WFP
World Food Programme

REPUBLIC OF KENYA

Water Harvesting in Practice:
Towards Building Resilient Livelihoods in Semi-Arid Zones

FIELD PRACTITIONERS GUIDE NO. 2

WFP Rural Resilience Programme

August 2018

Water Harvesting in Practice:
Towards Building Resilient Livelihoods in Semi-Arid Zones

FIELD PRACTITIONERS GUIDE NO. 2

WFP Rural Resilience Programme

August 2018

Water Harvesting in Practice: Towards Building Resilient Livelihoods in Semi-Arid Zones

Field Practitioners Guide No.2

Front cover diagrams
- (i) Illustration of rainwater harvesting and storage in a plastic-lined farm pond
- (ii) Illustration of road runoff harvesting with water storage in pan
- (iii) Illustration of zai pits for water retention growing a cereal crop
- (iv) Illustration of sand/sub-surface dam water storage with shallow well draw-off.

Citation:
WFP, 2018. Water Harvesting in Practice: Towards Building Resilient Livelihoods in Semi-Arid Zones. Field Practitioners Guide No. 2. Rural Resilience Programme, World Food Programme, Nairobi.

This Field Guide was compiled by Bancy M. Mati

Illustrations and diagrams drawn by: Munene Muverethi Mati

Research and publication was supported by:
World Food Programme,
Rural Resilience Programme,
Nairobi

Published by: WFP, Nairobi

Foreword

Kenya's agricultural sector is evolving each day, driven by among others; the gathering momentum of the devolved system of Government, the need to transform agriculture from subsistence to agri-business, a growing population with increasingly complex consumer demands, as well as innovations emerging from farmer trials, the information superhighway, innovations, research and technology.

At the same time, Kenya's agriculture responds to and is affected by international protocols, among these, the Sustainable Development Goals (SDG) whose clarion call is *"Leaving no-one behind".* This motto, when applied in the Kenyan context literally calls for special attention to be accorded to the arid and semi-arid lands (ASALs), which constitute 83 percent of Kenya's land area. It is in the ASALs where agriculture faces special challenges associated with aridity, erratic weather, lack of water, and rudimentary technologies in how water is managed. In essence, the *ASALs should not be left behind!*

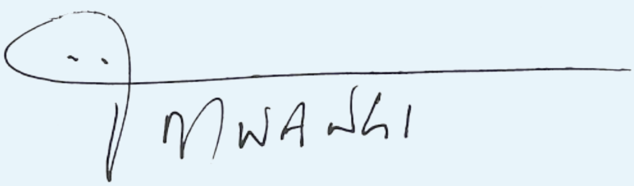
The Government of Kenya (GoK) is committed to implementing development initiatives that lead to food and nutrition security, national wealth creation and wellbeing, while also contributing to the achievement of the SDGs. In particular, the Ministry of Agriculture, Livestock, Fisheries and Irrigation (MoALF&I) is implementing programmes, projects and activities at national and county levels, which ultimately contribute to achieving the SDG-2: End Hunger, achieve food security and improved nutrition, and promote sustainable agriculture, whilst simultaneously contributing to a number of other SDGs (especially SDGs 1, 5, 6, 12, 13 and15). This will be achieved by infusing science, innovation and technology in smallholder agriculture, especially in the ASALs, where the knowledge gaps are greatest.

Aware of the complex nature and challenges that face agricultural development in the ASALs, the Ministry has been working with various development partners, among them the World Food Programme (WFP) towards supporting livelihoods in the ASALs. In particular, the WFP has in the past contributed to food relief efforts. However, as we implement the Agriculture Sector Transformation and Growth Strategy (ASTGS) and the BIG 4 on food and nutrition security, focus is now changing to support the most food-insecure communities (Flagship 6 of ASTGS) in the arid and semi-arid lands to become resilient and adapt to shocks such as drought and climate change, by becoming food producers rather than recipients of food aid.

This focus sees ASALs as having resources which include the human, natural, social and financial capitals. Resilience building therefore takes cognizance of the inherent potential and through complementary efforts with partners, implements activities on the ground. This relies heavily on support and collaboration with County Governments, the private sector, development partners, non-state actors and all stakeholders. These partnerships are necessary to facilitate infrastructure development, community mobilization, implementation of income generating activities; skills development among land users and decision makers and to enhance best practice in resource management and agricultural production.

In our continued efforts to build knowledge, reach the decision makers, extension workers and farmers on solutions and interventions that upgrade agriculture in the ASALs, these set of Technical Manuals and Field Guides developed by WFP in collaboration with MoALF&I brings on board innovations, technologies and best practices that will help upscale agricultural productivity and improve rural livelihoods. I expect the materials to be shared widely and utilized so that the knowledge in them is turned into action, thereby benefitting farmers, communities and the country.

Lastly, I wish to reaffirm the commitment of the Ministry in supporting good practices and innovations that improve rural resilience and upgrade agricultural production in the ASALs, and indeed in all parts of the country where sustainable agriculture is practiced, as we continue the journey of making Kenya food and nutrition secure.



Hon. Mwangi Kiunjuiri, MGH, EGH

Cabinet Secretary, Ministry of

Agriculture, Livestock, Fisheries

and Irrigation

Table of Contents

1. Runoff Farming for Crop Production: Zai Pits

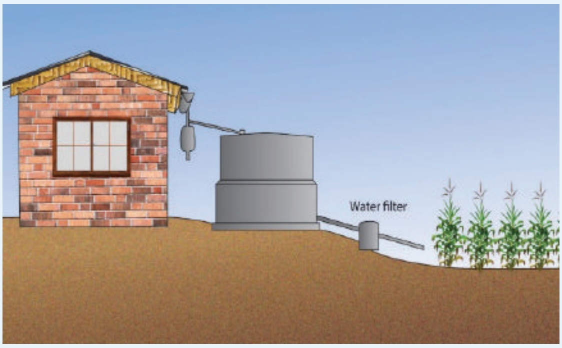
1.1 Introduction to Water Harvesting and Runoff Farming

1.1.1 What is water harvesting?

In the context of agriculture, the term Water harvesting (WH) encompasses **rainwater harvesting, floodwater** harvesting, and **in-situ water harvesting and conservation,** respectively as illustrated below:

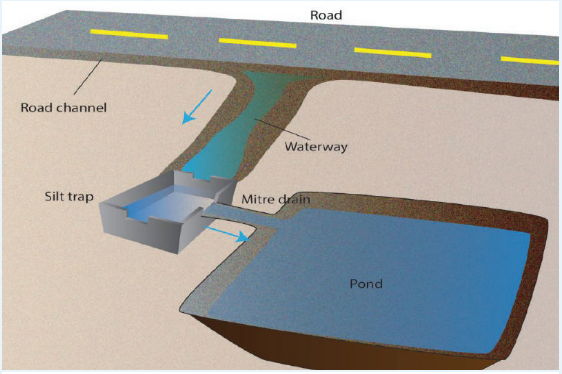
(a) Rainwater harvesting (RWH):

The collection, conveyance, conservation and storage of rainwater in structures and in for future use. The water may be used for various purposes (domestic drinking water, livestock watering or irrigation).



(b) Flood water harvesting:

The diversion of surface runoff and its storage in reservoirs (dams, weirs, sand dams, tanks, farm ponds or pans). It also includes flood diversion and storage in the soil profile/ crop root zone, e.g. spate irrigation.



(c) In-situ water harvesting and conservation

The harnessing and conservation of rainfall where it falls. It includes soil and water conservation structures such as terraces, retention ditches, stone bunds and vegetative barriers, as well as agronomic practices e.g. mulching, deep tillage, and soil management.

1.1.2 What is runoff farming?

Runoff farming is use of runoff water to augment natural rainfall or simply water harvesting for crop production. In areas with annual rainfall ranging 100 to 700 mm, runoff farming may provide a workable solution if irrigation water from other sources is not available. In runoff farming, there is deliberate collection of rainwater from a surface (called a catchment) and its conveyance onto a cropped area (or run-on area), so that the soil profile absorbs more rainfall. This is illustrated below.

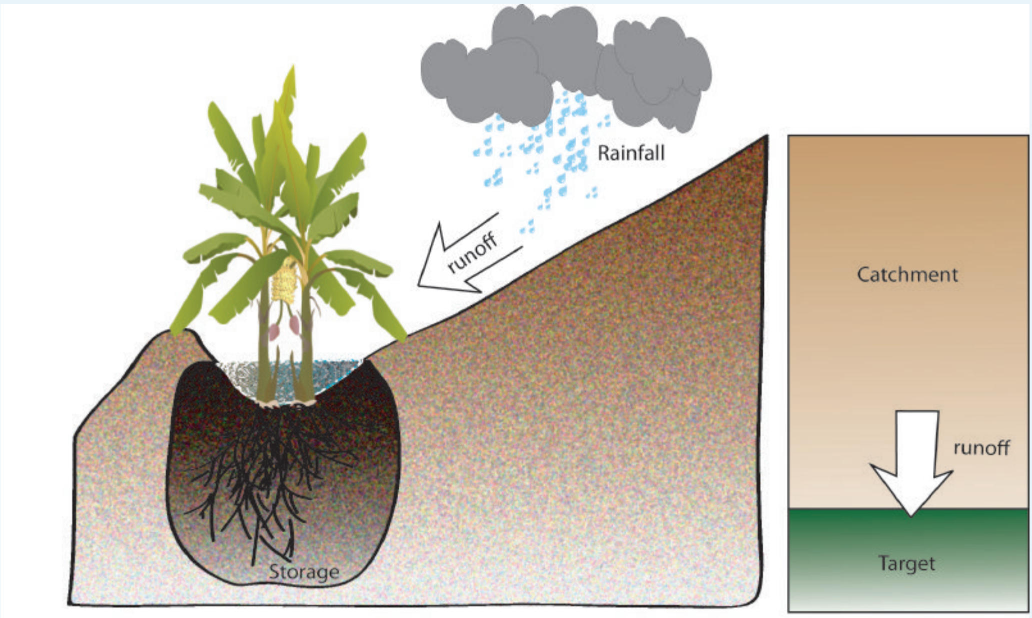


Figure 1.1 Illustration of a runoff farming system

- **Catchment area** is the part of the land from which rainwater collects or runoff emanates from. It can be small, less than a meter to several meters or sq.km.
- **Conveyance system –** usually a channel or space that connects the harvested runoff from the catchment to the target/ponded area.
- **Cropped area- is** where the harvested water, ends up, in a specially prepared cropped area, such as a ditch, pit, basin, or terraced land.

1.1.3 Benefits of water harvesting

Water harvesting is an ingenious way of improving the productivity of semi-arid zones. The major advantages include:

- Water harvesting stores excess rainfall, thus reducing runoff and converting it from a destroyer into an asset

- Restoring the productivity of land which suffers from inadequate rainfall.
- Increasing vegetation on denuded rangelands,
- Offers resilience in food security through supplemental irrigation
- Minimizes the impacts of drought, prolonged dry spells
- Combating desertification by establishment of vegetation in rangelands
- Provides water for domestic use and livestock consumption,
- Climate change adaptation and resilience by re-greening agricultural and rangeland ecosystems.

1.1.4 Limitations

Runoff harvesting faces many constraints which discourage farmers from adopting the techniques. Some of the most common ones include:

(i) Runoff farming systems are reliant on rainfall, hence they still carry a risk of failure if rainfall fails or is excessive.

(ii) The combination of an impervious catchment area while the adjacent cropped area has soils with high moisture retention is difficult to get.

(iii) High evaporation and deep percolation losses are common problems in most runoff harvesting systems.

(iv) Many runoff farming techniques have high labor requirements, which can be a constraint among poor and marginalized communities,

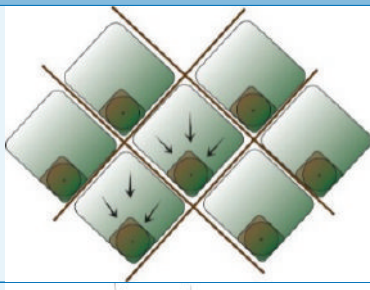
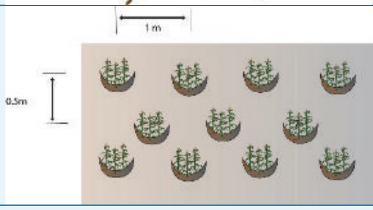
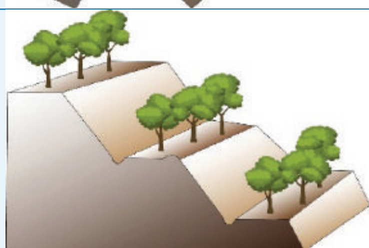
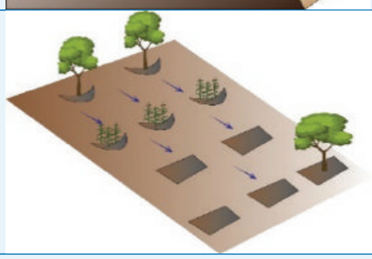
(v) Some of the structures constructed for runoff farming are temporary and must be re-built each rainfall season.

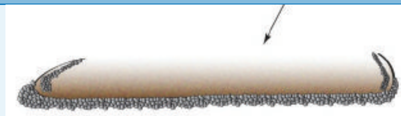
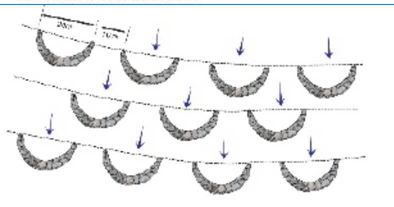
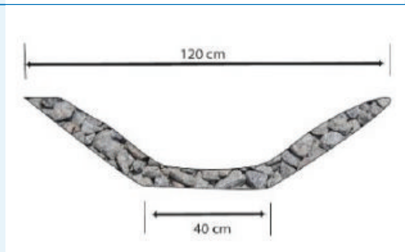
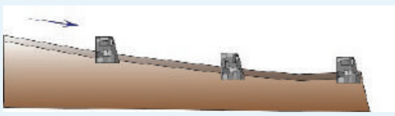
(vi) A good technical background in water/engineering is necessary to design structures and such capacity may be lacking.

1.1.5 Types of runoff harvesting systems

There are many types of runoff farming technologies, grouped as either within-filed systems – in which runoff emanates from within the farm, or external catchment systems, where runoff emanates from beyond the cropped area. The basic parameters of each of these systems are indicated in Table 1.1

Table 1.1. Basic design criteria of various runoff farming techniques

Type	Illustration	Parameters
Negarim		C= 3 – 250 CA= 1 - 10 C/CA= 3 : 1 - 25:1 PREC= 150 - 600 mm/a SL = 1 - 20%
Pitting		C= 0.25 CA= 0.08 C/CA= 3:1 PREC= 350 - 600 mm/a SL= 0 - 5%
Contour ridges		C= 100 CA= 20 C/CA= 5:1 PREC= 300 - 600 mm/a SL= 5 - 25%
Semi-circular hoops/demi-lunes & Triangular bunds		C= 24-226 CA= 6-57 C/CA= 4:1 PREC= 300 - 600 mm/a SL= 2 - 20%
Contour bench terraces		C= ~2-16 CA= 2-8 C/CA= 1:1-8:1 PREC= 100 – 600 mm/a SL= 20 - 50%
Eye brow terraces; & Hillslope micro-catchments		C= 5 – 50 CA= 1 - 5 C/CA= 3:1 - 20:1 PREC= 100 – 600 mm/a SL= 1 - 50%

Type	Illustration	Parameters
Stone dams		(extreme variations) PREC= 300–600 mm/a
Semi-circular bunds		C= 750 - 10,000 CA= 50 - 350 C/CA= 15:1 - 40:1 PREC= 200-400mm/a SL= 1 - 10%
Trapezoidal bunds		C= 5 - 3 x 105 CA= 3,500 C/CA= 15:1 - 100:1 PREC= 200–400 mm/a SL= 1 - 10%
Cultivated reservoirs		C= 1,000 -10,000 CA= 100 - 2,000 C/CA= 10:1 - 100:1 PREC= 150 - 600mm/a SLC = > 10% SLCA = 0 - 10%

Source: Prinz, D. 1996. Water harvesting, past and future

Legend: C = Catchment size (m^2)

PREC = Precipitation

CA = Cropping area (m^2)

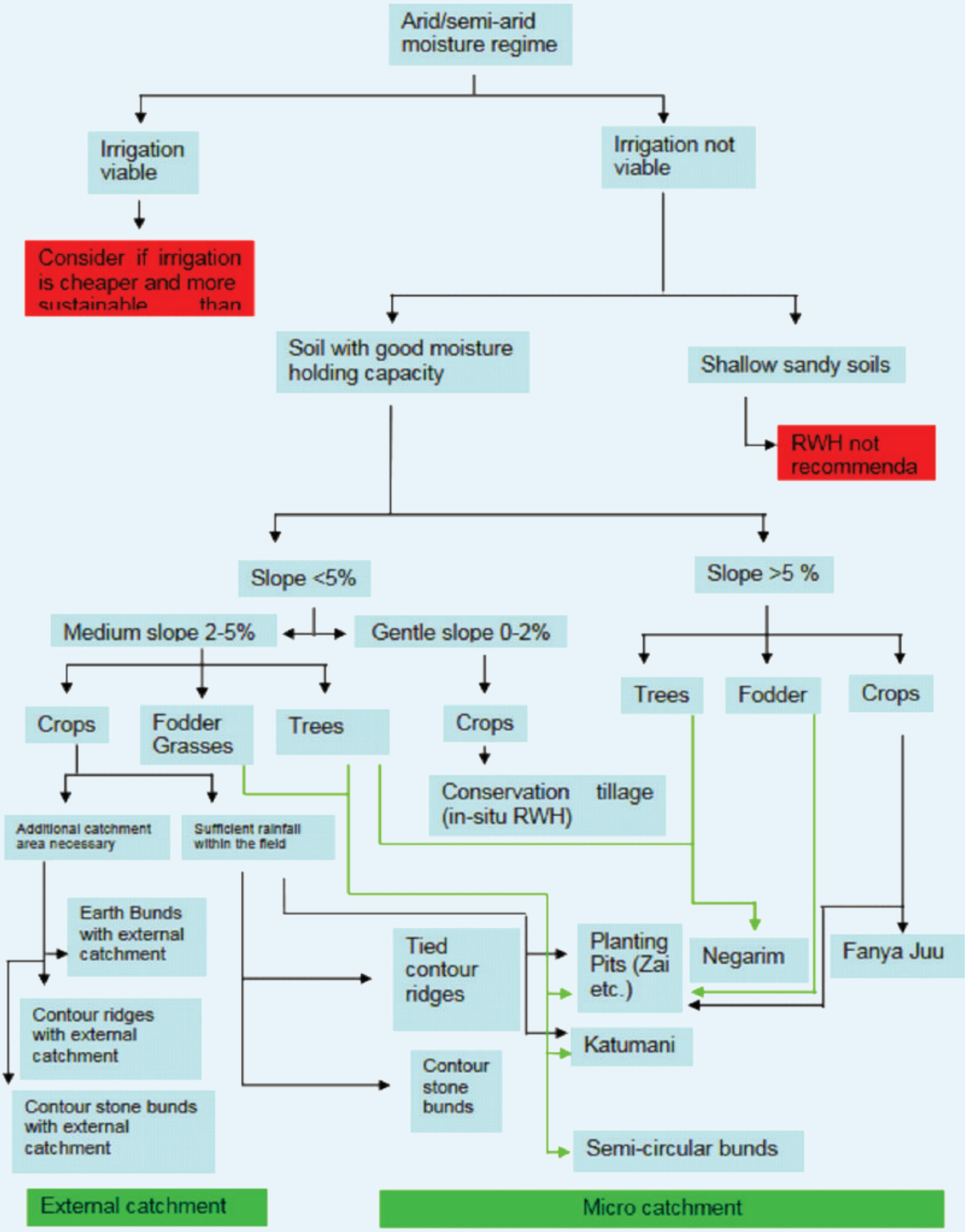
SL = Slope

C/CA = Catchment: Cropping Ratio

SLC= Slope of catchment area

SLCA= Slope of cropping area.

1.2 Decision Tree for selecting type of runoff farming system



In this Chapter, the **Zai Pit** is described. This is because although simple and widely applied, the Zai is much misunderstood in Kenya.

1.3 About the Zai System

1.3.1 What is a zai pit?

"Zai", zay or Zaï planting pits (figure 1.2), offer a runoff farming technology that emanated from northern Burkina Faso, and which in the Tahoua region of Niger is referred to as "tassa" in the Haussa language. The English terms used to describe zai pits include "planting pockets", "planting basins", "micro pits", fertility basins, fertility pits and "small water harvesting pits."

1.3.2 Where are zai pits likely to be most relevant?

Zai pits are used in semi-arid zones where soils are poor, encrusted soils receive low and often highly variable rainfall. The pits are important for water harvesting and conservation. Zai pits are especially relevant to areas receiving 300- 800 mm annual rainfall. Higher rainfall amounts could cause water-logging of the pits. The zai system allows farmers to concentrate both soil fertility and moisture in the crop roots and, improves crop production, when faced with inadequate rainfall.

(a) Newly excavated zai pits in Burkina Faso

(b) Millet grown in planting pits in Burkina Faso

Figure 1.2 Zai pits are small round or square pits for growing cereal crops

1.3.3 Benefits of zai pits:

- Simple to construct
- Infiltration of rainwater that would have runoff
- Improves plant production by concentrating runoff around growing plants
- Improves soil fertility and structure when manure/compost is added in pits
- Once prepared, pits can be re-used for up to four crop seasons or two seasons without need to add more manure

- Other measures can be combined with pitting
- Can be used to establish trees and shrubs.

1.3.4 Design features

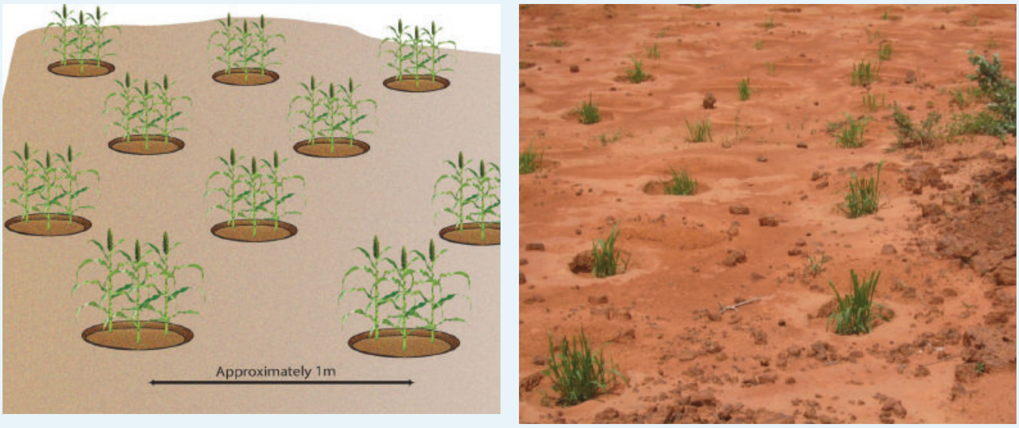
The zai system consists of small individual basins spaced about 1 m apart and large enough to catch all the rainfall that falls. The pits are shallow and wide, measuring about 30-60 cm diameter and 15-30 cm deep. The topsoil is separated from the subsoil. The topsoil is mixed with well composted manure and returned to the pit, ensuring that a certain depth of hole is left to act as ponding zone. The subsoil is used to create a small bund on the downhill side of the pit (Figure 1.3a). When it rains, the pits fill up with water improving moisture conservation (Figure 1.3b).

(a) Digging zai pits – small, shallow pits

(b) Zai pits hold and retain rainwater

Figure 1.3 Digging Zai pits with a hoe and the same pits after the rains

Cereal crop seeds are then planted in the pit, i.e. about 4 -12 seeds of maize, sorghum or millet (Figure 1.4). Due to soil fertility and moisture retention, crop yields are usually improved when farmers adopt the Zai system. The pits may be reused for two to three crop seasons.



(a) Sketch of Zai pitting system with cereal crop

(photo courtesy of Poda, J.N.)
(b) Zai micro-catchment system with millet

Figure 1.3 Zai micro-catchment system for cereal crops

Table 1.2 Suitability of zai pits to climate and soils

Rainfall	**Soil**	**Slope**	**Topography**
200-750 mm/yr Semi-arid climate	Shallow, clayey, poor infiltration, soil with surface crust	preferably <2%	Even topography not required

Pit depth	**Pit diameter**	**Distance between pits**	
5-15 cm	10-30 cm	50-100 cm	

1.3.5 Digging zai pits can be mechanized

A lot of manual labor is usually required in digging various types of planting pits. For instance, digging zai pits takes up 20,000-25,000 holes/ha (depending on size and spacing of holes) which is quite labor intensive. This discourages adoption. The zai pitting system can be mechanized. On hard, encrusted soils, digging pitting may be easier than tilling an entire field. Nevertheless, considering the labor-intensive task of digging pits, smallholder farmers could benefit significantly from machinery or equipment that makes it easier and faster to dig the pits.

(a) Digging Zai pits with a manual hoe

(b) A motorized auger drilling machine

Figure 1.6 Comparing manual digging of zai pits with motorized system

1.3.6 Other considerations for zai pits

(a) Costs

The cost of the *zai* is considered in terms of the time which it takes the farmer to dig the holes and fill them with organic matter. Depending on the hardness of the ground, the input required is between 30 and 70 person-days per hectare for the digging of holes and 20 person-days per hectare for applying manure and compost.

(b) Variations / Adaptations:

- Pits in line or in staggered rows
- Combined with stone bunds along contour line
- Zaï pits with soil bunds of grass strips
- Planting on ridge rather than in pit to maximize root depth for shallow soils
- Zai pits are dug during the dry season
- Farmers may sow into existing holes in the second year.

(c) Effectiveness of the Technology

In the regions where zay are used, zai are usually constructed on abandoned or unused ground. Thus, crop yields resulting from this practice bring a benefit of 100%. Yields range between 0.7 and 1.0 t/ha for sorghum.

(d) Suitability

The planting pits meet the criteria for three types of conservation practices at the same time (soil conservation, water conservation, and erosion protection) on encrusted and filled soils. Although the technique can be adopted for use on degraded canals and encrusted surfaces, it generally is applied on silt and clay soils.

(e) Environmental Benefits

Zai improve groundwater recharge. *Zai* also limit the volume of runoff and, hence, the extent of soil erosion. Advantages *Zai* increase infiltration into the ground. After several years of employing this practice, the soils may re-acquire its porosity and permeability. For this reason, zai are used for regeneration of the soil.

1.4 Tumbukiza Pits

Tumbukiza pits (or **Katumani pits)** are relatively larger pits used for fodder and fruit tree production, especially bananas. *Tumbukiza* in the Swahili language means, "throw all in." *Tumbukiza* pits have been popular in Kenya for smallholder dairy development on small plots of land and for banana production. Tumbukiza system is used in both micro-catchment and external catchment water harvesting systems.

Design features

Tumbukiza involves digging huge pits, which are least 0.6-0.9 m square or in diameter and with similar dimensions in depth. The pits are then filled with crop residues, any available vegetative material and farmyard manure and topsoil. A space is left within the pit to create a ponding zone for water, while the subsoil is used to create a small earthen bund around the pit. A fodder or banana crop is planted in the pit (Figure 3.17). The general arrangement should allow runoff from surrounding areas to get into the pit and increase water storage.

Due to the large volume of the *tumbukiza* pit, the fodder therefore grows rapidly, making it possible to have at least a fodder harvest per pit per month. Moreover, the *tumbukiza* pit stores moisture much longer, enabling Napier grass to survive in drier environments and fodder production during the dry season. However, the high labor demands in excavating *tumbukiza* pits forms a major limitation of the system.

(Photo B. Mati)

(a) Newly excavated tumbukiza pit (Katumani pit)

(photo Faith M. Livingstone)

(b) Tumbukiza pits with banana crop

Figure 1.7 Tumbukiza pits (katumani pits) are suited to fodder or tree crop

1.5 Operation and Maintenance of planting pits

The holes, filled with runoff water, extend favorable conditions for infiltration for as long as possible after runoff events. In case of too much water, such as during a storm, the debris placed in the pits as compost soaks up the excess water easily, effectively storing the water and creating a damp environment around the plants. The pits are easy to manage. However, it is important to make sure that the holes are correctly dug and that the debris is evenly placed in each hole. The holes must be checked each winter to make sure that they are in good conditions, and they must be filled with organic matter as required.

1.6 Selected References

Critchley W and Siegert K. 1991. Water harvesting: A manual for the design and construction of water harvesting schemes for plant production. Rome: FAO.

Critchley, W.; Reij, C.; Seznec, A. 1992. *Water Harvesting for Plant Production. Volume II: Case Studies and Conclusions for sub-Saharan Africa*. World Bank Technical Paper Number 157. Africa Technical Department series.

Hai, M.T. 1998. *Water harvesting: an illustrative manual for development of microcatchment techniques for crop production in dry areas*. Technical handbook No. 16. RELMA. Nairobi.

Hassan, A. 1996, Improved traditional planting pits in the Tahoua Dep. (Niger): an example of rapid adoption by farmers. In: 'Sustaining the Soil – Indigenous Soil and Water Conservation in Africa' (eds. Reij, C, Scoones, I. and Toulmin, C.). Earthscan Publ.

Malesu, M.M., Oduor A.R. and Odhiambo O.J. (eds). 2007. *Green water management handbook*: *Rainwater harvesting for agricultural production and ecological sustainability.* Technical Manual No. 8 Nairobi, Kenya: World Agroforestry Centre (ICRAF), Netherlands Ministry of Foreign Affairs. 219 p.

Mati, B. M. 2005. *Overview of water and soil nutrient management under smallholder rain-fed agriculture in East Africa.* Working Paper 105. Colombo, Sri Lanka: International Water Management Institute (IWMI). www.iwmi.cgiar.org/pubs/working/WOR105.pdf.

Mati, B. M. 2010. Agricultural water management delivers returns on investment in eastern and southern Africa: A Regional Synthesis. In Mati, B.M. *Agricultural water management interventions delivers returns on investment in Africa. A compendium of 18 case studies from six countries in eastern and southern Africa*. VDM Verlag. 1-29.

Mati, B.M. 2007. *100 Ways to Manage Water for Smallholder Agriculture in Eastern and Southern Africa*. SWMnet proceedings 13. Nairobi, Kenya. www.asareca.org/swmnet/imawesa.

Mati, B.M. 2012. *Runoff Harvesting for Crop Production: Practical Solutions for Dryland Agriculture.* Training Manual 1. Nile Basin Initiative (NBI), Nile Equatorial Lakes Subsidiary Action Programme (NELSAP) - http://nileis.nilebasin.org/system/files/Run%20off%20Manual%201.pdf

Motis, T., D'Aiuto, C. and Lingbeek, B. 2013. Zai pit system.Technical Note No. 78. ECHO. ECHOcommunity.org. https://c.ymcdn.com/sites/echocommunity.site-ym.com/resource/collection/27A14B94-EFE8-4D8A-BB83-36A61F414E3B/TN_78_Zai_Pit_System.pdf

Oweis, T.; Hachum, A. and Kijne, J. 1999, Water harvesting and supplementary irrigation, for improved water use efficiency in dry areas. SWIM Paper 7, Colombo, Sri Lanka, International Water Management Institute.

Oweis, T.; Prinz, P.; Hachum, A. 2001. *Water harvesting. Indigenous knowledge for the future of the drier environments.* International Centre for Agricultural Research in the Dry Areas (ICARDA). Aleppo, Syria

Prinz, D. 1996, Water Harvesting: Past and Future. In: Pereira, L. S. (ed.), Sustainability of Irrigated Agriculture. Proceedings, NATO Advanced Research Workshop, Vimeiro, 21-26.03.1994, Balkema, Rotterdam, 135-144

Reij, C. and Waters-Bayer, A. (eds) (2001*) Farmer Innovation in Africa. A source of inspiration for Agricultural Development*. Earthscan, London.

Wright, P. 1984, Report on runoff farming and soil conservation in Yatenga, Upper Volta (Burkina Faso), Report to OXFAM, Oxford.

2. Water Harvesting with Lined Farm Ponds

2.1 Basics about Farm Ponds

2.1.1 What is a Farm Pond?

A farm pond (also known as an underground tank or sub-surface tank), is a water storage structure constructed below the ground surface. The term also includes structures that are partially below ground. Whereas a shallow well gets water from groundwater, a farm pond gets its water mostly from surface runoff.

A lined farm pond is one whose surface area is coated with some impervious material, e.g. dam-plastic, concrete, to prevent water losses by seepage.

(a) Farm pond lined with dam-plastic material

(b) Farm pond lined with concrete

Figure 2.1: Lined farm ponds (a) with dam-Plastic, (b) with concreting

2.1.2 Why do we need to store rainwater in Farm Ponds?

Drylands are regions that suffer seasonal water scarcity, albeit they receive some rainfall, which may be low and/or erratic. The Kenyan drylands receive between 250 and 850 mm of annual rainfall. But much of this rainfall is lost through surface runoff that end up in un-recoverable sinks e.g. ocean, and evaporation losses. Water harvesting and storage in farm ponds enables land users to utilize a "free" resource (rainwater) much longer after the rains have disappeared.

2.1.3 Where are Farm Ponds technically feasible?

Dos: Farm ponds are best located where rainfall runoff seems to collect after a storm. This will be land that has some slope gradient, and thus allows runoff to be easily channeled into the storage pond. Usually, a catchment is necessary above the position of pond, and this could be a home compound, road, footpath, hill, rocky area or grassland.

Don'ts: The soil profile should be stable. Avoid making ponds in areas that suffer gully erosion, landslides or other soil instability. Also, avoid areas where pollution e.g. industries, sewers, toilets or garbage, may enter the pond.

Farm ponds and underground tanks collect and store runoff from ground catchments such as home compounds, open grasslands, hillsides, roads, footpaths, and unpaved areas. Sometimes roof catchments are also channeled into farm ponds.

2.1.4 Advantages of Farm Ponds

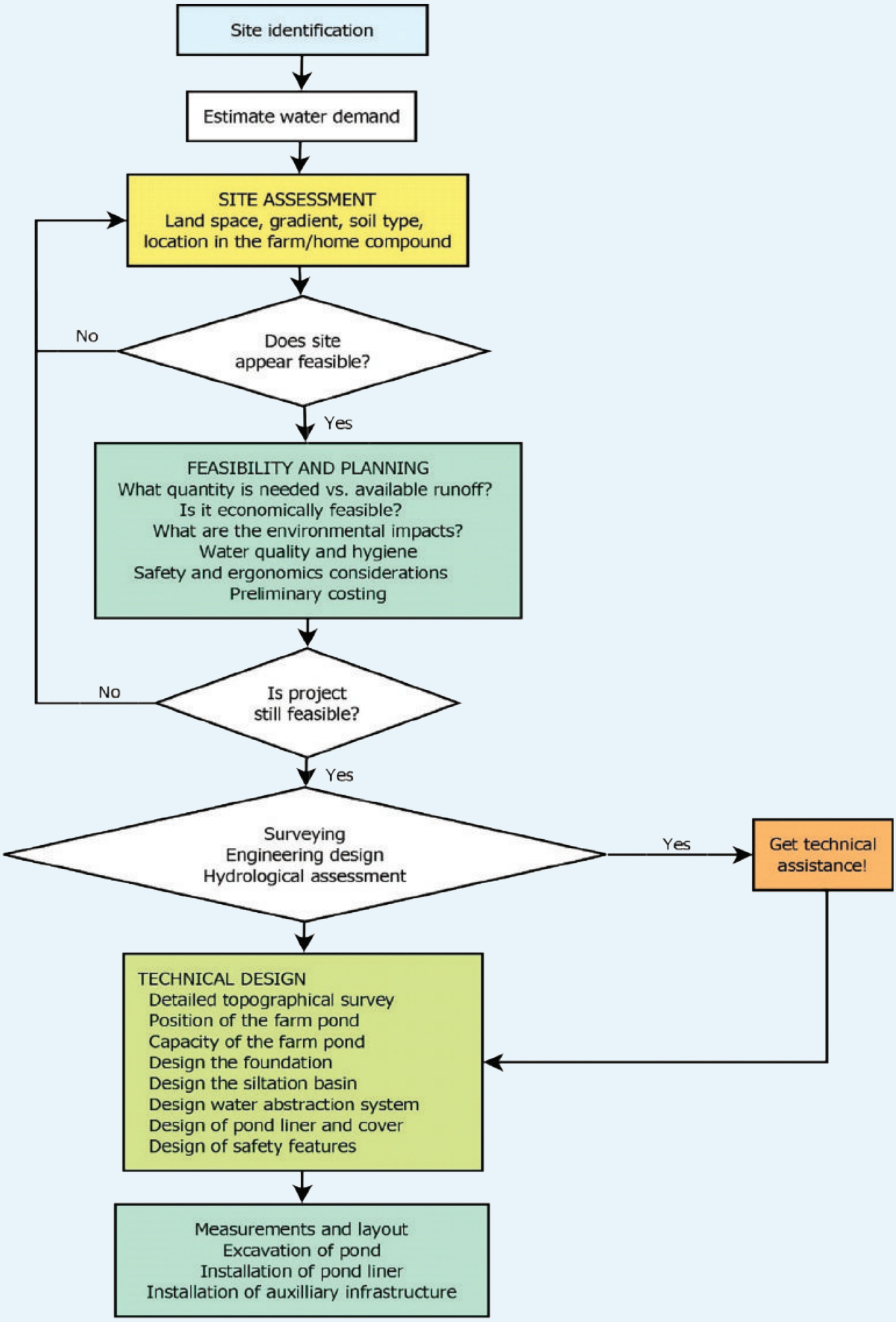
- Compared to roof catchment tanks, farm ponds have a larger capacity, and thus can supply more water, enabling supplemental irrigation and livestock watering – and thus increasing agricultural production.
- Farm ponds are situated at or near the home, water is closer to households
- They are suitable for households that do not front a river frontage or lacking groundwater (those who can't dig a well)
- Farm ponds utilize runoff from diverse sources including home compounds, roads and footpaths, hence can be appropriately positioned.
- They reduce flooding and land degradation, by storing excessive surface runoff for beneficial use to people and ecosystems.
- Lined farm ponds can be located almost anywhere, even in areas having seepage problems, making them versatile for community scale projects.
- As farm ponds are individually owned, they are better maintained.
- Being built underground, the ground offers support hence farm can be built with less reinforcement material.

2.1.5 Limitations of Farm Ponds

- The cost of dam-plastic or other lining material can be too high or unaffordable to smallholder farmers
- Since water is stored below the surface, farm ponds require a pump or some kind water lifting device
- The possibility of sediment inflows and water contamination
- High evaporation losses (unless the farm pond is covered)
- If not well managed e.g. properly covered, they pose danger to the safety of children and livestock.
- Leaks or failures may occur, as sometimes the plastic lining gets vandalized
- Tree roots can damage the structure from beneath.
- Compared to dams and water pans, water content of farm pond is still small and may only irrigate small gardens or supplemental irrigation.

2.2 Decision Tree for Identification and Planning a Farm Pond

The decision tree for a farm pond is much like that of any other water harvesting and storage structures, but targeted at individual households and farms. Decisions follow a logical process as depicted here below.


Site identification
Estimate water demand
SITE ASSESSMENT
Land space, gradient, soil type,
location in the farm/home compound
Does site
appear feasible?
No
Yes
FEASIBILITY AND PLANNING
What quantity is needed vs. available runoff?
Is it economically feasible?
What are the environmental impacts?
Water quality and hygiene
Safety and ergonomics considerations
Preliminary costing
Is project
still feasible?
No
Yes
Surveying
Engineering design
Hydrological assessment
Yes
Get technical
assistance!
TECHNICAL DESIGN
Detailed topographical survey
Position of the farm pond
Capacity of the farm pond
Design the foundation
Design the siltation basin
Design water abstraction system
Design of pond liner and cover
Design of safety features
Measurements and layout
Excavation of pond
Installation of pond liner
Installation of auxilliary infrastructure

2.3 Site Identification, Design, Layout and Construction

2.3.1 Site identification

The first step is to find a suitable site for the farm pond. Wherever possible, involve experts and the farmer in identifying the best site (Figure 2.2). It is when the site is known that the design of the farm pond can be done. A good site has the following characteristics:

- Adequate catchment area and some gradient so that runoff flows naturally into the farm pond
- Good source of runoff such as home compound, hillside, road or grass
- On stable soils such as clay or loam to avoid collapse
- Close to the home but not so close to buildings or else the foundations of the dwelling will be undermined
- Away from areas where children play or animals wander
- Away from trees – the roots of trees can be problematic
- Somewhere convenient for extracting water e.g. near cultivated area.

Figure 2.2 Site identification for a farm pond is a participatory process

2.3.2 Design of the Farm Pond

The design of farm ponds covers many aspects especially the water demand, pond storage capacity, its dimensions, runoff conveyance, inlets and overflow arrangements, including water abstraction, control of losses and safety.

(a) Design considerations

A farm pond is an engineering structure and should be designed using engineering and hydrological principles. The basic components of a farm pond is as shown in Figure 2.3. The main factors considered include:

- ***Shape of the farm pond:*** Can be circular, rectangular or square
- ***Depth of tank:*** should be deep enough for provision of sufficient water supplies allowing for evaporation loss.
- ***Side slopes*** (batter ratio) of the retaining walls - usually, this should be 3:1
- ***Freeboard****:* should be a minimum of 1 m above maximum water level.
- ***Overflow arrangements****:* The crest should be set at the maximum water level for the impounding structure.
- ***Silt traps and inlets*** – *should be* provided to reduce siltation and contaminants from entering the pond
- ***Ground condition*** - should be suitable for digging and for siting a farm pod

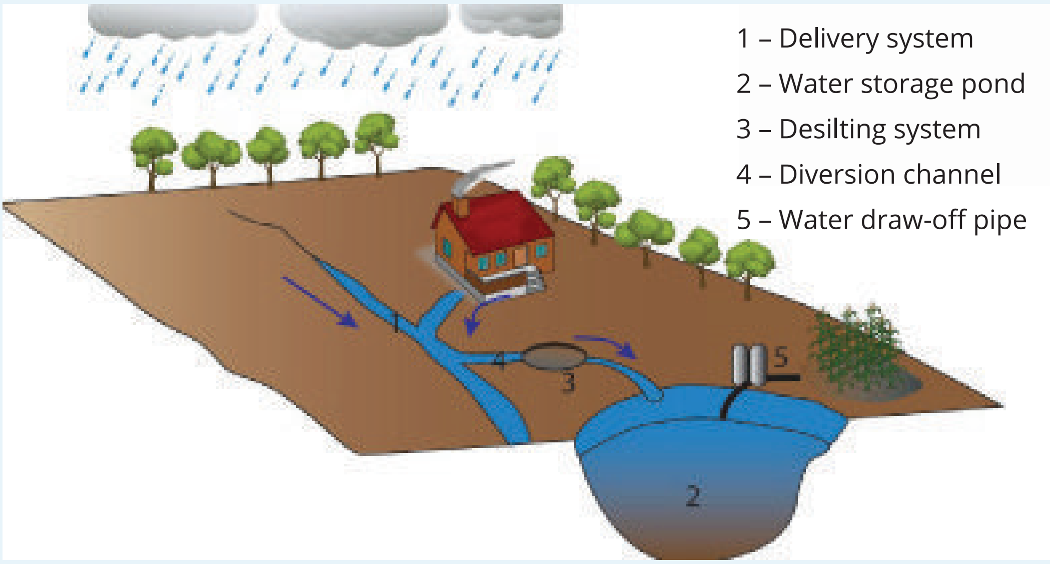


Figure 2.3: Basic components of a farm pond

(b) Storage requirements

It usually takes a few rainfall events for a pond to be filled up in normal rainfall years even in small runoff catchments. Assuming that the catchment area generates sufficient runoff to fill up the pond reservoir, the storage capacity of the farm pond can be matched to the seasonal crop water requirements computed from the size of the drip irrigation system.

(c) Calculating Water Demand

Water demand is the volume of water requested by users to satisfy their needs. Calculating the water needs of the user or household is relatively easy and involves a simple formula which includes the average daily consumption of water from the pond per person, livestock, and/or irrigation, the number of days in the dry season, and the numbers of people using the tank. The formula used is:

$$\text{Water Demand } (m^3) = \frac{\text{(No. of dry days in the year) x (daily water use)}}{\text{Efficiency factor}}$$

It is good to note that if the consumption is higher than estimated, the tank will run dry before the next rainy season. Hence an efficiency factor (e.g. 0.7) is used to take care of losses and unexpected use of the water. The next step is to decide on the appropriate dimensions and orientation of the farm pond. However, the sizes and dimensions of farm ponds are flexible and can be tailor-made to suit different landscapes, water demands, farmers' preferences and financial resources.

(d) Determining the storage volume of the structure

Most farm ponds have capacities ranging between 50 m^3 to over 1,000 m^3. But the volume of water storage structure is calculated differently depending on the shape of the pond. For convenience, the following derivations of the prismodal formula can be used depending on shape of farm pond as follows:

Equation for **Circular** farm pond:

$$V = \pi[R^2 + (R \times r) + r^2] \times {}^{D}/_{3}$$

Equation for **Rectangular** farm pond:

$$V = [(TL \times TW)+(BL \times BW)+[(TL \times BL)+(TW \times BW)]] \times {}^{D}/_{6}$$

where in all formulae:

V = volume (m^3)

R = radius of water surface (m)

r = radius of floor (m)

D = depth (m)

π = *Pi* equivalent to 3.14159

TL = length of water surface (m)

TW = width of water surface (m)

BL = length of floor (m)

BW = width of floor (m)

D = depth of water from surface to floor (m).

The pond should have a trapezoidal shape in order to avoid the collapsing of the sides and to enhance the lining effect (Figure 2.4).

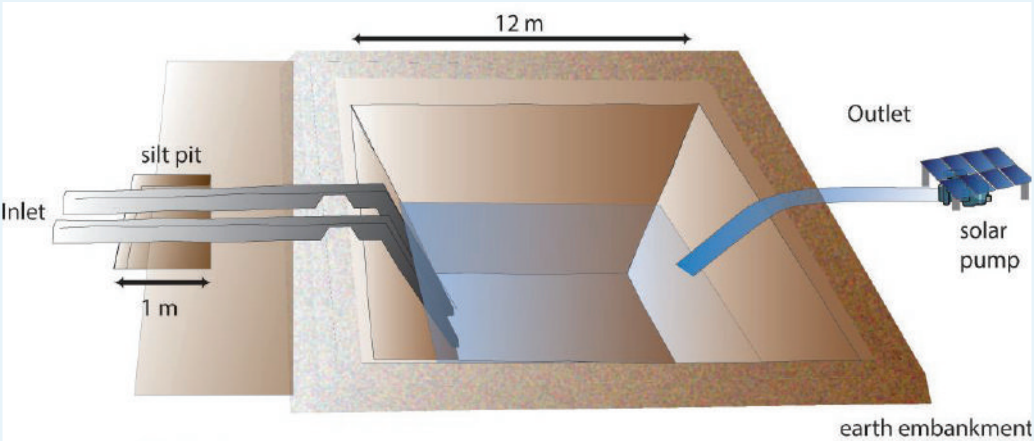


Figure 2.4: Basic design of a trapezoidal farm pond (or underground tank)

2.3.3 Planning

Planning is the first step and helps identify sites for suitability of water-impounding structure and other basic characteristics.

- It starts with a site survey and feasibility studies.
- The users and uses of the proposed farm pond are identified.
- It also considers the expected catchment yield (of runoff),
- Looks at the best option for siting the farm pond,
- It considers the catchment orientation, runoff flows (from experience), possible inlet, outlet and safe overflow disposal are also discussed.
- It considers the social, economic and environmental considerations.
- At this stage, a rough layout of the water storage structure is made and agreed upon with the users/household.

2.3.4 Layout and constriction of the farm pond

In places where the soils are clayey, and impervious, it is possible to build unlined sub-surface tanks, but they suffer from seepage, evaporation and poor water quality. The following steps can be followed steps

(a) Farm pond layout

After siting the farm pond, the top and bottom dimensions are marked out using strings, ash or powder. Prepare site by pegging and referencing corners (square and rectangular shapes) or structure centre (circular shape). Measure fall across site for calculation of any storage volume above excavation. Install a temporary bench mark in a protected location (Figure 2.5).

Figure 2.5 Farm Pond Layout *(Photo credit: Makueni WFP-AC project)*

(b) Excavation

Before excavation commences, the vegetation, trees, grasses, rocks and topsoil are removed and kept far from the pond location. The excavation then starts with the inner rectangular pit, which is dug up to the required depth of 2-3 m. Also, then the outer rectangle is sloped to the required slope (1:1) in order to form the shape of the farm pond (Figure 2.6).

(Photo credit: Makueni WFP-AC project)

Figure 2.6 Excavating the Farm pond

Then the farm pond side slopes are smoothened to retain a uniformly graded side slopes within the pond (Figure 2.8). This is necessary to allow for the installation of the UVR plastic lining material to control seepage.

(Photo credit: Makueni WFP-AC project)

Figure 2.8 Farm pond with smooth side slopes

2.3.5 construction of silt trap

A sedimentation basin or silt trap is normally constructed to minimize siltation and also act as a spillway (Figure 2.7). A silt trap has a double chamber (e.g. measuring 60 cm x 60 cm x 60 cm). However, for large farm ponds, the size of the silt trap should be increased accordingly based on the amount of expected runoff. The two chambers are made of masonry or bricks and plastered for ease of maintenance.

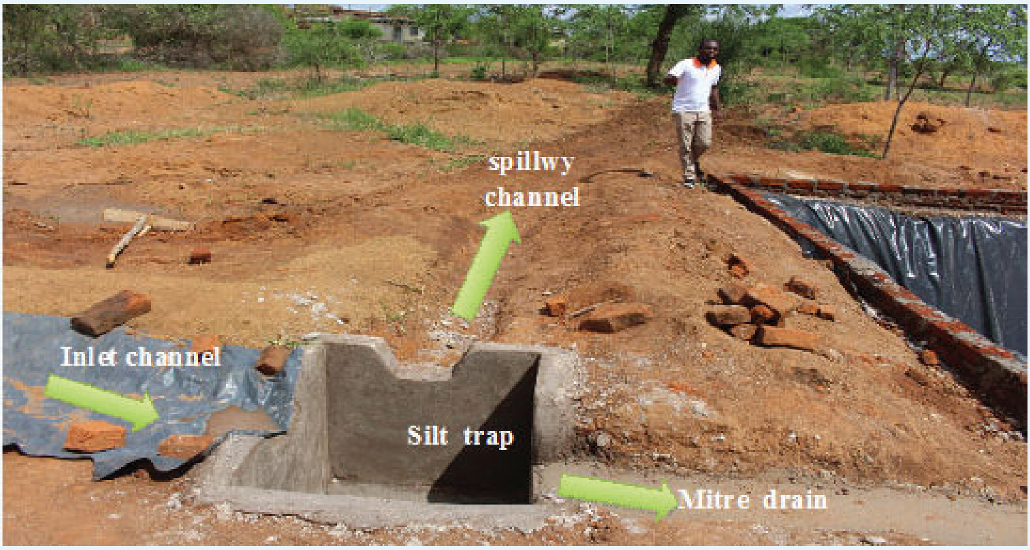


Figure 2.7 Construction of a silt trap *(Photo credit: Makueni WFP-AC project)*

There are two inlets fitted with PVC pipes and a screen filter to ensure that the runoff is well filtered. These are to prevent floating debris from entering the farm pond (Figure 2.8a). Siltation into the pond can be further reduced by placing a screen at the inlet to the tank.

The conveyance channel may also be designed in a zig-zag flows to reduce flow velocities allowing sedimentation to occur ahead of the siltation basin (Figure 2.8b). Another way is to plant grass sods ahead of the inlet, or to do stone pitching or pegs of tree branches to enable sedimentation ahead of the entry chamber.

(photos by B. Mati)

(a) Double chamber inlet silt trap

(b) Concrete zig-zag inlet channel

Figure 2.8 Construction of a silt trap

2.3.6 Fixing the plastic lining in the Pond

There are several ways of lining a farm pond. They include; clay grouting. cement mortar lining, stone masonry or brick lining, and use of special dam-plastic geo-membranes (figure 2.9a).

Plastic geo-membrane linings

These are specially made plastic linings used in dam construction, which withstand solar radiation and have a lifespan, ranging 5-10 years. Normally, the plastic lining is made to measure in a factory and the pond is constructed to fit its dimensions. The pond is lined with a UVR plastic sheet /dam liner to prevent water losses through seepage. The plastic liners are available for various thicknesses in the market (0.5 mm, 0.8 mm or 1 mm). As the plastic liner is made to measure and fixed perfectly into the pit (Figure 2.9b).

(photo by B. Mati)

(a) Dam-plastic liners ready for sale

(Photo credit: Makueni WFP-AC project)

(b) Fixing the plastic lining in the pond

Figure 2.9 Dam-plastic liners and fixing on farm pond

Advantages of flexible plastic liners for farm ponds

Compared to other sealing methods plastic liners have the many advantages.

- They can be installed by the user easily.
- They control seepage quite effectively
- Can be used on almost any soil. A
- The cost is getting lower as their popularity grows with more manufacturers and suppliers.
- Geo-membrane covers can be transported easily to place of use.

However, a major limitation is the shorter lifespan, which rangers 5-10 years. They can also be easily damaged by agricultural equipment

2.3.7 Construction of pond walls

To make the structure stable, a one-course masonry layer (using brick, dressed or rubble stone) is constructed along the upper boundary (perimeter) of the farm pond. The masonry layer is laid about 20 cm from the top dimensions along a shallow ditch (10 -20 cm deep) to hold the dam liner firmly to the ground and prevent side runoff from entering the reservoir (Figure 2.10). The short perimeter wall is provided with gaps at predetermined distances for fixing the anchors of the metallic roofing structure. The masonry work is done by trained local artisans with labor and locally available construction materials provided by the community or beneficiaries.

(Photo credit: Makueni WFP-AC project)
Figure 2.10 Construction of perimeter wall

2.3.7 Auxiliary structures

Auxiliary structures include the water lifting devices (Figure 2.11) and safety features. The pond should be fixed with a pump, which should be low cost and preferably using renewable energy, e.g. solar pump, manual or motorized pumps.

(Photo: Makueni WFP-AC project)
Figure 2.11 Completed farm pond with manual pump

2.3.8 Covering the farm pond

The farm pond should be covered to protect the water from evaporation, contamination and as a safety measure. This can be achieved by use of a shade nets, supported with meshed wire network, including anchoring masonry (Figure 2.12). A shade net accords 80% shading and thus can allow entry of direct rainfall and runoff. The covering is supported by a simple metallic structure.

(Photo: Makueni WFP-AC project)

Figure 2.12 Covering the farm pond with shade net

2.3.10 Fencing

The area around the water pan should be fenced with suitable material, e.g. barbed wire or life-fence (Figure 2.13). A lockable door should be provided to exceptionally avoid the reach of domestic and wild animals and small children. Holes underneath made by burrowing animals, e.g. moles, should be checked.

(Photo: Kitui WFP-AC project)

Figure 2.13 Fencing the farm pond with chain link

2.4 Operation and Management of Farm ponds

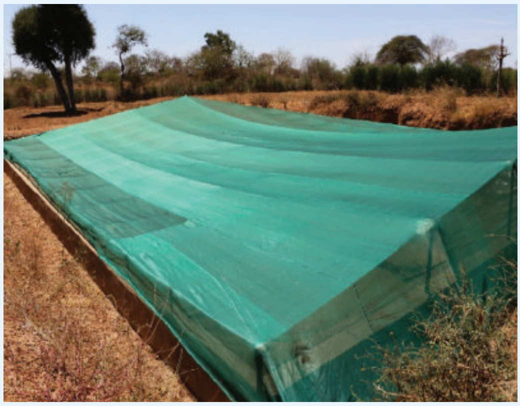
As with other water harvesting systems, farm ponds require proper operation and regular maintenance.

- There should be regular checks on the pond for seepage, cracking and piping
- The side slopes, inlets and outlets should be inspected any damages. If present and attended to early, most of these problems can be treated.
- The pond liner should be checked and if punctured, the membrane can be easily repaired by farmers themselves or local practitioners (by using used plastic products, heat, gluing using adhesives of bicycle inner tube maintenance techniques.
- Regular cleaning of inlets, silt pits and the tank itself of any of debris and eroded soil material should be done.
- The shade net/cover should be checked for any signs of tear which may develop into holes in the future. If the torn places are minor, the net can be removed and the torn places sawn with appropriate threads before returning it back to cover the pond.
- Vermin can burrow into inlets, outlets, embankments causing damage Vermin around the structure should be eradicated.
- The whole area around the tank should be fenced to improve safety.

- The fence should be checked to ensure that no animal or child can pass through. The spaces must be sealed as much as possible. For barbed wire or chain link, repair or replace as appropriate. For live fence, plant more stems in open spaces.

(photo by B. Mati)

(c) Plastic-lined farm pond with silt trap and hand pump



Source: WFP: https://insight.wfp.org/an-oasis-in-the-dry-plains-ca0a854b7921

(d) Farm pond covered with shade net

Figure 2.14 Well-maintained farm pond (a) desilted inlet, and (b) preserved covering

2.5 Selected References

AfDB. 2007. *Assessment of best practices and experiences in rainwater harvesting*. Rainwater Harvesting Handbook. African Development Bank (AfDB), Tunis.

Keen, M. 2005. *Excavated tanks and hillside dams*. Conservation Practices for Agricultural Land. Department of Agriculture, Australia.

Kitui WFP-AC project presentation (2018). Best practices and innovations in Kitui county. Project progress report.

Makueni County Asset Creation Programme (2018). Bridging Relief and Resilience in the Arid and Semi-Arid Areas. Project progress report.

Mati, B. M. 2010. Agricultural water management delivers returns on investment in eastern and southern Africa: A regional synthesis. In Mati, B.M. *Agricultural water management interventions delivers returns on investment in Africa. A compendium of 18 case studies from six countries in eastern and southern Africa*. VDM Verlag. 1-29.

Mati, B.M. 2007. *100 Ways to Manage Water for Smallholder Agriculture in Eastern and Southern Africa*. SWMnet proceedings 13. Nairobi, Kenya. www.asareca.org/swmnet/imawesa

Mati, B.M. 2012a. *Best Practices for Rainwater Harvesting from Open Surfaces with Storage in Structures.* Training Manual 2. NBI/NELSAP - Regional Agricultural and Trade Programme (RATP), Bujumbura, Burundi. http://nileis.nilebasin.org/content/best-practices-rainwater-harvesting-open-surfaces-storage-structures

Nega H, Kimeu PM. 2002. *Low-cost methods of rainwater storage: Results from field trials in Ethiopia and Kenya.* RELMA Technical Report Series 28. Nairobi, Kenya: Regional Land Management Unit (RELMA), Swedish International Development Cooperation Agency (Sida). 58 p.

Nissen-Petersen, E. 2003. *Water from ponds pans and dams*. A manual on planning, design, construction and maintenance. World Agroforestry Centre.

Nissen-Petersen, E., 1982. *Rain Catchment and Water Supply in Rural Africa:* A Manual. Hodder and Stoughton, Ltd., London.

Pacey A and Cullis A. 1999. *Rainwater harvesting: The collection of rainfall and runoff in rural areas*. Intermediate Technology Publications, London, UK.

RELMA, 2005. *Water from ponds, pans and dams: a manual on planning, design and maintenance*. Technical Handbook no. 32. Regional Land RELMA and World Agroforestry Centre, Nairobi, Kenya.

Teshome, A., Enyew, A. and Mati, B.M. (2010). Impact of water harvesting ponds on household incomes and rural livelihoods in Minjar Shenkora district of Ethiopia. *Ecohydrology & Hydrology*. Vol. 10: No. 2-4, 315-322

UN Habitat. 2005. *Rainwater Harvesting and Utilization*. Blue Drop Series. Book 2.

3. Water Pans for the Semi-Arid Zones

3.1 Basics about water pans

3.1.1 What is a water pan?

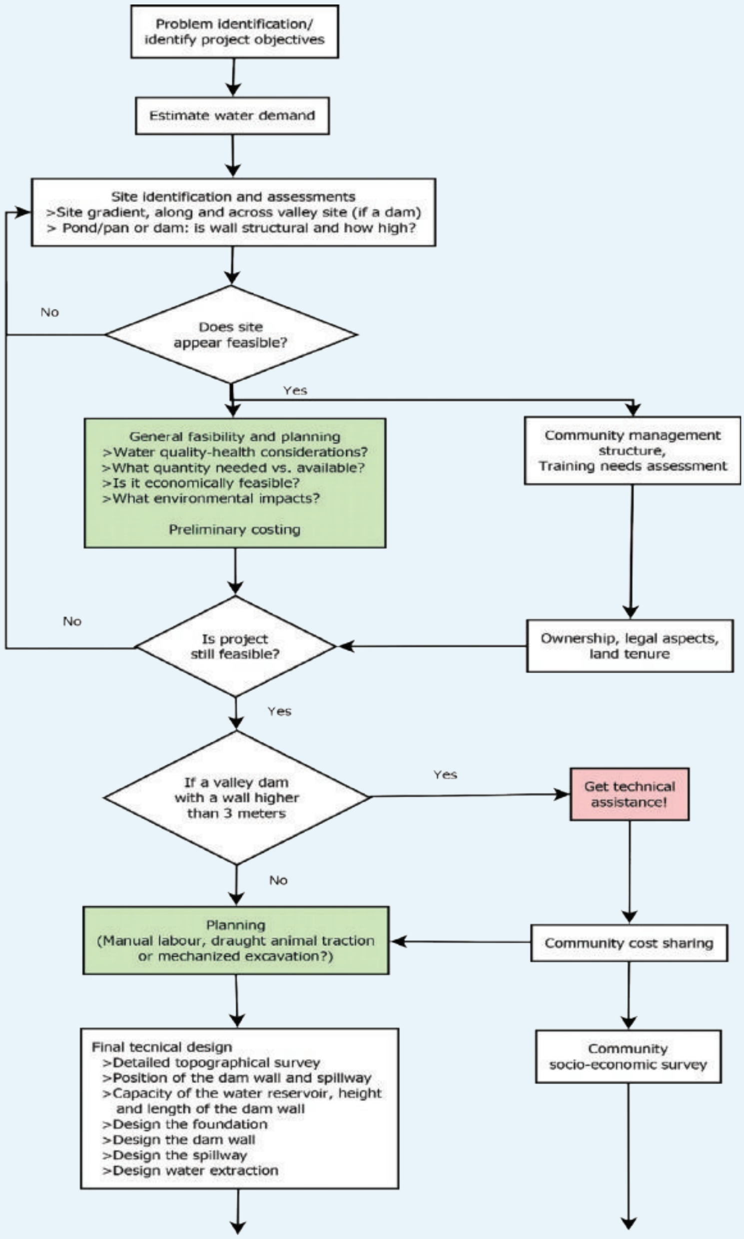
A water pans is a small reservoir, about 1 m to 3 m deep, usually dug off-stream with raised and compacted banks all around. They are constructed to collect and store runoff water from various surfaces including from hillsides, roads, rocky areas and open rangeland (figure 3.1). Water pans receive their water wholly from surface runoff. The capacity of pans can range from 500 to 1,000,000 m^3. Structures whose reservoir capacity is less than 500 m^3 are called tanks or farm ponds, while those exceeding 5,000 m^3 are called dams. The water collected can be used for drinking (after treatment), livestock watering and/or supplemental irrigation.

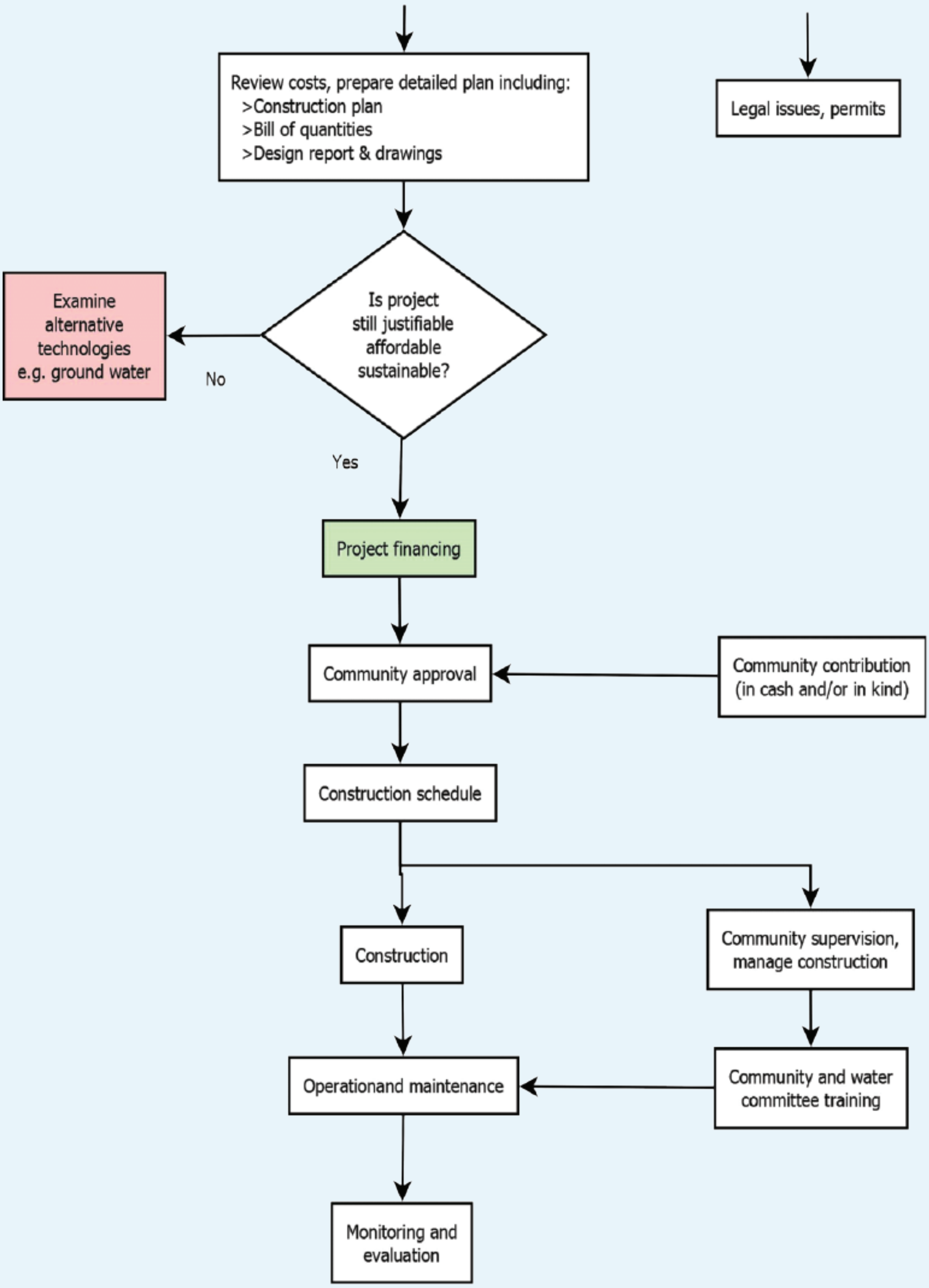
Figure 3.1 A water pan in a protected catchment collects clean water

3.1.2 Why construct a water pan?

Water pans are constructed mainly in locations where the topography does not have a suitable site for a dam e.g. on flatter or rolling terrain and instead only a scooped our excavation may be feasible. A major advantage of pans is that relatively larger volumes of rainwater can be stored when compared to tanks or farm ponds. The storage structure is easy to construct and use. Pans can be used to collect runoff from home compound, where houses are grass-thatched. Below is a decision tree for identifying suitability for a water pan.

3.1.3 Decision Tree for planning and design of a water pan





(Adapted from Nissen-Petersen, 2003)

3.2 Site Selection, Design, Layout and Construction of a Water Pan

3.2.1 Site selection

From an economic view point, the water pan should be located where maximum storage volume is obtained for minimum volume of excavation. They are generally built close to settlements, and on grazing lands rather than farmlands. Pans are excavated on gentle sloping lands; less than 2% or 1:50; this simplifies construction and minimizes erosion. The catchment land above must be gently sloping as well (Figure 3.2). Catchment should be grassed to help in trapping silt.

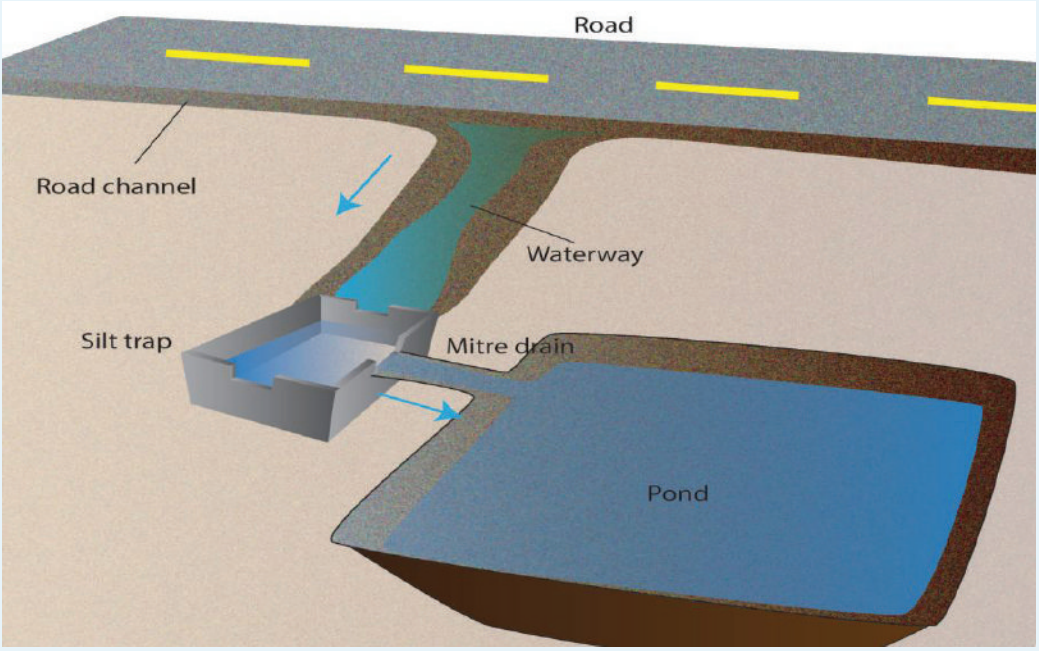


Figure 3.2 Illustration of a water pan collecting water from road runoff

(a) Characteristics of a Good Pond Site

A good pond site should have the following characteristics:

- (i) Be at the lowest point where water collects naturally after the rains
- (ii) The pan should sit in an area that is known to hold water after the rains, or where local indicators, e.g. certain trees, intimate

that the pan will hold water (not lose water by seepage or deep percolation).

(iii) The capacity catchment area ratio should be such that the pan can fill up in easily during the rainy season.

(iv) Pan storage should be able to be filled by 5% of mean annual precipitation in the catchment area.

(v) The capacity should not be too small to be choked up with sediments

(vi) The pan should be located where it could serve a major purpose e.g. if for irrigation, it should be above the irrigated fields

(vii) The catchment area should be put under conservation practices.

3.3.2 Design of pans and ponds

(a) Components of storage ponds

The components of a pan are quite similar to those of an underground tank or farm pond. Basically, a pan must have a catchment area, diversion channel, desitling basins, the reservoir and the water delivery system, mainly pipes and taps (Figure 3.3). A properly designed and constructed pan has an embankment which is covered with grass sod to prevent collapse or erosion of the banks.

- The inlet should be stone pitched to prevent soil erosion.
- A mesh should be provided at the inlet to prevent floating material from entering the pond. The slope of the sides shall depend on the soil condition.
- In order to prevent seepage losses through sides and bottom, these are lined with plastic sheeting. This should be embedded properly and the outlet stone-pitched to prevent soil erosion.
- A water extraction piping, pump or well is constructed at a suitable point of pond to facilitate withdrawal of water. The well has to be constructed by raising two masonry wing walls and one front wall. A suitable platform fitted with iron fixtures for simple pumps is necessary.
- A silt trap should be provided at the inlet point to prevent sediment load form entering the pond.

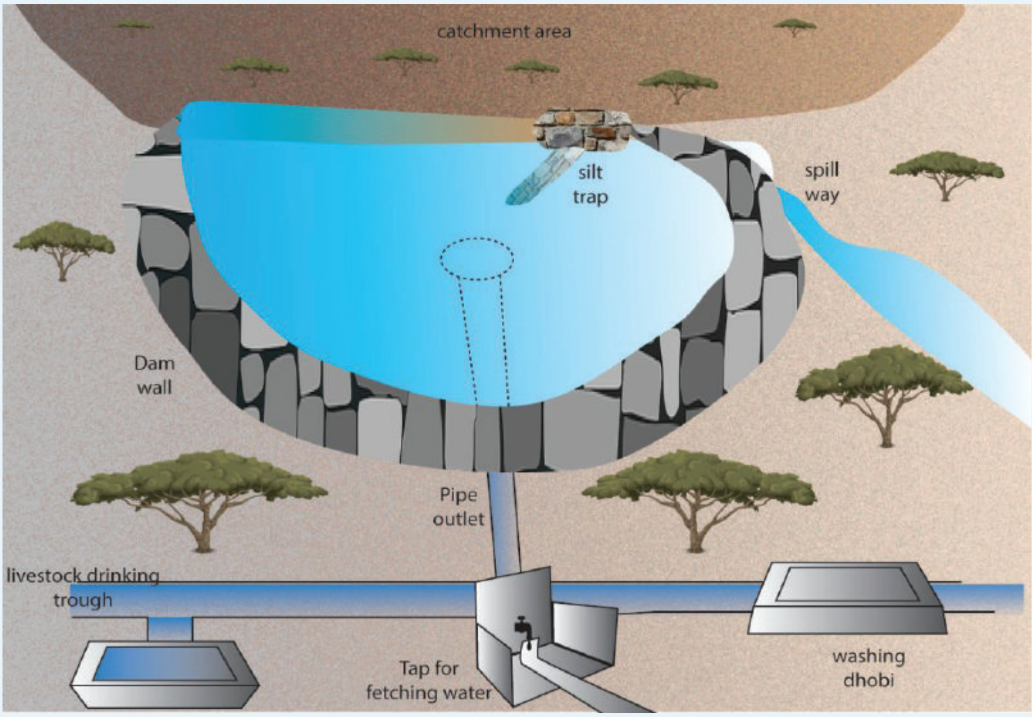


Figure 3.3. Major components of a water pan designed for integrated use

(b) Sizing the water pan based on water demand

Pans are usually designed for community use. Hence total water demand can be calculated as follows:

$$\text{Water Demand (m}^3\text{)} = \frac{\text{(No. of households) x (water use per household)}}{\text{Efficiency factor}}$$

An **efficiency factor** (e.g. 0.5) can be used to take care of losses due to evaporation, spillages and unexpected use of the water.

(c) Water demand

Household water demand can be estimated as the total water used by individuals (people and livestock) in each household. In Kenya, water requirement for human consumption on average are estimated at human 20lts/ person/day, while for large stock, it is 30lts/head/day, and for small stock 5 lts/head/day. The size of a pond/pan for water harvesting is usually dictated by runoff availability and adequate catchment area, which also includes roads, footpaths, home compounds or open grasslands.

(d) Determining the storage volume

A detailed survey is usually required to estimate the size of the catchment area and the reservoir storage for different water levels. For calculating the reservoir storage volumes, simple field surveys are carried out using a GPS and local skills. The equation for computing storage volumes, for different pond levels is:

$$V = \frac{(SD^2)}{2}(B + nD)$$

Where,

V = total storage volume of pan in m³
B = channel width B (meters) at bund site
n = bank slopes e.g. n: 1 (fall of 1 metre in a length of n metres)
S = bed slope of channel – S:1 (fall of 1 metre in a length of S metres along the channel bed)
D = depth of water above the channel bed (metres).

The storage capacity should be at least double the total water requirement to take care of evaporation and seepage losses. As a rough guide, 10 per extra storage may be provided for sediment deposition.

(d) Determining spillway dimensions

Ponds located in low rainfall areas may have peak discharges during rainy season are too small to require evacuation through a concrete or masonry spillway. Instead a pipe spillway may be provided. Normally the pipe should be large enough to pass the peak discharge without moderation due to the reservoirs. However, where the reservoir is large with considerable storage capacity the moderation effect may be considered using the following formula:

$$\frac{Q_o}{Q} = 1.25 - \left(\frac{1500V - 0.06}{RA}\right)^{1/2}$$

Where,

Q_o = Rate of outflow when the pipe first flows full in m³
Q = Peak rate of inflow in m³
V = Available storage in ham
R = Runoff in mm, and
A = Drainage area in hectares (same as watershed area)

The above equation provides a rough guide to estimate of the size of the mechanical spillway pipe required for a pan.

(e) Design for integrated use

Since water for domestic use is scarce in the semi-arid areas, a water pan should be designed and constructed for integrated use. The water will anyway be used for multiple purposes, including drinking, laundry, livestock watering or irrigation.

3.3.3 Layout of the water pan

Site surveys should be conducted to determine the land slope and orientation. A typical pan design should include the following drawings:

- Site map (google, 1:50,000 or 1:100,000 contour map);
- Site layout (showing water flows);
- Inlet channel cross section and longitudinal profile;
- Outlet channel cross section and longitudinal profile;
- Cross section (pan and silt trap);
- Control/spillway/overflow sill details;
- Inlet/outlet details/ramp details.

Photo credit: Baringo WFP-AC project)
(a)Surveying the site (b) Bush clearing and manual excavation

Figure 3.4 Surveying and land preparation works

Soil characteristics - The site should have soils with good water retention characteristics. For instance, black cotton soils with fine clay have poor percolation / seepage properties, providing good sites for pan location.

Topography - The site should have gentle slopes of 1% and a maximum 5%.Use community knowledge and or choose natural depressions known to impound water during rainy season.

Avoiding pollution - The pan sites should be located upstream of any pollution sources.

3.4 Construction of the Water pan

(c) Stripping

Excavation of pans starts with "stripping" the proposed area of 0.20 m - 0.30 m of topsoil. This topsoil is then stockpiled for later use as a cover to the excavated material. The excavated soil is disposed off.

(d) Excavation

Pans may be excavated by hand or using machinery. A small pan can be constructed with the use of a bulldozer where the bulldozer simply excavates and pushes material. Push distances should be kept less than 60 m. Larger pans will also require a bulldozer as well as some sort of loader (wheeled or tracked) and several tippers. However, for efficiency and precision, it is recommended that the pan be excavated using machinery (Figure 3.5).

(Photo: Baringo WFP-AC project)

Figure 3.5 Mechanized excavation of water pan

Excavation works: Whether human labor or mechanization is used, the excavated material should be placed on leeward side and compacted so that it does not fall back into the reservoir. The pan bed is then compacted upon completion to reduce seepage (Figure 3.6a).

Side slopes: - During the excavation of the reservoir, it is important to provide side slopes of 1:3 to facilitate ease of access in to the pan and prevent accident for people and livestock.

Spillway: - – provide spillway channel for excess water to flow behind the silt trap and provide a masonry sill at the off-take point to prevent erosion.

Bed slope: - the pan bed should have a slope of 5% from inlet to the embankment to provide non eroding flow of water.

Inlet: The inlets should be well placed and linked to the catchment drainage system to able to bring the maximum available run-off into the pan.

Sedimentation basin: A sedimentation basin or silt trap is normally constructed to minimize siltation. The silt traps will reduce velocity of surface runoff allowing sediments to settle so that cleaner water enters the pan, preventing siltation.

Seepage control: - Provide a clay blanket (a t least 300 mm thick) on the bed and sides of pan compacted in 150 mm layers. This seals cracks in the structure.

Fencing: – provide chain link fence or live hedge around the pan to avoid direct entry of people and/or livestock to the water. The fence also protects the catchment from degradation and resulting in clean water (Figure 3.6b).

(Photo credit: Baringo WFP-AC project)

(a) A newly cexcavated water pan

(Photo: B. Mati)

(b) Water pan fenced and in protected catchment

Figure 3.6 Water pan newly constructed and established in protected catchment

3.5 Water off-take infrastructure and safety

To avoid water contamination and siltation, pans should be designed and constructed in such a way that people and livestock do not go to the pan to collect water. Instead, the water should be delivered to community watering point and livestock watering bays through piping or a well connected to the reservoir.

Infiltration well: – Provide infiltration well by installing horizontal collectors buried in a gravel envelope; wells be at least 2m below the pan bed and fitted with hand pump with manhole cover. The horizontal collectors have provision for plugging to stop flow when the well is under maintenance. For drinking water supplies, the well may be disinfected with and water pumped out before use.

Water points for human use – Pipe the water away from the pan and provide stand pipes for domestic water supplies (Figure 3.7a).

Livestock drinking bays – Livestock should not directly access the pan. Provide livestock troughs on the downstream side of the water pan (Figure 3.7b).

(Photo: Baringo WFP-AC project)
(a) Water from pan piped to community tap

(Photo: Baringo WFP-AC project)
(b) Water supplied to livestock drinking trough

Figure 3.7 Water draw-off points from a piped to users

Health and hygiene: It is therefore imperative to provide a water pan that incorporates issues of safety, health, livestock, hygiene and sanitation. Whenever possible, amenities such as toilets, bathrooms and washing dhobi should also be provided, located downstream of the pan (Figure 3.8).

(Photos: B. Mati)

(a) Toilets and bathrooms downstream of pan

(b) Washing dhobi with water piped from pan

Figure 3.8 Sanitation amenities provided behind the pan

3.4 Control of common problems in water pans

(a) Water-borne diseases

Water pans usually hold stagnant water which can attract various pathogen, disease vectors and pollution. For instance, mosquitoes breed in rainwater storages and they are vectors of diseases such as malaria, yellow fever, dengue fever and filariasis. Careful use of the water is necessary. Reservoirs constructed for storing domestic water should not be used by livestock unless off-take facilities are provided.

(b) Water pollution

Due to its open siting and surface water inflows in pans, the water can become polluted and cause health hazards. Guinea worm, water hyacinth, mosses, algae may invariably invade the pond in large quantities. Infectious diseases like guinea worm are associated with the villages where surface pond water is in use. These can be avoided to by proper design and construction and treating the water before use.

(c) Seepage losses

Water stored in pans may leak or be subject to seepage. Seepage through the wall increases the risk of breaking and failure of the wall. The main factors contributing to this problem are the soil type and the amount of compaction of the embankment. This can be prevented by careful selection of the site for the structure. Sites with sand or gravel should be avoided. Seepage can be reduced by compacting the pond.

(d) Siltation

Siltation is caused by various factors including cultivation and poor land use in the catchment. The design of the structure can also contribute to siltation, especially if there are no siltation basins (Figure 3.11). An estimate of the sediment load in the water to be harvested can be made and the sediment trap efficiency deduced. Silt accumulation can be reduced by careful site selection to avoid highly erodible areas. Also, silt traps should be constructed at entry point of runoff into the structure.

(a) Water pan without siltation basin

(b) Same water pan with polluted water

Figure 3.11: Effects of water pan without a sedimentation basin

(e) Evaporation losses

Evaporation is a major problem in water pans. However, there are methods for controlling evaporation. They include a good design or site selection for surface reservoirs, whereby the ratio of storage volume to surface area is optimized. An alternative is to divide the reservoir into two or more compartments. If the storage is small, it can be covered with a roofing material or shaded to protect the water surface from wind and direct sun thus reducing evaporation.

3.5 Operation and Maintenance of water pans

- Engage the community from the very inception of the project so that they have ownership
- Establish a water user committee for responsible oversight of the management of the water pan

- Ensure capacity building of the committee on their roles and responsibilities and the community for prudent use of water and taking care of the pan
- Prepare a Motoring and evaluation system to track condition of the pan
- Leave in place a system for equitable sharing of water, gender mainstreaming, conflict management and environmental management as well as operation and maintenance of pumps and other accessories to enhance sustainability.
- Conduct faecal coliform & turbidity test and provide household level water treatment as appropriate
- Inlets should be cleaned regularly, be able to direct all the water from the catchments area while silt traps facilitate deposition of silt away from the pan during the rainy seasons.
- All potential problems must be repaired as soon as possible to safeguard the dam. side slopes should be cleared on a regular basis.

3.6 Selected References

AfDB. 2007. *Assessment of best practices and experiences in rainwater harvesting*. Rainwater Harvesting Handbook. African Development Bank (AfDB), Tunis.

Baringo WFP-AC project presentation (2018). Best practices and innovations in Kitui county. Project progress report.

Mati, B.M. 2007. *100 Ways to Manage Water for Smallholder Agriculture in Eastern and Southern Africa*. SWMnet proceedings 13. Nairobi, Kenya. www.asareca.org/swmnet/imawesa

Mati, B.M. 2012a. *Best Practices for Rainwater Harvesting from Open Surfaces with Storage in Structures.* Training Manual 2. NBI/NELSAP - Regional Agricultural and Trade Programme (RATP), Bujumbura, Burundi. http://nileis.nilebasin.org/content/best-practices-rainwater-harvesting-open-surfaces-storage-structures

Nissen-Petersen, E. 2003. *Water from ponds pans and dams*. A manual on planning, design, construction and maintenance. World Agroforestry Centre.

Nissen-Petersen, E., 1982. *Rain Catchment and Water Supply in Rural Africa:* A Manual. Hodder and Stoughton, Ltd., London.

RELMA, 2005. *Water from ponds, pans and dams: a manual on planning, design and maintenance*. Technical Handbook no. 32. Regional Land RELMA and World Agroforestry Centre, Nairobi, Kenya.

4. Sand and Sub-Surface Dams for Water Storage in Semi-Arid Zones

4. 1 What is sand river water storage?

A sand river (locally known as lagga in northern Kenya), is an ephemeral river mostly found in the dry areas, whose profile comprises mostly of coarse sand, and which carries short lived but heavy flash floods, also laden with sand.

Sand river storage is water harvesting and storage in reservoirs designed to hold both water and coarse sand. The main structure is normally a dam constructed across a sand river.

Why water storage in sand river beds?

Water in sand rivers can be tapped when other sources have dried up. Sand rivers are used as traditional water sources in semi-arid regions where communities dig holes or shallow wells within the sand bed to obtain water during the dry season.

How do you improve water storage in sand river bed?

Water level in the sand falls and may dry up during the long dry seasons. Sand river storage is improved by construction of three types of dams;

(i) Sand dam built of masonry,
(ii) Subsurface dams built of stone masonry, and
(iii) Subsurface dams built of clay.

What is a sand dam?

A sand dam is a reservoir created when a ***short concrete embankment*** is constructed across a sand river allowing the storage of both water and sand carried by the river flow into the dam.

What is a sub-surface dam?

A sub-surface dam is a reservoir created when a short embankment (made of concrete or compacted clay) is constructed **beneath the surface a sand river** allowing the storage of both water and sand carried by the river flow into the dam.

How do sand and sub-surface dams store water?

The dry river bed contains sand which has voids that can hold water. During the rains, these voids fill with water but it flows away. When a sand dam or subsurface dam is constructed, the water and sand accumulate in the dam till it is full up to spillway. The sand storage created can contain up to 35% water.

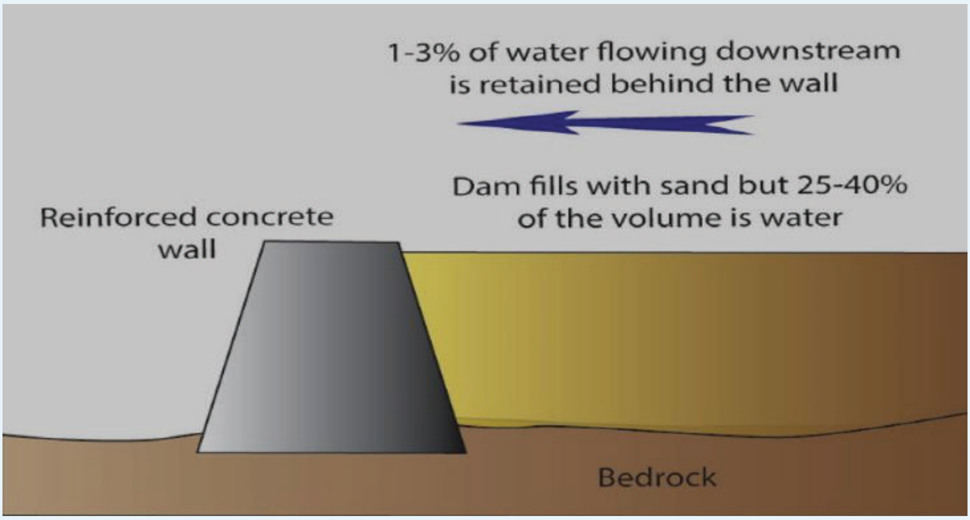


Figure 4.1 Illustration of sand dam water storage

Where are sand and sub-surface dams technically feasible?

There are 2 pre-conditions for a suitable sand dam site:

- Sand dams must be sited on a seasonal river with sufficient sandy sediment.
- Sand dams must be sited where there is accessible bedrock in the river bed.
- The catchment area should be stable (not eroded).

4.2 Benefits of sand and subsurface dams

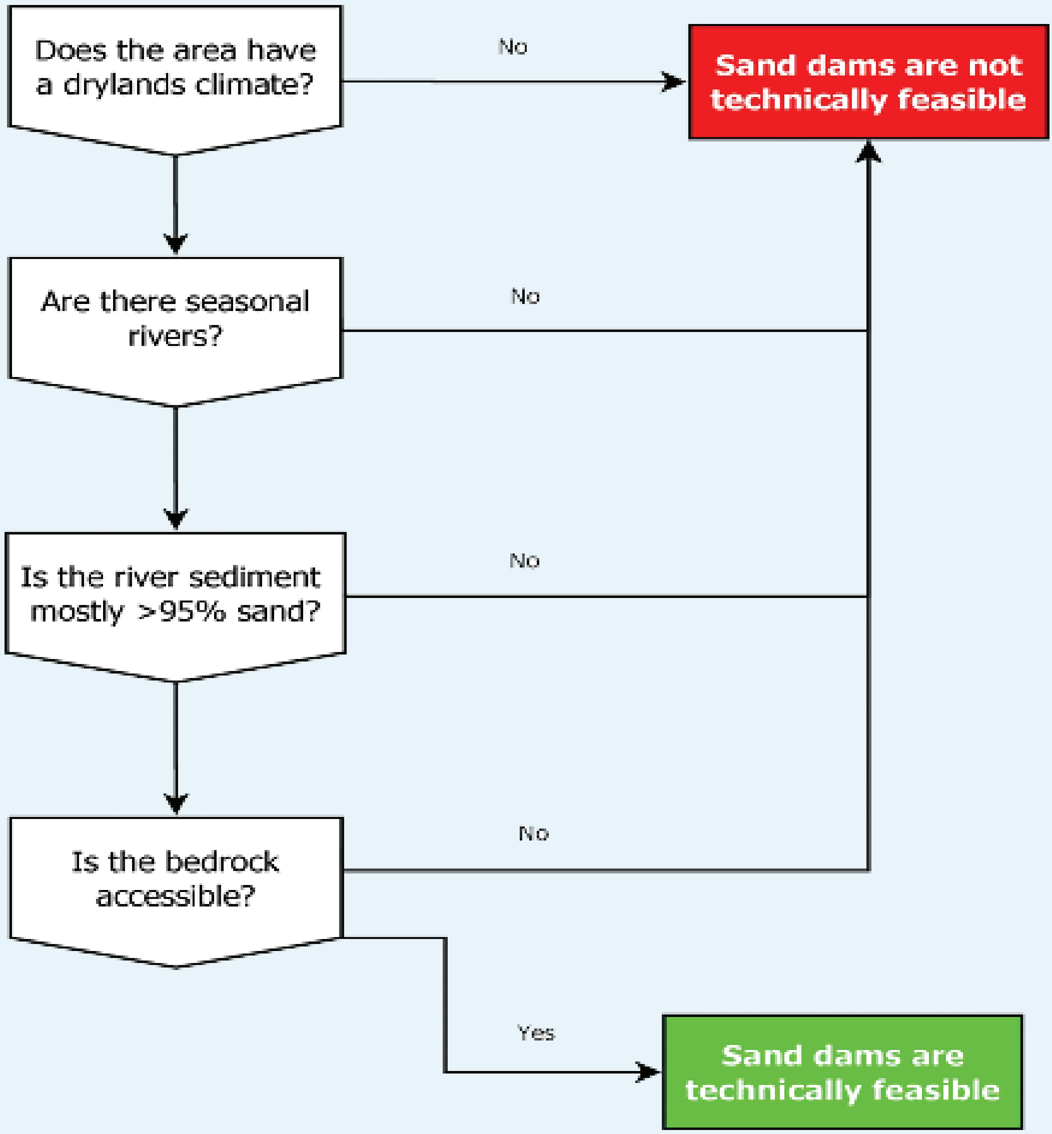
- Since the water is stored beneath the sand, it is not exposed to losses by evaporation are reduced. Evaporation can be zero when the water level is 60 cm or more below the sand surface.
- The water is good quality for drinking, as it has been filtered by the sand and is stored underground away from contamination.

- Mosquitoes, insects, frogs, snakes and organisms that carry water-borne diseases, cannot breed in underground water reservoirs.
- During high flows, floodwater can still pass over the dam to reach people living downstream.
- Once built, subsurface dams require little or no maintenance.
- Ground water dams can also be used to green up catchments by utilizing lateral seepage of subsurface storage.

4.3 Major limitations

- Subsurface dams store water below the ground, thus lifting devices or pumps are needed to extract the water for use.
- Finding natural dyke is difficult or the ideal site may be located in a remote area away from water users.
- Site selection requires intensive geological and hydrological investigation.
- Low effectiveness of water storage as water is stored in sand pores which is determined by effective porosity, about 20 to 35% of the reservoir volume.
- Interception of downstream groundwater flow a subsurface dam may prevent downstream groundwater flow, and exhausts groundwater in the downstream areas. It is also possible to design a dam with a structure that allows some of the reserved water to drain. Therefore, this problem can be avoided by appropriate site selection that considers groundwater flow.

4.4 Decision Tree for identification of sand and sub-surface dam



4.5 Site identification, Planning, Construction and Management

The following steps are following in site identification, planning, design and construction of sand and sub-surface dams.

1) Identify a suitable catchment

- Conduct a site survey

Good catchment

- A suitable catchment has stony or rocky hillsides
- Over 25% water may be extracted from coarse types of sand originating from stony hillsides
- A good catchment is rocky, gravelly, preferably covered by vegetation

Bad catchment

- Catchments with clay, silt or fine sand will produce runoff that clogs the sand/sub-surface dam.
- Less than 5% water can be extracted from fine textured sand originating from farmland
- A bad catchment – eroded lands and areas with silts, clays and fine sand

2) Identify a suitable riverbed

- Walk along the river profile

A good riverbed site for sand dam:

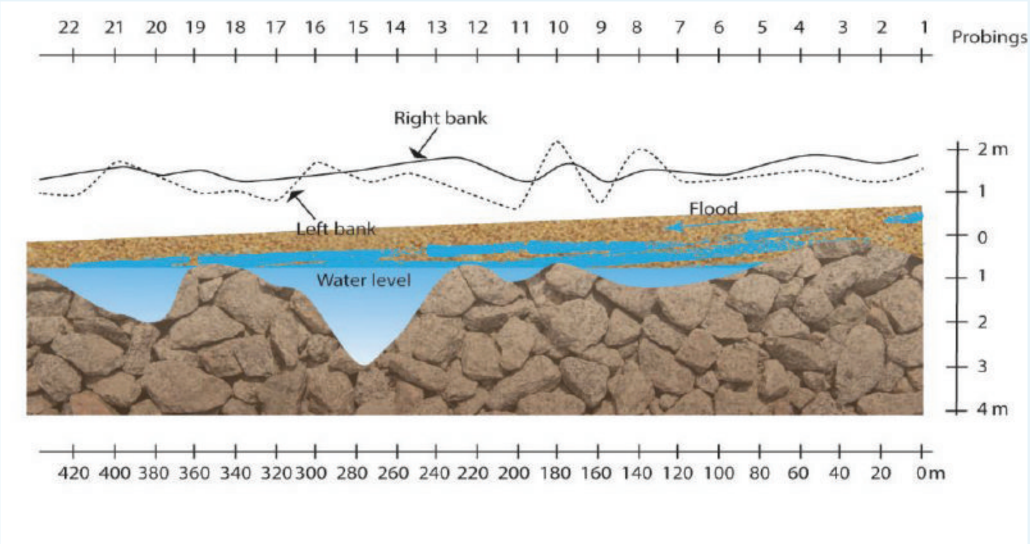
- Choose an ephemeral (seasonal) sand river (dry river bed) which is periodically flooded during a normal rainy season
- Stable riverbanks to avoid collapse
- A natural valley to contain the water reservoir upstream
- A natural underground dyke
- Alternatively, a rocky riverbed for good foundation for a sand dam.

A bad riverbed site for a sand dam

- River flows laden with silts and suspended sediments
- It could be actually a gully
- The banks are unstable and collapse easily
- The water is muddy during the rainy season

3) Locate a natural dyke
Why a natural dyke?

- Underground dyke gives free storage capacity and reduced construction costs for sand and subsurface dams.



Where to find natural dyke?

Easy to locate as where local people dig shallow wells in the riverbed during the dry season

Ask the local people.

How to locate a natural dyke
Alternative methods:
- Digging trial pits
- Probing with an iron rod hammered into the sand
- Dowsing with two rods made from a brazing rod cut in two halves

4) Assess the quality of sand for water release properties
- This assesses how easily the sand can release water.
- Sand should have a high porosity and extractable yield.
- Collect the sand samples from the river-bed
- The best soil type is coarse sand, which can yield up to 35% water by volume

Measure soil porosity

- Fill a container of known volume with a sample of dry river sediment,
- Saturate sample with water

Volume of water added <u>= Porosity (%)</u>

Volume of sediment,

Allow water to drain from the sample for 24 hours and measure the volume,

<u>Volume of water that freely drains</u> = Drainable Porosity (%)

5) Measure the yield of water from sand samples

A simple field method to measure water extraction capacities of sand is to use a drum, whose base has a filter

Use drums to measure the water-release properties of the sand

6) For sub-surface dam, identify the best clay material for making the dam embankment

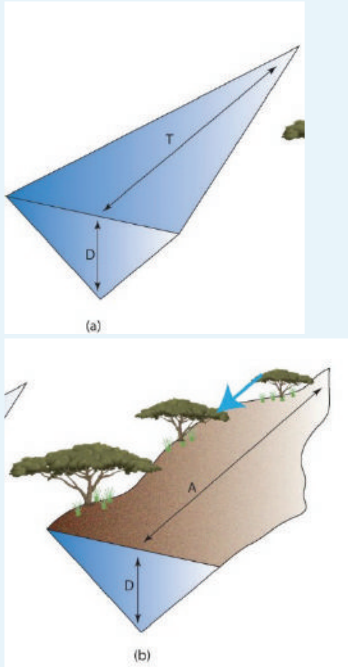
(photos: Nissen Peterssen, 2016)

The right clay could be on nearby river banks, or form another place

Measure the permebility of the clay Clay should be impermeable

7) Estimate (calculate) the storage capacity and yield of extractable water

The extractable volume of water from a sand dam is estimated using the formula below multiplied by the extraction percentage



$$Q = \frac{L \times T \times D}{6}$$

Where

Q is the storage capacity in cubic metres

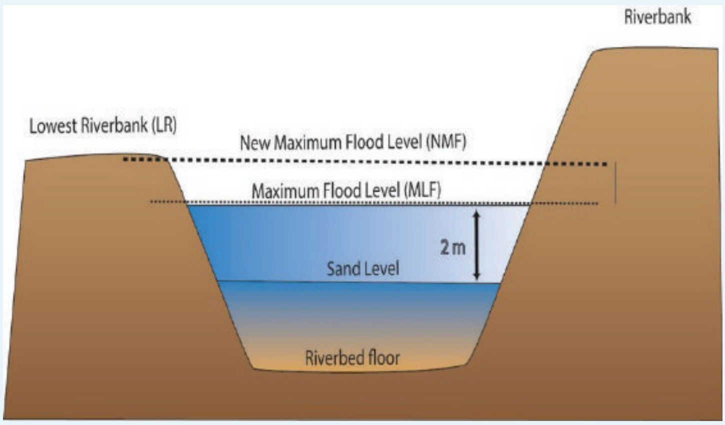
L is the length of dam wall at full supply

D is the maximum depth in metres, and

T is the throwback in metres

8) Determine maximum height of spillways

The maximum height of a spillway is found by deducting the maximum flood level (MFL) from the height of lowest riverbank (LR).



Note - Sub-surface dams:

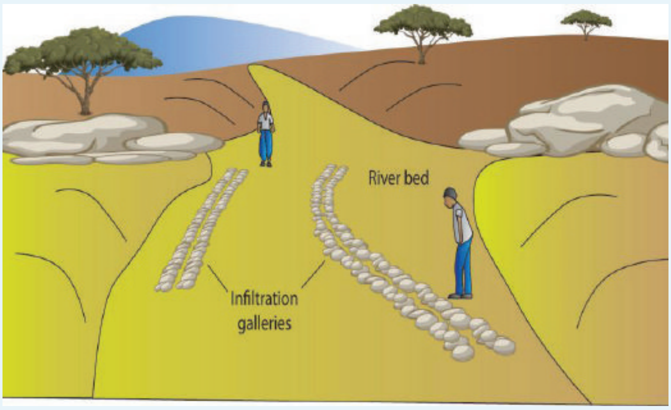
Since sub-surface dams are constructed beneath the surface, spillway is not needed

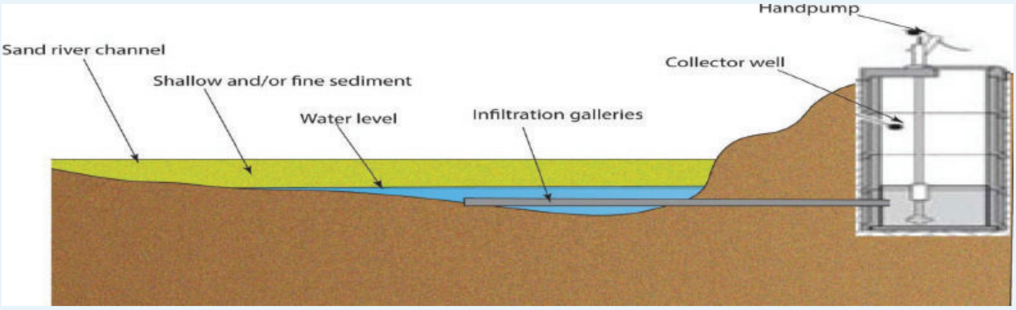
9) Prepare a good foundation

- Foundation should reach down to the impervious layer beneath the sand.
- Create a key trench, then foundation dug into a river bed floor
- Prevent seepage by building on clay or rock foundations

10) Install an Infiltration gallery

- An infiltration gallery is a horizontal pipe or network of pipes, usually plastic, with slots that is placed in the river bed
- Slotted pipes can be purchased pre-fabricated or fabricated at site.

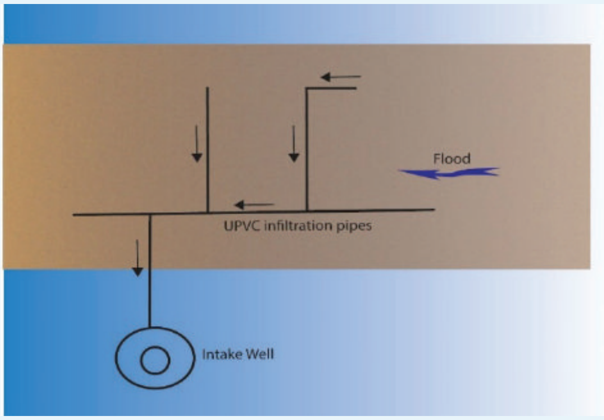




Longitudinal profile of the layout of infiltration galleries during construction

11) Auxiliary structures using an intake well.
These include:

- Draw-off pipes (or well)
- Taps and watering point for people
- Cattle drinking bays
- Catchment protection (grass & tree planting upstream of sand or sub-surface dam)
- Fencing the sand dam and catchment areas



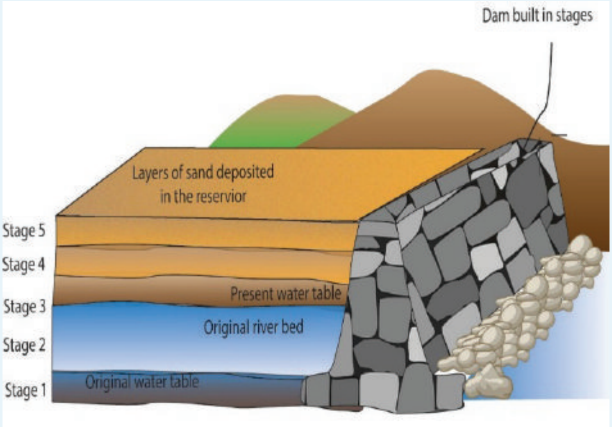
12) Construction of the sand dam

- Can use concrete or -stone masonry or rubble stones for the embankment
- But rubble stone masonry costs 30% less than concrete
- Reinforce the structure with iron bars
- Create a mould of two templates of timber for pouring in concrete.

13) Construct sand dam in stages

Correct way to construct sand dam

- Sand dams are "grown" since they are constructed over several years.
- Construct the structure in stages, preferably just 30 cm height per season



14) Construction of sub-surface dam

- Sub-surface dams are constructed beneath the surface
- They have a foundation
- The entire structure is beneath the surface
- Can be made using compacted clay

15) Intake well used for water draw-off point

- Domestic use (drinking, washing)
- Livestock watering
- Supplemental irrigation of crops
- Environmental conservation e.g. tree planting

16) Water draw-off using piped outlet

Where gravity allows, use piped draw-off to community water point

Provide livestock watering point

17) Hygiene and safety

- Ensure there is no open defecation in/ near the river bed or upstream
- Prevent bathing/ washing upstream of the dam
- Livestock should not drink water direct from the sand dam/ sub-surface dam
- There must be no pit-latrines on the bank upstream
- Do not dig unprotected wells in the sand storage river bed as these act as conduits of contamination

18) Protect the sand/sub-surface dam from pollution

- Provide fencing around the sand dam / sub-surface dam.
- Mobilize the community to take charge of the sand dam / sub-surface dam.

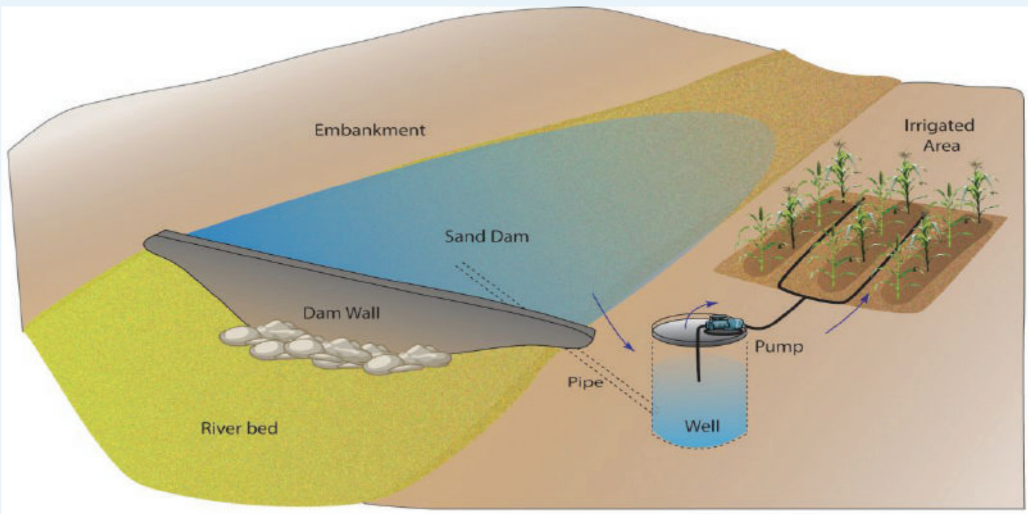


Figure 4.2 Illustration of a complete sand dam fitted with shallow well for irrigation

4.6. Selected References

Maddrell S. and Neal I. (2012), Sand dams: a Practical Guide, Excellent Development, London

Mati, B.M. 2012a. *Best Practices for Rainwater Harvesting from Open Surfaces with Storage in Structures.* Training Manual 2. NBI/NELSAP. http://nileis.nilebasin.org/content/best-practices-rainwater-harvesting-open-surfaces-storage-structures

Mati, B.M. 2012b. *Best Practices for Water Harvesting and Storage within Valleys.* Training Manual 3. NBI/NELSAP http://nileis.nilebasin.org/content/best-practices-water-harvesting-and-storage-within-valleys-training-manual-no-3

Nissen-Petersen, E, and de Trincheria, J. (2006). *Subsurface dams for water storage in dry riverbeds.* www.waterforaridland.com

Nissen-Petersen, E. 2000. *Water from sand rivers. A manual on site survey, design, construction and maintenance of seven types of water structures in riverbeds.* RELMA. Technical Handbook No. 23. Nairobi.

Nissen-Petersen, E. 2006a. *Water from Dry Riverbeds.* Asal Consultants, Nairobi.

WFP
World Food Programme

HARAMBEE
REPUBLIC OF KENYA