

**Introduction:**
Greater Burgan is the largest clastic reservoir in the world. Burgan reservoir discovered in 1938 and it mainly consists of three reservoir units namely Wara. Third. And fourth sand. The Wara Water Flood Pilot Project is the first clastic water-flooding pilot in Kuwait. Wara Reservoir producing below the bubble point pressure in many parts of the reservoir due to reservoir depletion phenomena, leading to formation of localized gas cap at many places of the reservoir. Once the gas saturation exceeds the critical gas saturation, free gas begins to flow toward the wellbore and gas-oil ratio increases. Such a depletion, it will affect the reservoir performance and reserve. In order to optimize Wara development water flood strategy, the field been split into sectors and this abstract discusses the case study in one of the sectors. Wara sectors is divided based on the fault and Wara channel. Wara reservoir is being developed with 5 spot patterns with the objective of:

- Enhance Wara wells productivity
- Improve oil recovery through mobilizing the oil saturation
- Water-Cut Development and management
- Understand reservoir connectivity and continuity
- Support Wara reservoir pressure

![Figure 1: Wara Pressure Map](image)

The pressure map shows three different areas with different colors, the green area shows the wells above bubble point, the yellow area is the transient area within bubble point, the red area is below bubble point.

**History of EWPMP**
Wara formation lays above Mauddud carbonate formation and below Ahmadi Shale, discovered in 1938, it was already documented that predominantly sand and shale separated Wara is falling below bubble point pressure, which would lead to significant loss in reservoir recovery. KOC established a multidisciplinary project team to handle water flood project and established thru systematic evaluation that water injection in a step-in peripheral scheme was most suitable for Wara reservoir, re-pressure the reservoir thru water injection. Water injection started in 2010 in some parts of the field. Current development plan aims to implement a full five spot pattern with a voidage replacement ratio greater
than one in some place to repressurize parts of the field. The voidage replacement ratio is the amount of the injection divided by the amount of the production supported by that injection. For Wara the voidage replacement ratio is calculated independently for each well and reservoir zone.

Figure 2: Wara Performance plot include oil, water, liquid rates

From the plot total oil production from wara around 322 Mbbl/D with total water cut = 48%
With the support from the surrounding injectors the voidage replacement ration for all wara around 0.8.

Method:
A thorough understanding of clastic reservoir sand channels is essential for effective reservoir management considering water encroachment patterns and assessing areal and vertical sweep. General strategy in Wara reservoir is to plan wells as injector or producer before they are drilled. Following a continuous regular pattern covering all the development area. This paper talks about the need for planning injector/producer wells in the patterns enhancing to the requirement of individual sectors and how the integration surveillance data helps in optimizing the whole process. As mentioned the 5-spot pattern water-flood strategy will inject volumes of water that will help to increase the pressure, however due to the delay of the facility for water flood connection equipment some of the planned producers in the sector got swept by the early water flood wells located in the flank, and another reason is the high heterogeneity of the Wara sand channels that is hard to predict. The team saw opportunity in shifting those producers into injectors and wells planned to be drilled as injectors to be converted as producers. This proactive strategy outcome will result in efficient oil recovery and proper water flood management.

After initiating Wara water field project, limited information was available concerning Wara reservoir regime. During Gathering Centres Shut in provided a valuable chance to collect full field pressure data acquisition:

- 100 Static bottom hole pressure (SBHP)
- 30 pressure build up tests (PBU)
- 120 PNC survey’s

The PNC campaigns covered nearby wells in the planned Pad, which indicated the Wara lower and Wara middle, got partially swept based on the historical PNC surveys campaign. The team integrated recent findings and agreed on the strategy to convert the producers into injectors to support nearby producers wells, which were declining in pressure and in near future these producers would be supported by the converted injectors. Based on the correlation between the injector and the produce the potential id
From the correlation between the injectors with the surrounding producer, it shows a good potential to convert the producers to injector and the injectors to produce and have a gain more than 6000 BOPD

**Conclusion:**

- The successful campaign of the data acquisition for the Wara water flood project resulted in better understanding of the impact of the water flood.
- PNC data confirmed water migration and identified areas of swept in some parts of the field including a planned Pad with producers, this allowed the team to be proactive and convert the PAD producers into injectors to support some of the nearby producers
- SBHP information established areas of depletion in parts of the Greater Burgan field along with increase in pressure due to water injection excellence
- The risks and uncertainties in Wara water flood have been managed by adopting a proactive approach which led to improve water flood development

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Reference:
1. Lessons Learned From the First Water Flood Pilot Project in a Clastic Reservoir in the Greater Burgan Field in Kuwait, Meqdad Al-Naqi, Ibrahim Al-Kandari, Mishari Al-Qattan, Badria A/Rahman, Kuwait Oil Company; Sami Bou-Mikael, Chevron; and Naz H. Gazi, Halliburton


