Code of Practice for Cost-Effective Boreholes

Zambia: Country Status – July 2009

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List of Abbreviations

BoQ	Bills of Quantity
COP	Code of Practice for Cost-Effective Boreholes
EIA	Environmental Impact Assessment
DWA	Department of Water Affairs
MLGH	Ministry of Local Government and Housing
PHCU	Public Health Care Units
SADC	Southern African Development Community

Executive Summary

Introduction

It is recognised that drilling interventions vary widely both nationally and internationally and are not always cost-effective. The objective of this consultancy is to identify and set out key procedures for cost-effective boreholes as appropriate for Zambia. This is the report of the international consultant, Tom Armstrong, who visited Zambia for 18 days from late June to mid July to analyse borehole cost-effectiveness in Zambia.

Context

The National Rural Water Supply and Sanitation Programme, (NRWSSP) in Zambia intends to construct over 10,000 new water points by 2015 of which UNICEF alone intends to construct 3,650 water points in the next five years. The Danish Government through Danida will also contribute a similar number. Boreholes in rural areas are normally drilled for handpump supplies. Drilling can take place for most of the year, to tap relatively shallow aquifers (between 24m and 85m).

Responsibility for rural water resource development is with the Ministry of Local Government and Housing (MLGH). The Department of Water Affairs (DWA) of the Ministry of Energy and Water Development still owns drilling equipment and there is a considerable knowledge base in the organisation (e.g. in hydrogeology and records). No guidelines and procedures have been developed to direct borehole drilling in Zambia although standard ways of borehole construction have been developed and adopted as a good practice by DWA. Geology and Hydrogeology

The geology of Zambia, comprises various rock formations consisting of igneous, sedimentary and metamorphic rocks from Precambrian to recent times. In Zambia, aquifers can be broadly categorised into three groups:

- Aquifers where Groundwater flow is mainly in fissures, channels and discontinuities, which are subdivided into highly productive and locally productive aquifers;
- Aquifers where intergranular groundwater flow is dominant
- Low yielding aquifers with limited potential:

The price of a completed borehole in Zambia tends to be in the range of $4,000 to $5,000 although it can be double this for some donor-aided projects.

Analysis of the Cost-Effectiveness of Current Drilling Practices

Who Drills?: DWA owns over 30 sets of drilling equipment, including rigs recently received from JICA. DWA drills throughout the country, including for private clients. DWA charges $3,000 to $3,500 to drill 100m, but the equipment costs have been undervalued; a sum of $500 goes to DWA for the equipment. As this is below market rates, DWA private drilling is effectively subsidised.

There are many national private water well drilling contractors in Zambia but no register or licensing of drillers. It is reported that many “brief case consortia” have been formed in response to tenders. Regulation of the drilling industry is seriously lacking. There is also no drillers association.

Procurement: Presently, substantial drilling programmes let out large contracts (of > 100 boreholes) which tends to favour larger companies and excludes small, yet competent drilling enterprises. A mechanism to enable small companies to participate would be to promote a *drillers pool*, with *roll-over packages* of work. This would enable contractors to work for more work as high quality and timely construction would win new work. Contractors with multiple rigs can take on several packages; those with one rig can work according to their capacity. Tender meetings to informed drilling contractors of expected conditions and describe the categories of risk are not currently utilised in Zambia.

Contract Management, Supervision and Payment: With the exception of UNICEF’s standard “service orders”, tender and contract documents for borehole drilling in Zambia are long, complex, and thus unlikely fully understood or even read entirely by the drilling contractor. Such contracts are un-appropriate and not necessary and could be significantly simplified. Boreholes which have been signed off as successful sometimes becomes dry within a short time due to poor quality construction. Unlike in other countries, there is generally no defects liability for borehole drilling in Zambia and the process of acceptance of the borehole drilling works varies.

In cases where contracts are paid under a "no water no pay" agreement, it is importance that the risk of the borehole being dry is determined. The study proposes a mechanism whereby three categories are used to define the risk: high (>90% success rate); medium (60-90% success rate) and low (<60% success rate). Each category has a particular proposed payment mechanism.

Poor supervision is one reason for borehole failure and in Zambia itself UNICEF has been criticised for ineffective supervision. In Zambia there is a lack of competent and experienced drilling supervisors and there appears to be a continual reduction in their numbers over time.

In order to obtain the minimal yield of 0.2 litres per second specified for handpumps in the Zambian national standard it is not always necessary to use geophysical equipment in order to maximise the yield. Under current procedures in Zambia (MLGH DISS Supplementary module 2f Borehole Standard and Construction Details 2002) the community selects areas in which the hydrogeologist identifies the actual drill site. However, there is scope to further strengthen this.

Drilling Technology: There has been experience gained in Zambia of rehabilitating and further developing hand-dug wells by drilling a further 10 or 20 meters within the well to pick up more water. The large diameter open well in the upper area still serves as enhanced water storage. With the deepening complete then a reinforced cover slab and hand-pump is installed.

With aquifers at depths between 24m and 85m, borehole drilling in Zambia is relatively shallow, to a depth of 60m on average, and certainly less than 100m. Drilling in rural areas is mostly undertaken for hand-pump supplies. However most of the drilling rigs presently active are heavier than required as they are suited to drill larger diameters to several hundred meters. Only two lightweight PAT rigs were found operating in the country. Through the consultants discussions it was clear that stakeholders in Zambia have little awareness of light rigs.

Hydro-fracturing is a system where water under extremely high pressure is forced into an otherwise dry or near dry bore which opens then up fractures and fissures to improve yields. This technology has been proven in several countries. There are areas of Zambia which would benefit from it but it is not well known.

Borehole Design and Construction: There is no national standard borehole specification for Zambia. The handbook entitled "*Borehole Standard Construction and Details*" 2002 indicates that finished diameters should be 4 inch for handpumps and 6 inch for motorised units. In practice, most specifications are 4 inch diameter casing in a 6.5 inch (165 mm) diameter hole but Danida and German Government funded projects both currently specify 8 inch (312 mm) diameter drilled boreholes and the current JICA-funded programme formation, specifies drilled diameters of 7.8 inch (200mm) to 9.75 inch (250mm). One of the reasons for these large diameters is apparently lack of confidence in the drillers to do a good job and in the ability of supervisors to ensure that satisfactory work is achieved. This raises fundamental questions about the pre-qualification and contract management processes being followed, as well as the skills and management of drilling supervision.

There are three general drilling techniques to achieve boreholes suitable for hand-pumps in Zambia:

- <u>Mud-circulation boring</u> 6.5"diameter drilling and 4" diameter casing to full depth in unconsolidated (sedimentary) ground.
- <u>Air-percussion boring</u> 6.5"diameter drilling and 4"diameter casing to full depth in consolidated (rock) ground; in certain fractured ground it is feasible to bore 6.5" install 5" permanent surface casing then drill 4.5" open hole (i.e. uncased) to final depth.
- <u>Combination boring</u> Mud-circulation drilling at 6.5" diameter through collapsible over-burden to rock, install 5" casing then air percussion drill at 4.5" diameter open hole (i.e. uncased).

There is currently no consensus as to whether all boreholes should be cased to the bottom irrespective of natural rock lining, although the common practice is to case fully. Many professionals are of the opinion that aquifers above 20m are not likely to yield sustainable supplies throughout the year but there are areas where shallow wells and hand drilled tube-wells do supply water throughout the year.

Some 30% of Zambia's land area, has very fine grain *"Kalahari Sands"* which are particularly difficult to drill and case. Historically drilling in these areas has involved large diameter, mud-circulation drilling with large diameters specified to enable good gravel packing without bridging. However experience from other countries shows that such fine grained material can also successfully be completed when bored at a smaller diameter.

The "tremmie pipe" is reportedly not used in Zambia to install gravel pack. In addition filter socks are not well known in Zambia.

Well Development, Test Pumping and Water Quality Analysis Requirements: There appears to be a tendency to over-specify borehole development and test pumping requirements although these aspects are not always adequately undertaken by the drillers. If the driller does not properly flush the screen and gravel pack area, this can result in reduced borehole efficiency and lead to blocking of the screen over time.

Data and Reporting: Presently, various drilling programmes and entities in Zambia use their own format for drilling completion and a standardised drilling completion format for the country has yet to be established.

Database and Record Keeping: A pilot project to establish a database of all borehole drilling is presently being piloted for Southern Province under German funding. Specific key data is abstracted from the Completion Reports and entered onto the Database. This pilot needs to be reviewed and extended nationally. It should be obligatory that all drilling programmes collate and present input for database entry. The national database needs to be properly established, kept up to data, be readily accessible to all, and ensure that there is no duplication of data entry (i.e. by using the individual borehole identification number and GPS information).

Conclusions and Recommendations

The specific conclusions and recommendations of the Zambia study are set out below.

Coordination and Cooperation

1. Coordination and Cooperation: DWA does not have a mandate for rural hand-pumped boreholes, but it owns drilling equipment and has an extensive knowledge base. Despite this, the coordination and cooperation between DWA and MLGH, which is responsible for rural water supplies, is limited. *It is thus recommended that coordination and cooperation between DWA and MLGH is improved*.

Regulation

2. Register and Licensing for Drillers (i): There are many private water well drilling contractors operating in Zambia but there is no formal registration or licensing of drillers in the country. There is no requirement for a drilling permit. Basically anybody can purchase a rig and drill anywhere without any regulation or control. *It is recommended that all drillers in Zambia are licensed on an annual basis.*

30. Register and Licensing for Drillers (ii): Currently, the preparation of completion reports by the contractor for all boreholes, including dry bores is not mandatory. *As condition of annual drillers licence renewal, it is suggested that it is made obligatory that drillers must submit a bound compilation of their "Completion Reports" of annual output for the preceding year.*

19. Management for small pumped reticulated systems: Given the interest in the development of small pumped reticulated systems, it is essential they are cost-effective over the long term. Although beyond the scope of the consultancy it is noted that *sustainable management mechanisms need to be established for such systems.*

Procurement, Contract Management and Supervision

3. Prequalification (i): Procurement processes for borehole drilling in Zambia tend to be undertaken as a one-step tender submission and evaluation. In the case of substantial programmes of borehole work there is need to establish pre-qualification processes, based on the company profile, equipment and staff resources, experience and reputation/references. *It is recommended that for substantial programmes of borehole work, drillers should process though a pre-qualification exercise.*

4. Contract documents: Most tender documents and contract documents for borehole drilling in Zambia unnecessarily complex. *It is recommended that tender documents and contracts, as issued by the Government of Zambia and agencies implementing drilling projects should be uncomplicated yet robust to adequately protect both parties.*

20. Pre-qualification (ii): Poor construction quality and inadequate supervision are cited as two main reasons for drilling costly large diameter wells on some drilling programmes in Zambia, which raises fundamental questions about the pre-qualification and contract management processes being followed (as well as the skills and management of drilling supervision). *Close examination of the pre-qualification documents including the method statement for these projects is recommended.*

5. Tender meeting (i): Reliable information on drilling conditions in a particular area is not always readily available to prospective bidders. In order to deal with this problem it is recommended that *a tender meeting is held during the tender process, with mandatory attendance, during which the contract terms, conditions and modalities of execution is clearly described.*

6. Tender meeting (ii): *Hydrogeologists from DWA should be engaged to inform the prospective bidders at the tender meeting.*

7. Roll-over packages for a drillers pool: Presently for substantial drilling programmes in Zambia, contracts are let for drilling large numbers of boreholes (>100), which favours larger contractors and exclude the numerous smaller outfits. *Rather than issue large contracts, it is recommended that clients consider "roll-over" contracts where drillers are pooled and assigned a smaller packages of boreholes.*

8. Defects liability period: In order to improve construction quality and prevent contractors from being paid to drill wells which run dry within a short time due to construction defects *it is recommended that a defects liability period is introduced.*

9. Procurement of materials: In order to stimulate the domestic and regional economy and avoid problems of inefficient logistics, storage and stock keeping and timely availability of materials, *it is recommended that the drilling enterprises themselves have the sole responsibility to source and procure all consumables items required for a boreholes drilling programme, including drilling polymer, uPVC casings and screens and hand-pumps* These can be from pre-approved quality-assured sources, or from other sources approved by the client and/or otherwise demonstrated they the materials are certified to be up to specification.

10. Signing-off: There is no uniform process of acceptance of the borehole drilling works in Zambia, and the community is not always involved in signing off works. *It is recommended that as standard practice, at the completion of each borehole there should be three signatures (i.e. community, supervisor and contractor) which "sign-off" and certifies satisfactory construction. Invoices presented with these certificates should trigger payment for the works.*

11. Streamlining Bills of Quantities: There is no standard bill of quantities for borehole drilling in Zambia and expectations of drillers to follow contracts with "no water no pay" are sometimes unreasonable. *It is thus recommended that Bills of Quantity (BoQ) are streamlined as far as practicable. Streamlining involves bundling some items together rather than using detailed unit costs for each item. For example inter-site mobilisation can be a lump sum per site, the rate for surface drilling and conductor casing can be integral to the overall drilling rate; there can be a lump sum for gravel pack and development.*

14. Risk with respect to "no water no pay" contracts: Although "no water no pay" contracts are easier to manage than payment according to a bill of quantities, there are limits with respect to what can be expected of the drilling contractor. *It is therefore recommended that a borehole drilling programme categorises the risk of non-successful drilling in a manner as described in Table 2.*

12. Drilling supervision: In Zambia there is a lack of competent and experienced drilling supervisors and there appears to be a continual reduction in their numbers over time. *It is recommended that supervisors have independent transport and receive good training in the field prior to the programme inception.* For example, batches of 15 supervisors can be trained over a two week period. As there will be natural reduction in numbers of trained staff over time, up to two training sessions per year should be held, with follow-up training of existing supervisors.

Private Sector Development and Support

35. Subsidised Drilling: In Zambia, DWA rigs are drilling boreholes for private clients at prices which are below the market rate. *Subsidised drilling operations should be avoided as far as possible.*

36. Drillers Association: There is currently no drillers association in Zambia, which could provide a forum for introducing information or represent the drillers to lobby government. *It is recommended that the formation of a Drillers Association in Zambia is encouraged.*

Drilling Technology

25. Drilling Technology (i): Despite the fact that light drilling equipment is ideal for drilling conditions, and the required handpump supplies in Zambia, most drilling rigs operating in the country are heavy duty. There is little awareness of stakeholders in Zambia of light rigs. *Smaller, cheaper all terrain rigs, as available on the international market and able to drill wells at much less cost are recommended for Zambia*.

26. Drilling Technology (ii): *It is also recommended that a consultant driller is recruited to commission and demonstrate the suitability of these light rigs to sector stakeholders and to drill at least 10 boreholes, particularly in the fine Kalahari sand*

27. Drilling Technology (iii): *A donor, or finance organisation should be engaged to procure a light drilling rig, which is then formally assigned to a private sector driller on a "lease to purchase" basis.*

37. Further improving hand dug wells: *The experience gained of rehabilitating and further developing hand-dug wells by drilling a further 10 or 20 meters within the well to pick up more water should be further utilised.*

39 Hydro-fracturing is as yet un-known in Zambia, even though there are areas of the country which could benefit from it. *Donor funding should be sought to support the introduction of hydro-fracturing.*

15. Borehole drilling in the Kalahari Sands (i): Currently, large diameter boreholes are drilled to deal with the fine Kalakari sands, which comprise 30% of Zambia's land cover. However, it has been demonstrated in other countries that such fine grained material can also successfully be completed when bored at a smaller diameter. *It is suggested that alternative, and proven methods to drill the Kalahari sands should be explored*

17. Borehole drilling in the Kalahari Sands (ii): *It is also recommended that contacts should be formally established with counterparts in Angola and that a select group of decision-makers from the Zambian sector should undertake an exchange visit there to see examples of drilling the Kalahari sands.*

Borehole Siting

13. Siting: There is scope for the strengthening of community involvement in borehole siting in Zambia. *It is thus recommended that each community is required to indicate three preferred areas to drill in their locale, and place these in an order of priority.*

Borehole Design and Construction

15. Determine the need for a minimum depth specification: Despite the fact that there are areas where shallow wells and hand drilled tube-wells do supply water throughout the year, many professionals re of the opinion that aquifers above 20m are not likely to yield sustainable supplies throughout the year. *Thus it is recommended that a study should be undertaken to determine whether an absolute minimum depth of drilling (say 30m) should set be for machined-drilled boreholes.*

18. Borehole drilled diameter: There is no national standard borehole specification for Zambia although there norms have developed for the different programmes. *It is recommended, that future borehole specifications require a 5 inch drilled diameter for handpump supplies.*

21. Open hole: Common practice is to case boreholes fully to the bottom, even in situations where the natural rock can allow the hole to be left open (which has been demonstrated as more cost-effective in other countries such as Sudan and Kenya). *It is recommenced that open holes in hard rock are adopted as the standard practice in Zambia.*

22. Gravel pack: The Zambian Guideline to Standard Procedures for Design and Construction of Protected Water Points should include the following: *Gravel pack material should be >95% silica, as feldspars calcite and laterite will easily decompose. In the borehole, the gravel needs to extend to 3m above the top screen and be sealed with 1m of clay/grout.*

23. Filter Sock: Given that the modern alternative to gravel pack of a filter sock is not well known in Zambia, it is recommended that *the filter sock is introduced to the drilling sector.*

24. Verticality: The Zambian Guideline to Standard Procedures for Design and Construction of Protected Water Points, and contract documents should specify that verticality be checked appropriately and routinely after casing/screen installation. *It is recommended that verticality (such that a standard hand-pump cylinder can be lowered into the borehole without meeting any resistance) should be a condition of the borehole being denoted as "successful".*

Well Development

28. Well Development: There is a mismatch between overly high specifications for well development, and a tendency to inadequately develop the well. *It is recommended therefore that the air-lift development process should be undertaken over a minimum period of 2 hours; but if the water has not by then become limpid, then the exercise should continue for up to 6 hours at drillers risk, and can continue yet further up to a maximum of 12 hours with the additional hours paid by the client.*

Data and Reports

29. Borehole completion reports: As yet, different drilling programmes use different formats for their borehole completion reports with the result that standard information is not collected. *It is recommended that drilling logs are compiled into borehole completion reports, which is in a format standardised the entire water well drilling sector.*

31. Borehole Identification numbers: Boreholes drilled in Zambia do not have unique identification numbers. *Each borehole should also have its own dedicated identification number which is stamped onto a metal plate on the hand-pump base and also engraved into the pump platform.*

33. Reporting: There is scope to improve the reporting on groundwater development projects in Zambia. *It is recommended that all agencies supporting drilling programmes are required to report the inputs and outputs of their drilling programmes on an annual basis* These should be in similar set format, compiled and published on the internet. It is important that the information is so structured that comparisons between different regions / districts and programmes can be readily undertaken.

Database and Record Keeping

32. National database: Specific key information is being abstracted from drilling Completion Reports and entered onto a Database for the Southern Province (under German funding). As *a priority, the Zambian Government should found and maintain a national database of all borehole drilling.* The database should be kept up to date, be accessible to all, with no duplication of data entry.

Monitoring and Evaluation

34. Monitoring and evaluation: Subjective observations suggest that past programmes undertaken in Zambia suffer from poor functionality. *It is recommended that regular and routine Monitoring and Evaluation of all programme outputs is actually undertaken*.

Long Term Functionality

38. Maintenance: Ensuring effective maintenance of handpumps supplies is still a challenge in Zambia. However, there are lessons that could be learnt from the water brigade system in Angola. *It is considered that this method of hand-pump maintenance may be also applicable in Zambia, and it is recommended that an exchange visit is arranged to share experience.*

1 Introduction

It is recognised that drilling interventions vary widely both nationally and internationally and are not always cost-effective. The objective of this consultancy is to identify and set out key procedures for cost-effective boreholes as appropriate for Zambia. A summary of a generic set of 10 specific principles, from which these key principles for Zambia will be drawn is given in Box 1. UNICEF internationally is in the process of developing a generic Code of Practice for Cost-Effective Boreholes (COP). It is intended that the COP would raise the level of professionalism by setting out clear procedures to be followed as well as defining minimum standards and clear reporting requirements. It is envisaged that all UNICEF WASH programmes, which support the provision of drilled water wells, will assist the development of a country-specific protocol which takes into account the guidance set out in the COP.

Between March and December 2009, studies are being undertaken in Burkina Faso, Ghana and Zambia which will test the principles of the COP and assist in identifying the strengths and weaknesses in the respective national sectors with regard to cost-effective borehole provision. This is the report of the international consultant, Tom Armstrong, who visited Zambia for 18 days from late June to mid July. He communicated and discussed with a dozen key stakeholders in the sector (see Appendix 2), reviewed documentation and presented his findings to the recently formed national working group on water supply.

The National Rural Water Supply and Sanitation Programme, (NRWSSP) in Zambia intends to construct over 10,000 new water points by 2015 of which UNICEF alone intends to construct 3,650 water points in the next five years. The Danish Government through Danida will also contribute a similar number. Key discussions were held with the hydro-geologist of the DANIDA appointed consultants COWI. This report draws on UNICEF programme experience and others including the Department of Water Affairs, Plan International, WaterAid and Consultants GITEC, who have just completed the implementation of a German funded (KfW/GRZ) programme for some 390 boreholes.

This report focuses on the 10 principles of the draft generic COP (Box 1), and reflects good international practice. During this visit the author discussed and conferred with the consultant appointed to draft a new national "**Guideline to Standard Procedures for Design and Construction of Protected Water Points**". This report thus directly compliments the development the national guideline (see annex 5 for draft structure).

The report considers the existing status of borehole drilling in Zambia. Chapter 2 reflects on the meaning of "cost effective" and key areas of concern are highlighted. Chapter 3 summarises borehole costs and prices in Zambia. Chapter 4 examines Zambian policies and practices with respect to the generic principles of the COP and the proposed structure of the "*Guideline to Standard Procedures for Design and Construction of Protected Water Points*" (Appendix 5). Headings in the report text include brackets which refer to the related numbered section in the proposed guideline structure. The Report text reflects on current practices, and recommends action for further consideration and inclusion. Recommendations are italicised in the text.

This consultancy is under the auspices of the Rural Water Supply Network (RWSN). Overall management was by SKAT and the work was supported by UNICEF, USAID and the Government of Zambia. The opinions and views expressed in this report are those of the consultant alone and not those of the aforementioned organisations.

Box 1. Draft Generic Principles for Cost-Effective Boreholes[1]

1. Who Drills? Construction of water wells and installation of handpumps should normally be undertaken by the lo private sector rather than Government or donor agencies. In countries where this is not yet the case, or private sec drilling capacity is weak, UNICEF (and other water sector stakeholders) should work with Government to develop a strate for achieving private sector involvement in a time-bound manner.

2 Procurement The engagement of construction companies for water well provision should be through a local (nation competitive bidding process, based on a multi-well package in a sensibly defined geographic area, preferably with simi hydrogeology. In order to build local capacity, contracts should not necessarily be limited to one year only. Procureme should be through national partner systems in preference to direct contracting by UNICEF.

3 Contract Management, Supervision and Payment. Adequate arrangements need to be in place to ensure proper contr management and supervision of the drilling contractor. Normally this should be based on systems and personnel of partn organisations. However, if necessary, further training can be given. Additional expertise can be brought in to cover capac gaps with a view to building expertise over the long term. Payment for construction works should be timely.

4 Borehole Siting Prior to preparing any well construction contract, a hydrogeological desk study and field reconnaissar should be carried out and the method of siting boreholes agreed upon, based on expert opinion. In proven areas where t geology is well understood and borehole success is high (say over 70%), it may not be necessary to site wells us expensive geophysical survey techniques. The final process of siting boreholes in the field must involve the community.

5 Borehole Design and Construction The design of the water well should be based on the minimum specification requi to provide a well which is fit for the intended purpose (usually a handpump installation). Overdesign of borehol especially excessive depth and/or diameter, is wasteful and should be avoided.

6 Drilling Technology The construction method chosen for the water well should be the most economical, considering t design and available construction methods in-country. Low cost methods, including hand dug wells and manual drilli should be considered before mechanised drilling if they are feasible and economical. Small drilling rigs which can provi the specified well are preferable to large rigs.

7 Data The data to be gathered during borehole drilling should be specified in the drilling contract. Responsibilities for da collection between the contractor and the supervisor should be clear. The data should be submitted to the appropria government authority.

8 Well Development and Test Pumping Requirements The procedures for well development and for test pumping sho be agreed upon and specified in the drilling contract. The drilled well must be developed until the water is free of solids a fine materials (fines). Test pumping requirements for a handpump should be realistic and not over-specified.

9 Record Keeping UNICEF and its partners should maintain good records of the borehole drilling work undertaken.

10 Reporting Government, UNICEF Country Offices (and other water sector stakeholders) should report on borehole drill programmes annually. These reports should be available to the public including publishing them on appropriate websites

2 The Meaning of "Cost Effective"

Meaning: Before considering the COP procedures, it is necessary to clarify the term "Cost Effective". This term means optimum value for money invested over the long term. This includes appropriate well siting, proficient systems of rig management, the correct choice of drilling rig and hand-pump technology, good data collection and hydro-geological mapping, competent procurement and contract management, proper and prompt payment, suitable supervision and correct quality assurance.

[1] Further explanations on each principle are given in the full document.

Drilling price: It needs to be kept in mind that in tender/contract evaluation, the lowest cost may not be the most cost-effective. For example, contractors can underbid if they are not well informed of the drilling conditions or risks involved. If this is the case then they may use short-cuts to recoup losses and may even default on the contract completely. Whatever problems of underbidding may befall, it will always tend to result in higher cost of contract implementation in the long term.

Appropriate Management and Specifications: The executive organisation, development and oversight of contract implementation should be competent, yet appropriate and limited. Borehole construction should not be over specified, but fit-for-purpose, which in the Zambian context is normally for a hand-pump. Unnecessarily increasing the diameter of a well or the drilled depth will naturally increase costs. The key here for cost effectiveness is what diameter and depth is necessary and appropriate for the conditions.

Supervision: The individual benefiting communities should be involved as far as possible in the supervision of the development their new asset. Specialist supervisors are engaged to oversee operations on behalf of the Employer. These supervisors need to be trained, competent, dedicated and work in empathy as intermediary between the community and the driller. Poor supervision can reduce cost effectiveness. There should normally be some confidence on the integrity of contractor themselves to perform; this appears to be distinctly lacking in Zambia. Drillers should normally be professional outfits, depend on satisfactory quality output for ongoing work and thus generally aim to do a good job.

Cost of Survey: Hydro-geological survey equipment is expensive to acquire and mobilise. It is also costly to support the necessary properly skilled resources to site. During project preparation it should be considered as to whether or not hydro-geological survey equipment really needs to be used for specific siting. There are many areas in Zambia where there is a low risk of drilling a dry borehole, and there is thus no need for survey with geo-physics. For hand-pump yields of a minimum 0.2 litres/second (0.72 m^3/hr) it is not necessary for optimise the potential yield, but best for the pump to be conveniently located for ready community access. Taking additional measures to increase yield to say 0.6 litres/second "just in case" is unnecessary and not economic. However on the other hand there are areas where competent survey is necessary to diminish the risk of dry drilling.

Cost of Failure: It is costly if a boreholes stops working at any time and for what ever reason; this includes abandonment from the community due to unacceptable water quality, or poor original borehole construction with plugged screen or collapsed borehole pump failure due to inadequate maintenance or materials.

Drilling Depth Diameter and Rig Choice: Generally borehole drilling in Zambia is relatively shallow at an average of 60m and in general less than 100m, and mostly done for hand-pumps, which is the pre-dominant technology used to serve the needs of the rural population. Drill rigs are more heavy duty than necessary and bores are largely drilled to diameters larger than required. This report examines how borehole drilling can become more cost effective through the use of lighter rigs and by drilling smaller diameter boreholes.

3 Summary of Borehole Costs and Prices

Historically in India, hand-pumped boreholes were a low cost solution to community water supply; unit rates were some US$700 to $1,500 per water well. In sub-Saharan Africa drilling has been a much higher cost solution at some $3,000 to $30,000 per water well. Today in Nigeria a $4,000 unit cost is typical, whereas in Southern Sudan the unit cost is some $9,000 to $15,000. When comparing the two countries, Nigeria has a good road network whereas South Sudan has poor infrastructure, huge distances and a limited dry season (sometimes as little as 4 months per year) during which drilling can take place.

In Zambia, many specifications for hand-pumped boreholes are appropriate, i.e. 4 inch diameter casing in 6.5 inch diameter bores (confirmed to the consultant by UNICEF, Plan International and Water Aid and consistent with other countries). Costs for drilling tend to be in the range of $4,000 to $5,000 for a completed borehole, but can be double this for some donor aided projects. Both Danida consultants COWI and Gitec for German bilateral funds specify 8" diameter borehole drilling. Table 1 provides an overview of how drilling costs for UNICEF Zambia have changed over time.

Table 1 Selected historical unit costs for UNICEF, including $400 for hand-pump

Year	B/Hs Nos	Province	Contractor	Unit price
2001	40	Southern	Foradex	$3,530
2003	15	Eastern	Zambezi	$3,650
2004	20	Southern	Coratom	$4,000
2005	52	East/South/Central	Foradex	$2,375

The rates given in Table 1 were on a "NO WATER, NO PAY" basis, such that the driller was responsible to site the boreholes and continue drilling on multiple sites until water was secured. On the face of it these rates would appear to be on the lower side leading to concern that drillers may have sought shortcuts because they found themselves in difficulties due to the relatively low cost but the limited scope of the consultancy was not able to examine this. The above rates however compare well with the current cost of a borehole drilled for private clients by the Department of Water Affairs to a depth of 100m for $3,000 to $3,500. As noted in section 3.1.1 below however, the equipment hire rates are below market rates.

Japan International Cooperation Agency (JICA) currently has an ongoing project in Luapula Province for 200 boreholes. JICA still have a reputation amongst sector stakeholders for "high quality but high cost" and being dominant in their dealings with government and communities. The JICA bore specification for drilling in consolidated ground is 6.5" but in unconsolidated rock is 8".

In order to be cost-effective, in Zambia where drilling can take place during most of the year, with relatively shallow drilling with 4 inch casing, a mechanised drilling rig should be able to target completion of some 100 water wells per year. In reality, production rates are often considerably lower than this, leading to higher amortization.

4 Principles of Code of Practice for Cost Effective Boreholes

This chapter examines the practices in Zambia in light of the ten principles for cost-effective boreholes as set out in the draft code of practice (summarized in Box 1) and wider international experience. Recommendations are provided *(in italics and numbered)* with respect to improving the status quo in Zambia with respect to each principle.

4.1 Who Drills? (C11)

4.1.1 Department of Water Affairs

Until 1994 the responsibility for rural water resource development and government borehole drilling in Zambia was under the Department of Water Affairs (DWA) of the Ministry of Energy and Water Development. The mandate for rural water supply was then handed-over to the Ministry of Local Government and Housing (MLGH). However DWA remains vigorous in drilling activities and was reported to have some 21 rotary and 12 cable rigs in use throughout the country. Over recent decades DWA has undertaken substantial programmes under JICA. DWA has recently acquired a number of Japanese rigs and equipment, much of which is serviceable.

The DWA actively drills production boreholes for private clients, nominally for "investigation" purposes. Whilst this activity is not subsidized, it is also not undertaken at the commercial rates; clients pay for labour, fuel and casings and contribute a percentage for "wear and tear". A DWA drilled borehole costs some 15-17m Kwacha ($3,000 to $3,500) for up to 100m depth and some 2.5m Kwacha ($500) goes to the DWA. By international comparison this is well below market rates for rig hire.

Internationally, government owned drilling rigs are renowned for generally low productivity rates and poor maintenance. On the face of it however, Zambia appears to "buck the trend" and the DWA is active. A reasonable target rate of production for a rig to drill shallow boreholes is 100 per year. Two Lusaka based DWA rigs drilled 160 boreholes in 2008 and during the first six months of this year one of these rigs drilled 43 boreholes. However it should be noted that this may not necessarily be representative of all the DWA drilling equipment. Appendix 4.1 sets out the DWA Guidelines for Drilling and Groundwater Development. Given the level of investment to date it appears likely that JICA will continue to support DWA in the drilling of JICA funded boreholes.

Whilst DWA no longer has a formal mandate which covers rural hand-pumped boreholes, it owns physical assets (drilling equipment) and there is considerable institutional resource and knowledge base in DWA (e.g. in hydro-geology and records). However there is currently limited connection between DWA and MLGH. *Recommendation 1 - Coordination and cooperation between DWA and MLGH needs to be improved*.

4.1.2 Private Sector Drillers

There are many national private water well drilling contractors in Zambia. Unfortunately, as there is no register, the exact number is not clear. The fact that there is migration from water well drilling to mineral exploration makes it even more difficult to determine who is active.

The national capacity is augmented given Zambia membership of SADC and an open policy to newcomers to the sector. It was noted that in a recent pre-qualification list of six drillers for a major drilling package (not named for purposes of confidentiality), there was three companies of Chinese origin, one South African consortium, one of Asian origin and one unknown. It is reported that many “brief case consortia” are formed specifically in response to call for international pre-qualification and bidding. Whilst thus there are many drillers in the supply market, there is a general air of scepticism amongst support agencies about the quality of their product.

In Zambia, there is no formal registration or licensing of drillers by Government. There is no control, no requirement for a drilling permit and no requirement for authorisation for borehole construction. This means that anybody can buy a rig and drill anywhere without any regulation or control. This is unusual as compared to other countries in Africa and worldwide, e.g. Box 2.

Recommendation 2: It is recommended that all drillers in Zambia are licensed on an annual basis.

Box 2. Licensing of Drillers and Authorisation to Drill in Kenya and South Sudan

In Kenya all drillers must be registered / gazetted and are required to renew their license on an annual basis. For a company to obtain a licence in the first instance there is an appraisal of the drilling rigs, associated equipment and competency. The drilling company is then obliged to perform and operate under the terms of the licence; this includes only drilling boreholes which have been duly authorised and submitting a completion report for each borehole drilled.

The Water Resource Management Authority is the Government body which issues an authority to drill. This includes the right to abstract a specified limited amount of water per day. To obtain a drilling authorisation, a client must submit a hydro-geological survey report which has been undertaken by a registered hydro-geologist, together with an Environmental Impact Assessment (EIA) or waiver from the National Environmental Management Authority. This authorisation is also required for boreholes fitted with hand-pumps. If a driller does not perform in accordance with the terms of the licence, then it can be withdrawn.

In contrast, in South Sudan all drillers are required to register with the nascent Ministry of Water and Irrigation, but authorisations to drill boreholes are not required. It is also the practice of certain drilling companies on an annual basis, to collate and present government with a bound set of completion reports for all boreholes drilled by that company during the preceding year.

4.2 Procurement (Zambia Guidelines C10, C11)

This section deals with the process of identifying and securing drillers and materials for a borehole programme.

4.2.1 Alignment of Tender Procedures

In an effort to reduce costs, deal with the disparate drilling prices, and align tender processes, the major donors in Chad routinely meet to issue tenders together. Such cooperation is gradually becoming established in Zambia, spear-headed by UNICEF. This should continue.

4.2.2 Drilling Contractor

In recent years UNICEF in Zambia appears to have relied on the services of two particular drilling companies to undertake borehole drilling. Whilst this may have been processed in good order and there are benefits to develop confidence in the output certain drilling companies, such restrictive selective practice is also open to abuse. Individuals and contractors may exploit overly familiar relations, at various levels of implementation.

It is regarded essential for substantial programmes of borehole work that drillers should process though a pre-qualification exercise [Recommendation 3]. Conventionally, such pre-qualification is based on the company profile, equipment and staff resources, experience, reputation/references. Once pre-qualified, drillers can submit a method statement for the works to be undertaken, which explains the contractors understanding of the requirements of the client, including the proposed technology. The method statement can be appraised for cost effectiveness. For example the size of rig proposed may preclude ready access to certain areas.

4.2.3 Simple Contracts

With the exception of UNICEF's standard "service orders", contract documents for water well drilling seen by the consultant were weighty tomes. Based on experience in other countries, drillers may not actually read the documentation and/or do not necessarily understand the content of standard contracts e.g. texts to FIDIC conditions or World Bank formats, which are both long, complicated and inappropriate. It should not be assumed that drillers actually comprehend the implications of a complex contract even though they may say they have read it and have even signed the document.

Recommendation 4: It is recommended that tender documents and contracts, as issued by the Government of Zambia and agencies implementing drilling projects, should be uncomplicated yet robust to adequately protect both parties.

The problem with contracts of more than one hundred boreholes is that they are likely to be restricted to larger companies as smaller, yet competent drillers, may not be in a position to meet the pre-qualification conditions, unless these are adjusted appropriately to include smaller outfits. Whilst smaller drillers could form joint ventures, which government and donors may encourage, in practice drillers are inclined to operate in isolation and tend not have confidence in their competitors. A mechanism for employers to promote a "drillers pool" is described in 4.2.5 below.

4.2.4 Tender Meeting

A tender meeting should be held during the tender process for mandatory attendance, during which the contract terms, conditions and modalities of execution is clearly described [Recommendation 5]. In the absence of reliable information from an existing database of the history of previous drilling in the particular area, this meeting should be attended by an informed hydro-geologist who is intimate with drilling conditions in the area and will describe the "categories of risk" to be applied for the potential for dry drilling in the respective areas to be covered, see 4.4.3 and box 4 below. *It is recommended that hydro-geologists from DWA are engaged to inform the prospective bidders at the tender meeting [recommendation 6].*

4.2.5 Roll-over Packages

Presently for substantial drilling programmes in Zambia, contracts are let for drilling large numbers of boreholes (>100); this tends to favour larger contractors and exclude the numerous smaller outfits. There will be more large programmes of borehole drilling such as are necessary to be undertaken to meet the target of >10,000 boreholes over the next 6 years.

Rather than issue large contracts, employers should consider "roll-over" contracts where drillers are pooled and assigned smaller packages of boreholes [Recommendation 7]. This could be undertaken as follows:

- Firstly a number of contractors are pre-qualified,
- Following a bidding process, selected companies are identified to serve in a "driller's pool" for a specified term, or drilling season.
- Borehole prices are then negotiated and agreed and set for respective areas to be assigned.
- Subsequently, smaller "roll-over" packages of say 20 to 30 boreholes are awarded to several individual contractors at the same time. As packages are completed, new follow-on packages can be awarded depending on satisfactory performance.

With such a system, the contractors are not competing "for the work" but "with the work"; thus good and timely work, can win more work. Contractors with multiple rigs can take on several packages, but the system does not exclude smaller worthy local contractors. It gives the client better control of the works being implemented and limits the risk of poor performance.

4.2.6 Defects Liability

Interviews held during the study indicated much criticism by sector stakeholders that often new boreholes do not sustainably yield water. In other words, a borehole may have been signed off as successful, but goes dry within a short time due to inadequacy of construction, and shortcomings of supervision.

In order to address this key issue, it is recommended that a defects liability period is introduced in Zambia [Recommendation 8]. This would mean that a financial retention of say 10% of contract value is held for 12 months in an insurance bond (preferred by driller), bank guarantee or cash (less preferred). Toward the end of the 12-month period, under the terms of the Contract, supervisors would be obliged to visit each community for their final sign off that the beneficiaries confirm their water point as viable. Pump maintenance problems are however to be excluded from the drillers responsibility.

4.2.7 Materials

Historically UNICEF programmes (in Zambia and beyond) have centrally procured certain materials such as casing and hand-pumps. However this is a restrictive practice, which is not necessarily cost effective or assures quality of the product. Further it does not stimulate the domestic or regional economy. Internationally there are examples of UNICEF having problems of inefficient logistics, ineffective secure storage, stock keeping and timely issue in-country. UNICEF Staff in Zambia acknowledge similar problems. *It is thus recommended that the drillers themselves should have the sole responsibility to source and procure all consumables items required for a boreholes drilling programme, including drilling polymer, uPVC casings and screens and hand-pumps [Recommendation 9].* These can be from pre-approved quality-assured sources, or from other sources approved by the client and/or otherwise demonstrated they the materials are certified to be up to specification.

To be cost-effective the materials may be procured internationally by individual drillers. Drillers in Malawi and Mozambique procure casings and pumps from the same accredited Indian sources which previously have been used by UNICEF. Similarly drillers in Southern Sudan, who have established that:

- All materials required sufficient for a 30 borehole programme (hand-pumps, rising pipes, rods, uPVC casings, re-bar, weld-mesh and tools) can fit into a 20 foot container
- uPVC casings and screens sufficient for 90 boreholes fit into a 40 ft container
- Sufficient hand-pumps, risers and rods for 90 boreholes fit into a 20 ft container

4.3 Contract Management, Supervision and Payment (Zambia Guidelines C10 & C11)

4.3.1 Dealing with the Drilling Contractor

In Zambia, the process of acceptance of borehole drilling works varies; if "signing-off" is stipulated, it may or may not include the community, which the key beneficiary. *As standard practice, at the completion of each borehole there should be three signatures which "signs-off" and certifies satisfactory construction [Recommendation 10]*; there should be one signature each from the community, supervisor and contractor. Invoices are to be presented together with these certificates as the essential trigger of payment.

As a matter of high priority clients should pay invoices promptly, certainly within 30 days, particularly if smaller outfits are engaged. Contractors may be working with little, even no advance payment on the contract and their liquidity is usually marginal, thus they invariably need their invoices to be paid promptly so that in turn their obligations can be met and progress sustained. With drillers procuring materials however then advance payment is justified.

Under previous UNICEF "Special Service Agreements" borehole rates are represented simply on a lump sum unit cost per borehole[2]; thus all unit rates are within the single lump sum per borehole. The simplicity of lump sum payment for each successful borehole is attractive in that there is less scope for manipulation, and is much less complex than having to complete a specific BoQ for each and every borehole. Whilst competent supervision is essential, assurance should also be taken with respect to the driller's integrity and reputation, and there is need for provision of a financial retention. Overall, it needs to clearly be in the driller's interest to produce a good and satisfactory product.

UNICEF has long practiced a "NO WATER NO PAY" policy in borehole contracts in many countries (including Zambia). It is a reasonable expectation that drillers can accept some risk of dry drilling; but that the risk should be within reasonable limits. There were examples expressed to the consultant of contractors being impracticably obliged to continue drilling in an area in search of wet bore. Zambesi Drilling quoted an example of drilling 6 dry boreholes in succession; in another case the contractor Coratom drilled a succession of 20 dry boreholes. Such examples are not a justified expectation on a drilling contractor; dry drilling should be limited. A system to do this is described in section 4.4 below.

Recommendation 11: It is recommended that Bills of Quantity (BoQ) should be streamlined as far as practicable. Streamlining involves maximising lump sum rates rather than using detailed unit costs. For example inter-site mobilisation can be a lump sum per site, the rate for surface drilling and conductor casing can be integral to the overall drilling rate; there can be a lump sum for gravel pack and development.

4.3.2 Supervision

Good quality of supervision and on-site authority is a key aspect of achieving cost-effective boreholes. Poor supervision is one reason for borehole failure and in Zambia itself UNICEF has been criticised for ineffective supervision. The following are typical problems of drilling anywhere in the world, which may result from driller's limited integrity and/or poor supervision:

- Driller claim bore is deeper than reality
- Incorrect screen placement
- Insufficient /poor specification gravel
- Lack of grout
- Not enough development
- Driller claim successful, but in reality dry bore.

[2] For examples see 4 Nos UNICEf Agreements SSA/ZAMA 2001/00000807, 2003/00000961, 2004/00001044, 2005/00000429

In Zambia, consultants are normally engaged for field supervision of drilling activities. Under some programmes the consultants terms of reference also includes hydrogeological survey and borehole siting. Stakeholders interviewed commented that field supervisors in Zambia tend to be:

- Few in number and lacking in experience
- Poorly compensated and
- Reliant on drillers for logistical support.

This in turn means that the supervisors may come under the undue influence of the Contractor. Internationally a common complaint from drillers is that they are supervised by inexperienced graduate hydro-geologists. As a result drillers can sometimes exploit their greater knowledge and experience to the detriment of programme implementation. In Zambia there is a lack of competent and experienced drilling supervisors and there appears to be a continual reduction in their numbers over time.

It is recommended that supervisors have independent transport and receive good training in the field prior to the programme inception [Recommendation 12]. However supervisors must not hinder the Contractor in the timely execution of operations. It is considered that batches of 15 supervisors can be trained, essentially in the field over a two week period. There will be natural reduction in numbers of trained staff over time, thus up to two training sessions per year should be held, with follow-up training of existing supervisors.

4.4 Borehole Siting (Zambia Guidelines C1, C2, C3)

4.4.1 Community Preference on Site Location Selection

A hand-pump can readily yield 0.33 litres/second or 20 litres per minute, which is also a reasonable rate of pumping and maximum rate water delivery to a user. To obtain a borehole with the minimal yield specified to Zambian national standard of 0.2 litres/second, (20 litres in 100secs), it is not always necessary to undertake hydro-geological survey to maximise opportunity and yield. In certain areas where aquifer and drilling conditions are known it can safely be assumed that a borehole drilled anywhere within the preferred vicinity of the users will yield water in excess of the minimum yield. Box 3 sets out an example from south Sudan to illustrate this point.

The driller seeks only to secure water and if the decision is left to the Contractor, he may opt to drill close to the road for easy access, or at a low elevation for less drilling depth, or possibly close to termite mound or a certain tree according to local traditional beliefs etc. The hydro-geologist on the other hand will select a site which will maximise yield. Boreholes being drilled for hand-pumps however should always be located, if at all possible, with central convenience to the users and not to the dictate of the driller, nor that of the hydro-geologist. This principle may already be adhered to by agencies but needs to be emphasised.

Under current procedures (MLGH DISS Supplementary module 2f Borehole Standard and Construction Details 2002) the community selects areas for a hydro-geologist to identify the actual drill site. Whether or not a hydro-geologist is subsequently engaged *it is recommended that each community is required to indicate three preferred areas to drill in their locale, and place these in an order of priority [Recommendation 13].* Whatever the different settlement patterns e.g. nucleated; ribbon (along a road, ridge, river or other feature) or dispersed, communities can select prioritised areas and/or maximum distance from a chosen spot.

Box 3 Siting, an anecdote from South Sudan

In Central Equatoria of South Sudan, mid/late 1980s, a private contractor had constructed some 350 boreholes into what is generally a consolidated basement rock area. Of these:

- Some 175 boreholes (50%) were drilled <u>with</u> expert consultant hydro-geological siting and supervision, resulting in 70% success and with payment received for both wet and dry bores
- Some 175 boreholes (50%) were drilled <u>without</u> expert consultant hydro-geological siting and supervision, resulting in 71% success and payment received only for wet boreholes

The difference between 70% and 71`%, is neither “here nor there”. The point is that for this contractor and this area, there was no difference as to whether the borehole was sited and supervised by a hydro-geologist or not.

4.4.2 Categorisation of Risk

It is a reasonable principle that if a borehole site has been surveyed and a driller is directed to drill there by the client, that the driller should be compensated for his work, whether or not the borehole is successful. However if the driller selects the site then the risk that he is accepting should be determined. Over recent decades, many agencies including UNICEF (in Zambia and beyond) have adopted an approach of "*No Water No Pay*" whereby a driller is contractually obliged to accept the entire risk of failure or drilling a dry well, and thereby the responsibility for site selection is with contractor. A fundamental problem with this strategy is that there have been cases where there is no limit to the number of dry bores (see section 4.3.1).

It is therefore considered necessary to propose further refinement and qualification to this principal as follows:

- Drill in a site to the convenience of communities,
- Engage expert hydro-geological siting only when appropriate,
- Limit drillers risk of the maximum number of dry bores, and yet
- Be protective and reasonable with client/donors funds,

It is therefore recommended that a borehole drilling programme categorises the risk of successful drilling in a manner as described in Box 4 [Recommendation 14].

Box 4 Categorising Success Rates and Payment Structures

At present there is no defined database by which to analyse drilling conditions. However detailed discussions by the author with two experienced principal hydro-geologists of DWA, has established that there is sufficient knowledge of all districts of Zambia for informed hydro-geologists to classify the drilling potential, without survey, in each community into the following categories:

Category	Success Rate*	Assumptions	Proposed Payment Arrangements
A High	> 90%	Geophysical survey not necessary. To drill at any site has a high chance of success. Thus, the first preference of the community is likely to be successful.	The risk of dry drilling is denoted as small and dry bores are not paid to the contractor, under any circumstance. Driller is to survey select site within the areas nominated by the community and his unit rates is to include the risk of dry bores.
B Medium	60 - 90%	Moderate success rate. The drillers themselves may elect to survey (either themselves or by their appointed hydro-geologist) and select the actual dill sites within the given preferred areas of community. A minimum drilling depth is however to be specified in the Contract.	Limited payment is made to the Contractor for dry bores to a certain depth, according to formula set out below: • 1st bore success: 100% paid; move to new location. • *If 1st bore dry: No payment* • 2nd bore success: 100% paid, move to new location. • *If 2nd bore dry: 50% (of a productive borehole) paid* • 3rd bore success: 100% paid, move to new location • *If 3rd bore dry: 50% (of a productive borehole) is paid move to next community* In the exceptional event of three dry bores, then no further drilling is undertaken in this community at this juncture. In effect this community locale will now become a Category C risk and requires expert hydro-geological survey to be commissioned by the Employer in order to ascertain define site(s) for any further drilling.

C Low	< 60%	Client to commission independent siting including use of geophysics (Resistivity profiling *and* Electro-magnetic (EM) assessment. Sites selected and contractor drills to minimum depth indicated	The employer has determined the actual site and depth; payment is made for both wet and dry bores.
*The suggested percentages applied above can be varied to suit, for example 85%, 55-85% and 55% respectively. A maximum of three dry boreholes may be made in any one community under the above arrangement, in accordance with their preferred sites. This however is both statistically and in practice unlikely, but rare cases can happen; in which case after 3 dry bores it is time to cease "random" drilling and undertake geophysical investigations before any further drilling.			

4.5 Borehole Design and Construction (Zambia Guidelines C4)

4.5.1 Geology and Hydro-geology of Zambia (Zambia Guidelines C1)

Maps and text which well describes the geology and hydro-geology of Zambia are found at Appendix 3.1, with acknowledged thanks to Dr Mpamba, Principal Hydro-geologist at DWA. Appendix 3.2 and 3.3 respectively provide geological and hydro-geological maps of Zambia in colour, with acknowledged thanks to Max Karen of Cowi consultants.

Hydro-geologists interviewed consider that generally throughout Zambia aquifers found above 20m are not likely to yield sustainably throughout the year. However, there are areas where shallow wells and hand drilled tube-wells do supply water throughout the year. There is a long dry season of up to 8 months in Zambia and the water table seasonally rises and falls. It is thus necessary to specify that the drilled depth should extend some 6m below the bottom of the last aquifer. *Thus it is recommended that a study be undertaken to determine whether an absolute minimum depth of drilling (say 30m) should set be for machined-drilled boreholes [Recommendation 15].*

4.5.2 Boreholes in Small Grain "Kalahari" Sands

Some 30% of the land area of Zambia, particularly in the Western Province, has very fine grain *"Kalahari Sands"* which are particularly difficult to drill and then case, and are usually combined with poor accessibility. Drilling in these areas needs a high degree of skill and is relatively costly. It is perceived that numerous boreholes have failed in the Kalahari Sands of the Western Province due to improper well design. Historically drilling in these areas has involved large diameter, mud-circulation drilling. Large diameters are specified to assure the gravel packs nicely around the screen casing without bridging. The Danida Consultants specify: "the diameter of the hole in the screened zone and down to the bottom of the borehole should be minimum 200mm in order to make sufficient annular space for gravel pack in the annulus between the hole and the screen (112 mm)".

One long experienced driller, who only owns heavy rigs, described what he considers the only way to effectively deal with the Kalahari Sands is to firstly install a 10"dia temporary steel surface casing, then to drill inside the 10"dia casing to enable to telescope in a uPVC 8"dia plain casing; again drill to install a 6" slotted and then drill again to finished depth to finally install 4"dia screen casing. The 10"dia steel casing is retrieved; the slot size is 0.2 - 0.3mm and the gravel pack is sized from 0.2 to 0.8mm, from a known and specified source, for example Chingola.

However from direct communication by the author with Peter Ball, a master driller of international repute, it is observed that boreholes in such fine grained areas can also successfully be bored at 165mm diameter. It was pointed out that: i) such small slots (0.2 – 0.3 mm) coupled with ii) small size of gravel pack, which is little more than coarse sand, and iii) a wide annulus, may all inhibit the proper cutting, cleaning and voiding of the drilling fluids from the borehole, and thus prevent the proper development of the borehole.

It is maintained by Peter Ball that it is entirely practical to drill small diameter boreholes as per the sketches attached in Appendix 6, which are taken from the drilling manual of PAT (Promotion of Appropriate Technology) as available on *www.pat-drill.com.* These graphically show the drilling techniques for fine sands with reduced diameter screen of 2inch diameter below the 4inch diameter casing to house the pump cylinder using telescopic casing for options for 1) natural development, and 2) even gravel pack. There are widespread successful drilling examples of such small diameter boreholes in similar fine grains in Angola (Oxfam), just across the border from Zambia's Western Province, and also in the delta areas of Bangladesh, Cambodia, and Vietnam*. It is suggested that this method should be explored [Recommendation 16.] It is also recommended that contacts should be formally established with counterparts in Angola and that a select group of decision-makers from the Zambian sector should undertake an exchange visit there to see such examples [Recommendation 17].*

4.5.3 Borehole Casing Diameters

National standards: Whilst there is no national specification for borehole design, there is a handbook entitled "***Borehole Standard Construction and Details***" 2002. This is one of a series (Supplementary Module 2f) from the Department of Infrastructure and Support Services of MLGH. This is a useful generalised training document but at para 4.12 it indicates that finished diameters should be 4 inch for hand-pumps and 6 inch for motorised units*. For future amendment it is recommended, that the latter may be reduced to 5 - see 4.5.4 below [Recommendation 18]*

Hand-pumped boreholes require a minimum of 4 inch nominal diameter casing to permit sufficient space for the pump cylinder and rising mains. Normally uPVC casing/screen is stipulated which has a minimum internal diameter of 103mm and an outside diameter of 113mm.

Motor-pumped boreholes for population centres, schools and Public Health Care Units (PHCU) need sufficient yield and should be completed with a cased pump housing of 5 inch nominal diameter in order to permit space for an electro-submersible pump. Whilst there are electro-submersible pumps, which can fit inside 4inch casing, eg the Grundfos SQ series at 2.75 inch diameter, these have high rpm and are considered less robust and have a shorter life than the regular 4inch SP pump which requires a 5inch casing. For a solar powered unit the Grundflos SQF 2.5-2 (approx. $3m^3$/hr) can fit inside 4 inch casing, but for higher yields (say $5m^3$/hr) to accommodate the Grundfos SQF5A-6 or the Lorentz SJ5-12, a 5 inch casing diameter is required.

Small Water Distribution Systems Concentrations of populations tend to grow and also aspire to reticulated water, which can be economically supplied from a pumped borehole and is indeed preferred over multiple hand-pumps. In schools the demand for water is periodic i.e. between lessons and at meal times and is also required at toilets for washing hands, where running water supplied at a modest pressure head is best. Under such circumstance, pumped and stored water is ideal and more appropriate than water supplied from hand-pump. As evidenced in discussion with several parties, particularly Water Aid and COWI, there is considerable interest to further develop small pumped reticulated systems for nascent concentrations of populations. Whilst there is clear demand, it is a concern that such interventions are done well and cost effective. *For sustainable management, the software aspects must properly engage the benefiting community develop a User Committee roles and responsibilities, for the system apart from the technical components of survey, design and construction [Recommendation 19]*. This is however beyond the scope of this consultancy.

4.5.4 Borehole drilled diameter

As indicated above a key focus of this consultation is the consideration of the appropriate bore/casing diameters for hand-pumped boreholes. For a 4 inch finished diameter borehole, a bore can in almost all circumstances be drilled at 6.5 inch (165 mm) diameter. This is entirely in accordance with international experience and practice; many agencies (e.g. PLAN International, WaterAid and DWA) in Zambia specify such. Contractors with whom the consultant discussed also agreed on these specifications, with the exception of fine Kalahari sands area, which is addressed separately in 4.5.2. Drillers in Zambia are equipped with and content to drill with whatever specified diameter and method. Essentially however the larger diameter and materials engaged, the higher the rates and less cost effective is the borehole.

Some programmes nevertheless do specify larger diameter drilling; these include the recently completed German government funded borehole drilling programme in North West Province under Gitec Consult, the currently being initiated Danida funded borehole drilling programme, presently in Western Province under COWI consultants, and the presently JICA funded programme, where drilling in unconsolidated ground is specified at 200 to 250mm.

In regard to drilling diameters, there was considerable, discussion and deliberation between the experienced hydro-geologist consultants of Gitec (Jim Anscombe), COWI (Max Karen) and the author. As may be expected with such divergent experience and views, the debate was not altogether concluded; and there was agreement to differ as regards to appropriate drilling diameter. Apart from this, it was perceived that fundamentally, the core of the problem lies in lack of confidence in the reliability of drillers to do a good job and the ability of supervisors to ensure that satisfactory work is achieved. It was stated that there are many non-functional boreholes in rural Zambia and this is due largely to too small bore diameters, as well as the inadequacies of the original drillers and/or supervision, or a combination thereof.

On the other hand it was emphasised this is not the case in other countries and is directly contrary to the experience of the author in Southern Sudan where smaller diameters are entirely the norm. Furthermore established drillers there often perform with little or no supervision to invariably generate good product; problems (see last paragraph of section 4.3) tend to be rare, unless with new drillers. The good name of the drilling company is generated over time and in itself is a guarantee of quality, sustainable boreholes; this feature may relate to a certain culture of good practice within the drilling sector there. There are however examples of heavy foreign based rigs, winning work with low prices and then not being able to perform. *For the Zambian context, close examination of the pre-qualification documents including the method statement is firmly recommended [Recommendation 20]*

In keeping with the above mentioned and hydrogeology (described 4.5.1 and 4.5.2) there are three general drilling techniques to achieve boreholes suitable for hand-pumps in Zambia. Together with appropriate dimensions, these are:

- <u>Mud-circulation boring</u> 6.5”diameter drilling and 4” diameter casing to full depth in unconsolidated (sedimentary) ground.
- <u>Air-percussion boring</u> 6.5”diameter drilling and 4”diameter casing to full depth in consolidated (rock) ground; in certain fractured ground it is feasible to bore 6.5” install 5” permanent surface casing then drill 4.5” open hole (i.e. uncased) to final depth, as below
- <u>Combination boring</u> Mud-circulation drilling at 6.5” diameter through collapsible over-burden to rock, install 5” casing then air percussion drill at 4.5” diameter open hole (i.e. uncased)

All the above is indicative of drilling at 6.5” diameter. Some experts hold the opinion that all boreholes should be cased to the bottom irrespective of natural rock lining. In the COWI consultant’s specification for the latter case of drilling in areas with unconsolidated overburden followed by hard basement rock, it is indicated therein that “*drilling must be carried through the overburden and highly weathered rock using a bit with diameter between 200mm to 250mm [!], and then through the moderately weathered rock and the fresh rock using a bit with diameter of 165/176mm*”. This then readily permits the insertion of 4 inch casing to full depth.

However it is observed that, as in other countries such as Sudan and Kenya, with sufficient air-lift/cleaning and development, leaving the bore open at depth is more advantageous, cost effective and from experience the borehole is not prone to failure; this is recommenced practice for Zambia [Recommendation 21].

4.5.5 Gravel Pack Placement, Filter Socks, Centralisers and Verticality

It is important that the casing is placed centrally within the open bore; this is particularly necessary with uPVC casing whish has a tendency to curve, especially if it has been exposed to sunlight for any length of time. A particularly effective design of centraliser, available in southern Africa was shown to the author by the COWI consultant; this is being copied by at least one contractor for use in his Zambian drilling programmes.

To avoid bridging of the gravel pack, it is important that gravel volume required for a borehole is calculated and that exactly this amount is installed gradually and very slowly. Proper process can be achieved and facilitated with the use of a "tremmie" pipe and funnel; although this technique is reportedly not practiced in Zambia, or indeed in many places. Use of tremmie pipe is where a temporary pipe is installed in the annulus and the gravel pack is introduced necessarily slowly through a funnel. It can be difficult to introduce a pipe into the small annulus between the casing pipe and the bore sidewall; this difficulty may go some way to explain why it is rarely used. However slow and steady insertion of gravel around the casing with sufficient care can avoid bridging.

It is important that the gravel pack is correctly graded and of proven good quality with rounded, smooth and uniform particles. Flaky angular materials such as schist and micas will block the slots. *The gravel should be >95% silica, as feldspars calcite and laterite will easily decompose [Recommendation 22]*. In the borehole, the gravel needs to extend to 3m above the top screen and be sealed with 1m of clay/grout.

A modern alternative to gravel pack is a filter sock or stocking, which is a kind of geo-textile material and is unrolled over the screen prior to insertion. The borehole is then naturally developed by air flush and the original bore side-wall material collapses onto the sock. There are several manufacturers of such including Boode, of Netherlands and UK. *This filter sock should be introduced to the Zambian drilling sector [Recommendation 23].*

Verticality should be checked appropriately and routinely after casing/screen installation such that a standard hand-pump cylinder should be able to be lowered into the borehole without meeting any resistance. *It is recommended that verticality should be a condition of the borehole being denoted as "successful" [Recommendation 24].*

4.6 Drilling Technology (Zambia Guidelines C4)

4.6.1 Rig Selection

Generally borehole drilling in Zambia is relatively shallow, to a depth of 60m on average, and certainly less than 100m with aquifers between 24m to 85m. Drilling is mostly undertaken for hand-pumps, which is the pre-dominant demand to serve the needs of the rural population. It is observed that drill rigs presently active in Zambia are generally heavier than are normally required for hand-pump boreholes, in that they are suited to drill larger diameters to several hundred meters. This has also been the case in several other countries[3]. In the context of borehole drilling for hand-pumps, such rigs have higher operational cost, and because they are heavy then off-road site access is restricted, particularly in the wet season.

Smaller light rigs are better suited to drill at 165mm (6.5 inch) diameter. They are cheaper to operate and can be mounted on the back of four-wheel drive pick-ups or on a single axle trailer and being light can better access off road, more readily traverse sand, cross frail bridges and use pontoons to cross rivers and waterways; all such conditions are common in Zambia

Decades ago the Swedish company, Atlas Copco, produced a light rig called an "LWD", which presumably stood for "light weight drilling". In recent decades PAT from Thailand have developed the technology and manufacture a range of light rigs. There are many hundreds of PAT rigs all over the world, but it appears that there are just two small PAT rigs in Zambia used for mineral exploration**.** Such small rigs require substantially less capital to procure and incur less depreciation; small rigs drilling smaller boreholes use less consumables and less fuel, which in turn produce more cost effective boreholes.

[3] Internationally there have been unease expressed regarding over-specified drilling rigs; Black and Talbot (2005) refer to rigs being procured in India some 30 years ago which have an "extraordinary capacity for drilling at speed", yet were cumbersome and over-equipped. Wurzel (2001) established that in Nigeria from 1990 to 2000 there was a number of Ingersoll-Rand TH-10s which can readily drill to 180m yet the average drilling depth there was 33m. Keast (2002) identified that the drilling rigs commissioned for drilling by UNICEF in Sierra Leone, could not reach many sites locations.

Smaller, cheaper all terrain rigs are available on the international market and can drill wells at much less cost and are recommended for Zambia [Recommendation 25].

4.6.2 Light Rig Demonstration

Through the consultants discussions it was clear that stakeholders in Zambia have little awareness of light rigs. It is perceived that a light rig from PAT, or other manufacturers should be introduced and demonstrated to the drilling sector; a PAT 301 rig, capable of drilling at 6.5"diameter to 100m, is considered the most appropriate size; photographs of this rig can be seen towards the end of Appendix 8, the power point presentation made to the working group. *It is also recommended that a consultant driller is recruited to commission and demonstrate the same rig to sector stakeholders and to drill at least 10 boreholes, particularly in the fine Kalahari sand [Recommendation 26].*

The rig and associated equipment and sufficient casing for 10 boreholes can be procured for say $100,000 (+/- to be costed in detail). *A donor, or finance organisation should be engaged to procure such a rig which is then formally assigned to a private sector driller on a "lease to purchase" basis [Recommendation 27];* for example the selected contractor will progressively purchase the rig over a number of boreholes. If say $100,000 is the capital investment then for example $2,000 may be deducted from the borehole billing cost of 50BHs. In recent years, such modality had successfully been engaged in order to enhance the drilling sector capacity in South Sudan.

4.7 Well Development and Test Pumping Requirements (Zambia Guidelines C5)

4.7.1 Appropriate Specification

Boreholes need to be properly developed following construction with casing and gravel pack and then yield characteristics need to be established. From interviews with drillers and hydro-geologist it appears that in Zambia and in general terms there is a tendency for borehole development and test pumping to be over-specified on one hand and yet for drillers not to adequately undertake these vital aspects on the other. The specification may dictate an unreasonably long time for the components of well development and test pumping, which is wasteful of the driller's time and resources. One driller complained that on one contract he was required by the supervisor to continue to develop for 6 hours as indeed stipulated in the specification despite boreholes being fully developed and water limpid within 2 hours. However conversely if the driller does not properly flush the screen and gravel packed area, this can lead to diminished borehole efficiency and potential for progressive blocking up over time.

It is noted that chlorine can be introduced into a well following before development, in order to "cut" the drilling polymer; this leads to more effective washing out of the drilling fluid. However in most specifications chlorine is only used as a disinfectant following well construction completion and in conjunction with pump installation.

The well development activity is best done with compressed air which is thoroughly applied within all screened areas and the borehole is flushed until the water is able to be air-lifted entirely clear of fines and turbidity for a continuous period of 30mins. *The air-lift development process should be undertaken over a minimum period of 2 hours; but if the water has not by then become limpid, then the exercise should continue for up to 6 hours at drillers risk, and can continue yet further up to a maximum of 12 hours with the additional hours paid by the client [Recommendation 28].*

Once the lifted water is clear, then the amount of water being voided from the well by the air-lift is to be quantified and the measured "airlifted yield" is recorded. For a hand-pumped borehole, this air-lift capacity test may be taken as the only evaluation of the borehole yield. The yield should be further qualified once the hand-pump is installed by continuous hand-pumping over a four hour period with the amount pumped quantified. In this case there is no need for test pumping itself.

However if test pumping is specified, then for hand-pump it is appropriate that it is undertaken for a continuous minimum period of 2 hours and maximum period of six hours. It can be done only until stable pumping water level is achieved for a constant rate of discharge; normally this discharge rate may be at least double (ie 1.44cum/hr) the minimum discharge for a successful borehole in Zambia, (ie 0.72cum/hr). For wells which are planned for submersible pumping then more complete test pumping should be undertaken for yield assessment together with drawdown / recovery analysis

Samples for water quality analysis for specific chemicals should be taken at the end of well development or from late in the test-pumping exercise.

4.8 Data (Zambia Guidelines C11)

4.8.1 Completion Reports

A standardised format has yet to be established in Zambia and this needs to be developed and promulgated. Presently various drilling programmes and entities use their own format. An example of the Completion Report presently adopted by DWA is included herewith at Figure 2 of Appendix 4.1; this has the bare essential information but does not have GPS, clear lithology nor penetration rates. A more complex but also concise example as taken up by the consultants Cowi for the Danida programme is found at Appendix 4.2. This includes a photograph of the generalised lithology.

It is recommended that drilling logs are compiled into borehole completion report which is in a format to be standardised for the national drilling sector [Recommendation 29]. Completion reports should be prepared by the contractor for all boreholes, including dry bores. This is to be a mandatory requirement.

The standard Completion Report should contain all the pertinent information required including: GPS location, depths, lithology, penetration rates, casing design, yield test / test pumping, water quality details and approximate number of persons served. It is considered that the format for a completion report should be as straightforward and uncomplicated, without being overly simple. Completion reports for a hand-pumped borehole may be different and simplified from that for higher production and a motorized pump; the latter may contain more detailed information for example on penetration rates, pumping tests (constant and step tests), comprehensive water quality details etc. It may thus be considered appropriate to establish two formats.

As condition of annual drillers licence renewal, it is suggested that it is made obligatory that drillers must submit a bound compilation of their "Completion Reports" of annual output for the preceding year [Recommendation 30].

Each borehole should also have its own dedicated identification number [Recommendation 31], which is stamped onto a metal plate on the hand-pump base and also engraved into the pump platform. This number identifies the district, year drilled, and borehole number which is to be pre-issued and allocated by the district authority

4.9 Record Keeping (Zambia Guidelines C11)

It is internationally accepted that to assess progress and status of national groundwater development and guide future planning, it is necessary to maintain good records of borehole drilling work as well as index and archive original documents in a manner which enables them to be readily accessed. Records should include:

- Pre-qualification and tender evaluation reports.
- Reports of community mobilisation and training.
- Schedules of construction supervision.
- Reports of post-construction water-point monitoring over time.

As a priority, the Zambian Government should found and maintain a national Database of all borehole drilling [Recommendation 32]. Specific key information is to be abstracted from the Completion Reports and entered onto a Database. This is presently being piloted for Southern Province under German funding but should be reviewed and extended nationally. It should be obligatory that all drilling programmes collate and present input for database entry. It is important that the national database is properly established, is readily accessible to all, and that there is no duplication of data entry. The individual borehole identification number and GPS information should assist to avoid any repetition.

4.10 Reporting (Zambia Guidelines C11)

It is important that government progressively acquires and maintains a clear picture of the status of groundwater development in the country. *For Zambia, it is recommended that all agencies supporting drilling programmes are required to report the inputs and outputs of their drilling programmes on an annual basis [Recommendation 33]*. These should be in similar set format, compiled and published on the internet. It is important that the information is so structured that comparisons between different regions / districts and programmes can be readily undertaken.

Annual programme reports should summarise and include:

- Regions / District areas and number of boreholes drilled with maximum / minimum / average depths, number of dry bores (rate of success), number and type of borehole rehabilitations, and the drilling costs.
- Details of Contracts should be summarised including names of drilling companies and amounts / dates paid.
- Trainings undertaken and guidelines produced.
- Financial overview of programme inputs/outputs and associated overall costs.
- Monitoring results post-construction, particularly at 1 year but also 2, 5 and 10 years as appropriate to include all boreholes in the areas covered.

It is recommended that regular and routine Monitoring and Evaluation of all programme outputs is actually undertaken [Recommendation 34]. This is all the more vital given subjective observations of poor sustainable functionality of past programmes undertaken in Zambia.

5 Additional Principles to Build a Healthy Drilling Sector

5.1 Avoid Subsidised drilling operations

Over recent decades, it has been demonstrated internationally that private sector rigs in a competitive environment promotes price efficiency in borehole drilling interventions. Rigs, equipment and their operations which are donated tend to ignore risk, do not work efficiently and furthermore destabilise the competitive drilling sector, not least by reducing the number of wells for private sector drillers. There is an example in Kenya of donated faith-based rigs drilling for the tourist sector. Similarly here in Zambia DWA rigs are drilling boreholes for private clients. *Subsidised drilling operations should be avoided as far as possible [Recommendation 35].* It is worth bearing in mind that drillers can only be sustained by drilling boreholes. Obtaining steady and regular work is essential to enable capital-intensive drilling enterprises to remain in business, and be efficient and cost-effective.

5.2 Support formation of Drillers Association

It is recommended that the formation of a Drillers Association in Zambia is encouraged [Recommendation 36]. Private sector drillers tend not to discuss with each other or cooperate in any way. Whilst this may be seen as normal in a competitive environment there are also advantages in such a group; networking and collaboration promotes professionalism. A drillers association can provide a forum for introducing information on technology and sector developments, for example on the economic use of small rigs, methods to handle Kalahari sands, upgrades on pump technology. It can represent the drillers to lobby government on policy and for example may serve to remove Value Added Tax (VAT) from Borehole Drilling and Services. This was effectively done in Kenya where a driller's forum was made in the Water Industries Association under the facilitation of the dominant pump supplier Davis and Shirtliff, who incidentally also have a branch in Zambia.

5.3 Hand-dug well rehabilitation

There has been experience gained in Zambia of rehabilitating and further developing hand-dug wells by engaging a contractor to drill down a further 10 or 20 meters to pick up more water. The large diameter open well in the upper area still serves as enhanced water storage. With the deepening complete then a reinforced cover slab and hand-pump is installed. *It is recommended that this technique is further utilised [Recommendation 37].*

5.4 Involvement of Urban Water Facility in Hand-pump maintenance

It is understood that in Angola, an innovative arrangement for water point maintenance has been established, whereby the water utility of the local district town has the mandate for borehole/hand-pump maintenance in the surrounding rural area. Each year the community is obliged to pay an amount (say $100) to the water utility; in return the water utility guarantees attention to any water point or hand-pump within 2 days. The local water utility therefore has an interest in the good construction of any new water points and can be incorporated in the supervision process. *It is considered that this method of hand-pump maintenance may be also applicable in Zambia, and it is recommended that an exchange visit is arranged to share experience [Recommendation 38].*

5.5 Hydro-fracturing

Hydro-fracturing is a system where water under extremely high pressure is forced into an otherwise dry or near dry bore which opens then up fractures and fissures to improve yields. This technology has been proven in several countries. It was successfully introduced and demonstrated some 10 years ago under the RUWASA project in Mbale Uganda, on almost 2000 boreholes by Interconsult under Danida funding. *There are areas of Zambia which would benefit from hydro-fracturing* and it is suggested that the Department of Water Affairs is ideally placed and resourced to pilot this technology in Zambia. *Donor funding should be sought to support this intervention [Recommendation 39].*

6 Recommendations

Working towards cost-effective borehole drilling in Zambia is not a short term process, but rather one which will take several years of dedicated attention and support, as well as champions within the country. This chapter synthesizes the many recommendations in this report, thus paving the way for agreed action points, and a “road map” for the way forward.

Coordination and Cooperation

Recommendation 1: There should be improved coordination and cooperation between MLGH and DWA, with efforts on both sides to attend shared meetings. DWA should be invited to, and attend tender meetings to brief prospective contractors on hydro-geological conditions and drilling potential in areas to be drilled; DWA should also actively participate in the training of supervisors.

Regulation

Recommendation 2: Drilling companies should be licensed such that some degree of formal control is introduced to the Zambian drilling sector. The renewal of the licence may be dependant on the submission of a compiled set of completion reports for boreholes constructed by the driller during the preceding year.

Recommendation 19: Small water distribution systems for population centres are increasingly in demand. However, proper development procedures are required to ensure that they can be cost effective.

Procurement and Contract Management

Recommendations 3, 4 & 20: Pre-qualify drilling companies and use simple robust, contract formats. Make tender meetings mandatory and utilise DWA hydro-geologists to inform prospective bidders on the expected conditions and risk of dry boring.

Recommendations 5 & 6: Make tender meetings mandatory and utilise DWA hydro-geologists to inform prospective bidders on the expected conditions and risk of dry boring

Recommendation 7: Rather than issue large contracts, employers should consider "roll-over" contracts where drillers are pooled and assigned smaller packages of boreholes

Recommendation 8: A retention or defects liability period of 12 months is considered necessary to ensure sustainable performance of the product over one year.

Recommendation 9: Materials for borehole programmes should be procured directly by the assigned drillers and not centrally. Advance payment is justified.

Recommendation 10: Payment of invoices should be triggered by three signatures certifying a borehole Invoices are to be paid promptly.

Recommendation 11 & 14: Lump sum rates per borehole have advantage over BoQ and in line with the "No water No pay" modality, which must however be limited. Drilling potential can be categorised into A) low dry risk, where no payment is made; B) limited risk where some payment is made for dry bores and payment; C) high risk where the employer identifies the drill sites and pays for all drilling activity.

Private Sector Development and Support

Recommendation 35: Avoid subsidised drilling operations which destabilise the private sector

Recommendation 36: Encourage the formation of a Zambian Drillers Association.

Technology

Recommendation 25, 26 & 27: The drilling sector in Zambia uses heavy duty rigs whereas light rigs are more appropriate for cost effective hand-pumped boreholes; it is recommended that a donor should introduce a demonstration rig and engage a consultant driller to demonstrate the lighter drilling rigs, including drilling in super fine Kalahari sands.

Recommendation 37: Use drilling rigs in the rehabilitation and deepening of hand-dug wells

Recommendation 39: Hydro-fracturing can improve yields of otherwise dry rock boreholes. Donor funding should be sought to introduce this technology through DWA.

Recommendation 17 & 38: An exchange visit with counterparts in Angola should be arranged such that the Zambian sector can learn from practice in Angola with small rigs and hand-pump maintenance, and the Angolans can also learn from Zambia.

Supervision

Recommendation 12: Good supervision is of fundamental importance to cost effective boreholes. Supervisor training should be high quality and sufficient numbers are to be trained to cater for natural attrition

Recommendation 13: In the first instance boreholes should be sited to the preference of the users who should identify three preferred sites within their community

Borehole Design

Recommendation 15 18 & 21: Boreholes finished diameters suitable for a hand-pump are appropriate at 4inch nominal diameter. Three methods of borehole construction are identified at or within 6.5 inch diameter boring and suggesting open hole in rock below surface casing is acceptable. Aquifers above 20m are not dependable all year around and minimum acceptable borehole depth should be 30m.

Recommendation 16: In Kalahari fine grained areas it indicated that drilling can still be at 6.5inch, with the use of 2inch diameter casing at depth as per the sketches at Appendix 6.

Recommendation 22: Gravel pack must be 95% silica, correctly graded, of measured quantity for each borehole and inserted slowly into properly centralised and vertical casing.

Recommendation 23: Filter socks should be introduced to the Zambian drilling sector as an enhancement or alternative to gravel pack.

Recommendation 24: Verticality is to be appropriately checked by the lowering of a hand-pump cylinder into a borehole such that there is no resistance.

Well Development

Recommendation 28: Well development and yield assessment for hand-pumped boreholes needs to be appropriately specified. Yield assessment from air lift is sufficient.

Data, Record Keeping and Reports

Recommendation 30: Standardised format(s) for borehole Completion Reports needs to be drafted which are to be filled by contractors for both successful and dry bores.

Recommendation 31: A system for a borehole identification number needs to be established.

Recommendation 32: Records of borehole drilling programme activity need to be centralised, indexed and archived. A database of all boreholes drilled must be established.

Recommendation 33: Drilling agencies must compile and publish standardised annual reports of their programmes.

Monitoring and Evaluation

Recommendation 34: Systems for monitoring and evaluation need to be established.

Operation and Maintenance

Recommendation 38: Consider the involvement of local water utilities in hand-pump maintenance programmes.

Appendix 1: Terms of Reference

Background

UNICEF was one of the pioneers in boreholes drilling for water supply and, in many cases, achieved remarkable results. However, UNICEF works in a highly decentralised environment and lacks a general policy with respect to borehole drilling. As a result, interventions vary widely and are not always cost-effective. In order to address this problem UNICEF is in the process of developing a Code of Practice for Cost-Effective Boreholes (COP). It will be used as the basis for decision-making and implementation of UNICEF country programmes that involve water well drilling.

The overarching aims of the COP are that:

- Policies and practices that bring about cost-effective borehole provision are supported.
- Country systems and procedures are used to the maximum extent possible. If this is not feasible, additional safeguards and measures that strengthen rather than undermine country systems and procedures are established.
- Performance with respect to water well provision is reported in a manner that is transparent and can be monitored as well as utilised for analysis.

The COP considers ten specific principles as listed in Appendix 1. It is envisaged that all UNICEF WASH programmes which support the provision of drilled water wells will develop a country-specific protocol which takes into account the guidance set out in the COP. Between March and October 2009, studies will be undertaken in Burkina Faso, Ghana and Zambia. These will test the principles of the COP and assist in identifying the strengths and weaknesses in the sector with respect to cost-effective borehole provision in country.

The National Rural Water Supply and Sanitation Programme, (NRWSSP) in Zambia intends to construct 10,000 new water points and rehabilitate 7,000 existing water points by 2015. As part of this, UNICEF alone intends to construct 3,650 water points in the next five years. However, In Zambia many well intended projects have failed due to problems that can be sourced to the construction of the water point. A study in North Western Province in 2001 indicated that the very high failure rate of boreholes and wells could be attributed to problems associated with their construction and installation. The problems associated with badly constructed water points not only deny the communities water, they have also been very expensive. Thus, it has been decided to create guidelines for the construction of protected water points, with the objective of improving the quality and therefore reducing future costs in terms of operation and maintenance. It is the intention that these guidelines would be for stakeholders in the sub sector of Rural Water Supply and therefore designed for a non technical audience.

Given that these encouraging initiatives are underway, the consultancy set out in this TOR will directly support the Ministry of Local Government and Housing and ensure that international best practice related to cost-effective boreholes feeds into these national guidelines. Thus, the so-called country protocol will not be a stand-alone document. Instead the consultant will set out key procedures for cost-effective boreholes, which shall ultimately form an integral part of the *Standard Procedures and Design for Construction of Protected Water Points for Rural Water Supply.* It is also anticipated that the *Guidelines for Implementing Community Water Supply and Sanitation Projects in Rural Areas* will link to these standard procedures[4].

The Zambia study will be undertaken over an 18 day period by an international consultant in collaboration with the Ministry of Local Government and Housing, the national working group for water supply and selected local Governments, private contractors and NGOs (Annex 3).

This document sets out the Terms of Reference for the international consultant to undertake the Zambia study.

Objectives

[4] The *guidelines* are to a large extent completed, whereas the *standard procedures* are currently being developed by the newly formed national working group on water supply.

The objective of the consultancy is to set out the key procedures for Cost-Effective Boreholes which are appropriate for Zambia.

Ultimately, the outcomes of this consultancy will feed into and strengthen the national standard for design and construction of protected water points for water supply.

Outputs

There are three specific outputs for the study as set out in the table below.

Part	Outputs
I. Study Assessment	Cost-Effective Boreholes Country Status Report specifying key areas of concern for in country stakeholders and as identified by the consultant (outline structure given in Annex 2)
II. Procedures and Action Points	Report setting out recommended amendments and key content for the *Standard Procedures for Design and Construction of Water Points*. Main report 15 to 20 pages in length plus annexes.
III. Lessons learned	Short report recommending improvements to the generic COP and study methodology in light of the consultancy.

Methodology

This work requires considerable collaboration between national government, the national working group for water supply and the consultant. In order for everybody to be well prepared before the consultant undertakes the in-country field work, stakeholders should have some understanding of the COP and have considered what they consider as essential.

The table below sets out the overall methodology, indicating responsibilities:

Item	Responsibility
a) **Introduction of the concept** of the COP and country-specific protocol in country and discussions with Ministry of Local Government and Housing as well as other key sector stakeholders.	Chief UNICEF WASH
b) **Agreement of TORs** for international consultant.	Chief UNICEF WASH/national working group for water supply
c) **Identification of focal person and study working group**. (Note that the Government is in the process of constituting a working group on **National Procedures for Design and Construction of Protected Water Points**, which will be ideally placed to serve as a study working group.	National working group for water supply.
d) **Collation of key supporting documents**. Note that soft copies of the following have already been emailed to kerstin.danert@skat.ch: a. *Guidelines for Implementing Community Water Supply and Sanitation Projects in Rural Areas*, Draft Amended Version June 2004, Ministry of Local Government and Housing b. *Proposed Structure of Guideline to Standard Procedures for Design and Construction of Protected Water Points,* (Developed by National Working Group) c. *Minutes of the first working group meeting held on 9th April 2007 at Ministry of Local Government and housing, Lusaka.* d. *TOR for Development of Standard Procedures and Design for Construction of Protected Water Points for Rural Water Supply*	Chief UNICEF WASH
e) **Study** – set out the key procedures for Cost-Effective Boreholes which are appropriate for Zambia. This will involve the country assessment in light of the Draft Code of Practice for Cost Effective Boreholes (separate document). Broadly the work will comprise: - Review of background documents - Introductory meeting with MLGH and UNICEF. The key focus areas for the study will be finalised at this meeting. - Two weeks of field work comprising interviews with government, private drillers, NGOs and	International consultant.

water users (Annex 4). - Presentation of study findings, key recommendations and action plan to key stakeholders for feedback	
f) Incorporation of feedback and submission of final reports (set out in outputs – above).	International consultant

Time Frame

This study is scheduled to commence on 17th June 2009 and end by 30th August 2009. The international consultant will undertake 25 days consultancy of which at least 18 will be in Zambia.

Details are presented below.

Dates	Part	Activities
16th June 2009		Finalisation of TOR
20th June 2009		Key documents collated and sent to kerstin.danert@skat.ch
29th June – 15th July 2009		In-Country field work and document review
30th July 2009	I	Study Assessment Report
30th August 2009	II	Report with Recommended Amendments and Action Points
30th August 2009	II	Report on Lessons learned

Consultant Qualifications and Experience

The study coordination will be undertaken by a rural water supply expert with:

- Extensive experience regarding groundwater provision for rural water supplies in sub-Saharan Africa (technologies and implementation approaches).
- Familiarity with NGO, Government and private sector (indigenous and foreign) participation in rural water supply.
- Knowledge of the Zambaian rural water supply context.
- Proven experience of managing cross-cultural and multi-stakeholder teams and working with relevant stakeholders (Government, development partners, NGOs, private sector).
- Excellent analytical skills and ability to integrate social, technical, institutional and economic issues which relate to rural water supply.
- Excellent communication and report writing skills.

She/he must have a history of on-time, high-quality product delivery and excellent report writing skills.

Accountability

The manager for this consultation is Dr. Kerstin Danert, SKAT.

Recommended Reading

RWSN. 2009. Second Draft Code of Practice for Cost Effective Boreholes

Carter, RC. 2006. Ten-step Guide Towards Cost-effective Boreholes. Field Note RWSN/WSP

Adekile, D and Olabode O. 2008. Study of Public and Private Borehole Drilling in Nigeria. Consultancy Report for UNICEF Nigeria Wash Section.

Danert, K; Carter, RC; Adekile, D; MacDonald, A; and Baumann, E Cost-Effective Boreholes in sub-Saharan Africa, Paper submitted to the 33rd International WEDC Conference

Carter, RC, Desta H, Etsegenet B, Eyob B, Eyob D, Yetnayet Ne, Belete M and Danert K. 2006. Drilling for Water in Ethiopia: a Country Case Study by the Cost-Effective Boreholes Flagship of the Rural Water Supply Network. Federal Democratic Republic of Ethiopia/WSP/RWSN.

Zambia Specific Literature

- *Guidelines for Implementing Community Water Supply and Sanitation Projects in Rural Areas*, Draft Amended Version June 2004, Ministry of Local Government and Housing
- *Proposed Structure of Guideline to Standard Procedures for Design and Construction of Protected Water Points*, (**Developed** by National Working Group)
- *Minutes of the first working group meeting held on 9th April 2007 at Ministry of Local Government and housing, Lusaka*.
- *TOR for Development of Standard Procedures and Design for Construction of Protected Water Points for Rural Water Supply*
- Borehole standard construction
- Tube well standard construction
- Jetted well standard construction
- Site selection
- Planning for construction and rehabilitation

TOR Annex 1 Code of Practice for Cost Effective Boreholes - Key Principles

This annex sets out the ten key principles given in the Code of Practice for Cost-Effective Boreholes. Further explanations on each principle are given in the full document.

1. Who Drills? Construction of water wells and installation of handpumps should normally be undertaken by the local private sector rather than Government or donor agencies. In countries where this is not yet the case, or private sector drilling capacity is weak, UNICEF (and other water sector stakeholders) should work with Government to develop a strategy for achieving private sector involvement in a time-bound manner.

2 Procurement The engagement of construction companies for water well provision should be through a local (national) competitive bidding process, based on a multi-well package in a sensibly defined geographic area, preferably with similar hydrogeology. In order to build local capacity, contracts should not necessarily be limited to one year only. Procurement should be through national partner systems in preference to direct contracting by UNICEF.

3 Contract Management, Supervision and Payment. Adequate arrangements need to be in place to ensure proper contract management and supervision of the drilling contractor. Normally this should be based on systems and personnel of partner organisations. However, if necessary, further training can be given. Additional expertise can be brought in to cover capacity gaps with a view to building expertise over the long term. Payment for construction works should be timely.

4 Borehole Siting Prior to preparing any well construction contract, a hydrogeological desk study and field reconnaissance should be carried out and the method of siting boreholes agreed upon, based on expert opinion. In proven areas where the geology is well understood and borehole success is high (say over 70%), it may not be necessary to site wells using expensive geophysical survey techniques. The final process of siting boreholes in the field must involve the community.

5 Borehole Design and Construction The design of the water well should be based on the minimum specification required to provide a well which is fit for the intended purpose (usually a handpump installation). Overdesign of boreholes, especially excessive depth and/or diameter, is wasteful and should be avoided.

6 Drilling Technology The construction method chosen for the water well should be the most economical, considering the design and available construction methods in-country. Low cost methods, including hand dug wells and manual drilling, should be considered before mechanised drilling if they are feasible and economical. Small drilling rigs which can provide the specified well are preferable to large rigs.

7 Data The data to be gathered during borehole drilling should be specified in the drilling contract. Responsibilities for data collection between the contractor and the supervisor should be clear. The data should be submitted to the appropriate government authority.

8 Well Development and Test Pumping Requirements The procedures for well development and for test pumping should be agreed upon and specified in the drilling contract. The drilled well must be developed until the water is free of solids and fine materials (fines). Test pumping requirements for a handpump should be realistic and not over-specified.

9 Record Keeping UNICEF and its partners should maintain good records of the borehole drilling work undertaken.

10 Reporting Government, UNICEF Country Offices (and other water sector stakeholders) should report on borehole drilling programmes annually. These reports should be available to the public including publishing them on appropriate websites.

TOR Annex 2 Country Status Report Structure

Chapter 1 Introduction

Chapter 2 Summary of Borehole Costs and Prices

Chapter 3 Principles of Code of Practice for Cost Effective Boreholes

3.1 Who Drills?

3.2 Procurement

3.3 Contract Management, Supervision and Payment

3.4 Borehole Siting

3.5 Borehole Design and Construction

3.6 Drilling Technology

3.7 Data

3.8 Well Development and Test Pumping Requirements

3.9 Record Keeping

3.10 Reporting

3.11 Other

Chapter 4 Principles of Code of Practice for Cost Effective Boreholes

Chapter 5 Conclusions and Recommendations

Annex 1 Itinerary and Stakeholders Consulted

TOR Annex 3 Key Stakeholders to Consult

- Ministry of Local Government and Housing
- UNICEF Zambia
- Department of Water Affairs
- Danida/COWI Consultant
- AfDB
- Key NGOs (as identified through the NGO forum)
- by the Ministry of Local Government and Housing and other key stakeholders
- Private Sector Drilling Contractors
- Equipment and Material Suppliers

Appendix 2: International Consultants Itinerary

Consultancy preparations and background study, 1 day June 2009

Travel Nakuru Kenya to Lusaka, In-country field work & return, 19 days 28June-16July 2009

Report Writing and Finalise, 5 days July/Aug 2009

Stakeholder Consultation

Ministry of Local Government and Housing: Introductory meeting

- Lytone Kanowa, Ms Marjourine Mwale and Mr Davy Ngoma 30 June

- Key Donors
  - UNICEF: Periodic Consultative Discussions throughout the mission
  - Danida: Peter Sievers (Counsellor Dev) Danish Embassy Not met
  - [African Development Bank: Mr Rees, Water Sector – out of country]
- Ministry of Energy and Water Development, Dept of Water Affairs (Drilling Section):
  - Mr Mpamba, Principal Hydro-geologist 1 July
  - Mr Simon Ngomba, Principal Hydro-geologist 4 July
- NGOs:
  - Plan International: Mr Maric Kangaba 2 July
  - Water Aid: Mr Humble Sibooli 8 July
  - [World Vision: Mr Maseka, who postponed 1st meet and did not make 2nd]
- Private Sector Drilling Contractors:
  - Zambezi Drilling, Mr Rau 3 July
  - Coratom Co Ltd, Mr Toma 4 July
- Equipment & Material Suppliers:
  - Lamasat, key domestic uPVC casing supplier 3 July
  - Davis &Shirtliff, key Pump Supplier (Grundfos) 4 July
- Consultant,
  - COWI Consultant, [Danida Programme] Max Karen: 9 & 12 July
  - Gitec Consultant, [German Prog.] Jim Anscombe 12 July

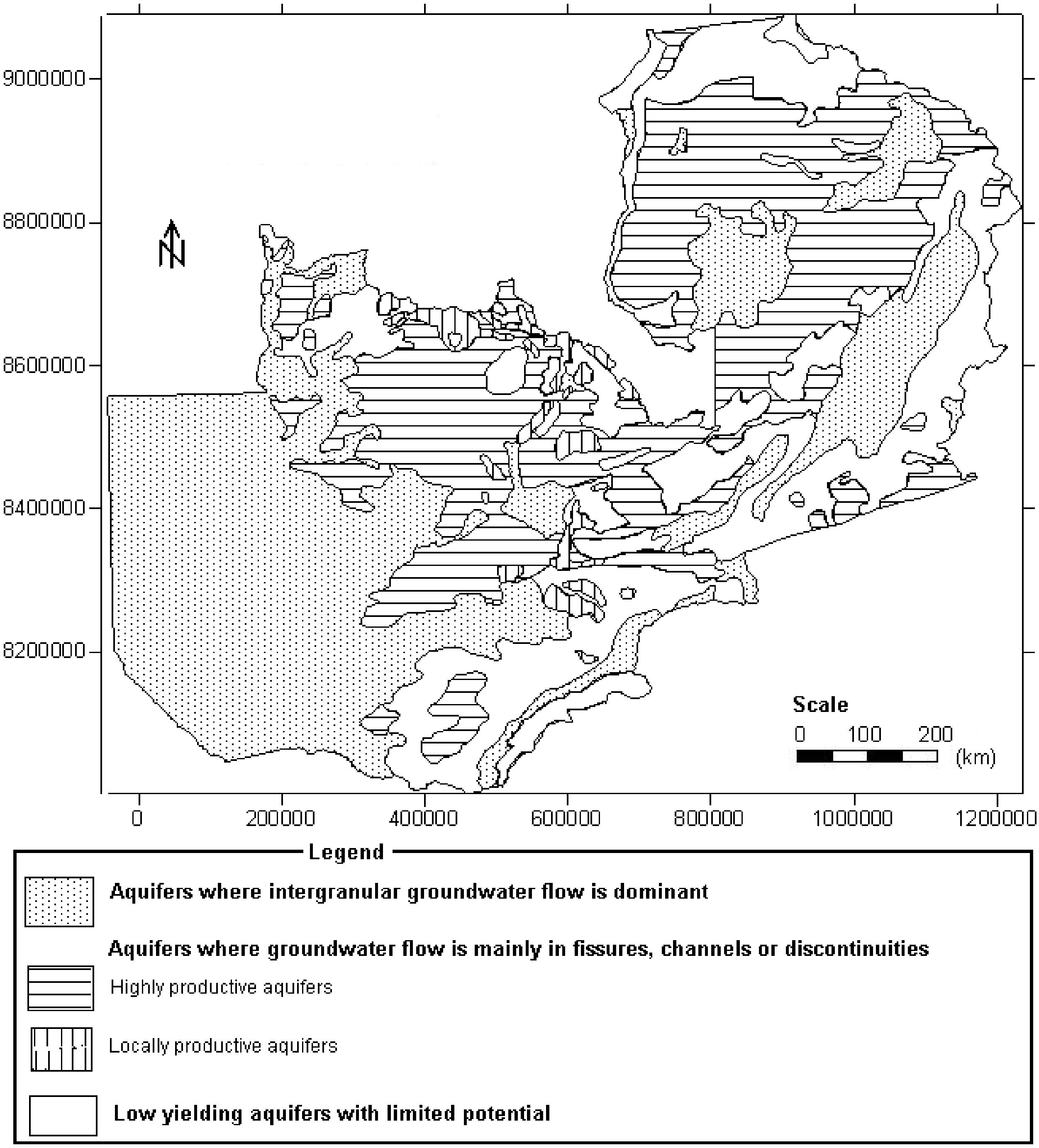
Presentation to Working Group and Wrap-Up Meeting 15 July

Attendees:

Lytone Kanowa,	Senior Engineer RWSSU MLGH	lytonekanowa@gmail.com
Ms Marjourine Mwale,	RWSSU MLGH	mwalemarjorie@yahoo.com
Musonda Cornelius	SCDO	cornmuso@yahoo.com
Chisakuta M Stanislaus	NRDC	chisakutasan@yahoo.co.uk
Henrik S Sorenson	TA/RWSSU MLGH	hhs@cowi.com
Patrick Tembo	PST Manager	patricktembo2003@yahoo.com
Jason Wamulume	Principal Planner MoH	jwamulume@gmail.com
Paulos S Workneh	UNICEF	pworkneh@unicef.org

Appendix 3 Zambian Geology and Hydrogeology

Appendix 3.1 Hydro-geology and Geology of Zambia



1. Hydro-geology

1.1 Aquifers Where Groundwater Flow is Mainly in Fissures, Channels and Discontinuities

Groundwater occurs in secondary rock features and structures such as weathered zones, faults, joints, fractures and solution features that usually extend to around 30m to 40m in depth within consolidated hard rocks. They may occasionally extend to more than 90m in depth. Such aquifers may be subdivided into two, namely:

- Highly productive aquifers: These include Upper Roan Dolomite and Kundelungu Limestone (1-70 l s-1), but have limited and very narrow area of distribution. Some large cities such as Ndola and so on are located on such aquifers.
- Locally productive aquifers: The Lower Roan Quartzite, Muva sediments, granites and undifferentiated Kundelungu Formations (0.1-10 l s-1).

1.2 Aquifers Where Intergranular Groundwater Flow is Dominant

These are found in the Alluvial Formation, Kalahari Group and Karoo Group. These aquifers are distributed mainly in the Western, Southern and Eastern parts of Zambia. They are also distributed around Chambeshi River and Lake Bangweulu (0.1 – 15 l s-1)

1.3 Low Yielding Aquifers with Limited Potential

These aquifers are mainly distributed in Eastern and Southern parts of Zambia (0-2 l s-1). They include the major part of Argillaceous Formation, Karoo basalts and older Basement Complex.

2 Geology

The geology of Zambia comprises various rock formations and layers consisting of igneous, sedimentary and metamorphic rocks from Precambrian to recent times (Table 2). These are summarised below:

Table 2: Stratigraphy of Zambia *(after JICA Report, 1995)*

Geological Age		Super Group	Groups or Formation	Rocks and Sediments
Cenozoic Era	Quaternary Tertiary	Cenozoic Super Group	Alluvium	Alluvium sands, Gravel with clay
			Kalahari Group	Fine sand, Sandstone with clay
Mesozoic Era	Cretaceous	Mesozoic Super Group	Lower Cretaceous Formation	Mudstones, Siltstones
	Jurassic Carboniferous	Karoo Super Group	Upper Karoo Group	Basalt, Interbedded sandstones, Sandstones, Mudstones, Siltstones
Palaeozoic Era			Lower Karoo Group	Mudstones with coal measure, Siltstones, Sandstones, Conglomerates
	Silurian Ordovician	Lower Palaeozoic Super Group		Quartzites, Shales, Sandstones
	Early Palaeozoic Precambrian	Katanga Super Group	Kundelung Group	Carbonate rocks with shales, Shales, Siltstones
Precambrian Era			Upper Roan Group	Dolomites, Argillites
			Lower Roan Group	Quartzites, Argillites, Dolomites, Conglomerate, Mine series shales
		Basement and Muva Super Group	Muva Group	Shales, Mudstones, Sandstones
			Basement Complex	Basement gneisses, Migmatites, Schists
Various age mainly older Precambrian		Intrusive and Metamorphic Rocks		Basic-igneous rocks, Meta-igneous rocks, Amphibolites, Metasediments, Metavolcanics

2.1 Cenozoic Super Group

The layers comprise tertiary sandstone, quaternary consolidated sand layers (duricrusts) and clay layers. In a larger part of the extreme west of Zambia (Barotse Basin), Cenozoic Super Group over lies the Mesozoic Super Group (JICA Report, 1995).

2.2 Mesozoic Super Group

It has an estimated thickness of 100m of mudstones judged to be cretaceous in age based on the discovery of certain fossils. The distribution is along the Zambezi River and to the west of Zambia, over-lying the basalt of the Karoo Super Group (JICA Report, 1995).

2.3 Karoo Super Group

Tillites of fluvio-glacial origin, mudstones coal measure, marls, conglomerates and basalts corresponding to the Carboniferous to Jurassic period compose the Karoo Super Group. It is distributed along the Luangwa River, mid-Zambezi Valley and western part of Zambia (Nyambe, 1993; JICA Report, 1995).

2.4 Lower Palaeozoic Super Group

It comprises shales, quartzites and arkose sandstones. Lower Palaeozoic Super Group is extremely limited and its existence is only evident in the mid-Zambezi Valley and western parts of Zambia, where it over lies the Katanga Super Group (JICA Report, 1995).

2.5 Katanga Super Group

The Katanga Super Group comprises shale, sandstone, quartzites, limestones, conglomerates and dolomite layers that range from Precambrian to Cambrian in age. It is distributed in the northern and central parts of Zambia (JICA Report, 1995).

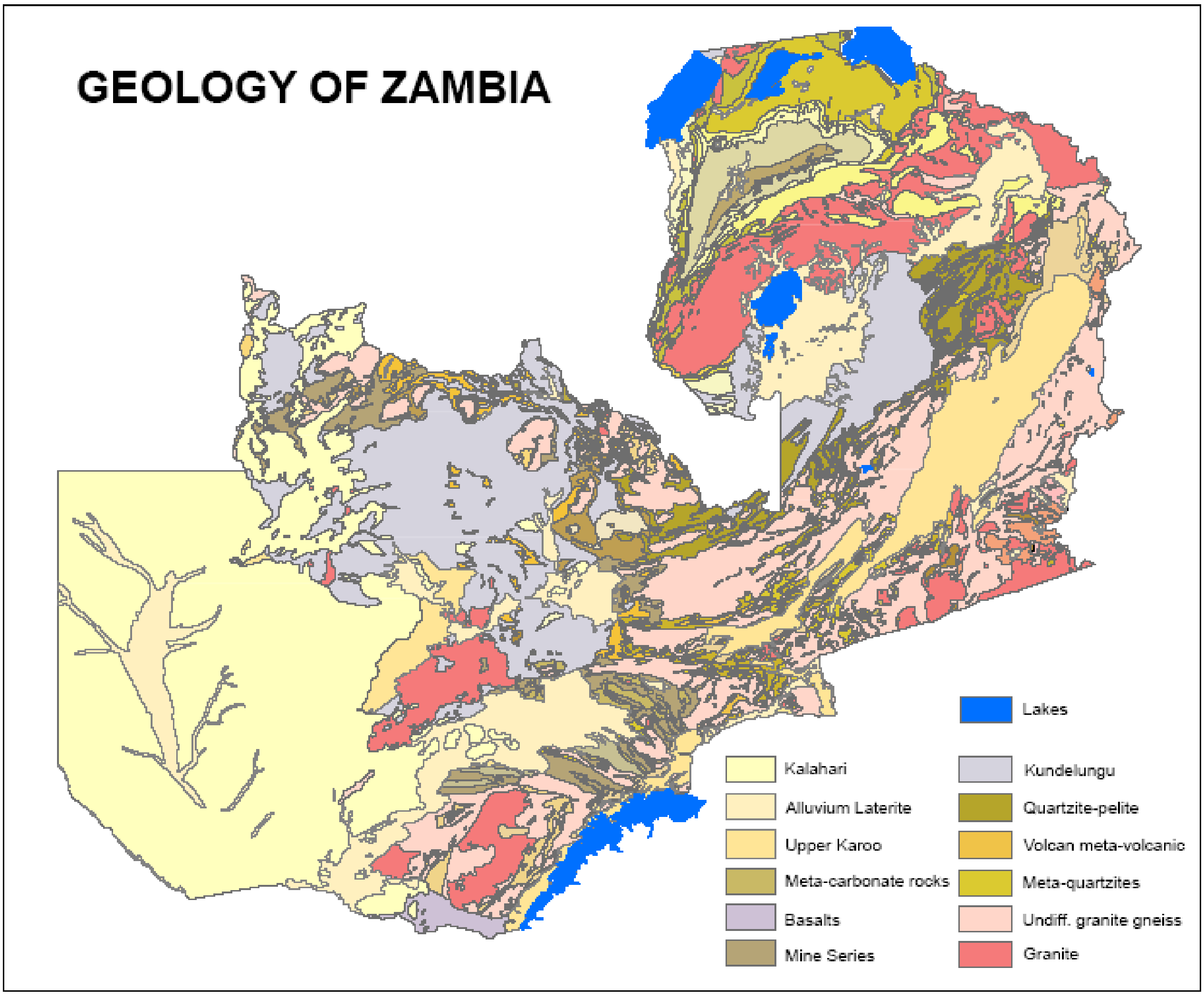
2.6 Basement Complex

It is the oldest system in Zambia that consists of highly deformed gneiss, schists, conglomerates, quartzites, crystalline limestone, migmatites and granites. The outcrops are mainly in the east and south-eastern parts of Zambia (JICA Report, 1995).

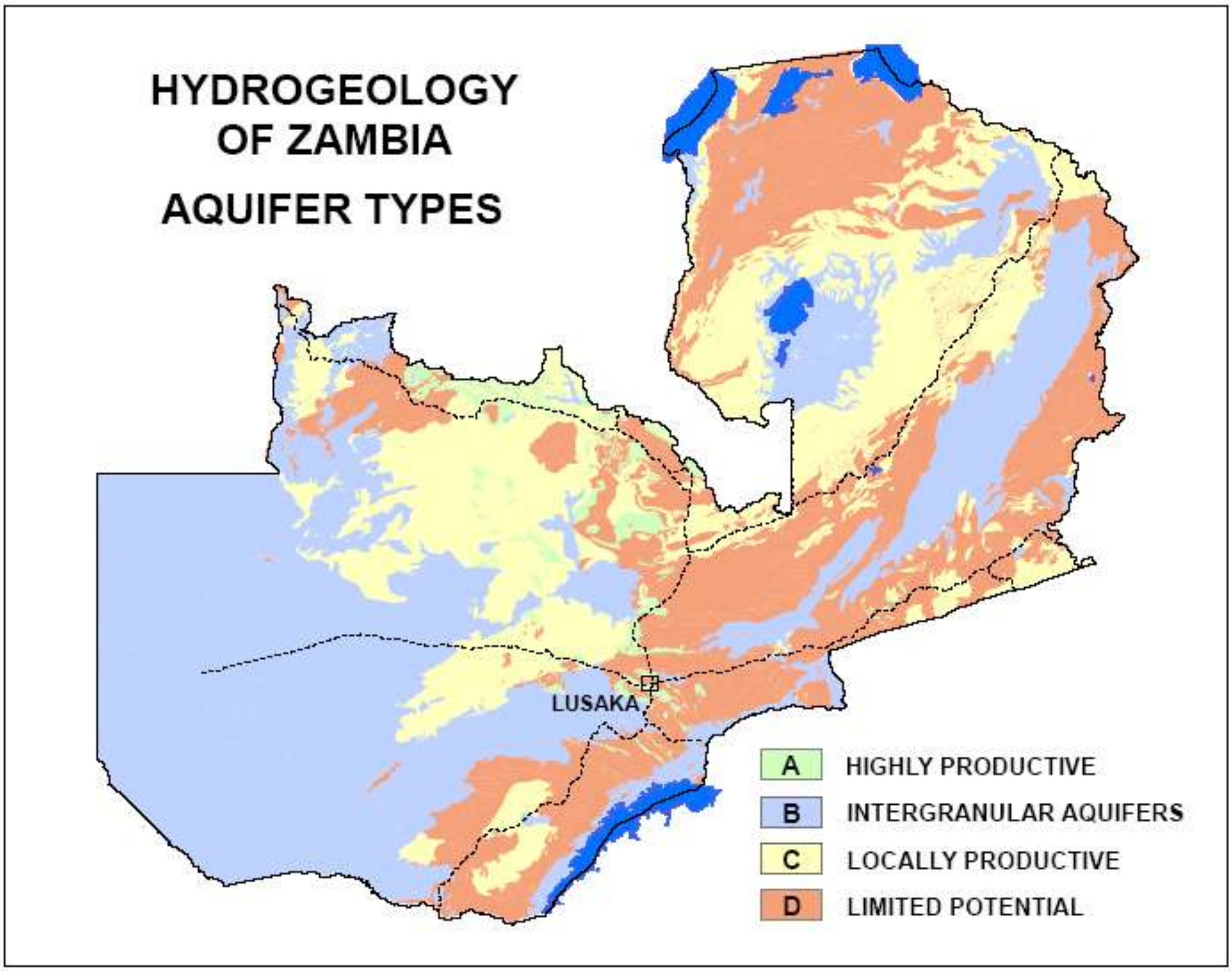
2.7 Intrusive Rocks

These are of varying age and type, which mainly intrude the Precambrian rocks and the majority are granites. The remainder are gabbros, dolerites, syenites, etc (JICA Report, 1995)

Appendix 3.2 Geology of Zambia



Appendix 3.3 Hydro-geology of Zambia – Aquifer Types



Appendix 4 Existing Guidelines for Drilling and Groundwater Development

Appendix 4.1 Department of Water Affairs: Guidelines and Procedures for Borehole Drilling and Groundwater Data Collection (proposed)

1. Borehole Drilling

Drilling guidelines and procedures are closely linked to reliable collection of hydrogeological data during borehole construction. These include, borehole construction details, materials used for construction, details related to aquifer lithology, yield assessment and preparation of borehole completion report. To date there are no guidelines and procedures that have been developed to direct borehole drilling in Zambia. However, over the years standard ways of borehole construction have been developed and adopted as a good practice by the Department of Water affairs (Table 2.1). These have helped to ensure good workmanship, to uphold high standards when constructing boreholes equipped with motorized pumps and boreholes meant for the various rural water supply projects. Most drilling contracts entered on between DWA and the private drilling contractors to construct boreholes on behalf of the Ministry of Energy and Water Development (DWA, 1980 – 2001) have been based on the same good practices.

Table 1: Borehole drilling guidelines and procedures followed by the Department of Water Affairs when constructing boreholes (after DWA, 1982).

Activity	Large Diameter Boreholes	Small Diameter Boreholes
Borehole verticality	Must be vertical	
Drilling diameter	At least 213mm to allow for casing with at least 150mm casing, gravel packing and pump installation.	At least 156.25mm to allow for casing, gravel packing and inserting with at least 100mm casing to allow for Handpump installation.
Lithology sampling	Every 3m and at the change of formation	
Casing	Cased to the bottom using suitable non – polluting material, screens at aquifer position and plain casings at non – aquifer position. Bottom plugged in loose formations.	
Gravel packing	Annular space must be gravel packed at the screen and aquifer position with durable and suitable size of material in respect to size of the aquifer materials.	
Well Development	Must be done with Airlift method for at least 30 minutes or until the water is clear of drilling cuttings.	
Yield	Must be done by Airlift method or motorized pump for .at least 6 hrs.	
Grouting	By placing concrete mixture up to 6m depth from ground surface.	
Dry Borehole	To be filled with drilling material.	
Report	Must be prepared for both dry and successful boreholes.	

2. Groundwater Data Collection

Figure 1 Summarised flow chart of proposed groundwater data and information capture (Mpamba, 2008)

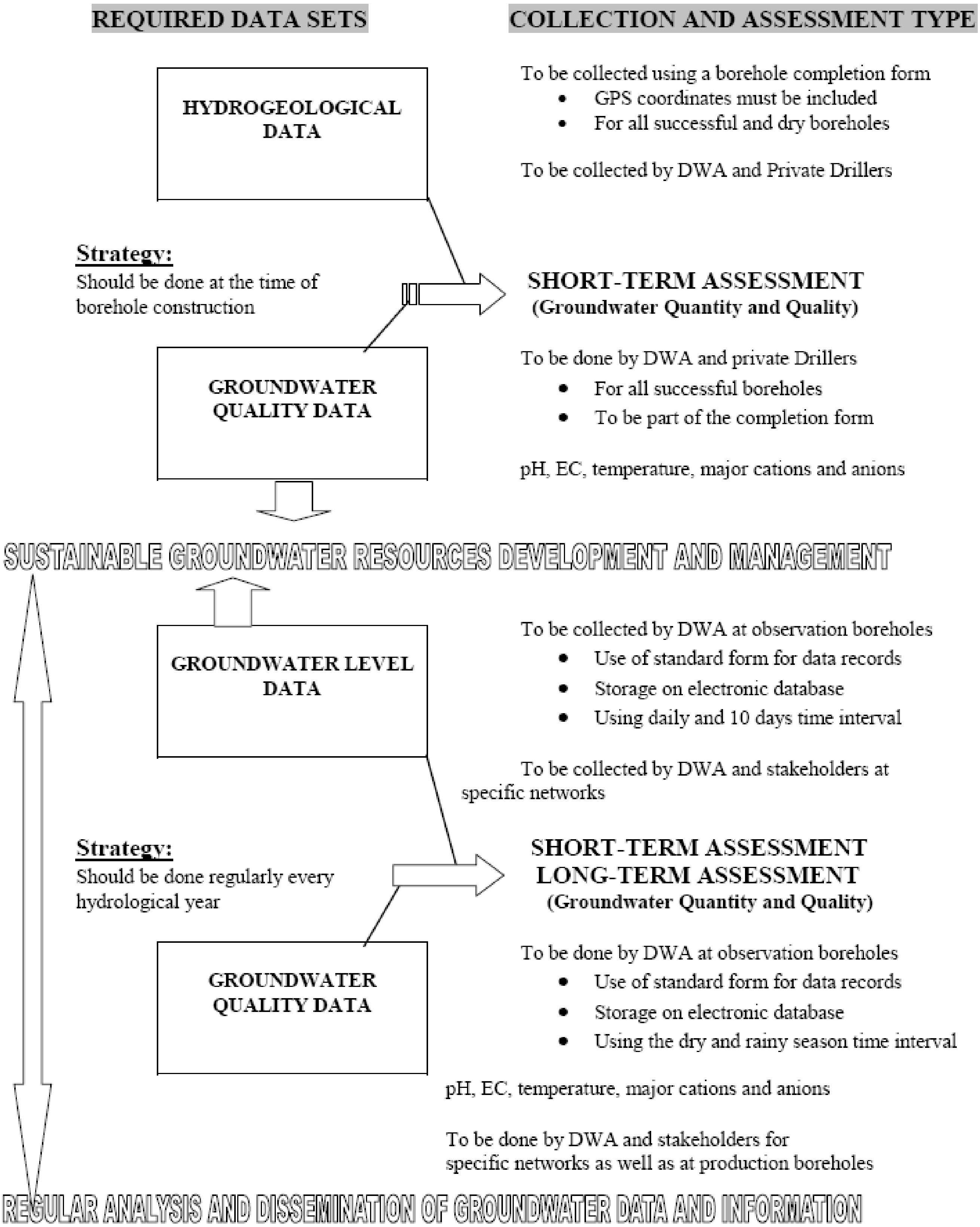


Figure 2 Borehole Completion Report Form used by DWA to capture borehole drilling data and information.

REPUBLIC OF ZAMBIA – WATER AFFAIRS DEPARTMENT

BOREHOLE COMPLETION FORM

Grid Reference:	**Locality:**	**Chief:**	**Borehole No:**
Name of Property:	**District:**	**Site Selected by:**	**Site No:**
Name of Owner(s)	**Province:**	**Drill Unit No:**	

Total depth borehole			meters
Depth from surface at which water first struck			meters
Depth from surface of main supply			meters
Depth from surface to which water rises			meters
Continuous bailer test	hours gave yield of		litres per second
Continuous pump test	hours gave yield of		litres per second
Depth of water from surface before test			meters
Depth of water from surface of pump intake			meters
Greatest depth to which water was lowered during test			meters
Does water return to original level after test?		Recovery	meters

Details of Casing in borehole

DIAMETER	LENGTH IN METERS	
	Plain	Perforated

Depth from surface to bottom of casing			meters
Diameter of unlined portion of borehole below casing			meters
Quality of water (State if fresh, brackish, or saline, etc)			
Total distance chargeable	Km at	K	

Remarks:

Depth in meters		Formation
From	To	

DAT

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The applicant is required to sign this report after having satisfied himself that it is correct

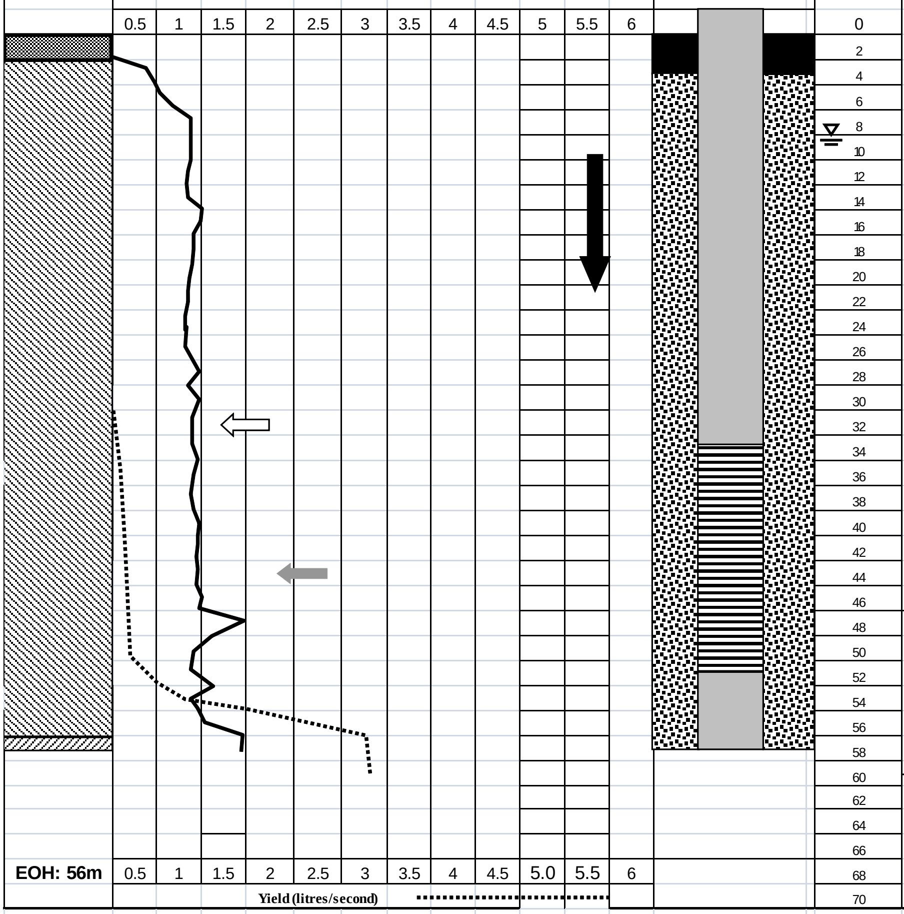
Signature of Applicant: **Foreman:**

Appendix 4.2 Drilling Completion Report (COWI-DANIDA)

- S - Soil (laterite, sand)
- W - Weathered Bedrock
- Fi - Fine Grained Rock (Mudstone/Siltstone)
- Fc - Fresh Crystalline Rock (Granite, Gneiss)
- UnS - Unconsolidated Sand
- CoS - Consolidated Sand
- Mix - Mictite
- ClS - Clay rich sand
- Oth - Other
- PVC plain casing (incl.centralizers)
- PVC slotted casing (0.75mm slots)
- Cement sanitary seal
- Formation stabiliser (gravel 2 - 5 mm)

Lithological Profile and Well Design

Geology	Penetration Rate and Yield	Well Design	Depth
(Drill Chips)	(Drilled with DTH Technique)	254 mm	(m)



Aquifer and Well Data

Parameter			Value
Yield zones	Aquifer	Depth	**l/s**
1st	Siltstone	21	**na**
2nd	Siltstone	29	**na**
3rd	Siltstone	32	**na**
Hydraulics (from pump test)			
SWL (m)			
Pump depth (m) (testing)			
DWL at 3hr CRT (m)			
Q (l/s) for CRT			
S avail. (m), (pump - DWL)			
S max (m), (SWL-DWL)			
S utilised (**S**m/**S**a).100%			
SC (**Q/S** max)			**#DIV/0!**
Main inflow (from PT)			**>10**
Other inflow (from PT)			
Recovery (90% in minutes)			
Recovery (m in 1st five minutes)			
Recommended pump depth (m)			
Pump Test comment			
Hydrochemistry (from pump test)			
Water quality (ppm)			
pH			
Fe (mg/l)			

Symbols

- First water (from drilling)
- Main water (from drilling)
- Static Water Level (from development)
- Penetration Rate
- Drilling Yield

Comment

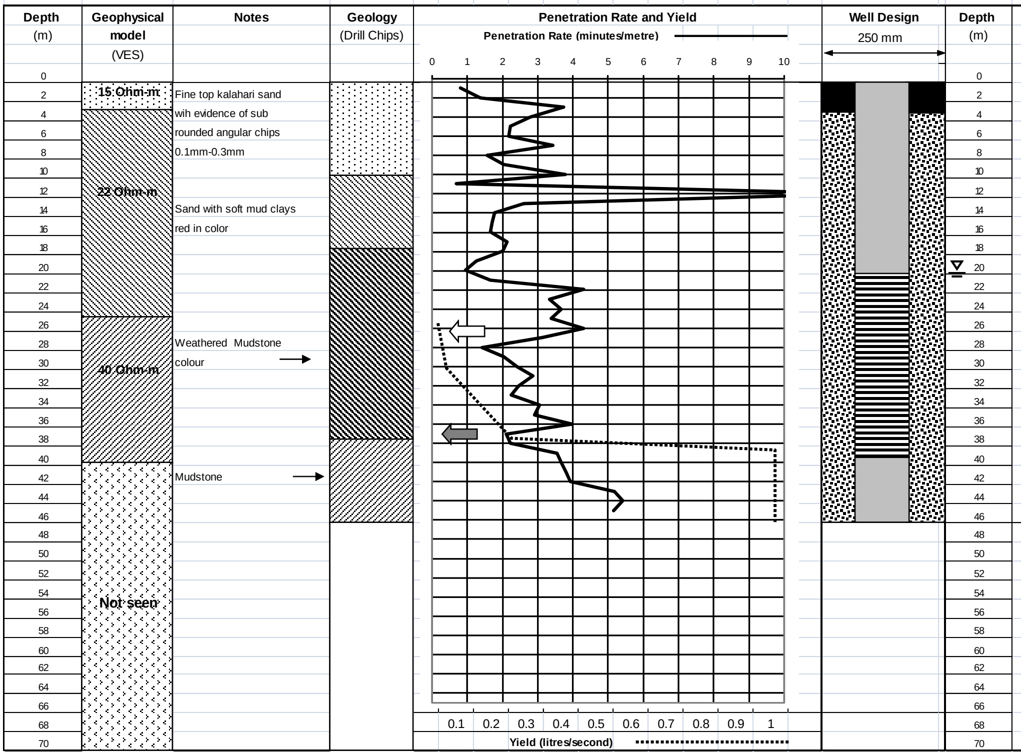
CODE		
KO 054A	Name:	MWATANGOCHO
	Ward:	KABULAMENA
	District:	KABOMPO
	Depth(m):	45.3
	Drilling date:	29. Mai 07

Easting	24.01878
Southing	-13.84355
Coordinates: (Decimal Degrees, WGS84)	

Legend:

- S - Soil (laterite, sand)
- SaP - Upper Weathered Zone - Saprolite
- SrK - Lower Weathered Zone - Saprock
- Fi - Fine Grained Rock (Mudstone/Siltstone)
- Fc - Fresh Crystalline Rock (Granite, Gneiss)
- UnS - Unconsolidated Sand
- CoS - Consolidated Sand
- Mix- Mictite
- ClS - Clay rich sand
- Other
- PVC plain casing (incl.centralizers)
- PVC slotted casing (0.75mm slots)
- Cement sanitary seal
- Formation stabiliser (gravel 2 - 5 mm)

Lithological Profile and Well Design



Drilling

Borehole and Aquifer Data

Drilling Technique/s	From	To
Mud Rotary	0.0	16.0
DTH	16.0	46.0
Construction	**From**	**To**
Casing	0.0	20.0
Screen	20.0	40.0
Casing		
Screen		
Sump	40.0	46.0
Hydraulics		
SWL (m)		20.0
Pump depth (m) (testing)		42.0
DWL at 3hr CRT (m)		29.0
Q (l/s) for CRT		0.5
Sw avail. (m), (Pump - SWL)		22.0
Sw max (m), (SWL-DWL)		9.0
Sw Used % (Sw max/Sw available)100%		41
SC (Q/Sw max)		0.056
Main inflow (from PT)		39
Other inflow (from PT)		27
Recovery (90% in minutes)		15
Recovery (m in 1st five minutes)		8.0
Recommended pump depth (m)		33.0
Hydrochemistry		
TDS (mg/l)		260
pH		7
Fe (mg/l)		0.2
N (mg/l)		0.0
From Pumping Test		

Symbols

- ⇦ First water (from drilling)
- ⬅ Main water (from drilling)
- ▽ Static Water Level (m)

Comment

PENETRATION RATE DATA

Min	Secs	Min.	Total Min	Min	Depth	Yield
	48	0.8	0.8	0.8	1	0
1	22	0.4	1.4	1.4	2	0
3	44	0.7	3.7	3.7	3	0
2	47	0.8	2.8	2.8	4	0
2	13	0.2	2.2	2.2	5	0
2	11	0.2	2.2	2.2	6	0
3	25	0.4	3.4	3.4	7	0
1	33	0.6	1.6	1.6	8	0
2	2	0.0	2.0	2.0	9	0
3	47	0.8	3.8	3.8	10	0
	41	0.7	0.7	0.7	11	0
12	17	0.3	12.3	12.3	12	0
2	36	0.6	2.6	2.6	13	0
1	46	0.8	1.8	1.8	14	0
1	42	0.7	1.7	1.7	15	0
1	39	0.7	1.7	1.7	16	0
2	8	0.1	2.1	2.1	17	0
2	0	0.0	2.0	2.0	18	0
1	15	0.3	1.3	1.3	19	0
	56	0.9	0.9	0.9	20	0
1	39	0.7	1.7	1.7	21	0
4	18	0.3	4.3	4.3	22	0
3	20	0.3	3.3	3.3	23	0
3	40	0.7	3.7	3.7	24	0
3	22	0.4	3.4	3.4	25	0.1
4	18	0.3	4.3	4.3	26	0.1
3	7	0.1	3.1	3.1	27	0.1
1	25	0.4	1.4	1.4	28	0.2
2	2	0.0	2.0	2.0	29	0.2
2	25	0.4	2.4	2.4	30	0.3
2	51	0.9	2.9	2.9	31	0.3
2	27	0.5	2.5	2.5	32	0.4
2	14	0.2	2.2	2.2	33	0.5
3	3	0.1	3.1	3.1	34	0.6
2	54	0.9	2.9	2.9	35	0.7
3	58	1.0	4.0	4.0	36	0.8
2	6	0.1	2.1	2.1	37	3
2	13	0.2	2.2	2.2	38	5
3	32	0.5	3.5	3.5	39	5
3	40	0.7	3.7	3.7	40	5
3	48	0.8	3.8	3.8	41	5
3	55	0.9	3.9	3.9	42	5
4	70	1.2	5.2	5.2	43	5
5	24	0.4	5.4	5.4	44	5
5	9	0.2	5.2	5.2	45	5
					46	
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					64	
					65	

NWP – RWS PROJECT PHASE I

PENETRATION RATE FORM

Borehole Code: **KO 054A**

PENETRATION RATE AND YIELD LOG

Depth (m)	Time (min)	Yield (mm)	Yield (l/s)	Inflow horizons	Depth (m)	Time (min)	Yield (mm)	Yield (l/s)	Inflow horizons
0-1	0.8				40-41	3.8			
1-2	1.4				41-42	3.9			
2-3	3.7				42-43	5.2			
3-4	2.8				43-44	5.4			
4-5	2.2				44-45	5.2			
5-6	2.2				45-46				
6-7	3.4				46-47				
7-8	1.6				47-48				
8-9	2.0				48-49				
9-10	3.8				49-50				
10-11	0.7				50-51				
11-12	12.3				51-52				
12-13	2.6				52-53				
13-14	1.8				53-54				
14-15	1.7				54-55				
15-16	1.7				55-56				
16-17	2.1				56-57				
17-18	2.0				57-58				
18-19	1.3				58-59				
19-20	0.9				59-60				
20-21	1.7				60-61				
21-22	4.3				61-62				
22-23	3.3				62-63				
23-24	3.7				63-64				
24-25	3.4				64-65				
25-26	4.3				65-66				
26-27	3.1				66-67				
27-28	1.4				67-68				
28-29	2.0				68-69				
29-30	2.4				69-70				
30-31	2.9				70-71				
31-32	2.5				71-72				
32-33	2.2				72-73				
33-34	3.1				73-74				
34-35	2.9				74-75				
35-36	4.0				75-76				
36-37	2.1				76-77				
37-38	2.2				77-78				
38-39	3.5				78-79				
39-40	3.7				79-80				

FW = 1st Strike SW = 2nd Strike MS = Main Strike

Records by:

Photograph of Generalised Lithology

Appendix 5 Proposed structure of guideline to standard procedures for design and construction of protected water points

CONTENTS (as developed by working group meeting)

A. How the guideline fits into the structure of the available WASHE manuals and modules available

B. Proposed guidelines

C. Main proposed sections of the guideline for new water points

1. Introducing groundwater
2. Site selection
3. Siting of the waterpoint
4. Construction of the waterpoint
5. Development of the borehole
6. Testing the yield of the water point
7. Water quality measurements
8. Construction of the surface works (design)
9. Construction of iron removal plant (design)
10. How the water point is costed - the bill of quantity
11. Other:
    - Gps
    - Databases
    - Dealing with the drilling contractor

A. **How the guideline fits into the structure of the available washe manuals and modules available**

WASHE IN ZAMBIA

The guideline is intended to fit into the existing structure of manuals and modules available. The WASHE manuals available are as follows:

Manual 1 – Understanding the WASHE concept

Manual 2 – WASHE in the Water Sector Reforms

Manual 3 – Introducing WASHE at District Level

Manual 4 – Establishing WASHE at District Level

Manual 5 – Planning for WASHE at District Level

SUPPLEMENTARY MODULES AVAILABLE:

1a Coverage Parameters for Rural Water Supply in Zambia

1b The Status of Rural Water Supply in Zambia

1d Partners in WASHE

2a Making the Right Choice

2d Tube Well Standard Construction

2e Jetted Well Standard Construction

2f Borehole Standard Construction

5a Options for Excreta Disposal Facilities

6a Participatory Health And Hygiene Education (Theory)

6b Participatory Health And Hygiene Education (Practical)

7b Making Appointments

7c Community Mobilisation and Sensitisation

7d Making Appointments

7e Formation of a Village WASHE

7f Site Selection

7g Planning for Construction and Rehabilitation

7h Community Participation During Construction

7i Village WASHE Committee Training

7j Community Problem Solving

7l Promoting Community Ownership

7m Community Participation in Monitoring

7n Well Completion Ceremony

7o Community Management And Evaluation

8 WASHE and Gender

The development of the guideline forms part of the workplan for 2009 for the National Rural Water Supply and Sanitation Programme (NRWSSP). The objective of the guideline is to combine and augment the modules relating to construction of a protected water point to provide guidelines to stakeholders in the subsector.

The guideline will principally concern and augment the modules 2f, 7f on borehole construction and site selection.

B. PROPOSED GUIDELINES

To complement the existing WASHE manuals it has been decided that two new guidelines will be created.

1. Guideline to Standard Procedures for Design and Construction of Protected Water Points
2. Guideline to Standard Procedures for Rehabilitation of Protected Water Points

C. MAIN PROPOSED SECTIONS OF THE GUIDELINE FOR NEW WATER POINTS

1. INTRODUCING GROUNDWATER
    - Where does it come from
    - How is it stored
    - Types of Aquifer in Zambia
    - Hydrogeological Map of Zambia
    - Assessing the groundwater potential of an area
2. SITE SELECTION
    - Involving the Community
    - Establishing Boundaries of the Village
    - Places to avoid
3. SITING OF THE WATERPOINT
    - How is a good site located
    - What is Geophysics

- The main types of Geophysical Surveys
- Discussing the results with the community

4. CONSTRUCTION OF THE WATERPOINT

- The two main types of water point: borehole and well
- Drilling techniques
- Construction of the borehole – the main elements
- Borehole designs
- Hand dug well construction

5. DEVELOPMENT OF THE BOREHOLE

- Why is development important?
- How is it done
- What to look for to make sure development is complete

6. TESTING THE YIELD OF THE WATER POINT

- Why do we need to yield test the water point
- Elements of the pumping test
- Other types of pumping test
- What the pumping tests tells us

7. WATER QUALITY MEASUREMENTS

- What do we mean by water quality
- How is it measured
- How can contamination be avoided

8. CONSTRUCTION OF THE SURFACE WORKS

- Why are the surface works important
- Main elements in the construction
- How to check the materials used and why they are important

9. CONSTRUCTION OF IRON REMOVAL PLANT

- How does the iron removal plant work?
- Main elements in the construction of the filter plant

10. HOW THE WATER POINT IS COSTED - THE BILL OF QUANTITY

- What is the BoQ
- Why the BoQ is important
- Detail description of each element of the BoQ
- Using the BoQ to check financial statements

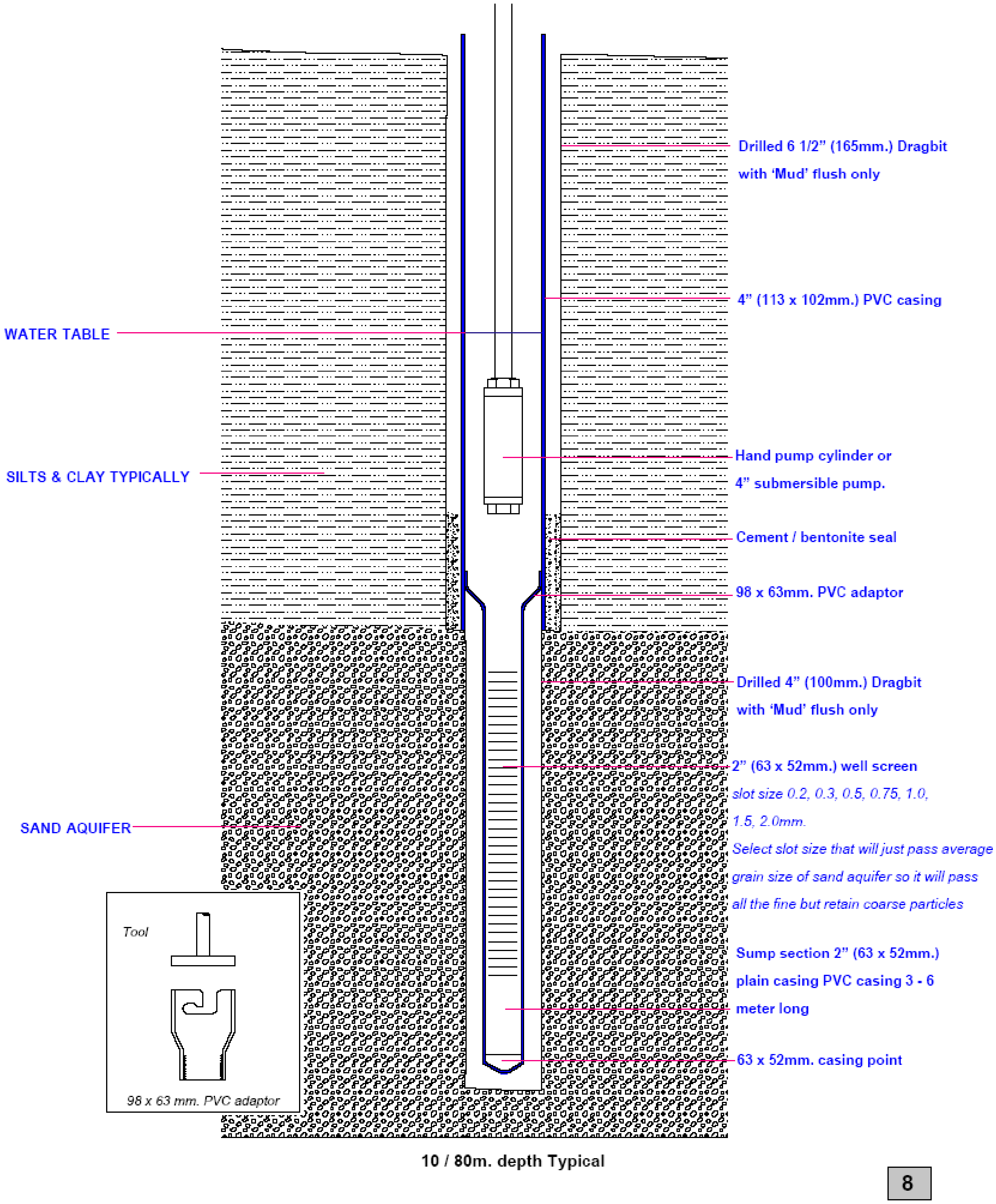
11. OTHER POSSIBLE SECTIONS

    - GPS
    - DATABASES
    - DEALING WITH THE DRILLING CON CONTRACTOR

Appendix 6 PAT: 4inch and 2inch Cased Boreholes

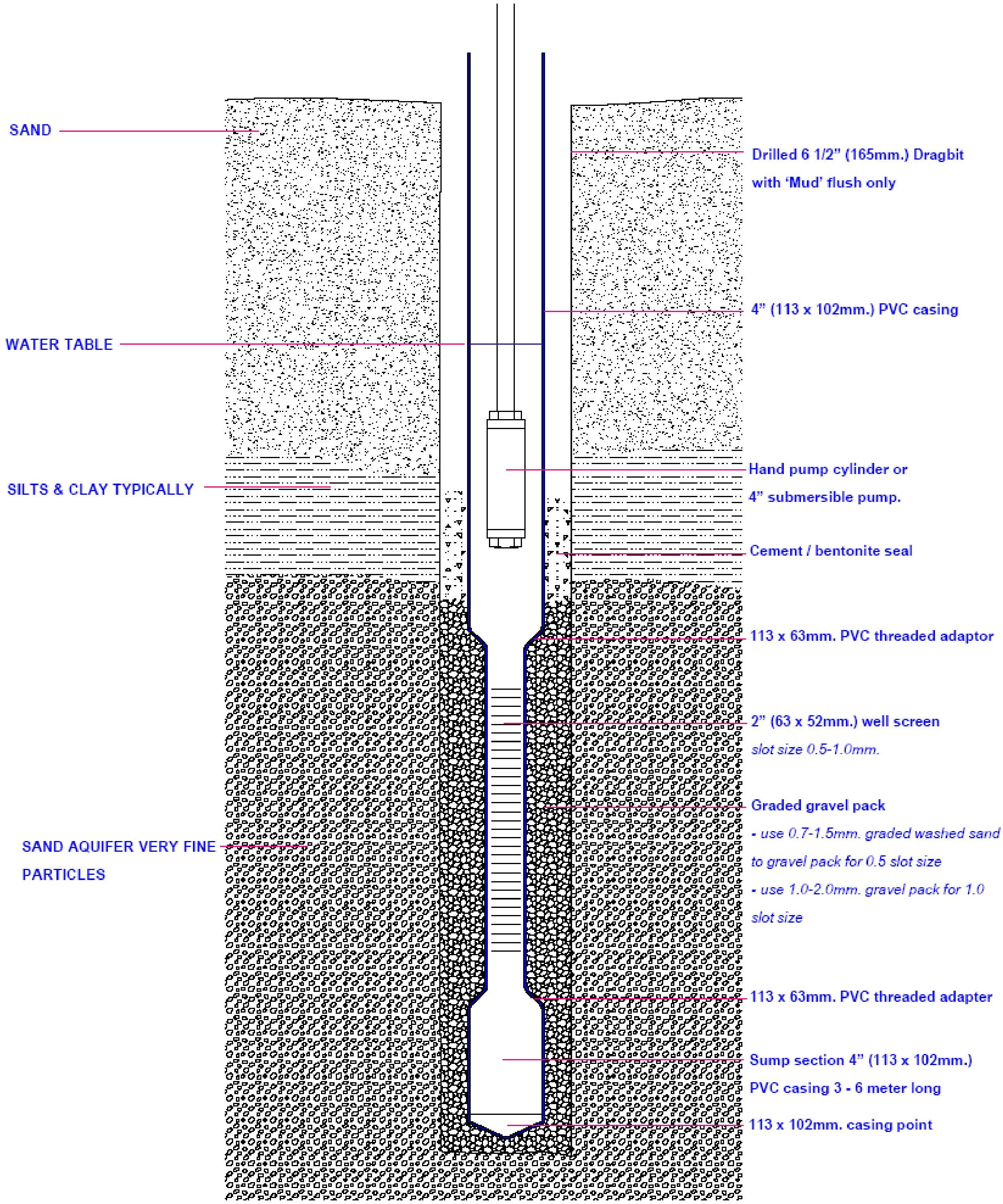
SEDIMENTARY

DESCRIPTION OF HOLE Telescopic casing for natural development only



SEDIMENTARY

DESCRIPTION OF HOLE Reduced diameter well screen for very fine sands requring an even gravel pack



15 / 150m depth Typical

6