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BUILDING RESILIENCE IN THE FACE OF CLIMATE CHANGE WITHIN TRADITIONAL RAIN-FED AGRICULTURAL AND PASTORAL SYSTEMS IN SUDAN

OPERATIONS & MAINTENANCE PLAN FOR WATER-RELATED INVESTMENTS

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1. Hafirs

1.1. Background

Several target localities are water-scarce, regularly experiencing extreme water shortage during periodic dry spells. Harvesting rainwater in reliable water storage structures represent opportunities to address water scarcity for both livestock and domestic purposes. One of the main water supply infrastructure proposed in this project is the “hafir”. They are selected because rain is the only water source and there are no or limited underground or surface water sources available.

A hafir is an artificial excavation (dugout enlargements) designed for harvesting rain water, carried during the rainy season by seasonal streams, to enhance the access of vulnerable communities to drinking water. Hafirs are usually constructed big enough to cater for the needs of the villagers/nomads and their livestock during the dry season. The average capacity of a hafir varies from 15,000 to 250,000 m3. The hafir is surrounded by earthen embankments and protected by thorny wire fencing from animals. Pictures of actual hafirs located in rural Sudan are shown in Figure 1-1.

Figure 1-1: Pictures of a hafir under construction (left) and an operation hafir (right)

1.2. Technical characteristics

Main steps in hafir establishment include: construction, community organization and management structures, capacity building, operation and maintenance and monitoring and evaluation. Recently, communities have a greater role and responsibility in the management and operation of their water supplies. However, the operation and management of a water supply requires awareness, skills and experience. The capacity of the community may need strengthening so they can manage their water supply. Capacity building should result in that the committees selected by the community gains skills on leadership, financial management and technical operation and management and water hygiene and sanitation.

1.3. Performance feasibility

The presence of a trained and functional management committee, or Water Management Committee (WMC) is the first step towards establishing a sustainable and well-performing hafir facility. The WMCs must represent the key stakeholders: representatives of the locality government and members from the communities using the hafir, including permanent residents and nomadic pastoralists passing through. However, the management committee should have clear roles and responsibilities and should receive proper training. WMCs will be actively linked

to the relevant government departments. In the target areas, women play a critical role when it comes to water, sanitation and hygiene, their representation and voices must be heard in WMCs and WASH Committees.

The training of WMCs is the key factor for efficient shouldering of the O & M. After the WMCs have been established, they will have a comprehensive training on management, O&M. Topics covered include participatory decision making, management of conflicts over natural resources, understanding basic concepts related to catchment management, gender issues related to water resources management, hygiene and sanitation practices and Participatory Action Plan Development (management of water stations, collection of money, follow up and evaluation and water uses, organizing meetings, taking decisions and writing reports). The availability of trained technical personnel within the community is important for the O&M of the system. Hence, training of such technical people and provision of continuous support is very critical for sustainability.

Lessons learned from previously constructed Hafirs revealed that the benefiting communities managed to establish a water tariff system for O&M. Based on this system, and in consultation with communities; the WMCs were actively involved in the determination of the revenue collection systems to meet at least the future maintenance expenses. To avoid such lack and delays of maintenance, heavily investment was made in training, organization, intensive mobilization and awareness campaign to improve knowledge and skills to create a conducive environment for sustainable functioning of Hafir. There are always a Hafir guard and operator with good management skills who is in charge of operation and day-to-day management including collecting fees, organizing watering operation and care for the facilities; under the supervision of the Water Management Committee (WMC).

Preventative maintenance is the key to ensuring a long life for hafir. Regular monitoring of the embankments, reservoir and catchment area should be carried out to make sure that maintenance needs are identified early enough to take action. Monitoring should be carried out by the individual or committee responsible for management and needs to be more frequent in the first year after construction, preferably once a month. Ideally a technician should assist in the monitoring for the first year. After the first-year monitoring can be carried out twice per year, preferably just after and before the rainy season.

Inspection forms should include, at a minimum, the following information: -

- Type of inspection (annual, seasonal, monthly, special conditions)
- Date of inspection
- Items to be inspected
- Record of any problems noted during inspection and follow-up actions that are required

1.4. Operations & maintenance

O&M costs associated with these activities are low, estimated at about $2,500 per year, mostly for fuel, lubricants, and spare parts. In addition, major maintenance outlays are assumed to occur every 5 years at a cost of $5,000. Underlying the operations and maintenance costs of hafirs are several key elements. These are summarized in Box 1-1. There are six (6) essential operation and maintenance activities of Hafirs, as described in the bullets below.

Box 1-1: Key elements in hafir operation and maintenance (O&M) plan include:

- Community-Based Operation and Maintenance
- Infrastructure designs will be chosen that have minimal operation and maintenance requirements.
- Development of local water management committees(WMCs)
- Comprehensive training programmes for O&M staff
- Hiring of local community members as clerk and operators
- Setting of realistic water tariffs
- Hafir should be inspected periodically: monthly, quarterly and annually and prior to the season and after every heavy rain.
- Linking the WMCs to the local authorities and rural water administration to strengthen sustainability of the service
- Reporting system for breakdowns.

1. *Desilting.* Removal of slit (desilting) is the most important maintenance operation, as silt and soil will fill up the storage system and hafir becomes shallow and reduce the volume of water and the evaporation loss increases as well. Desilting (by excavation) can be done using any of the techniques suitable (manual, draught animal traction or mechanical). Desilting should be done regularly, preferably once a year in areas where heavy siltation occurs. The depth of silt deposited (and hence the quantity to be removed) can be measured easily if a marked post is installed in the bottom layer at the time of construction.
2. *Rectification of the fencing.* Fencing regular checking is very important as it keeps livestock out and helps to maintain better quality of water. When fencing is in a poor state of repair, animals enter freely, accelerating bank erosion, increasing turbidity of the water and adding to the pollution hazards.
3. *Plant windbreaks.* Evaporation losses from hafir can be high in dry, windy areas. A dense stand of trees such as neem or other native species on the windward side of the hahir reduces evaporation. Windbreak trees stand need to be followed-up and maintained periodically (during the rainy season).
4. *Preventing leakage.* leaks through structure walls can occur due to inadequate compaction or old tree roots. Compaction of eroded parts of embankment must be done.
5. *Maintenance of inlets and outlets and obstructions removal*. Obstructions such as trees and bushes, carried by seasonal streams can block the way and water entrances. Inlets and outlets should be cleared from silt and debris before and during the rainy season. Separate gates or entrances for people and livestock should be established and controlled.
6. *Establishment of water user fee.* Contributing of users towards operational costs should be clearly understood and agreed upon by the community. The user fee amount should be agreed upon by the community and management committee (e.g. in cash per animal watering or per jerrican collected). Fees can be gradually increased once the community

consolidates a sense of ownership. Such fees can be used for the maintenance of haffir and necessary accessories.

Maintaining a well-functioning hafir requires the involvement of all stakeholders and skilled personnel. To ensure a strong and capable community management system, capacity of the community members will be carried out. The size and makeup of the management committee should ensure gender balance and representation of main stakeholders. A community based management system that is enforced by viable tariff and strong legislations is recommended. The WMCs and other stakeholders will be engaged to work out appropriate tariff levels. Revenue should be allocated to maintain and improve the facilities. Extensive training of communities and local authorities together with awareness campaigns on water sanitation must be carried out. The main stakeholders responsible for O&M are identified in Box 1-2.

Box 1-2: Key stakeholders who will be recruited to maintain hafirs include:

- Rural communities (farming and ago-pastoralist households)
- Pastoralist communities that seasonally migrate through the areas
- Community-based organizations(CBOs)
- Traditional local governance (Native Administration)
- Rural Water Management Authority (are responsible for the policy and strategy development, coordination, planning, management, monitoring and evaluation of water supply and sanitation facilities).
- State and Locality authorities and institutions
- NGOs working in the area

The principal maintenance objective is to prevent sediment build up and clogging, which reduce hafir capacity. Inspection for maintenance can be: monthly, pre-rainy Season, after heavy rain, end of rainy Season or (annual, seasonal, monthly, special conditions). The maintenance plan, including a description of activities and frequency at which they will be conducted, is summarized in Table 1-1.

Table 1-1: Hafir maintenance checklist and inspection frequency plan

Maintenance Task	Minimum Frequency of Task	Responsibility	Results expected when maintenance is performed
Removal of slit (De-silting) can be (manual, draught animal traction or mechanical).	Annually, before the rainy season	Community/RWA	Water flow and storage improved
Inspect and remove debris from hafir entrance point	A head before the rainy season and after heavy rain	Guard and operator /community	Water flow improved
Inspect seasonal stream systems and facilitate water flow/ inspect and prevent any backflow	Annually	WMCs/ RWA community	flow is normal and no backflow
Inspect and repair leaks if any for cracks (Compaction of eroded parts of embankment)	Every 3 months	WRMCs/ community	No leaking from water system
Inspect and clean water outlets (should be cleared from silt and debris).	Community/ Guard and operator	community/RWA	water flow and water quality are normal
Checking and controlling livestock and human separate gates or entrances for water access	Daily-basis	Guard and operator	organized water access and minimum water quality requirement kept
Rectification of thorny wire fencing	Every 3-6 months	Community	Pollution hazards reduced, and minimum water quality maintained
Windbreak trees stand need to be followed-up and maintained periodically	(during the rainy season).	Community	Reduced water evaporation

2. Water yards

2.1. Background

Due to lack of surface water resources in many areas of the project target states the population relies on groundwater pumped from considerable depths. “Water yards”, as they are known

locally, are essentially a water extraction and distribution complex which includes borehole, storage tank, animal watering basins and tap stands. The borehole is equipped with a pump, typically powered by a diesel engine. In the proposed project, solar-powered pumping is the chosen alternative. Pictures of typical water yards appear in Figure 2-1.

Figure 2-1: Pictures of water yards

2.2. Technical characteristics

The water yard is contained within a fenced compound, and under the control of a water yard clerk and pump operator. Mostly livestock basin is separate from the tap stands for human consumption by internal cross-fencing. Water is pumped into the elevated storage tank, which is usually constructed from prefabricated steel sections. The average nominal tank capacity is 50 m^3. From the storage tank, water is distributed by gravity to tap stands for filling containers for human consumption, and to metal basin for watering livestock.

Water for human use is drawn from the water yard to the home by a variety of means. Jerrycans of 18 litre (4 imperial gallons) capacity are commonly used and are carried to the home if the distance is short. For the longer distances, the jerrycans are loaded on donkey carts. Larger metal tanks on carts dragged by donkeys are also used. Children and women are the primary water providers.

2.3. Performance feasibility

A water yard is a proven low-tech option for providing water to meet household and livestock needs in rural Sudan. Historically, rural water yards are maintained by the Rural Water Corporation (RWC). A water yard operator is also employed by the RWC at each water yard. The operator's job is to start and stop the pump, perform routine and preventative maintenance to water yard equipment, and to notify the RWC when a major overhaul or repair of equipment is required. The water yard operator is frequently unable to perform routine and preventative water yard equipment maintenance, since he is not supplied with the necessary spare parts, lubricants and tools. The RWC considers that lack of preventative maintenance and lack of operator training are the major technical reasons for the breakdown of water yards when they occur. Key technical issues that constrain and hinder the operation and maintenance of water yards are as follows:

- Availability of diesel fuel and spare parts

- Aging of facilities
- Tariffs and cost recovery

Regarding the last bullet above, tariffs should be sufficient to pay for long term operation and maintenance including major equipment replacement, with a reserve for future improvement. Lessons learned have shown that the beneficiaries are willing and able to pay for good service. Previous experience indicated the essentially of community based operations and maintenance system and community based operation and maintenance system is already operating quite successfully in several rural water yards.

2.4. Operations & maintenance

Lessons learned from previously constructed water yards have been integrated into the post-project O&M plan. O&M costs are low, estimated at about $1,500 per year. In addition, major maintenance outlays are assumed to occur every 5 years at a cost of $5,000. There are several key elements involved in proper operations and maintenance of the water yards to be installed in the target villages, as described in the bullets below.

- *Development of local water committees.* An effective water committee will be formed in each community, with representation of the locality government and members from the communities using the water yard, including permanent residents and nomadic pastoralists passing through. Responsibilities of WMC include: imposing reasonable water charges to cover the costs of fuel and lubricants, to contribute in providing spare parts and to assist in minor repairs and general maintenance for fencing. WMC should receive proper training and actively linked to the relevant government departments. In the target areas, women play a critical role when it comes to water, sanitation and hygiene, their representation and voices must be heard in WMCs and WASH Committees
- *Training of Water Management Committees(WMCs).* The training of WMCs is the key factor for efficient shouldering of the O & M. After the WMCs have been established, they will have a comprehensive training on management, O&M. Topics covered include participatory decision making, management of conflicts over natural resources, understanding basic concepts related to water yard management, gender issues related to water resources management, hygiene and sanitation practices and Participatory Action Plan Development (management of water stations, collection of money, follow up and evaluation and water uses, organizing meetings, taking decisions and writing reports). The availability of trained technical personnel within the community is important for the O&M of the system. Hence, training of such technical people and provision of continuous support is very critical for sustainability.
- *Establishment of a community based revolving fund and the setting of realistic water tariffs.* revealed that the benefiting communities managed to establish a water tariff system for O&M. Based on this system, and in consultation with communities; the WMCs were actively involved in the determination of the revenue collection systems to meet at least the future maintenance expenses.

- *Hiring of local community members as clerk and operators.* Local clerks and operators will be hired from within the community and paid by the water committee out of community water revenues in the revolving fund. This will permit direct and effective supervision of the daily operations of the water yard and routine preventative maintenance of the equipment. The clerk will be trained in basic bookkeeping and report preparation and the operator in pump and engine operation, lubrication, preventative maintenance, and pipe repair.
- *Establishment of a supply of spare parts at each water yard.* A stock of lubricants such as oil and grease, and other supplies such as pump and engine gaskets and seals, filters, pipes and pipe fittings will be kept at each water yard. This will allow the pump operator to maintain the equipment and perform minor repairs. A portion of the revolving fund will be used to procure an adequate supply of water yard equipment, spare parts and replacements.
- *Development of a monitoring system for major breakdowns.* Preventative maintenance is the key to ensuring a long life for a water yard. Regular monitoring will be carried out to make sure that maintenance needs are identified early enough to take appropriate action. The proposed inspection protocols are outlined in Box 2-1.
- *Implementation of a maintenance checklist and plan.* A maintenance checklist and inspection is outlined in Table 2-1. Upon learning of a maintenance issue, the water committee will be responsible for reporting any serious breakdowns to the RWC/private services. The RWC will react by dispatching a repair team. The costs of providing this service, including vehicle operating costs, personnel costs, costs of spare parts and supplies will be paid for by debiting the community's account within the revolving fund. The RWC will also provide periodic water yard equipment inspections for a fee.

Box 2-1: Water yard inspection protocols

Monitoring should be carried out by the individual or committee responsible for management and needs to be more frequent in the first year after construction, preferably once a month. Ideally a technician should assist in the monitoring for the first year. After the first-year monitoring can be carried out thrice per year. Inspection forms should include, at a minimum, the following information:

- Type of inspection (annual, seasonal, monthly, special conditions)
- Date of inspection
- Items to be inspected
- Record of any problems noted during inspection and follow-up actions that are required.

Table 2-1: Water yard maintenance checklist and inspection frequency plan

Maintenance Task	Minimum Frequency of Task	Responsibility	Results expected when maintenance is performed
Rehabilitation of drilling	Annually	Community/RWA	Water supply and storage started and normal
Change of pump spare parts	When needed	Guard and Operator/WMCs	Water yard is operational
Inspect and repair if any for water leaks	Daily-basis	Guard and operator	No leaking from water system
Inspect water outlets	Daily-basis	Guard and operator	water supply and quality is normal
Checking and controlling livestock and human separate water supply	Daily-basis	Guard and operator	organized water access and minimum water quality requirement kept
Rectification of the water yard compound fencing	Every week- months	Guard and operator /Community	Damage and pollution hazards reduced
Emergency maintenance	When needed	Community/RWA	Water yard is operational

3. Sand water storage dams

3.1. Background

Sand dams are cost-effective rain water harvesting structures which are used as a response to conditions of water scarcity due to severe drought and climate extremes in drylands. A sand dam is a reinforced concrete wall built up to 5 meters high across a seasonal water stream valleys (wadis) that transport runoff-water from catchment areas to streambeds. They are designed like ordinary earth dams, but the spillway is raised to enable sediments to sit in the dam. Pictures of typical sand dams appear in Figure 3-1.

Figure 3-1: Pictures of sand dams

3.2. Technical characteristics

The sand dam is comprised of four main parts: the dam, spillway, wing walls and stilling basin. A sand dam is built to last over 20 years. Once construction is complete further operation costs are negligible and requires little maintenance. After construction, the dam must mature (which can take 2 to 7 years depending on the geologic and hydrologic conditions), as well as other conditions at the location and then water can start being extracted from the newly created aquifer. They provide a clean, local water supply for domestic and farming use.

There are two essential conditions for the choice of a suitable sand dam site, namely a) the presence of a seasonal river with sufficient sandy sediment, and b) accessible bedrock in the river bed. Moreover, it is important that river sediment is suitable, with a high percentage of poorly graded coarse sand as this promote greater storage and water abstraction potential from the dam.

To ensure that a sans dam prevents water flowing underneath the dam, they are built on bedrock to a point at least 1.5 metres wider than the typical flood width of the river. This prevents excessive seepage of water which, if not prevented, can become a steady flow that undermine the dam's foundation and/or divert the river's course around the dam. In addition, in the river does not continue to flow it its original course, the river may cause erosion upstream or downstream or even change course completely rendering the dam useless.

3.3. Performance feasibility

After construction, the first seasonal rains fill the dam area with water, silt and sand in both upstream and downstream directions. The coarser sand has the highest settling velocity and

deposits upstream of the dam. The newly deposited sand provides additional water storage capacity. Suspended material with smaller grain sizes, such as silt, will wash over the top of the dam and continue downstream. When the riverbed aquifer is full, usually within one or two large rainfall events, the river starts to flow as it does in the absence of the dam. Sand dams are carefully designed so that the natural flow of the stream is not altered, to avoid erosion downstream of the dam. The water held in the sand behind the dam spreads horizontally creating a permanent increase in the water table, allowing trees to grow naturally and transform the local ecology and also allow for small-scale farming through irrigation.

3.4. Operations & maintenance

Sand dams are simple structures and have lowest O&M costs compared to other known rainwater harvesting technologies. O&M costs are low, estimated at about $1,000 per year. In addition, major maintenance outlays are assumed to occur every 5 years at a cost of $7,500. There are three key elements underlying the O&M plan, as outlined below.

- Full involvement of the community to ensure operation, management and maintenance after completion.
- The water committee will have the responsibility of supervising the operation and maintenance procedures.
- Proper linkage between the local community, local administration and governmental sector to ensure technical and advisory assistances for the community.

To maintain the sand dams, a Dam Management Committee (DMC) will be formed. The DMC will include representatives from the locality government and members from the communities using the dam. Responsibilities will focus on providing assistance on minor repairs and for general maintenance. DMC members will receive training linked to the relevant government departments. After the DMCs have been established, they will have on technical trainings on operation, management and maintenance for the water committee.

A maintenance checklist and inspection is outlined in Table 3-1. Preventative maintenance is the key to ensuring a long life for dam. Regular monitoring of will be carried out to make sure that maintenance needs are identified early enough to take action. Monitoring should be carried out by the individual or committee responsible for management and needs to be more frequent in

Table 3-1: Sand maintenance checklist and inspection frequency plan

Maintenance Task	Minimum Frequency of Task	Responsibility	Results expected when maintenance is performed
Rehabilitation of drilling	Annually	Community/RWA	Water supply and storage started and normal
Change of pump spare parts	When needed	Guard and Operator/WMCs	Water yard is operational
Inspect and repair if any for water leaks	Daily-basis	Guard and operator	No leaking from water system
Inspect water outlets	Daily-basis	Guard and operator	water supply and quality is normal
Checking and controlling livestock and human separate water supply	Daily-basis	Guard and operator	organized water access and minimum water quality requirement kept
Rectification of the water yard compound fencing	Every week- months	Guard and operator /Community	Damage and pollution hazards reduced
Emergency maintenance	When needed	Community/RWA	Water yard is operational

the first year after construction, preferably once a month. A technician will assist in the monitoring for the first year. O&M costs are low, estimated at about $1,000 per year.

4. Summary of O&M costs

Operations and maintenance costs both during and after the implementation of the project will be fully borne by the GoS as is the case for all water-related infrastructure. The GoS is committed to provide sufficient funding to the federal Ministry of Agriculture and Forestry and state ministries to meet the funding requirements for routine and periodic maintenance of new and rehabilitated water infrastructure. A summary of total O&M costs is provided in Table 4-1 below.

Table 4-1: Average annual routine maintenance of new water infrastructure, averaged over the 25-year lifetime of the infrastructure

#	Description	Units	Qty	Unit cost (US$ per unit per year)	Total cost (million US$ per year)	Remarks
1	Hafirs	hafirs	75	$3,300	$247,500	Costs reflect annual maintenance costs of $2,500 and periodic (i.e., every 5 years) of $5,000
2	Water yards	water yards	80	$2,300	$184,000	Costs reflect annual maintenance costs of $1,500 and periodic (i.e., every 5 years) of $5,000
3	Sand water storage dams	dams	30	$2,200	$66,000	Costs reflect annual maintenance costs of $1,000 and periodic (i.e., every 5 years) of $7,500
	Total				$497,500	