In: Wilson and Bilger, eds.
The Best American Science
and Nature Writing. 2001.

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Troubled Waters

FROM *The Sciences*

IN JUNE 1991, after a leisurely lunch in the fashionable Washington, D.C., neighborhood of Dupont Circle, Alexei Yablokov, then a Soviet parliamentarian, told me something shocking. Some years back he had had a map hanging on his office wall depicting Soviet central Asia without the vast Aral Sea. Cartographers had drawn it in the 1960s, when the Aral was still the world's fourth-largest inland body of water.

I felt for a moment like a cold war spy to whom a critical secret had just been revealed. The Aral Sea, as I knew well, was drying up. The existence of such a map implied that its ongoing destruction was no accident. Moscow's central planners had decided to sacrifice the sea, judging that the two rivers feeding it could be put to more valuable use irrigating cotton in the central Asian desert. Such a planned elimination of an ecosystem nearly the size of Ireland was surely one of humanity's more arrogant acts.

Four years later, when I traveled to the Aral Sea region, the Soviet Union was no more; the central Asian republics were now independent. But the legacy of Moscow's policies lived on: thirty-five years of siphoning the region's rivers had decreased the Aral's volume by nearly two thirds and its surface area by half. I stood on what had once been a seaside bluff outside the former port town of Muynak, but I could see no water. The sea was twenty-five miles away. A graveyard of ships lay before me, rotting and rusting in the dried-up seabed. Sixty thousand fishing jobs had vanished, and thousands of people had left the area. Many of those who remained suffered from a variety of cancers, respiratory ailments, and other diseases. Winds ripping across the desert were lifting

tens of millions of tons of a toxic salt-dust chemical residue from the exposed seabed each year and dumping it on surrounding croplands and villages. Dust storms and polluted rivers made it hazardous to breathe the air and drink the water.

The tragedy of the Aral Sea is by no means unique. Around the world countless rivers, lakes, and wetlands are succumbing to dams, river diversions, rampant pollution, and other pressures. Collectively they underscore what is rapidly emerging as one of the greatest challenges facing humanity in the decades to come: how to satisfy the thirst of a world population pushing nine billion by the year 2050, while protecting the health of the aquatic environment that sustains all terrestrial life.

The problem, though daunting, is not insurmountable. A number of technologies and management practices are available that could substantially reduce the amount of water used by agriculture, industry, and households. But the sad reality is that the rules and policies that drive water-related decisions have not adequately promoted them. We have the ability to provide both people and ecosystems with the water they need for good health, but those goals need to be elevated on the political agenda.

Observed from space, our planet seems wealthy in water beyond measure. Yet most of the earth's vast blueness is ocean, far too salty to drink or to irrigate most crops. Only about 2.5 percent of all the water on earth is fresh water, and two thirds of that is locked away in glaciers and ice caps. A minuscule share of the world's water — less than one hundredth of 1 percent — is both drinkable and renewed each year through rainfall and other precipitation. And though that freshwater supply is renewable, it is also finite. The quantity available today is the same that was available when civilizations first arose thousands of years ago, and so the amount of water that should be allotted to each person has declined steadily with time. It has dropped by 58 percent since 1950, as the population climbed from 2.5 billion to 6 billion, and will fall an additional 33 percent within fifty years if our numbers reach 8.9 billion, the middle of the projected range.

Because rainfall and river flows are not distributed evenly throughout the year or across the continents, the task of adapting water to human use is not an easy one. Many rivers are tempestuous and erratic, running high when water is needed least and low when it is needed most. Every year two thirds of the water in the earth's rivers rushes untapped to the sea in floods. An additional one fifth flows in remote areas such as the Amazon basin and the Arctic tundra. In many developing countries monsoons bring between 70 and 80 percent of the year's rainfall in just three months, greatly complicating water management. When it comes to water, it seems, nature has dealt a difficult hand.

As a result, the history of water management has largely been one of striving to capture, control, and deliver water to cities and farms when and where they need it. Engineers have built massive canal networks to irrigate regions that are otherwise too dry to support the cultivation and growth of crops. The area of irrigated land worldwide has increased more than thirtyfold in the past two centuries, turning near-deserts such as southern California and Egypt into food baskets. Artificial oasis cities have bloomed. In Phoenix, Arizona, which gets about seven inches of rain a year, seemingly abundant water pours from taps. With a swimming pool, lawn, and an array of modern appliances, a Phoenix household can readily consume 700 gallons of water a day.

But while the affluent enjoy desert swimming pools, more than a billion of the world's people lack a safe supply of drinking water, and 2.8 billion do not have even minimal sanitation. The World Health Organization estimates that 250 million cases of water-related diseases such as cholera arise annually, resulting in between 5 and 10 million deaths. Intestinal worms infect some 1.5 billion people, killing as many as 100,000 a year. Outbreaks of parasitic diseases have sometimes followed the construction of large dams and irrigation systems, which create standing bodies of water where the parasites' hosts can breed. In sub-Saharan Africa, many women and girls walk several miles a day just to collect water for their families. Tens of millions of poor farm families cannot afford to irrigate their land, which lowers their crop productivity and leaves them vulnerable to droughts.

Even in countries in which water and sanitation are taken for granted, there are disturbing trends. Much of the earth's stable year-round water supply resides underground in geologic formations called aquifers. Some aquifers are nonrenewable — the bulk of their water accumulated thousands of years ago and they get little or no replenishment from precipitation today. And though

most aquifers are replenished by rainwater seeping into the ground, in a number of the world's most important food-producing regions farmers are pumping water from aquifers faster than nature can replace it. Aquifers are overdrawn in several key regions of the United States, including California's Central Valley, which supplies half of the nation's fruits and vegetables, and the southern Great Plains, where grain and cotton farmers are steadily depleting the Ogallala, one of the planet's greatest aquifers.

The problem is particularly severe in India, where a national assessment commissioned in 1996 found that water tables in critical farming regions were dropping at an alarming rate, jeopardizing perhaps as much as one fourth of the country's grain harvest. In China's north plain, where 40 percent of that nation's food is grown, water tables are plunging by more than a meter a year across a wide area.

On the basis of the best available data, I estimate that global groundwater overpumping totals at least 160 billion cubic meters a year, an amount equal to the annual flow of two Nile Rivers. Because it takes roughly 1,000 cubic meters of water to produce one ton of grain, some 160 million tons of grain — nearly 10 percent of the global food supply — depend on the unsustainable practice of depleting groundwater. That raises an unsettling question: If humanity is operating under such an enormous deficit today, where are we going to find the additional water to satisfy future needs?

Another harbinger of trouble is that many major rivers now run dry for large parts of the year. Five of Asia's great rivers — the Indus and the Ganges in southern Asia, the Yellow in China, and the Amu Darya and Syr Darya in the Aral Sea basin — no longer reach the sea for months at a time. The Chinese call the Yellow River their mother river, reflecting its role as the cradle of Chinese civilization. Today the Yellow River supplies water to 140 million people and 18 million acres of farmland. Yet it has run dry in its lower reaches almost every year of this past decade, and the dry section often stretches nearly 400 miles upstream from the river's mouth. In 1997 the dry spell lasted a record 226 days.

Not surprisingly, as water becomes scarce, competition for it is intensifying. Cities are beginning to divert water from farms in north-central China, southern India, the Middle East, and the western United States. Moreover, the world's urban population is expected to double to 5 billion by 2025, which will further increase the pressure to shift water away from agriculture. How such a shift will affect food production, employment in rural areas, rural-to-urban migration, and social stability are critical questions that have hardly been asked, much less analyzed.

Competition for water is also building in international river basins: 261 of the world's rivers flow through two or more countries. In the vast majority of those cases there are no treaties governing how the river water should be shared. As demands tax the supply in those regions, tensions are mounting. In five water hot spots — the Aral Sea region, the Ganges, the Jordan, the Nile, and the Tigris-Euphrates — the population of the nations in each basin will probably increase by at least 30 percent and possibly by as much as 70 percent by 2025.

The plight of the Nile basin seems particularly worrisome. Last in line for Nile water, Egypt is almost entirely dependent on the river and currently uses two thirds of its annual flow. About 85 percent of the Nile's flow originates in Ethiopia, which to date has used little of that supply but is now constructing small dams to begin tapping the upper headwaters. Meanwhile, Egypt is pursuing two large irrigation projects that have put it on a collision course with Ethiopia. Although Nile-basin countries have been meeting regularly to discuss how they can share the river, no treaty that includes all the parties yet exists. Shortly after signing the historic peace accords with Israel in 1979, Egyptian president Anwar Sadat said that only water could make Egypt wage war again. He was referring not to another potential conflict with Israel but to the possibility of hostilities with Ethiopia over the Nile.

The story of the shrinking Aral Sea underscores another form of competition: the conflict between the use of water in agriculture and industry, on the one hand, and its ecological role as the basis of life and sustainer of ecosystem health, on the other. After I returned from the Aral Sea, I was tempted to view the sea and the communities around it as tragic victims of Communist central planning. A year later, however, in May 1996, I visited the delta of the Colorado River and found a depressingly similar story.

The Colorado delta had once been lush, supporting as many as 400 plant species and numerous birds, fish, and mammals. The

great naturalist Aldo Leopold, who canoed through the delta in 1922, called it "a milk and honey wilderness," a land of "a hundred green lagoons." As I walked amid salt flats, mud-cracked earth, and murky pools, I could hardly believe I was in the same place that Leopold had described. The treaties that divide the Colorado River among seven U.S. states and Mexico had set aside nothing to protect the river system itself. More water was promised to the eight treaty parties than the river actually carries in an average year. As a result, the large dams and river diversions upstream now drain so much water that virtually nothing flows through the delta and out to the Gulf of California.

As in the Aral Sea basin, the Colorado predicament has caused more than an environmental tragedy. The Cocopa Indians have fished and farmed in the delta for more than 1,000 years. Now their culture faces extinction because too little river water makes it to the delta.

What was gained by despoiling such cultural and biological riches, by driving long-settled people from their homes and wildlife from its habitats? The answer seems to be more swimming pools in Los Angeles, more golf courses in Arizona, and more desert agriculture. To be sure, the tradeoff helped boost the U.S. gross national product, but at the untallied cost of irreplaceable natural and cultural diversity.

Given the challenges that lie ahead, how can the needs of an increasingly thirsty world be satisfied, without further destroying aquatic ecosystems? In my view, the solution hinges on three major components: allocating water to maintain the health of natural ecosystems, doubling the productivity of the water allocated to human activities, and extending access to a ready supply of water to the poor.

Just as people require a minimum amount of water to maintain good health, so do ecosystems — as the Aral Sea, the Colorado delta, and numerous other areas painfully demonstrate. As the human use of water nears the limits of the supply in many places, we must ensure the continued functioning of ecosystems and the invaluable services they perform. Providing that assurance will entail a major scientific initiative, aimed at determining safe limits of water usage from aquifers, rivers, lakes, and other aquatic systems.

Laws and regulations, guaranteeing continued health of those ecosystems, must also be put in place.

Australia and South Africa are now leading the way in such efforts. Officials in Australia's Murray-Darling River basin have placed a cap on water extractions — a bold move aimed at reversing the decline in the health of the aquatic environment. South Africa's new water laws call for water managers to allocate water for the protection of ecological functions as well as for human needs.

The United States is also making efforts to heal some of its damaged aquatic environments. A joint federal-state initiative is working to restore the health of California's San Francisco Bay delta, which is home to more than 120 species of fish and supports 80 percent of the state's commercial fisheries. In Florida an $8 billion federal-state project is attempting to repair the treasured Everglades, the famed "river of grass," which has shrunk in half in the past century alone. And across the country a number of dams are slated for removal in an effort to restore fisheries and other benefits of river systems.

The second essential component in meeting water needs for the future will be to maximize the use of every gallon we extract. Because agriculture accounts for 70 percent of the world's water usage, raising water productivity in farming regions is a top priority. The bad news is that today less than half the water removed from rivers and aquifers for irrigation actually benefits a crop. The good news is that there is substantial room for improvement.

Drip irrigation ranks near the top of measures that offer great untapped potential. A drip system is essentially a network of perforated plastic tubing, installed on or below the soil surface, that delivers water at low volumes directly to the roots of plants. The loss to evaporation or runoff is minimal. When drip irrigation is combined with the monitoring of soil moisture and other ways of assessing a crop's water needs, the system delivers 95 percent of its water to the plant, compared with between 50 and 70 percent for the more conventional flood or furrow irrigation systems.

Besides saving water, drip irrigation usually boosts crop yield and quality, simply because it enables the farmer to maintain a nearly ideal moisture environment for the plants. In countries as diverse as India, Israel, Jordan, Spain, and the United States, studies have consistently shown that drip irrigation not only cuts water use by between 30 and 70 percent, but also increases crop yields by between 20 and 90 percent. Those improvements are often enough to double the water productivity. Lands watered by drip irrigation now account for a little more than 1 percent of all irrigated land worldwide. The potential, however, is far greater.

The information revolution that is transforming so many facets of society also promises to play a vital role in transforming the efficiency of water use. The state of California operates a network of more than a hundred automated and computerized weather stations that collect local climate data, including solar radiation, wind speed, relative humidity, rainfall, and air and soil temperature, and then transmit the data to a central computer in Sacramento. For each remote site, the computer calculates an evapotranspiration rate, from which farmers can then calculate the rate at which their crops are consuming water. In that way they can determine, quite accurately, how much water to apply at any given time throughout the growing season.

As urban populations continue expanding in the decades ahead, household consumption of water will also need to be made more efficient. As part of the National Energy Policy Act, which was signed into law in late 1992, the United States now has federal water standards for basic household plumbing fixtures — toilets, faucets, and showerheads. The regulations require that manufacturers of the fixtures meet certain standards of efficiency — thereby building conservation into urban infrastructure. Water usage with those fixtures will be about a third less in 2025 than it would have been without the new standards. Similar laws could also help rapidly growing Third World cities stretch their scarce water supplies. One of the most obvious ways to raise water productivity is to use water more than once. The Israelis, for instance, reuse two thirds of their municipal wastewater for crop production. Because both municipal and agricultural wastewater can carry toxic substances, reuse must be carefully monitored. But by matching appropriate water quality to various kinds of use, much more benefit can be derived from the fresh water already under human control. And that implies that more can remain in its natural state.

The third component of the solution to water security for the future is perhaps also the greatest challenge: extending water and sanitation services to the poor. Ensuring safe drinking water is one of the surest ways to reduce disease and death in developing countries. Likewise, the most direct way of reducing hunger among the rural poor is to raise their productive capacities directly. Like trickle-down economics, trickle-down food security does not work well for the poor. Greater corn production in Iowa will not alleviate hunger among the poor in India or sub-Saharan Africa. With access to affordable irrigation, however, millions of poor farmers who have largely been bypassed by the modern irrigation age can raise their productivity and incomes directly, reducing hunger and poverty at the same time.

In many cases the problem is not that the poor cannot afford to pay for water but that they are paying unfair prices — often more than do residents of developed nations. It is not uncommon for poor families to spend more than a quarter of their income on water. Lacking piped-in water, many must buy from vendors who charge outrageous prices, often for poor-quality water.

In Istanbul, Turkey, for instance, vendors charge ten times the rate paid by those who enjoy publicly supplied water; in Bombay, the overcharge is a factor of twenty. A survey of households in Port-au-Prince, Haiti, found that people connected to the water system pay about a dollar per cubic meter ($3.78 per 1,000 gallons), whereas the unconnected must buy water from vendors for between $5.50 and $16.50 per cubic meter — about twenty times the price typically paid by urban residents in the United States.

Cost estimates for providing universal access to water and sanitation vary widely. But even the higher-end estimates — some $50 billion a year — amount to only 7 percent of global military expenditures. A relatively minor reordering of social priorities and investments — and a more comprehensive definition of security — could enable everyone to share the benefits of clean water and adequate sanitation.

Equally modest expenditures could improve the lot of poor farmers. In recent years, for instance, large areas of Bangladesh have been transformed by a human-powered device called a treadle pump. When I first saw the pump in action on a trip to Bangladesh in 1998, it reminded me of a StairMaster exercise machine, and it is operated in much the same way. The operator pedals up and down on two long poles, or treadles, each attached to a cylinder.

The upward stroke sucks shallow groundwater into one of the cylinders, while the downward stroke of the opposite pedal expels water from the other cylinder (that was sucked in on the preceding upward stroke) into a field channel.

The pump costs just thirty-five dollars, and with that purchase, farm families that previously were forced to let their land lie fallow during the dry season — and go hungry for part of the year — can grow an extra crop of rice and vegetables and take the surplus to market. Each pump irrigates about half an acre, which is appropriate for the small plots that poor farmers generally cultivate. The average net annual return on the investment has been more than $100 per pump, enabling families to recoup their outlay in less than a year.

So far Bangladeshi farmers have purchased 1.2 million treadle pumps, thereby raising the productivity of more than 600,000 acres of farmland and injecting an additional $325 million a year into the poorest parts of the Bangladeshi economy. A private-sector network of 70 manufacturers, 830 dealers, and 2,500 installers supports the technology, creating jobs and raising incomes in urban areas as well.

The treadle pump is just one of many examples of small-scale, affordable irrigation technologies that can help raise the productivity and the income of poor farm families. In areas with no perennial source of water, as in the drylands of south Asia and sub-Saharan Africa, a variety of so-called water-harvesting techniques hold promise for capturing and channeling more rainwater into the soil. In parts of India, for instance, some farmers collect rainwater from the monsoon season in earth-walled embankments, then drain the stored water during the dry season. The method, known as *haveli,* enables farmers to grow crops when their fields would otherwise be barren. Israeli investigators have found that another simple practice — covering the soil between rows of plants with polyethylene sheets — helps keep rainwater in the soil by cutting down on evaporation. The method has doubled the yields of some crops.

To avert much misery in this new century, the ways water is priced, supplied, and allocated must be changed. Large government subsidies for irrigation, an estimated $33 billion a year worldwide, keep prices artificially low — and so fail to penalize farmers for wasting water. Inflexible laws and regulations discourage the marketing of water, leading to inefficient distribution and use. Without rules to regulate groundwater extractions, the depletion of aquifers persists. And the failure to place a value on freshwater ecosystems — their role in maintaining water quality, controlling floods, and providing wildlife habitats — has left far too little water in natural systems.

Will we make the right choices in the coming age of water scarcity? Our actions must ultimately be guided by more than technology or economics. The fact that water is essential to life lends an ethical dimension to every decision we make about how it is used, managed, and distributed. We need new technologies, to be sure, but we also need a new ethic: All living things must get enough water before some get more than enough.