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IN AN UNCERTAIN ENVIRONMENT**

Professionalization of manual borehole drilling in Ghana

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This paper provides an overview of the first steps in the professionalization of manual drilling in Ghana with the initial training of two manual drilling businesses. The training follows the approach outlined in the “Toolkit for the Professionalization of Manual Drilling in Africa” (UNICEF, 2010) and began with the selection of appropriate businesses followed by training in basic hydrogeology and rotary jetting. These businesses will be used by the USAID funded Ghana WASH Project to drill forty additional boreholes for the project under the supervision of trained well drillers. In addition to the well drilling businesses project staff and staff from a local NGO also received training so that they can act as supervisors and coaches to ensure that the quality of the drilled wells is maintained. Furthermore a local workshop has been trained to make the drilling tools to make sure that replacement tools will be available in Ghana.

Introduction

In the forested Central Region of Ghana access to numerous villages is hindered by the forest cover and the streams that crisscross the landscape. This makes it difficult for large drilling rigs to reach many of the smaller villages. Improved water supply has relied on placing hand pumps on covered hand dug wells that only penetrate a meter or two into the aquifer. These wells generally do not exceed 8 meters in depth and dry up in the dry season forcing people to return to polluted unimproved sources. In order to improve this situation, EnterpriseWorks, using the approach from the toolkit (UNICEF, 2010), has begun the professionalization of the manual drilling sector in Ghana.

The goal is to develop a professional manual drilling sector in Ghana that can drill high quality boreholes that equal or exceed the quality of machine drilled ones. These boreholes are drilled using locally made tools and equipment that can be transported, even by head-loads, to less accessible sites. Manual drilling can provide an excellent complement to machine drilling for drilling in sedimentary formations where the water table is less than 25 meters from the surface.

Building local capacity

Selection of businesses

The USAID funded Ghana WASH (GWASH) program decided in 2011 to begin a program to professionalize the manual drilling sector in Ghana. GWASH has been working with local well construction and pump installation businesses over the past several years. These businesses were asked if they would be interested in learning to drill boreholes by hand, using the rotary jetting technique that EnterpriseWorks has used successfully in Senegal, Niger and Nigeria. After evaluating expressions of interest, two of the more reliable companies were selected to participate in a three week training course that was held in January 2012 covering hydrogeology for manual drilling and the practical basics of the rotary jetting method.

Training cost

The training cost for 21 people for 17 days including 5 days of classroom training in hydrogeology and 12 days of practical rotary drilling training including transportation, food, lodging, two expatriate trainers and

materials was approximately \$25,000 or \$1,200 per trainee. During the training 5 boreholes were installed. Thus the installed wells cost less than a machine drilled well even when the initial training costs are included. There will be two follow-up training visits by an expatriate trainer to ensure that the trainees have mastered both the theory and the practical drilling technique. This will cost an additional \$9,000 including airfare. Both of the selected businesses have experience in business management and tendering but further training in both of these areas for manual drilling will improve their economic viability.

Drilling tools

Prior to the start of the training program a set of tools for rotary jetting was acquired from Niger and these tools were copied in a local workshop. Drawings for most of the tools can be found in the manual on jetting in the toolkit (UNICEF, 2010). It is important that tools are available locally in order to ensure that the drilling businesses will have access to replacement tools in the event of loss or breakage. The design of the tools is changing faster than the manuals in the toolkit can be updated, so it is important to get an initial set of tools from people who are actively drilling. While the basic set of tools is standard (see Table 1), the bits will need to be modified to reflect the local drilling conditions.

Table 1. Tools for rotary jetting and well development		
Tools	Quantity	Cost in Ghana (USD)
5 HP motorized pump with 2-inch outlet with 10 m of Spiral reinforced hose (50 mm) and brass foot valve with strainer	1	\$375
Drilling rods (3 meter lengths) with machined couplings	12	\$1250
Sand/Clay Bit, Rock Bit, Swivel, Handle, Casing Clamps (2), Fishing Tool	1-set	
Toolbox- 24-inch pipe wrenches (2), pipe lifters (2), 1.5 kg sledge hammer, pointed chisel pointed, flat chisel, Allen wrench set, screwdrivers (3), 10 mm socket wrench, 13 mm socket wrench, locking pliers, needle-nose pliers, utility knife	1-set	\$400
Shovel (2), Pick (1) Wood Planks 5 x 15 x 100 cm (4), 1000-liter plastic containers (2)	1-set	\$310
TOTAL ROTARY DRILLING TOOLS		\$2335
Equipment for well development		
Tools	Quantity	Cost in Ghana (USD)
1HP submersible pump with 40 meters of 1-inch PE discharge hose, 40 meters of power cord, and connectors.	1	\$450
2.5 KVA gasoline powered generator	1	\$450
TOTAL DEVELOPMENT EQUIPMENT		\$900

The tools have been designed to be made locally, however, there are two parts that require particular care to make correctly, the swivel and the couplings for the drilling rods. Couplings with standard pipe threads are not strong enough to withstand the rigors of manual drilling, so special couplings, Figure 1, are made that use a square thread. These need to be turned on a lathe by an experienced machinist to ensure that all of the couplings have the same thread. The swivel, Figure 2, allows the drill shaft to turn while the hose

remains in place. It uses a ball bearing welded to the supply pipe and sealed with a metal plate to prevent leakage. Welding on a ball bearing requires care to ensure that the bearing is not damaged.



Figure 1. Coupling for drilling rod (50 mm)



Figure 2. Swivel to allow rotation of the drilling rod without tangling the hose

Hydrogeology training

Using the reference “Understanding Groundwater for Manual Drilling” from the UNICEF Toolkit a course was given to 18 trainees from the two selected business and 3 trainees from a local NGO that will provide supervision during drilling. The training program allowed the drillers to gain an understanding of groundwater flow and how geological strata are deposited over time. They also had practical exercises giving them experience in determining the texture and assessing the permeability of different strata that they will encounter while drilling. The course covered the importance of sampling and keeping an accurate drilling log. It provided trainees with practice in designing wells including the placement of the screen and gravel pack and the location of the sanitary clay seal based on the drilling log. The key factors in selecting a well site including distance from sources of pollution and the importance of protecting both the well and the aquifer from pollution and how to do it were also covered. Practical topics covering the use of drilling mud, hygiene, and well development were also addressed. Upon successful completion of the course the trainees had a better understanding of what is happening down the hole both during and after drilling than many of their machine drilling colleagues. The course provided them with the information that they will need to drill high quality boreholes.



Figure 3. Trainees making a drilling log from samples

GWASH Drilling Log			
SAGOMENS		Village	Mantemankabi
		Date	23 to 25 January 2013
		Well GPS	
		Latitude	N 05° 47.785'
		Longitude	W 001° 33.965'
Supervisor		Nana	
Depth (m)	Texture	Hard/soft	Colours
0	Sand	Fine/coarse	White
1	Sand		White
2	Sand		White
3	Clay		Red & White
4	Clay		Red & White
5	Clay		Red & White
6	Silty-Clay		Red & White
7	Silty-Clay		Red & White
8	Silty-Clay		Red & White
9	Silty-Clay		Red & White
10	Silty-Clay		Red & White
11	Silty-Clay		Red & White
12	Silty-Clay		Red & White
13	Silty-Clay		Red & White
14	Sandy clay		Red & White
15	Sandy clay		Red & White
16	Sandy clay		Red & White
17	Sand	Soft	Grey
18	Sandy clay		Grey
19	Sand/gravel		Grey
20	Sandy clay		Grey
21	Sandy clay		Grey
22	Sandy clay		Grey
23	Sand	Coarse	White
24	Sand	Medium	Brown
25	Sand	Coarse	White & brown
25.5	Sand	Coarse	White & brown

Pumping continuously for 3 hours at 35 liters per minute

Key	Solid Casing	Impermeable Layer	Gravel Pack	Backfill
	Slotted Casing	Permeable Layer	Clay Seal	Cement Seal

Figure 4. Drilling log for a well drilled during the training

Rotary Jetting Training

Rotary jetting is similar to rotary mud drilling and relies on a rotary motion of a drill bit to cut the soil and removal of the soil (cuttings) from the borehole using circulating water that has been thickened with a drilling polymer. Of the variety of manual drilling techniques, rotary jetting, under appropriate conditions, is the easiest and fastest technique. Some of the tools can be purchased on the local market and the rest can be made in local metal working and machine shops. The rotary jetting technique is described in the Toolkit for Professionalizing Manual Drilling in Africa (UNICEF, 2010) and shown in the video (USAID, 2010).

Following the five day theoretical training, the trainees were taken to the field for twelve days of practical drilling training with two experienced manual well drillers using the rotary jetting method. Practical experience under the guidance of experienced drillers is the best way to learn how to manually drill boreholes because there is no substitute for hands-on experience. During the training five boreholes were completed and four others were started. The goal of the training was to provide trainees with the opportunity to drill under different conditions so that they could learn the best combination of tools and techniques to use for the different strata. The trainees experienced a wide range of drilling conditions from clay and sand to gravel, mica schist and quartz stones and they learned how to free stuck tools and recover broken drilling rods.

The field training began with a meeting with the villagers to select an appropriate site for the well based on: village preferences, topography, likely depth of the water table and distance from sources of pollution (latrines and garbage dumps). Once the site had been selected the layout, digging and plastering of the mud pit was begun. The mud pit provides a reservoir for the drilling fluid and a place for the cuttings to settle out of the drilling fluid, Figure 5. The mud pits should be dug and plastered with cement mortar the day before the drilling crew arrives. The villagers should be asked to bring water to fill the plastic reservoirs so that drilling can begin as soon as the crew arrives on site.



Figure 5. Mud pit and plastic water reservoirs

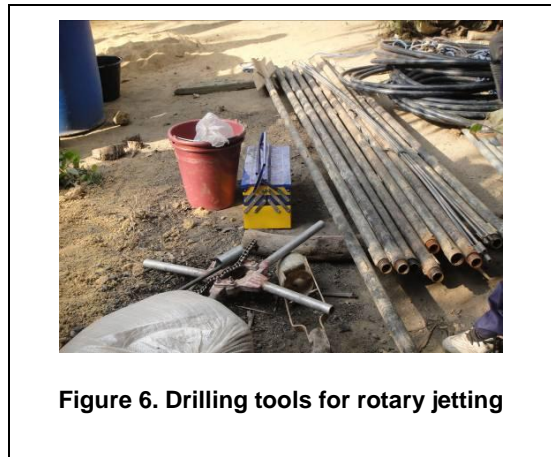


Figure 6. Drilling tools for rotary jetting

During the training well drilling continued until an impermeable layer below the water table was encountered. In most cases this was a rock layer consisting of quartz and mica schist that could not be penetrated with the tools that were designed for use in sand and clay. Additional more aggressive bits will be made to enable thin layers of rock and laterite to be drilled through more easily. After reaching the rock layer the borehole was reamed to 200mm diameter to provide a 30mm annular space for the gravel pack.

Once the drilling was completed the well was designed using the information from the well log to determine the location for the screen, gravel pack and clay sanitary seal as shown in Figure 4. A sump was attached to the 3m long factory cut screen (1 mm slots) and the solid pipe was prepared.

A rope is attached to the bottom of the 140mm diameter casing Figure 7 to allow it to be lowered slowly into the hole and to support it as additional sections are added. The rope remains in the hole along the outside of the casing after the well is completed. Once the casing and screen are placed in the correct location the polymer is removed from the well by pumping in a chlorine solution made up by mixing 5 chlorine tablets (NaDCC 1.67 g) in 220 litres of water and pumping it into the casing, Figure 8. The chlorine breaks down the polymer and forcing water down inside the casing cleans the screen and removes any polymer from the annular space around the casing. Once the polymer is removed from the well a gravel pack, consisting of purchased bags of graded gravel (the same material used by mechanized drillers), can be

installed by pouring it slowly into the annular space around the well screen. The depth of the gravel pack is measured using a simple tool consisting of a 30cm long 8mm diameter steel bar attached to a string with knots tied every meter.

After installing the gravel pack, Figure 9, a clay seal is placed above the gravel at the level of an impermeable or low permeability stratum. Often children in the village will be willing to prepare clay balls about 2 cm in diameter from the clay that is used locally as a building material, Figure 10. The balls are easy to drop into the annular space and they form a water tight seal to prevent pollution from travelling along the casing and into the aquifer. They are soft and compact as backfill is placed on top of them.

In order to keep the costs of manual drilling reasonable well development is achieved by pumping the borehole with a 1 HP electric submersible pump powered by a 2.5 KVA generator, Figure 11. The pumping rate exceeds the rate that will be required for a hand pump, generally in greater than 12 litres/minute. In addition to pumping at a higher than anticipated discharge, the well can be surged by using the submersible pump as a plunger. The 100 mm diameter pump is shut off and raised above the water level and then lowered rapidly a meter or two into the water creating a surge in the 125mm inside diameter casing. The surging helps to move fine particles from the aquifer through the gravel pack and redistributes the remaining material to increase the permeability close to the well screen. As can be seen in Table 1 the cost for the generator and submersible pump is much lower than the cost would be for a compressor to use the air lift method to develop the boreholes.



Figure 7. Preparation of the casing for installation



Figure 8. Flushing the drilling polymer out of the well



Figure 9. Installation of the gravel pack



Figure 10. Installation of the clay sanitary seal.

Drilling Feasibility and Costs

Manual rotary jetting is most feasible in sedimentary formations where layers of soft rock less than two meters thick are encountered. In areas with hard igneous stones or granite layers jetting becomes difficult or impossible and machine drilling is a better option.

Based upon the calculations for the forty boreholes that will be drilled by two newly trained businesses following the training, the cost of a 20-meter deep manually jetted well is \$3,100 which includes well construction, concrete pad, pump test and water quality testing.

During the contract period the well drilling businesses will purchase the drilling tools through a deduction of \$160 from the price of each borehole, enabling them to completely pay for the tools by the end of the 20-well drilling contract.



Figure 11. Developing well using a 1HP submersible pump and 2.5 KVA generator



Figure 12. Discharge during development 35 litres/minute

Conclusion

Two manual well drilling businesses in Ghana have begun the process of becoming professional drillers. They have drilled five wells and completed the hydrogeology course, but this is only the beginning. Following the training they will each be offered contracts to drill 20 boreholes for the project. This will give them the opportunity to continue to gain experience while being supervised closely. A return visit by one of the trainers will reinforce the training and help to resolve any issues that may arise during the contract drilling period.

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References

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