CHAPTER 4

The wonder of water

Water is life. Its management is one of the major themes of permaculture and water is likely to be the biggest issue of the twenty-first century, whether in the form of too much or too little.

Clean drinking water is no longer freely available to most of us on Earth. Rivers and lakes are usually undrinkable anywhere near cities, and treating water with chlorine and ammonia to kill pathogens means people must pay for safe drinking water and immediate health while the long-term effects of water disinfectants are unknown. Rivers, lakes, wetlands, aquifers and swamps are depleted for irrigation, housing, mining, industrial development, or are used as dumps.

Fresh water is the world's most critical resource. Some organisms can live without oxygen while none that we know of can live without water. And yet we take water so much for granted that it is difficult to realise how critical it is for our continued existence on Earth.

The amount of water in the world is finite; it cycles constantly and changes form from liquid to solid to gas. It moves from salty oceans to fresh rainwater, to ice, to rivers and soils, and back to salt water in a way that is unique in our solar system.

Of the world's total water supply, however, only 3 per cent is fresh water, and of this only 0.03 per cent is available to us at all. The rest is held in the ice caps, clouds, vegetation, aquifers and soils. The party is over. We are moving into an age of water decline—not drought, because that implies that rainfall will return to its earlier average. Instead, there is a consistent gradual decline in average annual rainfall. However, whether your water income increases or decreases during your lifetime depends on global warming. For example, climate change, or global warming, will account for a 20 per cent increase in water scarcity in eastern Australia, and severe floods and storms along tropical eastern coasts of continents.

Because of water's essential nature, permaculture designs must obey the precautionary principle for water security and design sites as if there will be immediate and ongoing decline in water supplies and quality and that the cost of water will rise very steeply. Permaculture has two imperatives for using water:

- Live within your local water budget—don't use more than your rainfall.
- Reuse and recycle water.

Our ethical task is to:

- respect all water and its origins
- accept responsibility for using water sparingly and maintaining water purity, thereby increasing ecosystem storage for the future of all Earth's community of life.

Our design aims for water use are to:

- carry out a water audit
- design strategies to reduce water use and

also to use it as many times as possible before it passes out of the system
- ensure we have two or more sources of drinking and cooking water
- start implementing a water-harvesting scheme to hold water on land in soil, tanks and dams
- design water systems that rehabilitate degraded land
- tackle water problems as close as possible to their origin
- slow down water flow
- recycle and cleanse water
- create vegetated landscapes that are resistant to droughts and floods
- switch from irrigated annual crops to perennial tree crops
- harvest more clean water for future generations.

If we don't have design aims for water use:

- we have disrespectful attitudes to water, leading to profligate overuse and pollution of it
- chemical pollutants are washed out of the sky as acid rain and pollute rivers, lakes and soils, and chemicals such as mercury, ammonia and acids enter rivers and oceans from industrial areas
- excessive use of fertilisers, particularly agricultural phosphates from agriculture, leads to ground water contamination, or algal blooms in rivers
- bacterial and viral water pollution occurs when urban water is not sufficiently aerated or lacks enough sunlight or the system is simply overloaded. Bacterial and viral toxicity can be fast and visible—typhoid and cholera—while chemical contaminants can show up as cancers or heart disease as much as 20 years later
- whole systems—animals, plants and soils—can be contaminated
- mining uses unconscionable quantities of water and pollutes rivers and ground water.

What water does for us

The environment is a legitimate user of water. When we try to dam it or drain it we are depriving the natural environment and eventually this will affect all of us. Nature uses water in wetlands, rivers, swamps, soils and ground water to regulate vegetation and climate and drought-proof the land. Modern enterprises reverse this.

There is no other liquid whose functions work for us in as many ways and forms as water does. Table 4.1 shows just a few.

The supply and release of water in many forms is inextricably linked. Damage to one part of the cycle affects others. For example, forest clearing results in rising water, which results in soil salinity, which results in desertification. Melting ice caps and glaciers raise saltwater levels affecting coasts and fish-breeding grounds.

TABLE 4.1: THE FUNCTIONS OF WATER

Form	Function
Gas	carries heat around the world humidifies airstreams
Liquid	is the basis of nutrition and absorption of nutrients for plants and animals is present at the conception of every life form is the universal solvent provides a home for many animals gives renewable energy is a fine transport system is important for health
Solid	it is a vast reservoir of fresh water it carves out valleys and carries huge loads it prunes trees it melts and allows whole nations to have running water for many months of the year as ice, it is a preservative assists climate stability

Carrying out a water audit

To ensure water security you need to have enough water from an assured source all year round for drinking, cooking and all forms of washing. The garden should be able to be watered from grey water. In permaculture every major theme, such as water, energy or food, requires you to design two or more separate sources in case one gets damaged, polluted or even stolen. So, if you are using tank water, then you should have two smaller tanks instead of one big one. You could also have town water and a tank, or a protected dam and a tank, and so on. Remember that if you control what goes into it then even dam water can be filtered and boiled. Generally, you can think about water as being first-class for drinking and cooking and second-class for showers, toilets, gardens and washing.

Water sources and risks

- Town supply can be vulnerable to loss, depletion, toxins, rationing and uncontrollable price increases.
- The quality of tank or rain water may be uncertain in cities yet you can substitute it for town supply in gardens and washing machines, to clean the car, wash the dog and flush the toilet.
- Spring water may dry up.
- River water is not reliable or safe.
- Bore water belongs to the earth and carries out special functions; it can also turn salty or dry up. The use of bore water has resulted in arsenic problems in South-East Asia and many other areas, and salinity problems in east coast India. In the future, most governments will meter bores and charge for water. UNICEF has reversed its single focus from bores as the only source of water to bores as supplementary water supplies in an effort to relieve bore water problems in developing countries.
- Snowmelt canals may be intercepted and the water polluted uphill from where it is used.

Water tanks are now mandatory in New South Wales, Australia, for all new houses. When tank water is plumbed to washing machines and toilets the water authority gives a substantial rebate on the cost of the tanks. Figure 4.1 illustrates how water for city or suburban homes enters clean and leaves dirty.

How to calculate your water security needs

To have water security you need to know:

- how much you get from rainwater
- how much you use
- how much you must store for the longest drought.

Most of us don't know how much water we use. We don't know how much falls on our land each year—our annual rainfall—and its distribution. Are we using more than falls? If so, will we eventually run out? We also don't know where and how water is disposed of once we've used it. Answering these questions requires you to perform what's called a water audit. You measure how much water comes in and how much goes out of your site. This will tell you whether you are living beyond your water means or whether you are using water sustainably.

If you rely on town supply you can expect the cost of water to increase significantly in the next few years and, if it hasn't already done so, for rationing to start. By ensuring your own water security now you are protecting yourself from price rises and the uncertainty of quantity and quality of supply, and you are conforming to the permaculture principle that encourages self-reliance.

To find how much water you use per day you can look up your last water bill, or you can do as Rob did (see Figure 4.2) and calculate it bucket by bucket, or as Leanne did (see Table 4.3) and study your water meter. Rob and Leanne, a permaculturist from Leura, both saw where water use was the greatest in their households. Figure 4.2 shows Rob's tally for a week and he also compares it with the average use for Sydney. With this he knew where to start to reduce his water use and which changes would make the greatest saving.

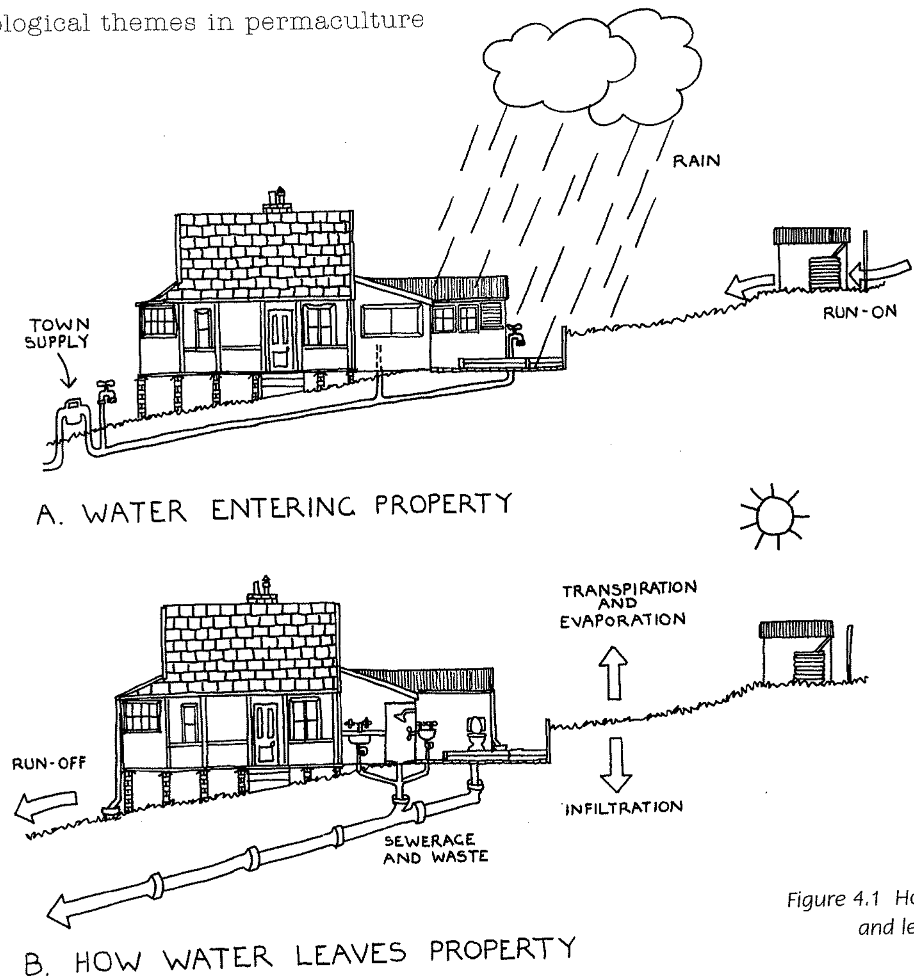


Figure 4.1 How water enters and leaves a property.

You also need to know how much water you can harvest. And to find this out, you need to do some simple calculations. You need to know your average annual rainfall, your roof area and the longest period without rain. Table 4.2 shows what I calculated for my household of three people. I have equipped myself against a six-month drought and still live well. In the severe Sydney drought of 2003 all my neighbours had to buy in water, which was expensive, while I still had one tank left when the rains came.

Figure 4.2 shows how to calculate your storage needs. Now do your own calculations for the storage you require to ensure your water security. Everyone should know how much water they use daily and where it comes from and where it goes.

How much should you use?

The World Health Organization (WHO) says we need 2 litres a day for personal consumption. And to wash clothes, dishes and ourselves, we need 45 litres a day. Californians use 1000 litres a day, and until recently West Australians were using about this amount. They got it from bore water which eventually ran out and now their situation is extremely serious.

So, what can you do if you are using more water than you harvest? You can:

- Increase your roof catchment by increasing the roof area or catch surplus off the roof and direct it to dams or ponds.
- Decrease your water use by using less, or you can clean and reuse water known as 'grey water'. Both Israel and Singapore have refined processes to clean grey water to a high standard of purity and reuse it. Singapore water is said to pass through seven people.

Grey water and tank overflow

These are both under-utilised resources. For example, my calculations show that I have 120

WATER AUDIT

	DAY 1 MON. 21/9	DAY 2 TUE 22/9	DAY 3 WED 23/9	DAY 4 THUR. 24/9	DAY 5 FRI 25/9	DAY 6 SAT 26/9	DAY 7 SUN 27/9	AVERAGE DAILY TOTALS	SYDNEY AVERAGE
DISH WASH 8 lt. / WASH	II (16 lt)	II (16 lt.)	III (24 lt)	—	II (16 lt)	III (24 lt)	I (8 lt.)	15 lt.	UP TO 18 lt./WASH
SHOWER 10 lt./ MIN.	I (AV. 7 min) (70 lt.)	I (70 lt)	I (70 lt)	I (70 lt)	—	I (70 lt)	I (70 lt.)	60 lt.	UP TO 250 lt./ SHOWER
TOILET 11 lt. / FLUSH	IIII (44 lt.)	III (33 lt)	III (33 lt)	II (22 lt)	III (33 lt)	IIIII (55 lt.)	IIII (44 lt.)	38 lt.	UP TO 13 lt./ FLUSH
HAND WASH 2 lt./ WASH	IIIII (10 lt)	IIIII (10 lt)	IIII (8 lt.)	III (6 lt)	IIII (8 lt)	IIIII (10 lt)	IIIII (10 lt.)	91 lt.	UP TO 5 lt./WASH
TEETH CLEAN 1 lt. / CLEAN	II (2 lt)	II (2 lt.)	II (2 lt.)	II (2 lt.)	II (2 lt)	III (3 lt.)	III (3 lt.)	2 lt.	UP TO 5 lt./ CLEAN
COOKING DRINKING x 1 lt.	IIII (4 lt.)	III (3 lt.)	IIII (4 lt)	II (2 lt)	III (3 lt.)	IIIII (5 lt)	IIIII (5 lt.)	4 lt.	8 lt./ DAY
WASHING MACHINE 150 lt./LOAD	—	—	—	—	—	II (300 lt)	—	42 lt.	UP TO 265 lt./ WASH
GARDEN UP TO 25 lt./MIN.	—	—	HOSE FOR 10 MINS (200 lt.)	—	—	SPRINKLER FOR 30 MIN (600 lt.)	—	114 lt.	UP TO 1,500 lt./ HOUR
MISC.			(5 lt)			(10 lt)		3 lt.	
TOTALS	146 lt.	134 lt.	346 lt.	102 lt.	62 lt.	1077 lt.	145 lt.	287 lt./DAY	

Figure 4.2 Water audit for Rob's household.

litres of grey water per day (840 litres of grey water a week) passing through my house. This grey water comes from the washing machine, bathroom and kitchen. The toilet water, called black water, is excluded. So I have about 500 litres a week available for the garden, glasshouse or other uses. Grey water from washing machines can be plumbed to the garden though soaker hoses under mulch. While 500 litres is enough water for a well-managed garden in a drought, it is not easy to

TABLE 4.2: THE AUTHOR'S WATER AUDIT

Data needed	My answers
1. The annual average rainfall	1400 mL/year
2. The longest dry period	six-month drought (340 days), not normal, probably climate change
3. Roof catchment	390 m² of roof
4. Total potential roof catchment/year	390 x 1400 mL = 546,000 L
5. Daily water use	120 L/day
6. Total use/year	120 x 365 = 43,800 L
7. Water needed for six months	120 L/day x 183 days = 21,960
8. Water storage required for water security of six months (longest dry period) + 20% contingency	22,000 + 4000 L (say, 1 x 10,000 L and 1 x 15,000 L tanks, or 2 x 15,000 L tanks, or any approximate combination

CALCULATING YOUR WATER STORAGE NEEDS

- FROM YOUR WATER AUDIT, CALCULATE THE FOLLOWING,

  HOUSEHOLD CONSUMPTION PER DAY 287 lt.
  HOUSEHOLD CONSUMPTION PER WEEK 2012 lt.
  HOUSEHOLD CONSUMPTION PER YEAR 104,624 lt.

- NEXT, FIND OUT THE AVERAGE ANNUAL RAINFALL FOR YOUR AREA

  1300mm

- CALCULATE THE SURFACE AREA OF YOUR ROOF CAPABLE OF CATCHING RAINFALL FOR STORAGE

  $91 \cdot 5m^2$

- IF YOU MULTIPLY YOUR AVERAGE ANNUAL RAINFALL BY THE SURFACE AREA OF YOUR ROOF, THIS IS IN THEORY THE AMOUNT OF RAINFALL IT IS POSSIBLE FOR YOU TO CATCH AND STORE EACH YEAR

  RAINFALL X ROOF AREA 118,950 lt./YEAR

- FIND OUT THE AVERAGE LONGEST PERIOD OF TIME BETWEEN GOOD FALLS OF RAIN

  2 MONTHS

- IF YOU NOW WORK OUT HOW MUCH WATER YOU WOULD USE DURING THIS DRY PERIOD, YOU CAN CALCULATE HOW MUCH WATER YOU NEED TO STORE

  DRY PERIOD X WATER CONSUMPTION 16,096 lt.

  (NOTE. THIS IS A MINIMUM AMOUNT AS IT IS ALWAYS BEST TO HAVE A SURPLUS FOR UNFORSEEN EMERGENCIES AND SEASONAL VARIATIONS)

- ESTIMATE THE SIZE OF TANKS OR STORAGE FACILITIES NEEDED TO HOLD THIS AMOUNT 2x 10,000 lt. tanks or (2x 4,000 Gal. tanks)

Figure 4.3 Calculating your water storage needs. This example has been filled in for Rob's place.

TABLE 4.3: LEANNE'S FAMILY'S WATER CONSUMPTION

Household consumption per day	600 L		Minimum annual rainfall	856 mm
Household consumption per week	4200 L		Maximum annual rainfall	1941 mm
Household consumption per year	219,000 L		Average annual rainfall	1400 mm
Surface area of roof: House 166 m²; Garage 24 m²; Chicken shed 7.5 m²				
Total annual rainwater collecting capacity = rainfall x roof area				
	Minimum		Maximum	Average
House	142,096 L/yr		322,206 L/yr	232,400 L/yr
Garage	20,544 L/yr		46,584 L/yr	33,600 L/yr
Chicken shed	6,420 L/yr		14,557 L/yr	10,500 L/yr
Storage for three months collected from house roof = consumption x time 54,700 L				
Size of tanks or storage facilities: 3 x 20,000 L tanks; 2 x 30,000 L tanks				

recycle 500 litres of grey water when it's raining. Combined with the average rainfall it is simply too much, especially if you are aiming for zero run-off or clean water run-off. This is a cogent reason to reduce your water consumption. Huge amounts of grey water from villages, towns and cities pollute rivers and oceans because the environment cannot effectively dilute and cleanse the surplus water. I endeavour to manage all my own waste, including grey water, by copying nature.

Rob redirected surplus water to his garden and increased biomass (or plant) infiltration and water cleansing by creating gutters in his driveway and contouring winding paths. He stored water in tanks to use in the dry periods. You will save energy if you place your rainwater tanks high off the ground so they can gravity-feed. If you use a pump, then have a high header tank and only pump up to it once a day.

A ten-year water audit by an Australian family

Table 4.3 shows the water audit calculations for Leanne's family of two adults and two teenagers. Based on these figures they implemented changes aimed at reducing their water consumption. Leanne said, 'The most important factor relating to all the decisions we have made is that all the water leaving our land goes directly into the Sydney catchment via Gordon Falls. We have therefore endeavoured to keep sediment and nutrient run-off to an absolute minimum.'

Leanne identified the following factors contributing towards high water use:

- no measures to control evaporation from garden beds
- high usage of a top-loading washing machine, using 300 litres per day
- no water-saving devices installed
- no regulations for length of showers.

Leanne kept records for ten years of her family's water use and its cost. Since she implemented water-saving methods at home her usage has gone down 30 per cent while her costs have stayed virtually the same because the price of water has increased substantially during that decade. Water consumption was very high initially, at a time when the cost of water was relatively cheap.

The family's water consumption began to fall after the initiation of the following strategies:

- Over ten years large garden beds have been established and continually mulched to retain moisture. To date Leanne has distributed 90 cubic metres of chippings, 57 bales of lucerne, continual recycling of compost and the chipped mulch from their own prunings.
- Plant selection has been aimed at choosing the right plant for the conditions.
- A front-loading washing machine was installed bringing usage down to 65 litres per day.
- Water-saving devices were installed: a dual flush toilet cistern (4.5 litres and 9 litres) and

reduced-flow shower rose (10 litres per minute).

- They only wash the car after a holiday at the coast (maybe once per year).
- The only plants watered are the newly planted shrubs until established and the vegetables and lemon tree.

According to Leanne, 'Around the year 2000 water consumption began to rise again! This coincides with the time that my two children decided that they didn't want to share a bath any more and would prefer to shower. This trend continued until 2004 when timed showers were enforced and with huge success. The consumption of water has continued to fall. Despite the drought, the garden is flourishing.'

Leanne has developed a 'grand plan' to ensure that water consumption will continue to be kept to a minimum.

- Use the 'if it's yellow let it mellow, if it's brown flush it down' approach to toilet flushing.
- Reduce shower times to three minutes (30 litres), and five minutes (50 litres) for hair washing.
- Ensure that the tap is not left running during teeth cleaning (reducing water use from 2 litres to 250 millilitres).
- The installation of a water tank for the house.
- The installation of gutters and a water tank for the chicken shed. The captured water supplies the vegetable garden, chickens and the duck pond.
- Investigate the feasibility of grey-water processing.
- Continue to top up the garden with mulch. (Chippings are purchased cheaply from a local tree lopper.)

Do these calculations for yourself using mine, Rob's or Leanne's calculations as a model. Would you have water security if the town supply failed or if there was a long and severe drought?

Reducing water consumption and still living well

A primary permaculture water principle is to reduce water consumption and reuse all water as many times as possible before it passes out of your system. Table 4.4 lists some water-saving strategies and you can think of others.

Cleaning and reusing domestic water

Seventy per cent of Israel's municipal grey water is treated and reused in agriculture. There are also some simple strategies for reusing domestic water and cleaning it. These rely on copying nature and lead to the second permaculture principle for water: ensure water is biologically filtered and cleansed by your system before it leaves your land.

Nature cleans water by:

- slowing it down so it can drop some of its load
- filtering it through mulches and soil
- passing it over river stones to oxygenate it
- sterilising it with sunlight
- feeding it through vegetation.

To filter and clean water before it leaves your land, use the following techniques:

- When you replumb grey water to the garden, deliver it slowly and under mulch.
- Put only into your household water what you want to eat—simple pure, zero- or low-phosphate soaps.
- Use the fall of the land to move water by gravity.
- Store water in very wet weather until you need it.
- Hot bath water can be stored, used to heat rooms and greenhouses by plumbing it to these places or switched to washing machines. By placing baths higher than washing machines or washing machines below baths, bathwater can be reused as the first clothes wash.
- Fit filters at the end of outgoing hoses and clean them regularly.
- If you store water in ponds, keep them

TABLE 4.4: DOMESTIC WATER STRATEGIES

Consumption	Saving techniques
Kitchen	One washing-up per day in a basin with the water emptied on the garden. Plumb the sink drain to the garden. Keep a basin in the kitchen sink for every rinsing and use it for the next pre-wash. Send kitchen grey water to orchards. In rural areas use rainwater only for drinking and cooking. Fit low-delivery taps.
Laundry	Only use washing machines with a full load. Wash clothes less often. Fit low-delivery taps. Plumb laundry water to garden biomass (plants).
Bathroom	Fit low-delivery taps and roses on showers. Re-plumb the handbasin to the toilet or garden. Fit push-button showers, or timers set for 3–5 minutes. Keep the plug in the handbasin and wash hands several times before sending the water to the garden. Fit half-flush toilets, or put a brick in the cistern, or bend the float arm to a lower level. Install a compost toilet.
Other	Mulch the garden. Bucket-wash cars. Fit new washers to dripping taps. Water the garden by hand. Turn the swimming pool into aquaculture and swim at beaches and rivers.

shallow so the sun can act as a steriliser and the wind can oxygenate it.

- The best way to reuse domestic water is to store it in biomass (the plants and animals in your garden). A diverse and densely planted backyard garden or a well-forested farm will store much more water in biomass than a lawn or bare field. This water can be harvested as mulch, fruit, firewood, etc. The systems that you design and the strategies you implement should increase water storage and yields for many years (see Figure 4.4).

Both soil and plants can clean water if you don't use too many chemicals. So make your shopping simpler, and your household safer, by buying and using the simplest soaps you can find. Make your own washing liquid for washing up and using in washing machines, and use vinegar in dishwashers.

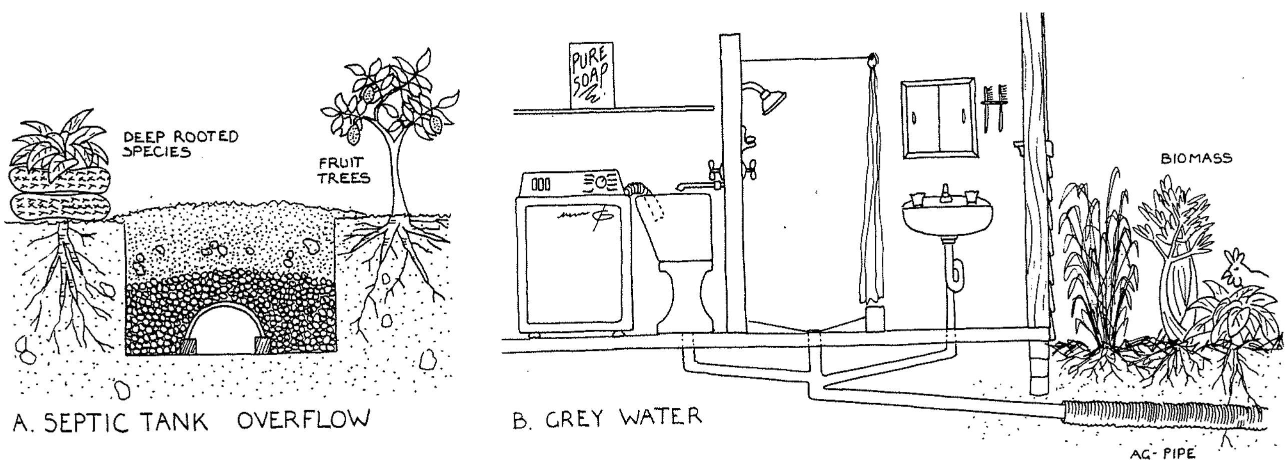


Figure 4.4 Recycling waste water. Plants placed beside the absorption trench of a septic system and greywater outlets assist in cleaning water (after B. Mollison, Introduction to Permaculture, *p. 111).*

Making a whole site water plan

You need to design a whole site water plan to achieve your objectives for water and not waste time and resources. This is the macro-design and involves placing all the water on your land so it works harmoniously. You will need to think how water moves across your land, is stored and leaves it, and what would be ideal and sustainable in the future. The present water storage and use is your water analysis, and the design you draw up is your sustainable plan. To do this you need to know more about water than just your water audit.

On your base plan show your whole site water analysis with the following features:

- How it comes in—and the risks and quality of that water.
- Where it comes in, for example, chicken-shed roof, garden shed, house, garage, and so on.
- How it is stored—44-gallon drums, tanks and their size, ponds, etc.
- Where it is used—bathrooms, laundry, kitchen (the wet areas).
- The quality and quantity of grey water—700 litres per week with only bland soap, shampoo, etc.
- Where the grey water goes—reed bed, gardens, underground, etc.

Look at my whole site water plan. I have done a plan view, that is, a bird's eye view (see Figure 4.5), so you can see the layout of the rooms, and an elevation or side view (see Figure 4.6). Draw a similar plan for yourself. What strategies and techniques do you use to reduce your water consumption? Keep records of your water consumption.

Water strategies for rural land

Water is the primary selection factor in choosing land. This means you need to know the rainfall, its distribution, run-off, streams, dams, rivers and watershed control before you buy. If available water is too little, then farming will be very discouraging. If the water is contaminated, you will want to leave.

Always plan your farm enterprises so you live within your water budget—your annual average rainfall. The following permaculture strategies will help you do this.

When you are working with water on farmland the unit of self-sufficiency and repair is the watershed. The very best water management comes from farmers working together across a contoured landscape to store and move water so as to benefit all the downhill slopes. This is also the best way of rehabilitating farmland. Working on their own, farmers risk being sabotaged by other non-participating farmers. Farmers need enough water for all and the revegetation and sharing of a watershed provides benefits that are beyond the individual farmer's ability to implement.

A farmer's two main priorities are to manage water and to store water.

The key objectives for managing water are to:

- try to let no run-off water escape from your property until all storages are full
- slow down water flow
- use water as many times as possible
- tackle excess water problems as close as possible to where they originate—the top of your path, or the top of your watershed
- clean water by passing it through biological filters or traps.

The key objectives for storing water are to:

- maximise water stored in soils, because it is the most efficient storage and requires least energy use
- maximise water in biomass—the plants and animals—because this form of storage is most efficiently harvested
- use Yeoman's Keyline (see page 41) to hold surface water held in dams and ponds.

These techniques can be used for small or large areas of land. On large rural areas, machinery is used, and in gardens, hand tools.

Increasing water in soils

Most soils you will work with hold a small percentage of the water they held originally under natural vegetation. Your priority is to increase water

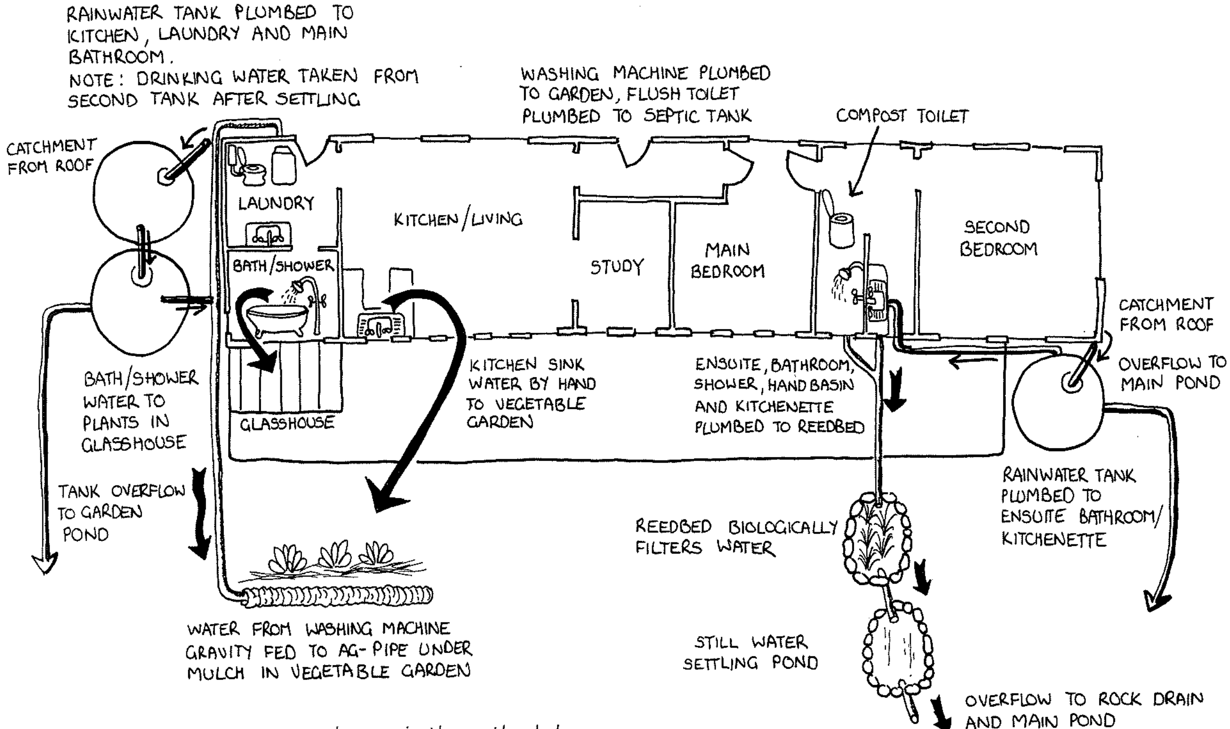


Figure 4.5 Water storage, use and reuse in the author's house.

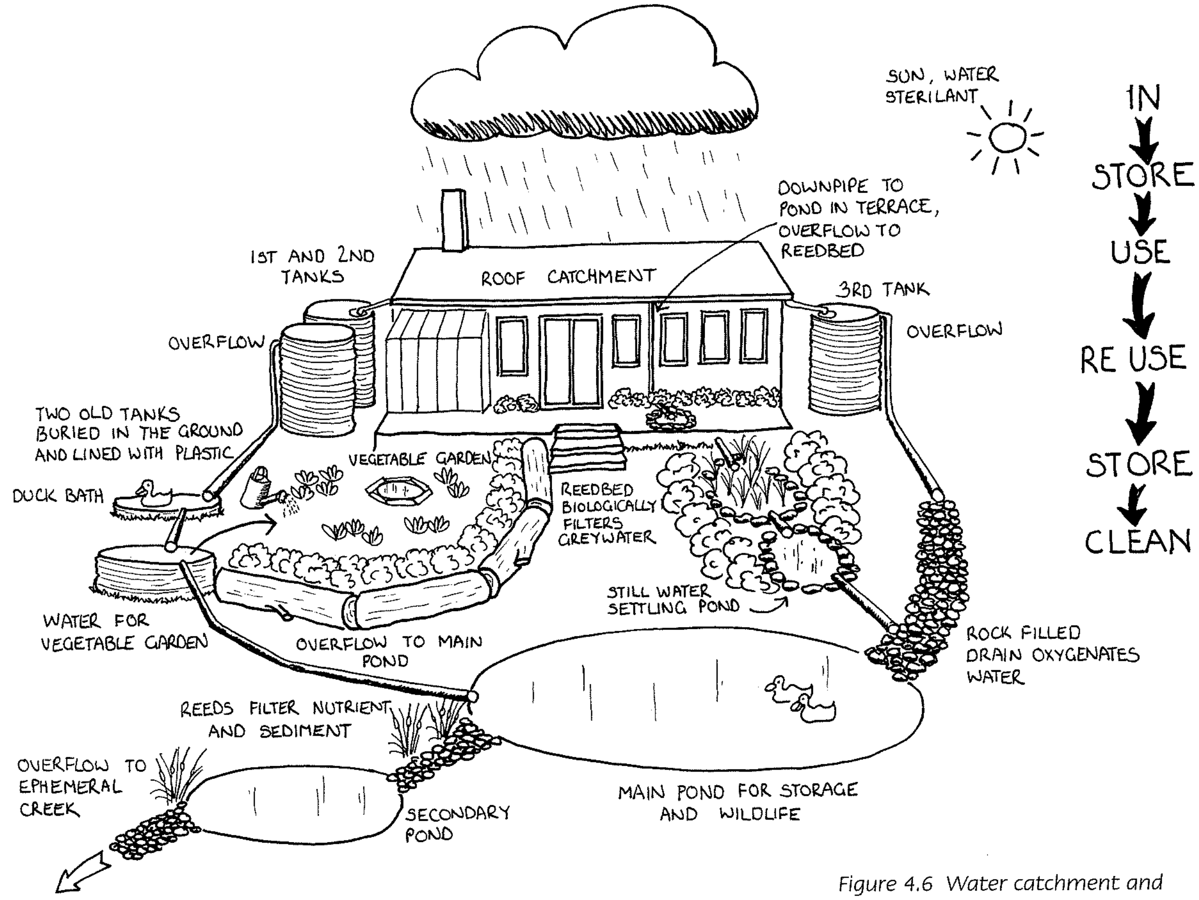


Figure 4.6 Water catchment and storage at the author's house.

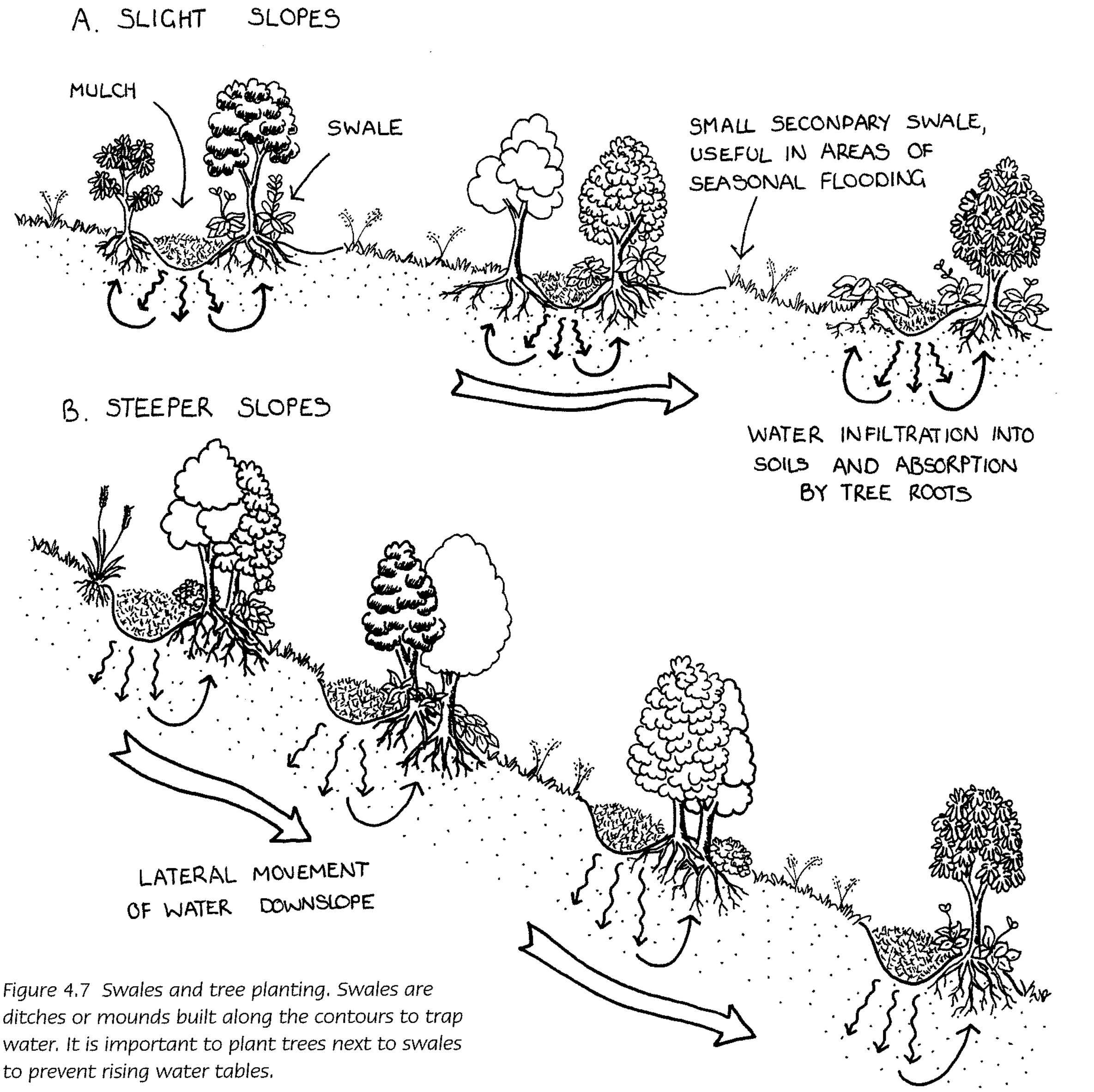


Figure 4.7 Swales and tree planting. Swales are ditches or mounds built along the contours to trap water. It is important to plant trees next to swales to prevent rising water tables.

in soils and their water-holding capacity. This is also the first step in the rehabilitation of soils.

Begin by trapping water as high as possible on the land by ripping the subsoil deeply without turning over the topsoil (see Figure 4.7). Then plant into the rip lines. Trees shed about 25 per cent of their root system each year and this, together with soil micro-organisms, becomes organic matter, which in turn holds large amounts of water in the soil.

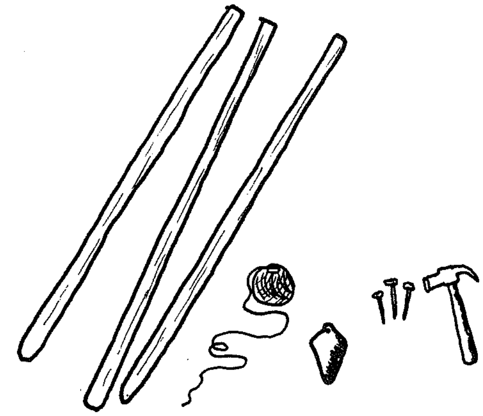
Next, make swales. These are ditches that slow water as it flows downhill, giving it time to be absorbed. They are constructed along the contours of the land with an A-frame or by survey, and any overflow water from one is caught by the next swale below it (see Figure 4.8). However, in principle, if swales overflow then there are not enough of them. The building of swales is site specific and these general rules apply:

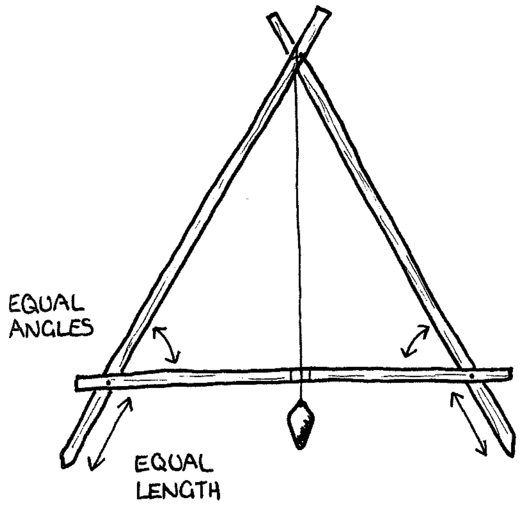
- The steeper the slope the closer the swales (almost terraces or steps).
- The less cohesive the soil structure the further apart the swales.

Swales recharge the soil's ground water, resulting in 85 per cent less run-off than from bare

YOU NEED THREE FLAT PIECES OF TIMBER OF EQUAL LENGTH, A HAMMER, NAILS, STRING AND PLUMB BOB.

MAKE AN A-FRAME. MAKE SURE THE ANGLES BETWEEN THE LEGS AND THE CROSS-PIECE ARE THE SAME AND THE LEGS ARE OF EQUAL LENGTH. TIE THE PLUMB BOB FROM THE TOP TO CROSS THE A.





PLACE BOTH ITS FEET ALONG A CONTOUR UNTIL THE PLUMB BOB CROSSES THE MIDDLE. MARK THE PLACE OF ITS FEET WITH SMALL STAKES. NOW SWING THE WHOLE FRAME ACROSS TO A NEW POSITION AND MARK IT WHEN THE PLUMB BOB HAS CENTRED. CONTINUE UNTIL YOU REACH YOUR BOUNDARY. LEAVE THE MARKING STAKES IN PLACE UNTIL YOU DIG YOUR SWALE.

ON A FARM, MARK THE LINE WITH LIME OR FLOUR AND THEN DIG YOUR SWALE WITH MACHINERY. OR YOU CAN PAY A SURVEYOR TO FIND YOUR CONTOURS.

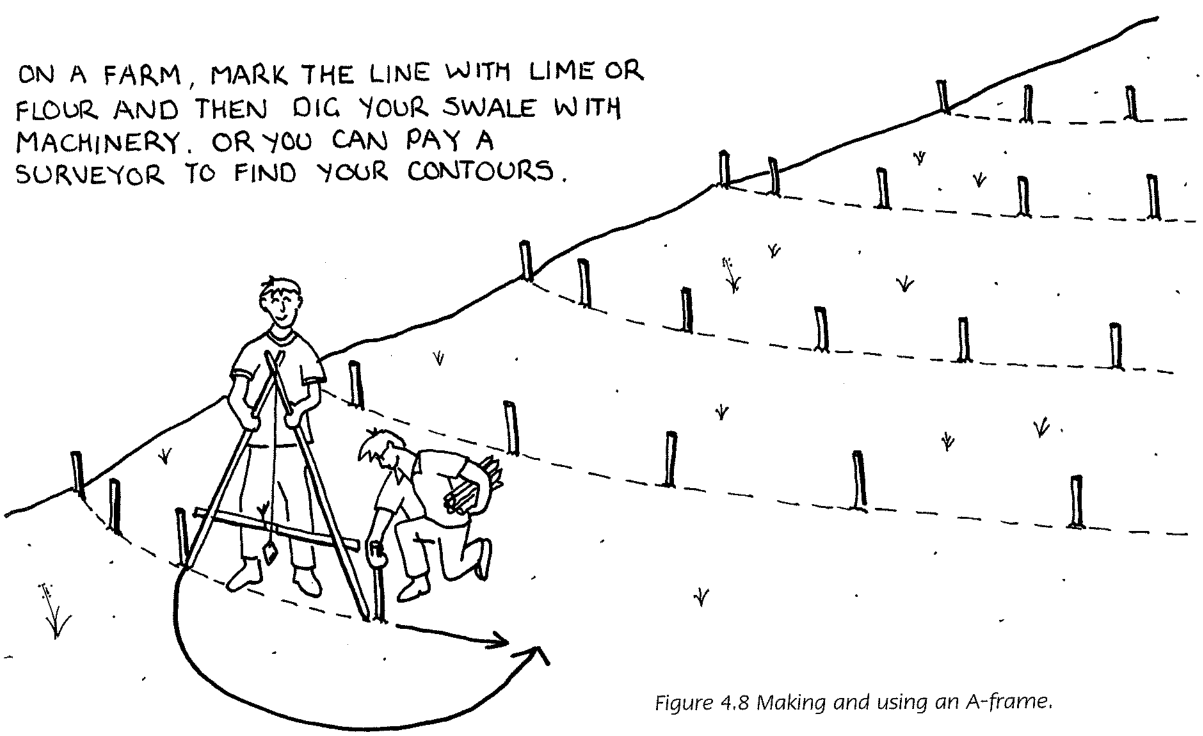


Figure 4.8 Making and using an A-frame.

land and a 75 per cent increase in the soil's ability to retain water. After the first rains dams and rivers will not fill or flow until the soil water is recharged. The surplus water moving to lakes, dams and rivers will then be clean because the water will have effectively dropped or filtered its load of sediment which it held. In many cases, after several years of good rain, the water will eventually break through lower down the slope, as a spring.

Storing water in soils and accompanying it with tree planting is the first step in drought-proofing your land.

Preventing evaporation by using mulches

To prevent the water held in the soil from evaporating the soil needs a cover. In fact you should feel uneasy when you see bare land—it's like skin with a layer missing. The most effective way to protect soil is to use mulches.

Mulch is a layer over the soil which protects it from the damaging effects of wind, sun and water. Mulches have several special functions and multiple benefits:

- They reduce soil evaporation and therefore inhibit soil salination and general water loss.
- They increase water infiltration by absorbing water on the surface and holding it until it has time to be absorbed.
- Mulches reduce erosion from gravity, wind and water.
- They regulate soil temperatures by reducing extremes of summer heat and winter cold.
- They suppress weeds, which also rob the soil of water.
- They can raise the light in a dark area or reduce light intensity and increase soil warmth.
- Mulches supply nutrients and organic matter to soils.
- They are one way of using up your garden surplus.

Figure 4.9 gives examples of some types of mulches and how they can be used.

Storing water in biomass

All living things are about 80–85 per cent moisture. When you increase water stored in the soil, you

INORGANIC/ SYNTHETIC	ORGANIC: LIVING	ORGANIC: DECEASED
USED IN ARID LANDSCAPES AND URBAN AREAS (SHORT TERM)	USED IN ZONE II, BROADSCALE AREAS, AND ZONE I IN HUMID TROPICS	USED IN ZONE I AS SHEET MULCH AND IN ZONE II AS SPOT MULCH
CARPETS BLACK PLASTC CORRUGATED IRON WEED MAT STONES GRAVEL RIVER SAND PATHS	COVER CROPS LEGUMES CLOVERS PUMPKINS POTATOES SWEET POTATOES CLOSELY PLACED HERBS SELF-MULCHING SPECIES NATIVE GROUNDCOVERS	MANURES STRAW LEAVES SEAWEED LAWN CLIPPINGS NEWSPAPERS WOODCHIP FOOD SCRAPS ANIMALS DENIM WOOLLEN CARPETS SAWDUST PINENEEDLES COMPOST

Figure 4.9 Types of mulches.

increase the quantity and variety of living organisms per hectare. You can also stock more densely, thereby increasing the diversity of productive plants in your landscape. This will increase productivity for many years. Water stored in biomass can be harvested as mulches, fruit, vegetables, grains, oils, dyes, juices, eggs, meat and fibres.

Surface harvesting and storage of water on farms

In tropical and cool temperate climates, having 15 per cent of water stored as surface water will reduce fire risk, provide a buffer against climate change and modify climate extremes. On seaward slopes, where it may not rain much yet the air is humid, fog fences—like fishermen's nets—hung over sheets of collecting plastic will harvest the water at night as it condenses and runs into containers. Sometimes roofs act like water condensers when the air is moist and the cool water will drip into your tanks.

Usually farmers place small, exposed dams at the bottom of the slopes and these dry up when farmers need them the most—in dry seasons or drought. It is the water-harvesting design strategy called Yeoman's Keyline Water Harvesting which is the most reliable water strategy and assists with whole farm planning throughout the watershed. This strategy is safe, environmentally friendly, relatively inexpensive and provides farmers with water security.

Yeoman's Keyline Water Harvesting

The Yeoman's design begins uphill with a study of the land's contours. The tops of slopes are the driest and most difficult to rehabilitate, and by starting high up on the land the flow-on effects downhill are greater. The first and most important dams are built high up on the land, and are kept clean and protected with close plantings of trees and shrubs around them. The water stored in these high dams is distributed by gravity to farm enterprises below them. The dams are linked into a network by a series of contour banks which, like swales, run mainly along contours. The contour banks have some fall and carry water along ditches from one dam to another surface catchment dam. These dams are also as high up on the land as possible. At every stage of the building of swales and contour banks, trees are planted. Water and trees go together like salt and pepper.

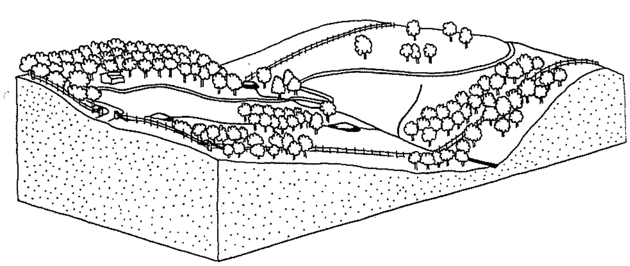
When a whole watershed has been keylined, the landscape becomes a series of dams linked by contour banks. No dam is very far from another. You will find details of this strategy in the book *Water for Every Farm: The keyline system*, by Allan Yeomans.

Low dams are used to hold grey water. They act as a productive aquaculture water system which, with its associated water plants and aquatic animals, cleans water and filters some toxins and excess nutrients before the water overflows and rejoins rivers or lakes.

In Australia dams are not permitted on rivers or creeks because they will inhibit environmental flows. Therefore, to store water you can run a channel or swale from the riverbank to a dam built parallel to the river course. During floods water will flow into it and be harvested in the dam. You are also prohibited from digging dams with a surface area of 1 hectare or more. The over-construction of many of these dams has prevented the environmental flows that are required to keep rivers flushed out and clean. Yeoman's strategy enables you to design many small dams across your land and you will have water security and total control over the use of your water. This design will serve you better because you can place dams close to the enterprises where you want to use water. An added benefit is that if one dam is polluted or goes dry you will still have multiple sources available (see Figure 4.10).

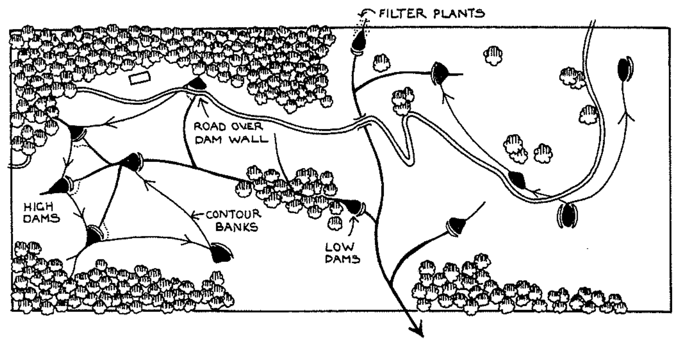
Biological water cleansing

Plants on the edges of lakes, swamps and rivers act as natural filters of dissolved chemicals and physical matter such as clay particles. Try to observe a natural ecosystem where this is happening and copy it. By copying these natural aquatic ecosystems, a biological filtration system can be



A: Sketch of Rosie's farm before water harvesting

Figure 4.10 Surface capture of water on Rosie's farm. Water is trapped on the high parts of the property and is gravity fed to the lower dams. Plants which can filter silt and chemical residues are planted around the dams and along the boundaries to prevent contaminated water entering the property (after B. Mollison, Permaculture: A Designer's Manual, *p. 18).*



B: Plan vew after implementation

constructed to treat grey water. Nutrient-rich grey water enters the system at one end and travels through a series of ponds which gradually filter and remove solid material and dissolved nutrients. The plants growing in the ponds can also be harvested for mulch.

The topic of grey water and its safety, effects on soils and risks to human health are completely covered in *Echo Development Notes* of July 2005 (see References). The main conclusion, after covering exceptions, is that grey water should always go through compost or mulches if it is to be safe. To use more comprehensive systems you can build a biological water filter which mimics a wetland.

A biological water filter system is based on the elements required to clean water naturally. The size of the system depends on the amount of water passing through it and the season. Some macrophytes (wetland reeds) die down in winter and the system also works more slowly. For a household, the system should be about 5 metres long and 2 metres wide. Figure 4.11 shows one possible design. The water leaving a bathroom is dropped 2 metres deep into a pond and slowly filters upwards before it moves into the pools. It moves through:

- gravel and sand to filter non-soluble materials like lint, seeds and clays

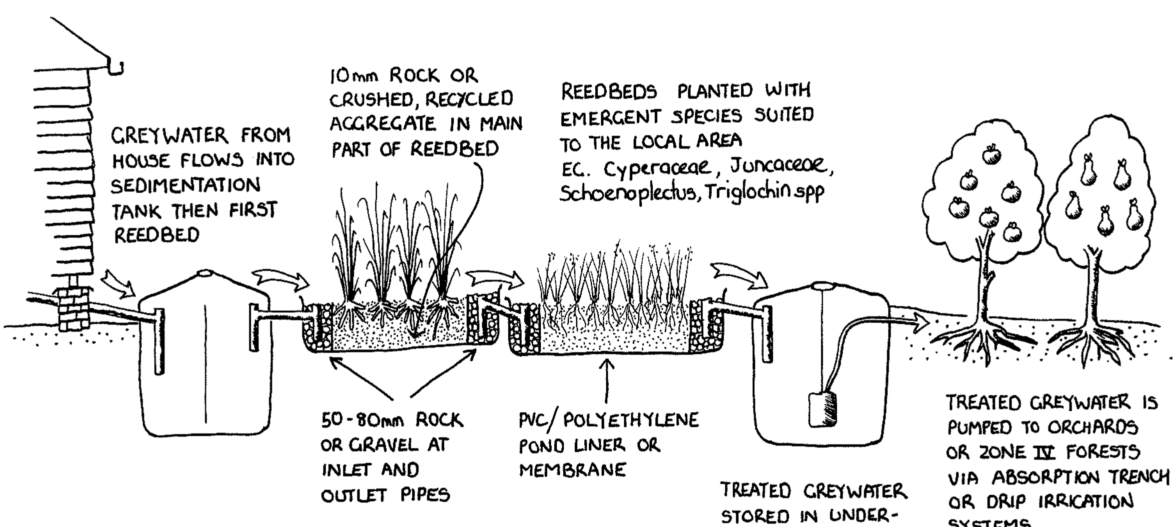
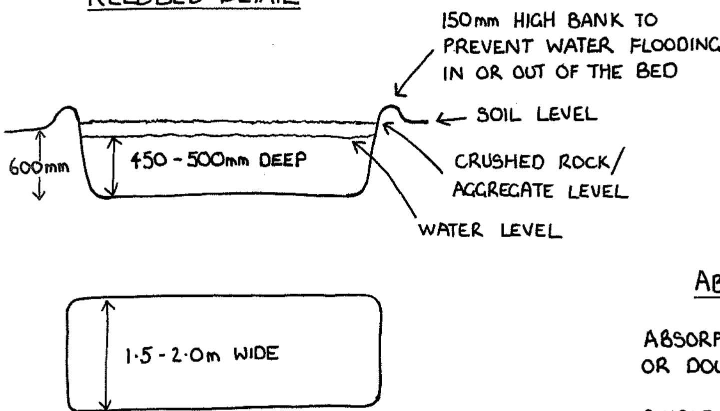


Figure 4.11 Schematic diagram of a biological greywater filter system using reedbeds (refer to detailed diagrams on opposite page).

Reedbed Detail



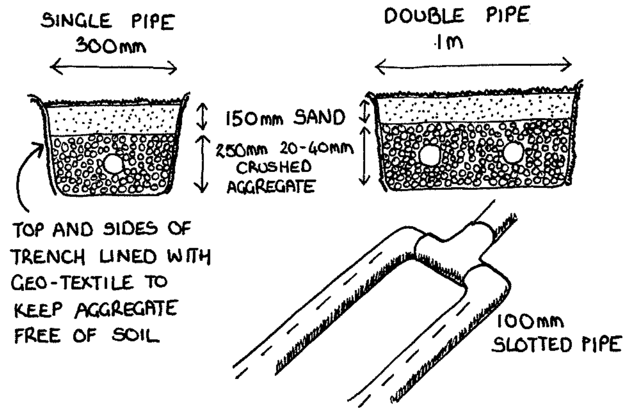
LENGTH TO WIDTH RATIO = 3:1 – 5:1

AREA OF REEDBED NEEDED PER PERSON BASED ON GREYWATER SOURCE

- WATER FROM LAUNDRY 1·5m²/ PERSON
- BATHROOM/ SHOWER 2·0m²/ PERSON
- ALL HOUSEHOLD GREYWATER 4·0m²/ PERSON
- COMBINED WASTEWATER (INCLUDING TOILET) 6·0m²/ PERSON

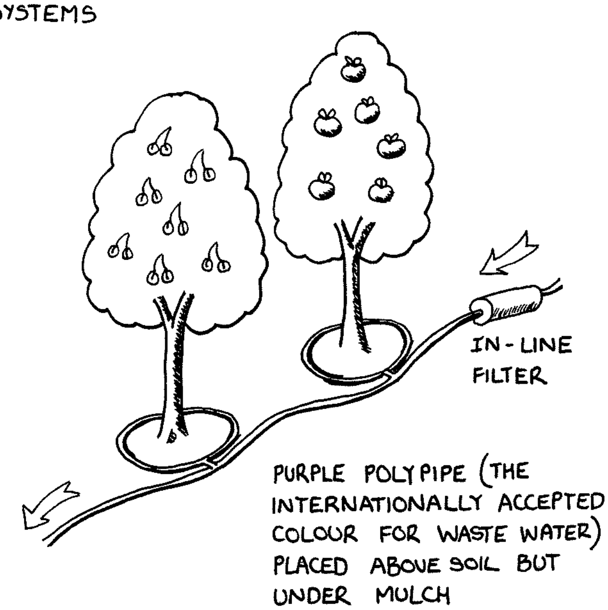
Absorption Trench Detail

ABSORPTION TRENCHES MAY HAVE SINGLE OR DOUBLE DISTRIBUTION PIPES

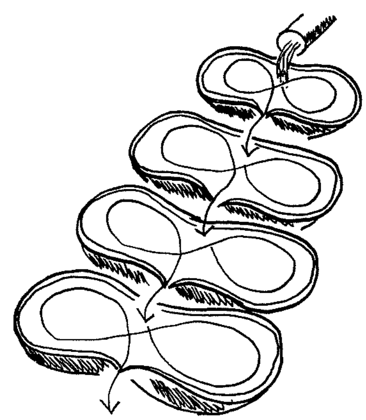


Drip Irrigation Detail

TREATED GREYWATER CAN ALSO BE PUMPED THROUGH DRIP-IRRIGATION SYSTEMS



Flow-Forms



A SERIES OF FLOW-FORMS MAY BE INCLUDED IN THE GREYWATER FILTERING SYSTEM AFTER WATER HAS PASSED THROUGH REEDBEDS. FLOW-FORMS OXYGENATE WATER

- bulrushes to absorb undesirable chemicals through their root systems
- lotus, waterlilies and water hyacinth to absorb specific pathogens or chemicals and to cool the water
- unshaded water pools so the sun can act as a steriliser and the wind can oxygenate the water
- water movement from one pool to another as the water is cleaned.

The importance of rivers, ponds, lakes, wetlands, bays, aquifers and soil moisture

Rivers are spirit paths. Songs, birds, water and trees travel along river valleys. If you have these on your land then you are lucky. If you haven't, then try to find even a small place for an artificial water body. A recent study of water across continents and its effect on climate showed that 'wetness' of the land is a critical factor in maintaining climate stability (*The Science Show*, Radio National, CSIRO report, February 2005). The study found that it is the wetness of the soil and the area of water bodies that are critical. So when forests are cut and the soil dries out, it is worse than when surface waters, such as rivers, dry up. Soil water evaporates very quickly with annual crops and annual cultivation. The solution is to plant perennial tree crops to shade soil and hold water in soil.

Most of the water associated with rivers runs underground. To keep these lines flowing, the hills and ridges must be kept in permanent forest. The underground waters link up with aquifers and wetlands, lakes and springs. They are a little-known landscape.

Rehabilitating rivers, creeks, streams and wetlands

We must rehabilitate and maintain in good condition all the surface waters that we have abused. This is achieved by keeping the edges of all surfaces under permanent vegetation and shade, which carry out the following functions:

- trap silt and run-off
- take up toxins and excess materials in the water (for example, fertilisers and biocides) as they run off our land, gardens, streets and industry
- hold the edges against erosion
- absorb the energy of floodwaters
- provide breeding grounds and protection for indigenous animals, both terrestrial and aquatic
- offer cooler water temperatures through shading.

We can start rehabilitation by removing dams on rivers and creeks and drainage from paddocks to let wetlands re-form. If riverbanks have been badly incised by erosion, begin by fencing the whole area off (see Figure 4.12). Place the fence boundary a minimum of 30 metres each side of the riverbank. Replant with a variety of indigenous plants and include reeds, shrubs and trees. Don't worry too much about weeds because if you plant densely they will be shaded out quite quickly, or you can remove them later. Around swamps and wetlands, water plants of the reed family used for water cleansing are essential.

If you have an incline or fall in the creek or riverbed and want to reduce the speed of the water, slow it down by weaving barriers from local indigenous shrubs—in my case this is tea-tree and hakea with seedpods on the branches—and place these across the flow at about 10-metre intervals (see Figure 4.13). These barriers will slow down the water, trap waste and send indigenous seed down the river to grow further downstream. Do not use straw as it composts, grows weeds and is bad for water quality.

Within a few years your creeks and rivers will be well vegetated, cool and damp. Ephemeral waters will run longer and cleaner after rain.

Record your work in your observation notebook because your results will be useful to others in your community. The increase in plants and animals and change in water quality will give you great joy.

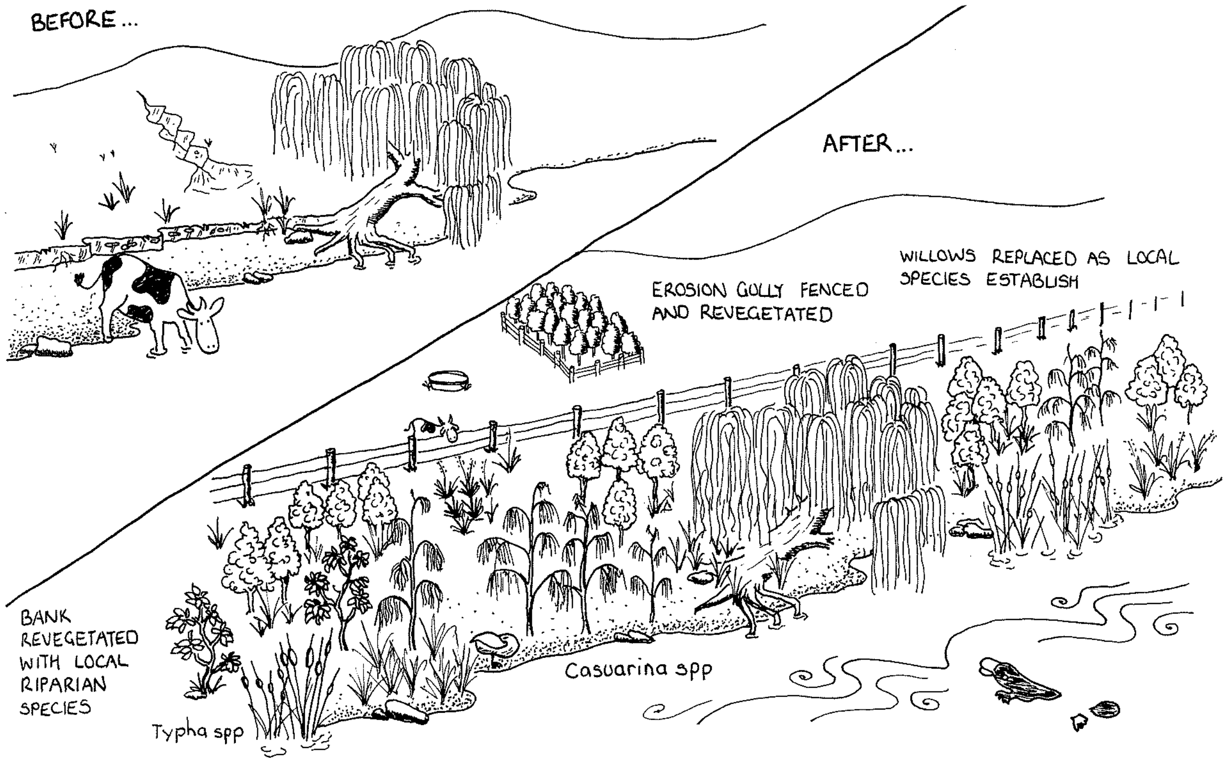


Figure 4.12 Rehabilitating creeks and streams. Begin by fencing off the area to prevent further erosion and replanting with indigenous plants.

Bores and ground water

Ground water is any water below the ground surface. It includes both water percolating down to the water table and standing water below the water table, and plays a huge role in what happens at the surface. Ground water is constantly recharged from precipitation and discharged through waterfalls, soaks and springs, and slowly feeds creeks and rivers as clean water. Whole ecosystems are defined by it. Salts dissolved in ground water are maintained at reasonable levels until the trees are cut down and then it rises and concentrates the salts at the surface and salinity occurs. Ground water must be kept clean. Caring for it would mean replacing water-hungry irrigated crops such as cotton with perennial income-earning crops that take less water.

When ground water is extracted by bores and wells, the natural dynamic balance is disturbed and the environmental consequences may be extremely unacceptable. There is little knowledge of the economic benefits of ground water extraction compared with leaving ground water in the ground, because we don't know the amount of recharge needed to sustain healthy ecosystems. As rainfall is declining, ground water recharge will be less. We have little understanding of how climate change threatens ground water resources. However, ground water and surface water are completely interdependent and reduction of one will rebound on the other.

The environment is a legitimate user of ground water and we must not steal from it. Many ecosystems carry out valuable functions and are dependent on ground water for their survival. As a corollary, if ground water is depleted, ecosystems can die. To maintain the integrity of ground water it needs:

- protection from unregulated bores and pumps
- recharge areas, which are the permanently timbered tops of hills that enable 5–10 per cent of rainwater to seep through to recharge the ground water.

Every farm design needs to demonstrate designated permanent recharge protection zones

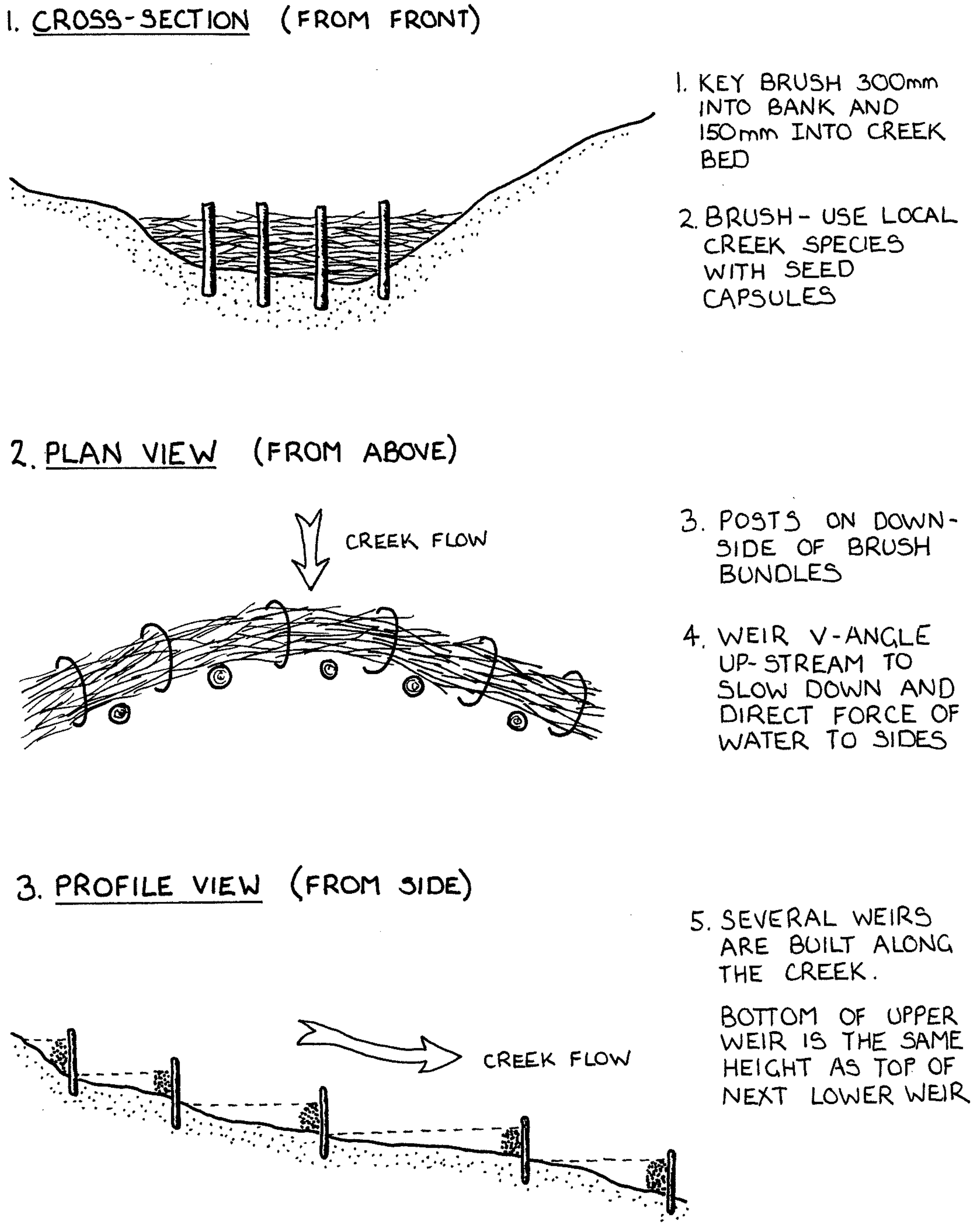


Figure 4.13 V-notch weir design for creeks slows water velocity, promotes sedimentation, provides indigenous mulch and reseeds downstream.

on hills, and carefully monitored and seldom-used bores and wells.

Lakes and ponds

Lakes and ponds are closed systems and, like ground water, are often difficult to flush out, so it is important to maintain their water purity. The first rule of managing them is to keep a permanent edge of reeds around the entire water body, and to have it fenced beyond that if the pond is a source of drinking water. It is important that animals such as pigs, ducks and dogs cannot reach the water because all these animals can carry diseases transmissible to humans.

Water entering ponds and lakes needs to be pure and free of shampoos, detergents or soaps

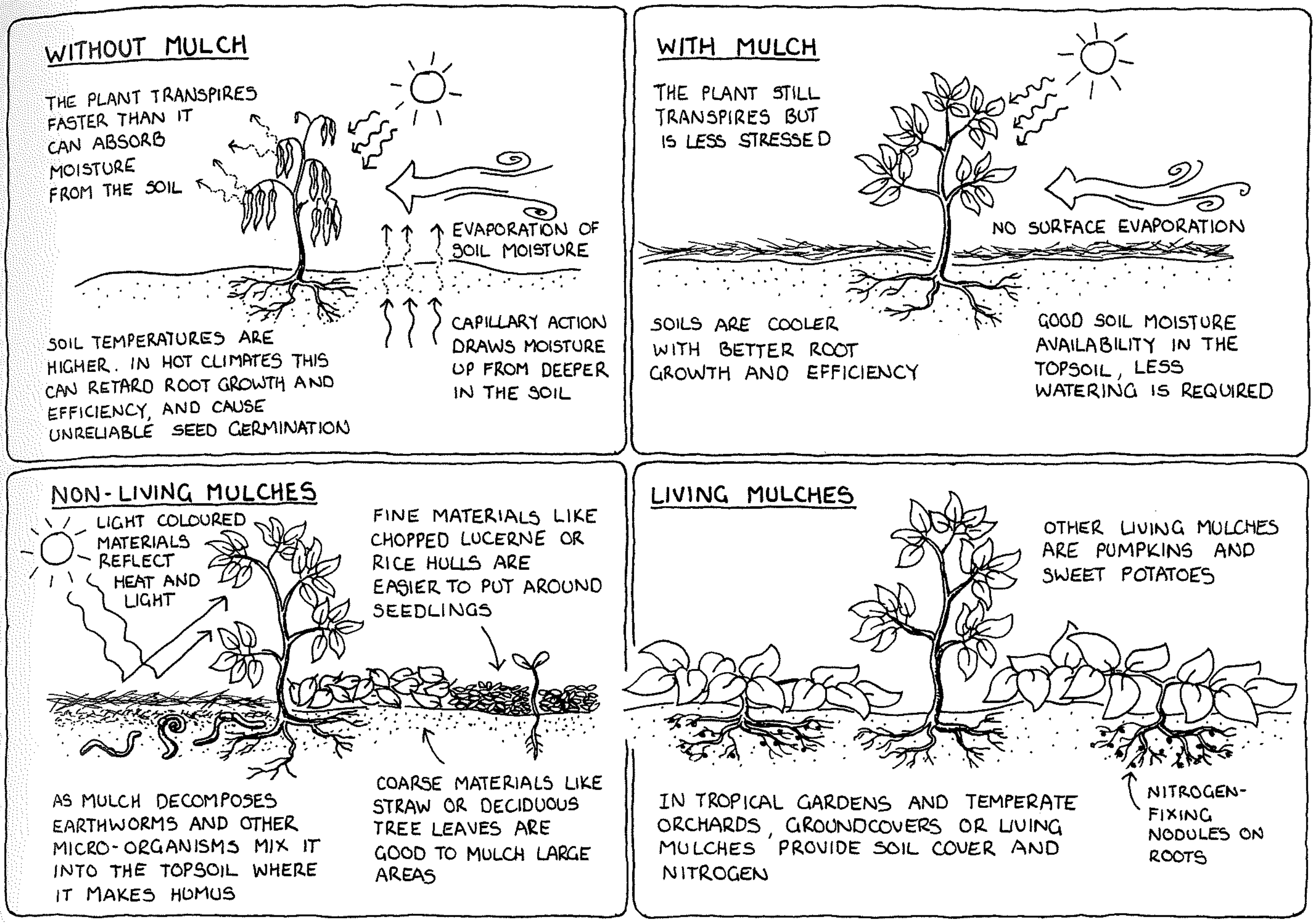


Figure 4.14 The functions of mulch.

unless you have very special products that do not contain phosphates or laurel stearate. In warmer climates the edge planting can be of productive plants such as lemon grass, lotus and water chestnuts. Water plants such as lotus, hyacinth and waterlilies covering 30 per cent of the surface area keep the water clean and cool. Note, however, that in Australia water hyacinth is a major water weed of rivers and should not be used. These water plants can be harvested for mulch or pig food.

Design techniques for dry land and drought in gardens and orchards

The principle behind techniques for caring for dry land in times of drought is to deliver the right amount of water to the plant and as close to its root system as possible. Spread mulches thickly.

Try these:

1. Put all the sources of incoming water on your site plan. Show the pipes bringing water in. Show roofs from which you could capture water.
2. Create a table in your workbook of your water consumption. This table is called your water audit and it is an analysis. Set yourself goals to reduce the amount of water you use.
3. Look at your land and identify 'run-off' areas, like driveways, roads, sheds and house roofs. Notice where they shed water; these are called 'run-on' areas. Now design water-capture systems for the soil and in biomass, so the water will stay where you want it.
4. Draw up specific techniques for repairing wetlands (including small undulations in your land) and rehabilitating streams and rivers.
5. Work out how to store water in land storage systems, even on very small land, so you will have water available during dry periods.