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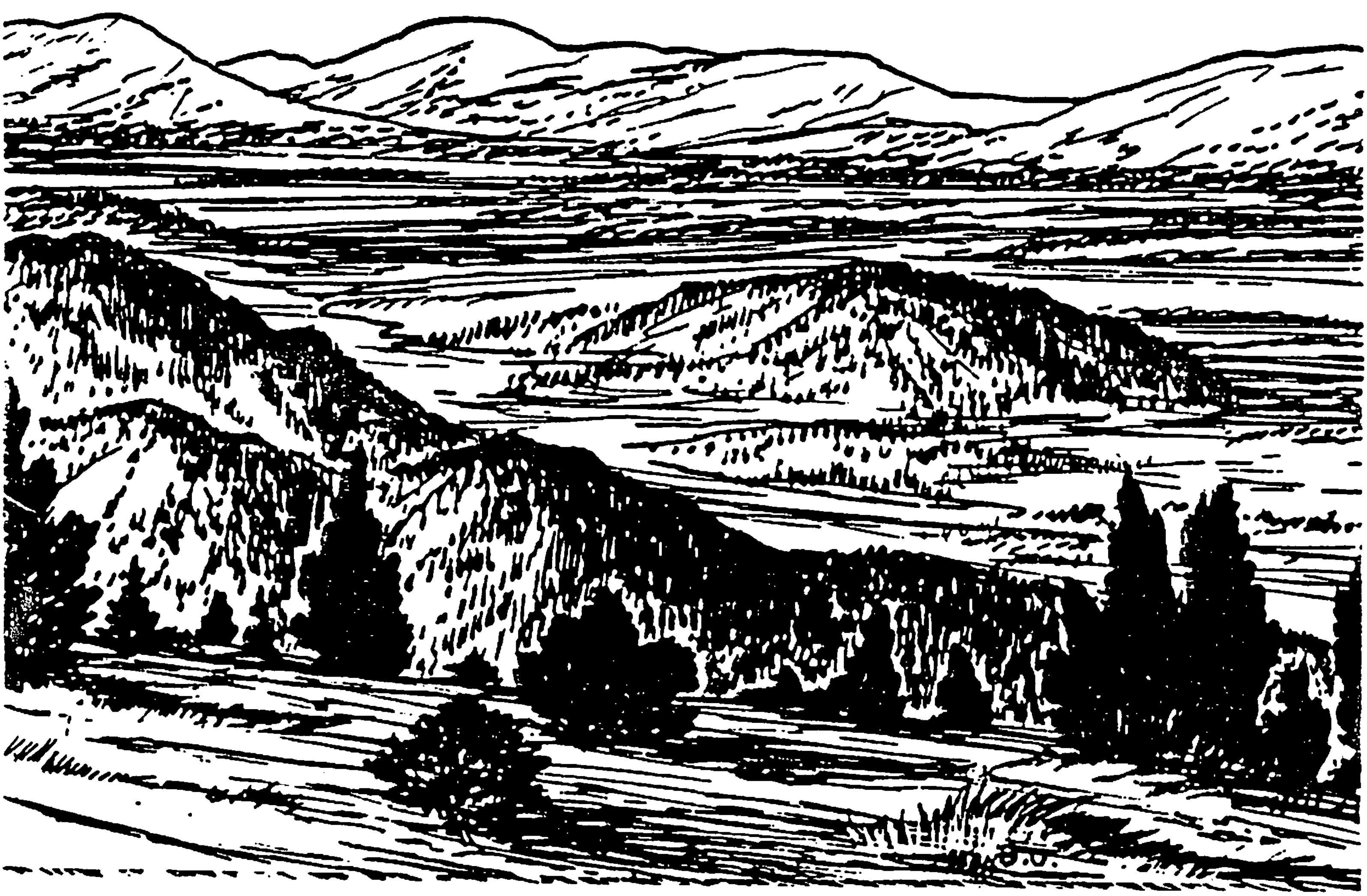

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WATER HARVESTING POTENTIAL AND APPLICATION AS A MEANS OF RANGE WATER SUPPLY

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ABSTRACT: Water harvesting techniques can provide the necessary quantity and distribution of animal drinking water for the proper management of rangeland resources. Typical water-harvesting systems consist of a catchment area of 700 to 2500 sq. yds. with storage facilities of 10,000 to 90,000 gallons. Total system costs range from $4,000 to $30,000, depending upon the type of materials used and the availability of labor and equipment.

INTRODUCTION

It has long been recognized that much of our rangelands have inadequate supplies of animal drinking water. When there is a poor distribution of animal drinking water, overgrazing occurs on areas adjacent to the water, while areas farther away are frequently unused. Herbel and others (1967) found that cattle would graze at distances of up to 3.5 miles from drinking water supplies. In many places this is an excessive travel distance for proper management of the forage resource. Frasier (1981) showed that when the average animal travel distance was reduced from 1 mile to 1/2 mile, the improved uniformity in forage utilization allowed the animal-carrying capacity to be increased by 30%.

There is no "best method" for increasing range water supplies. Common water development methods include wells, earthen ponds, spring development, water hauling, and pipelines. Each of these techniques have certain advantages and disadvantages. In places where these approaches are not technically or economically practical, water harvesting may be a possible alternative.

Water harvesting is simply the collection of precipitation from a small catchment area that is topographically modified, chemically treated, or covered with a membrane to reduce infiltration. The collected water is stored in a suitable container until it is needed. Water harvesting is not an inexpensive method of water supply augmentation, but it can be used to provide water supplies where other methods are not feasible (Cooley and others 1978).

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CATCHMENT AREA

The catchment area is the component of the water-harvesting system that collects and concentrates precipitation. Any area that is reasonably impermeable to infiltration can be used as a catchment surface. Paved highways and roofs of buildings are examples of surfaces designed for other purposes that can be used as a water collection area. The runoff water is diverted into a water storage container. Several types of common catchment treatments being used on operational water-harvesting systems are listed in table 1. The table includes some of the site conditions that must be considered when selecting a treatment, estimated installation costs, treatment life and runoff efficiency (defined as the ratio of runoff to precipitation).

Asphalt-Fabric Membranes

The asphalt-fabric membrane has been used in many places such as the hot deserts regions of the southwestern United States, the tropical rangelands of Hawaii and the high mountain regions of Colorado and New Mexico. The fabric, a random weave fiberglass matting or synthetic polyester filter matting, was unrolled on the cleared and smoothed catchment surface and saturated with an asphalt emulsion. Three to 10 days later, a second asphalt emulsion sealcoat was brushed on the surface to completely seal the membrane. The asphalt hardens as it cures and two to six months after installation the membrane is relatively resistant to damage by wind, animals and weathering processes (Myers and Frasier 1974). Runoff efficiency is nearly 100% and with periodic sealcoat applications at 5 to 7 year intervals the treatment has an expected life of at least 20 years.

Gravel Covered Sheetings

Many types of thin plastic sheetings have been investigated as potential membrane coverings for water-harvesting catchments. Most of these coverings failed in field installations because of mechanical damage to the exposed membrane by wind or animals. Placement of a gravel covering over the thin plastic or tar paper sheetings has been an effective treatment in some areas (Frasier and Myers 1983). The sheeting is the waterproof membrane and the gravel protects the sheeting from mechanical damage and sunlight deterioration. This treatment requires a good periodic maintenance program to insure that the gravel remains in place. Runoff is essentially 100% after the 'threshold' rainfall (the quantity of precipitation required to initiate runoff) has been exceeded (approximately

Table 1.--Site requirements, costs, and performance data for some water-harvesting catchment treatments

Treatment	Site Conditions		Costs[1]		Life	Runoff Efficiency
	Maximum Slope	Surface	Materials	Labor		
	(%)		($/yd^2)	($/yd^2)	(yrs)	(%)
Asphalt-fabric	10	all	$2.00	$0.50	20	95+
Gravel-covered sheeting	5	smooth	1.75	.80	10	85+
Paraffin wax	5	selected soils	1.00	.10	10	75+
Artificial rubber membranes	10	smooth	10.00	.50	20	95+
Sheet-metal coverings	10	all	15.00	.50	20	95+
Concrete	10	all	20.00	.80	20	60+
Rock surfaces		existing	.10	.10	20	30+
Land smoothing	5	selected soils	.00	.20	5	20+
Sodium salts	5	selected soils	.20	.20	10	50+

[1]Approximate onsite costs on a prepared site. Materials are based on 1980 costs. Labor is estimated at a rate of $10.00 per hour per man.

0.1 inch). Effective life of this treatment is about 10 years.

Paraffin Wax

The paraffin wax chemical soil treatment has been used in limited locations. Low melting point paraffin wax (125-130° F), sprayed onto the prepared catchment area, was initially deposited as a thin coating on the soil surface. When the soil surface was warmed above the melting point of the wax by the sun, the wax migrated deeper into the soil, coating each soil particle with a thin layer of wax. The wax treatment does not provide any permanent degree of increased soil stabilization. Instead, the waterproofing is caused by changing the surface tension characteristics between the water and the soil particles in the surface of the catchment. This treatment is not suited for soils containing over 20% clay, and should be used only where the soil temperature will exceed the melting point of the wax during some part of the year (Frasier 1980). The effective treatment life on suitable soils is probably in excess of 10 years, with an average runoff efficiency of 70-95%. Soil erosion of the catchment surface is a potential problem.

Artificial Rubber Sheetings

In the 1950's, many catchments were covered with sheetings of artificial rubber (butyl). The butyl sheetings were relatively easy to install and, based on results from accelerated weathering tests, the coverings had a projected life in excess of 20 years. Unfortunately, many of these installations prematurely failed. These coverings are flexible, and wind vibrating the sheetings against the soil surface rubbed holes in the membranes. These holes, and others caused by rodents or birds, allowed wind access under the sheeting which would rip the covering from the catchment area. Improper installation techniques contributed to many failures (Dedrick 1973).

Properly installed and maintained artificial rubber membranes can be an effective treatment in some areas. The membranes should be installed in a relaxed condition on a smooth surface and protected from wind uplift and vibration. They should be inspected frequently and any damage repaired. A properly installed and maintained surface will yield essentially 100% runoff with an effective life of 10-20 years.

Sheet Metal Coverings

Sheet metal roofs have long been used to collect rain water. Initially, these roof type catchments consisted of an above ground wooden framework in the shape of a shallow 'V' covered with corrugated sheet metal. These catchments were durable, effective water collectors, but the cost of materials and labor for the supporting framework has limited widespread use. Costs have been reduced on some installations by placing the sheet metal on a ground level framework. On some soils, a layer of washed gravel under the sheeting is necessary to prevent metal corrosion by the salts in the soil. Also, steel sheet metal must be coated (galvanized) to prevent rusting. Aluminum sheeting has been used on some installations. Sheet metal catchments are relatively durable, and yield 95-100% runoff (Lauritzen 1967). Life expectancy is in excess of 20 years.

Concrete

Most concrete catchments are relatively small units, primarily because of construction costs. Shrinkage cracks and expansion joints must be periodically sealed with some type of crack sealer. Many concrete surfaces will become partially porous with time, which increases the threshold rainfall. This effect can be partially countered by periodic treatment of the area with the paraffin wax or a water based silicone (sodium silanolate) water repellent. Runoff efficiency is 60-85%, and a life expectancy in excess of 20 years might be anticipated.

Rock Surfaces

Large expanses of rock outcroppings are natural surfaces that can be used as a catchment area. A small masonary dam or water collection channel constructed along the lower edge of the outcropping directs the water to the storage facility. Runoff efficiency from the rock surface may be quite variable, depending upon the porosity of the rock and the number of cracks. The cracks can be sealed using the same asphaltic sealer compounds used for sealing concrete cracks. On some porous rock surfaces, the runoff efficiency can be increased with a water repellent treatment.

Land Forming

One simple catchment treatment is a cleared and smoothed land surface. This treatment is used on some of the most extensive catchment areas in the world, the "roaded" catchments in Australia. The land is shaped in the form of "...parallel ridges ("roads") of steep, bare and compacted earth, surveyed at a gradient that allows runoff to occur without causing erosion of the intervening channels." (Laing 1981). In 1980, it was estimated that there were more than 3,500 of these roaded catchment systems in Western Australia, comprising a total area in excess of 10,000 acres. Many of these catchments have a top dressing, or layer, of compacted clay to increase runoff efficiency (Frith 1975).

These treatments are effective if properly matched to suitable soil types and topographic features. Runoff efficiency is 20-50%, with a life expectancy of 5 years. Improper design of slope angles and overland flow distances can result in serious damage by water erosion to the catchment surface (Hollick 1975).

Sodium Salts

On some soils, the runoff efficiency of compacted soil treatments was increased using a sodium dispersed clay or salt treatment. The sodium salt (common table salt, (sodium chloride) [NaCl]; or soda ash, (sodium carbonate) [Na_2CO_3]) was mixed into the soil or sprayed as a water solution onto the soil surface. During rain storms, the sodium disperses the clay aggregrates. The dispersed clay particles fill the soil pores and form clay lens which restrict the rate of water movement through the soil profile. This treatment is limited to specific sites where the soil has a minimum of 20% clay. Runoff efficiency is 50-80%, with an expected treatment life of 10-20 years. The breakdown of the soil aggregates increases the potential of soil erosion of the catchment surface.

WATER STORAGE

Water storage is a major expense with any water-harvesting system, and often represents over 50% of the total system cost. Any container which prevents seepage and evaporation losses is a potential water storage facility. Unlined earthen pits or ponds are usually not good means of water storage for a water-harvesting system because of seepage losses. Table 2 lists the types and comparative costs of some general water storage facilities.

Table 2.--Types and approximate costs of water storages (Frasier 1984)

Tank Type	Cost
	($/1000 gal)
Prefabricated	
(wood, steel, fiberglass, butyl, etc.)	200-400
Steel rim with:	
a) Elastomeric lining (butyl rubber)	200
b) Plastic lining (polyvinyl chloride)	160
c) Composite lining	150
d) Concrete bottom	100-200
Plastered concrete (ferro-cement)	110
Excavated earthen tank with:	
a) Exposed elastomeric lining	130
b) Exposed composite lining	100
c) Buried plastic lining	130

Costs are for on-site labor and materials for a 20,000 gallon tank. Materials costs based on 1980 prices. Labor costs estimated at $10/hr.

Prefabricated Storages

There is an almost infinite number of types, shapes and sizes of wooden, steel or reinforced plastic containers that can be used as storages on water-harvesting systems. Small tanks (< 20,000 gallons) are often preassembled and transported to the site intact. Larger capacity tanks usually require on-site assembly from preshaped pieces. Costs and availability in a given area are the primary factors for determining the suitability of these types of storages. Steel, wood, or fiberglass tanks commonly have a projected life in excess of 20 years.

There have been a limited number of installations using artificial rubber (butyl) bags for the water storage container. The butyl bags are susceptible to mechanical damage from animals and problems have been encountered with rainwater and snow accumulating on top of the bag (Dedrick 1973). The potential of mechanical damage limits the use of butyl bags to well protected and frequently maintained installations.

Steel Rim Tanks

These storages are a vertical-wall, cylindrical steel rim with a waterproof liner or bottom. The sides of the tanks are usually constructed from corrugated steel plate sections fastened together with bolts. Typical capacities range from 5,000 to 80,000 gallons, and are used for aboveground or partially buried installations.

One method of sealing steel rim tanks is to place membrane liner inside the tank. Various plastic and artificial rubber (butyl) sheetings have been used as liners. Nylon-reinforced butyl, 20 to 45 mils thick, has been used on some installations. These linings are relatively expensive but have a projected life of 15-20 years. Standard polyethylene (PE) is relatively low cost but is difficult to seam. Polyvinyl chloride (PVC) is easy to seam using heat sealing techniques but is susceptible to sunlight deterioration. A protective coating on the sheeting or a shade roof will reduce sunlight deterioration of the membrane. A typical storage of this type is an above ground swimming pool. With a roof cover to protect the liner, life expectancy of 5-10 years is possible.

A three-ply membrane of an asphalted fabric-polyethylene-asphalted fabric has been used as a tank liner in a few installations. This lining consists of a single sheet of polyethylene protected on both sides by an asphalted-fabric membrane. This lining is relatively resistant to sunlight deterioration and mechanical damage with an expected life of 10-20 years.

Steel rim tanks with poured concrete floors are common storages. The costs of pouring concrete can be a significant factor for remote areas. Backfilling around the base of the tank reduces the problems of the concrete bottoms cracking due to unequal thermal expansion of the steel rim and concrete base. Properly installed tanks have a projected life in excess of 20 years.

Plastered Concrete Tanks

The plastered concrete storage tank consists of a thin (3-4 inch) vertical circular wall of reinforced concrete with a dense plaster coating on the inside and outside surfaces. The sidewall reinforcing consists of two layers of standard concrete reinforcing woven wire. A one inch mesh woven wire (rabbit wire) is fastened to the inside and outside of the reinforcement wire to hold the concrete in place. The tank bottom is poured concrete. Maximum tank dimensions are 6 ft. high and 30 ft. in diameter (30,000 gallons). This storage type requires minimum materials, primarily cement and aggregate, but is relatively labor intensive to construct. Transportation costs of materials to remote sites can be a costly factor. Projected life is in excess of 20 years.

Excavated Earthen Storages

Seepage and evaporation control are two factors which have limited the use of excavated pits or ponds for water-harvesting systems. Both exposed and buried membrane liners have been used to control seepage losses.

Exposed nylon reinforced artificial rubber sheetings (butyl, 20-45 mil. thick) have been used. These linings, when properly installed and not subjected to tensile stresses, have a projected life of 15-20 years. The three-ply liner of asphalted fabric-polyethylene-asphalted fabric, previously described for the lining of steel tanks, has been used as an exposed lining. With a periodic application (5 years) of an asphalt sealcoat, the lining has a projected life of 15-20 years.

Various types of PVC and PE plastic sheeting (12-20 mil. thick) have been used for buried membrane linings. Care must be taken during placement of the soil cover to prevent puncturing the lining. These linings cannot be used on side slopes steeper than 1 verticle to 3 horizontal. Burrowing rodents have caused damage to some buried linings. These factors have limited the use of buried membrane linings to relatively large areas where earth moving equipment can be effectively used. Buried plastic linings have a projected life of 10-20 years.

Evaporation Control

Conserving the water collected from a water-harvesting system is a cost-effective method of maintaining an adequate water supply. Reducing evaporation losses is usually less expensive than increasing the size of the catchment area and/or storage volume. On a typical system in northern Arizona, the cost of the evaporation control was less than 4% of the total cost of the water-harvesting system (Cooley and others 1978). The most effective method of evaporation control is covering the water surface with floating covers or roof-type shades. These techniques are very effective on vertical walled storages which have a constant size surface area. It is significantly more difficult to control evaporation from storages with sloping sides where the water surface area changes with depth.

At present, the floating cover most widely used on water-harvesting systems is made of a closed cell, 1/4 inch thick, synthetic foam rubber sheeting. This material is easily seamed into a single cover with a contact adhesive. The material is susceptible to damage by mechanical means, but can be quickly repaired with small patches. Wind passing over a tank partially filled with water may disrupt the cover. A simple wire net across the top of the tank will reduce potential damage to the cover from wind. The projected life of the cover is 5-10 years.

Roofs of sheet metal on a framework above the storage have long been an effective method of evaporation control. The roof shades the water and reduces the wind velocity directly above the water surface. In some areas, the roof can be oversized and inverted to serve as an additional catchment area with little increase in cost. Roofs are potentially susceptible to damage by wind and snow loads. Properly installed roofs should have a projected life in excess of 20 years.

MAINTENANCE

Failure to maintain a water-harvesting system will result in the premature failure of the system. The failure to repair even minor damage can result in complete destruction of the entire system. Some types of catchment treatments and storage facilities require more frequent and intense maintenance than others. Most water-harvesting systems can be adequately maintained with biannual inspections and the immediate repair of any problems detected at other times. Scheduled inspection trips usually require less than 4 hours labor per visit.

WATER-HARVESTING SYSTEM DESIGN

For most installations, there will be several combinations of catchment and storage sizes which will provide the required quantities of water. Since water storage is one of the single most costly items, the lowest total-cost water-harvesting system will frequently be one with a reduced storage volume. Small storage systems will usually have some water loss by overflow during wet periods. The computations necessary for determining the optimum relative sizes of catchment and storage are not difficult but are tedious and time consuming when considering all possible combinations of precipitation, water requirements and costs. Frasier and Myers (1983) presented a procedure where the optimum catchment and storage tank sizes for drinking water supply systems can be approximated by a series of hand calculations or with a programable desk-top calculator.

Example-Design of an Animal Drinking Water System

Table 3 presents the precipitation and water requirements of a typical situation where additional livestock and wildlife drinking water supplies are needed on a ranch near Williams, Arizona. Sixty cows use the area for 5 months (Nov-Dec and Mar-May), and 30 deer use the facility yearlong. The cattle require 10 gallons/day/head, and the deer, 2 gallons/day/head. The catchment treatment selected is an asphalt-fabric membrane costing $2.50/sq. yd. with a runoff efficiency of 95%. The storage is a steel-rim tank with a concrete bottom and a floating butyl cover. Total unit storage costs are $135/1000 gallons. The optimum size combination of catchment and storage were estimated using the monthly water balance procedure of Frasier and Myers(1983). Figure 1 shows the sizes of catchment and storage, and the costs of 7 different combinations which will provide the necessary water. The range manager would decide which of the combinations is best suited for his operation, but would probably optimize for the least cost design of about $8000 provided by 3 combinations for this example. In other instances, the minimum cost combination may be more distinct. Some other factors which might enter into the actual sizes selected are; (1) the area available for the catchment apron, (2) the available sizes of the storage tank, and (3) the acceptable level of risk of having insufficient water during periods of below average precipitation. Also the materials and construction techniques selected must be compatible with the expected climatic conditions.

Table 3.--Precipitation and animal drinking water requirements for 60 cows and 30 deer near Williams, Arizona (Frasier and Myers 1983)

Month	Precipitation	Water Requirement
	(inches)	(gallons)[1]
Jan	1.98	1800
Feb	1.98	1800
Mar	1.80	19800
Apr	1.35	19800
May	.63	19800
Jun	.45	1800
Jul	2.79	1800
Aug	3.06	1800
Sep	1.44	1800
Oct	1.26	1800
Nov	1.08	19800
Dec	1.98	19800

[1]Williams, Arizona precipitation adjusted for runoff efficiency of 95%.

SUMMARY

Water-harvesting systems are technically sound methods of water supply for most parts of the world. There is no universally best system. Each site has unique characteristics that will influence the design of the best suited system. Any impervious area or surface is a potential catchment surface. With some exceptions, the higher the runoff efficiency, the greater the unit cost. The major cost item of a drinking water supply system is the cost of the water storage facility. In addition to the total annual water requirement there is also a seasonal distribution of the required water that

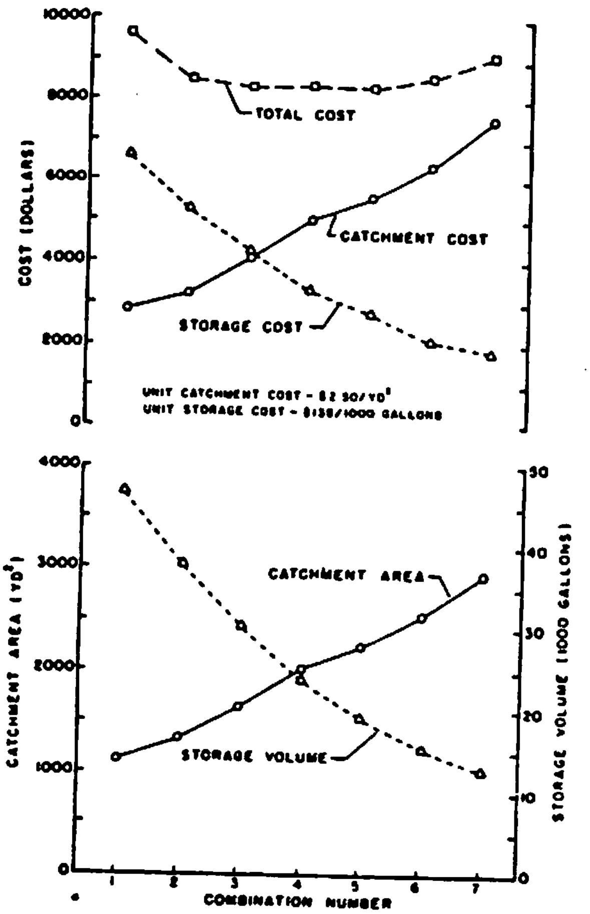

Figure 1.--Relative costs and sizes of 7 different combinations of catchment areas and storage volumes of a water-harvesting system.

must be satisfied by the water-harvesting system. The designer, installer, and user of water harvesting should become as familiar as possible with all techniques, and use the approach that is best suited for local conditions. Maintenance is a critical element of the success of a system. Without a periodic maintenance program the water-harvesting system will not be a satisfactory method of water supply.

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