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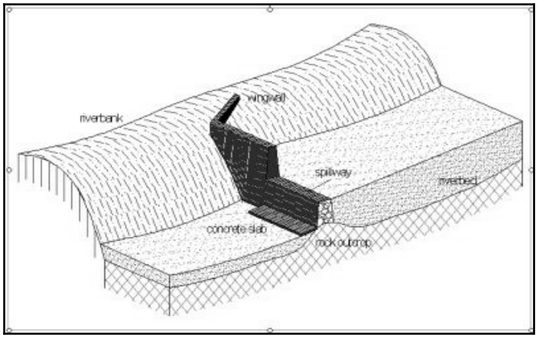
A practical guide to sand dam implementation as an adaptation of water supply to climate change

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.



RAIN
The RAIN Foundation (Rainwater Harvesting Implementation Network) was founded in December 2003. The RAIN Foundation aims to increase access to water on a global scale through the collection of rainwater to benefit vulnerable sectors of society (women and children in particular), with a focus on regions where other means of water supply are not viable or adequate. RAIN works as a global centre of expertise in rainwater harvesting implementation and related knowledge. RAIN's strength is in partnering with organisations that are effective in the differing contexts of its intervention regions and committed to meeting the water needs of those served.

Acacia Water
The Acacia Water, founded as the Acacia Institute in 2002, promotes the exchange of groundwater knowledge and the sustainable use and management of groundwater. Acacia, together with the SASOL Foundation, has initiated a program aiming to promote community based sand dams in regions of Kenya and surrounding countries.

ERHA
The Ethiopian Rainwater Harvesting Network is a non-governmental organisation founded in 1999 by Ethiopian citizens who recognised the imminent challenges resulting from water shortage at global and local levels. ERHA works to promote rainwater harvesting in Ethiopia through advocacy, networking, research and capacity building of its stakeholders. In 2005, ERHA was selected as Rainwater Harvesting Capacity Centre (RHCC) of the RAIN programme, to coordinate and manage the widespread implementation of RWH in Ethiopia.

AFD
Action For Development was founded in ??? and is an Ethiopian non-governmental organisation that implements a programme of integrated rural/pastoral development in selected drought prone and marginalized parts of Ethiopia. The overall objective is to contribute to the attainment of food security and sustainable livelihoods at the grassroots level.

SASOL
The Kenyan Sahelian Solutions Foundation was founded in 1992 to provide local people with water, following the droughts and famines which had struck the arid region. SASOL has since constructed almost 500 dams in the Kitui district in Kenya, providing approximately 120,000 people with water. SASOL plans to disseminate its expertise to other areas and East African countries.

Colophon

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Foreword

Still to be filled, probably by Paul van Koppen

Introduction

Large parts of the world cope with increasing water scarcity during periods of low rainfall and drought. This is further augmented by the impacts of climate change on spatial and temporal rainfall patterns, while growing populations increase the overall water demand. Overcoming periods of low rainfall and drought will thus become increasingly difficult. Maximizing storage of precipitation and runoff will be one of the main challenges in coming decades. Local storage of water is an important strategy in semi-arid and arid regions outside the reach of perennial rivers and where there is no (or little) groundwater available. In general, storage is sought in surface reservoirs. Surface reservoirs, however, are vulnerable to sedimentation and loss of water through evaporation. Thus, groundwater storage will play an increasingly important role, supplementing storage in open reservoirs. A successful example is the construction of sand storage dams in ephemeral rivers. Upstream of the sand storage dam sand accumulates, resulting in a larger groundwater storage capacity of riverbed and –banks. This reservoir fills during the wet season, preventing the loss of valuable rainwater as quick runoff out of the catchment (and out of the reach of the community). Consequently, water availability during dry seasons is prolonged and generally guaranteed. Moreover, compared to surface water storage, water quality is safer through protection against evaporation and contamination.

These techniques are not new however. Concentration of precipitation through runoff and storage, including sub-surface storage, for beneficial use, have probably been in use since 9,000 BC (Oweis et al 2001). Dams obstructing groundwater flow were constructed on the island of Sardinia in Roman times. Sand storage dams were known in the Middle East, but have also been used for water supply in the southwestern United States and northern Mexico since the mid 1800s. Other examples come from Namibia (Stengel, 1968). More recent, Sasol (Sahelian Solutions) has successfully constructed over 500 dams in the Kitui District, Kenya. The project has been evaluated by Acacia Institute (now Acacia Water), the Insitute for Environmental Research (IVM), Technical University (TU Delft) amongst others to define the lessons learned and to upscale the technique. Based on the defined criteria, Acacia Water together with the Rain Foundation, have initiated a project (awarded with the Swiss Re International ReSource Award for Sustainable Watershed Management) to build sand storage dams in southern Ethiopia.

This Agrodok is based on the experiences of the sand dam projects in Kenya and Ethiopia. It strives to give practical guidance to NGOs, local government staff and extension workers in. The publication explains the hydrological and sedimentological principles of sand storage dams (paragraph @@@@@@) and aims to be a guideline in siting (H@@), designing (H@@@) and building (H@@@@) a sand storage dam, including the community involvement which proved to be a key factor in the success of sand storage dams in Kitui District (H@@@@@). It is composed together with a website, www.sanddam.org, on which more detailed information can be found, as well as publications and up to date information on sand storage dam projects.

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1. Sand dam or subsurface dam

1.1 What is a sand dam?

A sand storage dams is a small concrete check dam build in the riverbed of a seasonal sand river[1], perpendicular to the flow direction. 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. When the aquifer is full, the river starts to flow as it does in absence of a sand storage dam. The groundwater flow through the riverbed is obstructed by the sand storage dam, creating a groundwater reservoir upstream of the sand dam. The groundwater flow (base flow) from the riverbanks towards the sand storage dam to the riverbed and the groundwater flow through the riverbed itself will refill the riverbed aquifer upstream of the sand storage dam. Leakage and water losses through evaporation and abstraction of water will still occur but continuous replenishment of the reservoir will take place through groundwater flow. A sand storage dam will however slow down this process, providing 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.

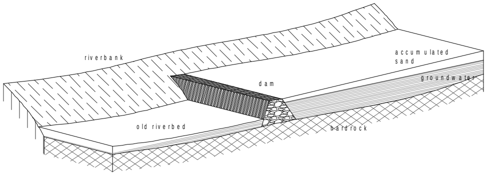

Figure 1a: Typical sand storage dam during the dry season (Borst et al., 2006)
Figure 1b: Schematic cross section of a typical sand storage dam (Borst et al., 2006)

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[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 meters high.

The volume of water available for abstraction is considerably larger than the volume present in the riverbed sands at the start of the dry season, because a large part of the water flows from the riverbanks recharging the sand dam reservoir.

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

Box 1: 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
- Unsuitable for breeding of mosquitoes (malaria) and other insects
- Inexpensive structures with a high level of community involvement.

1.2 Functions of a sand dam

The water within the riverbed and –banks (reservoir) can be used for domestic use, irrigation and watering of livestock. Other functions of sand dams can be:

1. <u>Increasing water supply by storing water in the sandy riverbed:</u>
   The main function of sand dams is to increase the volume of water which can be stored in the riverbed by enlarging the volume of sand in the riverbed[2] and -banks. Water is stored in the spaces (voids) in the sand, which can hold up to 35 percent of the volume of sand.
   Also, sand storage dams prevent flow of groundwater through the riverbed, resulting in a groundwater reservoir upstream of the dam.
2. <u>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, eg by regeneration of vegetation.

[2] In a case without a sand dam, all precipitation will leave the area as river discharge. This water will not be available anymore during the dry season when it is needed. A sand storage dam enables local storage of water, preventing the loss of water during the wet season and making it available during the dry season when it is needed.

3. <u>Sand harvesting and rehabilitating of gullies:</u>
Sand dams can rehabilitate 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 has to be impermeable. Usage of plastic bags filled with soil are more profitable for this purpose (Nissen-Petersen, 2006).

1.3 Types of sand dams

Sand dams can be classified into four types depending in the materials used for their construction (Negassi, A. et al, 2002):

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

2. <u>Reinforced concrete dam:</u>
A dam consisting of a thin wall made of reinforced concrete. It is a durable structure, relatively expensive but suitable for any dam height.

3. <u>Earth dam:</u>
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).

Next to different materials, a differentiation in designs can be made:

1. <u>Horizontal dam with u-shaped spillway:</u>
This dam has been constructed in Kitui Kenya by SASOL. It has been built in a single stage and has a u-shaped spillway. The downstream area of the dam has been reinforced (concrete slab) to prevent erosion of the riverbed by the flood water. This design has been proven to be most effective and practical after many years of experience in Kitui, Kenya. Building in stages has not been necessary because the characteristics of the catchments in Kitui Disctrict are very suitable for sand storage dams (Paragraph @@@).

(Source: Gijsbertsen, 2007)

There is always a danger of the sand storage dam filling with silt instead of sand, which will make the sand storage dam unsuitable. Building a sand storage dam in stages can overcome this problem (Paragraph @@@).

2. V-shaped dam with spill way build in stages:
   This dam with v-shaped weirs has been functioning for 50 years without failure. The spillway is raised in stages of 30 cm height above the level of sand deposited by floods to minimize sedimentation of fine material like silt (Nissen-Petersen, E., 2006).

3. Horizontal dam with several spillways:
   This dam has a double horizontal spillway. But because one spillway is higher than the other, one side of the spillway was heavily eroded by floods (Nissen-Petersen, E., 2006).

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 be constructed by local communities.

1.4 Hydrological and sedimentological principles of a sand dam

1.4.1 Sedimentation processes in a sand storage dam (after Gijsbertsen, 2007)

When a sand storage dam is built in the riverbed, filling of the upstream riverbed will occur after the first heavy rainfall. River discharge will be high, transporting a large quantity of sediments. The grainsize of the transported sediments is dependent of flow velocity. Since most of the land is bare at the start of the rainy season leaving the soils poorly protected against soil erosion, the silt and sand load in the water is high.
The sand dam will influence the flow velocity of the river at some distance upstream of the structure. This will result in sedimentation of sediments which can also be found in the riverbed prior to construction. These sediments form a ridge comparable to the formation of a delta due to the reduction in flow velocity. 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 2). Continuous repetition of this process causes the ridge of sand to move towards the dam, eventually filling the total volume behind the dam.

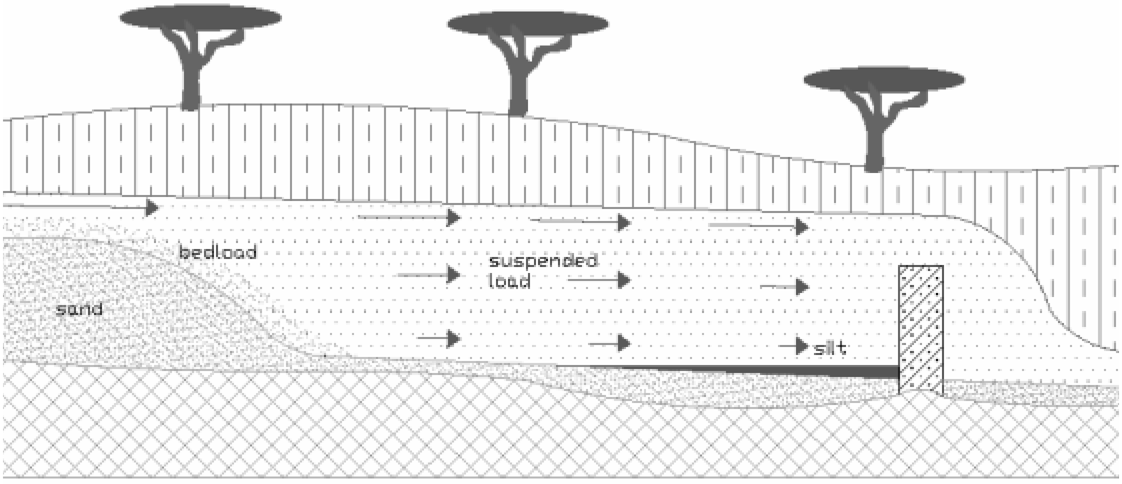

Figure 2: Schematic representation of the sedimentation process (Gijsbertsen, 2007)

The finer sediments have a lower settling velocity[3] compared to the coarse material and are therefore transported over the ridge directly towards the dam. Close to the dam, the flow velocity decreases dramatically. Water upstream of the dam is never fully stagnant during discharge due to turbulences caused by overflowing of the dam (3). Most fine grained sediments will therefore stay in suspension and will be transported over the dam. When river flow recedes, a pond forms upstream of the dam in which even the finest materials can sediment. Only a relatively small part will accumulate behind the dam, resulting in a silt layer directly upstream of the sand dam.

After a rainfall event, baseflow dominates river discharge. Coarse sediments can no longer be transported due to the low flow velocities and are deposited. Filtered of this material, the baseflow water has excess energy leading to erosion of the channel. Fine sediments will thus be (re)taken into suspension and transported out of the catchment, leaving the coarser grained material in the riverbed. Additionally, the silt layer which is left after the river dries, will dry, causing it to crack. Also, wind can erode this layer of fine sediments (Borst and de Haas, 2006). These processes will prevent the accumulation of silt behind the sand dam if the characteristics of the river catchment allow it.

[3] River flow velocity at which the sediment will settle.

These processes will continue until the ‘delta’ reaches the height of the sand storage dam. The sand storage dam is then –FULL-NOT MATURE-DAMS MATURE IN SEVERL SEASONS MEANING THEY REACH THEIR WATER STORAGE MAXIMUM POTENTIAL mature, filled with coarse sand. This can take several wet seasons, depending on the availability of coarse sediments, height of the sand dam, river discharge, slope and rainfall intensity.

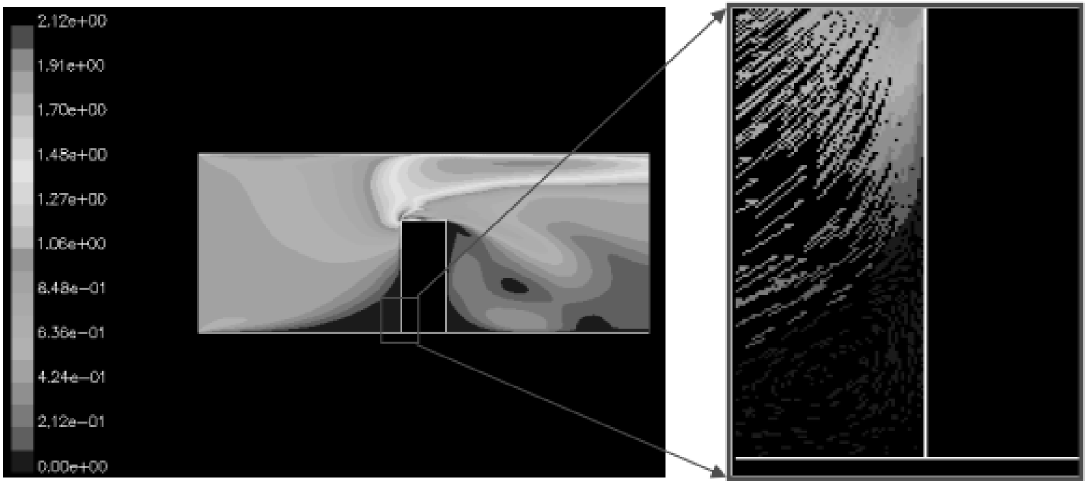

Figure 2: Flow velocity near a dam (m/s) and flow vectors on the right (Source: Gijsbertsen, 2007).

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 baseflow is small or absent. The optimum height of one stage is site specific. It is recommended to consult an expert on this matter.

1.4.2 Hydrological functioning of a sand storage dam

In semi arid areas, precipitation falls in one or two wet seasons. Precipitation is erratic and falls in high intensities over a relatively short period of time. Only a small fraction of the rain will infiltrate in the riverbanks, because these mainly consist of bare, low permeable (often crusted) clays and silts. Due to the high rainfall intensity, the infiltration rate of the soil is often exceeded. A large part of the rain will then flow towards the riverbed as surface runoff instead. This surface runoff water will reach the riverbed where a part of it will infiltrate in the permeable sand. The riverbed will saturate quickly because of its limited depth. Most of the rainwater is thus lost through surface runoff and river discharge. After the wet season, concentrated surface runoff in the roverbed will stop within a short period, since it is rainfall depended. Groundwater levels will start to drop, starting first in the most upstream parts, eventually draining the area.

A sand storage dam increases the groundwater storage capacity within the riverdbed- en banks, by enlarging thickness of the natural riverbed aquifer (the sand layer in the riverbed). Because the sand storage dam prevents groundwater flow through the riverbed, this water will maintain within the catchment and will be locally available in periods of water shortage. The processes are the same as described in paragraph 1.4.1.

After the first rainfall event, the groundwater level in the riverbed can be higher than in the riverbanks due to the low permeability of the banks (and thus slower reaction of the groundwater in the riverbanks) and the obstruction of groundwater flow through the riverbed. Nevertheless, the groundwater level rises higher in the riverbanks. After a few rainfall events groundwater levels in the riverbanks will be higher then within the riverbed upstream of the sand storage dam. From this moment on, groundwater will flow from the riverbanks towards the riverbed.

After a rainfall event, groundwater and river flow will result in drainage of the catchment area. Besides (groundwater) flow, levels will lower due to evapo(transpi)ration, water abstraction and leakage around the sand storage dam (Figure @@@; Hoogmoed, 2007; Jansen, 2007). Groundwater flow from the riverbanks to the riverbed will however continue (first resulting in river baseflow). The importance of baseflow to the functioning of sand storage dams is stated in Paragraph @@@. In the uppermost parts of the catchment baseflow is limited or absent due to the small catchment area contributing to the baseflow. When the waterlevel drops below the surface of the riverbed, baseflow will continue as groundwater flow[4]. A sand storage dam obstructs groundwater flow through the permeable riverbed, creating a groundwater reservoir upstream of the sand storage dam. Groundwater levels upstream of the sand dam are replenished by groundwater flow from the riverbanks and through groundwater flow in the riverbed originating in more upstream river segments (Figure @@@).

The raised groundwater levels directly upstream of the sand storage dam will cause the groundwater to flow through the riverbanks around the sand dam. A cascade of sand storage dams will overcome this water loss, since this water will be used to replenish the aquifer of the downstream sand dam. Water will be available as long as the groundwater flow from the riverbanks continues. The length of this period also depends on the quality of the sand dam in terms of leakage and the storage capacity of the aquifer. More downstream in the catchment, the

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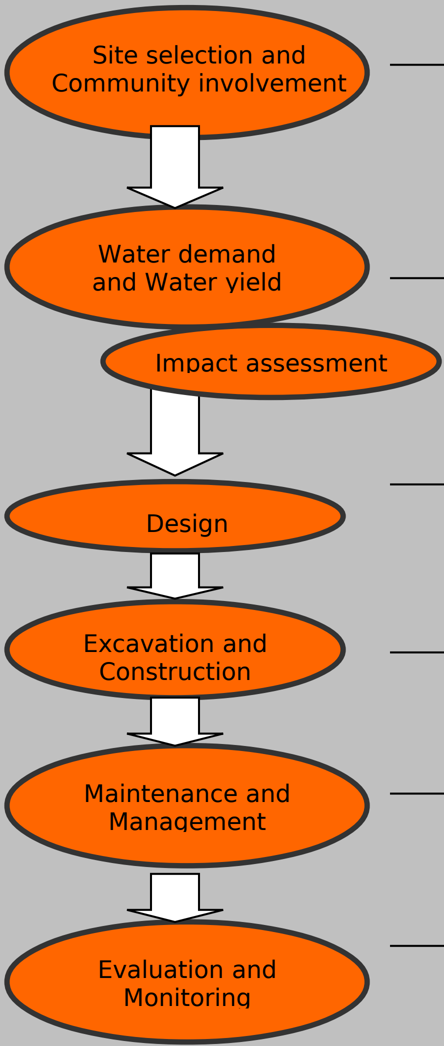
[4] This will occur first in the uppermost parts, gradually proceeding downstream. More downstream in the catchment, the baseflow may continue a few weeks after the last rainfall event of the wet season.

area providing (groundwater) baseflow is larger, as is the volume of baseflow. Groundwater levels in the riverbed will thus drop slower (Hoogmoed, 2007; Jansen 2007), and water will be available for abstraction longer (compared to smaller riverbeds and to the situation prior to sand storage dam implementation).

1.3 Stepping stones within a sand dam project

This manual will guide you trough 5 THERE SEEMS TO BE EIGHT OR THERE IS MERIT IN MAKING THE SUBCATEGORIES STONES.basic steps of sand dam construction. These steps are: site selection, water demand vs. water yield & impact assessment, design, excavation & construction and maintenance & management (see box 5). 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.

Box 4: Stepping stones in sand dam construction



Chapter 2:
1. Possibility map for sand dams (catchment level)
2. Involving/organizing local community(s)
3. Fieldwork: collecting field data, verifying possibility map and taken measurements at potential riverbeds for sand dams (riverbed level)
4. Selecting location(s) for sand dam(s)

Chapter 3:
1. Determining current water use, water usage and water demand,
2. Estimating water yield potential sand dam locations.
3. Determining social, economic and environmental impacts of sand dam(s) within the catchment.

Chapter 4:
1. Calculating maximum discharge in riverbed
2. Calculating maximum dam and spillway height
3. Designing the total sand dam
5. Calculating the Bill of quantities (materials and labour)

Chapter 5:
1. Setting the trench
2. Excavation of the trench
3. Construction of the sand dam

Chapter 6:
1. Training of local communities
2. Management
3. Technical maintenance

Chapter ???
1. Technical evaluation
2. Water user and usage assessment
3. Impact assessment

2. Site selection

2.1 Introduction

Site selection is the first and most important step in constructing a sand dam. The site selection will determine the success of the dam. It has two different aspects: selecting a suitable site based on both physical and social aspects of an area. This chapter will guide you through site selection by 3 steps:

1) Selecting potential catchments for sand dams from a possibility map for sand Dams (paragraph 2.2)
2) Selecting potential riverbeds for sand dams by combining the possibility map with field data (paragraph 2.3.1) by taking measurements along riverbeds and interviewing local communities (paragraph 2.3.2).
3) Selecting riverbed sections and the sand dam location(s) (paragraph 2.4)

2.2 Selecting potential catchments for sand dams

For quick evaluation of the suitability of an area for building sand storage dams, and thus making site selection more specific and efficient, it is important to first make a quick scan (desk study) of the selected catchment or area by using digital or analog data. The result of this study will be a probability map for building sand storage dams.
If available, the below mentioned data can be useful to provide a first indication whether a catchment is suitable for building sand storage dams.

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

   By knowing the characteristics of a catchment, riverbeds can be selected where sand dams could be suitable. A topography map gives general information about the catchment, such as where the villages are located. The presence of communities (the beneficiaries) in the area in the dry period (nomads or permanently) is a condition.
   It also shows where the rivers are located, and the size and general characteristics of the catchment. Rivers may have a maximum width of 25 meter (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). This usually indicates hardrock basement, which may produce sand (see also point 3: Geological map).
2. <u>Digital Elevation Model:</u>

A digital elevation model (DEM) contains information on the morphology of the area (elevation, slopes). A local drainage direction map can be calculated from it, which will give the drainage pattern of the catchment. Furthermore, information on the slopes (riverbanks and riverbed) within a catchment can be derived from the DEM. The most suitable locations for sand dams have a slope gradient between 1.5 to 4 percent. In some cases sand dams can be constructed in areas with slope gradients up to 15 percent. The particle size of sediments accumulated along streams and in riverbeds (and thus upstream of the sand storage dam) is proportional to the slope gradient, whereas the depth and the lateral extent of the 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 (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:

The local geology is responsible for the deposition of fluvial sediments in the riverbeds. A geological map can thus indicate whether a catchment has the potential to produce coarse sand. The geology is the source of the material in the riverbed. For example granitoid hardrock will produce coarse sand while shales will produces fine (clay or silty) material.
For example, the geology of Kenya is available USGS. This map is part of the open file report 97-470A, version 2.0 2002. with a 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:

By using aerial photographs and satellite images you can locate riverbeds by the morphology. Aster satellite images can be used to indicate sandy riverbeds and different types of geology through the reflection (ratio). These images can be downloaded from (@@@@@@@@@).

5. Precipitation and evaporation data:

The effectivity of sand storage dams appears to be less sensitive to precipitation (Borst and de Haas, 2006; Hoogmoed, 2007). However, when locating suitable regions for sand storage dams the precipitation will be important in influencing the availability of coarse grained material in the riverbeds. Higher annual precipitation will lead to an increase of storm events, these areas might have a higher potential than regions with a lower annual precipitation.

Also, to calculate the yield of a sand dam, it is essential to know the climatologically behavior of an area. By getting data on precipitation and evaporation, a analysis of the dry and wet seasons can be made while in the same time a estimation can be made of the expected water harvesting potential.

The Tropical Rainfall Measuring Mission (TRMM) satellite carries a precipitation radar with a spatial resolution of 4.3 km and covers the region between 35°N and 35°S. Data is a vailable on the internet on monthly basis (http://neo.sci.gsfc.nasa.gov/Search.html). Another option is using data from LocClim (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 for determining the maximum flood height and therefore the necessary height of the riverbanks (see also paragraph 2.2.1: criteria 2). It can provide information on the filling time of a reservoir and on the behavior of a catchment during rainfall.

Also, the potential riverbed has to be a seasonal river. Nevertheless, it is very important that baseflow does occur, because this prevents the sand storage dam of filling with fine (unsuitable) sediments (Paragraph @@@).

Local communities and local water authorities can indicate whether the river flow dries up immediately after a rainfall event or if the river will continue to flow although no additional rain has fallen.

2.3 Selecting potential riverbeds

2.3.1 Selection criteria for riverbeds

The results probability study described in paragraph 2.2 is a first evaluation of which catchments are suitable for constructing a sand storage dam. To fine tune to suitable river sections and finally to sand storage dam locations, community involvement is crucial. Also, community participation will prove to be the key in building and maintaining the sand storage dam.

The steps in creating community involvement are described in paragraph 2.3.1. Although members of the community should be involved all following steps of the process, especially step 2 is important in the phase fo identification of suitable sand storage dam locations. This includes:

- assessing the water problems of the targeted communities,
- organizing meetings or group dialoguing concerning the development issues within the project area,
- Informing and educating on the various types of water harvesting technologies, in particular the sand dam technology,
- assessing possible sand dam locations with the community.

After making a potential sand dam map, it is necessary to verify the potential locations in the field by site surveys. An important part is gathering information through dialogue with the community, indicating village locations, grazing lands in wet and dry season and an inventory of existing watering points (Subsurface Dams: a simple, safe and affordable technology for pastoralists, 2006).
The most potential stretches of a riverbed are identified by walking in them together with the community members. First draw a sketch of the riverbed. Then walk and dowse, if capable of that, in the riverbed while plotting the following information on the map:

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.

Botanical name	**Depth to water-level (m below surface)**
Cyperus Rotundus	3 – 7
Vangueria Tomentosa	5 – 10
Delonix Elata	5 – 10
Grewia	7 – 10
Markhamia	8 – 15
Hyphaene Thebacia	9 – 15
Borassus Flabellierfer	9 – 15
Ficus Walkefieldii	9 – 15

Table 2: Water-indicating vegetation with root depth.

2. Location of waterholes, hand dug wells and boreholes, their depth to the water table and quality of the water:

Waterholes (places where local community's gets water from the riverbed) are proof that water is present in the riverbed, and that it is not leaking away to deeper grounds. Pay special attention to the wells which will provide water for the longest period during the dry season.

The water quality in the waterhole is an indication of the quality of the water which can be harvested after the building of a sand dam. THIS IS NOT TRUE FOR SASOL HAS BUILT SAND DAMS ON KUNKER WHICH WASHES AWAY. IT ALSO HAS DAMS WHICH ARE BUILT ON SALINE SECTIONS OF RIVERS AND AFTER A CASCADE MATURES THERE IS NO SALINITY.However, protective measures of waterholes against animals can make significant improvements (paragraph 7.2).

3. Location and types of rocks and boulders.

Pay special attention to the presence of calcrete, 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.AGAIN THIS IS NOT TRUE SEE ABOVE 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 sand sedimenting upstream of the sand dam should be coarse enough to allow rapid infiltration of water. A good indication of the material which will sediment after construction of a sand dam is the material already present in the riverbed. Coarse sand has a larger infiltration capacity and water can be abstracted more easily.

5. Two high and strong riverbanks:

Suitable riverbeds must have two high riverbanks. During flood events the water should not leave the riverbed. If flood water is allowed to flow over the wing walls and riverbanks, it will erode the riverbanks and cause the river to change its course, thereby leaving the sand dam as a ruin in the riverbank. By using flood data and local information from local water bureau and community's, 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 + safety heightHOW DO YOU ESTABLISH THESE PARAMETERS WHERE THERE IS NO FLOW DATA. FURTHER WHAT IS

SAFETY HEIGHT? PEHAPS DATA SHOULD BE ON EXTENDING WINGS AT TIMES SUBSURFACE TO MITIGATE ABOUT RIVERBANKS. SEE SASAOL MANUAL

The safety height is depending on regional circumstances and experience.
The riverbanks should consist of bedrock or a strong THIS ARGUMENT ON STRONG SOIL TYPE IS DUBIOUS.SASOL IS AWARE THAT IT IS IN PAST MANUALS. SASOL AND UTOONI EXPEREIECE- NOW OF OVER 1,000 DAMS AND ALL TYPES OF SOILS AND RIVERS SHOWS THAT LOCATING A SAND DAM ON ANY TYPE OF SOIL LEADS TO SYSTEMIC LEAKS WHICH OVER YEARS NULLIFY THE DAM.soil type to ensure a strong anchoring of the dam into the riverbanks (see also paragraph 4.4). Dam walls should never be built on fractured rocks or large boulders because they can have cracks, which will drain water from the reservoir into the ground below.

6. A (preferred) maximum width of 25 meter:
A riverbed width preferably doesn't exceed 25 meters. THERE ARE MANY DAMS OVER THIS SIZE. THE KEY IS SOLIGDITY OF THE BASEThe reinforcement required for such kind of long dam walls is too expensive; hence the sand dam will not be cost-effective.

7. A impermeable (bedrock)layer:
To ensure storage of water within the sandy riverbed, the dam has to be built onto solid bedrock or an impermeable layer. Otherwise the water will infiltrate into the subsurface layers.

8. Type, suitability and availability of construction material:
This will help to decide what type of dam (as described in paragraph 1.2) to construct. Obviously a masonry dam is not a good choice if there are no stones in the area and transporting them from other areas is very expensive.

9. Presence of riverbed crossings:
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.

10. Names of houses, schools and road crossings near the riverbed:
In order to make an assessment of the number of people who will be using the sand dam(s), an inventory should be made. For transportation of materials it is important to know the most suitable roads or routes.

To avoid conflicts, care should be taken in areas where the dam site is owned or used by two or more villages or individuals. The new sand dam shouldn't lead water related problems for people living in downstream areas. A quick scan impact assessment has to be made of the area before starting the site selection, which include social, economic and ecological aspects. After completing the site selection, a detailed impact assessment can be made (see paragraph 3.2).

2.3.2 Community involvement and formation of Water Committee

Involvement of beneficiaries is the process of sensitizing and mobilizing communities to improve the quality of their life through collective self-help. Many types of community organizations 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 will contribute to the success of the construction and maintenance of the sand dam. 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.

Within each confirmed site, the community has to elect a committee to supervise the implementation, operation and maintenance procedures (Munyao et al, 2004). This so-called water committee consists of a representative group of the community and will take part in several trainings (further discussed in chapter 6). The community's awareness and the required level of their involvement in the project process will hence be ensured. The water committee will have the following objectives:

- to create a forum to critically examine the community's situation, identify their problems and suggest possible solutions.
- to explore which factors lead to failed projects and which factors make successful projects. The failure creating factors can then be avoided, whereas, the success promoters can be embraced.
- to examine the role of social structures, community institutions, processes and their interaction with other institutions for mutual benefits.
- to make an action plan to tackle their problems with suitable solutions, to achieve their goals and aspirations.

In attachment 3, the steps to be taken in community involvement during site selection are described in further detail.

2.4 Selecting riverbed section(s) and the 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:

1. Storage capacity and extraction percentage of sand:
Water storage and extraction depend on the riverbed material. Water extraction can be most profitable when extracted from riverbeds containing coarse sand than from riverbeds with fine textured sand. No water can be extracted from riverbeds containing silt, such as in sand dams whose spillways were built in stages higher than 30 cm. Silt and sand extractability was tested and classified as follows:

	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%

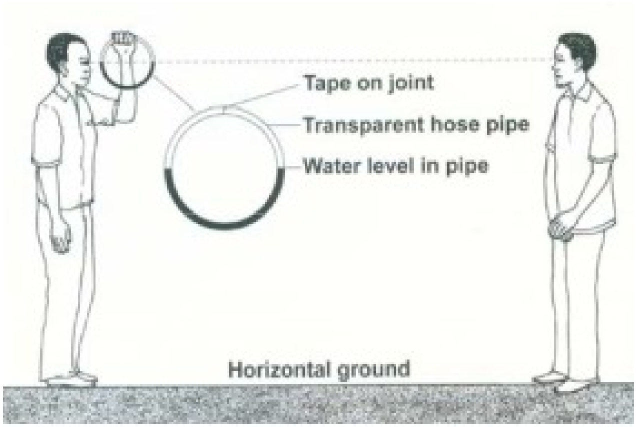
Table 3: Sand fractions, saturation and extraction rates (Nissen-Petersen, E. 2006).

The porosity and extractable capacity of sand can be determined through are found by saturating 20 liters of sand with a measured volume of water. The water is then drained out of the container and measured by removing a plug from the bottom of the container. By measuring the amount of water extracted and knowing the time of percolation, a good estimate can be made of the extraction rate of the riverbed sediment.

2. Gradient of the riverbed:
Measuring the gradient of the riverbed can be done by using a circular transparent hose, half-filled with water. The person standing at point No. 1 looks using the levelling tool. Another person should stand upstream of the person holding the levelling tool with a long polewhich is held vertically.
The person with the levelling tool should view the water levels in the tube in one line. He 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:

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



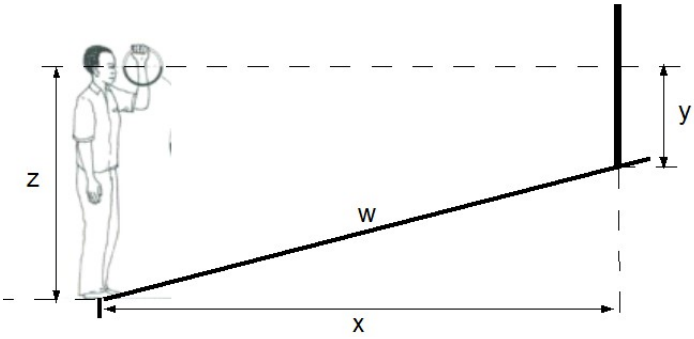


Figure @a Usage of the levelling tool at horizontal grounds (After Nissen Peterson, 2006a).
Figure @b Usage of the levelling tool at sloping grounds (After Nissen Peterson, 2006a).

The riverbed slope must be higher than 5% to ensure deposition of sand. Below 5% settlement of silt will occur.

3. <u>Field measurements for a plan, longitudinal and cross profile:</u>
Probing will be used to draw riverbed profiles to identify the deepest place from which water should be extracted and the shallowest place where the wall for a sand dam can be constructed.
The probing rods are 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. Also, a tripod ladder is used for hammering long probing rods into the sand and a mason hammer is needed for hamering the rod into the riverbed. Use a datasheet as shown in Appendix@@@@@@@@@@.
A probing rod was hammered down in the middle of the riverbed until it hit the floor under the sand with a dull sound. Then the level of the sand was marked on the rod and it was pulled straight up without twisting. The following data was noted on the data sheet:

- The depth of water is measured from the tip of the rod to the water indication mark.
- The depth of sand is measured from the marked sand level to the tip of the rod.
- The coarseness of sand is seen in the notches of the rod.
- The type of floor under the sand is seen at the tip of the rod.
- The width of the sand in the riverbed is measured.
- The height of the banks is measured with two long tape measures.
- The presence of water-indicating vegetation, waterholes, roads, etc. is noted.
- The next probing is measured at regular intervals, for example 20 metres.

The data gathered by the above described survey results in a map of the river section, showing information about the river length and width, locations of cross-sectional, longitudinal profiles, water-indicating trees and waterholes.

Figure 3 is an example of a plan. The plan shows information about the river length and width, locations of cross-sectional, longitudinal profiles, water-indicating trees and waterholes.

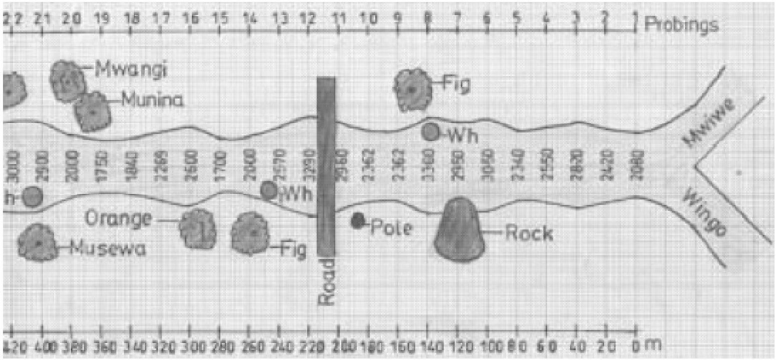


Figure 3: Example of a plan of a river section (Nissen-Petersen, E. 2006).

Figure 4 is an example of a longitudinal profile. It is important to locate the points where the sand is deepest (here: 3.0 m deep at point No. 14 and 1.75 m deep at point 21) and where natural subsurface dykes (of solid bedrock or impermeable soil) area located (here: point 11, 18 and 23). The locations with deep sand are the potential reservoir of a sand dam and the natural dykes are potential locations for a sand dam.

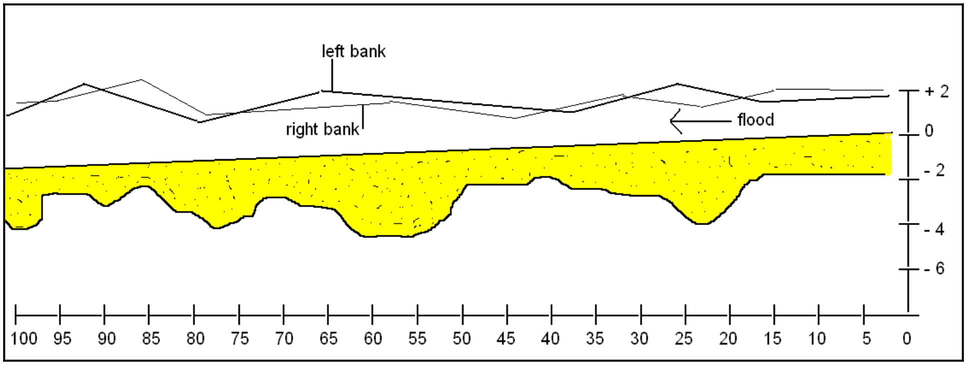
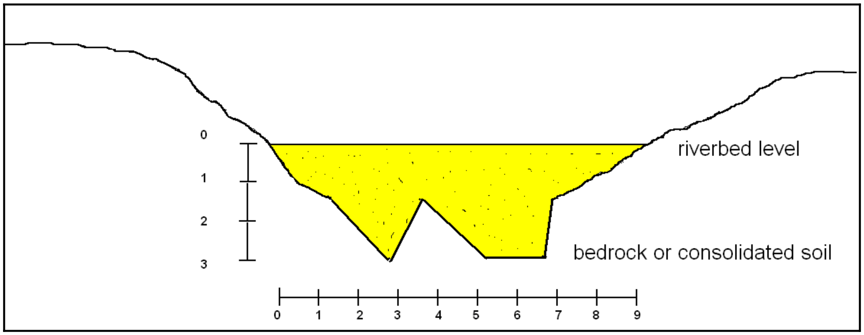


Figure 4: Example of a longitudinal profile of a river section.

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 4 this is at 60 metres. By knowing the longitudinal and cross-sectional profile, a calculation of the reservoir capacity can be made. In figure 5 an example is given of a cross-section where the sand is deepest. It is important to take measurements every 1 or 2 meter across the riverbed to determine the riverbed morphology.



Probing Number	Distance (m)	Depth of sand (m)	Type of sand
1	0	0.5	Sand
2	1	1.25	Coarse sand
3	2	2	Coarse sand
4	3	3	Sand
5	4	1.75	Coarse sand
6	5	3	Coarse sand
7	6	3	Sand
8	7	1.25	Sand
9	8	0.75	Sand
10	9	0.25	Sand

Figure 5: Example of cross profile and probing results.

The longitudinal profile showed that the natural underground dyke at point 18 is the most suitable for a sand dam (see figure 4). This is where the bedrock material or impermeable layer reaches closest to the surface. Therefore the excavation depth can be reduced which will reduce excavation time, manpower and material costs.

3. Water demand vs. water yield

3.1 Water use assessment

The water demand of the local community has to be investigated before starting a water project: it has to be clear that a community is really in need of an additional water source next to there current water sources. The community has to fully support the sand dam project and has to be aware of the advantages as well as disadvantages of a sand dam. This has already been described in paragraph 2.3.1. By creating awareness on the water problems, possibilities of a sand dam for solving these problems and ensuring full participation of the community,

The 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 you more insight into the basic water needs of a community and if there are shortages of water, water quality problems or other issues. Within a water use assessment, future aspirations can also be taken into account. The water use assessment has to be executed by the implementing organisation before locating 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 member of the water committee itself 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 4 a 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.

3.2 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 en 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 for a large part compensates the loss of water through leakage, evaporation and abstraction (paragraph @@@@). The riverbanks must be included in the calculation of the water yield. Appendix @@@ contains a calculation tool, which enables a rough estimation of the volume of water which can be abstracted.

Calculating the volume of water present in the riverbed is done using equation @@@.

The volume of water in the riverbank can be estimated using equation @@@@.

Box 2: General assumptions of the calculation tool:

- The calculations are a severe simplification of the actual situation, and thus only give an indication of the potential water yield of a sand storage dam.
- The results gained by these calculations are thus only intended for giving an indication of the potential water yield of a sand storage dam.
- Authors can not be held responsible for any data that is used as input or conclusion that is drawn based on this data.
- We strongly recommend an expert is consulted before proceeding with building a sand storage dam.
- More information on sand storage dams can be found on www.sanddam.org.
- Contact information can be found on www.acaciawater.com or

4. Design

4.1 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.

A sand dam has four main parts:

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

In the next paragraphs the design of each specific part of the sand dam will be addressed. Some of the sand dam dimensions are fixed in the SASOL approach. Below a summary of design criteria from Nissen-Petersen (2006) is given to provide some flexibility in the user's practice of designing:

- The width of the base should be *0.75 (3/4) of the height of the dam* and the thickness of the key of the wing walls should be *0.55 of the height of the dam*: to counter balance the force of the water and sand in dam reservoirs against the dam.
- The width of the crest and its height on the downstream side should be 0.2 (1/5) of the height of its dam wall.
- The front of the dam should leaning downstream with a gradient of 0.125 (1/8) of the height of the dam.

4.2 Dam and spill way height

To determine the dam and spillway height at a specific location, it is very important that the water level and flood line (in figure 5: New WL and New FL) will remain below the riverbanks after construction of the dam, or at a height that will not cause flooding up- or downstream 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 5).

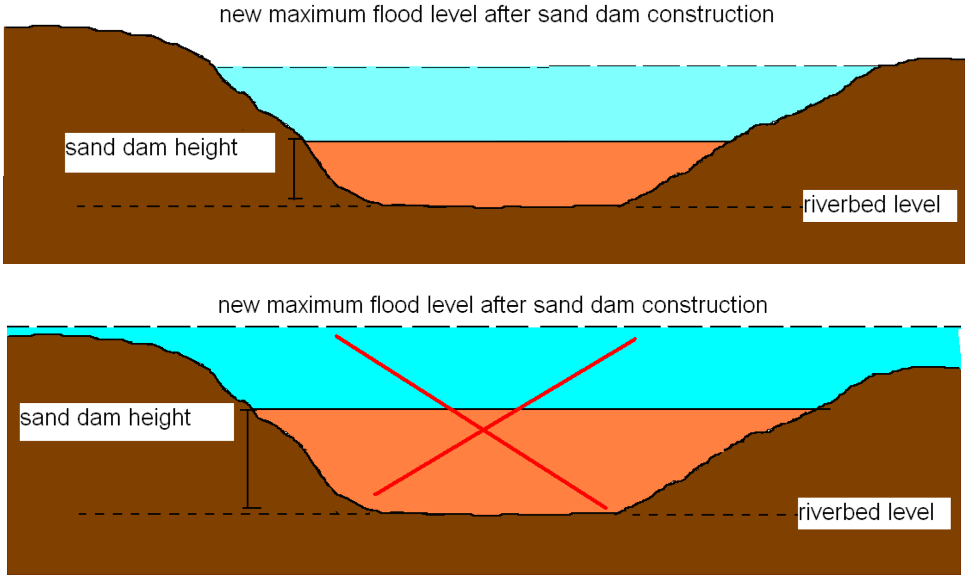


Figure 5: Examples of sand dam heights: do's and don't's.

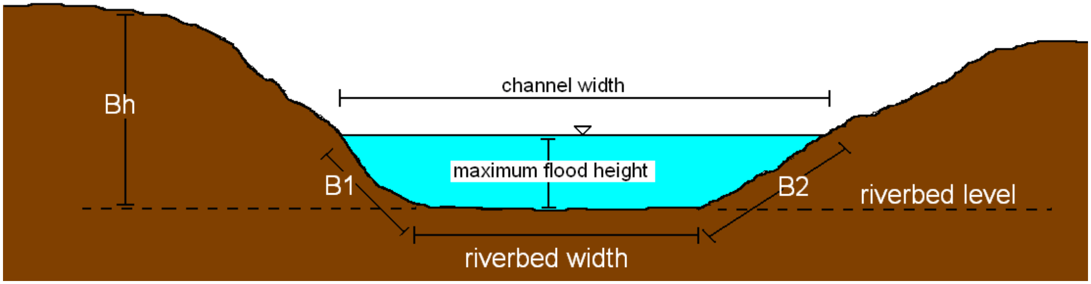
In figure 5 the top picture shows a sand dam height by which the maximum flood level will remain lower than the riverbanks, while the picture below shows a sand dam height by which the maximum flood level will exceed the riverbanks. In this scenario flooding will occur.

The most practical way of calculating maximum discharge is by getting information in the field and from the selected beneficiaries on flood levels.

The 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 25 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.



Maximum discharge in riverbed section:

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

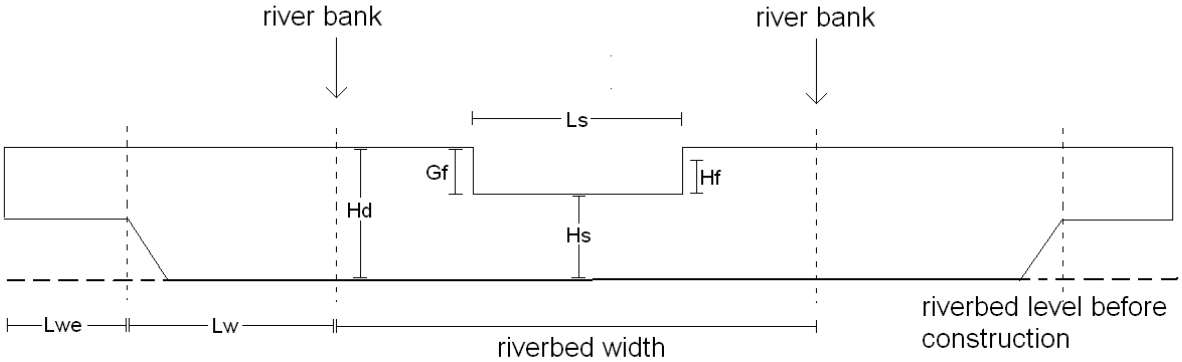
Q = maximum discharge in riverbed section (m^3/s)
n = Manning roughness of riverbed
A = wetted cross-sectional area (m^2), by: ½*(channel width + riverbed width)* flood height
P = wetted perimeter (m), by: B1 + riverbed width + B2
R = hydraulic radius (m), by: A/P
S = slope of riverbed (m/m)

4.3 Spillway, wing walls and stilling basin dimensions

The maximum discharge (as calculated in paragraph 4.2) is used to determine the spillway dimensions, calculated by the formula is given in the box below.

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)



Legend of cross-sectional profile width dimensions 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_s = length spillway (m)

L_w = length wing wall (m)
L_{we} = length wing wall extension (m)

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 meters into the riverbanks;
- in hard soils: approximately 5 meters into the riverbanks;
- in hard and impermeable soil: approximately 0 – 1 meter into riverbanks;

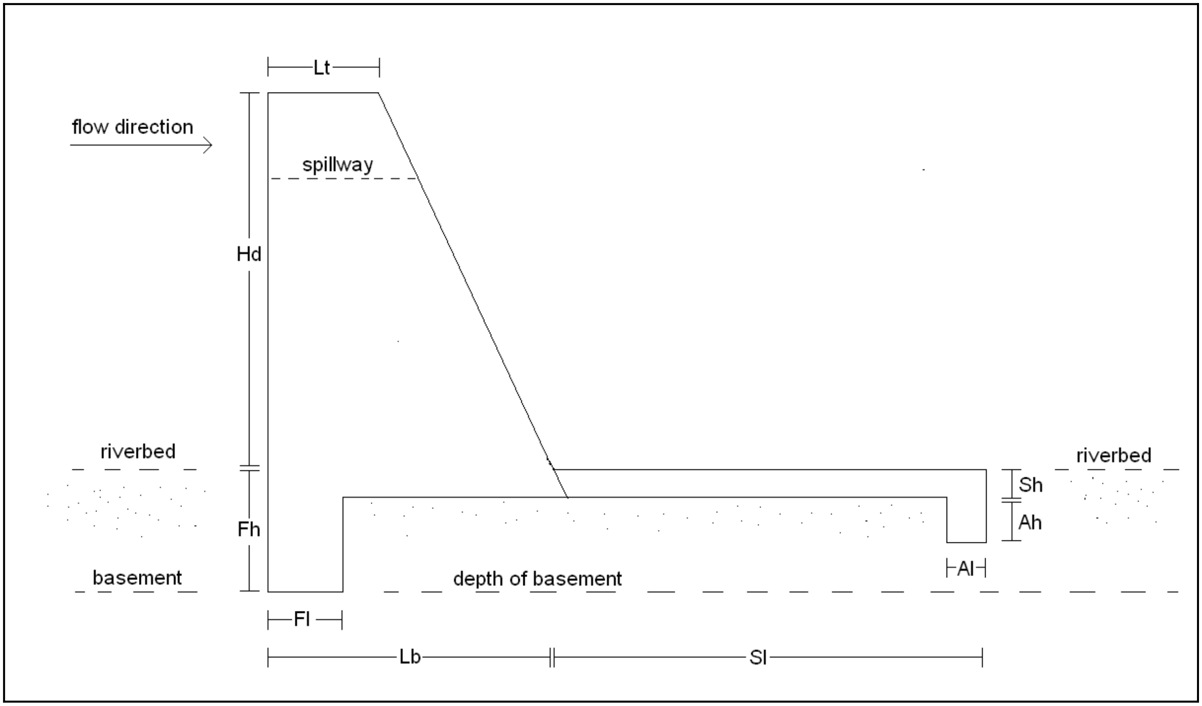
- in rock formation: no need of constructing in riverbanks.

The length of the wing wall (L_w) should be approximately 2 meters into the riverbanks. The length of the wing wall extension (L_{we}) should be approximately 5 meters. This is an example of wing wall dimensions in loose riverbanks.
Currently a research is done by SASOL and ACACIA Institute on the water balance at sand dams, 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



Legend of cross-sectional profile length dimensions sand dam

H_d = height of dam (m)
F_h = height of foundation (m)
F_l = length of foundation (m)

L_t = length of top of dam (m)
L_b = length of base of dam (m): 1 m

S_l = length of stilling basin (m): 0.1 m
S_h = height of stilling basin (m): 0.5 m

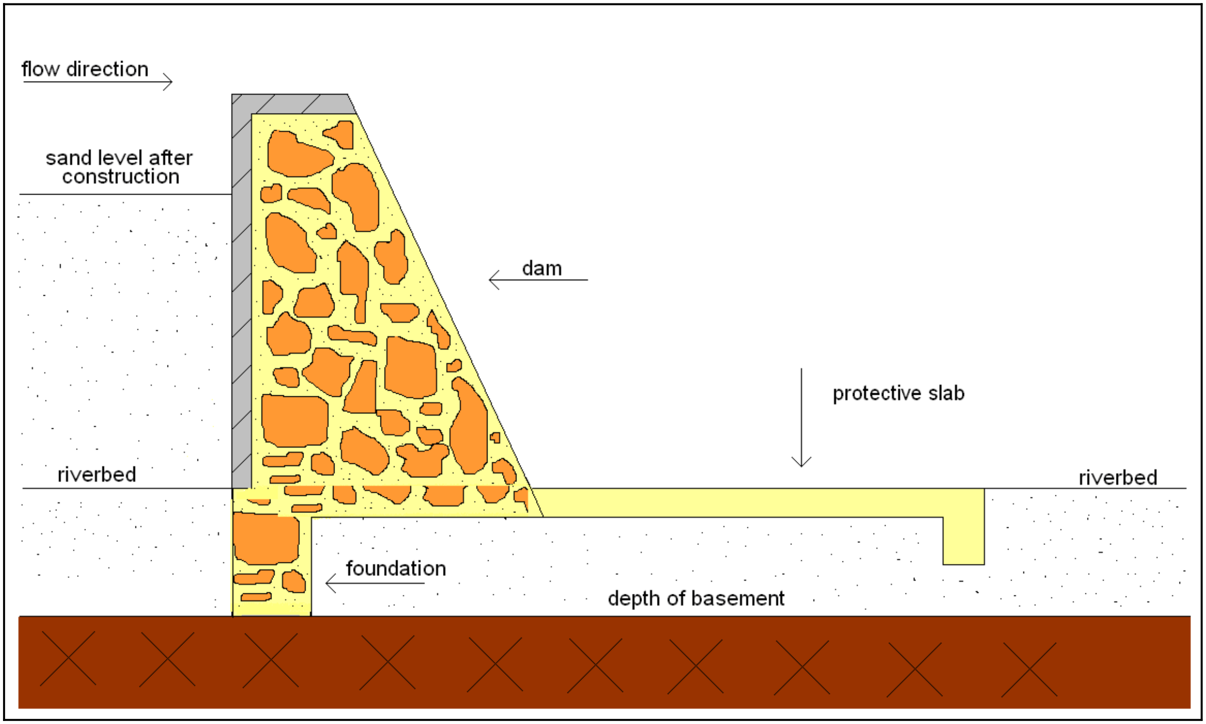
A_h = height of anchor (m): 0.4 m
A_l = length of anchor (m)

5. Excavation and construction

5.1 Materials and Labour

5.1.1 Materials

The types of materials needed to construct a sand dam depend on the type of dam (paragraph 1.2) 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 (reinforced) masonry dams.



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"	Foot?	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 core)*	m^3	31.25	233.2	2.99	7,288
Sand *	m^3	19	66.3	0.85	1,260
Water	m^3	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**

* 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.

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

In attachment 4 you will find the guidelines to calculate the quantity of the materials derived from the dimensions of the dam.

5.1.2 Labour

In table 5 an example is given of the bill of quantity for labour costs. As is mentioned before in paragraph 3.2.1, the contribution of community workers will reduce costs.

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 labor costs in ETB (2007).

5.2 The trench

5.2.1 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:
- Measure the appropriate distance from on one of the river banks depending on bank characteristics and fix a peg at the distance.
- 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.

The marked trench should resemble the figure shown below.

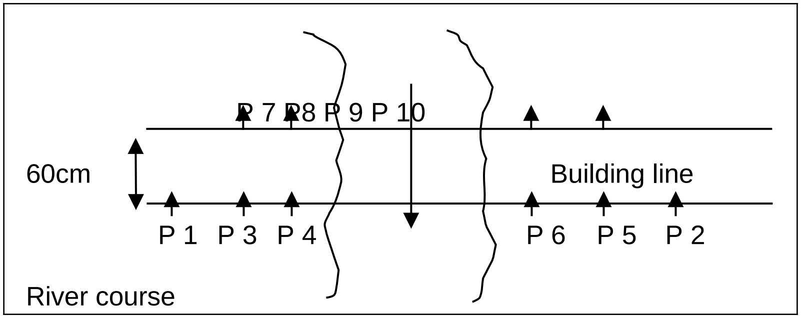


Figure 6: Example of setting a trench with pegs (Munyao et al, 2004).

5.2.2 Excavating the trench

The marked trench is dug guided by the building line (see figure 6). The depth of the trench is guided by the depth of impermeable material in the ground to avoid seepage below the wall. When scooping, the scooped material should be placed downstream to avoid filling the reservoir upstream. If the dam is build into bedrock material, it is advisable to cut a trench into the rock to ensure a secure jointing of the rock and mortar. Investigations should be carried to avoid fractures and areas of weathering. This can be done by poring water on the suspected weathered zones. The rock surface should be cleaned to avoid missing the fractures and areas of weakness. If clay or marrum is discovered, it should be dug into 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: RAIN Foundartion, R. Meerman (2007).

5.3 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 largeMEANING WHAT or highMEANING WHAT 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 5 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.

5.4 Water extraction from a sand dam

5.4.1 Types and locations of water extraction points

A well for a sand dam is practically the same as a shallow hand dug well. It must be covered and water will be extracted using a hand pump. The wells should be constructed at the deepest spots within the riverbed, which is not necessarily close to the dam. A maximum of 3 wells should be located on the upstream side and very close to the dam embankment: approximately within 3 to 10 metres. The yield of the potential well should also 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. If this cannot be identified, wells should be located 3 to 20 meter upstream of the dam and about 5 meters to the side of the embankments. Box 8 provides practical guidelines to identify potential well locations.

Photo: SASOL sand dam site,Kitui, Kenya (2007).

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 (Kitui) sand dams: Short mission report, November 2005).

Photo: MS Consultancy sand dam site, Ethiopia (2005).

Box 8: Practical guidelines for locating wells.

As the flow of water in the soil dependable on the geomorphology nature of the ground up stream of the dam, determining the right location to get the maximum yield of water requires a complex ground water flow analysis and investigation. However, experiences in Kenya and Ethiopia showed that practical site specific information can be used to locate wells. 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 deeper compared to the bedrock material or compacted layer:
  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.

5.4.2 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. If a well is constructed at the centre of a river, it 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 meter 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 5.

5.4.3 Water extraction systems from wells

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.

6. Management and maintenance and monitoring

6.1 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 projectPLANNING AND implementation;
- Enhanced awareness on the 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: SASOLAND UTOONI DOES SEVERAL TRAININGS FOR OVER AND ABOVE THE DAM ITSELF THE TOTAL PHYSICAL CATCHMENT NEEDS PROTECTION, A CASCADE CAN BE CONTAMINATED AND THE INVESTMENT MUST TRANSLATE TO INCOMES FOR A DAM IS NOT JUST FOR WATER BUT A PLATFORM FOR DEVELOPMENT.SYNTHESIZE THE ETHIOPPIAN AND THE KENYAN EXPERIENCE FOR PAST FAILURES HAVE BEEN DRIVEN BY THE TRAINING FAILURE.

- Sessions on the project planning, implementation and management of activities. This is already discussed in paragraph 2.3.1;
- 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 (see paragraph 2.3.1) and at least two other community members (future caretakers) to participate in the trainings and sessions.

6.1.1 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 9: 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 10: Sanitation and Hygiene training THE ISSUE IS NOT AWARENESS. IT IS USE.

This training focuses on creating awareness within the community on contamination risks of their water sources. 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.

6.1.2 Technical training on CONSTRUCTION operation, management and maintenance OF INDIVIDUAL DAMS AND UPSCALING TO CASCADE MANAGEMENT NEED TO BE COVERED HERE.

The water committee (see paragraph 2.3.1) 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 11: 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.

6.2 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.

6.3 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 8 some guidelines are described for small technical maintenance issues.

7. Monitoring and evaluation of the sand dam

Impact assessment > experiences ACACIA Swiss Re

- Ensure proper operation of the system i.e. the abstraction system,
- Ensuring the system is not exposed for external and natural damage
- Establish system that ensure the sustained operation of the system
- Follow up for observed short commanding and consulting concerned governmental body for required maintenance
- Ensure full participation of local beneficiaries in maintaining and ensuring efficient functioning of the system.

THE SASOL SYSTEM IS BASED ON COMMUNITY AND NOT GOVERNMENTAL PERSONS. THUS THE SEQUENCE ABOVE IS NOT APPLICABLE ALWAYS. IT MAYBE IMPORTANT TO SEGREGATE SYSTEMS WHICH INVOLVE GOVERNMENT FROM THE COMMUNITY DRIVEN ONES FOR THEIR OUTPUTS AND OUTCOMES ARE RADICALLY DIFFERENT.

Vulnerability Categories	Vulnerability indicators	Before dam construction	After dam construction
Agriculture	# of cash crops	1.5	2.8
	% 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	31.6	0

Table 5: Measured social and economic impacts of sand dams in the Kitui region, Kenya (Thomas, 1999).

7.2 Water quality

7.2.1 Treatment and the local context

As most public health problems are related to contaminated water and hygiene customs, access to good quality water is one of the most important factors to improve people's health. Generally treating and filtering of water seems the obvious method for obtaining a certain water quality. However, if contamination resulted from for example the use of toxic materials or by poor management or maintenance, re-contamination will certainly occur. By following a top-down method of preventing contamination, a more effective approach in preventing contamination can be reached (see figure 3).
THIS DIAGRAM DOES NOT MAKE SENSE IN TERMS OF THE STRUCTURE OF RURAL WATER PRODUCTION CONVEYANCING STORAGE AND USE-SEE SASOL MATERIALS.

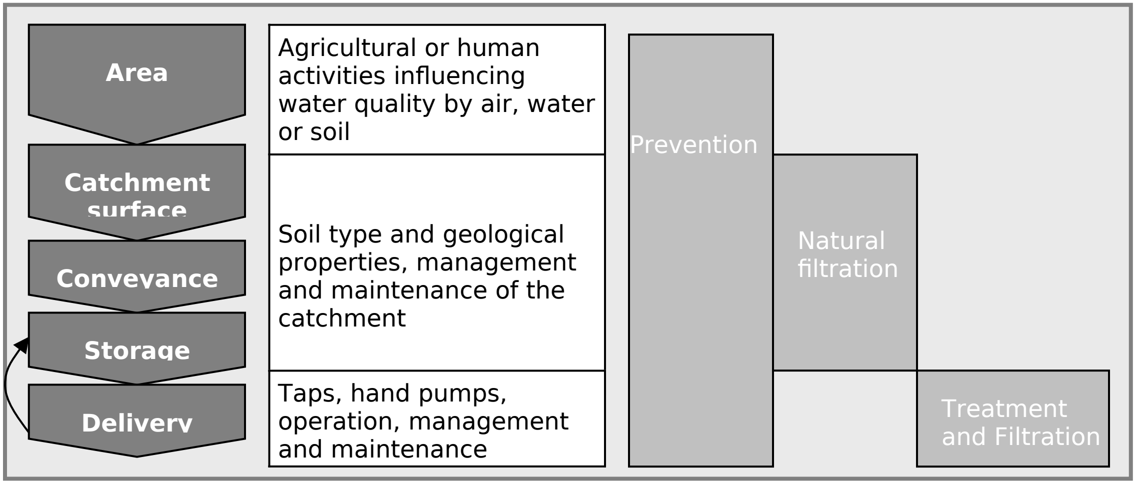


Figure 3: Mapping risks of contamination for sand dams (based on www.eng.warwick.ac.uk/DTU/rwh/components1.html)

For most small and remote settlements, especially in developing countries, water treatment is both impractical and often unrealistically expensive. The main desired impact of water supply projects is to improve health, and therefore treatment of water should only be applied if health is at risk. In contrast to most unprotected traditional water sources, drinking rainwater from wellmaintained catchments and storage facilities represent a considerable improvement. Water quality standards should therefore be seen within the local context and national standards. They should not impose a set of unrealistic (western) standards.

7.2.2 Recommended treatment and filtering methods

Water treatment only makes sense if it is done properly, and if hygienic collection, storage and use of water ensure prevention of recontamination. Due to the fact that RAIN works in remote areas, a selection has been made of practical and acknowledged treatment and filter techniques, presented in table 1.

RAINs recommended treatment and filtering methods for sand dams	
Solutions or substances to be added to water:	ChlorinationKENYAN EXPERIENCE SHOWS A LOT OF POISONING. DOWE REALLY RECOMMEND THIS?
	Silver coated ceramic balls
Filters:	Ceramic pot filter
	Bio-sand filter
Heat and UV radiation:	Boiling
	Solar disinfection

Table 1: RAINs recommended treatment and filtering techniques at a household level for water extracted from sand dams.

For a more detailed description of these methods, we refer to RAINs Water Quality Policy and Guidelines which can be downloaded from the RAIN website. Other information on these methods can be found on www.who.int/water_sanitation_health/ and www.who.int/household_water/.

8. Casestudies from Ethiopia and Kenya

8.1 Adaptation to climate change: sand dams in Kitui, Kenya

Input Sasol about siting, building (and so on) of a kitui sand dam case required!

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

The Borena 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 decentralized water source in areas where other means of water supply have little potential, like in Borena. However, roofwater 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 Borena.

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 Borena.

An 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 figure 6). The project will increase access to a reliable source of water for at least 10 communities in the critically dry Borena Zone and an environment for further upscaling in other parts of the country has been created.

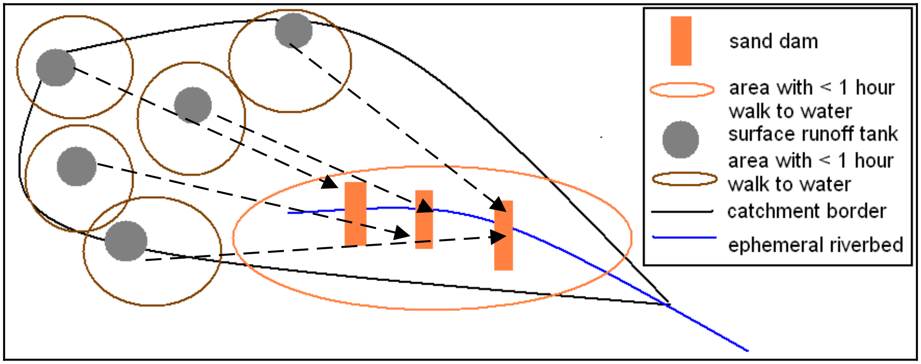


Figure 6: Hypothetical example of catchment approach in rainwater harvesting: combining sand dams and rainwater harvesting tanks in one (sub)catchment.

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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 meter	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.CREATING COMMUNITY PARTICIPATION?**

Step 1: Creating awareness and sensitizing the community.

Starting a sand dam project 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: Performing baseline survey.

- 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. The selected sites should be discussed with local authorities.
- The best-suited sites are once more visited and a dialogue with community is held. During this meeting, the project staff and community discuss the possible environmental and social impact (also see paragraph ???) of the development of sand dam within the area.

Step 3: Establishing a water committee.

- Establishing a water committee and defining its responsibilities 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 duty is to mobilize resources, plan the site works, record progress, supervise and monitor the implementation process. The committee must on weekly basis monitor and evaluate the progress.
- Drawing a Community Action Plan (CAP) which contains a 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.

- 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.

5. CREATING CASCADE MANAGEMENT SYSTEMSFOR SUSTAINABILITY

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

Current water use and needs in general:				
How much water do you use (for your family) for which purposes?				
Who is the responsible person for fetching the water?				
Who decides who uses the water?				
How do you manage your current water sources				
What kind of water sources do you use?				
Are these sources sufficient throughout the year?				
Are there any problems with your current water sources (for example: water contamination, borehole pump is not working, too much people are using the water source etc.)?				
What do you do and where do you get water if your current sources are not sufficient?				
Water use aspiration for the future:				
What would you do if you would be given half a million dollars? Where would you use it for?				
If you would have more water where would you use it for?				
If you could have cleaner water, would it make a difference compared to your current water source?				
Water use (average litres per person per day)	**Women**	**Men**	**Boys**	**Girls**
Drinking				
Hygiene				
Cooking				
Types of water use	**Household**	**Community**	**Health Centre**	**School**

Attachment 5: Wall dimensions and reinforcement requirements for different wall heights (Negassi, A. et al, 2002)

Reinforced concrete and masonry dams:

Height of the wall (m)	**Thickness (m)**		**Reinforcement bar diameter, main (mm)**		**Reinforcement bar diameter, tie (mm)**	
	Top	Bottom	Diameter	Spacing	Diameter	Spacing
< 1.5	0.15	0.15	10	200	8	200
1.5 – 3	0.15	0.25	16	210	8	220
3 – 4.5	0.15	0.35	20	155	10	150
> 4.5	0.15	0.45	20	95	10	130

Masonry dams:

Dam height (m)	**Wall thickness (m)**
0 – 1	0.5
1 – 2	1.2
2 – 3	1.7
3 – 4	2.2
4 – 5	2.7

Attachment 6: Calculating the quantities of materials

Cement (bags of 50 kg)

Total Volume of cement in masonry $= \frac{1}{14}(Vw + Vsw + VBF)$

Mass of cement $= \frac{\ell cem}{14}(Vw + Vsw + VBF)$

Bags of Cement $= \frac{1440}{14 * 50}(Vw + Vsw + VBF)$

Cement in masonry $= 2(V_w + V_{sw} + V_{BF})$

Cement is also in V_e, V_{us}, V_b, V_{PBF} *(Mixing ratio 1:3)*

Bags of cement $= \frac{\ell cem \times \frac{1}{4}}{50}(V_{sw} + V_c + V_{us} + V_b + V_{pBf})$

$= \frac{1440}{14 * 50}(Vsw + Vc + Vus + Vb + Vpbf)$

Cement in Mortar $= 7.0(V_c + V_{us} + V_b + V_{pBf})$

Total cement requirement $\mathbf{= 2(V_w + V_{sw} + V_{BF}) + 7.0(V_c + V_{us} + V_b + V_{pBf})}$

Hard Core

Total Volume of HC ($V_{H/C}$) = 9/14 x Total volume of HC

In which Total volume of HC = Hardcore in main wall + Hardcore in spillway + hardcore in back flow

$= 9/14\ (V_w + V_{sw} + V_{BF})$

Tonnes of HC $= \frac{9}{14} \times Vh.c \times \frac{Ph/c}{1000}$

Tonnes of H/C in masonry $= 1.4(V_w + V_{sw} + V_{BF})$

Sand

Total volume of sand = Sand in masonry + Sand in mortar

Tonnes of sand in masonry = 4/14 ¥ sand/1000(V_w+V_{sw}+V_{BF}) ¥ sand

= 1600

= 0.5(V_w+V_{sw}+V_{BF})

Tonnes of sand in mortar (1:3) = 3/4ρ sand/1000(V_c+V_{us}+V_b+V_{pBF})

with ρ sand =1600

Total tonnes of sand =0.5(V_w+V_{sw}+V_{BF})+0.3(V_c+V_{us}+V_b+V_{pBF})

Reinforcement Bars

Types of reinforcement bars used:

- Round bars 12 mm diameter and length of 12 m
- Round bars 8 mm diameter and length of 12 m

Spacing columns are spaced 2m side to side. Note that it is unwise to place columns at the extreme like it done in fencing posts

Number of columns = Ld/2-1

Total length of R 12 mm = Number of columns x 4 x D_e x.

$$\left(\frac{Ld}{2} - 1\right)4De$$

Number of columns of R 12 mm $= \frac{4De}{12}\left(\frac{Ld}{2} - 1\right)$

$$= 0.33De\left(\frac{Ld}{2} - 1\right)$$

<u>Example:</u> When D_e=2.0m, L_d=20 metres

Number of R 12 mm bars $= 0.33 \times 20\left(\frac{20}{2} - 1\right)$

= 6.60 – 0.66 = 5.94

= 5.9

= 0.4 x 4

= 1.6. >???

Rings

Number of rings per average columns $= \frac{De}{Spacing} = \frac{De}{0.5} = 2De$

Length of one ring of R 6.25 m

Total length of R 6.25 m average = Length per Ring x Number of Rings per column x Number of columns.

$= 1.6\ (2De+1)\ (\frac{Ld}{2} - 1)$

$= 1.6(DeLd - 2De + \frac{Ld}{2} + 1)$

Number of rings R 6.25 m $= \frac{1.6}{12}\ (DeLd - 2De + \frac{Ld}{2} + 1)$

$= 0.13\ (DeLd - 2De + \frac{Ld}{2} + 1)$

Example: When L_d=20, D_e=20.

Number of R 6.25 rings $= 0.13\ (20x2) - (2x2) - \frac{20}{2} + 1)$

= (5.2 –0.52+1.3+0.13)

= 6.11

Barbed Wire

Length Gauge 16 = 610 m, Spacing= 0.45

Average strands = 10

Total length of barbed wire = 10 x Ld

No of layers of Barbed wire $= \frac{De}{0.45}$

Total length of Barbed wire $= \frac{10Ld.De}{0.45}$

No of rolls of Barbed wire $= \frac{10Ld.De}{0.45x610}$

$= 0.04\ L_d D_e$

Example: When L_d=20, D_e =2

No of rolls of barbed wire = 0.04 x 20 x 2

= 1.6

Nails

1 kg on nails should be sufficient.

Timber

An average dam requires about 15 m of cypress timber 50 mm x 50 mm. A bigger dam may require about 30 m of the timber.

Water (litres)

Litres of water = 1.8 * V_T * 200

In which V_T = total volume of the dam (m^3)

Skilled Labour

Artisan and men days $= \frac{Vt}{1.4}$

Attachment 7: Guideline for sand dam construction

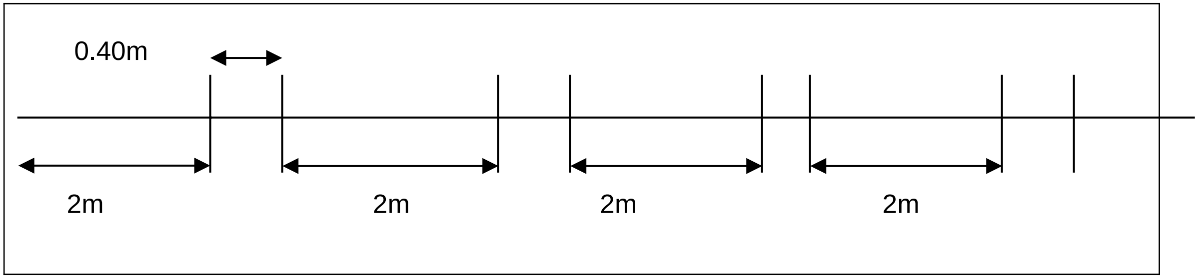
Step 1: Placing reinforcements

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

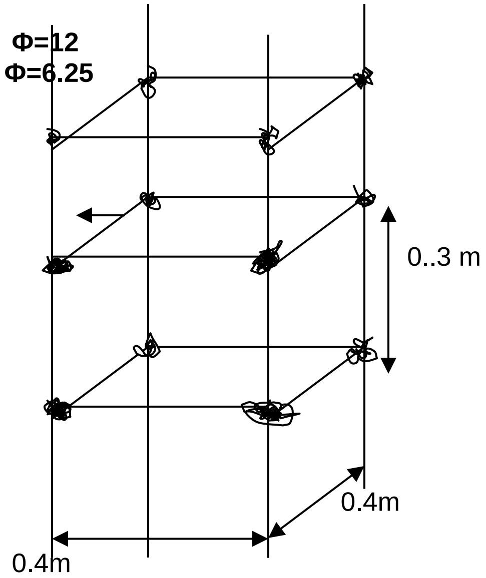
No of columns = $\frac{Ld}{2} - 1$ *For example: iIf* L_d*=10, Then No of columns =* $\frac{10}{2} - 1 = 4$

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

No 1 =2.5m, No 2=2.0m , No 3 = 3.0m



Marking of the reinforcement columns along the building line in the trench.



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

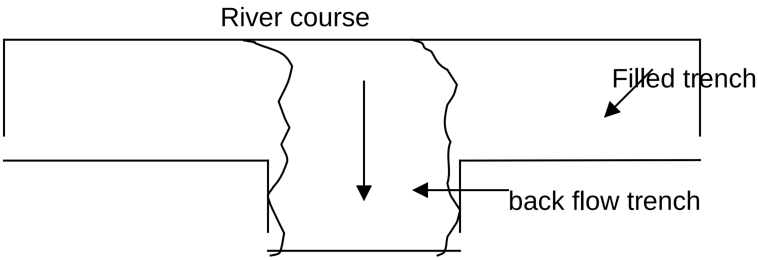
After the mortar layer 12 strands of barbed wire are evenly divided over the building slab along the dam.

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 height up to the

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 of…….???? 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 8: 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-meter radius.
- Dig the well using skilled man powerWHAT OF COMMUNITY BASED SYSTEMS as the well should be excavated straight for the diameter of 2?.
- Excavation of well continues until a depth at which sufficientWHAT DOES THIS MEAN 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 blocksSASOL USES SPECIALISED CONCRETE BRICKS TO INCREASE INFILTRATION SPECIFYING IS USEFUL are lowered one by one in a bucket. A cement and sand mortar mix (1-4)REALLY? 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 meters. 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.

HOW ABOUT LINING THE OUTSIDE OF THE WELL WITH SAND TO INCREASE INFILTRATION AS WELL AS TO CLEAN THE WATER FURTHER-SEE SASOL

Attachment 9: 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 reservoirIN KITUI COMMUNITIES DO THIS AS ROUTINNE AND SEND THE DSEDIMANT TO THEIR FILEDS.
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