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Diagnostic Study of Excessive water production in Aswad Oilfield, Libya

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Abstract Water production in oilfields is a complicated issue which has a serious economic and environmental concern. The treatment and disposal of produced water cost millions of dollars for a single field. On the other hand, high water production causes a severe reduction in oil production. This paper focuses on diagnostic plots to identify the mechanism of water production. Aswad oilfield produced with high water rate and its status as water flooded the reservoir, so diagnosing reasons for producing high water is by using the most common methods such as Chan plot well by well. The first method is to investigate the water problem by plotting WOR and derivative of WOR' then compare the plot with typical Chan plots to identify the reason for water production, which applied as a field and on three selected wells (B06 – B09A- B-11). The rate of water cut is 88% per day. Based on production data and previously applied techniques, this work identified water problems by using water diagnostic plot Chan plots. The methodology of this work initiated with the study the performance of Aswad field by analyzing the history of production. The work shows that multilayer channeling is the main reason for water production in wells with high permeability. Finally, Aswad field is water flooded due to high water cut that produced from reservoir that supported by water injection from early period of the field. Diagnose the study of water production behaviour is to optimize the reservoir productivity after controlling the excessive water production. The wells should be the primary candidate for water control.

Keywords: excessive water production, diagnostic, Aswad oilfield, case study, Libya.

دراسة تشخيصية للإنتاج المفرط للمياه في حقل ألاسود، ليبيا

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الملخص إن إنتاج المياه في حقول النفط قضية معقدة لها مخاوف اقتصادية وبيئية خطيرة. تكلف معالجة المياه المنتجة والتخلص منها ملايين الدولارات لحقل واحد. من ناحية أخرى، يؤدي ارتفاع إنتاج المياه إلى انخفاض حاد في إنتاج النفط. حقل الأسود أنتج بمعدل مرتفع من المياه ووضعه كمكمن مغمور بالمياه، لذا فإن تشخيص أسباب إنتاج الماء المرتفع، يتم باستخدام الطرق الأكثر شيوعاً مثل نموذج تشان. الطريقة الأولى هي التحقق من مشكلة المياه عن طريق رسم نسبة الماء إلى النفط ومشتقتها، ثم مقارنة المخطط مع نموذج تشان لتحديد سبب إنتاج المياه المفرط، والذي تم تطبيقه كحقل وعلى ثلاثة آبار (B06 - B09A- B- 11). بناءً على بيانات الإنتاج والتقنيات المطبقة سابقًا، هذا العمل حدد مشاكل المياه عن طريق استخدام مخطط تشخيص المياه لمخططات تشان، وعن طريق رسم WOR و WOR' لمقارنتها بمخططات تشان من أجل إيجاد حل مثالي. ينتج البئر المختار ما يقرب من 2200 STB / d إجمالي السوائل مع نسبة الماء 90 ٪، وهذا يعني أن معدل الزيت المنتج 220 STB / d. بدأت منهجية هذا العمل بدراسة أداء حقل الأسود من خلال تحليل تاريخ الإنتاج. وقد بدأت منهجية هذا العمل في دراسة أداء حقل أسود من خلال تحليل تاريخ الإنتاج. تركز هذه الورقة على التشخيص لتحديد آلية إنتاج المياه. يوضح العمل أن القنوات متعددة الطبقات هي السبب الرئيسي لإنتاج المياه في الآبار ذات النفاذية العالية. وأخيراً، يجب أن يكون هذا النوع من الآبار المرشح الأساسي للتحكم في المياه.

الكلمات المفتاحية: إنتاج مفرط للمياه، تشخيصي، حقل الأسود، دراسة حقلية، ليبيا.

Introduction

About 21 billion barrels of water per year is a produced water in United state compared with the annual oil 1.9 billion barrels of petroleum liquids and 23.9 TCF gas.

Aswad field has been produced with high water rate, and its status as water flooded reservoir, so diagnosing reasons for producing high water. The injection rate reached to 10,000 STB/day in early period of reservoir life then stabilized in 8,500 STB/day in last period, also the water production stable in 7,500 STB/day.

Also, in production performance the cumulative of oil, water and gas, cumulative oil production was 30 MMBBL, cumulative water production was 55 MMBBL and cumulative gas production was 32 MMSCF.

Channeling or coning is a serious problem that leads to excessive water production worldwide; other problems have limited propagation[1,2].

Water production takes place because of a mechanical failure/casing integrity or other reasons such as water channeling or water coning into a well.

Produced water presents in reservoir rocks and after all it produces to the surface with crude oil or natural gas. This water could either come from an aquifer or from injection wells in the water-flooding process.

It expected that water production would increase with a life of a reservoir. However, early increase in water production in any reservoir is an undesirable condition. Corrosion and scale problems of surface facilities due to water production. An

additional, consequences that ensure a reduce in the recovery factory as oil remains behind the displacement front, as a result reducing the performance of the reservoir. All these along with a decrease in the oil's quantity involve reduced profitability.

Water production increases the produced fluid head in the wellbore; it creates extra back pressure on the formation. This reduces the well's flow capability; also, artificial lift capacities increase as the volume of water production increases. Excessive water production decreases not only oil and gas production, it is often increasing operating expenses.

One of the most widely used methodology for diagnosing the source of water using log-log plots of water oil ratio and water oil ratio derivative (WOR/WOR') versus time is due to Chan (1995), [3]. Chan developed his plots using numerical simulation to investigate the behavior of WOR/WOR' versus time under different mechanisms of production. For the different mechanisms investigated, the plots had characteristic trend which was used to diagnose the water source. These plots actually matched simulated results but when applied to field cases, the effect of noise made it difficult to carry out a good decision.

Jassim and Subhi (2010) used Chan's method for an oil wells producing from sandstone reservoirs in Middle East using actual production history data to generate log- log plots of WOR (water oil ratio) and d WOR/dt (simple time derivative of water oil ratio) vs. time. The plots were found to be effective in differentiating whether the well is experiencing water coning (negative slope) or multilayer channeling (positive slope for the time derivative of water oil ratio curve). The diagnostic plots applied in this study provide a handy method for quick evaluation of excessive water production mechanisms in order to select wells candidates for water control treatment [4].

(Eduin et al., 2010) presented an integrated methodology for building a strategy to design water management system considering the production optimization plan and analyze the operational parameters such as wells type and their locations, flow condition; then using an economic evaluation to determine the optimum performance of the suggested field. (Arthur, 2011) Described, summarized and analyzed various produced water treatment systems developed by oil and gas producers, research organizations, water treatment service companies, and universities. Such as avoid production of water onto the surface, inject produced water, discharge produced water, Reuse in oil and gas operations, Consume in beneficial use [5,6].

Mohanned Mahgoup, Elham Khair, 2015, their work identified the sources of water problems and attempts to initialize a strategy for controlling the excessive water production in the field. The production data were analyzed and a series of diagnostic plots were presented and compared with Chan's standard diagnostic plot [7].

In general, water production problems related to well integrity was easier to solve. However, it would get more complicated to control water production if it related to the reservoir characteristics. The factors that reservoir related to excessive water production are discussed below.

1. Channeling

Channeling occurs because of the early breakthrough in the high permeability or fractured formations, especially in water flooding. Channelling is one of the most important water production resources. Furthermore, reservoir heterogeneity leads to the presence of high permeability layers. Induced fractures or natural fractures are the most common cause of the channeling between wells.

2. Water conning

Water coning refers to the change configuration of the oil-water interface, where a thick oil layer is underlain by a water-saturated layer, and the oil zone is partially penetrated by a well.

The specific problems of water a coning is listed below:

- Costly added water handling.
- Reduced efficiency of the depletion mechanism.
- The water is often corrosive and its disposal costly.
- The well may be abandoned early.
- Loss of the total field overall recovery.

Since coning can have important influence on operations, recovery, and economics, it is an important to provide the theoretical analysis of coning and outline many of the practical solutions for calculating water and coning behaviour.

3. Casing leak

Casing leak is a failure that happens in the casing because of the high pressures exerting against the casing by formation pressures or high hydrostatic pressure. Casing leak can happen by tension, collapse, biaxial loading, or casing buckling. The excessive water production considered as an indicator for the casing leak.

4. Cement failure

A lot of reasons guide to cementing failures like; miss-centralization, pipe movement, contamination of fluids, mud channels, and bridging. In the presence of cement failures, water could move easily from water formations to the perforation, which means water production.

5. Poor Completion Job

Completion into the zones where water saturation is higher than the irreducible water saturation allows the water to produce immediately. Often, impermeable barriers (e.g., shale or anhydrite) separate Hydrocarbon-Bearing Strata from water-saturated zone that could be the source of excess water production. However, the barriers can breakdown near the wellbore and allow fluid to migrate through the wellbore. Even if perforations are above the original water-oil or water-gas contact, proximity allows the production of the water to occur more easily and quickly through coning or cresting [8, 9].

The economics of unwanted water production is one of the most important problems in the oil and gas industry. Managing the cycle of water production, down-hole or surface separation, and disposal involves a wide range of oilfield services which are costly. Therefore, using a method that has a low cost for diagnosing water problem interests all [10].

Reduced oil or gas production caused by high water production in the following ways:

1. Reduced sweep efficiencies Area by ineffectively flooding all productive intervals-water cycling between injection and producing wells through their zones or high permeability intervals.
2. Increased fluid column head caused by higher density water in the producing string. This often causes significant loss of gas production in low pressure wells which lead to early shut-in.
3. Increased water saturation in the formation near the wellbore which reduces the relative permeability to oil or gas.
4. Formation damage by moving formation fines that usually trap near the producing wellbore area.
5. Scale precipitation in the wellbore, perforations, and close to wellbore formation pores.
6. Water blocking that creates increased water saturation in the near wellbore formation of a producing well and reduces the relative permeability to oil.
7. Construction of emulsions as crude oil and water mixture upon entering the borehole or down hole pump, this problem is more serious if the emulsion injected into the formation during a Work Over operation.
8. Hydrogen sulphide and carbon dioxide corrosion is enhanced by water production.
9. Sand production frequently related to the increase in water production rates.

Operators must differentiate between different types of water entering the well bottom hole; the problems can vary from simple such as tubing or casing leaks and oil-water contact moving, to adequate problems such as high permeability layers or conning.

Diagnose the water problems as field and as well by well performance to select the optimum solution for water problems [11].

Case Study

1. The Method of the study

The method of this work began with an analysis of performing Aswad oilfield by analyzing the history of production, injection and pressure history to evaluate and monitor the reservoir performance by using the Excel sheet to assess the data to optimize the research.

One of the main objectives of this study was to diagnose the field problem by using water diagnostic plot (Chan plots) and by plotting WOR and WOR' to contrast them with Chan plots. In addition, the effect of water production on productivity in the field was determined.

2. Overview of the Field

The Aswad field located in Sirte Basin, Southeast Sirte Basin, South of Zella Field, owned by Zueitina oil company and NC-74B concession. Drilling started by first drilling well in October 1978 was B01, and then started water injection in June 1979. There are 19 wells authorized for drilling, and 4 Wells have been abandoned, see Fig 1 ,and Fig 2.

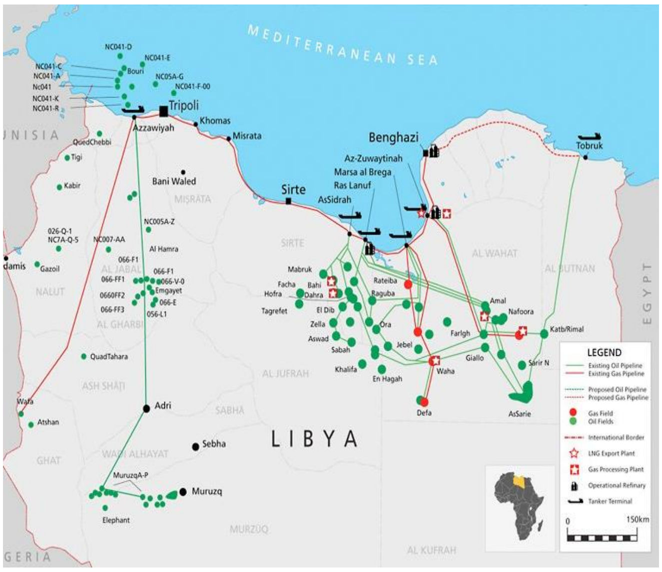

Fig 1. Map of Libyan oilfields

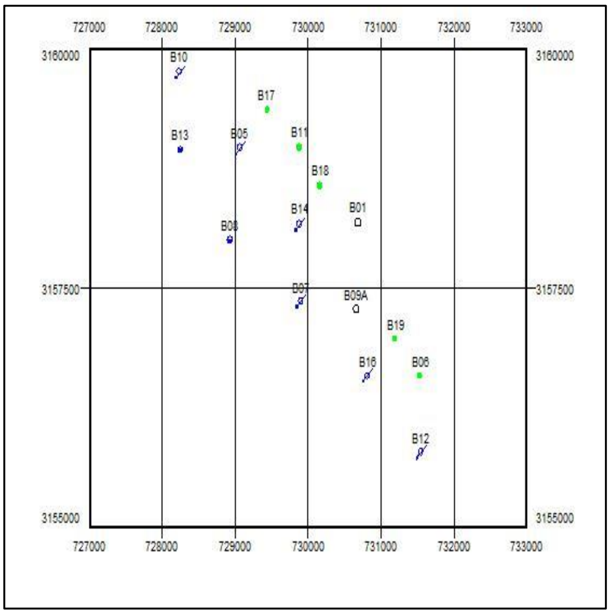

Fig 2. Aswad field wells Location

Aswad oilfield started production in October 1978 by drilling first well B-01 and then injection started in June 1979, The Total Drilled Wells are 19 Wells, 4 Wells are dry. Last rate of water cut is 88%, GOR 1500 SCF/BBL, cumulative oil production 29 MMbbl, and cumulative gas production 32.2 BSCF.

Results and Discussion

There is no actual plan for water management in the field, and only conventional shut-off methods have been tested with no success.

The main purpose of this work is to identify the mechanism of water production, and that is the focus of this work. Also, to recommend an optimum method and provide an effective treatment for the problem. No well logging data are available in the field understudy; therefore, the production data have been analyzed based on Chan's Diagnostic plots as it is a quick and reliable way and the lowest cost of all diagnostic methods.

Chen (2012) Evaluated numbers of technologies used in the disposal water treatment, also discussed the environmental effects of the produced water comparing between a world disposal standards 30 ppm OIW (oil in water), [12].

(Seright, 1998), several analytical and empirical techniques using information such as production data, water/oil ratio and logging measurements have been developed to determine the type of water production problem, locating the water entry point in the well and choosing the candidate wells to perform treatment methods. Water/oil ratio diagnostic plots are probably the most widely used technique in reservoir performance studies. Many oil companies to date rely on log/log plots of WOR and its derivative against time to identify the water mechanism caused by water coning or channeling. The production data required for these plots are routinely collected and accuracy of these data is usually reliable. Nevertheless, without taking other important reservoir parameters in to account, the WOR diagnostic plots could easily be misinterpreted and it has been demonstrated that applying these plots on their own could be misleading [13].

1. Field Production Overview

Aswad field started production in 1978 ,and production declined in 1985 but slightly as the number of wells increased. Instead, at last, the collection from the company in 2012 returned to decline again.

As shown in Figure (3), that presents oil, water and gas rates with time.

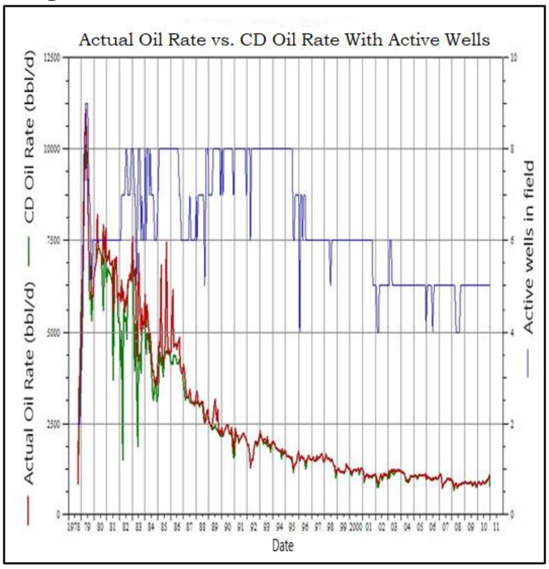

Fig 3: Aswad Field Performance.

Figure 4. Presents the performance of GOR and WC with time and the effect of water and gas on oil rate performance.

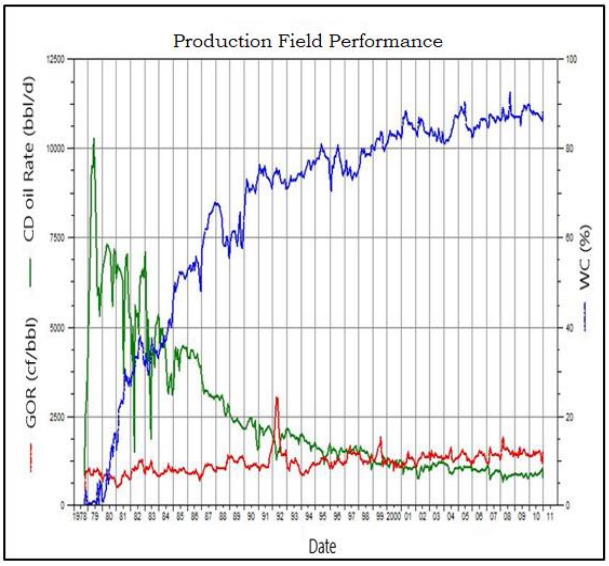

Fig 4: Aswad Field Production Performance

Figure 5. Shows the oil rate versus time with water injection rate and its effect on assisted reservoir pressure supported. The figure shows that the reservoir pressure is high in the early period compared to the reservoir pressure in the middle of the period

and how it's increased by increasing the water injection in last period of reservoir life.

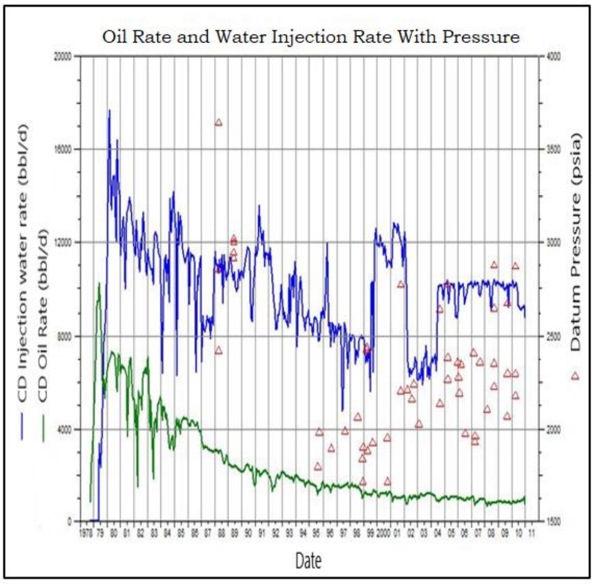

Fig 5: Aswad field pressure and Injection Performance

In figure 6, the plots of water that produced and injected from and into the reservoir with reservoir pressure show how the increasing in injection rate increased and supported of pressure during production period.

The injection rate reached to 10,000 STB/day in early period of reservoir life then stabilized in 8,500 STB/day in last period, also the water production stable in 7,500 STB/day.

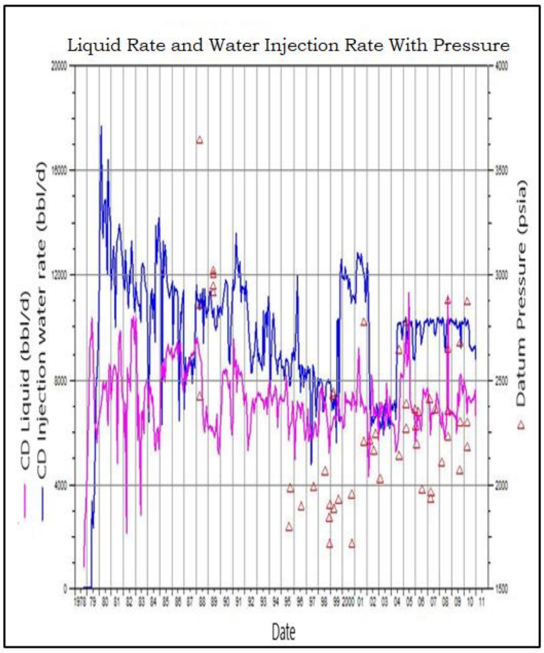

Fig 6: Aswad Field Pressure and Injection Performance

Figure 7. Shows same plots in figure (6) but it's also showing the number of injection wells were six wells in most duration.

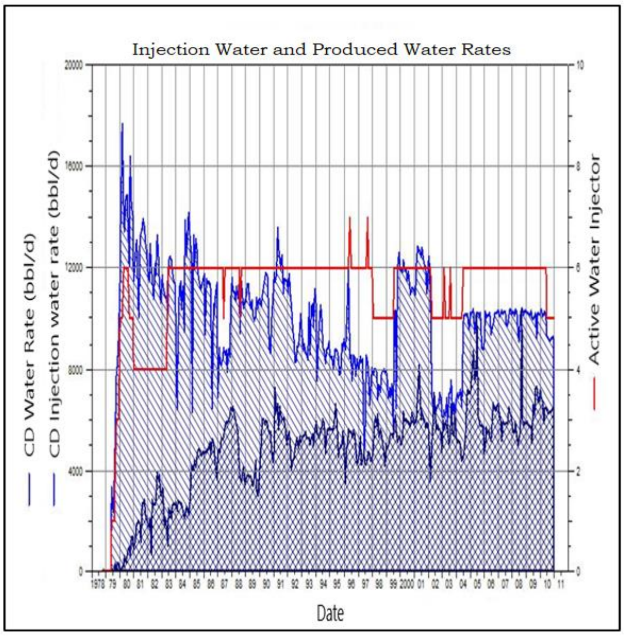

Figure (7): Aswad field water injection performance and number of injection wells

Finally, in production performance the cumulative of oil, water and gas as shown in figure (8), cumulative oil production was 30 MMbbl, cumulative water production was 55 MMbbl and cumulative gas production was 32 MMscf.

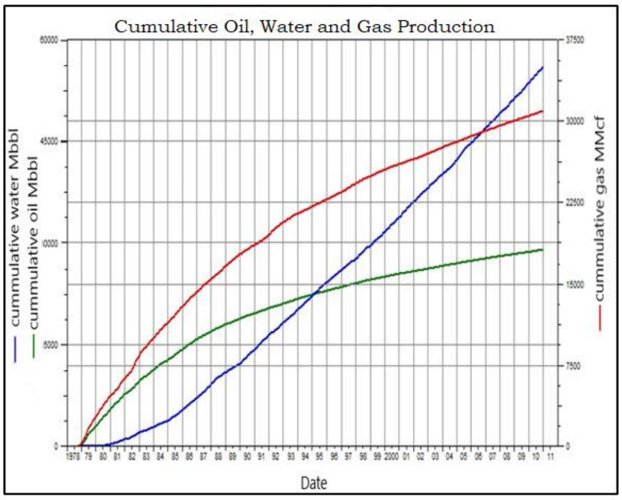

Fig.8: Aswad Field Cumulative Oil, Water and Gas Production

2. Water Problems Diagnosis

Aswad field has been produced with high water rate, and its status as water flooded reservoir, so diagnosing reasons for producing high water, is by using the most common methods such as Chan plot well by well and identifying layering method.

The first method is to investigate the water problem by plotting WOR and derivative of WOR' then compare the plot with typical Chan plots to identify the reason for water production, which was applied as a field and on three selected wells (B06 – B09A- B-11).

Figure (9), presents the diagnostic plot for Aswad field and as compared to the Chan plots and after this process the reason is Multiple Channels (Multilayer channeling).

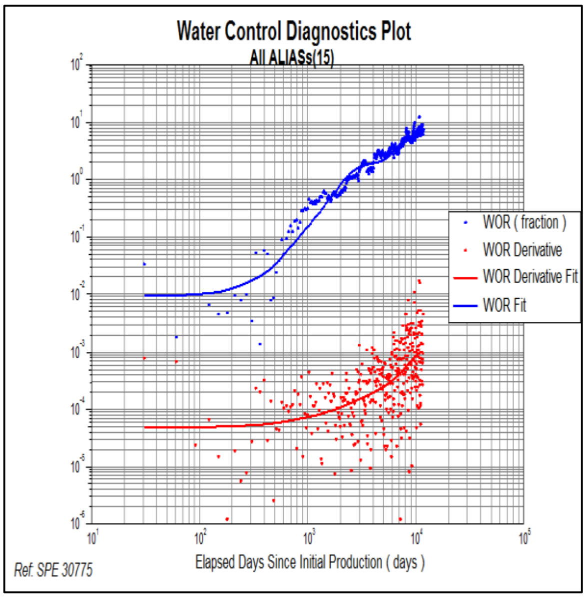

Fig. 9: The Field Diagnostics Plot

Figure (10) , Presents the diagnostic plot for well **B-11** and compared to Chan plots and after this process the reason is Multiple Channels (Multilayer channeling).

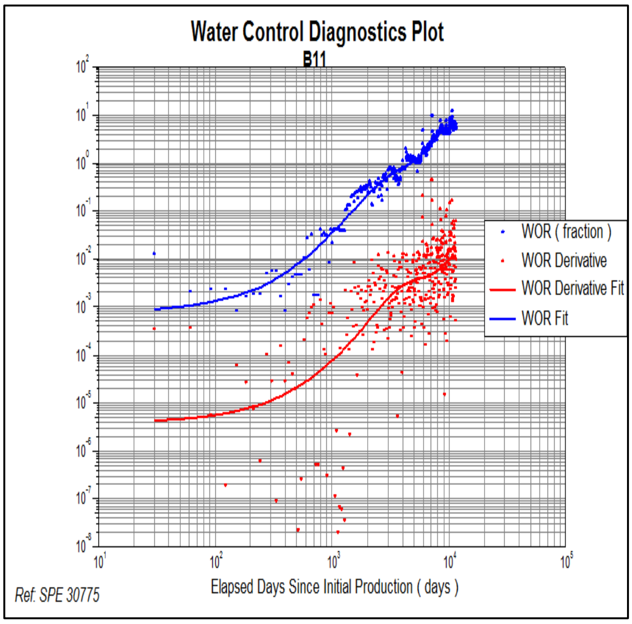

Fig. 10: Well B-11 Diagnostics Plot

Figure (11), Presents the diagnostic plot for well **B-6** and compared to Chan plots and the cause is Multiple Channels (Multilayer Ch anneling) the same as B-11.

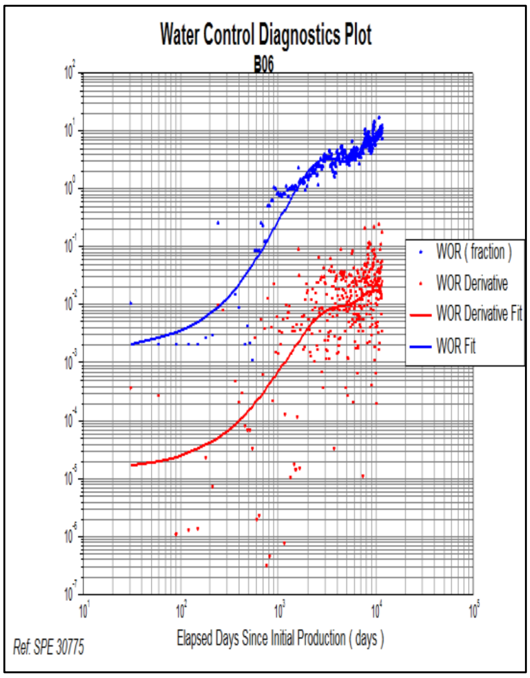

Fig. 11: Presents the diagnostic plot for well B-6 and compared to Chan plots

Figure (12), presents the diagnostic plot for well **B-9A** and compared to Chan plots and the reason for this method is Multiple Chann els (Multilayer channeling) close to other wells.

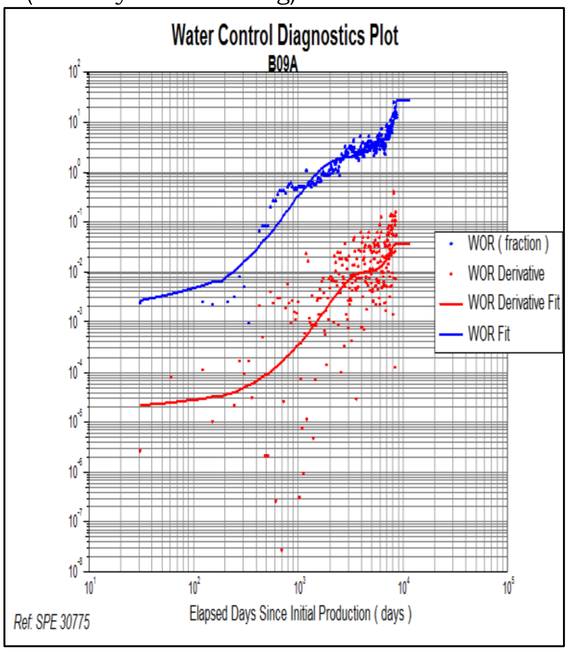

Fig. 12: Well B-9A Diagnostics Plot

For the field wells, a well card to summarize the wells status according to Chan's plot results, the dominated water production mechanism is the high permeability layer channeling and that is justified because of the wells strata, edge water drive and the permeability variation.

Conclusion

Aswad field is water flooded due to high water cut that produced from reservoir that supported by water injection from early period of the field.

Production performance of the field and well by well performance shows that the Aswad field produced as under-saturated reservoir due to water injection support.

Aswad field has high total fluid potential but due to highly water cut.

The water problem diagnostic was applied and performed as multilayer channeling.

Diagnose the study of water production behaviour is to optimize the reservoir productivity after controlling the excessive water production.

Recommendations

- Perform simulation study and study the proposed solution that achieved from this study and applied a solution to reduce the water production.
- This type of high water production should be the primary candidate for water control.

Acknowledgment

This paper could not have been written without the invaluable help of people in the **Aswad oilfield** and **ZUEITINA OIL COMPANY** in Libya for supplying so much invaluable information and materials.

Abbreviations

WOR' : Water Oil Ratio Derivative
WOR: Water Oil Ratio
STB/D: Stock Tank Barrel Par Day
GOR : gas oil ratio
SCF/BBL**:** Stock Tank Barrel
CD: Cumulative decline

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