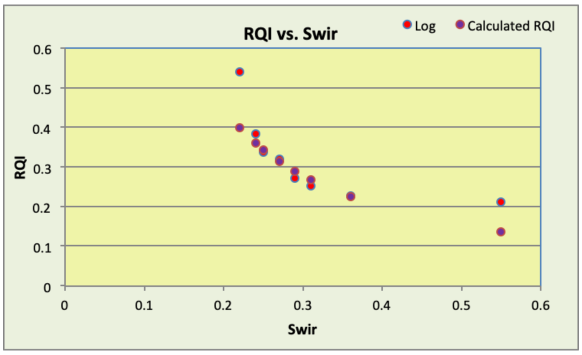

Figure-4: RQI vs Swir Plot, Calculated vs Actual

The Leverett J-function was used to normalize capillary pressure data to take into account variations in porosity and permeability. After getting the value of RQI and Swir for each data set, now it's time to calculate J-function and Swn values for individual data set. In this method, initially the capillary pressure vs. saturation data for all core samples is converted to a single J function by using equation (4). A plot between normalized saturation and J-function by combining all the data set was generated (Figure-5). The following relationship is representing the J-function trend.

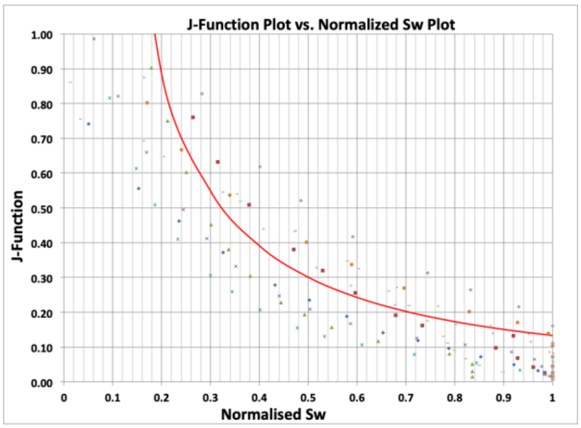

Figure-5: J-function versus normalized water saturation

$$J = 0.133Swn^{-1.176}$$

RQI and Swc relationship is later used to denormalise the saturations for each grid cells using the depth, porosity and phi-k transform.

Modelling using J-fucntion:

Once the water saturation model was built, it was applied to the wells and compared to water saturation calculated from well logs.

After verifying the authenticity of well X, the model was applied to 10 other wells of MHN field. The water saturation-versus-pressure model was converted to a water saturation-versus-height model by replacing the pressure attribute with height above free water level (in true vertical depth), reservoir porosity and permeability. The output was a water saturation curve which had no dependency on a resistivity log measurement. The height above free water level is considered at 990m, msl whereas the OWC is at 980m, msl. Comparison of Sw in few wells (Log Processed vs J-function) is shown in Figure-6.

There was good agreement between the two models (log saturation and saturation calculate using capillary & J-function). Moreover, J-function derived saturations were more reliable in terms of production performance of the wells.

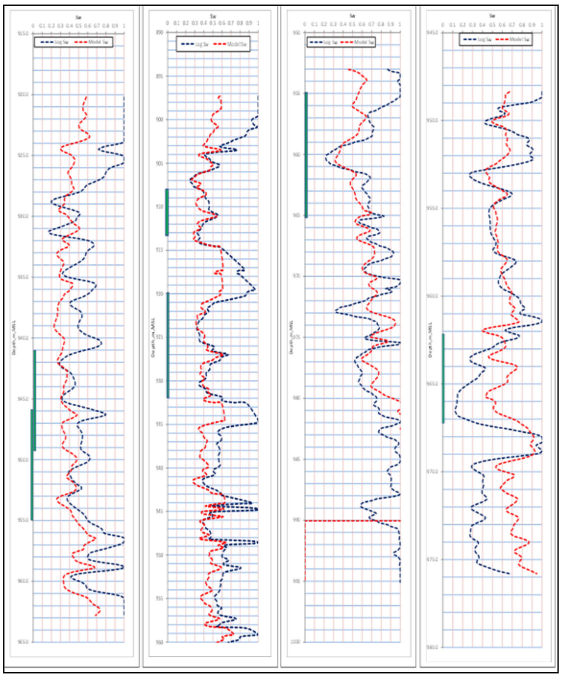

Figure-6: Comparison of Sw in few wells (Log Processed vs J-function)

A comparison of Log vs J-Function Derived water Saturations at the top of M2 reservoir is as shown in Figure-7.

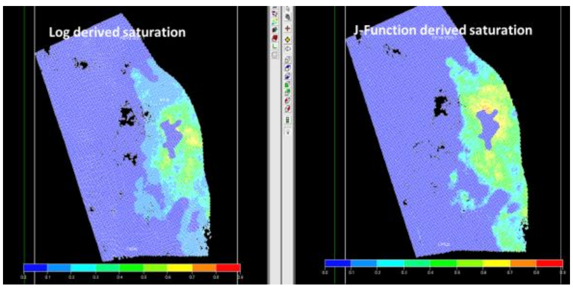

Figure-7: Log vs J-Function Derived water Saturations at the top of M2

History Matching & Validation:

A satisfactory field level match could be obtained with J-function calculated saturation distribution. The multi-layered completions of both the injectors and producers coupled with no-knowledge about the actual layer-wise intakes make it extremely difficult to match the water cut in all the wells. Moreover, there are no artificial permeability channels imposed in the model to force a match. Neither any attempt been made to produce water behind the casing through imposed completions in layers not recorded in the well history. However, the model is able to capture the water cut behaviour in majority of wells.

The field level water cut calculated from log derived saturation modelling shows high water cut at early stage of production which deviates from the historical data. However, water cut from J-function derived saturation model matches well with history further validating the reliability of saturation height modelling (Figure-8).

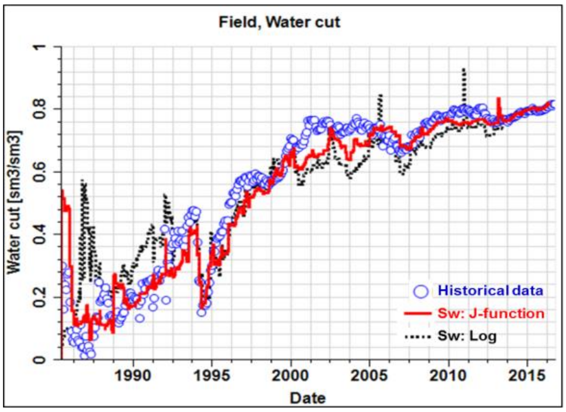

Figure-8: Field level water cut match using Log derived water saturation & J-function calculated water saturations.

Performance of one well 'Z' was predicted on the basis of this model as a test case. The model predicts this well to produce about 60 bopd oil with 90% water cut since the well is close to OWC. However, on actual performance this well performed much better with close to 300 bopd oil with initial water cut of 40%. While analysing the reason for poor performance of this well in the model it was found that this well encountered M2-B_a top at a depth of 8m shallower than the depth envisaged in the model (Figure-9).

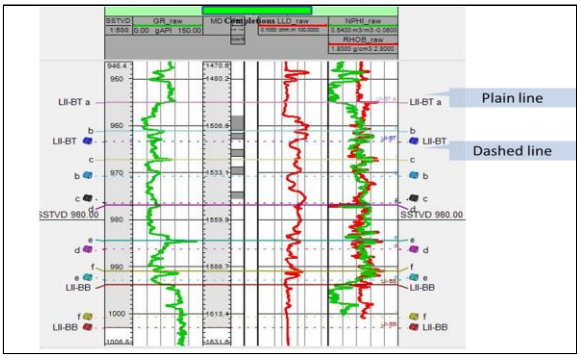

Figure-9: Well coming 8m shallow than the model depth with good saturation. Dashed lines are model mapped horizons and plain ones are well tops based on correlation.

The correct depth would have generated enough oil saturation on the saturation-height-model for a better prediction which further validated the reliability of our saturation-height model.

In some wells the match between log saturation and Pc saturation was not strong. So a comparison of saturation with actual well production performance was attempted. For example, in well Y the comparision is shown is Figure-10.

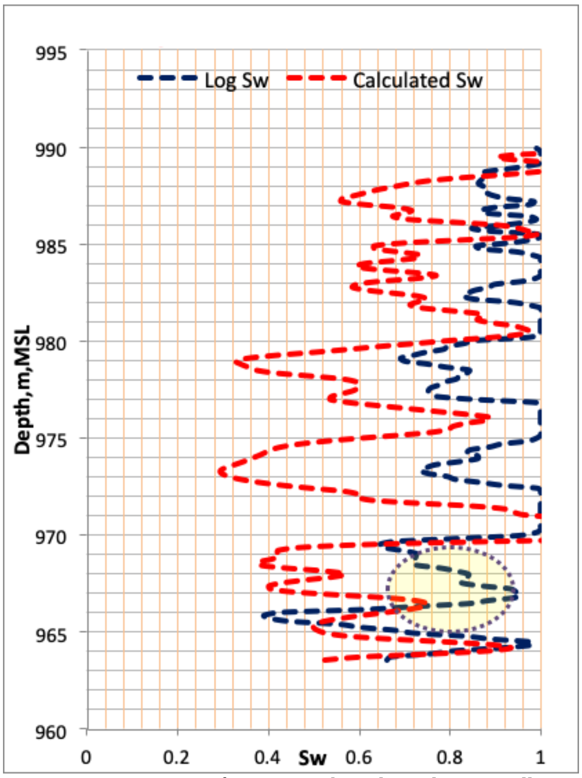

Figure-10: Comparison of Log Sw with Pc derived Sw in well Y

The production performance of the Y(Figure-11) shows that this well produced around 600 m3/d liquid with no water cut initially for a period of about five months from interval 959.4-963.6m, 963.6-969.4m. After production of five months the water cut jumped to 50% and then continue at a range of 80%. The significant feature is that this well produced about 0.25 MMm3 oil from near the OWC. The upscaled grid saturation based on the log saturation show oil saturation in the range of 35-40% in M2-B_b layer. However the J-function derived model saturations are able to sustain the well oil production rate. So the saturation calculated by Pc is more accurate than the log saturation.

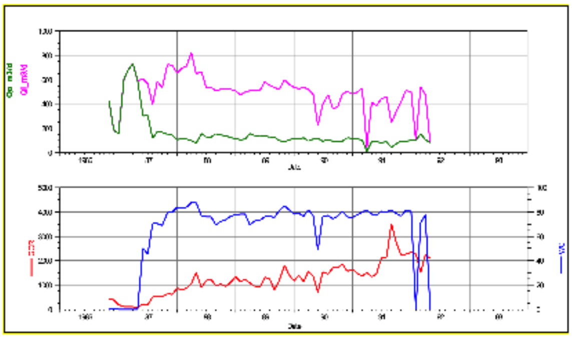

Figure-11: Production performance of well Y

Conclusions

The capillary pressure model developed from core data of one well effectively predicted the water saturation in other wells within the same field. The capillary pressure analysis of well X provided a more consistent indication of water saturation than using the traditional resistivity based computed saturation.

The analysis demonstrated the ability to use capillary pressure data from one well to calculate height above free water for any other well within the same connected reservoir.

By considering the capillary pressure derived water saturation in the existing model, the estimated fluid volumes are in agreement with approved reserves estimation. The derived saturation height model using J-Function was found to be better co-relatable with the well productivities and a decent history match was obtained at field as well as well level.

This method is a quick fit approach for modeling water saturation in complex reservoir with sufficient SCAL data accurately representing the reservoir for better history match and good predictability.

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