Domestic water supply is augmented by this roof-top catchment on a home near Mountain View, Hawaii.

Harvesting water for agricultural, wildlife, and domestic uses

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Collection and storage of precipitation from treated catchments provide an important supplementary water supply for livestock, wildlife, and humans when normal sources of supply fail in arid and semiarid regions

WATER harvesting can be a source of water for a variety of purposes in arid and semiarid regions when common sources, such as streams, springs, or wells, fail. In addition to supplying drinking water for people, livestock, and wildlife, water-harvesting systems can provide supplemental water for growing food and fiber crops. Often the necessary water can be obtained without large expenditures of energy.

The principles of water harvesting are not new. These techniques were used as early as 4500 B.C. by the people of Ur and others in the Middle East (9). In fact, researchers have reconstructed water harvesting systems used for runoff farming in Israel's Negev Desert 4,000 years ago (4). American Indians used similar systems 700 to 900 years ago in the southwestern United States (*11*).

In some parts of the world, precipitation collected from the roofs of houses provides a household water supply. However, development of central water supply systems for homes and large irrigation projects for agriculture have resulted in many water-harvesting techniques being forgotten. Future demands for water may well necessitate the rediscovery of some of these old practices.

Designing a water-harvesting system

Regardless of the ultimate water use, all water-harvesting systems have two basic components, a catchment apron for collecting precipitation and some type of water-storage facility. The collected water may be stored in a tank or reservoir or in the soil profile for runoff farming.

Most water-harvesting systems also re-

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quire peripheral equipment, such as conveyance pipes, drinking troughs, evaporation controls, and fencing. This equipment is important to the system's performance. A $5 float valve can cause a $20,000 water-harvesting system to fail at a critical time.

No water-harvesting system is suitable for all applications. There are a wide range of construction materials, site conditions, methods of installation, and uses for the collected water. Each system must be individually designed to fit the needs and conditions of a specific site and use.

Some design factors are easily estimated, for example, the time distribution of the required quantities of water. Other factors, such as rainfall quantity and frequency or probability, require careful consideration and judicious use. Other important factors include the availability of labor and equipment, a site's soil and topography characteristics, the site's accessibility, catchment runoff efficiency, and the relative unit costs of suitable catchment treatments and water storages.

Usually, certain key factors are selected, and the system is designed to satisfy these items. For example, catchment area and storage volume can be overdesigned to ensure that water is available during periods of below-average precipitation. This same system would be oversized for periods of average or above-average precipitation, however. The user must decide if the cost of the larger installation is justified by the assurance of having some water during critical periods. Smaller systems that cost less can be used if limited quantities of water in periods of below-normal precipitation are not critical.

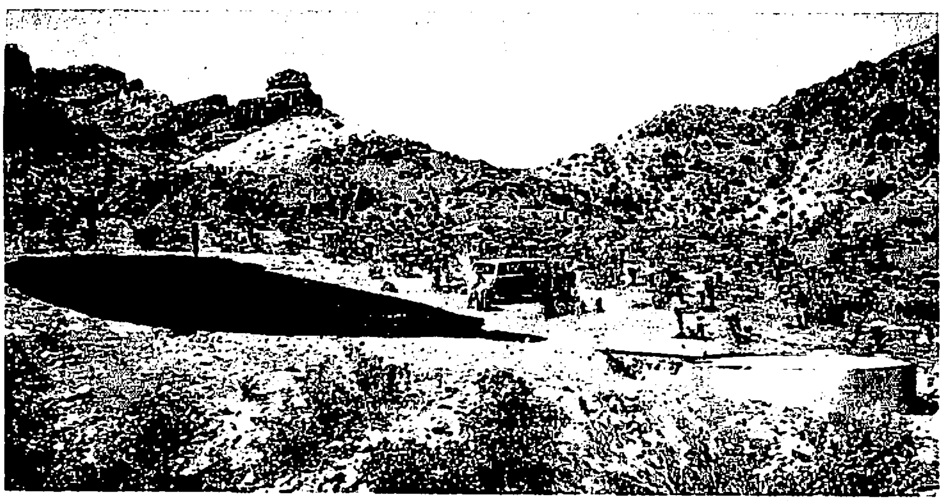
Catchment treatments affect the required sizes of both the catchment and storage facility. Sheet metal or membrane treatments, such as asphalt-fiberglass, have runoff efficiencies greater than 95 percent. They will collect water from rains of less than 0.1 inch. Treatments with lower runoff efficiencies (less than 50 percent), such as land smoothing or compacted earth, require relatively high rainfalls to initiate runoff. These less efficient treatments usually require larger catchment areas and storage facilities to provide water during periods when precipitation is less than necessary to produce runoff.

The site selected for a water-harvesting system should have a topography that minimizes the work needed to prepare the area. The catchment treatment dictates the required site conditions and the amount of surface preparation necessary to ensure satisfactory performance. Treatments based on soil modifications, such as "roaded" catchments and soils treated with water repellents, require careful attention to maintaining slope angles and lengths to minimize soil erosion on the catchment apron. Site conditions and surface preparations are not as restrictive for membrane treatments, such as sheet metal and asphalt-fiberglass. These treatments have been used on extremely rough surfaces with slopes up to 20 percent.

For many water-harvesting systems, the water storage facility is the single most expensive item. By minimizing the size of the storage, a system's cost can be reduced. However, minimizing storage size may result in water being lost as overflow with the storage facility during parts of the water year.

The presence or absence of subsurface rocks or rock layers within the soil profile may restrict storage alternatives to some form of above-ground storage facility.

If evaporation from the water storage facility is not controlled, the sizes of the catchment and storage must be increased to compensate for the quantity of water that will be lost by evaporation. Evaporation losses from a storage facility are often greater than the water quantities needed for the intended use.



An asphalt-fiberglass membrane covers this wildlife water catchment near Phoenix, Arizona.

Harvesting water for wildlife, livestock

The Forest Service, Bureau of Land Management, and other agencies use water-harvesting systems where more common types of water development are not feasible. Systems are being installed in areas accessible only by four-wheel-drive vehicles. Some relatively small systems furnish water for wildlife. Other units feature large catchments and storages capable of furnishing water to several hundred head of livestock. The systems are dependable water sources for both wildlife and livestock when other water supplies fail (2).

Catchment treatments. Two treatments of catchment aprons used extensively in the southwestern United States are asphalt-fiberglass membranes and paraffin wax soil treatments (*5*, *10*). The asphalt-fiberglass treatment is commonly used on catchment aprons up to or exceeding 3,000 square yards. The membrane is assembled in place by laying strips of chopped fiberglass matting across the catchment surface and saturating the matting with an asphalt emulsion. Once the asphalt has partially cured (2-10 days), a second coat of the emulsion is applied to seal the membrane's surface.

Some installations are coated with a pigmented paint to reduce the rate of asphalt oxidation and/or deterioration, which increases the life of the treatment. Installations without a protective coating usually require a new seal coat every 3 to 6 years. Catchments with protective coatings last 10 years or more. Unfortunately, protective coatings suitable for asphaltic surfaces are relatively expensive, more than $1 per square yard.

When initially installed, the asphalt-fiberglass membrane is flexible and conforms to irregularities in the ground surface. After curing, the membrane becomes semirigid, capable of withstanding minor mechanical damage. On several unfenced catchments, cattle and wild burros have walked across the surface without damaging the membrane. The asphalt-fiberglass membrane has a runoff efficiency exceeding 95 percent. Rainfalls of less than 0.05 inch produce runoff (*6*).

The paraffin wax soil treatment is being used successfully on catchment areas up to 4,000 square years. This treatment consists of spraying molten paraffin wax (average melting point 125-130°F) from a roofing tar kettle or asphalt distributor truck on a smoothed catchment surface at a rate of 3 to 4 pounds per square yard. The sprayed wax usually solidifies upon contact with the soil surface. Within a few days, the sun's heat will warm the soil surface enough to remelt the wax, which then soaks into the soil to a depth of about 0.5 inch. The wax coats each soil particle, creating a water-repellent layer that resists infiltration. The wax does not fill or plug the soil pores.

This treatment is particularly applicable to lighter, coarser textured soils (sandy, sandy loam) in areas where the temperature of the soil surface will exceed 130°F for a few hours during the day. The treatment is best suited for climates where soil temperatures exceed the melting point of the wax during part of the year.

A disadvantage of the treatment is the minimal soil stabilization achieved. Soil erosion is a problem on some soil types, especially on catchment slopes greater than 5 percent, with lengths greater than 100 feet. Inadequate waterproofing often results also on soils with a clay content greater than 20 percent.

Properly applied on sandy soils, paraffin wax treatments yield 80 to 95 percent runoff with rainfalls of 0.1 inch or more (*6*).

Other materials have been used at times for water-harvesting catchment treatments. Arizona's Game and Fish Department has installed many small wildlife watering units using galvanized corrugated sheet metal. A few catchments have been constructed using gravel-covered plastic sheetings, sodium salt dispersion of the clay in the soil, and concrete slabs. Catchments of butyl or artificial rubber sheeting were used extensively in the 1950s and 1960s, but wind and rodents damaged or destroyed many of these units. Improper installation often was a problem also. With suitable site and soil conditions, however, all of these treatments have been used successfully.

Table 1 presents some of the common catchment treatments being used and an estimate of the installation costs, longevity, and runoff efficiencies of each.

Table 1. Estimated installation cost, longevity, and runoff efficiency for various water-harvesting treatments.

Catchment Treatment	*Runoff Efficiency (%)*	*Estimated Longevity (yr)*	*Installation Cost ($/sq. yd.)*
Land clearing	20-30	5-10	0.01-0.02
Soil smoothing	25-35	5-10	0.04-0.06
Silicone water repellents	50-80	5-8	0.15-0.30
Paraffin wax	60-90	5-8	0.30-0.50
Concrete	60-80	10-20	2.00-5.00
Gravel-covered sheeting	70-80	10-20	0.50-0.75
Asphalt fiberglass	85-95	5-10	1.00-2.00
Artificial rubber	90-100	10-15	3.00-5.00
Sheet metal	90-100	20	3.00-5.00

Table 2. Summary of analysis of elements in parts per million (ppm) from samples collected from various water harvesting catchment surfaces.

	Catchment Surface					
Constituent	*Asphalt*	*Paraffin Wax*	*Butyl*	*Silicone Water Repellent*	*Galvanized Steel*	*Public Health Standard*
Cadium	-	-	<.001	-	<.008	.01
Calcium	0.5-35.0	6.4-46.0	2.1-32.0	3.8-14.0	ND*	-
Chromium	<.002	<.009	<.02	<.006	<.01	.05
Iron	<.0008	<.009	<.02	<.003	<.01	.3
Lead	<.01	<.02	<.03	<.02	<.01	.05
Magnesium	0.1-6.0	0.7-6.0	0.4-2.0	0.5-2.0	ND	-
Mercury	<.0007	<.0009	<.001	<.0008	<.0005	.002
Potassium	0.3-6.0	1.2-16.0	0.7-2.0	0.9-5.0	ND	-
Sodium	0.2-12.0	0.4-8.0	0.5-1.0	0.9-9.0	ND	-
Zinc	<.004	<.003	<.01	<.0001	0.2	0.15

*None detected.

Storage facilities. The storage facility of a water-harvesting system often accounts for over 50 percent of the system's cost. Failure of the storage facility renders the system useless. Typical storage facilities include butyl bags, steel tanks, and excavated pits with some type of waterproof lining. Most storages for animal water range from 5,000 to 80,000 gallons, depending upon the number and type of animals using the system.

Use of butyl bags for water storage is decreasing because of the bags' susceptibility to mechanical damage and problems with water and snow collecting on top of the bags. Butyl bags are relatively expensive also and generally limited to sizes less than 40,000 gallons. They are relatively easy to transport to a site and to install, plus there are no water losses because of evaporation.

Steel tanks suitable for water-harvesting systems come in a variety of shapes and sizes. Smaller installations (less than 20,000 gallons) often use a horizontal cylinder tank with welded steel ends. These self-contained units are easily installed, and there are no evaporation losses, but they are relatively expensive.

Another common storage facility is a vertical-walled steel rim tank with a poured concrete bottom. These tanks are durable, and they can be constructed onsite in relatively large sizes. Their major disadvantage is the problem of transporting materials for the concrete bottom into remote sites.

A limited number of steel rim tanks with a plastic sheet liner have been installed. Because of problems with the liner deteriorating above the water line, a cover or roof is usually placed over the tank.

High seepage losses restrict the use of earthen reservoirs or excavated pits as storage facilities in water-harvesting systems. In some installations, pits have been lined with some type of plastic or artificial rubber sheeting. There have been problems with wind and animal damage to these linings, however. In a few installations, a soil cover over the membrane lining has been used to reduce possible damage.

Evaporation control. Conserving the collected water is one of the most economical methods of maintaining an adequate water supply. The greatest research effort in controlling evaporation has been with monomolecular films of long-chain alcohols (cetyl alcohol). Despite promising laboratory studies, long-term field studies show an evaporation reduction of only about 20 percent (*7*). Other methods of reducing evaporation that have been investigated include changing the color of the water, wind barriers, shading, and floating covers (*1*).

For water-harvesting systems with vertical-walled tanks, the floating cover is one of the simplest, most effective means of evaporation control. One type of floating cover used on tanks up to 30 feet in diameter is made of a low-density synthetic foam rubber. Only minor problems have been reported, such as birds pecking the cover or wind blowing the cover off when the tank is full. Estimated cost of the water saved is less than $2.50 per 1,000 gallons (*3*).

Other materials used as floating covers include rafts of polystyrene sheeting and a

Livestock benefit from water collected by this northern Arizona catchment treated with paraffin wax.

continuous layer of paraffin wax. Neither of these methods is presently used in operational water-harvesting systems, however.

Many older water-harvesting structures had roofs constructed over the storage tank. These roofs effectively reduced evaporation, but construction costs were prohibitive for many installations. On some installations, the support framework of the roofs collapsed from excessive snow accumulations.

Water harvesting for domestic uses

Water harvesting for household use remains common in many parts of the world, particularly in isolated areas where local surface water or groundwater is unavailable or unsatisfactory because of dissolved chemicals. Many of the techniques for harvesting water for livestock can be used to supply domestic water.

Information on the quality of water collected by a water harvesting system is limited. With few exceptions, precipitation is almost pure water, without any contaminants harmful to animals or humans. There is the possibility that water from a catchment could contain water-soluble impurities or weathering by-products of the materials used to waterproof the catchment.

A 1977 study in Arizona and Hawaii looked at the quality of water collected from various types of catchment surfaces. Table 2 summarizes the results of an analysis for various inorganic elements. None of the elements existed in quantities that exceeded drinking water standards. Some elements detected in the water may very well have come from wind-borne dust deposited on the catchment surface. Rainfall could also trap some elements at locations near mining or manufacturing plants. Limited biological analysis showed that some form of water treatment, such as chlorination, would be necessary to meet biological standards for potable water.

Forage production and runoff farming

Soil moisture and nutrients combine to limit forage production in arid and semiarid regions of the world. As a result, potential meat production on the land declines. In many arid land areas, plants cannot efficiently use applications of fertilizer without additional water. The limited natural rainfall could be used more effectively with runoff farming techniques.

An Arizona study showed that by clearing and treating strips of land to increase precipitation runoff and by concentrating that runoff on adjacent strips of cropped land the average forage yield (based on total land area) of blue panicgrass (*Panicum antidotal* Retz.) could be increased by a factor of two over yields on plots with a solid planting of grass. With an annual precipitation of less than 5 inches during the growing season, some plots produced average annual forage yields greater than 2,500 pounds per acre (850 pounds/acre runoff area included), compared to yields of less than 450 pounds per acre on control plots.

The same study found that more nitrogen was used by the plants than was available from the nitrogen fertilizer and organic matter in the soil. With these results and with results of other studies in Brazil and Florida with similar forage plants, researchers concluded that some form of nitrogen fixation was occurring (*8*, *12*). While the potential increase in forage yields in these studies was significant, the costs of the treatment of the runoff area were relatively high compared with current returns from the grass in the form of meat production.

Future of water harvesting

Future water developments in many parts of the world may employ water-harvesting techniques. With the rise in energy costs, water harvesting can compete economically with more conventional water sources in many areas. Runoff-farming techniques may be used to grow forage plants as well as plants suitable for food and cover for wildlife and game birds and food grains for man.

The cost of present water-harvesting treatments developed for livestock is probably too expensive for many runoff-farming applications. But some form of land-forming, coupled with low-cost soil treatment, is feasible. It is also quite possible that water-harvesting systems could be designed to furnish both drinking water for man and animals plus water for runoff-farming applications.

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