CHAPTER 10

Springs

A CATCHMENT AND STORAGE TANK DESIGN

1 Spring catchments

Generally, springs offer high quality groundwater that is easy to exploit. They are frequently used in a traditional manner.

1.1 Flow measurement

Flow measurements are required to estimate the yield of springs over the year. For accuracy, it is essential to take measurements over a period long enough to take account of flow fluctuations*. In practice, it is often impossible to obtain quantitative information on flow over a long period, but local communities have a good knowledge of the behaviour of springs. It is therefore essential to carry out a field investigation in the company of a local person.

From the measurements carried out and the information provided by users, minimum and normal flows can be estimated. The minimum flow is compared to the demand of the population and forms the basis of the decision as to whether or not to build a storage tank. The normal flow forms the basis for overflow design.

Flow-measurement techniques are given in Chapter 3.

1.2 The hydrogeological context

At the time of the preliminary visit, it is important to identify the hydrogeological context of the spring's discharge zone (see Chapter 3). In general, the following types may be defined:**

- fracture springs, for instance emerging through cracks widened by the roots of a tree. These springs may be artesian, but their discharge zone is generally clearly delimited, and the use of a spring box may be envisaged;

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* A flow measurement period of sufficient length also gives the curve of the spring yield reduction, and provides information on the system's reserves.

** This classification does not correspond to the one commonly used in hydrogeology (artesian springs, overflow springs, emergence springs and discharge springs), which in practice does not have much application in the field.

– lowland springs, typical of bedrock zones, corresponding to the outcrop of an aquifer in a topographic depression. The discharge of these springs is often diffuse, and catchment via a drain or well is generally recommended;

– springs on slopes, that are often at a point where the piezometric level (unconfined aquifer) or the aquifer roof (confined aquifer) meets the topographic surface. The discharge zone of these springs is frequently diffuse, except in the case of ravines.

A summary geological section can be drawn to visualise the hydrogeological context.

It is also important to find the initial discharge of the spring, which may be concealed by debris, in a swampy zone, or in very uneven terrain. Again, the discharge zone may vary during the year. Site inspection must therefore be meticulous.

Some simple indicators also help to determine the context:

– seasonal flow variations give a picture of the system's inertia, and therefore of its transfer rate (transfer of pressure or flow);

– the response of the spring to an isolated downpour can provide an estimate of the response of the system to an impulse, and therefore its vulnerability;

– variations in water quality, especially turbidity, complement this information.

1.3 Spring catchments

The objective is to obtain maximum yield from the spring while protecting it from external pollution, especially of faecal origin.

Every spring catchment is a special case: it is not possible, therefore, to offer a model adapted to all situations. There are however two basic types, each corresponding to particular field constraints (Table 10.I).

The choice of catchment technique is determined during the site visit, but is mainly decided during the progress of excavation. The procedure is as follows:

- clear the discharge zone to locate the water outlets precisely;
- excavate towards the source of the water, taking care not to obstruct the flow;
- stop excavation when the impermeable level is reached:
  - if the discharge is clearly localised and not very deep (less than 2 m), construct a spring box and retaining wall to protect the structure;
  - if the discharge is diffuse and/or deep, construct a dam wall with a drain behind it;
- position outlets and overflows correctly below the discharge level;
- erect a protective fence.

Figures 10.1 and 10.2 show the principles of spring catchments using tanks and drains.

Structures, notably the drain dam wall or the spring box can be made of masonry or reinforced concrete. Infiltration galleries consist of 5-10 cm round pebbles, set behind the wall or in a gabion. A perforated PVC pipe can be laid in the drain to decrease head-losses.

Table 10.I: Spring-catchment techniques.

Catchment technique	Type of spring	Advantage	Disadvantage
Spring box	Discharge zone localised and not very deep	Catchment accessible	Often requires major construction work
Infiltration gallery	Discharge zone diffuse and/or deep	Easy to achieve	Catchment inaccessible

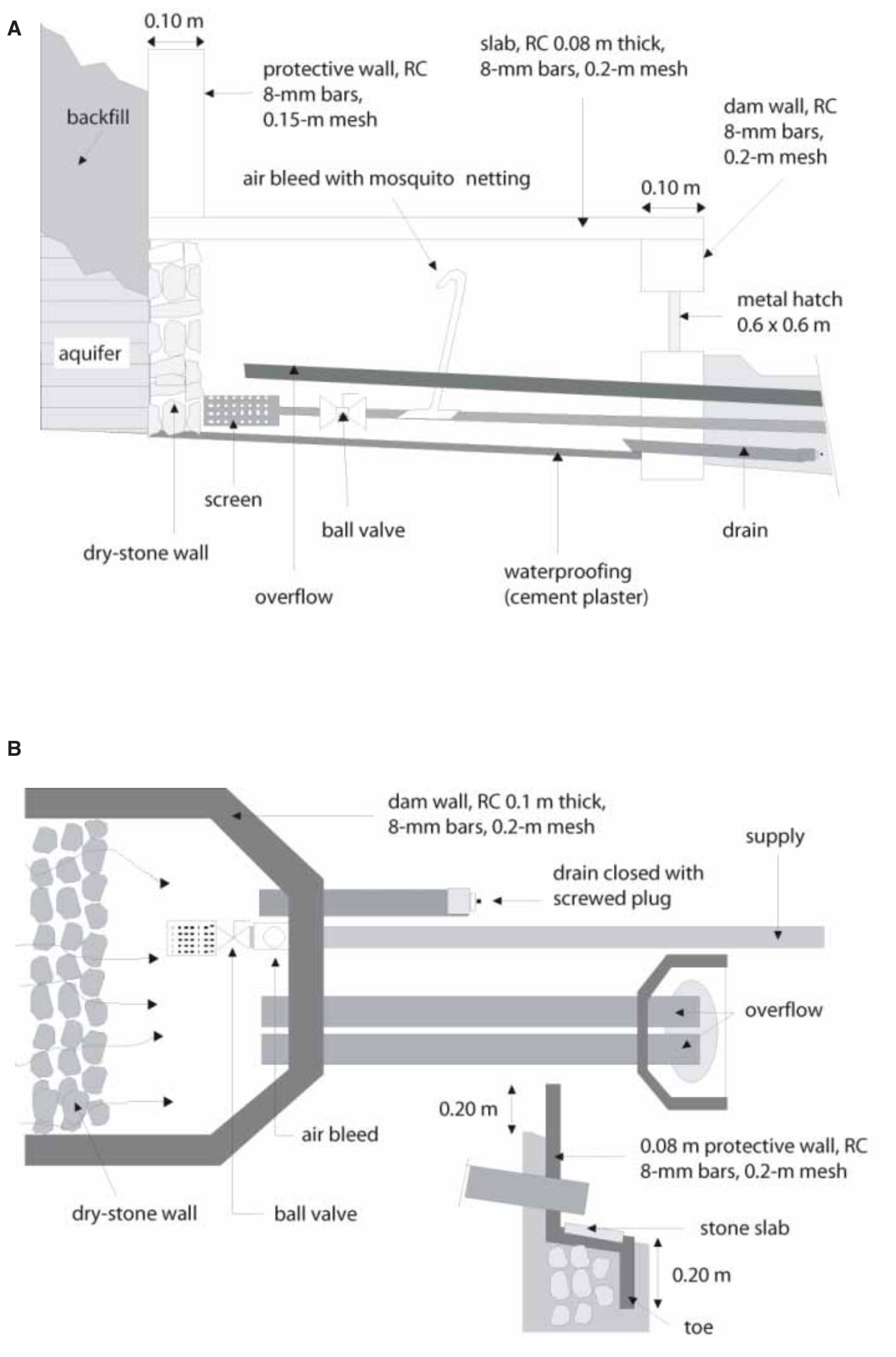


Figure 10.1: Spring box in reinforced concrete.
A: section. B: plan.

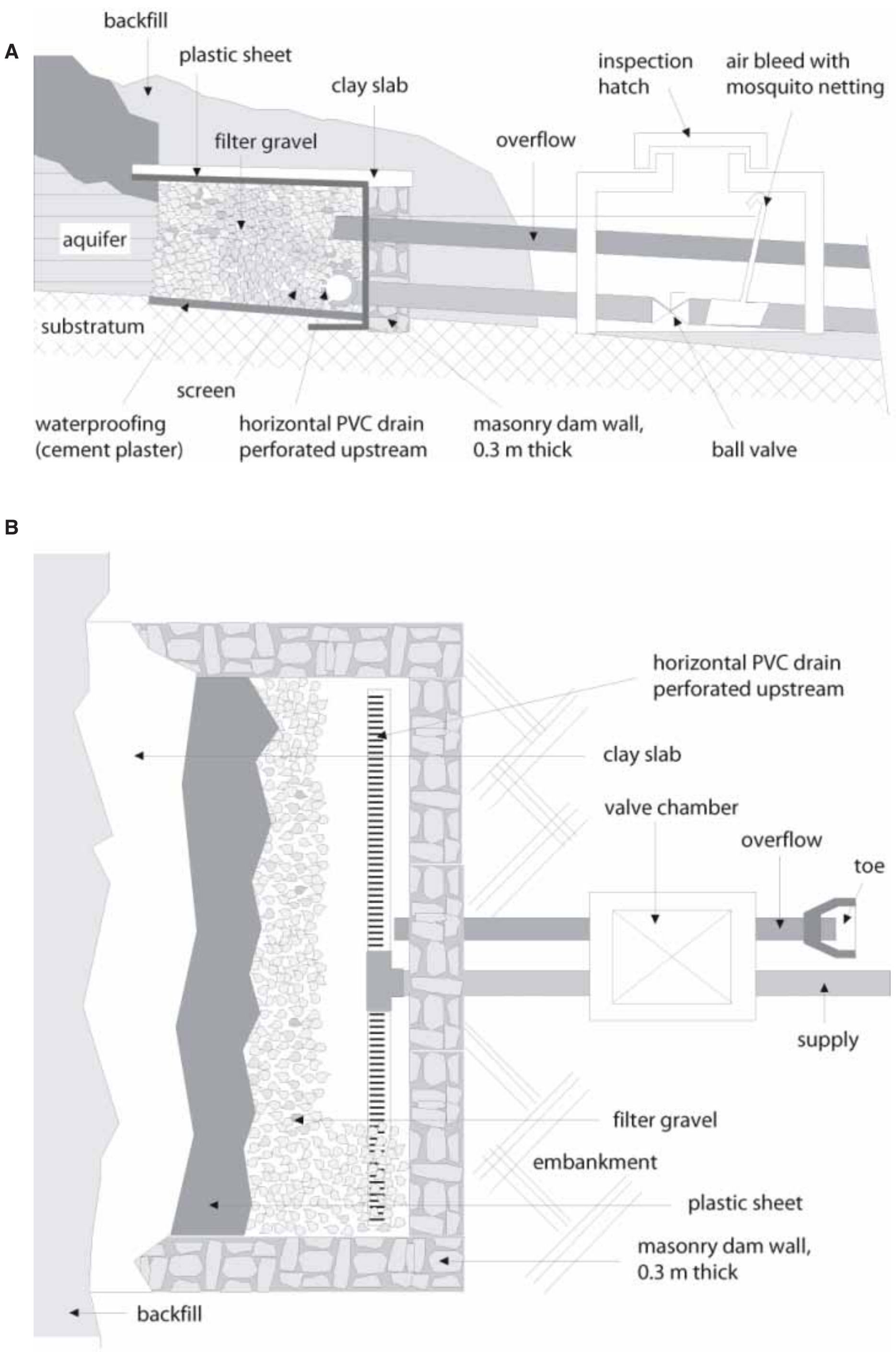


Figure 10.2: Infiltration gallery.
A: section. B: plan.

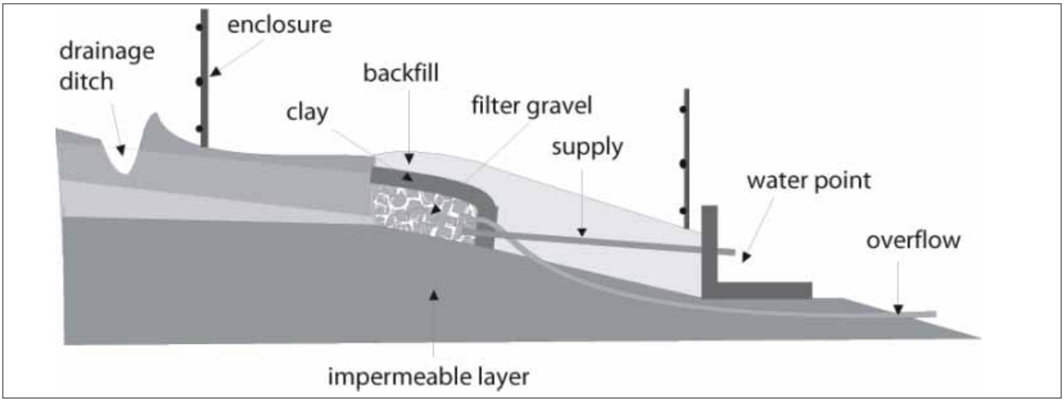


Figure 10.3: Infiltration gallery sealed with clay.

The technique of catchment by infiltration galleries sealed with clay (Figure 10.3) is currently used in zones where clay is extracted from the excavation (ACF, Rwanda and Burundi, 1996).

Three rules must be strictly observed in order to construct a reliable spring catchment:

The catchment must never be subject to back-pressure: the water level in the spring box or infiltration gallery must always be below the initial discharge level. The catchment must drain the aquifer while allowing extraction from the piezometric level, but must not increase pressure, or the spring could be lost. A reference peg can be used (set far enough away not to interfere with the excavation) to mark the initial discharge level. This acts as a reference mark at the time of the construction: the outlet and overflow are set below this level. However, to avoid accidental back-pressurisation, it is essential to create an overflow; in the absence of information on the maximum flow, the overflow must be over-sized (two or three 3” pipes).

The dam must be located on impermeable terrain: the excavation must reach down to the substratum. This sometimes requires substantial excavation, but is essential to ensure that water does not pass under the catchment after some weeks of use. The notion of *substratum* is sometimes difficult to define on site: it is therefore preferable to retain an idea of a less permeable layer over which water moves.

The catchment must be protected: the protective works are part of the catchment works. It is necessary to take care over sealing, especially the drain cover (clay, plastic sheeting etc.), and the construction of the tank.

1.4 Equipping springs

Springs should be equipped in such a way as to guarantee protection and ease of use. Establishing a protective zone is described in Annex 10. There are many models of water points for springs (Figure 10.4): the choice must be made in agreement with the users, taking account of cultural factors. It is also necessary to study site drainage so as to avoid the development of boggy ground and stagnant water.

Construction details are given in Annex 14.

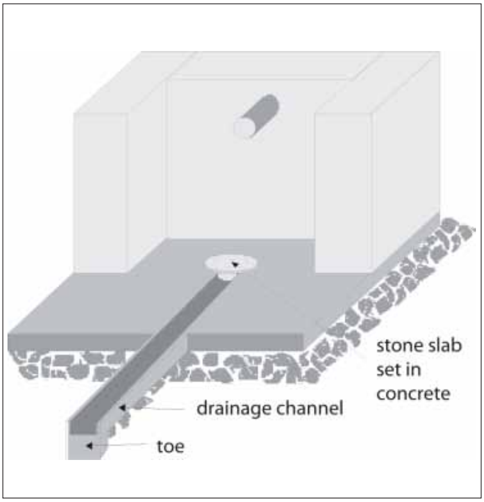


**Figure 10.4: Examples of water points.
A: simple water point (ACF, Burundi, 1995).**

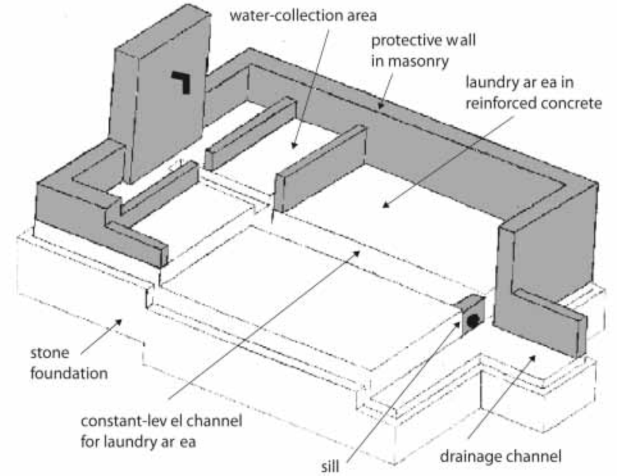


Figure 10.4: Examples of water points.
B: water point with laundry area (ACF, Ethiopia, 1993).

2 Storage tanks

2.1 Tanks on spring catchments

When the maximum hourly demand is greater than the volume produced by the spring in one hour, it is necessary to construct a storage tank. The principle is to store water in periods where demand is low, so as to be able to provide a greater flow when demand increases. The difference between demand and flow of the spring at various times of day is shown in Figure 10.5 (from the example of the Aloua system shown in Chapter 11).

Depending on the capacity of the spring, an open (continuous flow) or closed distribution system with taps and a tank may be considered:

– maximum hourly demand (m^3/h) < spring flow (m^3/h) → open circuit without a tank;

– maximum hourly demand (m^3/h) > spring flow (m^3/h) → closed circuit with a tank.

Calculation of tank capacity facilitates economic design. It is therefore important in larger installations (see Section 2.2).

For springs with very low flow-rates, it is taken as a first approximation that the volume of the tank must be equal to the volume of water produced by the spring overnight.

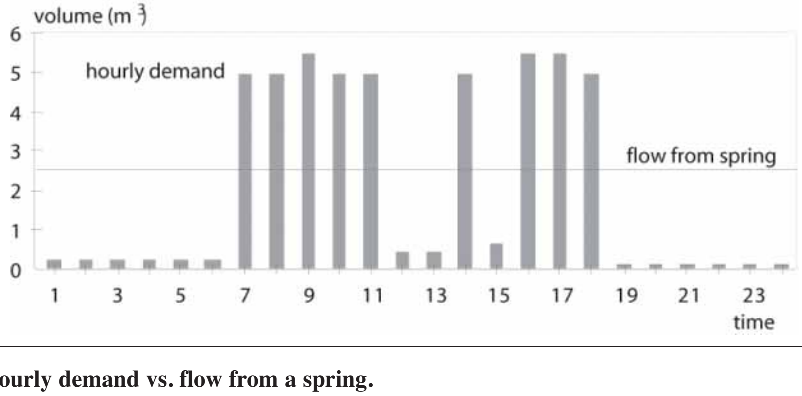


Fig 10.5: Hourly demand vs. flow from a spring.

2.2 Tanks with gravity network

When the spring has to supply a larger population via a distribution network, it is important to optimise tank design. The breakdown of demand into hourly sections is calculated using a consumption coefficient for every period (percentage of total consumption over 24 h). Table 10.II shows an estimate for the Aloua system. The most economical volume of the tank is the minimum required ro cover the hourly demand. If this tank volume allows most of the yield of the spring to be used, then a larger tank (optimal volume) should be built – 28 m^3 and not 17 m^3 in our example.

Levels of water in the tank based on time of day can be represented in the form of curves or given in a table. Table 10.III and Figure 10.6 are based on the Aloua example, assuming an empty tank at 18h00 and a volume of 17.5 m^3.

Table 10.II: Calculation of demand in hourly periods.
Aloua (Ethiopia), January 1995: flow 2.52 m^3/h; daily demand 49.56 m^3/day.

Period (h)	Coefficient of consumption (%)	Demand over the period (m^3)	Production of the spring (m^3)	Stock in the tank (m^3)
0-6	2.5	1.24	15.12	13.88
6-7	10	4.96	2.52	11.44
7-8	10	4.96	2.52	9.00
8-9	11	5.45	2.52	6.07
9-10	10	4.96	2.52	3.63
10-11	10	4.96	2.52	1.19
11-13	1.75	0.87	5.04	5.36
13-14	10	4.96	2.52	2.92
14-15	1.25	0.62	2.52	4.82
15-16	11	5.45	2.52	1.89
16-17	11	5.45	2.52	– 1.04
17-18	10	4.96	2.52	– 3.48
18-21	0.75	0.37	7.56	3.71
21-24	0.75	0.37	7.56	10.9
0-24	100%	49.56	60.48	stock max = 13.88 stock min = –3.48

Overflow = flow over 24 h - daily demand   OF = 10.92 m^3
Min volume of tank (economic) = max stock - min stock V_{min} = 17.34 m^3
Volume of the tank to use all the spring (V_{min} + OF) V_{tank} = 28.26 m^3

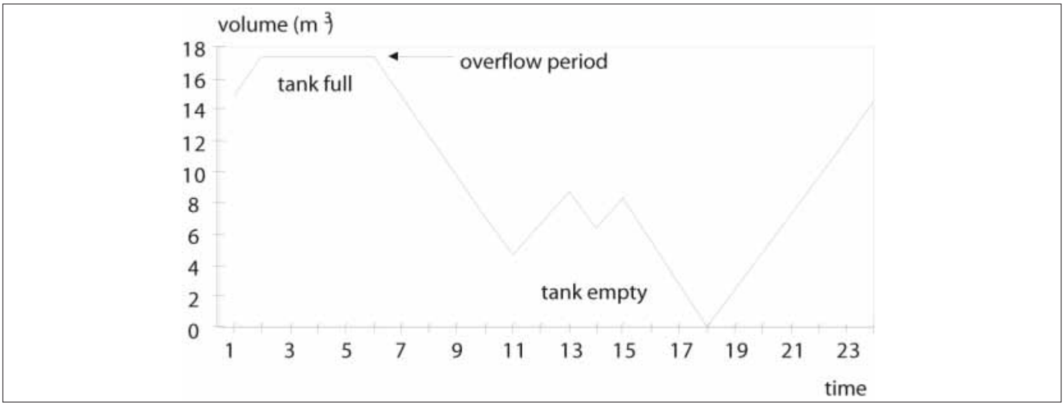


Fig 10.6: Representation of volume of water in a tank over one day.

Table 10.III: Calculation of water volume in tank.

Period (h)	Coefficient of consumption (%)	Demand over the period (m^3)	Production of the spring (m^3)	Stock in the tank at end of period (m^3)
0-6	2.5	1.24	15.12	17.34
6-7	10	4.96	2.52	14.90
7-8	10	4.96	2.52	12.47
8-9	11	5.45	2.52	9.53
9-10	10	4.96	2.52	7.10
10-11	10	4.96	2.52	4.66
11-13	1.75	0.87	5.04	8.83
13-14	10	4.96	2.52	6.40
14-15	1.25	0.62	2.52	8.30
15-16	11	5.45	2.52	5.37
16-17	11	5.45	2.52	2.44
17-18	10	4.96	2.52	0
18-21	0.75	0.37	7.56	7.19
21-24	0.75	0.37	7.56	14.38
0-24	100%	49.56	60.48	max = 17.34

As can be seen from Figure 10.6, the tank is refilled mainly from 18 h (there are also two brief refill periods during drops in consumption between 11-12h00 and 14-15h00 h). If the tank is designed for 17.5 m^3, the overflow functions from 01h40 discharging a total volume of 10.92 m^3 over approximately 4 hours.

2.3 Tanks in pumped systems

In the case of a pumped supply, the volume of the tank is calculated according to the capacity of the pump and the frequency of pumping. In practice, it is considered that a volume corresponding to the daily water demand is satisfactory. This in effect means that the pump needs to be run only once per day.

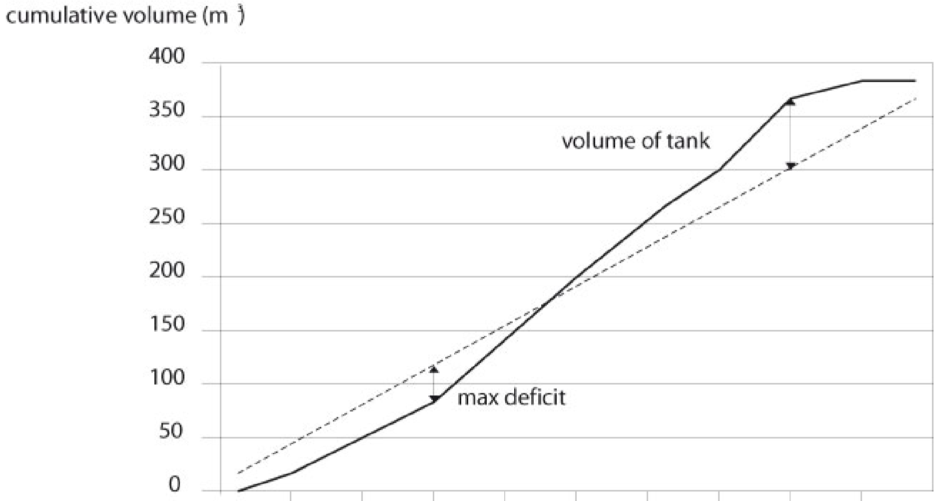
For solar-powered pumping, the minimum capacity of the tank should be equal to the daily volume produced.

In emergency programmes, the tanks used are generally of fixed size: 10, 20, 30, 45, 70, and 95 m^3, with the number of tanks determined by arrangements for water treatment (see Chapter 12).

2.4 Rainwater-catchment tanks

Rainwater-catchment tanks at the domestic or small collective level (school or health centre) are generally designed by comparing demand and cumulative monthly volumes over a year. For example, for a school in northern Uganda, with a roof area of 550 m^2, the ratio of rainfall to water collected was estimated at 80% (corrugated iron roof - see Chapter 3), and rainfall data was available on a monthly basis. Daily demand was estimated at 1 000 l (100 pupils x 10 l/pupil/day). Figure 10.7 compares demand and volume of recoverable water, cumulated over a year. The volume of the tank can be defined graphically as the difference between the maximum monthly surplus and cumulative demand over this period, or 60 m^3 (month of October). As this volume is slightly greater than the maximum deficit for the month of March, estimated at 54 m^3, demand should therefore be satisfied all year round.

In the absence of precise rainfall data, Pacey and Cullis (1986) suggest volumes shown in Table 10.IV.



	Jan	Feb	Mar	May	Jun	Jul	Aug	Sep	Oct	Dec
cumulative volume of recoverable water	5.3	10.6	36.9	121	169	208	263	294	360	374
cumulative demand	30	60	90	150	180	210	240	270	300	360

Figure 10.7: Design of a rainwater-catchment tank for a school (ACF, Uganda, 1996).

Table 10.IV: Volume of tank for domestic rainwater catchment.

Mean annual rainfall (mm)	Area of roof (m^2)	Volume of tank (m^3)	Volume of water available per day (l)	Reliability of the tank (% coverage over the year)
1 800 – no dry season (Jakarta)	30	3.6	30	99
800 – 2 rainy seasons (Ghana)	30	7.5	66	—
635 – 1 dry season of 6 months (Swaziland)	30	5	37	—
1 500 – 5 dry months (Indonesia)	30	5.1	30	99
1 300 – 4 dry months (Thailand)	30	5.8	45	95
1 200 – no dry season (Australia)	30	11.8	74	80
390 – no defined wet season (Australia)	30	10.5	25	80

2.5 Tanks for run-off catchment

On a collective scale, the volumes of tanks (*birkads* and ponds – see Chapter 3, Section 3, and Chapter 19) can be estimated from procedures used on the domestic scale. It is however preferable to work with 10-day rather than monthly data in order to optimise the design.

In the case of open storage (ponds), it is necessary to take account of losses due to evaporation and seepage.

Experience shows however that it is generally difficult to construct tanks large enough for storing large stream flows for collective consumption, because site conditions generally limit the footprint of tank possible.

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