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Status of Geothermal Drilling in Ethiopia, Drilling Fluid Consumption Cost Case Study:" of Aluto Langano" Appraisal Project

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ABSTRACT

So far since the beginning of 1980s Ethiopia has conducted 14 exploration wells and 2 appraisal wells. To meet the target of future plane commitment of one country government (policy) play a great rule to facilitate the coordinated way of geothermal drilling project work and also to satisfy the customers need of successful geothermal project management policy. One area of drilling project that affects both successful completion of a well and its cost is, the cost of drilling fluid program fluid consumption. The quality of reservoir also is affected by displaced mud which lead the formation to damage.

The aim of this project is to examine fluid formulation and various cost factors rather than comparison of total cost or cost per foot and provide a more realistic and understandable accounting of mud cost.

1. Introduction

Ethiopia is one of the east African countries where the land mass makes it host for geothermal fields having over 20 prospect area along Ethiopian main rift system which is part of the continental East African rift zone. Figure 1.1 shows the location of drilled wells and prospect areas. Figure 1.2 shows so far drilled wells.

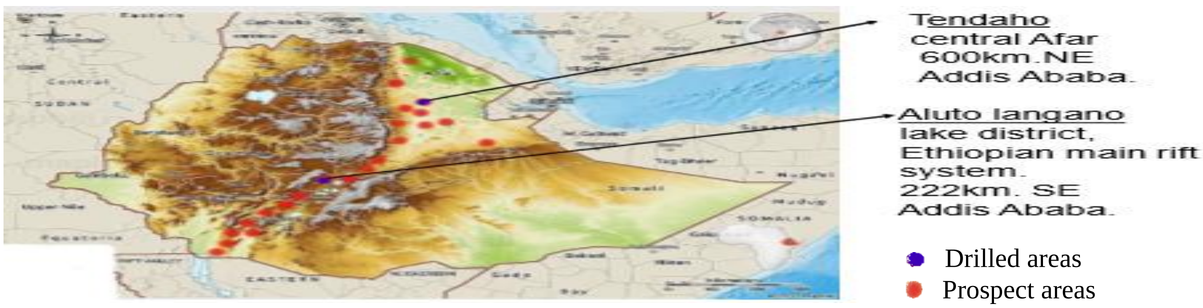

Fig. 1.1 Map of Geothermal Well Locations and Prospect Areas

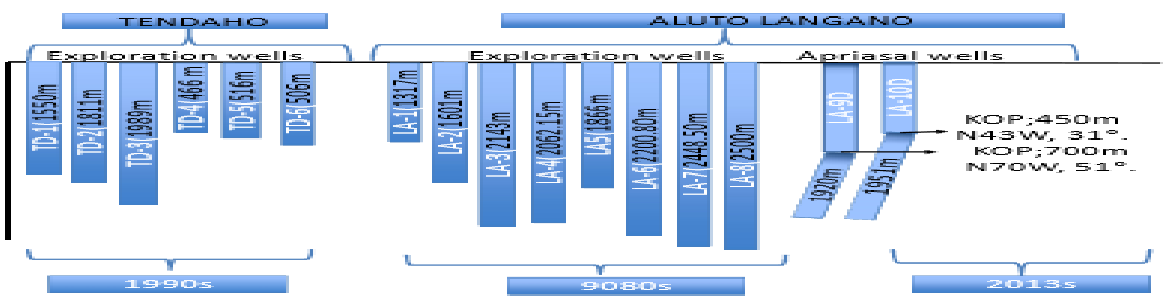

Fig. 1.2 So far Drilled Wells.

During drilling one task of formulation of displaced mud is to control the gas, oil, water pressure in the formation. As long as the hydrostatic pressure of the column of drilling mud in the well is higher than the fluid pressure in the formation penetrated, the formation fluids will be confined in the formation. If the differential pressure of hydrostatic head becomes negative the formation fluid invades the hole, displacing the drilling mud. Continued displacement results in blowout.

Therefore, drilling fluid material shall be selected to provide the required properties at the temperature anticipated for the particular drilling interval.

2. Drilling Fluid Consumption Cost, Case Study: of ''Aluto Langano" Appraisal Project, Well LA-10D

Well LA 10D was spudded on 25 June 2015 after kop @ 450m N43 W maximum inclination 31^0 and completed when the well reached to 1951m and 7" slotted liner was set on 2 October 2015. (figure A. shows the well casing design of LA-10D). The well was drilled to attain the following Geo-scientific objectives:

- To augment the steam supply of the future EEP Geothermal Power Plant.

- To drill and tap the geothermal reservoir existing at two faults approximately between 1,200 meters to 2,000 meters. and
- To intersect and avail of the permeability associated with G2 and R1 faults, along where the movement of hot fluid occurs. (refer figure B).

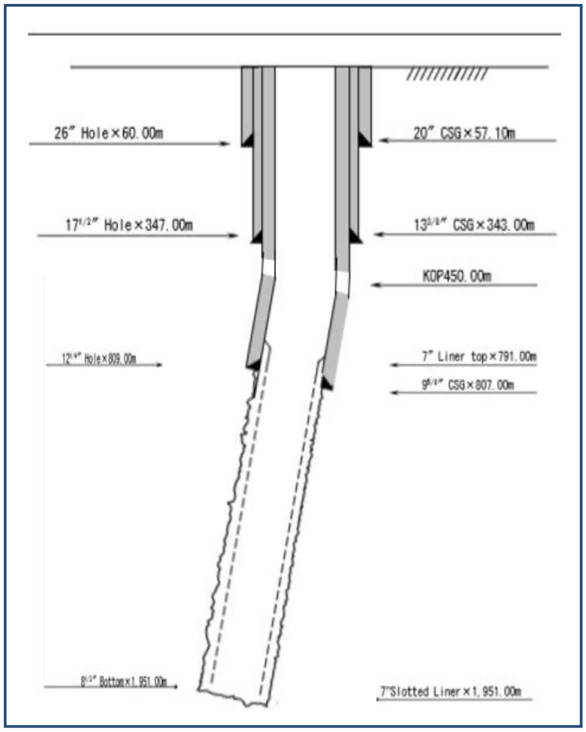

Fig. A. LA-10D Well Casing Design

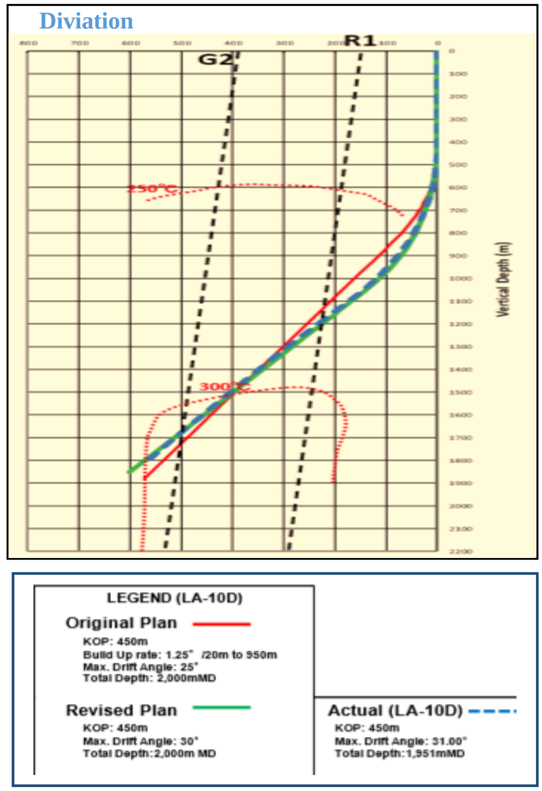

Fig B. Directional drilling Trajectory of LA-10D

Drilling fluid engineers play great role for successful drilling project and its cost. Controlling mud displacement prevents pipe from differential stuck. Drilling fluid costs are either direct or indirect. Indirect costs are those included in the purchase handling and utilization of the drilling fluid. In the other hand direct are costs which can be drown to the effects of the drilling fluid technology. (Table 2.1, up to table 2.4 shows for the price of displaced mud formulation cost with each system)

2.1 Summary of Product Usage for 26" Hole Interval

Casing setting depth:0m-57.1m
Depth: 0m – 60 mVD
It is important to treat drill water with soda ash and sodium bicarbonate to reduce water hardness and prevent cement contamination. Also, though the component of water-based drilling fluid is not unduly corrosive, the degradation of additives by high temperature/bacteria may result in

corrosive products. Also, contamination by acid gas such as carbon dioxide and formation brines can cause corrosion. Oxygen entrapped in the mud can accelerate corrosion. The significant of weight loss values should be considered along with other feature of a drill pipe coupon. A more severe problem arises if the corrosion is not detected and the pipe fails while drilling. As with many aspects of mud engineering, familiarity with corrosion value in the drill site area enables the mud engineer to interpret the corrosion rates correctly.

$$\text{Corrosion rate lbs. / ft}^{2.}\text{ Yr.} = \frac{K^*(\text{weight loss in grams})}{\text{exposure time in hours}}$$; K= a constant used for the area of the ring exposed

Product Name	Packaging	Amount Used	Unit Cost USD	Product Cost USD
Telgel	55 lbs/bag	117	16.18	1893.06
Asapura	25 kl/sx	248	16.18	4012.64
Telnite	44 lbs/bag		83.48	
Idthin 500s	44 lbs/bag		333.00	
Caustic Soda	55 lbs/bag	7	59.36	415.52
Soda Ash	55 lbs/bag	5	46.78	233.9
Sodium Bicarbonate	55 lbs/bag	3	52.19	156.57
Polymer H	44 lbs/bag	9	237.41	2136.69
Polymer L	44 lbs/bag		237.41	
Polymer X	55 gal		783.00	
Polymer P	55 gal		57.30	
LCM	15 lb/sx	13	0.00	
Subtotal				8848.38

Total Volume Mixed (bbls)	1977.00
Mud Volume Carried Over to next interval (bbls)	600.00
Net Volume Used (bbls)	600.00
Mud Cost Per Barrel (Material cost/volume mixed) (USD)	4.48
Net Material Cost (net mud volume used x mud cost per barrel (USD)	2685.40
Material Cost Per meter (USD)	47.36
Drilling Fluid Type ;Bentonite Coustic Soda	

Tab. 2.1 Price for Displaced Mud Formulation Cost for 26” Hole Interval

2.2 Summary of Product Usage for 17.5” Hole Interval

Casing setting depth: 0m– 343m
Depth: 60mMD-347mMD
Displaced mud is recommended to be treated with caustic soda in each hole section to maintain alkaline pH. The effects of the gases on drilling fluid differ. Oxygen can be measured with difficulties by oxygen meter, while hydrogen sulfide and carbon dioxide effects usually are

indicated by a rapid reduction in the alkalinity of the fluid. (table. 2.5 a. illustrates drilling fluid parameters of formulated displaced mud with each system.

Product Name	Packaging	Amount Used	Unit Cost USD	Product Cost USD
Telgel	55 lbs/bag	76	16.18	1229.68
Asapura	25 kl/sx	1542	16.18	24949.56
Telnite	44 lbs/bag	3	83.48	250.44
Idthin 500S	44 lbs/bag		333.00	
Caustic Soda	55 lbs/bag	66	59.36	3917.76
Soda Ash	55 lbs/bag	19	46.78	888.82
Sodium Bicarbonate	55 lbs/bag	16	52.19	835.04
Polymer H	44 lbs/bag	91	237.41	21604.31
Polymer L	44 lbs/bag	2	237.41	474.82
Polymer X	55 gal		783.00	
Polymer P	55 gal		577.30	
LCM	15 lb/sx		0.00	
Sub total				54150.43

Total Volume Mixed (bbls)	19017.00
Mud Volume Carried Over to next interval (bbls)	600.00
Net Volume Used (bbls)	8417.00
Mud Cost Per Barrel (Material cost/volume mixed) (USD)	6.01
Net Material Cost (net mud volume used x mud cost per barrel (USD)	50547.21
Material Cost Per meter (USD)	891.49

Drilling Fluid Type; Bentonite Polymer Costic Soda

Tab. 2.2 Price for Displaced Mud Formulation Cost for 17.5” Hole Interval

2.3 Summary of Product Usage for 12.25” Hole Interval

Casing setting depth: 0m – 807m
Depth 347 mMD -809 mMD
Observed an increasing flow line temperature from 500m while kick off was maintained by addition of ID Thin/G-500S which has proved effective in controlling temperature, fluid loss, and good rheology. As the temperature increase, the rate of corrosion generally increases since most chemical reactions increase with temperature. As temperature increase in closed loop system the oxygen cannot escape and thus at higher bottom hole temperature with more oxygen present, the corrosion rate will increase. In a closed system the oxygen is less likely to escape than in an open system.

Product Name	Packaging	Amount Used	Unit Cost USD	Product Cost USD
Telgel	55 lbs/bag	1474	16.18	23849.32
Asapura	25 kl/sx	110	16.18	1779.8
Telnite	44 lbs/bag	43	83.48	3589.64
Idthin 500S	44 lbs/bag	10	333.00	3330
Caustic Soda	55 lbs/bag	145	59.36	8607.2
Soda Ash	55 lbs/bag	4	46.78	187.12
Sodium Bicarbonate	55 lbs/bag	3	52.19	156.57
Polymer H	44 lbs/bag	271	237.41	64338.11
Polymer L	44 lbs/bag	1	237.41	237.41
Polymer X	55 gal		783.00	783
Polymer P	55 gal		577.30	577.3
LCM	15 lb/sx		0.00	0
Sub total				41499.65

Total Volume Mixed (bbls)	3600.00
Mud Volume Carried Over to next interval (bbls)	300.00
Net Volume Used (bbls)	3300.00
Mud Cost Per Barrel (Material cost/volume mixed) (USD)	11.53
Net Material Cost (net mud volume used x mud cost per barrel (USD)	38041.35
Material Cost Per meter (USD)	670.92

Drilling Fluid Type;Bentonite,Costic Soda,Polymer,Lignite

Tab 2.3 Price for Displaced Mud Formulation Cost for 12.25” Hole Interval

2.4 Summary of Product Usage for 8.5” Hole

Interval Casing setting depth: (7” Blind Liner) 791.0 m –815.5 m
(7” Slotted Liner) 815.5 m– 1,951.0 m

Depth:-809 mMD-1951mMD

Generally the hole drilled from 891mMD to TD @ 1950mMD has been effectively cleaned out by slugging 10bbls HVM half Kelly and has prevented pipe corrosion. Use of lignite also have proved good filtration control. To keep the productive fracture zone the funnel viscosity should be lower with production zone.

If hydrogen sulfide is encountered or expected to be encountered, the pH of the mud should be adjusted above10.This is because, hydrogen sulfide reacts with iron at the pipe surface to form iron sulfide (FeS) which liberates two hydrogen atom that penetrate the steel matrix. When Carbon dioxide form carbonic acid in water and a similar reaction with the steel can take place. And Iron carbonate will be formed and the hydrogen will again be released to inter the steel and causes corrosion.

Product Name	Packaging	Amount Used	Unit Cost USD	Product Cost USD
Telgel	55 lbs/bag	2117	16.18	34253.06
Asapura	25 kl/sx	406	16.18	6569.08
Telnite	44 lbs/bag	46	83.48	3840.08
Idthin 500S	44 lbs/bag	23	333.00	7659.00
Caustic Soda	55 lbs/bag	227	59.36	13474.72
Soda Ash	55 lbs/bag	7	46.78	327.46
Sodium Bicarbonate	55 lbs/bag	3	52.19	156.57
Polymer H	44 lbs/bag	361	237.41	85705.01
Polymer L	44 lbs/bag	7	237.41	1661.87
Polymer X	55 gal		783.00	
Polymer P	55 gal		577.30	
LCM	15 lb/sx		0.00	
Sub total				**153646.85**

Total Volume Mixed (bbls)	4800.00
Mud Volume Carried Over to next interval (bbls)	300.00
Net Volume Used (bbls)	4500.00
Mud Cost Per Barrel (Material cost/volume mixed) (USD)	32.01
Net Material Cost (net mud volume used x mud cost per barrel (USD)	144043.92
Material Cost Per meter (USD)	2540.46
Drilling Fluid Type;Bentonite,Costic Soda,Polymer,Lignite	

Tab 2.3 Price for Displaced Mud Formulation Cost for 8.5" Hole

2.5 Summary of Product Consumption of LA-10D

Mud costs are related to mud standards. The reduction of filter loss is frequently required to improve the effect of increase in % of total mud cost. Maintenance cost is related to the amount of daily water dilution. Therefore, drilling fluid cost is affected by three principal factors:

A. Water dilution
B. Unit mud cost
C. Day mud used

i.e.

Maintenance cost =Average mud volume(bbl.) *Dilution factor (%) *Unit mud cost $/bbl.) *N days

$$\text{Dilution factor (Df)} = \frac{\text{Average amount of mud formed}}{\text{Day through addition of water used for maintenance}}$$

N days = Number of days

Since water dilution is directly allied with build up from formation solids, it is obvious that improved drilling practice and pit design result in direct mud cost savings. As solid build up occurs in the mud due to excessive drill pipe erosion or pit design fails to provide proper settling of fine cuttings, fewer feet of hole may be drilled per barrel of water added, which when considering the unit cost of the mud to be prepared, results in higher mud cost per foot drilled.

DF Property	26"	17 ½"	12 ¼"	8 ½"
	Hole	Hole	Hole	Hole
Mud Weight, ppg	8.6- 8.7	8.7 – 9.2	8.7 – 9.0	8.6 – 8.8
Funnel Visc, spq	60 – 80	60 – 80	45 – 55	30 – 45
Plastic Visc, cent.	4 – 6	3 – 10	9 – 14	9 – 12
Yield Point	40 – 50	18 – 36	14 – 18	13 - 15
Gel Strength	12 – 18	18 – 36	14 – 28	7 – 10
API Fluid loss, cc		14 –20	12 – 15	8 – 10
Wall Cake 2/32nd		2	2	2
pH@25 degC	10	10.5	11	11
% Sand		0.3	0.2	0.2
% Solids		2.6	2.6	2.6
M, Depth	60	347	809	1951
Hole Size, in	26"	17 ½"	12 ¼"	8 ½"
Casing/Liner OD, in	20"	13 3/8"	9 5/8"	7"
Casing ID, in	19	12	9	6.4
Casing /Liner Depth	57.1	343	807	1951
Drilling Fluid Type	BC	BPC	BPCL	BPCL

Tab 2.5 a. Geometric Data of LA-10D

Product Name	Unit	26"	17 ½"	12 ¼"	8 ½"	Total	Unit Cost	Total Cost
	Size	Hole	Hole	Hole	Hole	Qty	USD	USD
Telgel	55 lbs/bag	117	73	1474	2117	3781	16.18	61,176.58
Asapura	25 kl/sx	248	1542	110	406	2306	16.18	37,311.08
Telnite	44 lbs/bag		16	43	46	105	83.48	8,765.40
Idthin 500S	44 lbs/bag			10	23	33	333.00	10,989.00
Caustic Soda	55 lbs/bag	7	66	145	227	445	59.36	26,415.00
Soda Ash	55 lbs/bag	5	19	4	7	35	46.78	1.3637.30
Sodium Bicarbonate	55 lbs/bag	3	16	3	3	25	52.19	1,304.75
Polymer H	44 lbs/bag	9	91	271	361	732	237.41	173,784.12
Polymer L	44 lbs/bag			1	7	8	237.41	1,899.28
Speeder X	55 gal					0	783.00	0.00
Speeder P	55 gal					0	577.30	0.00
Total Cost								323,282.71

Tab. 2.5 b. Total Consumed Cost of LA-10D.

3. Main Ricks and Challenges of Geothermal Drilling in Ethiopia

On the 27th of April 2000, the Tendaho well TD-6. was left discharging through 4" lip pipe after recording discharge parameters at 17:49 hour. Hydrothermal eruption occurred at about 21:00Hrs. The well site was covered by hot mud of about 15cm thickness. The well was discharging through the collapsed production test line into the pond and through the ½ inch side valve. The heat from the hot mud and steam around the well, sticky mud at well site, terrible noise from bleeding through the ½ inch valve and the darkness were the main problems that made operation of immediate well control activities difficult. After successful well control operation one operator leg slipped in boiling water while trying to sit on flouting system.

Leak of mud at the cellar of LA-9D was encountered. And this was as the result of less quality of grouting conducted. As a result of great deal of loss circulation, the original drilling plan to kick off @ 300m of LA-9D was cancelled and changed to 700 m KOP. Also cause to a serious of cement plug to 75times.

Due to bad Condition of rig engine during drilling LA 10D @ interval of 12 ¼" hole section it was decided to run the 9 5/8" casing @ 809m instead of @ 1000m.During drilling well LA-9D and well LA 10D the Desilter and the cooling tower had the same centrifugal pump source which reduced the efficiency of the Desilter. Inadequate logistics and great deal of rig maintenance of well LA9D and LA-10D contributed high NPT%.

4. Future Plan of Geothermal Drilling in Ethiopia

The Ethiopia government has expectations for the use of wind and geothermal resources for power generation. In particular, the geothermal resource potential has been estimated to consist of more than 10,000 MW in the East Africa Rift Valley region and is prioritized next to hydropower.

Prospect	Activities	Implementers
Aluto	22 wells	WB, EEP, GSE
Tendaho (Allalo beda	4 wells	WB, EEP, GSE
Tendaho Doubti	3 wells	JICA, EEP, GSE

Tab. 4. Future Plane of Geothermal Drilling.

5.Conclusion

Many of the drilling fluid effects are quite difficult to establish and very few programs are available. Available data has to be integrated in spatial data infrastructure which will be as input for decision making process at different level of the organization either for the customer request or internal production, and to meet the target of a proposed solution for geothermal drilling related problems which will put the country in capable of sustainable national development by enhancing the contribution share of the mining sectors

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