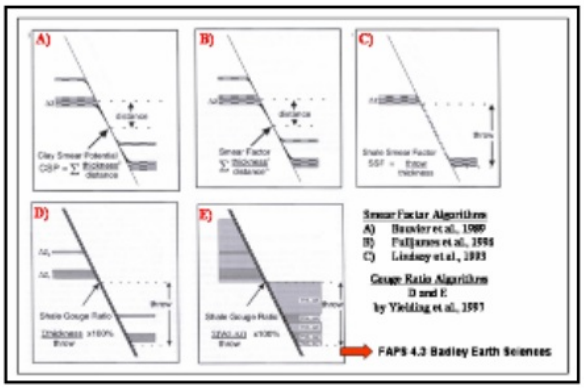

Fig. 7- SGR Calculation from Yielding, et. al. (1997)

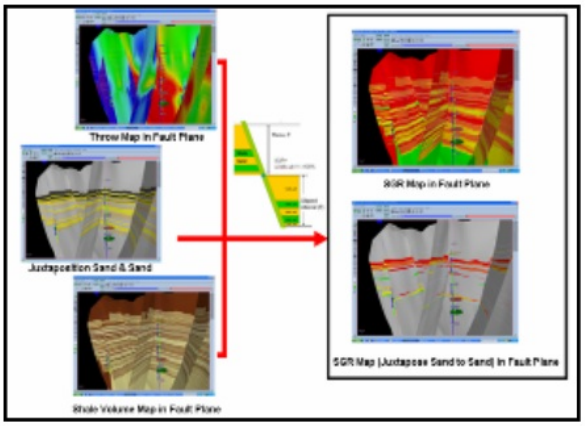

Fig. 8- Fault Seal Analysis Flow Chart

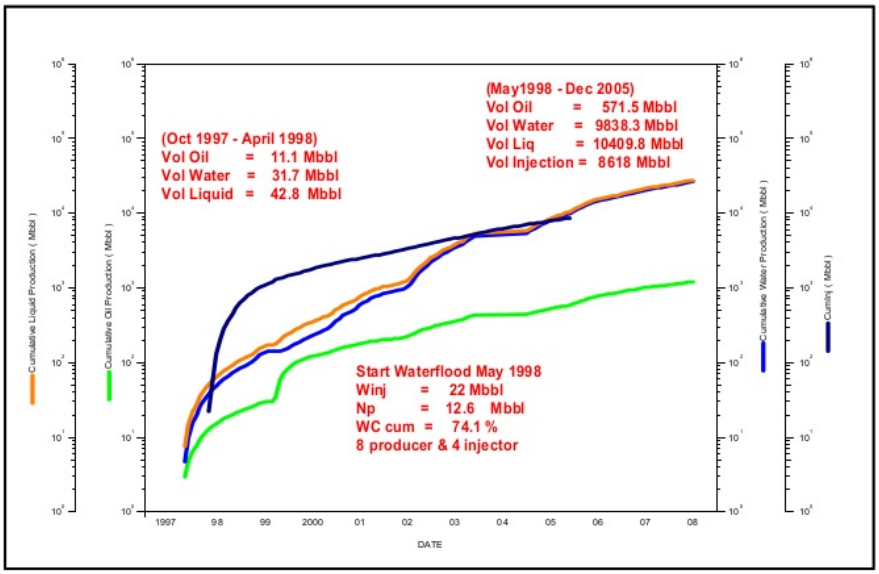

Fig. 9- Water Injection Analysis Block Q-51 S Layer of Limau Field

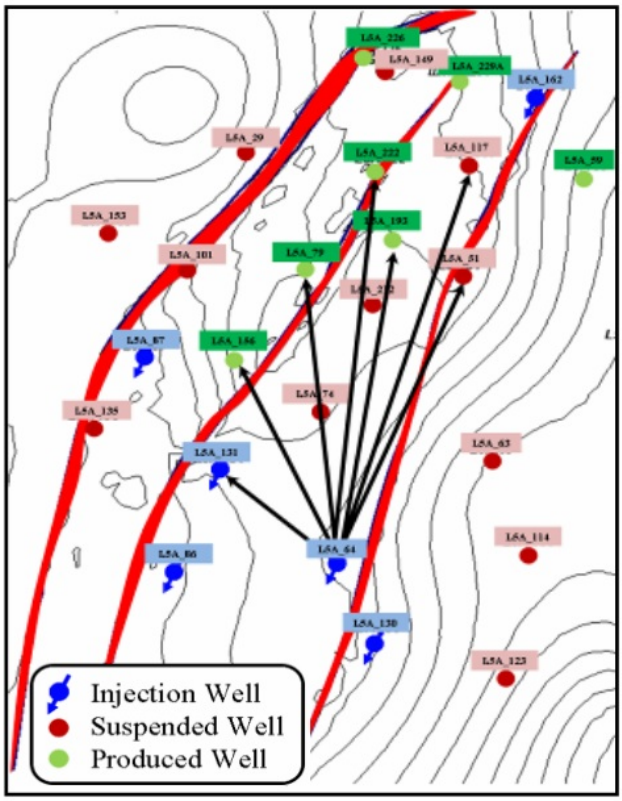

Fig. 10- Tracer Monitoring in Block Q-51 S Layer Limau Field

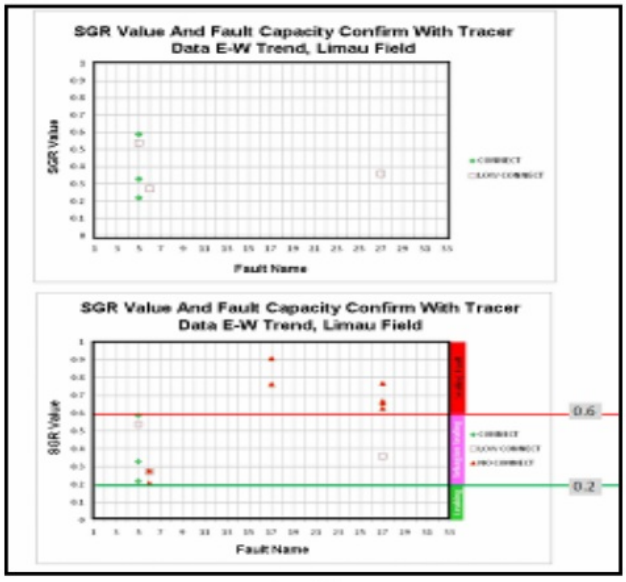

Fig. 11- SGR and Fault Capacity Cut Off Based on Limau Field Tracer Test

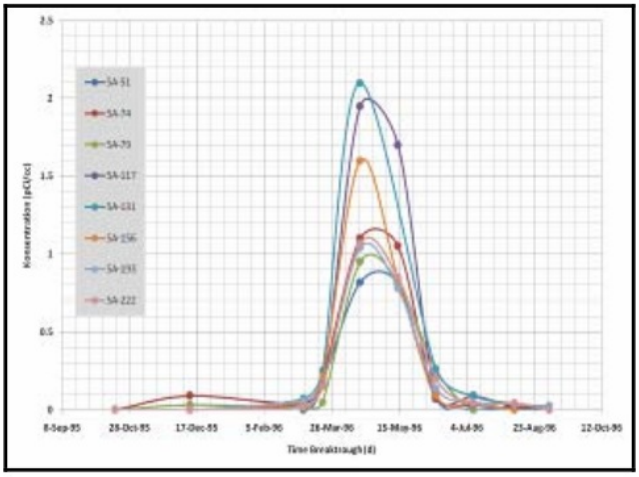

Fig. 12- Time Breakthrough vs Concentration Tracer Data

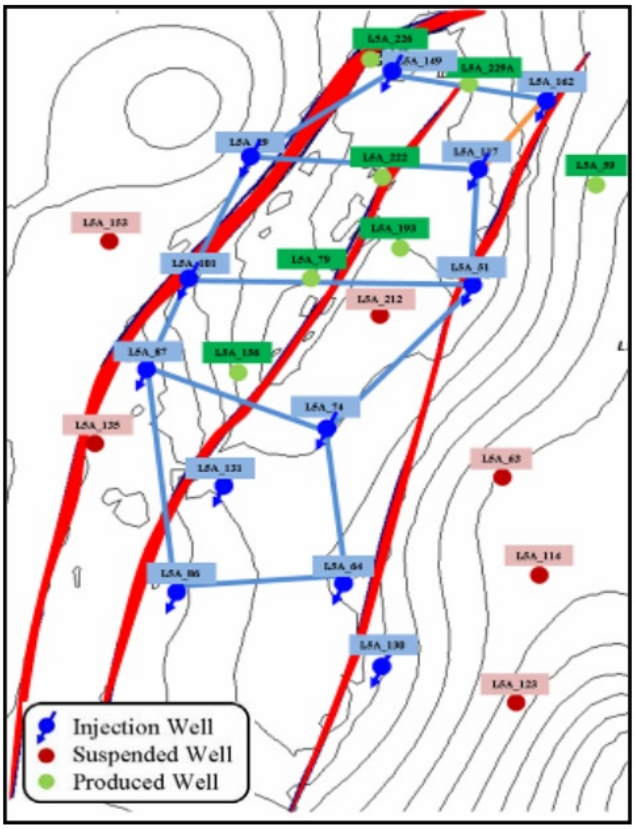

Fig. 13- Injection Pattern of Block Q-51 S Layer Limau Field

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