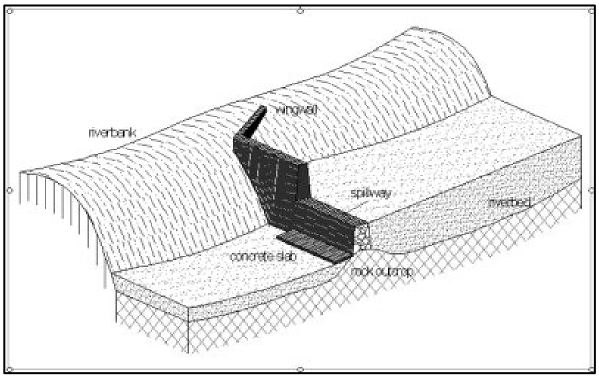
RAIN

Rainwater Harvesting Implementation Network

A practical guide to sand dam implementation

Water supply through local structures as adaptation to climate change



A guideline based on the Swiss Re 2007 award winning pilot project "Water harvesting to improve livelihoods in southern Ethiopia: from pilots to mainstream" and large-scale implementation of sand dams in Kenya.

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1. Case studies from Ethiopia and Kenya

1.1 Sand storage dams to improve rural livelihoods in Kituï District, Kenya

In the Kituï District of Kenya the SASOL (Sahelian Solutions) Foundation began constructing sand storage dams in 1995. Since this period, over 500 sand storage dams have been constructed. These vary in size according to valley dimensions and peak flows. On average the Kituï dams are between 2-4 metres in height and around 20 metres in length.

The main advantage of the Kituï dams is that they use simple inexpensive technology and can be constructed by local communities mainly with locally-available materials. The cost of an average sand storage dam with a minimum life span of 50 years and storage of at least 2.000 m^3 is about US$ 7.500. Some 40% of overall construction cost is provided by the community. They are involved in the construction of sand storage dams by provision of labour and raw materials through sand dam management groups. After construction, these groups ensure maintenance of dams and protection of the water quality as well as promoting ownership and thus sustainability.

Box 1: Quick facts Kituï region:

Area:	20.400 km^2
Population density:	25 persons / km^2
Climate:	semi arid (precipitation: 250-750 mm/year falling in two wet seasons, open water evaporation 2000 mm / year)
Geology:	Metamorphic and igneous basement covered with weathered rock
Soils:	Silty and clayey sediments, low fertility. In the western part black cotton soils

Sand dams are usually built in sequence because the ecological damage resulting from having a single point water source is avoided. Also, the water table rises higher and over a larger area compared to individual units. This will result in ecological regeneration. Apart from drinking water security, sand storage dams also provide water for development of rural commercial activities such as small scale irrigation (cash crops and tree nurseries), piped water supply to nearby villages and industrial activities (brick making). Furthermore, since less time is needed to fetch water (see table), school attendance increases significantly and more time can be spent on other income generating activities such as household industries (basket weaving, sewing).

There are examples of subsurface dams in Kituï that already have been in operation for 25 years, and most that have been constructed subsequently are still fully operational. Although normally a good constructed sand storage dam requires little maintenance, the sand dam committee is responsible for it. It is very important that attention is paid to this. Small deficits may otherwise lead to complete dam malfunction while if proper attention would have been paid, the dam could have been repaired. The committee should be trained to perform evaluations and report this to SASOL.

Vulnerability Categories	***Vulnerability indicators***	***Before dam construction***	***After dam construction***
Agriculture	# of cash crops	1.5	3
	% irrigated crops	37	68
Special aspects	Water collection Domestic (minutes)	140	90
	Water collection Life Stock (minutes)	110	50
Gender	Average walking distance women to water (km)	3	1
Economic	Income (US$./year)	230	350
Health	% households suffering from malnutrition	32	0

Table 1: Measured social and economic impacts of sand dams in the Kituï region, Kenya (after Thomas, 1999).

1.2 The catchment approach: an example project of combining water harvesting techniques in Borana, southern Ethiopia

The Borana Zone in southern Ethiopia is a semi-arid region in which rural communities depend mostly on livestock farming (mostly pastoralists) and small-scale agriculture. Both activities are highly constrained by water availability, there being no perennial rivers and with rainfall varying highly, both spatially and temporally. Communities live in very remote areas, with no access to water, electricity or sanitation facilities. Children in this region have the lowest school enrolment rate in the country, spending substantial amounts of time in collecting water and in addition to other domestic tasks.

Water harvesting has proven to be an attractive decentralised water source in areas where other means of water supply have little potential, like in Borana. However, roof water harvesting is not effective from thatched roofs and storage of surface runoff in tanks can only provide sufficient water for the dry period and the quality is questionable. Therefore the sand dam technology provides an attractive solution for the people of Borana.

Photo 1: Sand dam site after first flood event in Borana, Ethiopia (ERHA, 2008).

Photo 2: Woman fetching water from a surface runoff tank in Borana, Ethiopia (RAIN, 2007).

Communities are already known with the phenomenon of collecting water from ephemeral river beds. However the sand dam technology itself is not very common in Ethiopia. During an award winning pilot project which started in 2007, RAIN, ERHA, AFD, Acacia and SASOL conducted several trainings for 10 NGOs throughout the country and implemented 7 sand dams in combination with 10 surface runoff tanks in Borana. This innovative combination of infrastructure, to recharge groundwater and to harvest surface runoff water, will ensure drinking and productive use water in the short- and long-term for communities living both adjacent to an ephemeral watershed (by sand dams) and those further away (by rainwater harvesting tanks) (see figure1). The project will increase access to a reliable source of water for at least 10 communities in the critically dry Borana Zone and an environment for further upscaling in other parts of the country has been created.

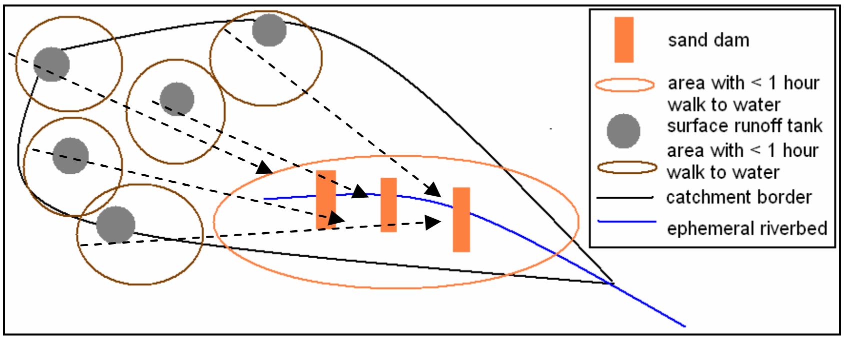


Figure 1: Hypothetical example of catchment approach in rainwater harvesting: combining sand dams and rainwater harvesting tanks in one (sub)catchment.

2. Basic principles of a sand dam

2.1 What is a sand dam?

2.1.1 Definition of a sand dam

A sand storage dam (or sand dam) is a small dam build on and into the riverbed of a seasonal sand river[1]. The functioning of a sand dam is based on sedimentation of coarse sand upstream of the structure, by which the natural storage capacity of the riverbed aquifer is enlarged. The aquifer fills with water during the wet season, resulting from surface runoff and groundwater recharge within the catchment. 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. However, the groundwater flow through the riverbed is now obstructed by the sand storage dam, creating additional groundwater storage for the community.

Photo 3: Typical sand storage dam during the dry season (Borst & de Haas, 2006)

During the dry season, water levels will drop due to abstraction of water, minor evaporation and possibly by leakage through the dam or vertical leakage into the bedrock. Meanwhile, subsurface flow (base flow) from the riverbanks towards the riverbed and through the riverbed itself will slowly and partly refill the riverbed aquifer. Because of the larger storage volume and he slower depletion, the river provides water throughout the dry season (when built under appropriate conditions), whereas otherwise the riverbed would have dried up long before the beginning of the new rains.

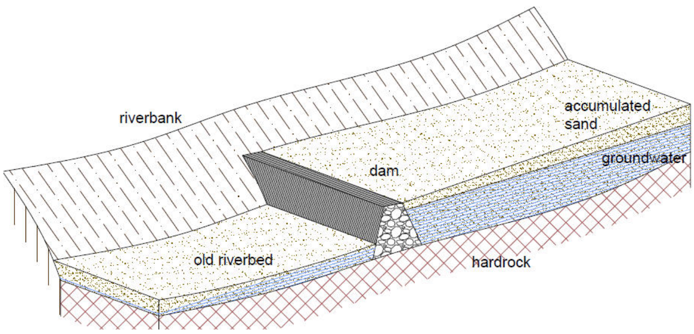


Figure 2: Schematic cross section of a typical sand storage dam (Borst & de Haas, 2006)

[1] Dry and sandy riverbeds are seasonal water courses that transport runoff-water from catchment areas into rivers or swamps once or a few times in a year. Dry riverbeds are also called ephemeral streambeds, seasonal water courses or sand rivers. Most of the rainwater being transported downstream in riverbeds appears as high flood events that can be up to several metres high. Sand rivers are only suitable for sand dams when coarse sands are available and the river must be underlain by impervious bedrock (or clays like black cotton soil).

The volume of water available for abstraction is considerably larger than just the volume present in the riverbed sands. This is because a large quantity of the water is additionally stored in the riverbanks, recharging the sand dam reservoir in the dry season (Borst & de Haas, 2006; Hoogmoed, 2007).

Sand dams effectively increase the volume of groundwater available for abstraction as well as prolonging the period in which groundwater is available.

Box 2: Advantages of a sand dam compared to surface water dams.

Sand storage dams have several important advantages over surface water dams, resulting in a higher water quality and improved environmental conditions.

- Protection against evaporation
- Reduction of contamination (by livestock and other animals)
- Filtration of water flowing through the riverbed sand (disinfection)
- Unsuitable for breeding of mosquitoes (malaria) and other insects
- Inexpensive structures with a high level of community involvement.

2.1.2 Functions of a sand dam

The primary function of a sand dam is increasing the water availability by storing water in the riverbed and -banks. Water is stored in the spaces (voids) in the sand, which can hold up to 35 percent of the volume of sand. Sand dams obstruct groundwater flow through the riverbed, resulting in a (continuous replenishment of the) enlarged groundwater reservoir upstream of the dam.

Besides this, sand dams can have other functions and positive side effects, like:

- <u>Regional groundwater recharge:</u>

A cascade of sand dams in a will cause a general rise in groundwater levels in a larger area. This positively affects the environment in the surrounding area of the dam, due to more water availability for people and vegetation.

- <u>Sand harvesting and rehabilitating of gullies:</u>

Sand dams can rehabilitate erosion gullies, while the sand sediments behind the dam can be harvested for sale. If a sand storage dam is built for this purpose, the dam doesn’t have to be impermeable. Usage of plastic bags filled with soil is more profitable for this purpose (Nissen-Petersen, 2006).

2.1.3 Types of sand dams

Sand storage dams can be classified according to their construction material (Negassi et al., 2002):

- <u>Stone-masonry dam:</u>

A dam built of concrete blocks or stones. This type of dam can be easily constructed by local artisan. A stone-masonry dam is also durable and suitable for any dam height. The dam is cheap when construction materials are available within the dam area.

Photo 4: Sand dam in Kituï (Gijsbertsen, 2006).

- Reinforced concrete dam:

A dam consisting of a thin wall made of reinforced concrete. It is a durable structure, relatively expensive but suitable for any dam height.

- Earth dam:

A dam consisting of impermeable soil material (mostly clay or clayey soils, or black soils). This type of dam is relatively expensive to construct and it requires special skill for its design and construction. An earth dam can easily be damaged and even destroyed by underground flow. Earth dams are not popular and are seldom used (only for minor works).

2.2 Hydrological principles of a sand dam

2.2.1 Filling of the sand dam aquifer (after Gijsbertsen, 2007)

Sedimentation upstream of the sand storage dam occurs during heavy rainfall events, when river discharge will be high, transporting large quantities of sediments. The grain size of the transported sediments is dependent on river flow velocity and the material comprising the riverbanks. Since most of the land is bare at the start of the rainy season, soils are poorly protected against soil erosion, resulting in a high silt and sand load in the water.

The sand dam will reduce the flow velocity of the river at some distance upstream of the structure. This drop in flow velocity results in sedimentation. The materials found in the river bed prior to construction are a good indication of the type of sediment that will be collected by the sand dam. These sediments form a ridge comparable to the formation of a delta. Upstream of the 'delta', flow velocity is higher and coarse sediments are transported. Where the 'delta' stops, a sudden drop in flow velocity occurs causing coarse sediments to settle, building the 'delta' further towards the sand dam (see figure 3). Continuous repetition of this process causes the ridge of sand to move towards the dam, eventually filling the total volume behind the dam.

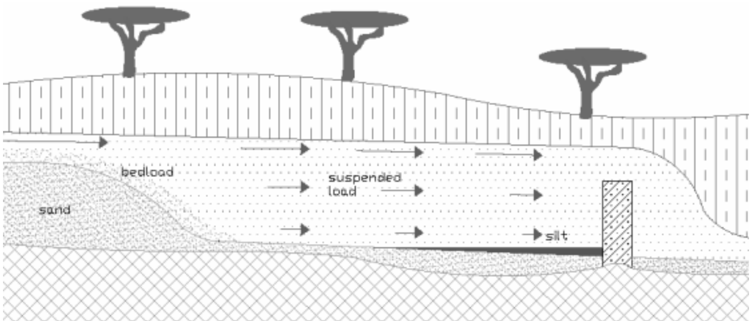


Figure 3: Schematic representation of the sedimentation process (Gijsbertsen, 2007)

However, the river also transports finer materials, like silt and clay. These sediments have a lower settling velocity compared to sand will largely stay in suspension and are transported over the dam. However, fine sediments can settle resulting in a silt layer directly upstream of the sand dam. After the rainfall event, base flow will dominate river discharge. Coarse sediments can no longer be transported due to the low flow velocities and are deposited. Without the coarse material, the base flow water has excess energy leading to erosion of the river bed. Fine sediments will be (re)taken into suspension and transported, leaving the coarser grained material in the riverbed. Once the runoff has stopped completely, residual silt layers on top will dry and crack. Animals and people walking on the riverbed will pulverize this dry silt layer, making it susceptible for wind erosion (Borst & de Haas, 2006). These processes limit the accumulation of silt and clayey material behind the sand dam.

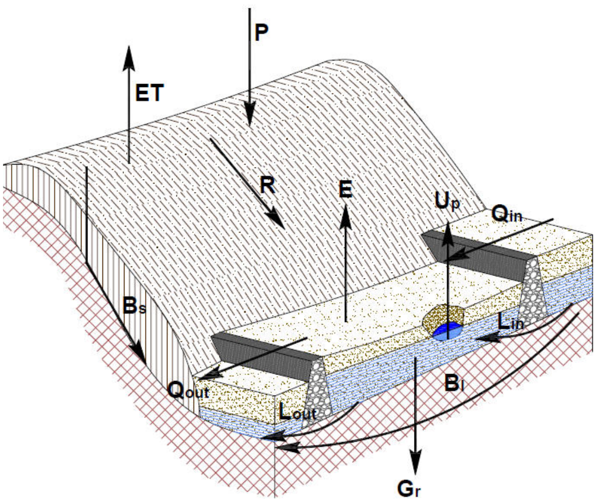
Sedimentation will continue until the ‘delta’ reaches the height of the sand storage dam. The sand storage dam is mature and filled with coarse sand. This can take several wet seasons, depending on the availability of coarse sediments, height of the sand dam, river discharge, catchment slope and rainfall intensity.

In upstream parts of a catchment it is recommended that sand dams are built in stages, since the availability of coarse material is generally limited and base flow is small or absent. The optimum height of one stage is site specific. The first stage is typically 50 cm. It is recommended to consult an expert on this matter.

2.2.2 Hydrological functioning of a sand storage dam

In most semi arid regions, rivers are only holding water during and short after rainfall events, especially in more upstream parts of catchments. Due to the often short and intense rainfall events in combinations with certain soil types like silt and clay, a large part of the rainfall will leave the catchment as surface runoff instead of infiltrating the soil and recharging the groundwater. Runoff coefficients up to 70% can be found.

A sand dam obstructs groundwater flow through the permeable riverbed. It only takes one or two heavy rainfall events to fill the enlarged riverbed aquifer completely, and after this the river will start to flow as it would in absence of a sand storage dam. The raised water table in the riverbanks results in a groundwater flow from the riverbanks towards the river bed. This leads to replenishment of the created reservoir (see figure 4). Water will be available in the riverbed as long as the groundwater flow from the riverbanks continues. Therefore it can be highly profitable to take soil- and water conservation measures in the upstream areas within the catchment, to increase infiltration of rain water creating more base flow within the catchment.



Water balance components

ET	Evapo(transpi)ration from slopes
E	Evaporation from riverbed
P	Precipitation
R	Surface runoff from slopes to river
B_s	Groundwater baseflow from slopes to river
B_l	Shallow and deep longitudinal baseflow
Q_{out}	River discharge outflow over downstream dam
L_{out}	Leakage underneath and around downstream dam
Q_{in}	River discharge inflow over upstream dam
U_p	Use of water (abstraction)
G_r	Loss of water into the ‘impermeable ground

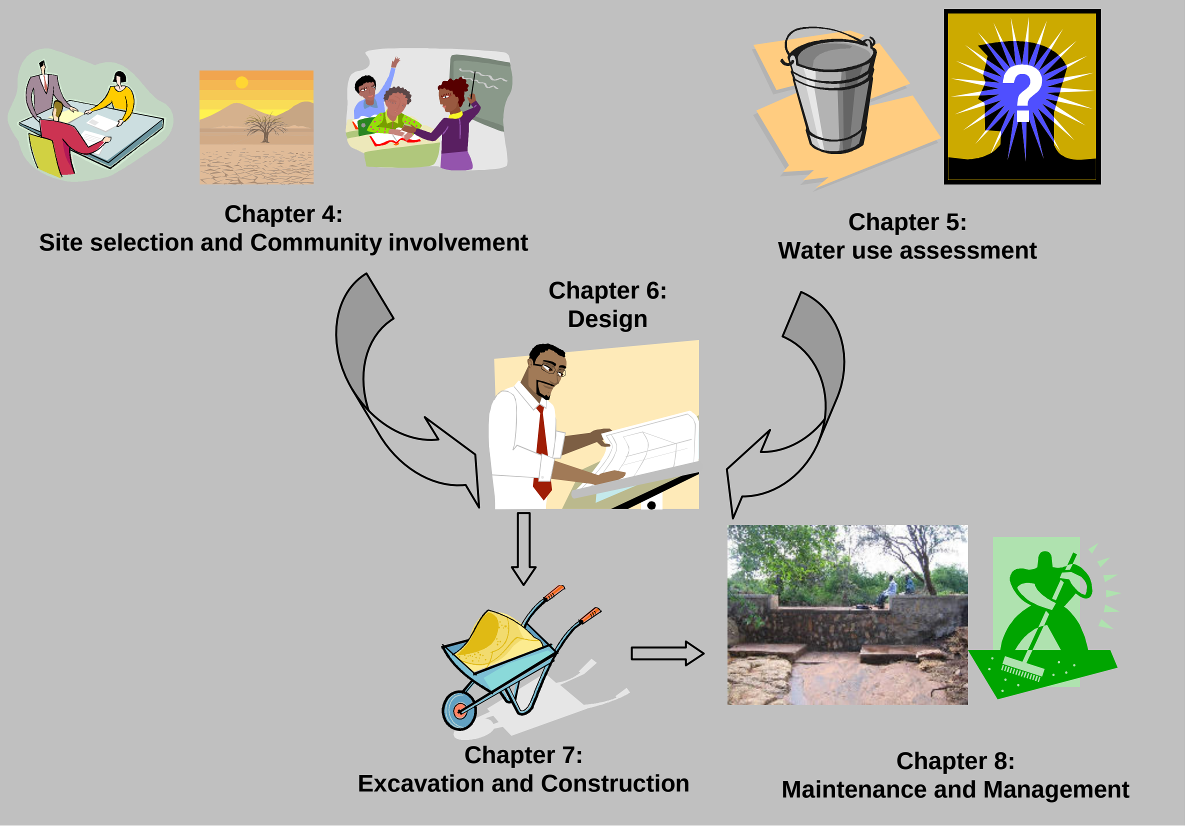
Figure 4: Important water balance components to the hydrological functioning (Borst & de Haas, 2006).

3. Practical steps within a sand dam project

In the previous chapter, you have learned what a sand dam is and how it is functioning. Understanding the functioning of a sand dam crucial in order to go through the following chapters which contain a sep-wise approach in how to implement a sand dam project. These steps are:

- Site selection and community involvement;
- Water use assessment;
- Design;
- Excavation and construction;
- Maintenance & management.

Box 3: Stepping stones in sand dam construction



In this manual we will focus on masonry dams with or without a reinforced foundation and a u-shaped spillway. After many years of practical experience and research on sand dam design by SASOL, this design has proven to be most effective, durable and easiest to construct by local beneficiaries. Although earth dams are most cost-effective, they can not store large quantities of water which makes them less suitable.

To keep this manual easy to read and understand, attachments have been added in which further information is given like checklists, design and cost calculation tools. Also a CD-rom has been provided with more information and tools.

4. Site selection

4.1 Importance of site selection

Site selection is the first and most important step in constructing a sand dam. Accuracy in site selection will determine the success of the dam. A construction site should be appropriate on both physical and social grounds. This chapter will guide you through site selection for sand dams in 3 steps:

- Selecting potential catchments from a probability map based on a desk study (paragraph 4.2)
- Selecting potential riverbeds based on field data regarding the physical and sociological aspects (paragraph 4.3).
- Selecting riverbed sections and the sand dam location(s) (paragraph 4.4)

4.2 Selecting potential catchments for sand dams

A quick scan is used to make a probability map of an area for building sand dams. This will make site selection more specific and thus efficient. The desk study can be performed using digital or analogue data. The result will be a map showing high potential areas. If available, the below mentioned data are for a first indication whether a catchment is suitable for building sand storage dams.

1. <u>Topography map:</u>

A topography map gives general information about the catchment, such as locations of villages and roads. The presence of communities (the beneficiaries) in the area in the dry period (nomads or permanently) is the first condition.

A topography map also shows locations of rivers, and the size and general characteristics of the catchment. Rivers may have a maximum width of 25 metres (otherwise other options may be more suitable, such as subsurface dams (Nissen Peterson, 2006)). The catchment should be hilly (see also point 2: Digital Elevation Map).

2. <u>Digital Elevation Model:</u>

A Digital Elevation Model (DEM) contains information on the morphology of an area (elevation and slopes). A local drainage direction map can be calculated from it, which will give the drainage pattern (rivers) of the catchment. Furthermore, information on the slopes within a catchment can be derived from a DEM. The most suitable locations for sand dams have a slope gradient between 2 to 4 percent. The particle size of sediments accumulated along streams and in riverbeds (which will also fill the sand dam) is proportional to the slope gradient, whereas the depth and the lateral extent of the river bed aquifer are inversely proportional to the slope gradient. The optimum relation between these two factors is found on the gentle slopes between hills and plains with a gradient ranging from 0.3 to 4 percent (Gezahegne, W., 1986).

Digital elevation data by the Shuttle Radar Topography Mission (SRTM) can be freely downloaded from the internet (http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp). The resolution of the data is rather coarse; 90 meter horizontal.

3. Geological map and soil data:

Catchment geology determines, together with discharge characteristics and slope, the grain size of the sand dam. A geological map can indicate whether a catchment has the potential to produce (coarse) sand. For example, granite hard rock will produce coarse sand while shales will produces fine (clay or silty) material.

For example, the geology of Kenya is available from USGS. This map is part of the open file report 97-470A, version 2.0 2002, scale of 1:5,000,000. The dataset is an interim product of the U.S. Geological Survey's World Energy Project (WEP) and can be freely downloaded from the internet.

If the riverbed itself contains large stones and boulders, seepage under the dam may occur. When large boulders occur, special care should be taken to site selection. This will need to be checked in the field. Soil data can give information on where to locate sandy areas within a catchment.

4. Aerial photographs and satellite images:

Aerial photographs and satellite images can help locating sandy riverbeds based on the morphology. Aster satellite images can also be used to indicate sandy riverbeds and different types of geology through the reflection (ratio), as has been done by Gijsbertsen (2007). Aster satellite images can be downloaded from http://asterweb.jpl.nasa.gov/.

5. Precipitation and evaporation data:

The effectiveness of sand storage dams appears to be quite insensitive to precipitation (Borst and de Haas, 2006; Hoogmoed, 2007). However, when locating suitable regions for building sand dams, precipitation will be important because it influences discharge characteristics (base flow) and thus also the availability of coarse grained material in the riverbeds. Higher annual precipitation will mean more storm events. These areas have a higher suitability based on precipitation compared to regions with a lower annual rainfall. Also, to calculate the yield of a sand dam, it is essential to know the climatologically behaviour of an area.

Tropical Rainfall Measuring Mission (TRMM) satellite images contains rainfall data with a spatial resolution of 4.3 km (In the region between 35°N and 35°S). Data is available on the internet on monthly basis (http://neo.sci.gsfc.nasa.gov/Search.html). LocClim also provides rainfall data (http://www.fao.org/sd/2002/EN1203a_en.htm, where the program can be requested for free).

6. Flood data:

Flood data can be used to determine the maximum flood height and thus the minimal height of the riverbanks (see also paragraph 6.2). It also provides information on discharge characteristics of a catchment during a rainfall event.

For example, the river has to be seasonal, although it is very important that base flow occurs since this prevents sand storage dams of filling with fine (unfavourable) sediments. Local communities and water authorities can indicate whether the river dries up immediately after a rainfall event or if the river continues to flow, showing base flow.

4.3 Selecting potential riverbeds

The result of the desk study described in paragraph 4.2 is a first indication of which (parts of) catchments are suitable for constructing sand dams. To fine tune this selection field visits are necessary (paragraph 4.3.2). From this stage onward, community involvement is crucial to the success of the project.

4.3.1 Community involvement and forming a Water Committee

Involvement of beneficiaries aims at sensitizing and mobilizing communities to improve the quality of their life through collective self-help. Many types of community organizations usually already exist within a community depending on their current needs, problems and aspirations. Before starting a sand dam project in an area, the community must be intensively involved to create a feeling of ownership which has proven to be the key factor in successful construction and maintenance of sand dams. The benefits of a sand dam project are mostly collective, but there can also be individual needs, like irrigation of specific land plots. An organization with sensitivities for collective as well as individual effort is therefore required for a sand dam project.

Photo 5: Beneficiary involvement during site selection in Borana, Ethiopia (RAIN, 2007).

A sand dam project in a catchment potentially suitable for implementation starts with sensitizing the communities' awareness on the project. Also, information on institutions, rules and habits of the communities should be identified. Secondly, a community meeting will be held with the project staff and community discuss the possible environmental and social impact of the development of sand dams within the area. The following aspects should be discussed in the community meeting.

- Assessment of water problems,
- Assessment of development issues within the project area,
- Informing and educating on the various types of water harvesting technologies, in particular the sand dam technology,
- First and indicative assessment of possible sand dam locations with the community.

Also, the community has to elect a committee from their midst. This so-called water committee consists of a representative group of the community and will take part in several trainings (further discussed in chapter 9). Awareness and involvement in the project processes will hence be ensured. The water committee will have the following objectives (Munyao et al, 2004):

- Performing baseline survey on water use within the community
- Joining in the riverbed surveys resulting in selection of the building location
- organising community mobilization for required participation works during the construction process;
- supervise the implementation, operation and maintenance procedures.

The steps in community involvement and its objectives are discussed in further detail in attachment 2.

4.3.2 Physical and social selection criteria

The result of the desk study described in paragraph 4.2 is a first indication of which (parts of) catchments are suitable for the implementation of sand dams. Then, the information from the community (paragraph 4.3.1) is integrated into this map, resulting in the most potential (parts of) riverbeds. These will be visited together with the water committee to collect valuable data based on which building location(s) are chosen. The following is based on practicalities from Nissen-Petersen (2006).

First draw a sketch of the riverbed and surrounding areas which will be visited and from which the following information will be gathered:

1. <u>Location and types of water-indicating vegetation.</u>

Vegetation that indicate the presence of water, can be growing on the banks where the reservoir will be located, as proof of the riverbed capacity to store water. In the table below some names of trees are given which indicate water at a given depth below the surface.

Botanical name	Kiswahili and Kikamba names	Depth to water-level (m below surface)
Cyperus Rotundus	Kiindiu	3 – 7
Vangueria Tomentosa	Muiru Kikomoa	5 – 10
Delonix Elata	Mwangi	5 – 10
Grewia	Itiliku Itiliku	7 – 10
Markhamia hildebranditi	Muu Chyoo	8 – 15
Hyphaene Thebacia	Kikoko Ilala	9 – 15
Borassus Flabellierfer	Mvumo Kyatha	9 – 15
Ficus Walkefieldii	Mombu	9 – 15
Ficus natalensis	Muumo Muumo	9 – 15
Ficus malatocapra	Mkuyu Mukuyu	9 – 20
Gelia aethiopica	Mvungunya Muatini	9 – 20
Piptadenia hildebranditi	Mganga Mukami	9 – 20
Acacia seyal	Mgunga Munini	9 – 20

Table 2: Water-indicating vegetation with root depth.

2. <u>Location of waterholes, their depth to the water table and quality of the water.</u>

Presence of waterholes especially after the rainy season) is an indication that the riverbed contains water and that it does not leak to deeper groundwater very fast. Pay special attention to those providing water the longest during the dry season. Also note the depth of the water table to the riverbed surface.

The water quality in the waterhole is an indication of the quality of water which can be harvested after building a sand dam. However, water quality can improve significantly by taking protective measures against animals can make significant improvements (see: RAIN water quality guidelines).

3. <u>Location and types of rocks and boulders.</u>

If large boulders are present in the riverbed, care should be taken in choosing the sand dam location. The sand dam is preferably build on (and its wings attached to) hard rock or a compacted and strong soil. If a large boulder is mistaken for hard rock, water can leak from the sand dam reservoir, leading to unnecessary loss and potential undermining of the sand dam. Check whether hard rock is present in the riverbanks and –bed by looking for rock outcrops.

Pay special attention to the presence of halite near the riverbed, which is a salty whitish substance that turns water saline. If salty rocks (white and pink mineral rocks) are situated in the riverbanks upstream of a dam, then the water may be saline and therefore only useful for livestock. Local

communities often know if there are any salty rocks, because livestock like to lick them for their salt content.

4. Coarseness of the sand in the riverbed.

The material which is present in the riverbed is a good indication of the material which will fill up the sand dam reservoir after construction. Coarse sand is preferred, since it has a larger infiltration capacity and water can be abstracted more easily.

5. Two high riverbanks.

Suitable riverbeds have two high riverbanks. During flood events the river should not flow over the riverbanks, because this can cause erosion of the riverbanks, flooding of downstream located villages and it might cause the river to change its course. In this case, the sand dam will be left as a ruin. By using flood data and information from local water departments and local knowledge of the community, the maximum water height during a flood event can be determined. The minimal height of the riverbanks should be:

Minimum height riverbanks = Height of dam + Flood height + max. 10% (safety height)

6. A (preferred) maximum width of 25 metre.

Riverbed width preferably shouldn't exceed 25 metres. The reinforcement required for such kind of long dam walls is too expensive; hence the sand dam will not be cost-effective. Other alternatives, such as subsurface dams, can be applied.

7. An impermeable (bedrock)layer.

To ensure storage of water within the sand dam aquifer, losses through leakage to deeper groundwater should be minimised. Therefore, the dam should be built on solid bedrock or an impermeable layer. This will also protect the sand dam from undermining through groundwater flow underneath the sand dam. This can be checked by using the geological map and outcrops in the area. Also, holes can be dug in the riverbed to find the depth of a consolidated layer or bedrock layer.

8. Type, suitability and availability of construction material.

The construction material locally available (such as sand, rock outcrops, bricks, etc.) can help to determine the type of sand dam (as described in paragraph 1.2) to construct. For example, a masonry dam is not the best choice if no stones are available in the area since transporting them from other areas is very expensive.

9. Presence of riverbed crossings and roads.

Rural roads often cross riverbeds. A sand dam is preferably located near these crossings, if physical conditions allow, because it will be easily reached through existing roads. Also, for transportation of materials it is important to know the most suitable roads or routes.

10. Names of houses, schools and shops near the riverbed.

This information is useful for organising the project. Also, an assessment of the water demand can be made.

11. Land rights.

To avoid conflicts, care should be taken in areas where the dam site is owned or used by two or more villages or individuals.

4.4 Selecting riverbed section(s) and sand dam location(s)

After having compiled the information listed above, a detailed survey is carried out in the parts of the catchment which seem most promising. This mainly consists of probing and evaluating the properties of the riverbed. Attachment 3 lists data which should be collected during this survey. These are:

- depth and coarseness of the sand at different levels and the type of basement from the probing rod.
- depth of water from the rod.
- width of the riverbed and height of the riverbanks.
- presence of water-indicating vegetation, waterholes, roads, etc. is noted.

This procedure is repeated at regular intervals, for example 20 metres. The data gathered by the above described survey results in a map and profile (paragraph 4.4.4) of the river section. This map shows information about the river length and width, locations of cross-sectional, longitudinal profiles, water-indicating trees and waterholes.

4.4.1 Storage capacity and extraction percentage of sand

Water extraction is more profitable from riverbeds containing coarse sand than from those with fine textured sand. The porosity and extractable capacity of sand can be determined through the following method. A 20 litre container with a plug in the bottom is filled with sand from the riverbed. The sand is slowly saturated with a measured volume of water. Then the plug is removed from the bottom of the container. The volume of water which has drained out of the sand within one hour is taken as a measure for the extractability. Table 3 gives values of extractability of water in different soils. This shows that the extractability of sand is highest; therefore coarse sand is preferred as aquifer material.

	Silt	***Fine Sand***	***Medium Sand***	***Coarse Sand***
Size (mm)	< 0.5	0.5 – 1.0	1.0 – 1.5	1.5 – 5.0
Saturation	38%	40%	41%	45%
Water Extraction	5%	19%	25%	35%

Table 3: Sand fractions, saturation and extraction rates (Nissen-Petersen, E. 2006).

4.4.2 Gradient of the riverbed

Measuring the gradient of the riverbed can be done by using a circular transparent hose, half-filled with water. One person should stand at the starting point, using the levelling tool. Another person should stand upstream of the person holding the levelling tool with a long pole which is held vertically. The person with the levelling tool has to make sure the water levels in the tube are in one line. He or she should indicate to the person holding the pole where this sight line crosses the pole. The height at which the line of sight crosses the pole should be measured from the surface of the riverbed (parameter y [m]). The distance between point No. 1 and point No. 2 should be measured (parameter x [m]). The height of the eyes of the person holding the levelling tool should be measured (parameter z [m]). Then, the gradient (parameter w [m]) can be calculated using the below formula:

$$W = ((z - y)/x)*100 = \text{gradient } [\%]$$

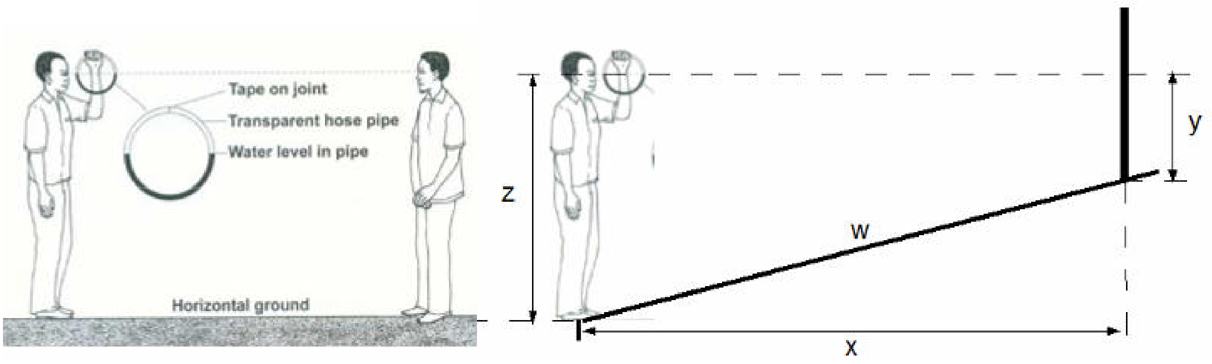


Figure 5: Usage of the levelling tool at horizontal grounds (left) and at sloping grounds (right) (Nissen-Petersen, 2006a).

4.4.3 Depth and type of basement and depth of groundwater

The depth of the basement or impermeable layer in the riverbed with respect to the riverbed surface is of importance to decide where the sand storage dam should be build. It should be constructed at the location where the impermeable layer is closest to the riverbed surface. Preferably, the basement upstream of this location is deeper, to get a larger sand dam aquifer. The depth of the sand in the riverbed can be surveyed by using an iron rod with a diameter of 16 mm (5/8") Notches should be cut in the probing rods for every 25 cm to collect sand samples when the rods are pulled up. A hammer is needed for hammering the rod into the riverbed, together with a tripod ladder used for hammering long probing rods. This can be done following the procedure below:

Hammer the probing rod straight down in the middle of the riverbed until it hits the floor under the sand with a dull sound. Mark the level of the sand on the rod and pull the rod straight up without twisting.

4.4.4 Example of longitudinal profile and cross section

Figure 6 is an example of a longitudinal profile. It shows the points at which the sand is deepest (here: 4.0 m deep between 55 and 60 metres) and where natural subsurface dykes (of solid bedrock or impermeable soil) are located (for example at 40, 70 and 85 metres). The locations with deep sand are the potential reservoir of a sand dam and the natural dykes are potential locations for a sand dam. After making a longitudinal profile of the selected riverbed section, the point where the sand is the deepest and therefore the largest reservoir can be selected. In figure 6 this is at 60 metres.

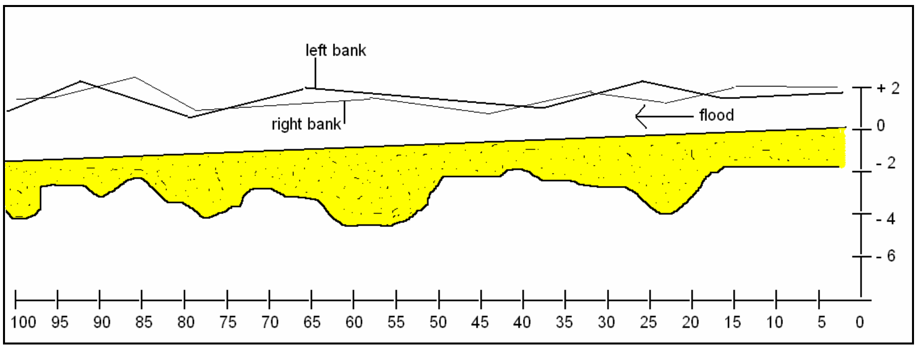


Figure 6: Example of a longitudinal profile of a river section.

By knowing the longitudinal and cross-sectional profile, a calculation of the reservoir capacity can be made. In figure 7 an example is given of a cross-section where the sand is deepest. It is important to take measurements every 1 or 2 metre across the riverbed to determine the riverbed morphology.

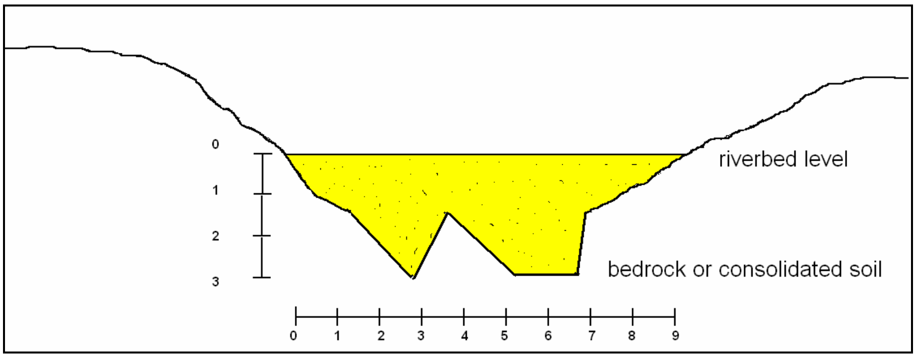


Figure 7: Example of cross profile and probing results.

5. Water demand vs. water yield

5.1 Water use assessment

The water demand of the local community has to be investigated before starting a water project, to understand the most important needs of a community. Next to this the community has to be aware of the possibilities and limitations of a sand dam. The water needs or water demand of a community is the amount of water currently used by people for domestic purposes as drinking, cooking and cleaning, as well as for irrigation or for cattle. This information gives insight into water demand, water use, future aspirations and water quality problems. The water use assessment has to be executed by the implementing organisation before selecting the locations of the sand dams. The information which needs to be gathered includes:

- the number of households within a community;
- the number of women, men, boys and girls;
- their current water needs for each water requiring activity;
- their aspirations / expectations for future water needs.

When executing a water use assessment, the water committee has to elect people from each group of the community (men, women, elder, youth etc) to contribute. This can be a member of the water committee itself as well as other members from the community. Water needs from each group of the community have to be reflected in the water use assessment.

In attachment 4a practical questionnaire is given. The questionnaire will provide a guideline to determine the water needs of a community. After finalization of the sand dam project (when the sand dam is mature and in full use), a second water use assessment should be carried out. The results of the water use assessment before and after the project can then be compared and conclusions about the success of the project can be made.

5.2 Water yield

Determining the volume of extractable water is not very straight forward in the case of a sand storage dam. The total amount of water is not simply the water which can be stored in the riverbed sand. Hoogmoed (2007) and Borst & de Haas (2006) have indicated that the riverbanks play a crucial role in the functioning of a sand storage dam because of the continuous groundwater flow from the riverbanks to the riverbed, which slowly and partly compensates the loss of water through leakage, evaporation and abstraction (paragraph 2.2.2). Therefore, the riverbanks must be included in the calculation of the water yield.

Calculating the volume of water which can be abstracted from the riverbed can be done using the calculation tool available at **www.sanddam.org**.

This is only an indicative estimation of the storage capacity. Sand dams depend largely on local factors, which are difficult to include in a model. Also factors like, irregularities or fractures in the basement, geomorphology of the catchment, rainfall events etc. can have a big influence on the success and yield of a sand storage dam. More information can be found on **www.sanddam.org**.

6. Design

6.1 Introduction

After determining the water demand and estimating the water yield at the selected sand dam location, the design can be made. There are different approaches in designing a sand dam, but this manual will focus on the designing approach of SASOL, combined with AFD. A sand dam can be defined in four main parts:

- the dam;
- spillway;
- the wing walls;
- and the stilling basin.

6.2 Dam height

To determine the dam and spillway height at a specific location, it is very important that the water level and the maximum flood level will remain below the riverbanks after construction of the dam,. If the flood level is higher than the riverbanks (Bh), construction of a dam is not advisable. The dam and spill way height are therefore determined by the maximum discharge and maximum flood height (see figure 9).

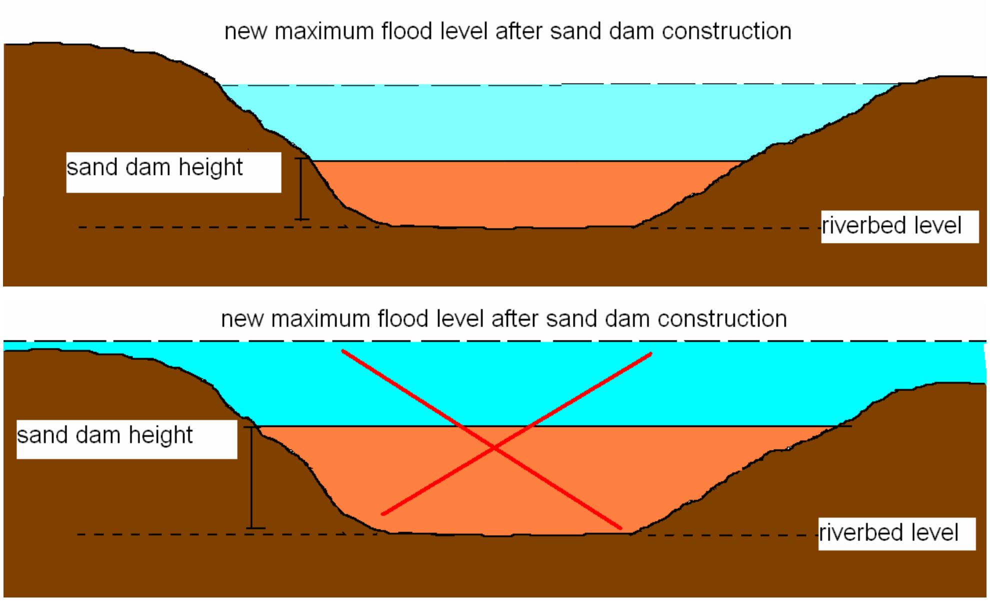


Figure 8: Examples of sand dam heights: do's and don't's.

In figure 8 the top picture shows a sand dam height by which the maximum flood level will remain lower than the riverbanks, while the picture below shows a sand dam height by which the maximum flood level will exceed the riverbanks. In this scenario flooding and thus severe erosion of riverbanks (eventually causing dam failure) will occur. The most practical way of calculating maximum discharge is by getting information in the field and from the selected beneficiaries on flood levels.

However, maximum discharge can be calculated in 2 different ways:

- Calculating the maximum discharge by the highest flood level (known by flood marks on the banks or information from local community's);
- Calculating the discharge at the selected location by using a certain return period (for example: a rain event with a return period of 50 years) by using a rainfall-runoff model or a mathematical formula for rainfall runoff.

In the picture below you see a cross-section at a dam location, with the different parameters that have to be measured to calculate the maximum discharge.

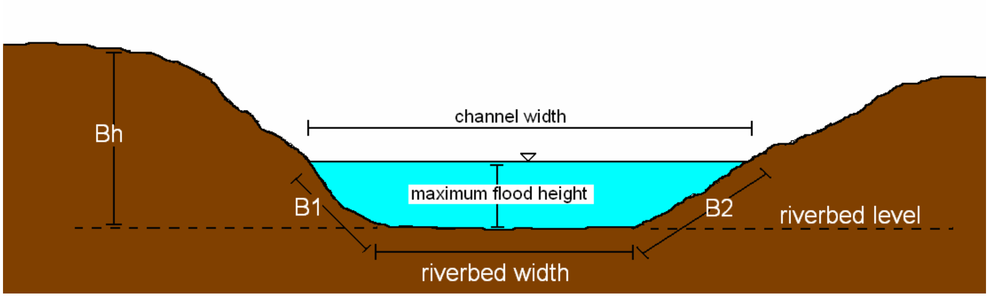


Figure 9: Cross section with maximum flood height to determine maximum discharge.

Maximum discharge in riverbed section:

$Q = 1/n * A * R^{2/3} * S^{1/2}$

Q = maximum discharge in riverbed section (m^3/s)
n = Manning roughness of riverbed
A = wetted cross-sectional area (m^2), by: ½*(channel width + riverbed width)* flood height
P = wetted perimetre (m), by: B1 + riverbed width + B2
R = hydraulic radius (m), by: A/P
S = slope of riverbed (m/m)

6.3 Spillway, wing walls and stilling basin dimensions

The maximum discharge (as determined using the equation in paragraph 6.2) is used to determine the spillway dimensions, for which the formula is given in the box below.

Using maximum discharge to calculate spillway dimensions

$Q = c * L_s * H^{3/2}$

Q = maximum discharge in riverbed section (m^3/s)
c = 1,9 (constant depending on spillway shape, here: broad crested weir)
L_s = length of spillway (m)
H = height of spillway (m)

Cros-sectional width dimension of a sand dam

G_f = gross freeboard (m)
H_f = height freeboard (m)
H_d = total height of dam (m)
H_s = total height of spillway (m)
L_w = length wing wall (m)
L_{we} = length wing wall extension (m)
L_s = length spillway (m)

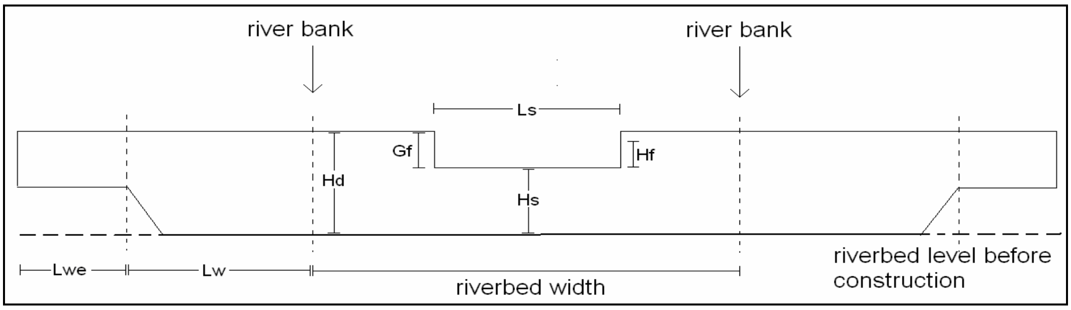


Figure 10: Cross section of a sand dam body and its dimensions.

When determining the distance the wing walls go into the banks, bank characteristics have to be taken into account (Munyao et al, 2004):

- in loose riverbanks: approximately 7 metres into the riverbanks;
- in hard soils: approximately 5 metres into the riverbanks;
- in hard and impermeable soil: approximately 0 – 1 metre into riverbanks;
- in rock formation: no need of constructing in riverbanks.

The length of the wing wall (Lw) should be approximately 2 metres into the riverbanks. The length of the wing wall extension (Lwe) should be approximately 5 metres. This is an example of wing wall dimensions in loose riverbanks. Currently a research is carried by SASOL and Acacia on the specific effects of sand dams on groundwater levels within a catchment, which will lead to more specific guidelines on wing wall dimensions.

Stilling basin dimensions

$S_L = c * L^{1/3} * H_2^{1/2}$

S_L = length of stilling basin (m) c = 0,96 (constant)
H_2 = height of freefall (m): height of water level upstream –height of water level downstream

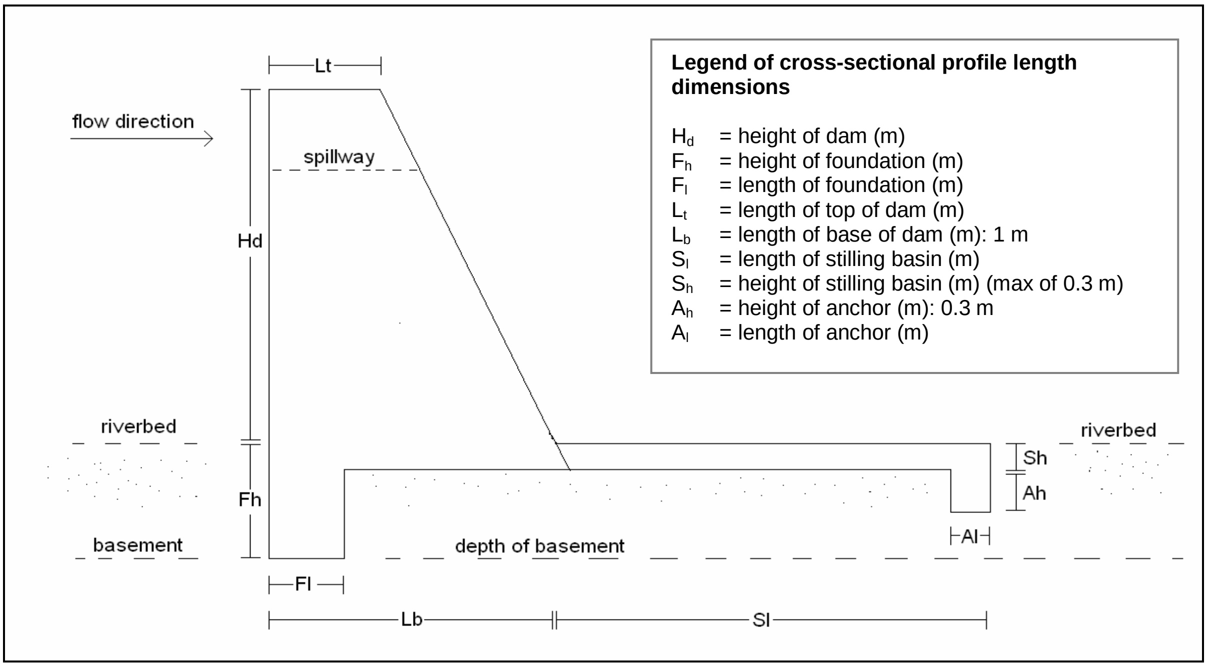


Figure 11: Cross sectional profile of a sand dam body and its dimensions.

7. Excavation and construction

7.1 Materials and Labour

7.1.1 Materials

The types of materials needed to construct a sand dam depend on the type of dam (paragraph 2.1.3) that is found most suitable at the selected location. This depends on physical properties of the catchment and on the materials available on the market as well as within the area of the selected sand dam location. If materials like stones and sand are locally available, this will reduce costs of materials and transport. In this paragraph we will focus on the bill of quantity for stone-masonry dams.

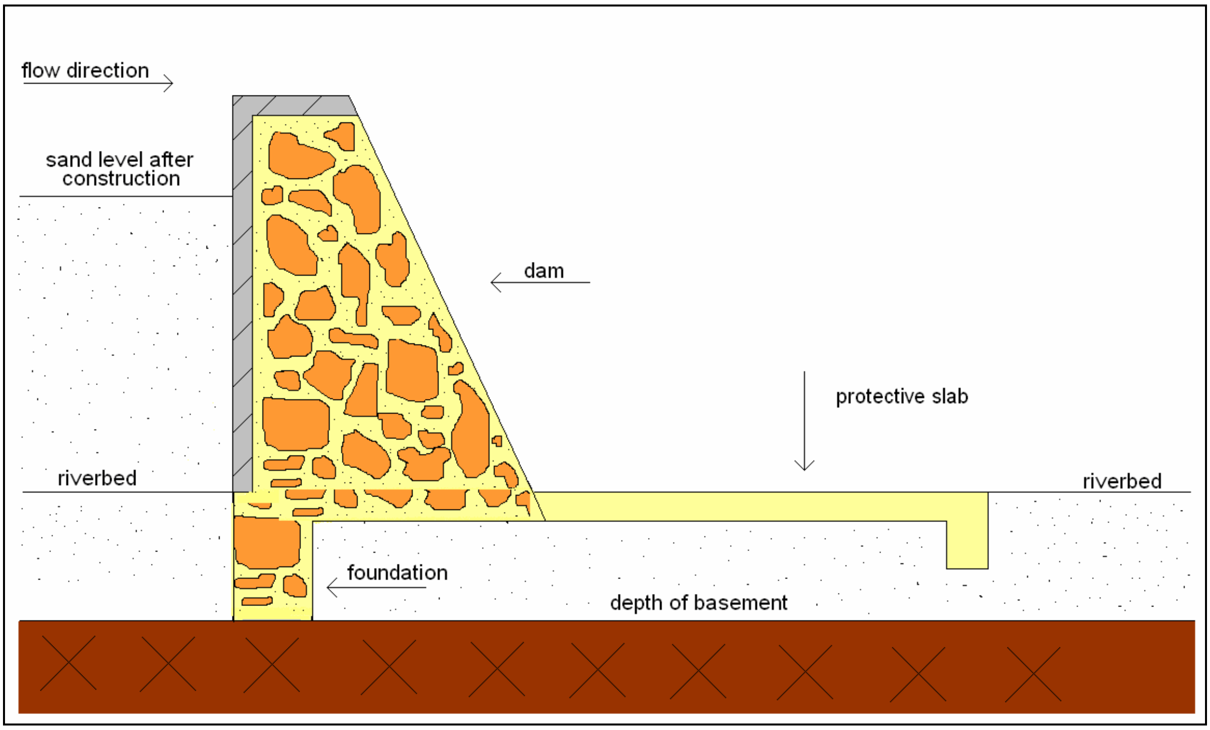


Figure 12: Cross sectional profile of a sand dam body.

Construction materials masonry sand dam

Stilling basin:
- 1:3 mortar
- Large boulders

Dam:
- 1:4 mortar with well interlocked stones, ratio cement:sand:hardcore = 1:4:9-12
- Upstream wall and top of dam plastered with 1:3 mortar (30 mm)

Foundation:
- 1:3 mortar foundation (100 mm)
- 1:4 mortar with well interlocked stones, ratio cement:sand:hardcore = 1:4:9-12
- (reinforcement bars of barbed wire (400 mm spacing)

Description	Unit	Unit cost (ETB)	Total quantity for a sand dam	Costs per Volume of work (ETB per m^3)	Total cost (ETB)
Cement	50 kg bag	130	241.8	3.10	31,434
Reinforcement bars ½ Dia' (12m)	pieces	0	0.0	0.18	0
Reinforcement bars ¼ Dia' (12m)	pieces	0	0.0	0.18	0
Barbed wire	20 kg roll	68	6.0	0.08	411
Timber 2"x 2"	m^2	12	52.0	0.67	624
Polythene paper g 1000	metre	15	104.0	1.33	1,560
Reinforcement bars Dia' (10m)	pieces	140	3.1	0.04	437
Reinforcement bars Dia' (6mm)	kg	14	51.5	0.66	721
Black wire	kg	14	3.9	0.05	55
C.I.S. Nails	kg	18	2.3	0.03	42
Stone hard core2	m3	31.25	233.2	2.99	7,288
Sand13	m3	19	66.3	0.85	1,260
Water	m3	140	37.4	0.48	5,242
Other construction equipment (V.tools, Hand pump, Mould for well concrete rig)	unit	7,500	1.0	1.00	7,500
Camping site for skilled labourers	unit	6,500	1.00	1.00	6,500
Total					**63,073**

Table 4: Example of a bill of quantity for materials and transportation costs in ETB (2007).

In attachment 6 you will find the guidelines to calculate the quantity of the materials derived from the dimensions of the dam.

7.1.2 Labour

In table 5 an example is given of the bill of quantity for labour costs: the contribution of community workers will reduce costs. The number of masons needed and days required to construct the sand dam depend largely on the size and location of the dam.

Description	Unit (days p.p.)	Unit cost (ETB)	Total days	Cost per Volume of work (ETB per m^3)	Total cost (ETB)
4 masons	45,8	50	183.3	2.35	9,165
10 mason assistant	31	15	312.0	4.00	4,680
15 community workers	50	0	750	0	0
Total					**13,845**

Table 5: Example of a bill of quantity for labour costs in ETB (2007).

7.2 The trench

7.2.1 Setting the trench

This is marking the position and the size of the dam taking in to account the size of the wing walls and working space during construction.

To estimate the size of the trench, the following should be taken into account:

[2] Refers to collection, preparation and loading of stone and sand that is expected to be covered by community participation. The cost planned is for renting a truck for transportation.

- Measure the appropriate distance (determined in paragraph 6.3) from one of the river banks depending on bank characteristics and fix a peg.
- Fix another peg across the river perpendicular to the river course at the appropriate distance.
- Use a plumb bob and line mark several points from the building line and fix pegs.

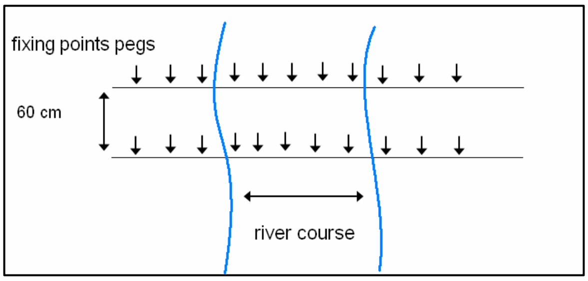


Figure 13: Example of setting a trench with pegs.

7.2.2 Excavating the trench

The marked trench is dug guided by the building line (see below photo). The depth of the trench is determined by the depth of impermeable layer in the ground which will obstruct seepage below the sand storage dam. The dug out soil should be placed downstream of the building location to avoid it filling the aquifer. If the dam is build into bedrock material, a trench should be cut into the rock to ensure secure jointing of the rock and mortar. Care should be taken to make sure no fractures or weathering zones are present in the basement rock. If suspected, this can be tested by poring water on the suspected weathered zones. If the water leakes away, the rock surface should be cleaned from the weathered rock or fractured rock. If clay forms the impermeable layer, the trench should be dug in for about 0.5 m to avoid seepage. After these conditions are met, the trench is ready for dam setting and construction (Munyao et al, 2004).

Photo 6: People excavating a trench (RAIN, 2007).

7.3 Construction of the dam

Construction starts with putting in place the reinforcement columns vertically in the trench followed by the construction of the foundation blinding slab. Reinforcement is only required if a very large or high dam is constructed. After this the second horizontal reinforcement layer is placed, followed by the second foundation blinding slab and then the actual masonry structure (of hard core and mortar) starts (Munyao et al, 2004). In attachment 7 you will find a detailed guideline for construction of a sand dam. Intensive technical supervision and monitoring is the major activity that should be attained during the construction process of a sand dam.

8. Water extraction from a sand dam

8.1 Types and locations of water extraction points

8.1.1 Traditional scoop holes

The most common way to abstract water from a sand storage dam is by means of a hand dug scoop hole in the riverbed. Water is scooped out at first, and the water that refills the scoop hole is abstracted. The method is susceptible for pollution, especially by animals. Therefore, animals and humans should use different scoop holes. The human scoop holes should be located close to the sand dam, on the upstream side. The animal waterhole should be at the downstream side of the sand storage dam. The riverbed will filter the groundwater as it flows through, so the distance between the waterholes for domestic use and cattle should be as far apart as possible.

Photo 7: Women using a scoop hole, Kituï District, Kenya (M. Hoogmoed, 2007).

Furthermore, to prevent animals from using the domestic waterholes, these should be barricaded all around by thorny bushes. The water from the scoop holes is relatively clean. Nevertheless should it be boiled or treated before drinking.

During the dry season the riverbed is often used as a road for cattle, which results in manure on the riverbed. At the start of the wet season, this manure will be flushed into the scoop holes, leading to contamination of the water. After the first river discharge, the water remaining in the scoop holes should not be used for drinking without treatment. The area close to the scoop hole, especially upstream should be kept clean of animal human interference and treatment or cooking before use is recommended.

8.1.2 Well with hand- or rope pump

A well is the better alternative for a scoop hole. It will protect the water quality because animals and river water can not enter. Many different types of wells exist. A well need to be covered (to prevent contamination, resulting in higher water quality) and a hand pump should be used to extract water. A maximum of 3 wells should be located on the upstream side and close to the dam embankment: approximately within 3 to 10 metres, since the sand reservoir will be deepest just upstream of the dam (depending on the longitudinal profile as described in paragraph 4.4.4). The yield of the potential well should be sufficient. If a well is located in the riverbank, the profile should be checked on permeable layers and their connection to the riverbed by making a test drill.

Photo 8: Men fetching water from a closed well near a sand dam in Kituï Kenya (M. Hoogmoed, 2007).

Box 4 provides practical guidelines to identify potential well locations. Water can be extracted from a well using a motor pump or hand pump. SASOL has been using rope and washer pumps and hand pumps. However, sustainability of rope and washer pump might be questionable as long as people are not trained in proper operation and maintenance. Hand pumps are therefore recommended.

Box 4: Practical guidelines for locating wells.

The well should just be located at the spot where the most water is available: this is closest to the am at locations where the bedrock or impermeable layer is deepest. Experiences in Kenya and Ethiopia showed that practical site specific information can be used to locate potential well locations. This includes:

- Identifying locations of existing scoop holes:
  Scoop holes are the best spots from communities' long-term experience to collect water from the river. Based on the locations of scoop holes, wells for a sand dam can be located at either side of the river embankment near the identified scoop holes.

- Identifying locations near the sand dam where the riverbed material is deep.
  A deep riverbed means more storage. Locating the well up stream of the dam at either sides of the river embankment in the direction of the riverbank where the riverbed material is thicker is found the best location for sand dam wells.

8.1.3 Outlet pipe with tap

An outlet can be installed as a perforated pipe at the bottom of the dam just above the impermeable layer. The pipe should be covered fully with filter material and geo-membrane to prevent entry of sand and silt. Disadvantages of an outlet, is that it can weaken the dam structure, maintenance is complicated and it is also found be an expensive option (Understanding the Hydrology of (Kituï) sand dams: Short mission report, November 2005).

8.2 Construction of wells

A well for a sand dam is constructed similarly as a shallow hand dug well, usually constructed for exploration of shallow ground water. It is important that the well abstracts the water from the deepest parts of the river sands. The deepest sands will produce the most safe water (bacteriological).The lining of the well should preferably have no openings at shallow depths. It could even be considered just to have an open well-floor, covered by gravel.

If a well is constructed at the centre of a river, it is extremely important to protect it from high flod damages. The well has to be a ‘hydrodynamic’ type to withstand the forces of a flood and must be protected from siltation by keeping its height about 0.5 – 1 metre above the surface of the riverbed. The top must be covered with a concrete slab (facing downstream to prevent entry of floodwater) to prevent contamination and mosquito breeding. The detailed construction process for a well and wellhead is given in attachment 8.

To protect the intake from high flood damages, alternatives can be considered. The intake can be constructed in, or close to the riverbank or by an outlet pipe through the dam. Creative alternatives are given by (Nissen Petersen, 2006).

9. Management and maintenance and monitoring

9.1 Training of local community

Based on the experiences of successful sand dam projects, facilitating community trainings on implementation, operation, management and maintenance are advised to be addressed during a community based sand dam project. Community trainings have the following objectives for the community:

- Full participation in the process of the project planning and implementation;
- Enhanced awareness on project management;
- Ensured technical and management skills after project completion;
- Enhanced awareness on management of the water quality and risks involved.

During the pilot sand dam project in Ethiopia community trainings have been divided into three categories:

- Sessions on the project planning, implementation and management of activities. This is already discussed in paragraph 4.3.1;
- Educational sessions on natural resources management, sanitation and hygiene;
- Technical trainings on operation, management and maintenance for the water committee.

The proposed methodology of all these trainings and educational sessions is based on carefully selected questions to guide group discussions. Each community elects five to seven members for the water committee and at least two other community members (future caretakers) to participate in the trainings and sessions.

9.1.1 Educational sessions on natural resources management, sanitation and hygiene

These educational sessions will be facilitated by a qualified person from the implementing organisation, preferably in cooperation with a representative from the concerning local government department. During these sessions, representatives of the water committee are educated on several subjects to ensure awareness and understanding of natural resources management, sanitation and hygiene. Natural resources management will mainly focus on the proper and efficient management and usage of the sand dam. These sessions will take 5 days in total and are organised within the community (Munyao et al, 2004).

Box 5: Natural Resource Management training

This training aims to facilitate ways and means of management of natural resources. With the help of a questionnaire the community gathers the necessary information about their available natural resources and explores ways and means of utilizing their natural resources to improve their livelihoods. By the end of the training, each community has developed a comprehensive list of the natural resources found in their village. They compile the potential ways and means of using these resources in an action plan.

In the absence of hygienic water practices, attempts to ensure high water quality will be futile. Safe rainwater can be easily contaminated after extraction from the system, for example by the use of contaminated jerry cans or by contamination present on the hands of users. Therefore, hygiene education and monitoring of the operation and maintenance of the system, along with sanitary practices, are essential if rainwater supplies are to fulfil their potential to provide clean water. Creating awareness on personal and system hygiene issues related to water is crucial. Local health organizations play an important role in educating consumers on water treatment methods, managing water supplies and giving specific guidance in managing, operating and maintaining RWH systems. Water supplies, sanitation facilities and hygiene behaviour work together as an integrated package: the quality of the approach in all components determines the outcome [Hygiene Promotion, Thematic Overview Paper 1, 2005].

Box 6: Hygiene training

This training focuses on creating awareness within the community on contamination risks of their water sources and giving guidelines for hygienic and practical guidelines on water usage. This training is based on the RAIN Water Quality Policy and on national and regional policies and programmes. At least one third of the local community is expected to participate, especially women since they are mainly responsible for collecting water, cleaning, washing and cooking: activities which have high risks of contamination.

9.1.2 Technical training on operation, management and maintenance

The water committee is responsible for proper operation, management and maintenance of the sand dam, which includes:

- Regular monitoring of the functioning and utilization of the sand dam;
- Establishing a demand driven payment scheme and;
- Effective management of the water reservoir as far as possible.

Two persons from the water committee or two community members will be trained on construction of the sand dam and wells by participating during construction. Technical knowledge and skills to execute maintenance and repair works is hereby ensured. These trained community members can become potential artisans for the construction of future sand dams within the area. They will become the caretakers of the sand dam, wells and surrounding area.

Box 7: Management training

In the project management training workshop the first step involves the examination of the community experiences in their projects for a previous five-years period, encompasses project undertaken, which were successful, which have failed, what aided to success and what caused failure. At the end of this analysis, the participants can draw lessons from past projects, understand the needs of the community and define solutions by them selves. This training will take 4 days and are organised within the community.

9.2 Management of a sand dam

Since the water committee and care takers have been trained and have coordinated community mobilization during implementation, the responsibility of the sand dam will be fully assigned to the water committee and care takers after completion of the construction of the sand dam. The water committee will be responsible for the management of the sand dam as well as the payment scheme and the caretakers will be responsible for the daily monitoring, operation and maintenance of the sand dam, wells and surrounding area. The water committee, with support and assistance of the concerned local government departments and the implementing partner, will monitor all activities to ensure sustainability of the project. This will be further discussed in chapter 7.

9.3 Maintenance

The approach on maintenance activities is based on the Kenyan experiences of SASOL. If a sand dam is properly constructed, it only requires little or no major maintenance. Maintenance of a sand dam can be assured if the following issues have been properly addressed during the project:

- Good workmanship during the construction of the sand dam.
- Full involvement of the community to ensure operation, management and maintenance once construction of the sand dams has been completed.
- Presence of a trained mason near to the sand dam project to ensure adequate repairs if there should be any serious damage to the structure, which is beyond the capacity of the trained caretakers.
- Proper linkage between the local community, local administration and governmental sector to ensure technical and advisory assistances for the community.

If these issues have been addressed as described in the previous paragraphs, maintenance can be kept at a minimum. In attachment 9 some guidelines are described for small technical maintenance issues.

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Attachment 1: Check lists for first and detailed technical site selection

Criteria for first site selection:	***compulsory***	***optional***
A stony catchment area (source of sand) and sandy riverbeds	x	
A sandy riverbed	x	
Two high and strong riverbanks	x	
A maximum width of 25 metre	x	
No fractured rocks or large boulders	x	
No salty rocks	x	
Presence of water-indicating vegetation		x
Presence of waterhole		x
Presence of riverbed crossings		x
Type of community structures within in the area, possible conflicts etc.	x	
Type, suitability and availability of construction material	x	

Steps for detailed site selection:	***compulsory***
Measuring the water extraction rate of potential riverbed(s) section(s)	x
Making a plan of the potential riverbed(s) section(s) with information on the river length and width, locations of cross-sectional and longitudinal profiles, water-indicating trees and waterholes	x
Making a longitudinal profile of the potential riverbed(s) section(s) by probing (see attachment 2)	x
Making cross-sectional profiles of the potential riverbed(s) section(s) by probing (see attachment 2)	x
Selecting different points in the riverbed section in which the sand is the deepest (potential reservoirs) and in which the natural underground dykes are most shallow (potential sand dams locations)	x
Selecting the point where the sand is the deepest and therefore the largest reservoir can be selected	x
Selecting the point where the underground dyke is most shallow and therefore the location of the sand dam	x
Making a cross-sectional profile of the potential sand dam location	x

Attachment 2: Steps to be taken in community involvement during site selection.

Step 1: Creating awareness and sensitizing the community.

Starting a sand dam project in a catchment potentially suitable for implementation (Paragraph 4.1) begins with sensitizing the community's awareness on the project, by undertaking regular visits to the project area and facilitating meetings with the representatives and members of community. All communication shall be carried out with respect to the existing institutions, rules and habits of the community.

Step 2: Community assessment and performing a water use assessment.

The best-suited sites identified during step 1 are visited and a dialogue with the community is held. During this meeting, the project staff and community discuss the possible environmental and social impact of the development of sand dam within the area. The following information needs to be gathered.

- Assessing the water problems of the targeted communities. During a plenary discussion problems and possible solution should be discussed by the community. Ownership, number of beneficiaries and their participation and involvement, timing of construction are discussed.
- Organising meetings or group dialoguing concerning the development issues within the project area. Project staff, community members including influential persons, local administrators, politicians, elders (both men and women), youth leaders and any other development agencies within the area should participate in these meetings.
- Informing and educating the community members on the various types of water harvesting technologies, in particular the sand dam technology. Advantages, disadvantages, feasibility, site selection criteria, the construction process and the level of community participation will be discussed.
- Assessing possible sand dam locations with the community. The community will be involved in site selection based on their local knowledge of the area (Paragraph 4.3.2). The selected sites should be discussed with local authorities.

Step 3: Establishing a water committee.

The water committee will need to be established, and its responsibilities will need to be defined in a binding document like a Memorandum of Understanding (MoU) between the water committee and the implementing partner. Each sand dam will have a water committee containing a maximum of nine members. At least 50 % of the committee members are selected from women representatives. Two members from the committee selected as care taker and will be responsible for operation and maintenance of the sand dam. Its duties are to mobilize resources, plan the site works, record progress, supervise and monitor the implementation process amongst else. The committee must on weekly basis monitor and evaluate the progress. On the part of the implementing partner, the MoU states:

- to supply all construction materials if not locally available;
- to supply in skilled labour;
- to provide technical supervision

Furthermore, the water committee and implementing partner will have to draw a Community Action Plan (CAP), containing an implementation schedule until completion. This is documented in a tabular format defining all the activities and responsibilities. It clearly defines the roles of each partner within the project i.e. the community and implementing organization.
The action plan will contain the following issues:

- Bill of Quantities for the material and labour in which the community will supply during the project.
- A work plan in which a clear and realistic time frame is given.
- Security of storage of materials and supervision on site.

On the part of the implementing partner, the MoU states:

- to supply all construction materials if not locally available;
- to supply in skilled labour;
- to provide technical supervision

Step 4: Organising community mobilization for required participation works during the construction process.

At the start of the construction process, the following activities are should be undertaken:

- The actual movement of resources like transportation of equipment and tools to the site,
- Involvement of skilled and unskilled labour. Elderly at the head of community committee are in charge of mobilizing community members because of their respected position and accepted authority in the community.
- The implementing partner will provide a representative at the grassroots' level; he/she will coordinate all activities. He/she advises elderly on community mobilization and participation.

Attachment 3: Data collection for the selected river section

The tools required for simple surveys as follows (Nissen-Petersen, E. 2006):

- Measuring rods made of 16 mm (5/8") iron rods for measuring depths of sand. Notches should be cut in the probing rods for every 25 cm to collect sand samples when the rods are pulled up.
- A circular levelling tool made of a transparent hosepipe for measuring the gradients of riverbeds.
- Two long tape measures, one hanging down vertically from the horizontal one, to measure width and depth of riverbeds.
- A tripod ladder for hammering long probing rods into the sand.
- A mason hammer.
- A 20 litres jerry can with water.
- Half a dozen of transparent plastic bottles with water.
- A knife and writing materials,
- A Data Sheet as shown below.

Example of a Data Sheet:

Measurement nr.	***Distance between measurements (m)***	***Width of riverbed (m)***	***Depth to water (m from surface)***	***Depth of the sand (m from surface)***	***Type of sand***	***Type of bedrock or soil under the sand***	***Height of the riverbank (m)***		***Items seen on the riverbanks***
							Left	Right	
1	0	20.8	-	0.5	Medium	Clay	1.5	1.9	Acacia tree
2	20	24.2	-	0.6	Fine	Clay	1.0	1.6	
3	20	28.2	-	0.7	Medium	Clay	1.4	1.84	Waterhole
4	20	25.5	0.30	1.25	Medium	Rock	1.3	1.7	
5	20	19.5	-	0.8	Coarse	Rock	1.4	1.65	Fig tree
6	20	21.3	-	0.7	Coarse	Clay	1.4	1.7	
7	20	18.6	0.8	1	Medium	Clay	1.97	1.55	
8	20	17	1.2	1.3	Coarse	Clay	1.3	1.64	Rock

Attachment 4: Questionnaire water use assessment

GENERAL						INTERVIEWER / NGO				INTERVIEWEE					
Date	Country	District	Village	GPS Longitude	GPS Latitude	Name Interviewer	Email and telephone nr.	NGO	Name employee NGO	Name	Gender	Age	Marital status	Main income generating activity	Other income generating activity

HOUSEHOLD (number of people living)					COMMUNITY					PERSON(S) FETCHING WATER in HOUSEHOLD				
Girls (0 - 15)	Boys (0-15)	Men (>15)	Women (>15)	Total	Girls (0 - 15)	Boys (0-15)	Men (>15)	Women (>15)	Total	Girls (0 - 15)	Boys (0-15)	Men (>15)	Women (>15)	Total

DRY SEASON									
Main water source	Distance (km)	Time one way (hours)	Use for drinking?	Treatment method	**Other water source**	Distance (km)	Time one way (hours)	Use for drinking?	Treatment method

RAINY SEASON									
Main water source	Distance (km)	Time one way (hours)	Use for drinking?	Treament method	**Other water source**	Distance (km)	Time one way (hours)	Use for drinking?	Treatment method

WATER USE DRY SEASON (average litres per person per day)									WATER USE RAINY SEASON (average litres per person per day)								
No. of months	drinking	cooking	shower	washing	livestock	agriculture	other	Total	**No. of months**	drinking	cooking	shower	washing	livestock	agriculture	other	Total

Attachment 5: Calculating the quantities of materials

I. Concrete

Mix Ratio – 1 : a : b

Where: 1 = cement proportion : a = sand proportion : b = coarse aggregate proportion

If the amount of concrete needed is C, then:

Cement Quantity (kg) = 1 * C * 1400 * 1.3 * 1.05/(1+a+b)

Sand Quantity (m3) = a * C* 1.3 * 1.15/(1+a+b)

Gravel Quantity (m3) = b * C * 1.3 * 1.15/(1+a+b)

II. Stone Masonry

For water tight structures usually 65% of masonry body is proposed to be stone and 35% cement mortar. So, if the volume of stone masonry work is S, then

Volume of Stone (m^3) = 0.65 * S * 1.3

Volume of Mortar, M (m^3) = 0.35 * S

If mix ratio of mortar is 1: C,

Cement Quantity (kg) = 1 * M * 1400 * 1.2 * 1.05/(1+C)

Sand Quantity (m3) = C * M * 1.2 * 1.15/(1+C)

III. Plastering

Follow the same formula used for mortar ingredients of stone masonry.

IV. Pointing

Pointing area is taken as 1/3 of plastering area and then follows the same way used for plastering.

V. Water

Water required for mixing, curing, washing dirty construction faces, workers construction and food preparation is roughly calculated from the total cement requirement of the site.

If Z Quintals of cement is required to complete the construction work,

Total volume of water = 280 * Z

Attachment 6: Guideline for sand dam construction

Step 1: Placing reinforcements

These are placed vertically across the entire length of the dam at an interval of 2.5m. They are round bars with a diameter of 12.5 mm and the length depending on the complete height of the dam. The amount necessary can be determined as follows:

No of columns = $\frac{Ld}{2} - 1$

With L_d : length of the dam in metres.

For example: iIf L_d =10, Then No of columns = $\frac{10}{2} - 1 = 4$

Mark the positions of the columns along the building line, then measure the vertical depths to the bottom of the trench and record them as follows.

No 1 =2.53m, No 2=2.27m, No 3 = 3.05m, No 4 = 1.97m

The round bars of the columns are firmly grouted into holes on 5cm deep that have been cut into the foundation at the requested depth (depending on the bedrock material or soil type).

Step 2: Making the foundation blinding slab

A layer of cement mortar (1:3) is prepared on the foundation to the depth of 5cm. When there is no foundation rock the vertical iron bars are placed in the mortar layer.

Step 3: Constructing the first horizontal reinforcement layer

After the mortar layer 12 strands of barbed wire are evenly divided over the building slab along the dam.

Step 4: Constructing the second foundation blinding slab

The barbed wire is covered by 5cm of foundation blinding slab.

Step 5: Masonry comprising hardcore and mortar substructure

After the foundation blinding slab sets and holds the columns firmly, the foundation trench is filled with masonry comprising clean hardcore and mortar (1:4). Mortar for filling should have more water. The joints between the rocks are filled 25mm of this mortar. The rocks should be tapped well to settle completely into all voids. When the filling reaches the level of the back flow, the construction of the backflow should be done along side that of the wall as shown. Masonry comprising is extended to the wind wells.

Step 6: Installation of templates above the sand level

The two templates made of timber are erected at the ends of the spillway for giving the outline of the dam wall, spillway and wing wall. Nylon strings have to be drawn tightly from the inner corners of the templates to pegs hammered into the soil next to the upper end of the wing walls. In this way, the position of the outer sides of the masonry wall can be determined.

Step 7: Constructing Masonry hardcore and mortar substructure within two templates

Flat stones have to set in cement mortar 1:4 along the inner lines of the strings. The next day, the space between the flat stones has to be filled with mortar, 1:4, into which round rubble stones were compacted. After that the flat stones were mortared onto the wing walls so that they could be filled with mortar and stones the following day.

Step 8: Preparation and construction of the stilling basin structure along with the dam body

The base of the dam wall, the spill-over apron and the spillway,(the latter being situated between the two templates), were only raised to 30 cm above the original sand level in the riverbed. A small flooding deposited a 20 cm layer of coarse sand that reached the first stage of the spillway. The spillway was therefore raised another 100 cm above the sand level, for the next stage of the spillway. The wing walls construction is executed at a time while extending each stage of the dam height construction.

Step 9: Stilling basin construction with the stone pavement for flood protection at the bank of the river

Large boulders were concreted into the spill-over apron, to reduce the velocity (speed) and speed of surplus water falling over the spillway and wing walls. Stone pavement were placed as a unit part of the stilling basin and extended at either side of the riverbank to down stream of the flood flow.

Step 10: Construction for the dam wall

The next flooding deposited coarse sand up to the level of the spillway. The spillway was raised another 30 cm above the new sand level. The process of raising a spillway in stages of 30 cm height, may be completed in one rainy season provided the required number flooding occurs and builders are ready for their work without delay.

Step 11: Plastering and pointing works

Exposed dam section at the upstream side, top surface of the entire dam and wing wall section are plastered with cement mortar of ration 1:3. The up stream section of the dam well plastered to be watertight. Down stream-exposed section of the dam wall and the stone pavements extended from the stilling basin were pointed with cement mortar mix ratio of 1:3.

Attachment 7: Guideline for well construction (based on Nissen-Petersen E, 2006)

Step 1: Excavation.

- Select the site and clear the area for excavation
- Mark out a circle of 1-metre radius.
- Dig the well using skilled man power as the well should be excavated straight for the diameter of 2 metres.
- Excavation of well continues until a depth at which sufficient water from the lowest water level of the sand storage can be extracted. Well digging is normally carried out in the dry season when the water table is lowest.
- While the digging process is on going, local construction materials such as sand, stones and preparation of crashed stone will be executed simultaneously.

Step 2: Construction of concrete ring and blocks.

Preparation of concrete ring. This ring will have an outside radius of 75 cm and inside radius of 55 cm. The width of the ring is 20 cm and the thickness is 25 cm. The ring is made in a circular trench carefully dug to the correct dimensions. A concrete of mix of cement, sand and crashed stone (1:3:4) is used and six round of 3 mm galvanized wire are used to provide reinforcement of the ring. Additionally, 16 vertical pieces of wire 60cm long are attached to the reinforcing for fixing rope when lowering the ring in to the shaft. The ring is kept wet for seven days to cure the concrete.

The concrete blocks are made in specially fabricated mould with curved sides. The block is 15cm high, 10cm wide and 50 cm long. The concrete mix is the same as for the ring. The blocks are placed on a plastic sheet and kept wet for seven days for curing.

Step 3: Construction of the well cover.

The well's cover is made with a diameter of 150 cm and thickness of 10 cm; it has a hole of 60 cm in diameter in the middle. This will be used for drawing water. An additional smaller hole, 10cm in diameter, is made to one side as outlet hole to allow an exchange of fresh air. The cover is cast in an excavation in the ground. The same concrete mix is used as before together with 8 rounds wire connected by 31 shorter pieces of reinforcement.

The well lid to cover the centre hole is made in a similar manner with barbed wire reinforcement of 50 mm thickness. Two handles of round bars should be made for lifting.

Step 4: Construction of the well shaft.

The well ring is lowered using ropes if sufficient depth of the well has been reached.

The con is lowered using ropes with the help of at least 15 men because of the weight. The concrete blocks are lowered one by one in a bucket. A cement and sand mortar mix (1-3) is used for the vertical joints and between the ring and the first course.

In the horizontal joints between the first and second course and the second and third course, no matter is used so that water can gain entry. One round 3-mm galvanized wire is used with mortar between the third and fourth course and a step made from a round iron bar is installed. The same sequence continues until there are six horizontal joints without mortar through which water can enter. All subsequent joints are mortared. Steps are installed every three courses. After every six courses, the surrounding space in the well shaft is filled with coarse sand to act as a filter.

The shaft is built till 60 cm above ground level to prevent surface runoff from entering the well. Barbed wire is left sticking out to joint with the reinforcement in the apron that will be constructed around the well shaft to keep the area clean and prevent contamination.

The apron extends around the well shaft and slopes outward to a distance of 1.2 metres. This area is first excavated and then back-filled with hardcore to a depth of 30cm, to which is added a 5-cm layer of ballast. A 5-cm layer of concrete (1:3:4, cement:sand:ballast) is laid on the surface, and barbed wire is placed concentrically and radially for reinforcing. A further 5 cm of concrete covers the reinforcing.

The apron is surrounded by al low wall with a gap to allow spilt water to drain away. Building two steps complete the work, each 30 cm high, to the well cover, plastering as necessary and placing the lid in position.

Before the well can be used, the community must remove all the water and clean the bottom.

Attachment 8: Guideline for sand dam maintenance

Repairing cracks and weak points in the dam
Sand dams require careful maintenance, and immediate repair, as flooding causes hundreds of tons of water to fall over the dam wall and onto the spill-over apron. Flood water may also spill over and erode the wing walls and, perhaps, even over the riverbanks during heavy rains. Extreme changes in temperature can cause the structure crack. If any cracks or weak points are observed in the sand dam, a technical engineer and mason should inspect the whole dam structure and execute repair works before the following rainy season.

Cleaning the well
The well should be covered and closed at all times. Regular checking of the water content is not recommended, since debris or human faeces could fall in the well and contaminate the water. If an animal, chemicals or other health-risk related substances have polluted the well, using the water for drinking purposes is strictly prohibited. The well should be inspected by an expert on water quality and a action plan should be made. If contamination is suspected which can be removed by simple and local water quality measures, then these should always be applied before use of the water.

Cleaning of the outlet
It is very important that the outlet isn't blocked with silt of other fine textured material. It is therefore important to have a good access to the outlet construction. Blocking of the outlet can be prevented by the designing criteria as mentioned in paragraph 3.2.3. Regular cleaning of the riverbed just upstream of the sand dam after a flood can prevent silt from percolating downwards into the riverbed and blocking the outlet. If contamination of the water is suspected which can be removed by simple and local water quality measures, then these should always be applied before use of the water.

Removing silt from the top of riverbed of the reservoir
The riverbed (especially just upstream of the sand dam) and the surrounding area of a sand dam have to be kept as clean as possible: rocks, branches, leaves, dead animals, animal dropping and fine textured material should be removed since they can lead to contamination of the water, reduce the capacity of the dam, lead to blocking of the reservoir and outlet or cause damage to the dam structure. Debris like rocks, branches, leaves and sediment are usually deposited after a flood event, so the time of inspecting is well known. But dead animals, animal dropping and other debris can be deposited any time. It is wise to have a strict schedule for inspection of the dam and its surroundings.