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We must change our water policies so that the cost of this resource reflects its value.

WATER

Not as Cheap as You Think

HUMANITY uses a little less than half the water available worldwide. Yet pockets of shortages and droughts are causing famine and distress in some areas, and industrial and agricultural by-products are contaminating water supplies. Since the world's population is expected to double in the next 50 years, many experts think we are on the brink of a widespread water crisis.

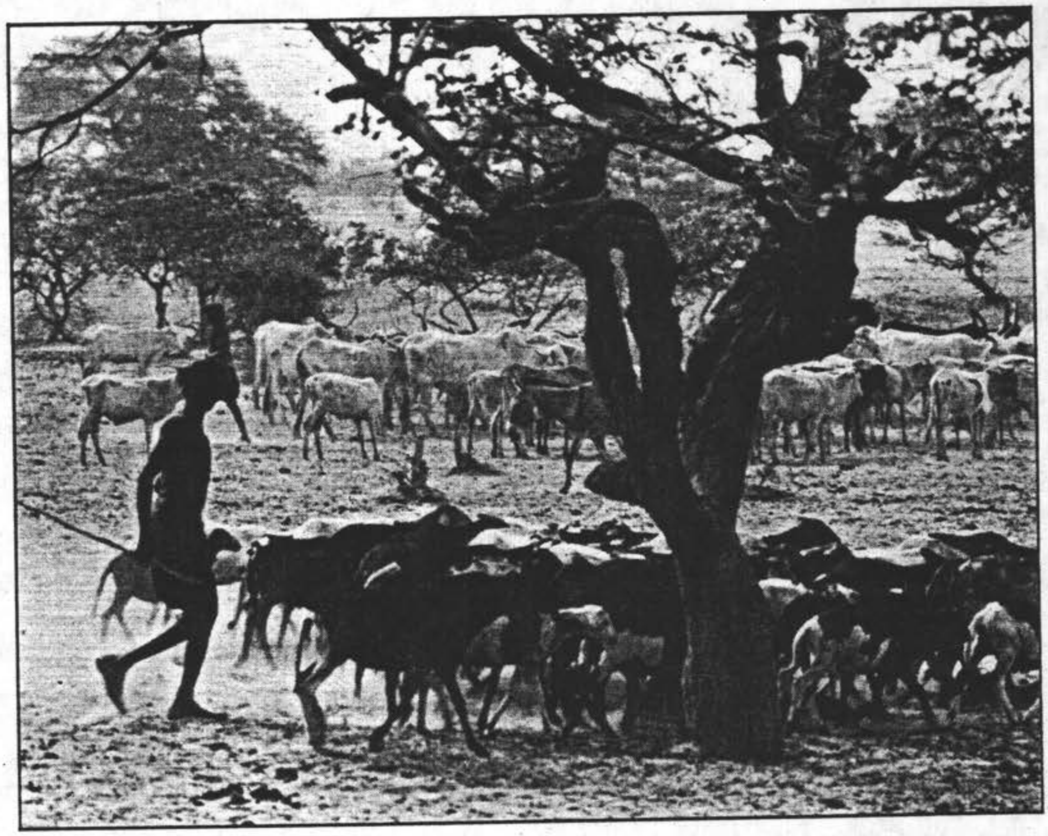
But that doesn't have to be the outcome. Water shortages do not have to plague the world—if we start valuing water more than we have in the past. Just as we began to appreciate petroleum more after the 1970s oil crises, today we must start looking at water from a fresh economic perspective. We can no longer afford to consider water a virtually free resource of which we can use as much as we like in any way we want.

Instead, for all uses except the domestic demands of the poor, governments should price water to reflect its actual value. This means charging a fee for the water itself as well as for the supply costs.

Governments should also protect this resource by providing water in more economically and environmentally sound ways. For example, often the cheapest way to provide irrigation water in the semi-arid tropics is through small-scale projects, such as gathering rainfall in depressions and pumping it to nearby cropland. Constructing large dams, on the other hand, often causes large-scale environmental damage and is more expensive than the use justifies. In fact, it is not economical for all regions to irrigate. Some countries would do better to import food than to undertake very expensive water projects.

PETER ROGERS

PHOTO: DEWITT JONES, WOODFIN CAMP & ASSOC.



Many areas can count on receiving less than half their annual average water supply in any one year.

No matter what steps governments take to provide water more efficiently, they must change their institutional and legal approaches to water use. Rather than diffuse control among hundreds or even thousands of local, regional, and national agencies that oversee various aspects of water use, countries should set up central authorities to coordinate water policy. Even some of the driest, poorest countries that have recently had significant population increases, such as Chad, Mali, and Kenya, could supply more water to their people if they changed some of their approaches to managing water.

Water, Water Everywhere

How much water is available around the world? Soviet geographer M.I. L'vovich, who has done the most comprehensive studies in the last two decades, estimates that total annual global precipitation is about 126,000 cubic miles. That's some 44,000 times the annual average flow of the mighty Colorado River at Yuma, Ariz. Unfortunately, 78 percent of this precipitation, or almost 99,000 cubic miles, falls over the oceans and cannot be readily used. Of the remainder, 64 percent evaporates, leaving only 10,000 cubic miles available each year as surface runoff or groundwater. Most of that runs directly to the sea during floods; rivers and reservoirs can be counted on to store just 3,000 cubic miles. Realistically, that amount should be whittled down even further to 2,000 cubic miles, since 1,000 cubic miles are available only in sparsely inhabited regions of the world.

But this global picture does not tell the whole story, for water is not always a reliable commodity. Some regions may experience droughts for years, or seasonal dry spells followed by heavy rains. Cherrapunji, Assam, in eastern India, for example, recorded 22 meters of rainfall in a year. Yet no rain fell in one 14-year period at Iquique in the Chilean desert. Many areas can count on receiving less than half their annual average water supply in any one year.

Most experts base their estimates of how much water is available on annual precipitation and water flows. However, the amount of water available also depends on how much people are willing to pay for it—which is determined by its scarcity. For example, in the Middle East much more water has become available since the 1950s because people have been willing to pay up to ten times more for it than residents of wetter climates. In that arid region, water is properly considered a very scarce resource, and people have traditionally had limited water supplies. But as money has been pumped into the area, many countries have financed major water-supply projects. Saudi Arabia, for example, has built extremely costly plants to desalinate ocean water. Libya is spending billions to pump out "fossilized" water that was deposited tens of thousands of years ago under what

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is now desert. This water is expected to be transported to Tripoli and coastal Libya beginning in the early 1990s via a huge pipeline now under construction.

Consumers in areas where water is more plentiful treat it as if it were virtually free, with plenty for all. Indeed, adequacy of the water supply has historically been a major component in the decision of where to locate a town or industry. As a result, most cultures do not assign a cost to the water itself, in addition to charging for storing, transporting, and treating it.

This omission obscures the competition that exists for water. In addition to basic human needs for water, practically all industries rely on the resource. It is used to produce electricity and to dispose of wastes. And there could be no agriculture without water. In fact, far more water is used for agriculture than for any other purpose today. In the United States, for example, agriculture accounts for 83 percent of the total annual water consumption. Unfortunately, farmers often use water very inefficiently, and governments frequently encourage these wasteful practices by subsidizing the cost of irrigation.

For example, through its Salt River project, the U.S. Bureau of Reclamation supplies water to farmers in the Phoenix, Ariz., area for highly subsidized rates—as little as $8 per acre-foot (the amount needed to cover one acre a foot deep, about 325,000 gallons). City residents and industries would gladly pay much more, since the public water utility will soon have to expand the municipal water supply at a cost of more than $300 per acre-foot. But the federal government granted farmers access to cheap water to encourage farming long before Phoenix became part of the Sunbelt boom.

The uncoordinated policies of myriad water agencies also result in inefficient water use. Few countries have clearcut policies concerning water use and pricing, the most effective means of promoting conservation. Agencies often set water prices according to political expediency rather than the costs of supplying it. The United States, for example, has at least 27 federal agencies involved with water authorities in every state, more than 59,000 water-supply utilities, and thousands of county and local organizations. Some oversee various kinds of actual water use, while others focus on the origins of the water supply, such as rivers or the ground.

Slipshod organization is also common in other countries. In India, the use of surface water is administered by the Central Water Commission, while the Central Groundwater Board oversees groundwater use. There is little practical integration of these agencies' plans, despite a formal agreement to cooperate. Each of India's 18 states also has its own department of irrigation, which usually deals only with surface-water supplies, while other departments focus on groundwater. In cities, municipal water is a local responsibility, but many individuals also sell water in small quantities to households. Rural households are almost always in charge of obtaining their own supplies. The result of such compartmentalization is that agriculture, industry, and municipalities use water inefficiently.

PHOTOS: UNITED NATIONS, WORLD BANK

World trade can redistribute water in the form of grain to nations that decide not to grow it.

Mishandling Irrigation Prices

Consider how several water management agencies have mishandled the pricing of irrigation water:

In the Sierra foothills near Sacramento, Calif., stands the partially built Auburn Dam, conceived by the U.S. Bureau of Reclamation in the 1960s and expected to cost $200 million to $300 million. In 1980, that agency proposed to average the cost of the water from the Auburn Dam with the cost of the rest of the water it supplies to area farmers. That would mean charging about $18 per acre-foot, even though the actual cost of the water supplied by the new dam is expected to be about $200 per acre-foot. One can justify irrigating almost any crop at $18 per acre-foot, but no crops can be grown economically at $200 per acre-foot. Construction was halted on the dam in 1984 after public protest at subsidizing such projects.

Today, the Bureau of Reclamation is looking for outside partners to share the dam's cost. If the project is finished, the water will likely sell at $200 per acre-foot—not to farmers but to municipalities, which should find that an attractive price since individuals need much less than farms. The bureau had to obtain special permission from its commissioner to reallocate the water for domestic and industrial uses.

In the Indian state of Bihar, the charges for the irrigation water that comes from river diversions and dams are so low and the attempts to collect the fees so feeble that the irrigation department is in serious financial difficulty. In 1979, efforts to collect fees for water cost 117 percent of the actual amount collected. The irrigation department has had to defer maintenance because of low returns, and the water system has deteriorated. Farmers have less incentive to pay for poor service, and a vicious circle has developed. Moreover, the low water charges have led farmers to use water inefficiently.

By contrast, in both the Punjab region in India and in areas of the United States that rely on water from private wells, farmers are far more conservative in how much they use because they pay higher prices. (Well water costs more because it is not subsidized.) Yet these farmers' crops aren't doomed to failure. When the cost of pumping in the Punjab increased in the 1960s, farmers began growing more water-efficient crops such as high-yielding wheat and cash crops such as cotton, tobacco, and oilseeds.

Such crop reallocations could benefit arid regions around the world. There is no reason why every country should grow grain, which requires, per ton, 2,000 to 3,000 tons of water. Where there is comparatively little water, it can have much higher value for other uses.

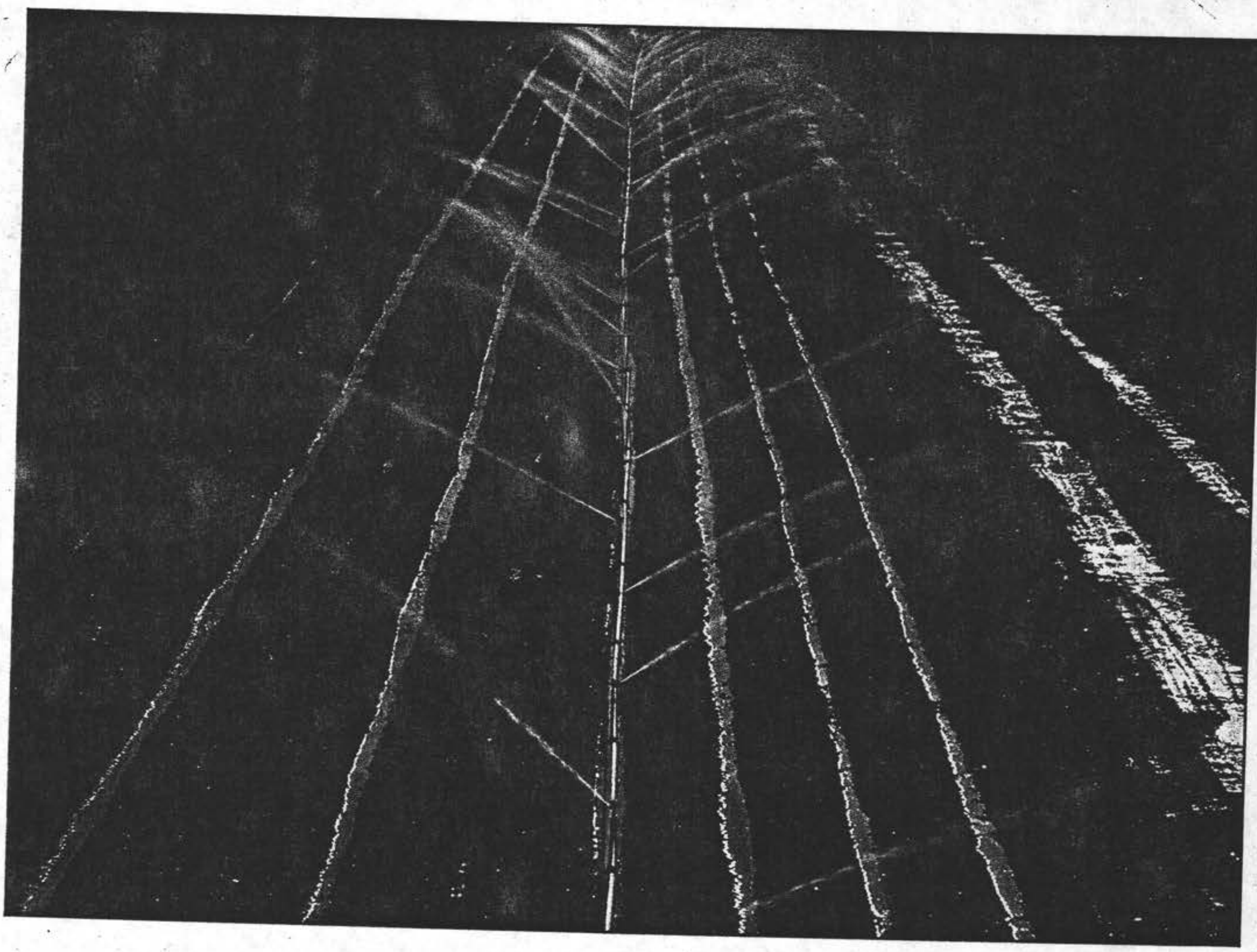
International trade can redistribute water—in the form of grain—to nations that decide not to grow it. Israel subscribes to this practice, emphasizing valuable cash crops such as fruits, vegetables, and flowers for the European market. Countries that take this approach should maintain stockpiles of the basic grains, since even though these are costly and can deteriorate, replacing spoilage is less costly than growing grain. Such nations should grow a diversity of cash crops so changing prices cannot devastate their economies.

In addition to changing the crops they grow, farmers who pay high prices for water regulate the amount of water they use, depending on the times when their crops need it most. They build catch pits to collect and recycle the run-off from irrigation systems. Some farmers in the Punjab even use lasers to level their fields so water won't collect in puddles. In some cases farmers who employ more efficient watering mechanisms save so much of the resource that they can grow water-intensive crops such as rice in addition to their other crops.

The efficient watering technologies available to farmers include drip, center-pivot, and spray systems. In drip irrigation, water flows through an underground plastic pipe to an outlet near the root zone of each plant. Crops usually absorb more than 90 percent of the water in this system, which is most useful for crops spaced far apart, such as grapes. More than 70 percent of the South African grape crop is irrigated in this manner.

Center-pivot irrigation systems consist of large pipes that rotate on wheels at ground level, spraying water downward in large circles up to a half-mile in diameter. Center-pivot systems, which reach efficiencies of more than 70 percent, have turned many areas of the Libyan desert green. Spray irrigation systems spread water directly onto crops from stationary nozzles at or above the plants' level. Plants can use 60 percent to 75 percent of the water applied this way.

Flooding, one of the most widely used irrigation systems in the Third World, is typically much more wasteful than other techniques. While flood irriga-



tion can work very well on level fields and with crops such as rice that need plenty of water, plants often use as little as 30 percent of that supplied. In furrow irrigation, another common and wasteful technique, water is sent through furrows between the crops. In this case the plants absorb as little as half the water.

No matter what technology is available, farmers should not necessarily irrigate their crops—despite what government planners and international funding agencies often think. Recent data collected by the World Bank on nine sub-Saharan nations—Kenya, Ethiopia, Somalia, Chad, Niger, Upper Volta, Mali, Mauritania, and Senegal—show that the capital costs for large irrigation dams and diversion projects are too expensive for the returns. Farmers in these countries would need to produce about three tons more wheat and rice per irrigated acre than per unirrigated acre to justify the project investments, a highly unlikely increase. These costly engineering projects probably would not be attractive even to help farmers produce other cash crops.

Such a situation presents a development problem without an easy answer. Countries that don't produce all their food have to buy it, but that requires income, which rural countries generate through ag-

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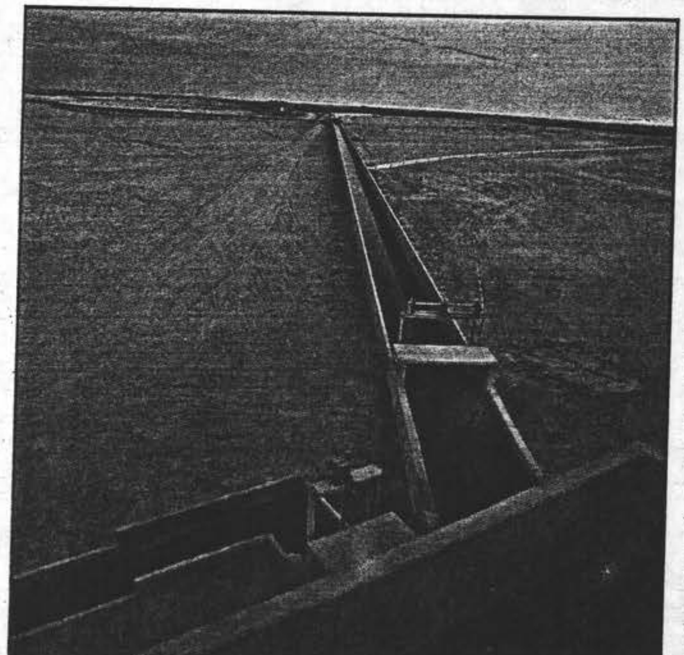
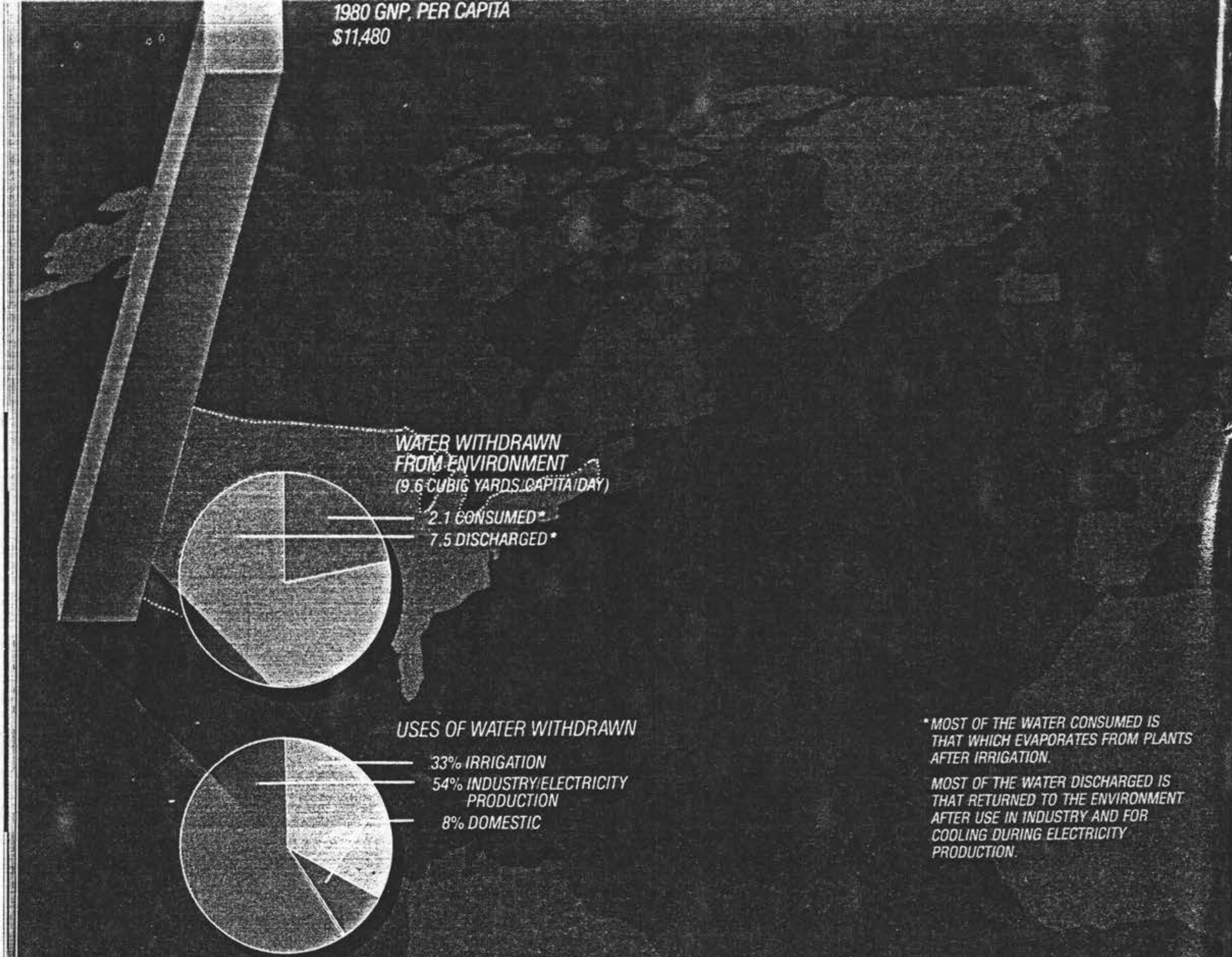


Top: Spray irrigation in Colorado. This technique is typically less wasteful than flooding crops. Bottom: A Saudi Arabian irrigation system contrasts with the desert. Irrigation in dry areas is often best used for crops more valuable than grain.



	UNITED STATES	SOVIET UNION	INDIA	CHINA
POPULATION (1980)	227 MILLION	266 MILLION	689 MILLION	983 MILLION
TOTAL WATER CONSUMPTION (CUBIC YARDS/DAY)	494 MILLION	585 MILLION	791 MILLION	1,032 MILLION
WATER PROGRAM EXPENDITURES (1979, PER CAPITA)	$185	$25	$5.90	$.50
PERCENT OF CROPLAND IRRIGATED	13%	9%	40%	37%

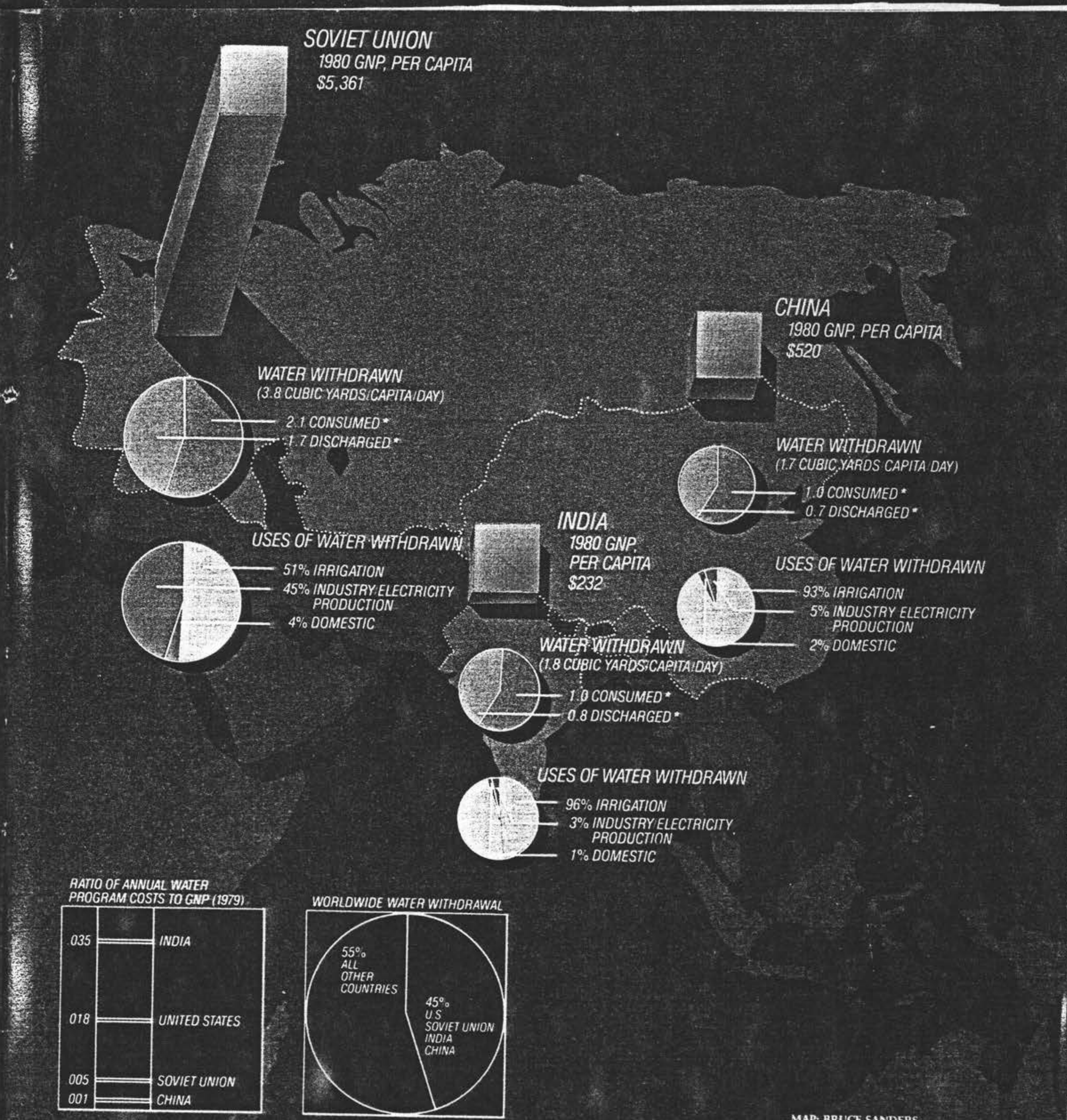
The World's Largest Water Users

THE press often focuses on severe water shortages in small countries such as Mali, Chad, and Niger. But it makes more sense to examine the four countries that contain the bulk of the world's population and land area, since each of these nations—China, India, the Soviet Union, and the United States—also faces water-supply and wastewater disposal problems. Together these countries account for 49 percent of the world's population and 70 percent of the globe's irrigated land.

The level of affluence seems to determine the types of water problems a country can expect. As per capita GNP increases, a country finishes developing the infrastructure for delivering irrigation water and spends more money on controlling water pollution and, to a lesser extent, on developing municipal water supplies. And its water use increases. The United States, for example, withdraws more than twice as much water per person as the Soviet Union, and five times more than either China or India.

These are the major water problems faced by China, India, the Soviet Union, and the United States:

□ China, with the world's largest population, has a very small amount of cultivated land per capita—about one-



MAP: BRUCE SANDERS

third of an acre, compared with about one and three-quarters acres in the United States and more than two acres in the Soviet Union. So the Chinese government's water policies focus on maintaining and developing the country's irrigation and flood-control systems. The Chinese have been cautiously increasing their irrigation capacity through low-cost, small-scale projects like wells.

The water demands of industries and municipalities are limiting the expansion of irrigation supplies from groundwater, however. So now China is debating whether to build a $20 billion dam that would transfer water from the Yangtze River basin to the Yellow River basin. This dam would be the world's largest, and would have enormous environmental consequences. As many as 3.3 million people would have to move from the area, and diverting the world's most silt-laden river would cause major silting and erosion problems, including the blocking of upstream irrigation canals. Downstream bridges could collapse because of erosion around their abutments.

China faces another problem in the vicinity of Beijing and Tianjin, where more water is being drawn from the ground than is replenished by rainfall. In some places the underground water level is dropping as much as 12 feet

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a year because of the extensive pumping for irrigation and industrial uses. This can't continue for very long. Not only does pumping become very expensive as water supplies are depleted, but in areas with clayey soil the land can start sinking.

Beijing and Tianjin will also need to spend substantial amounts on water treatment soon, since the amount of polluted water they generate has increased 2,900 percent in 30 years. Shanghai is also beginning to suffer from severe water pollution.

China is experiencing very rapid increases in domestic water demand. In 1978, Beijing residents used 40 times more water for domestic purposes than in 1949. Sharp increases in per capita income have led to the use of more appliances, which in turn has raised the average consumption to about 38 gallons per person per day. Concerned officials are trying to control demand by raising prices.

Of the four countries, China's water-management efforts appear to be the best organized because its per capita expenditures for water programs are relatively low. But that is partially a function of China's accounting system. Two years ago, for instance, the construction of a three-and-a-three-quarter-mile water tunnel was counted as a defense expenditure instead of a water program.

☐ India faces the major task of improving the efficiency of its water system. The country is spending about twice as much on water-resource programs relative to GNP as the United States. India, with the world's second-largest population, also has not been able to obtain high yields on its irrigated fields. In the late 1970s, it was producing less than one ton of crops per irrigated acre—less than half the amount grown by the Chinese on their irrigated land. The Indian government's planning commission has blamed this poor showing on delays in completing irrigation projects, and on farmers who overwater and waste the resource. Also, India's irrigation systems, which are based on river diversions, store very little water. Hence, the least amount of water is available during dry spells when water demands are highest. Where possible, it would be better to store water underground.

Despite better crop yields on land irrigated with water from relatively small private wells, Indian state governments are committed to developing large reservoirs and public well systems. Such investments have not proved effective in the past because of their large capital costs and, more important, failures in public management. And India plans to almost double the amount of irrigated cropland by early next century.

That effort would not be needed if the nation improved its current irrigation works. The amount of water available would stabilize if groundwater were pumped into canals before the monsoon season, so that the ground could soak up more water during monsoons. Also, insuring timely delivery of water to all farmers and increasing water charges would help double production on existing irrigated land. If the water system does not become more efficient, by 2005 all available surface and groundwater resources will have to be devoted to irrigation.

Today India spends most of its water budget on irrigation supplies. But the country also needs to improve its domestic water supplies for a population expected to rise to a billion people by the turn of the century. Currently, not enough clean water is available for the population. Water contamination from leaky sewers and dirty storage vessels is a serious problem in New Delhi, Bombay, Calcutta, and other cities. So far, the costs of conventional waste treatment have been too high to justify the expenditure compared with other public projects. This will have to change in the near future, however. Bombay is already involved in an ambitious wastewater-treatment program, involving collection and primary and secondary treatment.

☐ Although the Soviet Union is endowed with more precipitation than any country except Brazil, 80 percent of its people live in areas that receive just 40 percent of the water. The country's grain production is uneven from year to year. Plus, as much as 40 percent of Russia's irrigated land may be contaminated by salt, owing to poor management of soils with naturally occurring salt beds. Crop yields on salt-damaged soil are less than a third of those on well-managed soil.

To prevent massive salt concentrations deep in the ground, farmers have to place terra cotta drains under their fields, with attached pipes leading to rivers. This doubles the cost of irrigation systems.

The Soviet government has recently halted several major irrigation projects that would have reversed the direction of three major Siberian rivers to send more water south to grain-producing central Asia. The projects, conceived as a way to increase crop production, were stopped primarily because of their costs. The largest diversion would have cost an estimated $30 billion to $40 billion. There was also outcry among Soviet scientists about such environmental effects as temperature changes and nutrient losses in the Arctic Ocean.

Industrial and domestic water pollution is also becoming severe in the Soviet Union. But the country has allocated only a small percentage of its total water budget to deal with the problem.

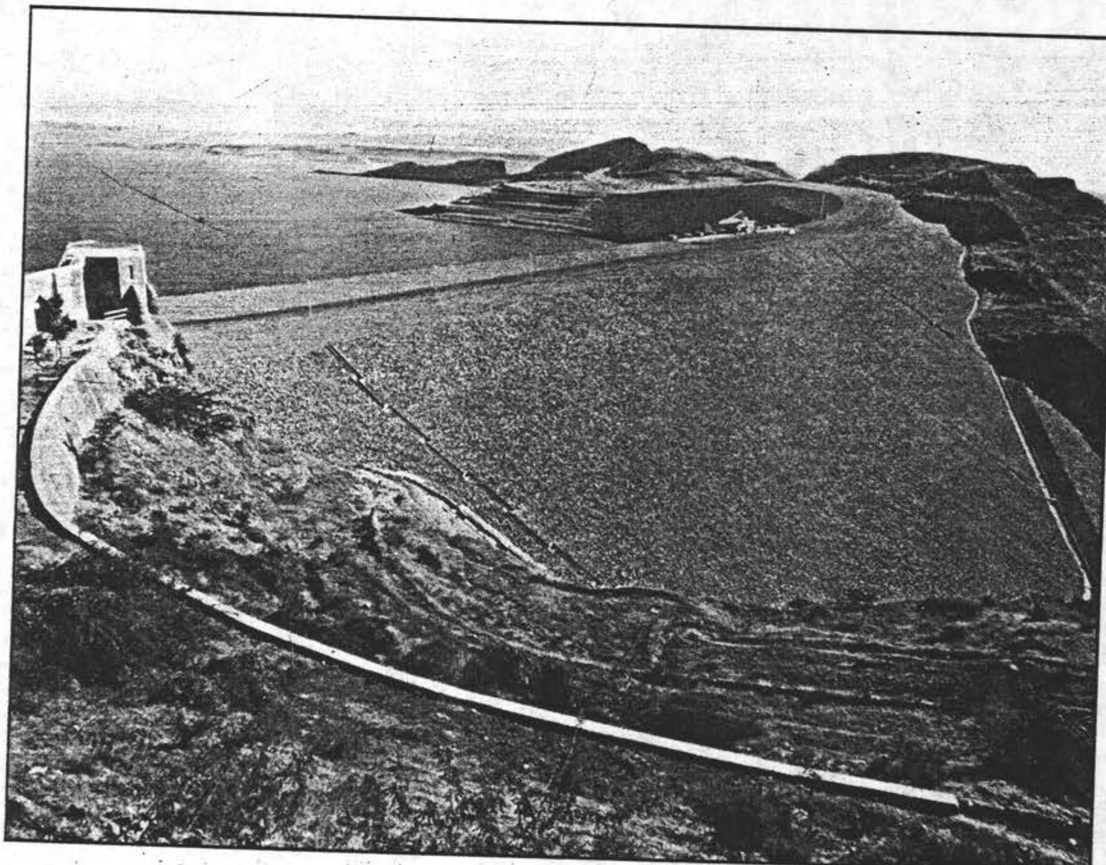
☐ The United States is the only one of the four nations that does not have to worry about increasing irrigation supplies. By the mid-1970s, it had more than twice the irrigated cropland it will need for domestic and export agriculture in the year 2000, according to an estimate by Iowa State University's Center for Agriculture and Rural Development.

The United States actually needs to reduce its amount of irrigated land, since farmers draw 20 billion more gallons of water daily from underground aquifers than can be replenished by rain. This situation cannot continue for long. Indeed, some farmers on the Texas high plains above the giant Ogallala aquifer have already stopped irrigating their crops, since the cost of pumping from the declining water table has become too great. They are returning to ranching or growing crops that need less water, such as dryland wheat.

Of the four countries, the United States has the most serious water pollution problems. Nearly half the water discharge is polluted with human or industrial wastes. The remainder is polluted with waste heat, which, depending on where it is released, may cause environmental problems. Indiscriminate chemical-waste dumping has contaminated some aquifers, a problem concentrated in older industrial areas in the East. Recently, almost 60 percent of the nation's water expenditures—$185 per capita in 1979, or more than that year's per capita GNP in India—has gone to clean wastewater. Affluence and effluents go together!

—*Peter Rogers* ☐

As an alternative to building large dams, water can be stored underground in the soil.



riculture. Their best option is to use many inexpensive, small-scale irrigation techniques, such as small pumps that can provide irrigation for one or two farms apiece, to grow as much food as possible. Investing in expensive irrigation projects such as pumping systems that service hundreds of farmers only makes the economic situations of very poor nations worse.

Increases in water prices affect users differently depending on the original water price. In 1970, B. Delworth Gardner of the University of California at Davis estimated that a 10 percent water price increase in California's San Joaquin Valley would cause only a 5 percent decline in water use when the original price was $4 per acre-foot. But in areas of California where the water initially cost $17 per acre-foot, a 10 percent price rise the same year would result in a 20 percent drop in use.

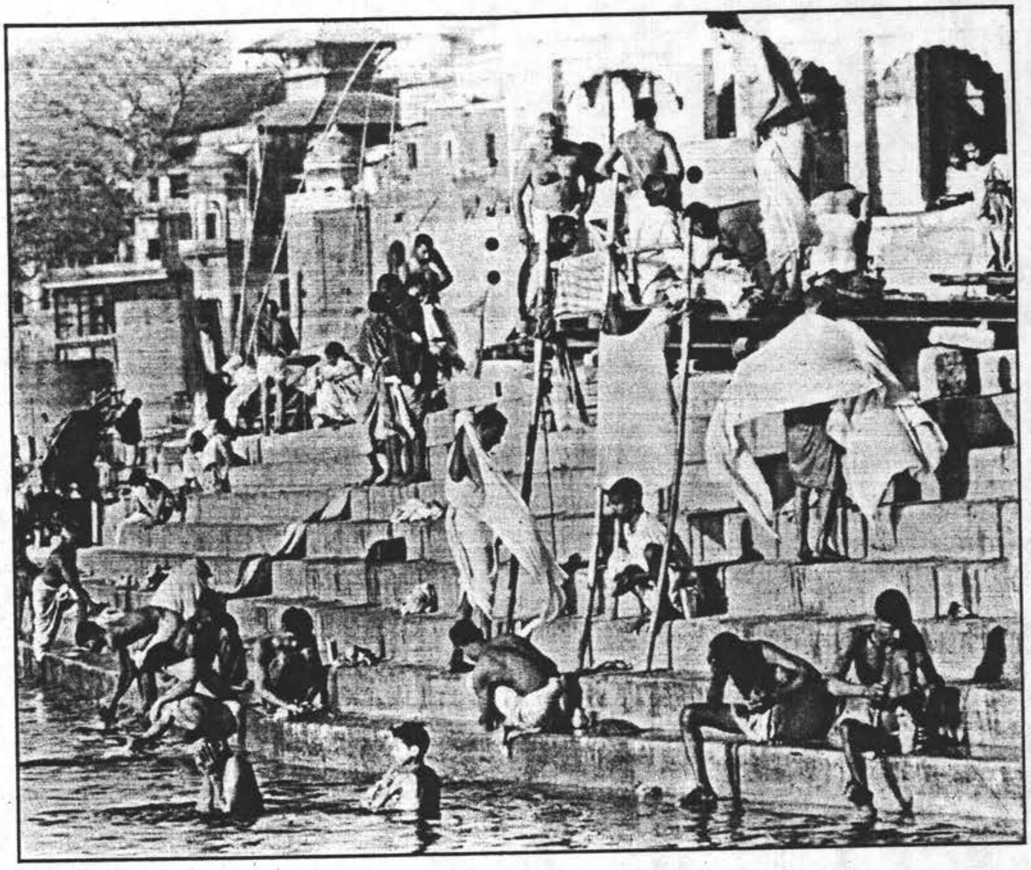
Cooling Off Industrial Use

Industry uses only 5 to 10 percent of all water supplied but still represents an important segment of demand. That's partly because industrial processes pollute a disproportionate amount of water. In Sao Paulo, Brazil, and Seoul, South Korea, for example, industrial pollution has turned many streams and rivers into open sewers. Developing countries should learn from the experience of the United States: it is much more expensive to clean up polluted water than to avoid polluting in the first place. Nations should charge industries for treating effluents so companies will have an incentive to control their pollution.

Partly because of water-pollution regulations that took effect in the early 1970s, U.S. industry was recycling its water an average of 2.2 times by 1975, and West German industry had a similar recovery rate. Japanese industry, which was subject to fewer penalties for pollution, used its water only 1.5 times before returning it to the environment. U.S. industrial recycling rates would improve even more if prices for industrial water, much of which comes from municipal taps, also rose.

Most electric utilities, which are major industrial users, use their cooling water inefficiently because they obtain it free except for the cost of pumping it from an ocean or river. Consider what would happen if a typical U.S. utility had to pay more for this water. If the water itself were priced at a penny or less per 1,000 gallons, the plant would employ "once-through" cooling, which uses 50 gallons for every kilowatt-hour of electricity produced. If the price increased to 5 cents per 1,000 gallons, the utility would build a cooling tower, which would require just 0.8 gallons of water for each kilowatt-hour of electricity. Thus, a fivefold price increase would lead to more than a 50-fold reduction in water. If the price of water rose to $8 per 1,000 gallons, the utility would use a dry cooling tower, which is a closed-circuit water system that uses a condensor to cool air mechanically. The price of electricity from plants

Only a small percentage of the world's rural population has adequate clean water supplies and waste-disposal facilities. Near right: People bathe in the River Ganges in India. Center: In 1973, when Senegal had been experiencing a drought for five years, water demand was great at one of the few active wells left in the Sahelian desert. Far right: A girl draws water from a new pump in the Congo.



with cooling towers would rise only slightly.

Joseph Harrington of the Harvard School of Public Health has documented more efficient water use by several industries in Sao Paulo in response to price increases. The industries, including pharmaceutical and food-processing companies, reduced their demand for water by 40 percent when the water utility started charging for treatment.

The ability to make such sharp responses to price should make industry extremely cautious when projecting its water "needs." If countries raised industrial water and wastewater charges, more industries would adopt innovative technologies such as dry cooling towers, and would use low-quality saline or reclaimed sewage water for cooling purposes rather than drinking-quality water.

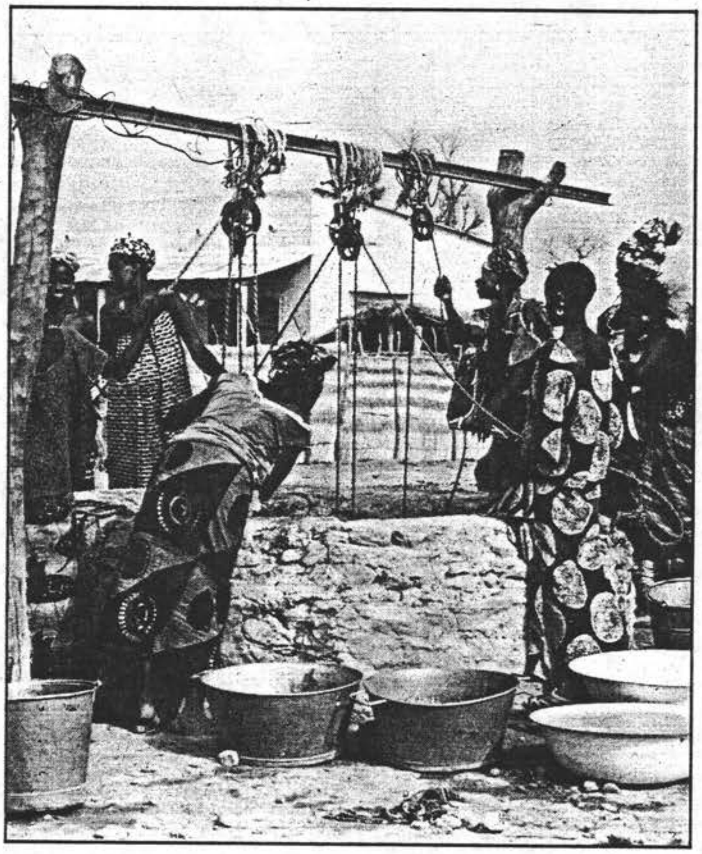
Cutting Household Demand

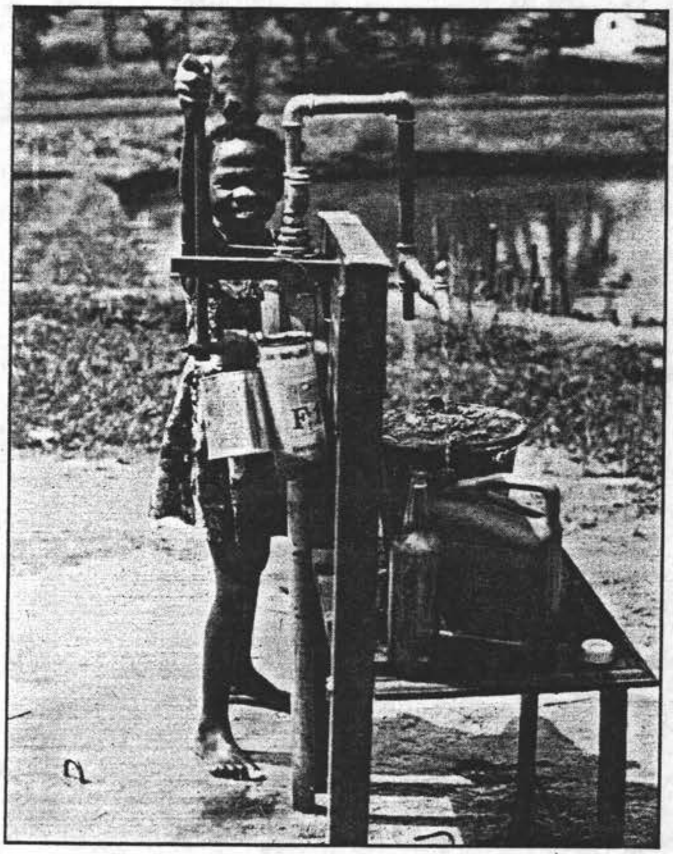
Researchers have found that in a number of countries—Israel, Canada, Great Britain, and the United States—household water demand drops by 3 percent to 7 percent when prices rise 10 percent. But too often water authorities set prices that are as low as possible—usually according to the average cost of supplying the water from a variety of sources.

Water would be used far more efficiently if it were priced according to the cost of producing it at the newest dam or other supply source. This would also indicate how much customers really wanted additional supplies in the future. Since the water from older sources would not cost that much to produce, the utility could return the windfall profit to the community in an annual lump sum. No municipality has yet switched to this kind of pricing, but some, including Tucson, Santa Fe, and Denver, have saved significant amounts of water by increasing domestic water charges somewhat above the average cost of supplying it.

Water meters also limit domestic demand because consumers are more conscious of how much they are using, and therefore how much they are spending. During a 13-year study in Boulder, Colo., metered households used up to 49 percent less water on their lawns than those without meters who paid flat fees. Bans on lawn watering and car washing usually do not reduce domestic water use permanently. Bans, which are typically imposed during droughts or peak demand periods in summer, reduce domestic water use by about 15 percent, but consumption levels rise again after the bans are lifted.

Many developing countries restrict household water use by supplying it intermittently throughout the day. However, when the pressure on the distribution system drops, water from outside the pipes leaks in, adding bacterial and other contamination. Another problem is that wealthy customers often build storage systems on the roofs of their homes. These increase demand when water is available and are another source of contamination. The result: even if a city provides its residents with high-quality water, they end up using heavily contaminated and poten-





tially dangerous water.

Developing countries generally charge about the same for domestic water as developed nations. For example, in 1978 water in Surabaya, Indonesia, cost an average of $1 per 1,000 gallons—about the average U.S. price. The effect is that water charges take a bigger bite out of family budgets in Indonesia and other developing countries, because they have more poor residents. Gilbert White of the University of Colorado found that middle-income workers in Nairobi spend as much as 8 percent of their income on water—more than they spend on fuel, transport, or household furniture and appliances. Therefore encouraging water conservation by increasing prices for household supplies could be very regressive in developing countries. Since domestic use accounts for only a small percentage of total water consumption, an exception should be made for the poor. What's more, residents of Third World countries need to consume more, rather than less, water from good supplies to improve their health.

Water Supplies and Health

Some 86 percent of the world's rural population—more than 2 billion people—lacks an adequate supply of clean water, while 92 percent lacks adequate facilities for waste disposal. A wide variety of diseases, from cholera and typhoid to guinea worm, threatens these people.

Ironically, some of the major water projects built in the past century have spread diseases. The classic case is the increase in schistosomiasis in Egypt that resulted when the Aswan Dam was built in the 1960s for irrigation water. This debilitating disease, which currently infects more than 200 million people worldwide, is carried by a snail that lives along the banks of reservoirs or in canals with slow-moving water. Schistosomiasis worms hatch in humans after larvae enter blood vessels through the skin.

To combat water- and wastewater-related diseases, the United Nations has set 1980 to 1990 as the International Drinking Water Supply and Sanitation Decade. The objective is to ensure "clean drinking water and sanitation for all." This goal is too ambitious to be reached by the end of the decade, but it could be achieved by the turn of the century.

Whether the goal can be met depends on how much money the world is willing to put forward. The World Health Organization estimated in 1984 that it would cost $22 billion per year in capital investments—or $10 billion more per year than the Third World countries now spend on water and wastewater facilities—to supply a latrine and an outdoor standpipe for every few households, and to collect excrement nightly. (That's the level of water-supply and sanitation facilities in Bombay.)

The World Bank estimates that supplying indoor plumbing and water-based flush toilets in regions without them would cost $350 billion to $650 billion in capital investments. That would represent an annual cost of $150 to $650 per household, including interest payments and operation and maintenance fees. The price would depend on local circumstances such as population density and topography. Needless to say, those prices would be a very large fraction of total family income in developing nations, and it seems doubtful that consumers could afford to spend so much.

The less costly project—supplying latrines and standpipes—is more realistic, but it is unlikely that international funding agencies will be willing to provide the additional funds even for these efforts, given the Third World debt situation. Instead, these countries will have to rely on domestic banks and local contractors and suppliers, and they will have to make this goal a priority. Unfortunately, even though public health is vital to economic development, most politicians would rather spend the money on military hardware.

Yet despite the diseases associated with poor water sources and sanitation, some of the world's poorest nations should first invest in other projects that generate income more directly. True, many health professionals believe that the benefits of clean water supplies relate directly to the size of the investment. They point to the significant improvements in public health that coincided with the widespread introduction of clean water and sanitation facilities in the industrialized countries. But Hillel Shuval of the Technion Israel Institute of Technology maintains that the potential health benefits from such projects partly depend on a population's income, education, class structure, and initial health. This suggests that public health in very poor countries can be little improved by investing only in community water supplies and disposal facilities. Programs to improve nutrition, education, and primary health care must accompany the water and sanitation efforts. Most countries sponsor these other programs, but it is difficult to integrate them with schemes to improve water quality because they are managed by different agencies.

Furthermore, a program focusing on just one goal, such as providing safe drinking water but not sanitation facilities, may not reduce people's exposure to infection sources enough to be worthwhile. In Bangladesh, for example, more than 100,000 wells were dug during the 1960s and 1970s to protect village water supplies, but there was no sanitation program to provide latrines and training in hygiene. The project did not lead to commensurate improvements in people's health.

Given this situation, many of the poorest countries should probably invest in industry, transportation, and other projects before water programs. If they disperse their money too widely—even into projects of great social worth—these countries cannot generate enough income to pay back their loans and to borrow more for added development. Such a policy may not be attractive politically, but it makes sense. This does not mean that these countries cannot accomplish a great deal by continuing programs such as building latrines in some areas. But nations should steer clear of massively redirecting their domestic policies and undertaking large-scale engineering systems until they can afford them. It is countries such as Thailand, Malaysia, the Philippines, Indonesia, and Kenya that are a step above the very poor that would probably benefit most from investing in capital-intensive water-supply facilities and wastewater treatment plants.

While many developing nations have inadequate water supplies, industrialized countries face a loss of water supplies from chemical contamination. Governments should act as swiftly as possible to stop water pollution from agricultural and industrial byproducts, some of which have no previous independent existence in the natural environment. Treating contaminated water is much more costly.

In fact, because of the cost, it's not realistic to treat all contaminated water. Municipalities should clean only the water needed for personal consumption, since the costs are small compared with the water's real value. For example, the use of granulated activated charcoal to purify water, a method that works well for most toxic chemicals and has become popular in Europe, would increase water costs in U.S. communities between 20 and 40 percent. Such increases would raise domestic water rates to less than half those paid by consumers in comparable European cities. After all, in 1983 the citizens of Boston paid $1 per 1,000 gallons of water, while the residents of Frankfurt, Germany, paid $2.82.

What Should Be Done

Just because we have not managed water supplies in the most appropriate ways so far does not mean that we cannot adjust. Nations should set up small, cabinet-level authorities responsible for reviewing, for-

Some poor countries should rely on small-scale irrigation techniques rather than large, expensive dams.

mulating, and coordinating water policy, with the power to force other agencies to implement the policy. These authorities are needed to promote the broader public's welfare over the political influence of powerful alliances—the so-called "iron triangles" consisting of particular water users, agencies, and legislators.

The central authorities should thoroughly analyze all water uses and supplies so the overall economic picture becomes clear. They also should require water agencies to base the price of water on the costs of supplying and treating it using their newest facilities, and to include a charge for the water itself. And each utility should have to charge all water users except poor households the same price.

In countries that promote a free-market system, users should be allowed to sell and buy water rights freely. For example, farmers near Phoenix should be allowed to sell to the city's water utility their rights to buy irrigation water from the Salt River project.

Many people argue that we can solve our water problems partly by avoiding large supply projects, since smaller developments have fewer environmental effects and tend to be more economical. Yet large projects can sometimes be made economical and their environmental impacts can be minimized through careful planning and design. The snails that harbor schistosomiasis in the Aswan Dam would not survive if water flowed through the irrigation channels more quickly or the water level was changed regularly, for example. We should avoid knee-jerk negative reactions to large projects just because they are big.

As an alternative to building large dams, water can be stored underground in the soil and pumped up as needed. To infiltrate the water into the ground, it may be necessary to scour dry riverbeds occasionally so that they will absorb floodwater, or to dredge channels so that floodwater will be diverted into gravel pits and other pervious areas. Not only do underground reservoirs cost two-thirds as much as reservoirs and dams built above ground, but they prevent the loss of water through evaporation. They do not create habitats that can spread water-related diseases, and people do not have to be displaced from their homes. An underground reservoir's main environmental impact is to decrease the nutrients that runoff would normally deliver to the ocean. An underground storage scheme is now being used to supply some of the water to Los Angeles and is the reason the once "mighty Santa Ana" River—which used to run during flashfloods—is always dry now.

The water problems that the world faces are not unexpected, given the common perception of water as a free and unlimited resource. It is a great temptation to believe that the problems have been caused by others, but each individual needs to appreciate water's real economic value. Only then will we use water differently and avoid serious shortages and the human suffering they entail. □