Chapter 6 -

RWH Dam construction

Introduction

The prospect of receiving a RWH tank of their own in their backyard, is a great incentive to households to engage in **FFP**. Households are required to establish an intensive food garden to qualify for the tank (or RWH Dam, as most rural households tend to call it). This is to avoid a rush of applications which may result in a large number of unutilised structures, which in turn may erode the standing of the RWH programme as a whole.

Preparation at the household level

REMEMBER: The construction processes at the household can start once the preceding processes, as mentioned under Chapters 3, 4 and 5, have been completed, namely:

- ☑ **Household has registered as a participant in the programme.**
- ☑ **Household has started to participate in the FFP workshops, has started and is maintaining an intensive food garden at home, and has planned their RWH garden layout, including three possible positions for their RWH Dam (Helicopter Plan).**
- ☑ **Household must agree to the conditions as listed on the DWAF Household Application Form FFP01 before excavation can start, agrees to store building material safely, and agrees any other contributions, which may include partial digging of the RWH Dam.**

Construction process – from the household's point of view

The process up to completion and commissioning of a RWH Dam in a particular household's backyard is as follows:

Construction processes at the household:

a RWH Dam is sited

b RWH Dam is excavated. The household may be required to dig a trial pit, and the excavation may then be completed by a digging team

c Building materials are delivered and the household stores them safely

d Once all the materials are on site, the builders are informed to start

e RWH Dam is built

f Household signs the 'Initial Tank Acceptance form' when construction is 'functionally complete.'

g Household 'user education' is done on essential aspects of safety and maintenance.

h RWH Dam is tested for leakage as soon as water is available (this would usually be after the next rains)

i Household signs 'Final Tank Acceptance form.'

Preparation of implementation teams: roles and reporting

Successful construction at the households requires the successful execution of a number of supporting processes:

- ☑ **Finalisation of the appointment and training of TECH, ISD and FFP staff**
- ☑ **Establishment of the site office, opening of a community bank account, and opening of the necessary sets of books and control systems for the project**
- ☑ **Households establish intensive food gardens at their homes, facilitated by FFP staff**
- ☑ **Bulk ordering (procurement), storage and control of building material, which is handled by the ISD staff in collaboration with TECH staff**
- ☑ **Monitoring and recording of all processes and quantities, captured in a separate 'job card' for each household. This is the responsibility of ISD staff, for which specific data is supplied by FFP and TECH staff**
- ☑ **Construction supervision, by TECH staff**
- ☑ **Accurate bookkeeping and reporting, by ISD staff**
- ☑ **Handling of payments – to staff, builders and suppliers. This is an ISD responsibility.**

The appointment and preparation of **TECH** staff, their relationships to other team members, and their reporting forms were dealt with in Chapter 3. The mentoring of **TECH** staff is critical.

Standard RWH Dam

RWH Dam structure

During the Demonstration Phase of the Pilot Programme, more than sixty experimental RWH Dams were constructed in 26 villages in four provinces. Several shapes, elevations, building materials and construction methods were tried out by five different implementing agents, with design assistance and construction advice provided by the Core Team. From the lessons of experience during this experimental phase, a number of recommendations were derived.

Recommended size, shape and elevation

- ❖ **Standard size: 30 000 liter**

  – this provides enough water for year-round vegetable and fruit production of 100-200m^2 in the yard (when combined with run-on RWH). This enables a constant year-round flow of micro-nutrients in the household to prevent malnutrition and stunting.

- ❖ **Shape: Round** [walls: cylindrical; floor: flat]

  – a round shape is geometrically stronger, and less prone to cracking and leaking than square or rectangular tanks.

- ❖ **Elevation: Underground**

  – tanks are built underground to catch both roof run-off AND surface run-off. In sloping areas, half-buried dams can still catch surface run-off.

Not recommended:

Above-ground tanks which rely on roof run-off only are good for drinking water supplies, but are not recommended for productive uses, for two main reasons, namely:
❖ **They store too little water**: three 10 000 liter tanks or six 5 000 liter tanks would be required to achieve the recommended 30 000 liter capacity; but the 10 000 liter tanks are 3m tall and thus physically too high to fit underneath the eve of most roofs.
❖ **They rely on a small catchment area (the roof only), which in most parts of South Africa cannot provide enough run-off for production.**

Example: Surface vs Roof run-off in an area with 600mm annual rainfall

	Summer	Winter
Rainfall	400 mm	200 mm
Roof run-off from RDP house roof (at 90% efficiency)	Roof run-off area =10m x 4m=$40m^2$ **Roof run-off** =$40m^2$ x 400mm x 90% efficiency =14 400 liter in 7 months =**2.1 kilolitre per month**	Roof run-off area =10m x 4m=$40m^2$ **Roof run-off** =$40m^2$ x 200mm x 90% efficiency =7 200 liter in 5 months =**1.4 kilolitre per month**
Surface run-off (yard only)* from 30m x 40m yard (at 20% efficiency)	Yard run-off area =30m x 40m=$1200m^2$ **Yard run-off** =$1200m^2$ x 400mm x 20% efficiency =96 000 liter in 7 months =**13.7 kilolitre per month****	Yard run-off area =30m x 40m=$1200m^2$ **Yard run-off** =$1200m^2$ x 200mm x 20% efficiency =48 000 liter in 5 months =**9.6 kilolitre per month*****

Clearly, in both summer and winter, the surface run-off is far larger than the roof run-off.

* *In this example, the surface run-off is conservatively calculated from the yard only. Quite frequently, much more surface run-off is available from larger areas around the yard, e.g. roads, veld, neighbouring yards and roofs, etc.*

** *This is more than double the monthly Free Basic Water allowance of 6 kilolitres per household*

*** *This is enough water to keep a food garden of 100m² going throughout a dry winter season, and thus keep a year-round flow of micro-nutrients available to the whole family.*

Standard RWH Dam

The 'Standard RWH Dam' shall be a sunken cylindrical dam with block or brick walls, standing on a mesh reinforced concrete slab, and roofed with IBR sheeting supported by two gum poles.

IMPORTANT NOTE:

In instances where deviations from the Standard RWH Dam are necessary, the RIA must report these instances to DWAF for monitoring purposes, but may proceed with the construction of an alternative design approved by a professional engineer recognized by DWAF as having the necessary level of experience in this field. These structures must also be inspected and signed off by the engineer prior to handover. The structure may not exceed the accepted cost of the Standard RWH Dam without specific written approval from DWAF.

Appendix F1 contains a full set of drawings for the Standard RWH Dam, showing the excavation, floor, walls, inlet and overflow structures, roof, mix designs, and the required quantity of materials. Appendix F1 can be printed for use on site, either as twelve separate A4 sheets (which could be bound together as a booklet), or as a one-sided A0, or a double-sided A1 sheet (which could be laminated for longevity). These drawings have been prepared as MS Excel sheets, and can therefore be easily emailed and printed.

The main features of the Standard RWH Dam are as follows:

Standard RWH Dam: Cement-block structure	
Volume:	30 000 liters
Shape:	cylindrical
Elevation	underground
Floor:	mesh reinforced concrete
Walls:	plastered cement-block
Roof:	IBR roof sheeting on wooden beams or treated poles

It became clear from the pilot program that this dam type was favoured above all the others for two main reasons: Firstly, it is a relatively cost effective solution in most situations. Secondly, the materials and method of construction are known and understood by local **builders**. Therefore this design has been selected as the 'Standard RWH Dam'.

Other advantages of the design include the following:

- it is relatively easy and quick to construct;
- the design lends itself to the use of simple mechanical devices which significantly speed up delivery – which clearly becomes important when large numbers of structures require building;
- cement blocks/bricks and reinforced concrete are strong and durable materials;
- cylindrical walls require much less steel reinforcing than do rectangular walls, and the arrangement of the reinforcing is also much simpler; and
- the excavation is relatively simple and not excessively deep.

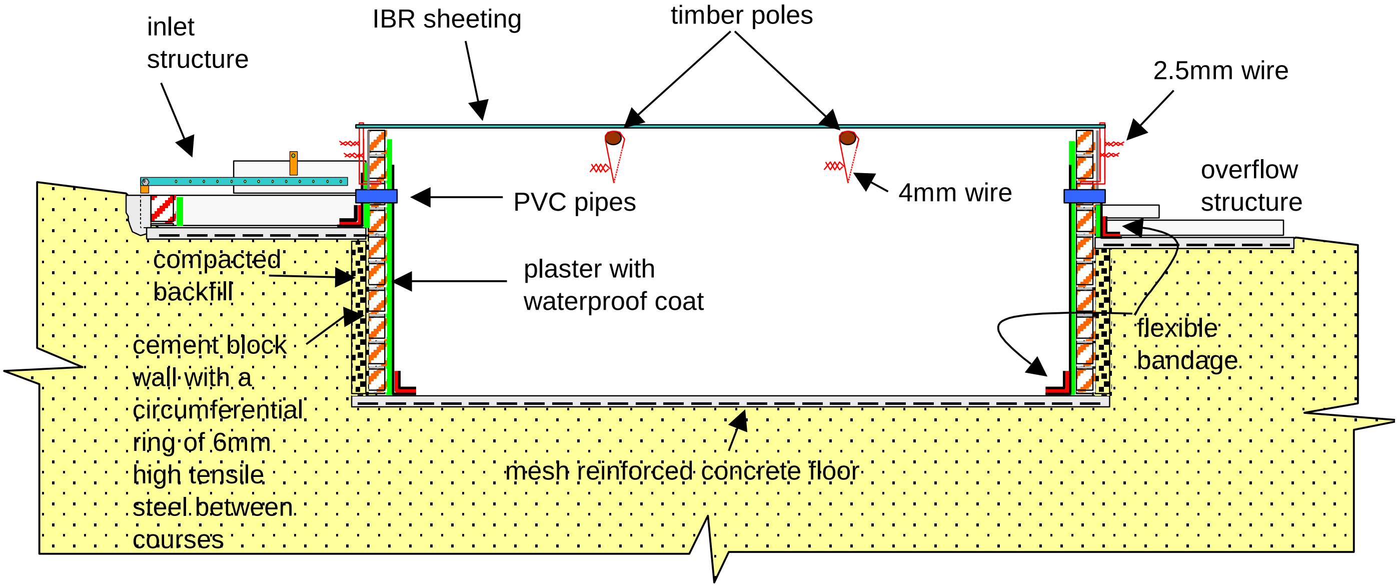

Figure 6.1 – Section through Standard RWH Dam: Cement-block structure

A brief description of the RWH Dam is given here. For more comprehensive details and discussions see Appendices F1, F3, F4 and F5.

The 'Standard RWH Dam' is cylindrical in shape with 2m high block walls, standing on a 100mm thick mesh reinforced concrete floor-slab. The wall is built directly on top of the concrete slab. A circumferential ring made up of 6mm high yield steel reinforcing bars is inserted in the mortar between the various block courses; three 6m long bars are spliced together with 400mm overlaps to make up this ring. The walls are plastered to a thickness of 15mm, and later coated with a waterproof coating. The roof consists of 0.5mm thick galvanized IBR sheeting, supported by two 100/125 mm gum poles. Both the gum poles and the sheeting are tied down to the walls by galvanized wire. A hinged trap door is created in one of the sheets for access into the tank. The inlet and overflow structures consist of blocks or bricks built on top of a mesh reinforced slab, and butt up directly against the dam. Three 110mm pipes built into the dam's wall, let water from the inlet structure into the tank, and likewise, three 110 mm pipes allow water to exit into the overflow structure on the opposite side once the dam is full. The inside diameter of the dam is 5.2m, while the height of the water from the floor to the invert level for both the inlet and overflow pipes is 1.43m. At full supply level the capacity of the dam is 30m^3.

Alternative Designs

- Notwithstanding the above stated advantages, there will be instances when other designs with different geometric shapes and/or different materials, would be preferable to the Standard RWH Dam, either from an availability/cost of materials consideration, or by reason of difficult terrain. Following are some typical situations where an alternative design would have alleviated problems experienced during the pilot phase:
- in areas where sand did not occur naturally, cement blocks tended to be extremely expensive (e.g. the same type of block costing R2.50 in Vhembe, was R8.90 in Port St Johns). In the latter case, a less sand-intensive building method would be preferred.
- in other areas, builders' stone was unavailable and had to be trucked in over long distances, and was thus expensive. In such instances, packed sand-cement structures would obviate the need for concrete stone.
- at one site, large boulders protruded into the floor and lower wall areas, requiring a reinforced concrete shell rather than the Standard RWH Dam.
- in some remote and inaccessible areas, all material had to be carried by donkey up steep hills, making any type of concrete structure inappropriate. Ironically, by their remoteness such households are often

most desperately in need of closer access to water, to prevent malnutrition. In such cases, a motivation could be made for alternative light-weight material, like geofabric and bitumen. However, special provision would need to be made to enable households to reseal such structures at the required interval (typically five-yearly).

Appendix F11: 'Alternative RWH Dam designs' gives an indication of possible alternative designs, but it should be stressed that these designs are departures from the preferred 'Standard RWH Dam' and the additional design and subsequent inspection costs incurred by RIAs when using alternative dam types will shift to the RIA.

Vital information for the RIA, and especially the Area manager and TOs involved with the construction of the dams, is contained in the following Appendices:
Appendix F1 – Standard RWH Dam: **Drawings**
Appendix F2 – Workshop Drawings for Central Pole & Radial Arm
Appendix F3 – Standard RWH Dam: **Specifications**
Appendix F4 – Standard RWH Dam: **Construction Manual**
Appendix F5 – Standard RWH Dam: **Step-by-step Illustrated Construction Sequence**
Appendix F6 – Standard RWH Dam: Construction Tools and Equipment needed
Appendix F7 – Standard RWH Dam: List of Consumable Items needed
Appendix F8 – Rainwater Harvesting Layout Examples
Appendix F9 – Excavation Considerations
Appendix F10 – RWH Dam Maintenance and Safety Manual
Appendix F11 – Alternative RWH Dam designs
Appendix F12 – RWH Dam Design Routines

Inlet and overflow structures

RWH Dams collect rainfall run-off during rainstorms. During dry months, households want to catch whatever run-off they can, every time there is even just a soft shower. Hard compacted areas are ideal to prevent all the water from soft showers soaking away into the ground even before it reaches the RWH Dam. However, during intensive summer rainstorms, the run-off streams can be large and rapid-flowing and may carry substantial amounts of sediment, consisting of silt, small stones, vegetation and debris. During such storms the RWH Dam may fill up rapidly to the level of the overflow pipes, and thereafter any inflows will simply result in outflows via the overflow structure on the other side of the dam. When the flows exceed the capacity of the inlet and overflow, excess water is diverted away from the inlet by simple but important earth structures and landscaping, namely the berms and spillways which channel the excess water around the dam at a safe distance. This helps prevent erosionin the immediate surrounds of the dam and prevents water from standing in pools against the dam. Appendix 8.1 illustrates how simple earth berms need to be constructed to divert water into the inlet structure for the purpose of filling the RWH Dam in the first instance, but then divert excessive flows around the dam via 'spillways' in the second instance.

A good inlet structure together with the related earth structures should therefore:

- Channel as much water as possible safely towards and into the RWH Dam;
- Channel excess storm water around the RWH Dam to prevent erosion and excessive wetness around the dam; and
- Reduce the amount of sediment and debris washing into the RWH Dam with the rainwater (e.g. through a sediment trap and chicken wire sausages in the PVC inlet pipes).

However, even the best engineered sediment trap will not prevent very fine particles such as silt and clay from entering the main reservoir, as these particles are held in suspension for a long time before they settle out. This material must therefore be removed from the RWH Dam by the household once a year. Both the inlet and the overflow structures should:

- Avoid water soaking the earth around the RWH Dam walls, which may cause its walls to subside, crack and leak; and
- Prevent any open standing water which may cause drowning or mosquito breeding. The inlet's sediment pit should have a protective cover to prevent small children accidentally falling in and drowning.

Standardised designs for simple inlet and overflow structures are included in these guidelines (i.e. see Dwgs 12 through 19 of Appendix F1, and section XI of Appendix F4). However, because of the wide range of conditions these structures need to cope with – both across the seasons and across the country – this is an aspect that could benefit from further innovation.

What about Malaria?

The malaria-carrying *anophaeles* mosquito breeds in shallow, dirty, open water; for instance, an animal hoof print in the mud surrounding watering holes, provides ideal breeding conditions.

These RWH Dams hold deep, relatively clean water, and are roofed, and should therefore pose no malaria threat themselves.

It is important to ensure that surrounding structures (like shallow silt traps) don't create breeding conditions for mosquitoes.

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Standard Inlet Structure

Water runs into the RWH Dam through three 110mm PVC pipes built into the dam wall slightly below ground level on the uphill side of the dam.

Water flowing from ground- and other surfaces uphill of the dam, gets channeled towards these 'holes in the wall', by positioning small earth furrows and bunds along the natural flow path of the water. The household can reshape and fine-tune these heaps and hollows over time to ensure that the rainfall run-off is successfully diverted towards the RWH Dam. However…

The RIA must ensure that the RWH Dam is positioned correctly
and must do sufficient ground preparation
to ensure good – and safe – inflows into the RWH Dam.

Before the water enters the RWH Dam through the 'holes in the wall', it runs through a sediment trap, where the water slows down so that most of the larger soil particles can settle out. A course mesh across the pipe openings (or a fine chicken mesh 'sausage' pressed inside the inlet pipes) keeps twigs, leaves, frogs, rodents and birds out, but must be scraped clean after each rainstorm. Leaves especially can quickly block the RWH Dam inlet holes, and so a lot of the potential 'rainfall harvest' may fail to enter the RWH Dam.

Figure 6.2 – Standard Inlet Structure

The inlet structure above (Rosinah Mutshotsho, Tshikonelo, Limpopo) shows the three 110mm PVC pipe inlets through the RWH Dam wall, and the low U -shaped wall built on a concrete floorslab, which forms the sediment trap. As can be seen, the pipes are slightly higher than the floorslab, which helps the courser sand and stone to settle out before water enters into the dam. Also notice the earth berm on the left and right, which helps to direct water into the inlet. There is not yet any chicken mesh 'sausage' inside the pipe inlets. A shortcoming of this silt trap, is that a shallow stagnant pool will remain after each rain event. Note too that this inlet does not have a protective cover and therefore poses a safety risk for small children – this is an irregularity that will not be permitted in the Standard RWH Dam.

The essential elements of a standard inlet are thus:

- PVC pipe inlets going through the wall of the tank;
- a mesh reinforced concrete floorslab;
- a low U-shaped wall, consisting of blocks or bricks, built on top of the floorslab. The blocks are plastered on the inside of the sediment trap;
- a flexible waterproofing bandage applied in the corners and edges where the inlet butts up against the wall of the dam;
- berms (raised earth mounds) or furrows that channel run-off into the sediment trap and inlet;
- chicken mesh 'sausages' inside the PVC pipes; and
- a hinged protective cover, which may be a steel grill or grate.

Standard Overflow Structure

Once full, the RWH Dam overflows through three PVC pipe openings in the downhill-facing wall of the RWH Dam. These are installed in exactly the same way as the inlet pipes, and at the same level, to maximise dam storage capacity.

The overflow structure is essentially a channel made up of two parallel block/brick walls on a mesh reinforced concrete slab (see Figure 6.3 for a typical overflow structure), which conveys overflow water away from the immediate surrounds of the RWH Dam.

The interface between the overflow structure and the RWH Dam should also be sealed as described for the inlet structure.

On sloping ground, there will be a drop from the PVC outlet pipes in the wall, to the horizontal floor-slab of the outlet structure, as indicated in Figure 6.1. Without the overflow structure, this would result in an erosion pool/pit developing. Furthermore, the zero slope of the floor-slab limits the acceleration of the flow as it travels along the overflow channel, thus minimizing scour effects at the end of the overflow structure.

Figure 6.3 – Standard Overflow structure

The overflow structure above (Mrs Mutshekwa Masia, Tshikonelo, Limpopo) is a simple channel that conveys water away from the immediate surrounds of the tank.

On steep slopes, the outlet floor could slope more sharply downhill, and energy can be dissipated by installing protruding rocks in the channel floor, and especially at the end of the channel.

The text given in this section is relatively brief. For detailed information and discussion on the inlet and overflow structures refer to Appendices F1, F3, F4 and F5.

Structural and component design routines

MS Excel routines have been developed for the structural design of all components of the Standard RWH Dam. These design worksheets are contained in a CD included in this file. Extracts from the RWH Dam Design Routine sheets are given in Appendix F12.

DISCLAIMER:

The Department of Water Affairs and Forestry takes no responsibility for any mistakes that may exist in these design routines. Adjustments to the standard designs supplied by the Department may be made only with written permission from the Department, and the consequences of such adjustments will remain the professional responsibility of the RIA.

These design routines enable the RIA to adjust the dimensions and design of RWH Dams, for instance where local conditions dictate the depth, and therefore the required diameter for a storage volume of 30 000 liters. They can be used to determine the cost of materials and labour.

Construction tools and equipment

The tools and equipment required to construct a Standard RWH Dam are listed in Appendix F6. The required items are considered under the various tasks of siting, excavation, floor, walls, backfill, plaster, roof poles, inlet & overflow, water proofing, roof sheeting. Furthermore, the items are arranged in rows under the headings of 'essential', 'hand', 'mechanical', 'power' and 'workshop'. This gives RIAs more than one approach to building the dams.

While the additional tools listed under the headings of 'mechanical' and 'power' are clearly more costly than opting for the 'hand' approach, these costs should be weighed against benefits to be derived, such as greater speed of construction and improved quality. It is obvious that where a large number of RWH Dams are to be constructed, that the amortization of these items will be relatively low per dam, and in this case the mechanical/power approach will make good economic sense. It is also possible to adopt a middle-of-the-road approach, whereby the mechanical items are opted for, but leaving out the power items.

It is recommended that a small workshop be established for making minor repairs to equipment that breaks (see 'workshop items'). The list shown under this heading could be extended substantially, and clearly, the larger the number of RWH Dams to be built in an area, the more useful does a well equipped workshop become.

Appendix F7 shows the consumable items required for the construction of a dam, and lists those related to the mechanical/power approach separately.

Construction process

Dam siting

The RWH Dam will be a dominant feature in the household's yard for many many years into the future, therefore its positioning is important to the household. As part of the household empowerment/ownership process, the RIA should always ensure that the household decides for themselves where their RWH Dam is to be situated. The **FFP Facilitator** and **FFP Assistants** will assist the households with their garden and RWH layout planning, which each household captures in their own 'helicopter plan', which is simultaneously a household food security visioning and a five-year food gardening action plan. During planning, the household is requested to indicate three possible positions for their RWH Dam on their 'helicopter plan'. A visit to the household is then arranged for the **TO** and/or **QA** to join the **household** and the **FFP** staff in final selection of the RWH Dam position.

The **TECH** staff should help the household to select the best options from among their three preferred sites. In the unlikely event that none of the preferred sites are technically feasible, the **TECH** staff should explain the principles involved in correctly positioning a RWH Dam, and assist the household in choosing a workable site.

The most critical consideration in positioning the RWH Dam is to ensure that adequate rainfall run-off will enter the RWH Dam during rainstorms. Where hard impermeable surfaces are available, the opportunity to capture occasional showers in the long dry season, would increase the effectivenes of the RWH Dam dramatically.

Secondary considerations include ground conditions, surrounding structures and proximity and elevation relative to the garden trenches to minimise the labour involved in extracting and carting water, although the latter has proven to be less of an issue than first anticipated.

Some principles and examples are illustrated in the sketches in Appendix F8 and are thus only briefly summarized here.

a. To start with, make a careful evaluation of the site in terms of which way the ground slopes, the location of all existing structures, the existing vegetable garden, any adjacent roads or fields that may be at a higher elevation, which areas are hard and which are soft, possible roof run-off, run-off from hard areas.

b. If the site has a steep gradient, then the dam should be constructed with an additional 'outlet' pipe at its floor level, that leads out and through the downside embankment, at which point there should be a valve. In this case, if possible, the garden should be situated below this point (see Figure F8.2). This means that the RWH Dam may sacrifice some catchment so that the garden may be gravity fed – a saving of human energy for the householders.

c. If the site has a substantial catchment from an adjacent field or road that is at a higher elevation, then the garden could be sited so that the flow from these areas would flood the collector-pathways around the trenches and only then lead onto the RWH Dam, which would then be situated at an elevation lower relative to the garden (see Figure F8.3).

d. Likewise, the garden followed by the dam should ideally be sited downhill of any hard ground such as court yards, driveways, or other impermeable surfaces, such as steel sheeted roofs.

e. Where irrigation is going to be via buckets, the garden and RWH Dam should be situated as close to one another as possible.

f. If the ground is soft and porous and unlikely to have much runoff, but the house has a relatively large steel roof, then consideration may be given to constructing an above-ground dam to harvest this water. An outlet valve at the floor level of the dam allows gravity feeding to the garden, which should ideally be placed down-slope of the RWH Dam (see Figure F8.4).

g. It may be advantageous to construct berms or trenches to redirect runoff towards the RWH Dam's inlet rather than allow it to run past (see Figure F8.1).

Excavation

Once a suitable site for the dam has been selected, the excavation team should start with the digging. It is recommended that the household digs the trial pit of 1.5m in diameter to the required depth, approximately 2.2m below the datum line (see step 5 of Appendix F5). This will give an indication of the hardness of the ground at the final depth, and if unpickable ground is reached, the site can be aborted without too much loss of time and effort, in favour of another position where the ground may be softer. (Note that a 1.5m diameter hole is only about 7% of the total volume of the eventual excavation, which should have a 5.8m diameter for a Standard RWH Dam).

Once the correct level has been reached, a central pole (a 42.8mm diameter galvanised steel pipe x 4m long) should be installed, complete with a radial arm and 'pole stabilisers' (to keep the pole in the upright position). See Appendix F5 which shows the full sequence of the excavation process and the installation of the central pole & radial arm, and also indicates how it is later used in the construction process. Figure 6.4 below shows how the radial arm revolves around the central pole.

Figure 6.4 – A typical radial arm which revolves around a central pole

Figure 6.4 shows a typical radial arm, pivoting on a central pole, which makes it a simple matter to lay horizontal courses and construct walls that are perfectly vertical. The radial arm can telescope in and out, so that it may be used for the excavation as well the block work and even for trimming the plaster. Had this radial arm been available for this excavation, the hole would have had a perfectly cylindrical shape rather than its current rather irregular shape. Note too that the central pole and radial arm may also be used to achieve a perfectly level surface in the concrete slab.

Construction

The construction sequence for a Standard RWH Dam is fully illustrated in Appendix F5: 'Step-by-step Illustrated Construction Sequence', and described in detail textually in Appendix F4: 'Construction Manual' and Appendix F3: 'Specifications'.

The various steps are summarized below for a Standard RWH Dam:

- Day 1: The RIA and **builder** set out the marking pegs for the inlet, the centre of the dam, and the overflow. Next four profiles are also established in the form of a Maltese cross, each profile being approximately 4.8m from the centre of the dam. Two fish lines are attached to the profiles, one fish line per opposite pair of profiles, and hereafter these lines will be referred to as the datum lines; they constitute the two major axes/centrelines of the dam. It is a further requirement that the profiles are set up such that the fish lines are perfectly horizontal *and* at a height of 600mm above the level of the ground at the start of the inlet structure. From this point forward, all future measurements and levels are be referenced to these datum lines. [The Day 1 activities are illustrated in steps 1 through 4 of Appendix F5].
- Day 2: A 1.5m diameter exploratory trial pit is dug at the centre of the dam to its final level, 2.2m below the datum level, and a further small hole is dug in the centre of the trial pit. [The Day 2 activities are illustrated in steps 5 through 6 of Appendix F5].

- Day 3: The **builder** installs the central pole in the small hole that was made at the bottom of the trial pit. [The Day 3 activities are illustrated in steps 7 through 9 of Appendix F5].
- Day 4,5,6: The **builder** slides the radial arm over the central pole, which in turn is stabilised by the pole stabilizers. The digging team proceeds with the main excavation, guided by the radial arm to obtain an excavation of the correct diameter and depth. [The Day 4,5,6 activities are illustrated in steps 10 through 18 of Appendix F5].
- Day 7: The **builder** installs Ref. 193 reinforcing mesh in the base of the excavation, and casts the 100mm thick concrete floor, guided by the radial arm to achieve a level floor. To ensure that the floor-slab is essentially impermeable, it should have a characteristic compressive strength of 25MPa (see Table 1 of Appendix F1 for typical proportioning by volume) and be finished with several cycles of wood and steel floating, with appropriate delays for evaporation of any 'bleed water' that surfaces. Thereafter the surface is covered with a PVC cover overnight, and then kept wet for a further 7 days. [The Day 7 activities are illustrated in steps 19 through 34 of Appendix F5].
- Day 8: The blocks are built on top of the floor-slab, and once again the radial arm is used to achieve a perfectly cylindrical shape with an inside radius of 2.6m – see Figure 6.4 above for a view of a block wall being built using the central pole & radial arm – see also Appendix F2.

  Circumferential 'hoops' made from 6mm high yield steel bars are built into he wall between the courses. By the end of Day 8 the wall should be approximately 1m above the floor-slab. [The Day 8 activities are illustrated in steps 35 through 43 of Appendix F5].
- Day 9: Some of the excavated ground should be backfilled in the space behind the wall, in horizontal layers not exceeding 100mm, and compacted using hand stampers. The ground should be earth moist for improved compaction, and backfilling may proceed all the way to the top of the previous day's block work.

  Three 110mm PVC pipes x 300mm long are built into the wall on the inlet side of the structure, such that their invert levels are 1.43 m above the floor-slab. Another three 110mm pipes are likewise built into the wall on the outlet side of the structure.

  Approximately 1.6m above the floor-slab, four 4mm galvanized 'pole anchorage' wires are built in which will be used to secure the two gum poles for the roof.

  Also at 1.6m above the floor-slab, 2.5mm galvanized 'sheet anchorage' wires are built into the wall at a spacing of 350mm around the full circumference of the RWH Dam.

  The final height of the wall should be 2m above the slab. [The Day 9 activities are illustrated in steps 44 through 50 of Appendix F5].
- Day 10: Backfilling may continue as in Day 8 until ground level is reached.

  The walls are plastered on the inside of the RWH Dam. It will be convenient to use the radial arm to skim off the excess plaster and thus establish the design thickness of 15mm. The wall is then wood floated for evenness and steel floated for increased density and smoothness.

  Following the plastering operation, the pole stabilizers, central pole & radial arm may be removed and taken to the next site. The PVC is removed from the hole in the slab, and the sheath hole is backfilled with a moist sand:cement mixture in layers of 50mm and thoroughly rammed with a 20mm steel rod.

  Two treated 125/100 gum poles, 5.4m long, are inserted into openings in the top course of the wall. They are then lifted to the correct height, positioned to the correct spacing, and then built in with bricks. Two channels with predrilled holes at the correct spacing are a convenient way of ensuring that the poles are correctly spaced and that their upper faces are flush with the top of the wall [The Day 10 activities are illustrated in steps 51 through 72 of Appendix F5].
- Day 11: The four 4mm galvanizing wires that were previously built into the wall are now used to secure the poles, one wire for each end of each pole. The un-plastered area corresponding to the bricked up zones may now be plastered to match the rest of the plaster on the inside of the tank.

  The excavation for the inlet and overflow structures are dug, ref 193 mesh is cut to fit and inserted, and an 80mm slab is cast for both structures. Once the floor has stiffened sufficiently (allow at least two hours), the walls may be built. [The Day 11 activities are illustrated in steps 73 through 84 of

Appendix F5].

- Day 12: The walls of the inlet and overflow structures are plastered on the inside face. Thereafter the walls inside the dam are coated with a waterproof coating (Chryso 228) according to the manufacturer's instructions. In the corners, at the wall/floor interface, a geofabric 'ABE membrane' is used to reinforce the coating. [The Day 12 activities are illustrated in steps 85 through 87 of Appendix F5].
- Day 13: The roof sheeting is positioned over the poles, and the trap door is cut from one of the sheets. Next the sheets are screwed down to the poles, trimmed to a circle (in plan), and tied down to the walls with the 2.5mm 'roof-sheet anchorage wires'. 10mm funnel shaped holes are randomly drilled in the troughs of the IBR roof-sheets, spaced approximately 500mm apart, to facilitate inflow of rainwater directly from the roof into the RWH Dam. Finally, the trap door is fitted with two brass hinges, and a 12mm hole is drilled in one corner to receive a brass padlock.

  The corners and edges of the inlet and overflow structures where they butt up to the dam also receive a waterproof coat, reinforced with a geofabric bandage strip.

  The section of the RWH Dam's wall protruding out of the ground is bagged (block brushed) on the outside with a sand:cement slurry.

  A 'sausage' shaped filter is made from chicken mesh and inserted into the PVC pipes to keep frogs, rodents and vegetation out of the RWH Dam.

  A protective grill/grate is fitted over the inlet to prevent small children from possible drowning when the shallow sediment trap is full of water.

  Mounds to direct water to the inlet are made using backfill and builders rubble. The site is cleaned up, building equipment removed, and excess building material is relocated to the next site. [The Day 13 activities are illustrated in steps 88 through 107 of Appendix F5].

The various dimensions of the excavation, floor-slab, walls, and roof are given in the drawings (see Appendix F1), the specifications (see Appendix F3), and the construction manual (see Appendix F4). Appendix F1 also contains the drawings for the inlet and overflow structures, and has a table (Table 2) that lists the various construction materials along with corresponding quantities for the RWH Dam, the inlet structure, and the overflow structure. These drawings also give a list of the required materials and how much of each is required.

Quality Assurance

Quality Assurance is the responsibility of the RIA technical staff, who must be fully capacitated not only to deal with the final quality assessment, but also the overall **QA**, starting from the setting out on 'Day 1' and ending with the final signing off of the RWH Dam when it had been tested successfully for watertightness (see Appendix C3.6: Books and Forms used by the **Quality Assessor**).

RWH Dam Testing and Commissioning

Once the construction process is complete, the RIA inspects the builder's work, going through the following checklists, which can be found in Appendix C3.6:

QA03: **QUALITY ASSESSOR CHECKLIST (FLOOR & WALL)**

QA04: **QUALITY ASSESSOR CHECKLIST (ROOF & WATERPROOFING)**

When the **builder** has corrected all mistakes to the satisfaction of the **QA** and the **TO**, and the tank is deemed 'functionally complete,' the household signs the following form:

QA05: **INITIAL TANK ACCEPTANCE form**

During the final household training workshop, all the various tank and water management tasks and the required frequency are workshopped with the household, and the household representative receives a RWH Dam Maintenance and Safety Manual (see Appendix F10). Special emphasis is placed on safety issues, such as keeping the trapdoor locked when not open for irrigation, keeping the grate over the inlet in the closed position, removing water and sediment from the sediment pit after every rainfall to prevent malaria, and not using the water for drinking without prior treatment.

After the first good rains, the RWH Dam should hopefully be full and may then be checked for leakage. This may be done by the householders themselves – by simply making a mark on the wall, and then measuring the drop in the water level the following day. Providing no water is taken out of the dam at this crucial period, and that no additional water flows into the dam, the level should have gone down by just a few mm, perhaps 5mm from evaporation. If on the other hand the level has dropped by 10mm or more, the RIA should be called in to verify that there is a problem, and if the situation does not stabilize by the end of the rainy season, arrangements are to be made for an inspection of the walls/floor when the dam is dry, and the application of an additional coat of waterproofing. Then after the next good rains, when the dam is again full, the measuring process is repeated to demonstrate that the dam is no longer leaking.

Once the tank has been tested successfully for waterproofness, the household signs the final tank acceptance form:

QA06: FINAL TANK ACCEPTANCE form

When the dam has thus been shown to be fully functional and not leaking and the household has signed final acceptance, the RIA may claim the final 5% retention from DWAF. This claim shall be accompanied by a completed Household Tank Certificate, with 'as built' detail, photographs and sketches as required, in respect of each completed tank. A laminated copy of the Household Tank Certificate is to be handed to the household.

QA07: HOUSEHOLD TANK CERTIFICATE

Ancillary equipment

Pumping

Manual pumping is provided for through the supply of a treadle pump. The RIA shall demostrate and supervise the assembly of the treadle pumps by the households themselves. The objective is to ensure that households have sufficient understanding of how the pump works, especially the elimination of air leaks to ensure proper functioning of the pump.