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DRILLING IN MENENGAI HIGH TEMPERATURE FIELD – MAJOR CHALLENGES AND RECOMMENDATIONS

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ABSTRACT

Drilling has been on going at the Menengai geothermal field since early 2011, by Geothermal Development Company. Wells within the Menengai geothermal field are planned to be drilled within sixty (60) days from spud in to capping of the well before the rig is mobilized to the next site. Due to several challenges, it has not been possible to complete the wells within the planned time. This paper looks at some of the main challenges faced drilling at Menengai and gives recommendations that would help drill the wells timely, safely and cost effectively.

1. INTRODUCTION

Wells drilled in Menengai geothermal field are of regular design with these hole sections as shown in Figure 1:

- 26″ hole cased with 20″ casing;
- 17½″ hole cased with 13⅜″ casing;
- 12¼″ hole cased with 9⅝″ casing; and
- 8½″ hole cased with 7″ slotted liner.

While drilling the different hole sections, different challenges are experienced. There is challenge of sufficient drilling water while drilling the top two sections due to high pump rates required. Casing collapse has been a major issue especially for the 13⅜″ casing and 9⅝″ casings that have been set deep and stuck pipe especially while drilling the 12¼″ and 8½″ hole sections have been major challenge.

2. INSUFFICIENT DRILLING WATER

Water for drilling at Menengai is obtained from boreholes drilled. Currently with the seven rigs operational at Menengai, the water is not always sufficient for drilling. Water requirements for drilling, especially for the top two sections, the 26″ hole and the 17½″ hole is high to achieve required annular velocities for sufficient hole cleaning for optimum drilling. Since the top two sections are fractured, quite often blind drilling is applied. Figure 2 shows that while drilling MW21A, a directional well, 54% of downtime while drilling the well was due to waiting on water. Most of wells drilled in Menengai have a similar data.

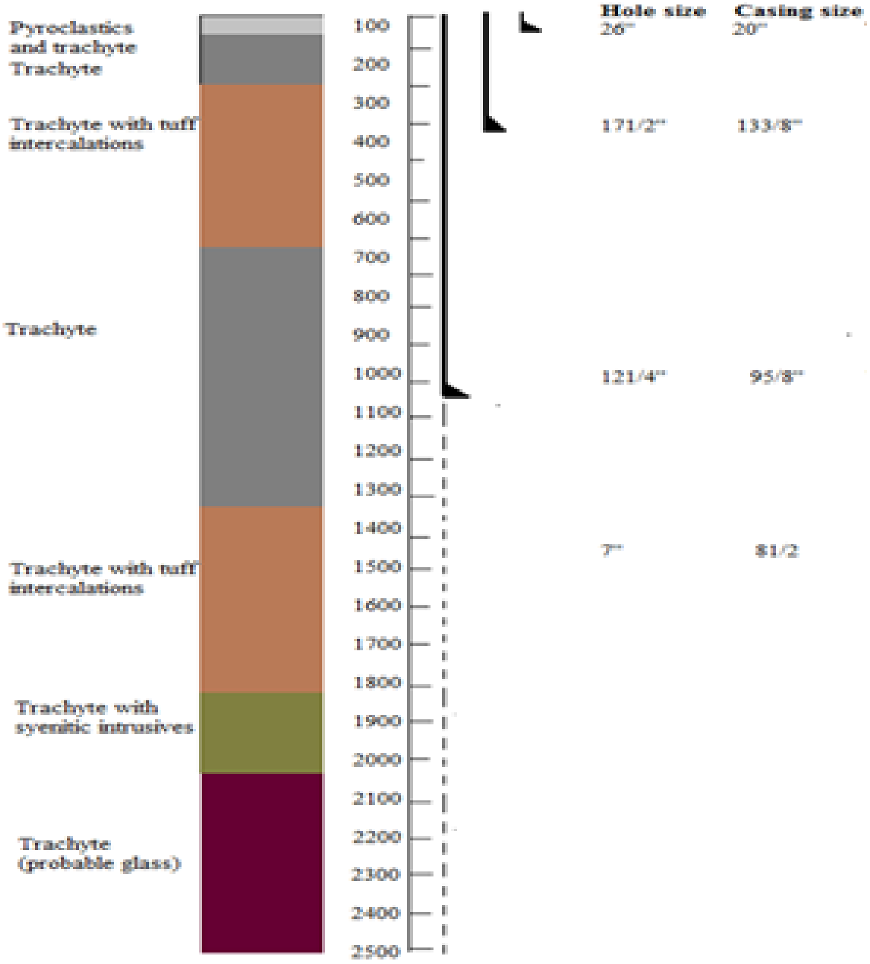


FIGURE 1: Menengai well profile

2.1 RECOMMENDATION

2.1.1 Foam drilling

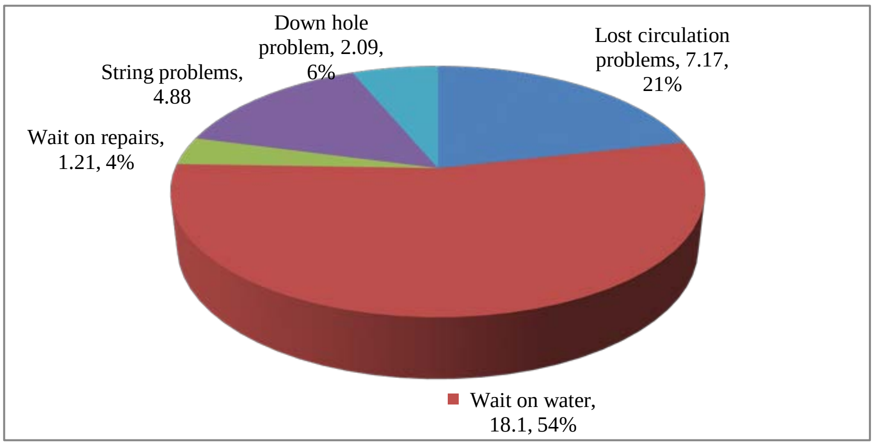


FIGURE 2: MW21A downtime analysis (Khaemba, 2015)

Foam drilling does not utilize a lot of water. The foam drilling set up shown in Figure 3 utilizes less water, between 300-500 litres per minute and the air drilling package to utilize the air hammer for drilling. Each rig is supplied with an air drilling package comprising of compressor (5) with capacity of 2700scfm, booster (3) of capacity of 2500psi, soap injection pump and mist tank with mist pump of 2500psi and related manifold and gauges.

Foam drilling can be utilized for drilling the 26″ and the 17½″ sections with the air hammer which uses percussion instead of rotation and grinding as shown in Figure 4.

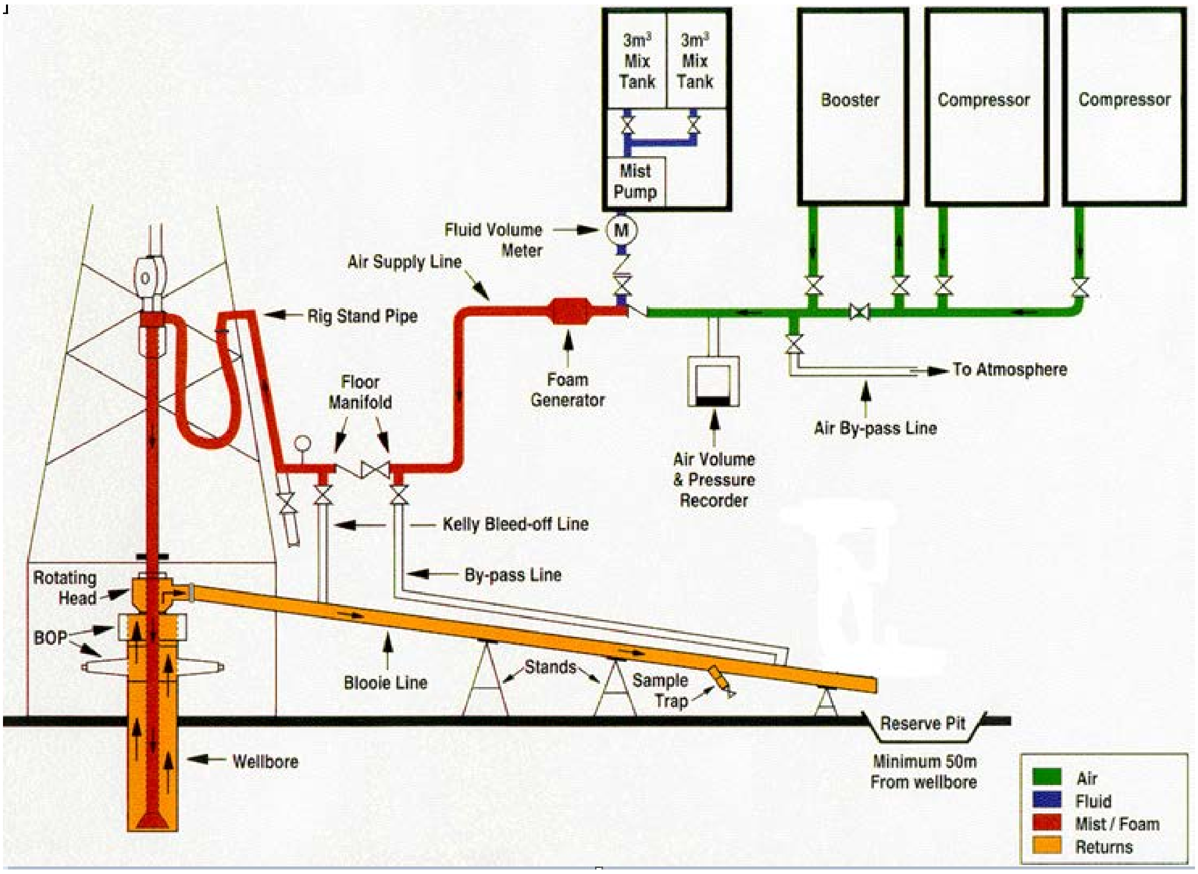


FIGURE 3: Foam drilling set up (Atlas Copco, 2011)

Features of foam drilling are:

- Foam is created by combining water, surfactants and air;
- Foam (stiff, shaving cream consistency) is circulated as the drilling fluid;
- Higher pressure losses (SPP) due to high viscosity;
- Annular velocities are typically 500 to 600 ft./min, similar to mud;
- Low volumes of air used; and
- Higher volumes of fluid (water) used.

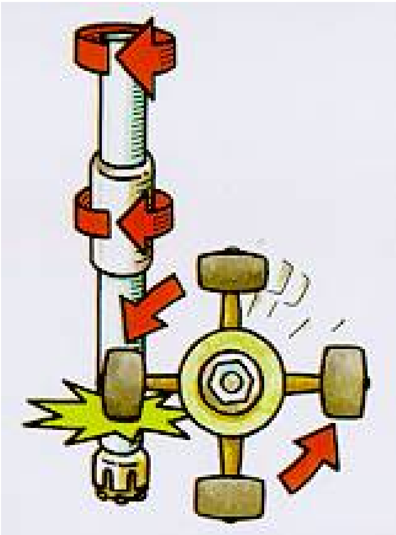


FIGURE 4: Hammer effect of hammer bit

2.1.2 Underbalanced drilling (12¼″ and 8½″ hole sections)

Underbalanced drilling utilizes two phase or lightened drilling fluid, mixing of gaseous and liquid phases to achieve desired drilling fluid density to enable formation fluids to flow into the well bore during drilling. The set up for underbalanced drilling is shown in Figure 5. A geothermal separator should be installed on the flow line between the BOP and the shakers to separate air from the return fluid and avoid form with bubbles on site as shown in Figure 6.

Advantages of underbalanced drilling include:

- Less drilling fluid is used (far much less pumping rates used);
- Faster rate of penetration;
- Improve reservoir performance due to reduction in formation damage; and

- Higher annular velocities which lead to better evacuation of cuttings.

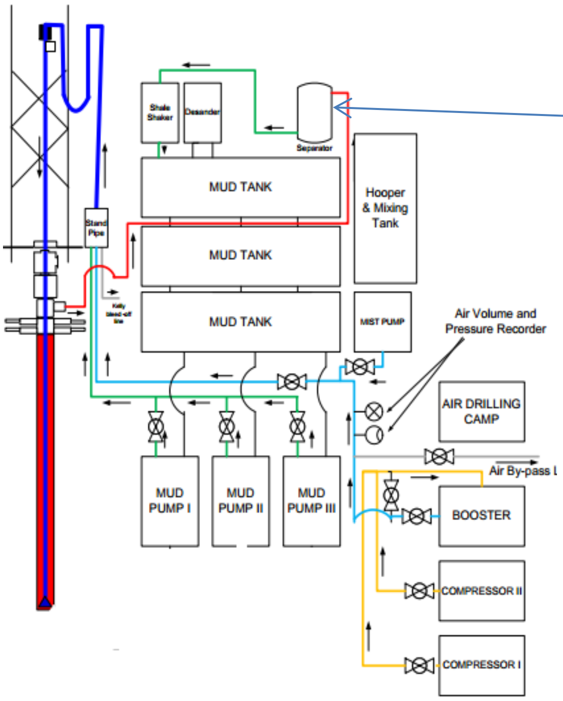


FIGURE 5: Underbalanced drilling set

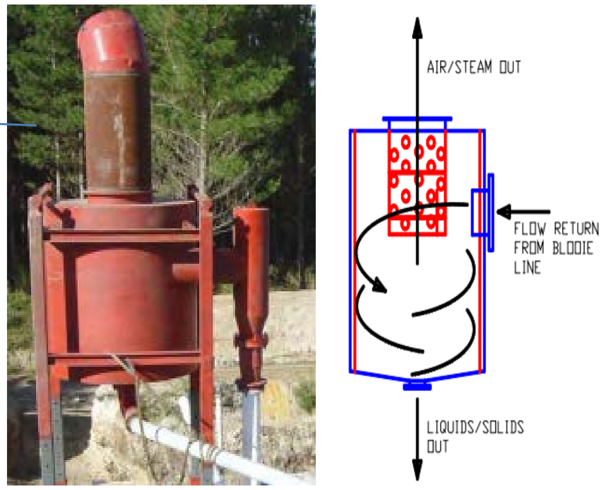


FIGURE 6: Geothermal Separator

3. STUCK PIPE

Common causes of stuck pipe are:

- Differential sticking;
- Settled cuttings;
- Shale instability;
- Fractured rocks;
- Cement blocks;
- Doglegs and ledges;
- Hole pack off (formation and BHA);
- Junk;
- Key seating;
- Mobile formations;
- Under-gauge hole; and
- Drilling into magma.

Indicators while drilling that show possibility of getting stuck are shown in Table 1.

TABLE 1: Common indicators of hole problems leading to sticking, Awili 2014

	TORQUE	**PRESSURE**	**DRILL RATE**
Poor hole cleaning	Increase	Increase	Gradual decrease
High overbalance	Gradual increase	No change	Gradual decrease
Mobile formations	Gradual increase	Increase	Gradual decrease
Fractured & faulted	Sudden erratic increase	May be unaffected	Sudden increase
Geo-pressurized. formations	Increase	Increase	Both
Reactive formations		Increase	Gradual decrease
Unconsolidated formations	Gradual increase	Increase	Decrease
Junk	Sudden increase	Increase	Sudden decrease
Cement blocks			Sudden decrease

From analysis of downtime while drilling MW01A as shown in Figure 7, stuck pipe condition accounts for more than 50% of the total downtime. Stuck pipe is common occurrence while drilling in Menengai, especially in the 8½″ hole section. Stuck pipe often leads to fishing operations and in extreme cases leads to abandonment of wells.

Different mechanisms of stuck pipe that have been experienced in Menengai are shown in Figure 8.

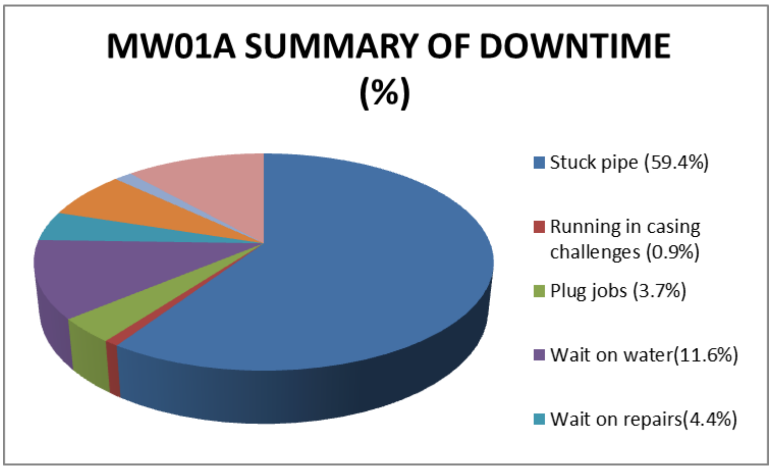


FIGURE 7: Downtime Analysis for MW01A (Makuk, 2014)

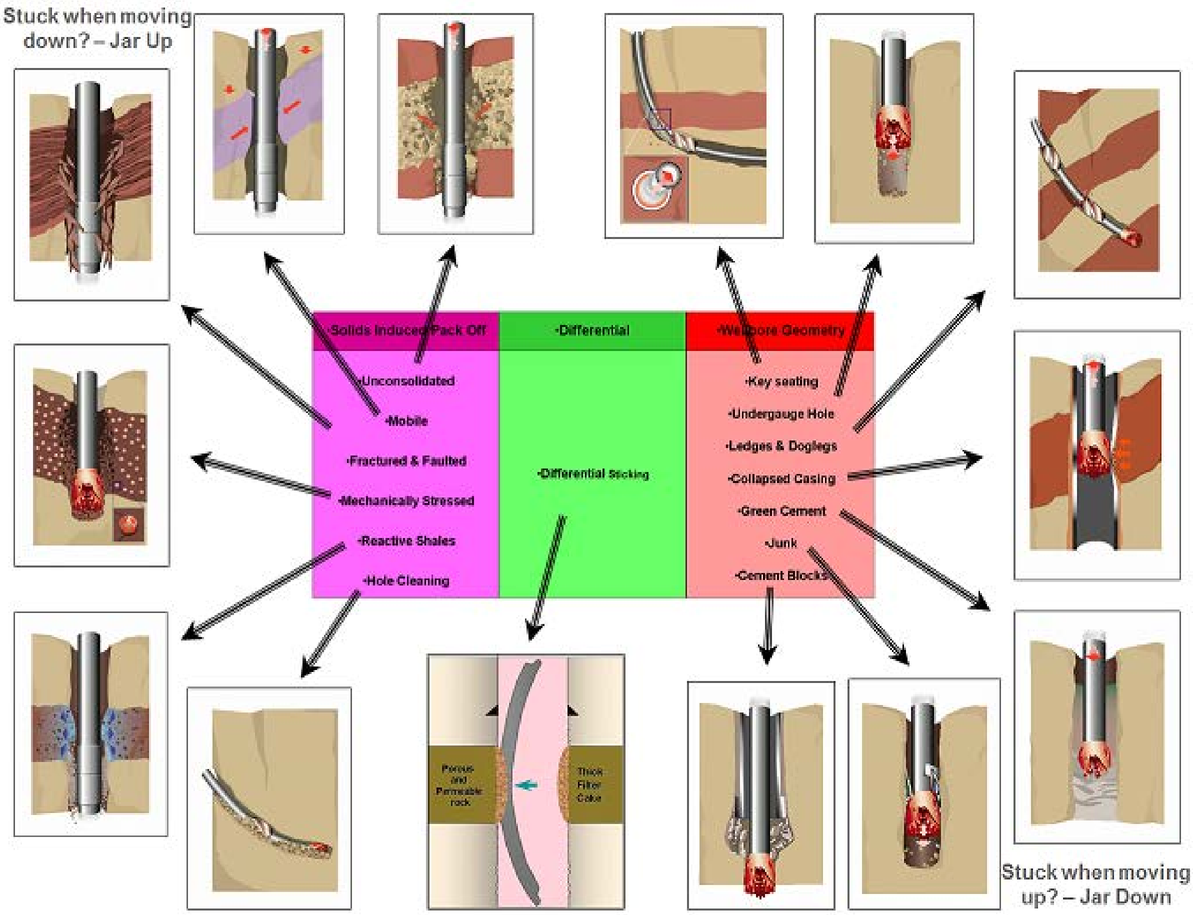


FIGURE 8: Sticking mechanisms experienced while drilling at Menengai

3.1 Stuck pipe prevention and mitigation

1. While planning the well
    a. Casing plan
        i. Consider section length and the clearance between strings and bore hole.
    b. Drilling fluid plan, Aerated operation
        i. Keep proper mixed flow rate. Keep hole clean.
        ii. Prepare loss circulation material, lubricant pill and pump promptly if needed.

   c. BHA program.
      i. Understand the string weight and tensile capacity of all components
      ii. Prepare drilling Jar and design its effective placement in case of jarring operation.
   d. Fishing tool and pipe disconnect procedure.
      i. Prepare fishing tools that match the BHA Plan.
      ii. Prepare a safe pipe disconnect procedure in case of overshot operation and sidetrack operation.
2. BHA planning and drill string running
   a. Operate BHA and String within limits
   b. Keep the BHA as simple as possible
   c. Run a drilling Jar whenever possible
   d. Whenever possible use Spiral Drill Collars
   e. Stabilise the BHA to minimise wall contact
   f. Always gauge Bits and Stabilisers accurately before they are run in hole or rerun
3. While operating
   a. Communicate effectively especially crew handover
   b. Plan prior to operation
   c. Listen to the hole constantly, checking parameters and returns
   d. Maintain good mud or enough air
   e. Keep the pipe moving always
   f. Clean hole as fast as you can drill
   g. Take action early especially pipe stuck
4. Maintenance of equipment- these equipment should be properly maintained,
   a. Mud pump and discharge lines.
   b. Air compressors and booster.
   c. Rotated head.
   d. Solid control system and mud mix system.
   e. Draw works, rotary table and generator.
   f. Always maintain stand by equipment.
   g. Always prepare critical parts included spare.

3.2 Stuck pipe prevention during operation

1. Drilling
   - Select hole cleaning to match rate of drilling
   - Monitor the hole for changes in drilling trends
   - Perform wiper trips as hole conditions dictate
   - Wipe/ream the last stand before making a connection
   - Wipe the last stand or single before taking a survey
   - When drilling to casing point, calculate a target depth
2. Tripping
   - Plan the trip
   - Know the swab and surge pressures
   - Circulate clean prior to tripping
   - Ream and condition the hole while tripping in
   - Be careful while running with new bits
   - Agree on a first response to tight hole
3. Running casing
   - Ensure the hole is clean and mud properties are as required
   - Calculate running speeds - do not exceed the running speed
   - Centralise the casing string
   - Wash the casing through problem formations

- Know the theoretical thickening time of cement before drilling out
- When drilling cement establish circulation before drilling, drill with low weight on bit

Figure 9 below represents a sample decision making process when a stuck pipe occurs.

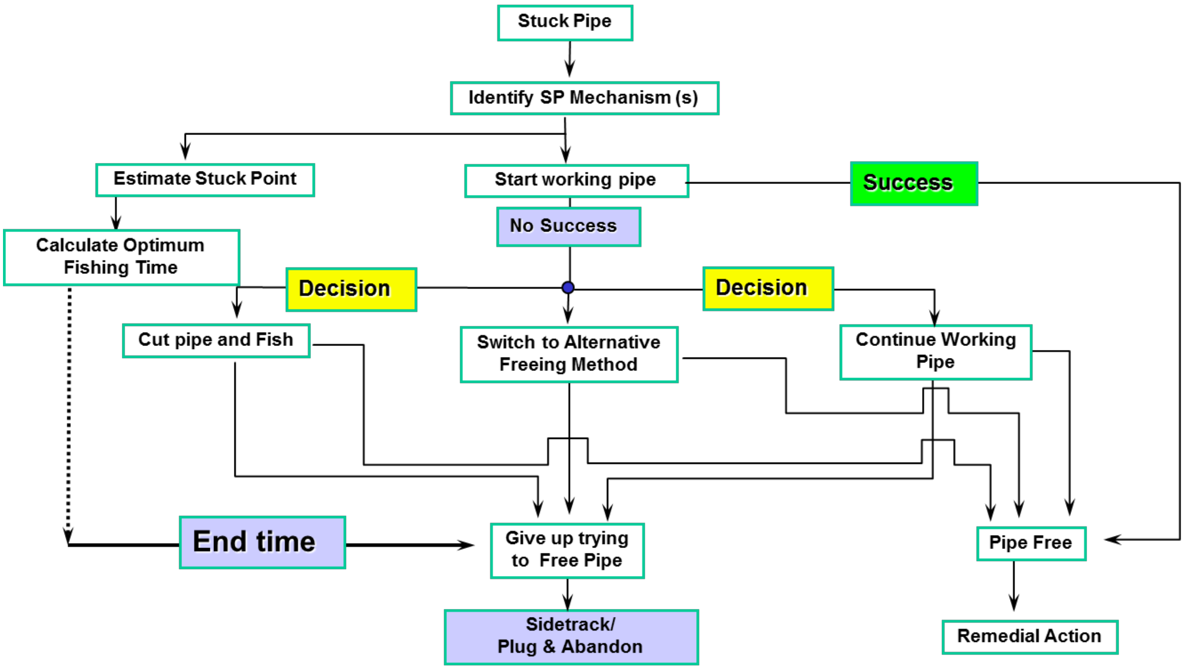


FIGURE 9: Stuck pipe decision chart

4. CASING COLLAPSE AND CEMENTING

Collapsed casing has also been one of the challenges that have led to considerable downtime while drilling geothermal wells at the Menengai field. This is caused by running casings which are damaged, improper torqueing of the joints while running the casing or poor cementing around the casing, leading to water pockets trapped between two casings, which expand on being heated leading to casing collapse.

From Figure10, downtime analysis for MW11, total of 15 days downtime was experienced due to collapsed 13⅜″ casing. The collapsed casing had to be milled, the milled cuttings fished before a cement plug done inside the casing before resuming drilling, contributing to considerable downtime.

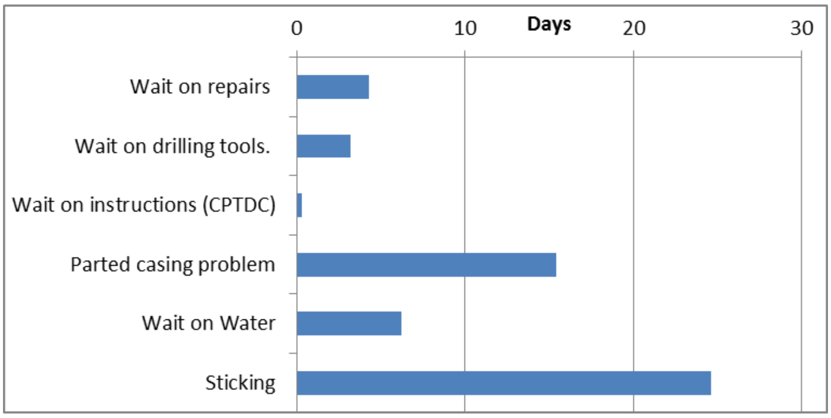


FIGURE 10: Graphical representation of MW11 downtime (Nganga, 2015)

4.1 RECOMMENDATIONS

4.1.1 Welding casings

The bottom six joints, including the shoe joint and the float joint should be weld after torqueing them up to secure them as indicated by arrows in Figure 11. This ensures that the joints will not be affected when drilling out cement inside the casing. Use of baker lock (permanent thread compound) can be used instead of welding. Welding should be done on both ends of the coupling.

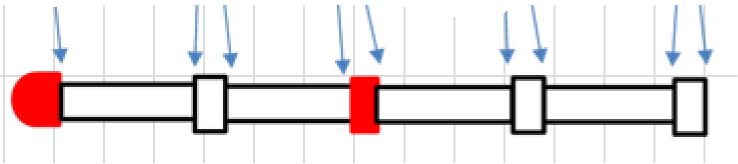


FIGURE 11: Arrows denoting positions to be weld

4.1.2 Caliper logs

Electronic tools equipped with several arms to measure diameter of casing. Arms centralize the tool in the hole. Electrical motor inside opens and closes the tool, controlled at the surface through the cable. Positions of arms are detected through variable resistor. Figure 12 shows caliper log with a casing break at 175m and the caliper tool respectively. Caliper logs are used to (Steingrímsson, 2014)

- Evaluate depositions in casings, calcite or silica;
- Evaluate casing corrosion; and
- Evaluate casing damages.

The practical solution of casing implosion is to take all necessary measures to avoid fluids including unset cement getting into the well bore according to Southon (2005).

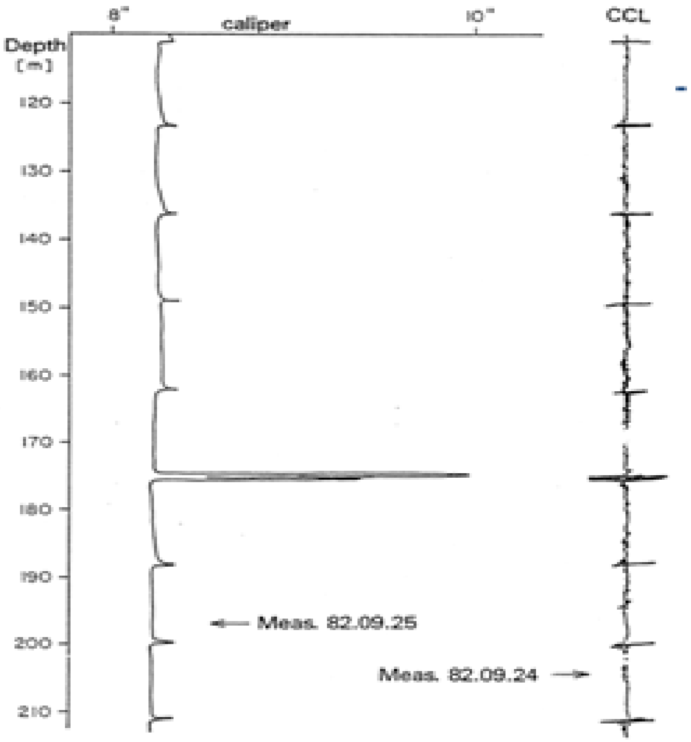
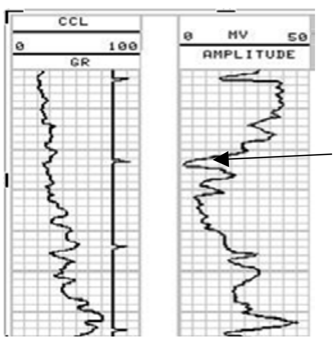


FIGURE 12: Caliper log output (Steingrímsson, 2014)

4.1.3 Cement bond logs (CBL)

Cement bond log (CBL) uses acoustic amplitude curve to indicate cement bond integrity. CBL uses conventional sonic log principals of refraction to make its measurements. Sound travels from the transmitter, through mud and refracts along casing mud interface back to the receivers. The amplitude is recorded on the log in millivolts or as attenuation in decibels/foot or as bond index. A travel curve is also presented. The actual value measured is the signal amplitude in millivolts. Attenuation is calculated by the service company based on its tool design, casing diameter and transmitter. Good cement is indicated by low amplitude, high attenuation and high bond index. Casing that is still unbonded (high amplitude railroad tracks on early arrivals on the VDL), amplitude curve reads high, BUT late arrivals on VDL have shape and track porosity log shape. Figure 13 shows high amplitude variation at depths with casing problems and inadequate cementing.



Very low CBL amplitude indicates casing break

FIGURE 13: CBL log output (Steingrímsson, 2014)

4.2 CEMENTING

In Menengai only single stage cementing has been used. Casings are run with shoe and float placed one joint off the bottom. Pre-flush fluid is pumped at 1.00SG, then the spacer at 1.5 SG. The lead slurry is mixed in the cementing equipment and pumped at about 1.72 SG with the tail slurry being pumped at 1.85 SG. The density is checked using pressurized mud balance on the cementing unit. The wiper plug is bumped then displaced with casing capacity volume. Pressures are recorded while displacing and before bumping the plug. If returns are not received on surface, annulus is flushed with water then cement top fill done after 8 hours. Top jobs are done until cement returns are received on surface.

Using inner string cementing to the loss zone is a more appropriate cementing method. Water should be pumped through the annulus at a constant rate to ensure the loss zone remains open, and then pump cement to the loss zone. The primary cementing job should be followed immediately with a backfill targeting to fill up the annulus to the surface while the annular rams on the BOP are closed as shown in Figure 14. The inner string method is more advantageous as its faster to circulate and cool the well as circulation is done through drill pipes (capacity of 9.05l/m- Gabolde and Nguyen, 2014) compared to single stage cementing where circulation is done through the 9⅝" casing (Capacity of 38.18l/m- Gabolde and Nguyen, 2014) taking more time to circulate and effective having less annular pressure to lift cuttings that may have dropped below the shoe. Due to the differences in the capacities it takes a shorter time to perform the inner string cementing.

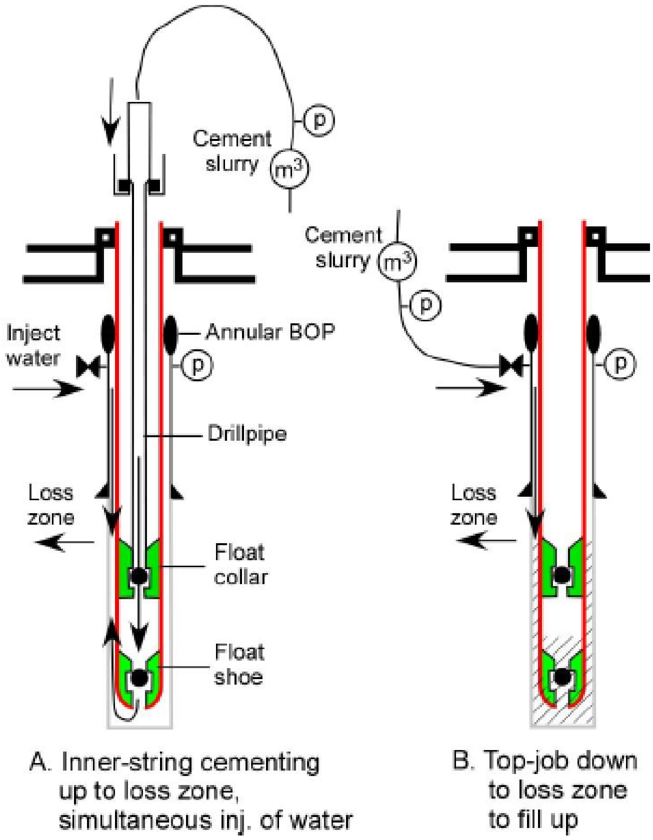


FIGURE 14: Inner string cementing to loss zone

5. CONCLUSION

The above three challenges have really contributed to major down time, hindering wells drilled in the Menengai field being completed in the planned time. To reduce these down time, implementation of the recommendations stated here will go a long way in enhancing drilling efficiency in the Menengai geothermal field.

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