CHAPTER 5

CONCLUSIONS AND FUTURE WORK

5.1 Conclusions

In this study, we investigated the applicability of the Layered Stabilized Flow Model developed by El-Banbi and Wattenbarger as an improved approach in estimating the original gas in place in commingled gas reservoirs. The technique uses the layered stabilized flow equation derived from the material balance equation and the gas flow solution to come up with a model rate equation for each layer in the commingled reservoir. In this work, the model rate equation was simplified by using normalized pseudo-pressures in the gas flow solution. The unknown parameters G, J_g and G_p' of each component layer were initially guessed and the analysis was then performed by matching the model rate equation with the actual production history of the well. Non-linear regression using the Gauss-Marquardt algorithm was performed as an optimization routine to determine the correct OGIP and flow coefficient of each layer.

The validation of the model was performed in five cases: three simulated cases and two actual field cases. The results obtained from the model were compared with other methods to confirm the capability and efficiency of the model.

From the application examples, we can make the following conclusions:

1. The LSFM can be used to reliably predict the production performance and original gas in place of individual layers in a commingled gas reservoir if stabilized flow exists. However, careful selection of the calibration period is required. If the history matching includes data where transient flow exists, the OGIP tends to be underpredicted.

2. Based on the cases considered, the model rate equation using the simplified gas flow solution can be used for low to moderately permeable reservoirs.

For reservoirs with high permeability, the form of the gas flow equation may need to be modified to account for non-Darcy flow effects.

3. In a commingled gas reservoir, the values of *kh* and pressure drawdown in each layer determine the relative contribution of each layer to the total production. When the layers have the same initial reservoir pressure, the layer with the highest *kh* predominates the total production especially at the onset of production. When the layers are at different initial pressures, the relative contribution from each layer will depend not only on the *kh* values but also on the pressure drawdown of the layers.

4. The use of normalized pseudo-pressures to simplify the gas flow equation was proven to be applicable in all the cases considered where the pressures range from moderate to high. The use of the normalized pseudo-pressures at low pressures warrants further investigation.

5. Based on the field cases analyzed, it is important to have accurate flowing bottomhole pressure measurements in order to have a good model rate equation profile. If flowing bottomhole pressures are derived from flowing wellhead pressures using a multi-phase flow correlation, all flow rate data need to be accurate as well. Inaccuracies from these figures result to a lot of noise or data scatter in the model rate profile.

6. Care must be taken in selecting the multi-phase flow correlation for converting flowing wellhead pressures to flowing bottomhole pressures as this may result to inaccurate OGIP prediction. Comparison of different multi-phase flow correlations is suggested. It is also recommended to calibrate the pressure gradient plots generated from correlations with actual measured gradient survey data.

7. Filtering the actual production rate history helps improve convergence. Since the LSFM allows the use of non-contiguous data points, transient

production data after the well has been shut-in for a while can be eliminated in the calibration period.

8. The main limitation of the model is its non-uniqueness when dealing with reservoirs of more than two layers. It is therefore important to have good estimates of the permeability-thickness of each layer and use this as the basis for allocating the relative flow contribution from each layer to arrive at the most accurate prediction of the OGIP.

5.2 Future Work

The program was created as an Excel Spreadsheet due to the ease of use and availability of this program. The non-linear regression calculation was found to be slow especially when modeling four or more layers. Therefore, it will be necessary to try using other programming softwares to speed up the calculation for the optimization routine.