Guidance Note

Borehole Drilling Supervision

February 2015

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1. Purpose of this Guidance Note

This guidance note has been prepared by Concern Worldwide to assist geologists and engineers in charge of the supervision of borehole construction as well as programme managers. This guide details the responsibilities of the drilling supervisor at the different stages of borehole construction. It explains the actions to be carried out at each stage that will ensure that the driller delivers the borehole as specified in the contract. The supervisor is expected to display great professionalism in carrying out his or her duties. Good knowledge of geology, hydrogeology and borehole construction is essential. The supervisor represents the client and is therefore expected to act with honesty, impartiality and fairness in any dispute over the contract.

2. Objective of Borehole Drilling Supervision

To generally represent Concern Worldwide in all technical matters and issue directives concerning the details of the technical specification and the execution of the Work in accordance with the contract document. Good supervision is essential for a high quality bore-hole, even if a competent drilling contractor is employed. Without good supervision, the quality of the work may be compromised. Good supervision of borehole drilling is essential for the provision of long-lasting boreholes.

A well-constructed borehole continues to function through the lifespan of 20 to 50 years. In some African countries, as many as 60% of groundwater sources are not working. Poor borehole construction contributes to this alarming figure. One of the best ways to tackle this problem is to improve the quality and professionalism of borehole drilling including supervision (Rural Water Supply Network, 2014)

3. Understanding of the Contract document

The following documents shall be deemed to form and be read and construed as part of the drilling contract:

(a) the contract (terms and conditions),
(b) the technical specifications,
(c) the design documentation (drawings),
(d) the completed price schedule (after arithmetical corrections)/price breakdown,
(e) General Conditions of contract
(f) the tender submitted by the contractor,
(g) any other documents forming part of the contract.

The drilling supervisor must read and understand all the clauses in the contract so as to ensure adherence of the same throughout the drilling process.

4. Type of Supervision

While supervision can be (a) Part time milestone supervision, (b) end of contract supervision, or (c) Full time supervision, Concern worldwide adopts **full-time supervision** whereby a Supervisor stays with the drilling team throughout the drilling process, from the inspection to demobilisation. On large drilling programmes with multiple rigs, several Supervisors are deployed in the different areas and they stay in the Drillers' camp and go out with them each morning.

5. Community Involvement

Whichever level of supervision is adopted it is essential that community members are involved in the entire drilling process. This should foster the spirit of ownership and understanding of post-construction operation and maintenance.

6. Drilling Supervisor's Equipment

It is essential for the drilling supervisor to have the following equipment on site:

a) Depth meter,
b) Electronic dipper,
c) EC meter,
d) PH meter,
e) Global Positioning System (may be needed only during setting up of the rig)

Contractor's equipment can also be used by the drilling supervisor but they must be inspected and confirmed to be well functioning and well calibrated.

7. Borehole Construction Workflow and Steps

Steps in Borehole Construction	Driller's Responsibilities	Supervisor's Responsibilities
1. Inspection	Assemble equipment & personnel for inspection.	Inspect equipment and confirm all relevant personnel are availed
2. Siting	Locate the exact site of drilling as per Technical Specifications	Approve drilling site
3. Pre-Mobilisation Meeting	Raise specific questions regarding the contract requirements.	Together with Concern, thoroughly discuss the design, materials and procedures for each step of the contract.
4. Mobilisation	Submit program of work and move equipment to site.	Liaise with the community; approve drilling equipment & materials; guide driller to site.
5. Drilling	Set up and operate the rig; collect samples; keep drilling record.	Monitor drilling; advise depth to stop drilling; log the borehole.
6. On-site Design	Install casing and screen; gravel pack; sanitary seal; report.	Instruct screening and casing depths; ensure gravel pack and sanitary seal properly placed.
7. Borehole development, pumping test ,completion	Develop the hole; undertake test pumping; collect water sample;	Ensure water is clean; proper disinfection; supervise pumping test; ensure samples are taken and well head constructed as per design in contract.
8. Demobilisation	Remove all equipment and clear the site; report.	Ensure the site is restored to its former state.
9. Complete documentation and handover	Submit all records including borehole completion details.	Certify completion of work with details of quantities; Hand over borehole to community; Prepare Borehole completion Report.

7.1 STEP 1: INSPECTION

Prior to mobilisation, the contactor should be asked to confirm the availability of the approved equipment and personnel as indicted in his tender; A typical drilling unit comprises of the following:

Drilling Equipment	Test pumping Unit	Personnel
1 drilling rig	Assorted submersible pumps	1 drilling manager
1 *compressor*	Generator	1 hydrogeologist
1 mud pump	Electric dipper,	1 rig operator
1 water tanker	EC meter, PH meter,	1 driver
1 support truck		1 mechanic
Adequate lengths of drill pipes to drill the deepest hole		2 rig assistants
Drill bits of the right diameter		
Casings, screens, gravel and filter pack, drilling mud		
Global Positioning System		

The **equipment** that is to be used by the contractor should be checked to make sure that it is all in working condition.
The material to be used, such as drilling fluid, casing and screens, gravel pack are specified. The Driller should submit samples of the materials for the Supervisor's approval. The grading of gravel pack, type, slot size and wall thickness of casings and screens should be checked.

7.2 STEP 2: SITING

Reference to the technical specifications and hydrogeological survey should be made to locate the exact site marked for drilling. Use of a GPS is necessary to eliminate possibility of drilling at the wrong site. Community members present during the marking of the site should also be involved in locating the drilling site. Once the site has been located correctly, the drilling supervisor approves the set-up of the drilling rig and drilling.

7.3 STEP 3: PRE-MOBILISATION MEETING

Prior to mobilisation, a meeting between the Concern Worldwide, Contractor and drilling Supervisor is essential. At the meeting, all three parties go over the design, materials and procedures for each step in the contract. Roles and responsibilities need to be clarified in detail. This provides an opportunity for any ambiguity to be resolved and the contract amended as necessary.

Many contractors do not read the contract, but simply add their prices into the Bill of Quantitie once the work has been completed. The pre-mobilisation meeting ensures that everything set out in the contract is clarified verbally, thus preventing conflicts while on site. Without this, there is always a danger that the wrong equipment or inferior materials will be taken to site, and the Supervisor compromised due to time-pressure.

7.4 STEP 4: MOBILISATION

It is essential that, before the contractor arrives on site, the drilling Supervisor has had several discussions with the Community about the project and details of the drilling process and their expected obligations and contributions with the main contact persons or Community representatives. **Data collection forms** should be printed and carried to site. Once all equipment, materials data forms and camp materials are assembled the Drilling supervisor should direct the Contractor to the drilling area.

7.5 STEP 5: DRILLING

The critical aspects at this step are:

(a) Safety
While it is clearly stipulated in the contract that the Concern takes no responsibility of safety and will not compensate for any injury or damage to personnel, animals and machinery/equipment, the Supervisor must be constantly vigilant to prevent accidents, and to minimise injuries should accidents occur. The Supervisor should look after his or her own safety and be aware of risks to the Driller's crew and the public. A drilling operation is a novelty, and it quickly attracts a crowd, particularly children. Spectators should be kept behind a clearly defined barrier where they cannot be struck by falling objects, such as a drill pipe, or a hose breaking loose from a compressor or mud pump which could be fatal. A community representative can be asked to support the process of policing the site.

(b) Rig Position
It is essential that the rig is horizontal and the mast vertical, otherwise a bent hole may result. Verticality of the drill pipe should be checked with a spirit level. The rig should be jacked on a robust wooden block so that verticality remains throughout. The rig should be positioned exactly over the marked site. The Driller should ensure that the weight on the drill string is adequate to maintain a straight hole. The use of a heavy drill collar is recommended on at least the first three metres of length behind the hammer. The first drill rod could have welded wings, adding weight as well as scraping to get a circular, straight bore. Also, the Driller should not drill with too much pull-down on the rods.

(c) Monitoring Drilling diameter and Depth and
The drilling diameter of the borehole needs to be large enough so that pump, casing, screens, gravel pack and sanitary seal can all fit without snagging. The Drilling Supervisor needs to know the depth of the drill bit at all times to ensure that proper data logging is being done, to know the depth at which to tell the Driller to stop and to compare the drilled depth with the depth recommended in the contract. The drilling depth can be monitored by measuring the length of the drill pipe and multiplying the number of full pipes that have gone down into the hole.

(d) Penetration rate
This is the time taken to drill a particular interval. A fast penetration rate can indicate an aquifer, although this is not always the case. Less porous strata, such as fresh granites, are often slower to drill through.

(e) Drilling fluids & air-lift yield
Drilling fluids are used to remove cuttings from the borehole and to stop the hole collapsing during drilling. The type of fluid should match the drilling method:

- Rotary drilling: drilling mud (water + additive). Be aware that bentonite clay is commonly used but in some cases it can do permanent damage to the aquifer. Biodegradable polymers should be used;
- Percussion drilling: fluids generally not used;

Monitoring the drilling fluid colour and viscosity is the responsibility of the Driller. Viscosity is checked by measuring the flow rate of the drilling fluid through a the flowing channel or Marsh funnel. In the case of air-percussion drilling, the air-lift yield should be measured using a container. All observations and measurements are recorded regularly.

(e) Drill cutting samples

To collect the samples, the Driller stops drilling, flushes all cuttings in the hole to the surface, resumes drilling, and then collects the cuttings. In air drilling, the samples are caught in a bucket placed in the stream of air jetting from the borehole. In mud drilling the samples are collected by inserting a spade into a small collection pit as the cuttings flow to the main pit. It is the Driller's responsibility to ensure that the mud pump is of such rating and condition that it can lift the cuttings out of the hole. If the hole is not properly flushed, cuttings may become mixed up and not lifted out so that during lining, the casings do not get to the required depth.

The **drill samples** should be bagged in strong transparent bags, labelled with indelible ink, and stored in a position that they will not be contaminated by site conditions or drilling operations. The label should contain the sample number and depth. A photograph of the samples should be taken as a permanent record as shown below. In mud drilling, the samples would have mixed with the drilling fluid. The samples should be washed before bagging, but care should be taken in washing soft rock material, such as clays, as they could disintegrate in water. Samples should be collected at every 2 meters, but drilling conditions may require that this is reviewed

Photograph of Drill samples

(f) Strata Log

Drill samples should be described and a strata log prepared by the Drilling Supervisor. Description is based on identifying and describing (a) the colour, (b) texture, (c) grain size and shape, (e) material (f) rock type.
From the strata description, the Supervisor will prepare a geological strata log which will form part of the final borehole report.

(g) Final borehole depth

It is the responsibility of the Drilling Supervisor to instruct the Driller to stop drilling when the right depth has been reached. The decision to end drilling will depend on the information gathered in the course of drilling. The factors will include:

- what has been stipulated in the contract, which may be based on hydrogeological investigations report of average depth of boreholes in the area;
- depth of the water strikes/aquifer;
- the estimated yield from the borehole

The typical signs for adequate yield and drilling depth vary with the type of formation and the drilling method. It needs to allow for proper installation of the pump. It also should allow for 3 to 6 metres of sump (blank casing) below the screen as a sand trap. However, if the yield is not clearly so good, continue to drill to the next strike horizon, until the yield is sufficient. ***NB*** *Variation in depth of drilling must be approved by Concern's Programme Manager.* The yield increments should be monitored by measurement using a container of know volume and a watch. In cases where there is fine saprolite in the upper sections, these should be cased off to prevent silt from entering and filling the sump.

(h) Drill Report:

The data from the drilling should be recorded both for the final design and as a reference for future bore-hole projects. The Driller needs to keep a daily drilling log. The Supervisor should insist that this is done as Drillers often consider this an unnecessary intrusion into their work. The Supervisor should keep the record of the drilling activities and all measurements in a field note book. The most important data will go into the Casing and Well Completion Form, which will be collated, filed or bound together as part of the final project report and submitted to Concern for filing. Even data from dry or aborted holes needs to be recorded.

7.6 STEP 6: ON-SITE DESIGN

The Supervisor is responsible for on-site design modifications. Every borehole design is unique because it has to be adapted to the local geology, which cannot be predicted with absolute certainty during preparation of technical specifications.

(a) Installing casings and screens requires great care and attention to avoid installing blank casing in the aquifer horizon. Once the depth of the borehole and the depth interval for screening are known, a sketch of the proposed assemblage of casing and screen should be made. The casings and screens should be laid out according to the sketch. They should be placed next to the drill collar ready to go into the well. The Supervisor should take a photograph of the layout for the record. Once all of the materials are inserted, the drilled depth needs to be reconciled against the casing and screen depth. If the discrepancy is more than 3m, there is need to reconsider whether the screen is actually sitting where it is supposed to, or if there has been some collapse of the well. If something is wrong, the contractor must remove the casing, clean the well, and re-insert it until the Supervisor is satisfied.
Joints should be strong enough to support the entire weight of the casing during installation. Both male and female threads should be properly cleaned with a brush and cloth before they are joined. Steel casing and screen should be joined by threaded joints that are water-tight. Where welding is used, the weld should be fully penetrating and continuous. The casing and screen assembly should be lowered into the hole under the force of gravity. A 3m length of sand trap should be part of the well design when boreholes are cased to the bottom and the bottom casing sealed with an end cap.

(b) Gravel pack: is coarse sand or river gravel installed in the annular space between the borehole screen and the wall of the drilled hole to prevent the caving of formation material and damage to the screen. The material should be carefully chosen and sieved to make sure it is of uniform size and bigger than the slot size of the screen and will not flow into the borehole. Large pieces should be sieved out as they can bridge in the *annulus* and prevent subsequent gravel from reaching the bottom. The material should be washed and carefully introduced into the hole and should extend several meters above the screened interval but stop at least 6m below ground surface.

It is essential that the casing, screen and gravel pack are available on the site once drilling commences. Once the drilling pipes are withdrawn, the hole has a potential to collapse. Thus the casing and gravel pack need to be placed without delay. Under no circumstances should this wait until the following morning.

7.7 STEP 7: BOREHOLE DEVELOPMENT, PUMPING TEST AND COMPLETION

(a) Borehole development is about cleaning the area of the aquifer immediately around the screens. The method of development shall be stated in the technical specification and in most cases shall be by *air-lifting*.

The Supervisor's duty is to ensure that eventually, the water coming out from the borehole is clear of mud and is sand free. Samples of the water are collected in a clear container and checked to see that there are no sediments collecting at the bottom of the container. As part of this, the Supervisor needs to record the time taken in the development process. In case the water fails to clear even after several hours of borehole development, the supervisor has to decide whether a borehole should be accepted or declared abortive. If the borehole is to be aborted, the Supervisor also needs to determine whether the Driller should re-drill the borehole at his own expense or not. This will depend on the terms and conditions of the contract.

(b) Sanitary seal: It is essential to prevent contamination of the aquifer and to ensure that the users obtain safe, clean drinking water. When the Supervisor is satisfied with the yield, and development has settled the gravel pack, then the annulus of the borehole is backfilled with the cuttings, or clayey soil, up to 6m below the ground surface. A sanitary seal is placed in the top 6m to prevent surface water which may be polluted from flowing down the bore-hole annulus into the aquifer. The sanitary seal should be cement slurry in the mixture of 25l of water to 50kg of neat cement, or bentonite.

(c) Pumping test provides the means to determine the likely success of the borehole in terms of yield and drawdown. It provides information on the properties of the aquifer and on the borehole itself. The common type of pumping test in Somalia is the constant discharge test. During the pumping test, the Driller usually measures the water levels, discharge and time. The pumping rate and the water level are measured at the same time and recorded along with the time of measurement. The pumping rate can be measured with a flow meter, but it can also be established by recording the time it takes to fill a container of known volume. This is measured several times during the test. The Supervisor is responsible for ensuring that the pumping test is carried out correctly.

There are several ways of **analysing pumping test data**, and some are quite complicated. However, for the purpose of this guidance note, what is important to the Supervisor is whether the borehole will deliver the required amount of water for the required pumping duration or not. The specific capacity of

the borehole, which expresses the relationship between the yield and the drawdown, is the most important quantity, i.e.
Specific Capacity = yield /drawdown (m3/h per m drawdown)

This enables the Supervisor to predict the likely drawdown at different pumping rates and whether the borehole can deliver sufficient water.

(d) Water quality testing: Groundwater from boreholes is often of good quality, but sometimes it may contain chemicals which render it unsuitable for domestic use without treatment. The technical specification have given the parameters to be tested. It is the Supervisor's duty to ensure that the samples are taken by the Driller in a clean bottle of at least one-litre volume. Note that some parameters change between sampling and reaching the lab and so need to be tested on, or close to the site (including pH, EC, temperature).

(e) Borehole disinfection: The borehole should be disinfected after construction to kill bacteria that might have entered during construction. Chlorine is normally used as the disinfecting agent, leaving a residual in the disinfectant water. WHO (2012) recommend that a litre of 0.2% chlorine solution is used for every 100 litres of water in the borehole. This corresponds to a concentration of 20 mg/l. After adding the disinfectant, the borehole should not be pumped for at least 4 hours, if not longer. Care must be taken when mixing and adding chlorine to the borehole as it is poisonous when not diluted.

(f) Successful or abortive boreholes: The success and suitability of a bore-hole for acceptance will depend on the following:

A dry borehole or one with a lower yield than the desired should be declared abortive. This may not be the fault of the Driller, but if the agreement is that the Driller is only paid for successful boreholes, then re-drilling is at his/her own cost. However, even after attempting drilling in 3 locations in a community, the yield from the bore-hole may fall short of the minimum allowed. At this stage, a major reassessment of the drilling strategy may be required, with appropriate contracts drafted. Where the shortfall is less than 30% of the minimum specified, and there are no other safe sources of water, then the Supervisor may decide to accept the borehole and complete it if there is no alternative to improve the water supply. However, this may not be a viable long-term solution for the community.

The ***sand content*** of the water should not be more than 10 parts per million by volume. The Supervisor should collect three 20l samples at the end of the pumping test. The volume of sand in the samples should not exceed 0.2 cubic centimetres. If a borehole should be aban-doned because of excessive sand content, then the Drill-er shall be responsible for constructing another borehole at his/her own cost. The wrong drilling technique or poor gravel packs and well development cause this.

Every borehole should be ***cased straight and vertical***. The Supervisor may ask the Driller to carry out a test for straightness and verticality. The Driller should provide the plumb and carry out the test. Should the plumb fail to move freely throughout the length of the casing to the required depth or should the borehole vary from the vertical in excess of two-thirds of the inside diameter of part of the borehole being tested per 30 metres of depth, the borehole should be re-drilled by the Driller at his/her own expense.

The Supervisor will determine whether the ***chemical and bacteriological quality*** of the water is adequate to serve as potable water supply. If the borehole contains hazardous chemicals it shall be abandoned. The contractor shall not be penalized for this. However, it if becomes contaminated

because of an action or inaction by the Driller, the Driller should be asked to disinfect the bore-hole and if necessary construct a new borehole at his/her own cost.

(g) Platform casting*:*

All boreholes need a concrete apron around the length of casing above the ground for protection against soil erosion and surface water flowing into the bore-hole. Platform casting is usually undertaken by a dedicated construction team and may take place after *de-mobilisation* of the drilling equipment. However, the Supervisor will be responsible for ensuring that platform is built to the design specified in the contract and that the quality of the materials and the construction is good and durable.

7.8 STEP 8: DEMOBILISATION

On completion of the pump installation, the Supervisor must issue a Work Completion Certificate. For this, he has to ensure that the Driller has complied with all the stages of the contract specification. Before demobilisation, the Supervisor should check that the borehole record has been completed and all information filled in.

7.9 STEP 9: COMPLETE DOCUMENTATION AND HANDOVER

The finalization and submission of drilling records (to the appropriate national authority and supporting bodies) is essential. Concern Worldwide shall make the submission.

When the Supervisor is satisfied that the borehole is ready for use, a day is set aside for **handing over** the borehole to the Concern who shall then hand it over to the Community. It is common practice for the handing over certificate to be signed by three people representing Concern Worldwide, the Government and the Community.

During the **defects liability period**, the Supervisor will monitor and liaise with community members on the functionality of the boreholes during periodic visits. If there are any defects, the supervisor will instruct the Driller to make repairs at his own cost, depending on what is specified in the contract.

Drilling routine may seem monotonous - one of continuously lowering and pulling out of drill rods, watching rods rotate and cleaning mud pits but there are continuous changes. The Supervisor therefore needs to be watchful at all times. There could be arguments later on, and if the Supervisor has not been vigilant, then he/she could be cowed or hoodwinked by experienced or unscrupulous Drillers.

8. Positive Relationship with the Driller & Great Professionalism

A two-way relationship between the Supervisor and the Driller is necessary for an efficient and successful outcome to the project. The Supervisor should therefore strive to understand the Driller's technique, avoid being overbearing and not try to teach the Driller how to drill. Where cooperation is established, the Driller can give the Supervisor important information that is not always recorded in the driller's log, e.g, a change in the sound of the drill string, an abrupt fluctuation in penetration rate not always seen on the penetration rate log, a change in the level of the drill fluid in the mud pit. However, if a Driller is smarting from perceived injustice by the Supervisor he/she will be less inclined to be helpful, which may be detrimental to the project.