Planning Directional Boring Projects in Rock

by Frank McKenney

Directional drilling in rock formations can alter normal project planning considerations significantly from typical soft formation bores due to increases in job duration, downhole equipment costs, surface equipment requirements and possibly rig size. Accurate pre-planning can be the key to successful and efficient project completion.

The initial step in planning, once the product line has been established, is to design the bore profile. Subsurface geology should be seriously considered during profile design. Potential geological problems should be identified and hopefully be avoided or minimized before drilling even begins. Below are examples of how the subsurface geology can affect profile design:

- **Soft to hard formation interfaces -** These areas can cause many drilling difficulties depending on gravel, cobble or loose sand content and length of exposed bore by caving or sloughing the bore, misalignment of backreaming cutters to the pilot hole, doglegs, etc.

- **Cobble and gravel -** Virtually impossible to directionally drill in thick layers or long lengths.

  Ultimately, the problems described above impede drilling progress, causing drill string seizure, twistoffs, dogleg bores, lost circulation, loss of directional control, project incompletion, etc.

On the brighter side, however, incorporating solutions to overcome geological obstacles can be designed into the profile:

Entry/exit sides may be selected for advantage. For example, it is usually easier to enter on the side with the harder formations and exit into the softer formations, or entering on the side with the lowest elevation may offer better drilling fluids return. Hole openers or reamers are more easily pushed or pulled from hard formations into soft formations.

- Final bore size may need to be larger than normal in formations with high cobble content to allow clearances for the product line. On the other hand, in a good solid formation where the bore can be swept clean, it should be smaller than normal, possibly saving a backreaming stage.
- Radius and depth can be adjusted to steer clear of geologic problem areas.

Obviously, it is very important to gather as much geological information as possible. Unfortunately, adequate data is not always supplied to the drilling contractor prior to bidding. Ideally an extensive geological report is desired including multiple test cores across the planned bore profile identifying rock types and compressive strengths at encountered depths. If this is not available, a site visit to collect surface rock specimens and visual evaluations might have to suffice.

The rock samples can be analyzed or even sent to a laboratory for identification and hardness testing. Geologic information gained will help predict the drilling tools cutting structure required, cutter duration and rate of penetration.

1600-ft x 12-in. Line x 17.5-in. Bore				14,000 psi Limestone			
RIG PARAMETERS 50,000 lbs x 135 gpm Pump 3.5-in.-Diameter Drill Pipe with 2 3/8-in. Connections							
HOLE SIZE Inches	**TORQUE** Ft-Lbs	**DRAG POUNDS** Push/Pull	**ACTUAL VOLUME** GPM	**ANNULAR VELOCITIES** Ft-Min	**REC. VOLUME** GPM	**OPTIMUM VELOCITIES** Ft-Min	**REC. RPM**
4.75	**1950**	**1500** to **6000**	**90** to **120**	**250**	**90** to **120**	**270**	**40-50**
12.25	**2750**	**10,500** to **17,500**	**135+**	**24**	**590**	**104.7**	**40-60**
17.5	**4575**	**17,500** to **23,500**	**135+**	**11.2**	**880**	**73.3**	**40-55**

Figure 1

Physical Requirements

The next planning phase addresses the physical requirements of and operational parameters necessary to complete the bore described. This includes evaluating the drill rig and its components to ensure they are capable of completing the task.

A torque and drag program (as shown in Figure 1) will assist in evaluating rotational torque requirements, push/pull forces and drill string limits.

- Also, the hydraulic program (also in Figure 1) can determine mud pump output requirements and pressures required to adequately remove drilled cuttings from the bore, power directional motors and clean cutters and bits. These programs should be calculated for pilot hole and backreaming operations.

1600-ft x 12-in. Line x 17.5-in. Bore						14,000 psi Limestone
12-Hour-Per-Day Operation						
HOLE SIZE-in.	AVG. FT. PER HR.	AVG.FT. PER DAY	TOTAL DAYS *	RECOM. W.O.B.	RECOM. GPM	NO. & CUTTER TYPE
4.75	35	250	7	1500 to 6000	75 to 120	2 Sealed Bearing TCI Rock Bits
12.25	29	260	6	8000 to 15,000	135+	2 Sets Sealed Bearing TCI Cutters
17.5	22	200	8	12,000 to 20,000	135+	1 Set Sealed Bearing TCI Cutters
RIG UP			.5			
PULL BACK			1			
RIG DOWN			.5			
TOTAL PROJECT			23			
MOBILIZATION			1			
DEMOBILIZATION			1			
TOTAL EQUIPMENT TIME			25			

* The estimated production rate per day is based on 7 net drilling hours per day and 9 net reaming hours per day.

Figure 2

After determining the project is physically feasible, a time/cost analysis (shown in Figure 2) will determine financial feasibility. The first step is to specify the drilling tool bottom hole assemblies to provide the lowest cost per foot. (Note: This may not mean the lowest unit cost tools.)

Drilling tool components should be selected considering rock hardness and abrasiveness; bore length to drill; compatibility with rig components: mud pump output, drill pipes size, rotary and push/pull capacities; and number and sizes of backreaming stages required for final bore size to install product line.

Proper cutter selection for drill bits and backreamers should be the most cost-effective consideration of rate of penetration, duration and footage for a particular application or project. For example, a two-type aggressive TCI insert drill bit may drill a hard sandstone at 40 feet per hour and last 1200 feet. A less aggressive three type insert drill bit may drill 36 feet per hour but last 1600 feet, and therefore be more cost-effective or the lower cost per foot bit on a 1600 foot project because the time to change the bit and the cost of a second bit outweighs the 5 foot per hour difference.

Time Estimates

After selection of the drilling equipment with specified operation parameters is completed, a project time duration estimate can be calculated (as shown in figure 2). Note that:

- The chart refers to an average 12-hour day, using average experienced crews. The average varies depending on rig type, crew experience and equipment maintenance.
- The average ft per hour considers connection time, directional survey or sonde readings, orientations, wireline connection and the estimated rate of penetration in the given geological condition with the selected drilling equipment.
- The average ft per day is based on the average ft per hour net time in a 12-hour work day of actual drilling time.

These calculations should be separate for pilot hole and each backreaming stage size. Obviously, rig size will affect the net time per day spent on each operational phase: pilot hole drilling, reaming, rig up/down, product line pullback and MOB/de-MOB.

.An "estimated price analysis" summarizes the time/cost analysis by itemizing required drilling tools, quantify requirements, pilot hole costs, hole opening costs and total project cost.

Pre-project "preventative planning" or taking measures to reduce chances of equipment failure, downtime lost in hole equipment, and the costs related to these items can make a significant positive difference on rock bores. Forces encountered drilling rock will subject tools and equipment to higher rates of fatigue and stress. Below are a few examples of preventative planning measures:

- **Inspections -** Metallurgical inspection of threaded connections on drill pipe, crossover subs and other drilling tools should be standard operating procedure. Inspections identify possible problems before failure occurs. These tools can be repaired or replaced prior to commencement of drilling operations.
- **Backup equipment -** The cost of having backup tools on location in case of tool underperformance or failure is a prudent cost-effective practice. The downtime and logistics cost to rush components to a location is prohibitive. Drill bits and some cutters can be returned for credit after the project if they are unused.
- **Equipment operation efficiency -** Proper drilling fluids and solids control systems increase drilling efficiency by more effective cuttings removal, thereby reducing wear on drilling tools and equipment.
- **Product line pullback tools -** Swivels, preferably sealed bearing type, should be greased and checked. Utilization of an under gage reamer slightly larger than the pipeline is recommended. This phase of the operation is critical. All the previous work is depending on successful product line installation.

Working with subcontractors and suppliers ensures the best chance for success. Accurate pre-planning including realistic equipment capabilities, analysis and project duration/cost calculations justify project feasibility and can be the key to completing the project on time and on budget.

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