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Digital Optimization to Enhance Oil and Gas Recovery

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Abstract: ***This paper is about the role of digitalization with optimization in Drilling technology. In 2015, Indian Prime Minister set a target for the government to decrease oil import dependence by 10 per cent by 2022. India's oil import dependence stood at 78.6 per cent in 2014-2015.India records lowest crude oil production in past few years. Still in 2020, India is heavily dependent on crude oil and LNG imports with 82.8% import dependence for crude oil and 45.3% for natural gas/LNG. COVID-19 pandemic crisis hits oil and gas sector badly. Digital transformation can act as a key enabler to revive the industry from numerous crises at competitive figure. This study was a multidisciplinary effort combining the real time operation center and Geological expertise with drilling engineering expertise. Domains involved will be DCS (Data and Consulting Services) and DEC (Drilling Engineer Centre). The study aimed at achieving the optimum development plan for six MA wells out of which two wells will be multilaterals. Experts from each domain jointly worked together to obtain the optimum well designs through sensitivity analysis.***

Keywords: Conservation and optimization of Energy. Value to organization, Client and National resources

1. Introduction

A feasibility study of well placement and drilling optimization for one of their development fields that would help organization to minimize risk using the latest tools and digital technology available.

2. Background

India is currently in the development phase. They have so far drilled 59 exploration and 15 development wells. They now want to move from the development phase to the production phase. The target wells for this are the MA wells. A peak production of 40,000 barrels of oil production per day is expected from these wells. Therefore there is a very high focus from RIL upper management on these wells. This project gives ORGANISATION an excellent opportunity to partner with RIL on one of their most important projects.

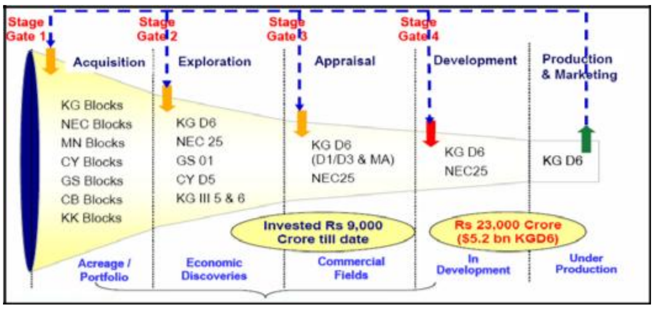

Figure 1: Reliance Development through years

RIL plans to develop their KG-D6-MA1 field with 6 horizontal / multilateral wells with subsea completions. Initial plan was to drill these wells from scattered well head locations. We brainstormed the idea of moving the well head locations closer and placing a common subsea choke manifold for production.

The concept was taken further by providing some simple trajectory iterations to instill confidence that the alternate idea was feasible with their current rig fleet.

Based on the above, RIL has awarded Organization the work to check on the feasibility and optimization of the development drilling plan for the MA field.

Project Objectives

- Design the wells such that they may be drilled in the most feasible manner with minimum exposure of drilling and geological risks.
- Maximize revenue by providing technical recommendations for new technology if found suitable for the client.
- Showcase the unique benefits of a strong Multidisciplinary team that can offer and deliver.

Drilling Engineer Center

- As a part of Design – Execute – Evaluate procedure, this study mainly intended around the design phase. However, as the project progressed and the drilling started a number of further recommendations emerged. This project focused on Well Trajectory optimization, BHA optimization, Rig Sizing and conducting drilling optimization analysis for the two most difficult wells.
- The well trajectory for a multilateral well was drawn to meet the basic trajectory requirements to run Organisation multilateral junction.
- In conjunction with DCS, recommended the LWD Logging Program. Recommended MWD/DD tools and different survey techniques.
- Multisegmented integration was a key challenge of this project. The challenge was overcome by coordinating efficient information flow between segments. An information flow diagram is shown below.

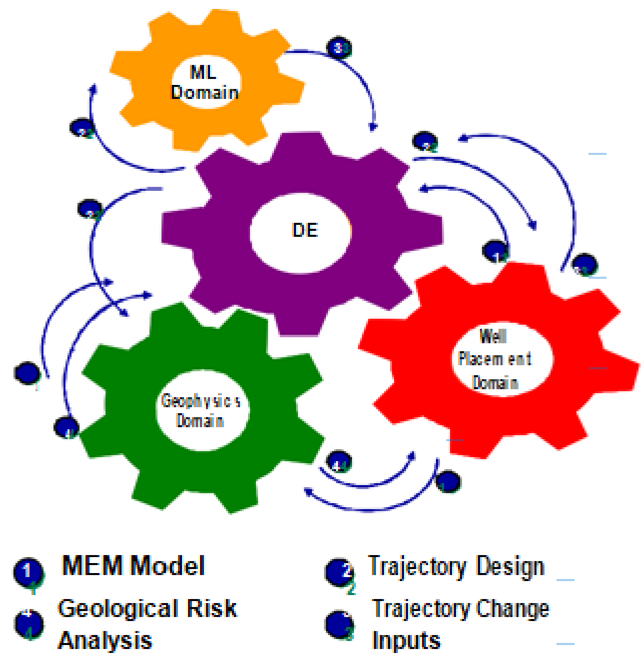

Figure 2: Information flow between participating segments

Drilling Engineering Work Flow

This GFE project concentrated on the drilling engineering part of the study. The work flow followed is detailed below.

- The analysis started with Trajectory planning.
- Once the plan was optimized a suitable BHA was designed.
- The plan and BHA were used for torque & drag, and hydraulics modeling.
- The inputs from the modeling were fed back to trajectory planning. The cycle was carried out until the plan and BHA were optimized, and no evident torque & drag and hydraulics issues were present.
- Post this rig sizing analysis was carried which constituted the last phase of the study.

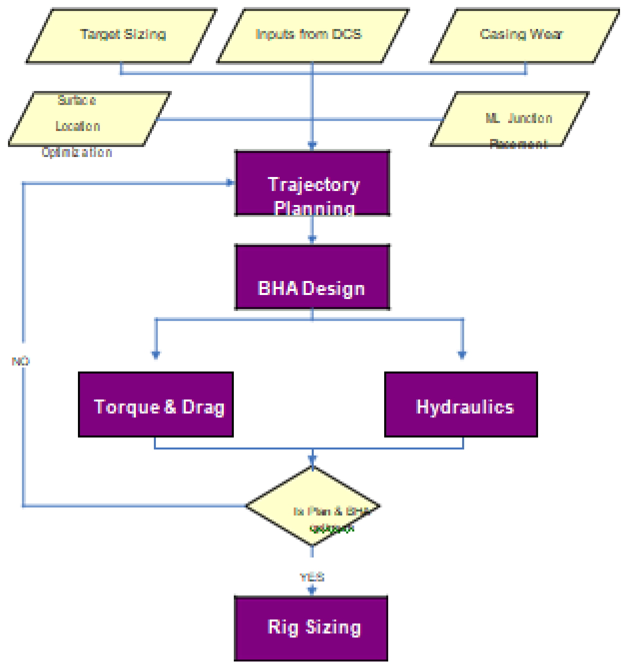

Figure 3: Drilling Engineering Work Flow

The sub processes of the work flow are discussed below.

Trajectory Planning

Surface Location Optimization

Aim

- Find the best surface location to hit all targets with minimum overall footage.
- Optimize well head locations to avoid wells colliding with each other.
- Do not block well paths of future wells.

Solutions provided

- Encouraged RIL to forecast all future well directions and made well plans for not just the current wells but future wells as well. This helped in avoiding any potential collision issues.
- Planned kickoff at different depths to mitigate the risk of collision and maximize the distance between wells.
- It took 67 well plan iterations to finalize the surface location.

Target Sizing

Lateral Uncertainty

The ways to reduce lateral uncertainty to give a bigger drillers target is to

- Resurvey the hole with a tool with better accuracy. For e.g. Gyro in comparison to MWD
- Change MWD tools in between runs to decrease the systematic error associated. This method reduces error however due to rig time involved in changing the tools it may not always be practical
- Run software to reduce drill string magnetic interference if any. For e.g. ORGANISATION uses DMAG software to correct the azimuth error caused by drill string magnetic interference
- Do a local field study that models the declination value, local crustal magnetic field of the area that we are drilling in and corrects the inaccuracies present in global magnetic model. This process is called GMAG etc.

The ways that we applied in MA3H and MA Hypothetical well to reduce the error were

- Gyro Runs to resurvey borehole
- DMAG correction

TVD Uncertainty

The ways to reduce TVD uncertainty to give a bigger drillers target is to

- Run SAG correction – Reduces absolute and relative TVD uncertainty
- Run MCT – High definition Surveys – Reduces relative TVD uncertainty (relative to a known TVD marker)
- Run Smart Depth – A software that takes into account all the expansion/contraction of drill pipe in the drilling conditions present in the borehole and applies depth correction accordingly. – Reduces relative TVD uncertainty (relative to a known TVD marker)

In this project we ran SAG correction. TVD uncertainty predicted after running SAG was 3m at the heel point and

6m at the toe point. To add to the complication, BHI claimed that they had a mechanism to reduce this uncertainty to 3m at the toe. Their method was the application of Survey Tool error model - Dual Inclination. This model has some assumptions which can not be justified and ORGANISATION survey specialists do not believe in using this model.

To explain these assumptions to the client, a presentation by our survey specialists was organized. The first part of the presentation discussed the inaccuracies in the dual inclination model and second part presented another solution to the problem which is MCT- MWD Continuous Trajectory.

This solution entailed removing errors from the continuous surveys from MWD and converting them into definitive surveys and making a high definition survey profile.

It emphasized the need to move away from absolute TVD uncertainty due tool inaccuracy error issues to minimizing TVD error in relative terms. In addition to the positional uncertainly benefits this type of surveying will expose the true wellbore tortuosity.

The image below illustrates how a poor survey interval fails to accurately represent the true well trajectory. Both well paths have identical surveys but arrive at different TVD values.

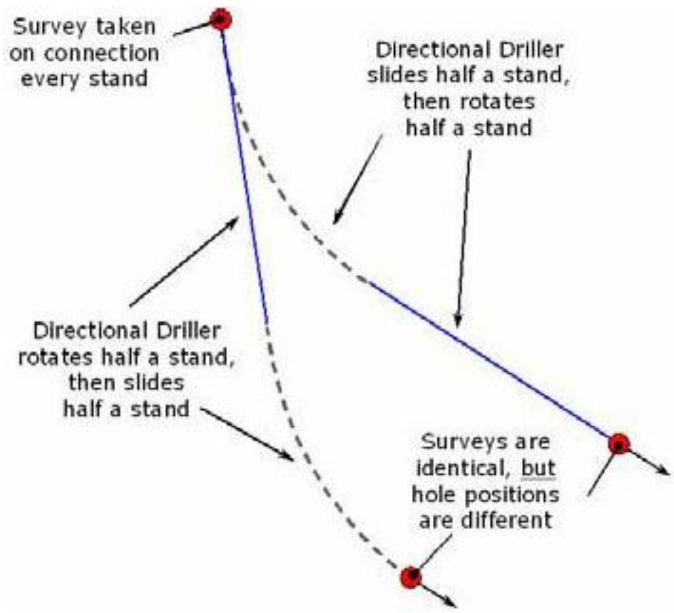

Figure 4: Result of low frequency survey

Through the introduction of this technique, we were able to successfully diffuse the competition threat and generate sell up opportunities.

Inputs from DCS

With the interaction with DCS, numerous inputs were received to make the well profile more optimum find out the risk areas. Some of them are listed below.

- Angle at which the GOC should be cut.
- Worst stress azimuth
- Pore Pressure, Fracture gradient
- Mud weight window.

Casing Wear

One of the tools used to optimize the well plan was casing wear. RIL had planned to drill pilot holes for each hole to identify the Gas oil contact and then a sidetrack was planned from the pilot hole to land the well and drill the drain hole. For Well MA3H there were two scenarios for the well plan as shown below

- Sidetrack Point at 3400m from the pilot hole. The plan required the angle to be built to 70 deg and then dropped to 59 deg to avoid collision with the pilot hole.
- Sidetrack Point at 3100m from the pilot hole. The plan did not require any drop in angle. The only drawback was that it required extra 300m to be drilled.

RIL believed that a drop in inclination in plan 1 as shown in figure below would cause higher torque and side force compared to no drop at all. The torque and drag analysis showed marginal increase in torque for plan 1 as compared to plan 2. To ascertain the effect of side forces on casing damage, a casing wear analysis was done. The analysis showed that in both plans the maximum casing wear was about 6%. Taking these results into account it was decided that it would be advisable to stick to plan1 as it reduces the amount meterage required to be drilled. This was suggested to RIL and the recommendation was accepted. This potentially saved them 130,000 USD which would be the approximate cost of drilling 300m extra.

Plan 1 **Plan 2**

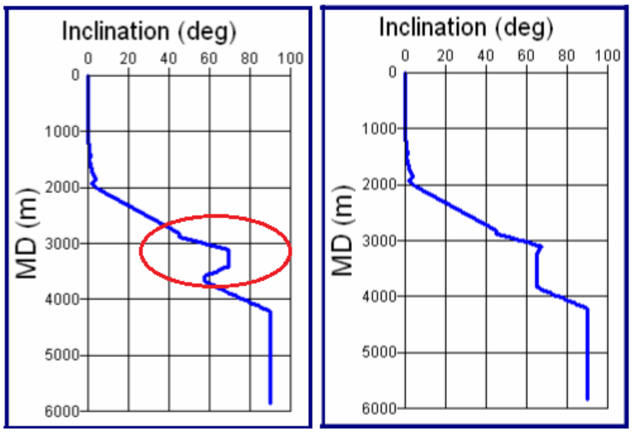

Figure 5: Inclination plot for MA3H Plan 1 & 2

Multi Lateral Junction Placement requirements

RIL had been contemplating running Multi Lateral (ML) junctions and this project came as the right opportunity for that. We gave RIL the idea of running them in this well and reducing their wells from 8 to 6. We incorporated the ORGANISATION ML Junction placement requirements in the well plans. This required modest changes to the well plan, however it assured RIL that they could use ORGANISATION ML junctions in this project as the trajectories have been designed to meet all their requirements.

This has resulted in a request for proposal by RIL which was submitted in November second week.

BHA Design, Torque & Drag and Hydraulics Optimization:

BHA optimization, Torque & Drag (T&D) and Hydraulics analysis are interdependent. A change in BHA affects the engineering analysis and to optimize a BHA we need to run T&D and Hydraulics.

When drilling a well, there are two types of friction losses that cause us special concern:

Torque losses, which are defined as the difference between the torque applied at the rig floor and the torque available at the bit.

Drag losses, which are measured as the difference between the static weight of the drillstring and the tripping weight.

Torque losses are referred to as rotating friction and drag losses as sliding friction. In theory both these types of friction are supposed to be identical, but in practice the uncertainties on surface torque and hookload measurements do not allow a definitive conclusion. T&D is affected by the tortuosity in the well bore and borehole contact area with the drill string that causes friction. For this reason, it is suggested to minimize Heavy weights and Drill collars in high angle sections as it increases the T&D substantially due to high friction generation.

Our aim was to reduce the torque and drag and come up with a optimum BHA that

- Does not buckle while drilling or running in.
- Does not break under the axial, torsional and bending stresses present in the borehole.
- Does not produce too much sideforce that could damage the casing and the tools in the drill string.
- Gives the required BHA tendency.

We use a set of friction factors to determine the T&D for a particular section.

Friction factors represent the resistance against drillstring movement due to its contact with the borehole in rotation, translation (sliding), or both (reaming). The value is between 0 and 1. The Translation friction coefficient is a drag coefficient. It represents the drag resistance to axial movement of the drill string. The rotational friction factor represents the torque. For reaming we use both. The translation friction coefficient is then low

Friction factors depend on mud type (air, foam, oil base, polymer, etc.) and the roughness associated with the surface of different borehole sections (casing, open hole). This determines the level of lubrication. Therefore a well drilled with Oil Based Mud will have lower friction factors than with Water Based Mud (see Slide).

For this field we used 0.2 Friction Factor in cased hole and 0.3 Friction factor in open hole.

Hydraulics

To drill a well safely, successfully, and economically depends upon a thorough understanding of the drilling hydraulics. The mud properties and flow rate need to be optimized to provide adequate hole cleaning and fulfill the hydraulic requirements of the downhole equipment (e.g. motors, MWD and LWD tools, bit nozzles, etc.), while at the same time remaining within the safe operating limits of the equipment and the pore pressure / fracture gradient limits of the formation and formation fluids.

To be able pump more fluid and therefore have better hole cleaning, it is important to large ID pipes in the BHA. In the wells drilled in MA field we see that there is a requirement of 6 5/8" Drill pipe due to pressure limitations of mud pumps.

The BHA is optimized such that it gives us the right balance between hydraulics and torque and drag. For e.g. 6 5/8" DP will improve hydraulics but will also increase torque and drag.

The T&D and Hydraulics modeling was done for the wells to design a optimum BHA.

Bit Comparison

Bit comparison was not in the scope of work but it helped the client understand the issues relating drilling inefficiency on the job. This study enhanced success in the project substantially.

A bit comparison was done for the bits run in MA3H & MA4H 12.25" section. The three bits used were S519EPBX, HCR506ZX and S619EPX

The Bit analysis showed that Bit S519 gave the best ROP of all the bits and was least stable too. This conforms with the basic principle of aggressiveness being inversely proportional to stability.

However, bit HCR 506 and S619 showed an unusual result (See graph below). HCR506 is a less aggressive bit than S619 but it gave better ROP and more stick slip. This leads us to believe the bit performance was not optimized while drilling.

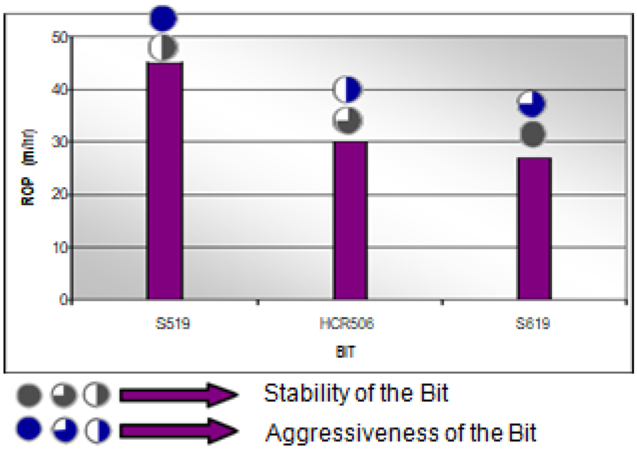

Figure 6: Bit comparison of bits run in MA3H & MA4H well in 12.25in section

It was seen that drilling parameters are more or less unchanged throughout the run (see graph below). It is recommended to vary the drilling parameters to find out the right parameters that best optimize the bit. In the graph below, the green ROP is line is the penetration rate achieved by Bit HCR506 and blue line is the rate achieved by S519. The graph shows that when the RPM for the HCR506 but was changed, its ROP improved. This leads us to believe that the drilling efficiency was not optimized as during the course of the well the drilling parameters were not varied much to arrive at the best drilling parameters combination.

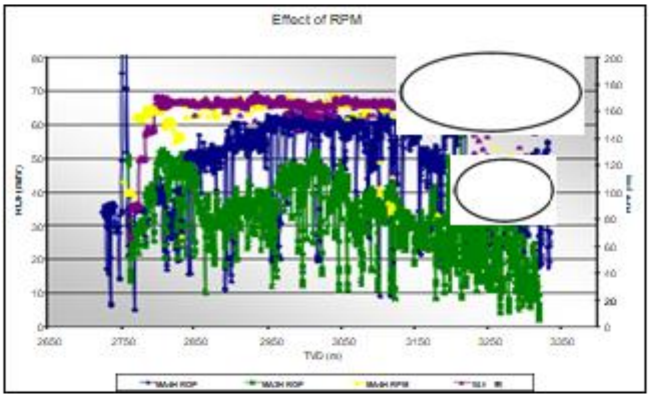

Figure 7: Effect of changing RPM on ROP of the bit

Also it was noticed that during the end of the landing section the ROP became very poor. This could be a good opportunity to run vortex here and maximize the ROP. This suggestion has been given to RIL and they are now actively pursuing us to give them Vortex for 8.5" hole section.

Rig Sizing

RIL wanted to deploy two rigs to drill in this field – Discoverer 534 (D534) and Deep Water Frontier (DWF). They were unsure of the capabilities of these rigs so they asked us to perform a rig sizing analysis for them. All the specifications from the both the rigs were taken and an indepth analysis was done to ascertain if these two rigs would be able to drill the proposed MA well plans.

Rig D534

It was found that Rig D534 would not be able to drill the 17.5 and 12.25 in section due to hole cleaning issues. The rig has three mud pumps out of which one was allocated to boost the riser. The two pumps that were left could go upto a maximum of 100 spm. This limited the flow discharge capability of the mud pumps. To maximize the flow from the mud pumps, there was a need to use big liner sizes which have low pressure limitation.

Another limitation of the rig was that it did not have 6 5/8" drill pipe. There were huge pressure losses predicted with 5"DP in the drill string. The large pump liners would be unable to cope with such stand pipe pressures. Therefore a suggestion was given to them to upgrade their pumps or get more 6 5/8" Drill pipe. RIL has taken the suggestion of ordering 6 5/8" DP and has procured 1100m of it now.

D534 has a maximum draw works hp of 2400HP. At high hookloads this would cause a constraint on the tripping speed. There would be a need to control the tripping speed as the hook load rises. To help them control the tripping speed a simple chart was provided which plots maximum tripping speed vs. hookload (see below).

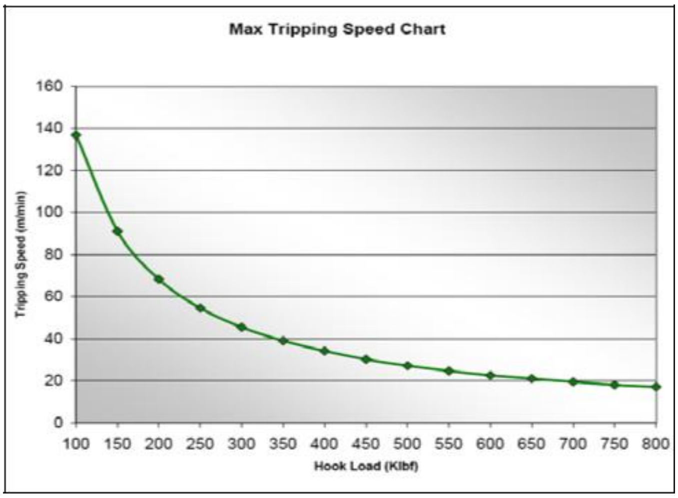

Figure 8: Maximum tripping speed chart

The top drive maximum Hp for Rig D534 is rated to 1100 HP. At high surface torque the RPM of the string would need to be limited to avoid maxing out the Top Drive horse power. To help them control the RPM, a chart similar to the maximum tripping speed chart was provided which plots maximum RPM vs. Surface Torque (see below).

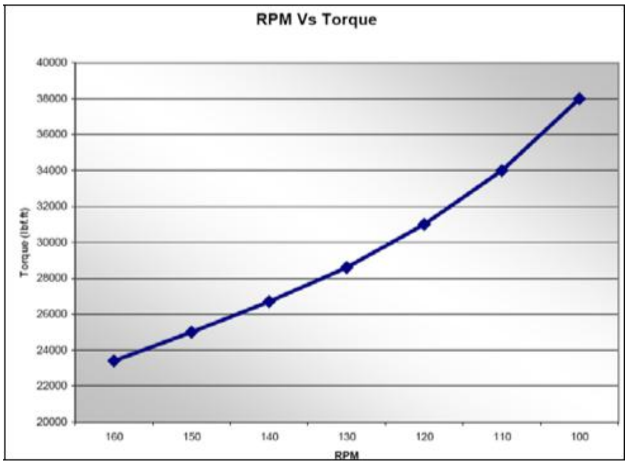

Figure 9: Maximum RPM chart

Rig DWF

It was found that Rig DWF would be able to drill all the sections. The only point of concern was high torque. The torque and drag analysis suggested that 5" Drill pipe will not be able to withstand the torque generated. There was need to have a bigger OD pipe from 3000m to the surface (when bit was at TD). The drill pipe available on the rig was 6 5/8" pipe. However due to the ID restriction below 2600m the 6 5/8" tool joint OD would not be able to pass. Therefore it was suggested to the client that they procure some 5.5" Drill pipe for transition between the 5" and 6 5/8" pipe. To convince the client for the need of the 5.5" DP a single point torque and drag chart was provided. A single point analysis considers the scenario that the bit is at TD and calculates the torque at every point of the drill string. This is the scenario for maximum torque that a component will see during drilling the section. Please the chart below that was provided to the client to convince them for the need of 5.5" DP.

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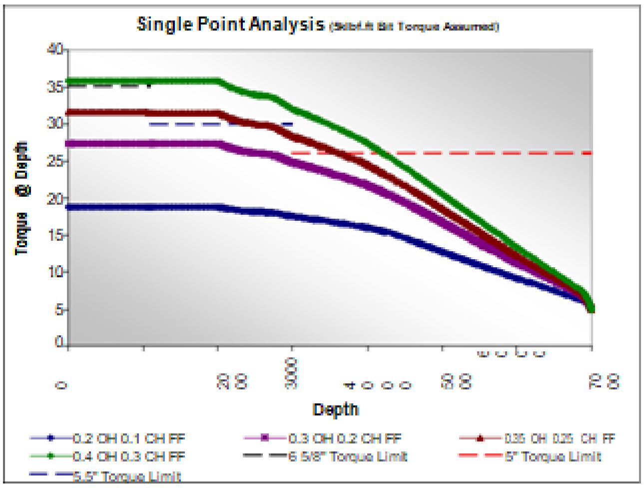

Figure 10: Single point torque and drag analysis at different friction factors

The graph has been made considering different friction factors and the torque generated at those friction factor.

In the legend, OH implies open hole Friction Factor and CH implies cased hole friction factor.

The graph shows that if the friction factor is about 0.2 in Cased hole and 0.3 in Open hole then there will be a requirement to use 5.5" DP or 6 5/8" DP from surface to 3000m. Due to the ID restriction from 2600-3000m it is suggested to use 5.5" pipe there.

If a friction factor of 0.25 in Cased hole and 0.35 in Open hole is seen, then there will be a requirement to use 6 5/8" DP from surface to 3000m. In that case the 9 5/8" liner will have to set lower than 2600m. There will be a further requirement of 5.5" pipe from 3000 till 3600m.

On the basis of the above analysis, we recommended to the client to procure 5.5" pipe as it has higher torque capacity. They have taken our suggestion and are in process of procuring the 5.5" pipe.

Project Deliverables

1) A feasibility study for KG-D6-MA1 Field Included – From DCS

- Post Drill Mechanical Earth Model for the two offset wells.
- Initial Pre-Drill Mechanical Earth Model for the first two wells.
- Geological Risk Analysis.

2) From DE
Well Planning for the feasibility study
- Well Trajectory Design
- BHA Design for the two most difficult wells.
- Design and Planning Summary Report.
- Technical recommendation for the tools to be used.

Value to organization
The value to Organization will be:
1) Partner with RIL in their most important Project. WIN – WIN
2) Client recognition of our Multi-disciplinary expertise.
3) Competition opportunity negated and ORGANISATION opportunity created. MCT, DMAG, SAG – 0.6M USD
4) Potential pull-throughs.

Value to Client
The value to the client will be:
1) Time to production reduced.
2) Reduction in rig move time and cost between wells by 90%. Initial rig move cost was 6M USD. It came down to 634K.
3) Improved flow assurance of the hydrocarbon. Due to low subsea temperature the following problems occur
   - Solidification of oil
   - Formation of Gas hydrates
   - Internal waxing of the subsea umbilical cords

   With shorter pipeline all these problems can be countered. This is an intangible benefit and was the biggest concern for RIL
4) Reduction in the completion costs by using shorter pipelines. The original length of the pipeline was estimated to be 5500m. The pipeline meterage was reduced to 1100m, a reduction of 80%.
5) Elimination of 2 top hole sections with Multi Laterals. Approximately 6.4Million USD would saved by this.
6) Additional cost savings through recommendations.
7) **Aggregation and Visualization**: Seamlessly integrate rig-based data and stream to WITSML viewers and applications
8) **Advanced Drilling Analytics:** With advisory that will support automated predictive interpretation of drilling data to identify risks and mitigate them while drilling to transform overall drilling performance
9) **Operational Efficiency:** Benchmark and monitor KPIs for identification of lost time issues and continuous improvement through diagnosis and remedial measures
10) **Domain Expertise:** Drilling, geoscience etc. experts to transform workflows with intervention and advisory support, while also supporting capability development and addressing capacity stretch.
11) **Common shared environment**: Where both experts (drilling, geoscience etc.) and stakeholders (management) can collaborate to make critical decisions on time. The web-based environment can be accessed from anywhere with tablet, mobile, laptop etc.

Personal Contribution
My contributions to this project have been in multiple roles such as Drilling Engineering, helping the sales team and coordinating the project.
1) Identify the opportunity
2) Convert the opportunity into award of work by
- Participated in the brainstorming session
- Worked on the technical proposal

3) Manage the multidisciplinary team
   - Client Interface.
   - Ensured quality and timeliness of the project delivery from various domain experts.
   - Led the weekly progress meetings.

- Optimized the Well Trajectory design and BHA Design and carried out the Rig Sizing Analysis
- Liaised with Multilateral experts to ensure the trajectories are suitable to place ML junctions.

4) Identified numerous sell up opportunities for Organization.

Acknowledgements

- Ravindra Kumar Jain, HOD - Energy SGVU.
- Mukesh Kumar Gupta, Energy. SGVU
- Somesh Bahuguna – Well bore stability advisor for the project.

3. List of recommendations given:

In the table below all the recommendations are listed. The acceptance of these recommendations is indicated by Y for Yes, N for No or O for Open for discussion

Sno	Recommendation	
1	Move well heads closer and use a common subsea choke manifold.	Y
2	Drill Multilaterals and reduce the no of wells from 8 to 6.	Y
3	Plan all wells to be drilled in the field in the beginning to avoid collision risk	Y
4	Use Sag correction for inclination correction and DMAG correction for azimuth correction. Additionally reduce the relative TVD uncertainty by having a high definition survey through MCT (MWD Continuous Trajectory)	Y
5	Sidetrack the MA3H mainhole from 3400m instead of 3100m as it would reduce the extra 300m drilling. This was confirmed by running casing wear analysis on both plans which gave the same result.	Y
6	Eliminate drilling Pilot Holes. As the Gas oil contact can not be identified accurately from the pilot hole, they could avoid drilling the pilot hole and instead use our well placement tools to place the well in right place.	O
7	Acquire 5.5” drill pipe for DWF as they are able to withstand more torque than 5” DP.	Y
8	Acquire 6 5/8” drill pipe for D534 as they less pressure drop and reduce the stand pipe pressure in comparison t o 5” DP.	Y
9	Provided a chart for D534 that would help the driller control the tripping speed and high hookloads to avoid crossing the draw works maximum horse power	Y
10	Provided a chart for D534 that would help the driller control the RPM and at high surface torque to avoid crossing the top drive maximum horse power	Y
11	Recommended Vortex to achieve higher ROP	Y