Nigeria has a long history of borehole drilling. The drilling sector which was previously a preserve of expatriate practitioners has been taken over by indigenous companies but the sector is still confronted by several challenges; there is still a big gap in water supply coverage in the rural areas of the country. This paper reviews borehole provision practices in the country against the backdrop of the Code of Practice for Cost Effective Boreholes developed by the Rural Water Supply Network. It identifies lack of transparency in contract awards, lack of adequate supervision and non payment for dry holes as the drawbacks in the cost effectiveness of borehole provision in the country.

Introduction
Borehole drilling in Nigeria dates back to 1947 when the Public Works Department purchased a cable tool rig and began drilling. The first private drilling company was registered in 1951. The first major water supply drilling programme was between 1956 and 1962 when 280 boreholes were drilled in the north eastern part of the country to explore the artesian aquifers of the Chad basin (Adekile and Olabode, 2008). However currently 58% of the rural population, most of who depend on groundwater sources have no access to improved water sources (JMP, 2010). To bridge the gap and increase the water coverage in the rural areas it is essential that boreholes be drilled and delivered in a cost effective manner.

Nigeria has a population of 150 million and operates a federal constitution with 36 states, a federal capital territory and a federal government at the centre, as administrative units. All the units are active in rural water supply through borehole provision and are supported by external agencies and non-governmental organizations.

Description of the Case Study – Approach or technology
This paper evaluates drilling practices in the country in line with the Code of Practice for Cost Effective Boreholes developed by the Rural Water Supply Network (RWSN, 2010). The Code of Practice focuses on nine principles which need to be adhered to in borehole provision for it to be cost effective. The Code of Practice enables organizations to evaluate their approach to borehole delivery in accordance with best international practices. The evaluation is based on the field experiences of the authors, one as a drilling contractor and the other as a hydrogeological consultant.

Main results and lessons learnt
Principle 1 Construction of drilled water wells and supervision should be undertaken by professional and competent organisations which adhere to national standards and are regulated by the public sector.
Drilling companies in Nigeria

Borehole drilling in Nigeria is currently mostly carried out by the private sector, nearly all Nigerian owned companies except for a few Chinese companies. In the past, some public sector agencies were involved in drilling but they were unable to overcome the restrictions imposed by having to conform to civil service conditions and were inefficient and therefore were closed down. However recently (2010, 2011) the Japanese International Cooperation Agency (JICA) has been providing some rural water supply agencies in the country with drilling rigs and other equipment to carry out JICA supported drilling programs.

The Water Well Drilling Association of Nigeria founded in 2009 has a directory of 350 drilling companies but the number of drilling contractors in the country could be up to 1000. The drilling companies can be classified into 2 categories:

- conventional drilling contractors with equipment and a management structure
- artisan drillers engaged in manual drilling or using locally fabricated rigs

Several of the conventional drilling contractors are headed by hydrogeologists and engineers who either previously worked with expatriate companies or in the public service. They are small companies which drill between 50 and 100 boreholes a year. The equipment used by them is of several makes and comes from all over the world e.g. China, England, Germany, Nigeria, USA and Thailand. Some of the companies have proven to be competent and reliable. Their clients include the federal and state governments, international agencies such as the UNICEF and WaterAid and the private sector.

The artisan drillers engage in manual drilling and some use locally fabricated drilling rigs. Their clientele is mostly the private sector such as householders, farmers and other small scale industries. Their prices are very competitive because their overheads are low. However despite the low prices they are not often patronised by the government.

There is however a third category of actors in the drilling sector. These cannot be classified as drillers. They are businessmen who see an opportunity for quick money in borehole drilling. They have not invested in equipment and drilling personnel. They are usually well connected with political office holders if they are not politicians themselves and are therefore able to lobby for and win drilling contracts. They subcontract or simply sell the contract to the conventional drillers. This lowers the profit margin for the subcontractor which in turn could lead to compromising standards. In 2010 a state government awarded half of a 700 borehole project to this category of brief case drillers. The situation is similar in many states.

Thus the contract award process is not always transparent. Until recently there was no regulation in setting up a drilling company and therefore it is difficult to identify the real drilling companies. The World Bank and RWSN have been encouraging and supporting the setting up of a drillers association in the country to professionalise drilling and for the identification of the drilling contractors. The Federal Ministry of Water Resources through the National Water Resources Institute has developed a National Code of Practice for Water Well Construction in Nigeria (FGN/NWRI, 2009). The Code of Practice makes it a legal requirement for every drilling company to be registered and licensed and also to obtain a permit for every borehole drilled.

Principle 2: Appropriate siting practices utilised “and competently and scientifically performed”.

General compliance

There is significant compliance to this principle in the country. Even the man on the street in Nigeria knows about geophysics and its implication for borehole success. There is however evidence that siting requirements are not properly understood by some project designers and that it is not in all
cases that geophysics is required. On all government projects geophysical investigation is the first item on the bill of quantities. Even in well documented regional sedimentary aquifers such as the Coastal Plains Sands with several successful boreholes providing direct information on the aquifer parameters where geophysics will not reveal much, geophysical survey is still specified.

**Siting by trained geologists**
The universities have produced hundreds of competent geologists, some of whom have understudied experienced hydrogeologists and are involved in groundwater exploration. There is a better understanding of geophysical methods in groundwater development in crystalline terrains than what obtained 20 years ago and the drilling success rate has increased accordingly. The siting procedure in crystalline terrain is a combination of geological reconnaissance and geophysical surveying involving resistivity sounding and in some cases electromagnetic metering.

**Siting by trained technicians**
Some technicians have acquired geophysical survey knowledge through their work experience with consultants and government agencies and are involved in siting boreholes for drilling contractors. There have been some complaints from professional geologists that the technicians do not carry out reliable and competent work as they are not usually well grounded in geological knowledge. To curb the situation there is a proposal to the Council of Nigerian Mining Engineers and Geoscientists (COMEG) which has the responsibility for regulating practices in mining and geosciences in the country, that all siting reports must be signed by only hydrogeologists accredited by the council. This is also included in the National Code of Practice.

**Siting by drilling contractors**
The current trend is that more and more clients are giving the responsibility for siting boreholes to the drilling contractor and thereby adopting a policy of “no water no pay” i.e. the driller does not get paid for dry holes. In the early days of mass produced boreholes promoted by external support agencies, consultants were hired to carry out geophysical investigation and supervision of drilling. The client allowed for a certain percentage of dry holes in the budget accepting that geophysics at best is an approximation of several ground parameters and not 100% accurate. The drilling contractor was paid for work carried out and verified, up until a borehole was declared abortive. In trying to indemnify themselves against a high percentage of dry holes some government institutions adopted the strategy of non payment for dry holes. The approach could give a wrong impression of project performance as the project can record a 100% success rate when it does not fiscally account for dry holes. Clients should bear the responsibility for siting and supervision. The possibility of a dry hole is a fact of life and not a function of faulty drilling. Once the supervisor certifies that the driller has done the work according to the specification then payment should be according to the bill of quantities.

**Principle 3:** The construction method chosen for the borehole is the most economical, considering the design and available techniques in-country. Drilling technology needs to match the borehole design.

In the past the expatriate drilling companies imported heavy duty multipurpose drilling rigs. Adenle and Beale (1989) provides an inventory of 68 Ingersoll Rand rigs operating in the country in the 80s. There is now a consciousness dictated by experience and market forces to use the most economical drilling method specific for a particular terrain. As approximately 75% of the aquifers (in geographical extent) in the country comprise weathered crystalline rocks and shallow sedimentary aquifers where drilling depths are not more than 100 m, drilling contractors are therefore moving towards light and medium duty rigs suitable for such terrains.

**Locally fabricated rigs**
Drilling rigs are being fabricated in Nigeria from discarded materials. The phenomenon started in the mid 1980s (Adekile et al, 2011). The engine, the chassis, the mast, control valves, are sourced locally from scrap yards. A survey of drilling in 6 states of the country found that 30% of the rigs
being used by drillers in the survey were made locally (Adekile and Olabode, 2008). These are light and medium duty rigs capable of drilling between 100 and 200 m. The rigs cost about a quarter of imported rigs of the same capacity and the spare parts are easily available from the same scrap yards. Because of the lower initial capital outlay, the users are able to offer competitive prices.

**Hand Drilling**

Where appropriate, hand drilling is used. Some of the conventional drillers also engage in hand drilling. It started initially as a means to reach shallow alluvial aquifers for irrigation tubewells but the phenomenon has spread to water supply. Borehole prices are as low as a third of machine drilled boreholes. In the shallow sandy aquifers (30-40 m deep) of Port Harcourt city in Rivers State, hand drilling is about the only method of drilling. Machine drilling is just not cost effective. The use of locally fabricated rigs and hand drilling provides lower borehole prices and has enabled householders to own their own boreholes.

**Principle 4:** Procurement procedures ensure that contracts are awarded to experienced and qualified consultants and drilling contractors.

Procurement of public goods and works in the country including boreholes is guided by the Public Procurement Act of 2007 which is followed by all government and international agencies. The regulations set the following procedure in the procurement of services:

- advertising of projects and requests for expressions of interest
- prequalification of contractors
- verification of prequalification submission
- short-listing of contractors
- submission and evaluation of tenders
- contract award

Prequalification requirements include evidence:

- of past contracts of similar nature
- cost and complexity
- personnel capabilities
- equipment capabilities
- financial capability
- litigation history

As stated above, in spite of the laid down regulations the process is not always transparent and political patronage does sometimes come into play.

**Principle 5:** Construction - The borehole design is cost-effective, designed to last for a lifespan of 20 to 50 years, and based on the minimum specification to provide a borehole which is fit for its intended purpose.

**Standard designs**

There is a conscious attempt to ensure that borehole designs fit the purpose and the expected yield. 110 mm and 150 mm diameter PVC lining are standard finishing for handpumps and motorised boreholes respectively. The Federal Ministry of Water Resources adopts up to five different basic designs depending on the terrain. Lagos State Rural Water Supply and Sanitation Agency uses only 150 mm diameter lining for handpumps with the plan of upgrading to motorised schemes as demand increases and funding is available. Tables 1 and 2 below show various designs employed by both the federal government and some state agencies.
### Tables 1 Borehole designs used on Federal Ministry of Water Resources

<table>
<thead>
<tr>
<th>Aquifer type</th>
<th>Borehole design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weathered basement complex and shallow sediments depth less than 60 m</td>
<td>110 mm dia. PVC lined max. 60 m depth fitted with a handpump</td>
</tr>
<tr>
<td>Sediments with aquifer at depths greater than 60m</td>
<td>150 mm steel lined to 75 m depth fitted with a motorised pump</td>
</tr>
<tr>
<td>Sediments with aquifers greater than 120 m</td>
<td>150 mm steel lined to 150 m depth fitted with motorised pump</td>
</tr>
<tr>
<td>Sediments with very deep aquifers c. 300 m</td>
<td>150 mm steel lined to 300 m depth fitted with motorised pump</td>
</tr>
<tr>
<td>Sediments with aquifer depths greater than 600 m</td>
<td>150 mm steel lined to 600 m depth fitted with a motorised pump</td>
</tr>
</tbody>
</table>

### Tables 2 Borehole designs used by state rural water supply agencies

<table>
<thead>
<tr>
<th>Organisation</th>
<th>To 50 m depth on the crystalline terrain for handpumps</th>
<th>To 75 m depth on sediments fitted with motorised schemes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hadejia Jammaare River Basin Development Authority</td>
<td>110 mm diameter uPVC</td>
<td>150 mm diameter uPVC</td>
</tr>
<tr>
<td>Kano State RUWASSA</td>
<td>110 mm diameter uPVC</td>
<td>150 mm diameter uPVC to 80m</td>
</tr>
<tr>
<td>Rivers State RUWASSA</td>
<td>110 mm diameter uPVC</td>
<td>150 mm diameter uPVC to 80m</td>
</tr>
<tr>
<td>Lagos State RUWASSA</td>
<td>150 mm diameter uPVC</td>
<td>150 mm diameter uPVC</td>
</tr>
</tbody>
</table>

**Open holes**

All drilling contracts in the country specify that boreholes are lined the full depth despite the inherent strength of the underlying hard rock formation on the Basement Complex. Most drillers reject the idea of an open hole because of the possibility of the material from the weathered mantle migrating down and blocking the hole. Better the extra cost of lining material than the risk of losing the entire hole.

**Principle 6: Contract Management, Supervision and Payment - Adequate arrangements are in place to ensure proper contract management, supervision and timely payment of the drilling contractor.**

**Contract management and payment**

Public contracts are awarded in the country based on well established government systems. Contract documents are prepared comprising the general conditions, technical specifications and bill of quantities. It is the law that public sector procurements are based on approved budgets and that payments are made within 60 days. Payments are however often delayed far beyond the 60 days stipulated and drilling contractors are too weak to challenge the delay and invoke the penalty clause for delayed payment. This is one of the reasons why many conventional drilling contractors accept to work as sub contractors to the “brief case” drilling contractors as they can get a substantial advance payment and also as this is a private arrangement the subcontractor does not have to wait until the main client (government) pays, for the final payment.

**Supervision**

The percentage of non functional boreholes in the country could in some states be up to 60% (Keast, 2007). This can be attributed in part to poor supervision of construction of boreholes and installation of pumps. Past successful projects such as the Agricultural Development Project and the Petroleum Trust Fund rural water supply projects, engaged consultants to carry out siting and supervision of the boreholes. Supervision is rather weak on recent projects because of;
• the “no water no pay” policy
• most projects do not budget for supervision
• lack of experienced personnel to carry out the supervision

Not paying for dry holes lulls the client into believing that what is most important is the post construction supervision which in reality is a site inspection to check that the facility is functioning. There is thus no budget for full time supervision where there is a supervisor on every site from mobilization to demobilization and defects liability period.

There is also a shortage of trained and experienced personnel available for supervision. Supervision, where carried out at all is often by inexperienced young geologists who cannot stand their ground against experienced drillers they are supposed to be supervising. Most of the senior hydrogeologists in the public service are involved in administration. Those in the private sector have been lured into the ranks of drilling contractors as there is no continuity of engagement as supervising consultants.

Principle 7: Data and Information - High quality hydrogeological and borehole construction data for each well is collected in a standard format and submitted to the relevant Government authority.

and

Principle 8: Database and Record Keeping - Storage of hydrogeological data is undertaken by a central Government institution with records updated and information made freely available and used in preparing subsequent drilling specifications.

Up till the 1980s, the Geological Survey Department was the repository of data from all boreholes. There was a Form GS 10 – Borehole Completion Record which was filled by drilling companies and submitted to the Geological Survey Department. The system fell into disuse in the 80s and thousands of boreholes have been drilled without any central collection point for the data generated. The National Code of Practice for Water Well Construction in Nigeria has tried to revive this system. It has developed forms for both borehole drilling permits and borehole completion record which must be obtained, completed and deposited with the National Water Resources Institute. The Code of Practice was published in 2009 and its impact is yet to be felt.

It must be stated that the “no water no pay” policy and the lack of adequate supervision also means that when a borehole is dry, the contractor is not obliged to submit the data on the borehole. Yet dry boreholes are an essential source of useful information.

Principle 9: Monitoring - Regular visits to completed boreholes are made to monitor their functionality in the medium as well as long term with the findings published.

According to the National Rural Water Supply and Sanitation Program Strategic Framework (2004) the local governments and state rural water supply agencies have the responsibility for monitoring borehole functionality and support the communities in the maintenance. The communities have the responsibility for operating and maintaining the water facilities in their communities. Monitoring and maintenance are weak hence the large number of non functional boreholes in the country. Both the local governments and state agencies presently lack the capacity to monitor the large number of boreholes within their areas of operation. Until the situation improves there will continue to be a lot of wastage in borehole provision. External support agencies and NGOs have been assisting some states to increase their capacity for monitoring and maintenance.

Conclusions and Recommendations
The Federal government of Nigeria by the Procurement Act and the National Code of Practice for Water Well Construction in Nigeria has put in place systems and the legal framework that could lead to cost effective borehole provision in the country but the systems are yet to be implemented in their
Contract award process still has to be made more transparent by ensuring that contracts are awarded to only licensed drillers and National Code of Practice for Water Well Construction enforced.

The Water Well Drilling Association needs further support in its attempt to professionalise borehole drilling in the country. The country needs to define its drilling capacity and identify the committed and professional drilling contractors.

The weakest link in cost effective borehole provision in the country is inadequate supervision and the associated non payment for dry boreholes. Clients should take responsibility for siting and supervision. Competent personnel should be trained and consultants identified to supervise borehole construction.

References