WASH

WATER AND SANITATION
FOR HEALTH PROJECT

Operated by
CDM and Associates

Sponsored by the U.S. Agency
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1611 N. Kent Street, Room 1001
Arlington, VA 22209-2111 USA

Telephone: (703) 243-8200
Fax (703) 525-9137
Telex WUI 64552
Cable Address WASHAID

AFRICARE NIGERIA: FIELD INVESTIGATION OF CAUSES OF FAILED WATER SUPPLY BOREHOLES AND PUMPING SYSTEMS IN IMO AND AKWA IBOM STATES, NIGERIA

WASH FIELD REPORT NO. 286

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Prepared for
USAID Nigeria and Africare
WASH Task No. 115

WASH Field Report No. 286

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Prepared for USAID Nigeria and Africare
under WASH Task No. 115

by

Mike Webster
and
B. Johnson

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ACRONYMS

CWADEP	Community Water and Agricultural Development Project
DFFRI	Department of Food, Roads, and Rural Infrastructure
gpm	Gallons per Minute
gpf	Gallons per Foot
ID	Interior Diameter
LDS	Church of Jesus Christ of Latter Day Saints
LGA	Local Governing Area
OD	Outside Diameter
UNICEF	United Nations Children's Fund
USAID	U.S. Agency for International Development
WASH	Water and Sanitation for Health Project

EXECUTIVE SUMMARY

Over the past three years, Africare's Community Water and Agricultural Development Project in Nigeria has drilled seven boreholes in Nigeria. For a variety of technical and logistical reasons, two of the water systems are incomplete and four of the five formerly operational boreholes were not working as of October 1989. At the request of Africare and the U.S. Agency for International Development (USAID) Nigeria, the Water and Sanitation for Health (WASH) Project sent a drilling consultant to Nigeria in November 1989 to help local staff and communities develop solutions to recurrent problems in these water systems. The consultant was also asked to recommend ways Africare might avoid similar problems in the future in order to make the best possible use of Africare's drilling equipment and staff.

Findings

1. The 6-inch boreholes drilled at Umuelum and Amapu villages are deemed operational provided they are equipped in compliance with the recommendations. The borehole yields in each village can provide an acceptable per capita consumption rate for drinking and cooking uses.

2. The 4-inch boreholes located at Isiala Ngwa and Ukat Aran are not deemed operational due to the boreholes being out of both plumb and straightness. Modifications to the pump systems such as adding lift rod stabilizers would not necessarily prolong the service life of the pump systems formerly used. The borehole at Ikot Eyo collapsed over a year ago and is neither operational nor reparable.

3. The 4-inch boreholes located at Ntit Oton and Edem Idim can possibly be equipped with modified pumping systems that should extend the failure period.

4. The boreholes listed in findings 2 and 3 are all equipped with below-grade 4-inch PVC well casings that are unacceptable for use in boreholes.

5. The borehole drilling diameters used for all 4- to 6-inch wells now completed were below acceptable diameters.

6. The India Mark II pump systems installed in the 4-inch boreholes at the sites identified in findings 2 and 3 are incompatible with the borehole maintenance requirements. No provisions are incorporated into the pump well head body for allowing chlorine to be introduced into the boreholes to control growth of iron bacteria.

7. Closed-type cylinder pumps were used in the sites listed in findings 2 and 3; however, open-type cylinders would have greatly reduced maintenance equipment required and would have eased work efforts.

8. The driller is insufficiently trained to drill and complete water boreholes.

9. The mud rotary drill rig is inadequately equipped and tooled to drill water boreholes.

10. The cable tool percussion drill is unacceptable for drilling water boreholes.

11. Africare's operational budget earmarked for the drilling project is insufficient to provide equipment and tools needed to properly complete water boreholes or to hire a drilling manager, train personnel, or recruit trained personnel.

Recommendations

1. Equip the boreholes located in Umuelum and Amapu villages with electric submersible pumps and connect them to water storage/distribution systems.

2. Abandon the boreholes in Isiala Ngwa and Ukat Aran, and cement them to the surface. New boreholes should be drilled at these sites provided recommendation 4 or recommendations 5,6,9,10(A,B,C) are met.

   An alternative to this recommendation is to hire a private contractor to complete the boreholes to specification when adequate funds become available.

3. Refit the boreholes at Ntit Oton and Edem Idim with open-cylinder pipe type pumps, as recommended, and trial them.

4. Pass the equipment, operation control, and logistic support of the drilling project to an organization that can fund and manage the program. A joint venture with an organization so equipped is also feasible. (This recommendation is made in view of Africare's budget constraints and lack of trained operational personnel.)

If Africare is determined to continue independent drilling activities in Nigeria, the organization should implement recommendations 5 through 11.

5. Acquire locally or import an adequate supply of PVC casings/screens with wide enough wall diameters to provide collapse strengths suitable for deep boreholes.

6. Use a standard borehole drilling diameter. For a 4-inch PVC casing, a diameter of at least 7-7/8 inches, preferably 8-1/2 inches, should be used.

7. Use the locally made NIGER Mark II (manufactured by Nigerian Foundries Ltd., Lagos). These pumps are very similar to the India Mark II but have

improved characteristics for local conditions (pump-head body openings for administering chlorine).

8. Use open-type pump cylinders with all future handpump-equipped boreholes if the boreholes' pumping levels are deemed to be 130 feet (40 meters) or less. If pumping levels are below this depth, closed-type cylinders are to be used. (Both types are available from Nigerian Foundries, Ltd.)

9. Give the driller further training in all aspects of water borehole drilling and completing, particularly in boreholes drilled/completed by direct mud rotary method. The driller should preferably spend six months to one year apprenticing with a professional drilling contractor in the United States (contractor to be recommended by the American National Water Well Association (NWWA) Ohio).

   An alternative is for the driller to attend a two-year drilling course offered by Sir Stanford Fleming College in Lindsay, Ontario, Canada (or other comparable formal training program).

   Another alternative is to recruit a trained driller.

10. A. Put levelling jacks on the Midway-type mud rotary drilling rig.

    B. Procure the following down hole tools/items: stabilizers, float valve substitutes, soft formation tricone rock roller bits, drag bits, drill collar.

    C. Get a water truck that has a 50-barrel capacity (U.S.) at least. The truck should be equipped with overhead pipe racks and a portable gas engine driven centrifugal loading pump complete with hoses.

11. Stop using the cable tool percussion drill for drilling water boreholes. The drill is improperly equipped for that use and unfeasible to modify. The machine would make an excellent pump setting/pulling unit for handpump-equipped boreholes.

Chapter 1

INTRODUCTION

1.1 Background

In 1987, Africare received a grant from the Church of Jesus Christ of Latter Day Saints (LDS) in the United States to implement a Community Water and Agricultural Development Project (CWADEP) in southeastern Nigeria. The funders donated a small cable tool percussion drill to use in the project and provided funding to hire a small local staff and procure borehole components and agricultural inputs. The project was designed to drill at least four boreholes and equip them with hand pumps, in addition to organizing and overseeing several community garden and agricultural training projects. The church also sponsored a U.S-based professional driller to visit Nigeria and train the local project driller.

The consultant driller found the casing and other borehole components available in the country to be inferior, and the rig proved difficult and tedious to operate. Nevertheless, four boreholes were eventually drilled and equipped in Cross River State (now Akwa Ibom State) using the small rig. Each well operated for several months to a year before failing. Two of the wells have been repaired several times, one collapsed after several months of use, and the fourth was reported to have failed during the consultant's visit.

Attempts were made to drill other wells in several communities in Imo state, but the water level was too deep to be reached with the small drilling rig. At the request of the Nigerian driller, the U.S. drilling consultant procured and refurbished a mud rotary drill rig capable of reaching greater depths. The rig was shipped to Nigeria and arrived at the project site headquarters in late 1988. A second, experienced Nigerian driller was hired on a temporary basis in early 1989, and the U.S. driller returned to Nigeria in March 1989 to train the Nigerian staff in use of the new rig. Three sites were selected and boreholes drilled in each site.

Because of the depths involved and the large number of people to be served by each borehole[1], Africare and the LDS church decided to install electric submersible pumps at each of the three sites. However, the pumps were not installed before the American driller departed, and subsequent attempts by the Africare staff to purchase and install pumps have failed because the staff lack experience and technical training in submersible pump selection and installation. Pumps purchased were too large for the boreholes, and the wrong sizes of cable and riser main were also purchased. Furthermore, a number of technical difficulties arose: as before, Africare was unable to obtain adequate-quality casings and other materials locally; getting water delivered to the sites was a recurring problem; bentonite and other supplies were in scarce

[1] Up to 15,000 by some reports, although no census data are available for these communities.

supply; and at one point even petrol and diesel were unavailable. Finally, the rig itself was inadequately equipped; (for example, it has no levelling jacks so could not be adequately stabilized to ensure that boreholes were drilled plumb). And, as mentioned above, the staff were inadequately trained for the job. The second driller left Africare's employ in July of 1989.

As of September 1989, none the three new boreholes had been equipped with operating submersible pumps. One of the boreholes (at Isiala Ngwa) had been temporarily equipped with a handpump, but it failed after approximately two months and was removed. After some consultation--with the United Nations Children's Fund (UNICEF) Nigeria, commercial drilling companies in Nigeria, the U.S. Agency for International Development (USAID), Nigeria, and Africare Washington--Africare Nigeria asked the Water and Sanitation for Health (WASH) Project to send a consultant to advise on how best to complete and equip the new boreholes and how to more permanently repair the handpump-equipped boreholes in Akwa Ibom state.

1.2 Scope of Work

The goal of the consultancy was to investigate the nature of the failed pumping systems and make recommendations that would enable Africare to provide potable water to the seven communities where boreholes have been drilled and, if feasible, to additional communities in the future. These were the specific objectives of the consultant's visit:

1. Review technical aspects of pumping systems incorporated (handpump and electric submersible), borehole construction techniques used in 4- and 6-inch boreholes, and equipment used.

2. Provide advice on obtaining components and pumps (hand and electric submersible) for existing boreholes and make recommendations for any similar future work.

3. Advise on the needs for operation and maintenance of boreholes.

4. Work with Nigerian drilling counterparts to develop a schedule of activities for completing the work.

5. Outline a follow-up visit to plan operations and maintenance efforts.

The consultant was to leave a technical report that would assess and make recommendations on shallow and deep water boreholes, and, if possible, on future use of the drill rig. In addition, the consultant worked with local staff to implement as many of the necessary repairs and corrections as possible during his four-week stay in Nigeria.

Chapter 2

PROJECT CONSTRAINTS

In Nigeria, drilling boreholes and equipping them with pumping equipment is a very difficult and time consuming undertaking. The typical method of equipping boreholes with casings and pumps is based on whatever happens to be available in the market place. Rarely do these items meet required specifications for borehole construction, and there is little or no technical data available on the purchased items to check for conformation to specification. Thus, boreholes are seldom properly constructed or adequately equipped, and subsequently fail. For example, the Department of Food, Roads, and Rural Infrastructure (DFFRI), the body responsible for providing water to rural Nigeria, reportedly has a borehole failure rate that exceeds 80 percent in some states.

Another constraint is the time required to procure even the simplest items. The Nigerian market place is very competitive, so much so that profit margins rarely permit businesses to have adequate stocks, premises, or telephones. The companies large enough to have telephones seldom have on-shelf stock; moreover, reaching these companies by telephone is a trying and time-consuming task. So people generally shop in the shanty town business districts, although even there a full day of stall-to-stall visits may be required to locate a single item.

When found, the item may be mislabeled or lacking a label altogether, and the source of the item is usually unknown. Sometimes used or refurbished items are sold as new, and customers may be shorted.[2] Even new items are rarely in their original packaging, and accompanying literature such as pump curves, warranties, and other information is generally not provided. When the needed item is purchased, the supplier usually insists on cash payment even for major purchases because checks take 30 days to clear in Nigerian banks, and credit cards are not accepted in Nigeria.

Transporting purchased items from the shop or storage site to the field is also fraught with difficulty. Police roadblocks abound in southeastern Nigeria, and, to avoid being threatened with an unscheduled trip to court, transporters not only must carry the original sales receipts and waybills for items transported, but also must ensure that their vehicles are in good repair and equipped with road emergency equipment. Sometimes ordinary civilians will play the role of traffic policemen and set up random roadblocks, where they harass drivers and passengers in an effort to obtain pocket money.

Specialized or specific required items may be impossible to buy in Nigeria, and repair or service of these items may be just as difficult. For example, the supplier of the project's 3 hp pump had his pump electrician try out the pump in his shop. The electrician had no electrical instruments and wired the pump

[2] On one occasion, project staff purchased what was purportedly 100 meters of new cable, only to discover on site that they had two unconnected pieces of cable totaling only 80 meters. This depleted their splicing materials and necessitated another trip to town for more cable.

by trial and error until the unit ran. And the two recommended local electricians who came to connect the pumps and starter boxes to the power supplies seemed uncertain about the correct procedure.

The most important project consideration is that all equipment procured and installed be simple in nature and purely mechanical, if possible. Only commonly available brands should be selected for which parts and repair can be readily obtained locally. All items with rigid specifications (casings/drill bits/drill tools) that are normally unavailable in Nigeria should be imported in enough quantity to last for a given period. Such a supply would ensure conformity to specification and greatly increase project productivity.

Although electric submersible pumps are recommended for installation at two sites, such a recommendation would not normally be made because of these pumps' complex electrical systems, which are difficult or impossible to trouble shoot and repair in country. Such pumps are recommended here because they are the only systems that could be used in these specific boreholes, given the inadequacy of the construction methods used. No future consideration should be given to these types of systems; instead, wholly mechanical pump systems should be used.

Chapter 3

COMMUNITY PARTICIPATION

3.1 Church Role

With the exception of Nkwo Udara, where Africare and the Imo State Ministry of Health operate a clinic and food processing plant, all borehole sites are located in communities where the LDS, or Mormon, church has a strong presence. In some of these communities, many local leaders are church members. The interest of the U.S. church in providing water to these communities led the church to request Africare's help in implementing the project.

Thus, local LDS churches were the first and major point of contact in these villages, and community input and decisions regarding the boreholes generally centered around the churches. This is especially true in Akwa Ibom State where the first four wells were drilled. In two of these sites the boreholes were actually drilled on church property, contrary to the specifications of the agreement between the donor (the LDS church) and Africare. This proximity, combined with the fact that (at the donor's recommendation) Africare hired a local church member to be trained as their driller, has created community confusion about the relationship of Africare and the Mormon church. Although water is reportedly available to everyone in the community when the boreholes are functioning, the extent to which nonmembers participated in decisions about construction, use, and maintenance of the four boreholes in Akwa Ibom State is unclear.

3.2 Community Contributions

The level of overall community participation in borehole construction and maintenance varies significantly from community to community. All communities were asked to contribute to the borehole construction effort. In sites equipped with handpumps, this contribution generally took the form of donating the land for the boreholes and providing labor and low-cost items (such as sand) for construction. In the sites to be equipped with submersible pump systems, considerably more was requested of the communities, including cash contributions.

Umuelum/Ibeku, the largest and most prosperous of the communities and the site where the project has experienced the most serious setbacks, has made the most generous contribution. Umuelum and Ibeku have no nearby river or other source of water to draw upon during the dry season, and past attempts by local government officials and community members to install a functioning community water system have failed within a few months. Thus, the community leaders are desperate to get a water system functioning and have become well-organized in their attempts to support Africare's efforts. Community contributions include N 14,000 (about US $2000) for the purchase of steel casing for the well; purchase and installation of approximately 500 feet of electrical wiring to connect the pump to a generator (also at a cost of about U.S. $2000); labor to assist with drilling and to guard the rig and equipment for over a month when the rig was on site; and installation of all pipes needed to connect the borehole to the previously laid underground pipe system and overhead tank (installed by the local government some years ago for a municipal water project that failed to materialize). In addition, the local "Prince," a traditional leader, agreed to contribute the use of his 50 KVA generator as an electrical source, since there is no public electricity as yet in the community.

Although this is a generous gesture, it is disturbing to have the water supply depend on electricity provided by someone's private generator. Obviously, the water will flow only when the owner decides to run the generator (currently he claims to operate it about eight hours per day; thus, only one-third of the potentially available water will be forthcoming for the foreseeable future). Additionally, the entire community will be beholden to this already-powerful figure, particularly those poorer community members who find it difficult to obtain funds to purchase water from private tankers (the only source of water currently available in the communities during the dry season). And the community will have little recourse in the case of a generator breakdown. Nevertheless, the existence of at least a temporary electrical source makes it feasible for Africare to provide a submersible pump to these communities. Town leaders report that the national electricity grid is being extended along the main road through Umuelum and Ibeku, so within the next year a public electricity supply may be available to operate the system.

Amapu, the other community where a large submersible pump and overhead tank system was envisioned, has fewer resources than Umuelum and is less well-organized. Nevertheless, there is a water committee that has met with Africare repeatedly to plan the project, and the community did raise N 12,000 (about U.S. $1,800) as a contribution toward an overhead tank. These funds were raised by selling community fruit trees. The community also provided some in-kind donations such as community land, unskilled labor, and security for the rig during overnight stays in the community. Africare's original intention was to provide the borehole with submersible pump, generator, and overhead tank. However, the original cost estimates for this system were too low, and Africare's depleted resources combined with the country's rampant inflation leaves the organization with insufficient funds to provide all these components. See section 4.1.2 for recommendations regarding this problem.

In Nkwo Udara (Isiala Ngwa), the site of the Africare Child Survival Project, most contributions have been made by the project itself, which is a combined activity of Africare and the local government. Although the community provided unskilled labor during the drilling process, the project contributed the land for the borehole and repaired the project generator so it would be powerful enough to power a small submersible pump. As an interim measure, the project provided the handpump from its rain tank, which was installed in the borehole; however, the handpump system failed within a few months of installation and was returned to the rain tank. As it turns out, the borehole is poorly constructed and will unlikely accommodate either a handpump or submersible pump (see section 4.1.3).

3.3 Community Role in Maintenance and Repair

Several communities have a designated water committee to oversee borehole construction and use; however, the committees have not taken on the role of conducting routine borehole maintenance. Instead, the committees usually ask Africare for assistance when breakdowns or delays occur. At present, most of the communities have no one trained to perform routine maintenance independently. Another shortcoming is the lack of women's participation in planning and organizing borehole construction and maintenance. Although women are the primary bearers and users of household water, they are unrepresented on the decision-making bodies of the various communities.

The communities of Umuelum and Amapu, where submersible pumps are to be installed, have been requested to designate one person to oversee the functioning and maintenance of the borehole and generator. They have agreed to do so. In Umuelum, a local electrician has been given the responsibility to install the switch box, connect it to the generator, and oversee pump performance. Other committee members are to oversee completion of the pipe system, monitor water use, arrange necessary repairs, et cetera. In Amapu, the community is to designate one person, under the direction of the local chief, to monitor the collection of a monthly contribution from each household for fueling and maintaining the generator and pump. It remains to be seen how effectively this system will work.

Chapter 4

TECHNICAL FINDINGS AND RECOMMENDATIONS

4.1 Well Sites

4.1.1 Umuelum/Ibeku

The adjacent villages of Umuelum and Ibeku fall within the Aboh Mbaise Local Government Area (LGA) of Imo State. About three thousand people live in Umuelum, about twelve thousand in Ibeku.

Table 1

Umuelum/Ibeku Borehole
Completed June 1989

Depth	360′	Drilled Diameter	8"
Cased Depth	322′	Casing Diameter	6"
Casing Type	Steel	Screen Diameter	6"
Screen Set	278-317′	Type	V-notch, stainless steel
Slot Size	Unknown	Gravel Packed	Yes
Gravel Size	1/8"	Gravel Set	15-366′
Cement Grout	Yes	Cement Set	0-15′
Pump Test	No	Well Yield	Unknown
Aquifer Depth	80-n/a	Static Water Level	130′
Developed	Yes	Develop Method	Air
Develop Time	Unknown	Drilled By	Mud rotary

Note: the well completion report (Appendix A) mentioned that a smaller-diameter casing was mistakenly installed in line at a unlisted depth. The actual length and diameter are not known but are estimated to be a 5 1/2-inch diameter X 20 feet. The depth at which this is inserted is estimated to be around 200 feet.

Table 2

Original Pump At Umuelem/Ibeku

Pump Type	Electric submersible; manufacturer unknown (reportedly Sumo)
Pump Horsepower	7.5
Pump Stages	3
Pump Power Requirements	380 volt, 3 phase, 50 cycle
Pump Electrical Cable	3 wire individual insulated, 14 gauge
Pump Cable Diameter	3/8"
Pump Length	5'
Pump Diameter	5 3/8"
Pump Set	260'
Riser Main Type	Steel, threaded and coupled
Riser Main Size	4"
Pump Rated Discharge at Set Depth	Unknown

Africare was worried about connecting the pump to a power source and trying out the well. At installation, the pump was very tight going in, and with good reason: the borehole had a known restriction of perhaps 5-1/2 inches, the pump had an outside diameter of 5-3/8 inches, and the electrical cable running along the pump had a diameter of 3/8 inch. Combined, the total pump diameter was 5-3/4 inches, 1/4 inch larger than the borehole restriction A 6-inch cased borehole should have a pump no larger than 4 inches outside diameter (OD). Other problems arose: nobody knew what the borehole could yield, what the pump when installed could produce, or how much water the community actually needed.

Initial Recommendation

- Calculate Community Water Requirements.

  Africare has published an acceptable rural Africa water requirement of 4 to 9 US gallons per day (per capita) for domestic use (drinking/cooking). A UNICEF Nigeria report by L. Donaldson/M. Karim (December 1988) lists the minimum requirement as 15 liters per day or 3.9 U.S. gallons (per capita).

The estimated population in the two communities is approximately 15,000 people (Africare well completion report). If we use the minimum figure of 4 U.S. gallons per day, the borehole would have to able to produce 60,000 gallons of water daily or 41.6 gallons per minute (gpm) (60,000 divided by 24 divided by 60). The minimum well yield requirement would therefore be 41.7 gpm.

- Remove Pump.

  The 7.5 hp pump was withdrawn (with luck and effort).

- Determine Yield.

  A specific-capacity yield test was deemed appropriate, in which an estimation of the well yield could be obtained by calculating the amount of water the well could produce compared with the amount of drawdown at a given pumping rate. This would require a pump just large enough to initiate a drawdown. Africare had in their inventory a 1.5 hp electric submersible pump that was deemed acceptable for the test. However, an examination revealed that the pump (much to Africare's surprise), had only .75 hp. The unit was trialed on experiment and found unsuitable for the test. A 3 hp electric submersible pump was then acquired and installed in the borehole.

Test Results. Before the test, the static water level was 181 feet. The pump was started with an immediate drawdown of 26 feet 10 inches occurring within 40 seconds (readings at 5-second intervals were attempted but could not be obtained by the rapid drawdown occurring). The pump discharge was immediately measured at 27.27 gpm by placing a measured-volume 5-gallon (U.S.) bucket under the discharge pipe and timing the seconds that passed until the 5-gallon volume was achieved (the bucket filled in 11 seconds). The calculation is 60 seconds divided by 11 seconds (5.45) multiplied by 5. The dynamic pumping level was recorded at progressively longer intervals (i.e, 10 seconds, 20 seconds, 30 seconds, 1 minute, 5 minutes, etc.) up to intervals of 30 minutes to 3 hours.[3] The dynamic level remained constant at a drawdown of 26-foot 10-inch and the discharge remained constant at 27.27 gpm.

Test Analysis. The borehole produced 1.06 gallons per foot (gpf) of drawdown (27.27 gallons divided by 26.83 feet equals 1.06). In theory, if a pump were set at a depth of 260 feet, the borehole could produce 83.74 gpm. (At 260 feet, subtracting static water level of 181 feet equals a drawdown of 79 feet, which, multiplied by 1.06 gpf, equals 83.74).

Note: The author is not qualified to analyze valid pump test data. These calculations are theory only and can be construed as rough estimations at best.

[3] An initial test time of 6 hours was planned; however, due to the excitement of the villagers taking advantage of the water, the test was closed at this time.

Many considerations of aquifer characteristics must be analyzed by a trained professional to determine true yields. However, this test was carried out to determine an estimate of yield so as to size a pump that would fall roughly within range of well capability.

Test Conclusion. The borehole should be able to sustain a community requirement of 41.6 gpm pump rate.

Initial Pump Recommendations

- Install a 4-inch diameter pump that can pump approximately 42 gpm while actually lifting the water an estimated 270 feet. At 42 gpm, the pumping level should be at approximately 220 feet (42 gallons divided by 1.06 gpf of drawdown equals a total estimated drawdown of 39.6 feet. Static level at 181 feet plus 39 feet equals 220 feet). However, since the pump must discharge into an overhead tank approximately 50 feet high, the pump must actually lift the water 270 feet (220 plus 50).

- Set the pump at an operating depth of 260 feet. The riser main should be threaded and coupled 2-inch galvanized steel, and have a wall no thinner than 1/8 inch. The electric cable from the pump should be secured to the riser main every 10 feet, and the cable splice to the pump motor leads in accordance with procedures demonstrated. (Africare will most likely procure a 5 hp model with at least 20 stages. The power requirement will most likely be 380 volt/3 phase/50 cycle. The total load amperage is estimated to be in the 12 amp range. This power requirement is compatible with the power available at the site.)

- Upon installing and connecting the pump, check the well yield at the surface discharge and also check the pumping level of the borehole. Under no circumstances should the pumping level fall below 250 feet. If the pumping level falls below this depth, the pump unit must be immediately stopped, and the well given time to recover. The 2-inch gate valve located on the well head pump discharge must then be progressively closed, with the pump running, until the borehole pumping water level stabilizes at 240 feet. (If a pump is procured with a performance curve very close to the requirements, the actual pump rate may be significantly over/under the stated curve. Thus, the pump may actually deliver considerable more volume and over-pump the borehole, which can result in a burnt out pump.) If by chance the pump produces considerably more than expected with a pumping level less than 240 feet, this will be acceptable.

- Procure surface-installed electrical pump protection devices that are available only in the U.S. These devices protect pumps from running dry, from current overload, and from power fluctuations. Although the units are very complicated, with little hope for service in Nigeria, it is better to have these units fail than the pump. Two U.S. suppliers who carry these *units are Coyote Manufacturing/1-800-468-1177*; and *SymCom Inc., Rapid City, S.D./1-800-843-8848.*

Pump Installed. Africare luckily found a pump with the required specifications and performance curve, and the pump was installed. On the initial installment, the pump operated approximately 5 minutes before the unit quit. When the pump was removed and examined, the impellers and diffusers were sand locked. This condition indicated improper well development. (A well is considered developed when it produces completely sand-free water.) When redeveloping the borehole, it was found to be filled with large gravel and sand from a depth of 270 to 320 feet. Using high-pressure air, the borehole was developed until the sand content of the water became minimal, and the pump was reinstalled and trialed. This test was very successful with the borehole producing 30 gpm of sand-free water. Due to cautions on initially over-pumping the well, the discharge rate is recommended to be increased slowly until a 45-50 gpm capacity is obtained. Interestingly, no drawdown occurred in the well after it was properly developed; therefore, the estimations on well capacity are voided. New calculations using the specific capacity method cannot be used with a no-drawdown condition.

4.1.2 Amapu

Amapu falls within the Isiala Ngwa LGA in Imo State. The village has about 8,000 inhabitants living on either side of the Aba Enugu highway.

Table 3

Amapu Borehole

Depth	320'	Drilled Diameter	8"
Cased Depth	300'	Casing Diameter	6"
Casing Type	PVC	Screen Diameter	6"
Screen Set	253-293'	Type	PVC Cut Slot
Slot Size	Unknown	Gravel Packed	Yes
Gravel Size	1/8"	Gravel Set	10-320'
Cement Grout	Yes	Cement Set	0-10'
Pump Test	No	Well Yield	Unknown
Aquifer Depth	Not Clear	Static Water Level	115'
Developed	Yes	Develop Method	Air
Develop Time	Unknown	Drilled By	Mud Rotary

Note: The well completion report (Appendix B) is very ambiguous. Several stated casing set depths are contradictory, with no information regarding the aquifer boundaries.

Africare had a borehole ready to service the community and a 7.5 horsepower pump was purchased for this well. However, based on the complications that arose from installing a similar pump at Umuelum/Ibeku, this pump was never installed at Amapu. Africare did not know how to equip the borehole with an electric submersible pump, nor did staff know the type or size of pump to install. Also, the community's water requirements were unknown.

Initial Recommendations

- Calculate the community water requirements.

  According to the well completion report, approximately 8,000 people would use the borehole. (Africare does not know the accuracy of the report made to them.) At 4 U.S. gallons per day, per capita, the requirement would be 32,000 gallons daily or 22.2 gpm.

- Determine Yield.

  As in Umuelum, the specific-capacity method was recommended. A 3 hp pump (also used at Umuelum) was set at 180 feet and three-hour test conducted, with the well stabilizing almost immediately at a high discharge rate.

Test Results. The static water level taken before the test (before pump installation) was 152 feet. A recording chart with progressive longer reading intervals was previously drafted and the test started. A drawdown of 11 inches immediately occurred and stabilized. The pumping rate was determined at 42.8 gpm (the five-gallon bucket filled in 7 seconds). Both pumping level and discharge remained constant for 3 hours. Again, a longer test was planned, but the villagers taking the discharged water became too unruly for the test to continue.

Test Analysis. The borehole produced an estimated 46.6 gpf of drawdown (42.8 gallons/11 inches=3.8 gallons per inch x 12 inches a foot = 46.6 gpf).

Test Conclusion. The borehole yield was substantially more than the community required.

Pump Recommendation

Install an electric submersible pump no larger than 4 inches in diameter that can pump a minimum of 22 gpm at a total head of 200 feet.[4] (No overhead storage tank is on site at present.) There is no apparent reason why the 3 hp pump used in the test cannot be used. This pump is probably the best choice since a moderately small generator can power it. The power requirements of the generator should be 220 volts/3 phase/50 cycle. A generator with at least an 8 KVA rating should be used. The pump should be set at 180 feet on 2-inch galvanized steel threaded and coupled riser main. (See Section 4.1.1. for correct procedures to check the pumping level and for normal installation procedures. The recommendation for the pump protector device found in that section also applies to this pump system).

Africare had intended to install a complete water system in Amapu. Quotations were received from various suppliers and a budget was then drawn up to meet the cost of the quotations received. However, because of inflation and unrepresented quotations, Africare now finds the funds allotted for this activity insufficient. Since Africare can complete only a part of this system now, they should procure the generator needed instead of the water tank. Africare will then have control on procuring a properly sized power plant, which is much more important than the water tank to the success of the operation.

Until the community can raise the funds to construct its own tank, a surface-level tap could provide water at certain times of the day when the generator is turned on.

[4] For future considerations, the total operating head when the water is raised to the tank will be approximately 203 feet, allowing a tank height of 50 feet.

4.1.3 Nkwo Udara

Nkwo Udara, a village of eight thousand, lies within the Isiala Ngwa LGA in Imo State. The village is located along a railroad line.

Table 4

Nkwo Udara Borehole

Depth	240'	Drilled Diameter	6"
Cased Depth	205'	Casing Diameter	4"
Casing Type	PVC	Casing Wall Thickness	1/8"
Screen Set	170-200'	Type	Cut Slot PVC
Slot Size	Unknown	Gravel Packed	Yes
Gravel Size	1/8"	Gravel Set	Unknown
Cement Grout	Yes	Cement Set	0-12'
Pump Test	No	Well Yield	Unknown
Aquifer Depth	240'	Static Water Level	120'
Developed	Yes	Developing Method	Air
Develop Time	Unknown	Drilled By	Mud Rotary
Completion Date	Unknown		

A 4-inch, purportedly 1.5 hp pump (actual size .75 hp) was bought to install in this borehole. Because of concerns about problems encountered at the other proposed submersible sites, and because the generator at the site was reportedly in poor working order, Africare decided not to install the unit until they got technical assistance. As a temporary measure, an India Mark II handpump was installed, which failed shortly after insertion. Africare wished to discover why the handpump system failed and to have technical expertise present before installing the electric submersible. Another worry was installing the 3-7/8 inch OD pump in a 4-1/4 inch ID casing; Africare suspected that the pump was too large for the casing. The pump was to supply a small overhead tank that would provide water mainly to the on-site Child Survival Clinic, where a small quantity of water would service the clinic and production unit (food processing) and any additional water could go to the surrounding local community.

Initial Recommendations

- Make a yield determination using the .75 hp pump to obtain the data required for properly sizing and depth setting the pump. (These pumps are quite often successfully installed in 4-inch boreholes as per the listed dimensions with low to moderate pumping capabilities.) The recommendation was approved by Africare Nigeria.

- Inspect Borehole.

  The drill rig was moved over the borehole and the pump lowered to approximately 12 feet, where it completely hung up and could be lowered no further, despite considerable efforts to do so. The pump was withdrawn and a visual inspection of the borehole was carried out using reflected sunlight from a mirror.

Casing Misalignment. The obstruction was a protruding ledge of a casing connection-joint. The borehole was severely out of plumb and crooked. (The drawdown gauge wire was lowered into the borehole and aligned in the center. The deviation could be visually checked by noting the plumb hanging position of the weighted cable in relation to the alignment of the surrounding well casing.) The casing was severely doglegged at an estimated depth of 30 feet, where the visual inspection subsequently ceased.

Borehole Unfit For Pump Installation. Being out of plumb and crooked, the borehole cannot accommodate the submersible pump. The cause of the handpump failure was relevant to these same conditions. Although the handpump was actually installed, the entire riser main was out of vertical position, causing it to be in a leaning position, which causes the inner lift rod to lean against the inside of the riser main. This creates wear by friction, and since the pump cylinder piston is side-loaded, seal/piston wear occurs on the loaded side of the piston. In summary, the submersible pump cannot be used at this site because it cannot be installed. A handpump, if reinstalled, will experience the same short life as the unit before.

Considerations For Stabilizer Use. One available handpump modification--the use of stabilizers on the lift rods--will likely accelerate the wear process. If stabilizers are used, the lift rod will be mechanically pushed from the side of the riser main, increasing the side-loading pressure by the natural tendency of the rods to be in as straight a position as possible (not bent). This increased pressure will therefore be transmitted through two contact points of the stabilizers, concentrating considerably more force on the riser main in a very small bearing area. The rapid wear that occurs at the contact points of the stabilizers will cause either the stabilizers to wear down quickly or the riser main to perforate. Another likely problem is difficulty in operating the pump. The stabilizers, with high-pressure contact to small bearing area, will tend to bind the reciprocating motion of the lift rod and thereby make actuation very difficult or impossible.

Recommendation

Abandon the borehole and cement it to the surface. Drill a new borehole that conforms to all recommendations (see Recommendations in Executive Summary)

Alternative Recommendation

The following may be worth trying; however, success is far from certain. If an open-type cylinder can be installed in the borehole, it would open up the confining area between the lift rod and riser main, therefore lessening the force of their contact. With lesser side forces applied, the wear period should be longer before the pump fails (ultimately it will fail). Stabilizers should be used at only two points on the lift rod: immediately above the piston cylinder (2-3 feet) and 10 feet above the cylinder. This positioning would tend to align the lift rod to the pump cylinder, thereby centering the forces to aid in even piston-seal wear. The additional time before the pump would fail cannot be estimated; however, water would at least be available until other measures were initiated (if any).

The greatest constraint to this alternative is the low chance of actually installing the open cylinder pump, with its larger 2-1/2 inch riser main that is considerably more rigid than the 1-1/4 inch riser main used on the closed type unit. The borehole is so deviated that the rigidity of the 2-1/2 inch main will likely prevent the system from being inserted.

4.1.4 Ntit Oton

The Borehole. The well was drilled in February 1988, with the cable tool drill. The total depth is listed at 120 feet, the water table at 70 feet. A 20-foot screen was installed inline on the 4-inch PVC casing. The depth of the screen placement is from 100 to 120 feet. The well log mentioned that the well was gravel packed. The drilling diameter is unknown and no well yield is given.

Note: The PVC casing used was approximately 1/16 inch in wall thickness, which is totally unacceptable.

The Pump. The pump was an India Mark II set at 70 feet. The pump barrel was a closed-type unit. Although this was the longest serving handpump-equipped well, it failed during the consultant's visit. The pump and borehole needed to be inspected to discover the nature of their faults.

Initial Recommendation

- Remove and Inspect Pump. Upon removal (from 70 feet) it was discovered that threads connecting the galvanized riser main to a coupler (at the second union, down 20 feet) were severely rusted through, causing water to leak from the riser main back into the borehole. The threads were stretched on one side, indicating that the riser main was pulled off center. When the pump cylinder was disassembled, the seals were completely worn--mostly on one side. The piston was severely worn and gouged, suggesting that a foreign object had fallen down the riser main and bound the piston movement. The lift rods were examined and found to be wearing on one side of the couplers (on each and every coupler). A visual inspection of the borehole (using a mirror) showed it out of plumb and doglegged. The static water level was taken at 43 feet. Only half of the water could be seen from the surface, indicating degree of the dogleg. The entire pump and riser main were very discolored and thickly coated with rust. The villagers watching the inspection complained that the water was no good because of its color and taste; they also complained that the water would stain their clothes.

The pump was obviously failing because of its out-of-plumb position and doglegged condition. The riser main was becoming bent because of the deviation causing an interface of riser main and lift rod. This contact was causing wear between the riser main and lift rod, pump piston and seals, as well as exerting stress on the riser main unions and causing them to fail. The borehole has an iron bacteria problem, but there is no way to add chlorine on a monthly basis to control the growth. (India Mark II on site is not equipped with a body port to introduce of chemicals into the borehole).

Recommendation

Fit the borehole according to the recommendations in the Executive Summary.per Alternative Recommendation C-9. The pump should be a model NIGER Mark II equipped with open cylinder (also equipped with a body port for adding chemicals). One stabilizers is to be installed immediately above the pump barrel (just over the first lift rod connector), another immediately above the third lift rod connector above the pump (approximately 23 feet from pump barrel). The pump should be set at 50 feet and checked for suitable water yield. (If unsatisfactory, lower pump another 10 feet and recheck.) Chlorine should be added monthly into the borehole (standard-sized bottle of liquid washing bleach acceptable), and the pump then operated until the discharged water smells and tastes of bleach. The well then should be left idle overnight. The following morning, pump the well until the bleach is not noticeable and reopen the well for public use.

Note: This recommendation is based on the assumption that it is feasible for this pump to be installed.

4.1.5 Ukat Aran

Borehole. The borehole is identical in construction with Ntit Oton, although 5 feet deeper (total depth 125 feet.) The pump was not operational on trial.

Pump. An India Mark II was installed with 1-1/4-inch stainless steel riser main and a closed-type pump cylinder. The pump was continually failing; this was its third failure. The pump was thought to be misaligned due to borehole deviation.

Initial Recommendation

- Pull pump and inspect pump and borehole.

  When the pump was pulled from its depth of 70 feet, the riser main (stainless steel) showed no indication of leaking or lift rod wear. However, all the lift rod couplings were extremely worn on one side as were the pump piston seals. The static water level was taken at 43 feet. On a visual inspection, the borehole was so severely doglegged at 30 feet that sighting beyond that point was impossible. This borehole deviation is causing repeated pump failure. Also iron bacteria was noted on the riser main and pump barrel.

Recommendation

Cement this hole to the surface and abandon it. If funds permit, the well should be redrilled provided that key recommendations 3,4,7,8 (a,b,c,) are met. Although Africare may attempt to try the open-barrel pump, this unit probably will not pass through the dogleg. Ukat Aran's is the most deviated borehole. Cement this hole to the surface and abandon it.

4.1.6 Edem Idim

Borehole. The borehole was completed by the cable tool method. The borehole is similar in construction to the Ntit Oton and Ukat Aran boreholes. Total borehole depth is 110 feet with the static measured at 47 feet. The borehole was also equipped with very thin-walled PVC casing.

Pump. Edem Idim has an India Mark II handpump equipped with the closed-cylinder type barrel (at 80 feet). The pump has 1-1/4-inch stainless steel riser main. During the site visit, the pump was not operational.

Initial Recommendation

- Pull pump and carry out inspection.

  On its removal, the pump hung up very tightly at 15 feet from the surface, and extra force was necessary to pull through the restriction. Once the pump was disassembled, the piston seals were evenly worn. The lift rods showed wear on the couplers, indicating that the borehole was drilled in a plumb position. Inspection (using reflected sunlight), showed the borehole casing collapsed at approximately 15 feet. It appeared that only a small section was collapsed, approximately 3 to 4 feet; otherwise the borehole seemed straight and fairly plumb.

  The pump failed for no apparent reason other than probable insufficient maintenance. The cylinder seals were evenly worn, but the amount present indicated that the seals haven't been replaced. The borehole may collapse entirely at any time, due to its inadequate casing.

Recommendation

Normally one would recommend abandoning the borehole due to its improper construction. However, if Africare wishes to gamble on an open-cylinder type pump, this could probably be forced through the collapsed casing area. Since it would be an open-cylinder type pump, the riser main would stay within the borehole and piston seal replacement could be accomplished by lifting only the piston and lift rods. If the casing collapsed further, the riser main would be impossible to remove but the well would probably still be operational. It is recommended that Africare try it.

4.2 Support Equipment (Water Truck)

4.2.1 Water Needs

When drilling, the mud rotary drilling rig requires large volumes of water at the drill site. The water is mixed with various drilling chemicals but mostly with a bentonite powder (dry clay with special properties). A large pump then circulates the mud down through the drill string and up the drilled borehole, carrying the cuttings from the drilling to the surface. Once on the surface, the heavily laden mud is routed into large settling pits where the cuttings naturally settle to the bottom. The mud is then recirculated down the borehole. This process requires large volumes of water to fill the borehole and mud settling pits, and to provide for water to be absorbed into the borehole walls.

Africare now uses a 500-gallon tank loaded on a trailer that is pulled behind a small 4 x 4. The volume of water this tank carries is totally inadequate; furthermore, the little truck can haul the tank only at half capacity. Successful drilling operations require a ready supply of water when needed. If mud-rotary-drilled boreholes are stopped while awaiting water, the physical properties of the bentonite mud deteriorate, many times causing the filter cake to weaken and the borehole walls to collapse. Once this has happened, it is very difficult for even experienced drillers to recover the hole. The time lost hauling an inadequate supply of water is counter productive and can jeopardize the completion success of the borehole.

Recommendation

Procure a water truck with at least a 50-barrel (U.S.) capacity. The water truck should be equipped with appropriate hosing and a 3 to 4 hp gas-powered portable loading pump (to enable the crew to fill the tank from rivers, ponds, etc.). The truck carrier should be in line with parts and service available within the country.

4.3 Boreholes

4.3.1 Out-of-Plumb Boreholes

An out-of-plumb borehole has been drilled into the earth's crust at a nonvertical angle. It may be perfectly straight, but if pumping systems such as mechanical reciprocating pumps are used, the riser mains installed will also be tilting in the borehole. This condition, causing riser main-to-lift rod interference and uneven piston seal wear, is one of the most common causes of handpump operational failure. The drilling rig Africare now uses has no leveling jacks, which prevents properly plumb borehole construction. Another problem that occurs when operating without levelling jacks is extensive drill bit/string damage and severely deviated boreholes caused by drill bit "chattering." The drilling forces created in drilling hard, slanted hydrogeologic formations or through boulders in unconsolidated formations cause the bit and drill string to jump up and down. Their movement is further accelerated by the entire drill rig's bouncing on its undercarriage spring suspension, which breaks the teeth on the drill bits and causes entire cones to break off the bit. This bouncing often causes the borehole to "take off" in various directions, which in turn causing a deviated borehole.

If boreholes are to be constructed in a plumb fashion and drill bit/drill string damage minimized, the drilling rig must be perfectly stable and level on all axes before and during the drilling operation.

Recommendation

Equip the drill rig with at least three hydraulic levelling jacks, and preferably four. In light of Africare's budgetary restraints, simple hand-operated hydraulic jacks would be adequate. The jacks should have a rated hoisting capacity of 10 tons each. Adequate planking will also be required to support/raise the jacks.

4.3.2 Crooked Boreholes

Crooked or doglegged boreholes change direction one or more times within the depth of the well. Special downhole drilling tools are used to keep the boreholes as straight as possible during drilling operations.

If boreholes are not straight (i.e, doglegs, corkscrews), the casing placed within the boreholes will follow the path of the hole, causing difficulties in equipping the boreholes with dependable pumping systems. For example, the boreholes at Isiala Nwga and Ukat Aran cannot be equipped with handpumps because the holes are so crooked that the pump riser mains are operating in a bent condition, which causes rapid wear within the pump and then failure. Special downhole drilling tools must be used to ensure the construction of straight boreholes, especially boreholes with handpumps.

Recommendations

Equip the Midway rotary drill with an 8-inch OD spiral rib (welded blade) *stabilizer*. The stabilizer should have a rib length of at least 10 feet. The top thread connection is to be a 2-3/8-inch API Reg. Box connection housed within a 2-7/8-inch external upset tool joint with breakout lugs. The bottom connection is to be a 4-1/2-inch API Reg. Box connection. Also required will be a 4-inch OD x 15-foot *drill collar*. The drill collar should have a through hole of 1-1/2 inches and a top connection of 2-3/8-inch API Reg. Box housed within an 2-7/8-inch external upset tool joint equipped with breakout lugs. The bottom connection will be a 2-3/8-inch API Reg. Pin connection. A *float valve* will be required to prevent bit plugging. The float valve rotary substitute should be equipped with a 2-inch OD removable valve cartridge assembly. The top thread connection should be a 4-1/2-inch API Reg. Pin connection, the bottom a 4-1/2-inch API Reg. Box connection.

4.3.3 Borehole Diameters

The inline screen/gravel-packed construction method now exclusively used in the project creates borehole drilling diameters that are insufficient for proper gravel packing to occur; thus, no tolerances exist for possible borehole deviations. If boreholes are slightly doglegged, the larger-diameter drilled hole permits the casing to be inserted in a straight condition and allows proper annular area to place gravel.[5] (The generally accepted formula calls for a borehole to be at least 4 inches larger than the casing size to be installed, thereby giving a 2-inch annular area around all sides of the casing.)

Recommendation

Adopt a standard drill-bit diameter of 8-1/2 inches for 4-inch cased boreholes. This size will allow the casings to be set straight in minor-deviated boreholes and will allow proper annular area for gravel packing. The 8-1/2-inch drill bits to be supplied are the soft formation tri-cone rock roller bits equipped with 4-1/2-inch API Reg. Pin connections and 8-1/2 inch tungsten carbide insert drag bits (preferably "Blue Demon Stabilizer Equipped Type" from Sandvac Rock Bit Co. in Virginia). Drag bits are to be equipped with 4-1/2-inch API Reg. Pin connections.

Note: The Midway kelly bar rig now used has only a nonretractable rotary table capable of handling drilling tools and casings up to 9 inches in diameter. This opening prevents the proper size of stabilizers required for drilling holes to accept 6-inch casings. (A 6-inch cased well should be drilled with a 10-3/4-inch drill bit; therefore, a 10-inch stabilizer would be required.) This drill should not be generally used for 6-inch cased well boreholes.

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[5] The drill bits to be used in the envisioned Africare/UNICEF joint venture 4-inch PVC well program in Niger State are not currently up to acceptable diameters. The 4-inch PVC boreholes now completed have all been drilled by 6-inch diameter drill bits. If the 4-inch cased boreholes have casings that were installed in straightness, even with crooked boreholes, the high pump failure rate now experienced should be eliminated.

4.3.4 Borehole Casings

All but the borehole at Umuelum were completed with PVC casings (six boreholes). Two have already collapsed and three nearly completed boreholes (Umuelum) collapsed as soon as development procedures began.

The PVC casings, especially the 4-inch diameters, have walls approximately one sixth of proper PVC casing thickness. These thin walls cannot support hydrostatic pressures that occur within the borehole, and the casings collapse. Africare will continue to have borehole casing failure if proper PVC casing is not acquired.

Recommendation

Procure either local or important PVC casings with at least 40-schedule wall thickness or casing with specifications that meet deep-borehole requirements.

4.4 Recommended Order of Down Hole Tools

The drill-string makeup will comprise the following order of tools, beginning at the bottom.

- drill Bit—either tri-cone or drag bit as required
- float valve equipped rotary substitute
- 15-foot x 8-inch OD spiral ribbed stabilizer
- 15-foot x 4-inch OD drill collar
- normal drill pipe

4.5 Suitability of Cable Tool Drill

The cable tool drill donated to Africare is a very simple machine that is very labor intensive as well as unsuited for local drilling conditions. The unit is basically a convertible trailer to derrick equipped with an engine directly driving a mechanical winch.[6] The operator lifts and drops the drill tools manually with a lever. Because the unit is not equipped with a "sand line" winch, there are long delays in removing the one working line from the drill stem and connecting to a bailer, and vice versa when boiling is completed. The rope socket that connects the drill wire rope to the drill stem is a nonswivelling type. This prevents the drill stem from turning as the tools are raised and dropped, which causes severe borehole deviations to occur. The

[6] A conventional cable tool drill is actuated automatically by a mechanical device. The rate of lifting and dropping the drill tools is usually around 55 strokes per minute.

maximum depth capability is limited both to the amount of wire-rope cable spooled on the machine and to engine horsepower. This particular unit has enough cable for a 125-foot borehole.

Its labor intensiveness discourages the driller from using the drill. And such a slow and unproductive machine limits the unit's effectiveness on a production-oriented program. Also, the unit is not equipped to drill straight holes and it very shallow depth capability.

Recommendation

The unit should not be considered for borehole construction. It would, however, make an excellent workover rig for servicing handpump-equipped boreholes as well as servicing the boreholes themselves (cleaning out, etc.).

4.6 Driller Training

Africare's current driller is not yet capable of drilling and constructing boreholes. His experience is limited (four boreholes), and he does not understand many of the major techniques of drilling and completing: identifying aquifers when drilling with the mud rotary drill, selecting proper screen sizes, developing a well properly, determining well yield, writing proper well completion reports, and maintaining the drill rig. Nor does he understand the principals of well hydraulics and the importance of proper borehole construction. The driller is bound to make some very costly mistakes, which will greatly restrict productivity, consume time in fixing the errors, and waste funds.

Recommendations

Africare should take one of three actions:

- Provide the driller with additional practical training on a mud rotary type drill rig. He should apprentice for at least six months to one year under a recognized professional drilling contractor in the United States (contractor to be recommended by the National Water Well Association in Ohio). A training course outline should be drafted to address the training needs listed.

- Provide the driller with formal training. Sir Stanford Fleming College in Lindsey, Ontario, offers a two-year drilling course in water well drilling and completing; however, the author is not knowledgeable on the actual effectiveness of the course.

- Recruit a trained driller.

PHOTOGRAPHS

1. Umuelum villagers taking advantage of yield determination test

2. Removing the improperly sized 7.5 hp submersible pump at Umuelum

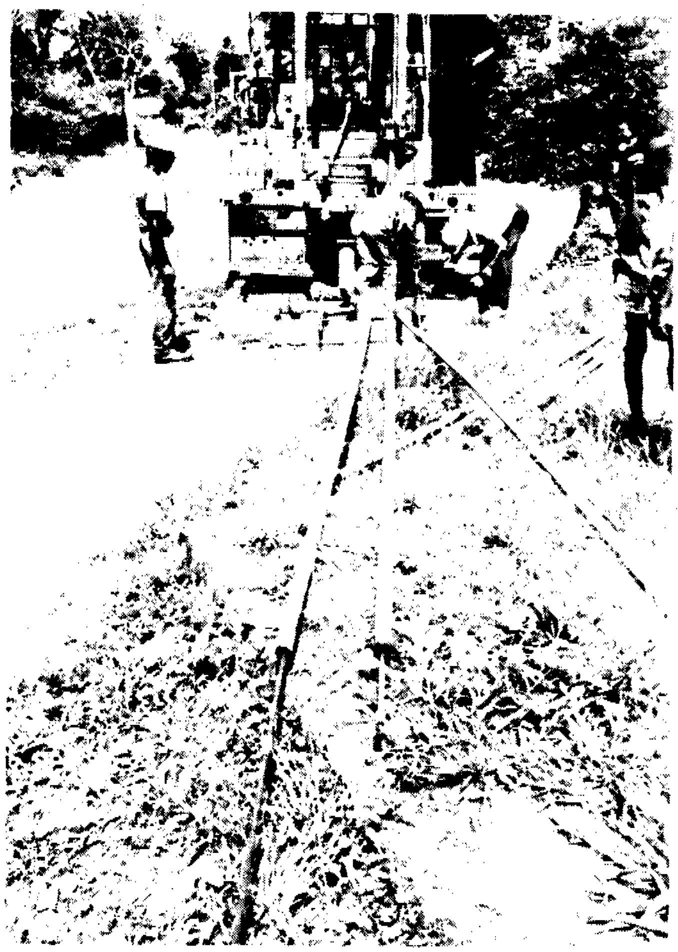
3. Electrical cable severely damaged, resulting from improper pump placement at Umuelum

4. The author with Umuelum Children

5. The woman in foreground is taking water from the road discharged by the yield determination test at Amapu. The commotion at the discharge pipe sometimes became violent, with the villagers attempting to fill their buckets with clean water.

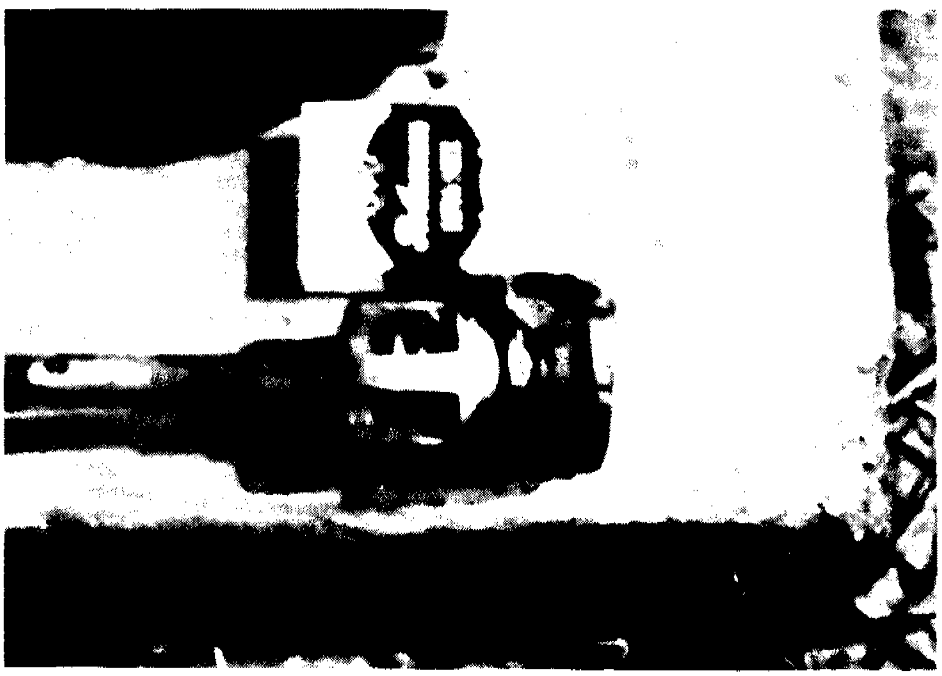
6. The rented power generator and pump electrical starter box during yield.

7. Taking borehole pumping level readings at Amapu



8. The removed India Mark II handpump at Ntit Oton. Note: Rusty-colored riser main, resulting from riser main failure at a connection, with water running down the outside of the main becoming rusty.

9. Riser main joint failure at Ntit Oton caused by severe iron bacteria and misalignment of the riser main due to borehole deviation

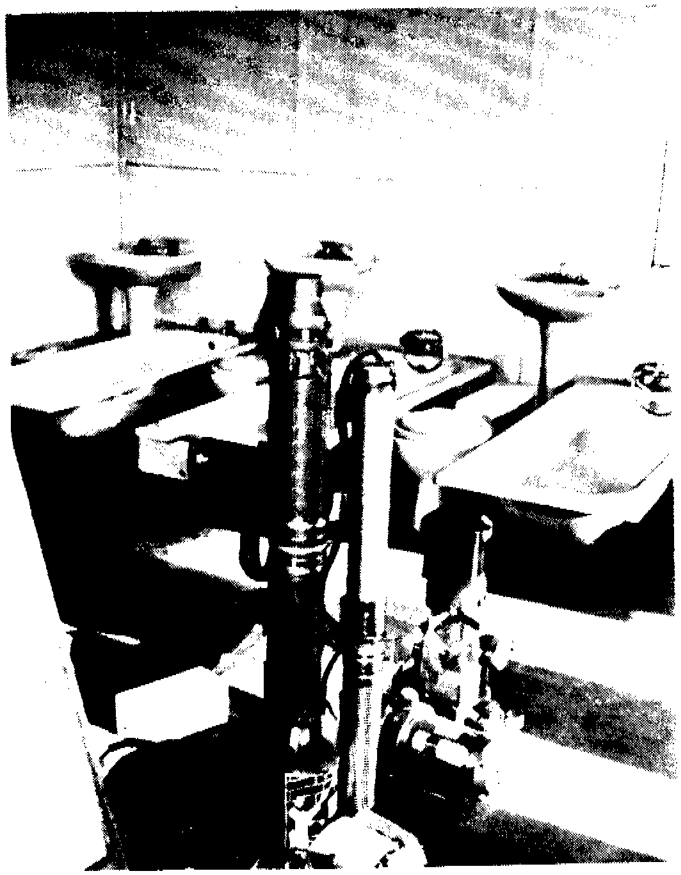


10. The severely damaged pump barrel piston from Ntit Odon. Note severe galling of the piston and seal failure on one side of the piston only.

11. Note the extremely small tolerance when fitting a 4" submersible pump in the 4" borehole at Isiala Ngwa

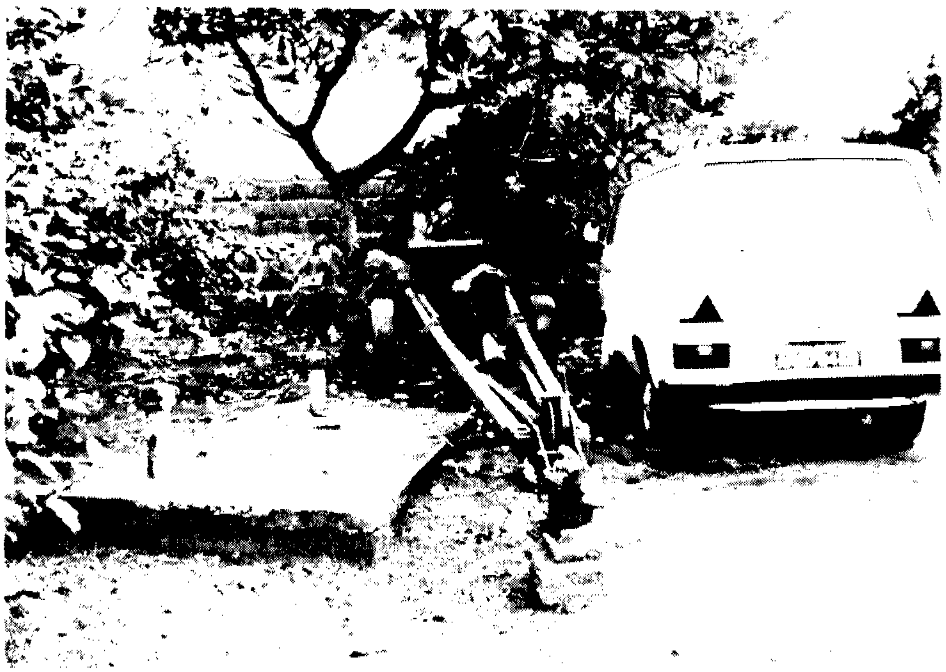
12. The rainwater catchment system at the Child Survival Clinic at Isiala Ngwa

13. A pump suppliers' electrician trying to understand a complicated submersible pump starter box. He eventually succeeded. Note the deteriorated condition of the instruction pamphlet.



14. The total pump stock of an Oweri pump supplier

15. A common steel pipe supply district. Each raised pipe rack represents a different supplier. Luckily, adequate riser main was found and bought here.



16. The very simple and inadequate cable tool percussion drill.

MAPS

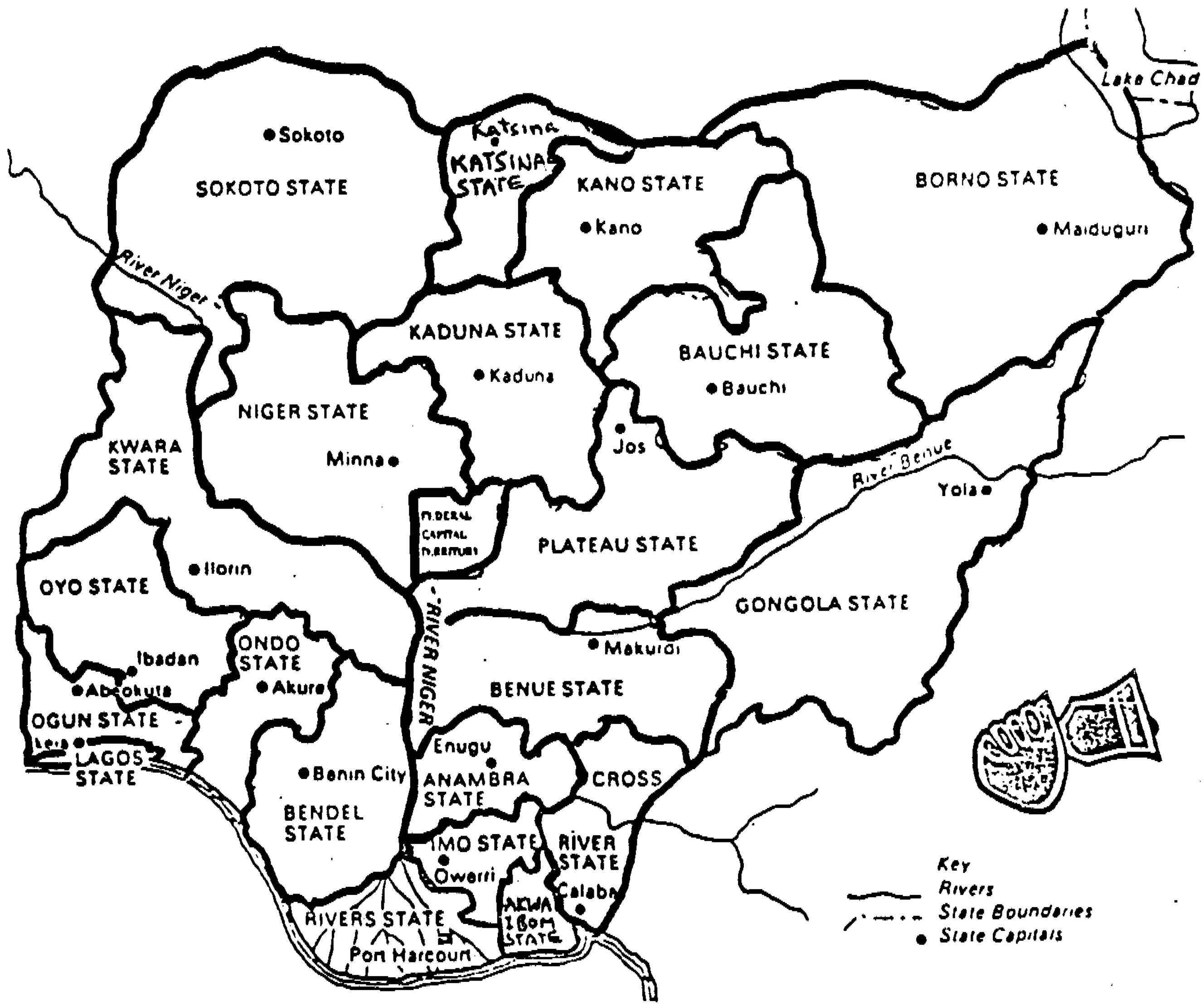
Map A

AFRICA


CEUTA
MELILLA
Tunis
Algiers
TUNISIA
Rabat
MOROCCO
Benghazi
Tripoli
Cairo
El-Ayoun
ALGERIA
LIBYA
EGYPT
WESTERN SAHARA
CAPE VERDE IS
Praia
MAURITANIA
Nouakchott
MALI
NIGER
CHAD
Khartoum
SENEGAL
Dakar
THE GAMBIA
Banjul
Bamako
BURKINA FASO
Niamey
Ndjamena
SUDAN
DJIBOUTI
GUINEA
Conakry
BENIN
Porto Novo
Bissau
Freetown
SIERRA LEONE
IVORY COAST
Abidjan
GHANA
Accra
NIGERIA
Lagos
ETHIOPIA
Addis Ababa
Monrovia
LIBERIA
TOGO
Lome
CAMEROON
Yaounde
CENTRAL AFRICAN REPUBLIC
SOMALIA
EQUATORIAL GUINEA
Malabo
SAO TOME E PRINCIPE
Libreville
GABON
UGANDA
KENYA
Nairobi
RWANDA
ZAIRE
CONGO
Brazzaville
Kinshasa
BURUNDI
Bujumbura
ZANZIBAR
TANZANIA
Luanda
SEYCHELLES IS.
ANGOLA
COMORO IS.
MALAWI
ZAMBIA
Lusaka
Harare
MOZAMBIQUE
ZIMBABWE
NAMIBIA
BOTSWANA
MADAGASCAR
SOUTH AFRICA
LESOTHO

Map B

NIGERIA



Map C

IMO STATE

APPENDIX A

Well Construction Report--Umuelem and Ibeku

Africare

Africare House • 440 R Street, N.W. • Washington, D.C. 20001
Telephone (202) 462-3614 • Telex 64239
Community Water/Agricultural Development Project
P.O. Box 3543,
Owerri.

WELL CONSTRUCTION REPORT

IMO STATE: ABOH MBAISE LOCAL GOVERNMENT AREA

VILLAGE: UMUELEM/IBEKU

LOCATION:

The villages of Umuelem and Ibeku are located in the Aboh Mbaise Local Government Area of Imo State. Umuelem is in Inyiogugu LAC while Ibeku is in Okwualo LAC. The two villages are seperated by a common boader. They have their community leaders as Nze Benard Onwudiwe for Umuelem and Princes Charles Ihoneto for Ibeku community. They have officers who help them with the everyday working of the communities. The population of Umuelem is approximately three thousand people, while Ibeku is about four times that number. They are mostly farmers who live and work arround the village farm lands.

DRILLING:

Work started in this well during the early months of June, 1989. The appropriate site was selected which happened to be the site of the overhead tank that had already been constructed by those communities. After making sure that all materials for the job were in site, the actual drilling started in earnest. The first day saw us drilling through the top layer which was hard to penetrate. The rate of penetration was so slow that we decide to lift up the drill-bit. This was done, and it was found to be the result of a worn-out bit.

../2

Subsequently the bit was replaced. By the end of the second day of drilling, we were penetrating into the top part of the water table which we identified at about 80ft. Here were found very hard formation and for hours, it became really hard and slow to make progress. When finally we went through this zone, the rest of the drilling went much more faster. By the end of the week, we were preparing our casings with a view to having them installed. The final depth which we found appropriate was 360ft. Before this final depth, we had gone through some of the best aquifers for good water production.

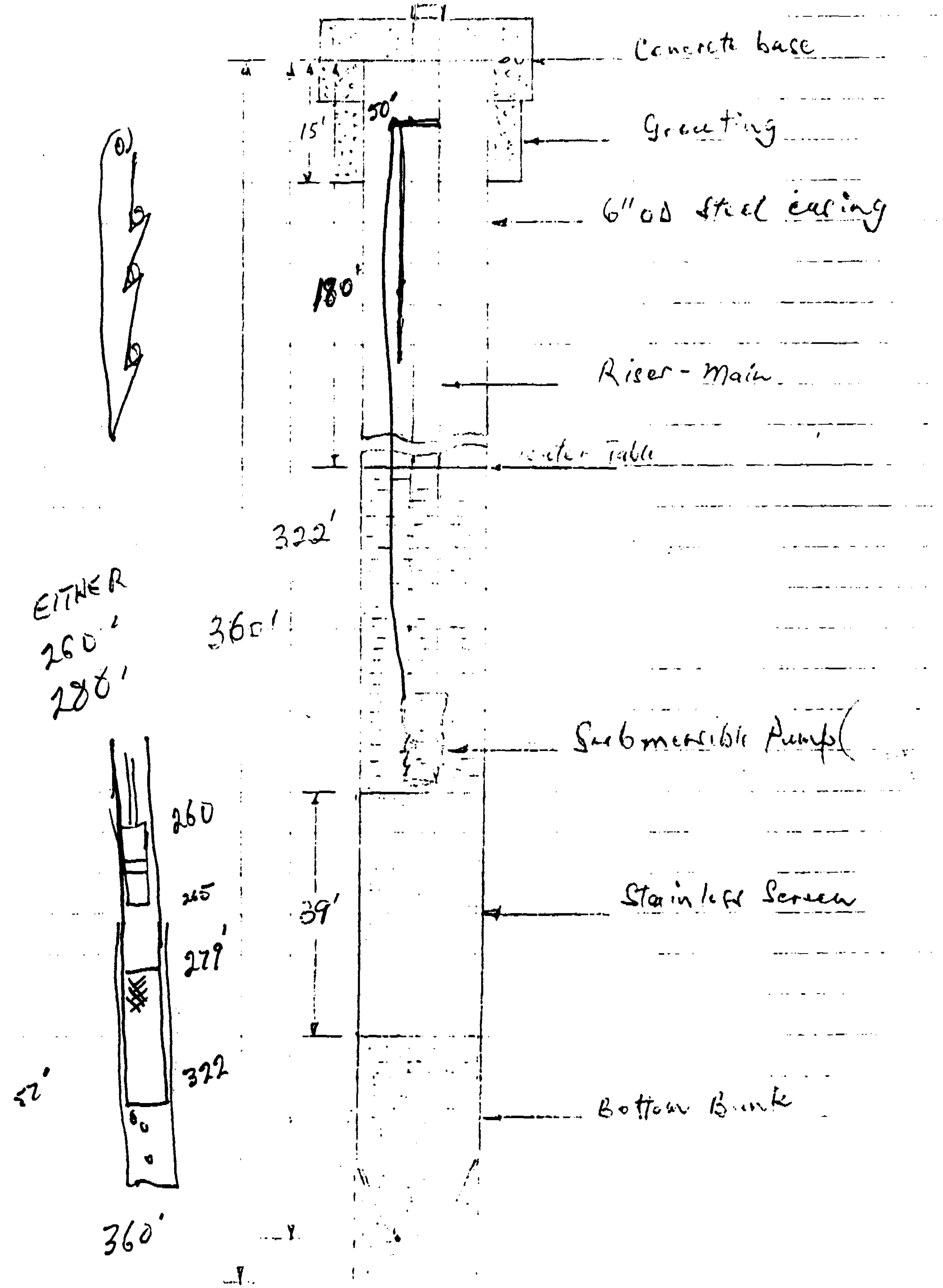
CASING & DEVELOPMENT:

The casing envisaged for this well was the steel type. This decision was taken in consideration of the fact that, we had already bursted three well casings which were P.V.C.(Plastic) types. Explaining the situation with the bursted well may not be appropriate in this report however, the choice of a steel casing was to prevent a possible fourth occurrence. The casings which were of the 6" outer diameter were together coupled with stainless screens measuring 39ft and lowered into the well. The actual depth cased, out of the total depth of 360ft, is 322ft. The best samples seemed to have come from this area. The necessary gravel packing which was with the $\frac{1}{8}$" pea size gravel was introduced into the well. We also did back-flushing which was designed to lift off the thick gel or drilling chemical deposited in the well, and also, to lighten this and dislodge it from inside the formation.

Finally, air was introduced into the well as the last phase of developing the borehole. This was done with the help of the rig's compressor. The air compression which was started about mid-day, went on till last light. The following day saw us compressing further to wash out the welll thoroughly. All necessary tests pertaining to the stage of work in progress was carried out. Compressing came to a halt when we had been satisfied of the yield potential of the well and other subsequent observations. Taking the above stated facts into consideration, one would rightly surmise that this well would be highly productive

TUES 21 - REPORT/HOTEL

MON 20 - WENT TO OWERRI, PORT HARCOURT IN SEARCH OF 5" PP/REN SET


Concrete base
Grouting
6" OD steel casing
Riser - Main
Water Table
Submersible Pump
Stainless Screen
Bottom Bank
15'
50'
180'
322'
360'
39'
EITHER
260'
280'
260
265
279'
322
52'
360'

APPENDIX B

Well Construction Report--Amapu

Africare

Africare House • 440 R Street, N.W. • Washington, D.C. 20001
Telephone (202) 462-3614 • Telex 64239
Community Water/Agricultural Development Project
P.O. Box 3543,
Owerri.

WELL CONSTRUCTION REPORT

IMO STATE: ISIALA NGWA LOCAL GOVERNMENT AREA

VILLAGE: AMAPU

LOCATION:

Amapu is a village located 70 km south east of Owerri the capital of Imo State. It is situated some 5km north of the toll plaza (Toll gate) along the Aba - Enugu expressway. Amapu could be said to be a big community spread out on both sides of the Aba Enugu highway. There are some 8,000 inhabitants in this area and they could be said to be directly involved or otherwise in the use of the amenity which is the bottom line of Africare effort in this important area. Amapu is governed by a committee of leaders who oversee the mobilization of the members of this community into action regarding development projects in the area. One of such leader is Chief Ehiodo who could be discribed a very enegetic and up to the task of encouraging his people in the area of self-help implimentary projects.

DRILLING:

Drilling started after series of meetings with members of this community. The idea behind the meetings being to make them be aware of the part they were supposed to play in the effort to construct, for them a borehole, supply them a submersible pump. In this same package would also, came a generator. The actual drilling was without much incident. Worthy of mention though, was the harrowing experience when during the casing of the well the glued/threaded coupling point gave way and the rest plunged down the well.

../2

Somehow the "shot in the dark" paid off and this was subsequently re-coupled. The water table came up to 115ft - static. All necessary monitoring was carried out and samples analysed. The final depth of 320ft was found adequate for this area in view of the yield potentials of the well. Mr Dewy Petterson who is of Petterson Bros Drilling Company, Bountiful Utah, U.S.A. actually did the drilling working with the staff of Africare.

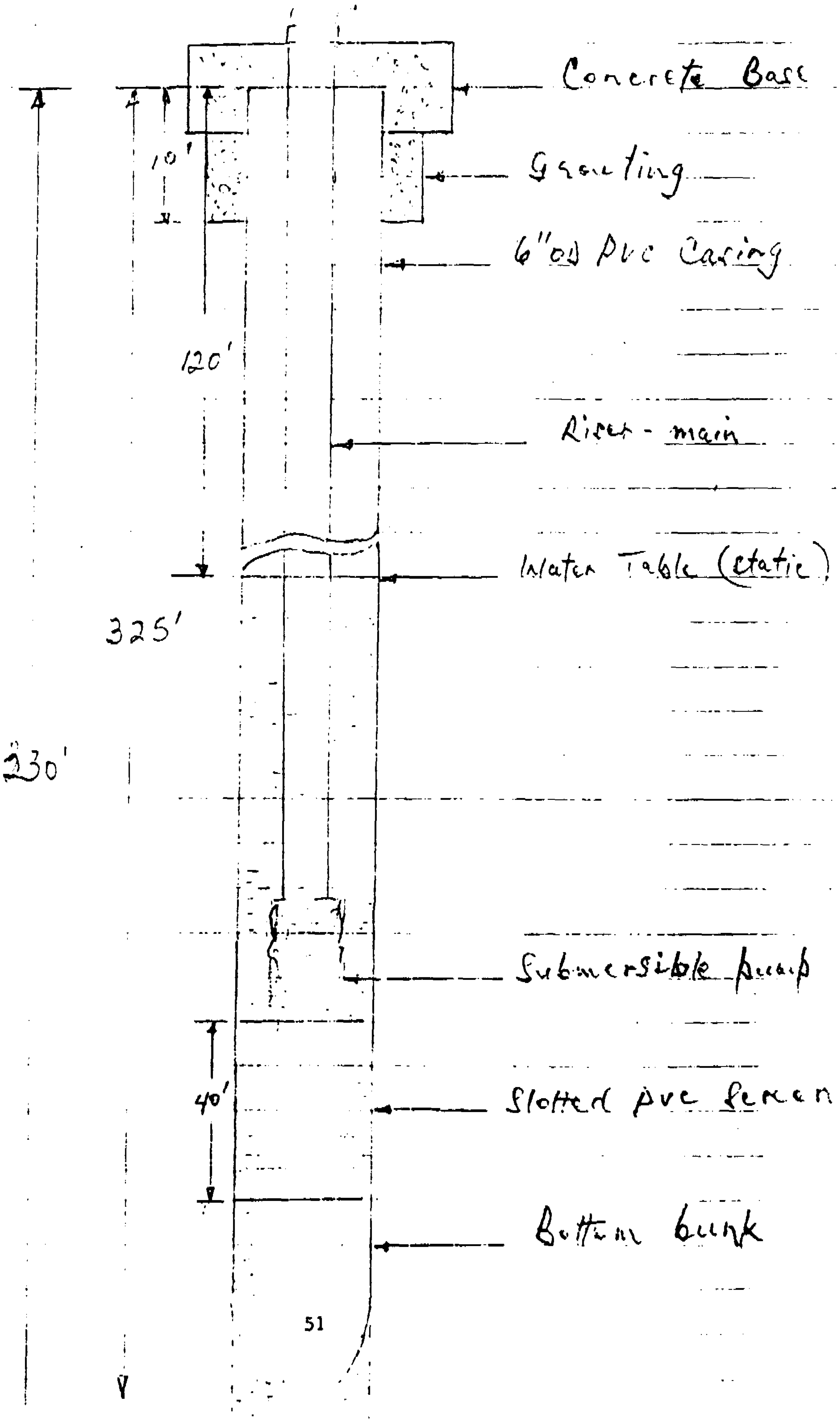
CASING & DEVELOPMENT:

The casing was of the 6" P.V.C. which is specified for borehole or pressure related construction purposes. The casings were therefore run in this order; 320ft drilled and 300ft cased. Also was installed a 40ft screen and a bottom bunk of 7ft. The casing which parted as mentioned above must have been the result of the weight of the bottom bunk. This was bourne from the fact that the amount of concrete poured into 7ft section was heavy enough to have had the effect previously described.

The eventual development comprised of the introduction of $\frac{1}{8}$" pea size gravel into the well. This is in keeping with the standard well development procedures. The effect of this is to form some porous element around the filtered or screened area of the aquifer. Again, the introduction of the gravel into the well, displaces some other loose particles that would be flushed out during the compression of the well. The well was compressed and the resultant monitoring done.

Base Structure and grouting. The final work on the construction of the well was the grouting (Solidifying the top few feet of the well) and the concrete base to stabilize the whole well structure.

Here it is worth mentioning the fact that the use of the P.V.C for well casing has been found to be cost saving and easier to handle during installation. The somehow effect of water on metal (iron) which generally is found in boreholes cased with the so called standard API Steel casing is completely absent.


Concrete Base
Grouting
6" OD PVC Casing
10'
120'
Riser - main
Water Table (static)
325'
230'
Submersible pump
40'
Slotted PVC Screen
Bottom bank

APPENDIX C

Well Construction Report--Nkwo Udara

Africare

Africare House • 440 R Street, N.W • Washington, D.C. 20001
Telephone (202) 462-3614 • Telex 64239
Coomunity Water/Agricultural Development Projec
P.O. Box 3543,
Owerri.

WELL CONSTRUCTION REPORT

IMO STATE: ISIALA NGWA LOCAL GOVERNMENT AREA

VILLAGE: NKWO UDARA

LOCATION:

The village of Nkwo Udara lies north-easth of Aba and its about ½hour's drive from there. It is located along the rail line from Aba to Umuoba; five kilometers to Umuoba to be exact. This village, like the rest of the villages in this part of Imo State is densely populated with an approximated eight thousand people. This takes into consideration. The fact that there are four communities which are all Autonomous, but they all are linked up in the Africare Child Survival Project facilities there. The Community leaders is Eze Adindu who in co-operation with the rest of the other neighbouring communities had donated an old court premises for the construction of the well.

DRILLING:

The site preperation in this area had been done in advance, and by the early days of march, work was started on the well. The drilling went on without a hitch as all materials had been procured and kept ready for this purpose. Four days of drilling saw us ready for casing at a good depth of 240ft. A sample check at this depth showed signs of good yield and in considering this fact, we went ahead to install the casing.

../2

This part of Imo State has its water table at 120ft. Our having to drill down to 240ft was to give ample hydraulic pressure to the type of pump that we may finally use. Another consideration is the multiple nature of the communities involved in the Project as mentioned above.

CASING SCREEN AND DEVELOPMENT:

The casing was of the 4in PVC pressure type. The casing went down to 205ft with a 30ft screen and a bottom bunk of 5ft. To enhance filteration, a $\frac{1}{8}$" size gravel was introduced into the well as standard proceedure in well construction. Since the type of drilling used in this well was of the rotary type, using drilling mud (Bentonite) there was the necessity to apply air pressure to force the mud out of the well and to loosen the formation outside the well screen. Further to this would be a natural reaction occuring in the well as air is applied under pressure. There is this tendency for the smaller particles that would go past the screen to come into the well while the bigger ones lodge themselves outside the well screen thereby forming an effective layer of good size gravel to enhance filteration. Again the use of air pressure 'surges' the water in the well and this washes out all possible deposits of the drilling chemical. This operation is carried on for as long as there any reason to continue with it. This sometimes could continue for 8hrs or more.

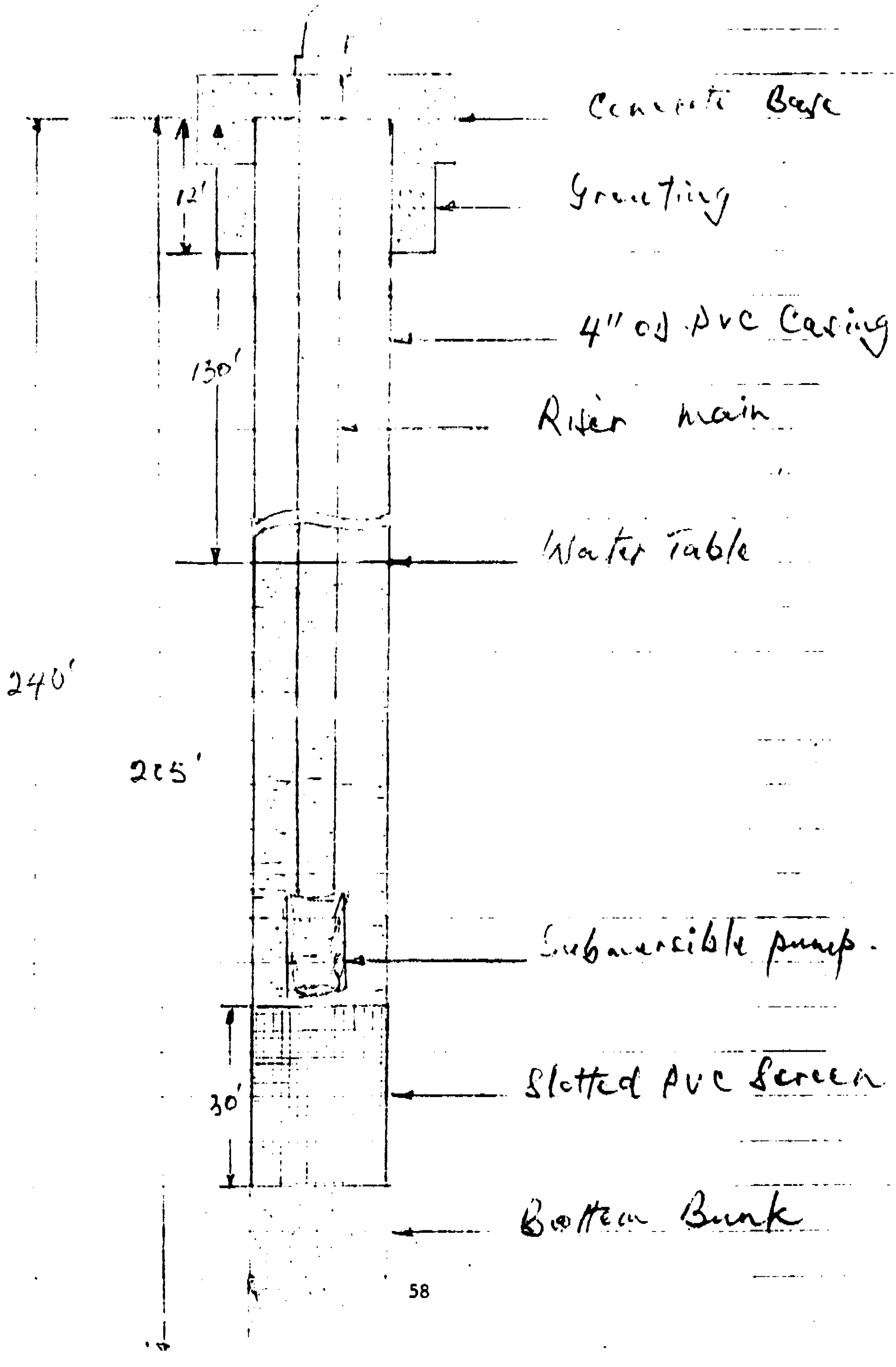
BASE STRUCTURE & GROUTING:

This operation involved the stabilization of the well structure and the sealing of the top part of the well inorder not to allow top water from above the ground from entering into the well by way of the top end of the casing or well head. After this operation, the well area was cleaned out in preperation for other activities in the well. like pump installation.

PUMP INSTALLATION:

For this well, a pump of 1.5hp was procured. This was to supply water to a 2,000 gallon tank errected to serve the facility and the community. Taking into consideration the size of the communities, this tank capacity and the size of submersible pump may not sound ideal. Provision had therefore been made for this taken arrangement to be boosted up in the near future by members of these communities in the form of self-help implimentation project.

NAME [illegible]


Concrete Base
Grouting
12'
4" od PVC Casing
130'
Riser main
Water Table
240'
225'
Submersible pump.
Slotted PVC Screen
30'
Bottom Bunk

APPENDIX D

Well Drilling Report--Ntit Oton Lac

VILLAGE: NTIT OTON LAC - WELL DRILLING REPORT

LOCATION

The village of Ntit Oton lies within the area of the former Etinan LGA It is also located South East of Etinan Oton. There are easy access to this village through Edem Idim Okpot to the East, Ukat Aran to the West and the main road atery from Etinan to Eket. The community leader who deputises for the traditional ruler there is Mr. Victor Inwang who was the supervisory councelor for health in the recently desolved Etinan Local Government. The village of Ntit Oton is the largest of the communities in this areas of the state. There are numerous schools and because of its accessibility, the village attracts people from around the country side who come to buy and sell commodities during the market days. With the above mentioned, it would be seen that the siting of the borehole project there was considered a blessing by these people whose one source of surface water was heavely polluted and drying up too.

DRILLING

Negotiation on site selection started in earnest in the early months of 1988. The actual drilling started by the end of February of that year. The site chosen was the site of the community hall which the villagers attested to as being more central than the intersection which looked more commercialized. The actual drilling was without incident as we went down at a regular pace. There was the solid top layer that extends to about 60ft or more before the saturated layer which herald the beginning of the water bearing strata.

Again at 70ft we came to the top part of the water table. Here, it would be worth mentioning that the type of rig we are using in this areas which is a Cable Tool Rig has the added advantage of drilling without drilling mud (Bentonite) like the rotary Rigs. With the use of the bailer, one could know exactly when there is any change in the formation. It is therefore possible to know when one is in any formation and be able to identify such formation.

In view of the type of sample from this well, we drilled down to 120ft. There was a lot of coarse sand which indicated good porosity which in turn means good water bearing aquifer. We have found it necessary to do this wells within the range where the use of the India MK II pump would not be obsolete, hence the depth as they are.

. . . / . . .

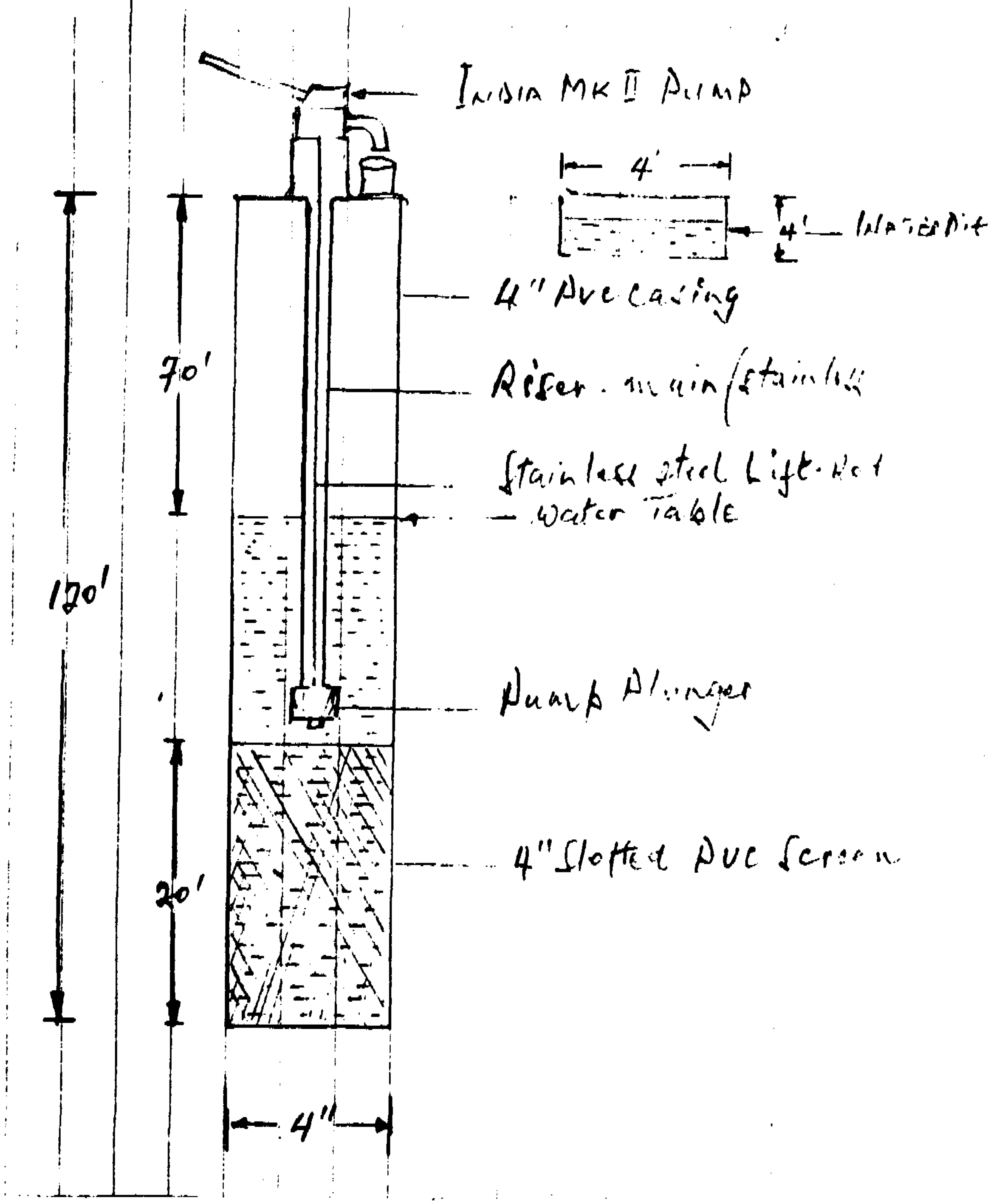
CASING DEVELOPMENT

We ran the casing at the depth mentioned above, using the standard P.V.C. 4in casing which is suitable for mono pump installations. A 20ft screen was incorporated and this we found adequate in view of the coarse nature of the water bearing formation. The job of development was carried out as necessary. This consists of lowering in and lifting the builder in the water to create some form of turbulence which shake and loosen particles outside the screen and at the same time, allowoing those that can go past the slotted screen into the well to be evacuated out by the bailer. This process has the effect of 'washing' out the well until the water become's clean and free from sediments.

Finally, arrangement was made to construct the cement base and grouting after the gravel packing which of course was done while developing the well. The construction of the water pit was also arranged. All in all, this well was seen at completion of activities as a high yield well.

IEC:rai
28/7/89

NTIT OTON WELL



APPENDIX E

Well Drilling Report--Ukat Aran

AKWA IBOM STATE - NSIT UBIUM LGA

VILLAGE: UKAT ARAN (L.A.C) - WELL DRILLING REPORT

LOCATION:

The village of Ukat Aran lies centrally without the area that was formally Etinan LGA. Like most areas of its nature, it is primarily a farming community. Ukat Aran is located South East of Etinan and North West of Eket and is half an hour's drive from Etinan. Chief Sunday Ukpong is the head of the community who helped our team to choose the location of the well. The population of this community is well over 4,000 people. Like the rest of these other communities, there is a secondary school with a large students population and a scartering of primary schools in the area.

Work started in this area about the middle of August 1987. The site chosen seemed central and is situated almost opposite the secondary school. This site chose for the well was confirmed by Chief Ukpong to be centrally located and within reach of the members of his community.

DRILLING

The first day of drilling after site preparation brought us down to 40ft. On the following day, we were able to reach the top part of the water table at 70ft. The marked difference in the water table stems from the fact that the site was on a hill. In fact, we seemed to be on the highest ground in the whole of the area. The necessary equipment were employed to enable us penetrate deeper into this water bearing aquifer. By the end of the second week after commencement of drilling, we were in a favourable position to case the well at the depth of 125ft. Unlike our previous experience at Ikot Eyo, there was little or no obstacle in the way of construction of a good high yield well.

CASING AND DEVELOPMENT

The well was finally cased and developed. We used the standard 4in P.V.C. and slotted screen of the same material for the final structure. Here it is worth mentioning the fact that only in Ikot Eyo did we experience the heaving up of the strata which may have eventually contributed to the colapse of the well using the standard P.V.C. as in the former well at Edem Idium Ikpot. Developing this well was indicative of its yield capability. There was so much water in it that we reckoned there was no need to go any deeper for after all, what is envisaged was a Mono pump.

PUMP INSTALLATION AND TESTING

The standard India MK II pump was installed and 4hrs of pump test carried out. There was no problem of any sort except that we had to adjust our lift-rod to enhance better stroke which is related to the amount of water being lifted for discharge. The members of the community were made to operate the pump and were also imstructed as to its proper use.

BASE STRUCTURE AND GROUTING

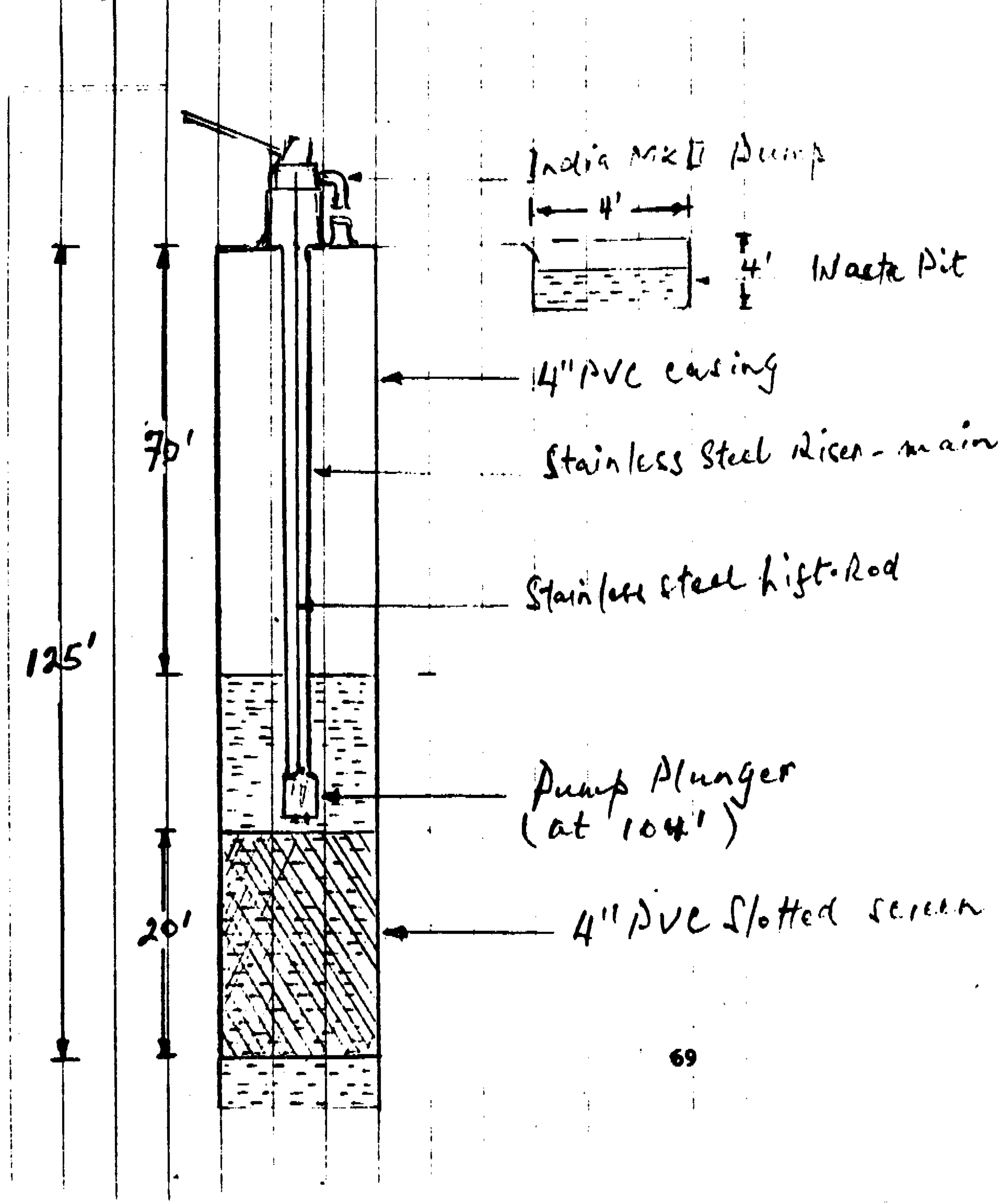
Arrangements were made to construct the base and grouting. Also, we gave directions regarding the construction of the waste water pit. It has been found necessary to construct this pit whenever a well is located otherwise there would be a situation where the excess water runs all over the place; sometimes forming ponds where mosquitoes would breed and contribute to or enhance further the health hazard of the people.

REMARKS

Since the commissioning of this well, we have had to do two repairs. Each of this repairs had involved the replacement of the riser - main which got cut through by the lifting rod. The solution to the perenial problem of the India MK II pumps would be the incorporation of some form of stabilizer that would have the effect of centralizing the lift rod and thereby preventing it from rubbing against the side of the riser - main. Our observation shows that the part of the riser - main most or commonly affected is the last price before the pump main body.

IEC:rai
28/7/89

UKAT ARAN [illegible]


India MK II Pump
4'
4'
Waste Pit
4" PVC casing
Stainless Steel Riser-main
Stainless steel Lift-Rod
Pump Plunger
(at 104')
4" PVC Slotted screen
70'
125'
20'

APPENDIX F

Well Drilling Report--Edem Idim Okpot

AKWA IBOM STATE - NSIT UBIUM LGA

VILLAGE: EDEM IDIM OKPOT (LAC) WELL DRILLING REPORT

LOCATION

Edem Idim Okpot is a farming community located in the former Etinan LGA of Cross River State. Its population is estimated to be four thousand. There is a secondary school in the community and there also are primary schools. The community leader name is Chief Ekpo William Ekpo.

DRILING

Work on the borehole envisaged for this community started in earnest about the early days of June, 1987, after the initial site selection and preparation. Because of the nature of the area, water was expected to be struck at about 70ft. The drilling continued until the later part of June. A depth of 110ft was found adequate for this formation in view of the prevailing aquiter. All necessary samples showed good prospect for high yield in this area.

In view of the above, the well was cased accordingly and a 30ft of screen installed. The necessary work of development (surging) to clear the water bearing area (aquifer) was carried out. Further to this was the disinfection of the well; this was also carried out. Subsequent to the completion of the drilling, casing and development, an India MK II mono pump was isntalled. It was also found necessary to contruct a drainage system where all waste water from the use of the well was made to drain into. A covered pit was incorporated into this drainage system to prevent creating a breeding ground for mosquitoes.

REMARK

In view of the fact that the nearest stream (possibility contaminated) is 3km from the centre of the village, the provision of this well has gone a long way in ensuring that the members of this community have access to good source of domestic water.

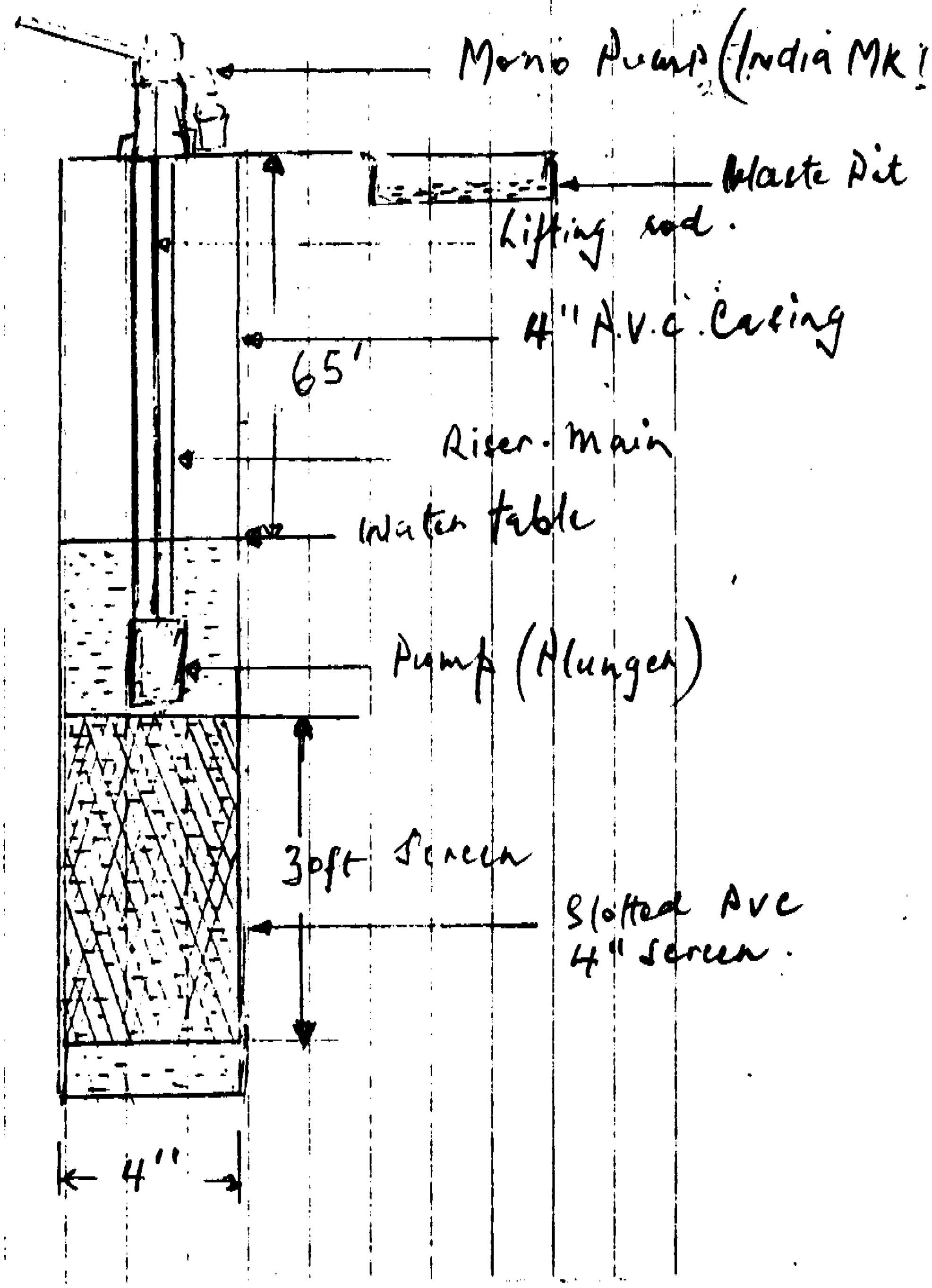
There has been breakdowns experienced in this well several months ago. The cause of this was traced to the joints on the lifting rod of the pump plunger. The lifting rod near the top of the riser main tended to rub at its joint, the inner wall of the riser - main thereby causing water to drain out instead of its continuing up to the pump discharge tank. The repair procedure had been to change the defective riser - main. A more permanent approach would be to incorporate some form of stabilizer which would effectively centralize the rod in the riser - main.

. . . / . . .

Generally speaking, this well would be said to be highly productive in view of the number of people using it and its yield capability.

IEC:rai
28/7/89

Rolery Jaim Okaot Well 1



APPENDIX G

Performance Curve of Model D24 Submersible Pump

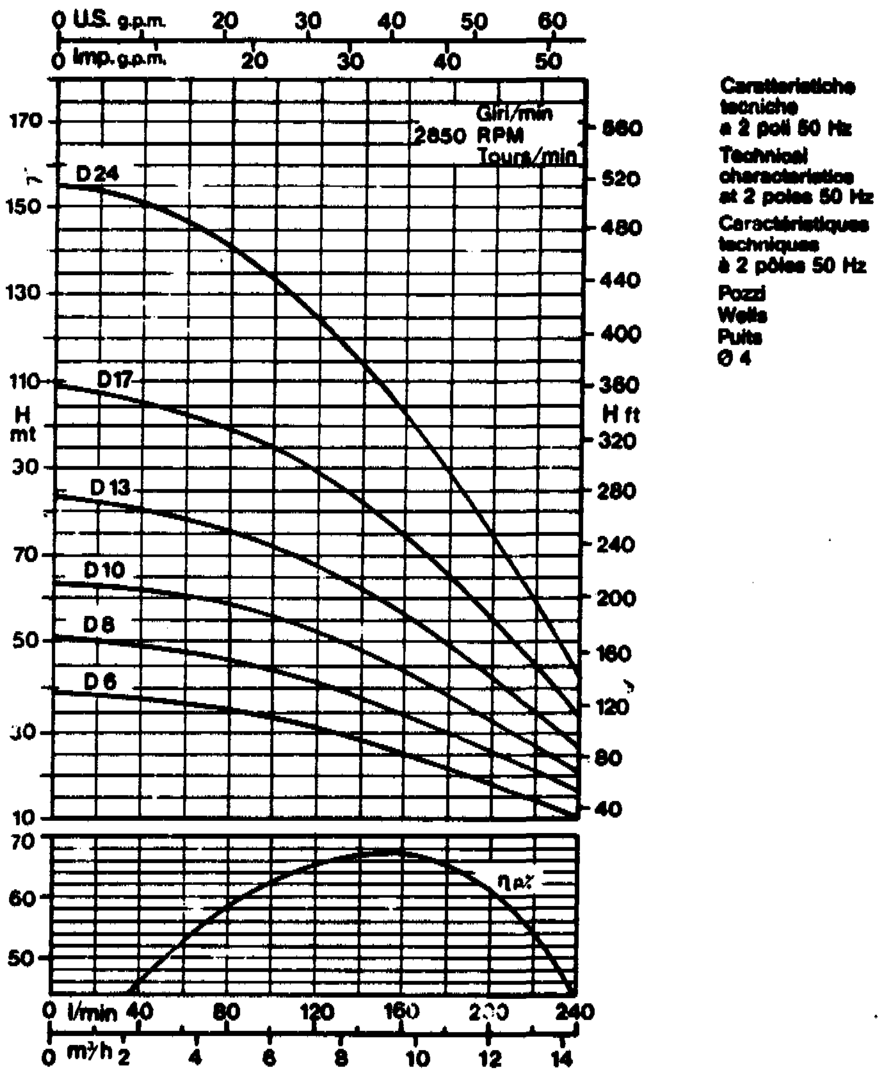
SAER
ELETTROPOMPE

LM 95-D

Elettropompa sommersa centrifuga pluristadio
Pompa multicellulare centrifuga
· Supporto di mandata e di aspirazione in ghisa meccanica. · Accuratamente verniciato internamente ed esternamente con vernice epossidica. Griglia di aspirazione in acciaio inox. Motore serie MF. Statore protetto da una [illegible] policarbonato con inserti in acciaio inox [illegible] rasamenti. · Albero e giunto in acciaio inossidabile. · Griglia di aspirazione e asta proteggi cavo in acciaio inox. · Motore di tipo asincrono trifase e monofase. Statore avvolto con filo di rame isolato in PVC. · Albero in acciaio inox. · Bussole in bronzo antifrizione. · Supporti in ghisa meccanica verniciati con resina epossidica. · Cuscinetto reggispinta in acciaio inox temperato e controparte in lega · Uscite albero e quote di accoppiamento a norme NEMA. · Caratteristiche di funzionamento 2850/giri. · Di serie viene montato il motore tipo MS.

Multi-stage submersible centrifugal electric pump
Multi-stage centrifugal pump
Delivery and aspiration support constructed from engineering cast iron. · Carefully painted in and outside with epoxy powder paint. · Built-in, non-return valve made from die-cast brass. · Impellers and diffusers made from polycarbon steel with stainless steel reinforcements at rotation points. · Shaft and coupling made in stainless steel. · Intake grill and cable protection shaft also in stainless steel. · Three-phase and single-phase asynchronous motor. · Wound stator with PVC insulated copper wire. · Stainless steel shaft. · Anti-friction bronze bushings. · Supports made from engineering cast iron painted with epoxy resin. · Thrust bearing in tempered stainless steel. Support section made in special alloy. · Nuts and bolts made in stainless steel. · Shaft outputs and coupling dimensions in accordance with NEMA standards. · Operating characteristic: 2850 RPM. · A MS Series motor is the standard mounting.

Electropompe immergee centrifuge a plusieurs etages
Pompe multicellulaire centrifuge
· Support de refoulement et d'aspiration en fonte mécanique. · Soigneusement verni à l'intérieur et a l'extérieur avec de la poudre époxyde. · Boupape de retenue incorporée en laiton moulé sous pression Couronnes mobiles et diffuseurs en polycarbonate avec parties intercalaires en acier inox dans les épaisseurs. · Arbre et joint en acier inox. · Grille d'apiration et tige protege-câble en acier inox. · Moteur de type asynchrone triphasé et monophasé. · Stator enveloppé avec fil de cuivre isolé en PVC. · Arbre en acier inox. · Douilles en bronze antifriction. · Supports en fonte mécanique vernissés avec résine époxyde. · Palier de butées en acier inox trampé et support en alliage spécial. · Visserie en acier inox. · Sorties arbre et cotes d'accouplement selon les normes NEMA. · Caractéristiques de fonctionnement 2850/tours. · Pour les modèles de série nous montons le moteur du type MS.



Caratteristiche tecniche a 2 poli 50 Hz
Technical characteristics at 2 poles 50 Hz
Caractéristiques techniques à 2 pôles 50 Hz
Pozzi
Wells
Puits
Ø 4

Tipo Type - Type	Motore Motor Moteur		Trifase Three-phase Triphasé in ampere in amps. - en amp.		Monofase - Single-phase Monophasé in ampere in amps. en ampèr.	Condensat. Condensers Condensat.		Portata - Capacity - Debit - m³/h / l/min.							
								0	4.8	6	9	10.8	12	13.2	14.4
								0	80	100	150	180	200	220	240
	HP	Kw	220v	380v	220v	μF	V min	Prev. tot. in mt. - Tot. head in m. - Haut. man. tot. en m.							
LM 95 - D 6	1.5	1.1	4.7	3.3	9	40	370	39	37	34	27	22	18	13	10
LM 95 - D 8	2	1.5	7.3	4.2	11	60	370	51	46	43	37	31	27	21	17
LM 95 - D 10	3	2.2	9.5	5.5				64	59	55	47	38	32	28	22
LM 95 - D 13	3	2.2	9.5	5.5				83	75	71	59	50	43	35	27
LM 95 - D 17	4	2.9	13.5	7.8				109	99	94	78	65	55	40	[illegible]
LM 95 - D 24	5.5	4	15.6	11				155	140	134	108	90	75	60	45

APPENDIX H

Performance Curve of Model SP-8-15 Submersible Pump

GRUNDFOS

SP 8

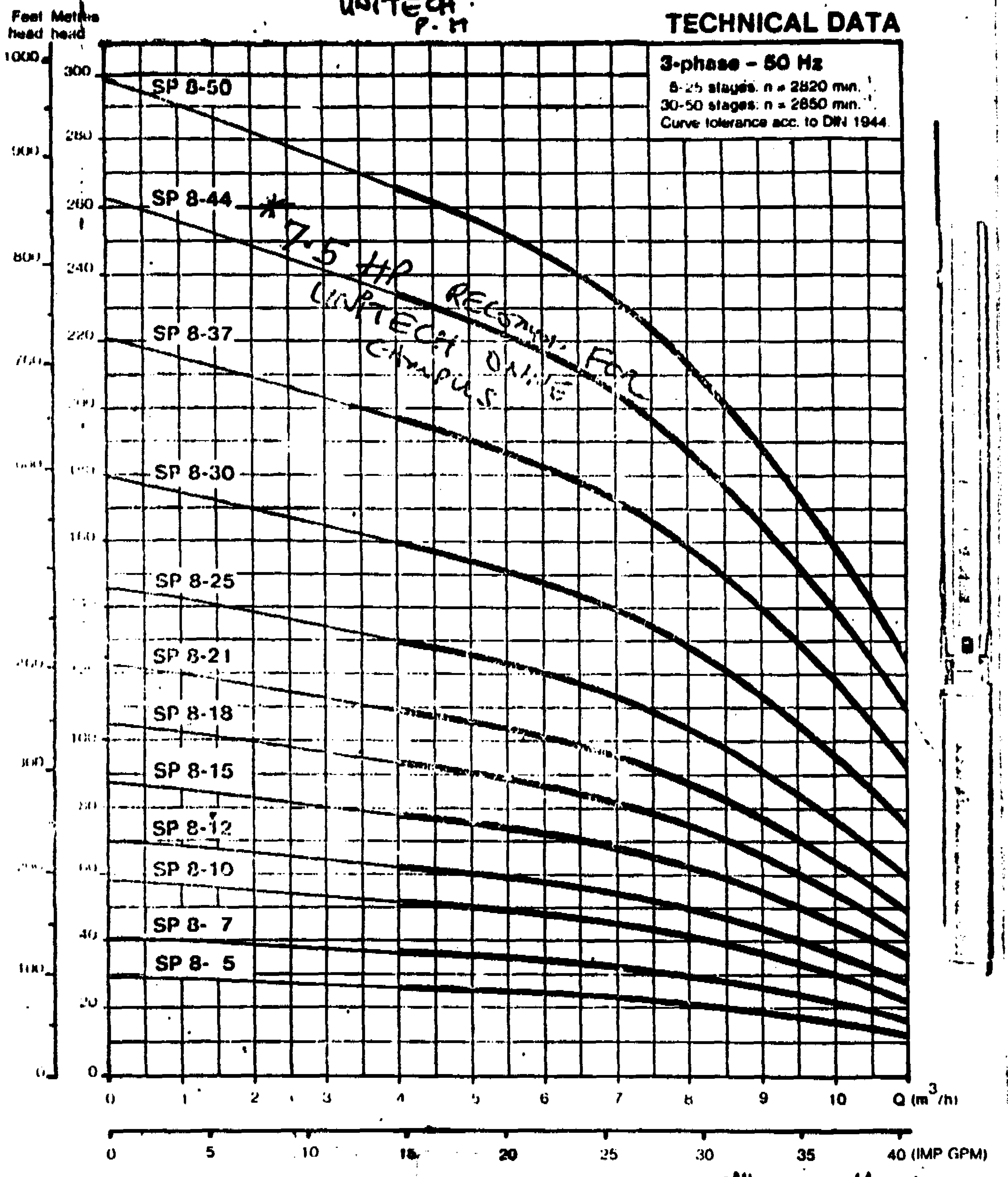
GB

SUBMERSIBLE PUMP

50 Hz

*ATTN: DIRECTOR OF WORKS
UNITECH
P. M

TECHNICAL DATA



SP 8 flow range: **4-11 m³/h** (15-40 IMP GPM).

83 30 GPM. 44 GPM

The GRUNDFOS submersible pump range covers flows from 0.1-160 m³/h (0.4-587 IMP GPM).

5.55 hr 3.78 HR.

APPENDIX I

Schedule of Activities

APPENDIX I

Schedule of Activities

October 26	Depart Boston to Washington.
October 27	Team planning meeting WASH headquarters; depart Washington to London.
October 28	London to Lagos.
October 29	Meet with Africare country representative in Lagos.
October 30	Visit pump, electrical cable, and hardware suppliers in Lagos.
October 31	Communicate with UNICEF drilling coordinator; Visit U.S.A.I.D; Fly to Port Harcourt.
November 1	Help procure welding gear in Port Harcourt.
November 2	Pull pump in place at Umuelum borehole site.
November 3	Travel to Isiala Ngwa and remove generator; travel to Umuelum and attempt to pump borehole.
November 4	Travel to Port Harcourt; procure 3 hp. pump, riser main, and required fittings.
November 5	Free day.
November 6	Remove .75 hp pump and install 3 hp. pump at Umuelum; trial run pump.
November 7	Proceed with yield determination test at Umuelum.
November 8	Repair trailer at Owerri; travel to Isiala Nwga and reinstall generator; travel to Aba to rent appropriate generator (failed to do so).
November 9-10	Return to Aba, search businesses to rent generator (not successful).
November 11	Stay in Owerri; start report, Umuelum.
November 12	Free day.
November 13	Return to Aba to find generator; travel to Amapu to trial test pump (successful).
November 14	Proceed with yield determination test at Amapu.

November 15	Travel to Aba to return generator; return to Owerri and unload pump gear.
November 16	Travel to Ntit Oton and pull hand pump; inspect pump and borehole.
November 17	Travel to Ukat Aran/Edem Idim and pull pumps; inspect pumps and boreholes.
November 18	Write report, Owerri.
November 19	Free day.
November 20	Travel to Port Harcourt to search pump suppliers for 5 hp pump-- Umuelum (not successful); return to Owerri and order pump from Lagos.
November 21	Organize drill crew to install pump; write report, Owerri.
November 22	Write report, Owerri.
November 23	Install/remove pump at Umuelum.
November 24	Develop borehole/run pump at Umuelum.
November 25	Write report, Owerri; Lagos to London.
November 26	London to Boston.