



The Republic of Uganda

**MINISTRY OF WATER AND ENVIRONMENT**

**DIRECTORATE OF WATER DEVELOPMENT**

**SUPERVISOR'S MANUAL FOR  
DRILLING AND TESTPUMPING**

**March 2007**

**(Water and Sanitation Sector District Implementation Manual Annex 8.2)**

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## **1.0 INTRODUCTION**

This manual has been produced as a practical guide for Supervisors of private sector Contractors involved in construction and test pumping of rural water supply boreholes. It is envisaged that the manual will be used by consultants under contract to District local Government to undertake supervision and District staff who managing such contracts. As well as constituting a Supervisors guide, the manual also outlines various general aspects of borehole drilling, development and test pumping, and provides a summary of the broad principles of contract management.

## **2.0 GROUNDWATER AND THE HYDROLOGICAL CYCLE**

Groundwater refers to sub-surface water that occurs beneath the water table in soils and geological formations that are fully saturated. Examples of such geological formations include gravel, sand, sandstone, weathered granite and gneisses, and schist.

### **2.1 THE HYDROLOGICAL CYCLE**

The term 'Hydrological Cycle' refers to the continuous circulation of water between oceans, rivers, lakes, the atmosphere and the land surface.

The main components of this cycle are Rainfall, Runoff (to the rivers, lakes and oceans), Infiltration (to the groundwater body), Evaporation and Evapotranspiration and Discharge (from groundwater via springs). These components are illustrated in Figure 1 below.

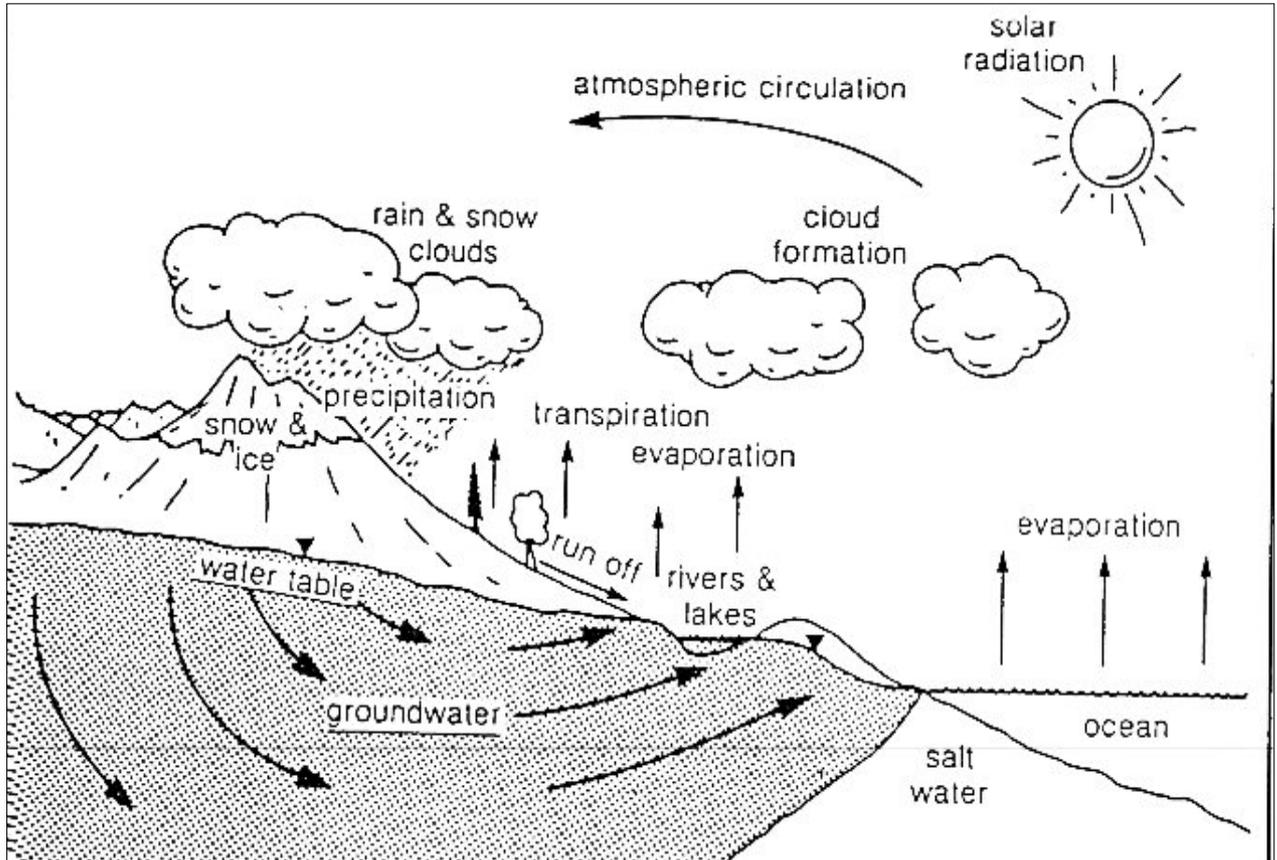
The surface component of the Hydrological Cycle is called Runoff, in which some of the Rainfall concentrates to form rivers and streams which flow to lakes and oceans.

Some of the Rainfall also percolates into the ground to form shallow aquifers which may be tapped by shallow wells and which may discharge as springs. Some of this shallow groundwater may also infiltrate further down into fractures in the underlying rock, which moves as base flow along the fractures. This deeper groundwater may then provide water to boreholes that draw water from the fractures. At both the shallow and the deeper levels groundwater flows laterally, generally following the topographic slope, towards surface water bodies which form the groundwater base level and which (often) constitute areas of groundwater Discharge. These surface water bodies, as well as areas where the groundwater is very close to the surface, are where direct Evaporation and/or Evapotranspiration occurs, and from where water is returned as water vapour to the atmosphere.

### **2.2 GROUNDWATER**

Where groundwater occurs unconsolidated material (soils; overburden) or in consolidated but porous geological formations (sandstone) it exists in spaces between the solid particle matrix. Particles that are large (like those of sand) also have large (pore) spaces between them, and thus will allow water to move

through them more easily, whereas formations with fine particles (like clay) will have small pore spaces and will not allow water to move through them easily. In Uganda saturated soils, sand and weathered rocks (collectively termed ‘overburden’) frequently constitute shallow aquifers, which will yield water to shallow dug or drilled wells (Figure 1).



**Figure 1. Occurrence of Groundwater**

In the case of massive consolidated rocks such as granite, gneiss, quartzite etc (collectively termed bedrock), there are no pore spaces and water does not penetrate the rock mass at all. Groundwater can only infiltrate into and exist in such rocks in fractures and other fissures. Any aquifers in these formations are termed ‘fracture aquifers’. Such fracture aquifers are usually relatively deep (30–100 metres below surface), are usually of limited dimensions and may or may not be interconnected with other similar aquifers. Fracture (bedrock) aquifers will most often provide relatively higher yields to deeper drilled boreholes than shallow (overburden) wells, since fractures allow easier and more rapid groundwater flow than pore spaces in overburden materials.

### **Groundwater Movement**

The natural level of groundwater in an aquifer is termed the ‘water table’, except in circumstances where the groundwater is under natural hydrostatic pressure (is ‘confined’) when it is termed the ‘piezometric surface’. The water



## **3.0 COMMON DRILLING METHODS**

### **3.1 MUD ROTARY DRILLING**

In this method of drilling the borehole is created by a drilling bit attached to the bottom of set of drilling rods which are of a lesser diameter than the bit and which are rotated by means of a hydraulically driven drive unit on the drilling rig. The rotation of the bit together with the weight of the drilling 'string' (ie the drill rods, any drilling collars used to provide weight, and the bit itself) cuts and breaks up the rock/soil as it penetrates the formation. In order to remove this broken material a circulating fluid (loosely termed 'drilling mud') pumped via a number of 'mud pits' is used.

In a conventional fluid flush system drilling mud is pumped from a 'suction pit' through the rotating drilling string and out through holes in the drill bit. This mud picks up the soil/rock materials cut by the bit in the bottom of the bore ('cuttings'), then flows upward in the 'annular space' between the drill rods and the wall of the borehole, carrying the cuttings to the ground surface and clearing the hole. The drill string and bit will then continuously move downwards and deepen the borehole. The greater the fluid flow, the more efficient the hole cleaning process and, in general, the faster the drilling penetration.

At the surface, the returning drilling fluid (drilling mud + cuttings) flows to a 'settling pit' where the cuttings are allowed to settle out of the fluid to the bottom of the pit. From the settling pit the recovered fluid then overflows back into the suction pit from where it is sucked up by the mud pump and re-circulated again through the drill string.

### **3.2 AIR ROTARY DRILLING**

The essential components of the air rotary method are the same as the mud rotary method, except that compressed air is used as the circulating fluid that is forced down the drill string, through the drill bit and back via the annular space to the surface. The cuttings are forced up through the annular space by the pressure the ascending velocity of the air, and are carried to the surface. At the surface the cuttings are collected either in a bucket trap or an 'extractor'.

This drilling method requires no mud pits or pump, but the efficiency of the hole cleaning and hence drilling penetration is very much influenced by the volume and pressure of the air (ie the capacity of the compressor).

### **3.3 AIR PERCUSSION DRILLING**

This drilling method is the now most commonly used in Uganda, and is essentially the same as the air rotary method, except that air pressure is used to operate a down hole percussion 'hammer'. The hammer relies upon percussive impact and rotation rather than solely rotary action to break up the rock and

create the borehole. Cuttings produced by the hammer are similarly returned to the surface by the rising column of air, with the rate of penetration and the efficiency of hole cleaning depending greatly on the pressure and volume of the compressor.

A very significant advantage of this method of drilling is that the percussive action of the hammer bit (which is usually tipped with hardened tungsten carbide 'buttons') allows the rapid penetration of hard formations which may not be easily penetrated by the rotary method.

### **3.4 'CABLE TOOL' PERCUSSION DRILLING**

A cable tool percussion rig operates by repeatedly lifting and dropping a heavy string of drilling tools on a cable into the borehole. The heavy solid steel drill bit on the bottom of this string mechanically breaks or crushes consolidated rock into small fragments. If water is present in the penetrated formation the crushed rock will form a 'slurry'; otherwise water must be added to the hole to create the slurry.

As drilling proceeds slurry accumulation increases and eventually reduces the percussive impact of the drilling tools. When the penetration rate becomes unacceptable, the slurry is removed at intervals from the hole by a sand pump or bailer. Bailers used to remove the slurry consist of a pipe with a simple check valve at the bottom, which is open as the bailer is dropped into the slurry, but closes as the bailer is raised. A sand pump or suction bailer is fitted with a plunger so that an upward pull on the plunger tends to produce a vacuum that opens the valve and sucks sand or slurred cuttings into the tubing.

Although the cable tool percussion drilling method requires relatively unsophisticated equipment and is adaptable to varying geological environments (both soft and hard formations), it has the disadvantages that the penetration rate is generally slow (particularly in hard rocks). It may also be difficult to ensure a truly straight hole (due to the absence of a rigid drill string), particularly in hard fractured formations.

## **4.0 RESPONSIBILITIES OF THE SUPERVISOR**

The Supervisor is the representative of the Client (or Employer) at the drilling or test-pumping site. In the context of this manual the Supervisor may be either an employee of District local Government, or an employee of a Consultant appointed to provide supervisory services, although usually the latter is the case.

The primary role of the Supervisor is to ensure that the Contractor executes the Contract according to the Conditions and Technical Specifications of the Contract. At the same time, the Supervisor must act in the best interests of the Client (or Employer) in order to achieve Contract completion within the budget and time approved for the Contract. The Supervisor must thus make decisions on site that ensure professional workmanship to the highest standards, that minimise costs to the Client, that maximise efficiency of operation, and that wherever possible ensure a harmonious working relationship with the Contractor.

### **4.1 SUPERVISION REQUIREMENTS**

With respect to both drilling and test pumping supervision the output of the Supervisor is largely similar and should be adapted from the list below as necessary for each activity. Supervisor's outputs shall be:

- The contractor and supervisor must be familiar with and agreed on the borehole design. This is based on the siting report.
- Supervisor's logbook with daily entries.
- Minutes of site meetings between contractor, consultant and District Staff.
- Written site supervision instructions to the contractor, including decision regarding final drilling depth and installation of casing and screen.
- Certification of contractor's borehole record.
- Certification of contractors monthly statements and preparation of payment certificates.
- End of drilling report.
- Report covering number of boreholes for a particular contract schedule.
- Certification of completion of works.

The following forms must be completed for each borehole:

- *“Daily log for drilling supervision”*
- *“Borehole Pump Test Supervision”*

- “Check list for various materials and equipment to be provided by the Contractor during drilling, installation of casing and screen, development and test pumping”.
- *Feedback form* which compares drilling log with geophysical survey
- *Performance Evaluation form* (after drilling work is completed)

#### **4.2 DUTIES AND RESPONSIBILITIES OF THE SUPERVISOR**

The duties and responsibilities of the Supervisor shall also include, but not be restricted to, the following:-

- Issuing necessary instructions using a triplicate book so that the Consultant keeps a copy of all instructions given, and one copy can be filed in the project file. All instructions shall be clearly written, dated and signed.
- Be responsible for the decision on final drilling depth and screen positions during borehole construction.
- Monitor and supervise all drilling operations, construction supervision (whether temporary or permanent), borehole development and test pumping. Ensure that all operations are performed in a professional manner and to the best standard of workmanship, in accordance with the relevant clauses in the Contractors contract (Technical Specifications).
- Fill in all pertinent data sheets showing operations, instructions, events and measurements, number of installed casings/screens, observations on penetration rate and geological conditions, test pump data etc. for documentation. Present the data sheets to the Project Manager (either the Consultant or District ) at the completion of work at each site.
- Prepare “Daily Log for Drilling Supervision” and “Borehole Pump Test Supervision”, for each borehole.
- If any incident take place which influences the performance of work which is not in accordance with the specifications in the contract or the work plan, the Supervisor shall note this and ensure it is signed by himself and the Contractor. Subsequently, the Supervisor shall inform the Project Manager of the incidence and any decisions made.
- Measure and inspect all borehole lining materials before installation to ensure that they meet the contract prescribed specifications, are of new stock, undamaged, with no deformations and are of correct dimensions. Inspect all filter pack before installation.
- At regular intervals inspect the Contractors base camp, the set up and all stored materials and satisfy himself that materials and storage conditions are appropriate and according to the contract. Upon abandonment of camp ensure that Contractors' clean up of the site is satisfactory.

- Participate in scheduled meetings as required by either the Consultants or the Contractors Contract, normally every month, and prepare minutes of these meetings.
- Approve the Driller's reports and verify and approve the Contractor's payment certificates and monthly statements for work done.
- Present a report on each group of boreholes drilled during a particular signed contract schedule.
- Complete the feed back form relating the information obtained from drilling to the information derived during the hydrogeological and geophysical investigations.
- Prepare Certificate of Completion of Works

## **5.0 CONTRACT PRE-COMMENCEMENT CHECKS**

### **5.1 ACCESSIBILITY**

Before the drilling rig and equipment is taken to the selected drilling sites for the construction of boreholes, the following should be noted:

- The road tracks leading to the selected drilling sites should be repaired or cleared.
- Trees and/or branches close to the roads should be cut so that there is no obstruction when transporting the equipment.
- The Contractor and the Supervisor must inspect the roads and the selected sites to make sure that the drilling rig and all the equipment can reach safely. ( Please note that this is supposed to be carried out by the siting hydrogeologist and community mobiliser)

### **5.2 SITE INSPECTION**

Any sites selected for drilling should always conform to the following:

- The ground around the site should be firm and solid for proper jacking up during rigging up.
- Sufficient space around the site should be cleared by the villagers (future water source users) of any tree stumps and any other obstacles to the drilling rig and equipment.
- For safety precautions, the community around the drilling site should construct a perimeter fence with enough inside working space.
- The community near the drilling site should construct a temporary shelter. The shelter will act as a working place for the Supervisor and the Contractor and as a temporary store for the drill samples.
- Sanitation conveniences should be ensured near but not very close to the drilling site.
- The Supervisor and the Contractor in consultation with the local authorities should select suitable areas for the Contractors mobile camp, which should be inspected at intervals to ensure adherence to environmental guidelines.

### **5.3 EQUIPMENT AND MATERIALS INSPECTION**

(A check list of standard equipment)

All machinery and equipment provided by the Contractor must be inspected by the Supervisor and the Clients representative at the Contractor's yard at the start of the contract, and after every 5 boreholes. The purpose of the inspection

is to verify the specifications and state of repair of all major items of drilling plant. Particular emphasis should be placed on the following: diameters and state of drilling bits; number, diameter and length of drilling rods and temporary casings, and state of repair of service trucks.

**Some of the major items to be inspected should include the following:**

- i. Drilling rig (top head drive, air rotary percussion)
- ii. Compressor (700 cfm or greater, truck or rig mounted)
- iii. Support truck (at least one per drilling team)
- iv. Water tank (truck or trailer mounted)
- v. Light support vehicle (preferably 4WD pickup)
- vi. Tricone roller bits
- vii. Drag bits
- viii. DTH button bits
- ix. Temporary casings
- x. Drilling rods - total length about 120m with max. diameter 4 ½"
- xi. Grouting pump and accessories, including tremmie pipes.
- xii. Hammers (to accommodate different bits)
- xiii. Borehole caps (wooden)

#### **5.4 STAFF INSPECTION AND FAMILIARISATION**

The Contractor should always introduce the drilling crew to the Supervisor. The staff should include the Driller himself, technician, helpers and camp attendants.

The Supervisor should inform the drilling crew about the whole programme and how it will be accomplished.

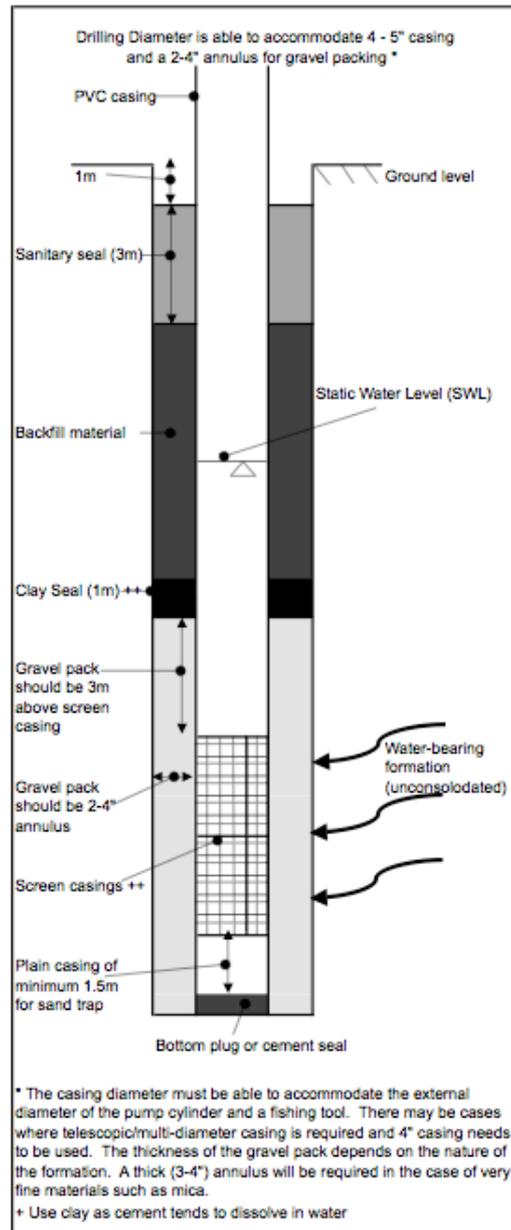
According to the locations of the selected sites, a drilling programme should be established by the Contractor in co-operation with the Supervisor. This programme should be maintained for easy communication with the Project Office (PO) headquarters in Mbale. Any change in the programme should be communicated immediately to the District Water Office via the Supervisor.

*In the case of a Consultant supervised contract all formal communication from the Contractor to the Client (or the Employer) should be through the Consultant. Only the Client (or the Employer) is supposed to communicate with the public e.g. the press and Govt officials, about the whole exercise of drilling for that contract period.*

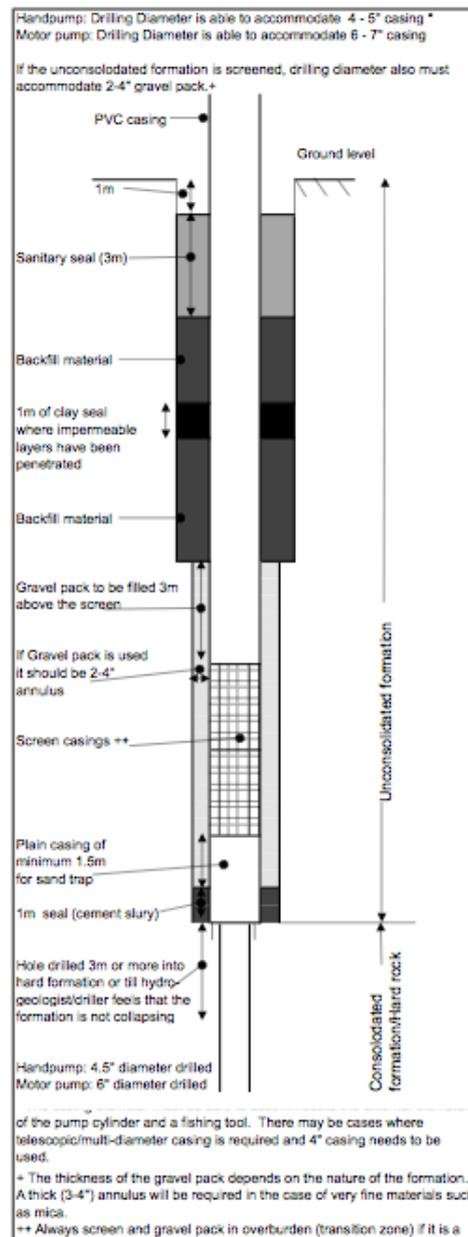
## 6.0 DRILLING SUPERVISION

Figure 1 and Figure 2 set out the recommended well designs for borehole drilled in unconsolidated and consolidated formation respectively. It should be noted that the key in terms of drilling diameter is that the pump cylinder can be installed, and, in the case of unconsolidated formation, that a 2-4" annulus of gravel pack can be inserted, depending on the nature of the fines.

**Figure 1 Drilled well design for unconsolidated formation**



**Figure 2 Drilled well design for consolidated formation/hard rock**



Borehole construction can be divided into five main operations. These are:

- drilling the hole,
- installing plain and screen casings,
- cement grouting for sanitary seals,
- installing filter pack,
- developing the borehole to ensure sand and silt free water.

Supervision requirements for each of these operations are noted below.

## **6.1 INITIAL INSTRUCTIONS AT THE BEGINNING OF A HOLE**

The Driller should be given instructions, which must be signed by both the Supervisor and the Driller, on the following:

- To drill the borehole at the exact locations where the peg was placed by the surveying Hydrogeologist.
- To align the machines properly during rigging up in order to drill a plumb borehole.
- To note date/day/time when drilling of the hole commences.
- To record all details on borehole location, and to enter all details of subsequent construction activities as they take place.

## **6.2 INSTRUCTIONS DURING DRILLING**

- To drill through the overburden using either a drag bit or a DTH up to the hard weathered rock. If the formation is collapsing, to use foam (biodegradable polymer), or temporary casing, to stabilise the walls of the hole.
- When hard formation (rock) has been reached, to pull out the drill string and the bit. To drill 4-6 m into the hard formation using a 4 ½" diameter DTH bit to prove that the formation is bedrock and not a hard band in the weathered zone.
- To continue drilling with the 4 ½" diameter DTH bit to final depth. The final drill diameter in hard formation must be able to accommodate the pump cylinder (115mm or 4 ½" in the case of a handpump) and (150mm or 6" in the case of a motorised pump). This can be achieved by reaming the hole.
- To estimate the yield in m<sup>3</sup>/h during drilling process and development. The estimation should be done using a calibrated bucket.
- To monitor drilling penetration rates and record any sudden changes in penetration rate and blowouts yield.
- To monitor daily drilling progresses and keep records. This should be done independently from the driller's log.

- To note daily drilled depth, first and main water struck depth at which diameters change, depth and length of screen etc.
- To note reasons for stopping drilling, reasons for shutting down of drilling rig should be adequately recorded with date and time. (e.g. breakdown of equipment, weather conditions or ground conditions etc).

**As a guideline, the final depth of the borehole will depend on the following:**

- If the Supervisor, based on observations during drilling and especially the airlift tests, feels convinced that the borehole will give a sustainable yield at 1000 l/hr., the drilling should be stopped.
- The drilling should be stopped if the Supervisor concludes that the probability of finding more water-bearing zones at greater depth is very low.
- The drilling should normally be stopped at the depth indicated in the borehole siting report, unless the yield is low and at this depth there is a clear indication that more water bearing zones may be found at greater depth.
- When deciding the final completion depth, the Supervisor should allow for 'sump' of 3 metres at the bottom of the hole.
- For any boreholes that are to be hydrofractured, the depth of drilling into hard rock should be as per guidelines provided by the Client (or the Employer).

### **6.3 OPERATIONAL GUIDELINES DURING DRILLING**

The Supervisor should take note of the following operational guidelines during drilling, and should issue appropriate written instructions to the Driller as necessary. All items noted below form part of the Contractors obligations under his contract.

#### Formation sampling

- The Driller should collect representative lithological samples of the strata penetrated for each change of colour or texture, or 1m interval, and in a continuous order. The Driller should always take every precaution to guard against sample contamination or mixing during the sampling process.
- The representative samples should not be washed.
- The Supervisor should do the geological logging of the lithological samples.
- The Driller should ensure that samples are put into suitable bags or tubes labelled with the following: location data, borehole number and depth intervals, and stored such that they will not be contaminated by site conditions or drilling operations.

- Samples of each drill hole should be kept separately in sealed boxes and delivered by the Contractor to the Department of Geological Surveys and Mines, Entebbe.

#### PVC Plain Casings (4" diameter for handpump, 6-7" for motorised pump)

After drilling through the overburden (collapsible formation), if no substantial amount of water is struck PVC plain casings should be installed into the hard rock and grouting undertaken. Approximately 0.5 m of casing should be left above the ground surface.

#### PVC Screens (4" diameter for handpump, 6-7" for motorised pump)

If enough water is struck in the overburden aquifers, PVC screens should be installed to tap this water. The casing string should have one plain casing at the bottom followed by the specified number of screens, with more plain casings placed at the top to prevent collapse of topsoil.

**N.B.** The Supervisor must always carefully record the number of PVC (plain casings and screens) used on each borehole.

#### Cement Grouting

With respect to this operation the following should be noted:

- Cement for mixing of slurry must be clean and free of lumps. If any small lumps are found in the dry cement, these must be sieved out.
- The cement slurry should be mixed in a clean and empty oil drum.
- The slurry should be prepared by mixing 24 litres of water per 50 kg of cement.
- Mixing should be done vigorously to obtain uniform slurry.
- The slurry (grout) should be injected into the annulus between the casing and the walls of the hole using a tremmie pipe. It is not acceptable for the Driller to pour the grout down the hole, as it may clog the screens and will probably not reach the bottom of the casing string as intended.

**NB.** The Supervisor should be carefully record the amount of cement used on each borehole (in bags).

#### Gravel Packing

Gravel should consist of well-rounded particles of uniform grading. The size of the gravel should be of uniform grading between 2.5 and 4.0 mm and shall comprise 90% siliceous material and must contain no clay, shale, silt, fines, excessive amounts of calcareous material or crushed rock. The following point should be noted:

- After installation of casings and screens and after grouting has been completed, the annular space between the sides of the drilled hole and the screens should be filled with gravel pack.
- Sufficient gravel pack should be placed against the screens i.e. from below the lowermost screen to above the uppermost screen. The gravel pack should extend to approximately 2 m or more above the uppermost screen to allow for settling during well development.
- The gravel pack should be capped with a clay seal (pure clay) to prevent contamination via the annular space.

**NB** Amount of gravel (in 100 kg bags) used on each borehole should be carefully recorded by the Supervisor.

#### Back-filling the Borehole

The annular space above the clay seal should be back-filled with inert drill cuttings. The upper 4m of annular space should be left, of which 3m should be sealed with cement slurry. The uppermost 1m should be left for pump pedestal construction.

#### Well Development

The main objective of well development is to remove finer materials like native silts, clays, sand, drilling fluid residues deposited on the borehole walls during the drilling process from the borehole and immediate surroundings (gravel pack and the aquifer). The pack and the aquifer are cleaned and opened up so that water can flow into the well more easily. The following points should be noted:

- The well should be developed before the borehole is back-filled up to ground level. The reason for this operation is that the gravel pack around the screens will settle and become compact during development, and therefore more gravel has to be added up to the design level, before any other back-fill is put into the borehole.
- Development can be done by either of the following methods:
  - Continuous airlift until water is free from sediment OR
  - Intermittent airlift development. The cycles to be determined depending on the rate at which water is clearing. Typical cycles are 10 minutes airlifting followed by 5 minutes recovery. Intermittent airlifting should be carried out until water runs clear to the satisfaction of the Supervisor.
- The Supervisor should always accurately record date and duration in hours for well developing. After well development, the plant can be rigged down.

### **6.3 INSTRUCTIONS AT THE END OF DRILLING**

### Sealing the Borehole

The upper 4m of annular space should be left, of which 3m should be sealed with cement slurry to provide an effective seal against entry of contaminants.. The uppermost 1m should be left for pump pedestal construction.

### Capping the Borehole

The borehole should always be capped with a wooden cap after well development.

A borehole reference number should be marked on the borehole casing above the ground surface,

### Clearing the Drilling Site

On completion of the construction of the borehole the site should be left clean and free from all debris, hydrocarbons and all sorts of waste. All dug pits should be filled with soil or murrum free of hydrocarbons. Only then can the drilling plant and equipment be transferred to the next drilling site on the programme.

### Low Yielding and Dry Boreholes

Boreholes drilled in unconsolidated formation (Figure 1) with yields less than 300 l/hr or which are completely dry should be back filled with native soil from the bottom to within 3 m from the ground. Two metres are then to be sealed by concrete, cement grout or neat cement, with upper 1 m of the borehole back filled with native soil.

Boreholes drilled in consolidated formation (Figure 2) are not to be back filled but should be capped whether they are low yielding or are completely dry.

## 7.0 TEST PUMPING SUPERVISION

For every successfully drilled borehole it is important to carry out test pumping. This will provide data on aquifer performance and the quantity of water that can be drawn out in a given time. The data is also used to determine the optimum depth at which to place the pump.

During test pumping a sample of water (1–2 litres) is collected and taken to the laboratory for analysis of physico–chemical properties in order to determine potability and acceptability. *It should be stressed that there are agreed water quality as well as quantity limits below which no installation of hand pumps is permitted.*

### 7.1 TEST PUMPING PROCEDURES

#### Step Tests

Such tests are only considered viable or useful if the borehole indicates an airlift (Driller's) yield of greater than 1500 l/hr. In this case a step test comprising a minimum of 4 sequential steps with each step being of 60 minutes duration should be undertaken in order to determine well characteristics. The Supervisor should set the range of discharges such that a reasonable spread of yields is obtained, with the first step being undertaken at the minimum acceptable hand pump yield of 800 l/hr. If possible the increment in discharge between the minimum and maximum yield should be at least 300%. The final draw down for the first step can be used in determining the optimum depth at which the hand pump (U3) should be set. Data from other steps at higher yields with greater draw down can subsequently be used to determine other borehole (and aquifer) characteristics.

The Supervisor must ensure that the Contractor records the initial test information and collects data during the test at the frequency required. The specifications for step testing should form part of the Contractors contract.

The Contractor should also record water quality parameters (pH, Total Dissolved Solids and/or Electrical Conductivity) at least twice during each step, at 30-minute intervals.

#### Constant Discharge Rate

If the borehole indicates an airlift (Drillers) yield of less than 1500 l/hr, a constant rate test should be undertaken at a discharge close to this airlift yield, or at 800 l/hr, whichever is the lesser. The length of the test should be as provided for in the Contractors contract, or for a minimum period of 3 hours. However, if draw down is minimal (implying that the Driller may have grossly under estimated the airlift yield), the Supervisor may consider repeating the test at a higher yield.

The Supervisor must ensure that the Contractor records the initial test information and collects data during the test at the frequency required. The specifications for constant rate testing should form part of the Contractors contract; if not, then data collection should be as per the form attached in the Annex to this manual.

Water quality parameters (pH, Total Dissolved Solids and/or Electrical Conductivity) should also be recorded by the Contractor at least twice during the first 60 minutes, at 30 minute intervals, and thereafter every 2 hours.

#### Recovery Monitoring Test

At the end of both the tests discussed above, the Supervisor should ensure that recovery monitoring is undertaken. This test also provides information on the production capabilities of the aquifer and acts as a back up where error may have occurred during the draw down tests.

The Supervisor should ensure that recovery measurements are taken for a minimum period of not less than 25% of the total pumping period, at the same frequency as during the draw down test.

## **7.2 PRE-TESTING CHECKS**

The Supervisor must ensure that all the required equipment and tools are on site and in good working order before starting the test pumping. In addition, it should be confirmed that the Contractors technicians on site are the ones specified in the contract documents. Any staff alterations can only be made with the consent of the Client (or Employer).

A list of standard equipment that should be expected at a test-pumping site is presented below:

#### Pumping System

On the basis of earlier testing results, most of the aquifers to be tested have a yield in the range 0.5 m<sup>3</sup> /hr to 4 m<sup>3</sup> /hr. It is therefore important that the Contractor has on site suitable submersible pumps to accommodate these yields. A non-leaking valve system for adjusting discharge rate must also be available.

The riser pipes (or hose) for suspending the pump in the borehole should be 50.0m, or at least long enough to install the pump at depth specified by the Supervisor.

The discharge (delivery) pipe should also be at least 100 m in length to ensure water is discharged at an adequate distance from the borehole.

A diesel/petrol generator able to reliably power the pump during tests without failure during the required pumping time is essential. The generator should be filled with enough fuel to complete the test, preferably a full tank

### Discharge Measurement

Calibrated containers should be available for measuring the rate of discharge of the water. For low discharges these should preferably be 10 or 20 litre buckets, with a drum of 100 or 200 litres for higher discharges.

An accurate and reliable stopwatch should be available for measuring the rate of discharge (time taken to fill a calibrated container), and to record time intervals for measuring water levels during draw down and recovery monitoring.

### Water Level Measurement

An electric contact gauge incorporating an accurately calibrated measuring tape (accurate to 5mm) must be available for measuring the static water level, and for monitoring the dynamic water level during the draw down test and recovery monitoring.

### Water Quality Monitoring

For regular measuring of the electric conductivity and pH of the discharge water (as per the test specifications), suitable portable digital meters should be provided by the Contractor. These meters should be reliable (good batteries) and should be calibrated prior to the start of testing.

To enable the collection of water samples for submission to the laboratory the Contractor must provide a suitable number of clean 1liter plastic sample bottles with tight fitting caps. The number of bottles will depend on the testing schedule, and any requirements for 'acidified' bottles will be as per set out in the Contractors contract document.

## **7.3 INSTRUCTION AT THE BEGINNING OF TEST PUMPING**

On the basis of information obtained from the drilling reports and in accordance with the relevant clauses in the Contractors contract, the Supervisor should issue written instructions to the Contractor on site before commencement of the test pumping. Such instructions may be subject to modification during the course of the test, but any modification made by the Contractor must be with the approval of the Supervisor. Key instructions to be issued by the Supervisor at the beginning of a test should include the following:

- On arrival at site, the location details of the site should be entered on an approved test pumping data sheet.
- After removing the borehole cap, the static water level should be measured and recorded.

- The entire riser pipe and pump assembly should be examined to ensure all are securely connected, and then installed to a depth specified by the Supervisor.
- Immediately after switching on the pump, the gate valve should be adjusted to about 800 l/p/h for the 1<sup>st</sup> step of the step test, otherwise set to the recommended yield for a constant rate test. The initial discharge rates must be confirmed using the calibrated container.
- The step test should be for 60 minutes each step, while the constant rate test should be for three hours or until the Supervisor feels the dynamic water level has attained equilibrium.

#### **7.4 INSTRUCTIONS DURING TESTING OPERATIONS**

Additional instructions to be given to the Contractor during the course of the testing operations may include the following:

- The discharged water should be disposed of beyond the radius of influence of the test on the aquifer. The distance should be at least 100m from the borehole, but may be reduced or increased where deemed necessary by the Supervisor.
- Readings of the dynamic water levels should be taken in accordance with the time intervals specified on the test pumping test sheet. Each step during a step test should be recorded on a separate sheet.
- Electrical Conductivity and pH measurements should be taken periodically and whenever required by the Supervisor.
- Water samples should be collected as specified in the Contractors contract, or as required by the Supervisor.
- The Contractor should note any changes in watercolour, discharge rates and technical failures during the entire operations.
- The final step of the step test should not lower the final dynamic water level to less than 3m above the level of the pump.
- The pump should be switched off at the end of the final step, and monitoring of aquifer recovery should commence immediately. If feasible within the time allowed (i.e. 25% of the total testing time) the water level should recover to 95 % of the draw down before recovery monitoring is terminated.

#### **7.5 INSTRUCTIONS ON COMPLETION OF TESTING OPERATIONS**

After completion of the testing schedule at any particular site, instructions from the Supervisor to the Contractor may include the following:

- After recovery monitoring, the equipment should be taken out of the borehole with care to avoid the pump or pipes falling back into the borehole.
- The borehole capping should then be replaced and protective branches put around the borehole.
- The site should be cleared of any foreign materials introduced during the testing.
- Any water samples collected by the Contractor should be passed on to Supervisor before the Contractor leaves the site. The Supervisor should ensure that samples are delivered to the laboratory within 7 days of being collected.