Case study 6

Below ground low cost water storage cistern 4 to 10 cubic metres, Uganda

Introduction

This tank (or cistern) was developed in Uganda by members of the Development Technology Unit, Warwick University and members of the Uganda Rural Development and Training Programme (URDT), between 1995 and 1997. Work is still continuing on the refinement of the tank. URDT is a service NGO located at Kagadi in Mid-Western Uganda. Several of these cisterns were built and tested with the aim of developing a low cost (under US$150), alley, domestic, water storage technology for the surrounding region. The information for this Case Study is taken from a document titled Underground storage of rainwater for domestic use by T. H. Thomas and B. McGeever, which is available as a working paper from the Development

Technology Unit (see the list of partners on our home page).

Uganda is well suited to RWH practice for several reasons:

- rainwater harvesting is a technology which is traditional to Uganda, albeit on a very ad hoc, very low-tech basis, e.g. buckets under the eaves to catch water during storms, or old 200 litre oil drums used for short term storage.
- it has a bimodal rainfall pattern with very short dry seasons which are rarely completely dry.
- annual rainfall in many parts of the country is in excess of 1200mm, which means that even the smallest house would have sufficient roof collection area to provide sufficient rainwater to meet demand (based on 15 litres per capita per day).
- corrugated iron roofs are becoming common, even in rural areas .
- the lateritic soils in the area make well sinking a difficult task (yet provide ideal ground conditions for below ground tank construction).
- there are many hilly areas where water (for irrigation and domestic use) has to be carried uphill from the valleys.

- gravity fed piped water is rare outside the main towns both because it is technically difficult (absence of strong high level springs, lack of mains electricity) and because the organisation to install and operate gravity water supplies is lacking in rural areas.

Ntale[1996] carried out a study of costs of existing water storage technologies based on a tank capacity of 8000 litres. The results are shown below.

- $340 in total for unreinforced mortar jars (at least 4 jars),
- $390 for a brickwork tank, 50% more if reinforcing is deemed necessary,
- $450 for a galvanised iron tank,
- $1432 for a PVC tank,
- $480 to $880 (various sources for E Africa) for a ferrocement tank,
- $182 (quoted from Brazil) for a plastered tank of stabilised rammed earth, a material currently hardly known in Uganda..

These sums seem generally beyond the purchasing capacity of Ugandan rural households where even finding $200 for an iron roof is often not possible, although the last technique has promise.

Technical detail

Materials, tools and skills

The paper describes how to make a 6,000 to 10,000 litre underground cistern, suitable for construction where the soil is firm and hard but not rocky. *Variant A* has a 20 mm thick cement-mortar dome (mix = 1:3), a 25 mm cement mortar lining to its Chamber, and employs a little chicken mesh reinforcing. *Variant B* has a 20 mm cement/lime-plastered Chamber. Both variants have similar shapes and construction procedures. The materials necessary for the tanks construction meet the test of ready availability even in African small towns. They are, for an 8,000 litre cistern:

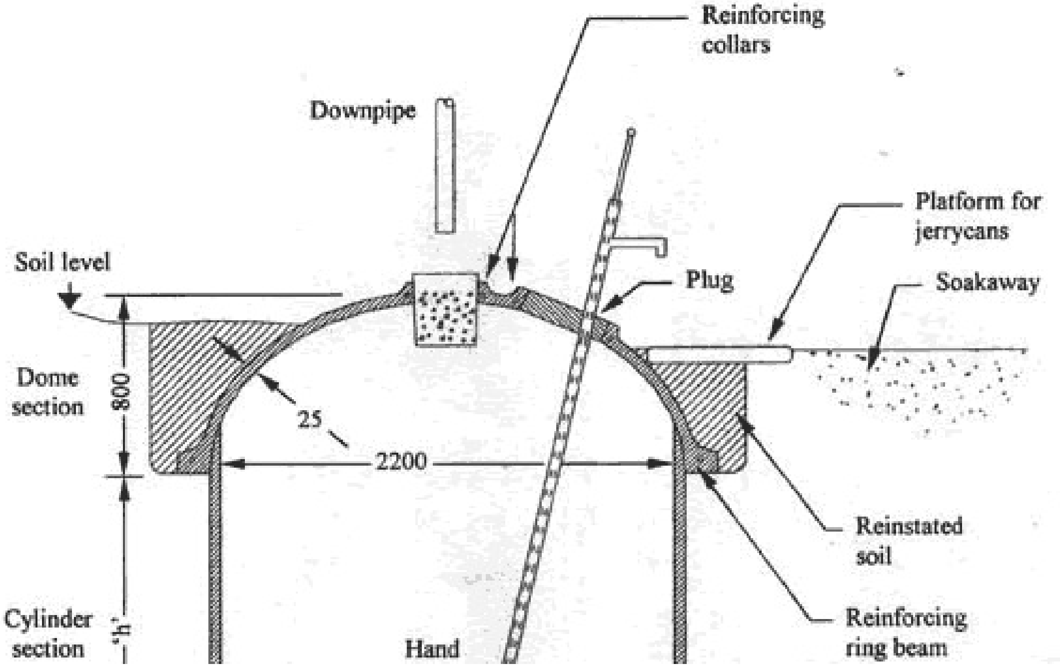
Material	Quantities	
	Variant A	Variant B
bags (ea. 50 kg) cement		

	$5^1/_2$	$3^1/_2$
bags (ea. 25 kg) lime	0	3
wheelbarrows of sand	15	15
lengths (ea. 12m) of 6mm reinforcing bar	1	1
chicken mesh (1.8m width)	1.5m	0
plastic bucket, say 10 litre	1	1

(also wood to make the template mentioned under *Step 1* below - 130 cm x 100 cm thin ply or 3m x 300 mm x 20 mm plank - and a large plastic washing bowl)

The tools needed for tank production are:

- digging and plastering tools
- a large plastic basin (say 45 cm diameter)
- a bucket on a rope for lifting out soil
- a spirit level
- a template for the dome (see *Step 1*)



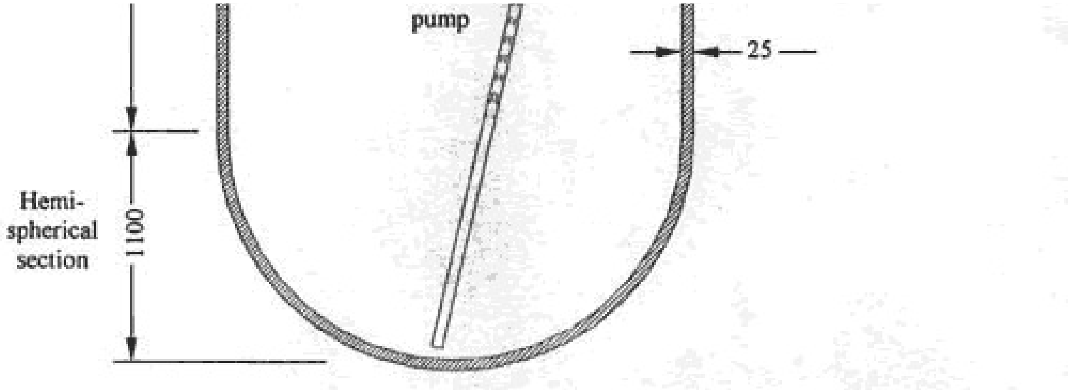


Figure 1 - General side view of cistern with pump

Parts of the DTU/URDT rainwater storage cistern and steps in its construction

The cistern is divided into four parts, namely the Chamber, the Cover, the Pump and Extras. Figure 1 shows a sectioned elevation view of the tank and pump (what you would see if you could dig it out and cut it in half from top to bottom).

The Chamber has to have adequate volume and be waterproof. Because the overall cost of a cistern is dominated by the cost of the walls and cover, these should be as small as possible. For a given cistern volume, their total area is a minimum, for either a rectangular or cylindrical tank, when the tanks depth equals its width. However for certain sorts of cover it is difficult to span widths of more than say 7 feet (2.2 meters). The cistern we are about to describe has a rounded Cover and a rounded bottom and has an internal diameter of 2.2 meters. The depth of the straight part of its sides for different capacities is as follows:

usable capacity in litres	4,000	6,000	8,000	10,000
depth of cylindrical sides	0 meters	0.5 m	1.0 m	1.5 m
depth from dome to bottom	1.9 m	2.4 m	2.9 m	3.4 m

The Cover has to stop the water from evaporating, keep the water clean, prevent anyone falling into it and keep out light and mosquitoes. It has to be pierced by a big hole to let the rainwater in very rapidly and smaller hole through which water can be pumped out. These holes must also be mosquito and light proof, and at least one of them must be large enough for a man to squeeze through in order to inspect or replaster the inside of the tank. It is recommended that the Chamber is excavated through the main hole in the Cover. This method allows the cover to be cast easily in situ without the need for shuttering or special tools. An earth mound is constructed for this purpose below ground level, as shown in Figure XX. The Cover should be shaped so that it leads any run-off from nearby ground away from its inlet. It must be strong enough to bear the weight of many people, provided that it has been covered with earth so that only the top of the dome is above the ground.

The pump

Thomas and McGeever discuss the requirements of a handpump for poor rural communities in Uganda:

A pump for a household cistern should:

- be cheap (in Uganda a ceiling price of USh.15,000 = $US15 was chosen);

- permit an adult to raise 10 litres per minute (a rate generally obtained from protected wells) from a depth of 4 meters without undue effort and also be usable by a child of 6 years;
- be self-priming, delivering water within a few strokes of starting to pump even when the pump has been out of use for some days;
- reach water within 20 cm of the bottom of a tank;
- fit into the mortar plug in the cover (dome) of a cistern so that light, mosquitoes and surface water cannot enter, yet permit the riser pipe and foot valve to be withdrawn through that plug whenever they need any maintenance;
- lift at least 100,000 litres under household conditions of use before requiring replacement;
- lift at least 10,000 litres before requiring maintenance, all such maintenance being possible using skills and materials available in most African villages;
- be economically manufacturable in each country of use;
- discharge conveniently into a jerrycan or other collection vessel.

In addition it is desirable that:

- the foot valve does not leak faster than 0.1 litre per minute, so that if the pump is used twice within say 10 minutes it does not have to be (self) re-primed for the second use;
- the intake is constrained to avoid drawing up sediment in the tank by being located say 10 cm above the tank bottom; however for cleaning purposes it is helpful if dirtied wash water can be lifted from as little as 2 cm from the tank bottom.

Some development of a handpump which aimed at achieving this specification was carried out, but the authors feel that it was far from ideal. We will not, therefore, consider this pump in this case study.

The Extras include some means of seeing the water level inside the tank without having to open the Cover, a coarse filter for water entering the tank and provision for safe disposal of any overflow water. There is some interest in putting a layer of sand at the bottom of the tank as an output filter, however this would require the pump intake to be connected to a perforated pipe running under the sand. (Experiments to test such a filters performance have yet to be done.)

During construction of any cistern, there are three choices in how one might combine the Cover and the Chamber. In some cistern designs, the Chamber is dug first and then the Cover built over the Chamber. In other designs the Cover and Chamber are made side-by-side and then the cover is lifted onto the top of the Chamber. For our design, we recommend a third method: the Cover is made first (in its final position at ground level) and then the Chamber is dug through an access hole in the Cover. It is not too difficult to do this if excavation is manual (although the procedure effectively excludes mechanical excavation and is therefore not recommended for high-wage countries) and it allows the use a cheaper dome-shaped Cover than if the cover had to be lifted. So the sequence for construction is as follows:

Steps in Constructing the Cistern

- (If necessary), make a new template to shape the dome with, as shown in Figure 2
- Mark and dig out the ring trench; use the template to shape the mound

of soil above it, as shown in Figure 4

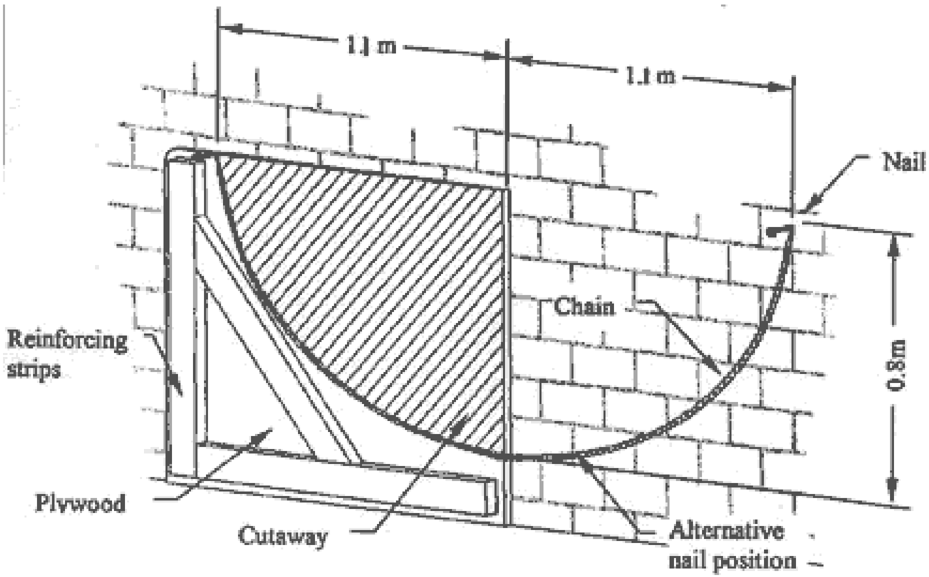


Figure 2 - Making the template

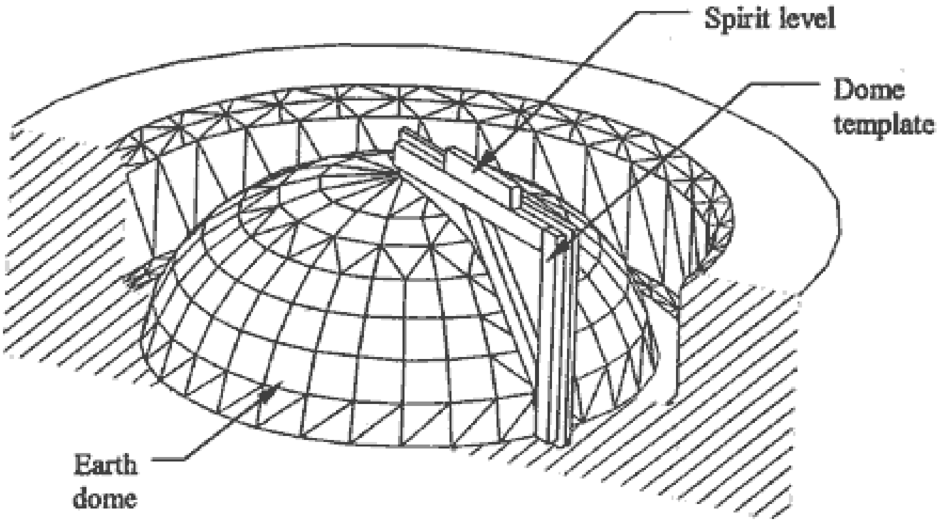


Figure 3 - Forming the earth dome mound

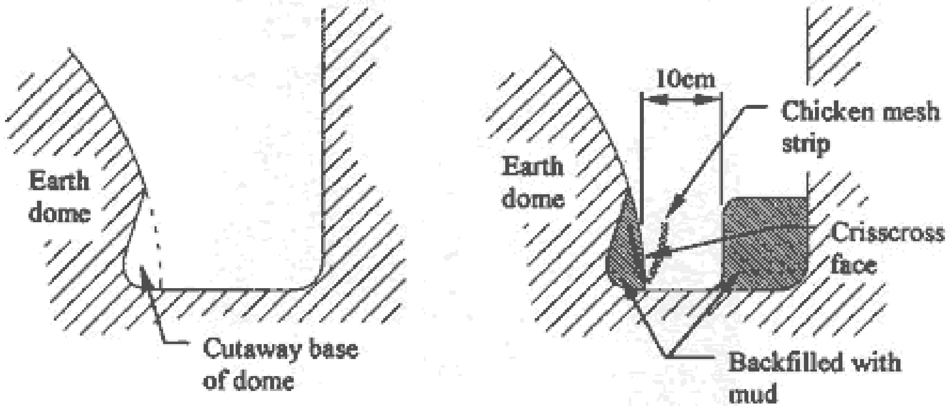


Figure 4 Detail of joint between dome and wall

- Prepare reinforcing bar (and perhaps mesh) to place in the trench and round each hole in the dome
- Place mortar to form the ring beam and the dome with its two holes
- Cure the mortar then cover the dome with soil

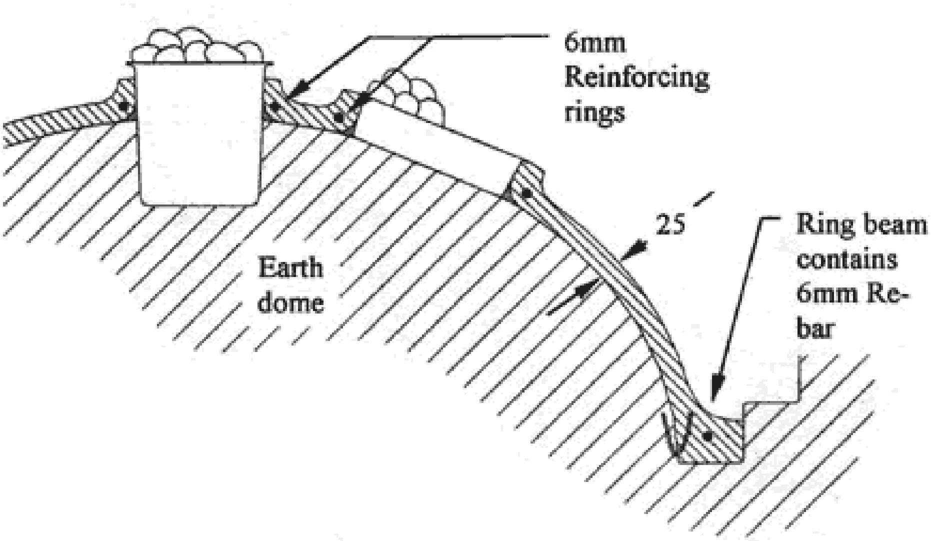


Figure 5 - Completed dome showing the position of the bucket and basin during casting

- Through the larger hole dig out the Chamber
- Plaster the inside of the chamber and allow this plaster to cure
- Make the pump

- Set the pump into the dome
- Construct the tank inlet with its gravel filter

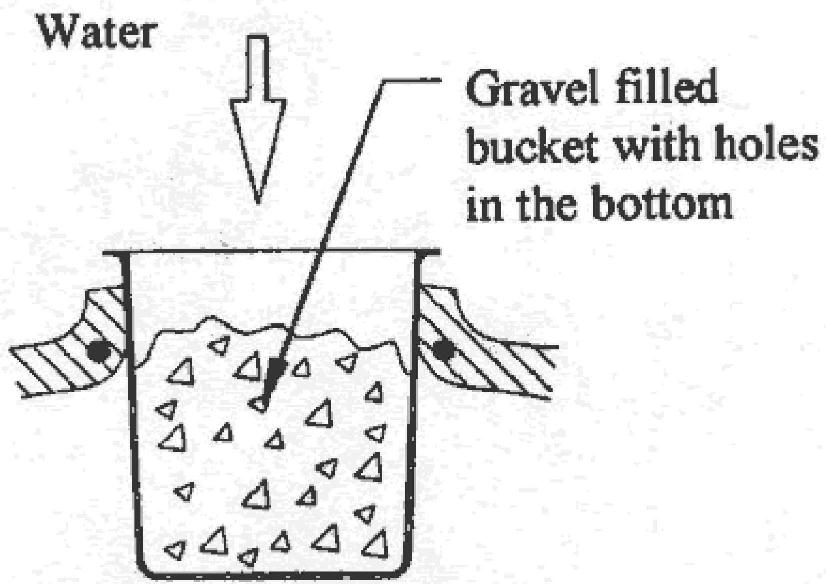


Figure 6 - Water inlet with coarse gravel filter

- Provide drainage and arrange the hard standing for pumper and water containers

The tank takes about 24 man-days to construct. However the mortar dome and later the plaster in the chamber should each be left to cure for 2 weeks, so it needs a minimum of 6 weeks from when construction starts to when the tank can be used. Most of the work is digging but for 2 days an experienced plasterer is required. The pump can be made in a few hours.

Further work and field trials

Three tanks of 8000 litres were built and tested in the town of Kagadi. Tests on dome strength, leakage and chamber integrity and flexure were carried out and the results were very reassuring. Tests were also carried out a very low-cost pump design which proved to be unreliable and has therefore not been included in this Case Study.

Tank costs

Cistern costs (8,000 litre capacity with 20 mm dome and 2-coat chamber lining)

Item	_Quantity_	_Cost (US$)_
Cement/lime (including transport)	250 kg	65
Sand (assumed from a nearby source)	18 wheel-barrows	3
6 mm reinforcing bar	12m	5
Chicken mesh	3 m^2	4
PVC Bucket + 0.5 m of 50 mm piping		3
Unskilled labour for digging (9 m^3) etc.	20 person days	40

Plasterer	2 person days	8
Supervisor + say 25 km travel	1 person day	10
Tools (say)		5
	Total	143

Design variants

Some design variations have been discussed in this paper.

The dome of the tanks built in 1996 were 25 to 30 mm thick. Those recently tested for strength were 20 mm thick and performed well. 20 mm will be used henceforth as a norm. Moreover both mortar and concrete have been used for the dome. Concrete uses less cement, but requires fine aggregate (which is not widely available in rural areas) and is much harder to work smoothly as a plaster. There is some danger that these workability problems could lead to serious cracks in inexperienced hands. The mortar dome looks better. Mortar is more vulnerable than concrete to shrinkage during curing, but this should not matter in a largely unconstrained dome. On balance we recommend mortar despite the 33% higher cement requirement.

The chambers of the 1996 cisterns were single plastered to a thickness of 30 mm. The later tanks are using 20 mm applied as two layers (e.g. 15 mm plus 5 mm) rather than one. The tank most in danger of earth tremors has just been plastered with a 2-layer lime-cement mortar; it may take some years before the benefits of using this slower curing but more flexible plaster can be assessed.

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