Edge Water Breakthrough in each of the major zones within Mishrif reservoir in West Qurna phase 1

الاختراق الجانبي للمياه في كل من الوحدات الرئيسية لمكمن المشرف في حقل غرب القرنة 1

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Abstract

The Mishrif reservoir (Upper Cretaceous) considered the main discovered and developed reservoir at West Qurna I field in southern Iraq and has been on production intermittently since 1999. Mishrif reservoir has been deviated into six main zones from youngest to oldest are mA, CRI, mB1, CRII, mB2 & mC.

The West Qurna Phase I Field (WQI) has pressure depletion since production commenced in 1999. More than 450 wells penetrated Mishrif Formation, to date, almost all of the production has been from the Mishrif formation (2180 to 2505 m true vertical depth, subsea) with minor oil production from the Lower Cretaceous Zubair formations. Geoscientist and reservoir engineers are looking for producing dry oil especially there are limited surface facilities at West Qurna phase 1, for that purpose and as part of Reservoir Management, It was very important to monitor the Formation & injection water movement across Mishrif reservoir with the time. Cased hole logs (Saturation logs & Production logs) and Open hole logs for new drill wells are being integrated to describe the water encroachment in Mishrif in order to Study behavior of aquifer movement and water injection, Validate the geologic reservoir model, assess the vertical and horizontal water sweep & enhance perforation strategies.

In West Qurna 1 (from 2010 to date) have been ran more than 500 PLTs (Production logs) and 300 PNLs (Saturation logs) and open hole logs for new drill wells, all these logs have been analysis and interpreted (using Geolog &Emeraude software) then were created different water movement maps for each main productive zone mA, mB1 & mB2 in 2013, 2014 & 2016 (by Petrel).

Different water encroachment behavior among the different zones due to heterogeneity in reservoir rock quality, Integrating production rate allocated by zone with water encroachment maps shows excellent relationship between production and flood front by zone, the maps showed that quicker water movement in the Meshrif reservoir compared to the model, these maps are using for perforation strategy, and the maps will be updated periodically every 12 months.

Introduction

WQI commenced production in 1999, predominantly from the Middle Cretaceous Mishrif formation (2180 to 2505 m true vertical depth, subsea) with minor oil production from the Upper Cretaceous Sadi and Lower Cretaceous Zubair formations.

There are six discovered reservoirs in West Qurna 1 from oldest to youngest are Yamama, Zubair, Mauddud, Mishrif, Khasib & Sadi reservoir. The main reservoir in WQ1 is Mishrif reservoir with proximately OOIP 40 GBO Figure (1). More than 460 wells had been penetrated Mishrif formation with spacing 200 acre (900m).

The Mishrif formation has been divided into six stratigraphic zones, two with poor reservoir quality (Caprock 1 and 2). The main producing intervals from youngest to oldest are the mA, mB1, mB2, & mC with Caprock intervals (associated with sequence boundaries) at the top of mB1 and mA intervals Figure (2).

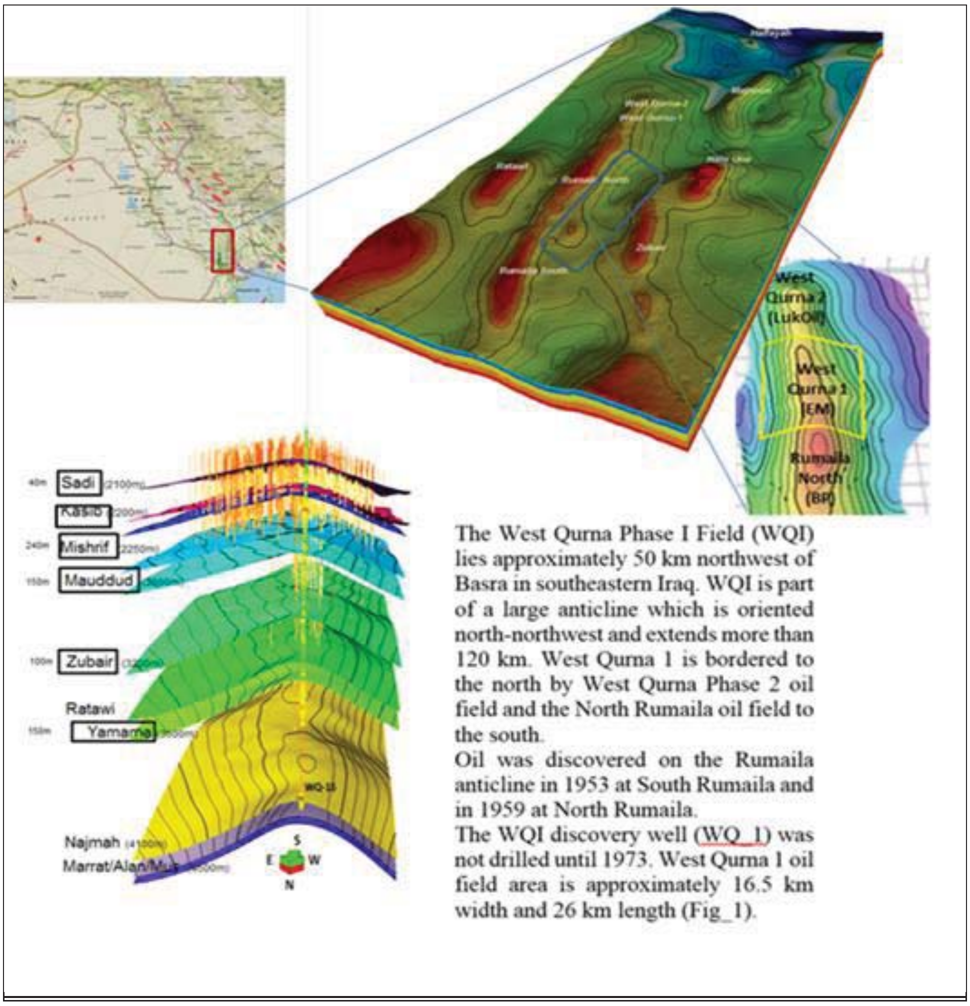


Fig. (1) WQ1 oil field area (16.5 km width and 26 km length)

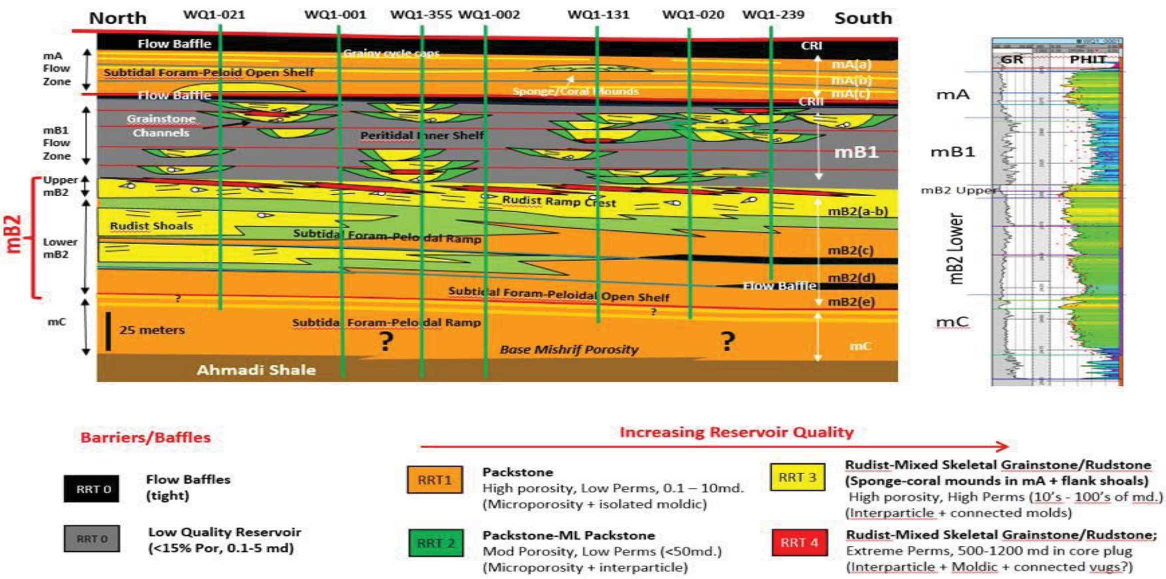


Fig. (2) The top of mB1 and mA intervals

Pressure data shows that all zones within the Mishrif are in pressure communica-tion in response to primary depletion Figure (3).

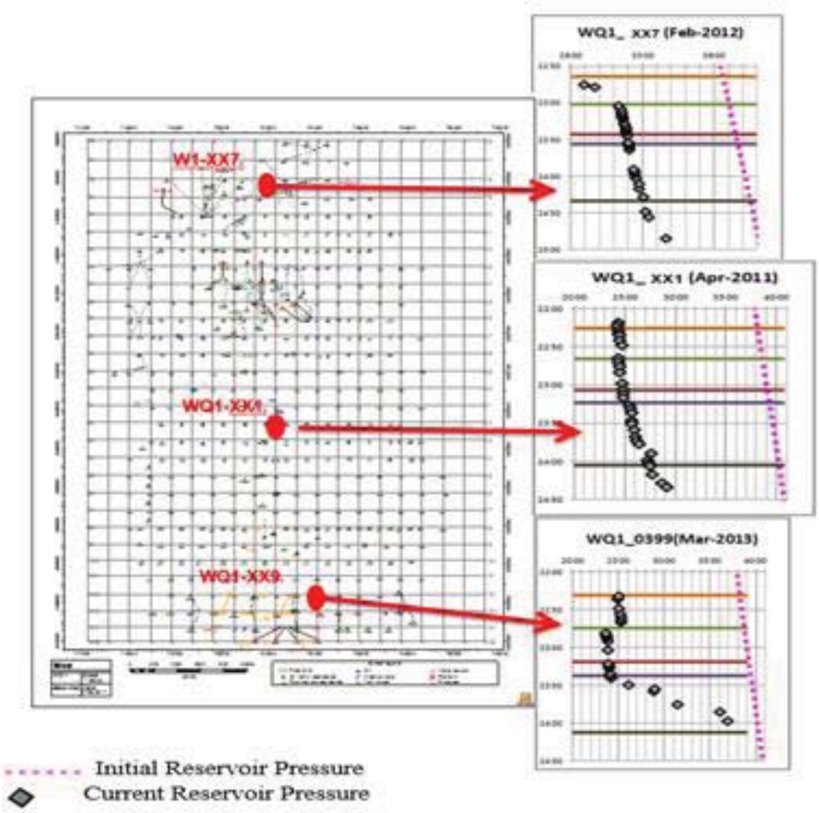


Fig. (3) Example- Initial vs. Reservoir pressure for some WQ1 wells

As part of Reservoir Management, Water breakthrough is identified for each zone and Water arrivals are mapped for each reservoir zone for each year from surveillance data

1- Saturation Logs (PNL_s)
2- Production Logs (PLT_s)
3- Open Hole Logs for new drilled wells

These maps will be utilized as a Reservoir Management tool to:

- Study behavior of aquifer movement and water injection.
- Assess the vertical and horizontal water sweep.
- Enhance completion strategies.
- Assess economic viability of potential future infill drill wells.
- Validate the geologic reservoir model.
- Evaluate the reservoir model history match.

➢ WQ1 Pulsed Neutron Logging (PNL)

In West Qurna 1 (from 2010 to date) have been ran more than 340 PNLs (RST, RMT, RPM, CRE,…)

Determining water saturation behind casing plays a major role in reservoir management. Saturation measurements over time useful for tracking reservoir depletion, planning workover, enhanced recovery strategies and diagnosing production problems such as water influx and injection water breakthrough.

Traditional methods of evaluating saturation are thermal decay time logging and Carbon/Oxygen (C/O) logging [6].

Essentially the saturation logs provides three types of measurements: reservoir saturation from C/O or Sigma, lithology & borehole fluid Figure (4)

Sigma – Sigma is measure of how fast thermal neutrons are captured [7], TDT technique provides good measurements when formation water salinity is high, constant and known [6].

The raw sigma measurement contains contributions from the borehole as well as the formation. To isolate the formation sigma, the neutron generator is pulsed in dual burst pattern: a short burst followed by long burst. Near-detector measurements are strongly influenced by the borehole environment and hence borehole sigma. Far-detector measurements are influenced by formation sigma.

Row sigma measurements are also affected by neutron diffusion and environmental variables related to the borehole, casing, cement and formation [7].

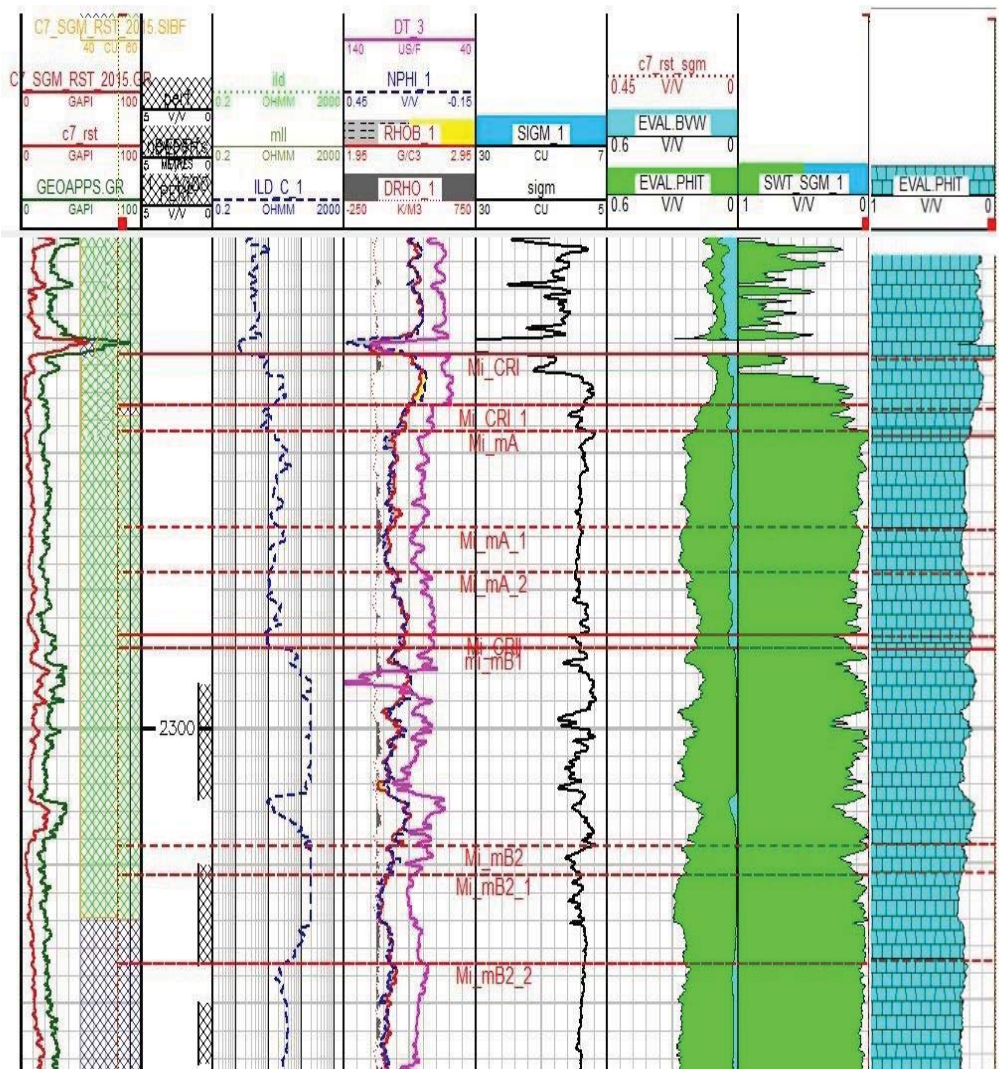


Fig. (4) RST log result in WQ1-XX8, track 1 shows the oil-water contact ins- ide the wellbore at 2334m within mB2. Water satur- ation S_W is derived from Sigma (track 7) and (track 8) shows the lithology.

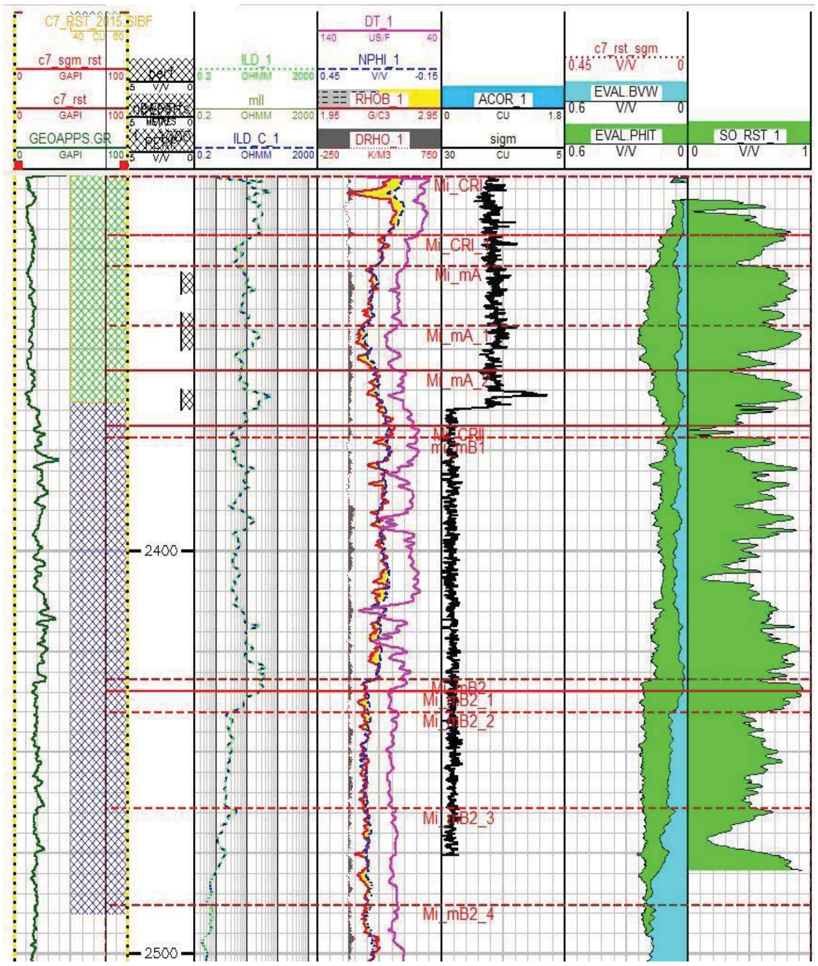


Fig. (5) RST log result in WQ1-X40, track 1 shows the oil-water contact ins-ide the wellbore. Water saturation S_W is derived from Carbon/Oxygen (track 7)

Carbon/Oxygen – in the low-salinity water (less than 3500 ppm), the sigma cannot accurately differentiate between oil and water, which have similar neutron capture cross section. When the salinity of formation water is too low or unknown, C/O logging can be used. C/O logging measures gamma ray emitted from inelastic neutron scattering to determine relative concentration of carbon and oxygen in the formation. A high C/O ratio indicate oil bearing formation, a low C/O ratio indicates water or gas bearing formation. The major drawback to C/O logging tool have slow logging speeds and are more sensitive to borehole fluid than formation fluid, which affects the precision of the saturation measurements. Figure (5)

The strategy is once mostly capture mode (Sigma) or C/O have been interpreted to produce water saturation S_W. these measurement should be compare to Open hole water saturation S_W to monitor water movement figure (4) or may be repeated PNL later and direct comparison Sigma or C/O curves to have more confident data about reservoir fluid movement Figure (6)

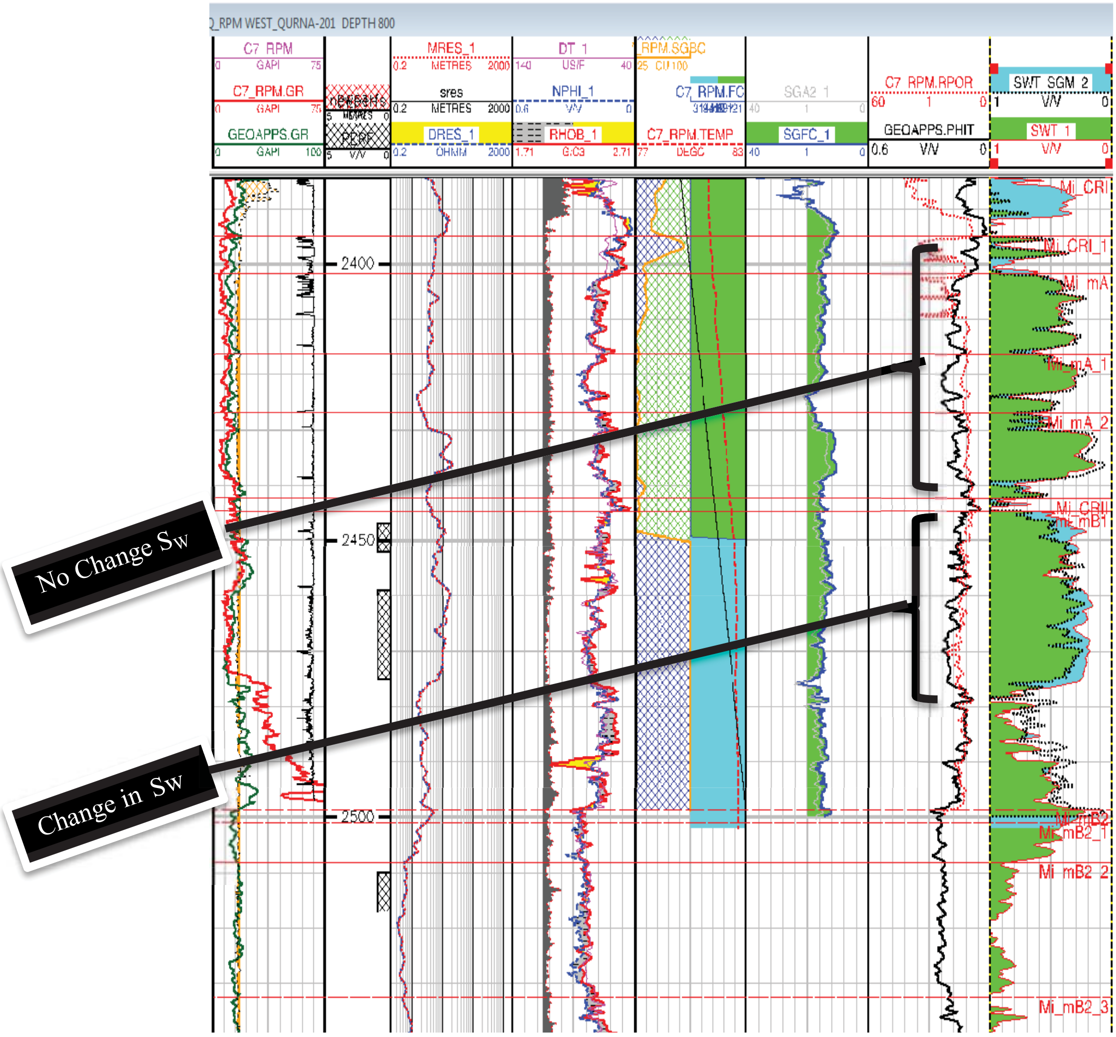


Fig. (6) RST log result in WQ1-XX1, track 8 shows there is no water saturation change in mA and there is some change in mB1

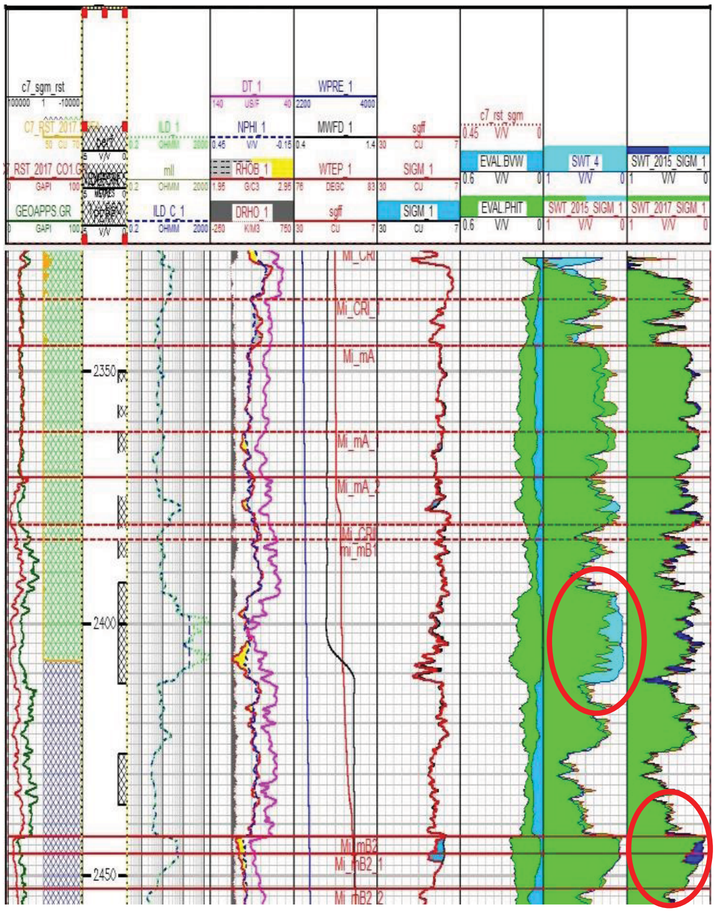
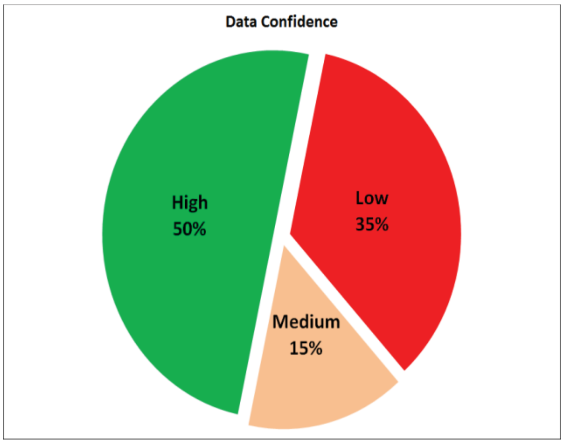


Fig. (7) RST log result in WQ1-XX7, bore hole has water below 2407m (track 1).

Track 8 shows water movements between open whole S_W and first sigma Sw. After two years the second sigma has been ran and by direct comparison Sigma curves (track 9) it's easy to figure out that there is significant change in water saturation across mB2_upper (dark blue)

Saturation Change (Delta Sw) was classified into 3 categories:

- Low confidence 35% from total data (low quality data due to bore hole fluid or acid stimulation job or lack of cased hole base line PNL for time-lapse comparison ;unknown no base line for comparison.
- High confidence 50% from total data (good data un-perf zone and no acid job and confirmed by other factor; no change).
- Medium confidence 15% of total data

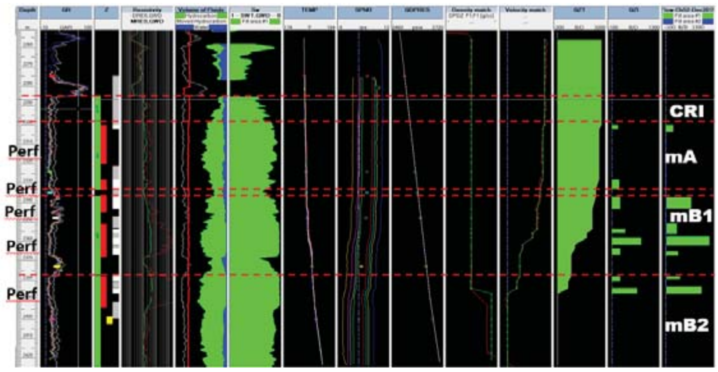


(slightly affected by previous factors).

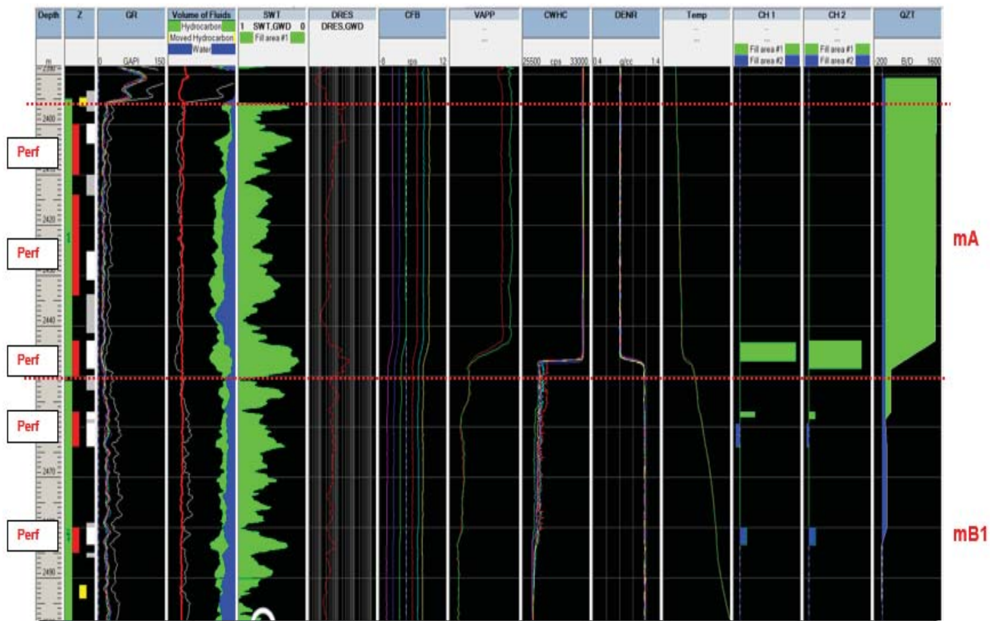
- Water encroachment tool was based on medium and high confidence data

➤ WQ1 Production Logging (PLT$_S$)

Production Logging normally has spinner with many sensors such as pressure, temperature, density, capaci-tance and probe holdup measurements.



Once interpreted together provide accurate flow rate and describe the nature and behavior of fluids in or around the borehole during production. So the PLOT have been used to determine if the well is wet or not and where does the water come from? Figure (8).



Interval	Inflow zone	Oil 32" (STB/D)	Water32" (STB/D)	Oil 50" (STB/D)	Water50" (STB/D)
mA	2400-2430 m	0	0	23	0
mA	2443-2447 m	717	0	937	0
mB1	2457-2458 m	195	0	117	0
mB1	2459-2464 m	0	-68	0	-40
mB1	2480-2484 m	0	109	0	146
Total		**903**	**41**	**1077**	**106**

Fig. (8) PLT interpretation WQ1-XX0, two chock (32/64" &n 50/64") shows that most of oil production coming from mA and the mB2 is making water.

This well is close to the edge of the field,So most likely the water is coming from aquifer.

- **Open Hole Logs for new drilled wells**

New drilled wells specially the wells which have been drilled on the edge of West Qurna Phase 1, the Quad combo were interpreted and the water saturation was calculated by Archie equation Figure (9)

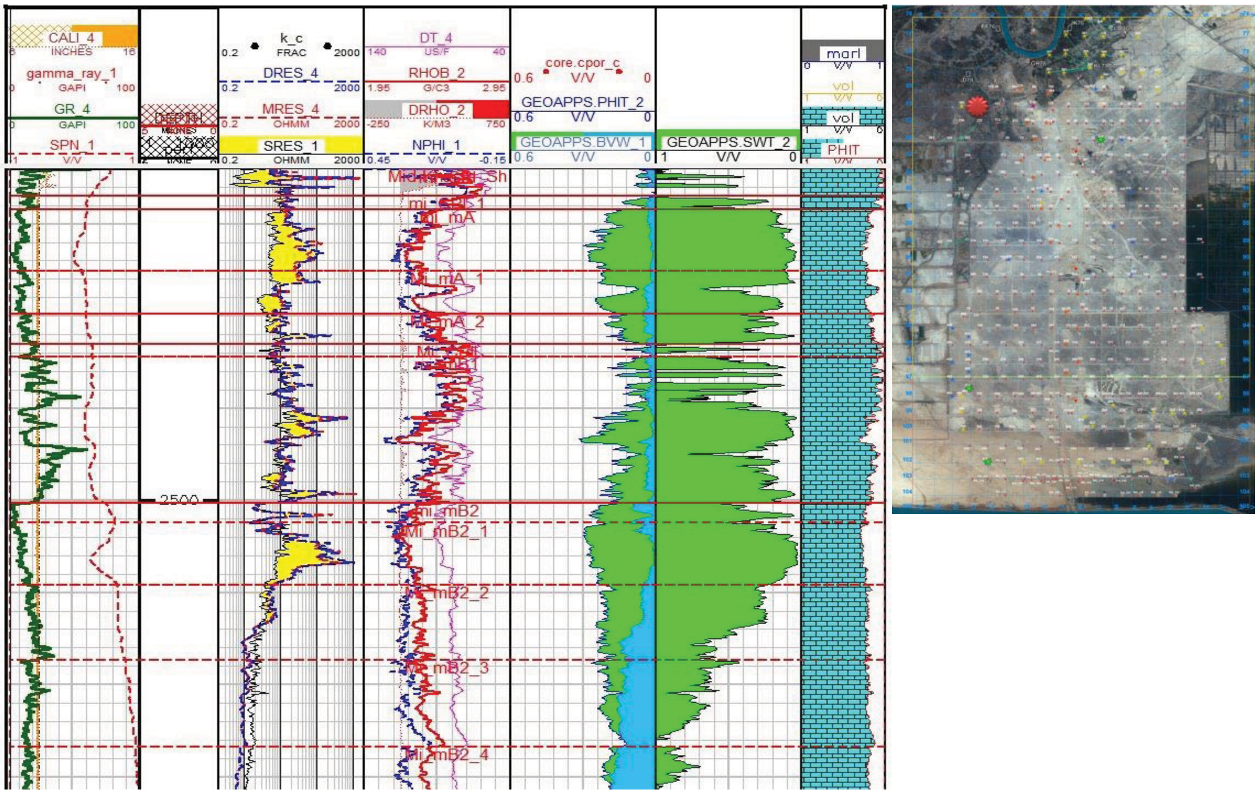


Fig. (9) Open hole logs interpretation for WQ1-XX3 by Archie Equation

Change in water saturation (water movement) possible to be identified by comparison between water saturation curve from Archie equation ($S_{W,\ Archie}$) and the water saturation (S_{WPC}) which has been expected from Special core analysis (SCAL)
(Fig-10 &11)

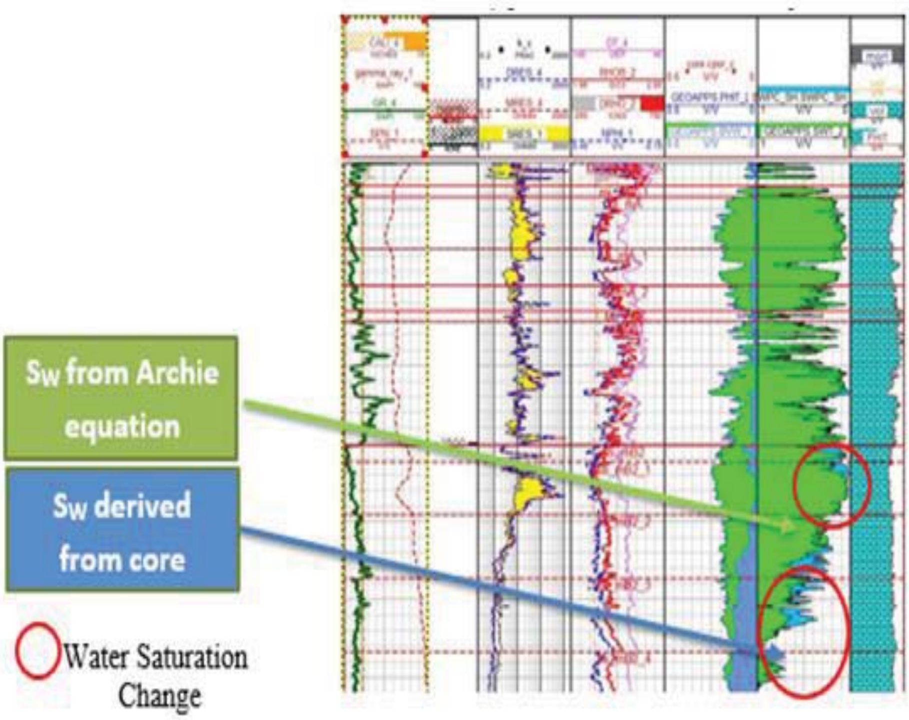


Fig. (10) $S_{W,\ Archie}$ & S_{WPC} for WQ1-XX3

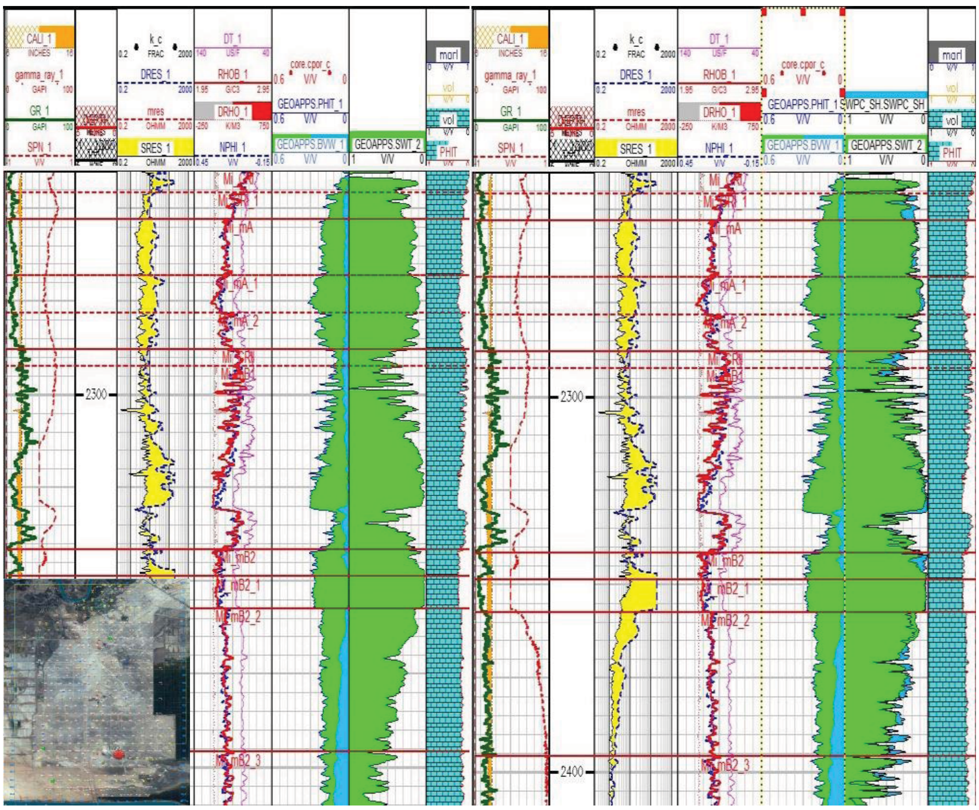


Fig. (11) Open hole interpretation ($S_{W,\ Archie}$ & S_{WPC})

Results:

In order to monitor the Formation & injection water movement across Mishrif reservoir with the time. Cased hole logs (Saturation logs & Production logs) and Open hole logs for new drill wells are being integrated to Study behavior of aquifer movement and water injection,
All these logs have been analysis and interpreted (using Geolog &Emeraude software) and then different water movement maps for each main productive zone mA, mB1 & mB2_upper in 2013, 2014 & 2016 have been created by Petrel software. Figures (12, 13, 14**).**

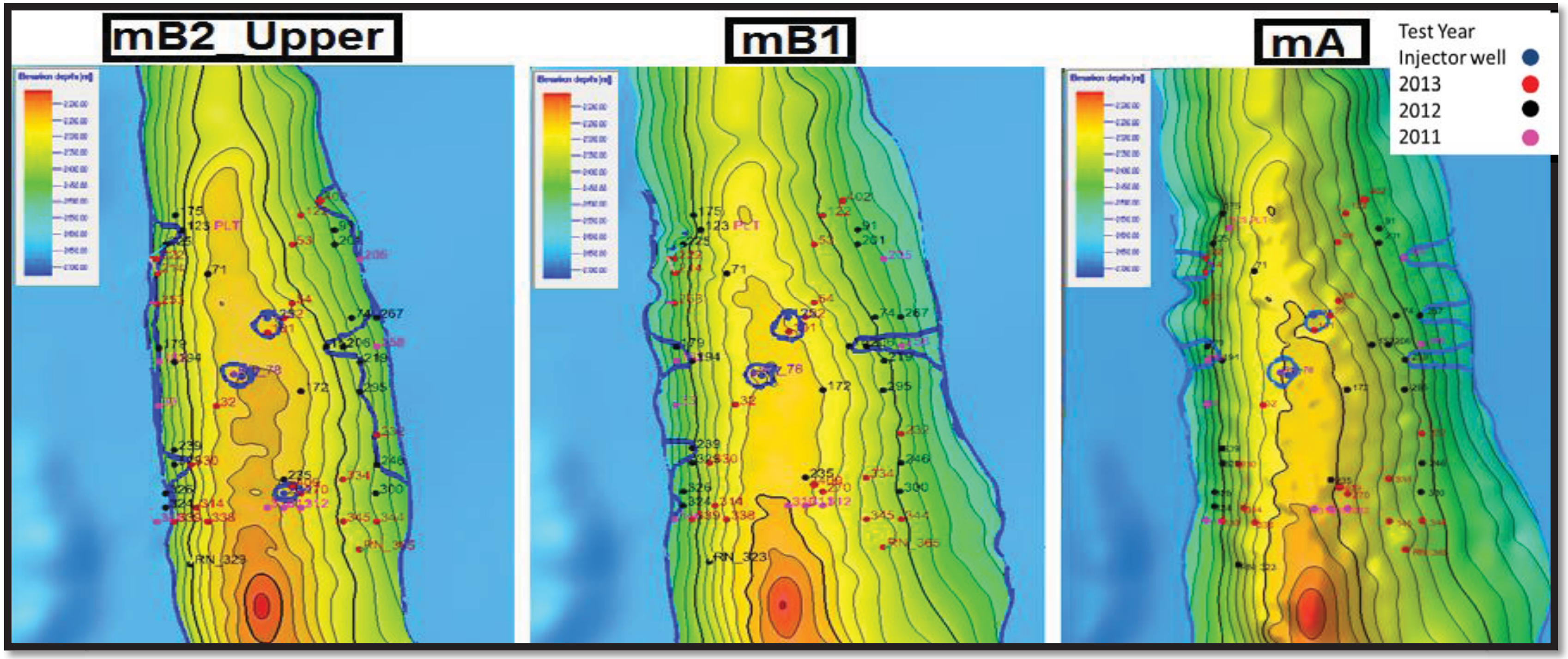


Fig. (12) 2014 Water Encroachment Maps (mA, mB1 & mB2_upper)

- Water movement ma.p represents saturation changes in wells with high and medium confidence
- Water Saturation change in all three zones noticed in both flank to crest.
- The east flank has gentle slope, so more encroachment on the East Flank.
- Relatively more uniform water advancement in mB2_upper than mA & mB1.
- Only 9, 9, 22 wells used for mA, mB1 & mB2_upper map construction respectively.
- Uncertainty in some regions due to no data.

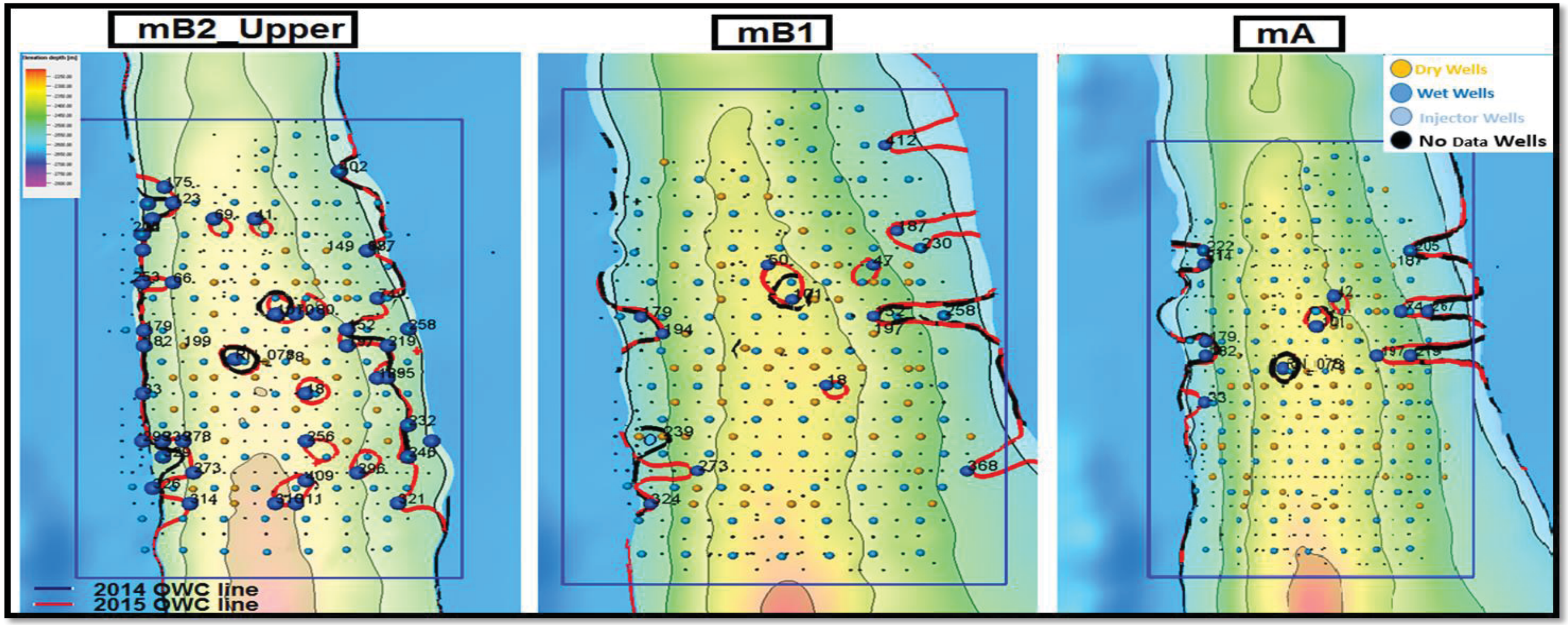


Fig. (13) 2015 & 2014 Water Encroachment Maps (mA, mB1 & mB2_upper)

- Water movement map represents saturation changes in wells with high and medium confidence.
- Due to different dip, more saturation change is noticed on the east flank and less change is observed on the west flank.
- Some saturation change has been noticed near some injector wells.
- 14, 14, 41 new saturation, PLT & OpenHole wells used to update water movement map for mA, mB1 mB2_upper map construction respectively.
- Uncertainty in some regions due to no data.

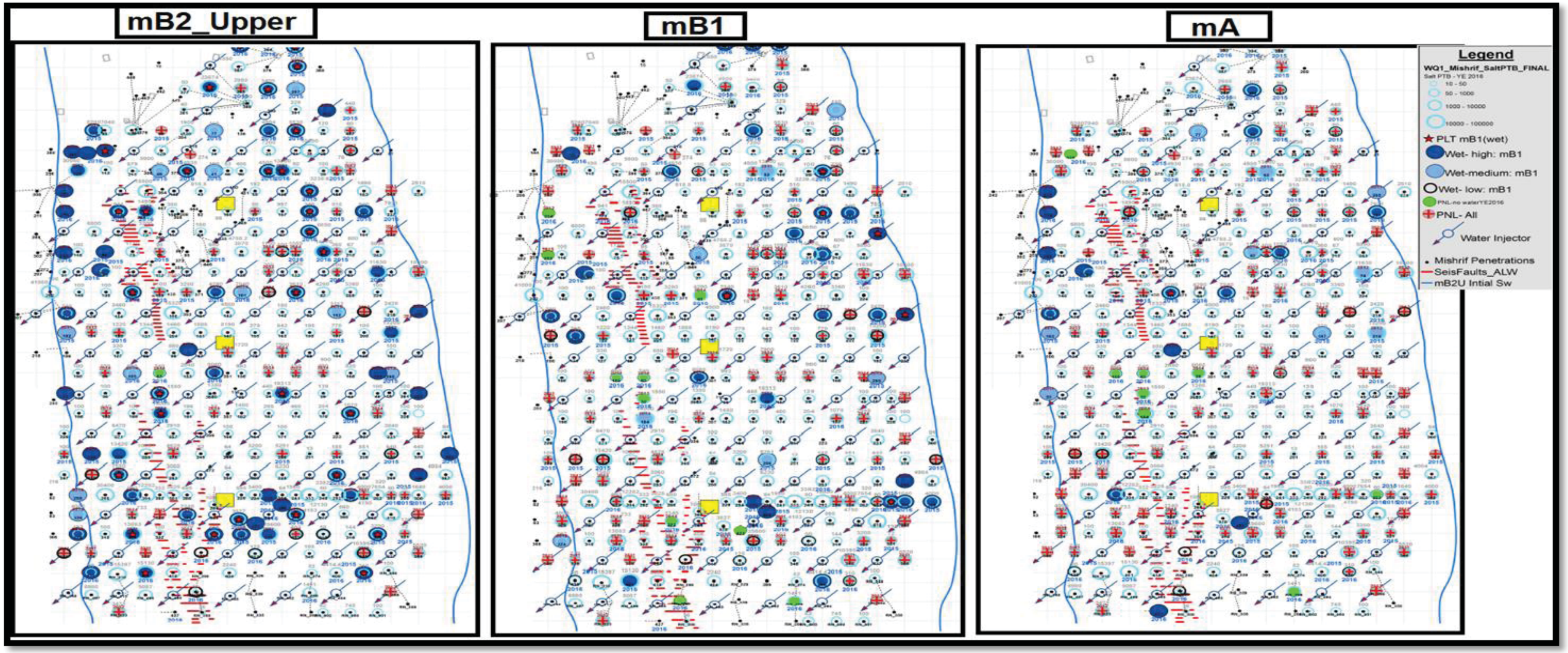


Fig. (14) 2016 Point maps for (mA, mB1 & mB2_Upper)

In 2016, water encroachment line maps were replaced with point maps because with years of water injection, it is no longer possible to accurately determine whether water detected in a well is from injection of from the aquifer and also point maps show multiple sources of data on each wellbore in the field, including PNL confidence, PLT observations and salt measurement.

We can distinguish between the wells where no water was observed versus wells where no was obtained, by showing all the data on the wells.

Conclusion:

1. Water Saturation change in all three zones noticed in both flanks.
2. Due to different dip, more saturation change is noticed on the east flank and less change is observed on the west flank.
3. The maps demonstrate quicker water movement in the field compared to the initial simulation mode 1 prediction.
4. The mA has heterogeneous reservoir quality so saturation change is interpreted as finger or lenses.
5. New PLT data in mA show thinner connected grainstones.
6. Saturation change in mB1 are interpreted as water movement in east-west oriented grainstone-filled channels.
7. mB2 is more homogeneous with good reservoir quality over the whole field, relatively more uniform water advancement in mB2_upper than mA & mB1.
8. As expect the breakthrough from injectors is more predominant than the water encroachment from flank due to increase in water injection.
9. Increase breakthrough expected due to increase in VRR in surrounding wells, especially in good quality regions.
10. Uncertainty in water movement in some regions due to lack in data.
11. The maps are used for guiding perforation strategy, assess economic viability of potential future drill wells. & enhance completion strategies.
12. Additional data is required, so it's required to run more PLTs, PNLs & WC measurement to identify which zone encountered saturation change.
13. In 2016, water encroachment line maps were replaced with point maps for the following reason:

- With years of water injection, it is no longer possible to accurately determine whether water detected in a well is from injection of from the aquifer
- Point maps show multiple sources of data on each wellbore in the field, including PNL confidence, PLT observations and salt measurement
- By showing all the data on the wells, we can distinguish between the wells where no water was observed versus wells where no was obtained

14. The maps should be updated periodically, at least every 12 month.

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Nomenclature:

C/O Carbon-Oxygen Ratio
CRE Cased-Hole Reservoir Evaluation
(Weatherford Saturation Tool)
GBO Billion barrels of oil
OOIP Original Oil In Place
PLT Production Logging Tool
(Baker Hughes Saturation Tool)
PPM Parts Per Million
RMT Reservoir monitor Tool
(Halliburton Saturation Tool)
RPM Reservoir Performance Monitor
(Baker Hughes Saturation Tool)
RST Reservoir Saturation Tool
(Schlumberger Saturation Tool)
TDT Thermal Decay Time