DATABASE DEVELOPMENT
FOR DIAMOND CORE DRILLING BIT SELECTION
USING FIELD DATA

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ABSTRACT

DATABASE DEVELOPMENT FOR DIAMOND CORE DRILLING BIT SELECTION USING FIELD DATA

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Drilling bit optimization is one of the key concepts in drilling engineering. It is considered as one of the economical factors in an overall well budget. Computers are strictly used as decision-making systems in the optimization calculations. Formation parameters are easily processed according to drilling bit selection criteria by the help of computer programs. Although computer program is an interface by which user makes computer do some jobs, database is another important part of this decision-making systems. Data is stored and can be modified in the database. Also necessary calculations can be accomplished by database so that results of these calculations and data can be reached by the computer programs. In this study, a database, holding field data is designed and a computer program calculating necessary parameters and related excel file holding output are prepared. Although mostly lowest cost per foot is preferred and there isn't an absolute method for choosing optimum drill bit, this design can be helpful in selection period.

Keywords: Drilling bit, optimization, database, computer program.

ÖZ

SAHA VERİSİ YARDIMIYLA ELMASLI KAROT SONDAJ MATKABI SEÇİMİNDE VERİTABANI GELİŞTİRİLMESİ

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Aralık 2005, 46 sayfa

Sondaj mühendisliğinde en önemli konulardan biri optimum sondaj matkabı seçimidir. Optimum sondaj matkabı seçimi bir kuyunun bütçesinin hesaplanmasında yeralan anahtar faktörlerdendir. Optimum sondaj matkabı seçimi için yapılan hesaplamalarda karar verme sistemi olarak bilgisayarlar ciddi olarak kullanılır. Formasyon verileri bilgisayar programı yardımıyla seçim kriterlerine göre kolaylıkla işlenirler. Programlar bilgisayarlara hükmetmek için bir arayüz olmalarına rağmen bu karar verme mekanizmalarının diğer bir önemli tarafı da veritabanlarıdır. Veritabanlarında veriler saklanır ve kolaylıkla değiştirilebilir. Gerekli hesaplamaların çoğu veritabanı tarafından yapılır ve programların bu sonuçlara ulaşmaları sağlanır. Bu çalışmada verilerin saklanacağı bir veritabanı tasarlanmış, hesaplamaların yapılmasına aracılık edecek ve gerekli grafikleri çizmek için Excel dosyası oluşturacak bir bilgisayar programı yazılmıştır. Optimum sondaj matkabını belirlemede kesin bir yöntem olmasa da bu tasarımın matkap seçiminde yardımcı olacağı düşünülmektedir.

Anahtar Kelimeler: Sondaj matkabı, optimum, veritabanı, bilgisayar programı.

To My Family

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CHAPTER 1

INTRODUCTION

Drill bit is a key part of drilling process. Drill bits have different properties according to: Grading, roller bearing, cooling roller bearing, sealed roller bearing, sealed journal bearing, sealed journal gaging. Most important property is hardness. Their hardness vary due to lithology to use. Also the rock type is another key concept to mention about optimum drill bit selection.

In this study, field data obtained at Zonguldak hardcoal Basin(with HQWL at Kilimli, Bartın and Kandilli) has been used [9]. According to data in hand, rock type, depth interval, used drill bit size, pump pressure, pump volume, bit rotation, bit load, rock quality designation, discontinuity frequency, quartz content, unconfined compressive strength, pressure loss, penetration rate values are available.

Designed database keeps above data and calculates necessary calculations by the help of written computer program. Program is designed to insert data into database, modify and delete present values and show calculation results and transfer these results to an excel file for drawings.

CHAPTER 2

DRILLING ROCK BITS

2.1 Drilling Information

In a drilling process, a borehole is drilled by rotating a bit at the end of drill pipe. Borehole cuttings are removed by continuous circulation of a drilling fluid as the bit penetrates the formation. The drill pipe is connected to the drill engine. Drilling fluid is pumped down through the hollow drill pipe using a centrifugal pump (mud pump) to a drill bit. Figure 2.1 represents the drilling equipment setup.

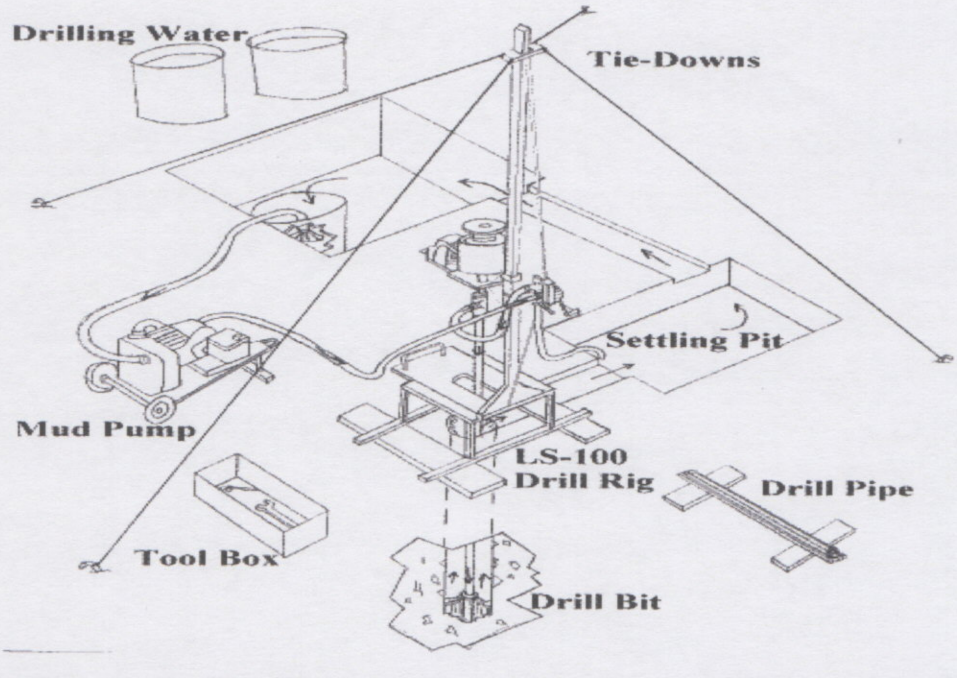

Figure 2.1 Drilling Equipment Setup [17]

2.2 Types of Drilling Bits

As easily seen below, drill bit is a key part of drilling process. There are two types of drill bits used in oil or natural gas drilling rigs, a drag bit, and a rock bit:

A drag(Figure 2.2) bit is used for soft rocks, like sand and clay. The drill stem is rotated, and teeth on the bit tear up the rock.

A rock bit (also called a roller bit, Figure 2.3, Figure 2.4, Figure 2.6) consists of teeth on wheels which turn as the drill stem is rotated. These teeth apply a shearing pressure to the rock, breaking it up into small pieces.

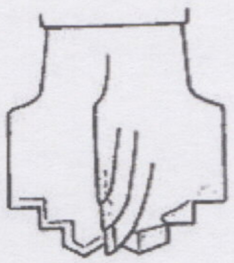

Figure 2.2 Drag Bit [18]

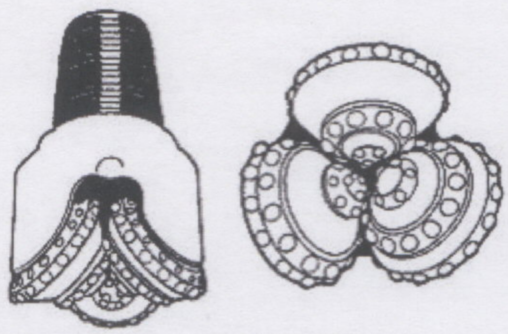

Figure 2.3 Roller Bit [18]

The original patent for the rotary rock bit was issued to Howard Hughes Sr. in 1909. It consisted of two interlocking wheels. In 1933 two Hughes engineers invented the tricone bit. This bit has three wheels and is still the dominant bit in the market today. The Hughes patent for the tricone bit lasted until 1951, after which time other companies started making similar bits. However, the Hughes's market share is still 40% of the worlds drill bit market [13].

2.3 Drilling Bit Classification

IADC codes: The Bit Classifier utilizes the International Association of Drilling Contractors' (IADC's) classification system(Figure 2.5) for roller cone and fixed cutter bits. Table 2.1 shows Drill Bit Classification and Table 2.2 shows main specifications of PDC Bits [14].

Figure 2.4 Roller Bit [16]

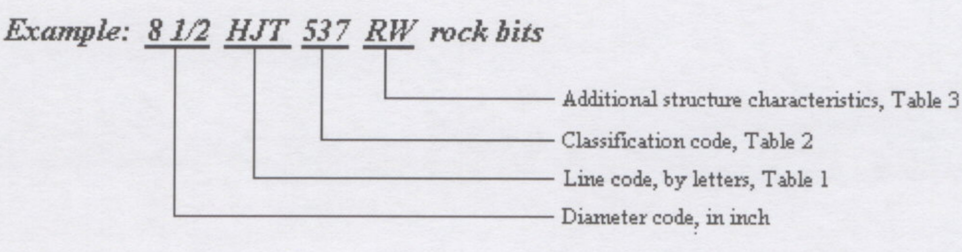

Figure 2.5 Rock Bit Classification [16]

Table 2.1 Drill Bit Classification [13]

Classification	Formation			Structure features						
	Series	Lithology	Grading	Normal roller bearing	Air cooling roller bearing	Roller bearing &gaging	Sealed roller bearing	Sealed roller &gaging	Sealed journal bearing	Sealed journal gaging
Steelteeth Bit	1	Soft with low compressive strength and high drillability	1	111			114	115	116	117
			2	121					126	127
			3	131			134	135	136	137
			4							
	2	Medium to medium hardness with high compressive strength	1	211			214			217
			2	221						
			3							
			4							
	3	Hard formation with semiabrasive and abrasive	1						316	
			2	321						
			3							
			4						346	347
Carbide Teeth Bit	4	Very soft with low compressive strength and high drillability	1					415		417
			2							427
			3					435		437
			4					445		447
	5	Soft to medium with low compressive strength	1		512			515		517
			2							527
			3		532			535		537

Table 2.1 Drill Bit Classification (Continued)

	Formation			Structure features						
	Series	Lithology	Grading	Normal roller bearing	Air cooling roller bearing	Roller bearing &gaging	Sealed roller bearing	Sealed roller &gaging	Sealed journal bearing	Sealed journal gaging
Carbide Teeth Bit										
			4					545		547
	6	Medium hardness with high compressive strength	1		612			615		617
			2							627
			3		632					637
			4							
	7	Hard formation with semiabrasive and abrasive	1		712			715		
			2							
			3		732					737
			4							
	8	Very hard formation with high abrasive	1							
			2							
			3		832					837
			4							

Table 2.2 Main Specification-PDC Bit [15]

Bit	Size (inch)	Cutter (pcs)	Gage lg (mm)	Nozzle (pcs)	API reg pin (inch)	Gross weight (kg)
B264F/M131	6 1/2-12 1/4	21-52	89-140	3-6	3 1/2-6 5/8	73-290
B264F+/M131	8 1/2-12 1/4	25-52	89-140	4-6	4 1/2-6 5/8	95-290
B268/M434	6 3/4-12 1/4	33-100	76-152	4-7	3 1/2-6 5/8	75-290
B268+/M434	6 3/4-12 1/4	33-100	76-152	4-7	3 1/2-6 5/8	75-290
B321/M112	8 1/2-12 1/4	10-18	60.5-125	6-8	4 1/2-6 5/8	102-265
B331/M112	8 1/2-12 1/4	14-21	89-127	6-9	4 1/2-6 5/8	90-265
B361R/M132	6 12-1/4	18-59	57-127	3-6	3 1/2-6 5/8	75-295
B461/M232	8 1/2-12 1/4	37-64	89-120	4-6	4 1/2-6 5/6	107-290
B461R/M232	6 12-1/4	20-70	57-125	3-6	3 1/2-6 5/8	75-290
B461RD/M232	6 12-1/4	21-73	57-127	3-6	3 1/2-6 5/6	70-290
B461W/M232	8 1/2	43	86	4	4 1/2	107
B561LG/M232	8 1/2-12 1/4	57-95	89-164	3-6	4 1/2-6 5/8	107-295
B562/M433	8 1/2	50	86	4	4 1/2	107
B564N/M333	6 1/2-9 7/8	29-59	64-102	3	3 1/2-6 5/8	75-170
B664N+/M433	8 1/2-12-1/4	54-94	89- 153	3-6	4 1/2-6 5/6	112-280
B664W/M433	8 1/2	54	86	4	4 1/2	102
B669L/M434	8 1/2-12 1/4	58-107	80-152	3-6	4 1/2-6 5/8	107-295

2.4 Diamond Drilling in General

Diamond drilling is performed via drill bits, which are fitted with diamond particles of changing sizes. The particles are either surface set or impregnated on the steel tool, mixed with "sintering material". Thereby comes the two main types of diamond bits; namely "surface-set" and "impregnated".

The bits are the bottom part of the drill string, which consists of reaming shell(reams the hole for easy working of the bit), core-barrel (intakes the core, cut by the bit), drill rods (steel rods, added together as drilling progresses) and water swivel (through which drilling mud circulation occurs).

Drilling rig with required capacity turns the drill rods, by exerting a torque which depends on the horse power and bit rpm. The turning effect is transferred to the bit, which starts the cutting action under enough bit load. Continuity of drilling or the cutting action depends on the clearance of the cut pieces or chips, which are removed by the drilling mud, circulated at required volumes by the mud pump.

By careful regulation of the operational parameters with regard to the properties of the rock cut, optimum penetration rates can be achieved. Reaching at optimum penetration rates needs a very detailed information on operational parameters, such as bit load, bit rotation, mud circulation volumes and pressures with bit wears and knowledge on the rock properties as well; including uniaxial compressive strengths, rock quality designations, discontinuity frequency and quartz content.

2.5 Choosing the Suitable Drilling Bit

Drag bits have short blades, each forged to a cutting edge and faced with tungsten carbide tips. Short nozzles direct jets of drilling fluid down the faces of the blades to clean and cool them (Driscoll, 1986). A blade bit is a drag bit in which the blades can be replaced. Drag bits have a shearing action and cut rapidly in sands, clays and some soft rock types. Most drilling is done using the Drag bit (especially in clay and sands). However, it does not work well in coarse gravel or hard-rock types. Whenever possible, drag bits should be used to drill pilot holes because they produce cuttings which are easiest to log.

Roller bits have three or more cones ("rollers" or "cutters") made with hardened steel teeth or tungsten carbide inserts of varied shape, length and spacing. They are designed so that each tooth applies pressure at a different point on the bottom of the hole as the cones rotate. The teeth of adjacent cones intermesh so that self-cleaning occurs. The cutting surfaces of all roller bits are flushed by jets of drilling fluid directed from the inside (centre) of the bit. Roller bits exert a crushing and chipping action, making it possible to cut hard rock types. If possible, use roller bits for reaming the 10 cm pilot hole open to 15 cm because they produce minimal amounts of clay smearing etc on borehole walls.

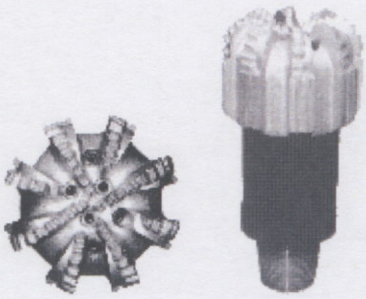

Figure 2.6 Roller Bit [15]

The three roller Tricone bit is the most common roller bit. It has conically shaped rollers on spindles and bearings set at an angle to the axis of the bit. It is used as an all-purpose bit in every rock types.

As a general rule, hard rock roller bits should be used at much slower speeds and higher bit weight than blade bits used for drilling soft rocks.

A reamer bit is later used to widen the hole to 15.24 cm (6 in). A reamer bit consists of hardened cutting surfaces attached to drill pipe; it is screwed just above the drill bit. A reamer bit is used in sandy soils or in clay if the roller bit becomes too gummed-up with clay and/or there are problems keeping the hole straight. A

10.16 cm (4 in) roller or blade bit is fitted ahead of the reamer bit and runs in the existing 10.16 cm pilot hole. This makes it easy to keep the borehole very straight during the reaming process [17].

2.6 LITERATURE SURVEY

Estes [1] has studied on selecting the proper Rotary rock bit. In the study, as a rule,it is stated that if enough weight cannot be applied on a bit, softer formation bit should be used. Bearing life determines the bit life. Bearing life is somewhat related to the bit class because bits with higher class numbers have greater bearing capacity. Another outcome from the study is to use softest formation bit that will obtain an economical run. If the rock type is not responsive to weight on bit,use the softest formation bit practical. With high clay-solid-muds, use the softest formation bit.

Bilgesu et al [5] has stated that the relationships between formation properties, drilling fluid characteristics, bit design, and operational parameters in these patterns are not easily understood. The conventional approach in bit selection is to use performance data from offset wells. The two commonly used criteria for selecting the bit for the next interval is the bit type with the highest rate of penetration or the bit with minimum cost per food.

Newcomb [3] defined the the drilling performance in terms of drilling duration and penetration rate. Rock bit performance can be noticably different between geographic districts and is due to differences in drilling conditions of weight, rotary speed, and mud, and the rock bit drilling efficiency in the formation at depth.

Another study was held by Lyon et al [4] . To prepare a good usable bit selection program following conditions should be met.

1.Current and accurate offset well data must be collected.

2.Complete analysis of the offset information must be performed before the program can be initiated.

3.Analysis of bit records and geological data has led to the development of a method of bit selection by matching bit types to the formations.

4.When the well is finished or as the well is being drilled, a comparative analysis of the bit program, bit record and drilling data should be performed to locate areas for improved planning techniques.

Karpuz et al [10] has stated that an ANN program, which was tested for several real cases, could very well be a front-end system for rock bit operational parameter selection that could help engineers in decision-making analysis. The input data covered six years of MTA's (Mineral Research and Exploration of Turkey) exploration drilling activities collected from Zonguldak hard coal basin at Kilimli, Bartin and Kandilli regions. The field studies focused on the main operational parameters including bit load, bit rotation and mud pump circulation rate. Individual values were obtained by varying one of the parameters, while keeping the others constant, and recording the corresponding penetration rates. Rock mass properties like rock quality designation (RQD) and discontinuity frequency (DF-total number of visible cracks per meter), were logged from the core recovered. Pump pressure losses were also recorded during drilling (from the relevant pressure gauges), together with the respective depth range. The data were then used to train the ANN model which was then used to analyze the drilling data.

A new approach by Akın et al [11] that harnesses individual strengths of artificial neural networks and fractal geostatistics for optimum rock bit program estimation is proposed. The accuracy and efficiency of the developed ANN program that requires sonic and neutron log data input was tested for several real and synthetic cases. The model produced reasonable rock bit programs for a development well to be drilled within the known boundaries of a field and a wildcat well drilled in a nearby field with similar rock properties to the training field.

CHAPTER 3

STATEMENT OF THE PROBLEM

Although rock bit is used in every drilling operations in the drilling engineering, there isn't certain method used to select one. Cost per foot is the main concern, but generally all companies use drill bit in hand. So, this makes drill bit selection process complicated and case-special. In this study, field data is used to offer a reflection of past selected drill bits due to field parameters. Database and graphical user interface help end-user to get selection data according to available data and provide necessary conditions to make further study.

CHAPTER 4

DATABASE DESIGN

4.1. The Importance of Good Database Design

Good database design is crucial for a high performance application, just like an aerodynamic body is important to a racecar. If the racecar doesn't have smooth lines, it will produce drag and go slower. The same holds true for databases. If a database doesn't have optimized relationships—normalization—it won't be able to perform as efficiently as possible.

Beyond performance is the issue of maintenance. Database should be easy to maintain. This includes storing a limited amount of repetitive data. A lot of repetitive data and one instance of that data undergoes a change (such as a name change), that change has to be made for all occurrences of the data. To eliminate duplication and enhance ability to maintain the data, one would create a table of possible values and use a key to refer to the value. That way, if the value changes names, the change occurs only once—in the master table. The reference remains the same throughout other tables.

For example, suppose you are responsible for maintaining a database of students and the classes in which they're enrolled. If thirty-five of these students are in the same class, called "Advanced Math," this class name would appear thirty-five times in the table. Now, if the instructor decides to change the name of the class to "Mathematics IV," thirty-five records should be changed to reflect the new name of the class. If the database were designed so that class names appeared in one table and just the class ID number was stored with the student record, you would only have to change one record—not thirty-five—in order to update the name change.

The benefits of a well-planned and designed database are numerous, and it stands to reason that the more work to do up front, the less have to do later. A really bad time for a database redesign is after the public launch of the application using it—although it does happen, and the results are costly.

So, before coding application, a lot of time should be spent to design database [8].

4.2. Understanding Normalization

Normalization is simply a set of rules that will ultimately make life easier when you're wearing your database administrator hat. It's the art of organizing your database in such a way that your tables are related where appropriate and flexible for future growth.

The sets of rules used in normalization are called normal forms. If your database design follows the first set of rules, it's considered in the first normal form. If the first three sets of rules of normalization are followed, your database is said to be in the third normal form.

Before launching into the first normal form, you have to start with something that needs to be fixed. In the case of a database, it's the flat table. A flat table is like a spreadsheet—many, many columns. There are no relationships between multiple tables; all the data you could possibly want is right there in that flat table. This scenario is inefficient and consumes more physical space on your hard drive than a normalized database.

4.2.1. First Normal Form

The rules for the first normal form include

- Eliminate repeating information.
- Create separate tables for related data.

4.2.2. Second Normal Form

The rule for the second normal form is

- No non-key attributes depend on a portion of the primary key.

In plain English, this means that if fields in your table are not entirely related to a primary key, you have more work to do.

4.2.3. Third Normal Form

The rule for the third normal form is

- No attributes depend on other non-key attributes.

This rule simply means that you need to look at your tables and see if more fields exist that can be broken down further and that aren't dependent on a key. The greatest problem in application design is a lack of forethought. As it applies to database-driven applications, the design process must include a thorough evaluation of your database—what it should hold, how data relates to each other, and most importantly, is it scalable?

4.3. The general steps in the design process are:

1.Define the objective.

2.Design the data structures (tables, fields).

3.Discern relationships.

4.Define and implement business rules.

5.Create the application.

Creating the application is the last step—not the first! Many developers take an idea for an application, build it, then go back and try to make a set of database tables fit into it. This approach is completely backwards, inefficient, and will cost a lot of time and money.

Before starting any application design process, sit down and talk it out. If you can't describe your application—including the objectives, audience, and target market—then you're not ready to build it, let alone model the database.

Once you can describe the actions and nuances of your application to other people and have it make sense to them, you can start thinking about the tables you want to create. Start with big flat tables because, once you write them down, your newfound normalization skills will take over. You will be able to find your redundancies and visualize your relationships.

The next step is to do the normalization. Go from flat table, to first normal form, and so on, up to the third normal form if possible. Use paper, pencils, Post-it Notes, or whatever helps you to visualize the tables and relationships. There's no shame in data modeling on Post-it Notes until you're ready to create the tables themselves. Plus, they're a lot cheaper than buying software to do it for you, which range from one hundred to several thousands of dollars!

After you have a preliminary data model, look at it from the application's point of view. Or look at it from the point of view of the person using the application you're building. This is the point where you define business rules and see if your data model will break. An example of a business rule for an online registration application is, "Each user must have one e-mail address, and it must not belong to any other user." If EmailAddress weren't a unique field in your data model, then your model would be broken based on the business rule [8].

4.4. Design

Proper database design is the only way your application will be efficient, flexible, and easy to manage and maintain. An important aspect of database design is to use relationships between tables instead of throwing all your data into one long flat file. Types of relationships include one-to-one, one-to-many, and many-to-many.

Using relationships to properly organize your data is called normalization. There are many levels of normalization, but the primary levels are the first, second, and third normal forms. Each level has a rule or two that must be followed. Following all of the rules will help ensure that your database is well organized and flexible.

To take an idea from inception through to fruition, you should follow a design process. This process essentially says "think before you act." Discuss rules, requirements, and objectives, and then create the final version of your normalized tables [8].

4.5. Oracle Database

An Oracle database, strictly speaking, consists of a collection of data managed by an Oracle database management system or DBMS. The term "Oracle database" sometimes refers - imprecisely - to the DBMS software itself.

One can refer to the Oracle database management system unambiguously as Oracle DBMS or (since it manages databases which have relational characteristics) as Oracle RDBMS.

Oracle Corporation itself blurs the very useful distinction between:

1.Data managed by an Oracle RDBMS,

2.An Oracle database, and

3.The Oracle RDBMS software itself

when it refers nowadays to the Oracle RDBMS (the software it sells for the purpose of managing databases) as the Oracle Database. The distinction between the managed data (the database) and the software which manages the data (the DBMS / RDBMS) relies, in Oracle's marketing literature, on the capitalisation of the word database.

Oracle Corporation produces and markets the Oracle DBMS, which many database applications use extensively on many popular computing platforms.[13]

4.6. Database Setup Procedure

First step of the database setup procedure to define the parameters which will occur in the database, and then as calculated ones. According to database logic, these parameters should be analyzed and, if necessary, divided into logical tables. Parameters would be columns of these tables.

In this study, first of all these parameters were examined and table structure is created according to data in Table A.1. In this case, number of the tables is only one because of the data in hand. For the normalization criteria, a unique constraint was developed. This constraint does not allow any repetitive line in the table.

After design process, Oracle software was installed on a PC. In this Oracle software multiple databases can be created. One database was created for this study. Table and constraint were created according to design procedure in the created database.

CHAPTER 5

ASP.NET TECHNOLOGY AND GRAPHICAL USER INTERFACE

5.1 What is ASP. NET Technology

ASP.NET, the next version of ASP, is a programming framework used to create enterprise-class Web Applications. These applications are accessible on a global basis leading to efficient information management. The advantages ASP.NET offers is more than just the next version of ASP [19].

5.2 Advantages Using ASP.NET

1 ASP.NET drastically reduces the amount of code required to build large applications.

2 ASP.NET makes development simpler and easier to maintain with an event-driven, server-side programming model.

3 ASP.NET pages are easy to write and maintain because the source code and HTML are together.

4 The source code is executed on the server. The pages have lots of power and flexibility by this approach.

5 The source code is compiled the first time the page is requested. Execution is fast as the Web Server compiles the page the first time it is requested. The server saves the compiled version of the page for use next time the page is requested.

6 The HTML produced by the ASP.NET page is sent back to the browser. The application source code you write is not sent and is not easily stolen.

7 ASP.NET makes for easy deployment. There is no need to register components because the configuration information is built-in.

8 The Web server continuously monitors the pages, components and applications running on it. If it noticies memory leaks, infinite loops, other

illegal software or activities, it seamlessly kills those activities and restarts itself.

9 ASP.NET validates information (validation controls) entered by the user without writing a single line of code.

10 ASP.NET easily works with ADO .NET using data-binding and page formatting features.

11 ASP.NET applications run fater and counters large volumes of users without performance problems [19].

5.3 Differences between ASP.NET and Client-Side Technologies

Client-side refers to the browser and the machine running the browser. Server-side on the other hand refers to a Web server [19].

5.3.1 Client-Side Scripting

Javascript and VBScript and generally used for Client-side scripting. Client-side scripting executes in the browser after the page is loaded. Using client-side scripting you can add some cool features to your page. Both, HTML and the script are together in the same file and the script is download as part of the page which anyone can view. A client-side script runs only on a browser that supports scripting and specifically the scripting language that is used. Since the script is in the same file as the HTML and as it executes on the machine you use, the page may take longer time to download [19].

5.3.2 Server-Side Scripting

ASP.NET is purely server-side technology. ASP.NET code executes on the server before it is sent to the browser. The code that is sent back to the browser is pure HTML and not ASP.NET code. Like client-side scripting, ASP.NET code is similar in a way that it allows you to write your code alongside HTML. Unlike client-side scripting, ASP.NET code is executed on the server and not in the browser. The script that you write alongside your HTML is not sent back to the browser and that prevents others from stealing the code you developed [19].

5.5 Graphical User Interface Setup

After database is created, user interface can be designed. In this study, graphical user interface(GUI) of the program is prepared by using the benefits of ASP.NET technology. Microsoft Visual Studio .NET 2003 was used as a tool to generate ASP.NET code. First of all, a blank project is created and webforms were created. Webform refers to html page in ASP.NET technology, but much more developed than a html page and has additional built-ins . By drag 'n' drop, textboxes were created in the webform as equivalent of database table columns. After submit buttons were placed , some make-up was put on the pages (Figure 5.1 and Figure 5.2).

Other advantages of this program are :

1 Program can easily be uploaded to any web server, so it can easily be opened via internet or intranet.

2 Users directly reaches the GUI via browsers.

4 Code changes can be accomplished through web servers, so end users is not affected by any changes .

5.5 Program Details and Execution Plan

GUI of this program is composed of two main pages. Figure 5.1 is Data Entry and Query Page and Figure 5.2 is Drill Bit Selection Page.

Data Entry Page provides data to be saved and query to update or delete data through database. According to program, when a new data is proceeded and insert button is pressed, data is saved and then program returns the Entry and Query Page. This page is always ready to save data. When a query is executed by pressing query button , results come to screen within a datagrid which is shown on lower portion of the same page. Table 5.1 shows the structure of datagrid, update hyperlink is used to update or delete the desired rows.

To select optimum rock bit within the available data, Drill Bit Selection Page is used. In this page, at least one of indirect parameters should be supplied as intervals to get any result. Table 5.2 shows datagrid of Drill Bit Selection Page. toExcel button in the Drill Bit Selection Page is used to transfer datagrid to an excel document in the same page.Data obtained by the program can be transfered and desired addition and subtractions can be done by this helpful method.

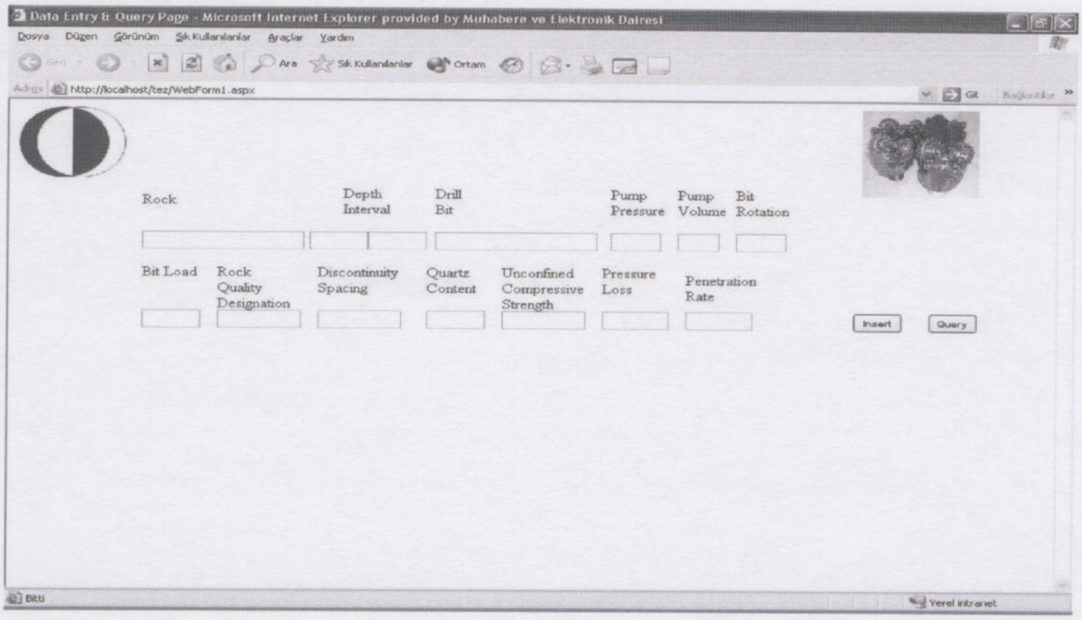

Figure 5.1 Data Entry and Query Page

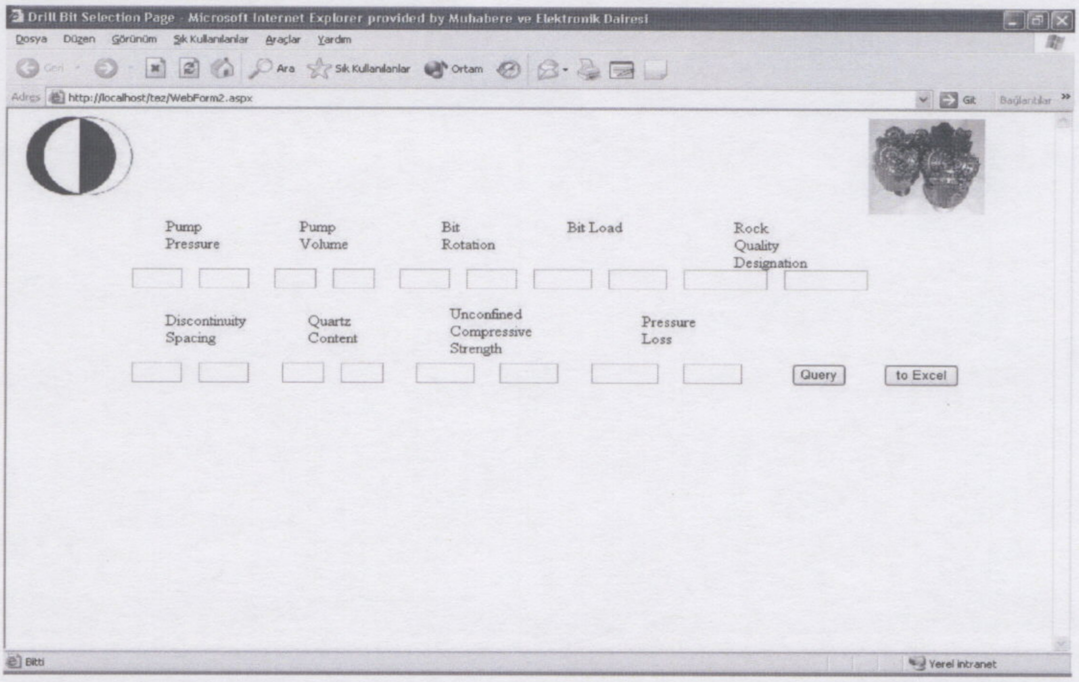

Figure 5.2 Drill Bit Selection Page

Table 5.1 Datagrid of Data Entry and Query Page

Rock	Depth Start (m)	Depth End (m)	Drill Bit	Pump Pressure (kg/cm2)	Pump Volume (l/min)	Bit Rotation (RPM)	Bit Load (kg)	Rock Quality Designation (%)	Discon. Spacing (#/m)	Quartz Content (%)	Unconfined Comp. Strength (Mpa)	Pressure Loss (psi)	Penetration Rate (cm/min)
Sandstone,Bartın	114.00	114.20	NQWL 40/60-18	35.0	50.7	350	1296	47	9	18	127		4.5
Sandstone,Bartın	114.20	114.40	NQWL 40/60-18	35.0	50.7	400	1296	77	4	15	127		7.4
Sandstone,Bartın	114.40	114.60	NQWL 40/60-18	35.0	50.7	400	1620	93	1	15	127		8.9

Table 5.2 Datagrid of Drill Bit Selection Page

Rock	Depth Start (m)	Depth End (m)	Drill Bit	Pump Pressure (kg/cm2)	Pump Volume (l/min)	Bit Rotation (RPM)	Bit Load (kg)	Rock Quality Designation (%)	Discon. Spacing (#/m)	Quartz Content (%)	Unconfined Comp. Strength (Mpa)	Pressure Loss (psi)	Penetration Rate (cm/min)
Sandstone,Bartın	114.00	114.20	NQWL 40/60-18	35.0	50.7	350	1296	47	9	18	127		4.5
Sandstone,Bartın	114.20	114.40	NQWL 40/60-18	35.0	50.7	400	1296	77	4	15	127		7.4
Sandstone,Bartın	114.40	114.60	NQWL 40/60-18	35.0	50.7	400	1620	93	1	15	127		8.9
Sandstone,Bartın	114.60	114.80	NQWL 40/60-18	35.0	50.7	300	1296	54	7	18	127		5.0
Sandstone,Bartın	114.80	115.00	NQWL 40/60-18	35.0	50.7	468	1296	67	6	15	127		6.5
Sandstone,Bartın	115.00	115.20	NQWL 40/60-18	35.0	50.7	400	1296	48	8	18	127		4.5
Sandstone,Bartın	115.20	115.50	NQWL 40/60-18	35.0	50.7	470	1296	60	6	20	127		5.7
Volcanics,ARP1	112.00	121.00	PQWL 60/80-40	13.6	75	300	1800	26	15	0	36		2.4
Volcanics,ARP1	121.00	129.00	PQWL 60/80-40	13.6	75	300	1500	29	14	0	36		2.7
Volcanics,ARP1	129.00	131.90	PQWL 60/80-40	13.6	75	300	1600	29	14	0	36		2.7

CHAPTER 6

RESULTS AND DISCUSSION

Field data (Table A.1) used in this study was obtained from Zonguldak hardcoal basin(with HQWL at Kilimli, Bartın, Kandilli) by General Directorate of Mineral Research and Exploration (MTA).

6.1 Case I

In this case, only Bit load interval is given as indirect parameters. Bit load interval is chosen as 600 kg to 700 kg and program gave a datagrid as in Table 6.1. It is obvious that program gathers all 600 kg to 700 kg applied bit load choice within the datagrid.

6.2 Case II

In this case, aim is to narrow the results of Case I. Bit load interval as 600 kg to 700 kg and Rock Quality Designation as 70 % to 100% were chosen .Table 6.2 shows the accurate approach of this program through succesfull narrowing of Case I.

According to Table 6.1 and Table 6.2 drawn by the program, it can be easily seen that program works well. As decided curves may show desired results and look accurate, some other figures which are not designed to plot by the program can be considered to helpful to optimize the rock bit selection process.

By scalable and adoptable database design, database table and programming tools, new and necessary add-ons can be created within a very short time.

In the study, as a database (Oracle Personal Database) was used. Oracle is accept as most powerful and reliable database but its personal which means it only works on a personal computer and does not have network support. Database and program should work on the same pc.

Another important factor in optimum drill bit selection is cost per foot analysis. Cost per foot is calculated by the help of bit cost, trip time, rotating time, rig cost per hour and section drilled. Unfortunately in this study most of them aren't available. So, this widely used method cannot be held.

Table 6.1 Datagrid of Case I

Rock	Depth Start(m)	Depth End(m)	Drill Bit	Pump Pressure (kg/cm2)	Pump Volume (l/min)	Bit Rotation (RPM)	Bit Load (kg)	Rock Quality Des.(%)	Discontinuity Spacing (#/m)	Quartz Content (%)	Unconfined Comp. Strength (Mpa)	Pressure Loss (psi)	Penetration Rate (cm/min)
Sandstone,Bartın	517.40	517.50	NQWL 40/60-18	35.0	50.7	358	648	44	9	20	50		4.0
Sandstone,Bartın	517.70	518.00	NQWL 40/60-18	35.0	50.7	425	648	43	10	20	50		4.0
Sandstone,Bartın	518.00	518.50	NQWL 40/60-18	35.0	50.7	468	648	54	7	18	50		5.0
Sandstone,Bartın	518.50	519.00	NQWL 40/60-18	35.0	50.7	468	648	62	6	18	50		5.7
Sandstone,Bartın	519.20	519.50	NQWL 40/60-18	35.0	50.7	480	648	87	2	15	50		8.5
Claystone,Kilimli	664.80	665.30	NQWL 40/60-18	35.0	50.7	350	648	91	1	0	64		9.0
Sandstone,Bartın	480.00	480.10	NQWL 40/60-18	35.0	50.7	300	648	22	16	25	50		1.9
Sandstone,Bartın	480.10	480.20	NQWL 40/60-18	35.0	50.7	327	648	22	16	25	50		1.7
Sandstone,Bartın	480.20	480.30	NQWL 40/60-18	35.0	50.7	356	648	36	11	23	50		3.3
Sandstone,Bartın	480.30	480.60	NQWL 40/60-18	35.0	50.7	425	648	26	15	23	50		2.3
Sandstone,Bartın	480.60	480.80	NQWL 40/60-18	35.0	50.7	465	648	41	10	23	50		3.7
Sandstone,Bartın	480.80	481.00	NQWL 40/60-18	35.0	50.7	500	648	51	7	23	50		4.7
Sandstone,Bartın	483.10	483.30	NQWL 40/60-18	35.0	50.7	468	648	38	11	20	50		3.5
Sandstone,Bartın	483.30	483.50	NQWL 40/60-18	35.0	50.7	500	648	54	7	20	50		5.1
Sandstone,Bartın	483.50	483.70	NQWL 40/60-18	35.0	50.7	425	648	47	9	20	50		4.5
Claystone,Kandilli	50.60	50.80	NQWL 40/60-25	35.0	81.4	468	600	58	7	0	64		5.5
Claystone,Kandilli	52.00	52.10	NQWL 40/60-25	35.0	81.4	350	600	71	5	0	64		7.0
Sandstone,Kilimli	342.10	342.50	NQWL 40/60-25	35.0	81.4	350	648	77	4	12	64		7.1
Sandstone,Kilimli	342.50	343.00	NQWL 40/60-25	35.0	81.4	450	648	100	1	12	64		11.3
Sandstone,Kilimli	343.00	343.20	NQWL 40/60-25	35.0	81.4	500	648	100	1	12	64		10.9
Sandstone,Kilimli	343.20	343.30	NQWL 40/60-25	35.0	81.4	400	648	100	1	12	64		10.0

Table 6.1 Datagrid of Case I (Continued)

Rock	Depth Start(m)	Depth End(m)	Drill Bit	Pump Pressure (kg/cm2)	Pump Volume (l/min)	Bit Rotation (RPM)	Bit Load (kg)	Rock Quality Des.(%)	Discontinuity Spacing (#/m)	Quartz Content (%)	Unconfined Comp. Strength (Mpa)	Pressure Loss (psi)	Penetration Rate (cm/min)
Siltstone,Bartın	381.00	381.50	NQWL 40/60-25	35.0	81.4	300	648	28	15	22	64		2.1
Siltstone,Bartın	381.50	382.00	NQWL 40/60-25	35.0	81.4	425	648	38	11	22	64		3.2
Siltstone,Kilimli	389.80	389.90	NQWL 40/60-25	35.0	81.4	400	648	40	10	22	64		3.5

Table 6.2 Datagrid of Case II

Rock	Depth Start(m)	Depth End(m)	Drill Bit	Pump Pressure (kg/cm2)	Pump Volume (l/min)	Bit Rotation (RPM)	Bit Load (kg)	Rock Quality Designation (%)	Discontinuity Spacing (#/m)	Quartz Content (%)	Unconfined Comp. Strength (Mpa)	Pressure Loss (psi)	Penetration Rate (cm/min)
Sandstone,Bartın	519.20	519.50	NQWL 40/60-18	35.0	50.7	480	648	87	2	15	50		8.5
Claystone,Kilimli	664.80	665.30	NQWL 40/60-18	35.0	50.7	350	648	91	1	0	64		9.0
Claystone,Kandilli	52.00	52.10	NQWL 40/60-25	35.0	81.4	350	600	71	5	0	64		7.0
Sandstone,Kilimli	342.10	342.50	NQWL 40/60-25	35.0	81.4	350	648	77	4	12	64		7.1
Sandstone,Kilimli	342.50	343.00	NQWL 40/60-25	35.0	81.4	450	648	100	1	12	64		11.3
Sandstone,Kilimli	343.00	343.20	NQWL 40/60-25	35.0	81.4	500	648	100	1	12	64		10.9
Sandstone,Kilimli	343.20	343.30	NQWL 40/60-25	35.0	81.4	400	648	100	1	12	64		10.0

6.3 Case III

In Case III, relationship between operational and indirect parameters are tried to examine. RQD, discontinuity frequency, unconfined compressive strength, quartz content, depth, rock type versus pump pressure, bit rotation, bit type, pressure loss, penetration rate relationships are considered. According to Table A.1, pressure loss data is not available. Pump pressure values of Case I are constant. Unsuitable conditions of these values conclude lacking of necessary figures. Case I data was exported to an excel file through the Drill Bit Selection Page (Figure 5.2) and figures between Figure 6.1 and Figure 6.14 were drawn by Excel program. From Figure 6.1 to Figure 6.14 shows that this drill bit selection program is able to save, update and filter and transfer desired output and helpful to examine relationships between operational parameters and indirect parameters.

All plots except Figure 6.6, Figure 6.7 Bit, Figure 6.10 don't yield absolute conclusions. This probably means that drilling operations were made by drill bits in hand. On the other hand, Figure 6.6 and Figure 6.10 explicitly shows that penetration rate is inversely proportional to discontinuity frequency and quartz content. Figure 6.7 shows that NQWL40/60-25 rock bit is used for high unconfined compressive strength values rather than NQWL40/60-18.

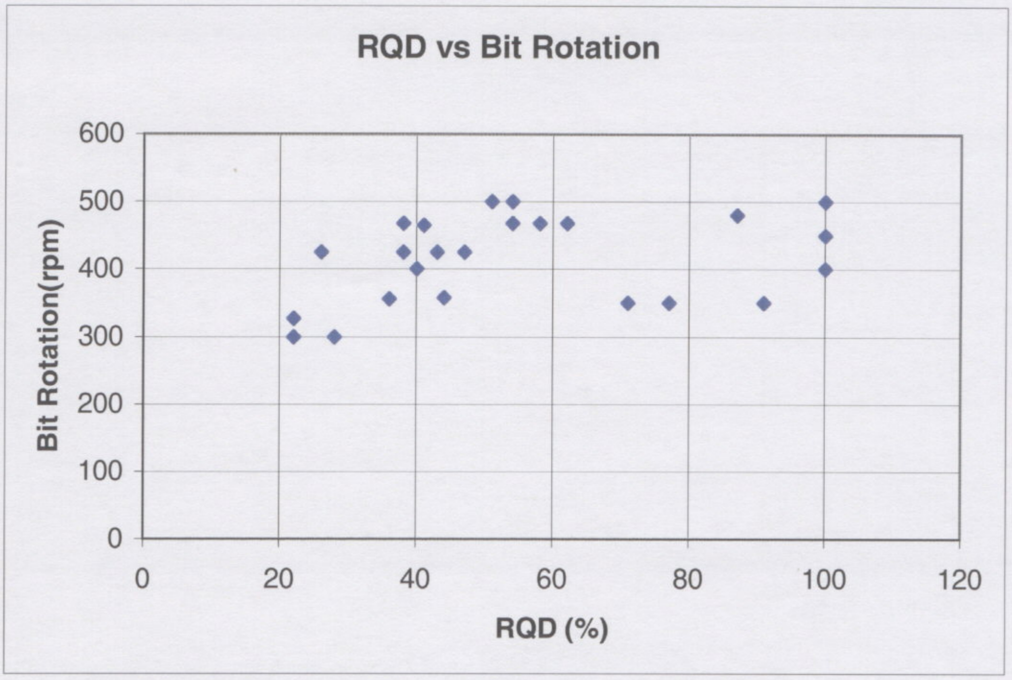

Figure 6.1 RQD vs Bit Rotation Plot

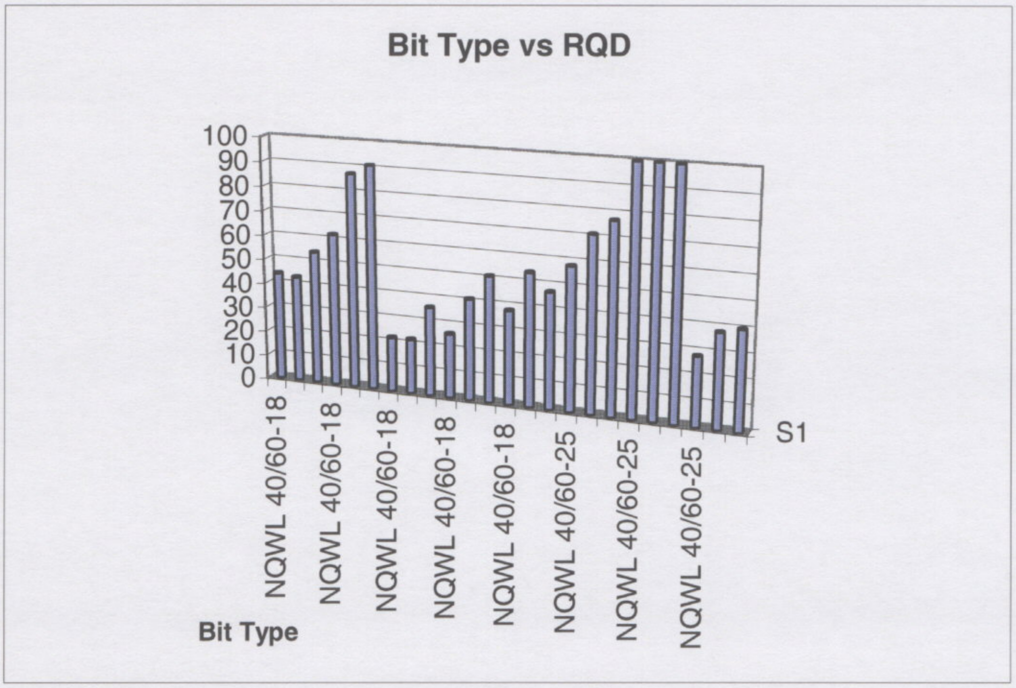

Figure 6.2 Bit Type vs RQD Plot

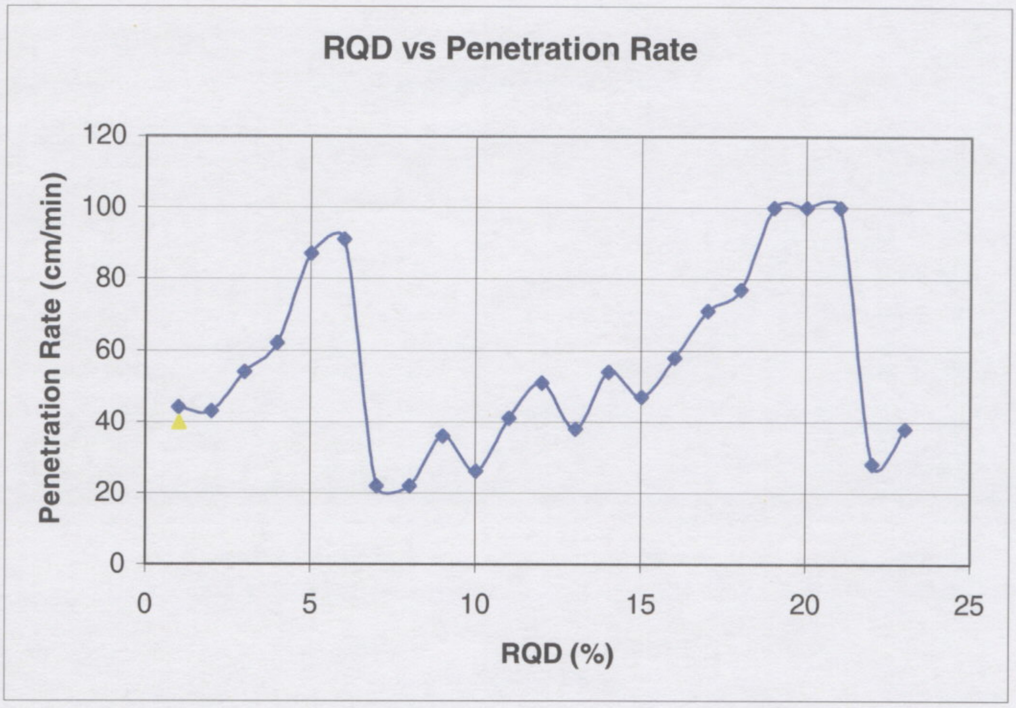

Figure 6.3 RQD vs Penetration Rate Plot

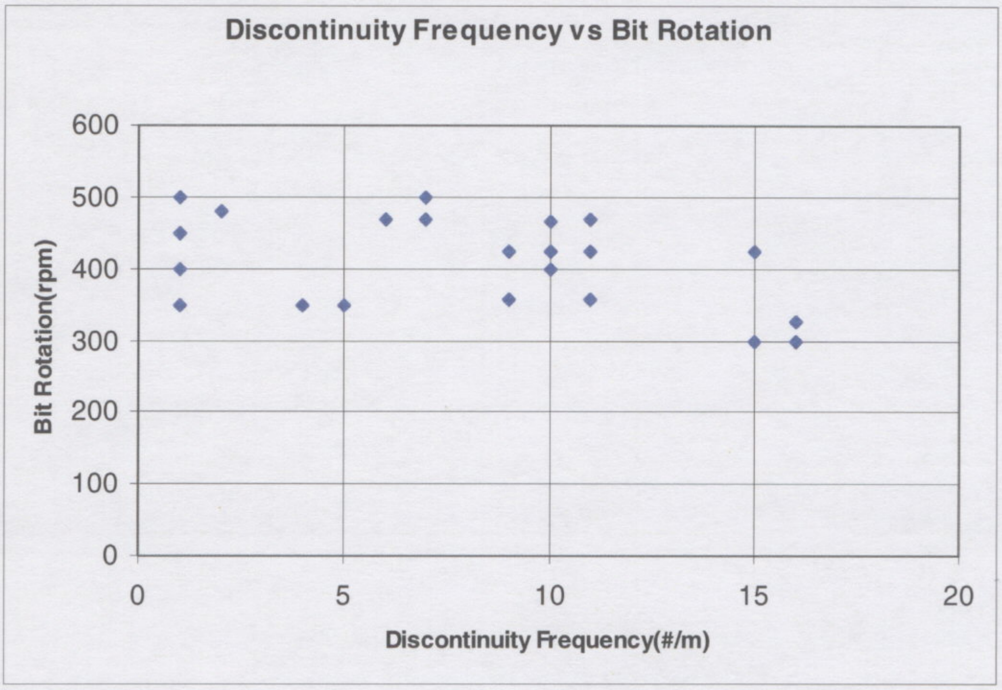

Figure 6.4 Discontinuity Frequency vs Bit Rotation Plot

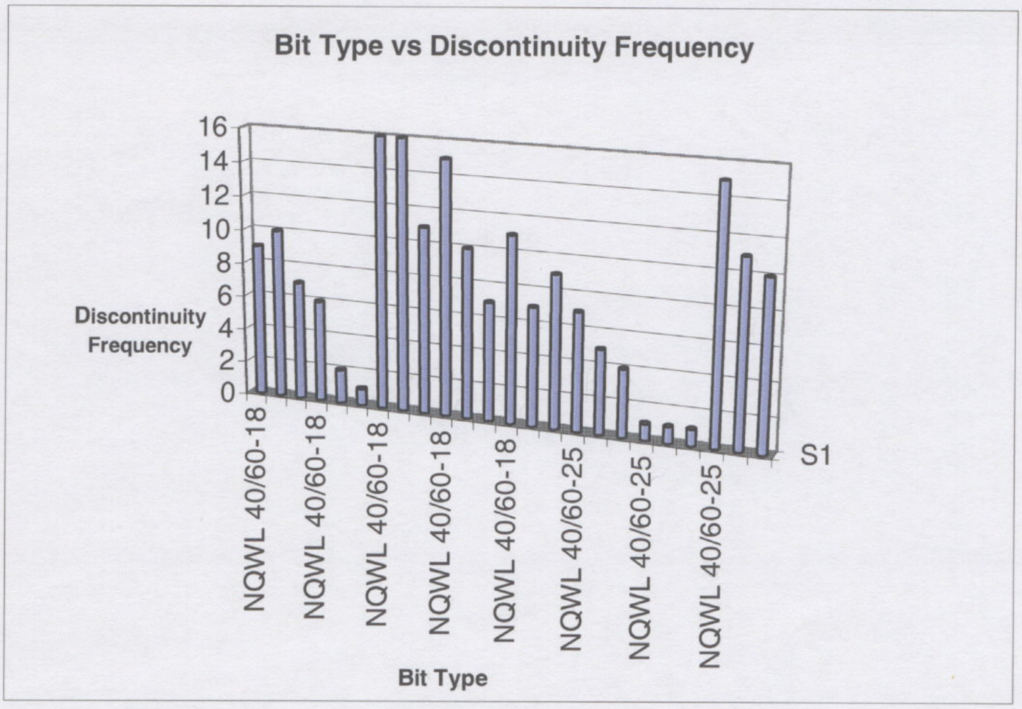

Figure 6.5 Bit Type vs Discontinuity Frequency Plot

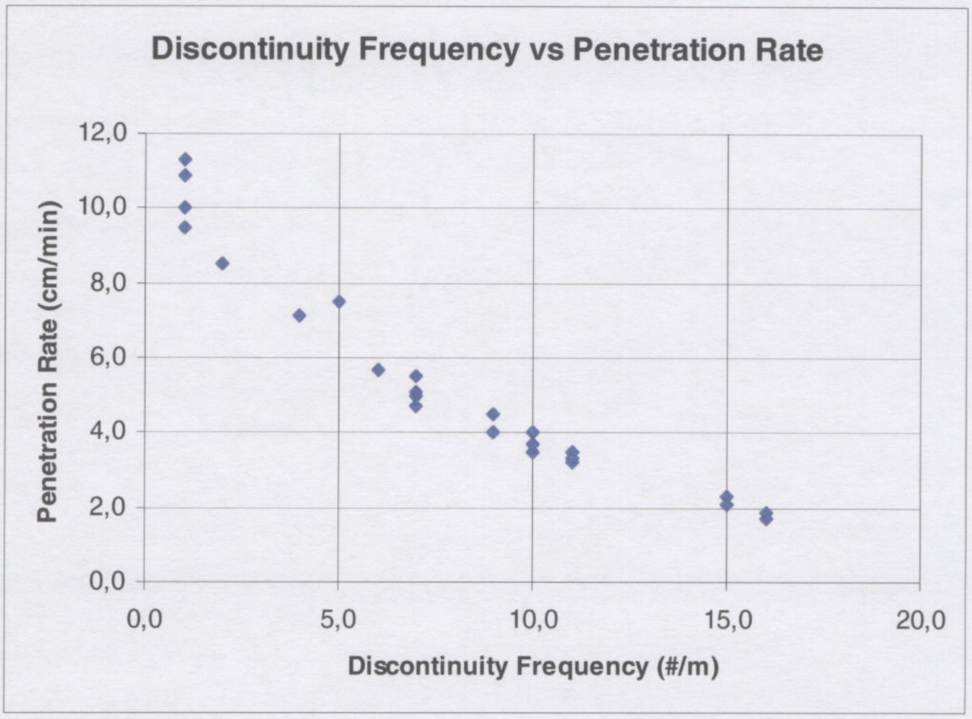

Figure 6.6 Discontinuity Frequency vs Penetration Rate Plot

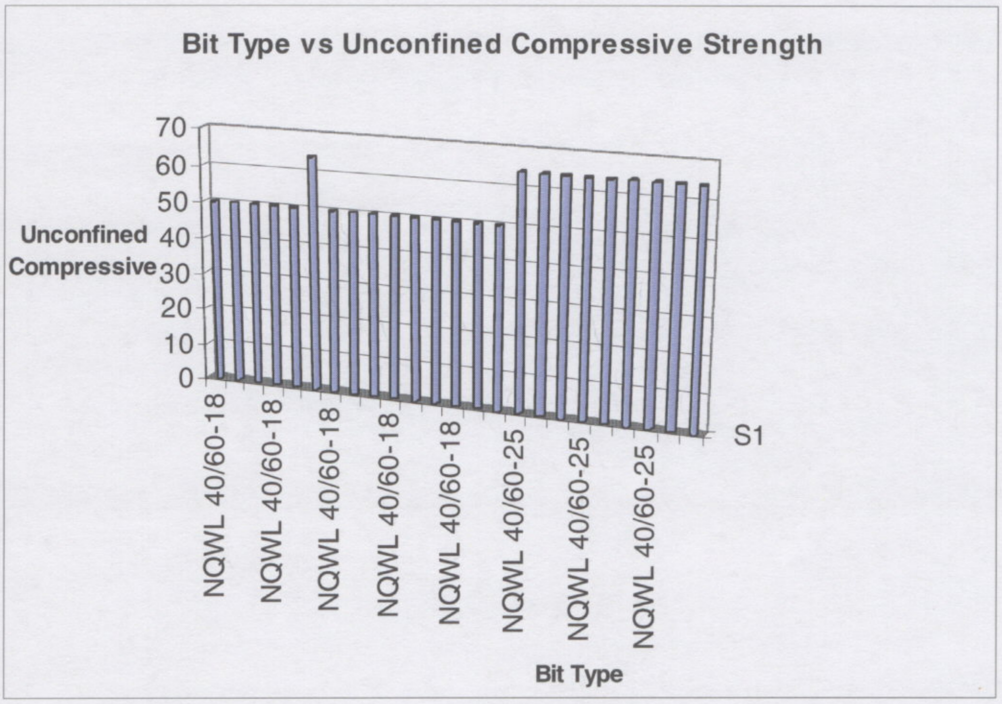

Figure 6.7 Bit Type vs Unconfined Compressive Strength Plot

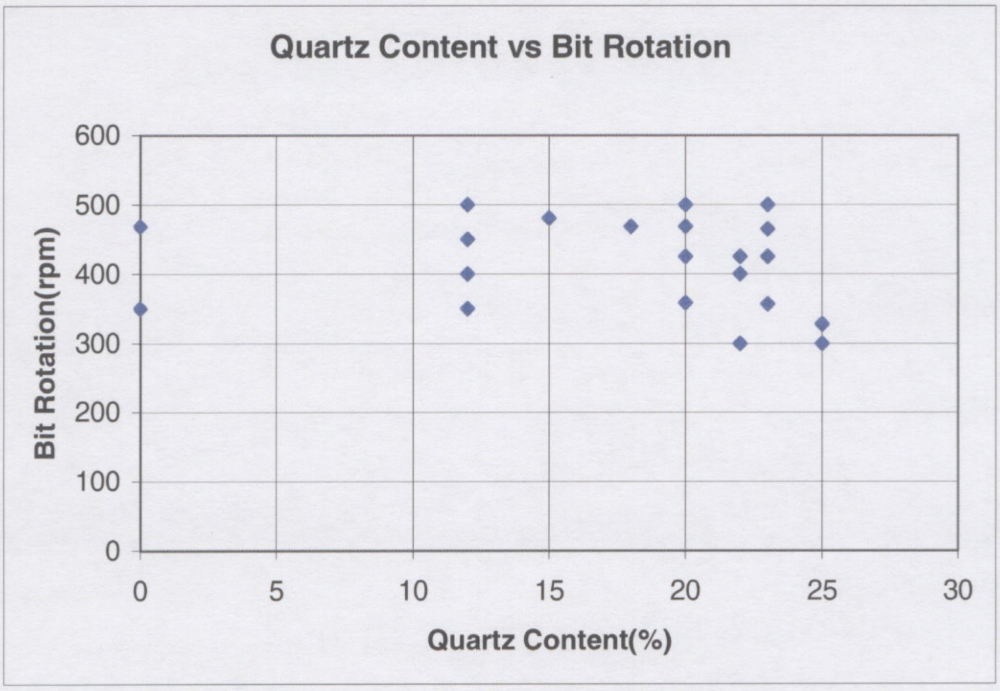

Figure 6.8 Quartz Content vs Bit Rotation Plot

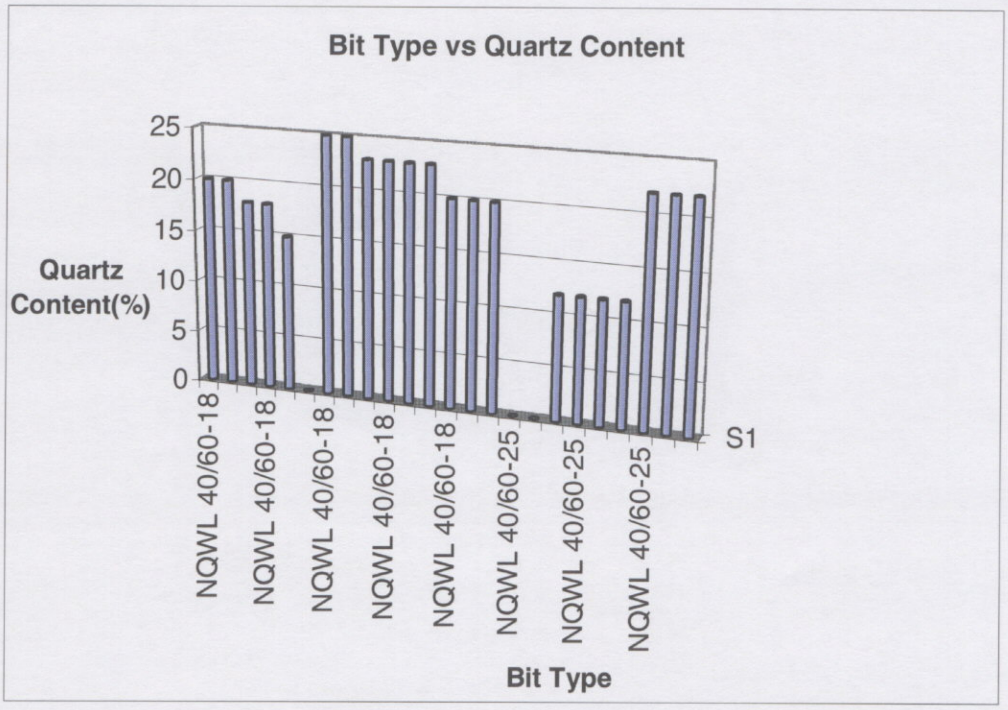

Figure 6.9 Bit Type vs Quartz Content Plot

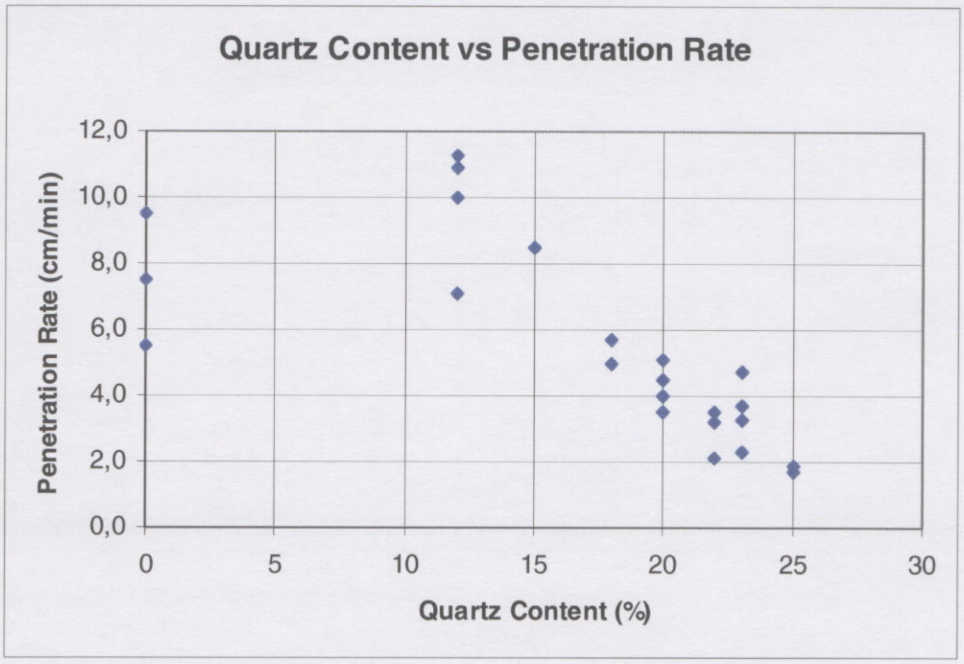

Figure 6.10 Quartz Content vs Penetration Rate Plot

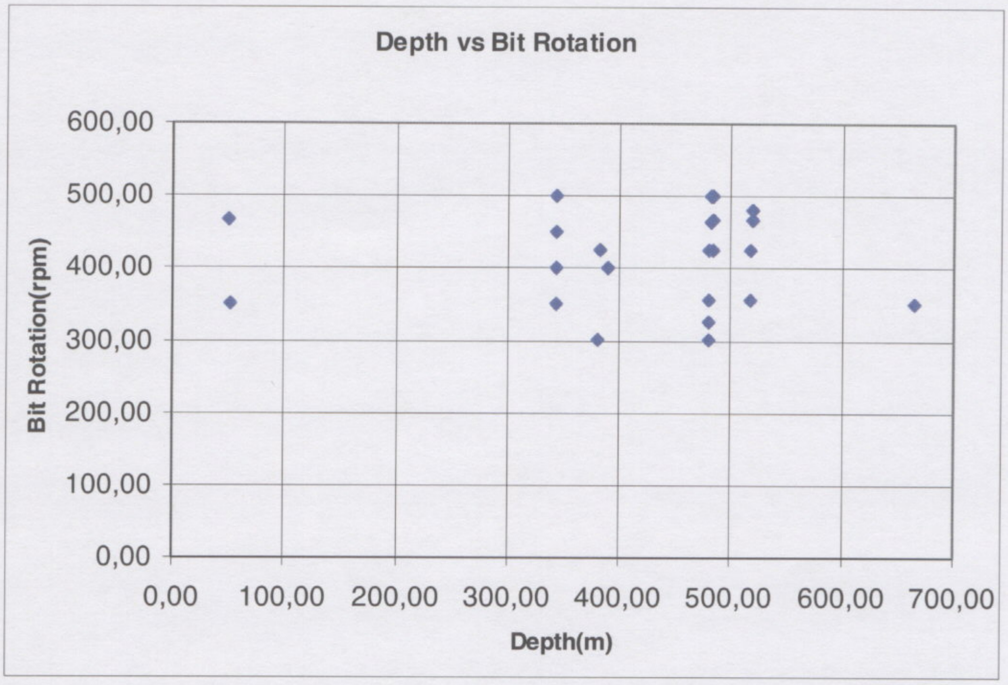

Figure 6.11 Depth vs Bit Rotation Plot

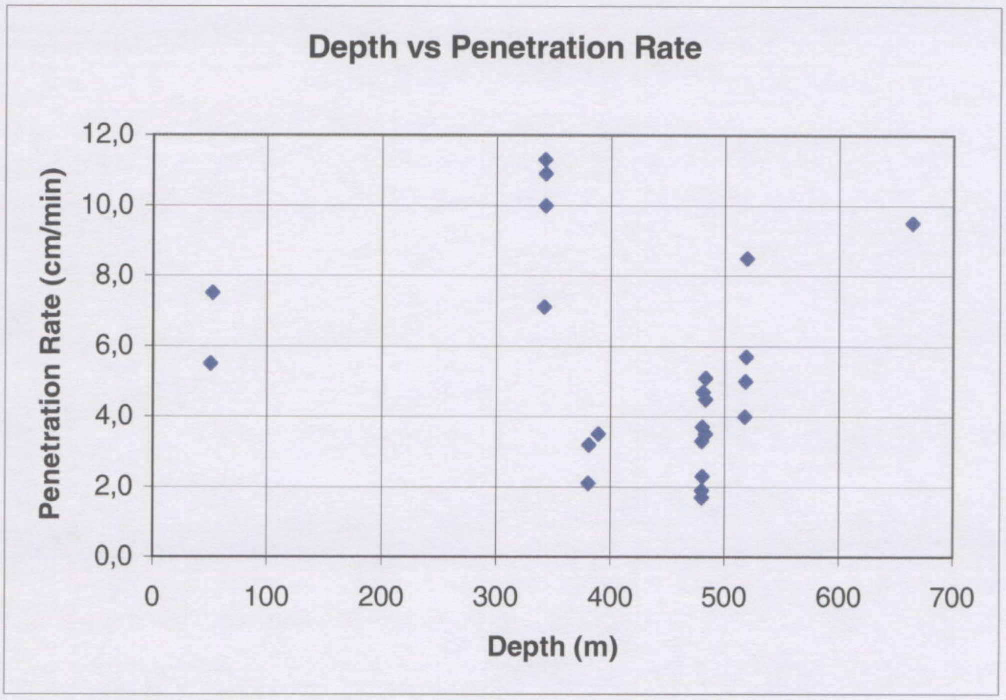

Figure 6.12 Depth vs Penetration Rate Plot

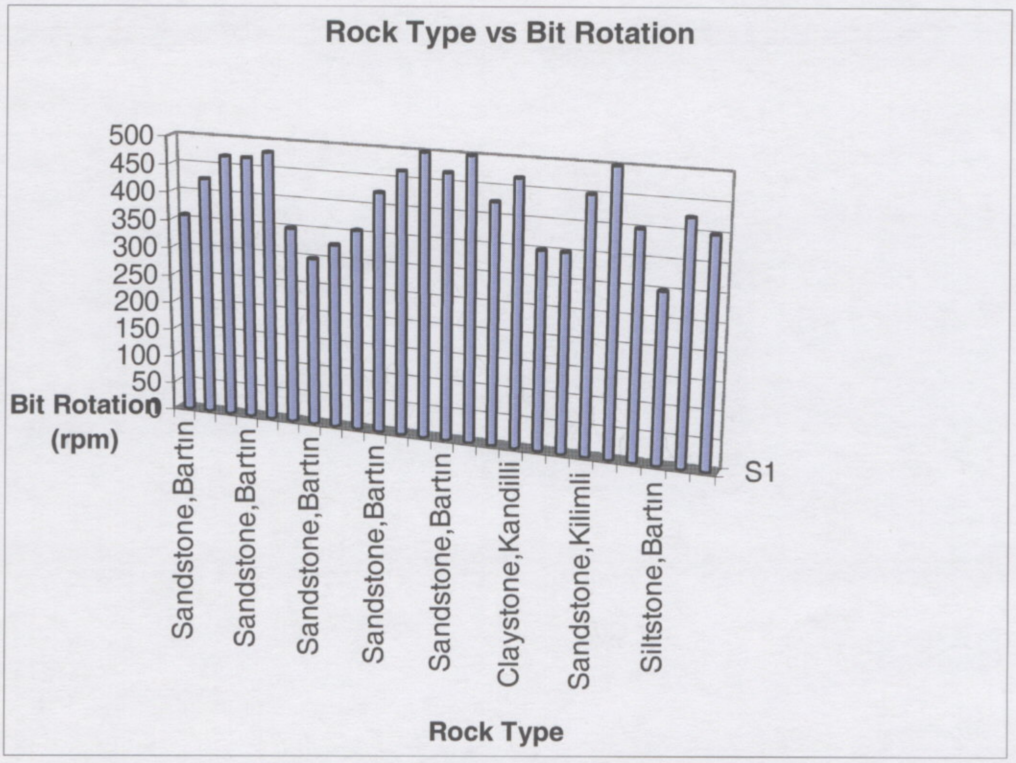

Figure 6.13 Rock Type vs Bit Rotation Plot

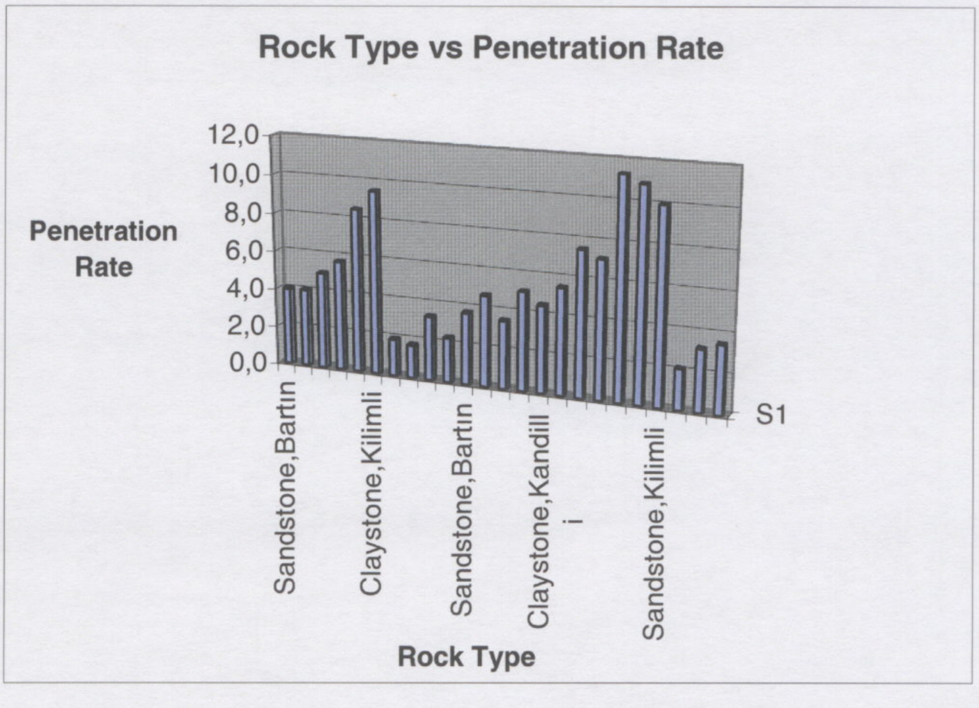

Figure 6.14 Rock Type vs Penetration Rate Plot

CHAPTER 7

CONCLUSIONS

Optimum drill bit selection is an inevitable process for drilling engineering. Although too many approaches and computer programs are used to select optimum drill bit, there is not an exact method for everyone.

In this study, the main idea was to build a system that has a database and program to help and shorten the decision of optimum drill bit selection process. By database opportunities, data is kept, modified and retrieved safe, calculated necessary figures accurate and performance is satisfactory.

By program which was coded by object oriented programming methods, makes computer work in a desired manner and shows necessary items and figures in a very short time.

Field data used in this study was obtained from Zonguldak hardcoal basin(with HQWL at Kilimli, Bartın, Kandilli) by General Directorate of Mineral Research and Exploration(MTA). All the data is inserted into database and lots of trial and errors fulfilled.

Results showed that database performance is high and data come to program in a fast way. Related calculations and figures are accurate. According to results, product looks like a industry-favorable design.

CHAPTER 8

RECOMMANDATION

In this thesis, a computer program is written for optimum drill bit selection and an interacting database is set due to program. Whether query parameters are restricted by operational or indirect data, all available parameters are seen as output. This means that user interface and interacting database are accomplished the necessary selection tasks in a healthy way.

In the future it is recommended to extend this scalable database for a far developed application. If bit performance(working time, travelled distance, etc.) or bit properties are known addition to data in hand, this study would be much more meaningful for end-users and optimum rock bit selection. This simply yields only addition of necessary tables to database, nothing to do with the structure of the database or relationships of the tables.

ASP.NET is a suitable code editor for user interface changes, so extension in the database wouldn't be a problem for the program.

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APPENDIX A

OPERATIONAL AND INDIRECT PARAMETERS DATA TABLE

Table A.1

Rock	Depth Interval		Drill Bit	Pump Pressure	Pump Volume	Bit Rotation (N)	Bit Load (F)	Rock Quality Designation(RQD)	Discontinuity Spacing (DS)	Quartz Content (Q)	Unconfined Compressive Strength (UCS)	Pressure Loss (PL)	Penetration Rate (PR)
	start(m)	end(m)		(kg/cm2)	(l/min)	(RPM)	(kg)	(%)	(#/m)	(%)	(Mpa)	(psi)	(cm/min)
Sandstone,Bartın	114.00	114.20	NQWL 40/60-18	35.0	50.7	350	1296	47	9	18	127		4.5
Sandstone,Bartın	114.20	114.40	NQWL 40/60-18	35.0	50.7	400	1296	77	4	15	127		7.4
Sandstone,Bartın	114.40	114.60	NQWL 40/60-18	35.0	50.7	400	1620	93	1	15	127		8.9
Sandstone,Bartın	114.60	114.80	NQWL 40/60-18	35.0	50.7	300	1296	54	7	18	127		5.0
Sandstone,Bartın	114.80	115.00	NQWL 40/60-18	35.0	50.7	468	1296	67	6	15	127		6.5
Sandstone,Bartın	115.00	115.20	NQWL 40/60-18	35.0	50.7	400	1296	48	8	18	127		4.5
Sandstone,Bartın	115.20	115.50	NQWL 40/60-18	35.0	50.7	470	1296	60	6	20	127		5.7
Sandstone,Bartın	517.20	517.40	NQWL 40/60-18	35.0	50.7	327	648	33	13	18	50		3.0
Sandstone,Bartın	517.40	517.50	NQWL 40/60-18	35.0	50.7	358	648	44	9	20	50		4.0
Sandstone,Bartın	517.50	517.70	NQWL 40/60-18	35.0	50.7	358	810	48	8	20	50		4.5
Sandstone,Bartın	517.70	518.00	NQWL 40/60-18	35.0	50.7	425	648	43	10	20	50		4.0
Sandstone,Bartın	518.00	518.50	NQWL 40/60-18	35.0	50.7	468	648	54	7	18	50		5.0
Sandstone,Bartın	518.50	519.00	NQWL 40/60-18	35.0	50.7	468	648	62	6	18	50		5.7
Sandstone,Bartın	519.00	519.20	NQWL 40/60-18	35.0	50.7	468	810	74	5	15	50		7.0
Sandstone,Bartın	519.20	519.50	NQWL 40/60-18	35.0	50.7	480	648	87	2	15	50		8.5
Sandstone,Bartın	519.50	519.70	NQWL 40/60-18	35.0	50.7	480	810	100	1	10	50		10.5

Table A.1(Continued)

Rock	Depth Interval		Drill Bit	Pump Pressure	Pump Volume	Bit Rotation (N)	Bit Load (F)	Rock Quality Designation(RQD)	Discontinuity Spacing (DS)	Quartz Content (Q)	Unconfined Compressive Strength (UCS)	Pressure Loss (PL)	Penetration Rate (PR)
	start(m)	end(m)		(kg/cm2)	(l/min)	(RPM)	(kg)	(%)	(#/m)	(%)	(Mpa)	(psi)	(cm/min)
Sandstone,Kilimli	683.00	683.20	NQWL 40/60-18	35.0	50.7	350	810	53	7	20	84		5.0
Sandstone,Kilimli	683.20	683.40	NQWL 40/60-18	35.0	50.7	450	810	53	7	20	84		5.0
Sandstone,Kilimli	683.40	683.60	NQWL 40/60-18	35.0	50.7	350	972	64	6	15	84		6.0
Sandstone,Kilimli	683.60	686.00	NQWL 40/60-18	35.0	50.7	450	972	64	6	15	84		6.0
Sandstone,Kilimli	686.00	686.20	NQWL 40/60-18	35.0	50.7	350	810	48	7	20	84		4.5
Sandstone,Kilimli	686.20	686.40	NQWL 40/60-18	35.0	50.7	450	810	51	6	20	84		5.0
Claystone,Kilimli	663.30	663.80	NQWL 40/60-18	35.0	50.7	350	810	80	3	0	64		8.0
Claystone,Kilimli	663.80	664.30	NQWL 40/60-18	35.0	50.7	450	810	91	1	0	64		9.0
Claystone,Kilimli	664.30	664.80	NQWL 40/60-18	35.0	50.7	350	972	95	1	0	64		10.9
Claystone,Kilimli	664.80	665.30	NQWL 40/60-18	35.0	50.7	350	648	91	1	0	64		9.0
Sandstone,Bartın	480.00	480.10	NQWL 40/60-18	35.0	50.7	300	648	22	16	25	50		1.9
Sandstone,Bartın	480.10	480.20	NQWL 40/60-18	35.0	50.7	327	648	22	16	25	50		1.7
Sandstone,Bartın	480.20	480.30	NQWL 40/60-18	35.0	50.7	356	648	36	11	23	50		3.3
Sandstone,Bartın	480.30	480.60	NQWL 40/60-18	35.0	50.7	425	648	26	15	23	50		2.3
Sandstone,Bartın	480.60	480.80	NQWL 40/60-18	35.0	50.7	465	648	41	10	23	50		3.7
Sandstone,Bartın	480.80	481.00	NQWL 40/60-18	35.0	50.7	500	648	51	7	23	50		4.7
Sandstone,Bartın	481.00	481.70	NQWL 40/60-18	35.0	50.7	350	810	41	10	22	50		3.8
Sandstone,Bartın	481.70	481.90	NQWL 40/60-18	35.0	50.7	325	810	33	13	22	50		2.8
Sandstone,Bartın	481.90	482.10	NQWL 40/60-18	35.0	50.7	300	810	28	15	22	50		2.4
Sandstone,Bartın	482.10	482.40	NQWL 40/60-18	35.0	50.7	425	810	28	15	22	50		2.6
Sandstone,Bartın	482.40	482.60	NQWL 40/60-18	35.0	50.7	465	810	50	8	22	50		4.6
Sandstone,Bartın	482.60	482.70	NQWL 40/60-18	35.0	50.7	500	810	57	7	15	50		5.5
Sandstone,Bartın	482.70	482.90	NQWL 40/60-18	35.0	50.7	425	972	32	13	18	50		2.9
Sandstone,Bartın	482.90	483.00	NQWL 40/60-18	35.0	50.7	468	972	44	9	18	50		4.3

Table A.1(Continued)

Rock	Depth Interval		Drill Bit	Pump Pressure	Pump Volume	Bit Rotation (N)	Bit Load (F)	Rock Quality Designation(RQD)	Discontinuity Spacing (DS)	Quartz Content (Q)	Unconfined Compressive Strength (UCS)	Pressure Loss (PL)	Penetration Rate (PR)
	start(m)	end(m)		(kg/cm2)	(l/min)	(RPM)	(kg)	(%)	(#/m)	(%)	(Mpa)	(psi)	(cm/min)
Sandstone,Bartın	483.00	483.10	NQWL 40/60-18	35.0	50.7	500	972	73	5	12	50		6.7
Sandstone,Bartın	483.10	483.30	NQWL 40/60-18	35.0	50.7	468	648	38	11	20	50		3.5
Sandstone,Bartın	483.30	483.50	NQWL 40/60-18	35.0	50.7	500	648	54	7	20	50		5.1
Sandstone,Bartın	483.50	483.70	NQWL 40/60-18	35.0	50.7	425	648	47	9	20	50		4.5
Mudstone,Kilimli	447.70	447.80	NQWL 40/60-25	35.0	50.7	350	1620	68	6	0	64		3.8
Mudstone,Kilimli	447.80	448.00	NQWL 40/60-25	35.0	50.7	450	1620	42	10	0	64		2.0
Mudstone,Kilimli	448.00	448.20	NQWL 40/60-25	35.0	50.7	350	1458	54	7	0	64		2.8
Mudstone,Kilimli	448.20	448.30	NQWL 40/60-25	35.0	50.7	350	1458	60	6	0	64		3.0
Mudstone,Kilimli	448.30	448.50	NQWL 40/60-25	35.0	50.7	450	1620	48	8	0	64		2.5
Claystone,Kandilli	50.60	50.80	NQWL 40/60-25	35.0	81.4	468	600	58	7	0	64		5.5
Claystone,Kandilli	50.80	51.00	NQWL 40/60-25	35.0	81.4	350	810	95	1	0	64		10.5
Claystone,Kandilli	51.00	51.50	NQWL 40/60-25	35.0	81.4	350	1620	80	3	0	64		8.0
Claystone,Kandilli	51.50	52.00	NQWL 40/60-25	35.0	81.4	468	1458	71	5	0	64		7.0
Claystone,Kandilli	52.00	52.10	NQWL 40/60-25	35.0	81.4	350	600	71	5	0	64		7.0
Conglomerate,Kilimli	441.60	441.70	NQWL 40/60-25	35.0	81.4	350	1458	15	20	25	64		1.2
Conglomerate,Kilimli	441.70	441.90	NQWL 40/60-25	35.0	81.4	450	1458	17	22	25	64		1.3
Conglomerate,Kilimli	441.90	442.10	NQWL 40/60-25	35.0	81.4	350	1620	17	22	25	64		1.3
Conglomerate,Kilimli	442.10	442.20	NQWL 40/60-25	35.0	81.4	450	1620	19	22	25	64		1.4
Conglomerate,Kilimli	442.20	442.30	NQWL 40/60-25	35.0	81.4	450	2106	22	16	25	64		1.7
Conglomerate,Kilimli	442.30	442.50	NQWL 40/60-25	35.0	81.4	450	2268	24	16	23	64		2.0
Sandstone,Bartın	259.70	259.90	NQWL 40/60-25	35.0	50.7	350	810	62	6	12	64		6.5
Sandstone,Bartın	259.90	260.00	NQWL 40/60-25	35.0	50.7	425	810	78	4	12	64		7.5
Sandstone,Bartın	260.00	260.50	NQWL 40/60-25	35.0	50.7	468	810	93	1	12	64		9.0
Sandstone,Bartın	260.50	261.00	NQWL 40/60-25	35.0	50.7	500	810	96	1	12	64		9.5

Table A.1(Continued)

Rock	Depth Interval		Drill Bit	Pump Pressure	Pump Volume	Bit Rotation (N)	Bit Load (F)	Rock Quality Designation(RQD)	Discontinuity Spacing (DS)	Quartz Content (Q)	Unconfined Compressive Strength (UCS)	Pressure Loss (PL)	Penetration Rate (PR)
	start(m)	end(m)		(kg/cm2)	(l/min)	(RPM)	(kg)	(%)	(#/m)	(%)	(Mpa)	(psi)	(cm/min)
Sandstone,Bartın	261.00	261.50	NQWL 40/60-25	35.0	50.7	425	500	67	6	17	64		6.5
Sandstone,Bartın	261.50	262.00	NQWL 40/60-25	35.0	50.7	468	500	74	5	17	64		7.0
Sandstone,Bartın	349.60	349.80	NQWL 40/60-25	35.0	50.7	400	1620	56	7	17	64		5.5
Sandstone,Bartın	349.80	349.90	NQWL 40/60-25	35.0	50.7	550	1620	100	1	12	64		9.8
Sandstone,Bartın	349.90	350.20	NQWL 40/60-25	35.0	50.7	350	1295	30	14	23	64		2.7
Sandstone,Bartın	350.20	350.40	NQWL 40/60-25	35.0	50.7	468	1295	45	9	21	64		4.3
Sandstone,Bartın	350.40	350.60	NQWL 40/60-25	35.0	50.7	468	1620	62	6	17	64		5.8
Sandstone,Bartın	350.60	350.80	NQWL 40/60-25	35.0	50.7	470	1620	70	5	17	64		6.7
Sandstone,Bartın	325.20	325.70	NQWL 40/60-25	35.0	50.7	300	1620	32	13	23	64		3.0
Sandstone,Bartın	325.70	326.70	NQWL 40/60-25	35.0	50.7	350	1620	38	11	23	64		3.5
Sandstone,Bartın	326.70	327.30	NQWL 40/60-25	35.0	50.7	400	1620	43	10	21	64		4.0
Sandstone,Bartın	327.30	328.30	NQWL 40/60-25	35.0	50.7	450	1620	48	8	21	64		4.5
Sandstone,Bartın	239.80	239.90	NQWL 40/60-25	35.0	50.7	327	1295	68	6	12	64		6.5
Sandstone,Bartın	239.90	240.00	NQWL 40/60-25	35.0	50.7	300	1296	55	7	17	64		5.3
Sandstone,Bartın	240.00	240.20	NQWL 40/60-25	35.0	50.7	350	1296	66	6	12	64		6.3
Sandstone,Bartın	240.20	240.40	NQWL 40/60-25	35.0	50.7	350	1458	96	1	12	64		9.3
Sandstone,Bartın	240.40	240.80	NQWL 40/60-25	35.0	50.7	468	1458	100	1	12	64		11.0
Sandstone,Bartın	240.80	241.10	NQWL 40/60-25	35.0	50.7	468	1854	100	1	12	64		11.4
Sandstone,Kilimli	342.10	342.50	NQWL 40/60-25	35.0	81.4	350	648	77	4	12	64		7.1
Sandstone,Kilimli	342.50	343.00	NQWL 40/60-25	35.0	81.4	450	648	100	1	12	64		11.3
Sandstone,Kilimli	343.00	343.20	NQWL 40/60-25	35.0	81.4	500	648	100	1	12	64		10.9
Sandstone,Kilimli	343.20	343.30	NQWL 40/60-25	35.0	81.4	400	648	100	1	12	64		10.0
Siltstone,Bartın	380.00	380.10	NQWL 40/60-25	35.0	81.4	327	486	29	14	22	64		2.5
Siltstone,Bartın	380.10	380.50	NQWL 40/60-25	35.0	81.4	327	972	41	10	22	64		3.5

Table A.1(Continued)

Rock	Depth Interval		Drill Bit	Pump Pressure	Pump Volume	Bit Rotation (N)	Bit Load (F)	Rock Quality Designation(RQD)	Discontinuity Spacing (DS)	Quartz Content (Q)	Unconfined Compressive Strength (UCS)	Pressure Loss (PL)	Penetration Rate (PR)
	start(m)	end(m)		(kg/cm2)	(l/min)	(RPM)	(kg)	(%)	(#/m)	(%)	(Mpa)	(psi)	(cm/min)
Siltstone,Bartın	380.50	380.70	NQWL 40/60-25	35.0	81.4	425	810	48	8	22	64		4.3
Siltstone,Bartın	380.70	381.00	NQWL 40/60-25	35.0	81.4	458	810	46	9	22	64		4.1
Siltstone,Bartın	381.00	381.50	NQWL 40/60-25	35.0	81.4	300	648	28	15	22	64		2.1
Siltstone,Bartın	381.50	382.00	NQWL 40/60-25	35.0	81.4	425	648	38	11	22	64		3.2
Siltstone,Bartın	382.00	382.20	NQWL 40/60-25	35.0	81.4	425	810	48	8	22	64		4.2
Siltstone,Bartın	382.20	382.30	NQWL 40/60-25	35.0	81.4	327	972	38	11	22	64		3.3
Siltstone,Bartın	382.30	382.50	NQWL 40/60-25	35.0	81.4	358	972	51	7	22	64		4.7
Siltstone,Bartın	382.50	382.70	NQWL 40/60-25	35.0	81.4	300	972	25	16	25	64		1.5
Siltstone,Bartın	382.70	383.00	NQWL 40/60-25	35.0	81.4	425	972	52	7	22	64		4.5
Siltstone,Bartın	383.00	383.20	NQWL 40/60-25	35.0	81.4	468	972	71	5	12	64		6.5
Siltstone,Kilimli	389.80	389.90	NQWL 40/60-25	35.0	81.4	400	648	40	10	22	64		3.5
Siltstone,Kilimli	389.90	390.10	NQWL 40/60-25	35.0	81.4	350	810	55	7	17	64		5.0
Siltstone,Kilimli	390.10	390.30	NQWL 40/60-25	35.0	81.4	350	972	66	6	17	64		5.5
Siltstone,Kilimli	390.30	390.50	NQWL 40/60-25	35.0	81.4	400	972	45	9	22	64		4.0
Limestone,DS1	0.00	2.70	NQWL 40/60-18	35.0	50.7	450	1750	77	4	5	60		3.0
Limestone,DS1	2.70	5.10	NQWL 40/60-18	35.0	50.7	450	1500	82	3	5	60		3.6
Limestone,DS1	5.10	8.20	NQWL 40/60-18	35.0	50.7	400	1000	75	5	5	60		3.0
Limestone,DS1	8.20	9.60	NQWL 40/60-18	35.0	50.7	400	1500	100	0	5	60		3.6
Limestone,DS1	9.60	10.70	NQWL 40/60-18	35.0	50.7	450	2000	66	6	5	60		2.7
Limestone,DS1	10.70	12.60	NQWL 40/60-18	35.0	50.7	500	2000	58	7	5	60		1.9
Limestone,DS1	12.60	15.60	NQWL 40/60-18	35.0	50.7	400	1500	85	2	5	60		3.6
Limestone,DS1	15.60	16.40	NQWL 40/60-18	35.0	50.7	400	1500	81	3	5	60		3.6
Limestone,DS1	16.40	19.50	NQWL 40/60-18	35.0	50.7	400	1500	89	1	5	60		3.6
Limestone,DS1	19.50	22.50	NQWL 40/60-18	35.0	50.7	400	1500	85	2	5	60		3.6

Table A.1(Continued)

Rock	Depth Interval		Drill Bit	Pump Pressure	Pump Volume	Bit Rotation (N)	Bit Load (F)	Rock Quality Designation(RQD)	Discontinuity Spacing (DS)	Quartz Content (Q)	Unconfined Compressive Strength (UCS)	Pressure Loss (PL)	Penetration Rate (PR)
	start(m)	end(m)		(kg/cm2)	(l/min)	(RPM)	(kg)	(%)	(#/m)	(%)	(Mpa)	(psi)	(cm/min)
Limestone,DS1	22.50	23.40	NQWL 40/60-18	35.0	50.7	500	1750	55	7	5	60		1.7
Limestone,DS1	23.40	26.50	NQWL 40/60-18	35.0	50.7	400	1500	89	1	5	60		3.6
Limestone,DS1	26.50	28.50	NQWL 40/60-18	35.0	50.7	500	2000	78	4	5	60		3.0
Limestone,DS1	28.50	31.60	NQWL 40/60-18	35.0	50.7	550	1500	98	0	5	60		3.0
Limestone,DS1	31.60	34.60	NQWL 40/60-18	35.0	50.7	550	1750	79	4	5	60		3.0
Limestone,DS1	34.60	37.40	NQWL 40/60-18	35.0	50.7	500	2000	69	5	5	60		2.8
Limestone,DS1	37.40	40.40	NQWL 40/60-18	35.0	50.7	450	2000	74	5	5	60		2.9
Limestone,DS1	40.40	42.50	NQWL 40/60-18	35.0	50.7	450	1750	74	5	5	60		2.9
Limestone,DS1	42.50	44.80	NQWL 40/60-18	35.0	50.7	400	1500	89	1	5	60		3.6
Limestone,DS1	44.80	46.10	NQWL 40/60-18	35.0	50.7	450	1000	74	5	5	60		2.9
Limestone,DS1	46.10	47.80	NQWL 40/60-18	35.0	50.7	400	1000	61	6	5	60		2.5
Limestone,DS1	47.80	50.00	NQWL 40/60-18	35.0	50.7	550	1250	73	5	5	60		2.5
Volcanics,ARP1	9.00	9.50	PQWL 60/80-40	13.6	75	200	1000	5	25	0	36		0.2
Volcanics,ARP1	9.50	13.10	PQWL 60/80-40	13.6	75	250	1000	22	16	0	36		2.0
Volcanics,ARP1	13.10	18.20	PQWL 60/80-40	13.6	75	350	1000	30	14	0	36		2.8
Volcanics,ARP1	18.20	21.20	PQWL 60/80-40	13.6	75	200	1250	15	20	0	36		1.4
Volcanics,ARP1	21.20	21.70	PQWL 60/80-40	13.6	75	300	1500	26	15	0	36		2.4
Volcanics,ARP1	21.70	24.30	PQWL 60/80-40	13.6	75	200	1250	36	11	0	36		3.2
Volcanics,ARP1	24.30	33.10	PQWL 60/80-40	13.6	75	300	1500	39	11	0	36		3.6
Volcanics,ARP1	33.10	40.60	PQWL 60/80-40	13.6	75	300	1250	30	14	0	36		2.6
Volcanics,ARP1	40.60	47.70	PQWL 60/80-40	13.6	75	350	2000	44	9	0	36		3.9
Volcanics,ARP1	47.70	58.90	PQWL 60/80-40	13.6	75	400	1500	35	13	0	36		3.2
Volcanics,ARP1	58.90	68.00	PQWL 60/80-40	13.6	75	300	1500	50	8	0	36		4.6
Volcanics,ARP1	68.00	78.40	PQWL 60/80-40	13.6	75	300	1500	38	11	0	36		3.5

Table A.1(Continued)

Rock	Depth Interval		Drill Bit	Pump Pressure	Pump Volume	Bit Rotation (N)	Bit Load (F)	Rock Quality Designation(RQD)	Discontinuity Spacing (DS)	Quartz Content (Q)	Unconfined Compressive Strength (UCS)	Pressure Loss (PL)	Penetration Rate (PR)
	start(m)	end(m)		(kg/cm2)	(l/min)	(RPM)	(kg)	(%)	(#/m)	(%)	(Mpa)	(psi)	(cm/min)
Volcanics,ARP1	78.40	82.30	PQWL 60/80-40	13.6	75	300	1500	45	9	0	36		4.2
Volcanics,ARP1	82.30	86.50	PQWL 60/80-40	13.6	75	350	1500	41	10	0	36		3.8
Volcanics,ARP1	86.50	106.70	PQWL 60/80-40	13.6	75	300	1500	24	16	0	36		2.2
Volcanics,ARP1	106.70	112.00	PQWL 60/80-40	13.6	75	300	2000	32	13	0	36		3.1
Volcanics,ARP1	112.00	121.00	PQWL 60/80-40	13.6	75	300	1800	26	15	0	36		2.4
Volcanics,ARP1	121.00	129.00	PQWL 60/80-40	13.6	75	300	1500	29	14	0	36		2.7
Volcanics,ARP1	129.00	131.90	PQWL 60/80-40	13.6	75	300	1600	29	14	0	36		2.7
Volcanics,ARP1	131.90	139.20	PQWL 60/80-40	13.6	75	300	1500	25	16	0	36		2.1
Volcanics,ARP1	139.20	144.80	PQWL 60/80-40	13.6	75	300	1000	22	16	0	36		2.0
Volcanics,ARP1	144.80	148.30	PQWL 60/80-40	13.6	75	300	1250	24	16	0	36		2.1
Volcanics,ARP1	148.30	154.40	PQWL 60/80-40	13.6	75	300	1500	30	14	0	36		2.7
Volcanics,ARP1	154.40	162.60	PQWL 60/80-40	13.6	75	300	1000	27	15	0	36		2.5
Volcanics,ARP1	162.60	168.70	PQWL 60/80-40	13.6	75	300	1500	12	20	0	36		0.8
Volcanics,ARP1	168.70	171.10	PQWL 60/80-40	13.6	75	350	2000	17	18	0	36		1.4
Volcanics,ARP1	171.10	175.20	PQWL 60/80-40	13.6	75	300	1500	17	18	0	36		1.4
Volcanics,ARP1	175.20	176.70	PQWL 60/80-40	13.6	75	350	1800	26	15	0	36		2.4
Volcanics,ARP1	176.70	180.60	PQWL 60/80-40	13.6	75	350	1000	28	15	0	44		2.5
Volcanics,ARP1	180.60	181.90	PQWL 60/80-40	13.6	75	300	1250	26	15	0	44		2.3
Volcanics,ARP1	181.90	187.00	PQWL 60/80-40	13.6	75	250	1500	28	15	0	44		2.6
Volcanics,ARP1	187.00	190.00	PQWL 60/80-40	13.6	75	300	1250	40	10	0	44		3.6
Volcanics,ARP1	190.00	194.90	PQWL 60/80-40	13.6	75	300	1500	51	7	0	44		4.4
Volcanics,ARP1	194.90	201.20	PQWL 60/80-40	13.6	75	300	1500	34	13	0	44		2.9
Volcanics,ARP1	201.20	206.60	PQWL 60/80-40	13.6	75	300	1500	42	10	0	44		3.8
Volcanics,ARP1	206.60	214.40	PQWL 60/80-40	13.6	75	300	1500	44	9	0	44		4.1

Table A.1(Continued)

Rock	Depth Interval		Drill Bit	Pump Pressure	Pump Volume	Bit Rotation (N)	Bit Load (F)	Rock Quality Designation(RQD)	Discontinuity Spacing (DS)	Quartz Content (Q)	Unconfined Compressive Strength (UCS)	Pressure Loss (PL)	Penetration Rate (PR)
	start(m)	end(m)		(kg/cm2)	(l/min)	(RPM)	(kg)	(%)	(#/m)	(%)	(Mpa)	(psi)	(cm/min)
Volcanics,ARP1	214.40	222.40	PQWL 60/80-40	13.6	75	300	1000	36	11	0	44		3.3
Volcanics,ARP1	222.40	232.70	PQWL 60/80-40	13.6	75	250	1000	27	15	0	44		2.5
Volcanics,ARP1	232.70	240.10	PQWL 60/80-40	13.6	75	250	1000	31	14	0	44		2.7
Volcanics,ARP1	240.10	248.00	PQWL 60/80-40	13.6	75	250	1000	22	16	0	44		2.0
Volcanics,ARP1	248.00	254.60	PQWL 60/80-40	13.6	75	250	1500	20	18	0	44		1.7
Volcanics,ARP1	254.60	259.40	PQWL 60/80-40	13.6	75	250	1000	30	14	0	44		2.6
Volcanics,ARP1	259.40	261.90	PQWL 60/80-40	13.6	75	200	1000	22	16	0	44		2.0
Volcanics,ARP1	261.90	263.90	PQWL 60/80-40	13.6	75	230	1000	41	10	0	44		3.8