Decision based uncertainty management in maturation of sub-surface opportunities with huge reservoirs uncertainties _Alpha Field in Niger Delta, Nigeria as Case Study

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Abstract

The management of subsurface uncertainties and complexities associated with development of 'green reservoirs' and resource volume estimation remains a challenge due to sub surface data quality, limited well penetration and data paucity at deeper reservoirs levels where seismic data is poor and chaotic. In the context of rising development costs for oil and gas projects, it becomes imperative to integrate all available data in maturation of sub-surface opportunities using decision-based approach. Decision based approach is deployed to quantify identified subsurface uncertainties and mitigate risks by creating a range of credible multi-scenario models within the solution space. In the case of maturation of sub-surface opportunities with huge reservoirs' uncertainties, the uncertainties ranges are made wide to capture all the subsurface realisations. The Alpha field is in the Niger Delta Basin of Nigeria and characterised by hydrocarbon accumulations in Agbada formation with occurrence of alternation of sandstones and shales. The block of interest is penetrated by only three (3) wells within an area of 4km x 0.6km. Key subsurface uncertainties that impact on the development plan of the reservoirs have been identified, and they are associated with structure and stratigraphy. By applying this decision-based approach, the big-ticket problems like structural issue due to poor seismic and correlation challenges encountered for this maturation study are reduced, leading to a more practicable range of volumes. This paper presents an overview of integration of all available subsurface data used to reduce the key subsurface uncertainties and risks by application of decision-based approach, and the resultant practicable and robust multi scenario models.

Keywords: Maturation, reservoir, uncertainties, formation, development, Opportunities

INTRODUCTION

Alpha field is located in onshore Niger Delta basin, and the block of interest covers an area of approximately 4km x 0.6km. The field was discovered in 1988 by ALPH-1 well. A total of three wells have been drilled in this block with comprehensive suite of logs. The wells encountered hydrocarbon-bearing sands in nine reservoirs, between depths of about 7500ftss to 11800ftss. All the reservoirs penetrated in the field are hydrostatically pressured.
The six studied reservoirs in Alpha field includes A1000, A2000, A3000, A4000, A5000 and A6000, and their In-place expectation oil (STOIIP) ranges between 1MMstb (A1000) and 37MMstb (A6000). Only the shallowest reservoir_A6000 is developed and producing currently at BSW >80%, while the rest five reservoirs are 'green'.

Alpha field essentially consists of several narrow, elongated sub-parallel fault blocks orientated in a NW-SE direction. The block of interest (Figure 1) has a structural configuration that is essentially fault assisted two-way dip closure. The sealing capacity of this fault dependent closures are not in doubt as most of them trapped hydrocarbon. Fault throws range from ca 70 to 350 ft. Well-by-well correlation and Seismic volume attributes (Semblance slice) extracted at depth suggest possibility of sub-seismic faults that could impact lateral connectivity.

The 3D Seismic data was reprocessed using the pre-stack depth migration (PSDM) in 2017 to further enhance the quality in order to achieve better structural resolution of the key hydrocarbon bearing reservoirs, which lie mainly in the deeper part of the field below 2600ms. The reprocessed seismic volume has improved signal to noise ratio and enhanced fault plane imaging, but the quality remains fair to poor below the A4000 reservoir level.

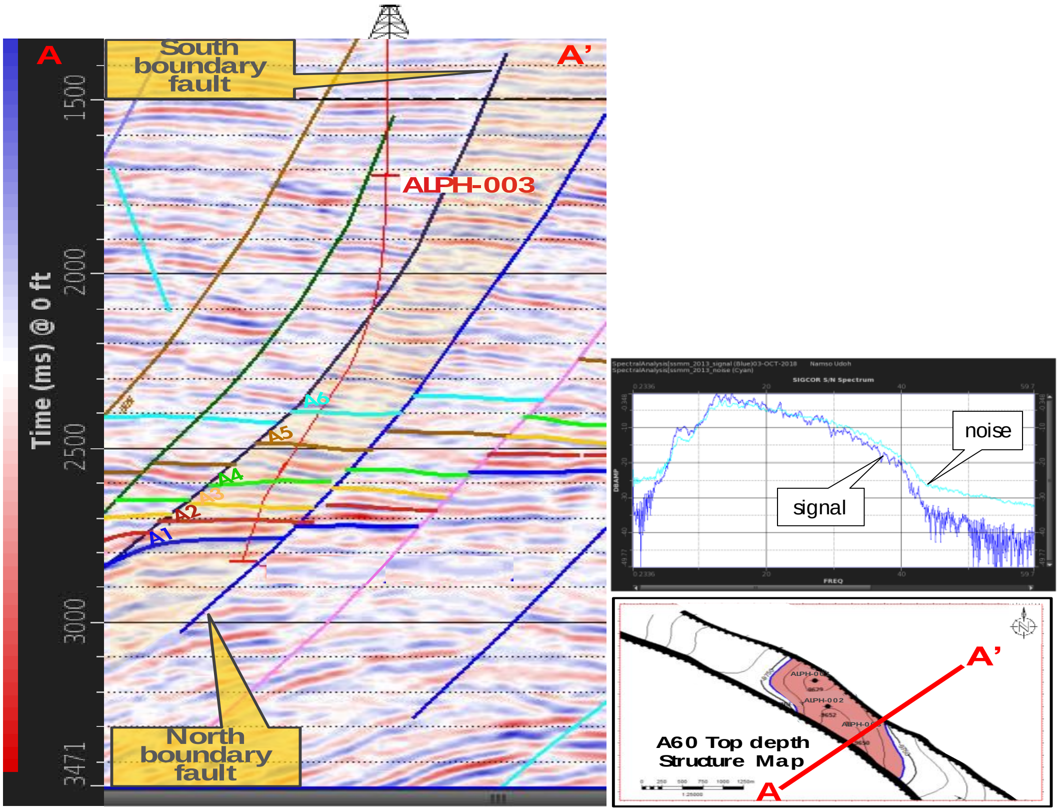

Figure 1: Alpha Field's Seismic cross section highlighting the fault block if interest.

The Alpha reservoirs exhibit a sequence of interbedded sandstones and shales characteristic of the paralic sequence of the Agbada Formation of the Niger Delta basin. Foraminiferal and palynological analyses of the sediments indicate an age of Late Miocene. The Facies are broadly laterally continuous shoreface deposits with tidal influences and varies in thickness from ca. 60 to 195 ft in the block of interest. Figure 2 is the correlation panel showing good stratigraphic correlation across the field. Relatively uniform thickness is observed in A6000, A2000 and A1000 sands, while A4000 and A3000 sands consist some channel stacks and show significant lateral thickness variation.

At the reservoirs of interest, the petrophysical properties are generally high and they indicate good reservoir quality. The Net-To-Gross ranges from 0.68 – 0.97, the Porosity ranges from 0.18 – 0.25, and the Permeability ranges from 1800 – 4500mD.

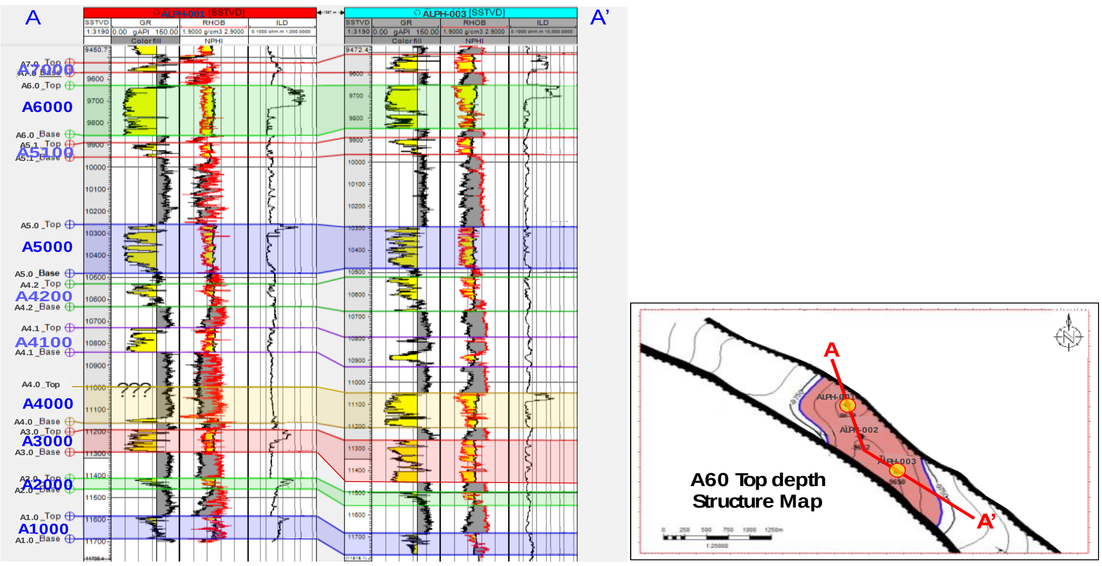

Figure 2: Alpha Field Stratigraphic Correlation (Wells Alph-001 & Alph-003)

The key uncertainties identified in the Alpha A-series reservoirs in the static domain are structure and stratigraphy. To address these uncertainties, a full reservoir maturation study was kicked off involving 3D static reservoir modelling, with the ultimate objective of selecting the optimum well count and well placement for the development of these reservoirs.

Prior to this phase of the project maturation, six opportunities were identified to be moved into the maturation funnel. At this phase, the maturation work requires integration of all geophysical, geological and petrophysical data to build subsurface realisations that will help manage some of the identified subsurface uncertainties. This study is schedule and cost driven and hence the determination for unit-development-cost reduction, effective uncertainty management and working efficiently to avoid recycle. Therefore, it becomes imperative to generate robust development strategies to fasttrack field development by drilling in reservoirs with minimal uncertainties while appraising the high-risk areas.

Challenge Statement

Two wells were proposed, each targeting 3 opportunities prior to this phase of the project. During the opportunity maturation in this phase that requires detailed definition of the scope before commencement of final investment decision (FID), some uncertainties were identified that posed challenges to drilling of these wells, and therefore the need to adopt a Decision based uncertainty management. The challenges include;

- Structural: The seismic quality at the interval of interest (below 2.6sec) is poor and chaotic.
- Correlation challenge: Issue with resolving A4000 well correlation around Alph-001 where missing section could be either structural or stratigraphic related.
- Production data: Production data from Alph-001 well raised questions about the viability of a new well in the A6000 reservoir that has already made about 54% of the Oil In-Place volume.

Data Availability

- 3D Seismic data (2017 re-processed PSDM volume)
- Logs
    - Good coverage of Log data (GR/SP/CAL/DEN-NEU/RES)
    - Pressure data available in Alpha-001 & -003 covers A5000 & A4000
    - PVT sample acquired in A6000 reservior
- Core and SWS
    - Core data was acquired in A6000 sand in Alph-003 with RCAL & SCAL done.
    - Only 1 Well (Alph-001) has SWS for all the reservoirs of interest
- Production data exist for Alph-001 well in A6000 reservoir

Maturation Work

The maturation work in this phase was carried out by building a static model, focusing on mitigation of the 2 identified key uncertainties (Structural and stratigraphic), HCIIP volume generation and well planning.

3 Structural realisations were built for the 6 reservoirs of interest giving rise to GRV ranges. 2 multi scenario models of the A4000 reservoir were built to mitigate the uncertainty with shale-out towards the Alph-001 well. One scenario is an increase in shale thickness due to faulting, while another scenario is the presence of a mud fill channel.

All available data was integrated in maturation of the sub-surface opportunities, while the well optimisation was carried out using decision-based approach.

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Decision based approach/methodology

Decision based approach is deployed by identifying the major subsurface uncertainties and risking them based on impact on project and adopting a proactive multi disciplinary solution using Decision sheet as seen in table 1 below. The decision adopted in the Alpha field to fastrack the six reservoirs development by targeting the 'quick win' opportunities first was done using six themes that were weighted against each other.

Decision table represents in tabular form possible situations that a project decision may encounter. It is best suited in taken qualitative decisions. For the Alpha reservoirs, six project decisions were created and used to match against each of the reservoirs. Those decisions were weighted in order of importance (1-3), with 3 being the most important decision(s). These reservoirs were then scored against each of those decisions between 0-5 points, with 5 being the highest point. Aggregate of the points per each reservoir from the six (6) decisions make up the total score. The reservoir with the highest total score eventually becomes the most preferred targeted reservoir for development.

a.) Quality of Seismic: Data re-acquisition required

This theme involved deciding on the quality of the existing Alpha re-processed Seismic and the need for further reprocessing to achieve better structural definition at depth. The shallower reservoirs (A6000 to A4000) were adjudged to have low developmental risk due to good Seismic quality and so were scored higher than the deeper reservoir levels below the A4000 horizon where seismic quality is poor as seen in figure 1.

b.) Structural Uncertainty due to well penetration

It involved deciding on the number of well penetrations on the structure for each of the reservoirs and their spread and ranking them accordingly. Apart from the Shallowest reservoir (A6000) that has three well penetrations, the other reservoirs have two well penetrations each at the structural flanks. This paucity of well data does not provide reliable structural control. A6000 reservoir was adjudged to have lower developmental risk and so was scored higher than the other reservoirs.

c.) Fault / Stratigraphic complexity?

Fault / Stratigraphic complexity theme involved deciding on whether there's ambiguity in either the presence of sub seismic faults or stratigraphic occurrence that can appear as uncertainty, requiring multi scenario approach. No evidence of faulting around Alph-001 that will account for ca. 130ft thick shale observe in the A4000 reservoir. Reservoir as seen in figures 2 and 3 was adjudged to have higher developmental risk and may require appraising prior to development. A4000 reservoir was scored lower than the other reservoirs in table 1 below. This theme has a higher weighting in the decision table.

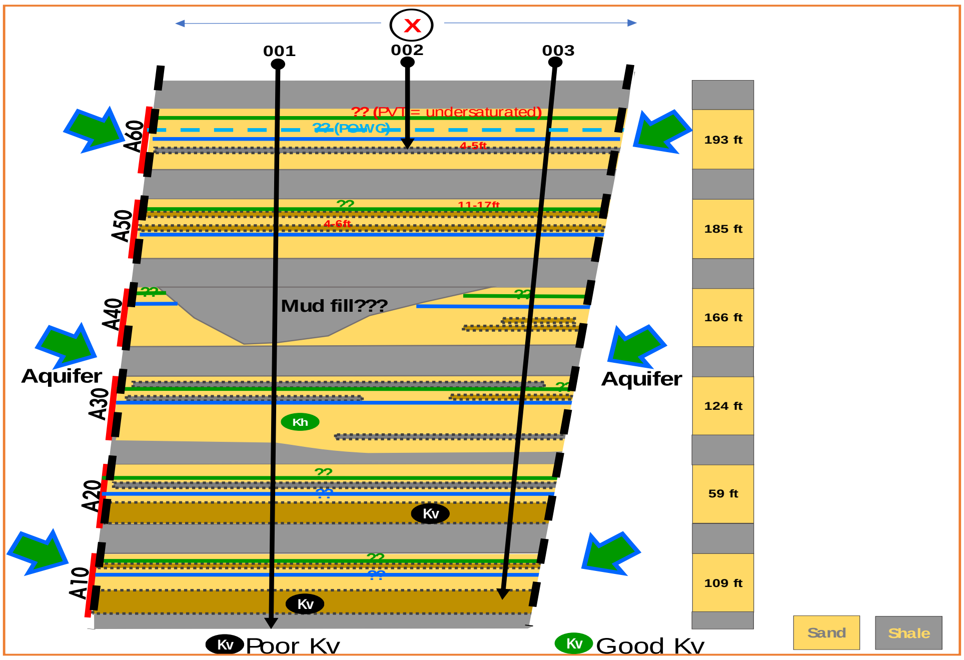

Figure 3: Plumbing Diagram of the six Alpha Reservoirs of interest

d.) Oil vol (STOIIP) combination of not more than 3 reservoirs = BC >65 MMstb

This theme involved deciding on the combination of not more than three reservoirs with cumulative STOIIP greater than 65 MMstb. A2000 and A1000 reservoirs were adjudged to bring lower rewards and were scored lower than the other reservoirs.

e.) Any Production in reservoir target? NP/STOIIP > 50%

NP/STOIIP > 50% theme involved deciding on whether the reservoir is producing or has depleted or has not even produced. For these reservoirs of interest, only A6000 has produced while the rest are still green with no production. The A6000 NP is already about 54% of the Oil In-Place volume, and so adjudged to have higher developmental risk and may require appraising prior to development to ascertain the POWC. This theme has a lowest weighting in the decision table.

f.) Appraisal required for Fluid contact / type

The theme involved deciding on whether these reservoirs require appraising to determine the fluid type and contact or not. The ready-to-go reservoirs are ranked higher than the non ready-to-go reservoirs with higher development risk. Alpha-001 which is the most crestal well encountered Oil-Up-To for all six reservoirs, with possibility of gas cap. However, the PVT data in A6000 suggests that reservoir is undersaturated. Alpha-001 also logged Oil-Down-To (ODT) for two of the reservoirs (A1000 and A4000) while the remaining reservoirs have clear Oil-Water-Contacts as seen in figure 4 below, and so adjudged to fall within the category of ready-to-go reservoirs.

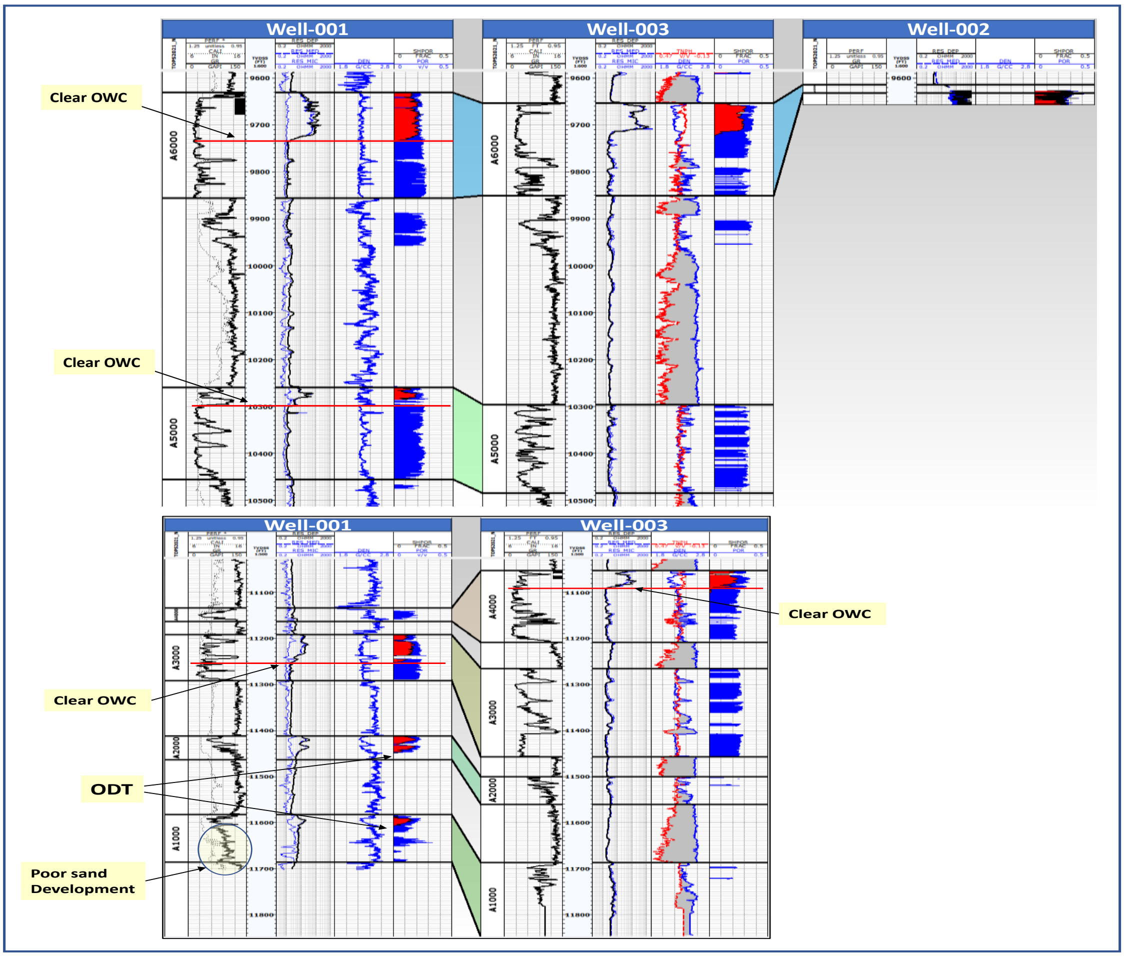

Figure 4: Alpha field Hydrocarbon Distribution Plot

Table 1: Alpha Reservoir Development Decision Ranking Sheet

RESERVOIR	ALPHA RESERVOIR DEVELOPMENT DECISION (SCORE IS 0 - 5 POINTS)						
	Quality of Seismic: Data re-acqusition required Weight = 3	Structural Uncertainty due to well penetration Weight = 3	Fault / Stratigraphic ? complexity Weight = 3	Oil vol (STOIIP) combination of not more than 3 reservoirs = BC >65 MMstb Weight = 2	Any Production in reservoir target? N_p/STOIIP > 50% Weight = 1	Appraisal Not required for Fluid contact / type Weight = 2	Total Score
A6000	12	9	12	10	2	6	51
A5000	12	6	12	10	0	6	46
A4000	9	6	3	10	0	6	34
A3000	6	6	9	10	0	6	37
A2000	6	6	9	0	0	4	25
A1000	3	6	9	0	0	4	22

RESULTS AND DISCUSSIONS

From the decision rank sheet, A6000, A5000 and A3000 reservoirs stood out as top three most prefered targeted development reservoirs to be drilled with the 1st planned well. The well will then be used to appraise the fluid type/contact for the A6000, A4000 and A2000 reservoirs. With the high cumulative production viz-a-viz the STOIIP, A6000 reservoir will be behind sleeve contingent on the outcome of the Present Oil-Water-Contact (POWC). The viability of the 2nd well will be predicated on the result/outcome of the 1st well.

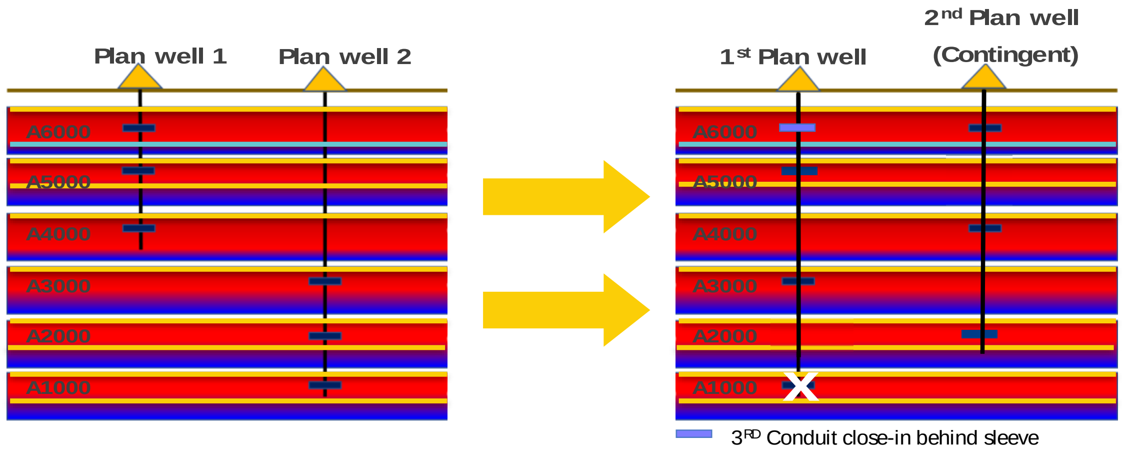

Figure 5: Development Strategy (Before and After)

This Decision based study approach has helped to refine the development strategy earlier adopted prior to this phase of work. Benefits include;

- ensures that the planned schedule is adhere to and there is no project slippage.
- targeting the low hanging fruits with better rewards, thereby making project competitive, and reducing unit-development-cost (UDC).
- ensuring a front-end loading where key decisions have been taken upfront, thereby ensuring effective uncertainty management and reduction in recycle time for maturation studies.
- guarantees fast track in field development by drilling in reservoirs with minimal uncertainties while appraising the high-risk areas. Figure 5 shows how decision-based study approach can help prioritize development plan.
- Reduces the downside risk through appraisal with the first well to test the commerciality of the opportunities before going ahead to drill the 2nd well.

CONCLUSION

In the context of rising development costs for oil and gas projects, it becomes imperative to generate robust development strategies to fasttrack field development by focusing on reservoirs with little or no uncertainty first,

and subsequently developing the de-risked reservoirs.
Development decision ranking sheet is deployed in decision-based approach by identifying the major subsurface uncertainties and risking them based on impact on project and adopting a proactive multi disciplinary solution. This has been applied in Alpha field to fastrack the six reservoirs development by targeting the 'quick win' using six themes ([1]Quality of Seismic: Data re-acquisition required, [2]Structural Uncertainty due to well penetration, [3]Fault / Stratigraphic complexity, [4]Oil vol (STOIIP) combination of not more than 3 reservoirs = BC >65 MMstb, [5]Any Production in reservoir target? NP/STOIIP > 50% and [6]Appraisal required for Fluid contact / type).

Proposal of two wells, each targeting 3 reservoirs was carried forward from a prior Phase of project. With the Decision based approach, 2 Wells scenario may not be feasible any longer in the light of the fact that A6000 reservoir's cumulative production is already 54% of the HCIIP volume, and A4000 reservoir's volume is risky and will require Appraisal/seismic re-evaluation.
Emerging development plan is to move forward with 1 well scenario that involves re-combination of the Alpha quick win opportunities. Possibility of 2nd well will be predicated on the result of the 1st well.

Some of the benefits of this study include managing schedule and avoiding slippage, reduction in UDC, effective uncertainty management and working efficiently to reduce cycle time for maturation studies.

Nomenclature

Km	*Kilometer*
STOIIP	*Stock Tank Oil Initially In Place*
MMstb	*Million Stock Tank Barrel*
HCIIP	*Hydrocarbon Initially In Place*
Np `	*Cumulative Production*
BS&W	*Bottom Sediment and Water*
UDC	*Unit Development Cost*
PSDM	*Pre Stack Depth Migration*
3D	*Three Dimensional*
BC	*Base Case*
POWC	*Present Oil Water Contact*
A1000-A6000	*The reservoirs nomenclature moving shallower with depth*

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