Control ID: 1063: **Integrated Reservoir and Well Performance Review to Maximize Field Production - Case Study from The State of Kuwait**

Saad Al-Rasdan[1], Pabitra Saikia[1], Suryyendu Choudhury[2], Ahmed Al-Boloushi[1], Abdul Aziz Al-Doub[1], Nourah Borashed[1], Talal AlAdwani[1], Fatma Taqi[1], Jose Garcia[1], Santiago Gonzalez[1], Ramil Mirhasanov[1], James Pennell[2], Abdullah Al-Kindi[2], Satinder Malik[2], Antonio Pico[1], Arun Kharghoria[1], Hisham Husain[2], Khalid Al-Dohaiem[1], Jacobo Montero[2], Matthias Thum[2], Obaid-Al Shammari[1], Abdullah Al-Rabah[1]

(Author affiliation: [1]KOC; [2]Shell)

Abstract

One of the heavy oil fields, in The State of Kuwait, produce oil from shallow, semi-consolidated siliciclastic reservoirs, with subsurface challenges like low-pressure support, multiple tilted oil water contacts and imbibition related uncertainties. Localized gas caps and lithology-controlled hydrocarbon distribution adds complexities to well and reservoir management. The field is currently under primary drainage with future developments planning for waterflood and subsequently enhanced oil recovery.

Extensive geological and reservoir engineering data analysis help to identify the wells which require optimization to overcome challenges like low productivity index, high water cut and gas production. Offset well correlation, mapping the reservoir properties and in-place oil saturation forms the baseline of modeling the in-flow performance both at well and reservoir level. Reservoir simulation models are used to improve understanding of vertical connectivity and access pressure varies across the field. Finally, scenario-based uncertainty analysis integrated with reservoir performance forms the basis of optimization for production enhancement.

Embedding Shell's WRFM process, several common themes were identified in low productivity wells. These includes reservoir heterogeneity (10%), formation damage due to drilling mud and completion fluid loses (13%), perforation tunnels plugged due to fines migration (20%) and excessive draw down applied (13%). In high GOR wells, the presence of localized small primary gas cap was observed which resulted in production losses due to the inability of the pumps to handle the high GOR (7%). For the high BSW wells, some of the wells were perforated very close (less than 10 feet) to the Oil Water Contact (OWC). An overall increasing BSW trend has been observed in wells (33%) located towards the edge of reservoir, and a potential edge water incursion is envisaged and mapped for future completion in these areas.

Delineation of free primary gas zones; bottom and edge water extension and monitoring of reservoir pressures aid in optimizing well and reservoir management. Recommended measures are to optimize drawdown, add more perforation opportunities, deploy surveillance measures, and maintain optimal stand-off from the OWC and gas bearing zones. These recommendations collectively improved the well productivity while reducing the water cut and GOR and thus contributed to increase and maintaining above the target field production within facility constraints.

The analysis, observations and practices followed for the Reservoir Management falls under the framework of WRFM to increase well productivity and maximized field production. Integration of all available data and working in a multi-disciplinary team is considered critical to the success for optimal reservoir management practices.

1. INTRODUCTION

The development of heavy oil resources from the Lower Fars formation in North Kuwait (NK) is an important strategic project for Kuwait Oil Company (KOC). Lower Fars in the Field is being developed in two phases and area by area. As per the approved strategy, the Field production needs to be enhanced by primary deletion and through water flood, by polymer flood at later stage. The development strategy for Field is an area-based, phased development (Fig. 1). To date, all production wells have been drilled in the southern part of the field, which is interpreted to have the best reservoir and greatest STOIIP density. The availability of abundant well data and production history, make the southern area, the best-defined part of the field. Following the completion of the IOR / EOR screening study, waterflood followed by polymer flood was selected as the most promising method of IOR and EOR respectively.

The timing of the waterflood is critical as the reservoir is currently under depletion production (since November 2015) and the pressure must be managed to prevent dropping below bubble point pressure. Based on reservoir simulation, continued depletion of the reservoir below bubble point pressure could reduce field ultimate recovery by 3%-5%. More importantly, however, geomechanical studies have confirmed that the mid-shale separating the S2 and the S1 sands may only be competent to hold back a pressure differential of 150psi. It is therefore essential that pressure support starts as soon as practically possible to avoid production deferment.

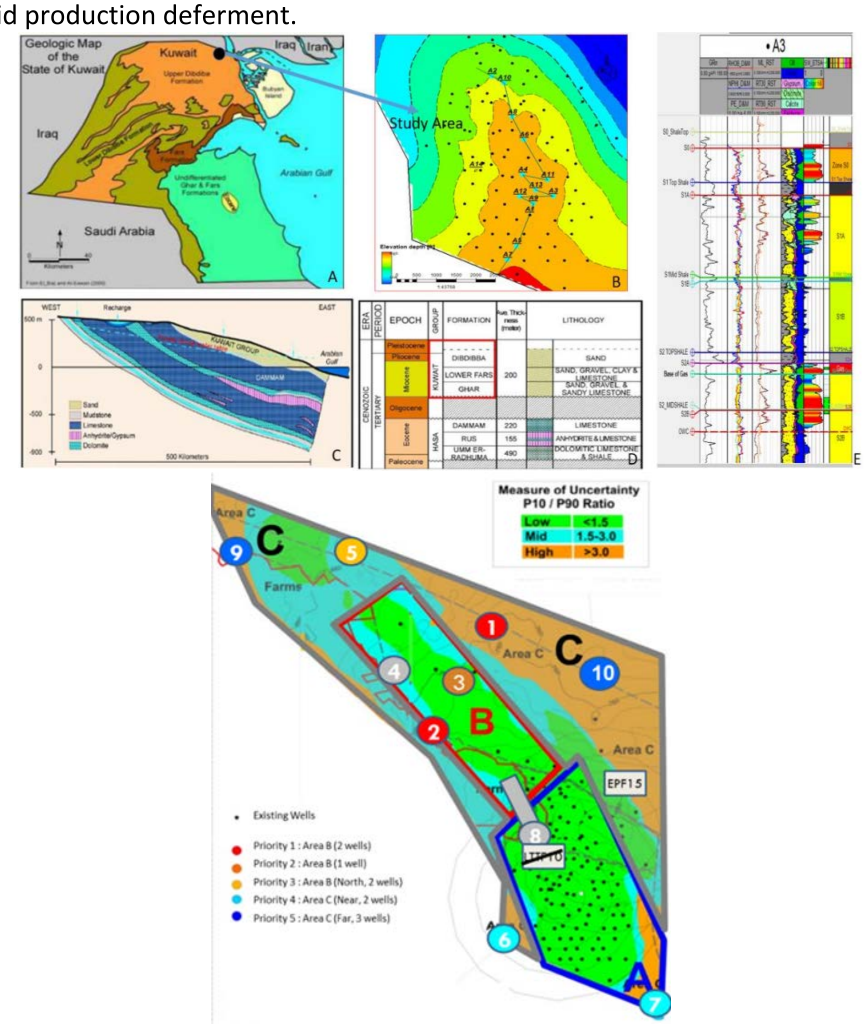

Figure 1: Field Location map, Stratigraphy and Area based staged development of the Field

The shallow-depth reservoir belongs to the Middle Miocene. The sealing shale at the top has trapped the oil and has undergone subsequent bio-degradation. There are two main pay zones, sand S1 and S2, which are further sub-divided in two sub-layers separated by silty cemented baffle zones. Both the sealing shale and the middle shale separating S1 and S2 are present, at varying thicknesses across the fields (Fig. 2). The dominant lithology within the reservoir is clean to slightly argillaceous and / or slightly cemented sandstone. Subordinate reservoir lithologies include sandy shale, dolomite and gypsum. The baffles and the Sealing and Middle shales are a mix of argillaceous cemented sandstone, siltstone, sandy shale and claystone. (Benham, P.H., 2018; Choudhary, P.K., 2018). Apart from localized early diagenetic cements the cored intervals are largely unconsolidated to poorly consolidated to the point that the high viscosity oil plays a role in holding the sand together when it is cored. Thus, the biggest challenge is not to alter the rock properties during coring, extraction, transport and plug collection. This holds especially true for the tighter clay rich intervals where Water Saturation, Sw is hard to quantify, and the slightest disturbance could result in orders of magnitude permeability changes.

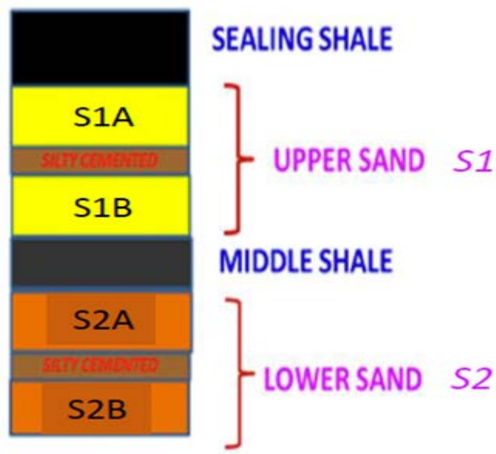

Figure 2: Typical Stratigraphic -Column of Kuwait Heavy Oil Reservoir

2. METHODS

KOC has been embedding Shell’s WRFM (Wells Reservoir Facility Management) process in the operate phase for Asset Management. The WRFM Process is described as a continuous improvement loop, given the cyclic nature of all activities that lead to optimization (Fig. 3). It is a decision based process to extract the maximum value from asset by creating a systemic understanding of reservoirs, wells, and facilities and optimizing their performance.

The purpose of the WRFM Plan is to describe how the process is to be executed in the asset in the upcoming business cycle, adjusted to the business environment, the characteristics of the reservoirs, wells, and facilities (“The Physical Asset”), the organizational capabilities, and the strategic value drivers defined for the process. It documents all key activities and resources required for performing WRFM successfully and closing the gap to an Asset’s potential. Well, Reservoir and Facilities Management establishes the requirements by which Assets continuously restore and safely optimize production.

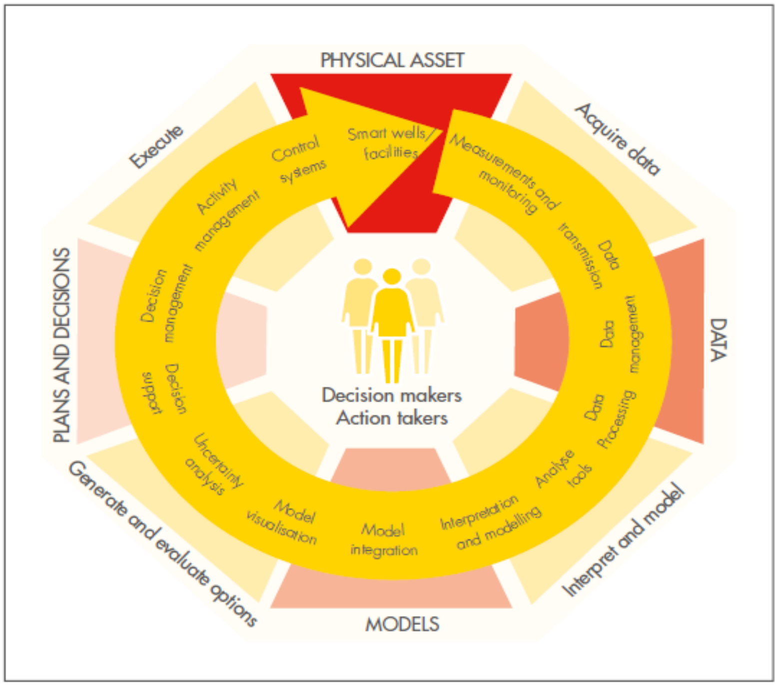

Figure 3. The WRFM value Loop

WRFM findings are used to proactively recognize emerging problems, and to optimize asset value. This involves developing a surveillance plan encompassing wells, reservoirs, and facilities; developing and updating fit-for-purpose models; review frequently and thoroughly the asset's performance using models and data; identifying and ranking new opportunities and evaluating the execution of these interventions and changes to the asset. Assessment of production behavior helps in optimization strategy, improving future field development decisions, recognize and address risks and opportunities.

The scope of WRFM includes the management of flow and impact of produced and injected fluids. Some common tactics applicable to WRFM are improvements in wells restoration (fail less and restoring faster) and wells, facilities, and reservoir optimization. Examples of these tactics have been captured under the "WRFM formula" (Fig. 4)

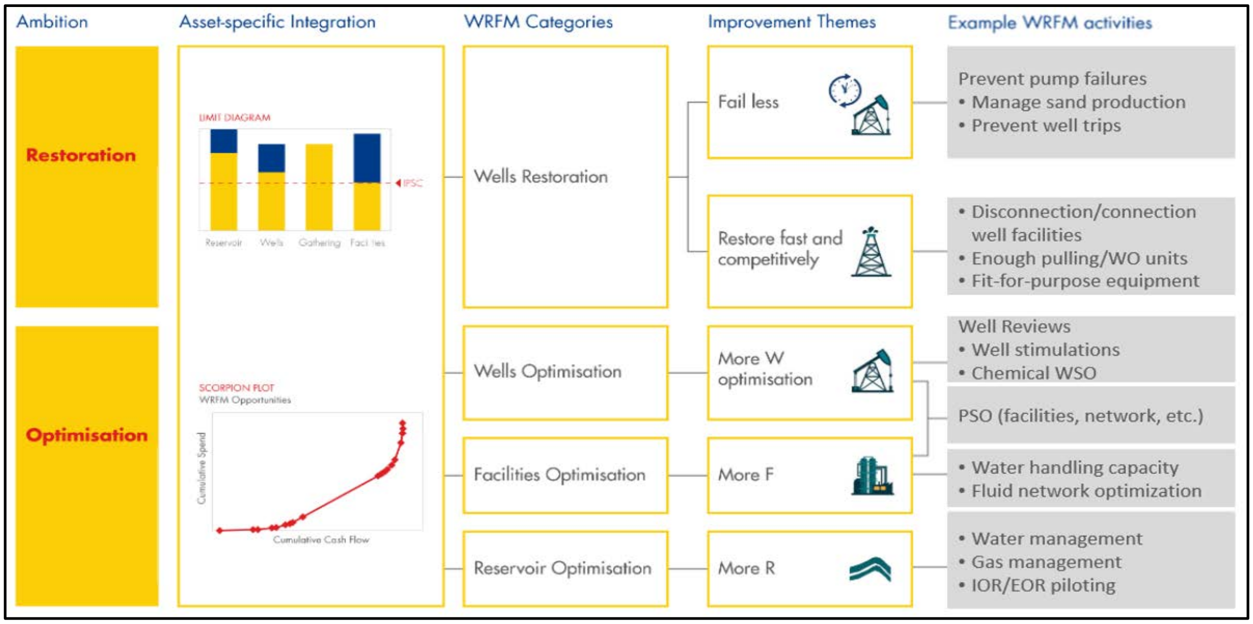

Figure 4: WRFM Tactics applicable and most impactful for the Field

As a part of day-to-day WRFM, Production Optimization Unit (POU) team ensures collaboration and coordination of the day-to-day activities to increase and optimize the production of Asset. The following are the key priorities which the POU prioritizes to achieving or exceeding production targets:

1. Work pro-actively to prevent or minimize production/injection losses, prevent well trips
2. Maximizing value of existing wells - revise perforation
3. Monitor and arrest water cut increment, edge water influx
4. Review – Wells, reservoir, facilities
5. Optimize water handling facility, rank opportunities and find "quick wins"

2.1 Well Optimization

Well Optimization is required to increase the contribution to production from well optimization to manage the offtake, control the BSW increase, and maximize the production from new wells. Well stimulation (e.g., screen wash, acid stimulation), well reperforations, and water shutoffs need to be pursued in earnest to maintain well capacity, delay water influx, and to compensate for any shortfall from other wells This work helped KOC to attain the following bottom line stretched targets.

2.2 Revised Perforation Strategy

The revised perforation strategy consisting of higher shot density (18 spf) with smaller EHD is currently being tested. All wells drilled under the exploration scope underwent initial production testing, where maximum sand-free (maximum 2% sand cut) rates of 100 – 300 BPD per well were achieved using a temporary test completion. The final completion typically consists of a 3-1/2" tubing down to the top of the perforations, with surface driven Progressive Cavity Pump (PCP) equipment.

2.3 Arrest Water Cut – Reservoir Management

Monitoring the water production and reservoir pressure via routine well testing and dedicated pressure surveys is a critical leading indicator for reservoir management. In parallel, proactively mapping and adjusting the well operating envelope play a success factor to delay water and gas breakthrough, and to intervene in the wells that experience an early breakthrough.

The regional aquifer does not show sufficient hydraulic connectivity and or pressure support to lead to early water breakthrough in all wells. A small aquifer has been included in the dynamic modeling work. However, the average field-wide water cut has increased after two years of production to the current level of 26%, indicating that in several wells water breakthrough took place, in most cases due to bottom water coning in wells with bottom perforation proximal to the OWC (Fig. 5). No significant gas caps have been logged in the field, but gas production is expected given the relatively high bubble point pressure. Gas shut off has been conducted in two high GOR wells, without further issues related to gas handling.

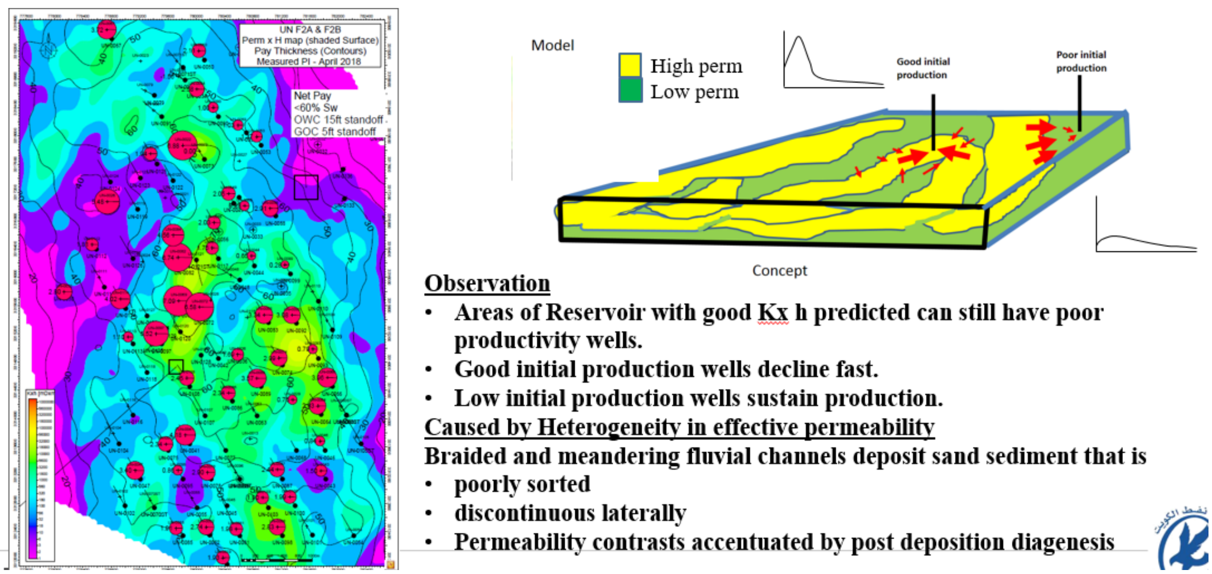

Figure 5: WRFM Tactics applicable and most impactful for the Field

2.4 WRFM Reviews

WRFM reviews aid in adding reservoir optimization opportunities. This includes focusing on well inflow and outflow enhancement activities that maximize the individual well performance, execution of efficient well restoration activities (minimizing the meantime to restore), and the implementation of identified sand management and artificial lift improvement opportunities, which extend the meantime to failure.

Well Review: intended to investigate a block or field's performance on a well-by-well basis and verify whether there is further medium to long-term opportunities to improve performance/recovery from the field. Shells' Annual Well Review Guideline is to be applied as best practice.

Facilities Review: intended to investigate the production facilities of a production system to ensure all potential bottlenecks and single-point failures are clear and actioned upon if required. The review considers not only optimization (i.e. debottlenecking) opportunities but also aims to identify opportunities to improve reliability and asset integrity improvement opportunities.

Annual Field Performance Review: Annual Field Performance Reviews are held to provide an opportunity to reach a common level of understanding between disciplines and functions related to the performance of the integrated production system (from the reservoir to the sales point).

2.5 Optimize facilities

Any brownfield development is challenged with handling produced water, and with increasing field life the water handling capacity become a key success enabler for WQRFM. The asset team is planning for upgrading utilities, delivery of a new oil train, parallel to the existing facility, upgrade associated water processing train to raise capacity to 80 % water cut. Further scope includes laying of Water Injection Network consistent with the urban plan. The POU is also responsible for the optimization of execution resources (PGOR, FBU, WO rigs, flowline hook up) to increase FIELD production. Hook-up and produce the new wells drilled; optimizing well performance; managing failure rate are critical success factors.

DISCUSSION

Regular performance reviews are core to the WRFM Process. The different types of reviews being carried out the WRFM team ranging from daily performance review, Production System Optimization (PSO) Review - a cross-discipline meeting to review well and facility behavior against various model expectations, and to identify remedial actions such as model improvements, well interventions, or removal of bottlenecks in the well or facilities.

Shell’s Minimum Standards prescribe yearly field, reservoir, well, and facility reviews. Reviews are executed per reservoir block, starting with an analysis of the performance of the pattern, followed by a review of individual wells. Annual field and facility reviews are done separately. Reservoir reviews intended to investigate the reservoirs on a block or field basis and determine whether the current understanding is still in line with actual production developments and whether there are new infill targets or risks to existing infill projects.

Opportunities identified during the reviews are captured in one common opportunity register for surface and subsurface opportunities. The opportunity register is used to monitor capacity gains and costs; compare both actual vs. planned production gains. Execution of surveillance activities is being tracked with a Surveillance Tracker and the progress is discussed monthly at WRFM meetings.

A WRFM Business Performance Review is held to improve the level of integration across the various disciplines and functional boundaries and enable more effective WRFM performance management. The meeting includes the tracking and discussion of KPIs, performance against plans related to execution and gains from WRFM activities (i.e. well and facility interventions), progress on the well and reservoir surveillance plan, and budget actual and Latest Estimates.

To monitor the delivery of WRFM as a process and the achievement of the WRFM strategy, several performance measures are tracked and discussed in the monthly POU reviews. Measures of the process are known as ‘Leading’ Key Performance Indicators (KPIs). Measures of the results of executing the process are known as ‘Lagging’ KPIs. Figure 6, highlights KPI structure currently being used for the Field.

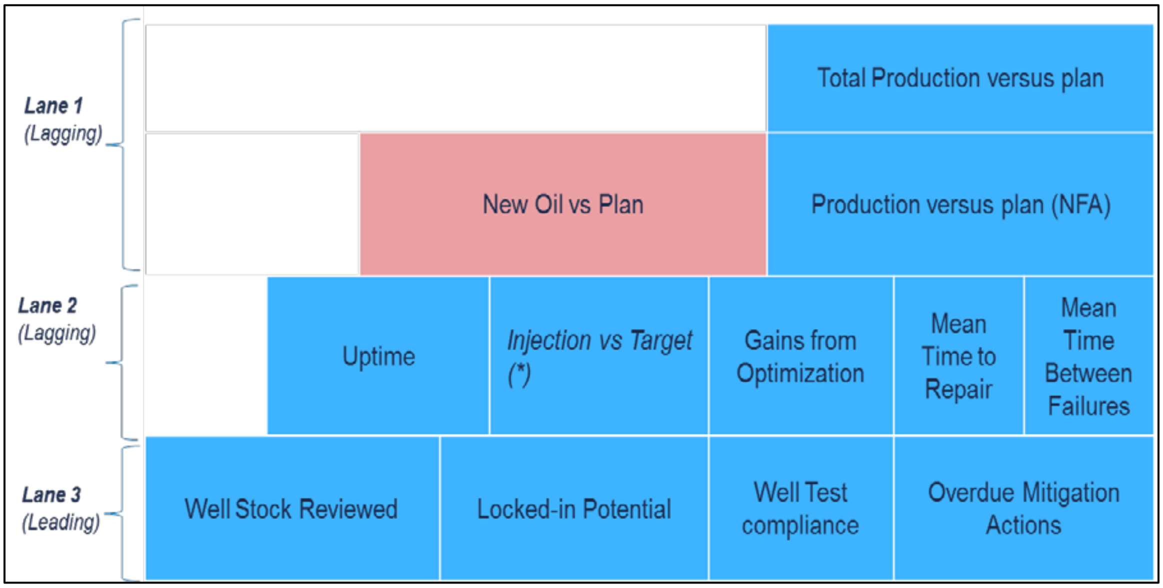

Figure 6: Key Performance Measures (KPIs) proposed for the Field POU.

Some of these KPIs, including e.g. Gains from Optimization, Well Stock Review, Locked-in Potential, and Well Test Compliance are very relevant to the WRFM Process. An example of the FIELD POU Dashboard all leading and lagging indicators are displayed and made available to all team members (Fig. 7). KOC is further strengthening it’s digitalization journey.

Figure 7: Example of Field POU dashboard.

ACKNOWLEGDEMENT

The authors are thankful to Kuwait Ministry of Oil and Management of Kuwait Oil Company for giving permission to publish the paper.

REFERENCE

1. Alsharhan, A. S., and Nairn, A. E. M., 1997, Sedimentary basins and petroleum geology of the Middle East: Elsevier, Amsterdam, p. 843.

2. Baker, R. O. & Bialowas, S. A. 2004. Simulated production behaviour of heavy oil pools with gas caps, JCPT, 43, 8, PETSOC-04-08-04

3. Choudhary, P., Ferdous, H., (Heavy oil G&G Team), Free gas issues and full field gas mapping in heavy oil reservoir in Kuwait. KOC internal report, p. 54, Jan, 2014

4. El-Baz, F., and Al-Sawari, M., 2000, Atlas of the State of Kuwait from satellite images: Kuwait foundation for the Advancement of Science (KFAS), Safat, p. 145.

5. Veedu, F. Koyassan., Dharanidharan, B., Tye, R., Prasse, E., Flagg, S., Hornbrook, J., Ahmad, F., Al-Dohaiem, K., Jha, M., Bagheri, M., Sanyal, T., Evaluation of development strategies and uncertainties of a newly discovered heavy oil field in Kuwait, SPE-184133-MS.

6. Ferdous,H., Choudhary, P., Ahmad, K., Dohaiem, K., Saikia, P., Bagheri,M., Haqqan, Ahmad,F., Collinson, J., Van Der Wal, J. & Abolghassemi, B., Modelling complex heavy oil reservoir system in Kuwait: Integration of genetic stratigraphy in petrophysical rock-type classification, SPE-184091-MS.