Chapter 4

DISCUSSION AND CONCLUSIONS

Discussion:

In this study, the reserves and cumulative production data given by PTTEP were used to estimate the accuracy of the simulations (Table 4.1). These reserves were derived from volumetric calculations and decline curve analysis. These reserves were calculated when only six well had been drilled in the field.

Table 4.1 Reserves and OIIPs calculated by PTTEP (PTTEP, 2000)

PTTEP's calculations	Low Case	Likeliest Case	High Case
Volumetric method	Reserves, MM STB		
	2,111	2,353	2,550
	OIIP, MM STB		
	7.037	7.843	8.500
Decline Curve Analysis	Reserves, MM STB		
	2,138	2,298	2,490
	OIIP, MM STB		
	7.127	7.660	8.300
Cumulative Production Data of the Lower Zone, MM STB			
Cumulative Production to 31st Oct, 1998		~ 1.988	
Cumulative Production to May, 2005		~ 3.023	

Accuracy:

In order to estimate the accuracy of the Monte Carlo simulation, the calculated reserves of Case 4 were used because the conditions for reserves calculation in this case are the same as the conditions that PTTEP used to calculate the reserves. The mean and mode of Case 4 were nearly the same as the high case calculated from the volumetric method and decline curve analysis by PTTEP. In Case 8, the mean of the simulated reserves is comparable to the actual cumulative production of the field. These observations show that Monte Carlo simulation can offer a good estimation of reserves. Moreover, this simulation can construct the probabilistic distribution curve for reserves, the thing that the volumetric method can not do.

Correlation between input parameters:

If correlations between input parameters exist, those relationships need to be taken into account because they affect the distribution of the reserves. Before running a simulation, the input parameters need to be tested for their correlations. One possible correlation may occur between porosity and hydrocarbon saturation (Murtha, 2002). The cross-plot of porosity and water saturation in the oil zones shows that there no correlation exists, or at least the correlations are not strong (Figure 4.1). It is believed that there are correlations between area and net pay and between net pay and recovery efficiency (Murtha, 2002). In this case, the data were not enough to show such a correlation exists. Area, thickness, and recovery factor were assumed to be independent parameters. Thus, all simulations ran without correlation.

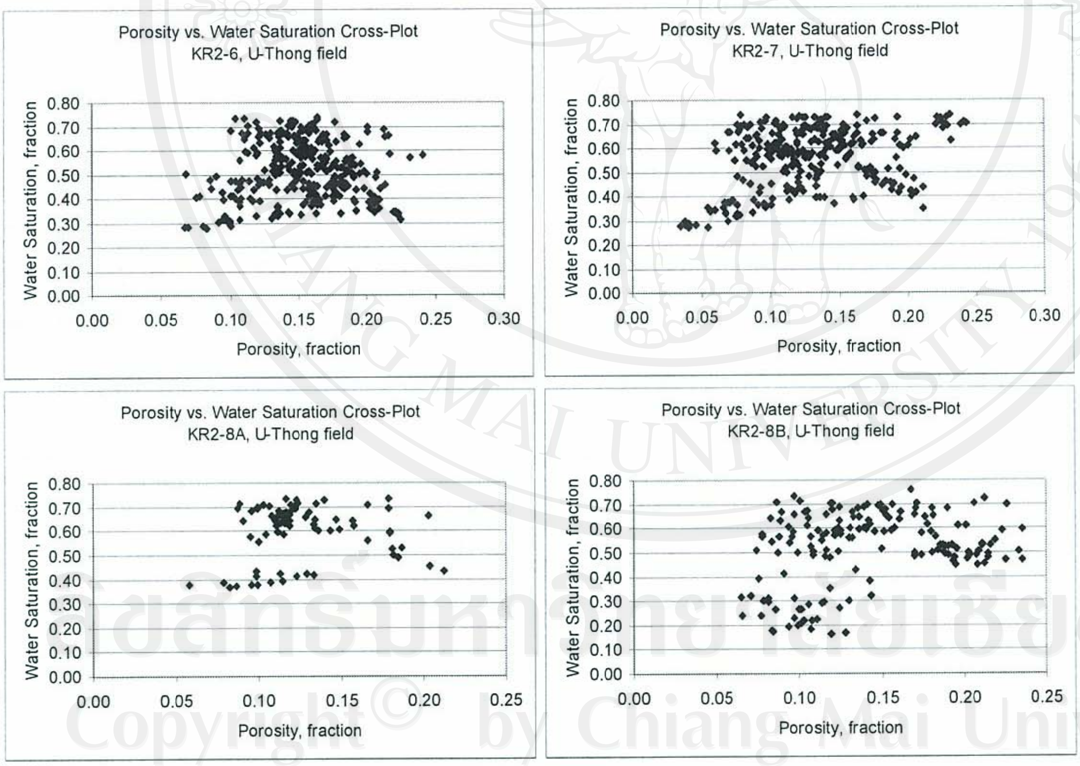

Figure 4.1 Relationship between porosity and water saturation

Effect of realistic range of distributions:

For a field with thin reservoirs, a small change in thickness will cause a great change in calculated reserves. For example, with the same area, when the reservoir thickness is 2 meter, the reserves are twice as big as those when the thickness is only 1 meter. In the early life of a field, with limited data of thickness, the actual range of thickness is not well defined and must be assumed. Case 1 and Case 2 considered different ranges of the same type of distribution of thickness. In Case 1, the uniform distribution of reservoir thickness was used with the range from the minimum to the maximum thickness measured in the two wells. In Case 2, everything are the same as in Case 1 except the range of the uniform distribution of thickness was from zero to a maximum value which was 20 % greater than the maximum thickness seen in the two wells. Since these two cases concern the early life of the field when only few wells had been drilled, the extent of the sand bodies and the variation of their thickness were not known well. Throughout the field, the interested sand body may pinch out somewhere. To describe that, the zero minimum for the distribution of thickness was used. Based on the seismic cross sections, the layers in the Lower Zone tend to thicken toward the crest of the structure. That supported to the assumption of a thickness that is greater than the values measured in the wells might occur. In this study, the maximum thickness was assumed to be 20 % thicker than the greatest thickness among the wells. Due to the lack of evidence for this assumption, the confidence of having greater thickness than the greatest thickness among the wells is assigned to be 5 % of probability in Case 3 (Figure 3.7). For the parameters abundant in data, the percentile of 10 was used. The mean of reserve distribution was strongly reduced from 2.772 in Case 1 to 1.940 in Case 2. In Case 2, if the maximum thickness among the two wells is used as the upper limit for the data range, the mean of the reserve distribution will reduce from 1.940 to 1.618. It shows that the realistic range of the input distributions significantly affect the mean of the estimated reserves. That is because the change in the realistic ranges may cause the means of the input distributions to shift. Choosing a wider range for the input distribution is preferred. It causes the range width of the reserve distribution to increase (from 4.078 in Case 1 to 5.464 in Case 2). It means that the chance for the simulated range to cover the real reserves becomes higher.

Thus, choosing the realistic ranges of the input distributions are very important, especially with low-value parameters such as thickness, porosity and water saturation.

Effect of distribution shapes:

In Case 3, to check how the shape of the distribution of thickness affects the calculated reserves, the reservoir thickness was described by normal distribution with the same range with Case 2. The results were compared with those of Case 2. The reserve distributions in the two cases are quite close together but a little separation can still be seen (Figure 3.8). It means that the shape of thickness distribution has a slightly effect on reserve distribution.

In Cases 1, 2, 3, 4, 7, and 8, the areas were described by triangular distributions using the minimum possible areas and maximum possible areas of the reservoirs and their average values as the minimum, maximum, and likeliest values. To check whether the distribution type of area affects the reserves calculation, Cases 5 and 6 were considered. In Case 5, the distribution of area was set to be the uniform type, using the same minimum and maximum areas used in Case 4. In Case 6, the distribution of area was set to be a lognormal type, with P10 and P90 as the minimum and maximum possible areas, respectively. The results were exactly the same as the results of Case 4 (Figure 3.18).

The results show that in a small field the shapes of the input distributions do not affect the simulation results or, at least their effects are too small to be observed.

Combining production zones to get field reserves:

As mentioned in item 2.2.1 in chapter 2, when one simulation trial is performed, the simulator creates a random number between zero and one. This value is the probability of each parameter in the mathematical model. Then, it reads the corresponding value of each parameter on the PDF plot of that parameter and feeds the read value to the model. In case of combining all layers together in one model, all parameter of all layers will have the same probabilities in one trial. If the reserve of each layer is calculated in an individual model, the probability of each layer will be not the same as that of the other layers. To check if that problem affects the calculated total field reserves, the reserve distributions of the field were estimated by two ways:

- The reserves of all layers were taken into the mathematical model. The simulation was run for all layers together and gave only one final distribution, Cases 4, 5 and 6.
- The reserve distribution of each layer from KR2-6 to KR2-8 was constructed separately with an individual mathematical model and with the same assumptions as for Cases 4, 5, and 6. This simulation was used again to combine those distributions together to give the final field reserve distribution, Case 7.

The field reserve distributions constructed by these two ways were compared. They were exactly the same (Figure 3.18). That means combining all layers together in only one mathematical model does not change the resulting distribution of total field reserves.

Conclusions:

1. Monte Carlo simulation is a powerful tool to construct the full distribution of field reserves. The means of the reserve distributions are nearly the same as the volumetric calculations.
2. The realistic ranges of the distributions are more important than their shape. Care must be taken as truncating the input distributions.
3. No correlation was seen between the porosities and water saturations of the Lower Zone of the U-Thong field.
4. To construct the total reserve distribution of the field, either of the two ways can be followed: running a simulation with the mathematical model that combines all layers, or zones, together or running simulation for each layer, or zone, and then combining individual distributions to get the distribution of total field reserves.