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OPTIMIZATION OF DRILLING OF VOLCANICS SECTION IN AN OIL/GAS WELL.

prepared by:

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DECLARATION

I, (Eng.) PETER NDUNG'U KARU, hereby declare that this project report is my original work and has never been submitted for any academic award in this or any other university No part of this report may be reproduced without prior permission of the author/University of Nairobi.

Signature *Date 2nd December. 2022*

Approval by supervisors

I confirm that the study was carried out under our supervision and has been submitted for examination with our approval as University supervisors.

Prof. J. A. Nyang'aya Signature Date 2nd
December. 2022

Dr. Aganda Alex A. Signature Date 2nd *December.*
2022

DEDICATION

I dedicate this work to the love of my life, my wife, Dr. Wairimu Karu Ngugi and my family, for supporting me through my academia and career; My parents Mr. and Mrs. John and Jecinta Karu; and my Nephews and nieces Ryan Wanyoike, John Wanyoike, Keysha Karu, Jessi Karu, Iyvan Karu, Jason Karu.

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ABSTRACT

The efficiency of the well drilling procedure is influenced by the drill bit, its characteristics, its hydraulics, and the downhole tools. During the well drilling at AMOSING 2, Block 10BB, the parameters selected in this study, including the combination of downhole drilling tools, were optimized for maximum performance. The drilling data from the offset wells were analyzed and optimized for the subject well's drilling.

The project report introduces the history of oil and gas drilling, documenting prehistoric drilling from the 1st century BC in China. The report highlights the evolution of modern-day drilling through Cable-tool drilling and the more popular Rotary drilling which is the focus of this study. The report introduces the Oil and gas sectors, through the definition of upstream, midstream and downstream energy sectors. The report also illustrates the typical oil-well, the stages in delivering a well, oil-well drilling procedures and the drilling consumables that led to the inspiration and justification for the study carried out. The methodology followed is exhaustively presented and the tools and equipment used in the study are fully explained.

The criteria used to determine the efficiency of drilling bits, downhole drilling tools, and operational parameters was the change in the “rate of penetration” (R.O.P)

Optimization resulted in improved drilling speeds/rate of penetration, better drill bit dull grading and better well profile. Improvement in energy consumption was realized in reduction of the quantity of No. 2 diesel fuel by 24,786.53 liters.

The study concluded that there is high value in the process of maximizing the efficiency of the drilling tools, drilling parameters and drilling practice. And recommended that during the process of drilling a well, collection/capturing of all pertinent data should be carried out simultaneously at each stage and data analyzed to establish parameters to optimize in consequent stages.

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ABBREVIATIONS

B.H.A. *–Bottom Hole Assembly. Bill of Quantities:* **-** *This represents all the tools that will be included in the downhole tools*
R.O.P.- *Rate Of Penetration*
N.O.V. *-National Oilwell Varco*
PPG *– Pounds Per Gallon*
MD *– Measured Depth*
In *– Inches*
GPM *– Gallons Per Minute*
mTVD *– Meters True Vertical Depth*
MSE *– "Mechanical Specific Energy"*
CCS *– "Confined Compressive Strength"*
DOC *– "Depth of Cut"*
TFA *– "TOTAL FLOW AREA"*
NM- *None magnetic*
DP- *drill Pipe*
HWDP- *"heavy weight drill pipe"*
Stab- *"Stabilizer"*
TD *– "True Depth"*
PDC- *"Polycrystalline Diamond Carbide (In relation to drilling Bits)"*
Deg*. Degrees*
PV/YP- *Plastic Viscosity/Yield stress*
Offset well- *An offset well is a wellbore close to a proposed well that provides information for the proposed well's planning. When figuring out how a proposed well will behave or react to certain treatments or techniques, data from an offset well can be helpful.*

Chapter 1:

INTRODUCTION

1.1. BACKGROUND

Around the 4th century AD, the first oil wells in the world were drilled in China. The Chinese dug these wells with straightforward bamboo poles. The dark, sticky material that they had extracted was then mostly used as fuel. Oil was discovered throughout Asia and Europe in later centuries. The black liquid was used for fuel and medical care by travelers and settlers.1]

In the middle of the 19th century, the modern oil industry emerged. Colonel Edwin Drake made the first discovery of an underground oil reservoir after drilling a well that was only 21 meters (69 feet) deep, on August 27, 1859, near Titusville, Pennsylvania (USA). The oil flowed easily. Additionally, it was simple to use and distill. A paraffin-like oil was the name given to this oil. The Pennsylvania Rock Oil Company, which wanted to use the oil to light street lamps, employed Drake. Drake's well initially generated 30 barrels of oil per day (b/d).One barrel is equal to 42 US gallons, or 159 liters.2]

The modern oil industry began as a result of its success. The scientific community soon began to pay more attention to oil. A wide range of products made from crude oil were eventually developed after some research. Kerosene for heating, for instance, was one of the first products. Soon after, additional engines-running fuels like gasoline and diesel were available for purchase. When mass production of automobiles began in 1890, there was a huge demand for gasoline and pressure on businesses to locate additional oil fields.

Since the first people started drilling holes in the ground, cable-tool drilling and rotary drilling techniques have been available. The Chinese used cable-tool rigs to drill wells more than 1,600 years ago, and they continued to do so into the 1940s. Drake and Smith dug the Oil Creek site in Pennsylvania with a cable-tool rig powered by steam. Cable-tool rigs were also used by early drillers in California and elsewhere. Cable-tool drilling operates in the same way that a child's seesaw does.

Prime movers, hoisting equipment, rotating equipment, and **circulating equipment** are the four categories of components that make up the fundamental rotary drilling system. —all work together to make rotary drilling possible. Oil, gas, and geothermal drilling today are all based on this rotary drilling method. In order to improve the drilling bits, drill pipes, and downhole tools, this drilling technology and drilling practice have consistently been improved through the discovery of new materials, improved material science, and processing methods.

Better understanding of drilling dynamics, vibrations modes and development of drilling variable monitoring systems has greatly increased the efficiency of drilling Geothermal, oil, and gas wells.

However, the objectives of drilling Geothermal, oil, and gas wells. remain the same. These can be summarized as: - Drilling a well to its planned depth, meeting and maintaining the directional objectives i.e., vertical well having to remain vertical (between 0-4 degrees) and directional wells achieving and maintaining their planned deviation, drilling the well with a competitive rate of penetration (R. O. P.) A high-quality well-bore should have a consistent diameter throughout, that is, one that does not reduce its diameter as the depth increases (Under-gauge well-bore) or one whose diameter increases as the depth increases (Over-gauge well-bore). A good quality well-bore allows for proceeding processes such as Casing, Cementing, Wireline logging to be challenge free.

There are three main subsets of the petroleum industry. “Exploration and production” are **upstream**, “storage, refining, and transportation” are **midstream**, and “supply and distribution” are **downstream**.

Upstream: The majority of the upstream segment consists of crude oil and natural gas exploration, development, and production. Because Kenya does not yet have production, this segment focuses primarily on exploration.

Midstream: The midstream segment includes the transportation, refining, and storage of crude oil into oil and gas products. The only refinery in Kenya at the moment is the Kenya Petroleum Refineries Limited, which is located in Mombasa. It is currently inactive.

Down-stream: A component of the downstream segment is the procedure by which refined goods are made available to consumers through supply and distribution, such as at gas stations and industries. Kenya has a lot of players today and a fairly well-developed transportation pipeline, storage, and retail outlet network.

This study focuses specifically on the drilling procedure and the upstream segment.

1.1. Structure of a typical oil well

A drilling in the earth called an **oil well** is made to bring hydrocarbons from petroleum oil to the surface. Typically, oil and natural gas are released simultaneously. A "**gas well**" is one that is only intended to produce gas.

Using a drilling rig that rotates a drill string with a bit attached, a hole with a larger diameter (1 meter) at the top and progressively smaller diameters for the various sections is dug into the ground. This creates the well. A telescoping well is the design profile of this well that is depicted in figure 1.1.

After the hole is drilled, Sections of steel pipe (casing) slightly smaller in diameter than the borehole are inserted into the hole. Cement can be placed between the borehole, or annulus, and the casing's exterior. The casing gives the newly drilled wellbore structural integrity in addition to isolating potentially hazardous high-pressure zones from one another and the surface.

Because these zones are safely isolated and the formation is protected by the casing, the well can be drilled deeper (into potentially more unstable and violent formations) with a smaller bit and cased with a smaller size. Two to five sets of smaller holes are typically drilled inside of one another in modern wells and each set is cemented with casing.

Figure 1.1 depicts a typical wellbore architectural diagram for an onshore well. The sizes of the holes and casings required to drill the well to the desired depth are depicted in the wellbore diagram

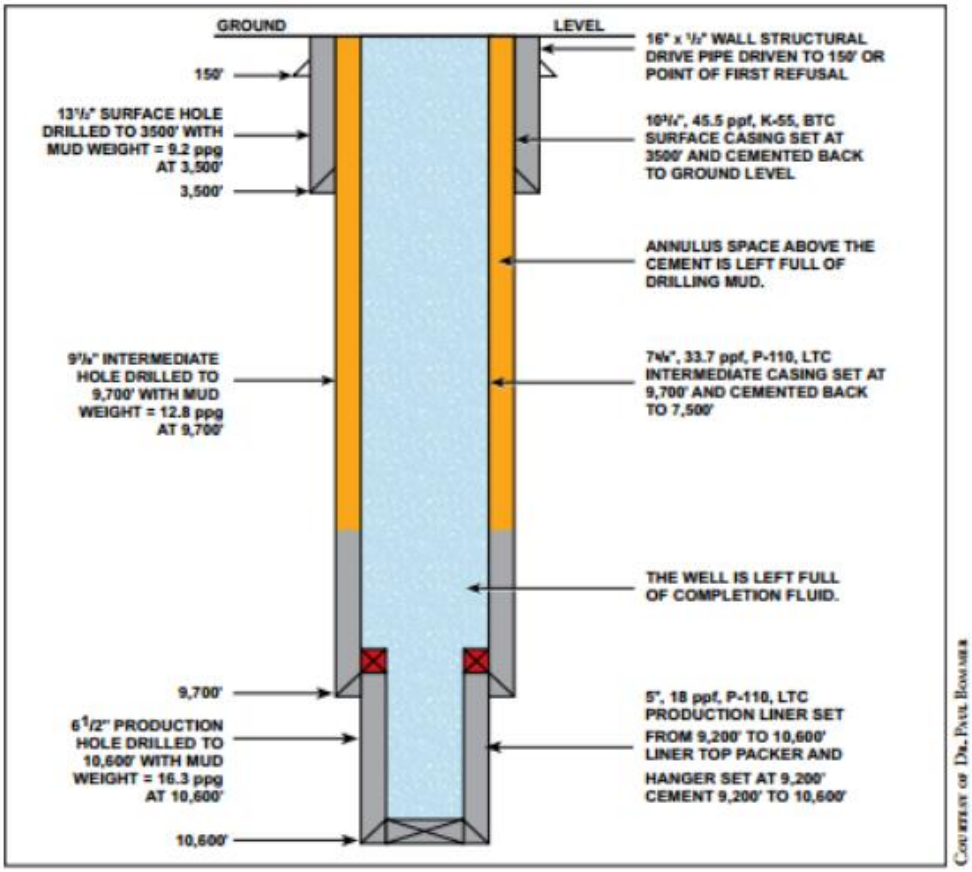


Fig 1.1. A typical well architecture. (ref-[2])

1.2. Stages in Oil well delivery

Before drilling, a geologist or geophysicist chooses a geologic target to achieve the well's goals. The goal is chosen for a production well in order to control reservoir drainage and maximize well production.

The goal of an exploration or appraisal well is to determine the extent or confirm the existence of a viable hydrocarbon reservoir. The goal of an injection well is to locate the point of injection in a permeable zone, which may allow for the disposal of gas or water and/or the injection of hydrocarbons into production wells nearby.

A trajectory will be created between the target, which is the well's end point, and a surface location, which is the well's beginning. When designing the trajectory, there are a lot of things to think about, like the clearance to any nearby wells (anti-collision), whether this well will get in the way of future wells, trying to avoid faults if possible, and whether certain formations are easier or harder to drill at certain inclinations or azimuths.

After determining the well path that will be drilled through to reach the target, a group of engineers and geoscientists will create a set of presumptive subsurface properties. These properties include pore pressure, fracture gradient, wellbore stability, porosity, permeability, lithology, faults, and clay content. Following the selection of the drill bits, the creation of a BHA (bottom hole assembly), the selection of the drilling fluid, and the writing of step-by-step instructions for safe and cost-effective well execution, a well engineering team uses this set of assumptions to design the well's casing and completion. Changing one aspect of a good design will have an effect on many others because of how they interact with one another. Typically, trajectories and designs go through several iterations before a plan is made.

This is then followed by **Drilling** the well to confirm the presence of Hydrocarbons. Data from drilling is used to map the geology of the area, and possibly to plan future wells in the area. During this drilling process, samples of drilled rock, through drilled rock core samples are collected and documented. Samples of the hydrocarbon are collected and transported to research laboratories to document the details, chemical composition and specifications of the samples.

After drilling and casing, a process called **cased-hole completion** is carried out. Perforations, or tiny holes, are drilled into the part of the casing that went through the production zone during this step. The objective is to create a route through the rock to allow oil to flow into the production tubing. In open hole completion, "sand screens" or "gravel packs" are frequently installed on the final drilled, uncased reservoir section. These maintain the structural integrity of the wellbore while allowing flow from the reservoir into it in the absence of casing. Screens also stop formation sands from getting into production tubulars and surface equipment. This can cause washouts and other problems, especially in offshore fields where the sand formations haven't consolidated.

Acids and fracturing fluids can be pumped into the well to fracture, clean, or otherwise prepare the reservoir rock for optimally producing hydrocarbons into the wellbore and stimulate its production. Last but not least, a smaller-diameter pipe known as tubing connects the portion of the well above the reservoir section to the surface. In addition to making, it possible to replace damaged sections, this arrangement serves as a redundant barrier against hydrocarbon leaks. In addition, the tubing's smaller cross-sectional area shields the casing from corrosive well fluids and produces reservoir fluids at a higher velocity to reduce liquid fallback, which would result in additional back pressure.

The natural pressure of the subsurface reservoir is high enough for oil or gas to flow to the surface in many wells. However, this isn't always the case, especially in depleted fields or oil reservoirs with low permeability where other producing wells have reduced pressures. Installing tubing with a smaller diameter may aid production, but artificial lift techniques may also be required. Common solutions include surface pump jacks, gas lift pumps, and downhole pumps. In the past ten years, numerous new systems have been developed for well completion. Multiple packer systems combined with frac ports or port collars have reduced completion costs and increased production in horizontal wells. These new systems enable casings to enter the lateral zone for optimal hydrocarbon recovery by positioning the packer/frac ports appropriately.

The production phase of a well is the most important one. The oil rigs and workover rigs that were used to drill and finish the well have left the wellbore by this point, and the top typically contains a set of valves known as a production tree or Christmas tree. In the event that additional work on the completion is required, these valves grant access to the wellbore. Additionally, they regulate pressures and flows. From the production tree's outlet valve, the flow can be connected to a distribution network of pipelines and tanks to get the product to refineries, natural gas compressor stations, or oil export terminals.

The **production stage** is all that is needed to produce the well as long as the reservoir's pressure remains high enough. An artificial lift method can be used if the pressure drops and it is considered financially viable. By this point, the oil rigs and workover rigs that were used to drill and finish the well have left the wellbore, and the top usually has a set of valves called a Christmas tree or production tree. These valves allow access to the wellbore in the event that additional completion work is required. They also control flows and regulate pressures. The flow can be connected to a distribution network of pipelines and tanks from the production tree's outlet valve to deliver the product to refineries, natural gas compressor stations, or oil export terminals.

Workovers are frequently required in older wells to complete new zones of interest in a shallower reservoir, use acid matrix, remove scale or paraffin, or install tubing with a smaller diameter. In this kind of remedial work, tubing can be pulled and replaced with workover rigs, which are also known as pulling units, completion rigs, or "service rigs." Coiled tubing-based well intervention techniques can also be used. Depending on the lift system and wellhead, changing a pump without pulling the tubing can be done with a rod rig or flush by.

Enhanced recovery methods like water flooding, steam flooding, or CO2 flooding can be used to create a "sweep" effect and push hydrocarbons out of the reservoir. These strategies require the use of injection wells, which are frequently selected from previous production wells in a pattern that has been carefully determined, when confronted with issues such as reservoir pressure depletion, high oil viscosity, or even early in the life of a field. Reservoir engineers may decide that applying a water flooding strategy earlier rather than later in the development of the field will, in some instances, increase the ultimate recoverable oil, depending on the reservoir's geomechanics. These enhanced recovery methods are frequently referred to as **"tertiary recovery."**

When a well's most efficient production rate does not cover its operating costs, including taxes, it is said to have reached its "economic limit." The well becomes a liability and is **abandoned** when the financial limit is reached. This procedure involves removing tubing from the well and filling sections of the well bore with concrete to separate the flow path between the gas and water zones from the surface. It would be inefficient and expensive to completely fill the well bore with concrete. After that, the surface surrounding the wellhead is excavated, the wellhead and casing are removed, a cap is welded in place, and the wellhead and casing are buried.

The reservoir frequently contains a significant amount of oil that cannot be recovered after reaching the economic limit. It might be tempting to put off physical abandonment for a long time in the hope that the price of oil will rise or that new methods for supplemental recovery will be perfected. To prevent tampering, temporary plugs will be inserted into the wellhead and locks will be attached.

Theoretically, an abandoned well can be reentered and brought back into production, or it can be converted into injection service for additional recovery or the storage of downhole hydrocarbons. However, reentry is frequently mechanically challenging and costly. Elastomer and cement plugs have traditionally been utilized, with varying degrees of success and dependability. Due to the materials, they are made of, they may degrade over time, especially in corrosive environments.

Additionally, conventional bridge plugs have extremely low expansion ratios, making them unsuitable for use in restricted wells. In contrast, high expansion plugs, such as inflatable packers, do not offer a gas-tight seal or the differential pressure capabilities required for many well abandonments. New tools have been created to make reentry easier. These tools have higher expansion ratios than inflatable packers and higher differential pressure ratings than traditional bridge plugs. In addition, they provide a V0-rated, gas-tight seal that cement cannot.

1.3. Oil well drilling procedure

The drill bit is aided in its ability to cut through the rock by the weight of the drill string above it. There are various varieties of drill bits; Some bits shear slices off the rock as the bit turns, while others cause the rock to break apart through compressive failure.

Drilling fluid, or "drilling mud," is pumped down the interior of the drill pipe from the drill bit. Drilling fluid typically consists primarily of water and clay, but it may also contain a complex mixture of fluids, solids, and chemicals that must be carefully formulated to provide the necessary physical and chemical properties for safely drilling the well. The rock cuttings are brought to the surface, the rock in the wellbore walls is prevented from becoming unstable, and the rock's pressure is overcome so that no fluids can enter the wellbore. The bit is cooled by the drilling mud. Some oil wells use **foam or air** as their drilling fluid.

The generated rock "cuttings" are picked up by the drilling fluid as it returns to the surface outside of the drill pipe. After that, "shakers" separate the bad fluid from the cuttings and return it to the pit. It is essential to monitor pit volume or rate of returning fluid and look for abnormalities in the returning cuttings in order to catch "kicks" early.

When the formation pressure at the bit's depth exceeds the hydrostatic head of the mud above, this is known as a "kick." Formation fluids and mud will rise uncontrollably through the annulus to the surface if the blowout preventers are not temporarily closed and the drilling fluid density is not increased.

By screwing in another 9 meters (30 feet), As the well gets deeper, the bit's pipe or drill string gets longer. "Joints," or sections of pipe beneath the Kelly or top-drive at the surface, are another name for them. This process is known as "tripping," or making a connection. Joints can be combined in stands with multiple joints for more effective tripping when pulling out of the hole. A typical triple, for instance, would stack pipes in the derrick by simultaneously pulling them out of the hole at three joints at a time. Modern rigs, or "super singles," trip pipes one at a time and rack them up as they go.

All of this is made easier by a drilling rig, which has everything needed to control downhole, remove cuttings from the drilling fluid, move the drilling fluid around, lift and turn the pipe, and generate on-site power for these tasks.

Figure 1.2. shows a layout of a drilling rig.

Fig. 1.2. Land rig and its components

The science of rotary drilling includes matching the type of bit and pull-down pressure to the formation, as well as using drilling fluids to maintain circulation to keep the hole free of cuttings and the bit lubricated and cool. A Kelly bar attached to the drill string's top joint and passing through a rotating table turns the drill string.

Methods for rotating the drill bit and applying pull-down pressure include: pull-down cables on a rotary table, a rotary table; top-head unit that is driven by hydraulics and has pull-down chains (more recent top-head-drive rigs are completely driven by hydraulics, so pull-down forces are not provided by cables or chains); and downhole motors, also known as downhole turbines, which control the rotational force exerted by the drill bit. The Turbodrill, which was patented in 1873, was the first downhole bit-driving device.

The force applied to the drill string to exert downward energy is known as force on bit. This force can be easily generated by the weight of the drill string, which has stabilizers and drill collars attached directly behind the bit. The weight of the drill string may, dependently of the size and depth of the hole, exert a sufficient downward force on the drill bit to guarantee continued penetration.

During drilling operations and when starting a new hole, pull-down pressure from the drill rig is frequently used. Hydraulic motors or a screw, cable, or chain arrangement can produce this pull-down force. Drill rigs made more recently typically have pull-down arrangements powered by hydraulics, whereas older rotary rigs typically have pull-down arrangements powered by screws, cables, or chains.

The driller is in charge of the pull-down pressure and, as a result, the penetration speed. It is important to note that matching pull-down pressure to the formation is an important part of the art of rotary drilling. Drill bits, drill pipe, and the borehole's accuracy can be damaged by excessive pull-down pressure. As a result, increasing pull-down pressure isn't always the best way to drill.

1.4. Drilling Optimization

Drilling optimization is the improvement of the drilling process primarily through increasing the rate-of-penetration (R.O.P.). The (R.O.P.) has significant role in reducing the cost of drilling a well. The numerous variables that have the potential to influence rate-of-penetration (R.O.P.) can be broken down into two broad categories: operational variables that can be controlled and environmental or uncontrollable variables. To reduce drilling costs, the parameters that can be controlled can be improved.

Information is collected and reviewed from wells that are similar in objective, geology, well profile and in a location similar to the subject well. these wells are referred to in the oil and gas industry as **offset-wells.**

By definition, an offset-well is an existing wellbore that is close to a proposed subject well and shares similarities in terms of formation lithology, oil well drilling methods, and operational issues. When there is no offset data, the well planner must be conservative when designing wells and include more contingencies.

1.5. Drilling consumables

The material used to drill an oil and gas well is the subject of this discussion. To make it easier to drill an oil and gas well, this material is crucial and absolutely necessary. A typical well's list of consumables can be found below.

- Fuel/Energy to run all applications- (Diesel, Electricity, Gas/LPG)
- Drilling Bits (PDC (Polycrystalline Diamond Compact Bits), Diamond Impregnated Bits, Roller-cone Bits, etc.), Fuel/Energy to run all applications bits for coring)
- Down-hole Tools example drilling jars, drilling motors, floats, directional survey tools, directional and verticality tools, Lost Circulation tools
- Drilling Mud
- Drilling chemicals (Weighting agents, viscosity agents, cooling agents

1.6. Problem statement

The goal of drilling of a well consists of drilling to the planned depth, maintaining directional objectives at competitive rates of penetration and high quality well bore. The objectives are addressed through preselection of drill bits, drilling tools and other general parameters. However, it is the hypothesis of this study that in depth analysis of performance of individual tools and processes will result in further improvement.

This study seeks to optimize the drill bits selected, their design features, hydraulics, working parameters, the drilling Tools selected and optimization of the drilling parameters and drilling practice. The main goal of the study is to increase the rate of penetration when drilling a particular well-bore section by optimizing these pre-selected non-optimized variables, upgrading them if necessary, and improving their cumulative performance. It is presumed that this will significantly reduce the overall time used to drill a section

Thereafter, analysis on the improvement (or lack thereof) is done and the energy/fuel saved is calculated. An **energy benefit analysis** and a **cost benefit analysis** are done, with respect to the energy/fuel used.

1.7. Objectives

Specialist knowledge on bits and down-hole tools was used to mitigate drilling challenges and complications. The identified well to be drilled was at Block 10BB.

The main objective was to Optimize the drilling of this planned subject well. The optimization was done from analyzing OFFSET wells, identifying their challenges, and synthesizing solutions of the most probable ones for the subject well.

The range of focus was from an entirely new *Drill Bit and Downhole drilling tool combination, redesign of the Bottom hole assembly, optimization of drilling variable and parameters* and *optimization of drilling fluids pressures and hydraulics.*

Specific Objectives

1. Review the drilling data operations of three (3) test wells, also referred to as OFFSET wells.
2. Review the drilling plan of selected subject well. This review considered the Drilling Bits selected, down-hole drilling tools and the drilling parameters .
3. Optimized the Drill Bits, Drilling Tools, and Drilling Parameters for both the planned and actual drilling of the subject well. This was done from the results of the OFFSET data analysis in point 1. Where the challenges were identified, and solutions synthesized to mitigate the drilling challenges identified.
4. Analyzed the change in the rates of penetration.
5. Determined the energy saved, in this case the Diesel fuel saved.

1.8. Hypothesis

We anticipate that by optimizing, the subject well will be drilled more effectively, resulting in a higher Rate of Penetration (R.O.P.) and shorter well delivery times. This reduction in well delivery time should result in significant energy (Fuel) saving.

CHAPTER 2:
Literature Review

Since the beginning of the campaigns, operators have always sought to reduce drilling costs, primarily by increasing drilling speed. In the drilling business, the wildcat well, or the first well drilled in a new field, typically has the highest cost. Optimized drilling could be implemented as the area became more familiar, lowering the costs of each subsequent well drilled until there is no more significant improvement [1].The goal is to figure out which combination of operating conditions results in the lowest drilling cost because the relationships between drilling parameters are complex [2].The goal of any drilling project's proper planning is to maximize operations while keeping costs to a minimum [3].The enhancement of technology and the system's efficacy are two additional essential aspects of optimization [4].

Due to the similarity of the drilling requirements among wells located at close distances, it is considered to have a significant impact on the rate of penetration and, consequently, the reduction in drilling costs when the optimal parameters are always in place. These are the fundamentals of drilling optimization: problems are identified from data gathered from wells close to the subject well, and solutions are developed to address those problems before being used in the drilling of the subject well. The drilling procedure can design for contingencies and mitigate difficulties in a proposed well by studying these wells. Modeling the major drilling variables that are thought to affect drilling rate of penetration (R. O. P.) is difficult [6]. As a result, there is currently no precise mathematical model of the rotary drilling penetration rate process. Numerous mathematical models have been proposed to combine known relationships between drilling parameters. The models worked to optimize the drilling process by selecting the best bit weight and rotary speed to deliver/drill a well at the lowest cost while simultaneously achieving the highest rate of penetration.

One of the most important properties is the formation properties, which cannot be controlled but are one of the most important factors in determining drilling performance. Drilling fluid properties and bit types should not be altered in typical bit runs, despite their controllability. However, hydraulics, the bit's weight, rotary speed, and other variables can be controlled.

The drilling activities' rate of penetration optimization will directly impact the reduction in energy consumption and the elimination of issues. Drilling optimization should be based on accumulated and statistically processed empirical data (that is, data that has been observed, measured, and recorded) rather than logical or theoretical relationships [7].

2.1. Factors Affecting Rate of Penetration

Controllable and environmental factors are two broad categories that cover the known factors that influence penetration rate. Controllable factors include things like bit weight, bit rotary speed, and hydraulics that can be changed right away. However, environmental factors like formation properties and drilling fluid requirements cannot be controlled. Due to the requirement for a certain density in order to achieve certain goals, such as having sufficient overpressure to prevent the flow of formation fluids, drilling fluid is regarded as an environmental factor. The drilling parameters, down hole pressure and temperature, type of bit, and most importantly, the rheological properties of the drilling fluid all have an impact on the overall hydraulics of the drilling operation. This is another important factor. The controllable and environmental factors affect the rate of penetration and performance. Equivalent Circulating Density (ECD) has been shown to generally increase the drilling rate of penetration. Cuttings transport is another crucial factor in determining the rate of penetration. [13], Conduct a comprehensive sensitivity analysis on the transport of cuttings when drilling for horizontal and highly inclined wells to determine the effects of the most crucial drilling parameters. Cuttings transport was found to be dominated by average annular fluid velocity, with a lower cuttings bed development associated with a higher flow rate. Taking into account the factors listed in Table 2.1 [14] is one of the most important aspects to take into account if you want a cuttings transported hole that works well.

1 Hole angle, degree	1.25 to 1.50
2 Fluid Velocity, ft/min, for three wells	414.17 to 581.24
3 Fluid Properties (rheological properties and density)	Vis=45-ta as, p.v=12, PH=10, 8.57ppg, 8.74 ppg
4 Cuttings Size, shape, and concentration	Coarse medium and fine grained
6 Rate of pipe rotation and pipe eccentricity	80, 90, 100, 125
7 Fluid flow regime (laminar or turbulent)	Turbulent flow

Table 2.1. Factors for efficient hole cleaning

CHAPTER 3:

Methodology

APPROACH

In the course of this study, a wide-ranging approach was adopted. This approach can be classified into Four major sections. These stages are, stage 1- study of the proposed (Tentative) drilling program of the subject well. Stage 2- the results of the first stage are used to establish a set of offset/benchmark wells. Stage 3- after establishing a set of offset wells that had been drilled earlier/prior to the planned subject well, these wells are studied to determine challenges that were experienced and that would be expected in the subject well based on the fact that offset and subject are expected to have similar characteristics. Stage 4- by determining the challenges experienced in the offset wells, solutions are designed for these solutions and these are incorporated into the planned drilling program for the subject well.

These deduced solutions are then optimized/ maximized for efficiency and applied to the subject well.

During the ***first stage***, the subject well's proposed drilling plan was exhaustively studied. From the study the subject well's physical location, that is the block number, the basin and the exact latitudes and longitude was established. After this, the drilling objectives were examined. These objectives include the well profile/ directional objectives, the total depths of each well section, the casing programs, the mud programs and the initial drilling bits, tools and drilling parameters.

During the ***second stage,*** the results from the study done on the subject wells were used to establish/determine a set of offset wells/ benchmark wells that were drilled prior to the subject well and fit the criteria of Offset wells. This offset criterion is based on selecting wells that exhibit physical and geological similarities to the proposed subject well. These should be similarities in well type (vertical/directional well), depth of well, drilling objectives of well (production wells vs. sample collection wells), location and proximity of the offset wells relative to the proposed subject well- wells should be within the same block.

During the ***third stage***, Analyze the challenges that were experienced while drilling the subject wells. After establishing these challenges, design of solutions or mitigation measures for the challenges are designed.

During the ***fourth stage***, the solutions that were synthesized for the challenges identified while drilling the offset wells in stage 3 are then incorporated into the revised drilling program for the subject well. These solutions are then optimized in their application for the planned subject well and monitored and changed in real time during the drilling of the subject well

3.1. Detailed approach to optimization of the subject well.

3.1.1. Subject well data collection

Data for the subject well was collected. This data was obtained from the detailed drilling program. The data collected for the purpose of the study is as listed below: -

- Official well name- AMOSING 2 well.
- The subject well's proposed BHA (Bottom Hole Assembly),
- The subject well's proposed Bit type- Bit design, Bit Properties and features.
- The subject wells drilling Mud type- Synthetic water-based mud.
- Drilling Mud Properties- Viscosity, density

3.1.2. Selection of the offset wells

By using the offset well selection criteria stated in section 1.4 page 11, it was possible to select offset wells. These wells were selected based on consistencies between the subject well and the offset wells. The criteria for selecting offset wells were: -

- Well proximity- the offset wells were close to the subject well or within a reasonable distance/within the same region
- Field- it was preferred that Offset wells and subject wells be in the same field for an accurate comparison.
- Block- Narrowing down the proximity to within the similar Block, for this study, all wells were to be located on the same block
- Geological stratigraphy results- geologically, the offset and subject well was to bear similarity in their geologies, for this study, the wells that were selected all experienced volcanic layers that caused a magnitude of drilling challenges

- Bit records- a record of all the bits used in the Offset wells and the subject well were available. This was to ensure that the comparison is similar and justified. That is, one must know the type of bits used in the offset well, so that the best bit is selected for the subject well.
- Well profiles- well profile refers to the "shape" of the well. This is what differentiate vertical wells from directional and extended wells. The drilling approach of these various wells determines the drilling practice and approach and consequently the optimization approach

From the above criteria, it was possible to select the wells listed below as offsets: -

- Amosing -1
- Ngamia-3
- Etuko-1

3.1.3. Collection of offset wells data

The data that was collected from the offset wells is listed below: -

- R.O.P. (Rate of Penetration) while drilling the challenging and problematic volcanic formation.
- BHA (Bottom Hole Assembly) of all the offset wells.
- Bit type- The type of Bit used, Bit Properties and features, Bit size.
- Drilling Mud Hydraulics- T.F.A. (Total Flow Area), H.S.I. (Horsepower per Square Inch)
- Drilling Mud type- Synthetic water-based mud.
- Drilling Mud Properties- Viscosity, density.
- Fuel consumption during drilling- calculated in Liters per hour during full capacity drilling.

3.1.4. Analysis of offset well data.

Analysis of data collected for the established wells was then done. This analysis involves the assessing of the offset drill bits dull. **Drill bit dull/wear** indicates the types of vibrations faced downhole, the type of formation that the bit drilled through (hard formation that may cause bit teeth and inserts to break off or chip away, abrasive formation, clay material that balls up around the bit etc.) The **rate of penetration** experienced while drilling the offset wells is also analyzed to determine sharp drops/slowdowns to indicate hard volcanic formations, quick increases in rates of penetration to indicate a change of formation to softer formations.

The analysis above was done on the premise that if similar wells to the subject well were selected, in the same area, within the same basin, drilled within a similar set of parameters, then the challenges experienced in the earlier wells, would ideally be expected while drilling the subject well.

These challenges could be due to formation (Hardness of formation, abrasivity of the formation, porosity of formation to cause losses of drilling fluid. Other causes of drilling challenge could be due to Hardware. Hardware in the context of drilling are the physical Bits and Downhole tools used, drilling mud and mud properties used, additives used etc. All these aspects need to be carefully analyzed.

3.1.5. Challenges experienced during drilling the offset wells

Data analysis was carried out to determine specific challenges. The process also “cleans the data”. This is done to remove any errors in the data such as repetitions, omissions and redundancy from the data sets.

The focus on data analysis included;

Bit dull grading- Analysis of bit wear can indicate the type of vibration modes the bit was exposed to. Further identification of the vibration modes can be checked from the parameters time based data. For instance, stick slip/torsional vibration is indicated on the bit by a dull condition called “Heat checking”, where the bit cutters show signs of thermal fatigue and wear.

Similarly, stick slip vibration on the parameter sheet is indicated by sharp increases and decreases of the rotational speeds of the draw-works. the rotation stalls for a short duration, then accelerates to very high rotations. this cycle continues through the drilling process.

Very low rate of penetration during drilling. This significant drops of rates of penetration are indicative of hard formation, bit failure, lack of proper drilling parameters (too low weight on bit (WOB)

Parameters do not correspond to the expected rate of penetration. The rate of rotation of the drill string and the amount of weight placed on the drill bit during drilling typically increase in tandem with the rate of penetration. When this variable changes but has no effect on the rate of penetration, it typically indicates that the bit has failed, either because the formation is extremely hard or because the bit is skidding along it.

Type of cutting retrieved from the shale shakers. The type of cutting retrieved from the shakers indicates the type of failure mode the bit is exposed to. for instance, if the cutting are long and elongated, it indicated that the bit is drilling through relatively softer formation that is being sheered. very fine cuttings are indication of abrasive formation.

Lost circulation. In drilling, lost circulation is an occurrence where the drilling fluid/mud, flows into the formation rather than back up through the annulus. This means that either the formation is porous or there is a fault where drilling mud flows into. On the drilling data, lost circulation is indicated by receiving less volumes of drilling mud back to surface than that which was pumped down.

The analysis of the above variables, facilitated design mitigation measures for the challenges that were identified.

The challenges were then classified into Hardware (Bits/Drilling tools/fluids) and/or parameters and drilling practice. This classification allows for the proper solutions to be made for the challenges.

3.1.6. Synthesizing the solutions to the drilling challenges.

Solutions identified to mitigate the identified challenges included;

- Switching of the bits from PDC to Roller-cone or vice-versa.
- Drilling Tools that complement the bit selected were recommended. specific drilling tools that give solution to specific drilling challenges were recommended at this stage. For example, a performance drilling tool was recommended at this stage to allow for the application of very high weights on bit, without causing torsional vibrations
- Parameters that work best with the recommended bits and downhole tools were calculated and recommended.
- Fluid flow optimization was done to match the bits and tools that have been recommended.
- Monitoring on location while drilling was done to ensure that drilling operations are strictly within the recommended parameters.

3.1.7. Drilling and optimization of the subject well

The drilling of the subject well, the Amosing-2, was then carried out according to the recommendations resulting from analysis of data from the offset well. Change of the controllable parameters known to result in immediate improvement of the rate of penetration (R.O.P.) without affecting the economics of operations [6]

The direct method of optimization is primarily based on the field's established standards and human drilling experience. In order to determine the point at which the drilling rate was maximized, the direct method of optimization was used, in which controllable drilling parameters were continuously adjusted at the surface. This was done to figure out where the drilling rate was at its highest. [7]

The optimized specific energy consumption was realized at that point, and fuel consumption was reduced by 24,786.53 liters.

3.2. Equipment required for the project.

The primary equipment used to measure and monitor performance parameters included the following:

3.2.1. Nozzle gauge

The Nozzle gauge was used to check the size of the nozzle orifice installed on the bit, or check if there was any wear on the nozzles as they are pulled out of the well. The nozzle gauge is used by inserting the lower side of the taper into the nozzle and reading the value that coincides with the top of the nozzle.

3.2.2. Ring Gauge

Ring Gauge- This device shaped like a ring that was used to measure the diameter of the bits after it has been used to drill a section. This was to determine if the well bore drilled is still “IN-GAUGE” or “UNDER-GAUGE”. An IN-GAUGE well bore means that the bore is the same size as the bit used to drill it.

3.2.3. Marsh funnel

The drilling mud's viscosity was measured with a marsh funnel, and the mud density requirements were checked to make sure they were within the range of the planned mud weight.

3.2.4. Viscometer (Viscosimeter)

A viscometer was used to measure the viscosity of a fluid. The fluid viscosity is necessary in calculating the drilling fluid flow rates and pump pressures. These was necessary in optimizing the fluid dynamics and ensure a preffered drilling fluid flow through the drill string and the entire system (avoid tabular flow and try achieve laminar flow at all times)

3.2.5. Computer and memory drives/flash drives

The computer was used to collect the time-based data from the offset wells. Programs in the computer like EXCEL are used to analyze this data, draw plots and tabulate the results.

Due to the size of the Time-based data, photographs, specification sheets of tools used in drilling of offset and subject wells, external memory or flash drives may be required

3.2.6. Digital Camera

Digital camera was used to document all the drilling hardware. This hardware includes the drilling tools, drilling bits. Photographic evidence of the hardware was taken before and after the drilling of the section.
Any damage or inconsistencies is recorded and noted for further investigation

3.2.7. Tape measure and stationery

A tape measure was used to measure the length of the percussion tool, drill bit gauge length, crossovers and drilling subs that were used in the bottom hole assembly (B.H.A.) and recorded

3.2.8. Mandatory well site Personal Protective Equipment (P.P.E.)

All well sites require that all personnel be dressed in safety clothes and adhere to the very high standards of safety observed.

3.2.9. Lithostratigraphic column

The geological science of stratigraphy deals with the study of strata, or rock layers. Lithostratigraphy is a subfield of stratigraphy. The lithostratigraphy column was used to predict the stratification and layering of the formation that would occur during the well's drilling.

A description of the underground or cliff structure is provided by the Lithostratigraphic column data. The location's geology can be better understood thanks to this description, which can also be used to determine whether oil or natural gas may be present. The various kinds of rocks, their relative thickness, and any potential fossils within them are shown in the column.

Below is a list of the data contained in a stratigraphic column:

1. Title, indicating topic, general location, and whether the section is single (measured in one coherent course), composite (pieced from two or more section segments), averaged, or generalized;
2. Name(s) of geologist(s) and date of the survey;
3. Method of measurement;
4. Graphic scale;
5. Map or description of locality;
6. Major chronostratigraphic units, if known;
7. Lesser chronostratigraphic units, if known;
8. Names and boundaries of rock units;
9. Graphic column composed of standard lithologic patterns;
10. Unconformities; Faults, with thickness of tectonic gaps, if known;
11. Covered intervals, as measured,
12. Positions of key beds; and
13. Positions of important samples, with number and perhaps data. Other kinds of information may be included.

3.1. Collection of DATA

Under the authority of the drilling company or license holder, **time-based drilling data** was gathered from the mud logging servicing company on the rig. A contract with the mud logging company is typically signed by the oil company (or operator). After that, they arrange this data in a graphic log with a wellbore representation of the data charted on it. Mud logging technicians observe and interpret the indicators in the mud returns while drilling. At regular intervals, they also record properties like the **drilling rate, mud weight, flow-line temperature, oil indicators, pump pressure, pump rate, and the lithology (the kind of rock that is in the drilled cuttings).** Mud logging necessitates a great deal of care and diligence. At predetermined intervals, the drilled cuttings must be sampled.

Mud logging involves gathering additional information about the drilling parameters, as well as observing and microscopically examining drill cuttings (formation rock chips), evaluating gas hydrocarbon and its constituents, and evaluating fundamental chemical and mechanical parameters of drilling fluid or drilling mud (such as temperature and chlorides). The data are then plotted on a mud log, a graphic log.

The following are some additional real-time drilling parameters that could be compiled: rate of penetration (ROP), which is also referred to as the drill rate, pump rate, pump pressure, bit weight, drill string weight, rotary speed, rotary torque, RPM (Revolutions Per Minute), SPM (Strokes Per Minute), mud volumes, mud weight, and mud viscosity, are all terms used to describe the rate of penetration. This information is typically obtained by attaching monitoring devices to the equipment of the drilling rig, with the exception of the mud weight and viscosity, which are measured by the derrick hand or the mud engineer.

The pressure of the mud column in the borehole and its relative counterbalance to the internal pore pressures of the encountered rock influence the rate of drilling. When the rock pressure is higher than the mud fluid, rock fragments tend to spall as they are cut, which can increase the drilling rate.

The data for this study were gathered on flash drives. This time-based DATA has a lot of recorded outputs and is quite large. From the entire collection of DATA, the output that was used in the optimization process was chosen.

A bit record is a historical record of how a bit performed in a specific wellbore. The bit record contains information about the rotating speed and hydraulic flow, as well as the depth the bit was inserted into the well, the distance it was drilled, the number of hours it was used "on bottom" or "rotating," the type and weight of the mud, the sizes of the nozzles, and the weight that was placed on the bit. The data are typically updated daily. When the bit is pulled out of the hole at the end of its use, both its condition and the reason for being pulled are recorded. Because operators and bit companies often share them, bit records are one of many useful sources of data from offset wells for well design engineers.

3.1.1. Fuel consumption.

The rig was powered by a set of diesel-fueled generators. These generators supplied power to the major rig components required in drilling operations as well as other auxiliary application. Information on the generator ratings and specifications was availed and fuel consumption during drilling was monitored, in Liters per hour.

Modern rigs have a trend sheet recording that monitors the power produced vs the consumption of fuel of each generator at every instant during operations. It is these recordings that were utilized for this study.

3.2. DATA analysis procedure

The offset well data was comprehensively collected, collated, sanitized (cleaned to remove, gaps, redundancies) analyzed to draw similarities in the challenges, and and recommendations made on the suitable parameters for the subject well.

The analysis of the data from the offset well facilitates deductions of potential challenges, drawing up of drilling charts and drilling programs.

Solutions were synthesized for all the various challenges noted, and these were recommended for application in the subject well.

Recommendations were in the form of change of hardware, that is, **drill bits, drilling tools, drilling tools specifications**, and in the form of **optimum variables** and **drilling** parameters, including the **drill bits' hydraulics**.

The recommendations were then carried out in the subject well and continuous recording of all the variables during the drilling operation.

3.3. Vibration modes identified in offset wells

All the bits drilling the hard volcanics had heat checking and a dull grading showing progressed wear on the outer cutters. This was a result of stick slip vibrations mode and the PDC bit and percussion tool combination was selected to allow for the application of high W.O.B. on the bit without the propagation of stick slip vibration.

Some of the symptoms and solutions of stick slip vibration are as follows;

Indicators of Stick-Slip vibration mode being present

- Surface RPM and torque fluctuations that are large and erratic, especially on a top drive BHA/rotary table, which can cause stalling
- whirring sound from damage to the top drive
- cutter or insert damage; under-gauge bits and stabilizers
- Shoulder damage to bits with heat checking and dull characteristics
- On larger diameter bits, nose ringing; poor hole cleaning;
- fatigue cracks in the connection due to under-gauge or washed-out holes;
- fractures in the parts of the BHA;
- damage to the thrust bearing cage (cage bar deformation or fractures) excessive drive assembly wear at articulating engagement points connection back-off Fragmented or cracked motor drive line components like bearing mandrels, driveshafts, or driveshaft adapters

Solutions to reduce or mitigate vibration mode

- Reduce WOB and increase RPM
- Increase weight and stiffness of BHA (Inclination <60°)
- Select PDC bit that includes Torque Control Components (TCC).
- The TCCs control the depth of cut and help prevent torsional vibration
- Increase the diameter of the drill pipe to allow for more efficient torque transfer to the bit and BHA
- Improve the tortuosity of the borehole by minimizing the motor bend setting and sliding over longer intervals
- Use stabilization or roller reamers to improve borehole quality
- Improve the lubrication qualities of the drilling fluid

CHAPTER 4:

Results and Discussion

Results

By using the approach detailed in section 3.1, the subject well was studied. Its drilling objectives, proposed depth, proposed bits and downhole tools and proposed drilling parameters were deduced. From the deductions, it was possible to identify and select a set of offset wells. These wells were selected using the criteria detailed in 3.1.2.

The offset selected for the purpose of drilling the amosing-2 subject wells were:

1. Amosing-1 well
2. Ngamia-3 well
3. Etuko- well

Upon selection of the offset wells, drilling data for the wells was collected. The offset well data collected was;

1. **Well objective** of the offset well. This was done to ensure that the offset wells selected had similar well objectives to those of the proposed subject well. These well objectives include the well profile (vertical well vs. directional wells), purpose of well (production well vs. exploratory well vs side track well).
2. **Drilling parameters**- the drilling parameters for all the offset wells was collected. This vast data was narrowed down to: -
    - The interval drilled- this is the depth drilled and it is the difference between **depth-out** and **depth-in**
    - "Rate of penetration" (R.O.P.) while drilling the section under study
    - "Weight on Bit" (W.O.B.) that was applied to the drill bit during drilling the section
    - "Rotations per minute" (RPM) of the drill string from surface when driven by the top drive
    - "Rotations per minute" (RPM) of motor (If a motor was used.
    - Flow rate of the drilling fluid/drilling mud

3. **Bit dull grading**: - this is a standardized indication of the wear of the bit and what location of the bit the wear is occurred

The data that was collected for the offset wells was as summarized below

4.1. OFFSET Well data (for AMOSING-1, NGAMIA-3 and ETUKO-1)

4.1.1. Well objectives

Amosing-1 well

The objective was to drill the 26" top hole to approximately 154 meters MD and achieve an average ROP of at least 2 m/hr through a section the prognosed hard volcanics. This well section was vertical/Non deviated.

Ngamia-3 well

The objective of the 12 ¼" was to drill from 52m to 833m. This well section was vertical/Non deviated.

Etuko-1 well

The objective was to drill the 26" top hole to approximately 233 meters MD. This well section was vertical/Non deviated.

4.1.2. Drilling parameters

The tables below indicate the drilling parameters from the selected offset wells. The tables indicate the interval drilled by the bit (Depth in –depth out of the bit), The number of hours taken to drill that interval, the rate of penetration, the weight on bit used in the section, the motor rotational speed and the flow rates and pump pressures.

The drilling parameters of the offset wells are as listed: -

Amosing-1 well

Depth In	Depth Out	Interval	Drilling Hours	ROP
14 m	154 m	140 m	74.35	1.9 m/hr
WOB	**String RPM**	**Motor RPM**	**Flow**	**SPP**
10 to 45 klb	30-75	n/a	400 to 900 gpm	-

Table 4.1: 26" Drilling Parameters

Ngamia-3 well

Due to a number of hole problems and directional objective four BHAs were used to drill this section. Two of those four BHAs drilled the 26m volcanic section (170-196m) on Ngamia-3. These are indicated below

BHA3

Depth In	Depth Out	Interval	Drilling Hours	ROP
52 m	78.5 m	26.5 m	2.19	12.1 m/hr
WOB	**String RPM**	**Motor RPM**	**Flow**	**SPP**
1.1 to 17.4 klb	44	54 to 58	490 to 525 gpm	600-780 psi

Table 4.2: 12 ¼" BHA3 Drilling Parameters

BHA 4

Depth In	Depth Out	Interval	Drilling Hours	ROP
78.5 m	195.5 m	117 m	16.7	6.5 m/hr
WOB	**String RPM**	**Motor RPM**	**Flow**	**SPP**
1.1 to 53 klb	43 to 88	N/A	298 to 507 gpm	55-380 psi

Table 4.3: 12 ¼" BHA4 Drilling Parameters

Etuko-1 well

Depth In	Depth Out	Interval	Drilling Hours	ROP
18.7	233.5	214.8 m	134.21	1.6 m/hr
WOB	**String RPM**	**Motor RPM**	**Flow**	**SPP**
15 to 30 klb	100 to 140	N/A	500 to 625 gpm	260 to 620 psi

Table 4.4: 26" Drilling Parameters

4.1.3. Bit Dull grading for the bits used in the offset wells

Amosing-1 well bit dull grade

The bit came above rotary with an excellent dull of **0-1-WT-G-E-I-NO-TD.** This bit had drilled through volcanic section.

Analysis of the vibration data revealed that a more aggressive Rollercone bit (IADC 435) and correct parameters yielded a faster ROP in the volcanics. The rig did have cellar pump problems which meant slowing down drilling, picking up off bottom or reducing the flowrate. This rig issues considerably affected the average ROP for the section.

Ngamia-3 well bit dull grade

The first bit (BHA3) came above rotary with a dull of **0-0-NO-A-E-I-NO-HP** after drilling 8.5m of volcanics. The first BHA hit the volcanics but due to losses it was decided to POOH, removed the motor and change the bit to drill through the hard volcanics.

The second bit came out with a dull of **1-2-WT-G-E-I-NO-PR**. This bit had been used to drill through the volcanic section

Etuko-1 well bit dull grade

The first bit was pulled for poor penetration **(2-2-CT-A-E-I-WT-PR),** it was then run back in to drill until the hours of the bearing were close to critical and had a final dull grade of **2-2-CT-A-E-I-CT-HRS**. The second bit had a dull of **1-1-WT-A-E-I-BU-TD.** Both these bits drilled through hard volcanic section

The 26" on Etuko-1 was drilled using two roller-cones (IADC 515) and three trips TD the section. The first bit trip was due to poor penetration rates, the second to change the bit as the hours for the roller-cone was close to critical and last trip was section TD. Both bits drilled with extremely low ROP due to the hard (43 kpsi Compressive strength) volcanic layers.

4.1. Results from Offset Analysis.

The offset data collected from the selected offset wells was analyzed. This was done by cross referencing and matching the vibration data trends, drilling parameters trends and the bit dull grading.

The results are as follows;

Bits and Stabilizer damage.

The bits and stabilizers dull grading was indicative of Bits exposed to a mode of vibration known as Stick slip.

Stick-slip, also known as micro-stalling, is torsional vibration caused by the bit, BHA, or drill string's cyclical rotational acceleration and deceleration. This speed change can be as little as zero RPM or as much as twice the surface-measured rotational speed. The client will ultimately incur costs as a result of these cycles' significant reductions in penetration rate and bit life cycle.

4.2. Implementation of recommendations AMOSING-2 subject well

4.2.1. New technology proposal-PDC Bit and percussion tool/Fluid hammer drilling tool recommendation

4.2.1.1. Percussion tool performance drilling tool

From the results of the offset data, it was observed that due to the extremely hard volcanic layers, a high Weight on bit (W.O.B.) was exerted on the bit in attempt to drill the volcanics. This high weight on bit (W.O.B.) caused the drill bit to stall/stop rotating.

For drilling the hard volcanics, a percussion drilling tool was introduced. During the drilling process, percussion tools raise and lower the bit/BHA slightly. By raising and lowering the bit, torsional stresses are prevented from building up, allowing the bit's weight to remain high without stalling.

This one-of-a-kind hammer assembly can be used for either air or mud drilling and is constructed from a high-quality oil-sealed motor without affecting the bit-to-bend distance. The bit remains in contact with the formation because the tool's percussive action is designed to hammer against the top of the drive mandrel, driving the bit into the formation. The percussive impacts significantly boost the roller cone and PDC bit's crushing efficiency.

Features and Benefits of the percussion tool

- Tool activated by Weight on Bit (WOB) and disengages when off-bottom
- Oil sealed with 100% mud flow going through the bit
- Compatible with most common power section configurations
- Reduces stick-slip/torsional vibrations
- Proven to increase ROP in both roller cone and PDC bits
- Aids in weight transfer

Application Considerations

- Use in directional applications to reduce stick-slip, make it easier to transfer weight, improve directional control, and increase ROP.
- Use in hard rock drilling with both PDC and roller cone drill bits to increase ROP through increased drilling efficiency.

- Use in applications with a long reach to help transfer weight, which significantly improves ROP and tool-face control.

Percussion drilling tool Configurations

Tool Size	Hole Size
11-1/4” **	14-3/4“to 26”
9-5/8”	12-1/4” to 14-3/4”
8” **	9-7/8” to 12-1/4”
6-3/4”	8-1/2” to 9-7/8”
6-1/2” **	7-7/8” to 9-7/8”
5”	6” to 6-3/4”

Table 4.5. Percussion Tool Sizes per Hole size

Percussion tools comes in various sizes that should be used for the corresponding well section sizes. the table above indicates the tool size against the well size range the tool should be used in.

The Percussion tool has a similar design to a mud motor, with additional components in the form of Cams added to create the oscillations/percussions movements. below is a cross section of a typical mud motor and its internal components.
A progressive cavity positive displacement pump (PCPD) is inserted into the drill string as a mud motor (also known as a drilling motor) to boost the bit's power while drilling. Drilling fluid, also known as "mud" or "drilling fluid," is used by the PCPD pump to produce eccentric motion in the motor's power section, which is then converted into concentric power for the drill bit.

4.2.1.2. 12- ¼" 616M PDC BIT

After analysis of the offset data, a bit proposal was made. The bit proposed was a PDC bit. The PDC (Polycrystalline Diamond Compact) cutter is sintered at high temperatures and pressure from PCD (Polycrystalline Diamond) powder, an activator (Cobalt or Silicon), and a WC (Wolfram Carbide) substrate.

The wear resistance, high hardness, good thermal stability, and impact toughness are some of its key performance indicators.

This drill bit recommendation was justified based on the drilling mechanism or failure principals of PDC bits. PDC bits fail the formation by *shearing* the surface of the formation. This mechanism is improved by high RPM of the bit and a significant WOB.

The PDC selected for the proposed subject was a 616 PDC Bit. This means that the bit had 6 blades and 16 mm cutters size. This selection is one that is "aggressive" enough to effectively fail the volcanic layers and in turn raise the rate of penetration.

PDC was selected to have features that enhance its performance while drilling hard volcanic formations.

These features include: -

High Efficiency Cutters- PDC bit selected had enhanced thermal efficient cutters. This provides a highly efficient cutting mechanism that stays sharper, longer due to the thermal toughness. This allows more efficient weight transfer resulting in much faster Rate of Penetration, reduced Mechanical Specific Energy and lower Cost Per Foot, without sacrificing durability.

Directional drilling enhancing features- PDC bits with directional drilling features were preferred because while drilling hard formation, the bits have a tendency to change direction (Referred as kicking) so bits that have directional features are preferred to maintain the drilling direction and are more responsive to corrective

Dual action gauge features- These components provide the bit with back-reaming capabilities and moderate side cutting ability when required. PDC Bits with this design features give excellent steer-ability on both push and point-the-bit RS tools.

Torque Control Components (T.C.C.)- Insert configurations that provide a predictable torque response to applied weight on bit and reduction in torque variance. Torque Control

The risk of torsional vibration is reduced and tool face and directional control is enhanced by components. Behind the PDC cutters is an insert configuration that dampens torque spikes caused by drilling by acting as instantaneous torque reducers.

Gauge Inserts: The gauge provides maximum gauge contact, reduces steerable resistance, and reduces torque, all of which improve ROP and extend the life of the bit and tool. On a steerable motor, this arrangement provides smoother steering in sliding mode and enhances borehole quality while rotating.

Gauge Protection: Gauge protection makes the gauge extremely long-lasting and smooth. When drilling through hard formation, which may cause the gauges on the bits to become brittle, this is absolutely necessary.

4.2.2. The Optimized Bottom Hole Assembly design for AMOSING-2 well.

An improved Bottom hole assembly (B.H.A.) was designed that incorporated the percussion tool, PDC bit and stabilizers that enhanced the stability of the drill string as it drilled the hard formation with high weights on bits (W.O.B.) and rotations per minute (R.P.M.)

The 9-5/8" percussion drilling tool with a high torque elastomer and high torque in combination with a 6 bladed 616 PDC bit and were selected to drill the 12 ¼" pilot section from surface to the planned depth of 150 m MD.

4.2.3. Optimization of Hydraulics for AMOSING-2

Hydraulics are optimized mainly to have as much efficiency as possible in the cuttings evacuation from the well bore. Insufficient evacuation of cuttings reduced ROP, because the drill bit will be drilling into already cut material and also, cuttings accumulation within the annulus of the well increase the chances of getting a stuck pipe situation.

The 12-1/4” hole was planned to be drilled vertically from 48.0m to 150m TVDRT (True Vertical Depth referenced to Rotary Table) through the remainder of the volcanics (to 126 m MD (measured depth)) and through sandstone with minor claystone stringers.

Continued drilling 12 ¼” hole directionally to planned section TD (Total depth) at +/-628m.

WOB:	10-15 klbs until all stabilisers below shoe, thereafter 15-30 klbs
RPM:	140 - 180
Flow Rate:	400 gpm until all stabilizers below shoe, then increase to 750-850 gpm.
ROP:	Expected 2 - 4m/hr through volcanics and +/-50m/hr thereafter.
Viscous pills:	Pump 20 bbl Hi-Vis pills (as dictated by hole condition)

Fig 4.1. Planned drilling parameters

4.2.3.1. Hydraulics optimization through nozzle selection.

See below snapshot/screenshot of hydraulics optimization done for the subject well, AMOSING-2.

The nozzle configuration selected was **X6 14/32”** Nozzles + **X3 12/32”** Nozzles.

This configuration resulted in a ***T.F.A. = 1.233in²*** ***for*** a flow rate of 800gpm. The mud weight for this well section was 9.1 ppg.

The Viscometer, mentioned in *section 3.2.4, page 23*, was utilized to measure the viscosity of the drilling mud prior to drilling the section. This is important because the hydraulics optimization is done with a mud weight and a mud viscosity that is predetermined. For this study, a mud weight of 9.1 ppg and a viscous pill of 20 bbl Hi Vis pill was used. These values were used throughout the drilling of the section. Any changes that would be made, must be communicated to ensure that the hydraulics can still be optimal with the changes.

The Nozzle gauges mentioned in *section 3.2.1, page 22* was used to ensure that the nozzles selected from the hydraulic optimization are installed in the selected bits.

BIT HYDRAULICSOPTIMIZATION

Bit Nozzles

1	2	3	4	5	6	7	8	9	10
14/32 in	14/32 in	14/32 in	14/32 in	14/32 in	14/32 in	12/32 in	12/32 in	12/32 in	

Flow	MW	Bit TFA	Bit ΔP	Bit Jet Vel	Bit Diam	HSI
800 gpm	9.1 ppg	1.233in²	353 psi	208.1 ft/s	12 1/4 in	1.40

Conversions

gr/lt	PPG
1050	8.7633

Client	Tullow BV
Well	AMOSING-2
Block	10BB
D.S.E.	PETER N. KARU
Mud weight	9.1 PPG

Fig 4.2: Bit hydraulic optimization results

Fig 4.9 above indicates the results of the optimization of hydraulics, for all the various nozzle sizes. This was done for mud weight of **9.1 ppg.** The main results that are of interest in the optimized hydraulics are Bit TFA, H.S.I and Bit jet velocity, relative to the nozzles that will be placed in the specific bit

4.2.4. Optimization of the drilling parameters for AMOSING-2 well

Optimization of parameters given the known flow rates, Mud details and the Bits and Tools specification was performed.

This optimization was done to result in Highest/Most competitive rate of penetration for this section, whilst maintaining/achieving the objective of drilling through the volcanics effectively.

Percussion drilling tool details

The 9 5/8” percussion drilling tool with below properties utilized for the Amosing project

Type	Lobe Config.	Bend Setting	Revs/gallon
9-5/8 HemiDrill	7/8 4.8 stages	0	0.11

Drilling mud Details

12 ¼" Section Mud Properties

Type	Mud Weight	PV / YP	Sand Content	Chloride
WBM Polymer	9 ppg	65 / 23	0.2 %	1100 mg/l

Optimized drilling parameters

Depth In	Depth Out	Interval	Drilling Hours	ROP
48.5 m	150 m	101.5 m	12	8.5 m/hr
WOB	**String RPM**	**Motor RPM**	**Flow**	**SPP**
5 to 35 klb	20 to 35	40 to 82	400 to 800 gpm	400-1050 psi

Table 4.6: 12 ¼" Section Drilling Parameters

The percussive action of the percussion drilling motor successfully increased the ROP through the volcanics and the bit came above rotary with a dull of **1-0-WT-N-X-I-CT-BHA**. The bit was put on a directional BHA to successfully drill a further 530m to TD. This was the first time a 9 5/8" percussion drilling tool and 616 PDC bit was used to successfully drill through volcanics in the East African region.

4.3. Subject well data and results for AMOSING-2 well

Data was collected during the drilling of the subject well.

Below is a sample/snippet of the Time-based data collected throughout the entire drilling of the **AMOSING-2** well. Similar excel data, in ASCII Format was collected and ''sanitized'' for use.

This time-based raw data that shows readings made by MWD-Measure while drilling tools- and recorded throughout the drilling process. Data collected is in ASCII Format

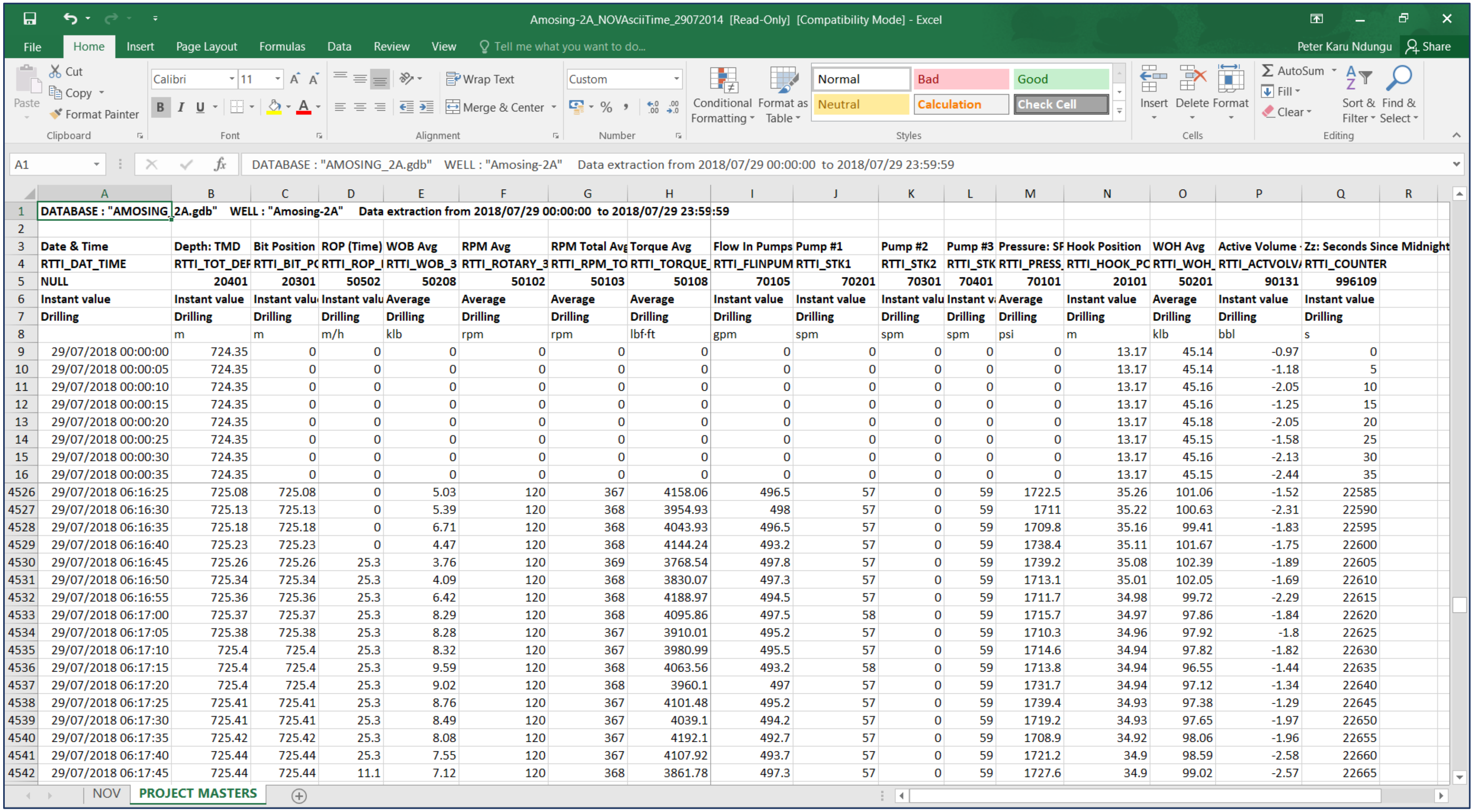
Variables collected are: -

- R.O.P. (Rate Of Penetration)
- Depth
- W.O.B. (Weight On Bit)
- Torque
- Flow-rate
- R.P.M.

- Volume
- Pressure

The above-mentioned parameters can be seen in the snippet below, Fig 4.1. They are arranged in columns, at a predetermined time interval. In this case, the time interval is every 5 second, starting from **00.00.00-29/07/2018 to 23.59.55-29/07/2018.**

AMOSING-2 DATA



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	DATABASE : "AMOSING_2A.gdb" WELL : "Amosing-2A" Data extraction from 2018/07/29 00:00:00 to 2018/07/29 23:59:59																
2																	
3	Date & Time	Depth: TMD	Bit Position	ROP (Time)	WOB Avg	RPM Avg	RPM Total Avg	Torque Avg	Flow In Pumps	Pump #1	Pump #2	Pump #3	Pressure: SF	Hook Position	WOH Avg	Active Volume -	Zz: Seconds Since Midnight
4	RTTI_DAT_TIME	RTTI_TOT_DEF	RTTI_BIT_PC	RTTI_ROP_I	RTTI_WOB_3	RTTI_ROTARY_3	RTTI_RPM_TO	RTTI_TORQUE_	RTTI_FLINPUM	RTTI_STK1	RTTI_STK2	RTTI_STK	RTTI_PRESS_	RTTI_HOOK_PC	RTTI_WOH_	RTTI_ACTVOLV/	RTTI_COUNTER
5	NULL	20401	20301	50502	50208	50102	50103	50108	70105	70201	70301	70401	70101	20101	50201	90131	996109
6	Instant value	Instant value	Instant valu	Instant valu	Average	Average	Average	Average	Instant value	Instant value	Instant valu	Instant v	Average	Instant value	Average	Instant value	Instant value
7	Drilling	Drilling	Drilling	Drilling	Drilling	Drilling	Drilling	Drilling	Drilling	Drilling	Drilling	Drilling	Drilling	Drilling	Drilling	Drilling	Drilling
8		m	m	m/h	klb	rpm	rpm	lbf·ft	gpm	spm	spm	spm	psi	m	klb	bbl	s
9	29/07/2018 00:00:00	724.35	0	0	0	0	0	0	0	0	0	0	0	13.17	45.14	-0.97	0
10	29/07/2018 00:00:05	724.35	0	0	0	0	0	0	0	0	0	0	0	13.17	45.14	-1.18	5
11	29/07/2018 00:00:10	724.35	0	0	0	0	0	0	0	0	0	0	0	13.17	45.16	-2.05	10
12	29/07/2018 00:00:15	724.35	0	0	0	0	0	0	0	0	0	0	0	13.17	45.16	-1.25	15
13	29/07/2018 00:00:20	724.35	0	0	0	0	0	0	0	0	0	0	0	13.17	45.18	-2.05	20
14	29/07/2018 00:00:25	724.35	0	0	0	0	0	0	0	0	0	0	0	13.17	45.15	-1.58	25
15	29/07/2018 00:00:30	724.35	0	0	0	0	0	0	0	0	0	0	0	13.17	45.16	-2.13	30
16	29/07/2018 00:00:35	724.35	0	0	0	0	0	0	0	0	0	0	0	13.17	45.15	-2.44	35
4526	29/07/2018 06:16:25	725.08	725.08	0	5.03	120	367	4158.06	496.5	57	0	59	1722.5	35.26	101.06	-1.52	22585
4527	29/07/2018 06:16:30	725.13	725.13	0	5.39	120	368	3954.93	498	57	0	59	1711	35.22	100.63	-2.31	22590
4528	29/07/2018 06:16:35	725.18	725.18	0	6.71	120	368	4043.93	496.5	57	0	59	1709.8	35.16	99.41	-1.83	22595
4529	29/07/2018 06:16:40	725.23	725.23	0	4.47	120	368	4144.24	493.2	57	0	59	1738.4	35.11	101.67	-1.75	22600
4530	29/07/2018 06:16:45	725.26	725.26	25.3	3.76	120	369	3768.54	497.8	57	0	59	1739.2	35.08	102.39	-1.89	22605
4531	29/07/2018 06:16:50	725.34	725.34	25.3	4.09	120	368	3830.07	497.3	57	0	59	1713.1	35.01	102.05	-1.69	22610
4532	29/07/2018 06:16:55	725.36	725.36	25.3	6.42	120	368	4188.97	494.5	57	0	59	1711.7	34.98	99.72	-2.29	22615
4533	29/07/2018 06:17:00	725.37	725.37	25.3	8.29	120	368	4095.86	497.5	58	0	59	1715.7	34.97	97.86	-1.84	22620
4534	29/07/2018 06:17:05	725.38	725.38	25.3	8.28	120	367	3910.01	495.2	57	0	59	1710.3	34.96	97.92	-1.8	22625
4535	29/07/2018 06:17:10	725.4	725.4	25.3	8.32	120	367	3980.99	495.5	57	0	59	1714.6	34.94	97.82	-1.82	22630
4536	29/07/2018 06:17:15	725.4	725.4	25.3	9.59	120	368	4063.56	493.2	58	0	59	1713.8	34.94	96.55	-1.44	22635
4537	29/07/2018 06:17:20	725.4	725.4	25.3	9.02	120	368	3960.1	497	57	0	59	1731.7	34.94	97.12	-1.34	22640
4538	29/07/2018 06:17:25	725.41	725.41	25.3	8.76	120	367	4101.48	495.2	57	0	59	1739.4	34.93	97.38	-1.29	22645
4539	29/07/2018 06:17:30	725.41	725.41	25.3	8.49	120	367	4039.1	494.2	57	0	59	1719.2	34.93	97.65	-1.97	22650
4540	29/07/2018 06:17:35	725.42	725.42	25.3	8.08	120	367	4192.1	492.7	57	0	59	1708.9	34.92	98.06	-1.96	22655
4541	29/07/2018 06:17:40	725.44	725.44	25.3	7.55	120	367	4107.92	493.7	57	0	59	1721.2	34.9	98.59	-2.58	22660
4542	29/07/2018 06:17:45	725.44	725.44	11.1	7.12	120	368	3861.78	497.3	57	0	59	1727.6	34.9	99.02	-2.57	22665

Fig 4.3. A snippet of the Time-based data for the Amosing-2 well collected for this study

About the time-based Data (Fig 4.1)

As the name suggests, the time-based Data above is a recording of all the parameters recorded when drilling a certain section. the columns, from far left to right indicate

- *Column 1: The time interval, in intervals of 5 minutes*
- *Column 2: Indicate the corresponding depth of the bit/ or the well depth if bit is not in hole at the corresponding time in column 1 above.*
- *Column 3: The Bit Position- indicates the depth position of the bit at any specific time.*
- *Column 4: R.O.P. This is the instantaneous Rate of Penetration.*
- *Column 5: W.O.B. This is the instantaneous Weight on Bit- the total weight that is being exerted/slacked onto the bit.*
- *Column 6/7: R.P.M. and R.P.M. Total this is the Revolutions per minute of the Bit and the total revolution per minute of the bit if there is a mud motor present.*
- *Column 8: Torque Average- this is the torque registered on the surface that the drill string is experiencing in the well.*
- *Column 9: Flow in Pump- this is the flow rate of the mud pumps.*
- *Column 10/11/12- these columns represent the pump rates of the individual mud motors.*
- *Column 13: Stand pipe pressure- this is the fluid pressure experienced by the stand pipe (after all mud pumps pump the drilling mud to the stand pipe*
- *Column 14: Hook Position- this is the position of the hook/travelling block relative to the rig floor*
- *Column 15: Weight on Hook- this is the weight of suspended pipe that the travelling block is supporting*
- *Column 16: Active tank Volume- this is the current volume of drilling mud in the active mud tanks*

4.3.1. AMOSING-2 LITHOSTRATIGRAPH COLUMN

A historical record of a bit's performance in a specific wellbore. The predicted lithostratigraphic column for the AMOSING-2 well can be seen below. It indicates the anticipated volcanic heights of 21 to 126 meters.

The lithostratigraph column in *figure 4.2* above is the prognosed/suspected/predicted arrangement of the different formation as they are layered in the ground.

The first two columns indicate the age or the formation dating of the formations. The third column indicates the actual formations present in the ground. The depth indicates how the layered formations are found and the different types of formations as they sit (they are explained on the key attached)

The formation of interest, that is Volcanics is indicated by red shading and highlighted on the figure below.

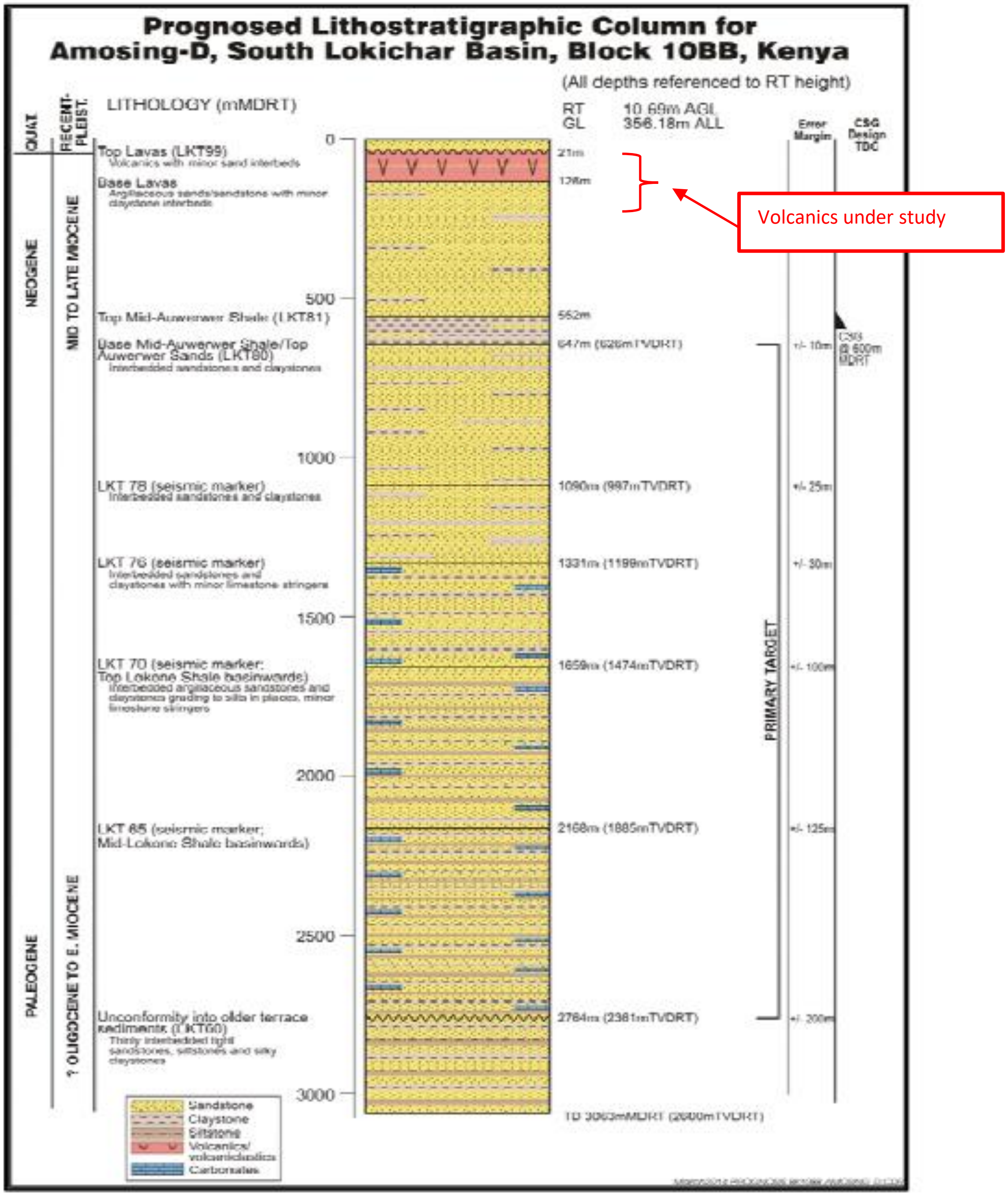


Fig 4.4. Prognosed lithostratigraphic column for the AMOSING-2 WELL

4.3.2. Volcanic Rock Strength analysis for Ngamia-3 well

The volcanic lithology in the wells drilled consisted mainly of a fine igneous rock called basalt with traces of obsidian and rhyolite. Rock strength Analysis software revealed that the basalts had sustained unconfined compressive strengths (UCS) of 43-45kpsi and occasionally peaking at 55kpsi. The slow drilling of 0.3-1.5 m/hr was also evidence of the high UCS of the basalt.

In the performance analysis to follow, only ROP values achieved in pure homogenous basalt was used. ROP values achieved through weathered volcanic was disregarded as this would give a false and exaggerated ROP performance increase. This is evident from the Ngamia-3 mudlog (see **Figure 4.6**)

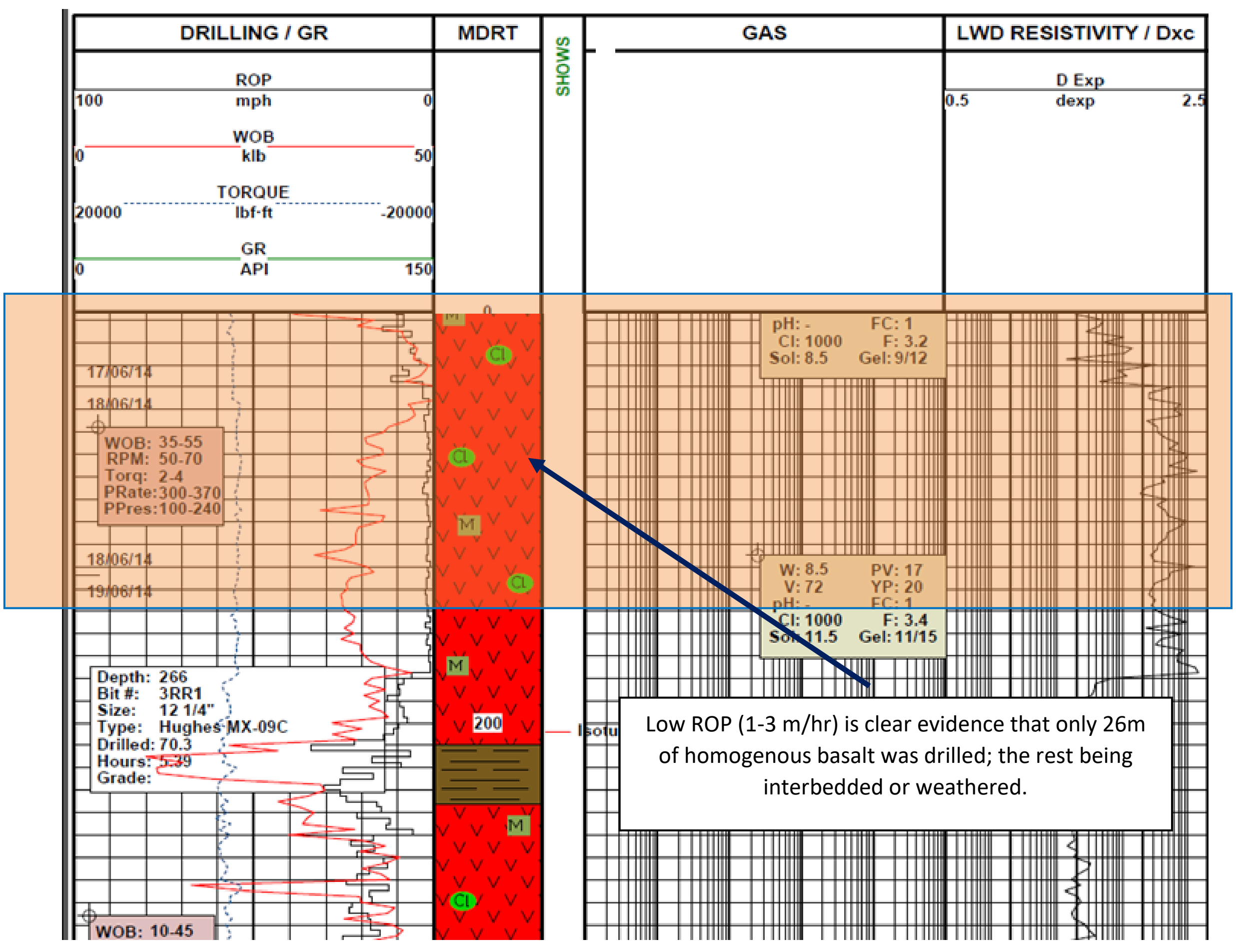


Fig 4.5: 12 ¼" Section Ngamia-3 mud-log

Fig 4.6: 12 ¼" Section Amosing-2 subject well mudlog, above indicates the parameters recorded while drilling the volcanics. The first column indicates the drilling parameters. The blue trend indicates the R.O.P. while drilling the formation, the red trend is an indication of the W.O.B. exerted on the bit, the dotted blue trend represents the Torque experienced by the drill string. The MDRT column indicates the formation that is being drilled.

From the figure, it was observed that the Low ROP (1-3 m/hr) is clear evidence that only 26m of homogenous basalt was drilled; the rest being interbedded or weathered.

The 26m of homogenous basalt is further confirmed by the rock strength Analysis software. See the UCS in the drilling dynamics log below

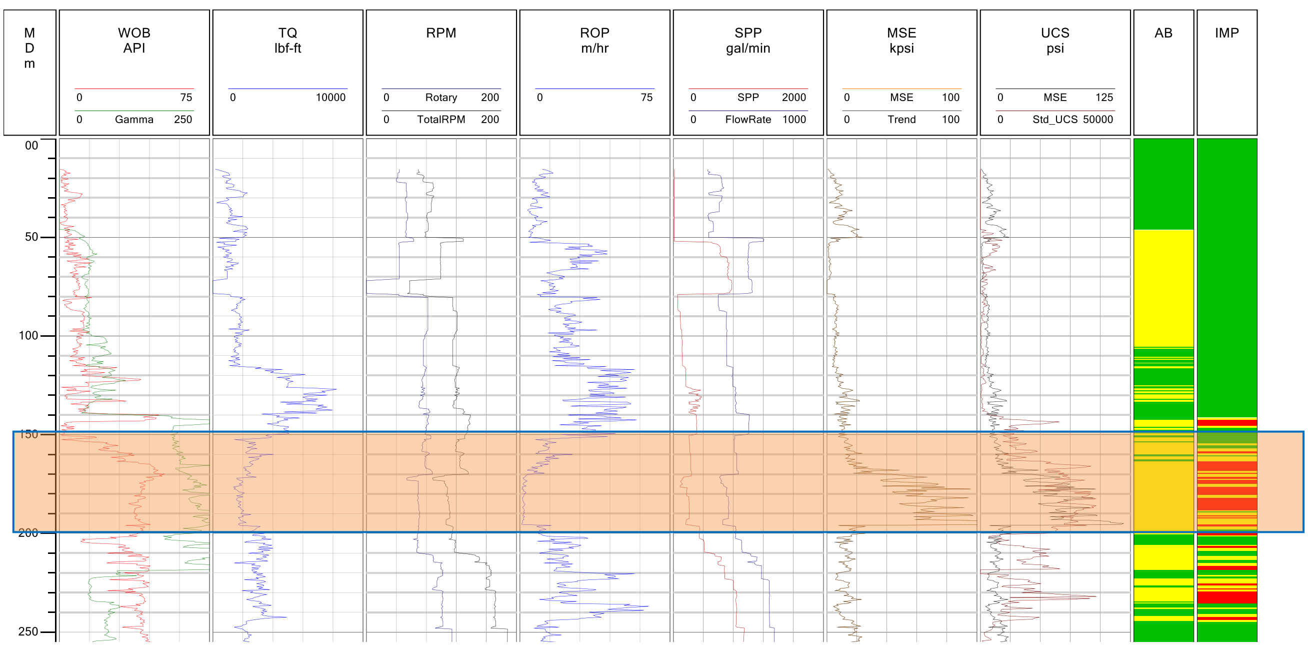


Fig 4.6: 12 ¼" section Amosing-2 Drilling Dynamics log

Figure 4.7 above indicates the recorded parameters of the Amosing-2 formation is being drilled. On the figure, it is observed that the W.O.B. increases, this was due to the hardness of the volcanics being drilled. It is also observed that the R.O.P. is relatively low, considering an increase in the W.O.B. the MSE AND UCS also observed to have spiked, indicating that the formation is being failed but at a very low rate, with very high parameters. This is evidence of volcanics.

4.4. DIESEL FUEL CONSUMED

The Rig is powered by three (3) CATERPILLAR 3512 series generator sets. These generators are switched on according to load demands, that is, when drilling at depth, all three are switched on (though NOT at 100% power) to avoid overloading and overworking an individual generator set.

Generator		**Series/Spec**	**Liters/Hour-DIESEL**
1.	GENSET NUMBER 1	CATERPILLAR® 3512	160.00
2.	GENSET NUMBER 2	CATERPILLAR® 3512	160.00
3.	GENSET NUMBER 3	CATERPILLAR® 3512	160.00
Total Consumption/hour			480.00

Table 4.7: diesel consumption per hour per generator

Discussion

The previous section discussed how pure volcanics is defined so that in the performance analysis a clear and true understanding of the PDC and FLUIDHAMMER™ performance is obtained.

This section looks at the volcanic intervals drilled in each well which was described from Sections 2-5, the ROP improvement and the dull condition of the bits.

Below are two graphs showing the actual volcanic interval drilled in each well (**Figure 5.1**) and the average ROP achieved in the volcanics (**Figure 5.2**).

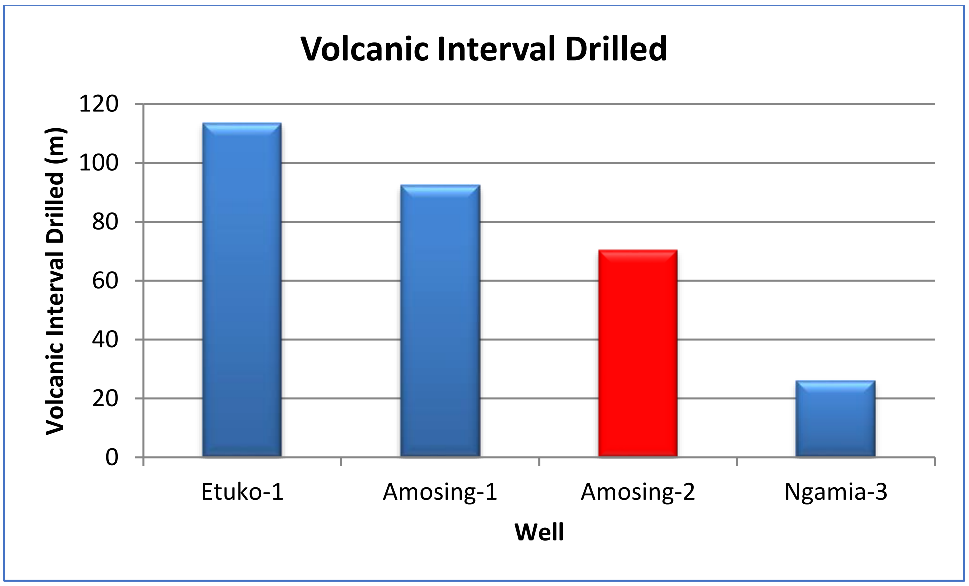


Fig 4.11: Graph representing the homogenous volcanic interval on each well

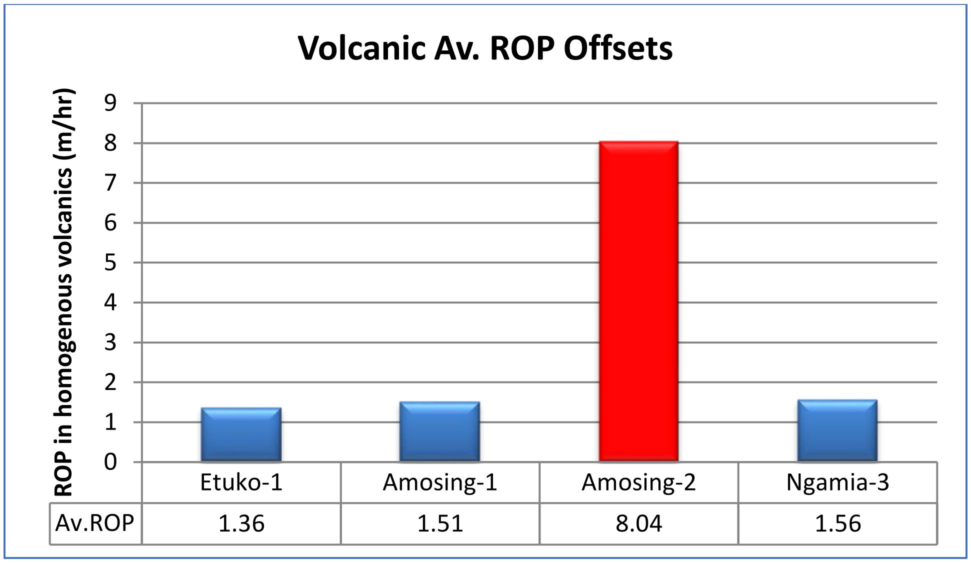


Fig 4.12: Graph representing the average ROP through homogenous volcanics

Compared to the best offset (Ngamia-3) The FluidHammer-PDC combination achieved a **415%** ROP increase. This is the highest ROP seen drilling through the volcanics. The bit drilled a further 530m to section TD through sandstone and claystone.

4.5. Post Run Bit Condition (Bit Dull Pictures)

The PDC bit (**SKHE616M**) had a dull condition of **1-0-WT-N-X-CT-BHA** when it came out. The dull pictures below, demonstrate the superior cutter technology of the SKHE616M. The gauge and cutters are still in excellent condition and the bit is re-runnable.

Fig 4.13: 12 ¼" SKHE616M Oblique View

The oblique view of the bit shows that there was no blade damage, lost nozzles or Brocken cutters. This is an indication that the bit, while being operated at high weight on bit, did not experience torsional vibration. this indicative that the percussion hammer was successful in mitigating torsional/stick slip vibration.

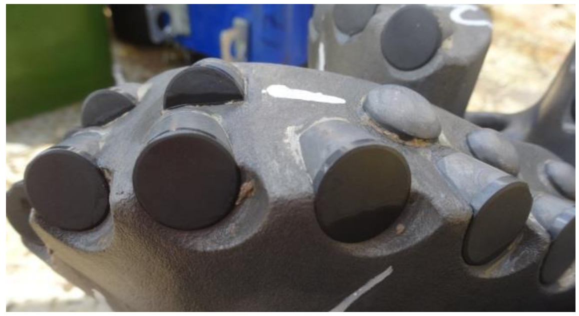


Fig 4.14: 12 ¼" SKHE616M Close Up Cutter View

The close up in Fig 5.4 above shows that the PDC cutters show very little damage to the cutters, an indication of reduced or mitigated vibrations

Fig 4.15: 12 ¼" SKHE616M Gauge View

Similarly, reduced wear on the gauge of the bit is indicative of reduced vibration modes that would otherwise cause the bit to vibrate laterally.

The above evidence of good bit dull grading indicates that the bit was working at optimized parameters that in turn reduce the occurrence and propagation of vibrations which in turn reduce the rate of penetration significantly, as well as cause (often visible) damage to the bit

4.6. Energy saving analysis

Using a consumption of 160Liters/Hour per Generator set, with a total of 480liter/Hour for the three generator sets running together during the drilling operation. The following energy consumption and saving analysis is based on drilling a 76- meter homogenous volcanic section which is the average thickness seen across all layers drilled on the 4 wells analyzed.

WELL	Average ROP (M/HR)	SECTION LENGTH (M)	HOURS	ENERGY CONSUMPTION/HR (L/HR)	TOTAL CONSUMPTION (Liters diesel)
AMOSING 2	8.04	76	9.5	480	4,560.00
Av. OFFSET WELL	1.47	76	51.7	480	24,816.00

Table 5.1: Table of energy consumption for equivalent section depths

ENERGY SAVING (LITERS OF DIESEL) PER METER

WELL	Average ROP (M/HR)	SECTION LENGTH (M)	TOTAL COMNSUMPTION (Liters diesel)	Diesel consumed per meter (Liters/Meter)
AMOSING 2	8.04	76	4,560.00	60.00
Av. OFFSET WELL	1.47	76	24,816.00	326.53
Energy saving			20,256.00	266.53

Table 5.2. Diesel consumption for the section and consequent diesel saved from optimization

This indicates an **81.62%** Liters per meter diesel consumption reduction over the offset wells.

Furthermore, the tool has the added advantage of being a sealed-bearing motor with adjustable housing so in theory could have continued drilling and completed the section without having to trip out of hole as the bit dull was still excellent. Based on rig observations from the technical engineer, it took 9.4 hours to trip out, rack the BHA and trip back to the same depth. Thus the following additional savings could have been realized:

TRIP DEPTH (M)	Time taken (Hours)	Diesel consumed
TOTAL TRIP TIME FROM 150M-0-150M	9.4	4,512.00

Table 5.3. Table of diesel consumed for the total trip out of hole from 150m to the surface

Therefore, the total diesel consumption savings was a total of 2**4,768.53L (=4,512.00+20,256.00)**

Doing a cost analysis strictly based on the diesel fuel saved, while considering the market value of Diesel in Kenya, based on the official price by the ENERGY & PETROLEUM REGULATORY AUTHORITY (see appendix 13.)

DIESEL SAVED (L)	PRICE OF DIESEL PER LITER	TOTAL COST OF DIESEL (KSH)
24,768.53	102.22	2,531,784.96

Table 5.4. Table of savings in KSH

Below is a tabulation of major variables before and after the optimization process, where the Offset wells are compared to the subject well

	OFFSET WELLS				OPTIMIZED WELL	
	Variable	**Etuko-1**	**Amosing-1**	**Ngamia-3**	**Amosing-2**	**Discussion**
1.	**R.O.P. (M/HR)**	1.36	1.51	1.56	8.04	There is a 415% increase in R.O.P from the best offset
	Total Diesel consumed for 76m(L/hr)	8,272.00	8,272.00	8,272.00	4,560.00	**81.62%** Liters per meter diesel consumption reduction over the offset wells.
2.	**Diesel Fuel Consumption(L/hr)**	108.84	108.84	108.84	60.00	**81.62%** Liters per meter diesel consumption reduction over the offset wells.
3.	**TOTAL TRIP TIME FROM 150M-0-150M(Hours0**	9.4	9.4	9.4	0	There was no tripping out to change the bit

Table 5.5. Table of overall improvement after optimization process

CHAPTER 5:

Conclusions

5.1. Conclusions

The following findings were arrived at:

1. Analysis of the Offset data wells, that is Ngamia-3, Amosing-1 and Etuko-1 indicated that all three wells had greatest challenges while drilling the Volcanics. This was indicated by the very low/uncompetitive Rates of Penetration (R.O.P.), signs of vibrations on surface on the draw-works and instrumentation, rock strength analysis and the bit dull grades.
2. It was established that all the OFFSET wells used Roller-cone Bits to drill the volcanic sections.
3. **Bits and Stabilizer damage**. The bits and stabilizers dull grading was indicative of Bits exposed to a mode of vibration known as Stick slip. The phenomenon of stick-slip, also known as micro-stalling, is torsional vibration that occurs due to cyclical rotation acceleration and deceleration of the bit, BHA, or drill string. This speed fluctuation can be to zero RPM or far in excess of twice the rotational speed measured at the surface. These cycles will greatly reduce the Rate of penetration and the Bit life cycle, which eventually translates into a cost implication for the client.
4. The following recommendations were implemented on the Amosing -2 well.
    a. Introduction of new Bit technology in the form of a PDC.
    b. Introduction of new technology in the form of the percussion tool to counteract the Stick-slip vibration
    c. Optimization of the Bit hydraulics
    d. Realtime optimization of the drilling parameters while drilling the subject wellby continuously observing the Rate of penetration (R.O.P.), the weight on bit (W.O.B.), rotations per minute (R.P.M.), fluid flow rates, pump pressures, torques were changed to achieve and maintain a high Rate of penetration (R.O.P.) through out drilling of the Amosing-2 well.

The above measures, resulted in significant increase in the Rate Of Penetration (R.O.P.) while drilling through the challenging volcanic formation.

The 12 ¼" top-hole on the well **Amosing-2** was selected to test the percussion tools ability to drill the hard-volcanic rock at higher penetration rates than previously achieved. An aggressive 6 bladed bit with 16 mm cutters, 12.25" 616 PDC bit was selection to drill in combination with the Percussion drilling tool, real time monitoring tools drilling parameters were selected.

The 12 14" section of Amosing-2 was drilled in 12 hours on the bottom at an average ROP of 8.5 m/hr through the prognosed hard volcanics section.

The ROP of drilling the Etuko-1, Amsoing-1 and Ngamia-3 offset wells was 1.36 m/hr, 1.56 m/hr respectively. This is as indicated in the results table 5.6 on page 52

The homogenous volcanic layer (70.4m) was drilled with an average on bottom ROP of 8.04 m/hr. This represents a **444% increase in ROP** compared to the 3 offset wells.

the total diesel consumption savings was a total of **24,768.53Liters.**

Overall cost savings of **KSH 2,531,784.96** comparing like-for-like sections drilled. On bottom drilling hours saved was **42.4 hours** (1.8 days). This saving includes the fact that there was no need to trip out of hole after the vertical section as the Fluid hammer could have acted as a conventional directional motor (cost saving here **was $461,216.64 approximately** that went unrealized)

References

1. *Azar J. J., and Samuel G. R., "Drilling Engineering", Penn Well Corporation, Tulsa OK, 2007.*
2. *Society Petroleum Engineering, March 2008, Petroleum Engineering, Drilling Engineering, Drilling Optimization, Practical Guidelines.*
3. *Carden, R. S., Grace, R. D., and, Shursen, J. L.: "Drilling Practices, " Petroskills-OGCI, Course Notes, Tulsa, OK, 2006, pp 1-8*
4. *Samuel G. R., and Miska S., "Optimization of Drilling Parameters with the Performance of Multilobe Positive Displacement Motor (PDM), " SPE 47791, IADC/SPE Asia Pacific Drilling Conference, Jakarta, Indonesia, September 1998*
5. *Short J. A., "Introduction to Directional and Horizontal Drilling, " PennWellPublishing Company, Tulsa, OK, 1993, pp 3*
6. *[6] "Improving drilling performance through optimizing controllable drilling parameters" Link. Springer.com/article/10.1007/513202-021-001116-2*
7. *[7] "Maximizing drill rates with real time surveillance of mechanical specific energy2 https://doi.org/10.2523/92194-Ms*
8. *[Wikipedia contributors. (2021, October 18). Oil well. In Wikipedia, The Free Encyclopedia. Retrieved 07:32, November 9, 2021, from https://en.wikipedia.org/w/index.php?title=Oil_well&oldid=1050524200]*
9. *Bourgoyne A. T. Jr., Millheim K. K., Chenevert M. E., and Young F. S., "Applied Drilling Engineering", Society of Petroleum Engineers Text Book Series, Vol. 1, Richardson, TX, 1986.*
10. *Drilling data management with server-based systems and proprietary software. World Oil, Vol. 229 No. 12, pp 78, December 2008.*
11. *Pickering J. G., Kreijger J., Grovik L. O., Franssens D., and Doniger A., "WITSML "Comes of Age" for the Global Drilling and Completions Industry," SPE 124347-MS, SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana, 4-7 October 2009.*
12. *Lummus J. L., "Drilling Optimization," SPE 2744, SPE 40th Annual California Fall Meeting, San Francisco. November 1969*
13. *Final Drilling Report well RH-39, Drilling Rigs (National E-610, Ideco E-1700), Drilling Department August -2006.*
14. *Final Final Drilling Report well RH-40H, Drilling Rigs (National E-610, Ideco E-1700), Drilling Department June -2006.*
15. *Final Final Drilling Report well RH-42S, Drilling Rigs (National E-610, Ideco E-1700), Drilling Department June -2007.*

16. *Ozbayoglu M. E., Miska S. Z., Reed T., and Takach N., "Analysis of the Effects of Major Drilling Parameters on*
17. *Cuttings Transport Efficiency for High-Angle Wells in Coiled Tubing Drilling Operations, " SPE 89334, SPE/IcoTA CT Conf. andExhb., Houston, TX, March 2004*
18. *Al-Betairi E. A., Moussa M., and Al-Otaibi S., "Multiple Regression Approach to Optimize Drilling Operations in the Arabian Gulf Area, " SPE 13694, Middle East Oil Symposium, Bahrain, March 1985*
19. *NOV Fluid Hammer™ report Tullow Kenya 2014 report.docx*
20. *1 Teale, "The Concept of Specific Energy in Rock Drilling"; Int. J. Rock Mech. Mining Sci.; Vol. 2; pg. 57-73.*
21. Formulas and Calculations for Drilling, Production and Workover by Norton J. Lapeyrouse. Second edition. (http://www.drillingformulas.com/formulas-and-calculations-for-drilling-production-and-workover-book-review/)
22. ENGINEERING MATHEMATICS –K.A. STROUD with additions by DEXTER J.BOOTH (5th edition)
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24. Mehaysen A. AL-Mahasneh. Optimization Drilling Parameters Performance During Drilling in Gas Wells. International Journal of Oil, Gas and Coal Engineering. Vol. 5, No. 2, 2017, pp. 19-26. doi: 10.11648/j.ogce.20170502.12-Received: November 29, 2016; Accepted: December 10, 2016; Published: March 22, 2017
    - **24.1.** International Journal of Oil, Gas and Coal Engineering 2017; 5(2): 19-26 http://www.sciencepublishinggroup.com/j/ogcedoi: 10.11648/j.ogce.20170502.12
    - **24.2.** ISSN: 2376-7669(Print); ISSN: 2376-7677(Online)
25. *Cuttings Transport Efficiency for High-Angle Wells in Coiled Tubing Drilling Operations, " SPE 89334, SPE/IcoTA CT Conf. andExhb., Houston, TX, March 2004*
26. *[14] Al-Betairi E. A., Moussa M., and Al-Otaibi S., "Multiple Regression Approach to Optimize Drilling Operations in the Arabian Gulf Area, " SPE 13694, Middle East Oil Symposium, Bahrain, March 1985*
27. *[15]* Formulas and Calculations for Drilling, Production and Workover by Norton J. Lapeyrouse. Second edition.(http://www.drillingformulas.com/formulas-and-calculations-for-drilling-production-and-workover-book-review/
28. https://www.tullowoil.com/operations/east-africa/kenya
29. http://nationaloil.co.ke/site/3.php?flag=upstream&id=1

30. https://www.nov.com/Segments/Wellbore_Technologies/ReedHycalog/ReedHycalog_Drill_Bits.aspx

- https://www.nov.com/ProductIndex.aspx

7. APPENDICES:

Appendix 1. HISTORY OF OIL AND GAS EXPLORATION IN KENYA

KENYA Petroleum exploration began in Kenya in the 1950s, and the first well was drilled there in 1960.In 1954, British Petroleum (BP) and SHELL began exploring Kenya, drilling ten (10) wells in the Lamu Embayment. Despite numerous signs of oil staining in untested zones with gas shows, none of the wells were fully evaluated or completed for production.

At FROBISHER ltd. in the Mandera Basin, CO. OF ADOBE OIL In 1975, several consortia acquired acreage in upper Lamu Basin. and BURMA OIL co. conducted photo geological field geology, gravity, aeromagnetic, and seismic surveys that did not result in drilling programs. In 1975, oil and gas shows in the Crateceous rocks were discovered when Texas Pacific et al. drilled Hargaso-1.In the southern part of the Anza Basin, Chevron and Esso drilled the wells Anza-1 and Bahati-1 in 1976.An interest in the offshore portion of the Lamu Basin resulted in the 1982 drilling of three deep wells—Simba-1, Maridadi-1, and Kofia-1—by a consortium of **Cities Services, Marathon, and Union.** It was suspected that the drilling mud of both of these wells contained hydrocarbons and microfossils, both of which tainted the geochemical and cuttings, respectively.

The Kenyan margin had salt diapiric structures, according to seismic data. In order to entice international exploration interest in Kenya, the petroleum exploration and production legislation was revised in 1986 to provide appropriate incentives and flexibility.

With **Petro-Canada International Assistance Corporation**, the Kenyan government began a joint venture exploration program in 1986. Kencan-1 was drilled to test deeper strata on the structure adjacent to the Garissa-1 well. Seismic work was also carried out.

Between 1985 and 1990, a group of companies led by **Amoco and Total drilled** ten (10) wells, eight of which were in the Anza Basin and two in the Mandera Basin. Although the wells were dry, there were signs of oil and gas. Amoco drilled Sirius-1, Bellatrix-1, Chalbi-3, and the Hothori-1 well in the South Anza Basin, while Total Exploration drilled Ndovu-1, Duma-1, and Kaisut-1 in the North Anza Basin.

Shell drilled Eliye Springs-1 and Loperot-1, which were discovered west of Lake Turkana in a Tertiary Rift Basin. Amoco sold half of its interest to Shell. On a repeat formation test (RFT), the Loperot-1 well recovered water and waxy oil from a Miocene sandstone interval that had a high Total Organic Carbon (TOC) content.

Fluorescence and gas shows were observed in the Hothori, Endela, and Ndovu wells, but no commercial reserves were discovered in any of these wells. Biostratigraphic research suggests that these wells may not have reached the source reservoir and seal within Sudan rift basins' Neocomian-Lower Albian sediments deep enough to test them.

As part of a long-term strategy to reevaluate the existing geological, geophysical, and geochemical data pertaining to each of the sedimentary basins in Kenya, National Oil initiated an internal study of the Lamu Basin in 1991.

In 1995, the Lamu Basin study was finished. Kenya divided the Lamu embayment—both onshore and offshore—into ten (10) exploration blocks, each with a distinct exploration play, based on the reports above. Since 2001, two additional exploration blocks have been constructed.

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Between 2000 and 2002, seven Production Sharing Contracts covering blocks L5, L6, L7, L8, L9, and L10 were signed as a result of promotional efforts that attracted new interest in the offshore Lamu Basin. Between August and October of 2003, Woodside obtained 2D seismic data covering Blocks L5, L6, L7, L8, L9, L10, L11, and L12 offshore Lamu Basin.

The Tertiary Rift Study was ordered by the Corporation in August 2000 and finished in March 2001.The petroleum system at work in the subbasins and the potential source and reservoir rock units in the study area were quantified through the tertiary rift study.

Seismic, well log, and other oil exploration reports, as well as aeromagnetic and gravity data gathered through petroleum exploration in this nation up to this point, are stored in National Oil's Data Centre. In addition, National Oil has constructed a storage facility for cores and drill cuttings, where the rock samples retrieved during petroleum exploration in this nation between 1960 and the present day are stored for use by those conducting exploration.

Kenya Oil block licenses and license holders

Fig 7.1. Kenya Oil block licenses and license holders

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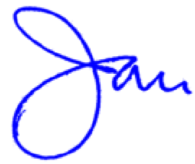
Prof. J. A. Nyang'aya Signature  Date *2nd December. 2022*

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