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Mitigating Variability in Uncertainty and Risk*

Robert C. Shoup[1]

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[1]Subsurface Consultants & Associates, Kuala Lumpur, Malaysia (rcs@clasticman.com)

Abstract

For management to make good decisions, they must have reliable estimates of the risked resources they can expect to encounter. The guidelines established in the Petroleum Resource Management System (PRMS) require companies to define the range of uncertainty for each project, typically defining the P_{90}, P_{50} or P_{mean}, and the P_{10}. It is important to understand that uncertainty is different from risk. Uncertainty is the range of an expected outcome. In estimating reserves and resources, we have uncertainty in area, net pay, porosity, hydrocarbon saturation, and the formation volume factor. For gas reservoirs, there is also uncertainty in the percent non-hydrocarbon gas. As geoscientists, our goal is to provide management the narrowest possible range of uncertainty for each of those variables yet be wide enough to cover the full range of uncertainty. Probability is the likelihood of realizing an outcome. We assess the risk, or chance of success (COS) by multiplying the individual chance for the various elements of the petroleum system, charge, migration, reservoir, trap, and seal. In practice, risk assessment is highly subjective which can add a systematic bias to evaluating risked reserves and resources. If systematic bias is eliminated and if enough wells are drilled companies can expect to find and produce the pre-drill risked mean. Conversely, if systematic bias is not eliminated a company can expect to drill more dry holes and sub-commercial wells. For companies to increase the likelihood of making money, management needs to eliminate the systematic biases that are common in prospect and field reserve estimation. This paper will examine interpreter-based uncertainty, method-based uncertainty, computer-based uncertainty, and risk.

Interpreter-Based Uncertainty

The first study examines the uncertainty introduced from different interpreters. Eight students were given a 3D data set over a prospect. All elements of the volumetric equation were provided except for the area of closure, which was determined from their maps. The un-risked mean volumes estimated by the students ranged from 85 to 202 MMBO (Table 1). That represents a range of uncertainty of 117 MMBO for a prospect with an average volume of 112 MMBO. In other words, the range of uncertainty is larger than the average prospect volume. The risked mean volumes exhibited an uncertainty of 10 MMBO, with values ranging from 13 to 42 MMBO, approximately half of the average volume. Outliers strongly skewed these distributions. Removing the high and low volumes gives us much more realistic range of 93 to 109 MMBO (unrisked) and 17.23 MMBO (risked). The challenge, however, is how do we ensure the maps provided to management are representative, or an outlier? To determine if any one map is an outlier, management would need to have a minimum of three maps. Since companies cannot afford to have three interpreters work the same prospect or field, they need a different means to determine if an interpreter's maps represent the norm or are an outlier.

Method-Based Uncertainty

The second study examines the range of uncertainty resulting from the methodology used to estimate the volumes. A field study was conducted, with the in-place reserves being estimated using multiple volumetric methodologies; deterministic, Monte Carlo, probabilistic, MBAL, decline curve analysis, and a static geomodel. Each method resulted in a different estimate of the volumes and the range of uncertainty (Table 2). The probabilistic method has the greatest range between the P1 and the P99 at almost 100 MMBO. Looking at the ranges from the deterministic method (42.6 MMBO) and the Monte Carlo Method (48.4 MMBO), one can conclude that the range of uncertainty in the probabilistic method is too great. However, looking at the range of the most likely or P_{mean} volumes for all the various methods the range is approximately 12% indicating that the field's P_{mean} volume has been reasonably well estimated.

Computer-Based Uncertainty

Almost all maps contoured in the workstation are wrong to some extent, even those based on 3D data. Furthermore, depending on the contouring algorithm, an interpreter can get radically different looking maps from the same data set. The net pay isochore maps shown in Figure 1 were generated with various contouring algorithms. Based on which map one uses, the net pay predictions for proposed wells in this field have a range as high as 100 feet. However, none of the maps in Figure 1 are even close to correct. The reservoir is a point bar sequence deposited in a meandering river (Figure 2). Net sand and net pay maps need to be interpretively contoured with the correct depositional model, something computer contouring algorithms are unable to do. As such, the range of predicted net pay for proposed wells is not uncertainty, it is interpreter error. Figure 3 illustrates two structure maps. The maps were contoured from the same gridded 3D seismic data set using two different contouring algorithms. Note the variation in the prospect (red outline) size, shape, and fault patterns between the two maps. These differences reflect computer-based uncertainty.

Risk

Risk assessment is highly subjective. This was illustrated in a study in which several individuals were asked to risk a prospect (Figure 4). The chance of success for everyone was very close (22 to 25%). However, everyone arrived at that COS by very different means, one assessing the key risk to be trap, another as seal, and the third identified the key risk as reservoir. This indicates that the individuals had a COS in mind, and then got to their preconceived COS by various paths. Although the overall COS determined by the various individuals was reasonable, the principle risk identified by the various individuals was different. Management must know the critical risk for any project to make sound investment decisions. The Delphi Method can be used to help management determine the critical risks for a prospect. In the Delphi method, a group of individuals review a prospect and then write down their assessment of the source, migration, reservoir, trap, and seal risk. After everyone has written down their assessment of the risk, the team reviews and discusses everyone's assessment. Following the discussion, each individual writes down their new assessment of the risk. This method eliminates peer and management pressure and helps the team to develop a consensus of the risk.

Conclusions

Management must know how to manage uncertainty when making decisions regarding portfolio and approving wells and developments. For most prospects and fields there can be considerable uncertainty in the reserves and resources due to the uncertainty ranges inherent in assessing volumes. Considerable uncertainty can be introduced to the reserve and resource assessment of a prospect or field by Interpreter bias, the methodology used to determine volumes, how the maps are contoured, and how the interpreters assess risk. These uncertainties reflect biases and are not inherent in the prospect or field volumes. For management to increase the likelihood of making money, they need to put in place a strategy to mitigate the effect of uncertainties introduced by bias.

There are three things management can do to mitigate interpreter-based uncertainty; conduct 3rd party pre-drill audits, conduct post-well reviews, and in the event of a discovery, have a different interpreter remap the prospect. Pre-well reviews or audits, especially when conducted by a 3rd party, can help identify maps and interpretations that are incorrect. These reviews can help companies generate better maps to assess the volumes and can help companies avoid dry holes by identifying major map busts. Post well or look-back reviews should be conducted for all wells, both dry holes and discoveries. Not only will post-well reviews help the team and management improve their understanding of the petroleum system, over time lookback reviews will help determine if an interpreter is introducing a systematic bias. If the predicted target depths or dip show variance of 10% or more, the structure should be remapped.

In the event of a discovery, the prospect should be remapped by a different interpreter. This will help determine if one of the interpreters is introducing bias. Of course, you will not necessarily know which interpreter is biased. Companies can also develop better volumetric assessments of a prospect or field by having interpreters use multiple methods to determine the reserve and resources. Pre-drill, volumes should be estimated using the probabilistic or Monte Carlo method as well as with a geomodel. After drilling the discovery well and perhaps an appraisal well, the volume assessments should be updated. Additionally, the interpreters should construct a net pay isochore map and calculate a deterministic volume. Decline curve analysis should be done annually after one year of production and the results compared to the volumes determined by the other methods. Since various computer contouring algorithms will result in different looking maps, interpreters need to understand the proper methods of contouring. Furthermore, since net sand and net pay maps cannot be properly contoured by the computer, interpreters must know how to hand-contour, and they must be familiar with the contour pattern for the various depositional environments. Management must also know how to critically review maps to identify potential map errors Finally, management should use the Delphi method to assess risk. This will remove a great deal of the subjectivity inherent in risk assessment and help them identify the key risk(s) of a prospect. The ideal time to apply the Delphi method is during a 3rd party pre-well review.

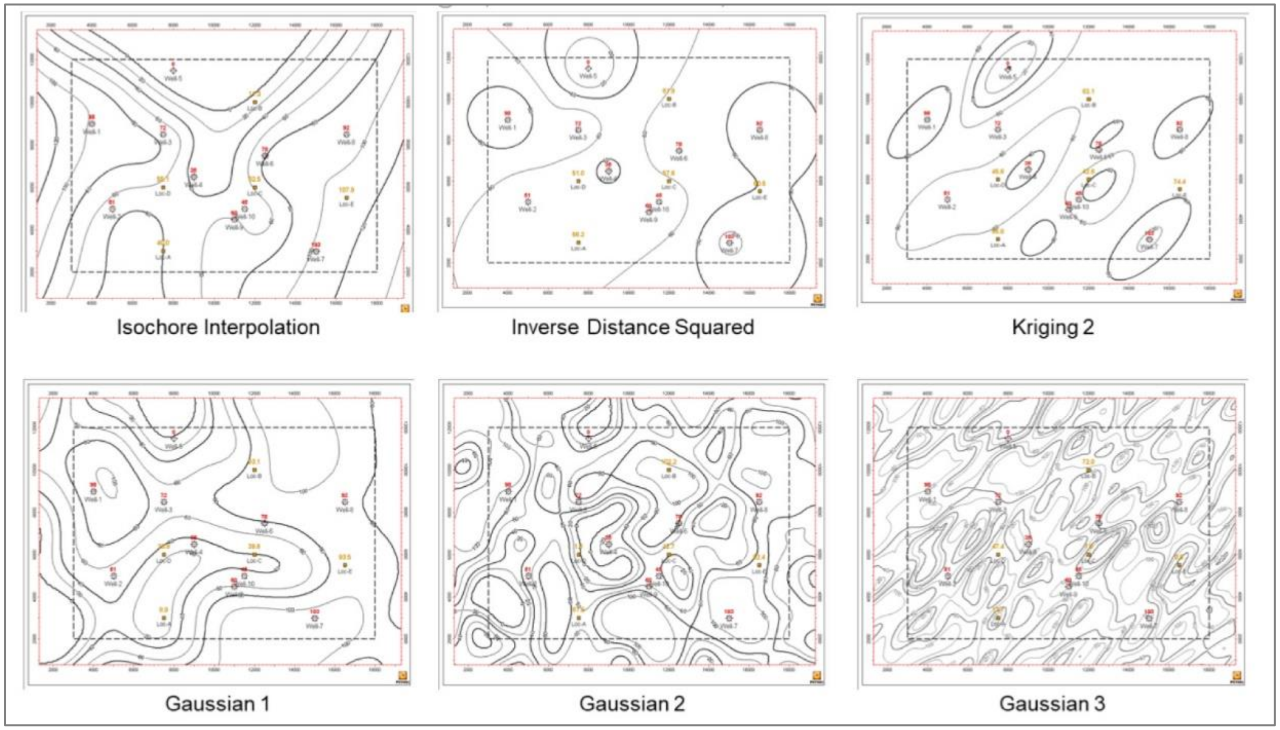

Figure 1. Net pay isochore maps contoured with different contouring algorithms. Source: Ryder Scott.

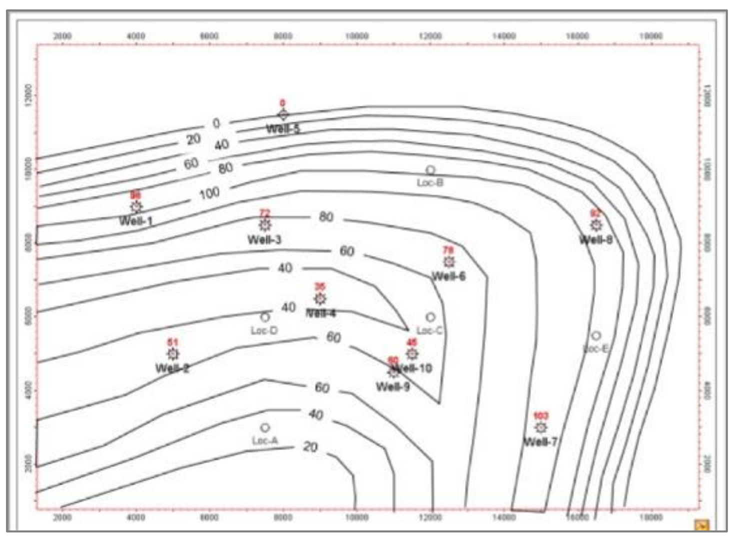

Figure 2. Net pay isochore map correctly contoured to reflect a point bar sequence.

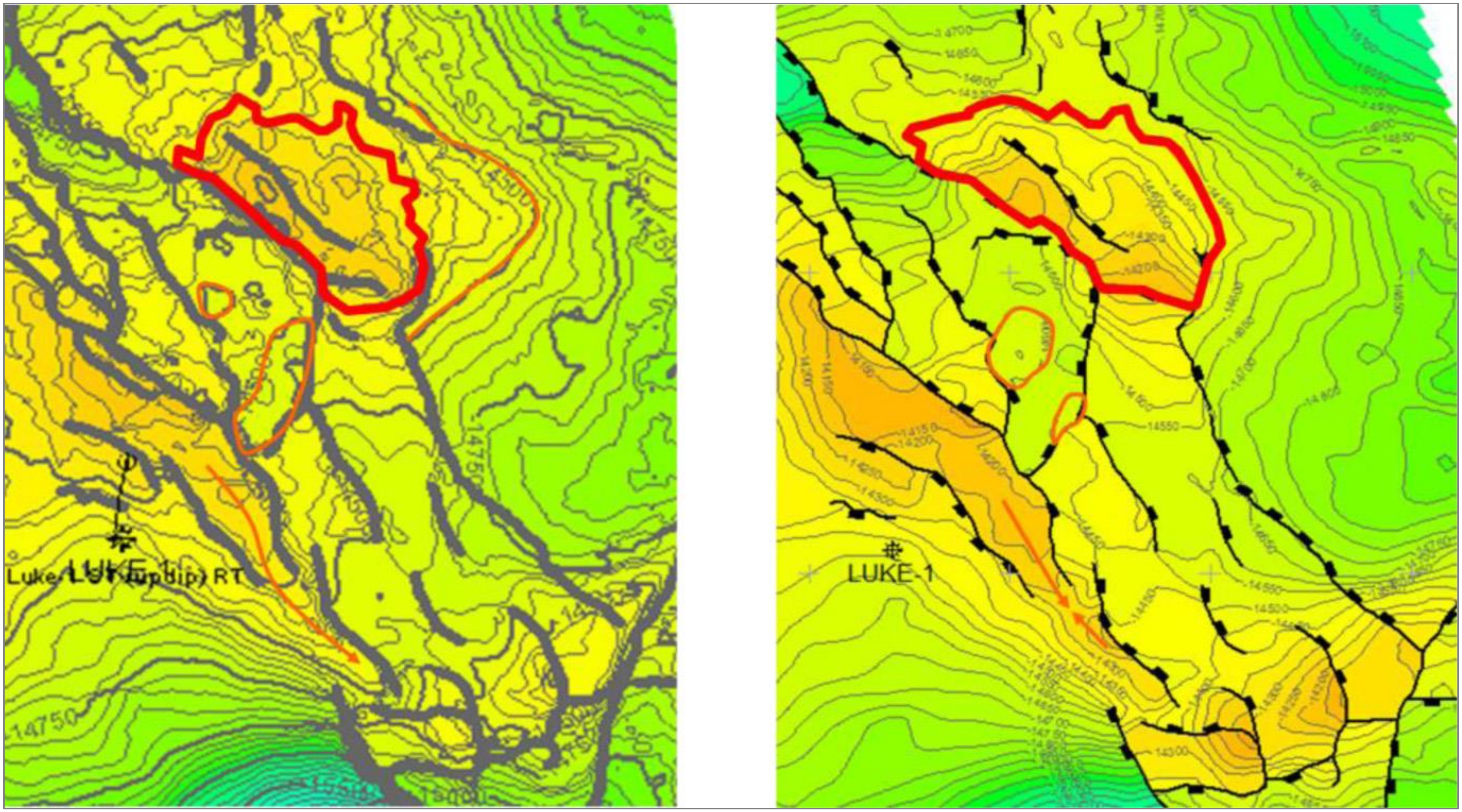

Figure 3. Structure maps generated with different contouring algorithms from the same gridded 3D seismic.

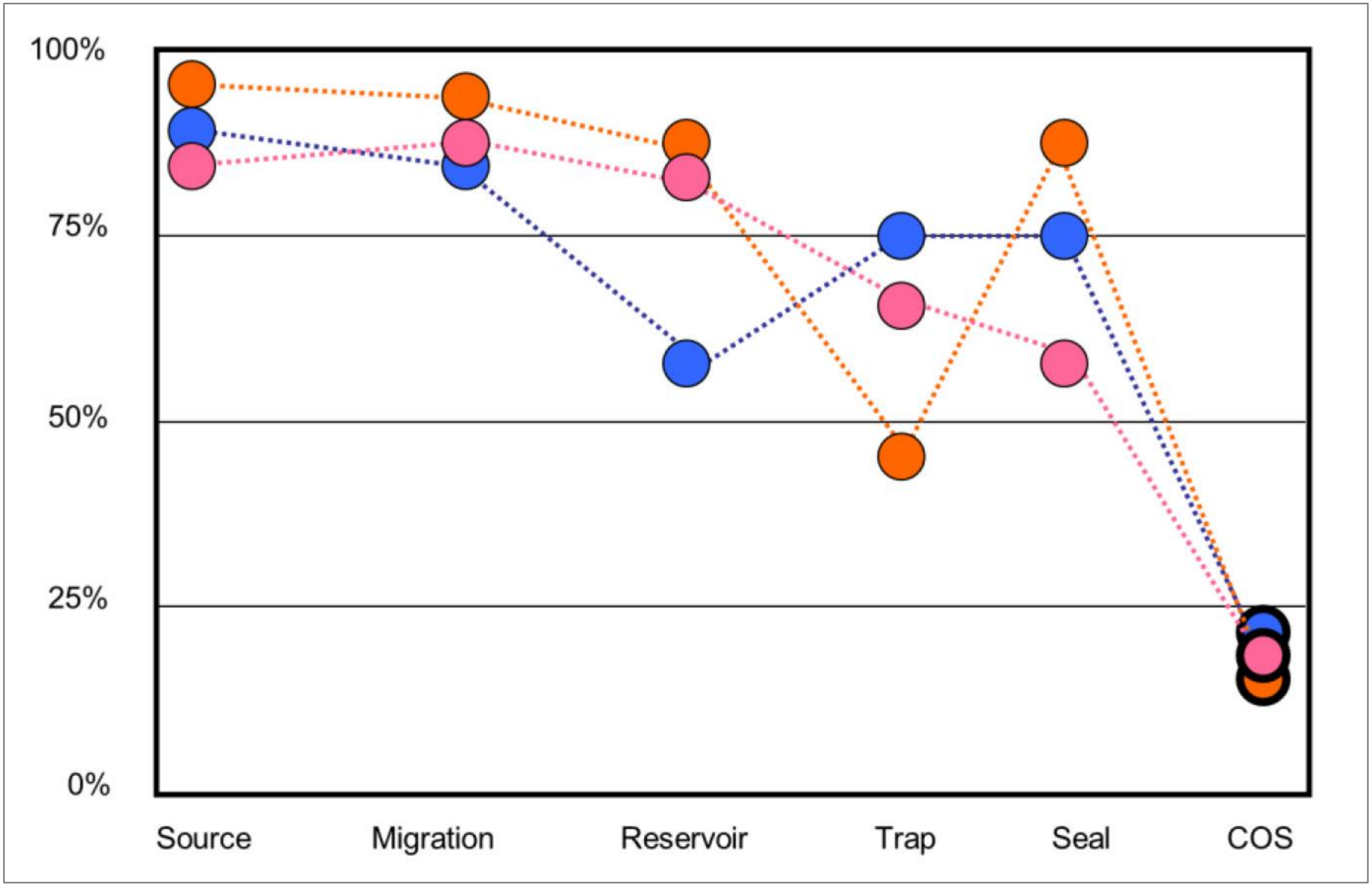

Figure 4. Chance of Success calculated by three individuals for a prospect. The teams all arrived at a similar COS but got there by different paths.

Interpreter-based Uncertainty			
Interpreter	Unrisked Mean STOIIP	COS	Risked Mean STOIIP
	MMBO	%	MMBO
1	109	21	23
2	104	19	20
3	95	19	18
4	102	17	17
5	108	20	22
6	93	21	20
7	202	21	42
8	85	15	13
Range	117	6	10
Average	112	22	22

Table 1. Range of prospect volumes estimated by 8 students. The interpreter-based uncertainty is 117 MMBO (unrisked) for a prospect with an average of 112 MMBO and 10 MMBO (risked) for a prospect with an average of 22 MMBO.

Method-based Uncertainty						
	Deterministic	Monte Carlo	Probabilistic	DCA	MBAL	Geomodel
P_1		107.7	143.8			
P_{10}	104.6	92.1	110.6	85		85.2
P_{mean}	87.6	82.6	80.1	77	88	79.1
P_{90}	62	74.6	58	73		71.9
P_{99}		59.3	44.6			
Range	42.6	48.4	99.2	12		13.3

Table 2. Range of field STOIIP (MMBO) estimated by various volumetric methods.