Increasing confidence in full field modelling and water flood planning for a giant reservoir under primary depletion through Material Balance modelling.

J H Al-Joumaa¹# and M S Al-Jawad²

¹Petroleum Technology Department, University of Technology-Iraq, Baghdad, Iraq
²Iraq, Baghdad, Baghdad University, Petroleum Engineering Department

#Corresponding author’s e-mail address: 150078@uotechnology.edu.iq

Abstract: One of the principle inputs to project economics and all business decisions is a realistic production forecast and a practical and achievable development plan (i.e. waterflood). Particularly this becomes challenging in supergiant oil fields with medium to low lateral connectivity. The main objectives of the Production Forecast and feasibility study for water injection are:

1- Provide an overview of the total expected production profile, expected wells potential/ spare capacity, water breakthrough timing and water cut development over time
2- Highlight the requirements to maintain performance, suggest the optimum development pattern
3- Increasing confidence in business decisions to develop the reservoir in question

The main tool used for these purposes is a sophisticated reservoir simulation software, namely CMG©, since it can predict reservoir behavior, honor physical constraints and capture the heterogeneity within the reservoir to accurately predict performance. However, the starting point for this kind of complicated studies needs to start from the basics, in order to understand the big picture and be able to plan properly for the scope to be delivered, hence, utilizing analytical tools like MBAL becomes quite necessary, if not crucial, to the success of full field modelling and choosing an optimum water flood pattern and design.

This paper covers the methodology for building the reservoir component utilizing a Material Balance model, of which the results will be used as an input to reservoir simulation to evaluate and accurately predict reservoir performance, which directly feeds into planning for water flooding projects and selection of an optimum flood pattern.

A Tank model was built at first to assess and understand the driving forces (energies) of the reservoir in question, utilizing pressure and production data from legacy wells, the prepared
model is also supported by geological and petro physical studies to give representative results. Acquired Static Bottom Hole Pressures (SBHPs) in wells were used as anchor points for the tank pressure and to test the validity of the history match. Multiple analytical methods to QC the results and STOIIP volume were conducted, e.g. the Havlena-Odeh method.

This methodology has been tested successfully in the stated super giant oil field, in which the reservoir in question is a carbonate rock formation. An example of this is covered in the paper. It was concluded that utilizing a history matched and coherent MBAL model before conducting a detailed reservoir simulation study can save a lot of time and effort by providing guidance to the path which needs to be followed, and sheds light on the critical elements to be looked after. This has also helped to uncover the driving mechanisms and energies in the reservoir, hence allowing the engineer to plan for the necessary voidage replacement and water injection rates to sustain the reservoir pressure and pattern development. Another technical advantage of the described method is the higher sustainability of the model.

The suggested method, in combination with geological and petro physical information available, can be applied to majority of the reservoirs. This combination is paramount to ensure optimum time and planning that is followed for each reservoir development study that involves water flooding.

1. Introduction

The main reason for constructing a material balance reservoir model is to provide insight into the production characteristics of the reservoir, help in history matching and to find the reservoir drive mechanisms and off course to determination of initial oil in place.

MBal program depends on the material balance equations in calculations. The data and the sorting and using steps are follows by using Linearized form of material balance equation used to estimate the initial oil in place (the intercept of the straight line) - Havlena and Odeh procedure,

It is of great importance to have history matched Material Balance models for any reservoirs targeted for any reservoir study in order to have a better understanding about the drive indices for the reservoir and be able to make decisions and plans with more confidence. The Material Balance model presented here were built using the three wells of interest mentioned earlier. Aquifer modelling for the reservoir was suggested based on the latest geological realizations as well as the field and regional understanding.

2. MBal model

Table 1. Summary of Hartha Reservoir rock and fluid properties that were used as input in preparing the Tank (Material Balance) model

| Property                      | Value   |
|-------------------------------|---------|
| STOIIP (MMSTB)               | 1973    |
| Porosity (frac)              | 0.19    |
| SWc (frac)                   | 0.1876  |
| Net thickness (meter)        | 88      |
| Radius (meter)               | 5710    |
| Temperature (oF)             | 186     |
| Initial Pressure (psi)       | 3555.5  |
| Bubble point pressure (psi)  | 2652.7  |
| Compressibility (1/psi)      | 4*10^-6 |
Table 2. Summary of suggested aquifer parameters

| Aquifer model                  | Hurst-Van Everdingen modified |
|--------------------------------|-------------------------------|
| Outer / Inner radius ratio (frac) | 3                             |
| Encroachment angle (degree)    | 270                           |
| Aquifer permeability (md)      | 108                           |

Figure 1. Assumptions of MBal input

As the Hartha formation is water-bearing in all of the surrounding fields; it was evident that the Aquifer size would fall on the high side when history match. Considering outer to inner radius ratio = 3, and the reservoir radius would be 18734 ft which is a reasonable assumption.

Figure 2. Production rates and Pressure behaviour for Hartha Reservoir.
Figure 3. History Matching using The Analytical Technique for Hartha Reservoir.

Figure 4. Energy Plot for Hartha Reservoir.
Figure 5. Havlena-Odeh QC plot for Hartha Reservoir.

Figure 6. Campbell QC plot for Hartha Reservoir.
3. Conclusions
the following are the results of the MBal model for the Hartha reservoir;

1- The Analytical method History Matching plot shows an exact match between the historical simulated data and the proposed model
2- The Simulated and History Pressure and Cumulative oil vs. time plot suggests a steady drop of pressure
3- The Energy plot suggests that the driving energy at first is mainly the pore volume expansion; with aquifer support coming into the picture after some depletion
4- Havlena-Odeh and Campbell plots suggests that the STOIIP input and the energies are in line and matching in the later periods
5- The model shows a hydraulic connectivity which means we are dealing with a tank unit that is similar in properties, that means we can use the same pvt tables for any well in building the reservoir models.

Acknowledgment
The authors wish to thank the Petroleum Technology Department at the University of Technology - Iraq for facilitating this work.

References
1- Mogbolu E, Okereke O, Okporiri C, Ukauku I, Esharegharan O, Taiwo I and Sukubo I 2015 SPE Nigeria Annual International Conference and Exhibition (Lagos, Nigeria/ SPE) p 2
2- Idogun I, Jeboda O, Charles D and Ufomadu H 2015 SPE Nigeria Annual International Conference and Exhibition (Lagos, Nigeria/ SPE) p 6
3- B. Havlena and A.S. Odeh, 1963 Journal of Petroleum Technology 15 898