DTU

NEW TECHNOLOGY FOR VERY-LOW-COST DOMESTIC ROOFWATER HARVESTING

DFID KaR Contract R7833

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THE·UNIVERSITY·OF WARWICK

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CONTENTS

1   INTRODUCTION

This report is an output from a 27 month research contract (R7833) for the UK Department for International Development and describes work done during the 4 month prototyping phase of that project. The prototyping phase has developed out of the practice descried in the report to the DFID "R1, Very-Low-Cost Domestic Roofwater Harvesting in the Humid Tropics: Existing Practice" and the constraints identified in "R2, Very-Low-Cost Domestic Roofwater Harvesting in the Humid Tropics: Constraints and Problems". The work itself was carried out by the DTU along with members of the Lanka Rainwater Harvesting Forum in Sri Lanka, Water Action in Ethiopia and ACORD in Uganda.

The Sri Lankan portion of this work would not have been possible without the facilities and kind assistance of the Nation Builders Association. In particular we would like to thank Mr Adikarum, Mr Amarasinge, Mr Widasecara and Mr Siripala for their help, insight and patience during our time there.

1.1 The need

Surveys carried out in the initial phase of the project have pointed to cost as the number one constraint facing users adopting roofwater harvesting so if it is to become an affordable option for poor people in developing countries, the cost of systems must be reduced.

In R2 a methodology for cost reduction of roofwater harvesting systems was discussed. The method revolved around the building of a rainwater harvesting service framework as shown in Figure 1.1 focusing on the quality of structure as well as the quantity of water delivered. By reducing the structural quality to a level closer to the quality of housing found in poor areas, large savings can result.

Figure 1.1: Service framework for rainwater harvesting systems
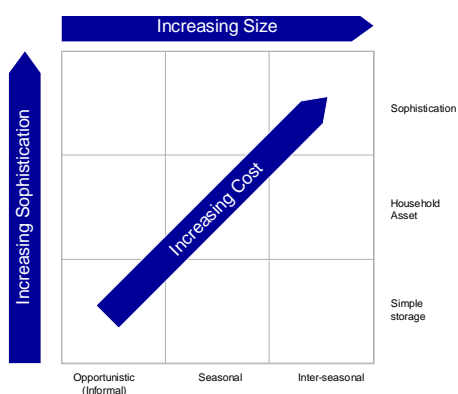
a. Framework   b. How current systems map onto the framework
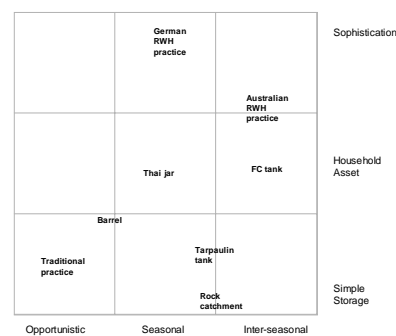
In reducing the quality, however, there are a number of critical functional constraints that should be regarded as a minimum specification:

- Gutters should deliver a good fraction of the water falling on the roof – dependent on the local rainfall, roof size storage size and demand pattern

- The tank should not have excessive loss through seepage or evaporation – <5% of the water drawn from it

- The tank should not present an excessive danger to its users, either by their falling in or by the tank failing violently
- The water must be of a quality consummate with its intended use – water that is used for drinking requires a certain care in transport and storage:
  - The catchment area should be smooth and free from accumulated debris
  - The water should be filtered to remove gross impurities or the first flush removed
  - The tank should be covered to prevent entry of light, and sealed against intrusion by vermin
  - The tank should be ventilated to prevent anaerobic decomposition of any washed-in matter

1.2   Methods of cost reduction

The methods used to reduce the cost of rainwater harvesting systems are covered in report R2, the methods described are:

- Material reduction (Improved formwork, Shape optimisation, Function separation)
- Material substitution (Using cheaper materials, use of "free" materials)
- Mass production
- Use of existing containers

1.3   Basis for cost comparison

Costing "rainwater harvesting systems for the poor" is more complex than simply adding up component costs on a bill of materials. Some materials are only available at a cost through purchasing channels, while others are available at no cost if one is willing to gather them. This report will group materials and labour into the following categories:

a. *Economic materials*; materials relying on industrial processes – in their purchase cash will be removed from the area

b. *Local economic materials*; materials which must be bought but where production is from local sources – the cash will remain in the community

c. *Skilled labour*; labour that must be paid for

d. *Local materials*; materials that can be gathered from the land – they may or may not have an economic value but tend to be freely available

e. *Householder labour*; labour that can be provided by the household – it may be skilled, but in locally used techniques (such as wattle and daub construction).

For the poor the latter two costs may be heavily discounted when compared to any cash outgoings, and consequently they will be are separated from the first three 3 in costings presented in this report.

Household labour is often ignored in costing programmes aimed at the poor, however this may become unrealistic if the household labour contribution becomes burdensome. Another approach is to allocate an opportunity cost of 50% of the unskilled labour rate to such a contribution to reflect the loss of time to the household. The real value of their time to a householder should lie between these two figures, so both will be quoted in this report They are referred to as "HH labour discounted" cost and "HH labour ignored" cost. A total cost with no discounting is also included for reference.

2   TANKS

2.1   Current state-of-the-art

Current practice is comprehensively described in report R1 so only a brief summary of current best practice will be given here as a baseline from which to judge new developments. Water storage forms the largest single cost component of a RWH system and so is the most likely candidate for cost reduction. Current state-of-the-art for storage tanks in developing countries is ferrocement construction, either based on a fixed solid mould or on an open framework. Generally, a solid mould results in a cheaper tank, as the wall thickness of the tank can be more tightly controlled and work is done against an inflexible surface. Open frameworks have the advantage of allowing greater flexibility in tank size but at the cost of plastering work taking place against an elastic backing which lets some mortar through resulting in greater and more variable wall thickness and a higher cost per tank. Tanks are also made from bricks which can reduce costs by material substitution but the savings are often not great although more of the money remains in the community. A graph of current costs of various techniques in the three study countries is given in Figure 2.1.

Figure 2.1: Tank costs
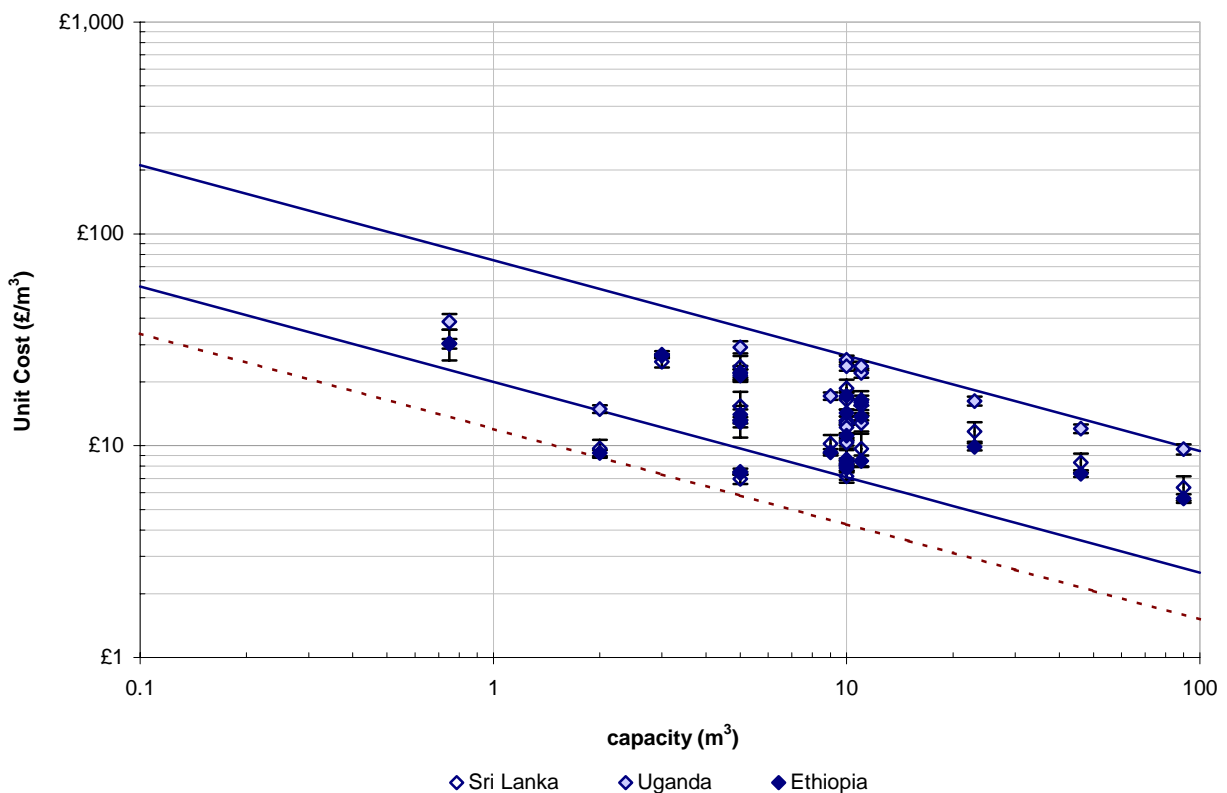
Notes: Points represent costs with household labour discounted, error bars represent the extremities when household labour is included in full or ignored altogether

Lines slopes correspond to a cost:capacity sensitivity of 0.6

A cost sensitivity to volume of 0.6 – 0.7 is the norm, so designs can be usefully compared over a wide range of capacities. The Solid blue lines represent the bounds of normal state-of-the-art. the dotted red line represents the lower limit of a region populated by "exceptional" designs such as the Thai jar and the Ugandan tarpaulin tank. It is this region that forms the target cost range. Tanks developed during the prototyping phase of the programme fall mainly into the benchmark range as shown in Figure 2.2.

Most of the designs also have a greater reliance on household labour and local materials so compulsory cash costs are kept lower still (as indicated by the bottom extent of the error bars).

Figure 2.2: cost comparison of tanks developed during the prototyping phase
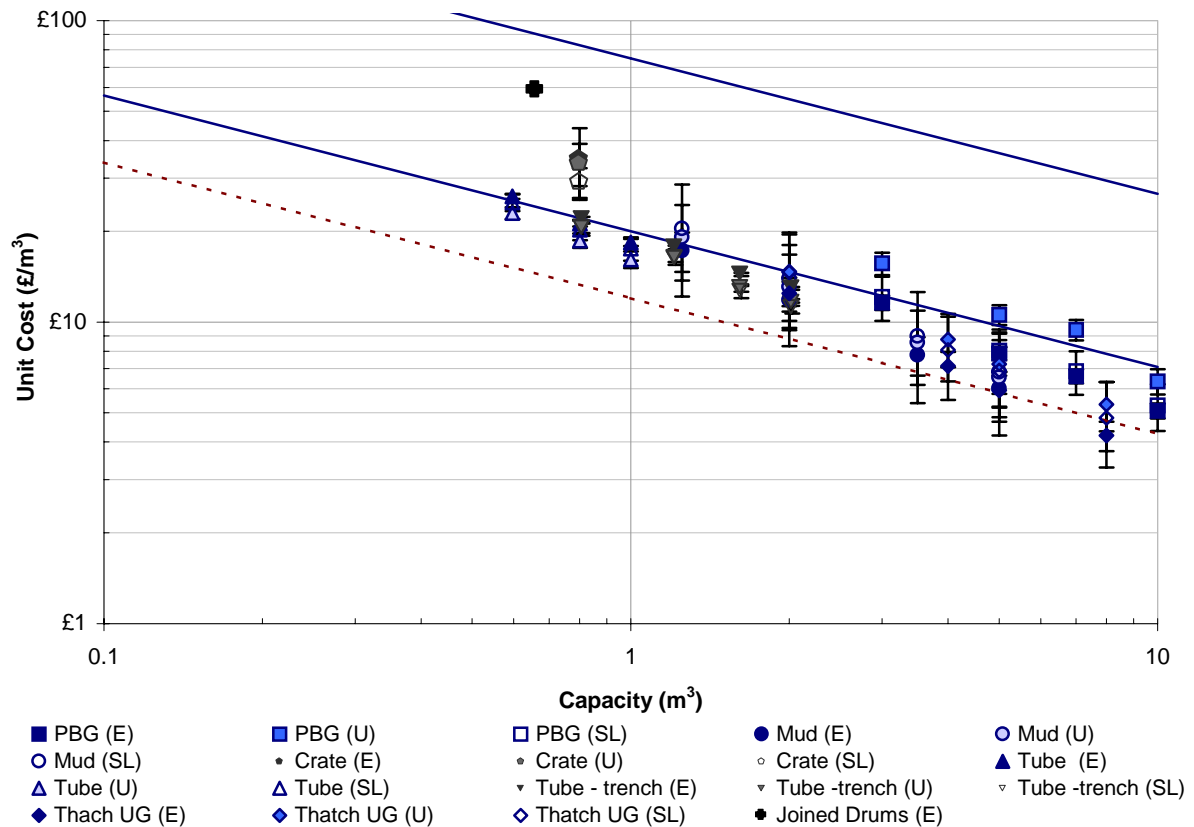
2.2 Below-ground designs

Below ground designs are the mainstay of low cost tank design. If built in stable soil, the ground itself will act as a stiff spring taking much of the load, reducing the role of the lining material to waterproofing. In these circumstances, tank wall thicknesses can be very small and materials that have good waterproofing properties but suffer from a low structural strength (such as polyethylene sheet) can be used.

Tube tank

The tube tank was originally developed by the DTU in July 2000 (Rees & Whitehead, 2000), as part of a technology development project funded in part by the Morris Laing Foundation. The design was based around a widely available plastic tube of about 500 microns thickness sold by the metre on a roll of 3ft width. The cost of this tube is £0.38 in Sri Lanka, £0.54 in Ethiopia and £0.40 in Uganda. When opened, the tube forms a cylinder of Ø54cm resulting in a volume of 0.23m^3 per metre length. The cost of storage, is therefore only £1.66, £2.33, £1.75 (SL, Et, Ug) per m^3 of storage for the tube itself. The original design (see Figure 2.3) was based on the partially below ground principle where most of the tank was below ground, but about 1m protruded as a brick parapet, avoiding stormwater ingress

and providing a visual presence for the tank. A hole was dug to accommodate the tube and a bag was formed by folding and tying off the end. The bag itself was fixed between two courses of bricks and an overflow pipe was fitted in a hole in the bag and sealed with a small amount of cement.

Figure 2.3: Original tube tank design. (all pictures from (Rees & Whitehead, 2000))

General arrangement of tube tank Mk 1   **Digging the hole**   **Bag tying**   **Overflow arrangement and fixing of the bag between brick courses**

The design was fairly successful and several of the tanks are in service however it has some problems, most which have become apparent after a year of use:

- The cost of the parapet wall dominates the overall tank cost and forces the design to compete directly with more robust and desirable designs such as the ferrocement jar

- The hole is difficult to dig

- The tied joint at the bottom can leak

- The liner is extremely difficult to remove if it is punctured – those that do leak have not been repaired

- The overflow can leak resulting in accumulation of water between the bag and the excavation walls

The new design (see Figure 2.4)addresses these problems by including the following changes:

- A more classic underground design using a precast concrete cover reduces the cost. The cover itself is similar to the arrangements found on some handpumps and so should be familiar to use. It is made using similar casting techniques to pit latrine covers (sanplats).

- The tube has been folded in two, eliminating the tied joint, making the hole 40% larger and consequently, easier to dig

- The tube itself is easily replaceable by using a retaining ring and binding wire to hold the tube in place.

- A variant folds the tank into a "L" shape reducing the depth of the excavation and replacing the vertical hole with a trench

Figure 2.4: Modified tube tank design.

General arrangement of tube tank Mk 2   **Retaining ring**   **Overflow**   **Horizontal folded tube tank being filled**
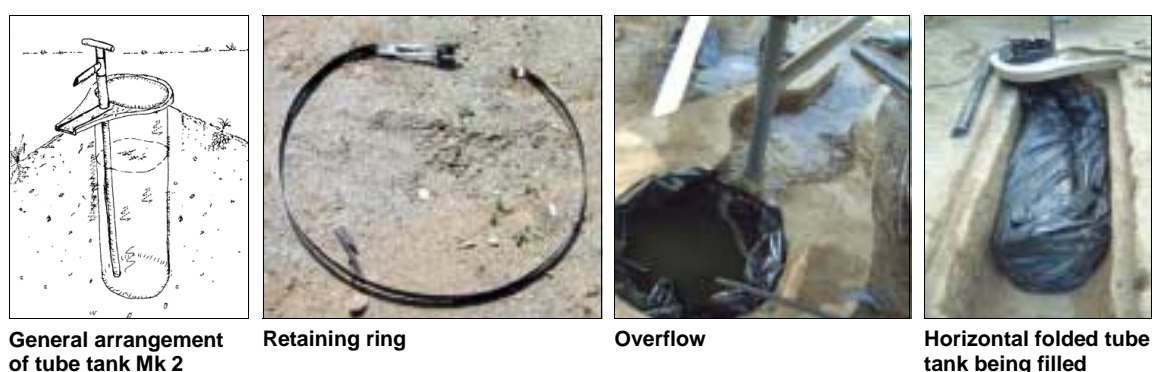
With these modifications, the design is extremely inexpensive at less than £18 for a 700l tank and £26 for a 2m^3 folded tank. Although the prototypes were made using in-situ casting in the ground, the slab has designed with pre-casting in mind and so is well suited to factory production where savings of up to 50% can be made by drastically reducing labour content.

The tank design is also ideally suited to rapid implementation projects such as refugee camps; if the excavation is done by the householders, an agency can simply transport a number of prefabricated parts and each tank can be assembled within an hour.

Tank size is determined by hole depth so the deeper a household digs, the larger the store, extra storage is relatively cheap as the cost of the tank is dominated by the concrete slab. The alternative horizontal folded design is more suited to less stable soils as the excavation itself is about 60cm deep and can be tapered if necessary, however the cost is higher due to the need to cover the trench over. Costs of several capacities of each type of tube tank are shown against benchmarks in Table 2.1.

Table 2.1: costs of tube tanks

a. vertical

Capacity (m^3)	0.6	0.8	1.0
Total	£16 – 17	£16 – 17	£17 – 19
Total (HH labour discounted)	£14 – 16	£15 – 17	£16 – 18
Total (HH labour ignored)	£13 – 15	£14 – 17	£16 – 18
Target range	£9 –15	£11 –18	£12 –20

b. horizontal

Capacity (m^3)	0.8	1.2	1.6	2.0
Total	£17 – 18	£20 – 22	£21 – 24	£23 – 26
Total (HH labour discounted)	£17 – 18	£20 – 21	£20 – 23	£23 – 26
Total (HH labour ignored)	£16 – 17	£19 – 21	£19 – 23	£22 – 26
Target range	£11 –18	£13 – 22	£16 – 26	£18 – 29

Thin shell cement slurry lining

Neat cement is about 40% stronger and twice as flexible as mortar. It is also almost completely impermeable, making the material ideal for the construction of very thin shells to line pits. Initial experiments on a 1m depth pit of Ø1.5m revealed leakage of less than 10 litres/day and the surface showed no cracks. A larger pit of 3m depth was also tried, however the cement was applied without

due care and cracks developed. The leakage from this pit is 80 litres/day, however no additional cracking has been observed as a result of the significant head of water acting on the shell.

The thin shell cement lining technique can result in material economies of up to 50% when compared to conventional mortaring, however the care with which it must be applied to the soil may make it unsuitable to unsupervised (free market) construction at a local level.

Direct application of mortar

It is common practice to put mesh in an underground tank when lining with mortar. Typically this takes the form of a layer or two of chicken wire. The given reasons are that it:

- adds strength
- provides a surface upon which to plaster (lath)
- Reduces cracking

Looking at the first of these reasons, a single layer of chicken mesh will have an in-line volume fraction less than 0.2% when compared to the mortar (assuming a 1cm mortar layer), so its contribution to the strength of the composite is fairly minimal (about 20% using the law of mixtures). Of course, the strength of an underground tank is mostly from the reaction of the soil itself.

The second may be true, but the initial layer of mortar is usually applied to the hole *adding* the mesh (indeed placing mesh directly on the soil is risky as it will certainly corrode from contact with moist soil). Further layers can be built up by scoring the original thus providing keys in the mortar itself. Such scoring is also simple to add to a hard soil and should provide a good keying for mortaring.

Crack reduction can be a useful property, particularly in tanks with large surface areas, however in smaller, domestic tanks cracking is not big problem as witness the popularity of mortar tanks in Thailand.

Thus the supposed advantages of using mesh may be insubstantial in this application and are certainly small compared to the advantages of using the strength of the soil wall.

Conversely, the mesh itself will cause problems when added to a concave surface such as the inside of a hole. The problem is basically one of overconstraint. If one considers, for the sake of argument a flexible sheet placed inside a cylinder. It can be either just the right size, too small or too big. If it is too big, the loose mesh forms bubbles, losing the benefit of the earth wall's support, if it is too tight it will stretch tight across the wall rather than following the curve, resulting in voids. Adding fixing points is the usual solution to these difficulties but this often simply turns one large problem into several small ones. The more fixings, the better the fit but also the greater likelihood of human error – the result can even be areas of too tight mesh next to bubbles of too loose mesh.

Directly applying mortar to the walls has proven to be a simple technique to apply in the field. A thin layer of 1cm can be applied with ease and with good quality control. The mortar itself has no need for high strength so can be as lean as 1:8 (cement:sand) in a good soil. Waterproofing is provided by a thin cement slurry applied while the mortar is wet. Several tanks have been built using this method to depths of up to 2.5 meters with no visible cracking and lower leakage than evaporation. The direct application of lean mortar with a slurry coat is the basis for two interrelated designs of tank, the below-ground cement tank with a cheap roof based on organic material and the partially below ground tank with a ferrocement dome.

Below-ground cement tank with organic roof

Ring beam with trench

Shuttering for pump and overflow mounting

low-cost tank cover under construction

Finished tank with cover in place

As the cost of the below-ground waterproof tank is reduced, the cover of the tank becomes the dominant cost. Organic roofs are used on many buildings in poor households and so the skills to build them are common. The materials themselves also tend to fall into the "gatherable" class. To put an organic roof onto a water tank, however, a number of precautions must be taken.

- The organic material must not fall into the tank and contaminate the water

- Runoff from the organic roof will be of low quality and so must not be allowed to enter the tank

- The roof must provide a good barrier to vermin entry, especially as some creatures make their homes in thatch.

- The wooden supports must not be exposed to the humid atmosphere inside the tank which will make them liable to rot

- To aid bacteriological die off, the roof must provide a good barrier against sunlight entering the tank

A polyethylene barrier fulfils the need to protect the organic matter from moisture and also to protect the water from falling debris. If the joining is handled well, it can also act as an excellent seal – completed by the use of inner tubes around the rim. Prevention of water entry can be afforded by the use of a sloped ring beam which will divert the water away from the tank and into a drainage channel.

Below-ground tanks also need care with avoiding floodwater ingress and also with overflow arrangements. The new design uses a syphonic overflow by employing an upwardly facing elbow connected to an outflow pipe which leads either to a nearby slope or to an infiltration pit. Stormwater ingress is handled by digging a channel around the ring beam to a width and depth determined from the runoff.

The overall combination of direct mortar application and low cost roof yields a tank that uses very little material but is quite householder labour intensive. The costs for the tank are shown in Table 2.2.

Table 2.2: Cost of underground mortar tank with organic roof

Capacity (m³)	2	4	5	8
Total	£28 – 40	£32 – 43	£33 – 46	£37 – 51
Total (HH labour discounted)	£25 – 29	£29 – 35	£30 – 36	£34 – 43
Total (HH labour ignored)	£19 – 23	£22 – 29	£23 – 29	£26 – 3`5
Target range	£18 – 29	£26 – 43	£26 – 48	£38 – 63

Partially below-ground tank with ferrocement dome

| Lining the pit | Fixing the frame for the dome | first layer of mortar for the dome | Finished tank |

A solution to the overflow and floodwater problems of an underground tank is a partially below ground design where most of the tank is underground takes advantage of the economies to be found from soil support but with some of the tank protruding. Partially below-ground tanks form a bridge between underground tanks and above-ground tanks. They are somewhat more expensive than purely underground tanks, as the above-ground section can cost 3-4 time more per unit volume than the underground section. The Below-ground cement tank can be upgraded to form partially below-ground tank by simply adding a ferrocement domed cover. The dome uses a removable frame that leaves behind only wire mesh as reinforcement. The mortar can either be applied without any other formwork by using one person outside to apply the mortar and one person inside to provide a backing (the addition of a small amount of sacking fibres to the mortar was found to help this process) or by making a temporary formwork from cardboard. The dome can be built when the tank is first commissioned or added later when more funds are available. The finished tank is slightly more expensive per litre than the organically roofed over tank but will require less maintenance. Costs for the tank are shown in Table 2.3.

Table 2.3: Cost of partially below-ground tank

Capacity (m³)	3	5	7	10
Total	£37 – 43	£41 – 51	£49 – 62	£54 – 71
Total (HH labour discounted)	£35 – 39	£39 – 47	£46 – 57	£51 – 65
Total (HH labour ignored)	£30 – 35	£34 – 43	£40 – 52	£43 – 59
Target range	£22 – 37	£29 – 48	£35 – 58	£43 – 71

2.3   Above-ground designs

Above ground designs are generally more popular than below ground solutions, however the cost is often also higher as the tank must now cope with the full force of the water pressure acting on it. The principle of functional separation allows some scope for cost reduction. Waterproofing can be done by either mortar or a liner.

Fabric tank

end of fabric tank with bracket

top sheet showing rubber seal

completed fabric tank

An above-ground tank is almost essential in poor crowded urban areas as the ground can be very contaminated. Ideally, a tank should also be fairly portable as tenure in such communities can often be insecure and many squatter communities live under constant threat of being moved on. The fabric tank goes some way to fulfilling these needs by providing a tank with a small footprint, protruding only 45cm from the dwelling. The tank can also be collapsed down into a long, thin package for transport. A polyethylene tube is placed within a fabric sleeve which is hung on a framework. The fabric takes the pressure load while the polyethylene provides waterproofing.

Unfortunately, the tank has proved problematic as the fabric itself stretches and puts high loads on its fixings which then fail. The fixings could be made stronger and more expensive fabrics should stretch less, however they will make the tank unaffordable.

Crate tank

lid with hole for inlet

delivering the crate to the household

Internal configuration

Finished tank in use

A similar design to the fabric tank has a wooden crate forming the load-bearing structure. The design has the same small footprint as the fabric tank but is not as portable as it can only easily be knocked down into its component walls. It is, however, much better protected from accidental damage than the fabric tank. The design is similar in concept to the tube tank with a retaining ring holding the top of the tube to the top of the tank providing an inlet. The tube than folds around and the other end is attached to the overflow. A tap is attached at the bottom of the "U" and sealed with bitumen. The outlet and overflow can be on any of three sides of the tank to help it fit in with its location. The total cost of the tank is slightly higher than the target range, however the need for a slender profile and portability may make the tank usable in areas where cheaper alternatives will be inappropriate. The manufacture of the tank employs only skilled labour but is very portable (deliverable) so it lends itself to mass production at a central location which could reduce the cost.

Table 2.4: Cost of crate tank

Capacity (m³)	0.8
Total	£23 – 28
Target range	£11 – 18

Wattle and daub tank

Bamboo frame   **Detail of manhole**   **Mud blocks used for testing**   **Finished tank**

A simple way of producing an above-ground tank with the economy of a below ground tank is to bring the ground up. Several earth technologies have been used in building for millennia and such techniques are often the mainstay of housing for the poor. Wattle and daub is a widespread practice for building from earth, particularly when householders their own homes. The technique uses unmodified mud to fill a frame structure made from roundwood. The materials necessary for this type of constructions are all in the "gatherable" class so cash costs are extremely low, being limited to the liner and plumbing.

A small sample of mud blocks from different sources were tested for tensile strength and it was found that they lay in the fairly narrow range of 730kPa to 900kPa with ant-hill mud generally at the higher end. This compares poorly with 2 – 5MPa for Portland cement mortar so walls have to me made quite thick – typically 15 to 20cm. Initial tests used cement as a liner, however the mud structure expands slightly under load and the lining cracked resulting in leakage and damage to the mud walls. The use of a plastic liner has proved much more satisfactory.

Table 2.5: Cost of wattle and daub tank

Capacity (m³)	1.25	2	3.5	5
Total	£25 – 37	£27 – 40	£31 – 45	£34 – 48
Total (HH labour discounted)	£22 – 26	£24 – 29	£27 – 32	£30 – 35
Total (HH labour ignored)	£16 – 18	£17 – 20	£20 – 23	£22 – 26
Target range	£14 – 23	£18 – 29	£24 – 40	£29 – 48

Rammed earth

The use of rammed earth provides a stiffer structure than wattle and daub and can be rendered internally with mortar. The earth can also be stabilised with Portland cement to provide a better wet strength than with mud construction. The DTU has done some previous work with this technique to build cylindrical tanks (Rees, 2000) however they proved difficult to construct due to movement of the round mould during manufacture. To combat this, trials have taken place to develop a rectangular tank using traditional corner jointing methods and reinforcing. The trials are thus far incomplete but show some promise for a controllable product that can be used in sandier soils where mud construction is impossible.

Connected drums

Drums form an easily accessible form of storage and many households already have at least one drum performing various duties, among them water storage and even opportunistic rainwater collection. Very few households employ more than one such drum however despite the extra water this could provide. Drums also have a small footprint and are light enough to be portable. They do suffer from problems such as the possibility of residual toxicity and solar heating of the water through the metal.

Several configurations of 2 or 3 drums have been tried, including two forms of vertical connection and one horizontal one. The pros and cons of these are detailed in Table 2.6. Initial Cleaning of the drums is usually done by using a locally produced caustic soda, however there is still some uncertainty about its effectiveness.

Table 2.6: pros and cons of different drum configurations

Type	Pros	Cons
1. Vertically stacked drums connected by means of pipefitting.	• Doesn't require welding or electricity. • The piped outlet allows incorporation of a slow-sand filter • Small footprint	• There is some leakage in the lower drum between the lid and circular clamp.
2. Vertically stacked drums connected by means of welding.	• The number of fittings is reduced • There is no leakage in the system • Small footprint	• Depends on the availability of a welder.
3. Horizontally placed drums connected by means of pipefitting	• An unlimited number of drums can be connected without leakage from the top • Repeated filtering provides different grades of water. • Doesn't require welding or electricity	• The required space is relatively higher compared to others and thus the material for the plinth is greater

The final design uses two vertically stacked drums with welded seams to prevent leakage and an internal slow sand filter. As the slow flow through the filter could reduce the storage, particularly in heavy storms, an optional separate tank has been added to catch this overflow. The overall cost is quite high by very-low-cost standards but still within state-of-the-art boundaries especially considering the design incorporates quite sophisticated filtering.

Table 2.7: Cost of drum configurations[1]

Type	1	2	3	final
Number of drums	2	2	3	3
Capacity (litres)	340	420	620	540
Total	£30	£31	£36	£38
Target range	£7 – 11	£7 – 12	£9 – 15	£9 – 14
Upper limit of state-of-the-art	£41	$47	£58	£53

Note: Costs are based on Ethiopian experience

Several connected jerry cans

Many households already have a fair storage in the form of several jerrycans. The cans themselves are inherently portable and can be distributed throughout the dwelling to save space and so are a good solution for crowded urban areas. The requirement is for a system of plumbing to connect these cans together to form a continuous storage. The cans then fill up in turn with the water quality improving in

each successive can. A system of siphons empty the plumbing into the last can or to an overflow so there will be no leakage when a can is removed for use, however the problem of accidentally leaving a can out of the chain (with disastrous consequences when it rains) is still unsolved. The cost of the cans themselves is also a problem and could make the system uneconomic unless the household already has a reasonable number available.

Cascade of water jars

Many households use water jars for water collection. These jars are well suited to stacking in an array. The water runs down the outsides of one jar into the mouth of another with quality improving as it moves down the cascade. The rounded jars do allow the water to progress unhindered to the next, however the overall storage is quite low at 75 litres. The framework necessary is also quite expensive and puts the entire array into the higher end of the state of the art at about £16. the jars themselves are fairly low in price, however and so a cheaper frame (e.g. a suspended chain) could make the system more economic but it will never be a very-low-cost option.

3   ROOFS

Another difficulty with roofwater harvesting is its reliance on an impermeable roof. Penetration of corrugated iron sheet roofs is growing rapidly and the costs are becoming competitive with professionally thatched roofs, however many poor houses in developing countries still have organic roofs. The reasons for this include cost, particularly where the roof is made by the householder, insulation and ventilation of the smoke from cooking fires.

There are five strategies for utilising organic roofs for rainwater harvesting;

1.   Use the water for secondary processes

2.   Treat the water

3.   Cover the roof with an impermeable cover

4.   Build a separate roof structure in the household compound

5.   Use a nearby public building

Covering the roof and roof structures are the most obvious technical solutions, however, it was found that covering an organic roof with an impermeable barrier can cause problems to the roof itself, as water cannot evaporate presenting ideal conditions for mould growth, and the ultimate rotting of the structure. The runoff water quality from a number of materials for that might be employed to either to cover a roof or on a separate structure was measured. The materials tried were corrugated iron sheet, corrugated asbestos sheet, polypropylene sacking, tar sheet and palm-leaf organic roofing (*cadjan*).. A typical set of runoff quality results is shown in Figure 3.1. The characteristic runoff quality follows a

power law decay with different materials having different starting points. Organic roofs predictably having the worst water quality while tar sheet, which is readily available and inexpensive has a good runoff characteristic, in line with asbestos but the water does contain petro-chemicals whose levels and rate of decay has not yet been quantified. Turbidity for the GI sheet is below the minimum level that can be discerned with the Del Agua turbidity meter used for this measurement and is therefore below the 5NTU level for turbidity set by the WHO (WHO, 1997)

Figure 3.1: Runoff quality of different roof types
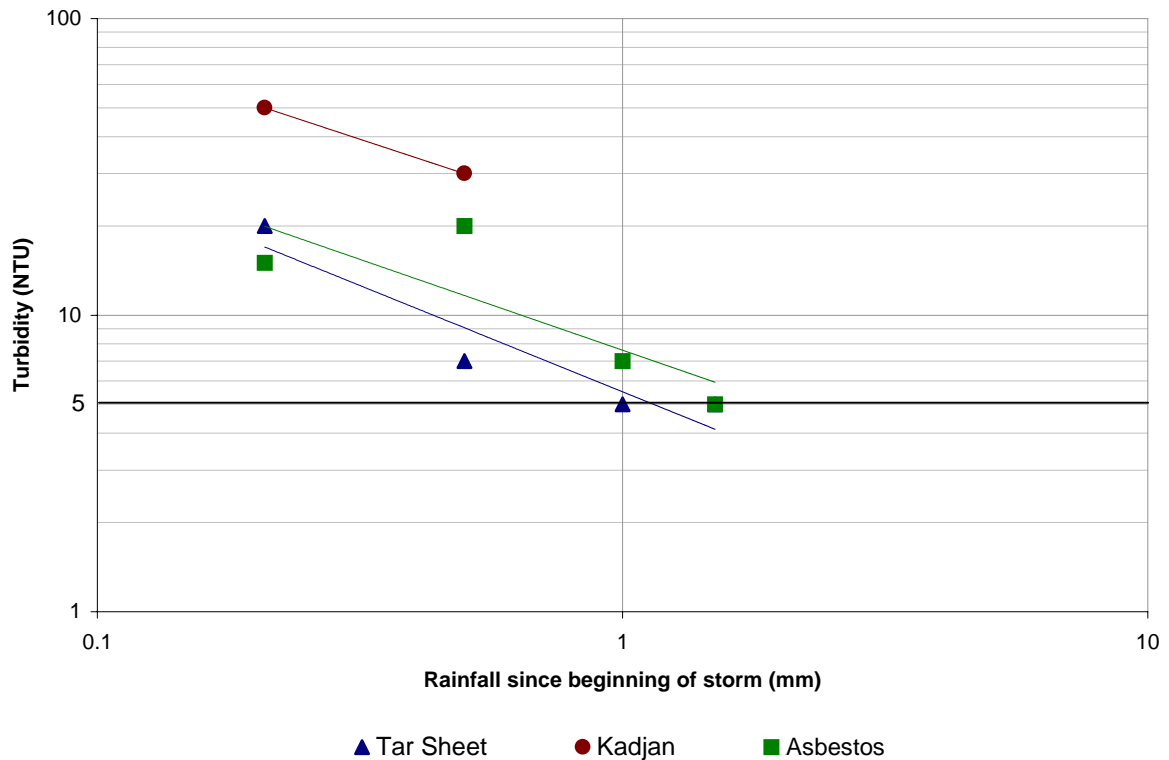
4   GUTTERS

Guttering on a very-low-cost roofwater harvesting system can take up a substantial amount of the cost so its optimisation is important here. Typical state-of-the-art gutters in developing countries tend to be quite expensive with a typical 10m length costing from £10 to £25. Some work has been done in East Africa with vee shaped gutters which have a typical cost of £8 for a similar length. Research at Warwick on optimising gutter size based on carrying capacity suggests that a vee shaped gutter of only 7.5 cm width is sufficient to carry water from all but the most severe downpours and will deliver more than 90% of the water it catches. Such a small gutter should cost less than £3 for a 10m run.

Water interception is a slightly more difficult issue. Water often has to fall some distance from the roof to the gutter and is thrown from the roof different distances depending on the intensity of the downpour. It can also be blown by wind in unexpected directions. Two solutions for this have been tried.

Figure 4.1: Gutters configurations
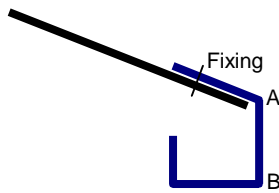
a. G-shaped gutter   b. extended vee
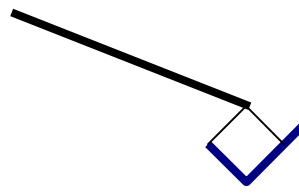
The first (Figure 4.1a) is a complete solution that captures the water at the end of the roof and directs it into the gutter below. The gutters are also very quick to install as the slope is determined by a variable manufactured length of vertical support (between A and B) so no adjustment is necessary. Cleaning is also simple as the inside edge is open for a brush all the way along its length. Problems with the gutter appear when the length to be guttered is longer than 5m or when thick roofs need to be accommodated. Under these circumstances the vertical support becomes very long and can flex causing the gutter to spill. This can be alleviated by using support wires with the loss of some ease of cleaning, however as the vertical support can use a substantial amount of material, the gutter starts to become expensive at over £9 for 10m.

The second uses the concept of a "upstand", where one side of the gutter stands proud of the other, effectively raising the catchment height of the gutter. In the design the usual square gutter has been simplified to a vee and the upstand is merely an extension of one arm of the vee. This extends the catchment of the gutter upwards and moves the centre of the catchment out from the roof edge better matching the profile of water flowing from a roof. The gutter is extremely cheap (less than £3.50 for a 10m run) and can be applied to any sized roof without the need for a facia board. Like all suspended gutters, the design does need adjustment to maintain the slope and the suffers from guy wires obstructing cleaning.

5   CONCLUSION

The cost of rainwater harvesting systems can be reduced by a number of methods several of which have been presented here. The most promising are:

- The use of thin shell cement lining as found in the underground cement tank with an organic roof and the partially below-ground tank with a ferrocement dome
- The use of free materials and local techniques such as wattle and daub construction and organic roofs
- Earth technologies such as wattle and daub and rammed earth
- Mass production methods and the use of plastic linings as used in the tube tank and crate tank
- Incorporation of existing structures such as drums
- Smaller profile, sheet-metal gutters which can incorporate features such as water guides or extended catchment surfaces

Less successful were such techniques as:

- Distributed storage in jerrycans and multiple pots
- Very portable, yet fragile tanks such as the fabric tank

- Over-thin plastering techniques that rely on excessive quality control such as Thin shell cement slurry lining

Special circumstances can also be incorporated at little cost

- Tall thin structures such as the crate tank and vertically stacked drums can be built for crowded urban areas
- Auxiliary roofs can be constructed at little cost as an alternative to poor quality organic roof catchments

But

- Very portable, yet fragile tanks such as the fabric tank
- Roof covering treatments that are built onto an existing roof

Are problematic and cannot be recommended.

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APPENDIX

Bills of materials and costings

Material	Unit Quantity	unit costs			Quantity Used			Ethiopia			Uganda			Sri lanka		
		Ethiopia	Uganda	Sri Lanka	0.6m3	0.8m3	1.0m3	0.6m3	0.8m3	1.0m3	0.6m3	0.8m3	1.0m3	0.6m3	0.8m3	1.0m3
Tank																
cement	bag	£2.67	£6.10	£2.69	0.4	0.4	0.4	£1.03	£1.03	£1.03	£2.36	£2.36	£2.36	£1.04	£1.04	£1.04
sand	m3	£3.57	£3.05	£3.32	0.037	0.037	0.037	£0.13	£0.13	£0.13	£0.11	£0.11	£0.11	£0.12	£0.12	£0.12
aggregate	m3	£15.25	£2.98	£11.07	0.061	0.061	0.061	£0.94	£0.94	£0.94	£0.18	£0.18	£0.18	£0.68	£0.68	£0.68
Plastic tube	m	£0.58	£0.41	£0.37	3.6	4.66	5.7	£2.10	£2.72	£3.33	£1.46	£1.89	£2.32	£1.35	£1.74	£2.13
Bracket	each	£0.70	£0.70	£1.39	1	1	1	£0.70	£0.70	£0.70	£0.70	£0.70	£0.70	£1.39	£1.39	£1.39
Basin 20"	each	£1.33	£0.41	£0.52	1	1	1	£1.33	£1.33	£1.33	£0.41	£0.41	£0.41	£0.52	£0.52	£0.52
Inner Tube 20"	each	£1.08	£1.08	£0.93	1	1	1	£1.08	£1.08	£1.08	£1.08	£1.08	£1.08	£0.93	£0.93	£0.93
Labour (skilled)	day	£2.50	£2.03	£2.80	1	1	1	£2.50	£2.50	£2.50	£2.03	£2.03	£2.03	£2.80	£2.80	£2.80
Labour (unskilled)	day	£0.58	£1.22	£1.87	1	1	1	£0.58	£0.58	£0.58	£1.22	£1.22	£1.22	£1.87	£1.87	£1.87
Sub																
Pump																
1 1/2" pipe	m	£0.70	£0.83	£0.17	1.9	2.4	2.9	£1.32	£1.67	£2.02	£1.58	£2.00	£2.42	£0.32	£0.41	£0.49
1 1/4" pipe	m	£0.88	£0.73	£1.74	1.575	2.075	2.575	£1.39	£1.83	£2.28	£1.16	£1.52	£1.89	£2.75	£3.62	£4.49
1 1/2" tee	each	£1.50	£1.02	£0.50	1	1	1	£1.50	£1.50	£1.50	£1.02	£1.02	£1.02	£0.50	£0.50	£0.50
1/2"pipe	m	£0.00	£0.00	£0.47	0.2	0.2	0.2	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.09	£0.09	£0.09
wood (2X2)	m	£0.00	£0.00	£0.00	0.1	0.1	0.1	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00
wood screw	each	£0.00	£0.00	£0.01	2	2	2	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.01	£0.01	£0.01
Labour (skilled)	day	£2.50	£2.03	£2.80	0.5	0.5	0.5	£1.25	£1.25	£1.25	£1.02	£1.02	£1.02	£1.40	£1.40	£1.40
sub								£5.47	£6.26	£7.05	£4.77	£5.56	£6.34	£5.08	£6.04	£7.00
Total								£5.47	£6.26	£7.05	£4.77	£5.56	£6.34	£5.08	£6.04	£7.00
Total (discounted)								£5.47	£6.26	£7.05	£4.77	£5.56	£6.34	£5.08	£6.04	£7.00
Total (ignored)								£5.47	£6.26	£7.05	£4.77	£5.56	£6.34	£5.08	£6.04	£7.00

Material	Unit Quantity	unit costs			Quantity Used				Ethiopiu				Uganda				Sri lanka			
		Ethiopia	Uganda	Sri Lanka	2m3	4m3	5m3	8m3	2m3	4m3	5m3	8m3	2m3	4m3	5m3	8m3	2m3	4m3	5m3	8m3
Tank																				
cement	bag	£2.67	£6.10	£2.69	0.9	1.5	1.6	2.2	£2.53	£4.10	£4.14	£5.90	£5.77	£9.38	£9.47	£13.47	£2.55	£4.14	£4.18	£5.94
sand	m3	£3.57	£3.05	£3.32	0.12	0.19	0.19	0.27	£0.43	£0.68	£0.70	£0.98	£0.36	£0.58	£0.59	£0.84	£0.40	£0.63	£0.65	£0.91
aggregate	m3	£15.25	£2.98	£11.07	0.06	0.06	0.07	0.07	£0.84	£0.84	£1.11	£1.11	£0.16	£0.16	£0.22	£0.22	£0.61	£0.61	£0.80	£0.80
6mm re-bar	m	£0.08	£0.16	£0.07	5	5	5	5	£0.39	£0.39	£0.39	£0.39	£0.78	£0.78	£0.78	£0.78	£0.33	£0.33	£0.33	£0.33
Binding wire	kg	£0.67	£0.81	£0.34	2	2	2	2	£1.33	£1.33	£1.33	£1.33	£1.63	£1.63	£1.63	£1.63	£0.67	£0.67	£0.67	£0.67
Bamboo	m																			
Thatch																				
Motorcycle tubes	each	£0.00	£0.00	£0.00	7	7	10	10	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00
Polythene	m2	£0.08	£0.14	£0.07	6	6	10	10	£0.50	£0.50	£0.83	£0.83	£0.81	£0.81	£1.36	£1.36	£0.45	£0.45	£0.75	£0.75
Basin	each	£1.50	£1.08	£1.08	1	1	1	1	£1.50	£1.50	£1.50	£1.50	£1.08	£1.08	£1.08	£1.08	£1.08	£1.08	£1.08	£1.08
24" Inner tube	each	£1.00	£0.93	£0.93	1	1	1	1	£1.00	£1.00	£1.00	£1.00	£0.93	£0.93	£0.93	£0.93	£0.93	£0.93	£0.93	£0.93
Labour (skilled)	day	£2.50	£2.03	£2.80	3	3	3.5	3.5	£7.51	£7.51	£8.76	£8.76	£6.10	£6.10	£7.12	£7.12	£8.41	£8.41	£9.81	£9.81
Labour (unskilled)	day	£0.58	£1.22	£1.87	11	11	12	13	£6.42	£6.42	£7.01	£7.59	£13.42	£13.42	£14.64	£15.86	£20.55	£20.55	£22.42	£24.29
Sub									£22.46	£24.29	£26.78	£29.40	£31.06	£34.88	£37.81	£43.28	£35.98	£37.81	£41.62	£45.52
Pump																				
1 1/2" pipe	m	£0.70	£0.83	£0.50	2	3.2	2.5	3.5	£1.39	£2.22	£1.74	£2.43	£1.67	£2.67	£2.08	£2.92	£1.01	£1.61	£1.26	£1.77
1 1/4" pipe	m	£0.88	£0.73	£0.43	1.675	2.875	2.175	3.175	£1.48	£2.54	£1.92	£2.81	£1.23	£2.11	£1.60	£2.33	£0.72	£1.24	£0.93	£1.36
1 1/2" tee	each	£1.50	£1.02	£0.45	1	1	1	1	£1.50	£1.50	£1.50	£1.50	£1.02	£1.02	£1.02	£1.02	£0.45	£0.45	£0.45	£0.45
1/2"pipe	m	£0.00	£0.00	£0.17	0.2	0.2	0.2	0.2	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.03	£0.03	£0.03	£0.03
wood (2X2)	m	£0.00	£0.00	£0.45	0.1	0.1	0.1	0.1	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.04	£0.04	£0.04	£0.04
wood screw	each	£0.00	£0.00	£0.01	2	2	2	2	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.01	£0.01	£0.01	£0.01
Labour (skilled)		£2.50	£2.03	£2.80	0.5	0.5	0.5	0.5	£1.25	£1.25	£1.25	£1.25	£1.02	£1.02	£1.02	£1.02	£1.40	£1.40	£1.40	£1.40
sub									£5.62	£7.52	£6.41	£7.99	£4.93	£6.81	£5.71	£7.28	£3.67	£4.79	£4.14	£5.07
Total									£28.08	£31.81	£33.19	£37.39	£35.99	£41.69	£43.53	£50.56	£39.66	£42.61	£45.76	£50.60
Total (discounted)									£24.87	£28.60	£29.69	£33.59	£29.28	£34.98	£36.21	£42.63	£29.38	£32.33	£34.55	£38.45
Total (ignored)									£21.66	£25.39	£26.18	£29.80	£22.57	£28.27	£28.89	£34.70	£19.10	£22.05	£23.34	£26.31

Material	Unit Quantity	Unit costs			Quantity Used				Ethiopia				Uganda				Sri lanka			
		Ethiopia	Uganda	Sri Lanka	3m3	5m3	7m3	10m3	3m3	5m3	7m3	10m3	3m3	5m3	7m3	10m3	3m3	5m3	7m3	10m3
Tank																				
cement	bag	£2.67	£6.10	£2.69	1.9	2.8	3.5	4.3	£4.99	£7.39	£9.31	£11.48	£11.40	£16.89	£21.28	£26.24	£5.03	£7.45	£9.39	£11.57
sand	m3	£3.57	£3.05	£3.32	0.2	0.3	0.4	0.5	£0.79	£1.06	£1.34	£1.63	£0.67	£0.90	£1.14	£1.39	£0.73	£0.98	£1.24	£1.52
aggregate	m3	£15.25	£2.98	£11.07	0.1	0.1	0.1	0.1	£0.84	£0.84	£1.11	£1.11	£0.16	£0.16	£0.22	£0.22	£0.61	£0.61	£0.80	£0.80
mesh	m3	£0.56	£0.75	£0.42	5.8	5.8	10.4	10.4	£3.24	£3.24	£5.77	£5.77	£4.39	£4.39	£7.81	£7.81	£2.42	£2.42	£4.30	£4.30
bolts	each	£0.07	£0.03	£0.03	10	10	16	16	£0.70	£0.70	£1.12	£1.12	£0.35	£0.35	£0.56	£0.56	£0.35	£0.35	£0.56	£0.56
Basin	each	£1.50	£0.41	£1.08	1	1	1	1	£1.50	£1.50	£1.50	£1.50	£0.41	£0.41	£0.41	£0.41	£1.08	£1.08	£1.08	£1.08
24" Inner tube	each	£1.00	£0.61	£0.93	1	1	1	1	£1.00	£1.00	£1.00	£1.00	£0.61	£0.61	£0.61	£0.61	£0.93	£0.93	£0.93	£0.93
Labour (skilled)	day	£2.50	£2.03	£2.80	5	5	5.5	5.5	£12.51	£12.51	£13.76	£13.76	£10.17	£10.17	£11.18	£11.18	£14.01	£14.01	£15.42	£15.42
Labour (unskilled)	day	£0.58	£1.22	£1.87	6.5	6.5	8.5	10	£3.80	£3.80	£4.96	£5.84	£7.93	£7.93	£10.37	£12.20	£12.15	£12.15	£15.88	£18.69
sub									£29.37	£32.04	£39.87	£43.21	£36.09	£41.81	£53.58	£60.62	£37.31	£39.98	£49.60	£54.87
Tooling																				
Frame		£0.56	£0.56	£0.56	10	10	16	16	£5.63	£5.63	£9.01	£9.01	£5.63	£5.63	£9.01	£9.01	£5.63	£5.63	£9.01	£9.01
6mm bar		£0.08	£0.16	£0.16	20	20	37	37	£1.57	£1.57	£2.91	£2.91	£3.13	£3.13	£5.79	£5.79	£3.13	£3.13	£5.79	£5.79
sub									£7.21	£7.21	£11.92	£11.92	£8.76	£8.76	£14.80	£14.80	£8.76	£8.76	£14.80	£14.80
sub/10									£0.72	£0.72	£1.19	£1.19	£0.88	£0.88	£1.48	£1.48	£0.88	£0.88	£1.48	£1.48
Pump																				
1 1/2" pipe	m	£0.70	£0.83	£0.50	2.2	3.4	2.9	3.9	£1.81	£2.64	£2.29	£2.99	£2.17	£3.17	£2.75	£3.59	£1.31	£1.92	£1.66	£2.17
1 1/4" pipe	m	£0.88	£0.73	£0.43	2.6	3.8	3.3	4.3	£2.01	£3.07	£2.63	£3.51	£1.67	£2.55	£2.18	£2.92	£0.98	£1.49	£1.28	£1.71
1 1/2" tee	each	£1.50	£1.02	£0.45	2.275	3.475	2.975	3.975	£1.50	£1.50	£1.50	£1.50	£1.02	£1.02	£1.02	£1.02	£0.45	£0.45	£0.45	£0.45
1/2"pipe	m	£0.00	£0.50	£0.17	1	1	1	1	£0.00	£0.00	£0.00	£0.00	£0.10	£0.10	£0.10	£0.10	£0.03	£0.03	£0.03	£0.03
wood (2X2)	m	£0.00	£0.00	£0.45	0.2	0.2	0.2	0.2	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.04	£0.04	£0.04	£0.04
wood screw	each	£0.00	£0.00	£0.01	0.1	0.1	0.1	0.1	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.01	£0.01	£0.01	£0.01
Labour (skilled)		£2.50	£2.03	£2.80	0.5	0.5	0.5	0.5	£1.25	£1.25	£1.25	£1.25	£1.02	£1.02	£1.02	£1.02	£1.40	£1.40	£1.40	£1.40
sub									£6.57	£8.47	£7.68	£9.26	£5.97	£7.85	£7.07	£8.63	£4.23	£5.35	£4.89	£5.82
Total									£7.29	£9.19	£8.87	£10.45	£6.85	£8.73	£8.55	£10.11	£5.11	£6.23	£6.37	£7.30
Total (discounted)									£7.29	£9.19	£8.87	£10.45	£6.85	£8.73	£8.55	£10.11	£5.11	£6.23	£6.37	£7.30
Total (ignored)									£7.29	£9.19	£8.87	£10.45	£6.85	£8.73	£8.55	£10.11	£5.11	£6.23	£6.37	£7.30

Material	Unit Quantity	unit costs			Quantity Used	Cost		
		Ethiopia	Uganda	Sri Lanka		Ethiopia	Uganda	Sri lanka
8 x 1 planks	m	£0.46	£0.45	£0.37	32.5	£15.06	£14.54	£12.15
tap	each	£0.92	£2.03	£0.70	1.00	£0.92	£2.03	£0.70
1/2" pipe	m	£0.25	£1.71	£0.17	0.20	£0.05	£0.34	£0.03
tap socket	m3	£0.21	£0.61	£0.21	2.0	£0.42	£1.22	£0.42
tap plug (?)	each	£0.21	£0.61	£0.21	1	£0.21	£0.61	£0.21
1" GI pipe	m	£0.25	£1.71	£0.70	0.2	£0.05	£0.34	£0.14
plastic tube	m	£0.58	£0.41	£0.37	5	£2.92	£2.03	£1.87
20" Basin	each	£1.33	£0.41	£0.52	1	£1.33	£0.41	£0.52
20" Inner tube	each	£1.08	£0.61	£0.93	1	£1.08	£0.61	£0.93
bracket	each	£0.70	£0.70	£0.70	1	£0.70	£0.70	£0.70
Labour (skilled)	day	£2.50	£2.03	£2.80	2	£5.00	£4.07	£5.61
Labour (unskilled)	day	£0.58	£1.22	£1.87	0	£0.00	£0.00	£0.00
Sub						$27.75	$26.90	$23.27
Sub (discounted)						$27.75	$26.90	$23.27
Sum (ignored)						$27.75	$26.90	$23.27

Material	Unit Quantity	Ethiopia	Uganda	Sri Lanka	Quantity Used				Ethiopia				Uganda				Sri Lanka			
					1.25m	2m	3.5m	5m	1.25m	2m	3.5m	5m	1.25m	2m	3.5m	5m	1.25m	2m	3.5m	5m
cement	bag	£2.67	£6.10	£2.69	0.4	0.5	0.6	0.8	£1.10	£1.36	£1.63	£2.07	£2.51	£3.12	£3.72	£4.73	£1.11	£1.38	£1.64	£2.09
sand	m3	£3.57	£3.05	£3.32	0.06	0.07	0.09	0.11	£0.21	£0.26	£0.31	£0.40	£0.18	£0.22	£0.27	£0.34	£0.20	£0.24	£0.29	£0.37
aggregate	m3	£15.25	£2.98	£11.07	0.10	0.12	0.15	0.18	£1.50	£1.86	£2.22	£2.82	£0.29	£0.36	£0.43	£0.55	£1.09	£1.35	£1.61	£2.04
Barbed wire	m	£0.03	£0.03	£0.03	31	41	50	66	£0.88	£1.14	£1.40	£1.84	£0.96	£1.25	£1.53	£2.01	£0.98	£1.27	£1.57	£2.05
Binding wire	kg	£0.67	£0.81	£0.34	2	2	3	3	£1.33	£1.33	£2.00	£2.00	£1.63	£1.63	£2.44	£2.44	£0.67	£0.67	£1.01	£1.01
Plastic	m2	£0.39	£0.27	£0.25	7	10	13	17	£2.83	£3.73	£5.22	£6.42	£1.97	£2.59	£3.64	£4.47	£1.81	£2.38	£3.34	£4.11
String	m	£0.00	£0.02	£0.01	0	0	0	0	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00
Mud	m3																			
Bamboo	m																			
Thatch																				
Basin	each	£1.50	£0.41	£1.08	1	1	1	1	£1.50	£1.50	£1.50	£1.50	£0.41	£0.41	£0.41	£0.41	£1.08	£1.08	£1.08	£1.08
24" Inner tube	each	£1.00	£0.93	£0.93	1	1	1	1	£1.00	£1.00	£1.00	£1.00	£0.93	£0.93	£0.93	£0.93	£0.93	£0.93	£0.93	£0.93
1 1/4" pipe	m	£0.88	£0.73	£0.43	1	1	1	1	£0.88	£0.88	£0.88	£0.88	£0.73	£0.73	£0.73	£0.73	£0.43	£0.43	£0.43	£0.43
1 1/4" elbow	each	£0.21	£0.21	£0.21	1	1	1	1	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21
1/2"pipe	m	£0.25	£0.83	£0.50	0.5	0.5	0.5	0.5	£0.13	£0.13	£0.13	£0.13	£0.42	£0.42	£0.42	£0.42	£0.25	£0.25	£0.25	£0.25
1/2" elbow	each	£0.21	£0.21	£0.21	1	1	1	1	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21
1/2" socket	each	£0.21	£0.21	£0.21	3	3	3	3	£0.63	£0.63	£0.63	£0.63	£0.63	£0.63	£0.63	£0.63	£0.63	£0.63	£0.63	£0.63
Tap	each	£0.92	£2.03	£0.82	1	1	1	1	£0.92	£0.92	£0.92	£0.92	£2.03	£2.03	£2.03	£2.03	£0.82	£0.82	£0.82	£0.82
Labour (skilled)	day	£2.50	£2.03	£2.80	2	2	2	2	£5.00	£5.00	£5.00	£5.00	£4.07	£4.07	£4.07	£4.07	£5.61	£5.61	£5.61	£5.61
Labour (unskilled)	day	£0.58	£1.22	£1.87	11	12	13.5	14	£6.42	£7.01	£7.88	£8.17	£13.42	£14.64	£16.47	£17.08	£20.55	£22.42	£25.23	£26.16
Sub									£24.75	£27.17	£31.14	£34.20	£30.59	£33.44	£38.13	£41.25	£36.58	£39.89	£44.85	£48.00
Sub (discounted)									£21.53	£23.66	£27.20	£30.11	£23.88	£26.12	£29.90	£32.71	£26.30	£28.68	£32.24	£34.92
Sum (ignored)									£18.32	£20.16	£23.26	£26.02	£17.17	£18.80	£21.67	£24.17	£16.02	£17.47	£19.63	£21.84

A collaboration between the DTU and Lanka Rainwater Harvesting Forum, ACORD Uganda and Water Action Ethiopia.