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The Method of Reducing Drilling Costs More Than 50 Percent

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Abstract

This paper shows how using the Drilling Optimization Simulator (DROPS) has been applied in the planning phase of two North Sea wells. Both the 12.25" and the 8.5" sections were optimized on Well #1 and the 12.25" section was optimized on Well #2. Geological Drilling Logs¹ (GDLs) were generated from offset drilling data in the same field for both the two wells. Both wells with the different hole sections were simulated with the available bit types and designs. The optimum bit selection and the drilling parameters every meter for the hole-sections were optimized. The hydraulic limitations of the pump and the planned mud weight program were used to optimize the bit hydraulics in conjunction with the bit operating parameters, different pull depths and bit designs.

The 12.25" sections showed savings potential of 72.4 percent on Well #1 compared to the last well drilled in the field. This included optimizing bit type, hydraulics, operating parameters and pull depths. Well #2 showed savings potential of 15 percent using oil based mud and 20 percent using water based mud compared to the two other wells drilled previously in the field with oil and water based mud respectively. It was concluded that Well

#1 could save \$ 1.3 million, while Well #2 was originally drilled close to optimum and only showed a potential savings of \$ 0.3 million when using optimum drilling parameters.

The optimization of the 8.5" section was more complex because of several coring intervals. The five full hole sections between the coring intervals were optimized. The five subsections were drilled through formations of different length and lithology. The bit designs, pull depths, number of bits, hydraulics and operating conditions were optimized for each section. In addition to optimization of the drilling parameters, simulations for reuse of bits were conducted to further cut the drilling costs. The cost savings on the 8.5" section for well#1 showed a maximum potential for saving varying from 23.4 to 78.8 percent for the different sections.

From the simulations it can be concluded that the optimum drilling scenario of the 12.25" and 8.5" full hole sections for well #1 would reduce the drilling cost with more than \$ 4.5 million.

Introduction

DROPS was used to optimize the drilling of both the 12.25" and 8.5" section of Well #1, and the 12.25" section on Well #2. Previously, DROPS had been used for drilling optimization and planning of other wells in the area of Well #1. This was the first time DROPS was applied for the 8.5" section as on Well #1. The GDL for the well was created from drilling data available for a previously drilled well in the same area².

The optimization of the 12.25" and the 8.5" section for Well #1 was for simplicity conducted in two separate operations.

The 12.25" section on Well #1 was to be drilled with full hole bits. This implies that only the optimum operating parameters, drilling bits, hydraulics and pull depths had to be found. The possibility of drilling the entire section with only one bit was also checked for.

Several coring intervals were planned for the 8.5" section on Well #1. Each full hole 8.5" section was to be drilled on relatively short intervals (varying from 35 – 220 m) between the coring sections. In addition to the standard optimization the reuse of previously used bit was also investigated. Each drilling section had to be optimized separately, and the cost savings percent reduction were calculated comparing the optimized results with the initial drill behind² result for that section.

Optimizing the 12.25" Sections

The optimization of the 12.25" drilling sections is a relatively straightforward procedure using DROPS. Field data from previously drilled wells in the two fields were used to generate the GDLs (Fig. 1-2). Simulations for different drilling scenarios were conducted to find the optimum drilling for each bit. Due to relatively high rig rates³ (185,000 \$/day) rotating time is the major contributor to the costs. The simulations of the 12.25" sections were therefore conducted with an emphasis on finding bits with high wear resistance, while maintaining a high ROP. It was possible to drill both 12,25" sections with only one bit. The simulation learning curve obtained using one bit for Well #1 is plotted in Fig. 3. Simulations for multiple bits were also conducted on Well #1, and the simulation learning curve for multiple bits on the 12,25" section of Well #1 is plotted in Fig. 4.

The GDL generated for Well #2 used the actual survey of the offset well and converted it to a TVD based GDL. The 12,25" section for the new planned well was to drill vertically about 300 meter and then kick off and build to about a 40 degree angle. After the 40 degree angle was held about 400 meter the well was to drop back to vertical. The planned directional survey for the well was input into DROPS which allows for drilling of any survey through different TVD based GDLs. Well # 2 was optimized using the available 12,25" bits

types. It was found that the well used to generate the GDL had used the optimum bit design.

The use of both oil and water based muds were also investigated and compared. Data existed from wells drilled in the area using both oil and water based muds. The optimization of this section was done using different bits, water and oil base mud, hydraulics and operating parameters.

Results for the 12.25" Sections

The drilling simulation using one bit for the entire 12.25" section of well # 1 shows a relatively high verity in optimum performance for the available bits (Table. 1). The ranking of the bits was done solely based on cost per meter. The optimum result from the optimization shows a cost reduction of 72.2 % compared to the drill behind well.

The five best results using two bits for well # 1 are reported in Table 2. The results from the optimization of multiple bits gave relatively the same cost reduction as for using a single bit. The best results indicate a total savings potential of 72.4 percent.

The simulations conducted on well # 2 proved that the previous well in this area was drilled with the correct bit selection and close to optimum operating parameters. A reduction of the RPM through the weaker formations in the upper section would provide more gage cutter life for the harder formations further into the bit run. The increase of cutter volume to spend through the harder formation towards the end of the bit run would give a higher average ROP. The optimum cost results for all bits simulated for Well # 2 are plotted in Fig. 5 for both oil and water based mud. It can also be seen that there is a relatively large difference in the use of oil versus water based mud systems. This mud system performance difference is accounted for in DROPS. It should be emphasized that the \$/m results did not include that mud system cost in this analysis. The use of oil based mud will drill the 12,25" section with larger savings excluding the mud costs. Including the mud costs the results are closer, but still with the oil outperforming the water based mud. The drill behind cost from two well drilled previously in the area where the oil based results were used to generate the GDL are plotted on the

last bar graph.

Conclusions for 12.25" Sections

The optimization of well #1 using DROPS is estimating a possible cost reduction on the next well of 72.4 percent compared to the drill behind result from the last well drilled in the area. The relatively same cost reduction can be obtained whether using a single bit, or two bits. It is therefore recommended to use a combination of two bits for the 12.25" section, since two bits will provide more flexibility and safety against possible unforeseen problems like, broken cutters, damage or readjustment to BHA or extended length of estimated drilling depth. Well # 2 has a relatively overall lower rock strength than well # 1, and one bit will therefore be able to drill the entire section with a satisfactory margin of safety. Drilling the entire 12.25" section of well # 2 with one bit will also give the best economics as was done on the previous well. The optimum results give a cost reduction of about 15 percent due to better hydraulics and better selection of the operating parameters for oil based mud. For water based mud the possible savings are about 20 percent compared to the last well drilled in the field with water based mud.

Optimizing the 8.5" Sections

Data was collected from a previously drilled well in the same area to create the GDL for the 8.5" section of Well #1. The GDL created for the entire 8.5" section is shown in Fig. 6, where the five full hole drilling sections are labeled from A to E.

Two sections with incomplete data (4500 – 4600m and 4700 – 4750m) had to be completed using average values to obtain a continuous GDL. The average of the data used to complete the GDL was obtained using the 10 meters before and after each incomplete section. The current well was planned to reach a TVD of 5500 meters, and the well used to create the GDL had a total depth of 5260 meters TVD. 240 meters of average values had therefore to be added at the end of the 8.5" section.

The optimization of the 8.5" production section was more complex than the 12.25" sections, because of several coring sections planned between each full

hole drilling section. The full hole sections all had to be optimized separately and each section varied in both length and lithology composition. The length varied from 35 to 220 meters and the lithology changed between claystone to sandstone.

The optimum drilling parameters were found using both a single and multiple bits for the longer sections. The shorter drilling sections were checked for the possibility of reuse of a previously used bit. After several simulations a learning curve was obtained for each subsection, and therefrom the optimum scenarios found.

Results for the 8.5" Section

The arrows in Fig. 6 indicate the sections that were optimized. Section A was a relatively long section (130 m), and it was found most cost effective to use only one bit. The optimum performance was nearly the same for the bits simulated, and the estimated wear out varied from 4.7 to 5.0. From the bit recommendations it can be seen in Table 3. The maximum possible savings for this section are 78.8 percent compared to the last well drilled.

Section B and C were both short sections, and the most cost-effective solution was to reuse the bit used in section B in section C. The bit wear out from section B varied between 1.8 and 2.0 for the different bits in order to obtain the best overall performance. The most cost-effective combination of drilling parameters was found for both sections. The total bit wear out varied from 5.1 to 5.4 for the bits tested. The bit recommendation for section B and C is presented in Table 4 and shows a possible 38.3 percent reduction in drilling costs.

The drilling of section D had to penetrate a 100m thick sandstone formation followed by a 15m shale formation. Using one bit for this entire subsection was found to be the most cost effective solution. The bit recommendation for section D is shown in Table 5, which resulted in possible savings of 23.4 percent.

Section E with a total length of 220m had to penetrate two different formations. The first formation was a 130m thick sandstone formation, and the second formation was a 90m thick shale formation. This was the longest full hole section to be optimized. The best result for drilling the entire

section E with only one bit gave an estimated bit wear out as high as 6.9. The recommendation for drilling section E with a single bit is shown in **Table 6**. Using a combination of two bits for section E it was possible to cut the costs by 29.4 % compared to the best result for one bit (**Table 5**).

Conclusions for the 8.5" Section

Section A should be drilled using only one bit for the entire section. The simulation indicated that all the bits tested would be able to penetrate the whole section with a good factor of safety. The differences in performance for the bits tested were relatively small, but bit A came out with the lowest cost and wear out.

The bit used in section B should be reused in section C to obtain the best result. All the bits were run at close to maximum parameters in both sections during the simulations, and the bit wear out still had an acceptable factor of safety.

The entire section D should be drilled with one bit. All the bits simulated were run at high WOB, but the RPM was kept relatively low to prevent the bits to come out under-gauge. Bit H showed the best performance for this section.

Section E can be drilled with one bit, but it is most preferable to use two bits. A combination of two bits for this section will provide much better economics and factor of safety. The results from the simulations indicates that any combination of the available bits would cut the costs by 29.4 % compared to the best result using one bit.

Final Conclusions

1. DROPS makes it possible to evaluate the combination of bits and drilling parameters in a relatively short time.
2. The optimization of the 12.25" section of Well # 1 showed possible drilling cost reductions of 72.4 percent on future wells in this area.
3. The full hole sections of the 8.5" section showed a potential for large savings. The optimization of subsection A–D showed a cost reduction potential varying from 23.4 to 78.8 percent compared to the last well drilled in the area.
4. The optimization of section E is not included

in the cost calculation because this section was not drilled on the well used to generate the GDL.

5. It is highly recommended that data from a complete and extensive database be used for the creation of GDLs and it is also recommended that multiple wells are used as references for the GDL creation, in order to make it as accurate as possible.
6. The potential saving of more than \$ 4.5 million was seen on well #1 including both the 12,25" and the 8,5". This does not include the 8.5" E section and the coring intervals.
7. The 12,25" section drilled on Well # 2 shows that the previously drilled well used the optimum bit selection. A 15 and 20 percent cost reduction could be obtained by improving the hydraulics and operating parameter selection for oil and water based mud respectively.
8. DROPS showed directly the effect of drilling mud type (oil versus water) on drilling cost.

Acknowledgements

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References

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Bit	Cost \$/m	Wear out	% Cost reduction
A	473.6	6.5	72.2
B	482.6	5.8	71.7
C	540.0	7.2	68.3
D	552.8	6.1	67.6
E	635.8	6.1	62.7

Table 1. Results for single bit 12.25" section.

Bit	Cost \$/m	Wear out	% Cost reduction
H	3739.0	5.7	23.4
F	3796.2	5.6	22.2
G	3872.9	5.7	20.6
I	4022.9	5.8	17.6
J	4109.5	5.2	15.8

Table 5. Results for section D, 8.5".

Bit Combination	Cost \$/m	% Cost reduction
A – B	469	72.4
B – A	473	72.2
A – A	474	72.1
B – C	484	71.5
E – B	489	71.2

Table 2. Best results for multiple bits 12.25" section

Bit	Cost \$/m	Wear out	% Cost reduction
F	8000	6.7	N/A
H	8045	6.7	N/A
G	8227	6.7	N/A
J	8818	6.7	N/A
I	8955	6.9	N/A

Table 6. Results for single bit section E, 8.5".

Bit	Cost \$/m	Wear out	% Cost reduction
F	4512.1	4.7	78.8
G	4584.2	4.7	78.4
H	4587.4	4.7	78.4
I	4742.5	5.0	77.7
j	4961.8	4.7	76.6

Table 3. Results for section A, 8.5".

Bit Combination	Cost \$/m	% Cost reduction
H – H	6182	N/A
H – F	6182	N/A
F – F	6182	N/A
I – H	6409	N/A
H – J	6455	N/A
I – I	6727	N/A

Table 7. Results for multiple bits section E, 8.5".

Bit	Cost \$/m	Wear out	% Cost reduction
H	6690.1	5.3	38.3
F	6816.3	5.2	37.2
G	6881.7	5.4	36.6
I	7042.6	5.4	35.1
J	7229.4	5.1	33.4

Table 4. Results for section B and C, 8.5".

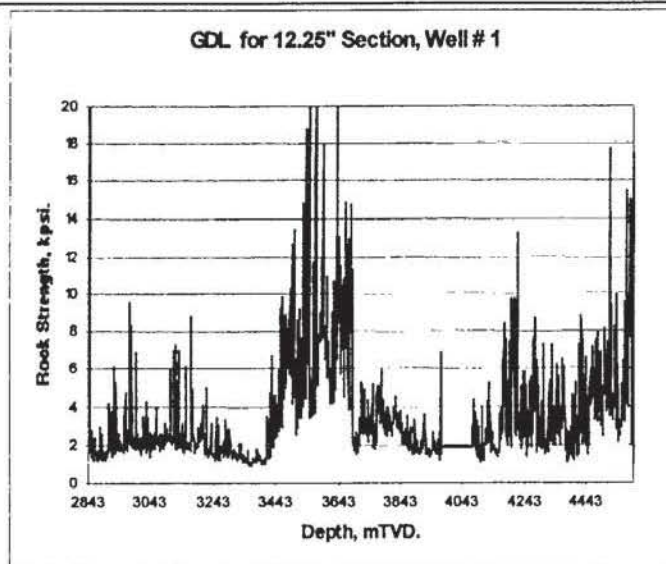


Figure 1. GDL for 12.25" Section Well #1.

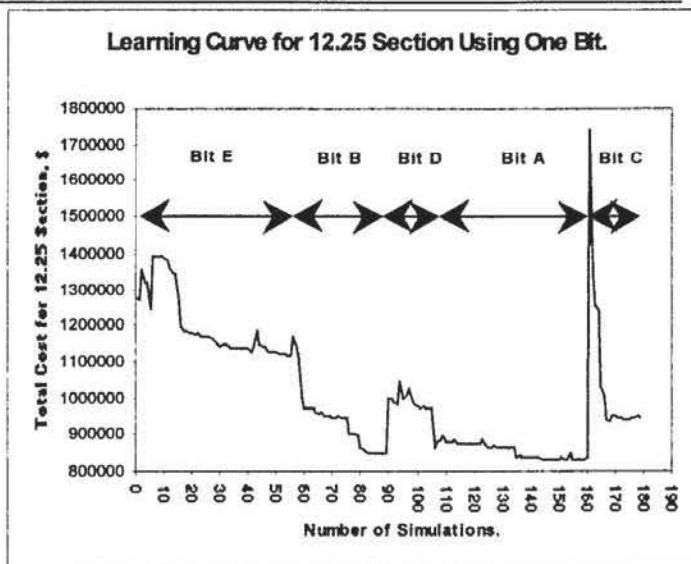


Figure 3. Learning Curve for Single Bit 12.25" Section.

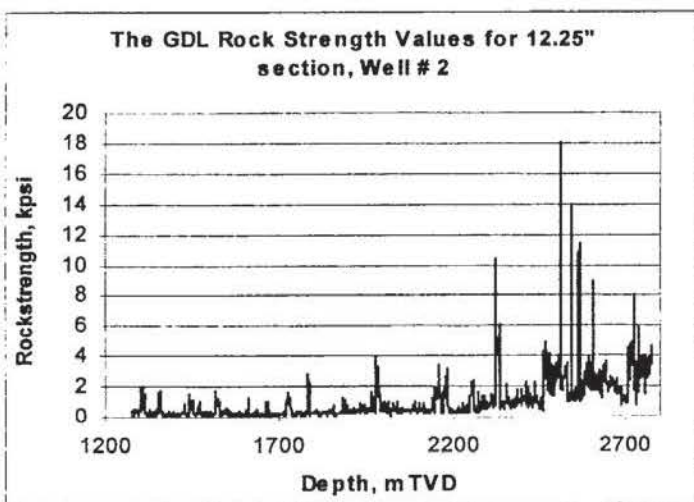


Figure 2. GDL for 12.25" section Well #2.

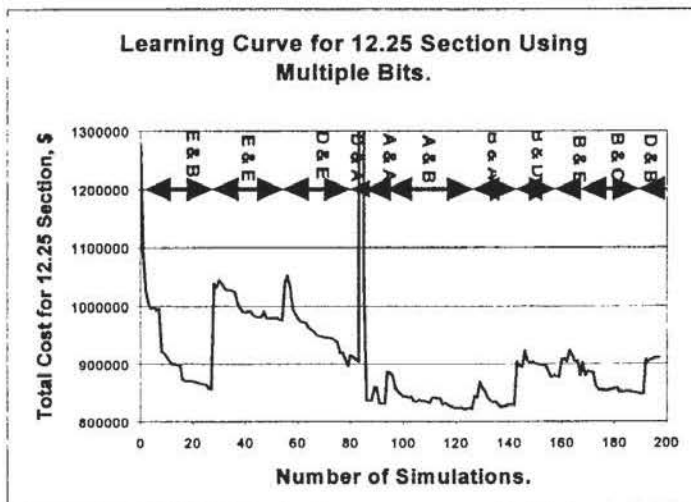


Figure 4. Learning Curve for Multiple Bits 12.25" Section.

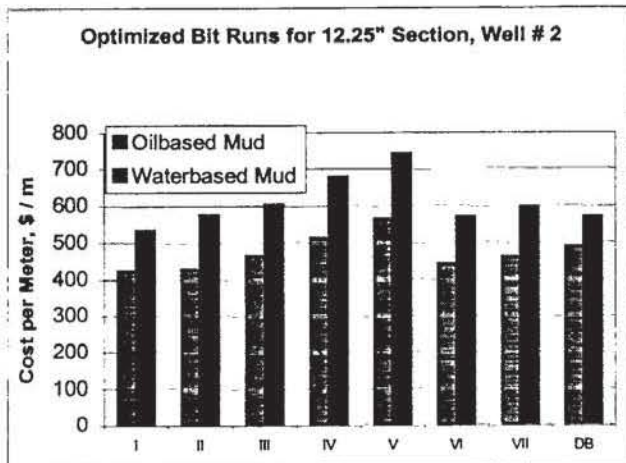


Figure 5. Optimum costs compared with the drill behind for Well #2.

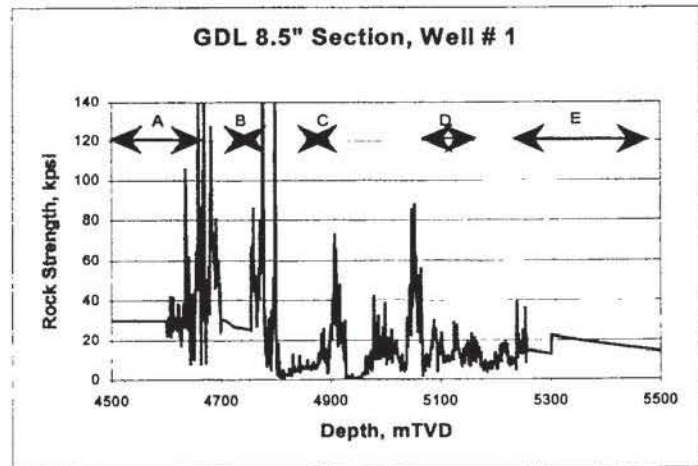


Figure 6. GDL for the 8.5" section Well #1