

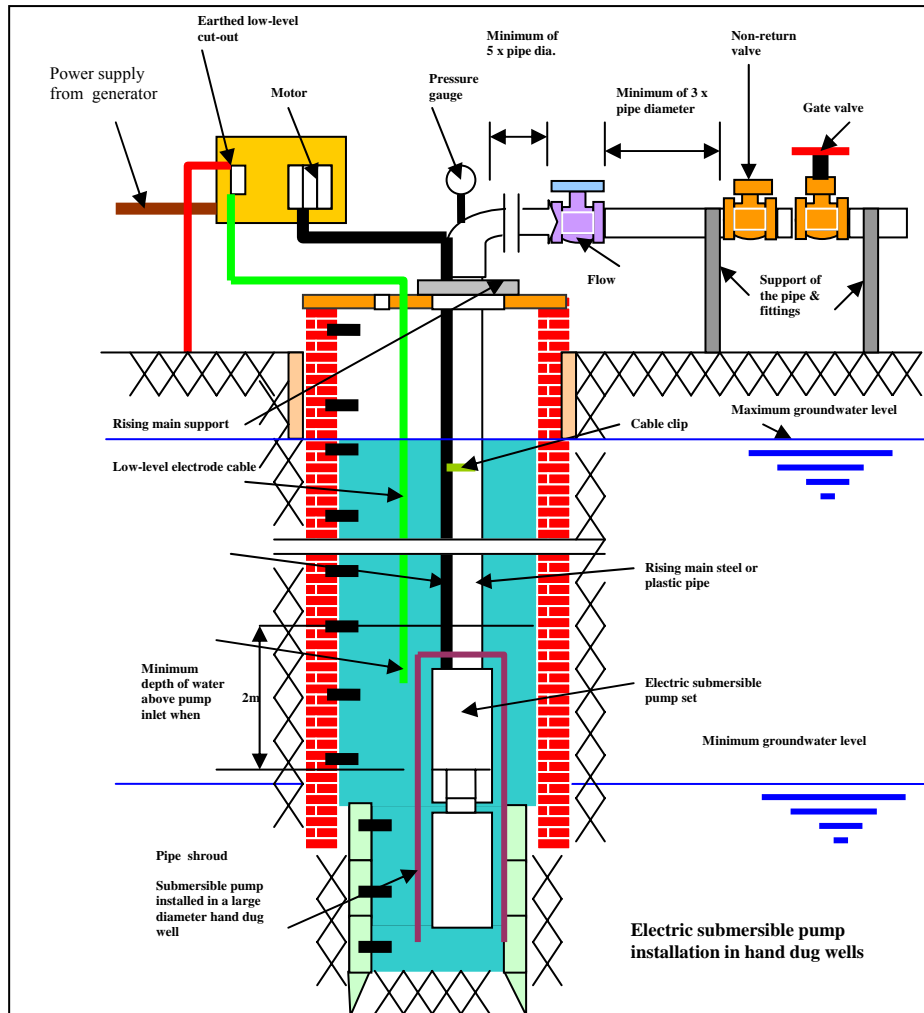


Public Water Corporation  
MIWR – GONU



MWRI - GOSS

## Technical Guidelines for the Construction and Management of Hand dug well Water yards



A Manual for Field Staff and Practitioners  
April 2009

DEVELOPED IN PARTNERSHIP WITH



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**Ministry of Irrigation and Water Resources – Government of National Unity**

**Foreword**

Significant progress in the provision of water and sanitation services in Sudan has been achieved in the last few years. This is attributed to the increased access to many remote villages as a result of the three major peace agreements, the Comprehensive Peace Agreement (CPA) between north and south Sudan, the Darfur Peace Agreement (DPA) and the Eastern Sudan Peace Agreement (ESPA), that were signed in 2005 and 2006 respectively. This access has allowed the Ministries of Irrigation and Water Resource (MIWR) of the Government of National Unity (GoNU), state governments and sector partners (including NGOs and the private sector) to expand water and sanitation services in many areas. This prioritizing of the expansion and sustainability of water and sanitation services in urban and rural areas throughout the county, including to the nomadic population has resulted in a steady annual increase in water and sanitation coverage for the citizens of Sudan.

With this expansion in implementation, the MIWR recognized the need to harmonize the various methodologies utilized by the various actors in the implementation of water and sanitation interventions. It was agreed that this could be best achieved through the development and distribution of Technical Guidelines, outlining best practices for the development of the 14 types of water supply and sanitation facilities in the Sudan. These Technical Guidelines, compiled in a systematic manner will undoubtedly set standards and provide guidance for all water and sanitation sector implementing partners.

The MIWR of the GoNU of the Sudan is grateful to UNICEF, Sudan for financial and technical support in the preparation of the Technical Guidelines.

I believe these Technical Guidelines will go a long way to improving WES sector programmes, allowing for scaling up implementation of activities towards achieving the MDG goal for water supply and sanitation in Sudan.

Minister  
Ministry of Irrigation and Water Resources  
Government of National Unity, Khartoum

Date .....

## **Foreword**

The historic signing of the Comprehensive Peace Agreement (CPA) in January 2005, culminated in the establishment of an autonomous Government of Southern Sudan (GOSS) and its various ministries, including the Ministry of Water Resources and Irrigation (MWRI). The CPA has enabled the GOSS to focus on the rehabilitation and development of the basic services. The processing of the Southern Sudan Water Policy within the framework of the 2005 Interim Constitution of Southern Sudan (ICSS) and the Interim National Constitution (INC) was led by the MWRI. This Water Policy is expected to guide the sector in the planning and monitoring of water facilities during implementation. The Water Policy addresses issues like Rural Water Supply and Sanitation (RWSS) and Urban Water Supply and Sanitation (UWSS). The Southern Sudan Legislative Assembly (SSLA) of GOSS approved the Water Policy of Southern Sudan in November 2007.

The importance of developing effective water supply and sanitation services is universally recognized as a basis for improving the overall health and productivity of the population, and is particularly important for the welfare of women and children under five. Considering the current low coverage of safe drinking water supply and basic sanitation facilities as a result of the protracted civil war in the country during the last five decades, there are enormous challenges ahead. With the unrecorded number of IDPs and returnees that have resettled in their traditional homelands and the emergence of new settlements/towns in all ten states of SS, the demand for water and sanitation services is immense. There is need for implicit policies, strategies, guidelines and manuals to ensure provision of sustainable supply of quality and accessible water and sanitation services.

The preparation of these WES Technical Guidelines at this stage is very timely, as it enables us to further develop our strategies and prepare action plans for the implementation of the Water Policy. It will also allow us to strengthen existing best practices as well as to test new experiences that will create room for future development.

During the development and finalization of these Guidelines for water supply and sanitation facilities, we have consulted WASH sector partners at State level and partner non-government agencies through successive consultative meetings, and appreciate their contribution, which has assisted in finalizing these documents.

The MIWR of the GOSS is thankful to UNICEF, Juba for financial and technical support for the preparation of these Technical Guidelines.

We call upon our WASH sector partners to give us their continuous feedback from the field for the improvement of these Guidelines. We believe that successful implementation and future sustainable service provision will depend on effective coordination and close collaboration among all partners including government, non-government and beneficiary communities.

Mr. Joseph Duer Jakok,  
Minister of Water Resources and Irrigation  
Government of Southern Sudan, Juba

Date .....

## **Acknowledgements**

Special thanks go to Mr Mohammed Hassan Mahmud Amar, Mr Eisa Mohammed and Mr Mudawi Ibrahim, for their directions on GONU's sector policy; Engineer Isaac Liabwel, on GOSS's water policy; Mr Sampath Kumar and Dr. Maxwell Stephen Donkor, for their direction on the WASH sector from the UNICEF perspective, and for the provision of relevant documents & information, and facilitating & organizing a number of forums to discuss draft documents.

The author would also like to thank WES and UNICEF staff of North Darfur, North Kordofan, South Kordofan, Sinnar, Gedaref, Kassala, Red Sea and Blue Nile States; the staff of DRWSS, and UWC in Central Equatoria, Western Bahr el Ghazal, Warap and Upper Nile States; and the staff of UNICEF Zonal Offices responsible for the arrangement of meetings with sector partners and successful field trips to the various facilities.

Many thanks to Emmanuel Parmenas from MWRI, and Mr Mohammed Habib and Mr Jemal Al Amin from PWC, for their contribution in collecting documents and information at the national and state levels, facilitating field trips and contacting relevant persons at state level and to the latter two for their support in translating documents and information from Arabic into English.

The completion of this document would not have been possible without the contributions and comments of staff of SWC, PWC, MIWR, MCRD, MWRI, MOH in GONU, MAF, MARF, MOH MHLE, MWLCT and SSMO in GOSS, UNICEF, National and International NGOs like Oxfam GB, Pact Sudan, SNV, SC-UK, and Medair, and review workshop participants at state and national levels and members of technical working groups.

## Acronyms

<b>APO</b>	Assistant Project Officer
<b>BS</b>	British Standard
<b>CPA</b>	Comprehensive Peace Agreement
<b>DG</b>	Director General
<b>DPA</b>	Darfur Peace Agreement
<b>ES (Es)</b>	Effective Size
<b>ESPA</b>	Eastern Sudan Peace Agreement
<b>GONU</b>	Government of National Unity
<b>GOSS</b>	Government of Southern Sudan
<b>IRC</b>	International Reference Center (International Water and Sanitation Center)
<b>MCRD</b>	Ministry of Cooperatives and Rural Development, GOSS
<b>MIWR</b>	Ministry of Irrigation and Water Resources, GONU
<b>MPN</b>	Most Probable Number (Faecal coliform counts per 100ml)
<b>MWRI</b>	Ministry of Water Resources and Irrigation, GOSS
<b>NEMA</b>	National Electrical Manufacturers Association
<b>NPSH</b>	Net Positive Suction Head
<b>NTU</b>	Nephelometric Turbidity Unit
<b>PM</b>	Project Manager
<b>PVC</b>	Polyvinylchloride
<b>PWC</b>	Public Water Corporation
<b>RPO</b>	Resident Project Officer
<b>RWD</b>	Rural Water Department
<b>SSMO</b>	Sudanese Standard and Measurement Organization
<b>SWC</b>	State Water Corporation
<b>SWL</b>	Static water level
<b>TCU</b>	True Color Unit
<b>TDS</b>	Total Dissolved Solids
<b>UC</b>	Uniformity Coefficient
<b>UNICEF</b>	United Nations Children's Fund
<b>WATSAN</b>	Water and Sanitation
<b>WES</b>	Water and Environmental Sanitation
<b>WHO</b>	World Health Organization

## Document Summary

This summary provides a brief overview of the document and is only meant as a quick reference to the main norms. Reference to the whole document is advised for accurate implementation

### Norms

- Digging of a hand dug well should begin with well established safety procedures, using local knowledge of hand dug well techniques wherever possible.
- Diameter of the well: 1.5 – 2.0m, depending on the type of lining material used. Lining materials could be plastic, concrete, brick or stone masonry.
- Maximum diameter of the well for plastic lining is 1.4m, for concrete lining 1.5m, for brick and stone masonry 2.0m. Where deepening of a well is anticipated due to drop down of groundwater level, all lining materials (except the plastic lining) can be used. The internal diameter of the current available plastic lining material is limited to 1.0m and does not allow deepening of the well for less than 1.0m diameter.
- Yield of the well: 3.2 m<sup>3</sup>/h and above
- Water quality should comply with Sudanese/WHO guidelines.
- Disinfection of the hand dug well is required prior to commissioning of the water supply system. Community's awareness of disinfection (chlorination of water) may be low, so information sessions are recommended.
- Types of pumps:
  - a) Centrifugal surface pump for well depth with dynamic water table less than 6m
  - b) Submersible pump for well depth with dynamic water table more than 6m
- Power supply to pumps:
  - a) Diesel generator or
  - b) Solar
- Number of people to be served for 8 hours operation time: 1400 – 2800 people
- Type of distribution:
  - Spot distribution alone
  - A combination of spot and a small distribution network
  - Distribution alone through a significant distribution network.

## **1. Introduction**

### **1.1 The purpose of this document**

The Ministry of Irrigation and Water Resources (MIWR), GONU, and the Ministry of Water Resources and Irrigation, (MWRI), GOSS, are responsible for the policy and strategy development, coordination, planning, management, monitoring and evaluation of water supply and sanitation facilities in the country. In order to reduce disparities, improve standards, accelerate implementation and to standardise design and costs, the two ministries agreed to harmonize the methodologies utilised in the implementation of WATSAN interventions. Currently, there is no standardised document providing Technical Guidelines for implementation by WES or other water and sanitation agencies and this is detrimental to the longevity of structures and the sustainability of interventions.

In 2006 MIWR and MWRI decided to develop Technical Guidelines for the construction and management of rural water supply and sanitation facilities. These Guidelines are a collection of global and national good practices in water and sanitation that have been collated. The process of the development of the Technical Guidelines is outlined in Annex 2.

These simple Guidelines are primarily intended as a reference for field staff and practitioners in the water and sanitation sector challenged by situations and conditions in the field.

Updating of the Guidelines is recommended biennially; to ensure newer and better practices are incorporated as they are developed/ introduced. Water and sanitation sector implementing partners should contribute in providing feedback to the MIWR and MWRI as necessary during the updating..

### **1.2 Technology options**

A number of global technology options are available for improved rural water supply systems. However, not all can be applied everywhere. In rural North Sudan, and Southern Sudan, the common choice is boreholes equipped with hand pumps or motorized pumps (water yards); hand dug wells (with hand pumps), Hafirs (with a combination of filtration systems and hand pumps), and from developed springs.

These Technical Guidelines focus only on hand dug wells with motorized (electrical or solar) pumps. The following general design considerations are recommended for the application of this technology option.

## **2 Design considerations**

### **2.1 General**

In order to ensure the supply of improved and adequate water to communities within the design period of any water supply system, due consideration should be given to the following parameters:

- **The population number:** A reliable forecast of the expected number of people utilizing this service is important. This can be extrapolated from the current population figure and the growth rate and/ or any other factors that might affect the numbers to be served.
- **The design period of components:** This should be identified and the implementation period agreed upon at the beginning of the planning stage as the life span of the components varies. Components can be implemented in phases depending on the availability of resources. Components like hand dug wells could initially be designed for 20 years or more, and pumps should be designed for the same period with a regular replacement of components.
- **The per capita water demand:** The per capita daily water demand should be in line with the government development strategy. In Sudan, the current daily water demand is set at 20 liter per capita per day (l/c/d). The Government of Sudan aims to reach to 50 l/c/d by 2015. With the current budget allocation, it is realistic to assume that the minimum per capita of 20 l/c/d will be maintained in the near future.
- **The quality of water:** The quality of water (in terms of physical, chemical and bacteriological content) has a significant impact on public health. Since this varies considerably from region to region in Sudan, the fluoride, sulphate and nitrate content in the groundwater sources needs to be examined as it may be higher than the rates allowed by the drinking water guidelines of Sudan
- **Distance to improved water supply facilities:** To the extent possible the distance to the improved water supply point should not be greater than 500m during emergencies and 1000m during normal times.
- **Choice of technology options:** Without compromising on the quality, quantity and sustainability of the system, a low-cost option should be prioritised.

## 2.2 Hydrogeological classification of the aquifers

The knowledge of the hydrogeological classification of aquifers in the various parts of the country and the quantity and quality of the groundwater in the various aquifers is vital, for an informed decision on the design of the water treatment system to be used. According to hydrogeological information from 1989, Sudan's hydrogeological units are divided into three main groups:

- A) Porous rocks of relatively high to low hydrogeological importance
- B) Fractured rocks of relatively medium to low hydrogeological importance, and
- C) Porous or fractured rocks with very low hydrogeological importance.

**A) Porous rocks of relatively high to low hydrogeological importance:** This group is divided into three sub-groups:

1. **Continuous aquifers of sub-regional to regional extent which are confined or unconfined and consolidated or unconsolidated:** Nubian Sandstone and Gedarif

Formations are categorized under this subgroup, whose saturated thickness is generally high; permeability varies but it is generally high; water quality is generally good and hydrogeological importance and potential is great.

Areas under this subgroup are: South Kordofan, North Kordofan, Gedarif, Khartoum and Northern States, North Darfur, Baggara Basin of South and West Darfur, South Darfur, Western Bahir el Ghazal, Northern Bahir el Ghazal and Unity States (refer to map 1: Sudan Hydrogeological Map).

2. **Continuous and sub-continuous aquifers of local to regional extent:** Um Ruwaba, Gezira, El Atshan, Butana, Nawa and Undifferentiated Paleozoic Formations are categorized under this subgroup which are consolidated or unconsolidated; with saturated thickness medium to high; and permeability low to high. The water quality varies though it is generally good and hydrogeological importance and potential is medium to great.

Areas under this subgroup are: All Southern Sudan except Western Bahr el Ghazal, West Equatoria and Central Equatoria.

3. **Continuous or sub-continuous aquifers of local to sub-regional extent:** Alluvium, Wadi fills and swamp deposits are categorized under this subgroup, which are unconsolidated and their saturated thickness generally small; permeability varies and the water quality is generally good; hydrogeological importance is generally great and the potential is variable.

Areas under this subgroup are: In Southern Sudan, they are sub-continuous and are found in Lakes and Central Equatoria States.

**B) Fractured rocks of relatively medium to low hydrogeological importance:** This unit is characterized by local aquifers restricted to fractured zones. It could be unconfined or confined. The permeability varies and it is generally low. The water quality is generally good. Thermal saline waters may occur. Its relative importance is medium to low and the potential is generally low. Undifferentiated volcanics are categorized under this unit.

Areas under this hydrogeological unit are: Gedarif, Eastern part of Eastern Equatoria, Jebel Mara area in Darfur and some pocket areas in North Darfur, (refer to map 1: Sudan Hydrogeological Map)

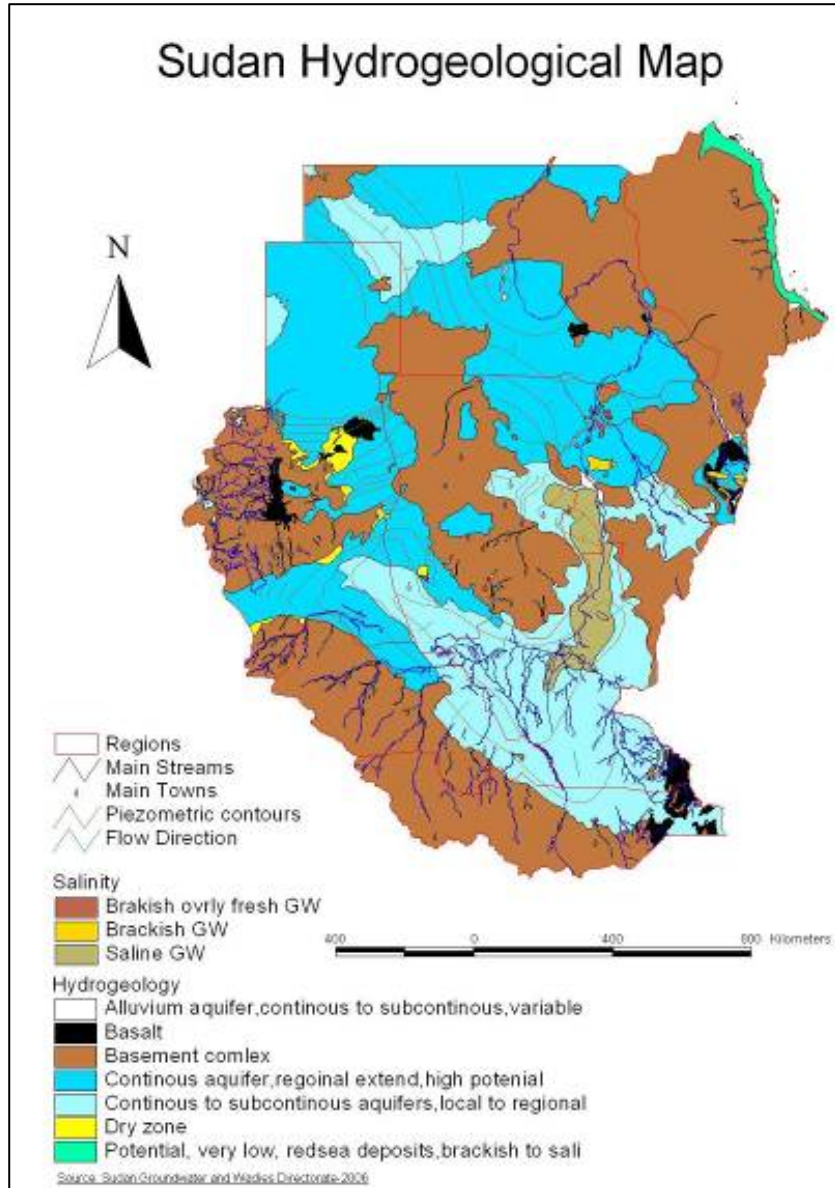
**C) Porous or fractured rocks with very low hydrogeological importance:** This unit is subdivided into two subgroups:

1. The Red Sea deposits are categorized under this subgroup, which are local aquifers that may be confined or unconfined. They are found in thin arenitic beds or lenses consisting of consolidated or unconsolidated sediments. Their permeability is low to very low. The water quality varies and near the coast it is often brackish or saline. The relative hydrogeological importance is generally low and potential is low as well.

- Undifferentiated Basement Complex and acid intrusions are categorized under this subgroup which are rocks that are generally non-water bearing. Water occurs in fractured or weathered zones. Local perched perennial or ephemeral aquifers may occur as well as thin saturated layers at depth and hydrogeological importance and potential is low.

Areas under this unit are: Blue Nile, Nuba Mountains, Western Equatoria, Central Equatoria, Eastern Equatoria, Western Bahr el Ghazal, West Darfur, Eastern States and some Northern part of Sudan (refer to map 1: Sudan Hydrogeological Map).

Practical problematic situations that are related to groundwater in different parts of Sudan are expressed in terms of high salinity, fine sand, loss of circulation, running sand & caving, thick mud-stone and other problems that will occur during drilling of boreholes like the presence of boulders. Areas affected with these problems are indicated in Table 2. The salinity zone has been indicated in map 1: Sudan Hydrogeological Map.



### Map1: Sudan Hydrogeological Map

High Salinity	Fine sand	Loss of circulation	Running sand & caving	Thick mudstone	Others e.g. Boulders
-Sud Basin (Jonglei) (Some parts of Northern Upper Nile, Renk County) Latitude 8-13 Longitude 3130-33 Umm Rawaba Formation, Unity State	-EnNhud Basin Nubian Sandstone, Northern Upper Nile	-Baggara Basin South Kordofan (Moo), South Darfur in Umm Rawaba Formation, West EnNhud Nubian Formation, Kapoyta area in Eastern Equatoria	-Basement complex	-Nubian Sandstone Fula Depression Fula West Omdurman Arak and Debban North State	-Boulders Upstream and midstream of Red Sea Wadis emerging from escarpment (high mount) Sinkat Jabeit Port Sudan area
-East Kordofan Basin East Kordofan, White Nile, Latitude 13-14 Longitude 3130-3230 (Tendalti)	-Haskanita East Darfur, Umm Rawaba	-East Kordofan Basin Umm Rawaba Formation	-Umm Leuna Northern Darfur	-Gedarif Basin Mudstone below volcanic rock Darfur	-Nuba Mountain Wadis Upstream
-Blue Nile Basin Jezira Formation, West Managil, Abuguta, North Central Gezira State, South of Khartoum 'between Niles', East of Nile Khartoum	-Baggara Basin	-Blue Nile Basin Sennar (North West) Nubian	-Nubian Formation Umm Hashaba Northern Darfur West Darfur Kulbus Wadi Sediment (100m)	-Malaha West Darfur Targmbout Nubian	-Jebal Marra Volcanic and upstream of wadis of Jebal Marra
-Gedarif Basin Southern part of the basin South of Gedarif	-Blue Nile Basin (Singa near river)	-Central Darfur Basin (Dabal) West Kordofan East Darfur	-Khartoum East Nile Um Dwit Nubian		-Basalt sills South of Khartoum and Omdurman
-Aroma	-South Darfur (Nubian)	-West Omdurman			-Basalt
-Delta Toker Downstream	-Khartoum East Nile, Kadarw (Nubian), Bageer (Nubian)	-Jezira State Umm El Gora (East of Blue Nile) (Nubian)			-Shagra Basin El fashir well field (180-250m)
-Red Sea Formation Red Sea at the shore line, downstream of alluvial in wadis in Red Sea m. system		-West Kordofan El Sederat Latitude 130858 Longitude 273488			-River Atbara (Boulders)
-Sinkat (Wadi sediment)					-Alluvium
-Basement (Dali & Mazamom) 6400ppm					

**Table 2: Groundwater problematic Zones – Sudan<sup>1</sup>**

<sup>1</sup> Source: Information Center (Kilo 10) Groundwater and Wadis Directorate, Ministry of Irrigation and Water Resources, August 2007

### 3 Mobilization of stakeholders

Identifying and mobilizing potential stakeholders is an important step in the realization and sustainability of a rural water supply system. Various stakeholders play various roles at different stages of a project cycle. Roles and responsibilities can be assigned using participatory techniques like participatory rural appraisal. Involvement of the community (including women) in decision making at all stages of the project will promote sustainability. For example in, site selection, technology choice, choice of preference design for the platform and drainage apron, community contribution for the construction, operation and maintenance of the water service, selection of the village health committee (for the management of water , sanitation and hygiene promotion activities in their villages) and village mechanics (that could be trained).

Local authorities also play a significant role in the facilitation of the implementation of the water supply system. Problems that may arise during the implementation of the water supply system such as for example, land ownership, can be more easily solved if the local authorities are brought on board and involved in the decision making process.

Problems can only be identified by the active involvement of all stakeholders in the decision making process. The long process involved in getting community engagement can be decreased by using a demand-driven approach.

### 4 Guidelines for hand dug wells

**Quantity of water:** The quantity of water that the well produces is a prime factor to determine whether the well should be fitted with a motorized pump. If the yield of the well is less than 0.5 l/s, the installation of a motorized pump is not recommended.

**Depth of the well:** This will influence the type of motorized pump required.

**Quality of water:** The choice of pump, motor body, and riser pipe, will also depend on whether the water is corrosive or non-corrosive. If riser pipes are not resistant to corrosion, a proper maintenance schedule must be in put in place if the water in the area is corrosive.

General groundwater quality parameters<sup>2</sup> in Sudan:

Water temperature	30 – 40 <sup>0</sup> C
pH	7 – 8.5
Total hardness	200 – 300 mg/l
Total dissolved solids	500-1000mg/l and at some places >1500 mg/l
Sand content	The water is moderately charged with sand particles

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<sup>2</sup> Source: NWC, Water Supply Design Criteria and Equipment Standardization

**Local capacity for operation and maintenance:** The building or strengthening of community capacity to manage, operate and maintain their water supply systems is important..

**Availability of spare parts:** Communities should know where to easily find spare parts for the pump or generator at affordable prices.

**Government policy on standardization of hand dug wells.** There are no government standards in place yet for minimum dug well diameter, unlike for elevated storage reservoirs for water yards, for which the standard volume recommended is 45m<sup>3</sup>.

**Type of storage reservoir:** The storage capacity preferred in rural Sudan for mini water yard is in the range of 2 to 10m<sup>3</sup>, these prefabricated steel reservoir can be rectangular or circular in shape, but rectangular is preferred. Storage reservoirs made of PE materials have been recently introduced in South Kordofan.

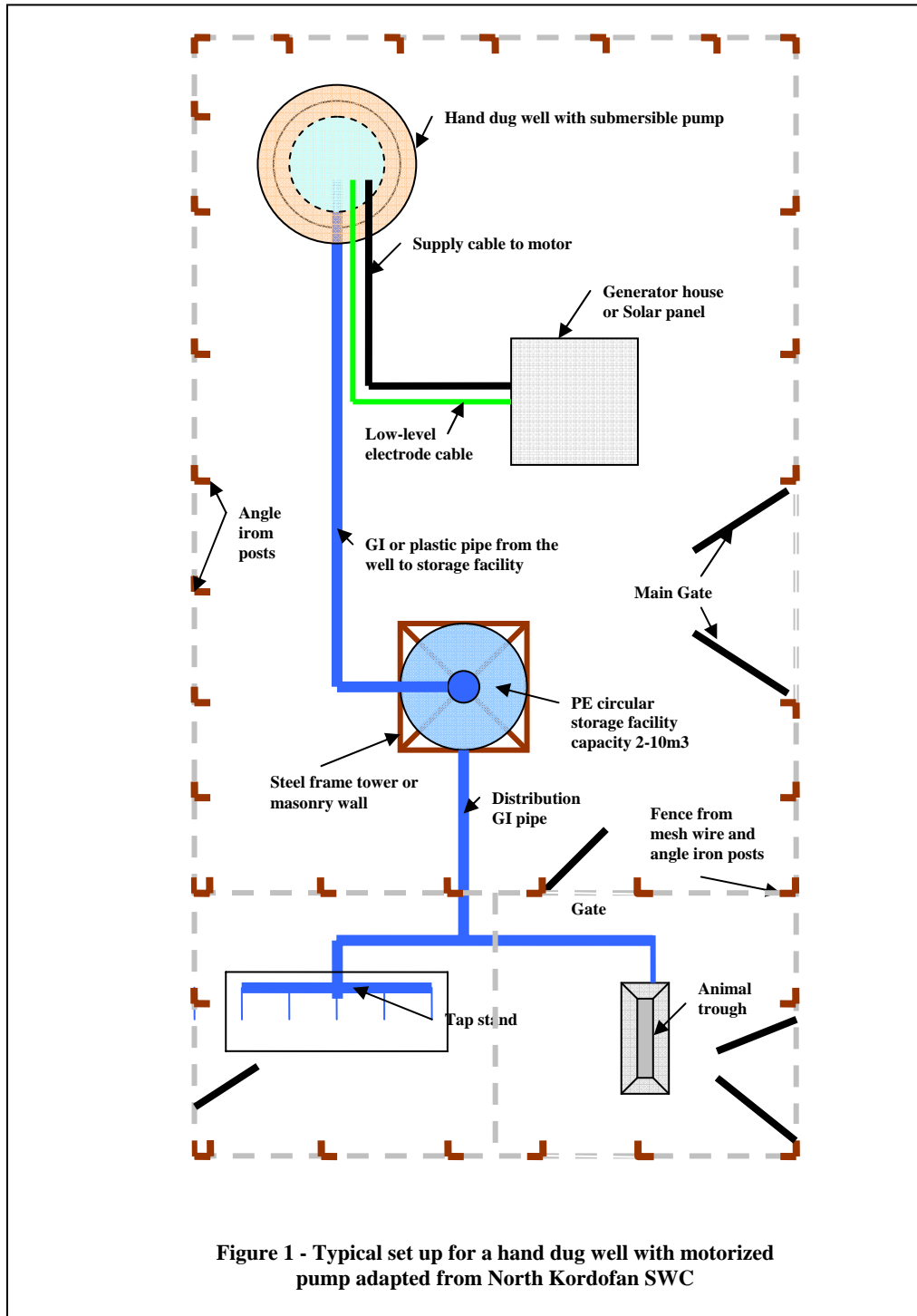
**Livestock watering:** Provision should be made for livestock watering facilities, although the yield of the hand dug well is very small.

## **5 Hand dug wells with motorized pumps**

### **5.1 Components of a hand dug well with motorized pump**

- **Hand dug well (the source of water)** Hand dug wells are required to produce a minimum of 0.5 l/s of water to allow installation of a motorized pump. The well can be equipped with a low head submersible electric or solar pump for water levels (both static and dynamic) greater than 6 m from the top of the well. A centrifugal pump is recommended for static water levels lower than 6m.
- **Prime mover:** The prime mover can be an electrical or solar power generator. A prime mover that works by both solar and wind could be an alternative, however its sustainability should be field tested and approved as an appropriate.
- **Storage reservoir:** Where there is a possibility of extracting reasonable amount of water from the well, the standard rectangular made of mild steel plates (or panels) or circular shape storage facility of PE material and steel frames (or masonry wall for PE) could be used. The volume of such reservoirs in rural Sudan ranges from 2 to 10m<sup>3</sup> capacity.
- **Supply and distribution pipes:** The supply pipe conveys water from the hand dug well to the storage reservoir (elevated tank), whilst the distribution pipe takes the water from the storage tank to water distribution points.
- **Water distribution points:** These are outlets from which water can be collected in containers for individual use, or for filling animal troughs.
- **Provision of drainage for wasted water:** There should be a proper system for conveying wasted water from the distribution points to a safe distance away from the facility. The wasted water can be directed to a soak pit, to a nearby garden plot , or dispersed on waste water evaporation beds in areas where infiltration into the ground is difficult due to the texture of the soil.

- **Motor house/shelter:** A shelter to protect the electric generating motor from rain, extreme sun and dust, and any kind of vandalism.
- **A fence:** The whole facility must be protected with a fence that restricts access of unauthorized persons and animals, and facilitates the management of people and animals during water collection or animal watering schedules.



## 5.2 National standards for hand dug wells with motorized pumps

There are no current government standards on the minimum diameter of a hand dug well diameter, and various sizes of concrete ring moulds have been manufactured at state level.

### 6 Design of hand dug well with motorized pump

#### 6.1 Hand dug well - general considerations

- **Location (or site):** The site of construction should be protected from potential pollutants. The nearest latrine should be located at a minimum safe distance of 30 to 50m. from the well, or more if there is a chance of underground pollution due to the hydrogeological characteristic of the soil type. Auger techniques can be used for suitable site identification for a hand dug well.
- **Determination of optimum yield of the well:** A pumping test is recommended to determine the optimum yield of the well during critical times of the year, especially before the rainy season, when the aquifer has not been recharged. Optimum yield must meet the demand. Static and dynamic water levels should also be recorded. The amount of water stored underground will depend on the nature and extent of the aquifer. Regular monitoring of groundwater levels must be part of the operation and maintenance activities.
- **Wall lining extension above ground level as a parapet or wall:** The provision of 75 to 80cm extended wall lining will protect from the possibility of flooding from surface water during the wet seasons. The lining should extend 0.5m above the most frequent flood level line.
- **Cover slab on the top of the well:** If fixed properly on the lining of the well, the cover will prevent entry of pollutants into the water in the well.
- **Motorized pump used to withdraw water:** Water should be withdrawn from the well only through the motorized pump, which must be housed in the pipe shroud. If the riser pipe is a GI pipe, it should be fixed on the top of the well with proper pipe clamps. If it is plastic, it should be supported by a rope tied to the horizontal supporting iron bar on top of the well.
- **Extension of the apron/platform around the well:** This extension, preferably of at least 2 m radius from the wall (or parapet) of the well, will provide protection against infiltration of nearby surface water into the well. It will also provide a solid ground (base) for the tripod during the installation of the motorized pump, where a service rig is not used.
- **Protection of Well head area:** The well head including the apron and the immediate surrounding should be protected with a fence from unauthorized people and animals.
- **Diversion of surface water:** Diversion ditches should be dug uphill, a reasonable distance from the well, to divert surface water from the settlement areas away from the well.
- **Design for sanitary protection:** In a completed well, polluted water from surface drainage or from formations other than an aquifer, can move downward through the annular space and contaminate the water being pumped from the well. A means for sealing an opening outside the casing must be envisaged; Provision must be made in

the design of a well for grouting the well casing in the ground from the surface down to an adequate depth ranging from 3 to 5 meters, depending on the geology and site conditions.

- **Well diameter:** This should be large enough to allow well diggers and their equipment into the well for future deepening of the well in case the water table level drops and sufficient water cannot be drawn. The recommended diameter for a concrete ring lined well is 1.50m, whilst the minimum diameter recommended for a brick lined well is 2.0m
- 

## 6.2 Elevated water storage tank - specifications

The water storage tanks for a hand dug well water yard are made from fiberglass, polyethylene (PE) or mild steel plates as shown in the following pictures and range in size from between 2 to 10m<sup>3</sup> capacity



Smaller size storage facilities in South Kordofan State made from PE material

These light weight facilities can be mounted on masonry foundations or simple steel metal frames depending where they are installed. Specifications provided by the manufacturers should be followed for installation.



**A storage facilities made of mild steel, North Kordofan State**

Specifications for storage facilities made from mild steel :

- **Tank body:** The tank should be manufactured from welded mild steel plates. Specification of the tank body: a) Bottom plates should be 6mm thick. b) Wall plates should be 5mm thick. c) Cover plates should be 3mm thick. The tank should be braced internally with 80x80x6mm mild steel angles. The first apron of mild steel angles should be at one third of the height measured from the bottom, the second at two third of the height and the third and last at the top of the tank internally. The tank body should also be reinforced with vertical angles of the same size at one third of each panel. Roofing plates should rest on two angle rafters of size 80x80x6mm at the top of the tank. d) The manhole at the top of the tank should be 600x600mm complete with a lockable cover. e) The cowl ventilator should be of 100mm diameter and covered with a mild steel bonnet with mosquito wire. f) The internal and external ladders should be manufactured from 50x6mm mild steel flat and mild steel round bars 6mm diameter, spanning 400mm with steps 300mm apart. g) The water level

indicator should be made with a mild steel pulley, float, nylon string and weight. Two angles 40x40x4.7mm should be welded at the face of the tank with graduations between them to indicate the water level inside the tank. h) The connection for water openings should be as follows: Inlet (50mm Q) threaded to BS 21, Outlet (50mm Q) threaded to BS 21, Washout (80mm Q) threaded to BS 21 and Overflow (80mm Q) threaded to BS 21. The washout and overflow pipes should be connected together below the tank. Their openings should be on either side of the tank and in line with each other.

- **Supporting tower:** The height of the tower should not be less than 6m to support the weight of the water and the weight of the , with a span of 2.3m one way and 1.15m the other way. Branch beam shall be of IPE 140x73x129 kg/m or equivalent. Main beams (architrave) shall be of IPE 200x100x22.4 kg/m or equivalent. The standions should be one bay with a total height of 6.0m manufactured from a) HPB 120x120 kg/m or b) IPE 200x100x22 kg/m. All wind bracings should be manufacture from 65x65x6 mm mild steel angles. The thickness of the foot plate and top plates should not be less than 16mm, whilst that of the gusset plates should not be less than 6mm. Holding down bolts, nuts and washers should be supplied in adequate sizes but not less than 16mm Q if 4 anchor bolts are to be used per footing..
- **Paints:** The tank and tower should be painted with an antirust prime coat, followed by another coat applied as follows. a) Tank: Internal coating - bituminous non-toxic paint, external coating - black and white oil paint (approved). b) Tower: bituminous black paint. The water level indicator should be painted white with red graduations.

#### **Specification for water storage facilities during emergencies:**

- Various types of rapidly erectable bladders and steel tanks (like Oxfam's T-tanks) are available for emergency situations. Bladder specifications include: the size of the bladder, inlet and outlet sizes, and the diameter and length of the flexible hose required. Bladders are available in the following sizes: 5,000, 6,000, 10,000 and 15,000 litres capacity. The capacity of T-tanks is indicated by letters and numbers e.g. T-11, T-45, T-70, where T-11 tank means that the tank capacity is 11,000 liters. Detailed specifications can be obtained from the manufacturers upon request.
- Bladders or T-tanks can be mounted on platforms made of earth, sand filled sacks, brick or stone masonry.

#### **6.3 Technical specifications for Submersible pumps**

The submersible pumps in hand dug wells should be installed with pump shroud to ensure continuous cooling of the motor. Pump specifications include:

- Flow or capacity at duty point in (m<sup>3</sup>/h)
- Total head at duty point in (m)
- Setting depth of submersible pump in (m)
- Fluid type: Drinking water
- Efficiency:  $\geq 70\%$

Motor data:

- Motor should be submersible, squirrel cage type to match the pump specification
- Frequency: 50 Hz
- Rated voltage: 380 – 415 V
- Nominal speed: ??
- Motor type: 3 phase
- Insulation class: F or H
- Degree of protection: IP 58
- Cooling system: Water
- Maximum outside diameter in (mm)
- Built in temperature transmitter for monitoring motor temperature

#### Operating limits

- Starts per hour:  $\geq 10$  times
- Pumped liquid temperature:  $\geq 40^{\circ}\text{C}$
- Contents of solids:  $\geq 20 \text{ g/m}^3$
- Density:  $998 \text{ kg/m}^3$
- Viscosity:  $\geq 1 \text{ mm}^2/\text{s}$

#### Construction materials' specifications

- Shaft: Stainless steel
- Shaft bush: stainless steel
- Ball bearings: Stainless steel
- Thrust bearings: fulfill NEMA standards
- Radial bearings: ceramic (stationary), tungsten carbide (rotating)
- Impellers: Stainless steel
- Column pipe: threaded and coupled black, either : 5L grade B or 53 grade B, or equivalent (in lengths not exceeding 3m each)
- Bowl body: Stainless steel.
- Delivery casing: Stainless steel
- Suction casing: Stainless steel
- Cable: Flexible water proof cable exceeding the setting depth by 20m, of the 4 core type, to suit the size of the power transmitted, and complete with pipe clips.
- Water level indicator shall be provided.

#### Starter

- Autotrans or D.O.L type (depending on motor capacity) and complete with the following protection devices:
  - Dry run
  - Phase failure and phase sequence
  - Over / under voltage
  - IP 58
- The following indicators and instruments must be fitted
  - Operation mode indicator
  - Stop mode indicator
  - Voltmeter with selector switch

- Ampere meter with selector
- Frequency meter

#### Accessories

- Power cable
- Sensor cable
- Sluice valve
- Check valve
- Pressure gauge
- Cable joint kit
- ASTM rising main
- Original manufacturers' pamphlets (catalogue) detailing the complete characteristic (performance) curves, specifications and mounting. The characteristic curves must indicate head, power, efficiency NPSH. Variations with discharge at rated speed.
- The particular model(s) offered should be clearly specified.
- A list of recommended fast moving spare parts and cost must be provided. The total cost should amount from 10% to 15% of the total value.
- One tool box per set

#### **6.4 Technical specifications for Electric motors**

The following specifications should be considered:

- The motor ratings should match efficiently the pump requirements.
- Motor shall be 3- phases, induction motor squirrel cage type, 415V, 50 Hz.
- Motors should have proper starting system with adequate guard against power supply irregularities complete with a panel board with main performance indicators.
- Manufacturers' brochures of specifications are to be supplied.
- Drawings showing complete mounting with pump shall be provided.
- The particular model(s) offered should be clearly specified.
- Motors shall be provided complete with cables, electric keys, and rescue compound and connection bor.
- Ambient temperature should be equal or greater than 40<sup>0</sup>C.
- Insulation class must be F or H.
- Built in temperature transmitter for monitoring motor temperature must be provided.
- The cooling system should be water cooled.
- The ingress protection should be IP 58.
- For outside motor cooling system, the pumped water velocity should not be less than 0.15 m/s (flow sleeve can be used to maintain the required velocity)

#### **6.5 Calculation of pump power and efficiency**

In order to calculate the pump power, we need to know the operating pressure head (H) of the pump or the total head, which is the sum of static head, friction head and velocity

head. As velocity head is small in magnitude, it is usually neglected. Therefore the total head is the sum of the static and friction heads as shown in Figure 2

The power output measured in watts (W) of a pump,  $P_w$  is given by

$$P_w = Q \rho g H.$$

Where

Q is the flow rate of water in  $m^3/s$

$\rho$  is the density of water,  $1000kg/m^3$  or  $1 kg/l$

g is gravitational acceleration  $9.81 m/s^2$

H is the operating pressure head (or total head)

A pump delivering 2 l/s against a 50m operating head would have a power output of  $P_w = 2 \times 9.81 \times 50 = 981 W$  or about 0.981 kW.

The required input power to the pump  $P_p$  is given,

$$P_p = P_w/\eta$$

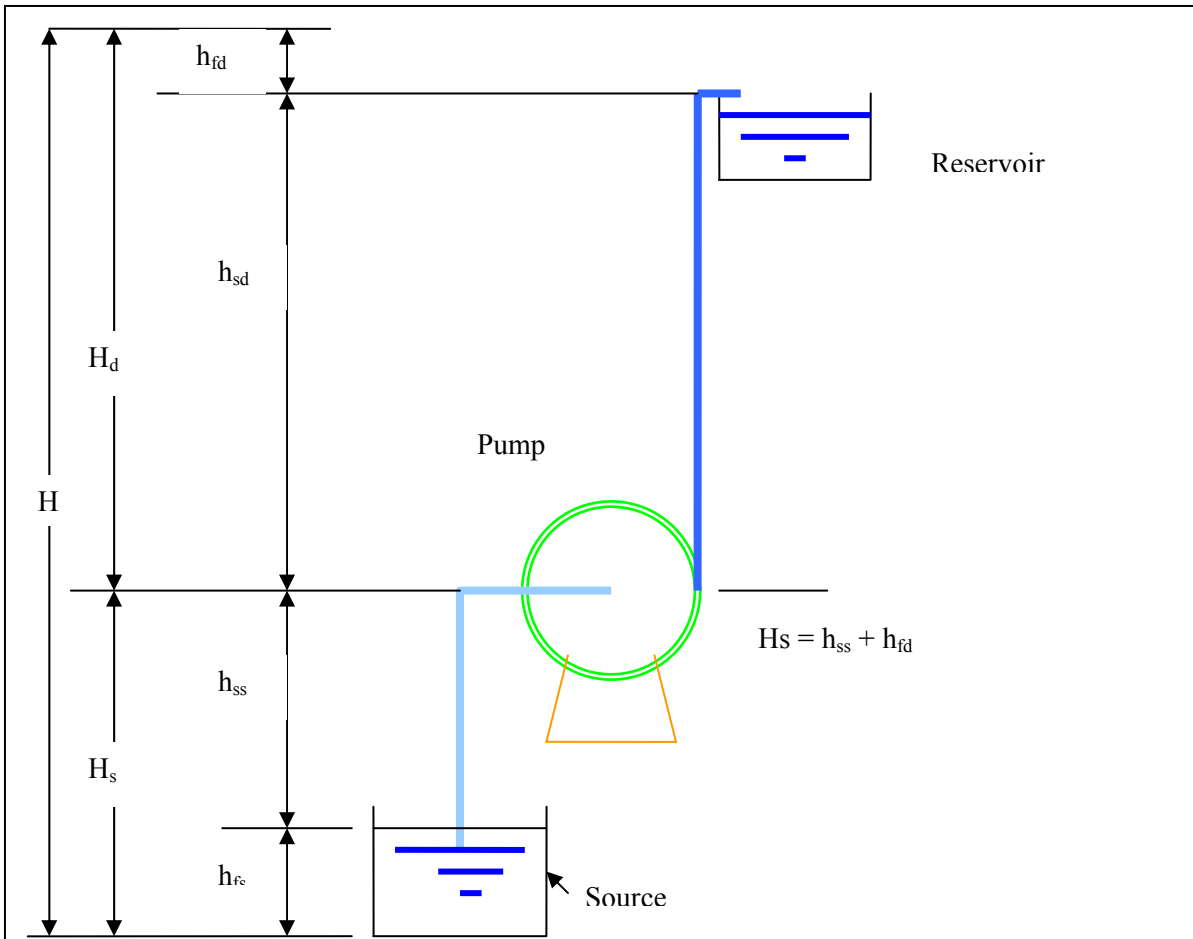
Where  $\eta$  is the overall efficiency with which power from the prime mover is converted into pump power and it varies from 40 to 60%. Therefore a pump delivering 0.981 kW and powered by internal combustion engine will typically require 1.962 kW or approximately 2 kW from engine.

## 6.6 Sizing and specifying generators

A generator supplying an electric motor must be able to cope with both the peak running load (full load) and the increased load due to starting (starting load). The magnitude of the starting load depends on the type of motor and the method of starting. In the absence of full information about a generator, the following general rule can be used to ensure that the generator is able to meet the load requirements on start-up:

- Generator full load kVA should be  $\geq 2 \times$  output motor power (in kW)
- Check the full load current (FLC) of the pump motor and ensure that the rated current capacity of the generator is able to supply the FLC plus 15%.

Do not procure an over-sized generator. If a diesel engine is run continuously on a light load, there is a risk of the injectors becoming clogged with carbon deposits of un-burnt fuel. Regular light loading can lead to excessive fuel and oil consumption.



- H Total head
- H<sub>d</sub> Delivery head
- h<sub>sd</sub> Static delivery head
- h<sub>fd</sub> Friction delivery head
- H<sub>s</sub> Suction head
- h<sub>ss</sub> Static suction head
- h<sub>fs</sub> Friction suction head

Total Head = Static Head + Friction

Figure 2 – Calculation of pump head

### Information needed to specify a generator<sup>3</sup>

Essential information	Recommended information
<p>It is essential to specify the following information to ensure that the generator will give the correct output:</p> <ul style="list-style-type: none"> <li>The supply required either: Single phase, 2 wire (phase and neutral) and system voltage, for example: 110V, 220V or 240V.</li> </ul> <p>Or:</p> <p>Three phase, 4 wire (three phase and neutral, and system voltage, for example: 380/220V, 415/240V.</p> <ul style="list-style-type: none"> <li>Supply frequency: 50Hz or 60Hz</li> <li>Continuous output kVA. List the pieces of equipment to be supplied by the generator and their power requirements. In the case of motors, give the method of starting.</li> </ul> <p>For example: One electric submersible pump with a motor size of 5.5 kW (6.6 kVA) started direct-on-line (DOL), one booster pump with a motor size of 4 kW (4.8 kVA) started DOL. Total is 9.5 kW (11.4 kVA).</p> <ul style="list-style-type: none"> <li>Site conditions: Temperature (maximum and minimum), altitude, and humidity. Note any particular problem, such as dust.</li> </ul>	<p>In addition, it is recommended to specify the following:</p> <ul style="list-style-type: none"> <li>Skid mounted or mobile</li> <li>Weather protection and internal protection (IP) rating. State whether the generator should be supplied as an open or weather protected set.</li> <li>Engine – any generator set of size will be diesel driven. State the following options: Air or water-cooled, hand and/or electric start, (even with electric start, it is useful to have a hand-start facility for when the battery is flat, or missing). Engine monitoring facilities – overheating, low oil pressure, battery charging ammeter or indicator. Automatic engine shut down in the event of overheating, low oil pressure, or broken fan belt. Base fuel tank and/or separate service tank.</li> <li>Control panel. Integral (set-mounted) or free standing control panel. Integral control panels must be mounted on anti vibration mountings. Instrumentation to include: one ammeter per phase, One voltmeter and selector switch (to monitor each phase-phase and phase-neutral voltage). Frequency meter. Hours-run meter. Engine monitoring meters and indicators may be mounted in the control panel.</li> <li>Exhaust pipework – run length and any bends.</li> </ul>

The following specific information is also required for a generator<sup>4</sup>:

- Engine: diesel (internal combustion) engine
- Cooling method: water
- Water pump type for the diesel engine: recommended centrifugal
- Governing type for diesel engine: recommended mechanical type
- Engine electrical system: Voltage / ground electrical starting method
- Gross engine power: 1.2 x required kW
- Aspiration for diesel engine: recommended turbo charged
- Ambient temperature for diesel engine: recommended  $\geq 45^{\circ}\text{C}$
- Relative humidity: 85%
- Fuel filter type: replaceable element
- Air filter type: replaceable element
- Oil filter type: spin-on, full flow
- Direct coupling for alternator and diesel engine

#### Alternator specifications

- Excitation system: recommended to be Shunt + PMG or Shunt + AREP to avoid over sizing of a generator.

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<sup>4</sup> NWC

- AC self excited synchronous brushless
- AVR capable to regulate voltage range stabilization and frequency
- Insulation class: H

#### Control panel specifications

- Control panel designed to be used on the (50 – 24 – 15) kW generating sets and should be easily operated and mounted on common chassis via anti-vibration rubbers and on the front panel fitted with:
  - Water temperature gauge
  - Oil pressure gauge
  - Running time gauge
  - Indicator related to low oil pressure
  - Indicator related to high water temperature
  - Low battery alarm
  - Battery charger failure alarm
  - Voltage meter and voltage transferring switch to transfer and observe three phase voltage.
  - Current meter and current transferring switch to transfer and observe three phase ampere
  - Frequency meter
  - Switch on indicator
  - Running time recorder
  - 3 poles ccB energized to cut power on under-voltage conditions
  - Emergency shut down knob
  - Panel control board (PCB)
- Generator should be connected through a switchgear.

### 6.7 Pipeline design

**Flow in pipes and losses:** Bernoulli's equation is used to express flow in pipes as indicated below:

$$H = P/\rho g + v^2/2g + z$$

where:

- H = total energy (m)
- P = pressure of water (N/m<sup>2</sup>)
- ρ = density of water (kg/m<sup>3</sup>)
- g = gravitational acceleration (m/s<sup>2</sup>)
- v = flow velocity of water (m/s)
- z = height of water above a datum (m)

Frictional losses in pipes can be calculated using Colebrook-White formula, or Hazen-Williams formula as shown below:

$$h_f = (10.9 L Q^{1.85}) / (C^{1.85} D^{4.87}) \text{ or}$$

$$Q = 0.275 (h_f/L)^{0.54} C D^{2.63}$$

Where:

$h_f$  = head loss in m

L = length of pipe in m

Q = flow in  $m^3/s$

C = Hazen-Williams coefficient where values are for PE and PVC pipes 150 and new GI pipe 130.

D = internal pipe diameter in m

Manufacturers often include pipe flow charts based on the Colebrook-White formula in their literature. For a particular pipe material, flow rate (l/s or  $m^3/s$ ) is plotted against loss of head (in m/1000m) for various pipe sizes.

Tables are an alternative to charts, which are produced to relate frictional head loss to pipe diameter and pipe roughness. The roughness of a pipe depends on the pipe material, method of jointing, age and condition.

In addition to friction losses, energy is also lost (secondary loss) at pipe entry and exit, changes of diameter and direction, pipe fittings and at obstructions. There are various methods of estimating the secondary loss, but in a long pipe with very few fittings, secondary losses can be neglected.

Water flow velocities in pipes: A low velocity will allow sediment to settle in the pipe whilst a higher velocity will enhance erosion and suspend particles in the water. Desirable water velocities are 0.7 to 2 meter per second (m/s).

Different types of pipes can be used for the water supply system, namely Polyethylene (PE) of different densities like Low Density (LDPE), Medium Density (MDPE), High Density (HDPE) and High Performance (HPPE), uPVC and Galvanized Iron (GI) pipes. In most countries LDPE and HDPE pipes are being replaced by MDPE pipes.

**PE pipe sizing and pressure ratings:** PE pipe sizes are specified by the nominal outside diameter (OD) and not by internal diameter. For all PE pipes greater than 25mm, the ratio between wall thickness and outside diameter is constant for a specific pressure rating. This is the standard dimensional ratio (SDR).

$$\text{SDR} = \text{Outside diameter} / \text{Minimum wall thickness}$$

The SDR and OD values provide the minimum wall thickness and hence the approximate bore size. Pressure ratings are related to SDR categories and are usually quoted for a temperature of 20°C. The pressure ratings must be significantly adjusted as temperature rises (for instance they decrease by 60% at 40°C)

#### **Pressure ratings of PE pipe at 20°C**

Type of PE	OD (mm)	SDR	Pressure (bar)
MDPE	20-63	11	12

	90-315	11	10
	90-1000	17.6	6
HPPE	90-500	11	16
	90-500	17.6	10
	160-1000	26	6

PE pipe can be supplied in lengths of 6 or 12 meters for diameters greater than 90mm, or in coils of varying lengths.

**PVC pipe sizing and pressure ratings:** PVC pipes are available in both imperial and metric diameters in standard 4m and 6m pipe lengths. The older imperial sized pipe is available in four classes with pressure ratings as listed in table 7 below.

Class		Maximum working pressure at 20°C (bar)
BS3505	ISO	
B	NP6	6
C	NP9	9
D	NP12	12
E	NP15	15

The newer metric sized pipe is available in two pressure ratings of 8 and 12.5 bars. For ambient temperatures above 20°C allow a pressure reduction of 2% per 1°C rise in temperature.

**Galvanized Iron pipe:** This is appropriate where the pipe sections are subject to high pressures, or cannot be buried such as hard rock areas, short gullies, streams or road crossings, across cultivated farmland, exposed pipe work at tap stands, tanks etc. GI pipe are commonly available in 3 or 6 m lengths with a diameter of up to 4 inches (100mm). Maximum pressure rating of GI pipe depends on the pipe wall thickness. For medium wall GI pipe the maximum pressure rating is 25 bar.

## **7 The construction and installation process of hand dug well with motorized pump**

### **7.1 The digging process**

The following steps are recommended to dig a hand dug well and install the pump:

Establishing safety procedures, digging of the well, water quality testing, lining of the well, completion of the hand dug well, disinfection of the well and pump installation

#### **Establishing safety procedure**

Before any work is begun, it is important to ensure that safety measures are in place. Careful preparation of the well diggers, their equipment and the environment is of primary importance to avoid accidents as a result of: lack of experienced supervision,

careless workers and work methods, tiredness and lack of concentration, faulty equipment, collapsing soil, poisonous gases from pump engines, explosives and naturally occurring gases, incoming water, excessive dust, interference by casual onlookers, animals and children playing on unattended well sites

Proper safety measures to minimize possible accidents include:

- Ensuring that the construction is supervised by experienced and competent staff
- Proper signal arrangements must be in place between the diggers and the surface to alert in case of danger
- Ensuring that there are no solo diggers: the requirement is a minimum of four people on a well at any one time.
- Ensuring safe and easy access to the well,
- Ensuring an additional entry and exit into the well, in case of emergency
- Protecting the hole during digging and securing the site during non-working periods, when workers are not on site, and especially at night to prevent people, animals and materials from falling in
- Ensuring all equipment including ropes, ladders, tripods, lifting gear, buckets, pick-axe and hammer handles and heads are in good working order.
- Ensuring the provision and use of essential safety equipment such as: safety helmets, protective footwear, gloves, and goggles ( this especially when breaking rock)
- Ensuring first aid training and equipment is provided as part of the overall safety measures
- Ensuring the use of safe and suitable de-watering equipment;
- Ensuring no combustion engine, petrol or diesel-powered pumps are lowered into the well for de-watering as exhaust gases are heavier than air and will sink to the well lower levels. They can cause suffocation for the well diggers.
- Ensuring petrol or diesel engines are positioned downwind of the well site at ground level
- Ensuring onlookers are kept a safe distance from the excavation

### **Digging of the well**

Points to note:

Once all the necessary safety measures are in place, mark the diameter of the well on the ground. The well diameter depends on the lining material that will be used. Dig a 1.5m diameter well for concrete lining or a minimum of 2.0m diameter well for brick lining.

Use local knowledge and expertise to the extent possible. In availing basic tools and equipment such as buckets, pick axes, crow bars, rope, ladder, tripod, pulley, dewatering pump etc, pick traditional, locally made when available. For example, shop-bought buckets are often not strong enough and can be unsafe. Make sure the handles are firmly attached and not likely to slide off a hook. A bucket full of soil falling into the well could cause serious injury.

If poles made from tree branches are available locally, a tripod and winch can be made for excavation of dug materials, and for critical operations such as getting in and out of the well. A 24mm diameter nylon rope is recommended.

In unstable soil, it is advisable to line the well as the excavation proceeds. In some cases, only a temporary lining may be necessary to support loose soil at the surface.

For efficiency and safety when digging in difficult soils and hot conditions, it may be necessary to change diggers every 15-30 minutes.

Use de-watering pumps to extract water and thus allow digging to a greater depth. An air-operated pump is appropriate where compressed air tools are already being used.

Ideally digging should be started in the dry season. However, if that was not possible, and the well is not deep enough at the end of the dry season, it can be deepened using the caissoning method. This method is suitable for digging in an unstable sand layer, or for deepening a well if the water table drops.

The well yield depends on several factors, but in particular the aquifer type, the depth of the well and the time of the year. The diameter of the well has little effect on yield, but will increase the amount of storage

### **Water quality testing**

The quality of the water from the hand dug well should be tested for bacteriological, chemical, and radiological contamination before commissioning for public consumption. Water from a hand dug well will most likely have been bacteriologically contaminated during the digging and lining of the well, so it needs to be disinfected. Once this has been done, the bacteriological contamination must be checked at field level with portable equipment like, H<sub>2</sub>S vials, or an Oxfam/Delagua Water Testing Kit. Chemical and radiological contamination should be verified by the Sudanese institute authorized to do this at state or national level. The quality of water should be checked against Sudanese/WHO guidelines for Drinking Water Quality Standard. For chemical and radiological tests, two samples, not less than 5 litres each, from each hand dug well should be sent to the authorized institute in clean and sealed water containers. Three samples of water in clean, sterilized and sealed plastic or glass containers, not less than 100ml<sup>5</sup> each should be sent for bacteriological analysis.

### **Lining of the well**

There are many ways of lining a hand dug well, however if a local method is available this is preferred. The two basic methods are in-situ lining (from the top-down or the bottom-up) and caissoning. In stable soils, wells are sometimes dug unlined down to the water table and then lined in situ from the bottom up. This is the simpler of many

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processes and has the advantage that lining can be done after water has been struck, avoiding the extra work in case the well is dry. The principal disadvantage in this method is the danger of collapse. In situ lining from the top down is a safer although technically more difficult option.

Caissoning is the sinking of a lining column as excavation proceeds. This method is used when dealing with collapsing soil and below the water table, to protect diggers as they work and to increase the well yield when groundwater table level drops. It is important to use a cutting edge with a slightly larger diameter than the lining column to ease and control the downward passage of the column. If a column moves out of the vertical, correct it immediately as straightening will be difficult at a later stage.

Lining materials can be selected from concrete, bricks, stone, corrugated steel culvert or plastic.

There are several methods of lining in concrete; using pre-cast rings, fixed in situ lining or caissoned in situ lining. Reinforcement may be needed for concrete rings which have to be transported but is not essential for concrete rings which are simply placed in position and are not going to be used for caissoning.

In situ concrete lining avoids the handling of heavy concrete rings on site. A concrete ring column can be caissoned by casting a stage at a time in situ as the column descends. This avoids the need to maneuver concrete rings into position.

According to British Standard 5328, the appropriate mixing ratio of concrete for  $1\text{m}^3$  of concrete, is 6 bags of cement (each 50kg), 490 liters of sand, and 800 liters of aggregate for 1:2:6 mix ratio for reinforced concrete in mild conditions. For a 1:3:6 ratio and unreinforced concrete the quantities would be 5.4 bags of cement, 510 liters of sand and 800 liters of aggregate for  $1\text{m}^3$  concrete. For uniform measurement of sand and aggregate use a gauge box of size 367mm (length) x 300mm (width) x 300mm (depth) that gives a box of volume  $0.033\text{m}^3$  which is the volume of a 50kg bag of cement. The amount of water in a mix is critical to the strength of concrete. For hand mixing, a water : cement ratio of about 0.55 by weight gives a strong concrete, so a 50 kg bag of cement will need 27.5kg (27.5 liters) of water. This ratio is for aggregates that are not absolutely dry. Where very dry aggregates are used, for instance in hot arid climates like in Sudan, a little extra water is needed or the mix will be too stiff for good compaction. Use 20mm size of aggregate and sand from naturally occurring deposits such as river beds. If using damp sand, increase the volume by 25%. Water should be as clean as possible.

Moulds can be used for pre-cast concrete (as shown on **Figure 4**) and formwork (shuttering) for in situ placement of concrete. Sufficient water is essential for the concrete to harden through hydration. The concrete must be kept moist or cured to ensure that it does not dry out. Poorly cured concrete will not attain its full strength and may shrink and crack. Particular attention is needed to curing in a hot, dry or windy climate when evaporation rates can be high. Curing can be done by covering or wrapping with plastic sheet, covering with wet cement bag papers which are kept damp and regular spraying

with water. Curing must be started as soon as the concrete has set, or immediately in hot and dry weather.

Lining with bricks or stones, unlike concrete rings, can be done with the minimum of equipment. Locally developed knowledge in brick lining is quite established in Sudan and priority should be given to the use of this methodology.

Ready made plastic lining material for shallow wells (diameter 1m and height 1m) is available, mostly, into two semicircular halves. These can be perforated or blind. The two halves can be fixed with bolts & nuts. When using plastic lining materials, it is important to check the specification of the plastic material which should comply with food grade polyethylene standards. The disadvantage of this lining material is that it is relatively expensive.

### **Completion of a hand dug well**

A completed hand dug well should have the following components/parts:

- A sanitary seal at the surface to prevent pollution from surface water seepage into the well.
- A concrete apron and effective drainage system to carry waste water away and not allow collection of water around the well.
- A concrete cover slab cast with a pump stand and a manhole sealed with a cover.

A hand dug well constructed in soft formation, especially loose fine sand, will need a permeable concrete plug or graded media at the bottom of the well to prevent the entrance of the aquifer's fine sands to the well with the incoming water.

Once a well is completed, documentation relating to the formation of the dug well, diameter of the dug well, the lining material etc. must be included in the completion report that is submitted to MWRI, GOSS and PWC/MIWR, GONU for incorporation into their water and sanitation database.

### **Disinfection of the well**

Disinfection is necessary initially during pump installation and if and when the well gets polluted. The well should be disinfected or sterilized with a chlorine solution yielding at least 50mg/l of active chlorine in all parts of the well. The chlorine solution may be prepared from calcium hypochlorite or sodium hypochlorite. In case bleaching powder is used for disinfection, 300g of bleaching powder should be mixed thoroughly in 15 liters of water and poured into the well.

The disinfectant should stay in the well for at least four hours at the specified concentration, after which water should be pumped out and discarded until the water smells strongly of chlorine. At this point, no more water should be pumped out for at least 24 hours, after which water should be pumped out and discarded until the taste of

chlorine is just noticeable in the water. A sample of water should be collected in a sterile bottle and sent for bacterial analysis.

### **Installation of a submersible pump**

Figure 3 represents a schematic drawing of the installation of a submersible pump in a borehole. The installation procedure indicated in the manual provided by the manufacturer must be followed. The manual can be ordered when the pump is procured

Additional recommendations include:

Make a note of the data on the pump name plate. If a spare name plate is included with the pump, attach it to the pump control panel.

- Ensure that there is a suitable gantry and adequate lifting tackle (including pipe clamps) on the site. Pumps and pipes can be very heavy.
- Check that the voltage, phase and frequency are compatible with the power supply available.
- Check that the motor cable and the supply cable are not damaged, and that the cables are adequately sized to ensure the correct voltage at the motor. Check the low-level cable and connection to the electrode for damage and continuity, and ensure that the low-level unit has a good earth return through a steel borehole casing, earthed rising main or separate earth return.
- Conduct insulation tests on the motor and the supply cable with a 500V insulation resistance and continuity tester (megger). The resistance between any motor lead and the motor frame should be greater than 1 Mega ohm. The resistance between the individual cores of the supply cable should be greater than 1 Mega ohm. If a megger is not available, carry out a careful visual check on all cable insulation material.
- Check that the borehole has a large enough diameter all the way to the pump setting depth to accommodate the pump, the riser pipe and the joint between the motor and supply cables.
- Check that the non-return valve in the pump is in working order.
- Check that the pump setting depth is such that the pump (not the static) water level will be 2m, or more, above the pump inlet (check against the borehole pumping test data).
- Check that the pump drive shaft turns freely. This can only be checked if the motor coupling is exposed and it can be turned by hand or spanner.
- A flow of water across the electric motor is necessary to cool it, so do not install the pump at the very bottom of a borehole, where water may enter the pump from above without flowing past the motor. If the pump is located where flow over the pump body may not occur such as in large diameter well, it must be surrounded by a pump shroud which ensures that water first passes over the motor before entering the pump.
- Insert the pump, riser pipe and cable into the borehole using lifting tackle and at least two pipe clamps to prevent accidental loss of the pump and pipe work. Never clamp the pump body.

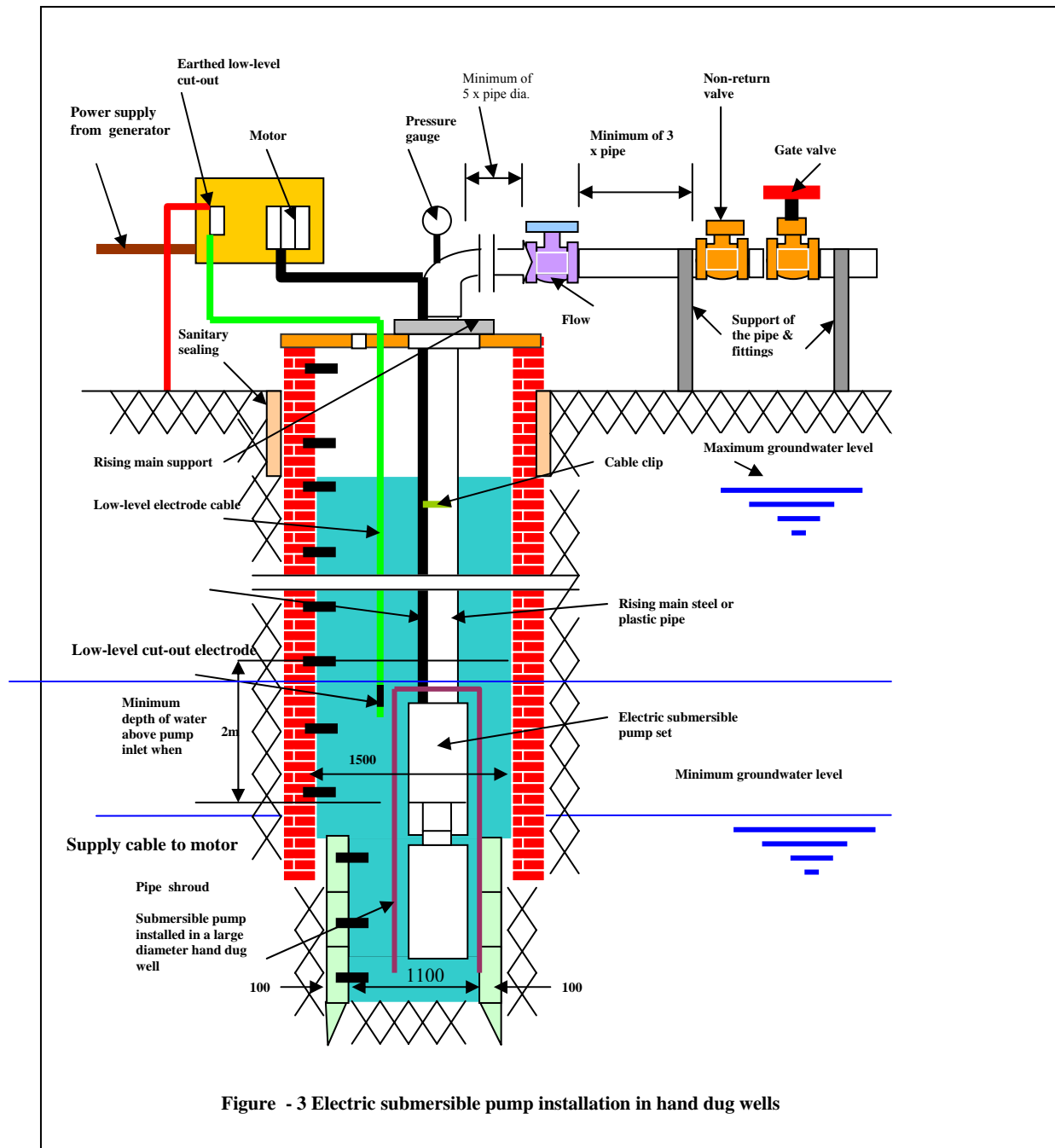


Figure - 3 Electric submersible pump installation in hand dug wells

- As the pump is lowered into the borehole, attach the supply cable and low-level cut-out electrode cable(s) to the riser pipe at 3m intervals. Leave some slack in the cables if the riser pipe is plastic, as the pipe will stretch slightly under load.
- If the pump and rising main do not sink easily, it may be because of the buoyancy of the empty rising main, fill the rising main pipe with water as you lower it..
- Some pumps have a connection for the attachment of a straining wire. The wire takes the weight of the pump for lowering and lifting. Attach the wire according to the instructions and secure it firmly at the top of the borehole after installation.
- When the pump is submerged, repeat the insulation test between the cores of the supply cable and an earth. If both the rising main and casing are plastic, use an earthing rod driven into damp earth.
- Clamp and support the rising main at the top of the borehole.
- Cover the top of the borehole to prevent the ingress of any contaminants.

## **7.2 Other civil works and electromechanical installation**

These include: Erection and construction of the elevated storage reservoir, pipe laying, construction of distribution points, construction of generator house/shelter, construction of toilet and fencing, and installation of generators

### **Erection and construction of the elevated storage reservoir**

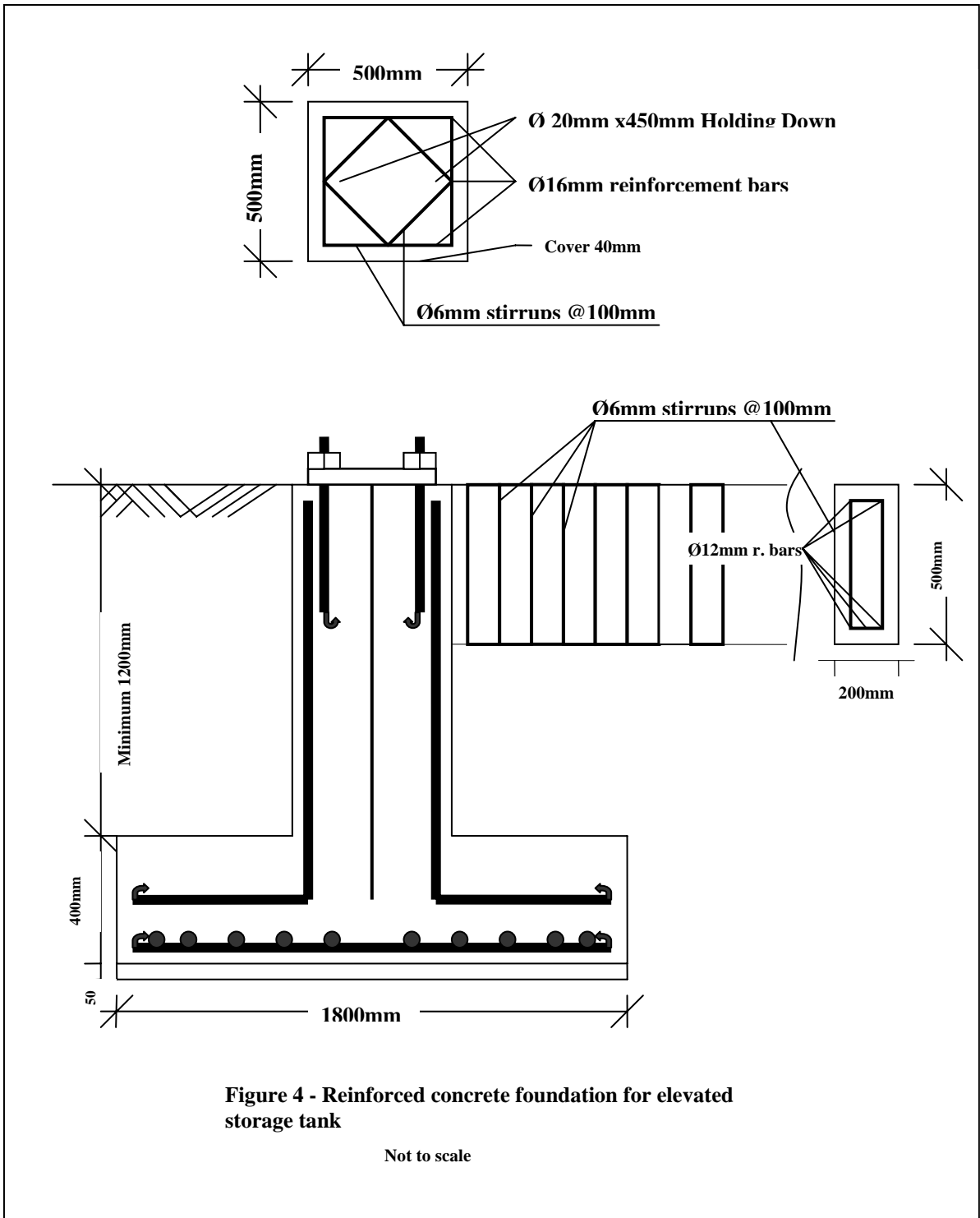
The erection of the elevated storage reservoir starts with the casting of a reinforced concrete foundation to support the tower indicated in figure 4, and as per the technical specifications described in section 6 above. The supporting tower is fixed on the foundation with anchor bolts once the concrete attains its full strength (usually 28 days). The mixing ratio of concrete is according to BS 5328. Once the supporting tower is in place, the tank can be mounted on the tower and connected to the supply and distribution pipe lines, making it ready for use. The tank must be disinfected before water supply to the consumer begins.

### **Pipe laying**

Two pipelines need to be laid; a supply line to convey water from the borehole(s) to the storage reservoir and a distribution line to take the water from the storage reservoir to the distribution points.

The pipelines need to be protected to ensure a lifespan of 20-30 years. Recommendations for laying pipelines include:

- a) Preparing the trench: The nature of the ground will determine the choice of flexible or rigid jointed pipes. Flexible joints are preferred to rigid joints to allow for settlement, which is likely. It is very important to ensure the alignment and bottoming up of the trench. Large stones must be removed from the bed of the trench. .



- b) Back filling: All trenches in hard formation need to be back-filled with 150mm of sand or any soft material, especially where the ground is stony. The material for back-filling must be soft and not contain lumps of rock or large stones. The pipe shall be covered with a minimum cover of soft material of 225mm then after the minimum cover bulk filling material in the trench is permitted.
- c) Handling and laying of pipes: Pipes must be handled with rope slings to preserve the protective coating, and prevent puncturing which could lead to corrosion. Care must be taken to ensure that the pipe ends retain their circular shape. Upon delivery, every pipe must be inspected and rechecked before it is lowered into the trench. Pipe-laying must be done by people who have been trained and have the right skills for the job.
- d) Cover for pipes: The minimum cover recommended is between 0.75 to 0.85m, although it can be thicker for pipes laid below roads (where a heavy traffic load is expected).
- e) Testing pipelines: Pipelines should be tested in reasonable length leaving the joints exposed to view. The test involves filling the pipeline with water under pressure, which exerts pressure of about 50% in excess of the working pressure. It could also be of extra pressure of a known value say 30m or 50m water head. Measure the amount of fall of pressure in a given time (usually between 20 minutes to an hour). Following this, pump sufficient water back into the pipe to bring the pressure back to its initial value. Measure the amount of water required.

CP 2010 Standard for testing pipelines: The following standard for field testing is outlined in CP2010 part 3. One litre of water per 10mm diameter of pipe per km length of pipeline for each 24 hrs and for every 30m head should be maintained. This standard can also be applied to steel mains. Air should not be used for testing water mains. The tests should be hydraulic and conducted between blank flanges bolted or welded to pipe ends. Where pipes have flexible joints the end pipe must be fully anchored. Tests should not be carried out between closed valves. Joints should be exposed for visual examination. To avoid air locks on the pipeline, air valves must be fixed on the pipeline which should be slowly filled with water. To ensure leaks are detected, it is recommended that the pipeline is left under pressure for 24 hours. A wet patch on the surface of the ground above the pipeline indicates a leak.

### **Polyethylene (PE) pipes:**

The common method of joining PE pipes is by fusion welding. This can be either electro-fusion or butt fusion. Other joining methods include push-fit systems and mechanical couplings. PE flange adaptors and compression adaptors allow joining of PE pipes to pipes of other material and flanged fittings. Compression joints are available for joining of PE pipes up to 110mm.

PE pipes can be laid directly in a trench if the soil is uniform and without sharp stones. Coarse sand, fine gravel and soft soil are suitable bedding and backfilling materials. Black MDPE pipes can be protected from ultra-violet rays with carbon and are therefore preferred to the blue MDPE for above ground use.. Significant changes in can be

expected where there are wide temperature variations. The following must be taken into account when handling and storing PE pipes to avoid damage and deformation:

- Pipes must be supported along their full length during transport.
- In storage, pipes should not be stacked more than 1.5m high and adequate support battens and lateral restraints must be provided.
- In hot and sunny climates, like Sudan, pipes must be kept under cover and well ventilated. Avoid storage in containers.

### **PVC pipes:**

PVC pipe can be joined by push-fit insertion joints or with solvent cement. Push fit joints cannot sustain end-loads and pipes must therefore be anchored in position by backfilling before pressurizing. Bends, blank ends and fittings must also be adequately anchored. Where solvent cement joints are used, the pipe joining involves the following procedures; abrading the pipe surfaces, marking the socket depth on the spigot, cleaning the mating surfaces with cleaning fluid, carefully applying the solvent cement, insertion the spigot in the socket in a clean and firm moving. Joints must remain undisturbed for 30 minutes at 20°C, and the pipe should not be pressurized for at least 24 hours. A hot climate makes solvent grouting even more difficult as solvent can evaporate from stored tins and jointing must be performed quickly. Compression joints of up to 110mm are available for the joining of PVC pipe. Flanged and threaded compression joint adaptors are also available for joining to GI pipes and fittings.

PVC pipes can be laid directly in a trench if the soil is fine graded, uniform and without sharp stones. The pipe should preferably be joined in the trench, to avoid separation of the joints by subsequent movement during pipe-laying. As push-fit joints cannot withstand end loads, all bends, valves, fittings and blank ends must be firmly anchored. Pipe installed above ground should be protected from sun light and supports should allow for expansion and contraction.

The following precautions should be taken when handling and storing PVC pipes:

- Stack pipes with sockets protruding and at alternate ends of the stack. Do not stack higher than 2m, and even less in hot climates like Sudan or if the pipes are nested.
- Support pipes along their length. Dig a shallow recess trench to take the sockets of pipes placed on the ground.
- In hot and sunny climates keep pipes under cover and well ventilated. Avoid storage in containers. In very high temperatures, pipes and plastic fittings can be stored under water.

### **GI pipes**

GI pipes are usually supplied with tapered pipe threads at the ends, with one straight connector per pipe. It is preferable to cut the pipe to length with a pipe cutter rather than a hacksaw.

To enable pipes and fittings to be removed for repair, threaded GI pipe should be joined with screwed unions on at least one side of a valve or fitting and in long lengths (>100m). GI pipes have flanged joints. Flange dimensions can vary widely so new

fittings must be carefully matched to existing pipe work. Ensure that there are sufficient gaskets for each flange joint. GI pipes can be welded, but this should be only be done for critical joints and for making up adaptors and special fittings.

Firmly anchor exposed GI pipes using pipe anchors of steel and concrete. Exposed empty GI pipes can become very hot in a warm and sunny climate. Care must be taken when filling hot pipes with cold water as the sudden contraction can damage threaded joints causing them to leak.

The following precautions should be taken when handling and storing GI pipes:

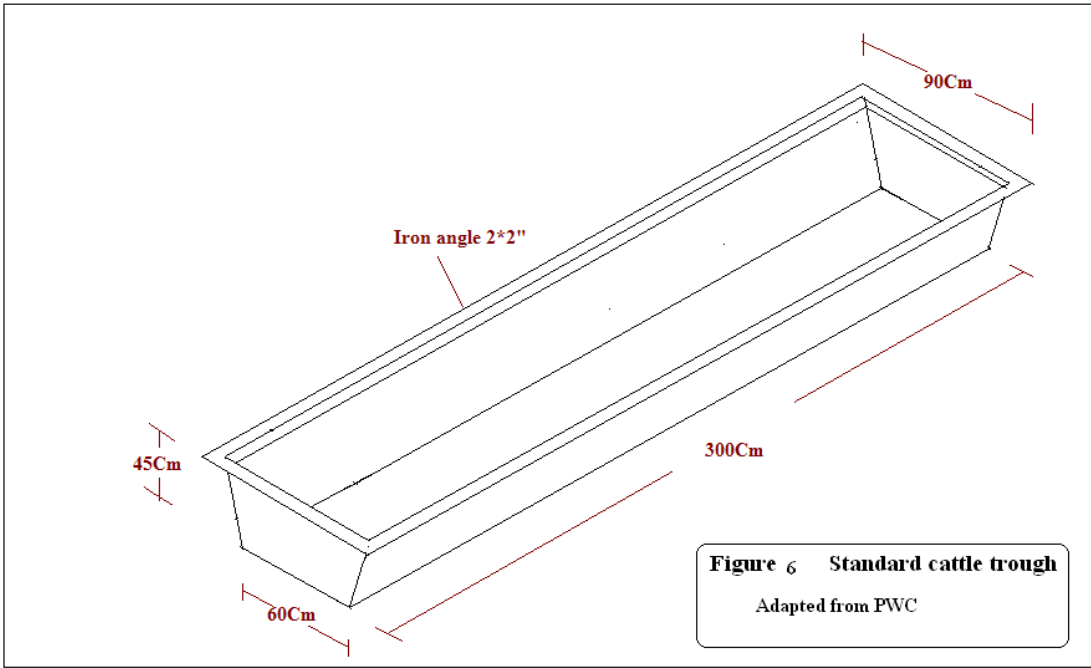
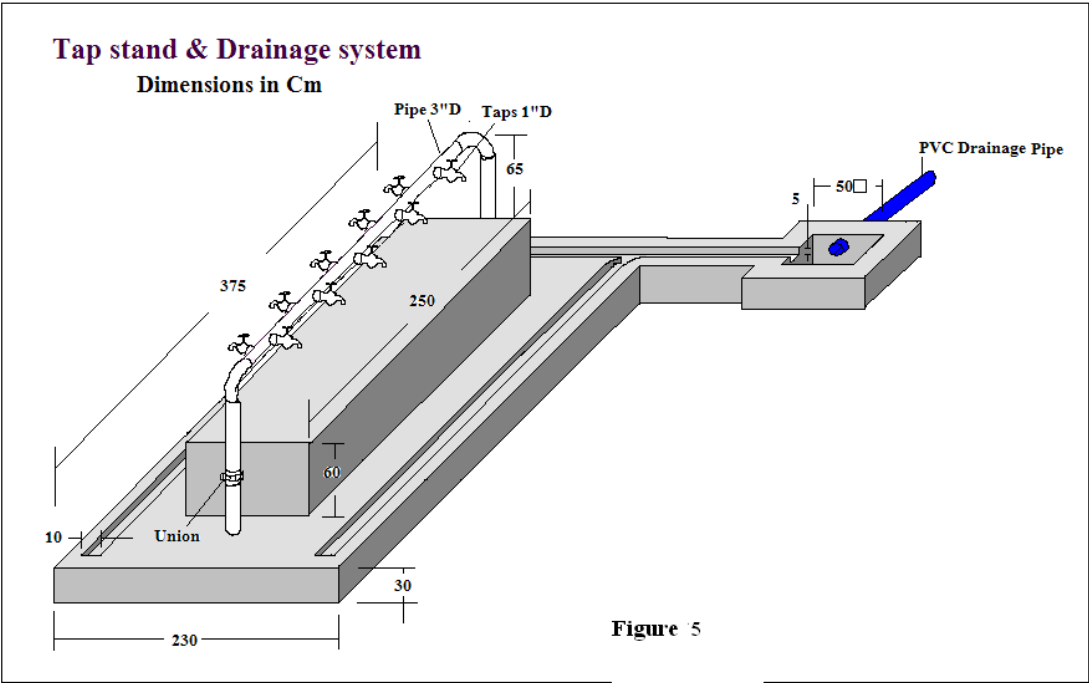
- Protect the threads in transit, and when loading and unloading as they can be easily damaged. A new GI pipe is normally bundled with a straight connector on one end and a thread protector on the other.
- In transit ensure connectors are firmly screwed on to each pipe as they can vibrate loose.
- In a hot and sunny climate, store a GI pipe under cover as the pipe can literally become too hot to handle.

### **Construction of distribution points**

Distribution points are mainly for the human population, however, provision must also be made for animal watering. Figures 5 and 6 below represent a schematic design for the construction of distribution points. The number of tap stands can be adjusted to meet the yield of the well and the number of people to be served .

Mixing ratio of concrete: According to BS 5328, 6 bags of cement (each 50kg), and 490 litres of sand and 800 litres of aggregate in a ratio of 1:2:6 respectively are required for 1m<sup>3</sup> of reinforced concrete in mild conditions. Un-reinforced concrete requires a ratio of 1:3:6, that is 5.4 bags of cement, 510 liters of sand and 800 litres of aggregate.

For the uniform measurement of sand and aggregate use a gauge box of size 367mm (length) x 300mm (width) x 300mm (depth) that gives a box of volume 0.033m<sup>3</sup> which is the volume of a 50kg bag of cement. The amount of water in a mix is critical to the strength of concrete. For hand mixing, a water to cement ration of about 0.55 by weight gives a strong concrete, so a 50 kg bag of cement will need 27.5kg (27.5 liters) of water. This ratio is for aggregates that are not absolutely dry. Where very dry aggregates are used for instance in hot arid climates like in Sudan, a little extra water is needed, otherwise the mix will be too stiff for good compaction. Use 20mm size of aggregate and sand from naturally occurring deposits such as river beds. If using damp sand increase the volume by 25%. Water should be as clean as possible. For masonry works use a typical mixing ratio of 1:6, cement to sand.



### **Construction of generator house/shelter (optional)**

Depending on the situation, a temporary shelter (in the case of emergency) or permanent generator house should be constructed to protect the generator from rain, dust and vandalism.

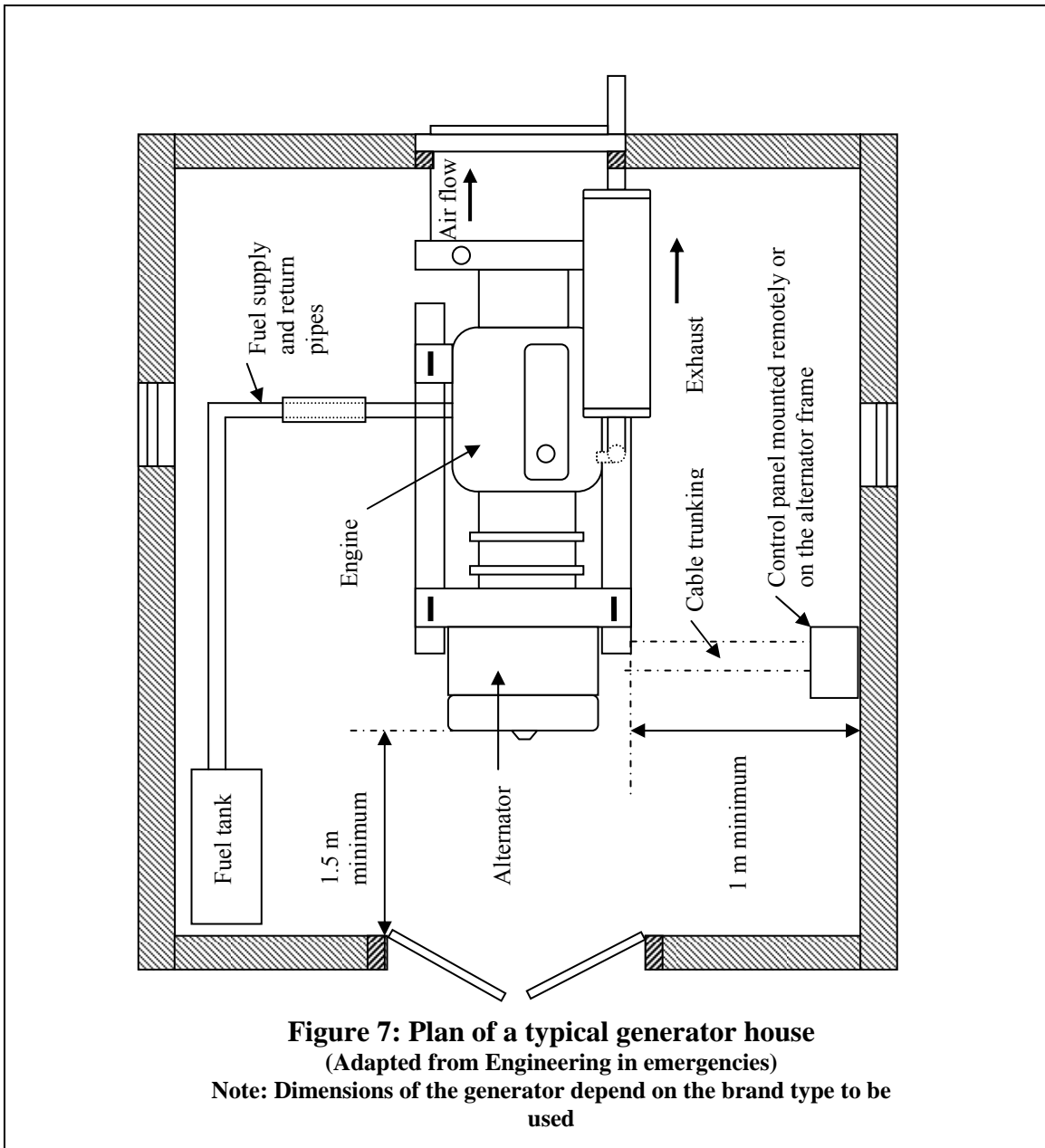
Temporary shelters are made from locally available materials.

A generator house/shelter should be so big enough to accommodate the engine, the generator and all accessories, and space should be allowed for the operation of the equipment and sufficient air circulation. A permanent building should have a concrete plinth foundation constructed according to the manufacturer's instruction and with the consideration of additional site situation.

### **Installation of a generator**

On delivery and before installation check the generator output (voltage, frequency, and power), control gear (switches, contactors, protective devices) and load (pump motors) making sure they comply with requirements. A generator must not be run inside a building without adequate ventilation to remove the exhaust gases. A generator must not be operated in the rain unless contained within a purpose made weatherproof enclosure.

Adequate air flow is necessary to supply the engine with air for both combustion and cooling. In a solid walled housing it is essential that hot discharged cooling air does not re-circulate to the cooling air inlet or the engine inlet. Provide cooling air intake holes near the bottom of the walls, and one in the wall nearest to the air filter to ensure a good supply of cooler air for combustion. Include air holes or a gap around the top of the walls to release accumulated hot air above the generator set. Direct the exhaust pipe over the cooling air outlet to exhaust in the same direction. Keep the exhaust system as short as possible, with the minimum of bends to keep back-pressure within limits. A build up of back-pressure prevents efficient removal of exhaust from the cylinders with a consequent loss of engine power. Leave at least 1m access space on each side of the generator. Leave 1.5m at the alternator end. Protect the cables in some form of conduit (such as PVC pipe) both between the generator and remote control panel (if not set-mounted) and from the generator to the load supplied. Refer to Figure 7 for the plan of a typical generator house. All generator sets should be earthed through a suitable protective conductor and earth electrode. If there is no generator earth terminal, connect the earth to the neutral terminal. The earth must be protected against damage and corrosion.



### 7.3 Capacity building

For proper operation, maintenance and sustainability of any water supply system, capacity building of the village mechanics/operators is vital. The water management committees need to be trained in basic management of the water and sanitation facilities and hygiene promotion activities so that they can operate and maintain the system in good working order. Based on community needs, training may include: the pump operator on basic operation and maintenance; village mechanics (who may cover a number of nearby water yards) in operation and maintenance and some special skills; and supporting agencies like WES/SWC on microbial analysis and extension work.

Availability of spare parts is one of the determining factors for the sustainability of the water supply system as is the supply of necessary tools and equipment.

## **8 Management, operation and maintenance of the hand dug well with motorized pump**

### **8.1 Management**

Currently, the management of mini water yards in Kordofan states is a one man management system. This manager is responsible for the operation of the system, conducting routine maintenance and reporting the need for major maintenance activities to the SWC. He is also responsible for the collection of water tariffs from users based on an established system of collection and for handing over the revenue to the SWC. He also performs guard duties during the day. This approach of management, although cost effective, is highly vulnerable to mismanagement, and to possible disruption of services in the absence of the manager.

In Southern Sudan, these types of water supply systems are managed by a water yard committee, supported by two skilled operators.

### **8.2 Operation and maintenance**

#### **Hand dug wells**

Hand dug wells are operated by installing motorized pumps (most of the time low head submersible pumps). As the wells are shallow and depending on the location where they have been constructed, they might be subjected to pollution by floods particularly during the rainy seasons. Therefore, particular attention should be given on protecting them against floods. Regular water quality monitoring should be, therefore, put in place after every rainy season (and after every flooding) to take appropriate action in time. In case the water in the hand dug well found bacteriologically polluted, the first action that needs to be taken is temporarily halt the supply, dewater the well using a dewatering pump and disinfect the well with available disinfectant. When there are no pathogens that are a concern to the public health, then it is possible to restart supplying of the water to the users. Regular inspection of the well head for any sign of cracks and any potential pollutant should be part of the operational procedure.

In case the static water level in the well drops, take out the submersible pump with its riser pipes, remove the cover slab of the well and deepen the well using the telescopic deepening procedure or caissoning as shown on the well design. After deepening completed, clean the well using dewatering pump, replace the cover slab, disinfect the well and reinstall the motorized pump.

#### **Submersible pumps**

Water flow, clearness and power consumption should be checked during pumping. If the water is turbid only during the first stages of pumping, the rising main is corroding. If turbidity continues the well has to be cleaned (or deepened), or the pump will wear out

quickly. It is important to maintain a logbook recording: hours of pump use; problems encountered; servicing; maintenance; and repairs.

Although general operation and maintenance procedure should be followed according to the manufacturer's manual (usually supplied with the equipment) other maintenance activities can be carried out on a regular basis to ensure longevity of the system. These include: removing pump and rising main from the well annually for inspection; checking inlet screens, check valve and pipe threads; re-cutting of corroded or damaged threads; replacement of badly corroded pipes; and inspection of electric cables and insulation between cables. Major repair works, like replacement of stages, should be done by a qualified technician.

### **Generators**

The engine must be operated by a trained caretaker (or operator). Every engine has its own typical operating instructions. The levels of fuel, oil and cooling water must be checked before starting and adjusted as needed. The fuel level, oil pressure, and engine speed and the functioning of the pump or generator must be monitored during operation. Some moving parts may need manual lubrication. When the engine is operated at a low speed, efficiency is low and carbon builds up rapidly in the engine, increasing the need for servicing. All data on liquid levels, running hours, servicing and maintenance must be recorded daily in a log book. In the absence of an hours-run meter, run times can be estimated from the fuel consumption. As a guide, diesel engine fuel consumption on full load is about 0.3 l/kWh. Some manufacturers quote fuel consumption in g/kWh. One litre of diesel fuel weighs about 850g.

Every day the outside of the engine must be cleaned and in dusty conditions the air filter must be checked and cleaned. In moderately dusty conditions, oil bath air filters are cleaned once a week, dry papers air filters a bit less frequently. The engine is serviced for preventive maintenance according to the number of hours it has run: Every 50 hours: clutch (if present) must be greased. Every 250 hours: clean all filters, replace if necessary, change oil. Check nuts and bolts and exhaust pipe. Every 1500 hours: major service overhaul: decarbonizing, adjusting valve clearance, etc. If the engine is connected to the generator with a Vee belt, this will need regular replacement.

Always start and stop a generator off-load. The generator engine should be started with the alternator isolator switch in the off position. Where the generator is supplying several items of equipment, do not switch them all on at the same time. Switch the loads on one at a time. Start with large motors first, followed by small motors. Finish with pure resistive loads such as resistive lighting circuits. If a problem is experienced in starting an electric motor, try starting that motor first, before switching in any other circuits. This enables the full capacity of the generator to be used in starting the motor.

Alternators and switchgear require limited attention, but frequent inspections are recommended in extreme temperatures or dusty conditions. Consult the manufacturer's handbook for guidance, and follow these recommendations:

Keep alternator ventilation openings clear. Use a dry air supply to clean internally.

- Grease alternator bearings as required.
- Check the functioning and condition of the switchgear: relays, contactors and protection devices.
- Check and tighten all machinery nuts and bolts, and terminals.
- Check the condition of the mountings and frame.
- In brush type generators, check the brushes and slip rings for wear, and replace if necessary.

The misuse of the battery is a common problem associated with electric start generator sets. Batteries are always in great demand. They may go missing temporarily to start someone's vehicle or they may disappear altogether. The charging circuit in a generator set can be damaged if it is run without a battery. Electronic protection modules can be damaged by 'jump-starting' sets with jump-start leads the wrong way around. It is, therefore, necessary to impress upon operators and supervisors the importance of keeping the battery in good condition and connected in circuit. Electronic protection modules should be diode protected to prevent damage in the event of incorrect polarity at jump-starts.

Do not change fuses or re-set circuit breakers without first isolating the supply, stopping the generator and correcting the fault. Do not attempt to start a generator with an electrical load connected. Care must be taken when testing insulation resistance as electronic components like automatic voltage regulator (AVR) may be damaged if not disconnected prior to the test.

### **Elevated storage reservoir**

Little intervention is required for operation of the elevated storage reservoir, except for draining and cleaning as and when necessary. Anti rust interior re-painting for the steel water tank is recommended only if rust is observed on the parts of the tank and the frame (generally annually). A leak, when discovered, must be repaired immediately to prevent higher maintenance costs.

### **Distribution points**

The taps are the weakest part of the system and likely to break frequently, and must be replaced, when they do. The drainage ditches that collect the wasted water must be cleaned and maintained regularly

## **8.3 Recommended spare parts**

Recommended spare parts for the diesel engine are listed in the manufacturer's handbook. It is good practice to have the following spare parts always available: Fuel, oil

and air filters, drive belt if the engine is connected with vee belt, nozzles, injectors, gaskets, bearings, fuel pumps etc.

Recommended spare parts for individual alternators include: fuses and/or circuit breakers of the appropriate ratings; an isolator switch; spare sets of brushes for brush type generators; diodes for direct current circuits; a spare AVR.

For distribution points: Different sizes of taps, gate valves and fittings according to the size of the pipeline and fittings installed in the water yard.

## **9. Recommendations**

The construction and installation of hand dug wells with motorized pumps may involve different disciplines and different contractors. The tender document has been prepared for the whole system. The specification part of the document can be modified according to the type of works required from the contractor. Hand dug wells should ideally be constructed using local know-how.

As this system is new, it is recommended that an assessment of the system, particularly the management and the maintenance costs be documented.

Electromechanical parts of the system that are already in use in country should be selected, to facilitate maintenance.

Proper operation and maintenance training should be in place, for unfamiliar electromechanical parts of the system.

The tap stands are, in most cases, the weakest part of the system. They are easily damaged and result in huge water losses due to leakage or may even prevent the provision of services as shown in the following picture. Regular maintenance and replacement when necessary is recommended.



**Lack of regular maintenance and replacement of taps makes the system non-functional**

Appropriate new designs should be encouraged, like the tap stands introduced in North Kordofan, to minimize frequency of maintenance works.

The standard cattle trough that is currently used is appropriate for the cattle and camels, but difficult for smaller animals like sheep and goats. It is recommended that the height be reduced by 50 percent.

## **Annexes**

1. Sudanese/WHO drinking water standards
2. The development of the Technical Guidelines
3. List of contacted people
4. Technical Working Group Members
5. Some selected bibliography and references

### Annex 1: Drinking Water Standards

No	Dissolved substances in water	Sudanese maximum permissible (mg/l ) by SSMO, 2008	WHO guideline value (mg/l), 2006
1	Antimony	<b>0.013</b>	0.02
2	Arsenic	<b>0.007</b>	0.01 (P)
3	Barium	<b>0.5</b>	0.7
4	Boron	<b>0.33</b>	0.5 (T)
5	Cadmium	0.002	0.003
6	Chromium (total)	<b>0.033</b>	0.05 (P)
7	Copper	<b>1.5</b>	2
8	Cyanide	<b>0.05</b>	0.07
9	Fluoride	1.5	1.5
10	Lead	<b>0.007</b>	0.01
11	Manganese	0.27	0.4 (C)
12	Mercury (for inorganic Mercury)	<b>0.004</b>	0.006
13	Molybdenum	<b>0.05</b>	0.07
14	Nickel	<b>0.05</b>	0.07 (P)
15	Nitrate as NO <sub>3</sub>	50	50 Short term exposure
16	Nitrite as NO <sub>2</sub>	<b>2</b>	3 Short term exposure
17	Selenium	<b>0.007</b>	0.01
18	Uranium	0.01	0.015 (P,T)

Microbiological contents			
No	Organisms	Sudanese guideline value by SSMO	WHO guideline value
1	All water intended for drinking a) E-coli or thermotolerant coliform bacteria b) Pathogenic intestinal protozoa	Must not be detectable in any 100ml sample	Must not be detectable in 100ml sample
2	Treated water entering the distribution system a) E-coli or thermotolerant coliform bacteria b) Total coliform bacteria c) Pathogenic intestinal protozoa	Must not be detectable in any 100ml sample	Must not be detectable in 100ml sample
3	Treated water in the distribution system a) E-coli or thermotolerant coliform bacteria b) Total coliform bacteria  c) Pathogenic intestinal protozoa	Must not be detectable in any 100ml sample Must not be detectable in any 100ml sample. In the case of large supplies where sufficient samples are examined, must not be detectable in 95% of samples examined throughout any consecutive 12 months period.  Must not be detectable in any 100ml sample.	Must not be detectable in 100ml sample

Maximum permissible limit for other parameters which affect the acceptability of water			
	Parameter	Levels likely to give rise to consumer complaints by SSMO, 2008	
1	Physical parameters Colour Taste & odour Temperature Turbidity pH	15 TCU Acceptable Acceptable 5 NTU 6.5 – 8.5	
2	Inorganic constituents Aluminum Ammonia Chloride Hydrogen sulfide Iron (total) Manganese Sodium Sulfate Total dissolved solids (TDS) Zinc	0.13 mg/l 1.5 mg/l 250 mg/l 0.05 mg/l 0.3 mg/l 0.27 mg/l 250 mg/l 250 mg/l 1000 mg/l 3 mg/l	0.4 mg/l
3	Organic constituents 2-Chlorophenol 2,4-Dichlorophenol	5 µg/l 2 µg/l	

Parameter	Permissible level in µg/l by SSMO, 2008	WHO guideline value in mg/l, 2006
Carbontetrachloride	2.7	0.004
Dichloromethane	14	0.02
1,2-Dichloroethane	20	0.03
1,2-Dichloroethene	33	0.05
Trichloroethene	13	0.02 (P)
Tetrachloroethene	27	0.04
Benzene	7	0.01
Toluene	470	0.7(C)
Xylenes	330	0.5 (C)
Ethylbenzene	200	0.3 (C)
Styrene	13	0.02 (C)
1,2-Dichlorobenzene	700	1 (C)
1,4-Dichlorobenzene	200	0.3 (C)
Di(2-ethylhexyl) phthalate	5.4	0.008
Acrylamide	0.3	0.0005
Epichlorohydrin	0.3	0.004 (P)
Edetic acid (EDTA)	400	0.6 Applies to the free acid
Nitrilotriacetic acid (NTA)	130	0.2
Hexachlorobutadiene	0.4	0.0006
Dioxane	33	0.05
Pentachlorophenol	7	0.009 (P)

Parameter	Maximum Permissible level in µg/l	WHO guideline value in mg/l, 2006
<b>Pesticides</b>		
Alachlor	15	0.02
Aldrin/Dieldrin	0.02	0.00003 For combined Aldrin and Dieldrin
Aldicarb	7.5	0.01 Applies to Aldicarb Sulfonide and Aldicarb Sulfone
Atrazine	1.5	0.002
Carbofuran	4.5	0.007
Chlordane	0.15	0.0002
Chlorotoluron	20	0.03
1,2-Dibromo-3-Chloropropane	0.7	0.001
DDT	0.7	0.001
2,4-Dichlorophenoxy acetic acid	20	0.03
1,2-Dichloropropane (1,2 DCP)	26	0.04 (C)
1,3-Dichloropropene	13	0.02
Isoproturon	6	0.009
Lindane	1.3	0.002
MCPA	1.3	0.002
Methoxychlor	13.5	0.02
Metholachlor	7	0.01
Molinate	4	0.006
Pendimethalin	13.5	0.02
Pentachlorophenol	7	0.009 (P)
Permethrin	200	0.3
Simazine	1.3	0.002
Trifluralin	13.5	0.02
2,4-DB	60	0.09
Dichlorprop	66	0.1
Fenoprop	6	0.009
Mecoprop	7	0.01
2,4,5-T	6	0.009
Cyanazine	0.4	0.0006
1,2 Dibromoethane	0.27	0.0004 (P)
Dimethoate	4	0.006
Edin	0.4	0.0006
Terbuthylazine	5	0.007
Chlorpyrifos	20	0.03
Pyriproxyfer	200	0.3
<b>Disinfectants and disinfectants' byproducts</b>		
Chlorine	3	5
Monochloroacetate	13	0.02

Bromate	6.6	0.01 (A,T)
Chlorate	470	0.7 (D)
2,4,6-Trichlorophenol	135	0.2 (C)
Bromoform	70	0.1
Dibromochloromethane	70	0.1
Bromodichloromethane	66	0.06
Chloroform	200	0.3
Dichloroacetate	33	0.05 (T,D)
Trichloroacetate	133	0.2
Dichloroacetonitrile	13	0.02 (P)
Dibromacetonitrile	50	0.07
Cyanogen Chlorides (CN)	50	0.07
Chlorate	470	0.7 (D)
<b>Disinfectants byproducts</b>		
Gross alpha activity	0.07	
Gross beta activity	0.7	

P= Provisional guideline value as there is evidence of a hazard, but the available information on health effects is limited.

T= Provisional guideline value because calculated guideline value is below the level that can be achieved through practical treatment methods, source protection etc.

C= Concentration of the substance at or below the health-based guideline value may affect the appearance taste or odor of the water, leading to consumer complaints.

A= Provisional guideline value because calculated guideline value is below the achievable quantification level.

D= Provisional value because disinfection is likely to result in the guideline value being exceeded.

TCU = True Colour Unit

NTU = Nephelometric Turbidity Unit

## **Annex 2: The Development of the Technical Guidelines**

The Technical Guidelines development process was completed in two stages: the preparation and the finalization.

### **A. The Preparation Stage**

The preparation stage began in April 2006 with the agreement to select eight WASH facilities. At the request of the GONU, 3 additional water supply facilities were added, making the total eleven. The preparation stage that included information collection and analysis was completed in December 2006.

#### **Collection of Information:**

Technical and managerial information related to the development of the 14 Technical Guidelines was collected from the following sources:

- PWC/WES, SWCs and GWWD
- UNICEF, WHO, World bank and NGOs
- National institutions like SSMO
- International institutions like IRC and WEDC
- Donors like DFID.
- Different countries' standards like BS, IS, DIN, etc.
- Field trips to 14 states in the northern and southern states of Sudan to visit the different existing facilities and to have live discussion with the sector professionals and community members.

#### **Analysis of collected information:**

The Steering Committee, which comprised senior staff from PWC, WES and UNICEF together with the consultant analysed the collected information, which led to the development of the outlines of the documents in a zero draft. The draft documents were shared with the Steering Committee at Khartoum level. The committee met to discuss the drafts, and provided comments, which were incorporated, resulting in the first draft. .

The first draft was widely circulated to PWC, UNICEF, various SWCs, INGOs and GoSS for information and feedback. All relevant feedback from the sector actors were incorporated into the documents and the second draft prepared and presented to the first national review workshop in December 2006. The relevant recommendations and comments of the national review workshop were incorporated into the documents resulting in a third draft. The first National Review Workshop recommended that this draft of the Technical Guidelines be shared with a wider range of stakeholders, including specific technical working groups.

### **B. The Finalization Stage**

The finalization of the 14 Technical Guidelines involved wider consultation with WASH sector partners through technical working group discussions, 3 regional review workshops, wider consultation and revision by GoSS and a national review workshop at the final stage.

**Technical Working Group Discussions:**

Professionals from various ministries participated in these technical working group discussions. MIWR, MOH, University of Khartoum, Sudan Academy of Science, private sector, NGOs, PWC/WES, UNICEF and Khartoum Water Corporation were also represented in these groups. This technical consultation process started in July 2007 and continued up to December 2007 resulting in the fourth draft of Technical Guidelines.

**Regional Review Workshops:**

Three Regional Review Workshops were conducted in Nyala, Wad Medani and Juba in November-December 2007 for GoSS and state level inputs into the documents. The Juba workshop recommended that the need for wider consultation within Southern Sudan to review the documents and to incorporate Southern Sudan specific contexts into the documents such as information relating to the location and different hydrogeological situations. These 3 workshops resulted in the fifth draft.

**Wider Consultation by GoSS:**

Based on the recommendation of the Juba Review Workshop, a wider consultation process was started in July 2008 and completed in October 2008. The process included state level consultation with sector actors, technical working group discussions and a final consultation workshop in Juba. The process was concluded by the finalization and the approval of the final draft documents which were reviewed at a final National Workshop.

**Final National Workshop:**

The final National Workshop was conducted in April 2009 in Khartoum under the guidance and the presence of H.E. Eng. Kamal Ali Mohamed, Minister of Irrigation and Water Resources of GONU, Eng. Isaac Liabwel, Undersecretary, Ministry of Water Resources and Irrigation of GoSS, Eng. Mohammed Hassan Mahmud Amar, DG of PWC and Eng. Adam Ibrahim, Minister of Physical Planning and Public Utilities of South Darfur State.

The workshop was attended by ninety two participants representing MIWR, MWRI, MOH, PWC, WES, GWWD, Engineering Council, SWCs, SMOH, University of Khartoum, UNICEF, WHO, IOM, ICRC, NGOs, USAID and private sector.

The National Workshop has reviewed the 14 WASH Technical Guidelines and approved them as national WASH Technical Guidelines.

The workshop recommendations included:

- Publication and wide distribution of the Guidelines;
- Translation of the Guidelines into Arabic and other major Sudanese languages;
- Organization of training and advocacy courses/workshops related to the Guidelines;
- Adoption of supportive policies, strategies, laws and regulations to ensure best utilization of the Guidelines;

- Development of a system of feedback to receive comments from implementing partners for inclusion in updates of the Guidelines. MIWR/PWC, MWRI and SWCs were selected as focal points for that purpose.

### Annex 3: People contacted

#### At Khartoum level

1. Mr Mohammed Hassan Mahmoud Amar, Director General, PWC
2. Mr Eisa Mohammed, National WES Coordinator, WES/PWC
3. Mr Mohammed Habib, National Project Coordinator, PWC
4. Mr Sampath Kumar, Chief WES Section, UNICEF
5. Mr Vishwas Joshi, PO, UNICEF
6. Mr Zaid Jurji, PO, UNICEF
7. Mr Stanely Hall, SPO, UNICEF
8. Mr Fouad Yassa, PO, UNICEF
9. Mrs Awatif Khalil, APO, UNICEF
10. Mr Samuel Riak, PO, UNICEF
11. Mr. Mohammed El Hassan Eldori, Director of Department of Groundwater, MOIWR
12. Mr Mohammed Ahmed Bukab, Mechanical Engineering Department, PWC
13. Mr Mohammed Salih Mahmoud, Mechanical Consultant, PWC
14. Mr. Yassir Ismael, WES/PWC
15. Mr Al Amin Ahmed Ibrahim, PWC
16. Mr Mohy El Deen Kabeer, Groundwater and Wadis, MOIWR

#### North Darfur, El Fashier

- |                              |          |                                  |
|------------------------------|----------|----------------------------------|
| 1. Osman Bukhari Ibrahim     | SMOH     | DG Environmental Health          |
| 2. Abdul Azim Ahmed          | SWC      | Mechanical Engineer              |
| 3. Abdella M. Adam           | WES      | Drilling Engineer                |
| 4. Mohammed Mohammedein      | WES      | Mechanical Engineer              |
| 5. Omer Abdurahman Adam      | GWWD     | Hydrogeologist                   |
| 6. Nour Eldin Adam           | WES      | Surveying Engineer               |
| 7. Abdella Adam Ibrahim      | WES      | Geologist                        |
| 8. Tayalla El Medomi         | UNICEF   | Water Engineer                   |
| 9. Mohammed Mohammedein Subi | SWC      | Acting DG & Manager of RWD       |
| 10. Salma Hassan             | WES      | Social Mobilizer                 |
| 11. Ahmed Abu Elgasim        | WES      | Acting GM                        |
| 12. Hassan Sheik Nur         | Oxfam GB | Public Health Engineering Coord. |
| 13. Jaka Magoma              | IRC      | Environmental Health Manager     |

#### North Kordofan, El Obeid

- |                         |         |                           |
|-------------------------|---------|---------------------------|
| 1. Hassan Adam Suleiman | ACU WES | Monitoring Officer        |
| 2. Ahmed El Abeid       | RWD     | Surface Water Section     |
| 3. Alehmin Ahmed        | WES     | Mechanical Engineer       |
| 4. Saeed Elmahdi        | WES     | Programme Manager         |
| 5. Asia Mahmoud Mohamed | ACU WES | W Coord. Kordofan Section |
| 6. Yassin Abbas         | PWC, NK | RWD Manager               |
| 7. Mahgoup Dahia        | WES, NK | Mini Water Yard Officer   |

8. Abeer Ali Elnour	WES, NK	Civil Engineer
9. Mutasim Hamad	WES, NK	Monitoring Officer
10. Makin Mohammed Toto	WES, NK	Drilling Engineer
11. Salah Mohammed	GWWD	Director General

#### South Kordofan

1. Adil Awad Farog	SWC	Geologist
2. Jakob Jebbrel	SWC	Engineer
3. Haidar Aariah Abdel Bari	SWC	Geologist
4. Mohammed Morgan Yhya	SWC	WES PA
5. Gamaa Aziz	UNICEF	APO
6. Fatima Toto	SWC	Urban Water Management
7. Sunaya Zroog	SWC	Urban Water Management
8. Mymona Taha	SWC	Urban Water Management
9. Adam Mohammed Ibrahim	SWC	Urban Water Management
10. Ali Gabaur Ahmad	SWC	Urban Water Management
11. Elzaki Eisa	WES	Drilling Engineer
12. Kamal Bashir	SC/USA	Watsan
13. Osman Elnour	SWC	DG
14. Dr Abdel Rahim Ahmed	UNICEF	APO
15. Hassaballa Hamad	SWC	Rural Water Management
16. Absaida	SWC	Mechanic
17. Awatif Elhag	WFP	Field Monitor
18. Al Amin Shawish	Sudan Aid	Coordination Officer

#### People Contacted in Southern Sudan, July 2008

1. Juma Chisto, Operator of Kator Emergency Water Supply, Juba
2. Habib Dolas, Member of Watsan committee, Hai Jebel
3. Andrew Wan Stephen, Member of Watsan committee, Hai Jebel
4. Francis Yokwe, Member of Watsan committee, Hai Jebel
5. William Ali Jakob, Member of Watsan committee, Hai Jebel
6. William Nadow Simon, Member of Watsan committee, Hai Jebel
7. Ali Sama, Director General, Rural Water Department, Central Equatoria State (CES)
8. Engineer Samuel Toban Longa, Deputy Area Manager, UWC, CES
9. Sabil Sabrino, Director General UWC, WBeG
10. James Morter, Technician, UWC, Wau
11. Carmen Garrigos, RPO, Unicef Wau
12. Sevit Veterino, Director General, RWC, WBeG
13. Stephen Alek, Director General, Ministry of Physical Infrastructure (MPI), Warap
14. John Marie, Director of Finance, MPI, Warap State
15. Angelo Okol, Deputy Director of O&M, Warap State
16. Santino Ohak Yomon, Director, RWSS, Upper Nile State
17. Abdulkadir Musse, RPO, Unicef Malakal

18. Dok Jok Dok, Governor, Upper Nile State
19. Yoanes Agawis, Acting Minister, MPI, Upper Nile State
20. Bruce Pagedud, Watsan Manager, Solidarites, Malakal
21. Garang William Woul, SRCS, Malakal
22. Peter Onak, WVI, Malakal
23. Gailda Kwenda, ACF, Malakal
24. Amardine Atsain, ACF, Malakal
25. Peter Mumo Gathwu, Care, Malakal
26. Engineer John Kangatini, MPI, Upper Nile State
27. Wilson Ajwek Ayik, MoH, Upper Nile State
28. James Deng Akurkuac, Department of RWSS, Upper Nile State
29. Oman Clement Anei, SIM
30. Abuk N. Manyok, Unicef, Malakal
31. Jakob A. Mathiong, Unicef, Malakal
32. Emmanuel Badang, UNMIS/RRR
33. Emmanuel Parmenas, DG of O&M, MCRD GOSS
34. Cosmos Andrug, APO, Unicef Juba

#### **Annex 4. Technical Working Group Members**

##### A) At Khartoum level

##### 1) For Slow Sand Filters

Dr Mohammed Adam Khadam, University of Khartoum  
Dr V. Haraprasad, UNICEF  
Mr. Ibrahim Adam, PWC  
Mr Eshetu Abate, UNICEF - Consultant

##### 2) For Borehole Hand pumps, Hand dug well Hand pumps, Hand dug well Water yards, Mini Water yards and Water yards

Mr. Mohamed Hassan Ibrahim, GWW  
Mr. Mohy Al Deen Mohamed Kabeer, GWW  
Mr. Abd el Raziq Mukhtar, Private Consultant  
Mr. Mohamed Salih Mahmoud, PWC  
Mr. Mohamed Ahmed Bukab, PWC  
Mr. Mudawi Ibrahim, PWC/WES  
Mr. Yasir Ismail, PWC/WES  
Mr Eshetu Abate, UNICEF - Consultant

##### 3) For Improved Small Dams

Dr. Mohamed Osman Akoud, University of Khartoum  
Professor Saif el Deen Hamad, MIWR  
Mr. Mohamed Salih Mohamed Abdulla, PWC  
Mr Eshetu Abate, UNICEF - Consultant

##### 4) For Improved Haffirs

Mr. Mohamed Hassan Al Tayeb, Private Consultant  
Mr. Hisham Al Amir Yousif, PWC  
Mr. Hamad Abdulla Zayed, PWC  
Mr Eshetu Abate, UNICEF - Consultant

##### 5) For Drinking Water Treatment Plants, Drinking Water Distribution Networks and Protected Springs & Roof Water Harvesting

Dr Mohamed Adam Khadam, University of Khartoum  
Mr. Burhan Ahmed Al Mustafa, Khartoum State Water Corporation (KSWC)  
Mr Eshetu Abate, UNICEF - Consultant

##### 6) For Household Latrines, School Latrines and Rural Health Institution Latrines

Mr. Sampath Kumar, UNICEF  
Mr. Fouad Yassa, UNICEF  
Dr. Isam Mohamed Abd Al Magid, Sudan Academy of Science  
Mr. Badr Al Deen Ahmed Ali, MOH  
Ms Awatif Khalil, UNICEF  
Mr Eshetu Abate, UNICEF - Consultant

B) At Juba level:

For all facilities:

Mr. Nyasigin Deng, MWRI-GOSS  
Ms. Maryam Said, UNICEF- Consultant  
Dr. Bimal Chapagain, UNICEF- Consultant  
Mr. Marto Makur, SSMO  
Ms. Jennifer Keji, SSMO  
Ms. Rose Lidonde, SNV  
Mr. Elicad Nyabeeya, UNICEF  
Mr. Isaac Liabwel, MWRI  
Mr. Moris Monson, SC UK  
Mr. Peter Mahal, MWRI  
Mr. Alier Oka, MWRI  
Mr. Emmanuel Ladu, MWRI  
Mr. Menguistu T. Mariam, PACT  
Mr. Manhiem Bol, MWRI-GOSS  
Mr. Eshetu Abate, UNICEF- Consultant  
Ms. Rose Tawil, UNICEF  
Mr. Mike Wood, EUROPIAN CONSULT  
Mr. Sahr Kemoh, UNICEF  
Mr. John Pangech, MCRD  
Mr. Joseph Brok, MAF  
Mr. Gaitano Victor, MAF  
Dr. Lasu Joja, MOH-GOSS  
Mr. Kees Van Bommel, MEDAIR  
Mr. Lawrence Muludyang, MHLPU  
Ms. Anatonía Wani, MARF  
Mr. Acuth Makuae, MCRD-GOSS  
Mr. Martin Andrew, RWD/CES  
Mr. Feliciano Logira, RWD/CES  
Mr. Philip Ayliel, MHLPU  
Mr. James Adam, MWRI

## **Annex 5: Selected bibliography and references**

1. Project profiles for Rural and Urban Water Supply, Ministry of Irrigation & Water Resources, National Water Corporation, September 2005.
2. Linking Technology Choice with Operation and Maintenance for low-cost Water Supply and Sanitation, Operation & Maintenance Group, Water Supply and Sanitation Collaborative Council, World Health Organization, IRC International Water and Sanitation Centre
3. Low-cost rural water supply and sanitation, a design manual for the government of Baluchistan, Pakistan - UNICEF
4. Engineering in Emergencies
5. Contract document for Borehole Drilling, National Water Corporation, March 2003
6. Balaji Industrial and Agricultural Castings, Technical Data on Direct Action Pump
7. WHO guideline for Drinking Water, 2004
8. Sudanese Drinking Water Standard, Sudanese Standard and Measurement Organization, 2002
9. Water supply design criteria and equipment standardization, National Water Corporation, November 1998
10. Technical guideline series: Towards better programming, A Water Handbook, UNICEF, 1999.
11. Technical Design Manual, Ethiopian Social Rehabilitation and Development Fund (ESRDF), April 1997
12. Sphere Minimum Standards
13. Technical Specification for Drilling Shallow Water Wells, UNICEF
14. Procurement of pipes, fittings and accessories for Harar Town Water Supply Project, Ministry of Water Resources, Ethiopia, April 2000

## Contact Addresses for Feedback by WASH Sector Partners

### **Mr Mohammed Hassan Mahmud Amar**

Director General  
Public Water Corporation  
Ministry of Irrigation and Water Resources  
El Sahafa South-Land Port West  
P.O. Box 381, Khartoum  
Tel: +249 (0)83 417 699  
Fax: +249 (0)83 416 799  
Email: [nwcarm@sudanmail.net](mailto:nwcarm@sudanmail.net)

### **Eng. Isaac Liabwel**

Under Secretary  
Ministry of Water Resources and Irrigation (MWRI)  
Government of Southern Sudan (GOSS)  
Hai el Cinema, Juba  
Phone: Office: +249 811 823557  
Cellular: +249 912 328686  
E-mail: [Isaac.liabwel@gmail.com](mailto:Isaac.liabwel@gmail.com)

### **Mr Sampath Kumar**

Chief, WASH Section  
Water and Environmental Sanitation (WASH) Section  
UNICEF Sudan Country Office  
House 74, Street 47, Khartoum 2  
P.O.Box 1358 – Khartoum - Sudan  
Tel.: +249 1 83471835/37 ext 350  
Fax: +249 1 834 73461  
Mobile: +249 912390648  
Email: [skumar@unicef.org](mailto:skumar@unicef.org)

### **Dr Stephen Maxwell Donkor**

Chief, WASH Section  
Water and Environmental Sanitation (WASH) Section  
UNICEF SCO, Juba  
Southern Sudan  
Tel. : +249 126 537693  
Email: [smdonkor@unicef.org](mailto:smdonkor@unicef.org)