Quest for Extra Water Follows Many Channels

Photograph: Forest management affects the amount of snowmelt that reaches streams. The equipment on this weir in a ponderosa pine forest measures both the volume and quality of water in the stream. (Photo by Malchus Baker Jr., Rocky Mountain Forest and Range Experiment Station, U.S. Forest Service.)

One reaction to not having enough water is to look for new supplies.

Several ways of adding to the Southwest's usable water supply have reached various stages of imagination, testing or implementation in the past two decades.

Seawater can be desalted. Icebergs from the Antarctic and rivers from the Northwest star in long-distance scenarios. The Colorado River could run fuller with cloud seeding to make extra snow in the Rockies. It could deliver more water downstream if losses from large reservoirs were reduced. More of Arizona's own rain and snow can be used, instead of lost to evaporation, by managing forests and chaparral areas

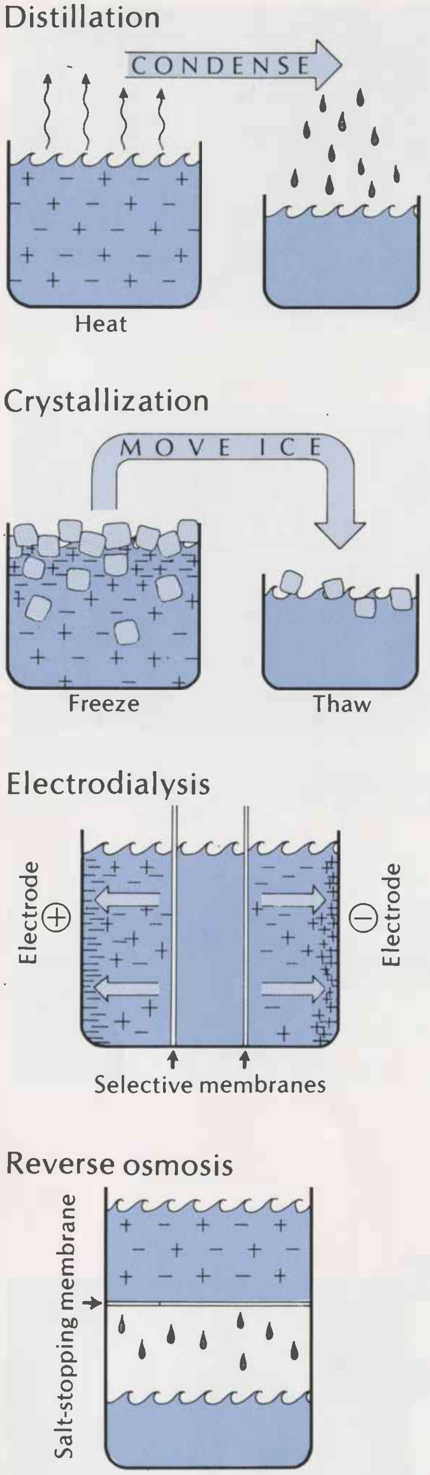


Figure 7: Methods of Desalting Water. Distillation is just boiling pure water out of a salty solution, then condensing the vapor. Similarly, crystallization uses the fact that, when a salty solution is frozen properly, the first ice formed is not salty. Electrodialysis pulls the charged salt ions toward electrodes. A membrane near each electrode lets through only the ions drawn to that electrode. It blocks oppositely charged ions from passing into the central section, where water is desalted. Reverse osmosis depends on a membrane that stops salt. Salty water is pressured against the membrane and unsalty water seeps through.

for more streamflow and by preparing water-harvesting catchments.

None of these will do much to keep the cost of water from rising or change the need to conserve water. Some may never leave the drawing board. Others may only help offset the drop expected in Arizona's Colorado River supply as water use in the upstream states increases. However, some may increase the amount of land that can be kept in crop production.

The value of additional water depends on the lowest-value use for present supplies.

For example, water for irrigation becomes unaffordable when its price pushes the combined variable costs of production higher than the value of the crop. Assume that water from a new source costs more than the value of water for irrigating alfalfa, but less than the top price municipal users would be willing to pay for household water. The municipal users would get water cheaper by buying out some of the farmers' supply than from that new source. So, the new source would not be developed, even if it were affordable.

At least three factors complicate this pattern: water quality, costs of moving water, and obstacles to free marketing of water and water rights. In general, however, potential new sources of water for Arizona should be considered on the basis of the lowest value of irrigation water rather than higher-value water uses.

Potentials and problems for some water-supply methods are described below. The sequence is not a ranking of feasibility.

Water, Water Everywhere . . .

The arid Southwest could have a virtually endless water supply from the ocean, but the age-old dream of turning seawater into freshwater still looks uneconomical for any large-scale project.

Seawater has a salt concentration of about 35,000 parts-per-million (ppm). Few Arizona farms use irrigation water as salty as 2,500 ppm. Even half that much salinity can lead to trouble on many types of soils and crops. For drinking water, the U.S. Public Health Service recommends a 500 ppm limit.

Cost estimates for treating ocean water vary vastly. In 1968, the U.S. Department of Interior projected a cost of $70 per acre-foot of desalted seawater, assuming the use of a power plant's waste heat and the sale of mineral byproducts of desalinization. Eleven years later, the U.S. comptroller general told Congress that desalinization of seawater would cost $1,400 per acre-foot. Neither figure is adjusted for inflation since its publication, and neither includes transport from the coast.

For landlocked Arizona to benefit from treated seawater would require arrangements with either California or Mexico.

Brackish water, too salty for many uses but less salty than the sea, lies in underground layers beneath parts of Arizona. The Safford, Casa Grande and Buckeye areas, among others, have large supplies of groundwater with 1,000 to 3,000 ppm of salt. Used water, such as irrigation tailwater or industrial effluent, can also be quite brackish. Desalinization of brackish inland water would not increase the state's total water supply, and some farms do irrigate with brackish water, but desalting can improve the quality or quantity of water available for some uses.

A 22-year-old electrodialysis plant at Buckeye produces water with 800 ppm salinity from groundwater about three times that salty. The plant turns out about 3 acre-feet a day for municipal use.

The biggest desalinization project in the United States is scheduled to be running at Yuma within five years. The federally sponsored Yuma Desalting Plant is designed to improve the quality of used irrigation water returning to the Colorado River. Now, that water makes the river saltier than acceptable for the river's flow into Mexico. A reverse-osmosis system will produce up to 270 acre-feet a day of desalted water from the 3,300-ppm drainage water of the Wellton-Mohawk Irrigation District. The U.S. Bureau of Reclamation estimates costs at $190 million initial investment, plus $116 per treated acre-foot (in 1979 dollars).

Desalting of brackish inland water incurs problems in acquiring the brackish water, delivering the treated water, and disposing of the concentrated brine that contains the removed salts. A 1973 study by the Arizona Water Commission tallied up costs of more than $200 per acre-foot for obtaining and treating brackish groundwater in central Arizona, with additional delivery costs for non-local users.

Some University of Arizona scientists are working on another approach to making salty water more useful. They are developing varieties of traditional and potential crops that can thrive on salty water.

Moving Mountains of Water

One source of water from the ocean needs no desalting: icebergs. They yield fresh water with only about 10 parts-per-million of salts. What's more, towing them to California may be cheaper than desalting seawater.

A Rand Corporation study in 1973 figured that preparing, moving and melting icebergs, plus delivering the melt-water to a distribution system on land, would cost about $30 per acre-foot of delivered water. That study and several others in the past decade have outlined ways to move and melt mountains of ice. However, much of the technology for such a project has never been tested, so unexpected costs could be significant.

Proposals favor Antarctic icebergs over Arctic ones. The southern ice cap more reliably sheds big, rectangular blocks of ice, the type sought for towing. One route to California would ride northbound currents along the west coasts of South and North America.

Transport ideas show imagination. The Rand study sees a 50-mile-long train of icebergs with nuclear-powered electric propellers attached to the icebergs. An Army Corps of Engineers study discusses a super tug for towing a 5.3-million-acre-foot iceberg. Other proposals include large paddlewheels on icebergs, an underwater tugboat, or propellers powered by turbines that run on the temperature difference between the melting iceberg and the warmer seawater.

Several environmental impacts of moving an iceberg and mooring it off the California coast have been anticipated. Local weather might change slightly. Adjacent ocean water would be cooled and diluted. A moored berg might break apart or break loose. These and other effects would have to be managed, and several legal issues resolved, before iceberg harvesting could become a continuing water source.

If this water source were ever developed, benefits to Arizona would depend on interstate agreements. California could exchange some of its Colorado River water for Arizona's contribution to delivering higher-quality iceberg water to California.

Greener in the Other Fellow's Yard

More water than in 10 Colorado Rivers pours into the ocean from the Columbia River. That high-quality water has tempted the thirsty Southwest for years. So have the Yukon River of Alaska, the Mackenzie of Canada, and other rivers of the Northwest.

One 1968 report described at least 13 plans developed since 1950 for transporting water to the Southwest (including southern California) from rivers to the north. Two proposals would run undersea aqueducts from Oregon to California. The rest would use more conventional engineering, but on large scale.

The grandest plan would connect most of the major watersheds on the continent into the North American Water and Power Alliance, proposed in 1964. It would include dams larger than any ever built, a reservoir in the Canadian Rockies as big as Lake Erie, and a vast system of canals, channels and tunnels. It would deliver 110 million acre-feet of clean northern water annually to 34 states plus Canada and Mexico, and generate 70 million net kilowatts of hydroelectric power. Construction costs were estimated at $200 billion in 1969 dollars. Arizona would get 12 million acre-feet per year and nine new reservoirs.

Other proposals keep a smaller scale, such as one to supplement the Colorado River by connecting the Yellowstone River to the Snake River and the Snake to the Green, which flows into the Colorado.

Capital-cost estimates from 1971 for several proposals fall in the range of $50 to $100 per acre-foot of Northwestern water delivered to the Colorado River. Besides the capital expense, projects would have costs for operation and maintenance, for adverse side effects, and for compensating the source area for its water. Users in central Arizona would also face costs of delivery from the Colorado River.

Northwesterners' reluctance to giving up water could bottle up any transfer proposal. Environmental impacts in the source, route and destination areas also would reduce the feasibility of such large-scale projects.

Everybody Talks About the Weather, But . . .

Cloud seeding from a ground-based station can increase snowfall on the western slope of the Rocky Mountains. Operational costs would be low: A 1974 study for the National Science Foundation figures on less than $2.50 for each resulting acre-foot of increased flow in the Colorado River.

However, adverse side effects that are predictable could almost double that cost, says the same study. Other environmental impacts might develop from repeated years of extra snowfall, or from buildup of the silver iodide crystals used for seeding. Also, political and legal disputes that could entangle such a project have already begun: Who will pay and be paid for adverse effects? Who will get the water that is produced by seeding?

Winter clouds climbing to cross a mountain range have made the only reliable target for cloud seeding experiments. Seeding on the Rockies' western slope could drop enough extra snow to add about 2.3 million acre-feet to the annual flow of the Colorado River, says the National Science Foundation analysis. Problems with the extra snow might limit this method to a level below the system's potential.

Snow removal, avalanche control, soil erosion, lost work days and risk of spring floods all add to the indirect costs of increasing the snowpack. Users of the increased water supply, possibly including Arizonans, would need to find enough benefit in the arrangement to afford paying for compensation or control measures. If the increased river volume reached all the hydroelectric plants on the Colorado River, it could generate about $2 worth of electricity per acre-foot, almost enough to cover direct costs of seeding.

Environmental effects of increased snowpacks could be monitored for early warning of unacceptable damage. The low start-up costs for cloud seeding would allow adjustments in activity level without loss of much investment.

With risk management built in, a project to increase snow in the Rockies might well produce benefits that outweigh costs, but the institutional and legal problems of sharing the costs and benefits could prevent the project. Also, even if more snow melt did add to water supplies in the upper Colorado River basin, increasing water use there might keep Arizona from gaining anything.

Cloud seeding has also been tried within Arizona to build up local water supplies. Dr. Louis J. Battan led a University of Arizona research project from 1957 to 1964 to try to increase summer rain in the Santa Catalina Mountains. This year, the Salt River Project started a study of winter storms over the headwaters of the Little Colorado, Gila, Salt and Verde rivers, with an eye on potential cloud seeding during drought periods. However, cloud seeding's success varies with atmospheric conditions, and its feasibility in Arizona is still uncertain.

An Acre-Foot Saved, An Acre-Foot Earned

Scoop up water in your hands and some will trickle through your fingers before you can drink it.

On a larger scale, some water that has been caught in reservoirs disappears before people use it. One way to increase Arizona's water supply would be to reduce the loss of water already "in hand."

About 15 percent of the Colorado River's flow evaporates off the surfaces of lakes Powell, Mead, Mohave and Havasu. That loss not only robs the Southwest of 2 million acre-feet of water every year, it also raises the salt concentration of the water that is left in the river.

Surface evaporation depletes smaller water supplies, too. In the Phoenix area, an acre-foot of water can vanish each year from every one-sixth acre of exposed surface.

Seepage losses through the bottom and sides of reservoirs and canals probably exceed surface evaporation. However, seepage is difficult to evaluate because water that seeps out of one supply may reach another available supply downstream or underground.

Either cooling or covering a surface of water reduces evaporation from it.

The lower layers of deep reservoirs can provide a source for cooling the top layer, but warmer water is lighter so it stays on top. The layers can be mixed by pumping air to the depths and letting it bubble up, or by large-scale mechanical stirring. Both methods have worked in water-quality improvement projects on some reservoirs, but have not been tried on the scale of the Colorado River's large lakes. On those lakes, 5 degrees F of surface cooling could slow water loss by about one-fifth. Further cooling could give further savings.

On Lake Powell, 140,000 acre-feet of evaporation could be stopped by artificial mixing of layers, a 1974 Utah State University study con-

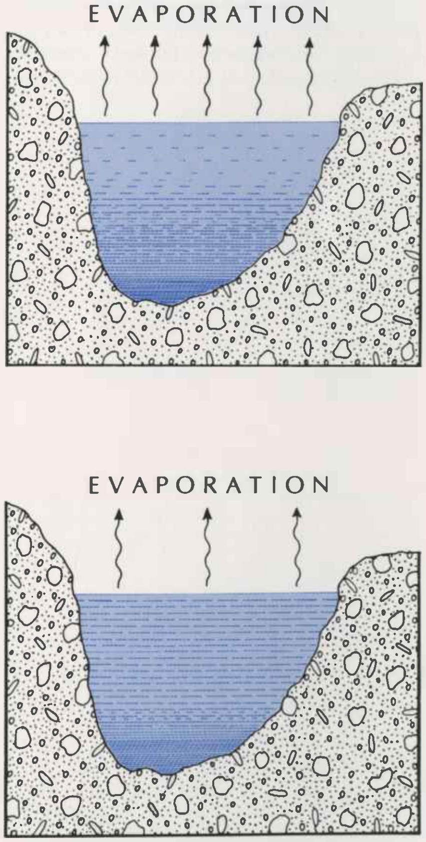


Figure 8: Reducing Evaporation from Lakes. Warmer surfaces give faster evaporation. Lakes in warm climates tend to get permanently stratified with warm water on top, cold water below and a distinct boundary between the layers. Stirring up the lake can cool the surface, thus reduce evaporation.

cluded. The mixing, called destratification, would cost $1 to $2 per acre-foot saved, said the same study.

If the salvaged water were run through the hydroelectric plant at Glen Canyon Dam, the electricity it generated would more than repay that estimated cost of mixing. Further benefits could result from hydroelectric use downstream, from lowered salinity of river water, and from the improved habitat for some fish in the lake due to deeper distribution of dissolved oxygen. Similar costs and benefits would apply to destratification of reservoirs lower on the Colorado.

The UA Water Resources Research Center, in 1979, ranked this method as the most feasible of 13 possible ways to increase the Tucson area's water supply. Delivery costs could be the same as for other water carried by the Central Arizona Project. The legal apportioning of different regions' claims to any water saved through destratification could pose a problem, though.

Researchers have checked two categories of surface coverings to reduce evaporation losses in the Southwest.

Film-forming chemicals, such as long-chain alcohols, can spread themselves evenly across the water surface. However, windblown turbulence lowers their effectiveness on large lakes, and floating rafts appear more efficient than films at slowing evaporation from small reservoirs.

Floating rafts, such as sheets of polystyrene foam, can stop more than 90 percent of evaporation from the surface they cover. Dr. Brent Cluff of the UA Water Resources Research Center has estimated costs of $10,000 to $15,000 for covering one acre with silicone-coated rafts. He has also developed dual-purpose rafts with photovoltaic cells to turn sunlight into electricity.

Research on reducing seepage losses from water supplies has identified many types of linings that can seal the bottom and sides of reservoirs and canals. Sheets of plastic or rubber, or layers of asphalt or concrete can do the job. Treatment with salt or other chemicals can also seal some types of soils.

Most canals and irrigation ditches in Arizona are lined to stop seepage losses. However, the economy of lining reservoirs depends on the value of water in the reservoir, which can vary greatly with quality and availability.

Managing Vegetation for More Streamflow

Eighty million acre-feet of rain and snow fall on Arizona in an average year. Only about 2 million acre-feet reach the nearest stream – about half a jigger for every gallon of rain. Almost all the rest evaporates out of the top few inches of soil or from plants.

The amount of streamflow in some areas of the state can be increased by altering plant growth. Clearing or thinning of deep-rooted trees and shrubs has doubled or tripled water yield in tests on several experimental watersheds. In some, the cleared vegetation was replaced with grasses or other shallow-rooted plants.

UA watershed hydrologist Dr. Peter F. Ffolliott and former colleague Dr. David B. Thorud, in a 1974 report, conclude from such tests that ponderosa pine forests, chaparral areas and mixed-conifer forests have the best potential for water-yield increases. Manipulations in those areas could increase the state's water supply by up to 1.2 million acre-feet, but balancing water yield with other uses for the same lands will prevent reaching this theoretical upper limit, they say.

In ponderosa pine forests, well-planned clearing or thinning can improve timber production, habitat for some wildlife, and forage growth for livestock and wildlife, as well as water yield. Taking multiple-use planning into account, Forest Service hydrologist Alden R. Hibbert estimates one-half acre-inch of potential increase in water yield from each treated acre of ponderosa pine forest.

Similarly, clearing or substantial thinning of areas within mixed-conifer forests can increase water runoff by about 1.5 acre-inch per acre, by Hibbert's multiple-use estimate.

Arizona has about 5 million acres of ponderosa pine forest and a quarter million acres of mixed-conifer forests. The fraction suitable for treatment depends on precipitation levels and ownership, as well as multiple-use considerations.

Management of forests for increased water yield has passed the experimental stage. Sections of forests are cut primarily for lumber, not water, but the way cutting is planned takes account of effects on water runoff, Ffolliott emphasizes. A Forest Service estimate says that ponderosa pine forests in the Southwest now yield 40,000 to 50,000 more acre-feet of water per year than they did before commercial lumbering began on them.

In chaparral areas, water yields climb when brush is removed and grass is grown in its place. Controlled burning, mechanical uprooting, herbicides and combinations of those methods have been used to clear chaparral in test watersheds. In some tests, washes that had carried water only intermittently became year-round streams. Converting dense brush to grass also improves food supply and mobility for livestock and some wildlife.

Estimates vary for possible increases in water yield through treatment of chaparral. Hibbert estimates 2.4 acre-inches per acre with multiple-use managment. His 1974 analysis judged treatment to be economical for about one-third of the 850,000 acres of chaparral in the Salt and Verde river basins. In the treated areas, about half the acreage would be converted to shallower-rooted plants and half left as chaparral. Arizona has about 3.5 million acres of chaparral.

In chaparral areas as in forests, water yield benefits alone do not pay for treatment costs, but chaparral managed primarily for livestock and wildlife benefits can yield extra water as a planned byproduct.

Another vegetation type may offer the chance for the biggest per-acre effects on streamflow. It is the water-gulping trees such as salt cedar, sycamore and cottonwood that grow along streambanks and in moist areas. Tests indicate savings of up to 2 acre-feet of water a year for every acre converted to shallower-rooted plants. However, consideration of other values, such as recreation and wildlife, makes extensive conversion unlikely.

A Forest Service researcher collects a sediment sample at a streamflow-measuring flume. The stream is in an area of pinyon-juniper forest treated to test effects of partial clearing on streamflow. (Photo by Malchus Baker Jr., U.S. Forest Service.)

Local Rain: Catch as Catch Can

Water harvesting is a trade of land for water.

The basic technique has centuries of history: Use one area as a sloped catchment surface for rainfall and direct the runoff from it to another area for use or storage. Modern research has shown how to get collection efficiency close to 100 percent.

Untreated catchments in desert areas shed as little as 3 percent of the rain that falls on them. Removing vegetation and compacting soil can raise that efficiency to about 30 percent until the plants grow back.

UA soils scientist Dr. Gordon R. Dutt has refined salt-treatment methods for water harvesting at the university's Page Ranch vineyard and elsewhere. In the right soils, salt reacts with clay particles to seal the surface and bind the salt. It can bring runoff efficiency to about 80 percent and inhibits regrowth of plants on catchment surfaces.

Soil surfaces that have been treated with wax mixtures, coated with asphalt, or covered with a layer of rubber, plastic or metal can shed 85 to 100 percent of the water they catch. USDA hydrologists Dr. Dwayne H. Fink and Dr. William L. Ehrler have tested wax treatments to supply water for plantings of Christmas trees, jojoba and other crops. UA watershed scientists Dr. John L. Thames and Dr. C. Brent Cluff used an asphalt coating for a water-harvesting project on coal mine spoil heaps at Black Mesa. Gary P. Nabhan of the UA Office of Arid Lands

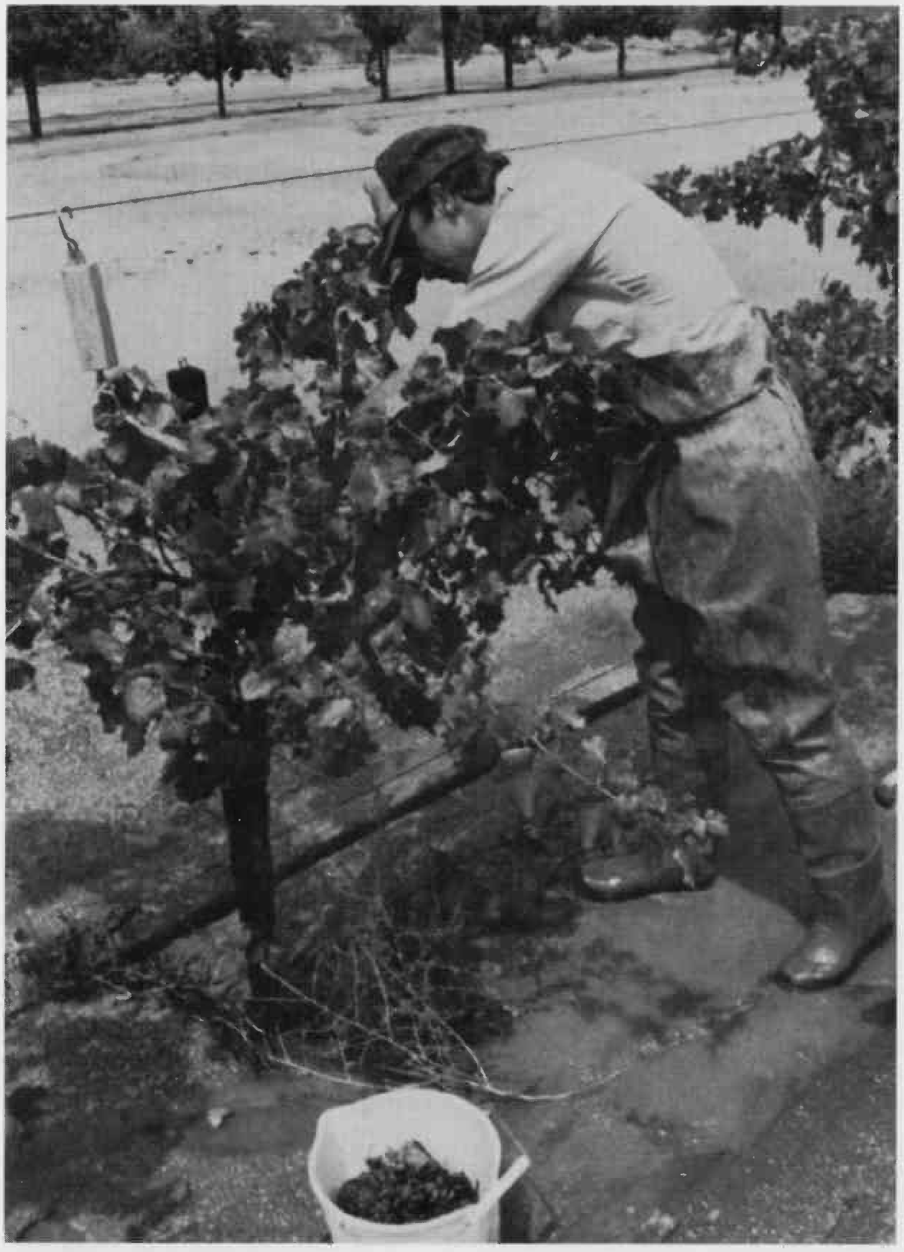
After a brief summer rain at Page Ranch, runoff from a water-harvesting system irrigates grapevines. The vines can also be watered through drip-irrigation tubing with water from a pond that stores extra runoff. (Photos by Ted Bundy.)

Studies is studying variations of the Papago Indians' traditional runoff-farming methods.

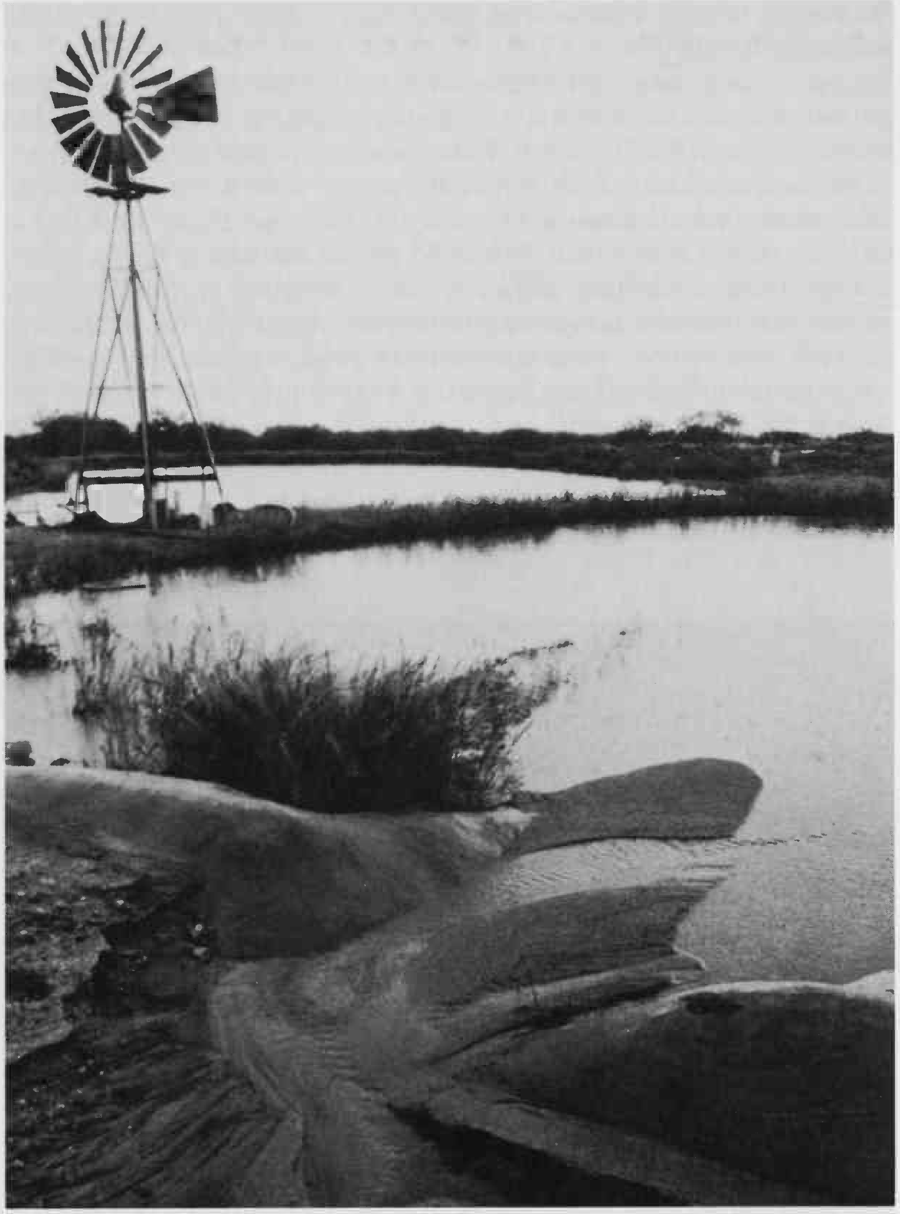
Costs of preparing salt-treated or wax-treated surfaces have each been estimated in the $350 to $400 range for the amount of land needed to harvest an acre-foot of water from every 12 inches of precipitation. Land costs are extra. Dutt forecasts decades more service from salted catchments that are already 10 years old. Fink and Ehrler hope for at least 10 years life for their 3-year-old waxed surfaces at Camp Verde.

Even from salt-treated surfaces, water harvesting provides less-salty water than most groundwater or river water. Small and moderate sized projects, with runoff water used on-site, present fewer environmental and political problems than large-scale water supply projects, and avoid long-distance delivery costs.

For years, water harvesting has filled some remote livestock watering



Research technician Dale Stevens harvests pinot noir grapes at the Page Ranch vineyard. The wide spaces between rows of vines are treated with salt to boost runoff.



Runoff that does not soak into crop rows at Page Ranch ends up in storage ponds. The wind pump can lift the water to an uphill tank for later use in irrigation.

tanks in Arizona, which also supply water to wildlife.

Another use in the state, mostly experimental so far, is for irrigating small plantings of horticultural or field crops. The areas most suitable for runoff farming are where water is expensive, land is not, and the soil holds water well. Much land of that sort is used for cattle ranching. Dutt figures that his two-tons-per-acre of grapes growing on runoff at Page Ranch make the land about 100 times as productive as it would be for growing beef at a good capacity of one cow and calf per 64 acres.

The College of Agriculture and City of Tucson have begun a water-harvesting project in Avra Valley to gauge the system's economics on formerly irrigated farmland. The test is on land that the city purchased for its groundwater supply.

In another application of water harvesting, runoff caught from roofs or paved surfaces in urban areas can be directed to garden or landscape irrigation. Or it can be stored (remember rainbarrels?) for later use.