



## Economic Evaluation of Specialist Bit Optimization Engineering in North Sea Exploration Drilling

B. Bjelland, Norsk Hydro ASA, and P. Casey, Smith International, Inc.

Copyright 2003 AADE Technical Conference

This paper was prepared for presentation at the AADE 2003 National Technology Conference "Practical Solutions for Drilling Challenges", held at the Radisson Astrodome Houston, Texas, April 1 - 3, 2003 in Houston, Texas. This conference was hosted by the Houston Chapter of the American Association of Drilling Engineers. The information presented in this paper does not reflect any position, claim or endorsement made or implied by the American Association of Drilling Engineers, their officers or members. Questions concerning the content of this paper should be directed to the individuals listed as author/s of this work.

### Abstract

The increased use of specialist engineering services in the application and optimization of drilling bits results in operator cost savings and continually encourages research that will find new ways to lower future costs. Despite tangible benefits, specialist engineering services are not yet widely accepted.

This paper uses case histories from twelve exploration wells and one sidetrack from the Norwegian Sector of the North Sea to describe the benefits realized from three operational areas from which cost savings are commonly sought:

1. The efficient re use of used bits and rebuilt bits.
2. Savings realizable through more efficient use of bits and hole openers, and;
3. Prospective savings resulting from savings in drilling time.

Existing offset wells were used to establish bit and hole opener AFEs and performance benchmarks. The cost of engineering services was incorporated into this evaluation. Offsets were also the basis for estimates of drilling time required for each well and as benchmarks in each exploration area.

### Introduction

The correct selection and utilization of drill bits has a major influence on drilling cost. While a bit, itself, represents a small increment of total drilling cost, the bit's productivity and its interrelationship with rig capability, bottom hole assembly, mud, and the formation being drilled significantly influence overall economic results. *Advanced Services Engineering*, a specialist engineering service, contributes to drilling cost reduction by providing special focus on drill bits and factors affecting their performance. The discipline is driven by in-depth evaluation of the drilling environment as it affects bit drilling efficiency. A comprehensive well plan is formulated, performance during the drilling phase is evaluated, and a post well analysis on each project well is completed for use both for measurement of the success of the plan and as reference for future development wells.

In the fall of 2000, Norsk Hydro established an objective to reduce exploration well costs by employing specialist engineering services. A specialist engineering services project was established in 2000 and given the mandate to drill as cost effectively as possible in designated offshore exploration blocks. The project continued until exploration drilling was suspended in 2002.

The effectiveness of specialist engineering services was to be evaluated based on direct material cost savings and indirect savings made as a result of improvements in drilling efficiency.

Direct cost savings were based on incremental savings achieved in two ways.

1. By re use of used bits in applications in which this practice would be economic but would neither compromise bit performance nor increase risk of premature tool failure.
2. By use of bits not suitable for re-use but in good enough condition to justify rebuild. Again, the practice was employed only in circumstances in which rebuilt bits were unlikely to compromise bit performance or result in premature tool failure.

Indirect savings were quantified by comparing:

1. Actual cost of bits, hole openers, and specialist engineering services to budget, and,
2. Actual drilling days to planned drilling days on a per well basis.

### Specialist Services Process

The concept of specialist engineering services was introduced to Norsk Hydro in 1996 and was therefore not new when the work described in this paper was initiated. Specific services acquired, and the sequence in which they are delivered are outlined by Figure 9. The process basically has three phases, Application Analysis, Development of Operational Synergy, and Post-Operational Review and Development of the Experience Base.

These are described below based on 12 exploration wells and one offset in the Norwegian Sector of the North Sea to describe the benefits realized from three operational areas from which cost savings were sought:

1. The efficient re use of used bits and rebuilt bits.
2. Savings realizable through more efficient use of bits and hole openers, and;
3. Prospective savings resulting from savings in drilling time.

Existing offset wells were used to establish bit and hole opener AFEs and performance benchmarks. The cost of engineering services was incorporated into this evaluation. Offsets were also the basis for estimates of drilling time required for each well and as benchmarks in each exploration area.

### Application Analysis

**Upon project initiation, the drilling team outlined systems (e.g. the Well Construction Group) and subsystems (e.g. the Hole Placement Team) to be used. This drilling team is an organization designed by the team members to ensure integration and equally weighted consideration of each planning facet for complex wells.**

The team defines well options, (i.e. drill a well from a semi-submersible rig to target X,Y,Z). With well options defined, the specialist engineer makes offset analyses for each of the well options to verify the feasibility of drilling the proposed well efficiently. The Drilling Team then makes final well option decisions.

At this point, the specialist engineer begins definition of application objectives (e.g. shoe-2-shoe section drilling etc.). These are based on analysis of well and pertinent offset data for each section. Offset performance, evaluation and processing of offset electric logs and mud logs are carried out by the specialist engineer to generate rock strength logs and offset parameter logs for offset wells. (Figures 1 and 2 provide examples of rock strength analyses). These assist bit type selection based on formation characteristics. The offset parameter logs are used to analyse the parameters used on offset wells, correlate these parameters to rock strength and help identify optimum drilling parameters for the proposed well to be drilled. (Figure 3 shows an offset parameter log). These analyses are used to develop a drilling performance database for the planned well. This specialist engineering sub-process ensures that selected top performing products are applied in the correct application within the well operation.

With a final draft, Drilling Performance Plan, (See Figure 4.); the specialist engineer confers with the drilling team for a *Peer Review*. Dialog from this review may lead to

redefinition of objectives and / or changes in the plan. Only when the complete team "buys into the plan" is it approved and finalized for operational use.

As each bit run is completed, the specialist engineering team up-loads available e-log and drilling information to the rock strength logs and offset parameter log analysis system for post/pre-well analysis. The rock strength logs and offset parameter log analysis system provides the specialist engineering team with a multi-disciplined approach to characterizing the drilling environment. With E-log input, the system first determines optimum cutting structure, hydraulic requirements, gage protection, and other bit design features necessary to optimally drill encountered formations in the lithological reconstruction of the drilled stratigraphic section. When available data have been uploaded, the lithology column built, and unconfined rock compressive strengths calculated, offset well data can be divided into sections, or drillability intervals, based on like rock mechanical units, (often incorporating several geological units), or lithologic units for continued formation analysis. The specialist engineering team statistically evaluates key parameters for each Drillability Interval. Sand / shale content combined with rock strength contribute to the model's determination of formation abrasiveness (sands) / stickiness (shale). Graphical outputs provide qualitative risk assessment of each planned bit run, in addition to a predictive geohazard tool, (See Figures 1 and 2.).

The post-well-analysis package allows the specialist engineer team to correlate drilling parameters applied to bit-BHA to be assessed in conjunction with the geological reconstruction for the well. By determining drilling parameters that have the largest effect on ROP, the team isolates their influence on other system components and proposes processes by which to further optimize the drilling system.

Optimized drilling parameters, high performance drilling bit-BHA systems, intimate application knowledge, combined with scenario planned contingencies for unscheduled events allow an iterative learning process from well to well to develop within the drilling team.

### Development of Operational Synergy (Syn-operations)

The specialist engineer in coordination with the drilling and logistics team is responsible for ensuring the proper primary bits and contingency bits are on site at the appropriate time in the drilling sequence and that the necessary ancillary equipment such as nozzles, bit breakers and ring gages are also on site for use with the bit. The specialist engineer is also responsible for making sure that the drilling bits are compatible with the planned rotary drive systems.

As mentioned above, execution of the specialist engineering *Drilling Performance Plan* during drilling

operations relies on unreserved buy-in by the entire drilling team. Development of synergy between the rig crew and the planning-support team is seen as critical. Thus, the *Planner Specialist Engineer* must also see himself / herself, and be seen, as the *Rigsite Specialist Engineer*. This ensures effective communication of the drilling performance plan to the rig crew by the engineer who analyzed, formulated and drew up the execution plan. In addition, a specialist engineer's drilling experience favorably contributes to quick identification of potential problems and appropriate actions by which they can be mitigated.

Bit selection is governed by the planning process and the rig decision trees developed from that process, (See Figure 5.). A selected bit is checked, dressed and gaged at rig site prior to make-up using correct M/U torque.

During RIH, the specialist engineer assists the driller in identifying bit-hazards and precautionary measures needed to safely negotiate them. Carefully tagging bottom and drilling ahead can be combined with active drill-off testing to provide mechanical formation data for future wells. The specialist engineer carefully monitors operating parameters and bit-BHA response to optimize the drilling system for speed and longevity. If appropriate, the specialist engineer initiates changes in drilling parameters to mitigate unwanted drilling events (e.g. Bit-BHA vibration).

As a run approaches its terminators, (planned or unplanned), the specialist engineer must be on site to assess and advise as to the validity of the "pull" in terms of overall performance. This ensures against unnecessary "bit trips" and prevents wasted rig time. Trips to surface can then be used to assess problematic zones to further enhance knowledge and application appreciation by the specialist team.

### **Post-Operational Review and Development of the Experience Base**

The specialist engineer conducts a post well analysis to correlate drilling parameters applied to the bit-BHA with a geological reconstruction for the well. He / she determines drilling parameters that have the biggest effect on ROP, isolate their effect on other system components and propose processes by which to further optimize the drilling system. Post well evaluation of actual versus planned performance and comparison to benchmarks is carried out along with a rationalisation of any changes in performance. Subsequent learnings are documented and incorporated into the optimisation process for subsequent wells.

The specialist engineer also ascertains the effects of unplanned events that occurred and re-analyzes contingency planning for each specific unplanned event. Furthermore, appropriate decision trees will be drafted to counter the effects of the reoccurrence of an unplanned event.

Specialist engineers have the responsibility to coordinate the retrieval of used / dull bits from the rig. These bits are then inspected and their potentials for re use or rebuild assessed. Preferably, the evaluation of used / dull bits is carried out in conjunction with drill bit suppliers so as to evaluate the prospect of improvement in bit performance through the use of improved materials and designs.

### **Actual Study and Methodology –vs- Evaluation of Direct Cost Savings**

Direct cost savings were evaluated and are summarized using case histories for twelve, sequentially drilled wells and one sidetrack. The summary details bits used for the well, color coded to indicate use of new, re run, or rebuilt bits. Savings resulting from re used and rebuilt bits are indicated in the summary. The summary also describes how often particular bits were reused. As a result of this methodology, a reduction in bit expenditure in excess of \$1,459,000 USD for the over twelve wells and the side-track was realized. (See Figure 6: *Exploration Bits Usage Report with Value Saved 2000 – 2002.*)

In order to minimize or eliminate prospects for either compromise in bit performance or premature tool failure, each previously run bit was inspected by the specialist engineer for wear and defects prior to reuse, or in the case of rebuilt bits as an element of the rework process. The specialist engineer has responsibility for the logistics of retrieval and inspection of used bits. In cases in which used bits were deemed suitable for rebuild and redeployment, the specialist engineer, in coordination with the drilling team, evaluated the economics of each case and coordinated the logistics of this process with drill bit suppliers.

A premature failure of one rebuilt bit led to an unscheduled bit trip and necessitated use of a new bit to TD the well. Use of rebuilt bits was subsequently discouraged for applications in which long bit trips were involved as the cost of risk exceeded potential for savings.

As part of the specialized engineering management process, remanufacturing processes utilized for bit rebuild were evaluated. These processes can fundamentally alter material properties and compromise bit integrity. Great care must be taken with rebuilding and

deployment of rebuilt bits.

### Evaluation of Indirect Cost Savings:

Indirect cost savings were evaluated, by well, using a combined histogram and spreadsheet format from which AFE cost for bits and hole openers and specialist engineering services were compared to actual cost. As specialist engineering services had not been budgeted, the cost of specialist engineering services was set against savings realized from improvements in bit and hole opener efficiency. Overall specialist engineering cost and bit and hole opener cost were presented separately to show their proportional costs.

Overall project budget for bits and hole openers was \$3,610,000 USD. Actual expenditure was \$2,745,000 USD, (rounded). This amounted to a saving of \$865,000 USD, (rounded), after deduction of specialist engineering services. 93% of total expenditure was attributable to drillbits and hole openers, 7% to specialist engineering services. (See Figure 7: *Exploration Actual Bit, Hole Opener, and Services Cost Versus AFE 2000 - 2002.*)

A second means of quantifying indirect savings compared AFE budget for drilling days, by well, to actual drilling days. (Drilling days are classified as days exclusively spent drilling to the exclusion of all other non drilling activities or "flat time.") This evaluation also utilized a histogram / spreadsheet format.

Actual drilling days were color coded against AFE drilling days and a second histogram used to illustrate days saved. Against an AFE plan for 166 days, 99 days drilling days were used in this drilling campaign which translated to a 59% reduction in actual versus planned drilling days. Rig rate was approximately \$230,000 USD per day. (See Figure 8, *Exploration Actual Well Drilling Days Versus Planned Drilling Days 2000 – 2001.*)

### Conclusions

1. Significant direct cost savings can be realised by reusing and rebuilding bits and these savings can be quantified in an effective way.
2. As the result of specialist engineering services, indirect savings from reduced drilling days can be realized and an effectively quantified.
3. As the result of specialist engineering services, indirect savings from reduced bit and hole opener costs can be demonstrated and accurately quantified.
4. It is possible to accurately quantify performance of specialist engineering services.
5. The use of specialist engineering services can lead to substantial improvement in drilling economics.
6. An intangible benefit of the assignment of specialist engineers within the drilling team is that it allows other team members to focus on drilling engineering and operational issues other than those relating to bits.

### Nomenclature

*AFE = authorization for expenditure*

*BHA = bottomhole assembly*

*HO = hole opener*

*M/U = make up*

*RIH = run in hole*

*ROP = drilling rate of penetration*

*TD = total depth*

*USD = United States dollars*

*WOB = weight on bit*

### Acknowledgements

The authors would like to thank David Conroy of Smith Bits Advanced Services Engineering Group and Kristin Nergaard from the Smith Bits Drill Bit Optimization Group for their invaluable contributions to this paper. Special mention also goes Terje Skram, David Tjøswoold and Helge Agotnes of Norsk Hydro Exploration for their immense contributions.

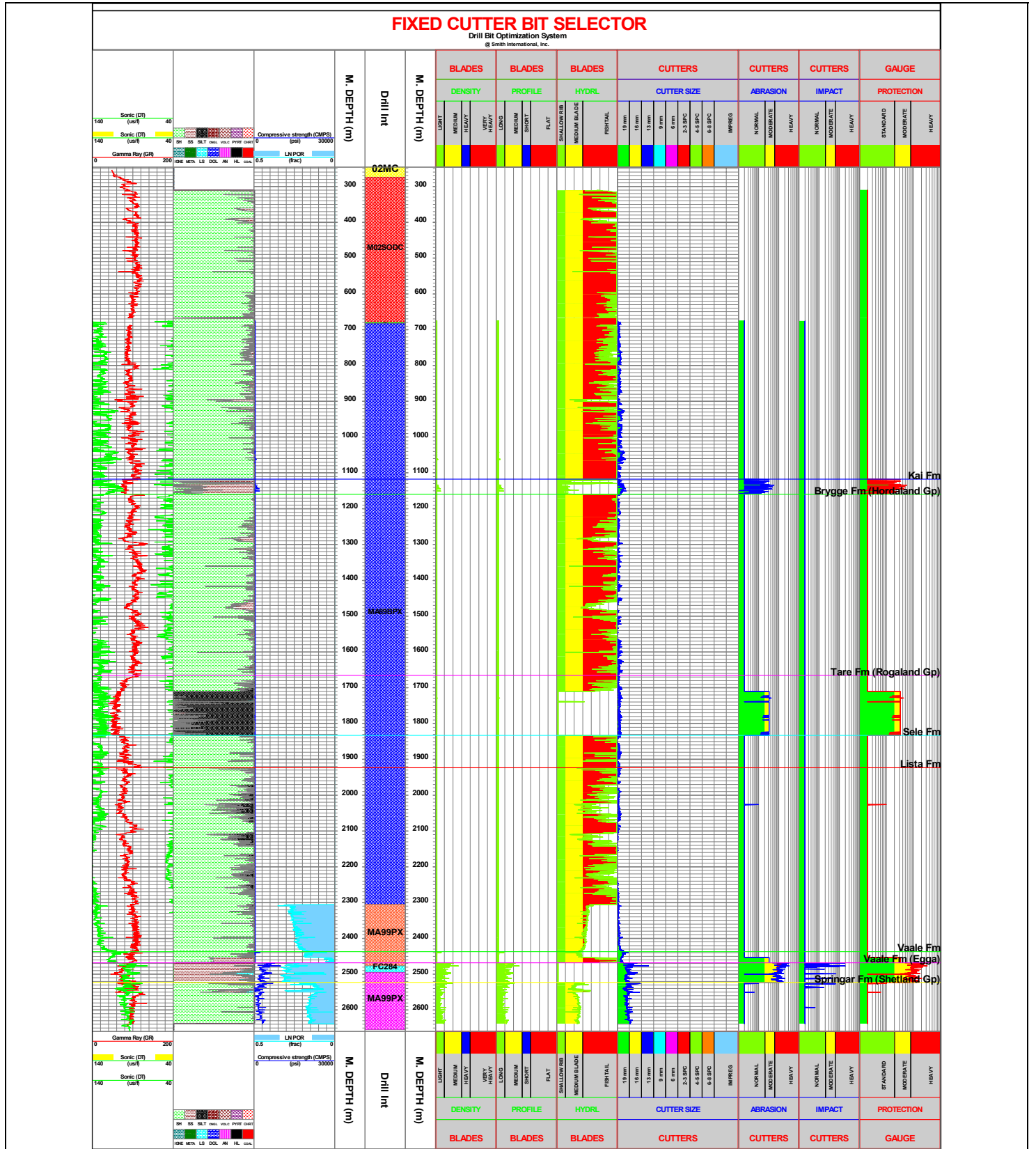


Figure 1: Fixed Cutter Bit Selector

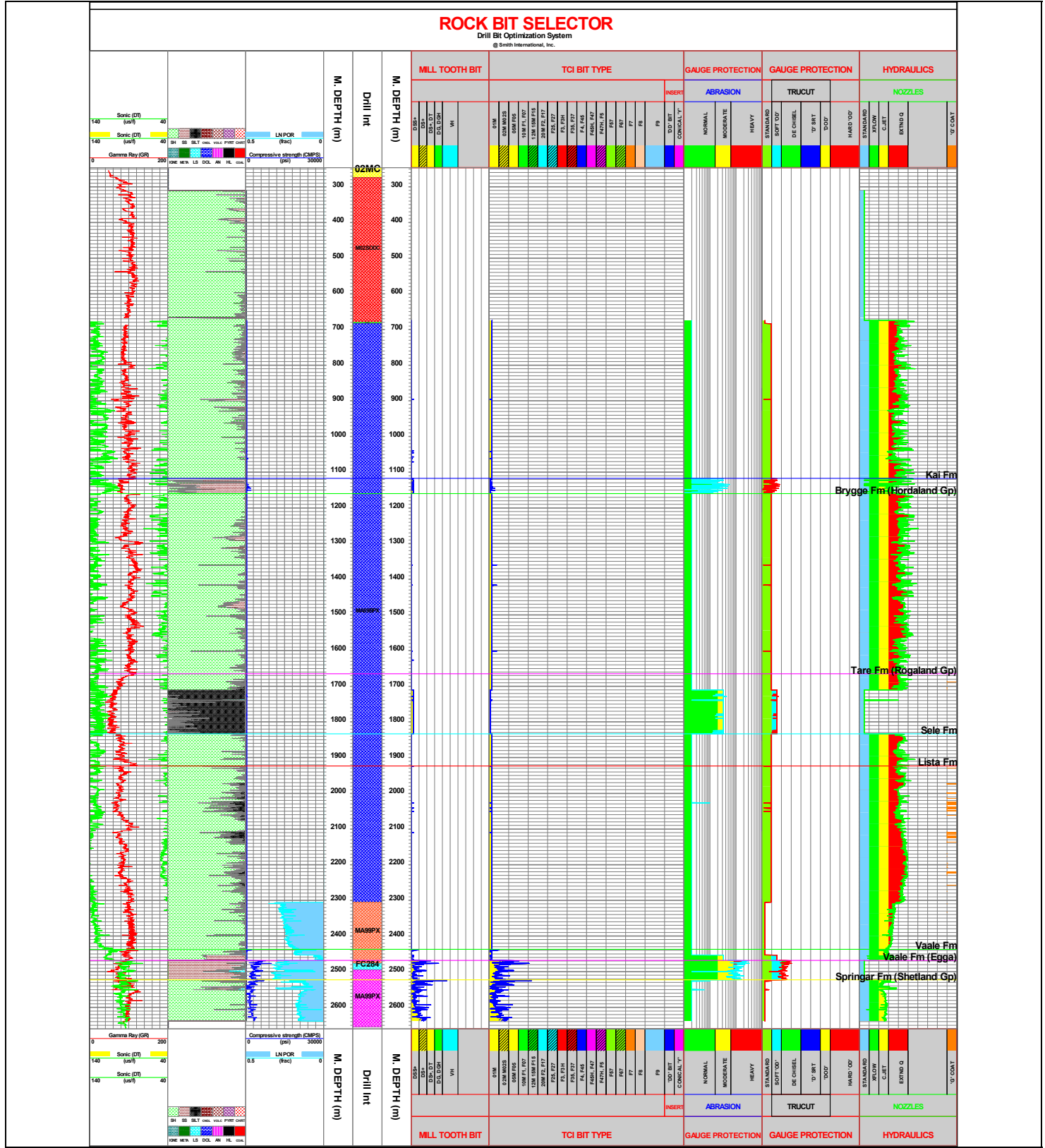


Figure 2: Rock Bit Selector

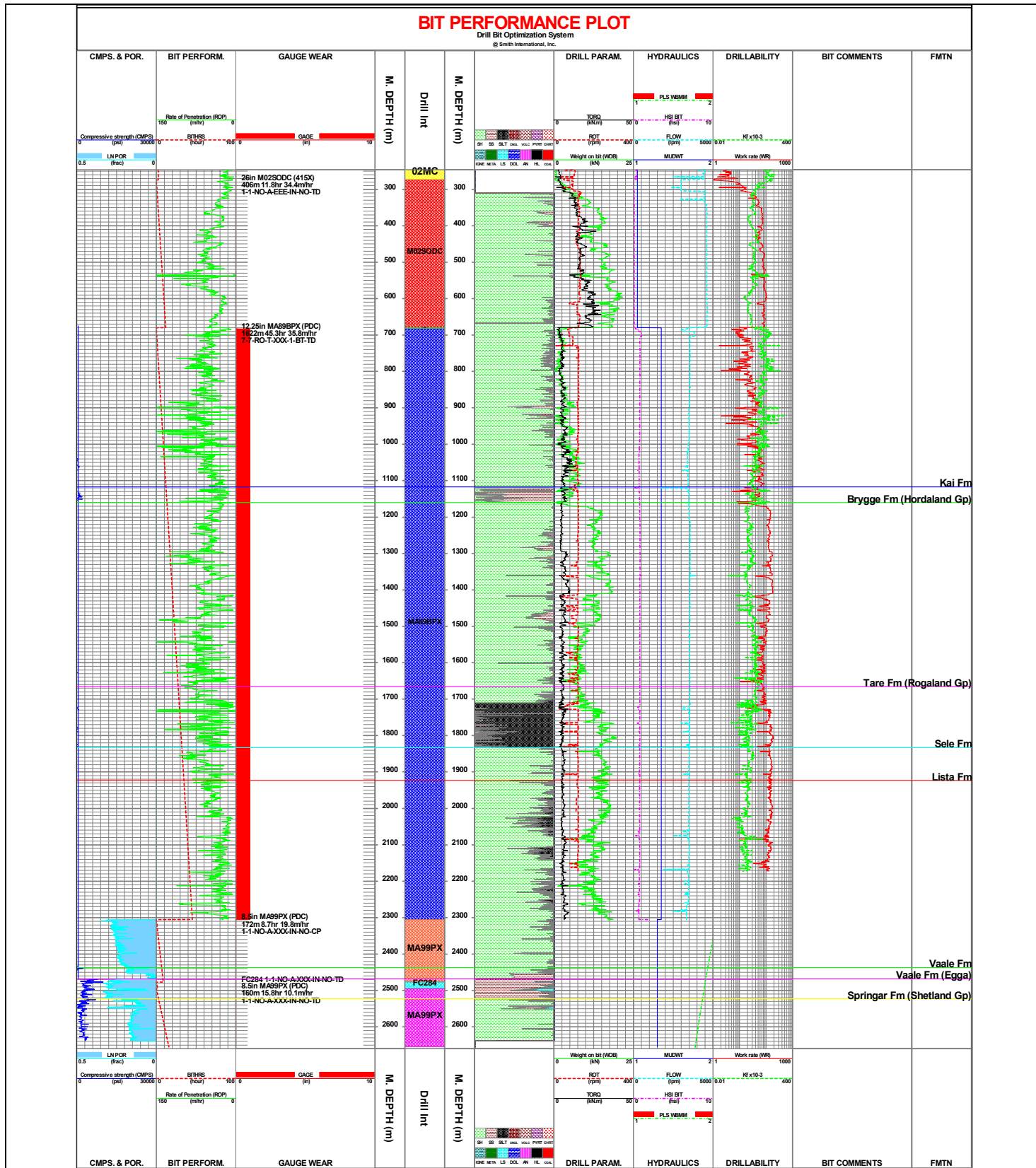
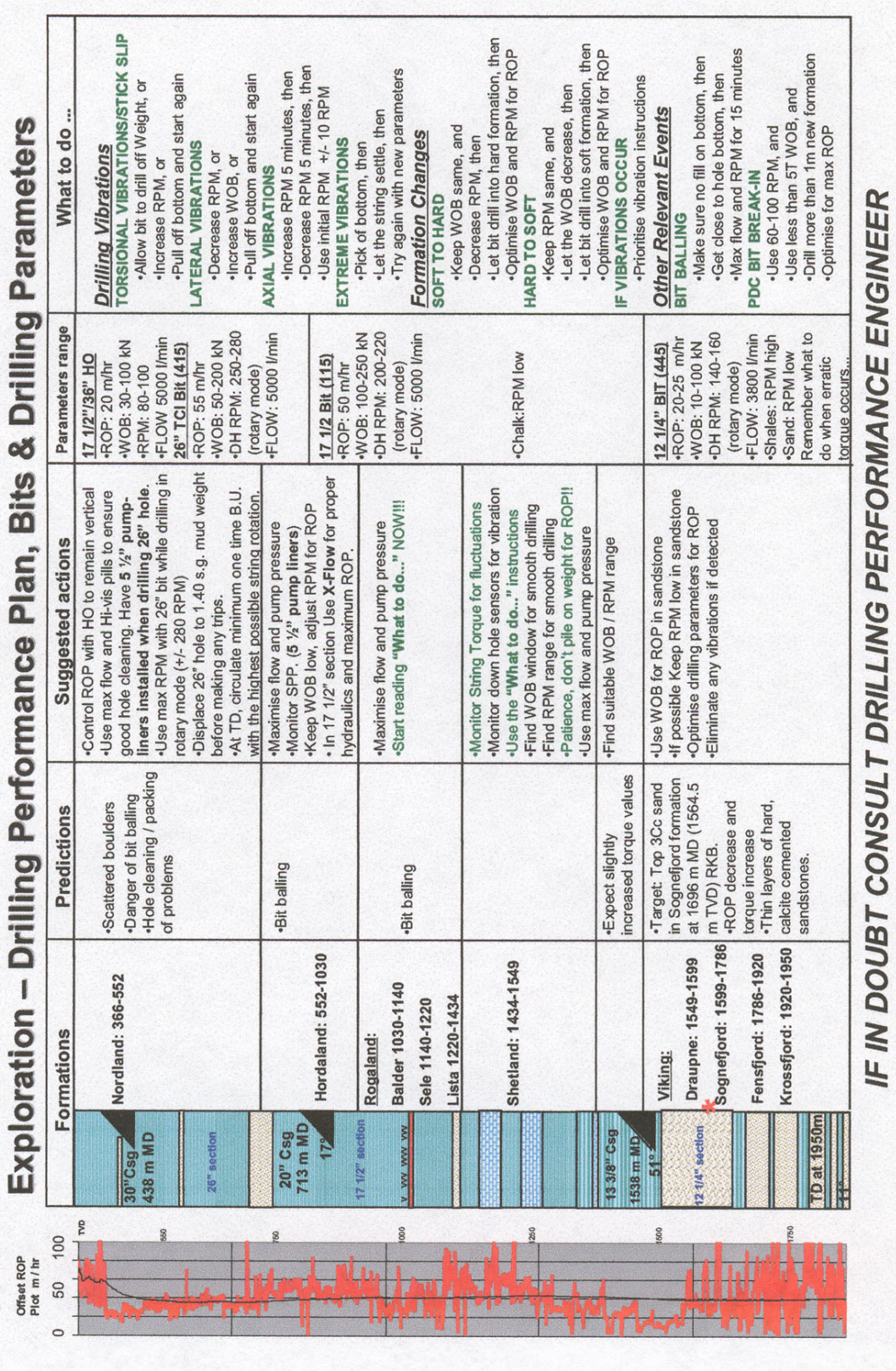


Figure 3: Bit Performance Plot



IF IN DOUBT CONSULT DRILLING PERFORMANCE ENGINEER

Figure 4: Sample Drilling Performance Plan

### 12 1/4" Section Performance Plan

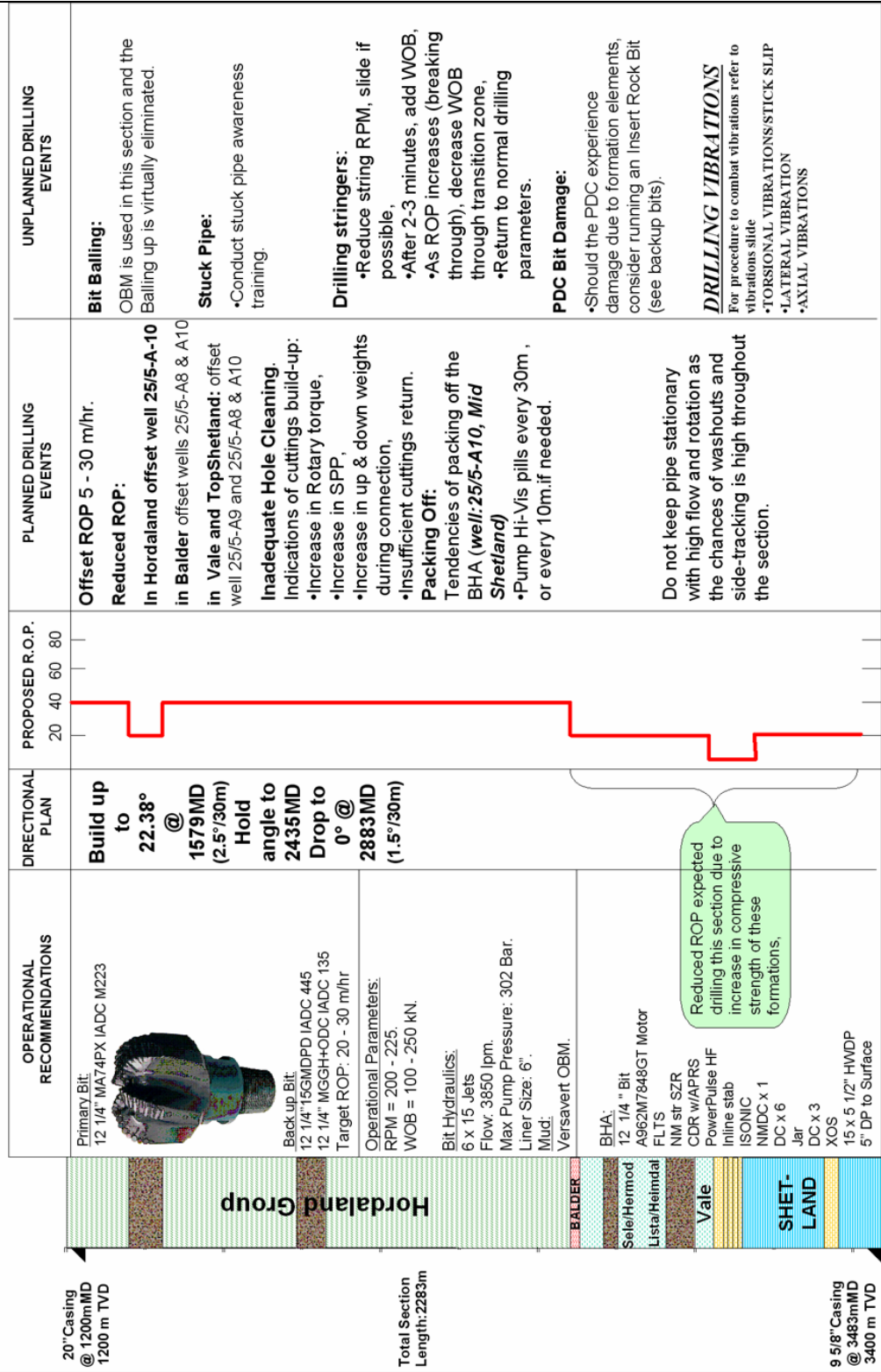


Figure 4a: Sample Section Performance Plan

### Decision Tree

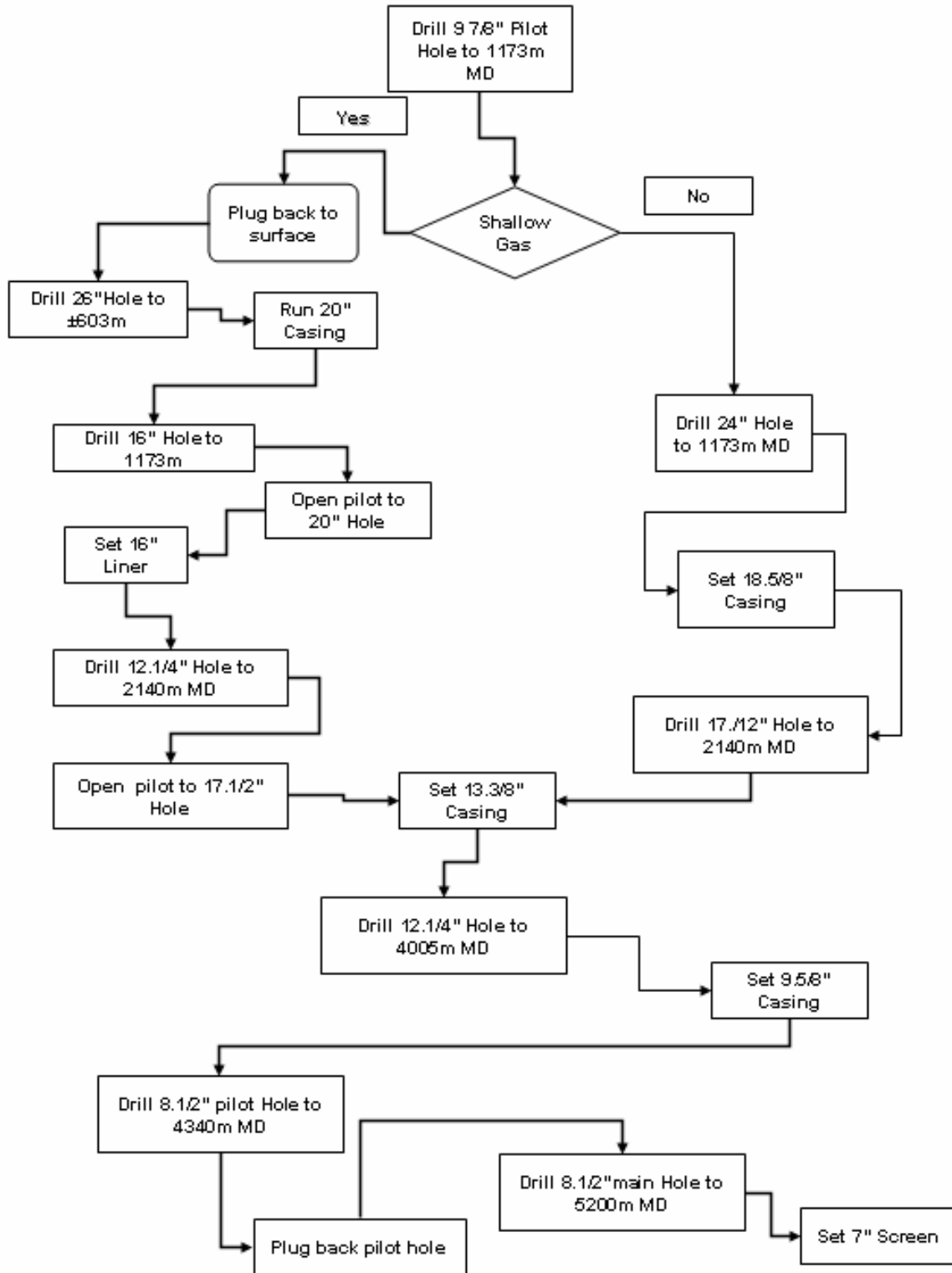


Figure 5: Decision Tree

Exploration Bit Usage and Savings 2000 - 2002													
Exploration Wells													
Bit Size	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10	Well 11	Well 12	Well 13
36"	17 1/2" TCI RR1 9 7/8" TCI 17 1/2" MT RR1	17 1/2" MT RR2 17 1/2" TCI RR2	17 1/2" TCI RR3 17 1/2" TCI RR4	17 1/2" TCI RR4 17 1/2" TCI RR4	17 1/2" TCI RR1 17 1/2" TCI RR2	17 1/2" TCI RR2 17 1/2" TCI RR2	17 1/2" TCI RR3 17 1/2" TCI RR4	17 1/2" TCI RR4 17 1/2" TCI RR4	17 1/2" TCI RR1 17 1/2" TCI RR2	17 1/2" TCI RR2 17 1/2" TCI RR2	17 1/2" TCI RR2 17 1/2" TCI RR2	17 1/2" TCI RR1 17 1/2" TCI RR2	17 1/2" TCI RR3 17 1/2" TCI RR3
26"	TCI RR1	MT		TCI	TCI	MT RR1	TCI RR1	MT RR2	MT RR3	TCI RR2		TCI RR3	TCI RR4
17 1/2"	MT	TCI		MT	MT RR1	TCI	TCI RR4	TCI	TCI	TCI RR1	TCI	MT	17" MT 14 1/2" MT
12 1/4"	PDC TCI	TCI		TCI TCI	PDC PDC PDC PDC PDC PDC PDC PDC PDC TCI	PDC	PDC RR1	PDC TCI PDC TCI PDC PDC PDC PDC TCI	PDC	PDC	PDC PDC	PDC PDC	PDC TCI
9 1/2"													
8 1/2"	PDC	PDC PDC MT			PDC PDC	PDC	PDC	PDC PDC RR1	PDC RR2	PDC RR3	PDC	PDC TCI	PDC
Re Run Value \$US	\$154,063	\$59,553	\$36,188	\$39,553	\$59,553	\$103,988	\$167,498	\$121,236	\$140,459	\$241,374	\$58,148	\$145,978	\$132,126
Re Run Value Nok	kr 1,371,161	kr 530,022	kr 322,073	kr 352,022	kr 530,022	kr 925,493	kr 1,490,732	kr 1,079,000	kr 1,250,085	kr 2,148,229	kr 517,517	kr 1,299,204	kr 1,175,921
					New Bit		ReRun Bit					Repaired Bit	
TOTAL \$US													\$1,459,717
TOTAL NOK													kr 12,991,481

Figure 6: Exploration Bit Usage Report With Savings 2000 - 2002

Exploration Actual Bit, H.O. and Services Cost Versus Bit and H.O. AFE 2000 - 2002

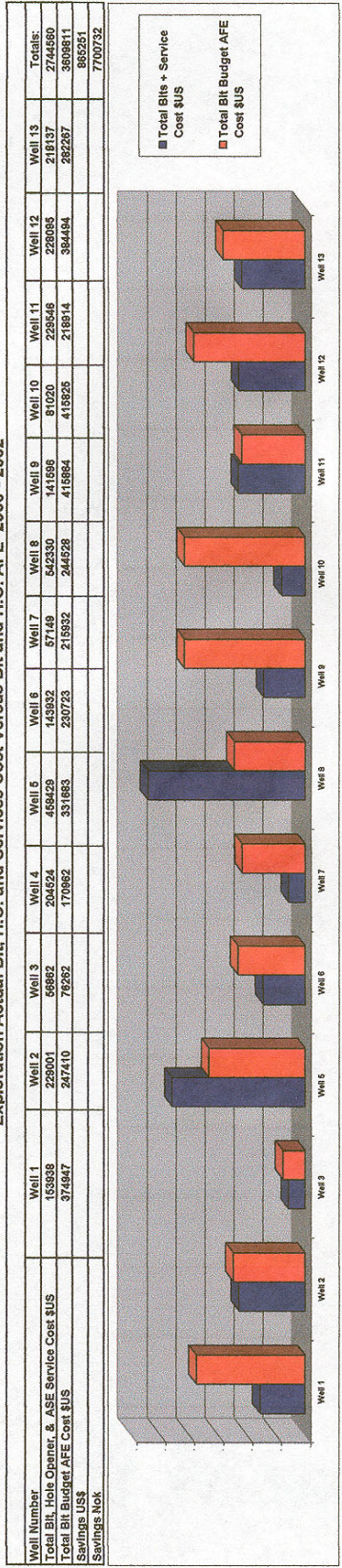
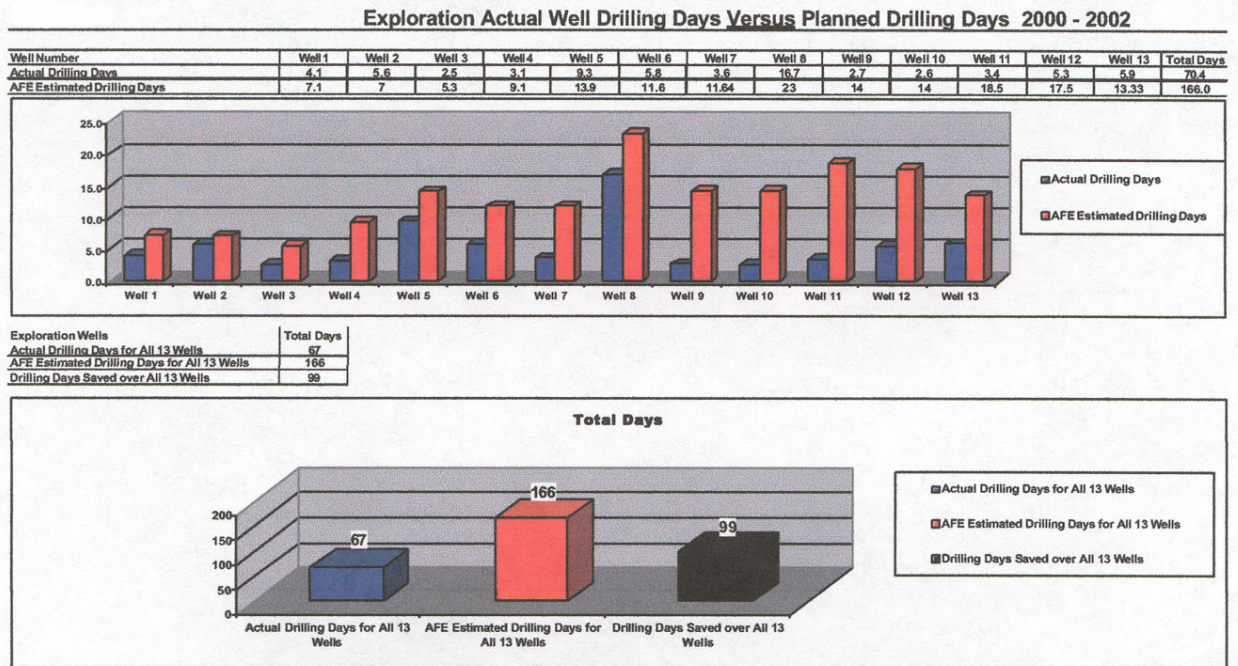


Figure 7: Exploration Actual Bit & HO vs. AFE 2000 - 2002



**Figure 8: Actual vs Planned Drilling Days**

## Advanced Services Engineering Process Used to Produce Results Reported In This Paper

### PROCESS STEP 1

**Analyze** of all relevant offset data pertaining to a planned well with a view toward optimizing bit selection and bit operating conditions. Relevant offset data would consist of a review of bit selection, operational parameter logs and bit performance on offset wells. Also evaluation and processing of offset electric logs and mud logs is carried out by the specialist engineer in order to generate rock strength logs and offset parameter logs for the offset wells. (Figures 1 and 2 provide samples of a rock strength analyses used to help select appropriate bit types based on formation characteristics. Figure 3 is an example of a offset parameter log.)

### PROCESS STEP 2

**Identify** drilling hazards based on offset well reports, offset data review and a review of the geologic prognosis.

### PROCESS STEP 3

**Optimize** well trajectory based on rock strength analysis.

### PROCESS STEP 4

**Make Primary bit selection** based on offset data analysis outlined above, the proposed well trajectory, BHA, casing design, proposed mud program and incorporating advances in bit technology. In addition, make contingency bit selection(s) to take into account possible unscheduled events.

### PROCESS STEP 5

**Draft the drilling performance plan**, by hole section, incorporating the information analyzed and data processed outlined in points 1-4 above. (See Figure 4 for an example of a section performance plan.)

### PROCESS STEP 6

**Draft decision trees**, where appropriate, to assist the rig team in the drilling optimization process and to counter the effects of reoccurrence of unplanned events. (See Figure 5 for an example of a decision tree.)

### PROCESS STEP 7

**Present the drilling performance plan** to the drilling team for dialog, changes, approval and subsequent release for operational use.

### PROCESS STEP 8

**Assist the driller** at the rig site in identifying bit hazards, recommend precautionary measures to avoid these and monitor operational parameters in order to optimize the drilling system for bit speed and longevity.

### PROCESS STEP 9

**Assess the validity of bit pulls** in terms of overall performance to ensure no unnecessary bit trips.

### PROCESS STEP 10

**Make post well analyses** to correlate drilling parameters applied to the bit-BHA in conjunction with the geological reconstruction for the well. Determine drilling parameter(s) that have the largest effect on ROP, isolate their effect on other system components and propose processes by which to further optimize the drilling system.

### PROCESS STEP 11

**Evaluate used/dull bits** and coordination with drill bit suppliers to improve bit performance through the use of new materials and alternative bit geometries.

### PROCESS STEP 12

**Document** acquired knowledge for future use.

**Figure 9: Advanced Services Engineering Process**