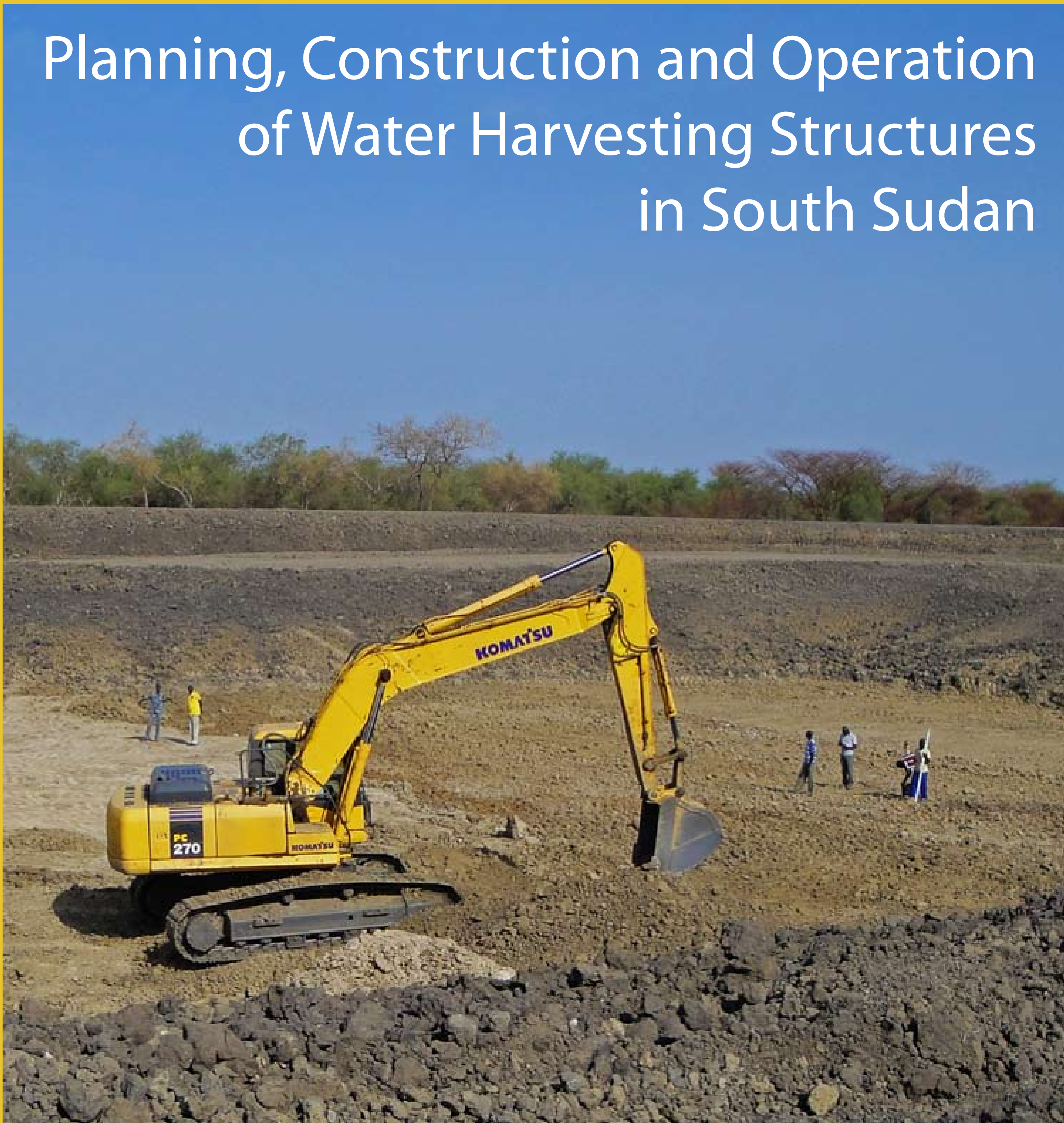
Ministry of Electricity, Dams, Irrigation and Water Resources

Planning, Construction and Operation of Water Harvesting Structures in South Sudan



TECHNICAL GUIDELINES

Food and Agriculture Organization of the United Nations

UNEP

PBSO
United Nations Peacebuilding Support Office

Cover Image: © FAO

Design and layout: Matija Potocnik, UNEP / PCDMB

Table of contents

Acknowledgements

These guidelines were prepared with technical support of the Food and Agriculture Organization of the United Nations (FAO).

The financial support for development of the guidelines was provided by South Sudan Peacebuilding Fund under the project entitled "Assessment of water harvesting structures for sustainable livelihoods and peacebuilding in South Sudan"

The guidelines have been prepared by Eshetu Abate Legesse, FAO SS Consultant and it was enriched by 32 trainees from 16 State Ministries responsible for rural water provision and livestock, and four National Ministries responsible for water, environment, gender and livestock (MEDIWR, MoE, MGCSW, and MoLFI of the Republic of South Sudan).

Acronyms

EES . . . . Eastern Equatoria State

FAO . . . . Food and Agriculture Organization of the United Nations

FGDs . . . . Focus Group Discussions

KII . . . . Key Informant Interviews

MEDIWR . . . . Ministry of Electricity, Dams, Irrigation and Water Resources

MGCSW . . . . Ministry of Gender, Child and Social Welfare

MoE . . . . Ministry of Environment

MoLFI . . . . Ministry of Livestock and Fisheries

PBF . . . . Peace Building Fund

RSS . . . . Republic of South Sudan

UNEP. . . . . United Nations Environment Programme

WES . . . . Western Equatoria State

WH . . . . Water Harvesting

Definition of terms

Boma . . . . The lowest administrative unit in South Sudan after payam.

Haffir . . . . Arabic word for a pond.

Payam . . . . An administrative unit in South Sudan below county administration and equivalent to district administration.

Rock catchment . . . . A structure that uses a large barren rock surface to collect rainwater like a roof water catchment structure. The collected rainwater is stored in a separate reservoir.

Sieve analysis . . . . . . Sieve analysis is the procedure used to assess the particle size distribution of a granular material. The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rock, clays or granite. The results will be put in a table with determined percentages of grain sizes of each particle.

Water barrier/pan . . . An impounding structure formed by a micro/small earth dam.

Water harvesting[1] . . . Water harvesting encompasses all activities where water is collected, stored and utilized in either the blue or green form. It includes harvesting rainfall directly, as well as floodwater harvesting. It is achieved in many ways, and the water can be stored in tanks, ponds, and dams or channeled into the soil profile. Therefore, water harvesting is a general term that encompasses rainwater harvesting and/or floodwater harvesting.

1 "*Best Practices for Rainwater Harvesting from Open Surfaces with Storage in Structures*", Bancy M. Mati, 2012: Training Manual 2. NBI/NELSAP - Regional Agricultural and Trade Programme (RATP), Bujumbura, Burundi.

1 Introduction

While the drivers of conflict in South Sudan are numerous, conflict over natural resources, particularly competition over access to traditional grazing lands and water rights, remains a fundamental challenge to peace and stability in the country. Various approaches and strategies are required to manage and resolve conflicts depending on the sources of the conflict. However, there is a general understanding between the Government, conflict-affected communities and development partners that resource-based conflicts can be mitigated or addressed through a combination of development and conflict transformation interventions. To this effect the Government of South Sudan and the international community have been investing in livestock water provision, including *haffirs*[2], over the last several years as a means to mitigate the conflicts arising from dry season water demand. Developing water facilities for livestock is an expensive intervention. Such investments should be accompanied by activities that aid in understanding the dynamics of pastoralists in conflict-prone areas for better planning, design, organization and management of water facilities. It is equally important to understand the effectiveness of *haffirs* in reducing conflicts between communities as well as other socio-economic and environmental impacts.

To better understand the effectiveness of water harvesting (WH) interventions in livelihoods improvement and conflict reduction and to contribute to policy discourse on WH in South Sudan, the Food and Agriculture Organization of the United Nations (FAO), in collaboration with the United Nations Environment Programme (UNEP), has embarked on a joint project entitled "Assessment of water harvesting structures for sustainable livelihoods and peacebuilding in South Sudan", financed by the United Nations Peacebuilding Fund (PBF) for South Sudan.

Based on the assessment findings[3], lessons learned and best practices, FAO and UNEP developed guidelines for livestock WH in South Sudan to maximize impacts on conflict reduction and peacebuilding. The guidelines addressed: technical issues (feasibility study, implementation, and operation and maintenance), natural resource management, environmental and social impact assessment and gender mainstreaming in livestock WH structures. The guidelines are intended to contribute to capacity building in the planning and implementation of WH interventions by the Government and other stakeholders through training and knowledge sharing.

After the assessment, four separate guidelines (technical, gender mainstreaming, natural resources management, and environmental and social impact assessment) have been prepared. This set of guidelines only covers technical aspects, but should be used in full conjunction with the other three sets of guidelines.

2 Haffir is an Arabic word for a pond.
3 Refer to Section 3 for details on the assessment.

2 Major findings of technical issues related to water harvesting structures

The technical[4] aspect of the assessment revealed that there are different sources for dry season livestock watering – both natural and manmade. Manmade WH facilities, however, have different technical issues that affect their functionality and sustainability. The major findings are listed below:

- Dry season livestock watering in South Sudan is carried out through both natural and man-made means. The natural sources are perennial rivers/streams, swamps (locally known as *toic*) and ponds. Man-made sources are community ponds, roadside dugout pits, rock catchments, water barrier and *haffirs*. The natural sources currently provide more water than the man-made facilities, which are technically limited in terms of functionality and sustainability.

- Of the man-made WH structures that have been implemented, some, like the *haffirs* in Jonglei, were preceded by feasibility studies whereas others, like the *haffirs* in Lakes State, were carried out without feasibility studies.

- Those *haffirs* without feasibility studies were found to have fundamental design problems related to sizing, location and lack of components.

- There is a lack of harmonization among the stakeholders with regard to the designs of *haffirs,* particularly the type, size, number of components and minimum standards.

- The current standard designs for 30 000 m^3 and 40 000 m^3 capacity *haffirs* need revision as these facilities are experiencing problems relating to water abstraction, siltation basin, number of cattle troughs as well as type and size of power supply.

- There is a need for more technical expertise in operating *haffirs* by management committees/operators.

These major findings suggest that WH structures are hampered by technical issues relating to sustainability.

Stakeholders such as funding development partners, Government ministries and non-governmental organizations (NGOs) have assisted pastoral communities by implementing *haffirs* as a means of peacebuilding. However, they must ask themselves "why only *haffirs* and why not other types of WH structures?" Construction of *haffirs* is expensive and requires a well-equipped (with different types of earth moving machineries) and experienced contractor.

As such, FAO and UNEP initiated the creation of these technical guidelines for future WH structures.

4 The technical aspect of the assessment was one of the four aspects of the assessment. The four aspects were, gender, natural resources management, environmental and socio-economic impact and technical aspects. These four aspects of the assessment have been prepared in one consolidated report. There are also four separate reports for each aspect of the assessment.

3 Purpose of the technical guidelines

These technical guidelines (along with those on gender mainstreaming, natural resources management and environmental and social impact) are meant to inform the different implementation phases of WH facilities.

These guidelines were developed after conducting a detailed assessment of selected WH structures in Lakes, Eastern Equatoria State (EES) and Western Equatoria State (WES) by a team of water engineers, natural resource management personnel as well as gender and environmental and social impact specialists.

The assessment was divided into two phases. The first phase was the WH inventory/mapping exercise that was carried out in the three states of South Sudan in March 2014. The second phase was conducted in the same three states on sample WH sites but with detailed aspects that included technical, environmental, gender and natural resources management issues in April and May 2014. The number of samples in each state was determined based on the accessibility of each WH site i.e. the distance and security situation within the given timeframe and the arrival of the rainy season. The selection of each WH site was carried out after consultation with state/county authorities and approval by UN security system. Fifty percent of existing WH structures were assessed in detail in Lakes and EES. Three fish ponds that were developed for asset building were also assessed in WES.

The assessment also looked into the technical issues relating to functionality and sustainability of the structures. As such, it was necessary to explore what happened at different phases, including planning and design, construction and implementation, and operation and maintenance.

The team reviewed literature and secondary data from various documents related to WH facilities in and outside of South Sudan. Additionally, the team made use of key informant interviews (KIIs), focus group discussions (FGDs) with communities and discussions with technical staff of Ministry of Electricity, Dams, Irrigation and Water Resources (MEDIWR), Ministry of Environment (MoE) at the national and state levels and on-site observations conducted during field missions.

These technical guidelines are for those who have a technical background and are directly or indirectly engaged in the provision of WH structures for livestock watering. Technical parameters required for detailed engineering calculations are not included here. Other specialized literatures should be referred to when required. This set of guidelines has, therefore, been prepared and structured in such a way that it addresses the processes of stakeholder identification and project implementation based on the findings of the technical assessment and experience from other countries.

4 Phases to implement a water harvesting project

An overview of the process of WH project implementation is provided in Figure 1.

4.1 Stakeholders identification and consultation (Phase 0)

Before initiating a WH Project, the first step is to identify all of the possible stakeholders and come to an agreement on the various roles and responsibilities. This will help in sharing the roles and responsibilities at different stages of project implementation and ensure grassroots level ownership from the beginning of a project.

Identification of stakeholders may take some time, i.e. until all stakeholders agree on their roles and responsibilities. Adequate funding should be allotted for this process as it is well worth the investment and should follow a participatory approach.

4.2 Project implementation phases

After the identification of stakeholders and agreement on roles and responsibilities, the next step is project implementation, which is divided into phases. The first phase is planning, which is followed by the construction phase. Operation and maintenance is the last phase of implementation; it is during this phase that users are expected to fully control their WH structures with little or no support from other stakeholders.

4.2.1 Planning (Phase 1)

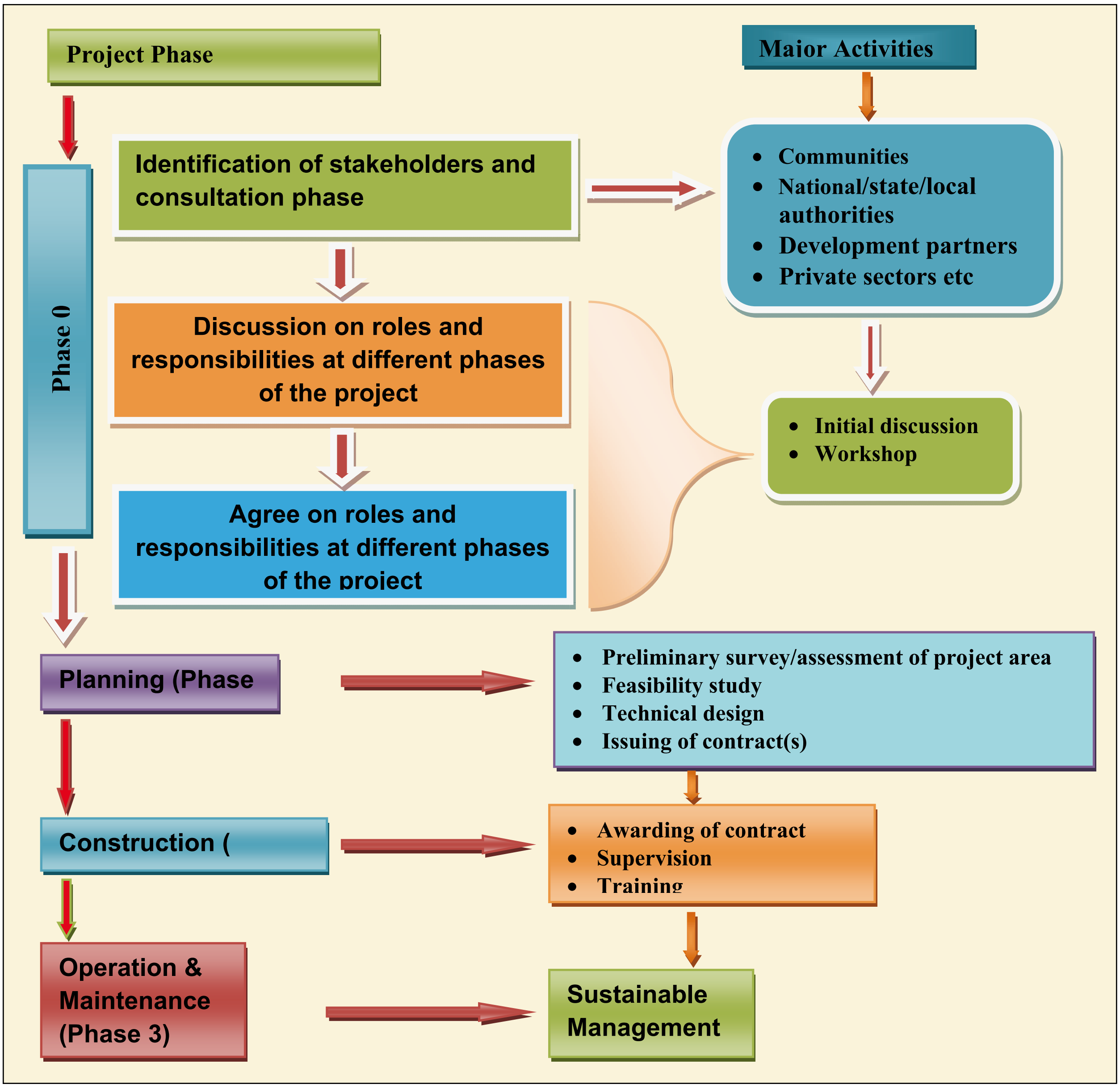
Better planning is a universal factor for success. This is also true for the implementation of WH structures. The planning phase must have, at the very least, the following major activities:

- **preliminary survey/assessment of project area**
- **feasibility study**
- **technical design**
- **issuing of contract(s)**

Preliminary assessment/survey of project area: This activity is the first step of conducting the feasibility study. It allows the stakeholders to: have a first impression on data collection; have first-hand contact with beneficiary communities; ensure the participation of other lower-level stakeholders; and determine the logistical arrangements for the feasibility study. Additionally, it will help to identify different potential types of WH facilities in the area.

Preliminary investigation must plan discussions at different levels (national, state, county, payam and boma) with the concerned authorities and community representatives in order to identify the site where the WH structure will be constructed. At this stage all stakeholders must agree on the purpose of the WH structure (single or multipurpose). With multipurpose WH structures, the amount of water required must be indicated.

Figure 1.   Process of WH project implementation



Feasibility study: In terms of technical issues, the following sub-activities will be carried out under the feasibility study once the site has been identified:

- topographical survey[5] of the site and the catchment area with clear delineation of the catchment area;
- soil investigation of the site;
- collection of meteorological and hydrological data that include rainfall, temperature, evapotranspiration, etc.;
- determining of the number of users (livestock/human population);
- determining the type of use (livestock or domestic) and quantity required;
- carrying out environmental and social impact assessments including mitigation measures;
- establishment of management committee; and
- identification of training needs for the management committee and operators.

5 Box 2 for example guides the use of topographic survey for a *haffir* site.

Box 1. Technical issues to be considered during feasibility study

- What type of WH structure can be considered? Community ponds, haffirs, rock catchments, small distribution systems/water yards or water barriers/pans. Refer to Table 1 of Annex I for possible choices.
- If a haffir is considered, the topographic survey needs to cover a minimum of 2 km2 for the catchment area.
- There must be a minimum of three locations for soil investigation.
- Establishment of management committee must take gender guidelines into consideration for all types of WH structures.
- Assess the technical capacity gaps for different stakeholders and address them.

Box 2. Topographic survey

Surveying is used to characterize the topography of some area of interest, such as a hill slope, reach of stream, flat areas, landslide scar, etc. The purpose of the detailed topographic survey at each location is to: come up with topographic maps showing the network of drainage channels feeding the haffir; establish benchmarks for setting out of works during construction; and determine the orientation of haffir with respect to terrain slope and seasonal streams (if any).

Technical Design: This is the activity in which the type, size, location and number of components of the WH structure are decided. Technical design is always site specific and it is better to come up with more than one option.

- The design should be detailed and include the construction, supervision and capacity building/training costs.
- The technology proposed in the design should be appropriate and easy for community management. The design should consider the pastoral/agro-pastoral livelihoods and local capacity.
- If the WH is an impounding structure and supported by a pumping system, the selection of an appropriate abstraction method is very important as the quality of water is turbid. The type of pump for abstraction should be compliant with turbid water whether it is a submersible or surface pump.
- The proposed designs need to be discussed/evaluated in a forum/workshop before approval.
- The responsible stakeholder for the costs must secure/allocate the necessary funds in time before proceeding to the next implementation phase.

In the absence of recorded data for the site, such as rainfall, the implementing agency can use, FAO's New LocClim software (a tool for spatial interpolation of regional agroclimatic data taken from the agroclimatic database of the FAO Agromet Group) to estimate relevant climatic parameters, including elevation, of the site using years of spot measurements from ten other surrounding regional climate stations.

The ongoing degradation of grazing lands in the Sahel region has led to increasing concern about the need to maintain the right balance between the available water supplies, vegetation for browsing and grazing and the intensity of use by livestock. To ensure that this concern is addressed, it is necessary to think of strategic water placement for WH sites.

Box 3. Technical elements (general design criteria) to be considered during technical design

- size of catchment area and estimated amount of water to be harvested;
- size and number of feeding channels;
- measures to minimize effects of evaporation;
- how the spillway is connected to the natural drainage system;
- siltation, seepage/infiltration control;
- no. of cattle troughs for both small and large stocks;
- protection measures against potential pollution/contamination;
- water treatment method for human consumption;
- source(s) of power supply;
- avoid inclined intake pumping systems;
- sources of construction materials as some of them may not be found in the project area;
- tender documents with material specification in the contract documents; and
- estimated engineering cost.

Strategic water placement in pastures impacts grazing distribution, particularly if cattle have to travel long distances to water. It is important that the proposed WH design takes this into consideration to ensure an even distribution of watering points and avoid herd concentration in one location and degradation of the site. This will also help to ensure good quality of water and adequate access to water.

Experience has shown that oversizing a *haffir* (instead of constructing an additional *haffir* in another strategic location) can attract people and livestock from other areas, leading to overuse and increased over-grazing by livestock and is likely to trigger conflicts.

Under-sizing a *haffir*, on the other hand, would result in emptying the *haffir* in a short period of time, which will create mistrust between the users and implementing agency, as the facility would not provide water for the entire year. It is, therefore, important to critically consider the above factors before deciding on the size of a *haffir*.

Whenever possible, it is always better to increase the depth of *haffir* than to increase the surface area. The smaller the surface area is, the lower the evaporation rate.

The slope of the embankments around *haffirs* should be 3:1 for clayey soil.

The *haffir* should have a retention pool or basin at the upstream location. This will serve at least two purposes: 1) to trap sediment particles before they reach the proper *haffir*, thereby reducing the turbidity of the water; and 2) to hold water in addition to the amount contained in the proper reservoir, enabling an increase in the overall volume of water.

4.2.2 Construction (Phase 2)

The design on the WH structure, which has been prepared during phase 1 with the consideration of the general design criteria as indicated in Box 3, will be executed on the ground under this phase of construction. A major portion of the budget is also allocated for this phase. In this regard, proper supervision mechanisms should be established before mobilization of the contractor and should be ready on site before work starts.

Box 4. Soil investigations

Hydrogeological investigations at the project sites and possible borrow areas need to be carried out to determine the suitability of the soil for foundation and abutments. The exercise is dependent upon the identification, availability and characteristics of embankment materials. This information governs the selection of a specific site and type of the structure. A minimum of three pits must be dug at each site to assess the suitability of the soil materials for haffir construction. Laboratory tests will be carried out on the collected soil samples from the trial pits for the following parameters: Atterberg Limits, permeability, optimum moisture content, maximum dry density, gradation tests.

Box 5. Considerations for when a haffir is the selected option of water harvesting

- catchment area to capture the rainfall with collection or feeding channels to collect and convey the runoff to sedimentation basin;
- sedimentation basin to hold the runoff for a specific time and allow sediment particles to settle before entering the reservoir;
- inlet structure to allow the water from sedimentation basin into the reservoir;
- reservoir to hold the entire quantity of water for dry season use;
- intake for the pumping system;
- delivery or distribution pipeline systems to the cattle troughs;
- cattle troughs for both small and large stocks;
- overflow to convey and direct excess water to downstream location;
- embankment;
- perimeter fence to protect the reservoir by blocking free access by people and livestock; and
- additional elevated reservoir where direct pumping supply to the troughs is not enough (optional). Where the human population shares the same water, the design needs to indicate components (like hand pumps or water points) for this purpose. The quality of water for human consumption should satisfy WHO's or SS Water Quality guidelines.

Box 6. Technical issues to be considered during construction phase

- The contractor should properly set out the plan on the ground according to the design.
- The supervision team must have clear terms of reference.
- Team members who participated in the feasibility study or have previously been engaged in similar assignments are to be assigned for supervision.
- The training activities should not be overlooked and adequate budgeting should be allocated.

Awarding the contract: Implementers should critically assess the capacity of contractors before awarding the contract, in spite of there being a limited number of experienced contractors in South Sudan. The assessment should be based on the required capacity (human resource, machinery, finances, past experiences, etc.) that is clearly indicated in the bid document.

Supervision: Poor supervision often leads to poor quality of work. The following pictures demonstrate the effects of poor supervision.

Figure 2. Wrongly set intake box (top); Poorly welded cattle trough (middle); Poorly fixed solar panels (bottom

Training: Different types of training are required at different levels as identified during the feasibility study. Trainings should be intensified at this phase. The management committee and operator(s) should be provided all necessary trainings at this phase.

Cattle often seek to cool themselves by standing in water, especially during the hottest part of the day. The resulting hoof action, urination and defecation lower the quality of water. To minimize these water quality-related problems, it is necessary that the WH structure site be fenced to restrict direct access to water supplies.

4.2.3 Operation and Maintenance (Phase 3)

It is under this phase that the WH facility begins to be managed in a sustainable manner. The following aspects must be ensured:

- **presence and functionality of management committee;**
- **establishment of user fee;**
- **availability of fuel or spare parts; and**
- **repair and maintenance works.**

The presence and functionality of management committee: The presence of a trained and functional management committee is the first step towards establishing a sustainable WH facility. However, the management committee should have clear roles and responsibilities and should receive proper training.

Establishment of water user fee: In South Sudan there is a misunderstanding and a lack of clarity among many politicians that water is free and no citizen should pay for it. The Government does not, however, support and entertain such a position. Instead, it encourages and promotes users to pay for the services they are provided, including water use operations.

If the the manner in which users are contributing towards operational costs is not clearly understood and agreed upon by the community, the WH facility will not be sustainable. The user fee amount should be agreed upon by the community and management committee and the initial charges should be small enough to encourage compliance. Fees can be gradually increased once the community consolidates a sense of ownership. Such fees can be used for the purchase of fuel for generators, maintenance of *haffirs* and necessary accessories.

Availability of fuel or spare parts: This is the determining factor for longevity of the WH facility. Care should be taken during the design stage to select appropriate technology options. If the manner in which the management committee accesses fuel or spare parts is not clear from the beginning, it is likely that the facility will fail after a short period of operation. It is, therefore, very important to establish clear mechanisms for the management committee to access fuel or spare parts for the WH facility in an affordable way.

Repair and maintenance works: When machinery is required for repair and maintenance work, it is unlikely that the community can afford the costs. The government at national, state and local levels should allocate funds for this purpose. If there is no commitment by the government(s) in this regard, the WH facility will not serve the community for long. The roles and responsibilities of stakeholders should, therefore, be clear regarding their commitments as agreed upon at the initiation of the project. It is worthwhile to note that investment costs of WH structures in South Sudan are generally high. It is because of the remoteness of WH sites, absence of good roads and an element of risk. Contractors charge more to work in conflict-prone areas. Furthermore, the cost of constructing WH structures depends on the type. For example, community ponds cost in the range of USD 5-7/m^3, *haffirs* cost USD 17-22.5/m^3, water barriers cost USD 17-22 /m^3, and rock catchments cost USD 7-12 /m^3. The local government and users must allocate approximately 0.25 percent of the construction cost annually for repair and maintenance works.

Additionally, controlled watering and grazing practices are highly recommended for the management of WH facilities. Water management committees should be established and engaged right from the beginning of construction work with clear terms of reference. These should clearly emphasize water regulation, group watering schedule, on-site grazing and access-related dispute management strategies. In order to ensure equal access and participation, the Natural Resources Management Committee should be comprised of members from the controlling neighborhoods/villages and local authorities (including the chiefs and active and influential youth) while taking gender aspects into considerations.

Box 7. Issues to consider for Operation and Maintenance Phase

A regular maintenance schedule and budget allocation for the maintenance is very important. A delay in maintenance of the WH facility will lead to greater costs or to complete failure of WH facilities.

Annex 1 – Comparison of different types of WH structures

No.	Type of WH structures	Appropriateness for livestock watering	Advantages	Disadvantage	Cost Effectiveness
1	Community ponds	Appropriate where there are a small number of livestock as such ponds are small.	· Can be constructed and managed by communities. · Community participation can be easily promoted. · Can be replicated in other communities.	· Can become silted unless constructed with soil and water conservation activities in their catchments. · Can be sources of Guinea worm if not fenced.	· Can be done with less capital investments (low per m^3 cost: in the range of 5-7 USD/m^3) · Community contribution can be significant.
2	Haffirs	If managed properly they are appropriate where there are ground and surface water limitations.	· Can serve many heads of livestock for longer periods.	· Require machineries for construction. · Community participation is limited during construction. · Can be affected by siltation if they are not designed properly. · Require proper community management training. · Abstraction of water requires the use of different sources of energy.	· Require significant capital investment for construction (USD 17-22.5/m^3).
3	Rock catchments	Appropriate where there are barren rocks for catchment and other water sources are limited.	· Siltation problem is limited. · Quality of water is relatively good. · Water can be delivered by gravity.	· Cannot be replicated everywhere. · Require proper community management training. · Capacity/volume is limited (depends on surface areas of barren rocks).	· Per capita cost is low to medium depending on the length of the gravity conveyance component.
4	Water barriers/ pans	Appropriate where impounding is required and topography and geology of the terrain is suitable.	· Can serve many heads of livestock for longer period.	· Require machineries for their construction. · Can be sources of Guinea worm if not fenced. · Community participation is limited during construction. · Can be affected by siltation if not designed properly. · Require proper community management training. · Abstraction of water may require the use of different sources of energy.	· Require significant capital investment for construction (USD 17-22/m^3).
5	Roadside dugout pits	Appropriate where water sources are limited	· Can serve as additional sources of water for pastoral/agropastoral communities.	· Locations depend on the availability of selected materials for road construction. · Cannot be constructed where the need is greatest. · Can be sources of Guinea worm if not fenced.	· Do not require any capital investment to the community.
6	Sub-surface dams or sand dams	Appropriate where there are seasonal rivers that have beds with thick sand layer and banks that have a hard and impermeable formation.	· Quality of water is relatively better than haffirs or water barriers. · Evaporation effect is minimal. · Can accumulate large amount of water depending on location.	Require machineries or expertise for construction. · Community participation is limited. · Cannot be replicated everywhere.	· Per capita cost can vary from medium to high depending on location, length and depth of the dam.

Annex 2 – A table for calculation of water requirement that determines the volume of WH structures

Livestock Class	Cattle		Goat		Sheep		Total
	Female	Male	Female	Male	Female	Male	
Livestock number							
Daily water requirement (litres/day)							
Total water requirement per dry season (about 5-6 months)							

Note: If other uses are incorporated, then increase the total volume accordingly.

Importance of water in livestock production

Livestock water requirement is the total quantity of water required by animals for their metabolic processes as well as body heat regulation. Water constitutes about 50 to 80 percent of an animal's live weight and is, therefore, essential for life. An animal may lose almost all of its fat and 50 percent of its body protein without serious consequence. However, a 10 percent loss of its body water can be fatal. Therefore, any factor that limits water intake will reduce animal performance more than any nutrient deficiency. Adequate and quality supply of water is, therefore, vital for animals' feed intake and production.

Factors influencing livestock water requirements

There are a number factors or combination of factor that influence livestock water consumption. These include: (i) kind and size of animal; (ii) physiological status of animal; (iii) level of animal activity; (iv) type of diet and dry matter intake; (v) water quality; (vi) air temperature; (vii) water temperature (10 °C desirable, 4-18 °C acceptable); and (ix) water trough space.

The minimum requirement of water intake is reflected in the amount needed for body growth, foetal growth or lactation and the amount lost by in urine, faeces and perspiration. Anything that influences these needs will influence the minimum requirement. In principle, the entire amount of water required does not need to be provided as drinking water. There are some feeds that are high in moisture such as green chop, silage or pasture and, hence, will provide part of the water requirement, while other feeds such as grain and hay offer very little moisture.

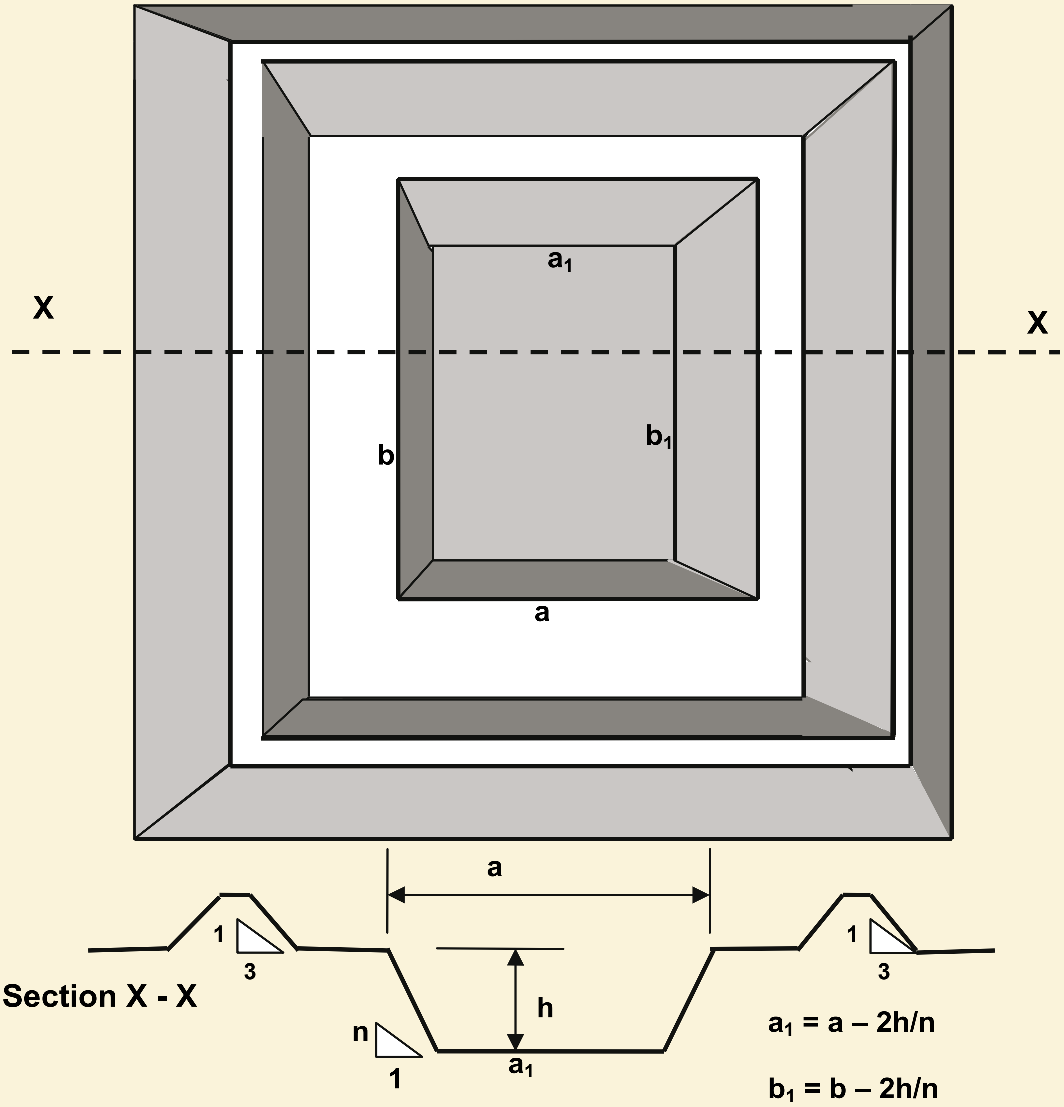
Daily livestock water requirement

Animal category	Litres /day/animal
Cow with calf*	45.4
Dry cow/mature cow*	37.9
Bull	45.4
Ewe/doe	9.5
Milking ewe/doe	13.2
Feeder lamb/kid	7.6

Sources: Farm Water Supply Requirements, Alberta Agriculture, Food and Rural Development; The Stockman's Guide to Range Livestock Watering From Surface Water Sources, Prairie Agricultural Machinery Institute.

Note: * For peak water use on days above 25 °C multiply litres per day figure by 1.5.

Annex 3 – Equation for calculation of any one dimension of a *haffir*



Equation for determination of dimensions of a rectangular haffir for a given volume

$$V = (A + A_1) \times (½) \times (h) = ((a \times b) + (a_1 \times b_1)) \times (½) \times (h)$$

$$= (abh) – (a+b) \times (h^2/n) + (2h^3/n^2)$$

Where, V is volume of a haffir, A is area of haffir at the top, A_1 is area of haffir at the bottom, h is depth of reservoir of a haffir, a is top width of a haffir, a_1 is width of a haffir at depth of h, b is top length of a haffir, b_1 is a length at depth h, n is vertical height of the slope of the sides of a haffir for horizontal distance of 1 unit.

Annex 4 – *Haffir* technical specifications

Every *haffir* should have the following components: catchment area, feeding channels, silt trap/sedimentation basin, spillway, inlet boxes, inlet pipes, reservoir, embankment, pumping system, power generating system, elevated tank (optional), troughs, water point (optional) and perimeter fence.

Catchment area: an area located at the upstream part of a *haffir* to collect the rainfall. The size of the catchment area depends on the amount of water (volume) required by the users, evapotranspiration rate, infiltration rate, other anticipated losses and possible amount of runoff.

Feeding channels: convey surface runoff from the catchment area to the silt trap or sedimentation basin.

Silt trap or sedimentation basin: retains the runoff for some hours before it flows into the reservoir. The size of the basin depends on the characteristics of the catchment area, such as the degree of vegetation coverage and slope of the catchment area. Barren or sloppy catchment requires a relatively large sedimentation basin

Spillway: diverts the extra amount of runoff to the nearby natural stream when the water in the *haffir* reservoir reaches its highest level.

Inlet boxes: are positioned between the sedimentation basin and the reservoir.

Inlet boxes

Inlet pipe(s): convey the runoff from the sedimentation basin to the *haffir* reservoir. It is best to install at least two inlet pipes. Minimum size of pipes should be 300 mm and maximum size should be 1 000 mm depending on the characteristics of sediment and suspended materials. Riprap or erosion protection should be placed at the outlet parts of the pipes, both at the bottom and side of the reservoir.

Reservoirs: store the entire amount of runoff for the intended duration until the end of the dry season. Its volume depends on the amount of water required by users, evapotranspiration rate, infiltration rate and other anticipated losses. However, reservoirs with smaller surface areas and deeper depths are preferred over broader surface areas and shallow depths owing to a high evapotranspiration rate in South Sudan. It is always better to increase the depth of *haffir* than to increase the surface area. The lesser the surface area is, the lesser the evaporation rate.

Embankments: are constructed, to the extent possible, from clayey excavated material around the reservoir. It is better to grass it with an endemic variety of grasses that can be managed by the users. The slope of the embankments around *haffirs* should be 3:1 for clayey soil.

Pumping systems: should be able to be managed by the local people; affordable in terms of operational costs; and required spare parts that are readily available. Selection of a pumping system with low operational costs to users is always preferable. Its capacity is determined based on the amount of water required by users during a specified time of the day and is dependent on the number of troughs and/or availability and size of overhead tank.

Power-generating systems: must produce sufficient power to run the pumping system; have affordable operational costs: and require spare parts that are readily available. Selection of a power generating system with low operational costs to the users is always preferable. If solar panels are used to generate power, they should be protected from vandalism.

Elevated tanks (optional): are to be considered for situations in which (1) water is used for both livestock and the human consumption; and (2) the human population is not served by hand pumps. When an alternative water supply for human consumption is available, such as from a borehole, this elevated tank may not be necessary. Material for the elevated tank should be durable and reasonably affordable.

Troughs: should be considered for both small and large types of livestock. Their numbers in each location depends on the population and duration of watering in a day. It is always good to have a more troughs than fewer troughs. Avoid subsurface troughs. The minimum width for rectangular troughs should be 750 to 1 000 mm. The depth can be 500 to 7 500 mm. Consider a separation wall for rectangular troughs that serves big stocks to hinder fighting between animals facing one another. Materials for construction can be metal, masonry or concrete - whichever is easily and cheaply available.

Elevated tanks


Troughs


Water points


Perimeter fences

Water points (optional): are necessary where drilling of a borehole is not possible or other alternative sources for human consumption are not available. Make sure that the quality of water at the point of consumption complies with WHO or South Sudan Drinking Water Quality Guidelines. It is, therefore, necessary to select appropriate treatment systems as the quality of *haffir* water is below acceptable standards and the turbidity is well above the allowed parameters.

Perimeter fences: are necessary parts of *haffir* construction because they prevent both pollution and the incidence of Guinea worm by hindering direct access to the water.

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