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PILLAR OF SAND

Can the Irrigation Miracle Last?

Sandra Postel

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WATER WARS I: FARMS VERSUS CITIES AND NATURE

Why would the billionaire Bass brothers of Texas, enriched by real estate and oil deals, make a play for a parcel of farmland in the hot, dry American Southwest? The reason has little to do with the lettuce, tomatoes, and melons grown in California's sun-drenched Imperial Valley, but everything to do with what allows crops to grow there—water. In purchasing more than 16,000 hectares of valley farmland, the Bass brothers were simply acting on a tip from an old but timely adage: water flows uphill toward money.[1]

About a fifth of the Colorado River's annual flow goes to the Imperial Irrigation District (IID), which irrigates nearly 200,000 hectares of cropland. Thanks to a century-old deal with the federal government, IID gets this water for free. Farmers within the district pay only for the cost of delivering the water, about 1¢ per cubic meter. A few hundred kilometers to the west in Los Angeles, the Metropolitan Water District (MWD), which is the water wholesaler for about 16 million southern Californians, pays up to 16¢ per cubic meter for water

that it sells to its customers for about 28¢ a cubic meter—28 times as much as the IID farmers pay.[2]

To astute investors, the math is compelling enough. But politics is weighing in as well. California has been using about 14 percent more Colorado River water than a 1922 interstate agreement entitles it to, and the U.S. government has put the state on notice that it must find a way to live within its allotted share. Any cutbacks would come out of urban supplies, since the Imperial Valley farmers have more senior water rights, and thus higher priority.[3]

Not long after buying their IID farmland in 1994, the Bass brothers began pushing the irrigation district, which actually owns the water rights, to strike a deal with San Diego, MWD's biggest customer. Three years later, in late 1997, the Basses hedged their bets and traded their $60-million investment in Imperial Valley farmland for $250 million worth of stock in the United States Filter corporation, the world's largest water treatment company. Meanwhile, IID did manage to strike a deal with San Diego. In 1998, the irrigation district agreed to transfer up to 246.8 million cubic meters of water a year to San Diego at an initial price of 20–27¢ per cubic meter. San Diego residents will benefit from lower costs and greater reliability of future supplies. IID will reap substantial profits, and if most of the water transferred results from increased efficiency and shifts to less thirsty crops, farmers will not necessarily need to take land out of production.[4]

Water grabs and power plays are legendary in the western United States. In the popular movie *Chinatown*, Hollywood capitalized on the drama of Los Angeles sucking farms dry in the Owens Valley. American writer and humorist Mark Twain captured the West's tension over water with his famous quip that "whiskey's for drinking, water's for fighting about." But as water becomes more scarce, the stakes are rising—not just in the western United States, but in many other parts of the world as well.[5]

For rapidly growing cities and industries, agriculture holds the last big pool of available water. Globally, irrigation accounts for about two thirds of all the water removed from rivers, lakes, and aquifers, and in many important agricultural regions, it claims 80 percent or more. As opportunities to expand water supplies dwindle, competition over existing supplies is mounting. How this competition plays out is about much more than whether rich investors get richer. It is about food security, social stability, the health of rural communities, the plight of the world's poor, and the ability of the aquatic environment to continue supporting a diversity of life.

Losing Out to Cities

On an average day in the developing world, about 150,000 people join the ranks of urban dwellers. Some are babies born to couples already living there. Others migrate in from the countryside, hoping for a better life. Most need shelter and a job. All need food and water.[6]

By 2025, nearly 5 billion people are expected to live in cities, about twice as many as in 1995. At that time, urbanites will represent a majority—59 percent—of the world's population, up from 46 percent in 1996. Mark Rosegrant and Claudia Ringler of the International Food Policy Research Institute in Washington, D.C., project that annual water demands by households and industries in developing countries will climb by 590 billion cubic meters between 1995 and 2020, and that the share of water going to these activities will more than double—from 13 percent of total water use to 27 percent.[7]

It is a fairly sure bet that a portion of these increased urban and industrial demands will be met by transfers of water out of agriculture. What is not known is how much water irrigators will transfer, whether they will transfer the water voluntarily, and how much crop production will decline as a result of the transfers. These are important questions. As Rosegrant and

Ringler conclude, the way the farm-to-city reallocation of water is managed "could determine the world's ability to feed itself."[8]

If farmers make little effort to save water by irrigating more efficiently or growing less-thirsty crops, transfers of water out of agriculture will cause crop production to fall. Yields will decline in farming areas that lose or sell some of their water. In some cases, farmers will take cropland out of production altogether. If, for example, half of the projected rise in urban and industrial demand by 2020 is met by shifting irrigation water to these users, and little improvement is made in irrigation efficiency, grain production could drop by some 300 million tons—about 1.5 times current global grain exports.

A quick reality check shows that the shift of water from farms to cities is already under way, and is likely to increase. In parts of north China, including areas around Beijing, reservoirs that had supplied irrigation water to farms are often now used almost exclusively to supply households and factories. Farmers in Daxing County, about 50 kilometers south of Beijing, for example, no longer receive irrigation water that used to be shipped in by canal from Beijing's reservoirs. In 1993, they told a *New York Times* reporter that it had been more than a decade since local farmers could flood a rice paddy.[9]

Nationwide, China has been urbanizing at a rapid rate. The number of cities has climbed from 130 in 1949 to more than 600 today. About half of them are already short of water, and there is increasing pressure to pull supplies away from agriculture to narrow the urban water deficits. A mid-1990s planning study by China's State Statistical Bureau and Ministry of Water Resources concluded that 40 percent of the projected demand gap in 2000 could be met by shifting water out of agriculture. Moreover, these gaps will widen over the next couple of decades. Eugene Linden notes in *Foreign Affairs* that "the great urban migration has only just begun in China, which is still more than 70 percent rural." The United Nations projects that more than half of China's people will live in cities by 2025.[10]

In China, as elsewhere, both politics and economics drive water's reallocation. A cubic meter of water used in China's industries generates more jobs and about 70 times more economic value than the same quantity used in agriculture. As supplies tighten, water will shift to where it is more highly valued. Moreover, because only a small fraction of urban and industrial wastewater is treated before being released back to the environment, a growing share of China's rivers and streams are becoming too polluted to use—worsening the water crunch. The Huai River in central China, for example, is so polluted that officials have banned farmers from using it to irrigate crops. Canadian geographer Vaclav Smil, a specialist on China's environment, has estimated that as much as one fifth of China's river water is too polluted for irrigation use, much less for drinking.[11]

Farmers in India face mounting competition over water as well. India will add some 340 million people to its cities between 1995 and 2025, more than the current populations of the United States and Canada combined. Reallocations are reportedly occurring to increase supplies for the cities of Madras, Coimbatore, and Tirupur and for a number of smaller towns. Tirupur, in the southern state of Tamil Nadu, suffers from a water deficit of some 22 million cubic meters a year and serious degradation of water quality, and has begun to import more water from outside the city. Many farmers within 35 kilometers of the city have abandoned farming and instead sell their groundwater to urban and industrial users.[12]

Rice farmers in parts of the Indonesian island of Java are losing water supplies to textile factories, even though Indonesian law gives agriculture higher priority for water. A study of one irrigated region in West Java found that factories often take more water than their permits allow and also take it directly out of irrigation canals, leaving too little for the farms. Some factories buy or rent rice fields from farmers just to get access

to the irrigation water, but then leave some of the fields fallow. The factories have also polluted local water supplies, which has lowered rice yields and killed fish in local fish ponds. Lacking legally enforced rights to the water they have been accustomed to using, the farmers have little recourse. Researchers Ganjar Kurnia, Teten Avianto, and Bryon Bruns note that "many farmers, suffering from lost production and insecurity of water supplies, feel they have no choice but to sell their land."[13]

Growing demand in the megacities of Southeast Asia, including Bangkok, Jakarta, and Manila, is already partially being met by overpumping groundwater, and so pressure will intensify to shift water out of agriculture in these regions as well. In addition to booming populations, cities in these areas also face increased demands from rising affluence. In Malaysia, for example, the number of golf courses has tripled over the last decade to more than 150, and 100 more are planned. Together, Malaysia, Thailand, Indonesia, South Korea, and the Philippines maintain 550 golf courses, with another 530 already in the planning pipeline. Besides chewing up farms and forests, golf courses in these countries typically require irrigation at the same time crops do—during the dry season, when supplies are usually tight.[14]

Overall, cities in industrial countries will likely pull less water out of agriculture because their water demands are rising much more slowly. But in rapidly urbanizing, water-short areas, such as the western United States, the city-farm competition is heating up. Cities are buying water, water rights, or land that comes with water rights in parts of Arizona, California, Colorado, and elsewhere. Not surprisingly, the biggest trades so far have involved the Imperial Irrigation District in southern California, which is within striking distance of urban areas that are home to 16 million people, and still growing.

In addition to the recent deal with San Diego, IID agreed to a trade in 1989 with the Metropolitan Water District in Los Angeles. MWD agreed to invest in efficiency improvements within IID in exchange for the water those investments save. The trade will shift up to 106,000 acre-feet (130.8 million cubic meters) a year from farm to urban uses for 35 years. MWD benefits because the cost of the conserved water will be less than 10¢ per cubic meter, much lower than its best new-supply option. IID benefits from the cash payments and an upgraded irrigation network. And because the water traded is generated through conservation, no cropland needs to come out of production.[15]

Another MWD deal, however, does require farmers to take land out of irrigated production. In 1992, the urban water wholesaler entered into an agreement with the Palo Verde Irrigation District, located on the west side of the Colorado River between Parker and Imperial dams. The agreement called for Palo Verde farmers to fallow a portion of their cropland for two years and transfer the resulting water savings to MWD.[16]

Facing unstable crop prices, 63 farmers signed on, fallowing a total of 8,181 hectares. MWD paid the irrigators $3,064 for each hectare left unplanted and, in return, received a total of 228 million cubic meters of water—the equivalent of about 10 percent of MWD's yearly deliveries. The transferred water was stored in federal reservoirs on the lower Colorado River for use any time MWD desired before the year 2000. As in its deal with IID, MWD benefits by obtaining additional supplies at a lower cost. Palo Verde farmers benefited from more stable income. But because land was taken out of production, farm workers lost jobs.[17]

Water transfers often affect people not involved directly in the sale, which makes a full accounting of costs and benefits hard to achieve. But the costs to so-called third parties, who rarely have a place at the negotiating table, can be substantial. These costs can also be cumulative, affecting rural communities, employment, the tax base, and the environment. Because poorer farm laborers may be the ones to lose jobs, even economically efficient water trades may worsen inequities. Water trades can also damage downstream wetlands and lakes. IID's

deals with both the MWD and San Diego, for example, could harm the inland Salton Sea, an important stopover for many species of migratory birds. (See Chapter 5.) Though polluted, IID's drainage is critical to sustaining the area and quality of the sea, which is already 25 percent saltier than the Pacific Ocean. As IID sends increasing amounts of its water to southern California cities, the sea will shrink and become even saltier.[18]

In sum, the limited evidence to date suggests that the impacts of water transfers are decidedly mixed, complex, and difficult to predict. Moreover, especially in Third World settings, irrigation water is often used for many activities other than farming, including household activities, home gardens, livestock, and fishing. In these cases, third-party impacts can be substantial, and without compensation to the losers, can worsen inequities and deepen rural poverty.[19]

So far, few countries have the institutions and incentives in place to steer water competition in both a productive and an equitable direction, and to compensate those negatively affected by water trades. In Chile, where government policies encourage water marketing, negative impacts seem to be minimal in part because farmers typically sell relatively small portions of their water rights to cities, while at the same time investing in more-efficient irrigation technologies and practices. This allows them to maintain their crop production levels even as some water shifts from farming to urban uses. (See Chapter 10 for more on water markets.)[20]

Without a doubt, cities will continue to siphon water away from agriculture. What is not known is how much water ultimately will be reallocated and how great an impact that reallocation will have on food production, on farmers, and on rural economies. Unless this competition is managed well, it could dampen food supplies in some areas, and make the rich richer and the poor poorer. And competition for water may force more rural dwellers to head for the cities—which, in a vicious circle, would intensify the problem.

Nature Stakes a Claim

Irrigated agriculture faces another major competitor for fresh water—the natural environment. In recent years, ecologists, environmentalists, and concerned citizens have sounded alarms about the decline of rivers, lakes, wetlands, and other freshwater ecosystems. Increasingly, these groups are calling not only for fewer new dams and river diversions, but also for returning to natural systems some of the water now going to human activities—including irrigation.

During just this decade, public values have changed markedly in favor of protecting natural ecosystems and the multitude of benefits they offer, especially in wealthier countries. Fishing, kayaking, rafting, and other recreational pleasures top most people's interests in healthy rivers, but there is also greater awareness of the so-called ecosystem services provided by intact freshwater systems. These services include controlling floods, purifying water supplies, maintaining fish and wildlife habitat, and conserving species richness.

As more scientists, citizens, and political leaders speak out about the need to protect these functions of rivers and natural ecosystems, the balance of power governing water use is changing in ways that could revolutionize water management. Engineers built the hundreds of thousands of dams that now block the world's rivers with four principal goals in mind—flood control, hydroelectric power production, water supply, and irrigation. Almost without exception, they paid little attention to the downstream effects of altering river environments. Now that scientists have uncovered serious damage from dams, levees, and other hydraulic infrastructure, and the public has spoken out about its increasing environmental concerns, the water equation is shifting. Legislatures, courts, and the public increasingly view the natural environment as having a legitimate claim to water, and they are deciding to return some water to nature.

Dams, diversions, dikes, and levees destroy aquatic habitat. They sever the connections a river has with its floodplain, its channel, its delta, and the sea into which it empties. They change the temperature of a river's water and its pattern of flow throughout the year. They also prevent a river from performing most of its natural functions, such as delivering nutrients to the seas to sustain fisheries, absorbing floodwaters by spreading them over its floodplain, protecting wetlands and their ability to filter pollutants, providing habitat for a rich diversity of aquatic life, maintaining salt and sediment balances, offering myriad recreational opportunities, and providing some of the most inspirational natural beauty on the planet.

Scientists have just begun to uncover the extent and magnitude of damage to the world's freshwater environment, so it is impossible to know how much corrective action—and water reallocation—ultimately will be needed. The evidence to date, however, suggests that it will not be trivial. Swedish scientists Mats Dynesius and Christer Nilsson examined the 139 largest river systems in the United States, Canada, Europe, and the former Soviet Union—essentially the northern third of the world—and found that 77 percent of them were moderately to strongly altered by dams, reservoirs, diversions, and irrigation. The remaining 23 percent were relatively small systems located in the far north, mainly in the boreal and arctic regions. Writing in the journal *Science*, they warned that because of the extent of river exploitation, key habitats such as waterfalls, rapids, and floodplain wetlands could disappear entirely from some regions, extinguishing numerous plant and animal species specific to running waters.[21]

More detailed studies of species imperilment confirm that these risks are real. Worldwide, one out of every three fish species is threatened with extinction, compared with one out of every four mammals, one out of every five reptiles, and one out of every nine birds. In the United States, the most striking finding of the most comprehensive assessment to date on native plant and animal species is the dire condition of species that depend on aquatic systems for all or part of their life cycle. Conducted by The Nature Conservancy and the Natural Heritage Network, the 1997 study found that 67 percent of freshwater mussels are at risk of extinction, along with 51 percent of crayfish, 40 percent of amphibians, and 37 percent of freshwater fish. As a whole, freshwater species are more in jeopardy than land-based species, and the leading cause of their imperilment is the destruction and degradation of their habitats.[22]

The legal and institutional means for protecting freshwater habitats vary by country. But even in the United States, conservation groups and others concerned about species loss face an uphill battle. Historically, the U.S. Congress gave control over water rights and allocations to the states, and there was little federal intervention. With passage of the Wilderness Act, the Clean Water Act, the Wild and Scenic Rivers Act, the National Environmental Policy Act, the Endangered Species Act (ESA), and other federal legislation, tensions arose over state-granted private water rights (which, under western water law, are as firm as property rights) and the new federal laws that were aimed at protecting the broader public interest. Although Congress has generally deferred to state water laws, the Supremacy Clause of the U.S. Constitution says that when conflicts between federal and state laws arise, federal law prevails. This means, for example, that state-granted water rights for irrigation may have to bend to requirements to protect critical habitat for species listed as endangered under the federal ESA.

For irrigators in the western United States, this possibility is no small concern. Of 68 fish species listed as threatened or endangered in the 17 western states in 1993, 50 had "agricultural activities" recorded as one of the factors behind their decline. Nearly one out of every five western counties contains habitat for one or more of these 50 species. Irrigated areas in California, Colorado, Idaho, and Utah that rely extensively on river water correspond closely with areas harboring high concentrations of ESA-listed species.[23]

Moreover, the number of listed species continues to grow. Since 1967, when 12 western fish species were found to be endangered under a law that preceded the ESA, the number of threatened or endangered western fish species has risen nearly sixfold. A species remains on the list until either recovery efforts sufficiently diminish threats to its survival or it becomes extinct.[24]

Federally built dams and diversions supply more than a third of the surface water consumed by irrigated agriculture in the West, and many of them are implicated in species destruction. They threaten Chinook salmon in the Pacific Northwest's Columbia River basin and in California's Sacramento basin, two fish species in Nevada's Truckee River–Pyramid Lake system, and the Colorado River squawfish in the Colorado basin, to name a few. Because the ESA requires federal agencies—including the Bureau of Reclamation, the largest water supplier to western irrigators—to ensure that their actions are unlikely to jeopardize a listed species, federal projects are in the front line of battles between species protection and traditional water uses. As University of Colorado law professor Charles Wilkinson puts it, the ESA could "prove to be a sturdy hammer for dislodging long-established extractive water uses that have worked over so many western watersheds and drained them of much of their vitality."[25]

That hammer has already been struck in a number of river basins. In late 1992, the U.S. Congress passed legislation aimed at revamping operation of the huge federal Central Valley Project in California in order to shore up the health of the Sacramento–San Joaquin River system. Among other aims, the law set a goal of restoring the natural production of salmon and other anadromous fish (those that migrate from salt water to fresh water to spawn) to twice their average levels over the preceding 25 years.

The Sacramento River has four salmon runs, each designated by the time of year the fish pass under the Golden Gate Bridge to begin migrating upstream. The population of winter-run chinook plummeted from a peak of 117,808 in 1969 to 533 in 1989—the year authorities listed the fish under the ESA. The 1992 law dedicates 800,000 acre-feet (987 million cubic meters)—about 10 percent of the Central Valley Project's annual water supply—to maintaining fish and wildlife habitat.[26]

Irrigators, not surprisingly, protested the loss of their water and fought relentlessly to roll back the reforms. After five years of haggling, the Department of Interior issued a compromise proposal in late 1997 that called for varying water allocations for fish according to river and fish conditions rather than abiding by the law's fixed allocation. Environmental groups fought back, and in April 1998, the Department of Interior issued a policy that ensures adequate water deliveries to wetlands and wildlife refuges in the Sacramento–San Joaquin River basin.[27]

California's water battlegrounds also include the San Francisco Bay delta, a highly productive aquatic ecosystem that harbors more than 120 species of fish (including the endangered delta smelt and the winter-run chinook salmon) and supports 80 percent of the state's commercial fisheries. The delta supplies water to some 20 million Californians, as well as for irrigating 45 percent of the nation's fruits and vegetables. For many years, fierce conflict has raged over how to balance competing demands on this hub of California's water system.[28]

Protracted negotiations among federal and state officials, farmers, environmentalists, and other affected parties led to a much-heralded consensus agreement in 1994. That accord laid out short-term water quality and outflow requirements for the delta and called for a three-year effort to develop a long-term solution. Five years later, the quest to forge a consensus-based solution continues, with attention and public comment now focused on a revised plan issued in December 1998. A final "preferred alternative" is expected to be announced by the end of 1999.[29]

In neighboring Nevada, home of the nation's first major federal irrigation project, agriculture has clearly lost some rounds in the shifting balance of power over water. Since 1903, irrigation projects have siphoned off much of the flow of the Truckee and Carson Rivers, the lifeblood of northern Nevada. Named after Senator Francis Newlands, architect of the 1902 Reclamation Act, the Newlands irrigation project diverted the Truckee, which flows out of Lake Tahoe down the eastern slope of the Sierra Nevada, past Reno, across 50 kilometers of desert and then through 800 kilometers of canals.

Over time, wetlands and lakes that had been sustained by these rivers began to dry up. Winnemucca Lake, once a wildlife refuge, disappeared in 1938. The Stillwater wetlands declined and were fed increasingly by toxic drainage running off of farm fields. Pyramid Lake, the Truckee's final destination, began to shrink from the diminished inflow, bringing two native fish species to the brink of extinction—the Lahonton cutthroat trout and the cui-ui. The shrinking fish populations alarmed the Paiute Indians, whose reservation surrounds the lake, since they depend on cutthroat trout anglers for income and view the cui-ui, a relic of the Ice Age, as central to their social, religious, and culinary traditions. In fact, the Paiutes' ancient name, Kuyuidokado, means "the cui-ui eaters."[30]

A coalition of federal, state, Indian, and environmental interests have now reordered the priorities for water use in the basin. Not surprisingly, the biggest losers will be the century's largest water consumers—irrigated farms. The several thousand farmers in the Newlands project used to receive more than half of the Truckee River's flow, but their share has now dropped to about a fifth. "For about 100 years it was everybody against the Indians," a lawyer for the Paiute told the *New York Times* in 1997. "In a very short period of time, that's turned around. Now, it's everybody against the Newlands project." With revolving loan money available through the federal Clean Water Act and funds from the Department of Interior, officials are now buying irrigation water rights and restoring flows to the Truckee River.[31]

In addition to public and private efforts to reallocate water to the environment, dams—the ultimate symbol of human control over water—are coming under greater scrutiny. A few dams have already been slated for removal because officials have judged their environmental damages, which were long overlooked, to outweigh their benefits. For example, officials have called for the removal of several hydropower dams in order to restore fisheries and recreational opportunities. Among them are Edwards Dam on Maine's Kennebec River and the Elwha and Glines Canyon dams on the Elwha River in Washington state.[32]

Much bigger proposals are afoot as well that collectively are nothing short of revolutionary. The U.S. Army Corps of Engineers is now studying the idea of breaching four dams on the Lower Snake River in the Pacific Northwest. Besides blocking the river, the dams create continuous slack water for about 220 kilometers upstream of the Snake's confluence with the Columbia, causing most salmon and steelhead to die during their migrations. The *Idaho Statesman,* a conservative newspaper in a conservative state, has endorsed the proposal.[33]

As one species after another has been added to the endangered species list, the dam debate has deepened and divided western interests. A dozen stocks of West Coast salmon, steelhead, and trout are now listed as threatened or endangered, and an additional 13 have been proposed for listing. Across the United States, some 200 separate runs of fish have gone extinct. Upon signing the landmark agreement clearing the way for the removal of Edwards Dam in Maine, Secretary of Interior Bruce Babbitt said that this "is a challenge to dam owners and operators to defend themselves—to demonstrate by hard facts, not by sentiment or myth, that the continued operation of a dam is in the public interest, economically and environmentally."[34]

Over the last two years, the radical idea of breaching one of

the Colorado River's megadams—Glen Canyon—and draining massive Lake Powell has gained force. The proposal has even gotten a hearing on Capitol Hill. Daniel P. Beard, former Commissioner of the reclamation agency that built Glen Canyon Dam, wrote in a 1997 *New York Times* editorial: "There is greater competition for water between cities and farms. Federal construction money has dried up, and environmental concerns have become more urgent. Draining a reservoir and restoring a canyon may just be the cheapest and easiest solution to our river restoration problems."[35]

Although they lack the drama of dam deconstruction, proposals to operate dams according to reordered priorities may have an even larger effect. The driving idea is to manage dams so as to recreate the river's natural flow patterns, thereby benefiting native species and the river system as a whole. Flaming Gorge Dam on the Green River in Utah, for example, is now operated in this way. After the U.S. Fish and Wildlife Service invoked the Endangered Species Act to protect critical habitat for endangered chubs, suckers, and squawfish, officials began dictating dam operations not by irrigation, flood control, and power needs, but in a way that would recreate natural habitat.[36]

Generally, this approach has involved trying to recreate the pre-dam flow patterns of the Green, a major tributary of the Colorado. Rather than storing as much water as possible for the peak irrigation and hydropower demands of late spring and summer, dam operators release a surge of water in May in order to mimic the natural spring flood and facilitate the spawning of native fish populations. Flows are then gradually reduced to a much lower level during the summer, simulating pre-dam conditions.[37]

Further downstream on the Colorado mainstem, federal officials have put similar regulations in place for Glen Canyon Dam in order to partially restore the natural habitat of the famously beautiful Grand Canyon. On the heels of promising results from a landmark test flood in March 1996, dam operators will likely release a major flood surge every 7 to 10 years, and smaller ones every spring. (Should the dam actually be breached, the regulations would of course become moot.)[38]

Although water rights and environmental mandates differ from one country to another, the conflict between private users and the public's interest in ecosystem protection is playing out elsewhere as well. In Australia, concern about the deteriorating health of the Murray-Darling River system is forcing an overhaul of water use and management there. Australia's largest river system, the Murray-Darling supplies about three fourths of all the water used nationwide. It is the main source of water for 16 cities, including Adelaide and Canberra, and some 70 percent of Australia's irrigated agriculture occurs within the basin.[39]

Together, farms, cities, and industries drain off 75–80 percent of the river's annual flow, leaving little for fish and other instream needs, especially during dry periods. The Murray-Darling harbors some 29 indigenous fish species, and—as in the United States—dams and river diversions are destroying their habitats. No national law akin to the U.S. Endangered Species Act safeguards these fish. A few Australian states have legislated the listing of threatened species, but have not followed up with management plans. In New South Wales, fish are not eligible for listing under threatened species legislation. Queensland has no such legislation at all.[40]

Nonetheless, the Murray-Darling basin states have recognized the dire condition of the river system, and have agreed to allocate 25 percent of the river's natural flow to maintaining the system's ecological health. This action is an important step forward, but its implementation—including negotiating each state's respective quota—will not be easy. In 1995, a basinwide freeze was placed on withdrawals for irrigation. In 1997, the Murray-Darling Basin Commission recommended capping allocations to major cities and towns at projected year-2000 levels of water use. The Commission is suggesting that cities

meet any demands above this level by purchasing water from irrigators. Thus in Australia, as in the western United States, farmers practicing irrigated agriculture will either learn to make do with less water or take land out of production.[41]

In developing countries, where demands for food and water are rising rapidly, environmental claims generally have a lower priority and compete for water less successfully. But at least a few regions are considering reallocating water back to nature as the cost of ecosystem deterioration becomes more apparent. The five principal countries of the Aral Sea basin, for example, have agreed that the sea itself should be regarded as an independent water user, and that the ecosystem deserves an allocation of river water just as the countries do. Conceptually, this is a huge and important breakthrough, but implementing the idea is extremely difficult.[42]

Any serious restoration of the Aral Sea would require a massive shift of water out of irrigated agriculture. Nikita Glazovsky, Deputy Director of the Institute of Geography of the Russian Academy of Sciences, estimates that stabilizing the sea at roughly its 1990 level would require that 35 billion cubic meters of river water flow into it each year—about five times the average annual inflow registered during the 1980s. To free up this much water by retiring farmland, more than half of the basin's irrigated cropland would have to come out of production—an unthinkable scenario given the region's dire economic and employment conditions. Discussions have generally focused on more modest restoration of the sea and the river deltas. Such efforts might require on the order of 13–19 billion cubic meters a year of river inflow to the sea—still a large portion of agriculture's current supply.[43]

As discussed in later chapters, farmers in the Aral Sea basin could save a great deal of water by improving irrigation efficiency and shifting cropping patterns. Such steps would also lessen the basin's terrible salt problem. But the incentives and institutions needed to accomplish these transitions on a large scale do not yet exist.

Political leaders in the Aral Sea basin continue to hang their hopes on a large diversion of water from Russia's Siberian rivers into the Aral Sea basin—a controversial, decades-old, $40-billion proposal that President Mikhail Gorbachev shelved in 1986 because of its high price tag and environmental risks. The scheme is a classic example of the tendency to look to unrealistic engineering solutions to water problems in order to avoid the politically difficult but more lasting solution of adjusting economic and agricultural activity to the limits of the available water supply. Meanwhile, even though political leaders have agreed on the need to shift water back to the environment, four out of the five basin countries have plans to expand irrigation to new lands. Such action would set the stage for even more intense competition between agriculture and the environment in the years ahead.[44]

Water Stress and the Global Grain Trade

Will the growing competition for water have global effects, besides local, regional, and national ones? The answer depends in part on how water is transferred from farms to cities and from farms back to the environment. There is, however, one fairly certain global impact that few researchers and political leaders have noticed—the effect regional water scarcity and competition will have on the global grain trade.

Because water is so unwieldy and expensive to transport long distances, countries running short rarely import it. Instead, they import grain—which Tony Allan of the University of London has called "virtual water." With each ton of grain representing about 1,000 tons of water, countries in effect balance their water books by purchasing grain from other countries rather than growing it themselves.[45]

Most economists view this practice as a sensible way to respond to water shortages. They point out that water-scarce

countries can generate much more income from their limited water by using it in commercial and industrial enterprises and then purchasing their grain on the international market. Israel, for example, has done nicely with this approach. As long as surplus food is produced elsewhere, nations with surpluses are willing to trade, and the countries that need food can afford to pay for the imports, it would seem that water-short countries can have food security without needing to be food self-sufficient.

This tidy logic is shaken, however, by the rapidly growing number of people who will be living in countries forced by water scarcity to follow this path. As a nation's net precipitation (also called runoff) per person drops below about 1,700 cubic meters, food self-sufficiency becomes difficult, if not impossible. In most countries, it is only possible to store and control 20–50 percent of the total runoff, so only a fraction of the water resource is actually available for use. As a result, below 1,700 cubic meters per person, there is often not enough usable water to meet the demands of industries and cities and to grow enough food for the entire population while at the same time sustaining river flows for navigation, fisheries, and other ecological functions. Countries in this situation then begin to import water indirectly, in the form of grain.

At present, 34 countries in Africa, Asia, and the Middle East have per capita runoff levels below 1,700 cubic meters a year. All but two of them—South Africa and Syria—are net importers of grain, and 24 of them already import at least 20 percent of their grain. (See Table 6–1). Collectively, these water-stressed countries import nearly 50 million tons of grain a year. World grain exports total about 200 million tons a year, so water scarcity is to some degree driving about one fourth of the global grain trade.[46]

As populations grow, per capita runoff will drop below the 1,700-cubic-meter level in more and more countries, and the countries already in this group will also have larger populations. By 2025, Africa will add 10 countries to this list. India,

Table 6–1. Grain Import Dependence of Selected Countries in Africa, Asia, and the Middle East with Less than 1,700 Cubic Meters of Annual Runoff per Person[1]

Country	Internal Runoff per Capita, 1995	Net Grain Imports as Share of Consumption[2]
	(cubic meters per year)	(percent)
Jordan	249	91
Israel	309	87
Libya	115	85
South Korea	1,473	77
Algeria	489	70
Yemen	189	66
Tunisia	393	55
Saudi Arabia	119	50
Uzbekistan	418	42
Egypt	29	40
Azerbaijan	1,066	34
Turkmenistan	251	27
Morocco	1,027	26
Somalia	645	26
Rwanda	808	20
Iraq	1,650	19
Kenya	714	15
Sudan	1,246	4
Burkina Faso	1,683	2
Burundi	563	2
Zimbabwe	1,248	2
Niger	380	1
South Africa	1,030	–3
Syria	517	–4

[1]Ten other countries have fewer than 4 million people each and are omitted from this table. Runoff figures do not include river inflow from other countries, in part to avoid double-counting. [2]Ratio of annual net grain imports to grain consumption averaged over the period 1994–96.
SOURCE: See endnote 46.

Pakistan, and several other Asian nations will join it as well. The total number of people living in African, Asian, and Middle Eastern countries with per capita runoff below the benchmark level will jump more than sixfold by 2025—from about 470 million to more than 3 billion. (See Table 6–2.) The vast majority of these people will be living in Africa and South Asia, where the deepest pockets of poverty and hunger are today.[47]

Like an M.C. Escher drawing, this larger picture of water scarcity's implications only comes into focus by standing back and absorbing all the parts at the same time. What appears to be a solid and sensible recommendation for any one country may appear just the opposite when applied to many. It seems dangerous to presume, as many economists and officials do, that there will be enough exportable grain to meet the import needs of all these countries at a price they can afford. And with world food aid at its lowest level since the mid-1950s, having dropped two thirds since 1992–93, relying on the generosity of grain-surplus nations to fill food gaps is a risky strategy.[48]

Water, long left out of the food security equation, may now

Table 6–2. Number of People in African, Asian, and Middle Eastern Countries with Less than 1,700 Cubic Meters of Annual Runoff per Person, 1995, with Projections for 2025

Region	1995	2025	Factor Increase
	(million people)		
Africa	295	908	3.1
Asia	86	1,957	22.8
Middle East	86	185	2.1
Total	467	3,050	6.5

SOURCE: See endnote 47.

be driving it. As domestic competition for water spills over into international competition for grain, it will be the poor, food-deficit nations that lose out. Without a concomitant rise in the income levels of the very poor, a rise in food prices could place the health and lives of many additional millions at risk. Confronting this threat head-on will take efforts to raise the food production and income levels of the poor directly. And as described in Chapter 9, irrigation has a key role to play in meeting this challenge.