

BORE HOLES – SUPPLEMENTARY TECHNICAL SPECIFICATIONS

TECHNICAL SPECIFICATIONS & PROCEDURES FOR DRILLING & CONSTRUCTION OF BOREHOLES FOR HAND PUMPS

Technical Specification

These technical specifications have been developed to guide the drilling of hand pumps and production boreholes for supplying water to various communities. They are based on various documents for borehole construction. In developing the specifications, different stakeholders, drilling contractors, hydrogeologists and engineers who have experience in the drilling industry have been involved and consulted.

Reference Indian Standards

IS 6926-1996 Diamond Core Drilling

IS 1892-1979 Sub-surface Investigation

IS 2132-1986 Code of Practice for Thin-walled tube sampling of soils

Preliminaries

The Contractor shall drill the borehole(s) at the exact location(s) designated by the Employer and Stakeholders agreed with the local communities or beneficiaries. Tracks required for access of drilling plant, gear, camp and accessories to the borehole site shall be made by the contractor with help of the beneficiary community and the local leaders. They should have minimal interference with existing cultivated land. Borehole locations shall be identified in agreement with the local communities/Stakeholders and in Consultation with the Client/Employer.

Site Works

- Site safety management of the drilling contractor would be under taken by contractor/ Firm.
- Technical direction of the drilling scope of work, including initial full-time hydrogeological site supervision and nominated by Company /Firm geologist, and provision of necessary procedures, guidelines, forms and checklists for the collection of hydrogeological information and data for the supervision of monitor bore drilling. To provide well-site supervision for drilling and completion of the production bore (within 7 days) with records submitted to Client or employer.

- The site supervision by drilling company/firm would include the collection of field measurements and observations during the drilling and bore construction, including, but not limited to:
 - Penetration rate log.
 - Lithological logging and descriptions.
 - Quality assurance of bore consumables: checking for defects in the casing, checking for compliance with technical specifications and soundness of materials.
 - Site specific bore design, determination of casing and bore consumables required, exact measurements of casing and bore consumables installed, maintaining records of as-built bore construction.
 - Hydrogeological field measurements during any air drilling and/or bore development including: airlift yield, water quality (EC/pH) and measurement of sand/silt content in the discharge water.
- Contractor/Firms should provide their geologist remote management/direction, support, and troubleshooting during the drilling and completion of monitor bores.
- On completion of each bore drilled and installed, or on a daily basis, the hydrogeological and geological data and information collected by the Drilling company/Firm geologist is to be forwarded to the Saprolite office for review. Feedback would be provided to ensure required information is collected, accurately recorded, with no omissions.

Baseline Testing

All completed and cased bores will be baseline tested onsite, including:

- Measurement of field water chemistry parameters, standing water levels and insitu EC profiling,
- Water sampling of the monitor bores, and water chemistry analyses by a suitable NATA certified (body recognized by Government of the country), analytical laboratory. The analytical laboratory would be engaged by Contractor/ Firm directly. The baseline testing would be undertaken during the test pumping work program (i.e. in-between tests). Should there be insufficient time to baseline test all holes within the 2 days allocated then the remainder of the monitor bores would be baseline tested concurrently during the test pumping program. NB Water sampling of production bores (3) would be undertaken as part of the test pumping works.

Transportation and Supply of Materials and Equipment

The Contractor shall provide all drilling machines and equipment, transport and set it up on the site and shall carry out the drilling all in accordance with the Engineer's instructions to be issued before commencement of the drilling work and during its progress.

The Contractor shall be responsible for the supply and transport of all materials and equipment needed for the orderly progress of the drilling operation according to the specifications and detailed directions issued by the Engineer.

The Contractor shall supply Casing pipes and slotted casing in the quantities and diameters required according to the approved drilling program and shall insert them in the Borehole in accordance with the specifications and the Engineer's instructions.

Drilling Work

Drilling Point, Depth and Diameters

The Owner and/or the Engineer will define the exact point of drilling. The point will be handed over to the Contractor upon signing the contract and it must be safeguarded by the Contractor until commencement of drilling.

The Contractor is by no means entitled to change or move the drilling point handed over to him by the Owner/ Engineer. Depth of drilling and diameters and length of the Casings and screens will be finally determined by the Engineer according to the results of Quality Tests after making the Pilot Hole and after performing geophysical logs. In the case of change in the diameter of the Casing a new meterage rate will be fixed by an agreement between the Owner and the Contractor.

The diameters and depths specified in Table No.4, and the actual diameters and depths and the location of the casings and screens will be finally determined by the Engineer during implementation and in accordance with the drilling and geophysical logging results.

For more preciseness in verticality (plumb vertical), drilling the borehole shall be started with 12" bit all the way to the required depth, then with 8" bit again to the required depth, and then the final diameter of 8". Ditto for the 8" borehole, which should be started with 12" and ended with 8.5" and all works must be done with conjunction with Bills of Quantities.

Drilling Method

The drilling method to be used shall be direct rotary drilling with air, water and foam as drilling fluid. The Contractor shall use only compressed air, foam and clean water. Should unexpected conditions occur, the Engineer might change the drilling fluid. However, the Contractor cannot change the drilling method without the Engineer's written approval.

Filter Gravel Packing and Grouting

The annular space between the casing and borehole wall is filled with filter packing materials in the screen intervals and back filling materials. The gravel packing mixture to be used depends on the sieve analysis results and the slot size of the screen. The contractor will do the sieve analysis and then determine the gravel pack materials. The sand or gravel should be of uniform size which is slightly larger than the size of the slots in the well screen. Well-rounded or sorted grain from river or ocean deposits shall be used. Packing sands / gravel are to be Silica based and clean. Iron and Calcareous grains will not be included in the gravel pack materials. Sand / gravel packing material will be stored in a way so as to avoid contamination or rain-washing finer materials.

Gravel packing is carried out as continuous feed operations done usually by two people filling uniformly around the circumference of the pipe. It is advisable to add some water with a pipe so that the gravel flows down. If the gravel gets inside the temporary casing, the casing is slowly pulled out and gentle well development is done to allow gravel to settle properly to a height of 3 meters above the top of the screen interval or the targeted water bearing formation. More gravel is added with development if the gravel settles down.

Backfilling and grouting is done when the Minimum acceptable yield of 0.25 liters/ second is confirmed by development. The borehole cuttings or clayey soils are back filled up to 6 meters below the ground surface.

The grouting is done with a concrete mix in the ratio of 1:2:3 of cement sand and gravel respectively. The gravel size should be not more than 6mm. Insert a 3 meter Steel casing of 6 inches diameter on to the PVC casing, both protruding above ground level by at least 60cm to facilitate installation of Bush Pump.

Borehole Development

On completion of drilling, the Contractor will choose a suitable and appropriate borehole development method. The borehole shall be developed for a period of at least three hours in order to obtain a maximum yield of water that is free of suspended matter. Developing shall be carried out by airlift pumping and surging, jetting and block surging, or other techniques the contractor feels is more appropriate and efficient to suit the casing, hydro-geological and drilling conditions prevailing in that borehole. All boreholes shall be presented for testing free of any bridging or obstruction to the total depth. The Contractor should provide the equipment required for verticality testing as required of drilling regulations.

Pumping and Recovery Testing

A pumping test is required on a routine basis for each borehole. The Contractor will estimate the discharge from the air lifting rates or blow test during borehole development. Based on the estimated discharge, the Contractor will certify the borehole as either "successful" or "lost". For successful boreholes for hand pumps, the Contractor will undertake a seven hour pump testing of which the first one hour is a three step draw down test. The discharges for the step drawdown test will be fixed by the contractor based on the well development results. High yielding

boreholes, with a discharge of more than 1 litre/second may be pump tested for 72 hours. The 72 hours pump test is conducted if the borehole is intended for a motorised pump. After conducting the step drawdown tests the borehole should be allowed to recover almost to the original static water level (1 hour) before the constant yield test is undertaken continuously for 4 hours at the chosen/predetermined rate.

The first step could be minimum acceptable discharge of 0.25 liters / sec. The second step will be at an estimated discharge from blow test (during the well development) and

the third step will be 50 to 75% more than the estimated discharge from blow test. As a thumb rule the range of the three steps could be 0.5 liter/Sec or above depending of development results, 0.75 liters /Sec and 0.25 liters/ Sec. and each step for 20 minutes (total 1 Hours) the continuous test of 4 hours will be carried out at a discharge at which the dynamic water level will stabilize. Annex 9 and 10 show the formats for recording pump test data. If the discharge is below 0.25 liters/second or dynamic water level is below 45 meters then the borehole will be regarded as "Lost".

Recovery test will be for one hour or such time when there is at least recovery of 80% of the static water level noted at the start of the pump test. The pump test data and the results of pump test should be presented in the drilling log report.

Readings of flow and water level shall be taken at the intervals defined on the test pumping form. For accurate measurement, an electrical/ sonic water level indicator with graduated tape for taking water level readings should be utilized. Recovery readings shall be taken for a minimum of 1 hour, during which period pumping equipment shall not be removed from the borehole.

Water Quality Testing

The contractor shall, make sampling and quality analysis of water from every borehole.

The water quality test should be conducted at a competent testing laboratory that is authorized by the client.

Water samples for chemical analysis should be collected at the end of the test pumping process and analyzed at the approved laboratory at the earliest possible time to facilitate timely handing over of the borehole for use by the community. Thus the pump handle should only be fitted after acceptable chemical analysis results. Samples for biological testing will be collected later in suitable batches so as to meet the time limit of 48 hours between collecting and analysis in the laboratory.

Sampling and Drill Time Logs

Representative samples of the strata intersected shall be collected every 5 meters or less depending on the change of geological formation. For collection, the Contractor shall cease drilling, circulate all cuttings to the surface, resume drilling and collect the cuttings then brought to the surface. The Contractor shall take every possible precaution to guard against sample contamination due to poor circulation, borehole erosion, or caving. Cutting samples shall be bagged, labeled with borehole depth at time of collection, and stored in a position where they will not be contaminated by site conditions or drilling operations. The Contractor shall supply strong, transparent sample bags and indelible labels as required. The driller in-charge will also record the drill time logs/penetration rate of each rod or at every three-meter interval.

Chlorination after Borehole Completion

Each successful borehole must be chlorinated following completion drilling operations. The Contractor will decide on the concentration of chlorine based on the volume of water in the borehole.

Protection

During the contract period, when work is not in progress, the boreholes shall be kept capped in such a manner as to prevent the entrance of foreign materials. The Contractor shall remove any foreign matter at his own expense. On completion of each borehole, the Contractor shall supply and fit an approved permanent lock-up cap. Casing shall terminate not less than 0.5 meters above ground level and are fitted with the approved lock-up cap. After successful completion of drilling, casing and testing head-works will be constructed in line with the guidelines given in the Head-work Manual which forms part of the documentation of this contract.

Hydrogeological reporting

Presentation of all drilling results and water quality data, including but not limited to:

- Well completion logs
- Baseline testing results (EC profiles and water chemistry).
- Presentation of all test pumping results, including hydraulic analyses and estimation of aquifer parameters, and pumping capacities.

Review SOP for Groundwater Monitoring, including analytical requirements, and monitoring equipment.

Assess impacts on Groundwater Dependent Ecosystems, with respect to abstraction of groundwater from the production bores, notably from paleochannel areas.

Provide brief discussion of the hydrogeological works in the context of the objectives and the WMP, and include conclusions and recommendations.

Test pumping work program

General

Test pumping will occur on:

- Two (2) pre-existing, equipped and operational production bores. It is recommended that dip-tubes are installed or provision is made to take water levels at the bore-well-head.
- One (1) proposed new production bore to replace the collapsed bore, this is assumed to be fully equipped and installed by Drilling Company/Firm, as per the pumping specifications of the adjacent collapsed bore, including the installation of a dip tube for water level measurement.

Included Work

Pump test will be responsibility of Drilling company and their engineers, test report must be submitted to Client by drilling company.

Test Pumping

Discharging the pumped water

The water pumped from the bore should be prevented from returning to the aquifer, and recharging it. This can be done by conveying the water through a larger diameter pipe (or lay-flat) a distance of 100 to 200 metres.

In accordance with the Environmental protection policy, there is to be zero discharge to the environment, and all discharge water is to be contained within pre-excavated sumps and evaporated.

Installation of Equipment

All production bores to be test pumped are to be fully equipped, powered and made operational prior to the mobilization of Saprolite personnel for test pumping. It will be required that the installed equipment will need to be operated continuously once the step tests and constant rate tests are commenced. This in turn will require a continuous power supply, and if by portable generator, would need to have an automated fuel delivery system including fuel tanks. Refueling and maintenance of the gensets would be the responsibility of Drilling Company/ Firms.

Details of the installed equipment, including pump specifications, and pump protection measures will be requested prior to mobilizing to site for testing. These details, as well as inspection of the installations at Wilson's and Corsair Bores, can be undertaken whilst the Principal Consultant is onsite at the commencement of the drilling program.

Conducting Pumping Tests

Pumping tests will not produce accurate data unless the tests are carried out methodically, carefully recording the time, discharge, and depth measurements. The pumping test to be carried out is as follows:

- Multi-rate step tests: to determine bore characteristics (where water levels can be measured), and optimum pumping rates for the constant rate test. The test is to comprise 4 equal steps of 100 minutes duration, with increasing rates of discharge (i.e. 1, 2, 3, 4 L/s, or 2, 3, 4, 5 L/s, or 3, 6, 9, 12 L/s etc). Measurements of water levels and discharge at given times are only obtained from the pumping bore.
- Constant rate tests: to determine hydraulic parameters of the aquifer, and estimates of bore/aquifer capacities (where possible), and forecast pumping yields. The constant rate test will be undertaken after a period of recovery from the step test. The test will comprise the bore being pumped at a constant rate for a period of nominally 48 hours. Measurements of water levels and discharge at given times are obtained from the pumping bore (where water level measurements are possible) and observation bores.

- Recovery tests: to determine hydraulic parameters of the aquifer. The test comprises water level measurements taken from the pumped bore (where possible) (and if possible, from observation bores) from the moment the pump is turned off at the completion of the constant rate test. The period of the test will be up to 12 hours depending on the rate of recovery. The recovery test can be stopped sooner than 12 hours if the water levels in the pumped bore (or observation bore) reaches 95% recovery.
- Preliminary Test Preliminary steps should be taken to assure the reliability of pumping test data recorded during the actual test. For instance, given the pump is installed correctly, and bore head-works are already in place, the pump should be pumped for an hour or so (after measuring the pre-test water level (where possible)) for the following reasons:
 - Ensure correct operation of the power unit, and that it had been fully serviced before any test pumping;
 - The best method to measure yield;
 - It is assumed the installed flow meters are appropriately calibrated to a $\pm 5\%$ accuracy; o
 - Check the range of flow rates that are available by opening the gate valve fully to obtain the maximum, and closing the valve (but not shutting it totally) to lower the flow rate, thus obtaining the minimum. Make some assessment of the impact on aquifer water levels as to avoid pumping the bore dry during the early part of the test.
 - Set the gate valve to give the desired discharge rate for the first step of the Multi-rate test.

Prior planning and experimentation with equipment during preliminary testing can eliminate errors that may occur during the actual pumping test. Never begin the actual pumping test however, until the water level in the bore has returned or nearly returned to the pre-test static level. Usually, 2-4 hours should suffice. However, often the following can be achieved depending on what time of day the preliminary testing was carried out. For example, if the preliminary testing commenced at 0600 hours, and stopped at 0800 hours, then by 1200 hours a 400min multi-rate step test could be started. The bore would then be left overnight and a Constant Rate test commenced in the morning, with the water levels having recovered overnight.

Environmental protection Policy of the site

Care must be taken in the handling and storage of drilling fluids, oils, greases and fuel to avoid introducing environmental contaminants and pollutants. The Contractor shall dispose of any toxic materials including drilling fluids, cuttings and discharged waters in a manner approved by the Client and so as not to contaminate/pollute public and private property. In addition to environmental protection policy referenced here, the Contractor shall adhere to the overarching Bidding Document with attention to:

- Section 2. Social and Environmental Responsibility of Section VI. KfW Policy Sanctionable Practice – Social and Environmental Responsibility
- “ESHS Policy” issued in Section VII Works Requirements.

The Contractor shall ensure that all their personnel are aware of Environmental protection requirements. The Contractor’s adherence to these guidelines will be closely monitored by the Supervisor, and any infringement by the Contractor may render unacceptable the particular portion of the Works to which it applies.

Materials for the works and workmanship

All materials that will form part of the complete works must be supplied new and used as specified in the technical specifications for the works.

Materials must comply with the minimum specifications in the relevant codes. Materials not specified in the technical specifications and which also do not comply with the minimum specifications in the relevant codes of practice shall not be used.

Where a national standard does not exist for the material, the relevant British Standard shall apply. The Contractor is expected to carry out all works as specified and in a professional manner, up to the best professional standards.

The Contractor shall carry out operations with due efficiency and dispatch in accordance with the terms of the contract and to the satisfaction of the Client.

The Contractor shall use suitable equipment, supply efficient and experienced staff.

The Contractor will provide an experienced project Coordinator to oversee the drilling to be carried out under this Contract.

The Contractor will maintain a full crew on each drilling unit and pump test unit with the necessary training, skills and experience to effectively and efficiently carrying out the contract.

If the Client is dissatisfied with the performance of a member of the crew, such member shall be informed of their shortcomings and warned by the Client’s representative/ supervisor. If no change results within a reasonable period, the Contractor will be notified and requested to take necessary measures on the unsatisfactory crew member.

Contractor to provide all equipment for the works

All necessary machinery, equipment and materials to carry out the drilling, test pumping, headwork construction shall be provided by the contractor. The Contractor shall specify the equipment type and capacity that is to be used to undertake the drilling works. Its capacity shall be sufficient to cope with the Works as stated in the Contract. It shall at all times be kept in full working order and good repair.

Test pumping equipment shall be independent from the drilling rig(s). Prior to mobilization the Client shall verify the specifications and state of repair of all major items of plant and

transport, and shall have the right to order the removal and/or replacement of any items which in his opinion are insufficient or in unsatisfactory condition. Acceptance by the Client or his representative of the Contractor's proposed plant and transport does not relieve the contractor of his obligations.

In cases where the plant and transport accepted by the Client fails to successfully complete the required works, the Client shall have the right to call upon the Contractor to put such equipment in good order within seven days; or alternatively to remove such plant and replace it with additional plant or equipment which the Client considers necessary to meet the requirements of the Contract. In the event that this requirement is not satisfied, the Client reserves the right to terminate the Contract immediately. No extra payment shall be made for the Contractor's change of drilling equipment, labor or other equipment required to complete the Works specified, nor for any incidentals thereto, the cost being deemed to be included in the schedule of rates. All machinery, equipment and materials to carry out the said Works shall be handled, transported and stored in accordance with the manufacturers' recommendations to minimize deterioration.

Supervision of the Work

The execution of the Works is supervised by the Client or Client's appointed Supervisor as named in the Contract Data. The supervisor / supervising hydrogeologist in most cases will also be responsible for geological survey and borehole siting. This hydrogeologist will also be duly registered and a holder of a valid license issued by Ministry of Water and Environment South Sudan.

Strata Sampling and Borehole Geodata

While the drilling operation progresses, representative samples (min. 100 grams) of strata penetrated shall be collected at intervals of (5) meters or as instructed by the supervisor. In general, the strata samples will also be taken at every change in colour, texture, grain size composition, profile and where water or an aquifer is struck. Cutting samples shall be bagged, labeled with borehole depth at time of collection, and stored in a position where they will not be contaminated by site conditions or drilling operations. The Contractor shall supply strong, transparent sample bags and indelible labels as required. The Contractor shall take every possible precaution to guard against sample contamination.

At completion of drilling, the contractor will be required to complete the borehole geo-log with all information describing the properties of the samples, appearances of water and aquifers, rock types and sampling details. The contractor will then complete the borehole log reports / forms and borehole completion reports / forms which shall include test pumping data sheets, water quality test certificates and installation data sheets and hand them over to the client. The Contractor will also be required to hand to the client complete borehole logs and all information from dry boreholes and boreholes considered unsuccessful as a result of poor water quality or other technical failures.

Borehole depth and diameter

The Contractor shall drill to the total depth 100m deep and at such diameter as will be instructed by the Employer or the Supervisor. No borehole will be acceptable if drilled to a depth not exceeding 80m and diameter other than that instructed in writing by the Client or his appointed Supervisor. The total depth will depend on the geological formation and yield requirements. The minimum diameter will be as per the specifications or contract or any other written agreement between the Client and the contractor. It is preferred that drilling starts with a described diameter, and then reamed to the right size.