PROBABILISTIC ESTIMATES OF DEEPWATER OFFSHORE FIELD ABANDONMENT COST

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Introduction

TSB Offshore, Inc. (TSB), formerly Twachtman Snyder & Byrd, Inc. and Proserv Offshore, utilize a comprehensive system of cost estimating which allows the experienced user to evaluate a particular abandonment project and develop a very clear picture of the likely cost. When the necessary work activities/tasks and required resources are determined, the process proves the best possible delineation of the cost. The conventional approach is to apply standard estimating procedures to achieve a single deterministic cost number, to which a contingency is applied for the purposes of arriving at the final budget figure. This approach is appropriate for many well understood project scenarios. However, deepwater field abandonment, well plugging and abandonment (P&A) in particular, presents a much higher level of uncertainty in which it is desirable to know the entire range of possible costs, as well as the confidence limits on the estimate. This can best be done by application of probabilistic methods in the cost estimating process. The following discussion describes the probabilistic estimating method which TSB uses for complex projects and its advantages over the conventional deterministic cost estimating approach. An example of the use of these procedures in a deepwater well P&A cost estimate is presented.

DETERMINISTIC versus PROBABILISTIC METHODS

The cost estimating procedure used in most projects can be classified as deterministic since it develops an ensemble of specific unit rates, task durations, etc., which result in a single cost figure. The individual values used in assembling the total cost are the best available values for each cost element (task time, resource rate, etc.) and the resulting total is the deterministic cost. In the current context these values may also be referred to as the "most likely" values. However, when we examine the estimating process closely we can show that there is virtually always some uncertainty in the individual values that make up the total cost. Even with experienced contractors performing familiar activities, the amount of time required to perform a particular task is never exactly the same from one job to the next. When we use the conventional approach we apply a contingency to cover these uncertainties, based on our past experience. When we are dealing with a situation which is relatively straight forward we are correct in our estimates and contingency provisions more often than not. Nevertheless, it is often desirable to know more specifically what the risk of a cost overrun is. This need becomes more acute as more uncertainty enters the estimating process. Uncertainty in general can come from many sources such as:

- Labor problems.
- Uncertainty in permit approvals.
- Failure of acceptance tests.
- New technology being available.
- Severe weather.
- Variations in contractor performance.
- Variations in site conditions.
- Political instability in a development area.
- Inadequate specifications.
- Delays in management reviews and approvals.
- Mechanical breakdown and malfunctions.

Fortunately, for field abandonments in the Gulf of Mexico we do not need to be concerned about many of these issues. However, uncertainties in site conditions, weather, contractor performance, etc., are always a consideration.

In the early days of the U S missile and space programs the government was faced with the task of estimating the time and cost requirements for projects in the face of great uncertainty. The best project management, cost estimating, and applied mathematics minds of the day were focused on the task of developing methods to deal with the problem. From this effort evolved the Program Evaluation and Review Technique (PERT) which was the forerunner of the Critical Path Management (CPM) procedures commonly used in project management today. A distinguishing feature of the early PERT procedure was its application of probabilistic methods for estimating time and cost. This involved the use of distribution functions for individual cost and time estimates, rather than a single number.

While the PERT procedure was shown to be very appropriate for large government programs, it required massive computer resources and technical support which was generally not available in commercial applications. The probabilistic features were generally discarded as CPM was developed for industry use. However, with the development of very powerful desk-top computers and the parallel improvement in commercially available software, it is now relatively straight forward to apply probabilistic cost and schedule forecasting methods to practical problems in project management. In particular, this allows us to use all of the information and experience which we have available to provide a complete picture of cost risk in any situation where uncertainty exists. The use of probabilistic methods in this context is generally referred to as Risk Analysis.

Probabilistic modeling involves the establishment of a numerical model of a project similar to a conventional cost estimate, but in a form such that its important cost elements, typically task times and resource rates, can be represented as distributions and repeatedly calculated in project "simulations". In our case the characteristic that we are most interested in is the total cost to complete the project. Each time the calculation is made; individual elements of the project that contribute to cost and which contain uncertainty are allowed to have different values in accordance with the assumed distribution. These varying elements might be such things as the time required to set up a semi-submersible drilling vessel over a subsea well, for example. The way in which these elements are allowed to vary is controlled by a specific probability distribution function, as will be discussed below.

The strength of the simulation process lies in the fact that we can usually identify the variability (uncertainty) in individual parts of a project - while we cannot always see how these individual variables interact to influence the overall project. In the past we have been forced to deal with this situation with the use of "what if" analyses which change a limited number of variables at any one time. To vary more than a few values at once makes this type of deterministic analysis too complicated to carry out and readily understand.

Powerful personal computers and the available software now give us a better option than the above approach. Since project task performance uncertainties are in most cases unrelated (random events), we are able to use a mathematical device called a random number generator, along with the individual element's distribution function, to select the particular values for each simulation cycle of the project. A pair of unloaded dice is a random number generator which produces a well-defined distribution of results after many tosses, thus the name Monte Carlo (MC) simulation. As with a single toss of the dice, we are not able to predict the outcome of a single simulation of the project. However, after many simulations the results form a pattern which describes the statistical characteristics of the project variables that are of interest, cost in this case. From these characteristics we are able to develop the distribution of possible cost results for the project and the likelihood (risk) that a particular result will be achieved, or not.

There are other possibilities, but this method is by far the most practical in project management applications. Probabilistic cost estimating is particularly suitable for complex decommissioning projects such as deepwater well P&A. This application will be the focus of the remaining discussion.

PROBABILISTIC PROJECT COST MODELLING FOR DEEPWATER WELL P&A

The process of developing a probabilistic model for use in project simulation is essentially the same as that for a conventional cost estimate. The project execution plan is developed in the form of a Work Breakdown Structure (WBS) which identifies the sequence and relationships between the various activities and events that make up the project. Figure 1 shows the activity/task network for a deepwater well P&A performed by a dynamically positioned (DP) semi-submersible (SS) mobile offshore drilling unit (MODU) in the Gulf of Mexico. Table 1 below shows the detailed WBS for the project. In the process of determining the relationships between individual activities/tasks and their durations, the resources (drilling rigs, tugs, barges, etc.) required to execute the work are also determined. It is at this point that the probabilistic cost estimating process deviates from the conventional approach. In the latter a single "most likely" value estimate would be required for each cost or time element. In the probabilistic model we develop a Probability Distribution Function (PDF) for each cost element that has uncertainty to replace the single value of a deterministic estimate.

In practice this means that we determine three values for each item that require a PDF: 1) the minimum likely, 2) the maximum likely, and 3) the most likely (mode) value. With these values we can define a triangular PDF for any cost element. An example of this type PDF is shown in Figure 2. In actual project situations there is always some chance that values could occur outside the range estimated. In this example we have selected a distribution which defines our selected minimums and maximums as the P10 and P90 values for this cost element. This means that these values have a 10% and 90% chance of not being exceeded, respectively. The "most likely" or statistical mode (highest probability) value would be the only value used in a conventional cost estimate.

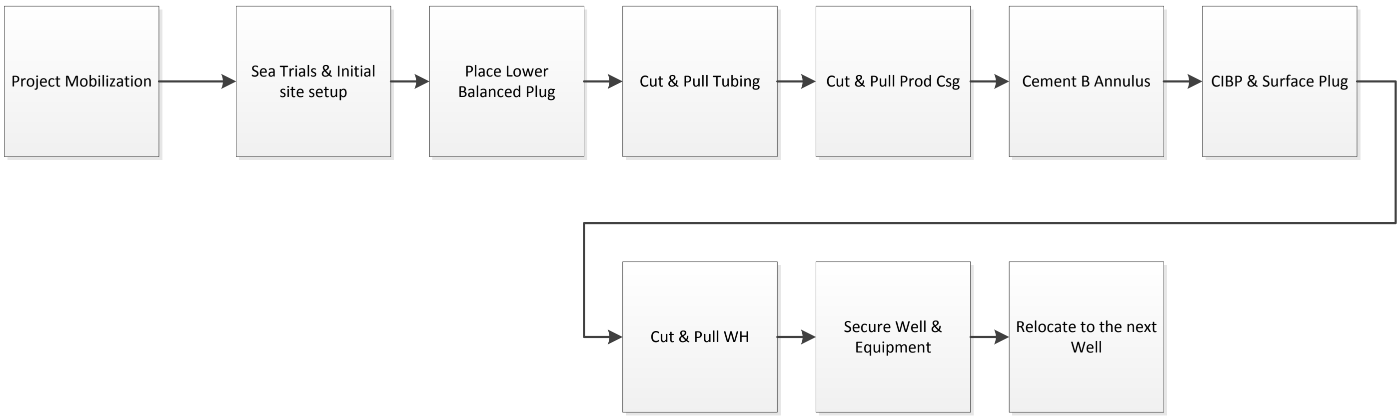

Figure 1 - Flow chart for a Deepwater Well P&A

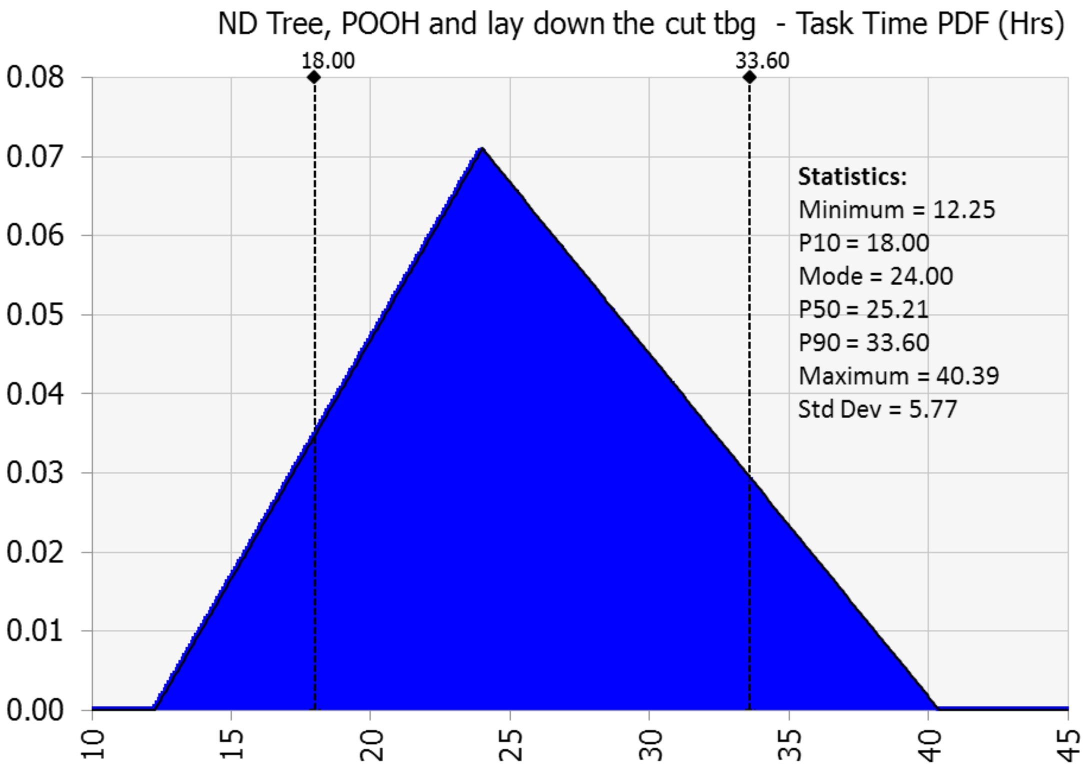

FIGURE 2 - TYPICAL TASK PDF – TRIANGLE WITH DEFINED P10 AND P90

In practice estimators and engineers always consider the range of costs which might occur when putting together a project cost estimate. Unfortunately, this information is not fully utilized in a conventional determinant estimate. In this case a specific set of assumptions and related costs must be selected, with the other possibilities contributing only to the contingency applied. Probabilistic modeling using tools like Palisade Corporation's @ RISKTM for Excel, used in this example, allows the use of everything that is known to produce the most accurate picture of the future cost performance of a project that is possible to achieve.

AN EXAMPLE OF A PROBABILISTIC DEEPWATER WELL P&A COST ESTIMATE

To illustrate how probabilistic cost estimating can be used, we provide below a variation of a cost estimate which TSB recently performed for an existing well in approximately 2700 feet water depth. The WBS and task details are shown in Table 1. The table also shows the minimum, most likely (mode) and maximum task times and the resulting "expected" task times. The expected value is defined as the numerical average, or mean, of all values in the sample set. This is specifically determined by the PDF type which was chosen. Table 2 shows the running times that are believed to be the most likely task times. For the purpose of this example, a variation of -25% and +40% is used to determine the minimum and maximum task times for all tasks except those involving waiting on cement (WOC). In an actual estimate to be used for project planning or execution, these values would be considered individually by knowledgeable persons for each task. This process has been shown to produce a very good cost estimate result.

The right-hand column in Table 1 shows the "expected" or mean cost of each task. This is derived by applying the individual task times to the expected SS MODU spread rate for each particular task. The makeup of this rate is shown in Table 3. For the purposes of this example, we have allowed for the possibility of a rig rate fluctuation of -25% and +40%, independent of the individual task fluctuations. This may not be a realistic rate range, but that would ultimately depend on the time period in which a particular project is to be contracted.

The results of this example probabilistic deepwater well P&A cost estimate is shown in Figures 3 and 4 and discussed below.

TABLE 1
RESOURCES FOR THE SEMI-SUBMERSIBLE MODU

Lowest Time (Hrs)	Most Likely Time (Hrs)	Highest Time (Hrs)	Expected Time (Hrs)	Work Breakdown Structure	Expected Cost
4.5	6	8.4	6.4	**Dock Loadout and unload is Shared btw # of wells**	$238,618
1.3	2	2.4	1.8	**Mobilize and Demobilize is Shared btw # of wells**	$67,167
4.5	6	8.4	6.4	**Sea Trials (Ballast)**	$238,618
9.0	12.0	16.8	12.8	RU riser, attach to well head, pull tree cap	$454,575
3.8	5.0	7.0	5.3	RU SL for dummy run, Run dummy run to perf depth	$189,406
6.8	9.0	12.6	9.6	RU e-line, RIH perf assy to perf to establish communication to each zone	$356,531
5.3	7.0	9.8	7.5	RU CT, RIH to perf depth	$265,169
6.8	9.0	12.6	9.6	Perform injectivity test, POOH CT, RIH CT with cement head	$340,931
3.0	4.0	5.6	4.3	RU cementing equipment, mix, pump, & squeeze perforations	$170,025
24.0	24.0	24.0	24.0	WOC	$854,092
3.8	5.0	7.0	5.3	Pressure test and Bubble test TBG and TBG x CSG, POOH CT	$189,406
				Lower Balance Plug	
6.0	8.0	11.2	8.5	RU e-line, RIH set plug above packer, POOH, RIH and punch tubing above packer, POOH	$310,850
6.8	9.0	12.6	9.6	RU CT, RIH to depth, establish circulation	$340,931
3.0	4.0	5.6	4.3	Circulate clean with 9.0 ppg SW	$151,525
4.5	6.0	8.4	6.4	RU, mix, pump, spot 200’ balance plug	$245,788
24.0	24.0	24.0	24.0	WOC	$909,150
4.5	6.0	8.4	6.4	Pressure test and Bubble test tbg and tbg x csg, POOH CT	$227,288
8.3	11.0	15.4	11.7	RIH E-line with gun, perf at 2500’ BML, POOH, RIH CT with cement BHA perform inj test	$399,259
4.5	6.0	8.4	6.4	RU, mix, pump, spot 300’ balance plug	$232,023
24.0	24.0	24.0	24.0	WOC	$909,150
3.8	5.0	7.0	5.3	Pressure test and Bubble test tbg, tbg x csg, and csg x csg, POOH CT	$189,406
				Cut & Pull the Tbg	
4.5	6.0	8.4	6.4	RU e-line, GIH and cut the tubing @ 700’ BML, POOH e-line	$235,088
4.5	6.0	8.4	6.4	Circulate well clean (2 Bottoms up)	$227,288
18.0	24.0	33.6	25.5	ND Tree, Recover & riser, RIH to recover cut tbg POOH and lay down the cut tbg	$909,150
		0.0	0.0	**Cut & Pull the Prod Csg**	
9.0	12.0	16.8	12.8	RIH cutting equipment & cut Casing, POOH	$462,375
13.5	18.0	25.2	19.2	ND Csg head, RIH Casing Spear, Pull and Lay Down	$681,863
2.3	3.0	4.2	3.2	Circulate well clean	$113,644
				Cement in B annulus	
5.3	7.0	9.8	7.5	RU e-line, GIH and set EZSV at 680’ BML, POOH, RIH and punch tubing at 450’	$272,969
3.0	4.0	5.6	4.3	GIH with CT, sting into EZSV, mix and circulate a 200’ surface plug in the csg - TOC @ 450’ BML	$170,025
24.0	24.0	24.0	24.0	WOC	$909,150
3.8	5.0	7.0	5.3	Pressure test and Bubble test tbg, tbg x csg, and csg x csg, POOH CT	$189,406
				CIBP & 200’ Cmt surface plug	
4.5	6.0	8.4	6.4	RU e-line, GIH and set CIBP in csg @ 350’ BML	$227,288
5.3	7.0	9.8	7.5	GIH with work string, mix and spot a 200’ surface plug in the csg on top of the CIBP - TOC @ 150’ BML	$283,669
18.0	24.0	33.6	25.5	PU work string and WOC	$909,150
3.8	5.0	7.0	5.3	Weight test with WS, POOH	$189,406
				Cut & Pull WH	
12.0	16.0	22.4	17.0	RIH cutting equipment & cut Casing, POOH	$613,900
6.0	8.0	11.2	8.5	RIH Casing Spear, Pull and Lay Down	$303,050
				Spot and secure Well and P&A Equipment	
6.0	8.0	11.2	8.5	Clean area of all debris	$303,050
3.0	4.0	5.6	4.3	Secure all equipment and prep for move or demob	$151,525
0.8	1.0	1.4	1.1	**Relocate to next well**	$39,770
	Expected Hours		404.2		
	Working days per well		16.5	Number of Wells	1
				Subtotal (Mean)	$14,509,673
	Total Hours		443.8	10% Weather	$1,416,589
	Total Days		18.5	10% Engineering	$1,447,168
				Mean Cost Total	$17,373,429

TABLE 2
MOST LIKELY RUNNING SPEEDS

				feet/hour
Ave Perf Depth=	7,848	SL run speed	First RIH	18,000
Ave Packer depth=	7,425		Sub RIH	25,000
		E-line run speed	First RIH	15,000
			Sub RIH	17,000
		CT-run speed	First RIH	3,500
			Sub RIH	5,000
		Riser run speed		500
		Pipe run speed		900

TABLE 3
RESOURCES FOR THE SEMI-SUBMERSIBLE MODU

COST DESCRIPTION	*Average Daily Cost for most equipment. Some cost are lump sum*
P&A: Rig / Lift Boat	
Semi Sub & IRS on DP	
MODU	505,000
Transportation	
Trucking	4,547
150' Supply Boat	5,000
170' Assist and Supply	7,500
Dock Service	971
P&A: Crew & Equip	
Cased Hole E-line	11,142
Slick line	9,318
Cutting & Milling	14,199
Wireline Purchases	23,328
Cementing crew & Equipment	7,639
Onsite Supervisor	5,000
Quarters/meals for 28 per	2,800
DP OPS Personnel	2,200
7.0 Package	
IWOCS Personnel	11,522
IWOCS Package	13,688
Archer Tongs	6,757
Wellhead Personnel	4,260
Coil Tbg	55,000
ROV	39,064
TEST TREE, BASS SYS	47,000
Drill Pipe & Drill Collars	8,000
Drill Pipe Riser	10,000
P&A: Purchases	
Fuel - P&A Equip	5,800
SOAP	2,125
TANK CLEANING	508

	Most Likely Cost	Risk Weighted Cost -25%, +40%
Average Spread Cost per Day on DP	$802,368	$854,092
Average Spread Cost per Day on DP	$33,432	$35,587
Average Spread Cost per Hour in Transit	$35,099	$37,361

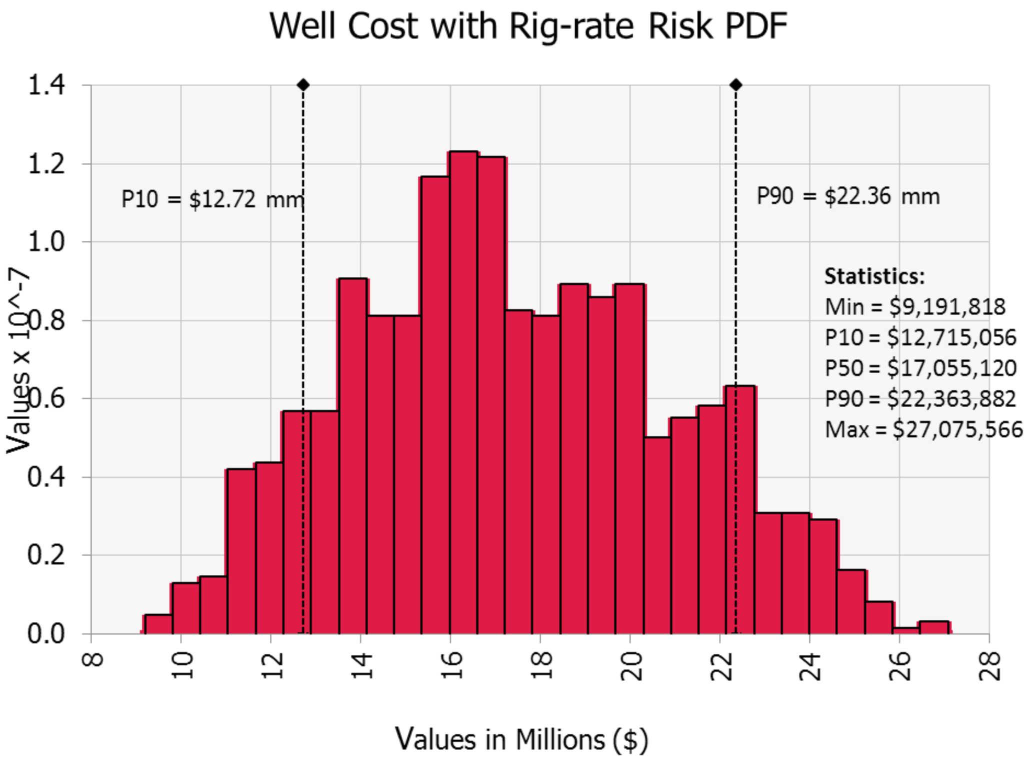

Figure 3 - Deepwater Well P&A Cost Probability Distribution Function (PDF)

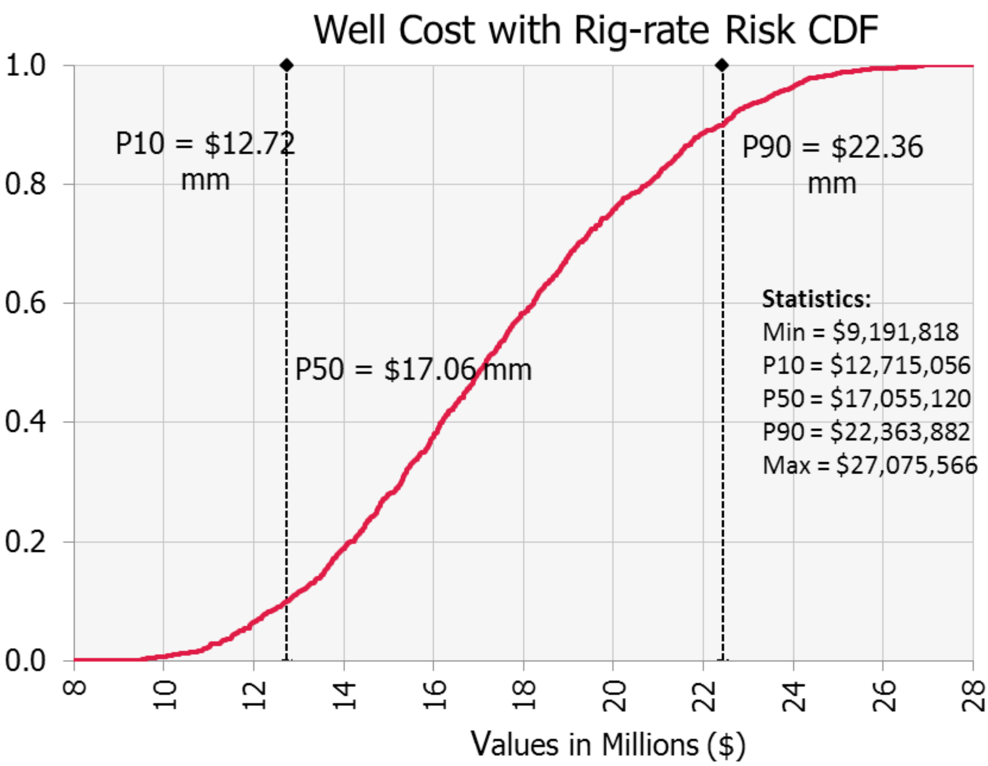

Figure 4 - Deepwater Well P&A Cost Cumulative Distribution Function (CDF)

There are a number of points to be noted about the cost estimate results, the most obvious being that the median (P50) cost for this well P&A is $17.1 million and that the possible range of costs is from $9.2 to $27.1 million. It is significant to note that the latter extreme cost outcomes have essentially "zero" probability of occurrence according to our project model. The practical range of outcomes is defined by the P10 and P90 values of $12.7 and $22.4 million. Other points that might not be as obvious are:

a. Referring to Table 1, the expected or mean well P&A cost is slightly different from the median cost, i.e., $17.4 versus $17.1 million. Noting that the mean cost is the numerical average of all project cost simulations, this difference reflects the fact that the distribution of cost is slightly skewed toward the higher cost end, per the PDF in Figure 3. This is not particularly unusual for this type of project. It is simply easier to screw a project up than it is to make it run better.

b. There is a relatively wide range between the P10 and P90 cost, i.e., $9.6 million or 57% of the P50 cost. This is a clear indicator that the cost risk is very high. This is also reflected in the relatively flat shape of the CDF curve in Figure 4. A steep curve with a relatively short cost range would reflect lower overall risk than a flat curve with a wider range of possible cost. We note that in this example the relatively high risk has resulted from our choice of a -25% and +40% range for the SS rig rate.

The challenge for the operator and its project managers will be to pick a budget for this particular well P&A. Typically that would be the P50 cost, $17.1 million. However, there might be good reasons to select a different figure. If the consequences of being wrong are very severe, a budget with a lower probability of being exceeded, e.g., a P60 or P75 budget might be in order. On the other hand, if the project team have a high level of confidence in their ability to control the project and the resource costs in particular, a lower budget might be appropriate. In any case it is very helpful to have a complete picture of the cost outcome possibilities.

CONCLUSION

The use of probabilistic cost estimates for deepwater decommissioning allows the project team to take advantage of all of the information that is available about the project at any particular time. The results do not produce a single cost number, but do produce a much more complete picture of the project cost risk. This provides for the best possible project planning and execution. This is particularly important for deepwater decommissioning and abandonment.