7. The water cycle

Of all the reserves of water in the world, all but 0.78 percent are tied up as either sea water or fresh water in the polar ice caps. However, this remaining amount still represents 2,360,480 cubic m of fresh water for each person in the world today. Even the rainfall alone represents 23,486 cubic m per person annually over the world's land surface. The detailed figures below give some idea of the enormous reserves of water that are available for human consumption.

		Per cent	cubic km
Total world water		100	1,386,000,000
Salt water		97.5	1,350,000,000
Fresh water		2.5	35,000,000
Comprising:	Polar ice caps	68.7	24,100,000
	Groundwater	30	10,500,000
	Comprising:		
	Lies up to 50m deep	75	
	Lies over 50m deep	25	
	Economically extractable	40	
	Lakes	0.26	176,000
	Rivers & marshes	0.03	12,000
	Soil moisture	0.05	17,000
	Atmosphere	0.04	13,000
Rainfall	On land	20	109,000
	Over sea	80	458,000
Evaporation	From land	12.5	72,000
	From sea	87.5	505,000
River run-off			45,000

Twenty per cent of water used is groundwater, and 80 per cent of water used is groundwater, and 80 per cent of water used is employed in agriculture.

The water on the earth is part of a continuous cycle (the Hydrological Cycle) with precipitation consisting of rain, snow, hail, mist and dew falling onto the earth's surface. It then either runs off over the surface into streams and rivers, or it infiltrates the ground and percolates through the ground to springs or rivers or until it reaches the ocean underflow. Water in the ocean as well as surface water on the land is turned to water vapour by the heat of the sun and so evaporates into the atmosphere. Water being used by plants and crops is also transpired into the atmosphere. This water vapour then condenses into clouds and under the right atmospheric conditions falls again to earth as rain.

The water cycle which is illustrated in this Technical Brief can also be written as an equation:

$$\text{Precipitation} - \text{Evaporation} - \text{Transpiration} = \text{Run-off} \pm \text{Groundwater outflow} \pm \text{Change in storage}$$

This equation can be used to determine the water resources of individual catchment areas or river basins. This is then used to ensure that only the correct amount of groundwater is taken out in order to prevent depletion of the groundwater over a number of years.

Source: World water balance and water resources of the earth, UNESCO, 1978.

The water cycle

Water quality

When considering how to improve a water supply it is necessary to consider the quantity, proximity and quality of the water. By enabling people to have more water, closer to home, significant health benefits can result, but in the long term it is vital to ensure that the water is also of a suitable quality.

Water easily collects all kinds of impurities which give it colour, odour, taste and turbidity (cloudiness). These impurities are either organic, derived from the decomposition of plants and animals and wastes, or inorganic such as soils, minerals and dissolved metals.

Drinking water should as far as possible be colourless, odourless and pleasant to taste. It should be free from disease-producing organisms and dissolved minerals which make the water 'hard'.

Guidelines for water quality are given below but it should be noted that whereas rainwater in rural areas will generally be of good quality if it is properly caught and stored, surface water is very likely to have been polluted and groundwater should be free from disease-causing organisms if taken from below a depth of 10m.

In unpiped water supplies, the bacteriological objective is to reduce the coliform count (statistically determined as the most probable number of a certain bacteria) to less than 10 per 100ml and to ensure the absence of faecal contamination (WHO 1984).

The chemical characteristics of rural water are not normally harmful apart from excessive fluoride and nitrate levels. However, they can cause people to reject improved water sources: for example, if iron in groundwater causes staining of clothes. It has also been noted that the hard water more typical of groundwater sources can lead to 42 per cent increase in cooking time – leading to a 44 per cent increase in the use of fuel.

mg/litre	Calcium	Chloride	Fluoride	Iron	Magnesium	Nitrate	Sodium	Sulphate	pH
Guideline values (WHO 1984)		250	1.5	0.3		10	200	400	6.5-8.5
Maximum permissible (WHO 1971)	200	600	2.0	1.0	150	100	400	400	6.5-9.2
Rainwater Example: S E Asia	2	3		0	2	1		4	5.6
Surface water Example: Sudan	7.2	10	<1	0.6	5.9	0.27	19	0.02	7.42
Groundwater Example: Granite USA	14	5.9		0	4.7		22	52	

Illustrations: Susan Ball, WEDC Group, Loughborough University of Technology, UK.

Text: Richard Franceys, WEDC Group, Loughborough University of Technology, UK.

Water demand

The Water Cycle illustrates the various sources of water and shows where water may be taken out of the cycle for domestic consumption. Detailed below is information about water usage with guidelines for design purposes.

Wells and improved sources

Source distance	Approx water usage litres per person per day
> 2,500m	5
250-2,500m	15
< 250m	15-35

The recommended design criterion is to plan for an improved water source for each population grouping of 200 to 250 people with a supply of 35 litres per person per day (45 litres per person if it is possible to design for future improvements in standard of living, but reducing to a minimum of 20 litres per day in difficult situations) within a distance of 250m of each household.

Standposts

Source distance	Approx water usage litres per person per day
< 250m	15-50 (dependent upon distance)

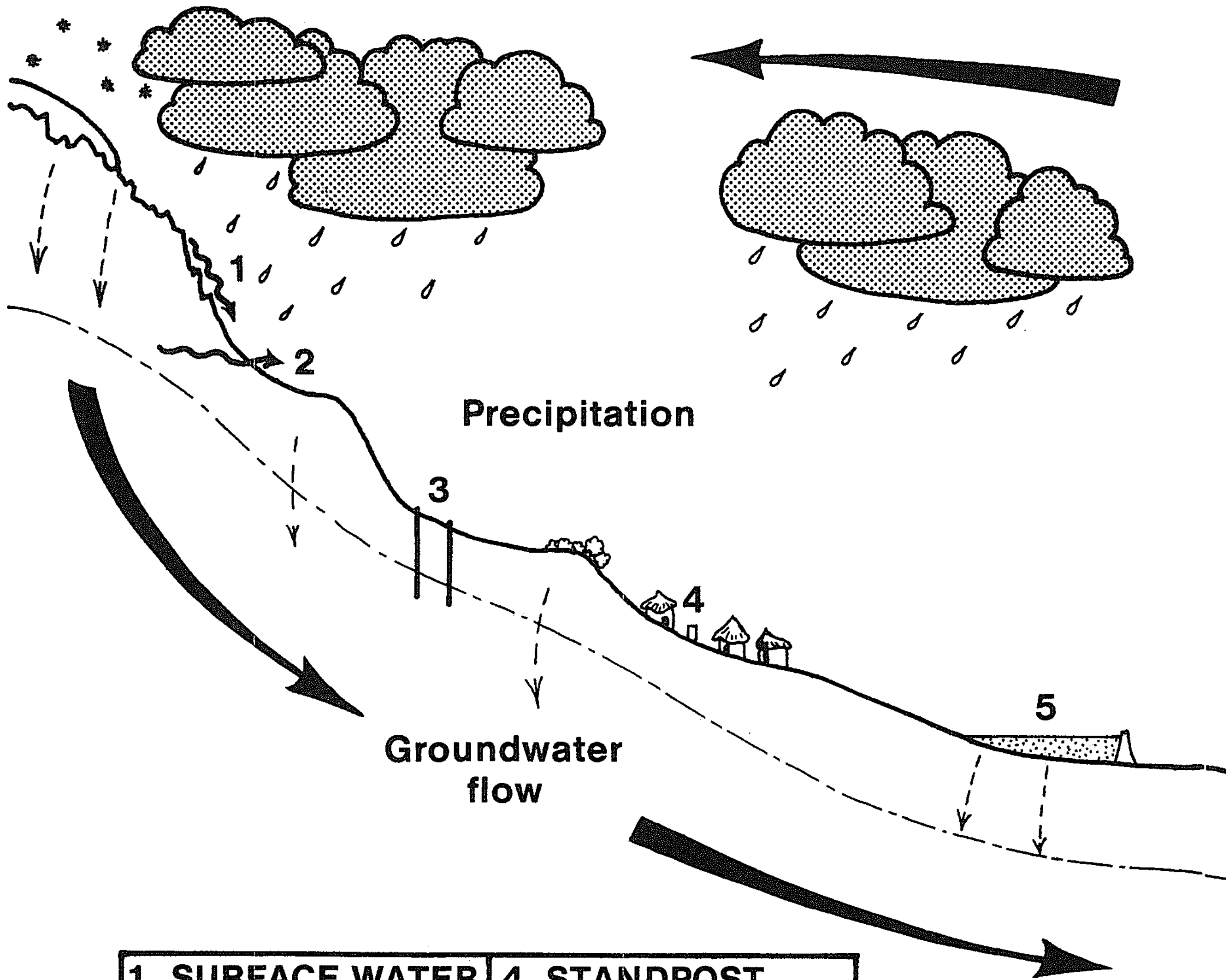
The recommended design values are the same as for wells. But it should be noted that approximately half to three quarters of the daily demand is likely to be consumed in the six hours between approx 6.30 am and 9.30 am and 4.30 pm and 7.30 pm.

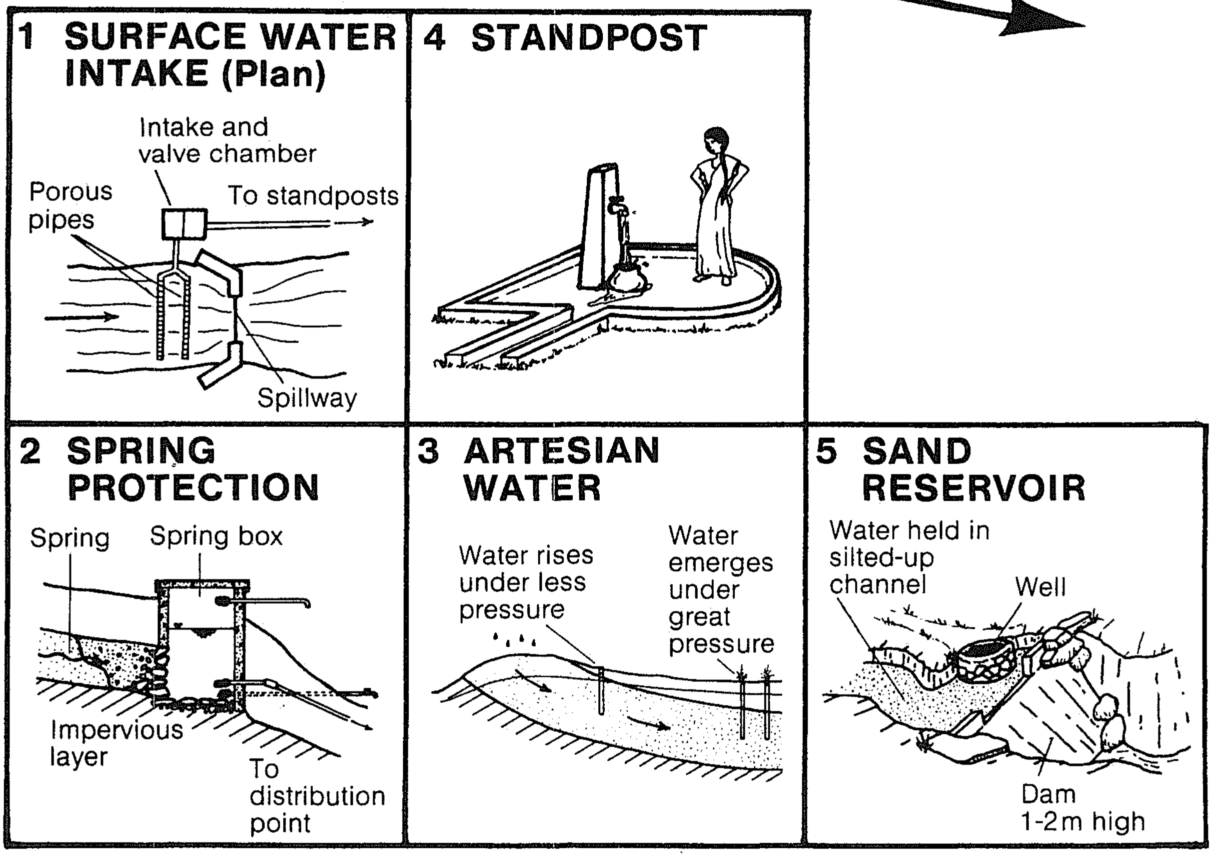
Piped supplies

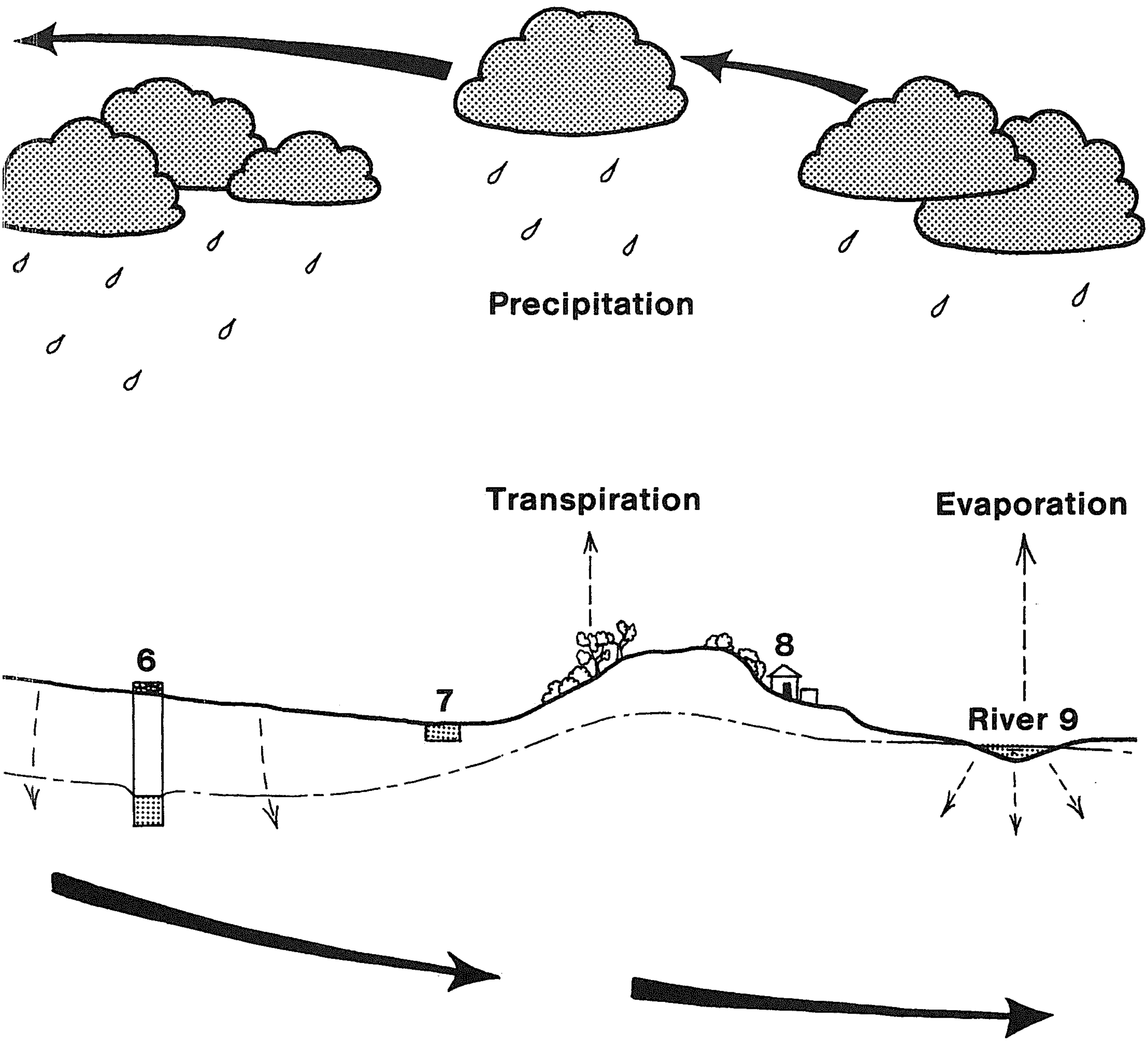
Type of supply	Approx water usage (litres per person per day)
Yard or single household tap	75
Schools: Day	25
Boarding	45
Hospitals	300 per bed
Government Offices	30
Livestock: Horses	35
Cattle	40
Pigs	15
Sheep	12.5
100 Chickens	15

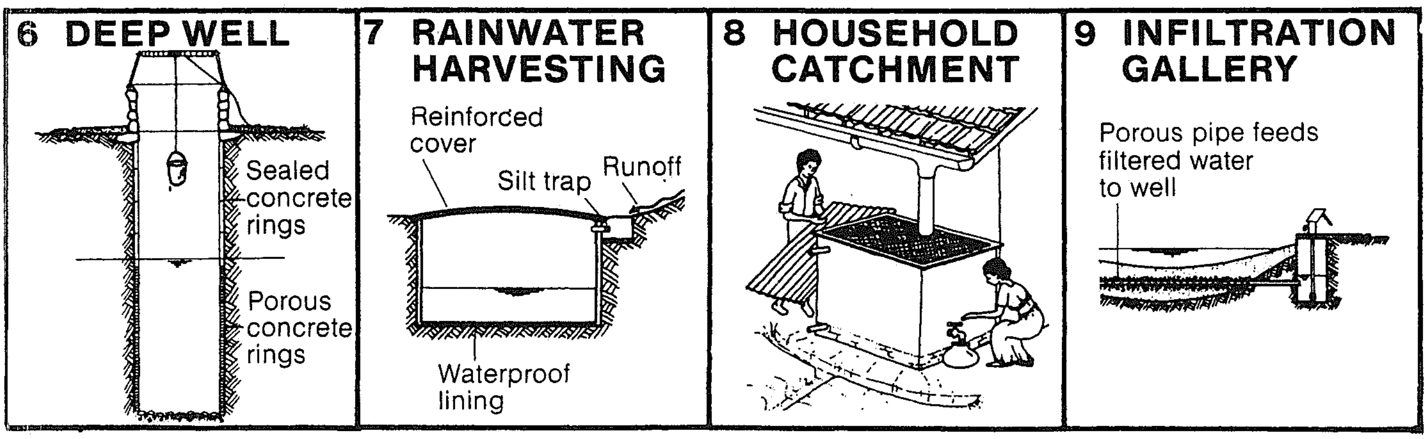
To put this into perspective, the water needed for agricultural purposes for irrigation is of the order of 750 litres per kilo of grain grown and 1,500 litres per kilo of rice grown. For small scale manufacturing 100 litres of water are required per kilo of paper made, 4 litres per kilo of bread baked and 100 litres per kilo of steel made.

The water cycle

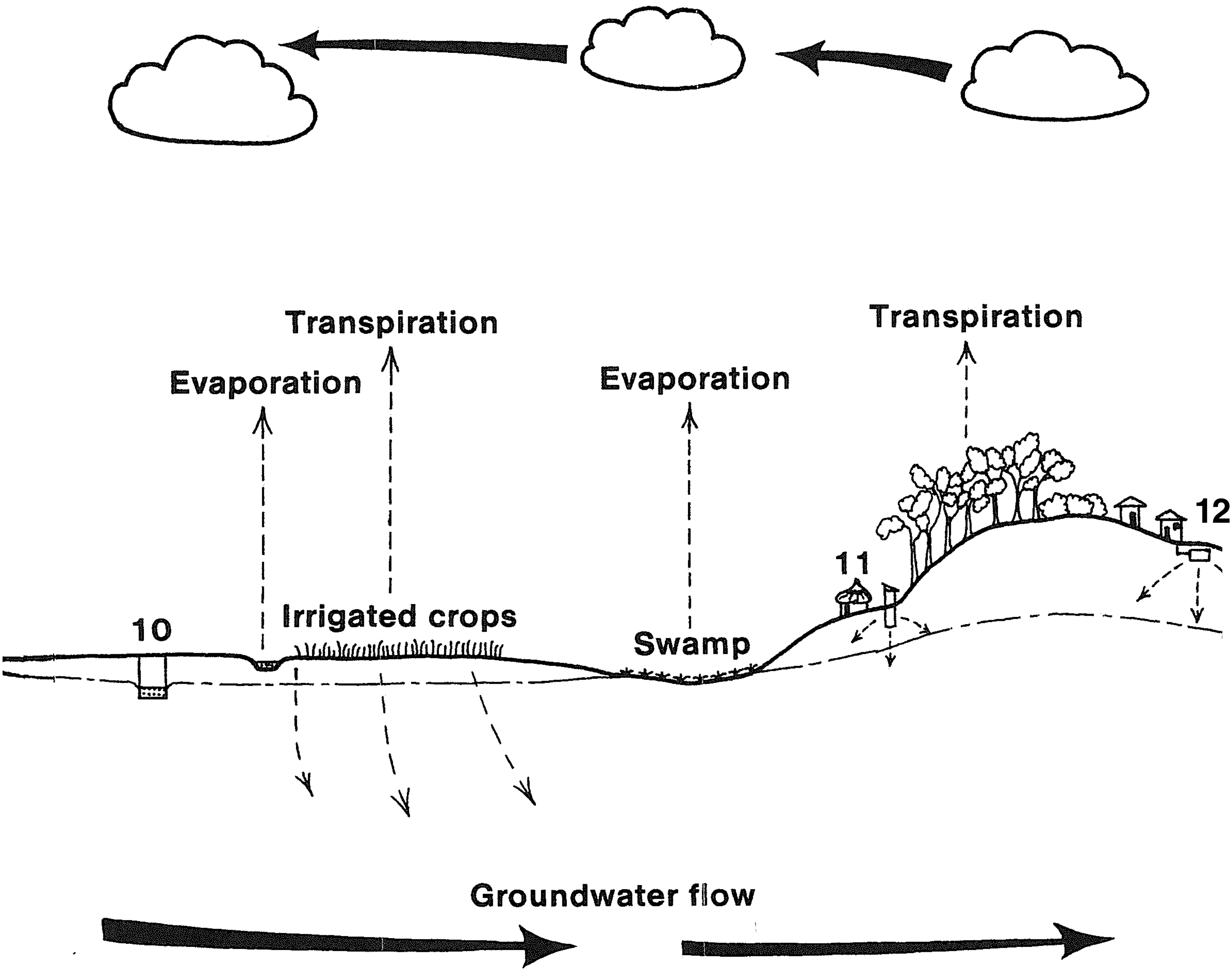


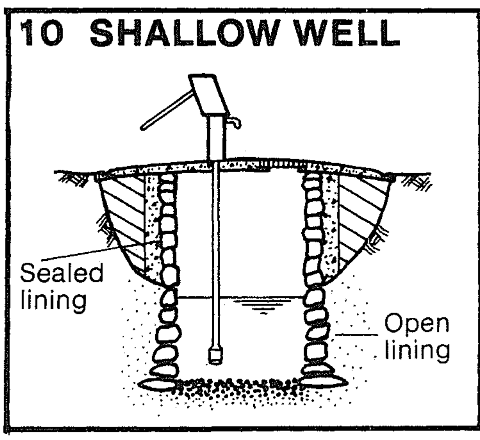


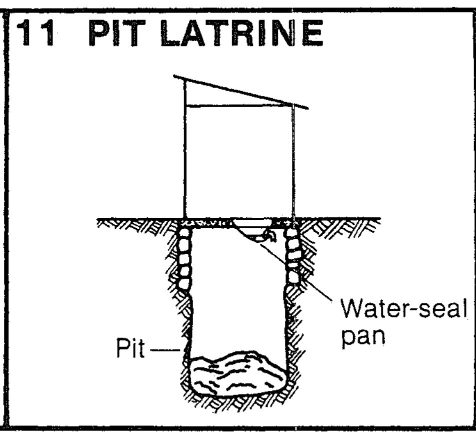

Precipitation
Transpiration
Evaporation
6
7
8
River 9

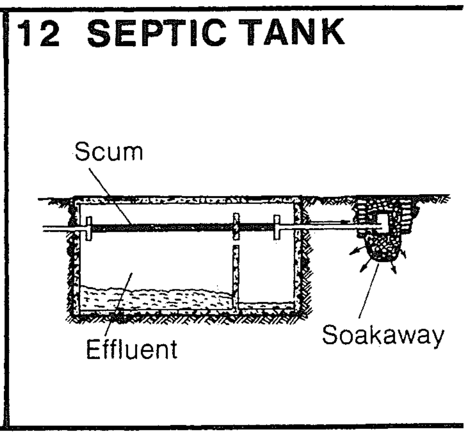

6 DEEP WELL
Sealed concrete rings
Porous concrete rings
7 RAINWATER HARVESTING
Reinforced cover
Silt trap
Runoff
Waterproof lining
8 HOUSEHOLD CATCHMENT
9 INFILTRATION GALLERY
Porous pipe feeds filtered water to well

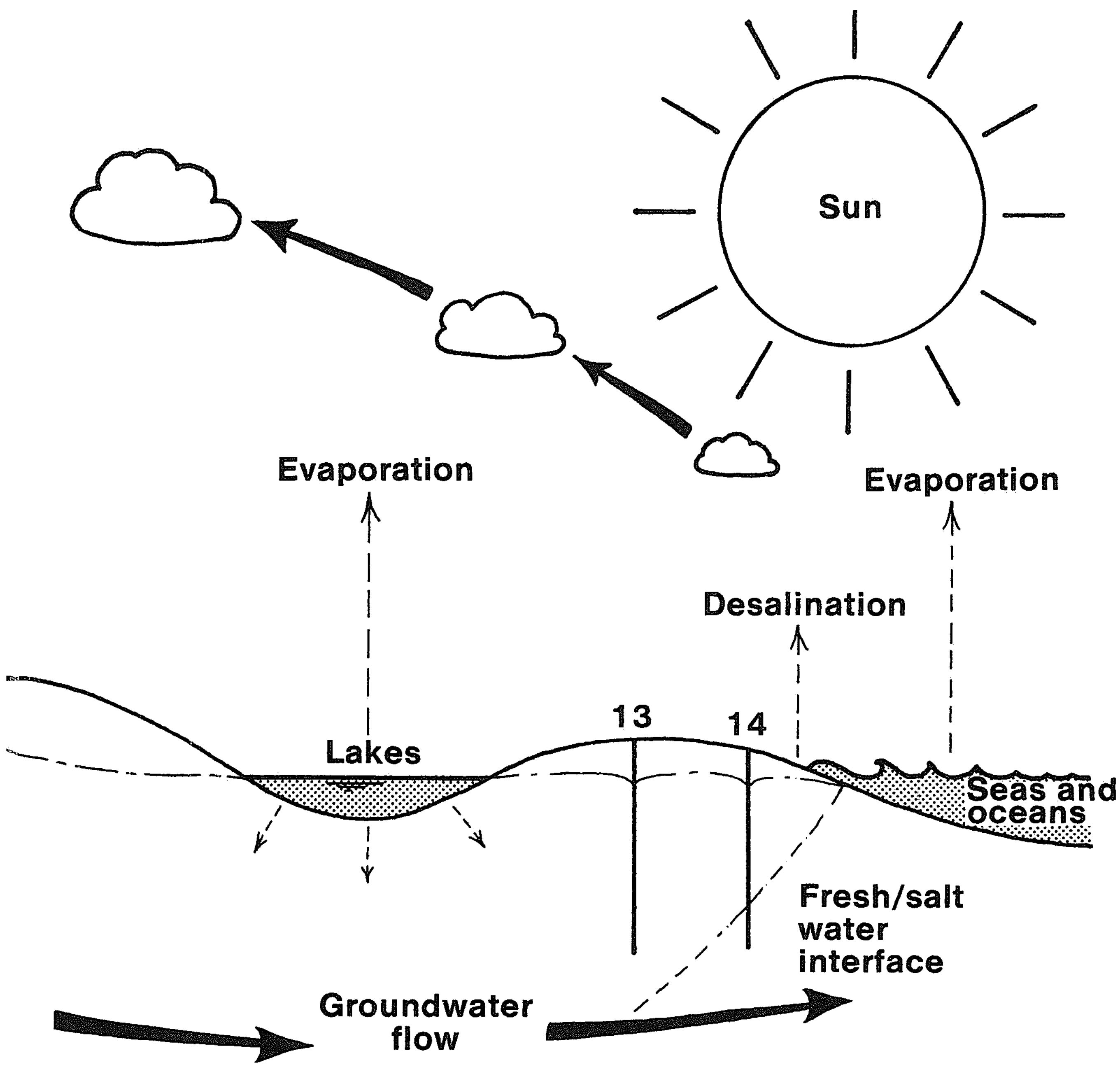
The water cycle



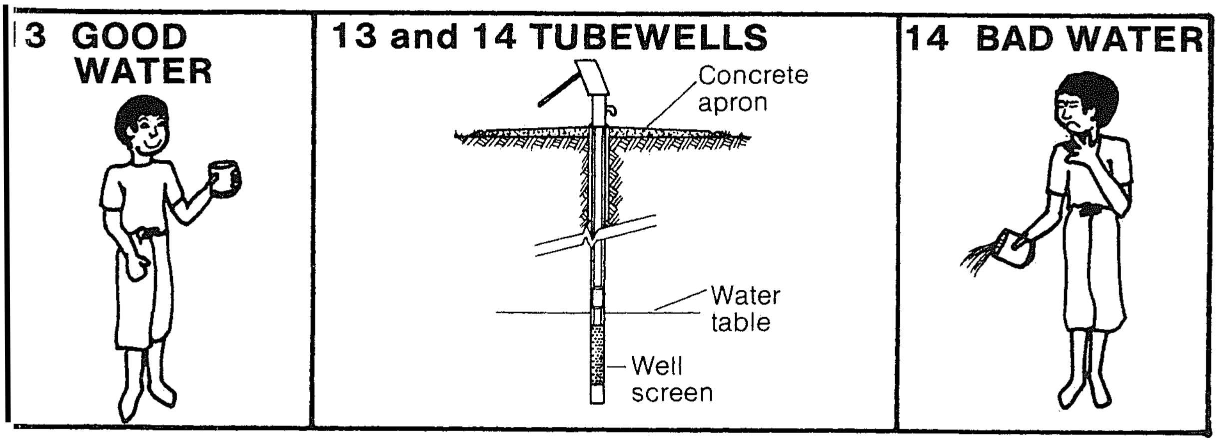








Sun
Evaporation
Evaporation
Desalination
13
14
Lakes
Seas and oceans
Fresh/salt water interface
Groundwater flow



13 GOOD WATER
13 and 14 TUBEWELLS
Concrete apron
Water table
Well screen
14 BAD WATER