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Diagnosing Water Problem for Asmari Reservoir in Abu Ghirab Oilfield Using Analytical and Numerical Approaches

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ABSTRACT

Asmari is the main productive reservoir in Abu Ghirab oilfield in the south-east part of Iraq. It has history production extends from 1976 up to now with several close periods. Recently, the reservoir suffers some problems in production, which are abstracted as water production rising with oil production declining in most wells. The water problem type of the field and wells is identified by using Chan's diagnostic plots (water oil ratio (WOR) and derivative water oil ratio (WOR') against time). The analytical results show that water problem is caused by the channeling due to high permeability zones, high water saturation zones, and faults or fracturing. The numerical approach is also used to study the water movement inside the reservoir. A three dimensional geological and a three phase reservoir model was constructed for Asmari reservoir. The simulation model was used to visualize the water front advance in order to evaluate the water production structurally. The numerical results also show that the channeling is the main cause of water production, as well as, oil-water contact advance problem was noted due to fault sealing behavior effects.

Keywords: Chan's diagnostic plots, WOR, wtc, Asmari reservoir, Geological model.

تشخيص مشكلة الماء لمكمن الاسمري في حقل ابو غرب النفطي بإستخدام الطريقة التحليلية والعددية

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الخلاصة

الهدف من هذه الدراسة هي لفهم الاسباب التي أدت الى إرتفاع القطاع المائي في أغلب ابار مكمن الأسمري في حقل ابو غرب النفطي. مكمن الأسمري هو المكمن الرئيسي المنتج في حقل ابو غَرب الواقع في الجنوب الشرقي لجمهورية العراق. حيث يتمد تأريخه الإنتاجي من سنة 1976 الى يومنا هذا. في الوقت الحالي، يعاني الحقل من مشاكل في الانتاج والتي تتلخص بإرتفاع إنتاج الماء مع انخفاض النفط في اغلب الابار. نوع مشكلة الماء في الحقل ككل وفي الابار تم تحديدها باستخدام رسومات جان التشخيصية (نسبة الماء للنفط ومشتقة نسبة الماء للنفط مع الوقت). النتائج التحليلية بينت وجود مشكلة القنوات المائية الناتجة عن

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ارتفاع النفاذية وارتفاع التشبع المائي ايضا لبعض المناطق في المكمن مع احتمالية عالية لمشاركة الصدوع والتكسرات في صنع هذه القنوات. التوجه العددي استخدم لدراسة حركة الماء داخل المكمن حيث تم بناء نموذج جيولوجي معقد مع نموذج مكمني ثلاثي الطور ـ ثلاثي الابعاد لمكمن الاسمري . نموذج المحاكاة استخدم لرؤية تقدم جبهة الماء داخل المكمن من اجل تقييم انتاج الماء يشكل تركيبي. حيث اظهرت النتائج العددية بأن القنوات المائية هي ايضا المسبب الرئيسي لارتفاع انتاجية الماء وتم ملاحظة ارتفاع الحد الفاصل بين الماء والنفط نتيجة لوجود الفالق الذي يسلك سلوك انغلاقي.

الكلمات الرئيسية: رسومات جان التشخيصية، نسبة الماء للنفط، القطاع المائي، مكمن الاسمري، الفالق.

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1. INTRODUCTION

Producing water alongside with oil from the reservoir is a normal situation in all natural reservoirs; the water can be either come from a natural resource (aquifer) or an artificial resource (injection wells). Water production rate may increase with the reservoir life causing many problems that affect reservoir performance, wellbore conditions and the efficiency of the surface facilities. Declining oil recovery is another important issue happens with excessive water production, which will reduce the profitability of oil by reducing its quality and quantity (**Duan & Guo, 2002; Yan &Yang, 2010**).

Globally, producing three barrel of water can produce one oil barrel, the cost of the water treatment ranges from 5 to 50 cent; this cost is a function of water cut so it's important to reduce the water production to reduce handling costs in addition to increase the profitability of oil. To control the water production effectively, the mechanism or the source of the produced water must be identified first, then the type of the water problem come in second stage. (**Bailey et al., 2000**).

In Iraqi oilfields the water problem i
s a common problem because most of fields are producing by depletion and water drive mechanism (**Awni, 2012**). Abu-Ghirab oilfield has a serious water problem, this study will identify the main mechanism of water production analytically and numerically and diagnosis the type of the problem in Asmari Reservoir.

The major reservoir in Abu Ghirab oilfield is Tertiary Asmari reservoir, which is subdivided into three major production formations as, Jeribe-Euphrates (unit A), Upper Kirkuk or Buzurgan member (unit B) and Middle and Lower Kirkuk (unit C). This division does not mean that each unit is considered as a separated reservoir with cap rock and water contact, but each unit is connected vertically with the other (**Missan oilfield technical report**).

Unit A: this unit represents Jeribe-Euphrates formation, which geologically belongs to Burdigalian age/lower Miocene epoch. It exists in Lagoon depositional environment and consist mainly massive dolomite, some inclusions of limestone and shale, and anhydrite on the bottom of unit, also small fissures and fractures exist. The minimum thickness (55 m) is observed in well AGCS-2, and the maximum (83 m) is observed in well AGCS-38. This unit is divided into three sub-units, A1, A2 and A3 (**Missan oilfield technical report**).

Unit B: this unit represents Upper Kirkuk(including Buzurgan membrane) formation which geologically belongs to Aquitnian to Chattian age / lower Miocene-Oligocene epoch, It exists in barrier complex to shallow marine depositional environment. It consist Limestone Intercalated with Argillaceous Dolomite and Sandstone and Claystone. This unit is fractured in places and contains tension joints filled with calcite while the stylolites filled by shale particles (**Awni, 2012**). Unit thickness varies from well to well according to the well position in the structure fold. The minimum thickness (75 m) is observed in well AGCS-30, and the maximum (141 m) is observed in well AGCS-44. It is considered as the main producer unit in Asmari formation and better characteristic from the overlying unit due to sand existence, which gives high porosity-high permeability, so most initial oil in place exist within it. This unit is divided into four sub-units, B1, B2, B3 and B4 (**Missan oilfield technical report**).

Unit C: this unit represents middle-lower Kirkuk formation which geologically belongs to Chattian age/Oligocene epoch. It exists in open marine depositional environment. This unit consist mainly sandstone which has high porosity-high permeability interbeded with shale. Unit's thickness is approximately 80 m in most wells and decrease toward the north then it disappears. The unit does not important for oil production because it is a water bearing zone (**Awni, 2012**).

2. METHODOLOGY

According to **Chan, 1995,** diagnostic plots are used to identify the specific water problem type by showing different characteristic trends. Log-log plot of (WOR), Eq. (1), against (time) is prepared, where three patterns types are noted (**Bailey et al., 2000**). Each pattern describes a specific water problem type; coning, edge water or flow through fault, fracture or a channel behind casing. Log-log plot of the water oil ratio WOR with time derivative, WOR', Eq. (2), is found to be an effective method for differentiating whether the increased in water production in a well is due to coning or multilayer channeling. WOR' is limited by the nature of field data, which must be not noisy and uncertain data. **Chan**, **1995** illustrate how to use WOR and WOR' together to differentiate between various water production mechanisms**.** In channeling problem WOR' curves should show an almost constant positive slope, while coning WOR' curves show a changing negative slope. When a negative slope is turning positive slope, the problem can be classified as combination of the two mechanisms coning with late channeling behavior. These plots have received a significant interest in the oil and gas industry, (**Alexis, 2010**).

$$WOR = \frac{Qw}{Qo} \tag{1}$$

$$WOR'_n = \frac{(WOR_{n+1} - WOR_{n-1})}{(t_{n+1} - t_{n-1})} \tag{2}$$

Q_w = water flow rate, STB/day
Q_o = oil flow rate, STB/day
n = time step number

A numerical reservoir simulation is a powerful tool for reservoir engineers to predict the future performance of a reservoir under various production conditions. This tool can be used to employ geological and reservoir data together in a single reservoir model which may help engineers to understand the behavior of fluids and rock properties in the reservoir and how they affected the reservoir performance in the future. Many parameters, properties, volumes and rates can be obtained from the model depending on the objectives of the study (**Luca, 2001; Abou-Kassem,2001; John, 2001, Baker and Awad, 2017**).

3. DISCUSSION

3.1. Diagnosis the water problem type for the field and wells using analytical method

WOR and WOR' versus time (log-log plot) are used to identify the problem type, it can identify two types of water problem, Coning and Multi-layers Channeling, Faults or Fractures. Physically, coning can occur if the bottom water raises to the perforations that located near the Water-Oil Contact, while Channeling occurs if a layer(s) in a multi-layers reservoir has a high permeability or high initial water saturation which can affect the speed of water invasion among the reservoir, it is worth mentioning that the channeling also can occur due to fractures and faults (**Bailey et al.,**

2000). In the present study, the field production is divided into four time intervals, the first one from Aug 1976 to Sep 1980, in this period the water rate was low comparing with oil rate, the second started from Sep 1980 to May 1998, in this period the field closed due to war conditions. The third interval started from May 1998 to July 2011, in this period there are no water production data. The fourth interval start from July 2011 to the end of 2016, the trend of water rate increased to high level while the oil production decreases at the same time.

Fig. 1 show the field plots of WOR and WOR' versus time. The first interval in the plot shows positive slope for WOR with negative slope for WOR' at the beginning, then the WOR' slope changed to positive. This indicate earlier coning with late time channeling **(Chan, 1995)**, while in **Fig.2** the fourth interval, the plot show equally positive trends for WOR and WOR', which may indicate that the layer channeling is the cause of water problem.

Discussing each well diagnostic plot is better than the entire field plot **(Alexis, 2010)**. All wells subjected to Chan's diagnostic plots but only the wells that show the best trends are selected to identify the cause of water production in the reservoir, which are,; AGCS-1(annular & tubular), AGCS-11, AGCS-20, AGCS-24, AGCS-33, AGCN-34 and AGCS-101. **Fig. 3** through **Fig.6** show the diagnostic plot for the selected wells. The trends of WOR and WOR' show positive slopes which prove that the channeling is the cause of water production in the reservoir.

In **Fig. 6**, one can see the effect of layers with varying permeability on slope of WOR trend. Well AGCS-101 exhibits three different positive slopes which indicate multi-layers channeling problem **(Chan, 1995)**.

From previous method it can be concluded that, the channeling that formed by high permeability zones, high water saturation zones, faults or fracturing with the edge water mechanism are likely to be the high nominated cause of water production in Asmari reservoir/Abu Ghirab oilfield.
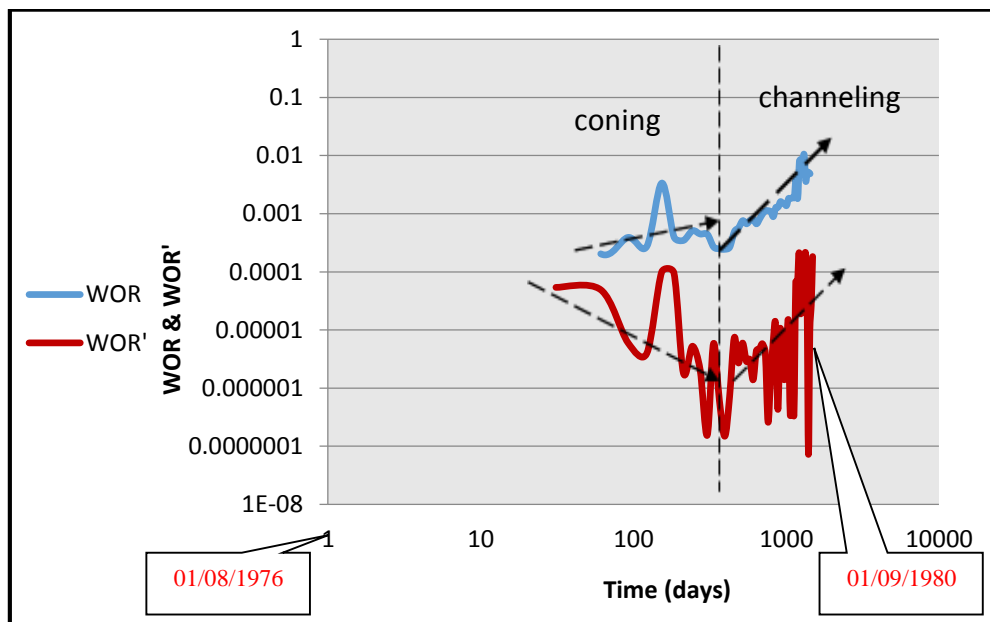
Figure 1. Diagnostic plot for first interval of field production from
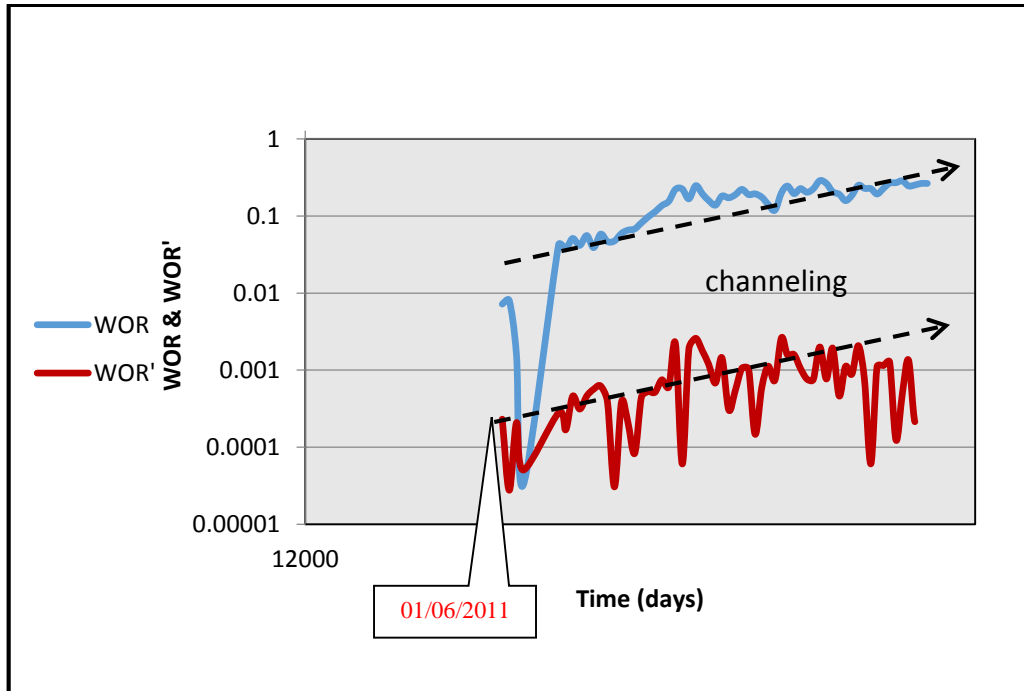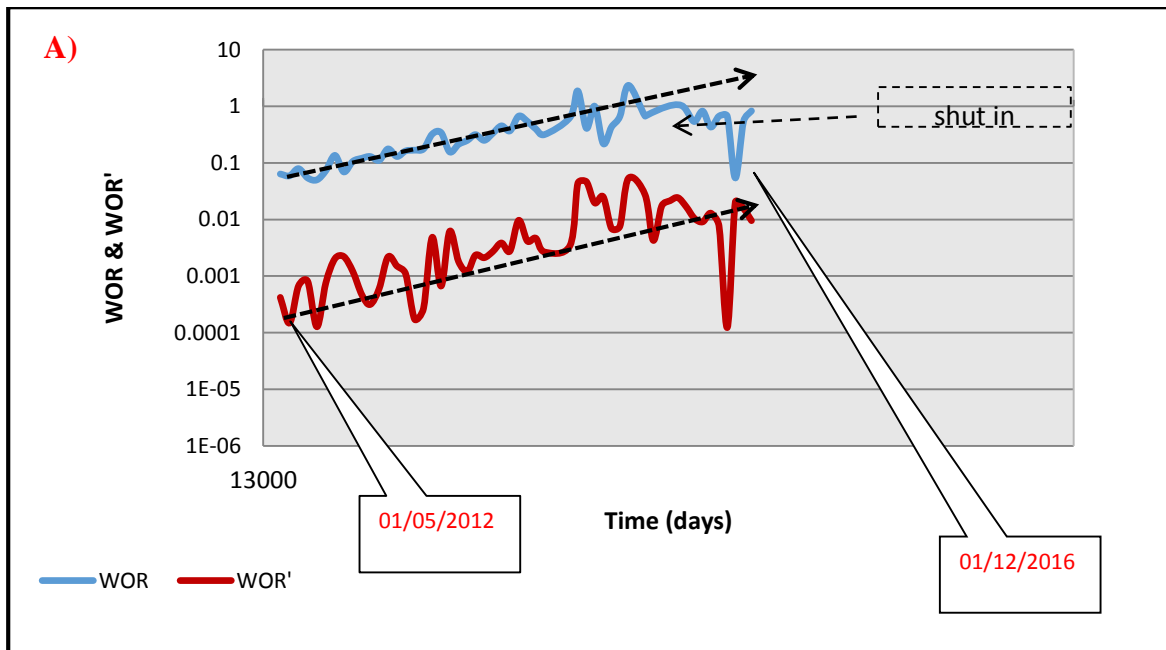Aug 1976 to Sep 1980.

Figure 2. Diagnostic plot for fourth interval of field production from July 2011 to the end of 2016.
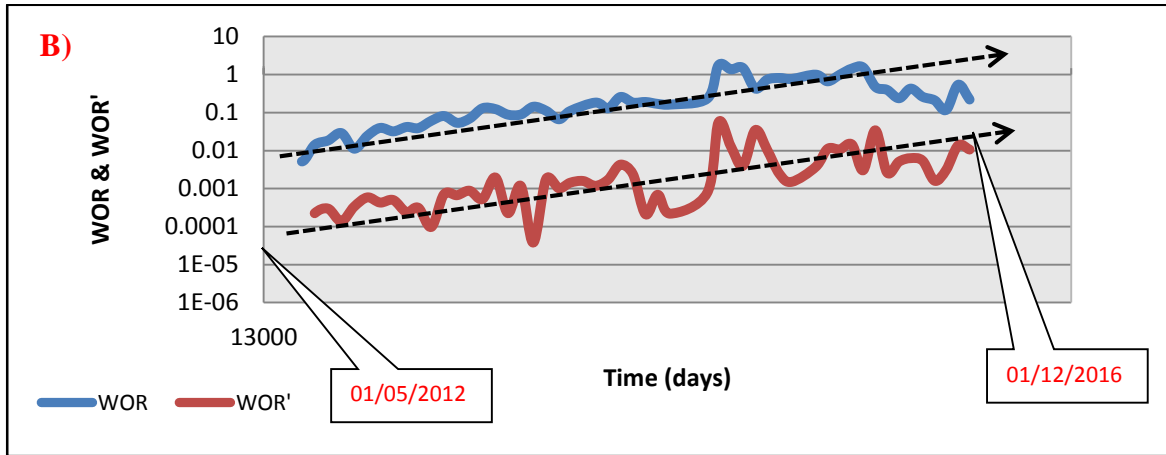
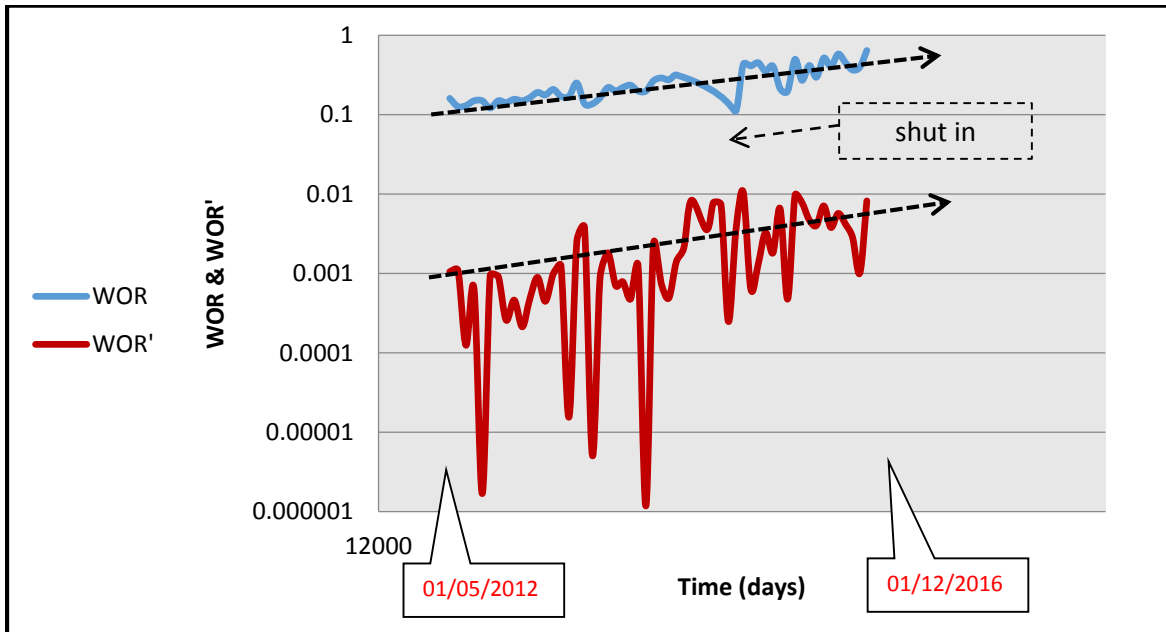**Figure 3.** Diagnostic plot for well AGCS-1 (A) tubular (B) annular production.
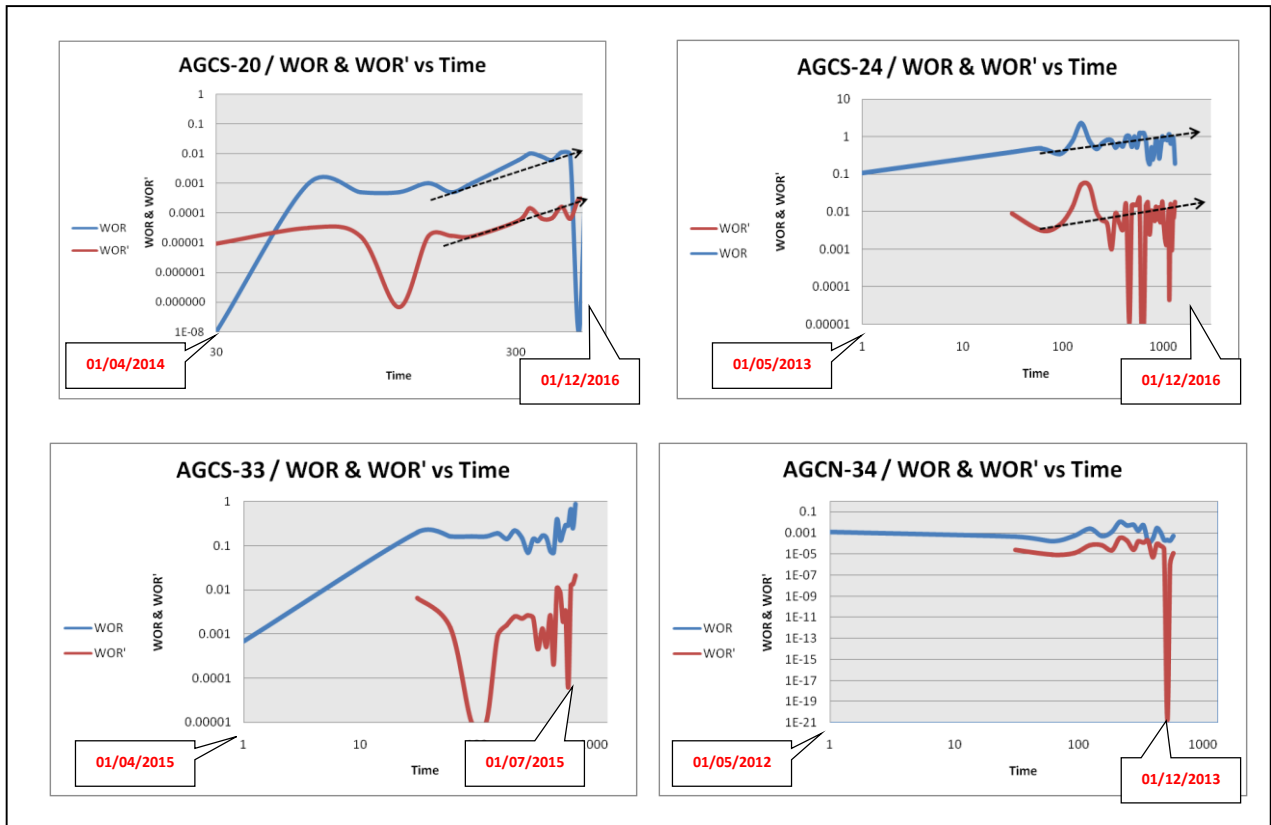
Figure 4. Diagnostic plot for well AGCS-11.
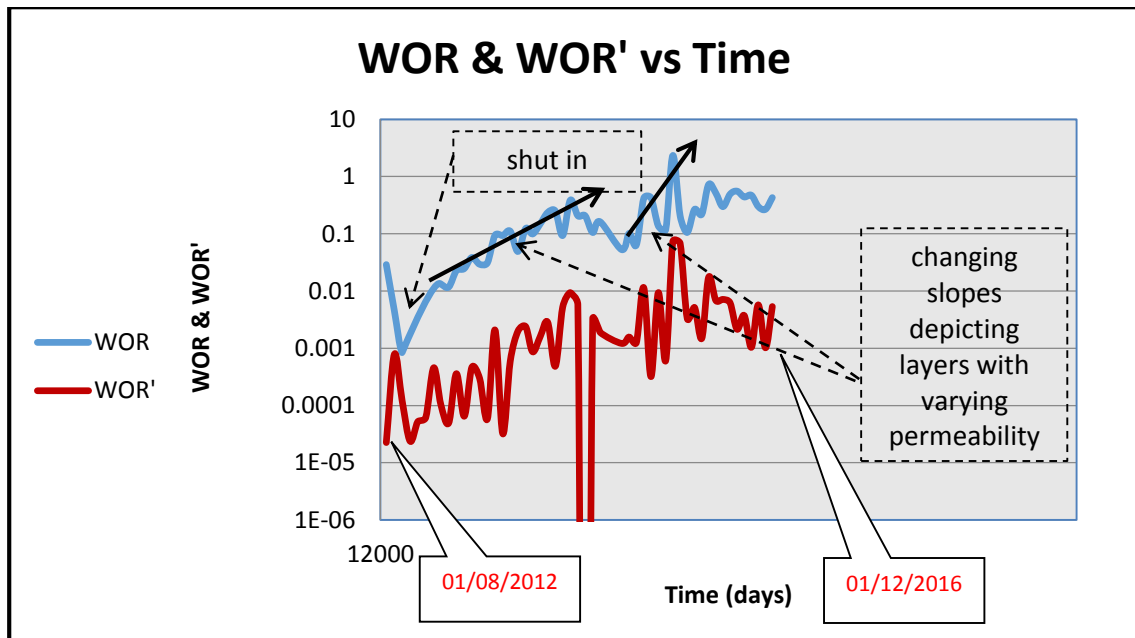
Figure 5. Diagnostic plot for four wells.

Figure 6. Diagnostic plot for well AGCS-101.

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3.2. Diagnosis of the water problem type for the field and wells using numerical model

It is important to study the water and oil movement inside the reservoir and to make comparison between the numerical model and the analytical methods; reservoir model was built by Petrel-2014. Abu Ghirab field dimensions are about 30 km long and 6 km width (**Awni, 2012**), the area of field is about 106.8 Km2. Geologically, Asmari formation in Abu Ghirab field has a complexity due its depositional environment and tectonic situation, also it belongs to unstable shelf (**Missan oilfield technical report**), so the folds and faults are formed in this reservoir. There are 38 faults vary in their size. The classification of fault rock is presented by (**Yangwen Pei et al., 2015**), based on this classification, one can predict the fault rock types of Asmari reservoir/Abu Ghirab field, which are probably clay/phyllosilicate smears and Phyllosilicate-Framework Fault Rocks (PFFRs) because of the level of clay content in the lower zone exceeds 40% (zone C) and form 15-40% in zone (zone B3), which there is a high probability of smear formation. The sealing type in Asmari is probably to be Juxtaposition sealing (self and separated) and Smears sealing, these faults were modeled and its behavior was studied by calculating its properties.

When the process of history matching was done, the behavior of water inside the reservoir has been noted, which can be used as a base to evaluate the water movement numerically. Some parameters must be taken into consideration for each zone during the study of reservoir fluids movement, which are, the permeability of (x,y & z), the relative permeabilities (water, oil & gas), capillary pressure, and barriers (shale beds, faults or fractures).

The multi-layers channeling phenomena was noted by using Intersection view, see **Figure 7**, the most layers that exhibited channeling are A1, A2 and B3. This figure depicts the sealing behavior of faults and its effect on water advance, where the foot wall of the major fault forming a barrier along the reservoir except in some parts of it, which result in reversing the effect of edge water mechanism and changing the path of water movement from lateral path to vertical path more rapidly (make the water advance from the bottom) specially in south dome in the high faulted parts. This problem was not noted in analytical methods, so it can be considered as another water problem with multi-layers channeling problem.

The faults regions can show the sealing behavior for each fault in the reservoir, some faults forming a seal for the fluid flow, others show partial or conductive sealing behavior, see **Fig. 8**.

The well AGCS-(101) is located in the south dome and there is no surrounding faults, water invasion the well region from south and east part, each zone show different water advance which confirm that the well exhibited to multi-layers channeling , see **Fig 9**.
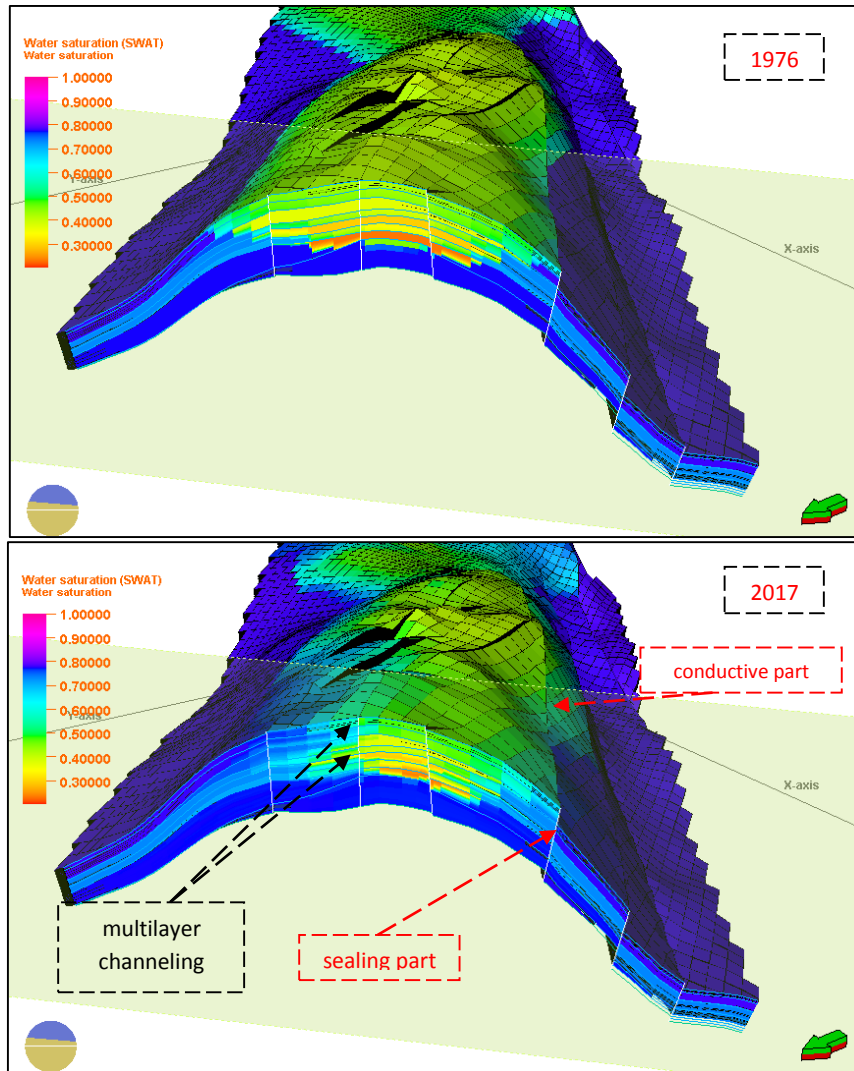
Figure 7. Intersection-3D windows for water saturation in *the reservoir* , during field history production from 1976 to 2017.
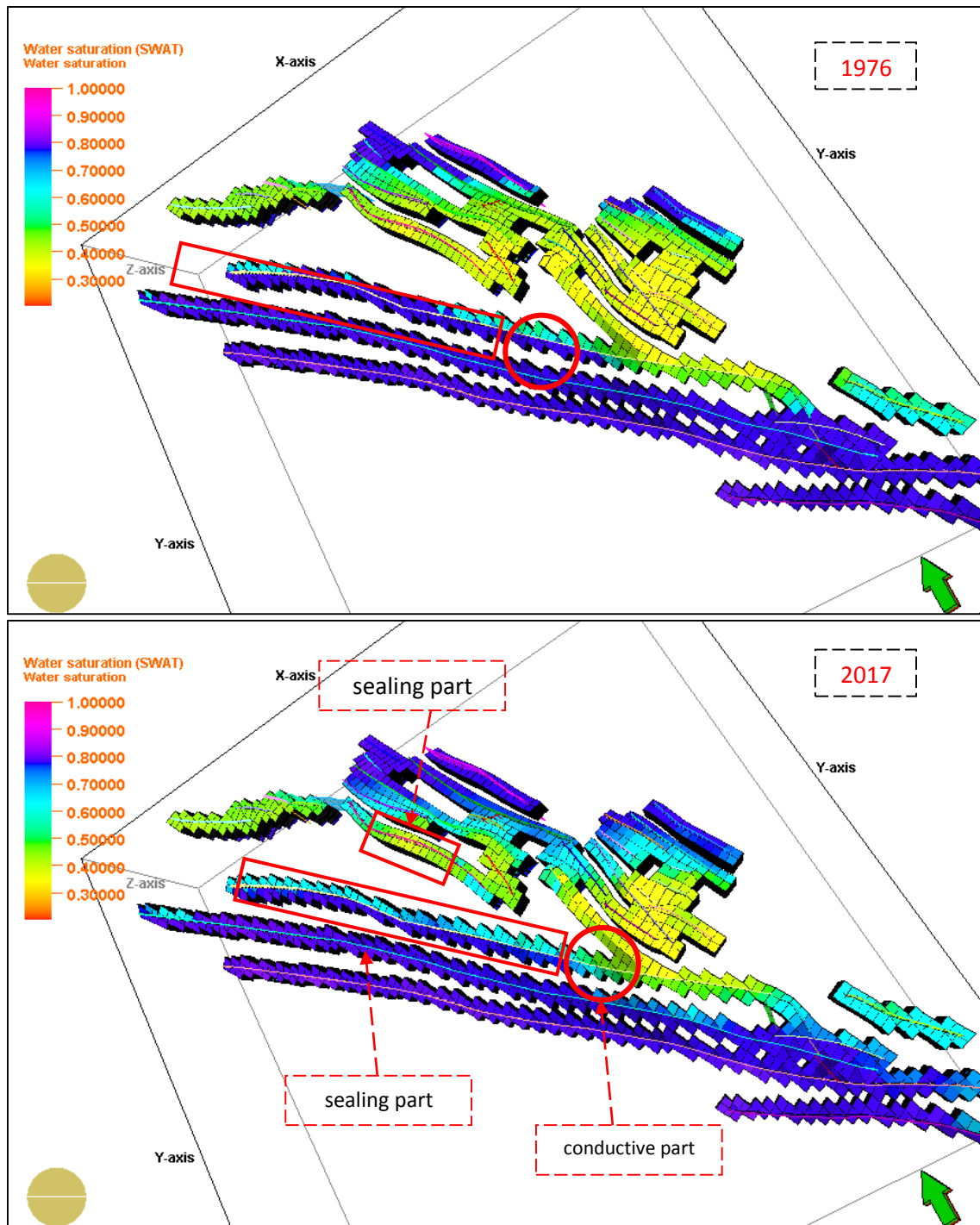
Figure 8. Fault regions with water saturation in *the reservoir*, zone A, during field history production from 1976 to 2017.
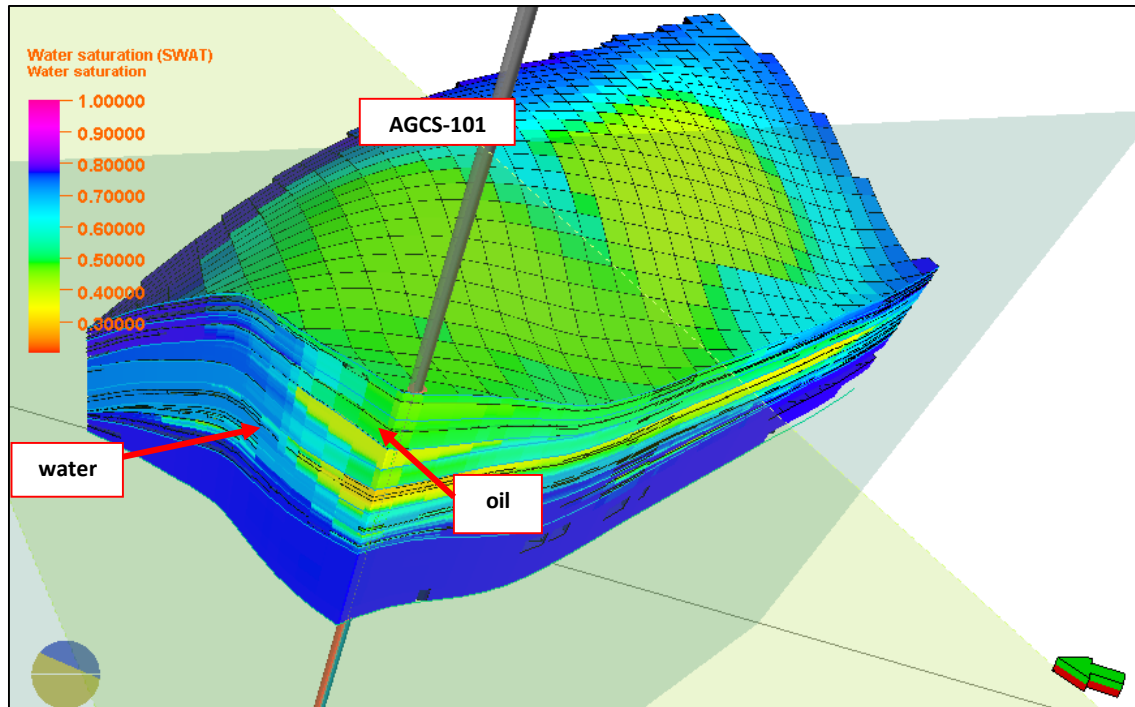
Figure 9. Intersection-3D windows for water saturation in *the reservoir,* well AGCS-101.

The Well AGCS-11 is existing between two faults in the east flank, in **Fig.10**, one can see how the water advanced in the reservoir zones (A1,A2 and A3) rapidly from the east more than the south. Zone A3 has the highest percent of water and this confirm again, the effect of multi-layers channeling in the reservoir. The effect of fault on water movement is clear in the model. One can see that the water in zone A1 has been displaced despite of fault effect existence, which means that the fault is working as path for water existed in the bottom zones.

Well AGCS-7, this well is the same as AGCS-11, also located between two faults in the east flank, see **Fig. 11**. While It is exposed to water invasion stronger than AGCS-11, especially from the east side, zone (A).

At the beginning of production of well AGCS-23, the water produced at level above or equal oil level for six month and this is probably because of high initial water saturation existed inside the formation, then it declined for 573 days, this is probably because of the depletion of all water inside the reservoir (zone A). After that, the water increased, this is probably because the effects of the fault that located close to well which work on feeding the regions surrounding the well by water, in addition to the multi-layers channeling that coming from the south, see **Fig. 12** to **14**.
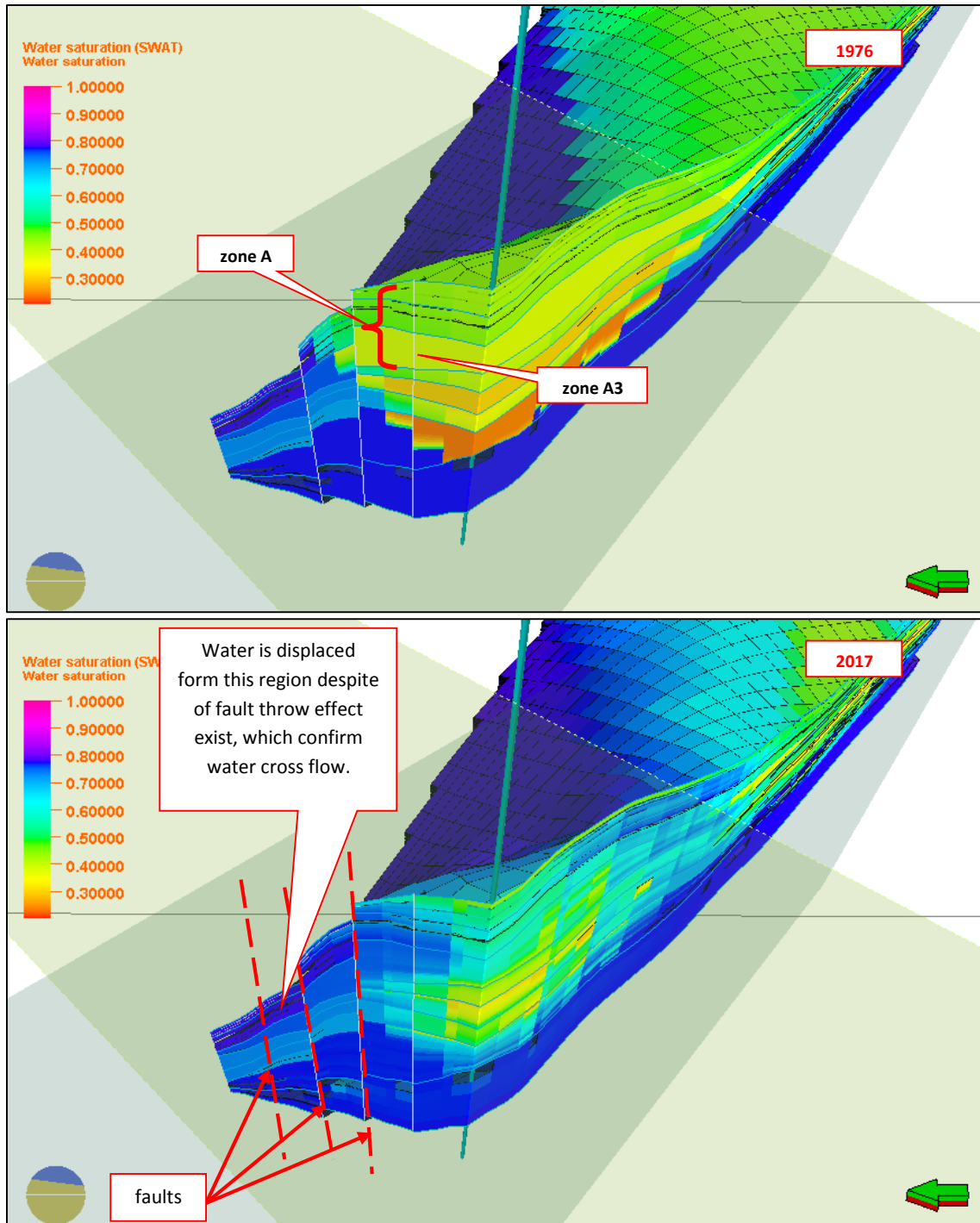
Figure 10. Intersection-3D windows for water saturation in *the reservoir,*, well AGCS-11.
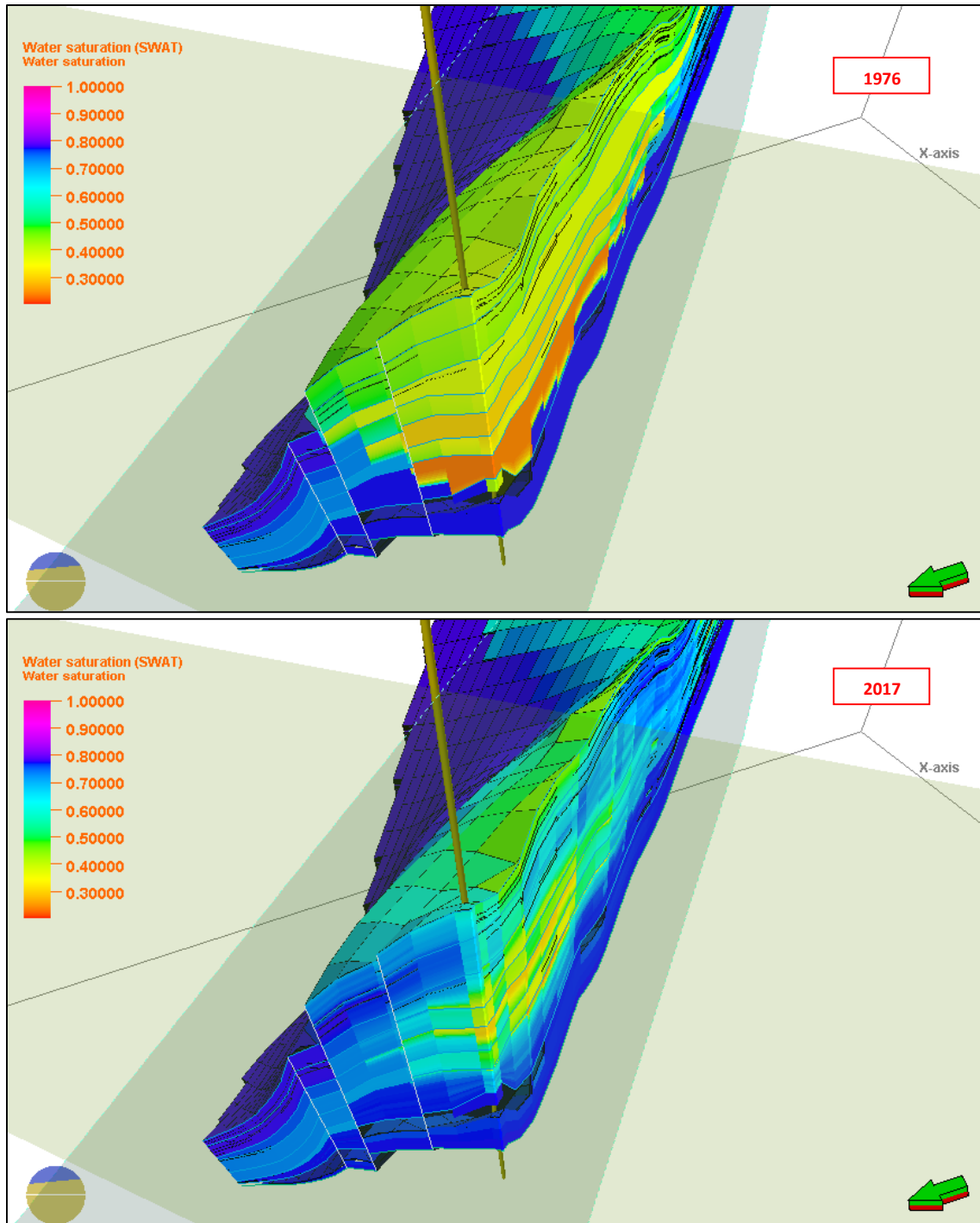
Figure 11. Intersection-3D windows for water saturation in *the reservoir*, well AGCS-7.
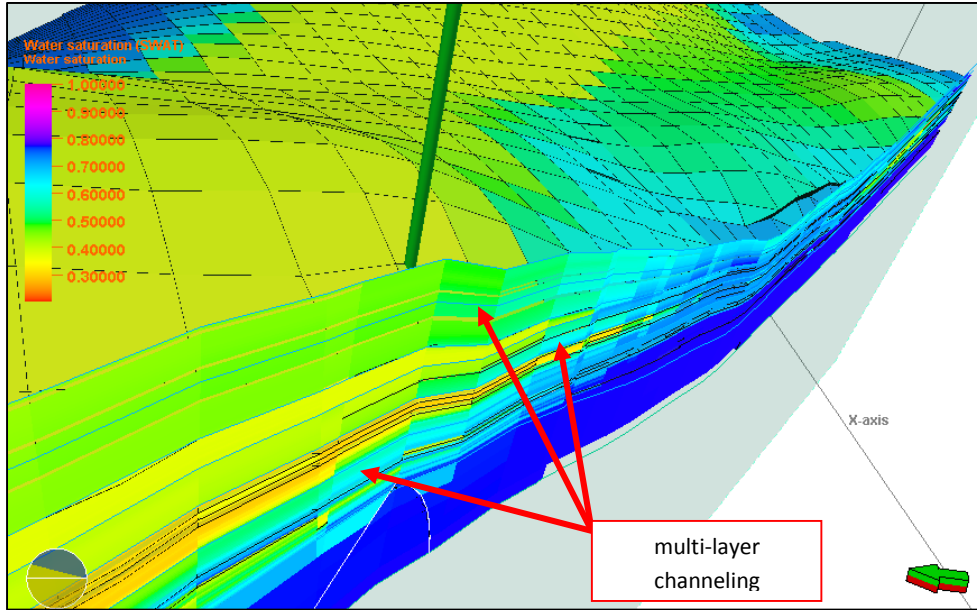
Figure 12. Intersection-3D windows for water saturation in *the reservoir* , well AGCS-23, at 2017-1-1.
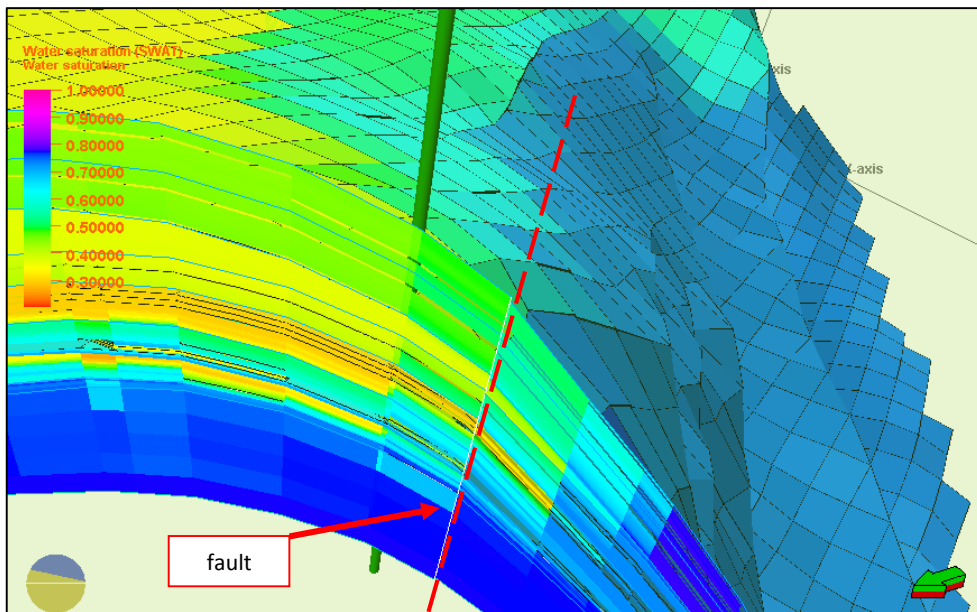

Figure 13. Intersection-3D windows for water saturation in *the reservoir* , well AGCS-23, at 2017-1-1.
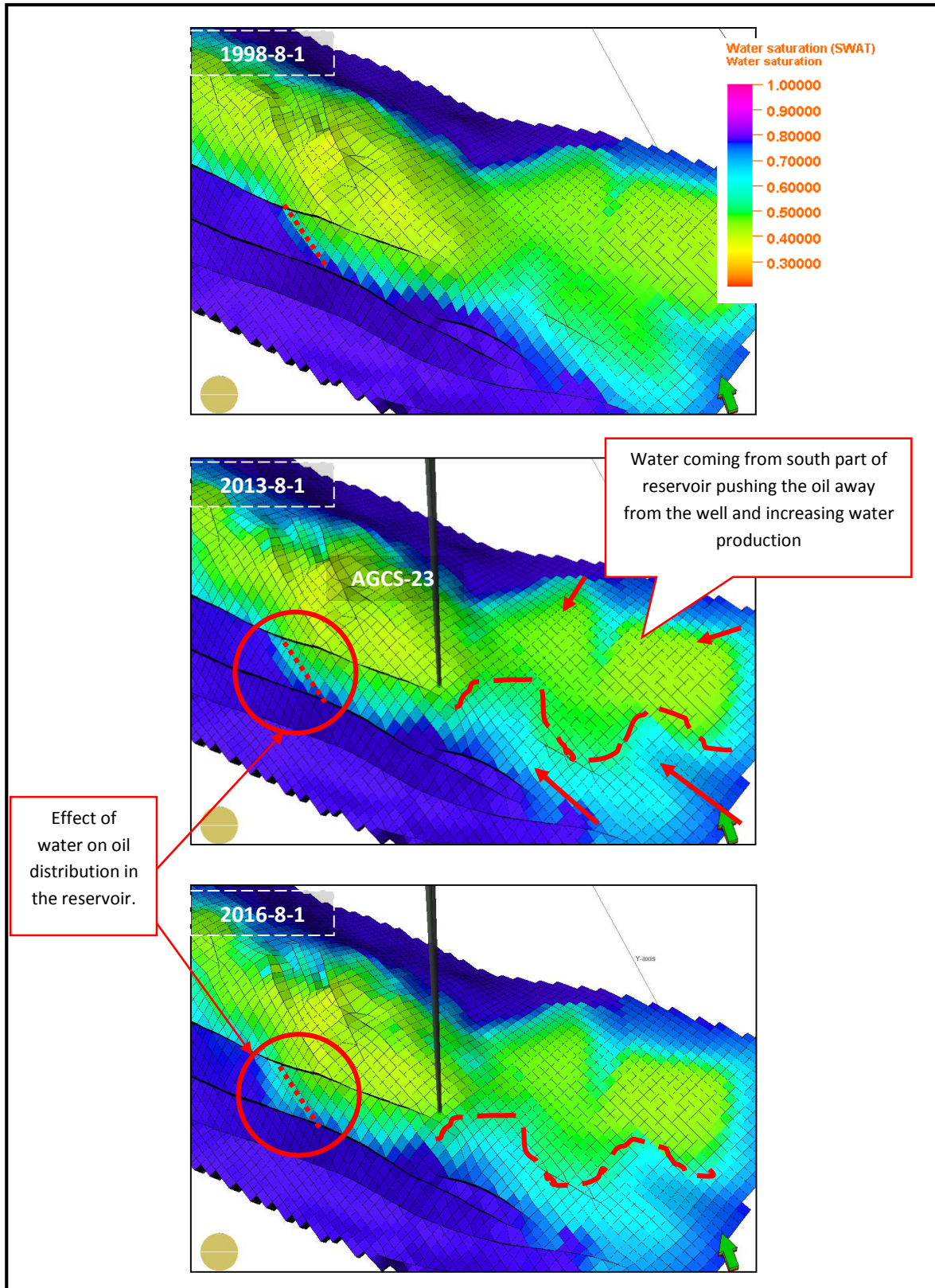
Figure 14. Intersection-3D windows for water saturation in *the reservoir,* zone A1, well AGCS-23.

From above discussion one can conclude that, the multi-layers channeling problem has been detected and confirmed analytically and numerically. The direction of edge aquifer has been noted numerically, which is strong from the north-east and south-east parts and weak from the west part because of major faults sealing effect. The major fault generates a new problem which is bottom water advance or oil-water contact advance problem, this problem detected numerically.

Two suggested solutions are recommended to control the problem:

- Ceasing the production from the wells located near to the east flank.
- Ceasing producing from zone A to reduce the water invasion that coming from the north-east and south.

4. CONCLUSIONS

- Water problem type is successfully identified by Chan's plots; it confirms that the multi-layers channeling is the main cause of water production in Asmari reservoir.
- Intersection views show the multi-layers channeling effect in the reservoir numerically, comparing these results with the analytical ones can confirm that the multi-layers channeling with edge water mechanism are the cause of water problem in Asmari reservoir .
- The edge water direction in the reservoir has been identified, which extending from north to south in the east side of the reservoir
- Some faults have partial sealing behavior in some parts of reservoir which result in an irregular water advance front.

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