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Reporting and Efficiency Analysis in Geothermal Well Drilling

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ABSTRACT

Effective management of geothermal well drilling requires proper collection, analysis and presentation of drilling data from the on-set to the completion and testing of the well. The interpretation and evaluation of all available information regarding geology, structure, geophysics, flow paths, temperature and surface conditions is done by an interdisciplinary team consisting of geologists, physicists, geochemists, reservoir scientists, drilling engineers who work together on a common platform as opposed to each discipline developing their own ideas independently. The integrated information and data collected from actual drilling operations can then be applied in the optimization of the drilling process resulting in improvements and consequently better well being drilled.

During the actual well drilling, the record of activities, the bottom hole assembly (BHA), casing, drilling fluids and other materials, directional information and other aspects of drilling must be recorded on a regular basis. These information helps in the operations analysis and performance of various drilling aspects.

This paper gives an outline of the reporting and reports generated during the well drilling process and uses RIMDrill software, which is a rig to office drilling information system for drilling contractors (Infostat, 2012), to store and analyse well data with the aim of using the information in optimizing the drilling processes. The Daily Reports data are entered at the rig site and transferred to a central office where data is consolidated for the entire rig fleet. The program defines the major time and cost areas and provides critical information for accounting purposes and in optimizing the drilling processes. It also supports analysis for management and for operational decision making which can significantly impact the drilling process, cost and time.

INTRODUCTION

The goal of any geothermal drilling project is to realize the well in a safe manner and according to its purpose and to complete it with minimum cost. Effective management of the well drilling requires proper management of the data collected on-site, from the period of drilling to completion and testing of the well.

Analysis of drilling efficiency considers whether the drilling operations are carried out with the shortest time and at a competitive cost. To be able to achieve this, a balance must be achieved between the drilling processes, materials selection and the design of the well itself. The drilling processes in terms of whether it is aerated drilling or otherwise, the type and quality of materials used directly affects the cost while the design in terms of whether it's a directional or vertical well also affects the efficiency of drilling the well.

This paper gives an outline of the reporting and reports generated in the course of drilling and uses RIMDrill software, which is a rig to office drilling information system for drilling contractors (Infostat, 2012), to store, analyse and report rig daily data with the aim of using the information for accounting purposes and in optimizing the drilling processes. Considerations applied in well design, drilling practices and associated challenges are discussed in this paper.

RIMDRILL SOFTWARE

RIMDrill software provides an array of options that can be adopted by different contractors in their daily operations and reporting. A comprehensive suite of business analysis tools uses the data in this central database to provide critical information to support analysis for management and operational decision makers. While the application is designed to be easy to use for rig site users it incorporates tools for flexible access to such critical information as rig downtime, KPI performance and HSE data. Before proceeding with data entry, several tasks need to be completed to configure RIMDrill correctly. For the purposes of this report and in the case of drilling operations in Olkaria, the following structure was selected for the reporting and analysis of information:-

- The system is configured as a rig installation where it uses RIMDrill to enter daily rig information and send database updates to an office site.
- Two tours (shift) for the daily IADC reports with start times of 0800hrs and 2000hrs named as day tout and night tour respectively.
- The units of measure are set as per the drilling data handbook (Gabolde and Nguyen, 2006).
- The IADC codes are used as they are inbuilt within the software.
- The KPIs used are the default ones with waiting on cement (WOC) and logging speeds (LOG) added by the author as additional KPI targets.

The software also provides room for adding or modifying the KPIs and other parameters as need arises over time. The program is comprehensive and most of its features are used without modifications.

REPORTING

DAILY DRILLING REPORT

Daily reporting of the drilling operations and all well related activities is important in the management and monitoring of geothermal well drilling. This is done in logging books and special forms or on computer programs.

The reports conform to the International Association of Drilling Contractors standards (IADC, 1992). The parameters and details captured include:-

- Rig information
- Drilling parameters
- Time record
- Mud record
- Deviational record
- Material inventory
- BHA and Bits
- Casing information
- Auxiliary equipment details
- Safety information
- Drilling crew details
- Equipment failures

The daily report gives an up to date progress of all the activities taking place at the rig and is filled out for every 12 hour shift. This is done either on a logging book or on a computer program. The Rig Daily Report describes the work, tracks time, material usage, cost, reports on upcoming activity. For purposes of this paper as part of the GRC presentation, the daily reports are recorded and analysed using RIMDrill software, which is widely used by geothermal drilling contractors. The data entry is done by the tool pusher (supervisor) at the rig during the shift.

TIME RECORDS

These must be well captured and documented since they are not only used as reporting parameters but also in the operational analysis to aid in the optimization of the drilling processes and in tracking the cost. The time distribution on the various operations in the process of drilling the well is key in the overall analysis making the time records vital part of the rig daily report. The various drilling processes are recorded and coded, among them:-

- Rigging up and down
- Actual drilling
- Reaming
- Circulating
- Tripping in and out
- Repair of rig and auxiliary equipment
- Cut and slip the drill line
- Wireline logging
- Running casing
- Cementing casing and cement plug operations
- Waiting on cement
- Nippling up the BOP
- Testing the BOP

Other operations including equipment testing, lay down and picking up singles among the others. There are about 80 operation codes that can be entered.

The time spent on each of the above operation is recorded, has a special numeric code, and the whole time record then used in the operations time analysis as part of the in-depth analysis of rig operational activities.

BITS

Optimization of the drilling process from the view point of time and cost is extremely crucial in the drilling of a geothermal well. Once the parameters are given, the selection of drill bits and correct configuration of the rest of the BHA can be made.

In the analysis of drilling operations (Miyora,2010), the tripping time normally constitutes a large percentage in the overall well drill time. This therefore implies that if it is possible to reduce or minimize the number of trips (pulling out of hole and running in hole), the total drill time will be significantly reduced. Selecting a drill bit that can drill more before wearing out can solve this problem. However the cost of a long lasting bit is usually higher and when optimizing the drilling process, cost is also a key factor and must be considered in the final proposal. For optimum selection, calculation of the bit cost per meter drilled is useful.

The bit record therefore provides a good avenue for analysing the performance of the bit in terms of the rate of penetration, fluid properties, and bit type with the intent of selecting the bit that lasts longer and drills more thereby reducing the overall drilling time and cost.

The bit records gives information on:-

- The hours run by the bit and total number of revolutions
- The depth interval of hole drilled by the bit
- Details of the bit including type (IADC code), size, make, model, size of jets, number of runs
- Gauging of the used bit (IADC grading system)

BHA AND DRILL STRING

The drilling performance is directly affected by the overall drilling system and the operational parameters that form the core of the engineering of drilling a geothermal well. This involves maintaining the integrity of the drill string, managing the hydraulic pressures, ensuring effective hole cleaning and determining the pressure limits of the open hole in order to maintain wellbore integrity. The drill string serves the following purposes:-

- Conduit for the drilling fluid from the mud tanks down to the bit
- Transmits the torque via the kelly drive or from the top drive to the drill bit
- Applies weight on the bit
- Lowering and raising the bit

The drill string is made up of three sections namely the BHA, heavy weight drill pipes and the drill pipes. The rig daily report gives details of the components of the BHA and drill string including most importantly the weights. The BHA is made up of the drill bit, bit sub with a check valve, the drilling stabilizers which keep the assembly centered in the hole and the drill collars which apply weight to the bit. For directional drilling a mud motor and MWD may be added just above the bit.

OPERATIONS ANALYSIS

RIMDrill is a rig to office drilling information system for drilling contractors. Daily report data are entered at the rig site and transferred to a central office where data is consolidated for the entire rig fleet. The output is an officially licensed IADC-formatted report. Defines key performance indicators (KPIs) allowing one to assess the performance of selected operational activities and compare that activity's measurements with similar activities on other rigs or on the same rig over time.

The efficiency analysis is given in terms of performance reports, graphs and schematics which provide both rig and office users with the tools to better understand and manage their operations. Standard query language (SQL) and a RIMDrill inbuilt operations query is used to retrieve the inforamtion from the RIMDrill database.

OPERATIONS CODE

From the time a record, the time spent on each operation is recorded, a special numeric code, is allocated to each operation which is then used in the operations time analysis as part of the in-depth analysis of rig operational activities. There are about 80 operations codes defined in RIMDrill. Examples are given in Table 1 below:

Table 1: Operation codes defined in RIMDrill

Code	Description	OpsGroup	IADCCode	PerformanceCategory
ANCH	Anchoring Operations	MOB	1	
BHA	Make Up/Lay Dn/Chge BHA	TRIP	6	BHA
BOPO	BOP Operations	BOPOPS	14	BOPOPS
BOPT	BOP Testing	BOPOPS	15	BOPTEST
CASE	Running Casing	CASING	12	CASING
CIRC	Circulate/Condition Mud	DRILL	5	
CMTC	Cement Casing	CEMENT	12	
CMTPL	Cement Plug Operations	CEMENT	12	
CMTS	Secondary Cement Operatio	CEMENT	12	
CUTDL	Cut and Slip Drill Line	UPGRAD	9	CUTSLIP
DRCMT	Drilling Cement/Shoe	DRILL	2	
DRIL	Drilling Ahead w/ Connectio	DRILL	19	
DRILR	Drilling - Rotating	DRILL	2	
DRILS	Drilling - Sliding	DRILL	2	
DST	Testing Operations, DST etc	EVALUATE	16	
EQINST	Equipment Installation	UPGRAD	21	
EVAL	Well Evaluation	EVALUATE	11	
FISH	Fishing Operations	PROBLM	19	
FIT	Leak Off Test	EVALUATE	13	
FLOW	Flow Check	DRILL	2	
IDLE	Idle	STACK	23	
KILL	Well Kill Operations	PROBLM	22	
LAYDN	Lay Down Singles	DRILL	21	LAYDOWN
LOG	Wireline Logging	EVALUATE	11	
LOST	Losing Circulation	PROBLM	5	
MAINT	Yard/Dock Maintenance	STACK	23	
PICKUP	Pick Up Singles	DRILL	21	PICKUP
PLUG	Plugging Operations	ABAND	17	
PRELD	Pre-loading Rig	MOB	1	

KEY PERFORMANCE INDICATORS (KPIS)

Key Performance Indicators (KPIs) can be defined as time taken to perform certain repetitive operations during the drilling of a well or over a specified time frame (Infostat, 2012). It can be used to measure how each rig performs these operations over a given time frame and how it compares with other rigs in the fleet or by different contractors. KPI data can also be used to establish a baseline level of performance for each defined KPI category against which each rig's individual performance can be measured. RIMDrill software besides its ability to capture KPI data also provides powerful output reporting tools for data analysis. The performance graphs are generated for individual rigs and allows for comparisons between other rigs with the ultimate goal of identifying best practises that can then be applied to optimize the drilling process.

The KPIs allow one to measure the performance of any operational activity and compare that activity's measurements with similar activities on other rigs or on the same rig over time. Effective use of KPIs requires both planning ahead for what KPIs to measure at what level of detail and a diligent approach to data collection. A KPI Type in the software can be assigned to any operations code, after which KPI data will be collected for that operation. The data can then be reviewed and analysed in KPI reports. For each KPI operation, multiple KPI sub-codes can be created to collect more detailed information for the operation. The default setting for RIMDrill software is for the users to enter KPI data but this can be made optional though it is not recommended.

1. KPIs can be measured with respect to four different metrics, called KPI types:
2. Time: this is a simple comparison of elapsed time spent performing an activity; for example, BOP Handling operations
3. Count rate: this is a count per unit of time (hour) for a particular operation; for example, picking up or laying down drill pipe.
4. Length rate hour: this is in feet or meters per hour for a particular operation; for example, running casing.

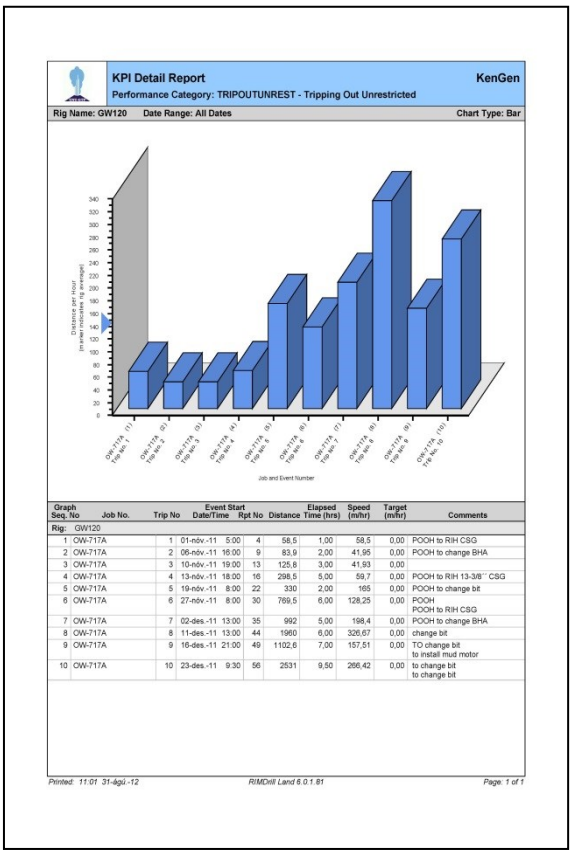
Depth rate hour: this is similar to length rate hour, but instead of a length, requires a start and end depth. A length is determined from the difference of the inputs. For example, tripping in or out of the well.

The performance categories defining the KPI selected for purposes of this paper are given in Table 2 below.

Table 2: KPI Targets and their codes selected for Olkaria

Code	Description	IADC Code	KPI Type	Event Name
WOC	Waiting On Cement	13	TIME	Event
WASH	Change Wash pipe	8	TIME	Event
TRPOUT	Tripping Out	6	DEPTH_RATE_HR	Trip
TRPIN	Tripping In	6	DEPTH_RATE_HR	Trip
PICKUP	Pick Up Singles	21	COUNT_RATE	Run
LOG	Wireline Logging	11	DEPTH_RATE_HR	Event
LAYDN	Lay Down Singles	21	COUNT_RATE	Run
CUTDL	Cut and Slip Drill Line	9	TIME	Event
CASE	Running Casing	12	LENGTH_RATE_HR	Event
BOPT	BOP Testing	15	TIME	Event
BOPO	BOP Operations	14	TIME	Event
BHA	Make Up/Lay Dn/Chnge BHA	6	TIME	Event

The KPIs are defined in the RIMDrill program with the option of adding more by the user, depending on the specific needs. The handing of the KPI is simplified by integrating its data entry with that of the daily operations reporting function. Figure 1 and 2 show performance graph for rig GW120 and a comparison between rig GW120 and GW116 respectively.



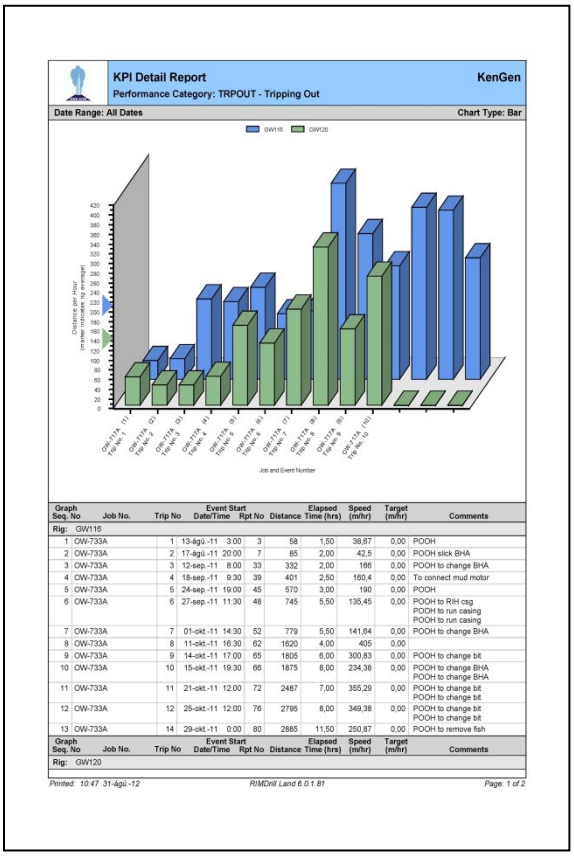


FIGURE 1: Performance graph for rig GW120

Figure 2: Comparison between rig GW120 and GW116

EFFICIENCY ANALYSIS

The analysis in this paper was done by use of the RIMDrill software after all the relevant data had been entered onto the program by the author. More information about RIMDrill Software and its application is discussed in a different section of this paper.

The performance of any operational activity can be assessed by using the KPIs.

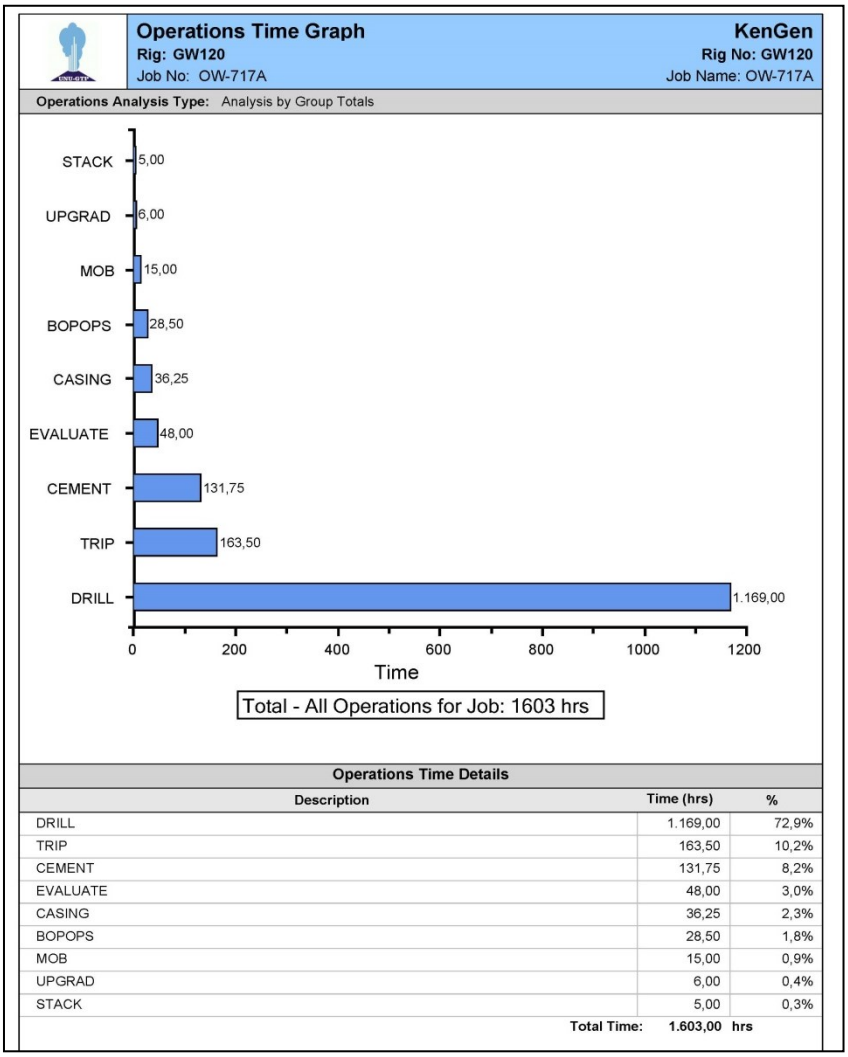
The KPI form provides numerous display options, including:-

- Single rig or multi-rig: View data for one rig or compare data for multiple rigs. For a single rig, you can view data for all jobs or one job. Figure 1 shows a performance graph for a Rig GW120 used for drilling well OW-717A. For multiple rigs, you can choose as many rigs as desired; the only limit is your ability to decipher the data in the resulting report. Figure 2 is an example of such output for multiple rigs, Rig GW120 and GW116.
- Date range: View a specific time segment of the KPI data. This makes it possible to obtain information for a certain range of time over the period of drilling the well. This is possible for a rig or multiple rigs and for a job and also for one or more performance categories.
- Performance categories: View data for any of the KPI Operations Codes. Print individual reports or one combined report for all KPI operations codes.

The efficiency analysis is finally given in terms of performance reports and graphs which can be retrieved by the use of operations query. The query gives a flexible report of operations activities; can be filtered by division, field, job, dates, phase, operations group, operations code, non-productive activities, and/or specific text in the activity description.

TIME ANALYSIS

Miyora, 2010 explains the normalization of workdays prior to analysis of types spent on each activity while drilling a geothermal well. On RIMDrill software, the numbers of hours spent on each operation on each shift of the day are entered into the operations section of the daily reporting page. These are then represented on operations time graph showing the percentage of the total time spent on each operation. Figure 3 shows an operations time graph for well OW-717A generated using the Rim Drill software.



Operations Time Details

Description	Time (hrs)	%
DRILL	1.169,00	72,9%
TRIP	163,50	10,2%
CEMENT	131,75	8,2%
EVALUATE	48,00	3,0%
CASING	36,25	2,3%
BOPOPS	28,50	1,8%
MOB	15,00	0,9%
UPGRAD	6,00	0,4%
STACK	5,00	0,3%
Total Time:	**1.603,00 hrs**	

FIGURE 3: Operations time graph for well OW-717A (Generated by RIMDrill Land 6.0.1.81)

As part of the rig operational analysis, the operations time analysis breakdown according to the IADC code. This gives a breakdown of the related operations as given in the IADC code and also gives an analysis of individual isolated operations.

The depth versus time graph is also provides a good overview of the progress of well drilling. From the planned progress data and the actual progress information inputted as the drilling continues an analysis on how many days behind or ahead of plan can be deduced. The graph also shows which section of the well contributed to the delay or to the faster progress. This can then be related to other sections of the overview reports such as rig downtime report.

COST ANALYSIS

The cost of drilling geothermal wells for production and reinjection is about 40% of the projects total investment explaining why the subject of cost and risk often comes up and how it can minimised (Thorhallsson, 2012). As a critical aspect of optimization of geothermal well drilling, the cost of materials and services must be well captured. The nature of the contract, whether one integrated contract or where there are many contracts, will advise on the way the cost is analysed. The costs report group includes the following reports:-

- Cost versus depth graph showing actual and planned costs for a single job and for group of jobs.
- Cost query where flexible report of daily costs; can be filtered by division, field, job, dates, account codes, and/or vendors.
- Daily cost report giving cost information for a single operating day.
- Job summary report showing a summary of actual costs for the job.
- Weekly costs giving daily cost expenditure by day of the week.
- Vendors costs showing daily costs report showing vendor cost associations; can be filtered by job, vendor, and/or date range.

During drilling, a close follow-up of the actual cost and a comparison with the estimated (and authorized) ones can be done on a daily basis on the RIMDrill platform. With RIMDrill software it is possible to analyse the cost per unit depth that is drilled, per section of the well, per shift to enable identification of efficient processes for the purposes of optimizing the drilling process.

GENERATION OF REPORTS

The system acts as a central data store for all rig data when used in the office environment. Over 40 summary reports, graphs and schematics are available to provide both rig and office users with the tools to better understand and manage their operations including the tracking of KPI data. The reports are designed to assist with operational, cost, and performance analysis. Directional reports, which include 3D report given in Figure 4, elevation report given in Figure 5 and plan report in Figure 6, are some of the important reports generated from RIMDrill software. Other reports that can be generated from RIMDrill software include (Infostat, 2012):-

1. Daily reports which comprise IADC daily drilling report, daily contractor report (single page or multi page version) and daily operator report.
2. Management overview reports which provide the management with an overview of rig activities. They include daily rig summary report, rig downtime report, job summary report, weekly operations report and operations time breakdown graph.
3. Rig operational analysis reports which are designed to give in-depth analysis of rig operational activities. They include operations time analysis breakdown shown in Figure 3, weekly/monthly operations summary report, operations activity chronology, day versus depth plot and operations query report.
4. Rig performance reports which are analysis for rig performance indicators and rig downtimes. They include rig individual performance report as shown in Figure 1, rig comparison report as given in Figure 2, and multi well days versus depth plot.
5. Engineering reports for analysing drilling engineering parameters. They include days versus depth, borehole schema, BHA graphical report, BHA list report, bit summary report, survey report and directional 3D graph.
6. Health safety and environment (HSE) reports which reports on HSE related information. These include safety report and medical/accident report.
7. Data integration tools which are reports designed to help streamline other in-house information processes such as payroll and customer billing. They include operational charge rate analysis, employee payroll report and summary payroll summary.

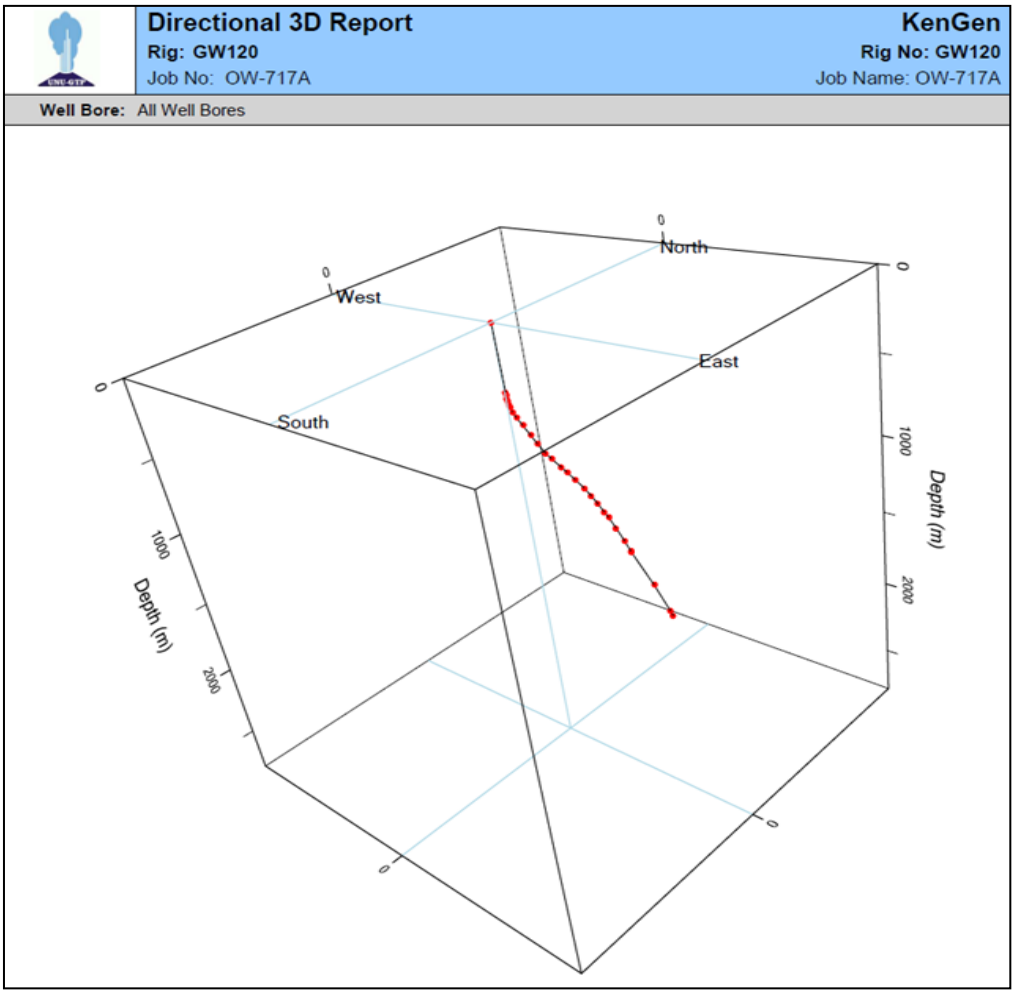


FIGURE 4: Directional 3D report for well OW-717A

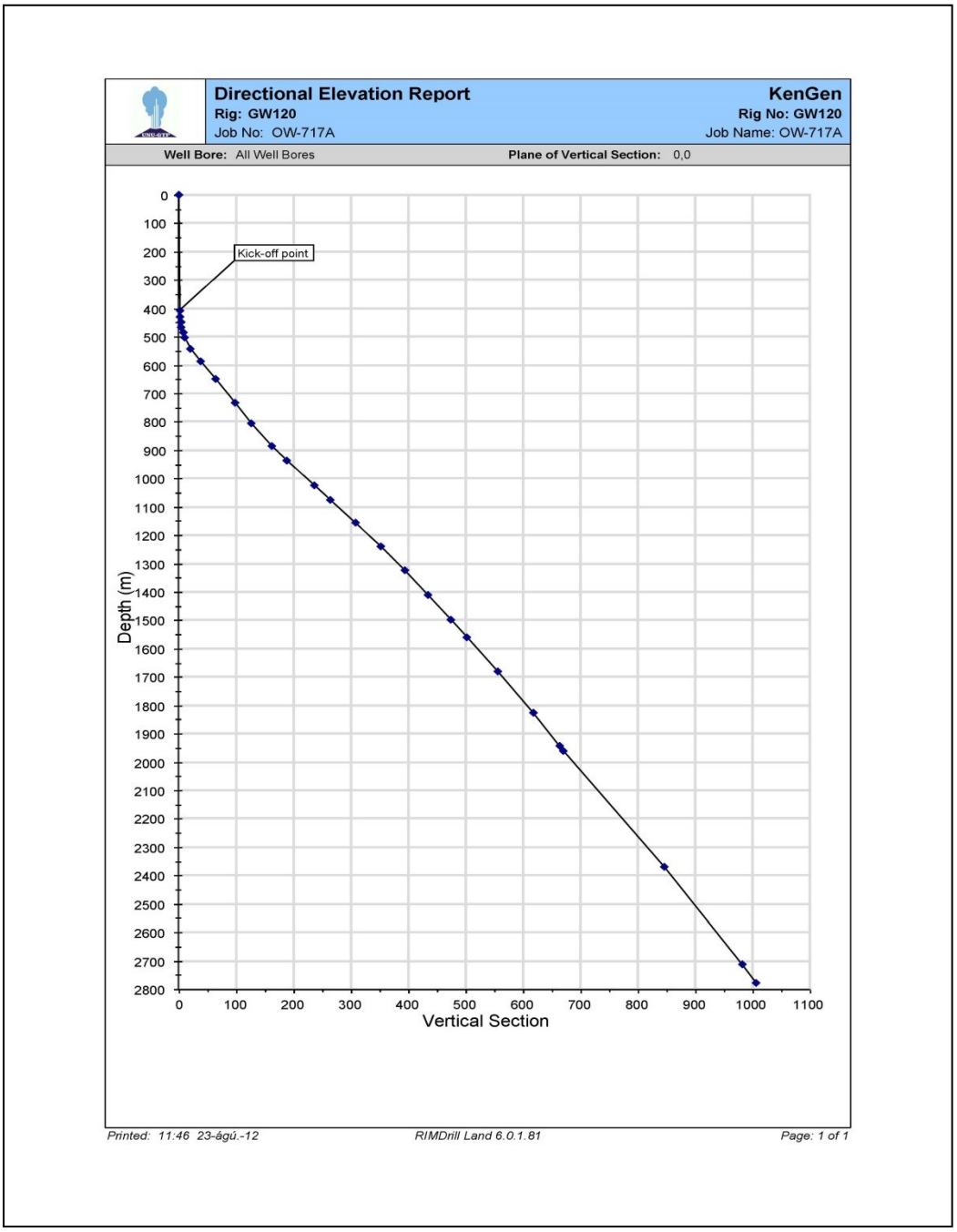


FIGURE 5: Directional elevation report for well OW-717A

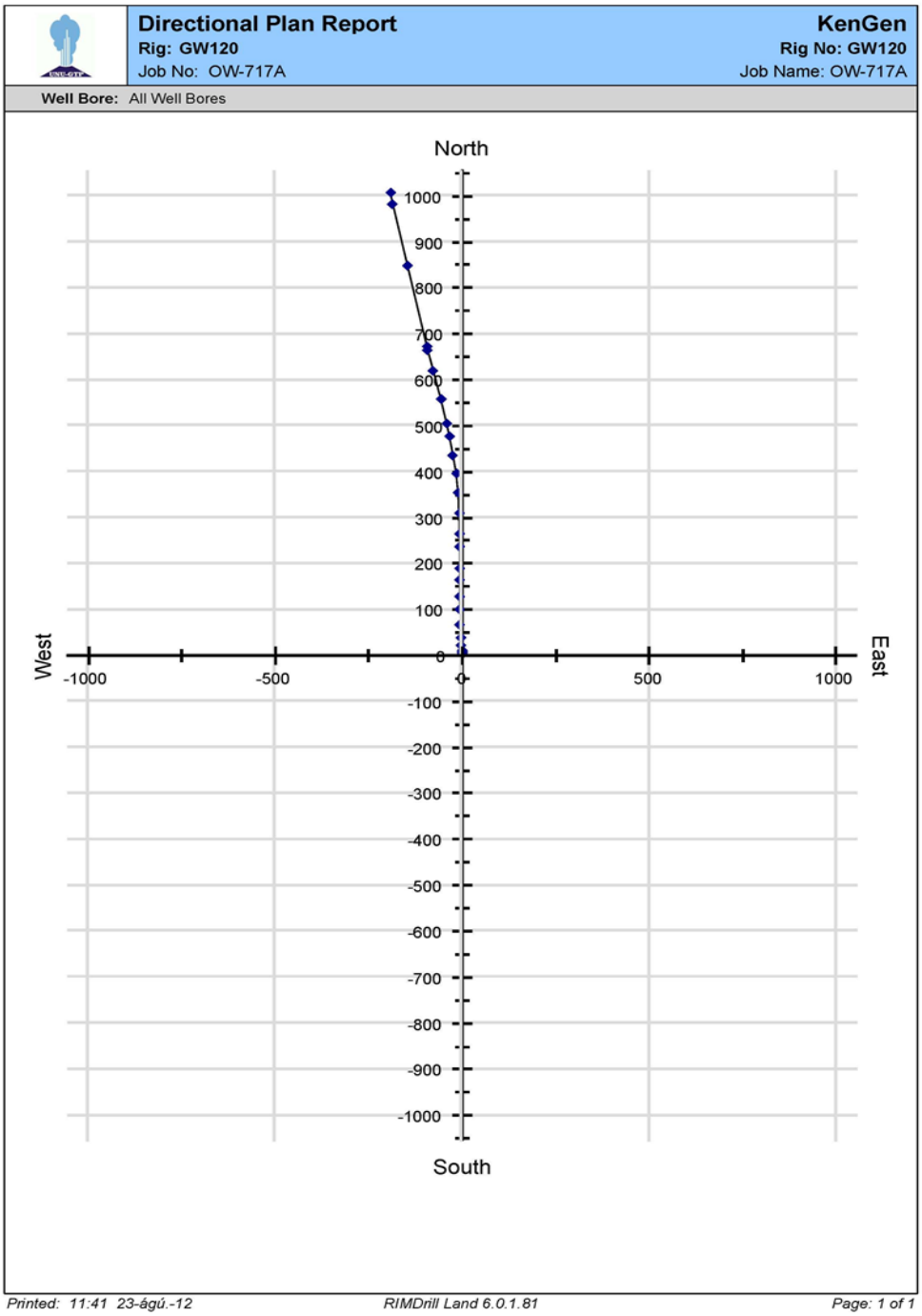


FIGURE 6: Directional plan report for well OW-717A

CONCLUSIONS AND RECOMMENDATIONS

This paper has discussed how information gathered during the process of drilling a geothermal well is reported and how the reports generated are used in analysing the performance with the intent of optimizing the drilling process. A lot of information is gathered and reported for all phases of geothermal development. For comprehensive and accurate efficiency analysis, the data must be well managed from the collection point and stored in standard format.

Computer programs make the handling, storage and processing of data much easier and the analysis faster and more accurate. RIMDrill software used for this paper enables successful data management and analysis.

KPI enables analysis of various aspects of the drilling from comparing performances of different crews, and equipment and setting a benchmark against which future drilling activities shall be gauged.

Drilling efficiency ensures that the drilling operations are carried out well within the shortest time and at a competitive cost. To be able to achieve this, a balance must be achieved between the processes, materials selection and the design of the well itself. Higher efficiency and better optimization of the drilling process can be achieved by undertaking among other things:-

- Using high mobility rigs which requires less time for mobilization.
- Simple drill sites and ponds for containment.
- BOP stacks that take less time to install.
- Using larger diameter drill pipes for lower pump power and oil consumption.
- Improving on time spent to run casing and for cementing.
- Minimal casing programs, less cement.
- Improved ROP by using the right bits, correct BHA configuration and accurate instrumentation. Automating processes like pipe handling to reduce on time and cost since the crew size will be reduced.

REFERENCES

Gabolde, G., and Nguyen, J.P., 2006: *Drilling data handbook* (8th edition). IFP publications, Editions Technip, 541 pp.

IADC, 1992: *Drilling manual* (11th ed.). International Association of Drilling Contractors, USA.

Infostat Systems, website: *http://infostatsystems.com/drilling-contactors-RIMDrill/RIMDrill-for-drilling-contactors*

Miyora, T.O., 2010: Controlled directional drilling in Kenya and Iceland. Report 20 in: *Geothermal training in Iceland 2010.* UNUGTP, Iceland, 365-390

Thórhallson, S., 2012: *Geothermal drilling technology.* UNU-GTP, Iceland, unpublished lecture notes.