CHAPTER 1

The Soft Path for Water

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> *. . . I shall be telling this with a sigh*
> *Somewhere ages and ages hence:*
> *Two roads diverged in a wood, and I,*
> *I took the one less traveled by,*
> *And that has made all the difference.*
> ROBERT FROST (1874–1963),
> “THE ROAD NOT TAKEN”

The world is in the midst of a major transition in the way we think about—and manage—our vital and limited freshwater resources. Earlier volumes of *The World’s Water* have described different aspects of this transition as the “changing water paradigm.” This chapter goes further, describing the transition in terms of a choice of paths we can take. People do not want to “use” water. People want to drink and bathe, swim, produce goods and services, grow food, and otherwise meet human needs and desires. Achieving these ends can be done in different ways, often with radically different implications for water.

There are two primary ways of meeting water-related needs, or more poetically, two paths. One path—the “hard” path—relies almost exclusively on centralized infrastructure and decision making: dams and reservoirs, pipelines and treatment plants, water departments and agencies. It delivers water, mostly of potable quality, and takes away wastewater. The second path—the “soft” path—may also rely on centralized infrastructure, but complements it with extensive investment in decentralized facilities, efficient technologies, and human capital.[1] It strives to improve the overall productivity of water use rather than seek endless sources of new supply. It delivers diverse water services matched to the users’ needs and works with water users at local and community scales.

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[1] Amory Lovins (1977) originally coined the term “soft path” for energy use. We warmly acknowledge his paternity in the terminology and many of the concepts discussed here. The Rocky Mountain Institute’s definition and discussion of the soft path for water is available at www.rmi.org/sitepages/pid278.php.

This chapter tells the tale of these paths up to the present. Decisions made today, and actions of future generations, will write the conclusion of the story.

Water is a critical and essential resource. In the past, water policy has typically revolved around the idea that regular additions to supply were the only viable options for meeting anticipated growth in population and the economy. This idea led to the construction of pipelines and aqueducts that bring water to many towns and cities and to the irrigation canals that bring water to dry but fertile soils. Once "easy" sources of raw water are captured, however, this path leads to more and more ambitious, intrusive, and capital-intensive projects that capture and store water far from where the water is needed, culminating in the massive water facilities that dominate parts of our landscape.

The traditional approach to water supply led to enormous benefits. The history of human civilization is intertwined with the history of the ways humans have learned to manipulate and use water resources. The earliest agricultural communities arose where crops could be grown with dependable rainfall and perennial rivers. Irrigation canals permitted greater crop production and longer growing seasons in dry areas, and sewer systems fostered larger population centers.

During the industrial revolution and population explosion of the nineteenth and twentieth centuries, the demand for water rose dramatically. Unprecedented construction of tens of thousands of monumental engineering projects designed to control floods, protect clean water supplies, and provide water for irrigation or hydropower brought great benefits to hundreds of millions of people. Thanks to improved sewer systems, cholera, typhoid, and other water-related diseases, once endemic throughout the world, have largely been conquered in the more industrialized nations. Vast cities, incapable of surviving on their local resources, have bloomed in the desert with water brought from hundreds and even thousands of miles away. Food production has kept pace with soaring populations largely because of the expansion of artificial irrigation systems that now produce 40 percent of the world's food. Nearly one-fifth of all of the electricity generated worldwide is produced by turbines spun by the power of falling water.

On the other hand, half the world's population still suffers with water services inferior to those available to the ancient Greeks and Romans. According to the World Health Organization's most recent study, more than 1 billion people lack access to clean drinking water, and nearly 2.5 billion people do not have improved sanitation services (World Health Organization 2000). Preventable water-related diseases kill an estimated 10,000 to 20,000 children each day, and the latest evidence suggests that we are falling behind in efforts to solve these problems. There were new, massive outbreaks of cholera in the 1990s in Latin America, Africa, and Asia. The number of cases of dengue fever—a mosquito-borne disease—doubled in Latin America between 1997 and 1999. Millions of people in Bangladesh and India are drinking water contaminated with arsenic. And population growth throughout the developing world is increasing the pressure on limited water supplies.

The effects of our water policies extend beyond jeopardizing human health. Tens of millions of people have been forced to move from their homes—often with little warning or compensation—to make way for the reservoirs behind dams. Certain irrigation practices degrade soil quality and reduce agricultural productivity, threatening to bring an end to the Green Revolution. Groundwater aquifers are being pumped down faster than they are naturally replenished in parts of India, China, the United States, and elsewhere. And disputes over shared water resources have led to violence and continue to raise local, national, and even international tensions (see the Water and Conflict Chronology in the Water Briefs section of this volume).

Negative impacts on natural habitat are also significant. More than 20 percent of all freshwater fish species are now threatened or endangered because dams and water withdrawals have destroyed the free-flowing river ecosystems where they thrive (Ricciardi and Rasmussen 1999). On the Columbia and Snake Rivers in the northwestern United States, 95 percent of the juvenile salmon trying to reach the ocean do not survive passage through the numerous dams and reservoirs that block their way. More than 900 dams that block almost all New England and European rivers keep Atlantic salmon from their spawning grounds, and their populations have fallen to less than 1 percent of historic levels. Perhaps most infamously, the Aral Sea in central Asia is disappearing because water from the Amu Darya and Syr Darya Rivers that once sustained it has been diverted to grow cotton. Twenty-four species of fish formerly found in the sea and nowhere else are now thought to be extinct.

A Better Way

In the twenty-first century we can no longer ignore these costs and concerns. The old water development path—successful as it was in some ways—is increasingly recognized as inadequate for the water challenges that face humanity. We must now find a new path with new discussions, ideas, and participants. In the 1990s, progress was made in building bridges among competing water interests and in expanding the venues for discussing and resolving disputes. In time, these efforts will lead to better ways of meeting diverse water needs in a sustainable and equitable manner. But the process of defining, developing, and implementing an alternative path has not yet been completed. Moreover, powerful groups in the water sector continue to claim that decentralized investments in capital and people cannot and will not be effective. They believe that bigger and bigger centralized facilities are just fine. They want to continue on the hard path, and they claim it is still the best way to meet global water needs.

We refer to the traditional path as the "hard path" and the newer, alternative path as the "soft path." The adjective *soft* refers to the nonstructural components of a comprehensive approach to sustainable water management and use, including equitable access to water, proper application and use of economics, incentives for efficient use, social objectives for water quality and delivery reliability, public participation in decision making, and more.

The soft path can be defined in terms of its differences from the hard path. The two paths differ in at least six ways:

1. The soft path redirects government agencies, private companies, and individuals to work to meet the water-related *needs* of people and businesses, rather than merely to supply water. For example, people want to be clean or to clean their clothes or produce certain goods and services using convenient, cost-effective, and socially acceptable means. They do not fundamentally care how much water is used, and may not care whether water is used at all (Box 1.1). Water utilities on the soft path work to identify and satisfy their customers' demands for water-based services. Since they are not concerned with selling water per se, promoting water-

Box 1.1 Meeting People's "Needs": How Much Water Is Really Needed?

People do not "need" water, except to drink and cook meals that maintain basic human health. People need services and goods such as food crops or waste disposal. Food production will always require some amount of water, but far less than is currently being used in most agricultural settings. Waste disposal does not require any water, although using some amount of water for this purpose may be appropriate.

Agriculture is the largest consumer of water worldwide: often 80 percent of water use in a country or region. The potential for water efficiency improvements from techniques such as furrow diking, land leveling, direct seeding, drip irrigation, micro-sprinklers, and water accounting is large. For example, micro-irrigation systems (primarily drip and micro-sprinklers) often achieve efficiencies in excess of 95 percent, as compared with flood irrigation efficiencies of 60 percent or less. As of 1991 (Postel 1997), however, only 0.7 percent of irrigated farmland worldwide was being micro-irrigated.

Toilet flushing is the largest indoor use of water in Western, nonconserving, single-family homes. New technology, however, can manage human wastes without water. Electrically mixed, heated, and ventilated composting toilets have no odors or insect problems and produce a finished compost that does not endanger public health (Del Porto and Steinfeld 1999). These devices safely and effectively biodegrade human wastes into water, carbon dioxide, and a soil-like residue. Although they use about 500 kilowatt-hours of electricity per year, they can displace an equal or greater amount of electricity currently used to deliver water and treat wastewater. At present, electric-assisted composting toilets cost much more than conventional flush toilets.

Whether water-efficient technology will become socially acceptable as it becomes economically competitive is an important question. Soft-path planners believe that farmers want to grow crops rather than use water and will implement any water-conserving technology that makes economic and social sense. Soft-path planners believe that most people want human wastes managed in a convenient, cost-effective, hygienic way, and that they will accept alternatives that use little or no water if these criteria are met. Hard-path planners assume that future choices will look like current choices, with very slow technological progress. This is because hard-path planners erroneously equate water supply with the underlying needs that must be satisfied.

use efficiency becomes an essential task rather than a way of responding to pressure from environmentalists. The hard path, in contrast, fosters organizations and solutions that make a profit or fulfill their public objectives by delivering water—and the more the better.

2. The soft path leads to water systems that supply water of various qualities, with higher quality water reserved for those uses that require higher quality. For example, storm runoff, gray water, and reclaimed wastewater are explicitly recognized as water supplies suited for landscape irrigation and other nonpotable uses. This is almost never the case in traditional water planning: all future water demand in urban areas is implicitly assumed to require potable water. This practice exaggerates the amount of water actually needed and inflates the overall cost of providing it. The soft path recognizes that single-pipe distribution networks and once-through consumptive-use appliances are no longer the only cost-effective and practical technologies. The hard path, in contrast, discounts new technology, and over-emphasizes the importance of economies of scale and the behavioral simplicity of one-pipe, one-quality-of-water, once-through patterns of use.

3. The soft path recognizes that investments in decentralized solutions can be just as cost-effective as investments in large, centralized options. For example, there is nothing inherently more reliable or cost-effective about providing irrigation water from centralized rather than decentralized rainwater capture and storage facilities, despite claims by hard-path advocates to the contrary. Decentralized investments are highly reliable when they include adequate investment in human capital, that is, in the people who use the facilities. And they can be cost-effective when the easiest opportunities for centralized rainwater capture and storage have been exhausted. In contrast, the hard path assumes that water users—even with extensive training and ongoing public education—are unable or unwilling to participate effectively in water-system management, operations, and maintenance.

4. The soft path requires water agency or company personnel to interact closely with water users and to effectively engage community groups in water management. Users need help determining how much water of various qualities they need, and neighbors may need to work together to capture low-cost opportunities (Box 1.2). In contrast, the hard path is governed by an engineering mentality that is accustomed to meeting generic needs.

5. The soft path recognizes that ecological health and the activities that depend on it (e.g., fishing, swimming, tourism, delivery of clean raw water to downstream users) are water-based services demanded, at least in part, by their customers, not just third parties. Water that is not abstracted, treated, and distributed is being used productively to meet these demands. Water is part of a natural infrastructure that stores and uses water in productive ways. The hard path, by ignoring this natural infrastructure, often *reduces* the amount and quality of water available for

Box 1.2 The Benefits of User Participation: Condominial Sewers

Most cities in less-developed parts of the world are surrounded by neighborhoods that have minimal or no piped water or wastewater services. Hundreds of millions of people live in these peri-urban areas, often as squatters in great poverty but also as legal homeowners with modest income. Traditional sanitary sewers are composed of a lateral line from each home to a trunk sewer line in or along the street that eventually connects to large-diameter sewer mains that service relatively large areas. Although main and trunk lines are usually built and maintained by a government agency, lateral lines and in-house plumbing are usually built and maintained by each household.

Brazilian engineer Carlos de Melo, working with residents of peri-urban areas in northeast Brazil, developed an alternative sanitary sewer system that cost residents only about one-third as much as the traditional system. His innovation was to replace conventional, deep, individual-house lateral sewers with shallow laterals that provide service to a series of homes, often passing through back and side yards in ways that reduce the total length of sewer required. This innovation would not be possible without the cooperation of groups of neighbors who share each "condominial" sewer lateral.

Involving users of the system has had advantages other than cost. For example, the system has built-in incentives for maintenance. If one household drain blocks, neighbors quickly bring it to the attention of the household and the problem is fixed rapidly. Less solid waste is disposed inappropriately down the sewers because blockages have immediate effects in the neighborhood. And the operations and maintenance cost for the formal sewer agency declines. Condominial sewer systems—a soft-path wastewater technology made possible by water user cooperation—are increasingly being used around the world.

Sources: World Bank 1992, Wright 1997.

use. The hard path defines infrastructure as built structures, rather than separating it into built (gray) and natural (green) components.[2]

6. The soft path recognizes the complexity of water economics, including the power of economies of scope. The hard path looks at projects, revenues, and economies of scale. An economy of scope exists when a combined decision-making process would allow specific services to be delivered at lower cost than would result from separate decision-making

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[2] "Gray infrastructure" is a term apparently coined by Lovins, though Falkenmark uses "blue" and "green" to refer to separate human and natural water uses.

> processes. For example, water suppliers, flood control districts, and land-use authorities (e.g., local government) can often reduce the total cost of services to their customers by accounting for the interactions that none of the authorities can account for alone. This requires thinking about land-use patterns, flood control, and water demands in an integrated, not isolated, way.

Dominance of the Hard Path in the Twentieth Century

The water-supply hard path has dominated water development in the twentieth century, at least in part for the legitimate reasons presented below. But rationales often outlive their usefulness. Furthermore, the choice of development paths is not an absolute choice between hard and soft paths. It is a choice about the path of water development after a basic built water infrastructure has been provided. Should we try to supply more and more water, or is it time to shift our focus from new physical supply to reassessing how fixed supplies of water can be better used to meet ongoing water-related needs? Should water managers stick with the kinds of projects and techniques they know and continue to fail to meet the water-related needs of some people and many ecosystems? Or is it time to emphasize new approaches that seem more likely to meet these needs?

Shared Water Sources versus Individual Water Use

Natural *sources* of water are typically shared. A "water hole" for every household is not realistic in most situations. Even when groundwater is the primary source of water supply and each household has a well, use or abuse of underground water by each household can affect neighboring households. Some degree of agreement and cooperation among users of a shared resource is desirable unless water is abundant. As a result, over hundreds and even thousands of years, people have created social, cultural, and legal rules and built facilities that govern and physically manage shared sources of water.

In contrast, *end use* of water is not shared. There is no compelling reason for users to discuss or improve end-use practices when water is abundant. Even when water is not abundant, end-use practices tend to be viewed as personal rather than community issues. As long as water is allocated in a way that is acceptable to the group, why should the group care how water is used? The belief that the customer is always right once water has been delivered to them—even when the customer is ignorant or wasteful[3]—is deeply embedded in the hard-path paradigm. The soft-path paradigm is emerging only as more efficient water use by individual customers is recognized to be a legitimate social concern because of the growing social (and environmental, economic, and cultural) costs of the failure to be efficient.

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[3] Water law in California and other places requires (in theory) that water use be reasonable and beneficial; that is, extremely wasteful practices are prohibited by society. But other than extreme situations, the difference between beneficial use and waste is an individual—not social—choice under current laws and customs in most parts of the world.

Economies of Scale in Collection and Distribution

Another reason for the dominance of the hard path is the economy of scale that often exists—or is believed to exist[4]—in water collection (e.g., reservoirs), treatment, and distribution systems. Each person carrying water from a well or river takes much more time and effort than building, operating, and maintaining a shared system of water pipes. And once a system is constructed, devices that increase use efficiency are of little value so long as water is abundant. In such circumstances, the marginal cost of water from the piped system is much lower than the marginal cost of water conservation efforts.

Economies of scale exist by definition when the cost per unit of water declines as the total amount of water that is managed increases. When shared water sources are difficult to expand further, the cost per unit of water will increase if the system is expanded. Once economies of scale have been exhausted, the marginal cost (or cost of each additional liter) of water from piped systems will (sooner or later) become higher than the marginal cost of water conservation efforts. For example, low-flow toilets were not a difficult technological advance and are inexpensive to purchase and install. But they became widely cost-effective in the United States only after the seemingly cheapest sources of surface and groundwater had been exploited. This is why the emergence of the soft water development path is an appropriate response to history as well as a change from historical practices.

Simple End-Use Technology When Water or Energy Is Abundant

Wherever fresh water was abundant historically, end-use technologies were simple. Washbasins, with or without running water, or pipes located at the proper height over well-drained surfaces were adequate for drinking, cooking, bathing, and clothes washing. Machinery that used water—such as electrically powered clothes washers—were designed much later to replace human labor, not to use water more efficiently. Sophisticated and technically efficient water-measurement and -use devices, a key component of soft-path water systems, were not necessary and did not develop as rapidly as did water collection and distribution technologies (e.g., dams, pipes, pumps).

Where water was not abundant, numerous soft-path techniques were developed. The choice of crops is a good example: people need nutritional food but can choose among a variety of crops to meet that need. Olives are an important part of Middle Eastern and Mediterranean cultures because they are well adapted to semi-arid regions. Rice was not grown in most arid regions prior to the availability of inexpensive

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[4] Conventional accounting is often criticized for failing to include social and environmental costs that do not require money expenditures by the project developer. For example, the cost of the Aswan High Dam did not include many environmental and social costs that were identified after the dam began operation. Consequently, we caution readers to carefully examine claimed economies of scale. Some economies of scale are real; others are not real but seem to be due to a poor choice of analytical method. It is also useful to think of the size of the "gap" between narrow and broader cost estimates as depending on the knowledge level and relative political power of those who bear the "unaccounted for" costs. Economist James Boyce points out that unaccounted for environmental and social costs (so-called external costs) will be larger, in theory, when the costs are imposed on as yet unborn future generations, living people who are unaware of the costs being imposed on them, or living people who are aware but are not politically powerful enough to force a fuller cost accounting.

energy, unless farmland was located downhill from water sources. Both crop choices are examples of simple end-use "technology" decisions when water is scarce and energy to bring water from distant places is expensive.

Myths about the Soft Path

Because the emergence of the soft path diminishes the power and influence of entrenched interests, there is resistance to it among practitioners of hard-path planning. This has led to myths—widely believed falsehoods—about the soft path. The next section explains and debunks the six most common myths about the soft path.

Myth: Efficiency Opportunities Are Small

Traditional water planners and managers often believe that opportunities for improving water-use efficiency are small. A side effect of the initial focus on structures to capture and deliver water was that water planning agencies and companies came to be dominated by engineers.[5] Engineers are understandably very cautious in their decision making and designs. After all, lives and livelihoods often depend on the engineer being right. But because efficiency improvements depend on the behavior of water users, rather than professional personnel of the water agency or company, engineers often have little experience with the potential for efficiency improvements. Even when improved end-use devices are involved, such as low-flow toilets, many water agencies and companies believe that reduced water use due to installation of such devices will be relatively small or transient. Without professional supervision, so the thinking goes, these devices will break down over time and use more water than when new, or customers may defeat the water-saving potential through misuse (e.g., double flushing).

Myth: Water Demand Is Relatively Unaffected by Market Forces

Water demand has traditionally been projected, erroneously, as independent of costs, prices, subsidy considerations, and market forces. This means that the price elasticity of demand has been implicitly assumed to be equal to zero.[6] Given this mindset, it is not surprising that most historical estimates of future water demand have greatly overestimated actual demand (Figure 1.1). In places where an effort has been made to identify and capture improvements in water-use efficiency, water demands have been cut by 20, 30, 40 percent, or more (Gleick et al. forthcoming).

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[5] On a personal note, both authors of this chapter have formal engineering degrees, and one (Wolff) is a licensed professional engineer.

[6] Because water is an essential and basic good, some argue that the price elasticity of water demand is small. That is the case in some instances, or over short time periods; but even then the price elasticity is certainly not zero. On the other hand, there are numerous examples of water users responding to price increases by significantly changing their behavior or investing in or inventing devices that reduce water use dramatically without a reduction in the final, water-based service that is desired. The price elasticity of water demand is high in many instances or over long enough time periods.

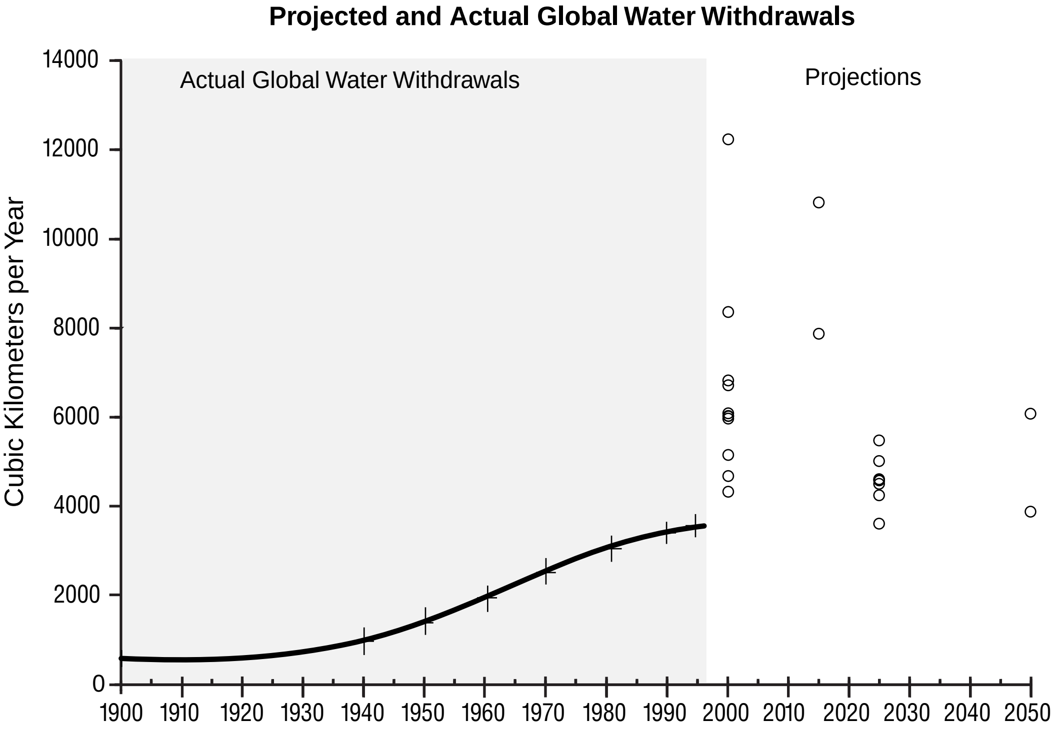

FIGURE 1.1 Many "projections" have been made of future water use. This figure shows actual global water withdrawals and projections made over the past 40 years. Almost all projections overestimated future water use—often substantially.
Source: Gleick 2000

Myth: Conserved Water Is Not "Real"

Another result of the difference in mindset between the hard and soft paradigms is the fundamental misunderstanding—or myth—that efficiency improvements involving nonconsumptive water uses are not real. Consumptive uses of water prevent that water from being reused. These include evaporative loss, contamination that cannot be removed by treatment, or discharge to a salt sink such as the ocean. Hard-path planners understand that greater efficiency in consumptive uses makes real, physical water available to other users. But they have been confused about nonconsumptive uses of water: uses that permit reuse (e.g., showers or runoff water from excess irrigation).

Consequently, a considerable number of confusing terms have appeared in the water conservation literature in the past few years. Among the terms used to describe the "kinds" of water that might be saved are *real* water, *paper* water, *applied* water, and *new* water. Some of these distinctions have been valuable in identifying where and when conservation is most beneficial, allowing planners to focus on the improvements in water-use efficiency that are the most appropriate and valuable (Keller and Keller 1995, Molden 1997, Seckler 1996, Gleick and Haasz 1998). Some of these terminological distinctions, however, have been misleading or have misrepresented the reality of efficiency improvements.

For example, water accounts for the Nile River (Molden 1997) indicate that only 20–30 percent of irrigation water diverted from the Nile is evaporated or transpired by crops. The remainder is return water that is reused downstream. Some have claimed that upstream reductions in nonconsumptive use are relatively unimportant because water loss is not the same as water waste (Palacios-Velez 1994). Of course this is strictly correct: irrigation return flows have not been "wasted." But upstream conservation would allow a larger upstream area to be irrigated, or would improve water quality for downstream natural systems or irrigators, or might improve the navigability of the Nile. These types of benefits need to be weighed against the costs of conserving water that is nonconsumptively used at present.

The California Department of Water Resources (CDWR) made a similar claim in the water plans prepared in the 1990s: upstream reductions in nonconsumptive use do not produce "new" water (CDWR 1998). Sacramento, under this line of thought, should not bother to install residential water meters or retrofit houses with low-flow showerheads or toilets since water conserved in Sacramento will be used downstream anyway. This error led state water planners to ignore improvements in urban water-use efficiency in inland regions (CDWR 1998). That, in turn, led to an overestimate of future urban demand in California in 2020 by more than a billion cubic meters (Gleick and Haasz 1998).

Of course, CDWR was correct in saying that "new" water was not produced. But the water savings from efficiency improvements in Sacramento would be real, nonetheless, because they allow new customers and new demands in Sacramento to be supplied with real water without taking more water from nature, or they allow higher quality flows of water for some distance downstream of Sacramento. Higher quality downstream flows would enhance natural systems that provide recreation, fishing, tourism, and other benefits. Whether the conserved water is "new" or not is irrelevant to the key issue: Does conservation of nonconsumptively used water create benefits that exceed the costs of conservation?

Myth: Efficiency Improvements Are Speculative and Risky

Even when hard-path water planners believe that the technical potential for water efficiency improvements is large, and the water saved is "real," they also tend to believe that relying on efficiency improvements is risky. Traditional water planners are happy to base water policy on assumptions about the probability a that there will be b people in the future using c amounts of water per person requiring d new reservoirs and treatment plants. Yet the same planners have historically rejected as speculation that economic or technical strategy w will lead to the installation of x high-efficiency toilets and showerheads that each save y cubic meters of water capable in total of eliminating the need for z new reservoirs and treatment plants. Hard-path water planners argue that our well-being and economic health rely on proven approaches rather than speculative policies that may not work.

Of course there is a germ of truth in the fear that decentralized efforts to curb demand may be unreliable. Left entirely alone, water customers may fail to notice that efficient water-using devices are no longer operating efficiently or may fail to continue their initially water-conscious and efficient behavior. One need only think about how often lights are left on in empty rooms when the public thinks that electricity is inexpensive and abundant. On the other hand, aggregate water-use patterns—such as seasonal and daily variations—are so predictable and reliable that water planners use them routinely. One wonders if rigorous statistical analysis would find that conservation is any less reliable than, for example, surface water supply in areas that experience periodic droughts.[7]

Furthermore, reliable and permanent efficiency improvements are achievable. They require training, public education, and on-going feedback to customers from the water supplier. Just as centralized water systems are unreliable when they are improperly designed, operated, or maintained, decentralized systems will be unreliable unless water users are reminded to behave in a consistent way and are rewarded or punished for failure to do so.

Achieving reliable reductions in water demand requires new "soft-path customer relations." Customers will need more information than in the past. For example, they need to know when their water use is higher than the average for similar users (e.g., single-family residences with similar floor size) or similar functions (e.g., irrigating a 100-square-meter garden). Whether their usage is higher or lower than average, they also need to be told when water-efficiency investments are financially desirable for them to make, taking into account savings other than on their water bill (e.g., energy bill savings from heating less water). Some customer classes (e.g., small businesses) may need help financing or obtaining credit with which to finance such investments.

Just as fire departments reorganized dramatically—becoming more specialized and professional—as buildings increased in height, the emergence of water scarcity is not just causing changes in water-use patterns (e.g., precision irrigation) but also causing water suppliers to rethink their roles and objectives. If supplying physical water is the only objective, demand management will seem speculative and unreliable. But when working closely with customers to meet their water-related needs becomes an equally important objective, demand management will be seen as a reliable way to stretch existing water supply.

Myth: Efficiency Improvements Are Not Cost-Effective

As mentioned above, centralized water facilities were historically lower cost—within a somewhat narrow accounting methodology—than decentralized investments in efficiency. This may still be the case in some circumstances. But the belief that efficiency improvements are more expensive than new or expanded centralized water supply is incorrect in most circumstances.

On the water-supply side of the economic comparison, recent centralized projects have cost considerably more than initially envisioned (Box 1.3) even without accounting for the environmental and social costs of new dams and reservoirs, which are usually neglected. Dams and reservoirs routinely end up costing two, three, or even more times their originally projected capital costs, and new facilities are many times more expensive than the first ones built in a region or watershed.

On the conservation side of the economic comparison, the cost of efficiency improvements has trended downward as technologies mature and comprehensive efforts are implemented. For example, some brands of early low-flow toilets (e.g., 1.6 gallons per flush), as well as a few still sold today, occasionally require double-flushing to provide equivalent service to older, more water-intensive toilets (e.g., 3.5 or 6 gallons per flush models). But the best low-flow toilets no longer have this problem, and they

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[7] We credit Bob Wilkinson for this penetrating question.

Box 1.3 Perennial Cost Overruns on the Hard Path

There are many anecdotal and documented stories of water-supply project cost overruns. According to international data, however, cost overruns are the rule rather than the exception. World Bank statistics on dam construction projects over the last four decades suggest that construction cost overruns averaged 30 percent on the 70 hydropower projects funded by the Bank since the 1960s. Another World Bank study found that three-quarters of the 80 hydro projects completed in the 1970s and 1980s had costs in excess of their budgets, and almost one-third of the projects studied had actual costs that exceeded estimates by 50 percent or more.

There are many reasons for cost overruns, including delays, design errors, poor quality construction, or corruption of project advocates and managers. For example, the Chixoy Dam in Guatemala was delayed for nine years by the collapse of some poorly designed tunnels. Its final cost of $1.2 billion was more than five times its initial cost estimate. The Yacyreta Dam on the Parana River between Argentina and Paraguay became known as a “monument to corruption” as the cost of the project increased to $8 billion from an original estimate of $1.6 billion. Cost overruns are not restricted to projects in less-developed countries: the recently completed Diamond Valley Reservoir in southern California had actual costs considerably higher than originally estimated. And last year, an economist at the U.S. Army Corps of Engineers blew the whistle on biased cost-benefit studies for projects along the Missouri and Mississippi Rivers, leading to calls for reform of the cost estimating and evaluation process.

Sources: World Commission on Dams 2000, International Rivers Network 2001

cost no more on average than inadequate low-flow models or the older wasteful models. As water suppliers have learned which models reliably save water, and provided this information to their customers, the cost of conserving water via low-flow toilet installation has fallen. This trend will continue as the technology for pressure-flush toilets (around 0.6 gallons per flush) and waterless toilets and urinals improves.

Another reason for the belief that efficiency improvements are too expensive is that hard-path water planners usually compare the cost of efficiency improvements without accounting for secondary benefits. Box 1.4 illustrates this problem with some common indoor residential water- and energy-using appliances. Without accounting for the avoided energy expense for water heating, only toilets and showerheads are cost-effective compared with water-supply augmentation at $325 or more per acre foot. After accounting for the energy benefit, washing machines and dishwashers are also highly cost-effective, even if new water supply could be obtained for free.[8]

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[8] This analysis was done assuming natural gas costs, but similar or better results would be obtained for electric water heating or other sources of heat.

Benefits of water-use efficiency, other than reduced water or energy bills, that are increasingly being discussed (Dziegielewski 1999) or quantified include the following:

- Reductions in *peak water system loads.* Peak loads determine the size of capital facilities required, hence capital costs. Lower peak loads mean

Box 1.4 The Importance of Secondary Benefits

One can estimate the cost of conserved water by dividing the amortized *additional* cost of a new high-efficiency water-using device (e.g., a new showerhead) by the average annual reduction in water use that the device will produce over its service lifetime, as compared with an average "conventional" water-using device. When high-efficiency devices are installed only when older devices would be replaced naturally (due to wear or remodeling), or are installed during new construction, the cost of installation is not part of the *additional* cost of high-efficiency devices. This is called "natural replacement." The "amortization divided by water savings" method, however, assumes that operation and maintenance costs other than water expenses are the same for both devices. This is a reasonable assumption for some devices, for example, toilets.

It is unreasonable for devices that use heated water. The following comparison of the cost of conserved water from four indoor residential water-using devices shows how important accounting for just one secondary benefit can be for water users in California. The only benefit other than water savings that we quantified was the reduced energy bill that results from using less heated water, assuming that natural gas is used for water heating. Electric water heating would only make these efficiency improvements more attractive. The negative cost estimates mean that the annual financial benefits other than reduced water expenses would justify the conservation investment *even if water were free.*

Device Installed (Natural Replacement)	**Cost of Conserved Water (in Dollars per Acre-Foot)**	
	Without Energy Benefit	**With Energy Benefit**
1.6 gallon per flush toilet	$45	$45
2.5 gallon per minute showerhead	$324	-$736
Average high-efficiency clothes washer (includes vertical and horizontal axis machines)	$865	-$177
Average high-efficiency dishwasher	$862	-$102

Source: Gleick et al. forthcoming

that existing capital facilities can serve more customers, avoiding or reducing the expense of these facilities.

- Reductions in *peak energy demands.* Energy and water-supply networks are similar in many ways. Reduction of peak energy demand caused by less water pumping, treatment, or heating will similarly allow energy utilities to serve more customers with existing capital facilities, avoiding or reducing capital expenses that are ultimately paid by energy purchasers.

- Reductions in *wastewater treatment expenses,* both operational and for expansion of existing sewers or treatment facilities.

- Reductions in *environmental damage* from water withdrawals or wastewater discharges in environmentally sensitive locations.

- Increases in *employment;* for example, by increasing the rate at which appliances or irrigation systems are monitored, serviced, or replaced. Investments in large, centralized capital facilities increase employment during construction but use relatively little labor once construction is complete.

The myth that efficiency improvements are not economically competitive with expansion of centralized supplies is slowly being overcome. Water planners are beginning to realize that the cost escalation, construction delays, and interest charges that so often plague large capital-intensive water projects do not have the same effect on conservation programs. It is an inherent characteristic of small-scale water-efficiency efforts that their lead times are substantially shorter than those of conventional big systems. This has been seen over and over again: for example, in Santa Barbara, California, a severe drought in the late 1970s stimulated local residents to support the construction of a large desalination plant, as well as a pipeline to connect to the centralized state water project. When the very high economic costs of those hard-path options were passed on to consumers, reductions in demand occurred so fast that the hard-path options became unnecessary. The desalination plant has not been put into routine operation and is currently in the process of being “mothballed” (partially decommissioned). If effective pricing programs, education, and community planning had been done first, the expense of these facilities could have been long delayed, perhaps completely avoided.

Whether in development, distribution, installation, or repair, producing small and technically simple systems is faster than designing, permitting, financing, and constructing large-scale reservoirs. As Lovins (1977) noted for the energy industry, the industrial dynamics of the soft path are very different from the hard path, the technical risks are smaller, and the dollars invested are far more diversified, reducing financial risk.

Myth: Demand Management Is Too Complicated

One of the reasons that *efficiency approaches* are difficult for traditional water agencies to adopt is that they *shift the burden from engineering logistics to social ones.* Traditional water agencies are usually dominated by engineering experts who know how to design and build large structures that can serve a million people. But these same experts are unfamiliar with methods for designing and implementing efficiency programs that reach a million individual customers. It is not surprising that working with individual customers and coordinating among many customers seems too complicated to engineers. These tasks are complicated, but no more so than engineering projects. But different professional skills and training are required, so demand management appears too complicated when one is not trained in people management, human capital investment (e.g., educators), and related disciplines.

It is also true that the types of information and technical assistance that water suppliers must offer to customers on the soft path would not have been as manageable a decade or two ago. There have been rapid advances in information processing, water-use monitoring, and more efficient end-use devices and practices. Even those who are skilled practitioners within the field may find it difficult to keep up with the newest information. This reinforces the perception that demand management is too complicated. As the demand management field matures, however, this perception—and myth—will weaken. Indeed, growing numbers of water agencies now have water conservation departments, and professional societies are adding water conservation experts and groups.

One Dimension of the Soft Path: Efficiency of Use

In this section we describe the water-use efficiency dimension of the soft path. Other dimensions of the soft path (e.g., matching water quality with type of need, public participation, etc.) are not described in detail in this chapter due to space limitations. Lens, Zeeman, and Lettinga (2001) and Wright (1997) are excellent introductions to the wastewater dimension of the soft water development path. Gleick et al. (1995) present a detailed quantitative assessment of future soft-path water development in California, and "Moving Toward a Sustainable Vision for the Earth's Fresh Water," Chapter 7 of *The World's Water 1998–1999,* included a qualitative global vision of a sustainable water path. We also expect to revisit this issue in future volumes of this biennial report.

Definitions and Concepts

The concept of integrating nonstructural water-management approaches into water planning goes back many decades. In 1950, the Water Resources Policy Commission of the United States published *A Water Policy for the American People,* which noted:

> We can no longer be wasteful and careless in our attitude towards our water resources. Not only in the West, where the crucial value of water has long been recognized, but in every part of the country, we must manage and conserve water if we are to make the best use of it for future development. (WRPC 1950)

In the early 1960s, Gilbert White called for broadening the range of alternatives examined by water managers who had previously only focused on structural solutions to water problems (White 1961). Under White's approach, managers should consider both structural and nonstructural alternatives, including zoning, land-use planning, and changing water-use patterns. Unfortunately, traditional water management has, in general, continued to concentrate heavily on the construction of physical infrastructure.

One of the first challenges along the soft path is to define conservation and water-use efficiency. Baumann et al. (1980) defined water conservation using a benefit-cost approach: "the socially beneficial reduction of water use or water loss." Under this definition, water conservation involves trade-offs between the benefits and costs of water-management options. This leads to economically efficient outcomes, by finding the level of conservation where the incremental cost of demand reduction is the same as the incremental cost of supply augmentation, taking into account all costs of water conservation and supply augmentation, including environmental and social costs. The advantage of this definition is that it focuses on comprehensive demand and supply management with the goal of increasing overall well-being, not curtailing water use.

In contrast, the term *water conservation* is presently used in most instances to refer to reducing water use by any amount or any means. *Technical efficiency* is a measure of water conservation: how much water is actually used for a specific purpose compared to the minimum amount necessary to satisfy that purpose.[9] *Water-use efficiency* is synonymous with technical efficiency. Under these definitions, the theoretical maximum water-use efficiency occurs when society actually uses the minimum amount of water necessary to do something. In reality, however, this theoretical maximum efficiency is rarely, if ever, achieved because the technology is not available or commercialized, because the economic cost is too high, or because societal or cultural preferences rule out particular approaches.

While technical efficiency and water-use efficiency can be useful concepts, they offer little guidance as to how much reduction in water use is enough (Dziegielewski 1999). In theory, a society could conserve too much water, expending some resources on water conservation that would be better spent on other goods or services. Consequently, the best use for numerical measures of technical efficiency is for comparison over time or between locations. Just as the speedometer in a car tells the driver how fast he is going, but not whether that is too fast or too slow, measures of technical efficiency help to know where we are relative to a social objective but are not adequate to establish social objectives.

Establishing social objectives requires a balance between costs and benefits, broadly defined. Because all costs and benefits cannot be quantified in most cases, social objectives for water conservation and efficiency improvements are best made through a democratic political process. Box 1.5 presents five terms that are useful when social objectives are being discussed and selected.

Finally, the concepts of *water productivity* and *water intensity* are also useful to soft-path planners. Unlike water efficiency, which is a percentage, water productivity is the amount of measurable output per unit of water that is used. The units of output can be physical (e.g., tons of wheat) or economic (e.g., the dollar value of the good or service produced). Figure 1.2 shows water productivity for the U.S. economy from 1900 through 1996. Productivity was relatively constant until the 1970s, when a combination of factors (such as rising environmental awareness, advances in technology, and the shift toward a service economy) caused water productivity to rise steadily.

Water intensity is the inverse of water productivity: the amount of water needed to produce a unit of output. For example, the 1996 data point in Figure 1.2 shows U.S.

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[9] The numerical measure of technical efficiency is calculated by dividing minimum use by actual use. Since actual use is larger than or equal to minimum use, reducing actual use will increase the ratio up to a maximum of 1.0 (100 percent efficiency). This measure has one mathematical oddity, however. When the minimum use is zero, the ratio will always be 0 (0 percent efficiency), no matter what actual water use is! Should actual water use fall to zero, the ratio will become undefined, since 0 divided by 0 is undefined.

Box 1.5 Some Water Efficiency Definitions

Best available technology (BAT): The most water-efficient, technically proven, commercially available technology for reducing water use. A good example is the electric-assisted composting toilet, capable of meeting all disposal needs without the use of water. These toilets are proven and commercially available. BAT is useful for quantifying a maximum savings *technically* available. This is an objective assessment of potential, independent of cost or social acceptability. Thus, the BAT for toilets uses no water.

Maximum available savings (MAS): For a given agency or region, MAS is an estimate of the maximum amount of water than can be saved under full implementation of BAT, independent of current costs.

Best practical technology (BPT): The best technology available for reducing water use that meets current legislative and societal norms. This definition involves subjective judgments of social acceptability and will change over time, but it defines a more realistic estimate of maximum practical technical potential, independent of cost. For example, the current BPT for toilets in the United States is the 1.6-gallon-per-flush ultra-low-flow toilet, though this value can continue to decrease over time.

Maximum practical savings (MPS): For a given agency or region, MPS is an estimate of the maximum amount of water that can be saved under full implementation of BPT, independent of current costs.

Maximum cost-effective savings (MCES): For a given agency or region, the MCES is the maximum amount of water conservation where the marginal cost of conservation is less than or equal to the marginal cost of developing new water supply. Any lesser amount of conservation will force customers to pay more for water-related services than they would pay with a little more conservation and a little less water.

water productivity to be $13.85 of gross national product per cubic meter of water. Therefore, overall water intensity in the U.S. economy in 1996 was about 0.07 cubic meters of water per dollar of gross national product (1/13.85 = 0.0722). Increases in water productivity imply decreases in water intensity.

Water productivity and intensity can be measured in a variety of ways. Figure 1.2 uses data on total U.S. water withdrawals from natural systems. These data capture both direct and indirect (embodied) uses of water.[10] *Direct use* is water used at the point of production. *Indirect use* is water needed to produce nonwater inputs used at the point of production. For example, the direct water use in producing a box of

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[10] Because some imports are used to produce economic output in the United States, some amount of indirect (embodied) water use is not accounted for in the Figure. However, we believe that the contribution of imports to overall water demands is very modest.

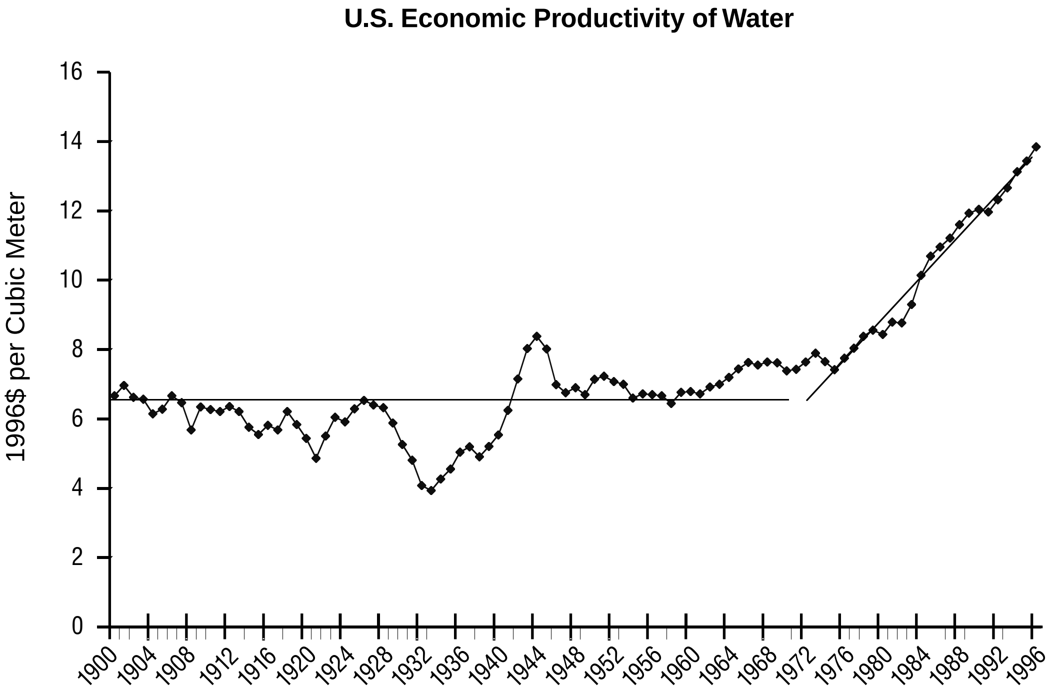

FIGURE 1.2 The economic "productivity" of water in the United States was relatively constant between 1900 and 1970 at around $6.50 of gross domestic product (GDP) per cubic meter of water withdrawn. After 1970, however, the economic productivity of water began to rise dramatically and now approaches $15 per cubic meter. All dollar figures are in constant 1996 dollars.
Source: Gleick 2000

breakfast cereal may be quite small, while the indirect water use embodied in the grains used to produce breakfast cereal is much larger.

This distinction means that measures of water productivity and water intensity can be based on direct water-use data or direct plus indirect water-use data. Direct water-use data, alone, may be misleading, as the breakfast cereal example shows. The best measures of water productivity or water intensity include both direct and indirect water use.

In the following section we provide some brief examples of the concepts and definitions. The examples only begin to demonstrate the numerous successes and opportunities along the soft water development path. Readers are referred to Gleick et al. (1995), Postel (1997, 1999), Vickers (1999), Owens-Viani, Wong, and Gleick (1999), Wilkinson (1999), and Vickers (2001) for additional or more comprehensive examples.

Efficiency improvements in agriculture. As noted previously, agriculture is the largest user of water worldwide: often 80 percent of water use in a country or region. Agriculture's place as the largest water-use sector implies that each 1 percent decline in agricultural water use reduces demand for water much more than each 1 percent decline in municipal, commercial, institutional, or industrial water use. For example, a 25 percent reduction in agricultural water use in an area where agricultural use is 80 percent of total use makes possible a doubling (100 percent increase) of water use in all other sectors combined.

The potential for water efficiency improvements in agriculture is large. Efficiency improving techniques include furrow diking, land leveling, direct seeding, drip irrigation, low-energy precision application (LEPA) sprinklers, low-pressure sprinklers, water accounting, and many others. Postel (1999) provides examples from around the world of the gains from these techniques.

One category of techniques—micro-irrigation systems (primarily drip and micro-sprinklers)—often achieves efficiencies in excess of 95 percent as compared with flood irrigation efficiencies of 60 percent or less, as noted in Box 1.1. Postel (1999) presents water productivity gains for a wide range of crops from shifting to drip from conventional surface irrigation in India. Although water use declined as much as 65 percent (sugarcane), water productivity increased as much as 255 percent (cotton). This is because more precise application of water can both reduce total water use and increase yields. Sugarcane and cotton yields increased 20 and 27 percent, respectively, along with substantial reductions in water use.

As of 1991, however, only 0.7 percent of irrigated farmland worldwide was being micro-irrigated (Postel 1997). While we expect this number has increased since 1991, more recent comprehensive data on global irrigation technology are not available. Israel and Cypress had demonstrated by 1991, however, that high percentages of irrigated land could be managed under these techniques (48.7 and 71.4 percent of the irrigated land in these countries, respectively). Because micro-irrigation has been expensive, historically, it has been used mostly on higher valued crops. But systems that cost only a fraction the cost of conventional precision systems are now available (Postel 1999), and will probably become even cheaper as time passes.

Another example is laser leveling of fields. This technique causes water to be distributed more uniformly, reducing the water required to ensure that all parts of the field are irrigated adequately. Recent experience growing wheat, alfalfa, and cotton in the Welton-Mohawk Valley of Arizona (Vickers 2001) found that water use declined between 20 and 32 percent as a result of laser leveling, and yields increased from 12 to 22 percent. This practice requires that land be leveled every two to five years at a relatively modest cost: about $40 per acre for each leveling.

Efficiency improvements at the municipal scale. A number of municipal water suppliers have implemented aggressive water conservation programs. Municipal conservation programs that are fully integrated have shown impressive successes. Box 1.6 lists elements of comprehensive programs. Postel (1997) includes an excellent summary of successful municipal programs in Jerusalem, Israel; Mexico City, Mexico; Los Angeles, California; Beijing, China; Singapore; Boston, Massachusetts; Waterloo, Canada; Bogor, Indonesia; and Melbourne, Australia. Reductions in water demand varied from 10 to 30 percent.

Vickers updates the results from the Massachusetts Water Resources Authority, serving the Boston area, and presents recent data for the city of Albuquerque, New Mexico (Vickers 1999). These municipalities have reported reductions of 25 and 18 percent, respectively. Similarly, Owens-Viani (1999b) presents results from the Marin Municipal Water District (MMWD) in northern California. The MMWD conservation management plan led to a reduction in demand of about 15 percent in the first 10 years of implementation, despite a 7.5 percent increase in the district's population. However, this is only about half of their 20-year target of up to a 32 percent reduction in absolute demand despite increases in population. After adjusting for population growth, this 20-year target—already half achieved—amounts to a reduction in water use of around 45 percent per capita.

Wilkinson (1999) provides a story that puts a human face, and some dollars and cents, on this type of soft-path success. The 815-acre University of California at Santa

Box 1.6 Elements of Integrated Water-Management Plans

Elements of fully integrated water-management plans can include

- monitoring and evaluation of water use;
- indoor and outdoor efficiency standards established and enforced under local ordinances;
- water budgets for nonresidential customers;
- conservation rate structures;
- a technical assistance program;
- landscape seminars;
- demonstration gardens and garden contests;
- rebates for decentralized investments that displace or delay centralized investments;
- ongoing public information campaign and school education program; and
- full economic integration of efficiency improvements efforts with development of new water supplies (including recycled water).

Barbara (UCSB) campus is like a small town, with its own fire department, police station, post office, medical clinic, food service facilities, offices, laboratories, housing for approximately 4,200 students and 150 faculty families, recreational and laundry facilities, and extensive landscaping. Total campus water use was reduced by nearly 50 percent between 1987 and 1994, even as the campus population served increased slightly. Total cost savings to the campus from 1987 to 1996 were $3.7 million, excluding energy and maintenance savings. Capital costs for water-efficiency measures during this period were estimated to be less than $1 million, including significant equipment replacement that would have taken place anyway for maintenance reasons.

A good example of the type of innovation that emerges on the soft path but is neglected on the hard path was the discovery that pool filter backwash water could be cost-effectively discharged into tank trucks that clean the sewer lines with high-pressure water. The UCSB program also demonstrates the human element of changing past practices. Maintenance staff, for example, claimed that sewers would back up if toilets were changed to 1.6 gallon per flush models, and that the landscape would have to become all cactus and rocks to reduce the quantity of irrigation water. The University responded by purchasing examples of nearly every available model of low-flow toilets and showerheads and asked skeptical maintenance staff to test them according to simple performance criteria. Preference tests were then conducted with campus residents to ensure satisfaction.

Installation was complemented by a strong educational program that communicated what was being done and why. Wilkinson notes that the direct involvement of maintenance staff and end users, and the pre-testing of technology, were major factors in the success of the program. Sewer problems actually decreased, in part because of an improved preventive maintenance program. And irrigation water savings were achieved without planting any cacti.

Efficiency improvements at businesses. There are many opportunities for commercial, industrial, and institutional (CII) customers to use water more effectively. Pike (1997) evaluates opportunities for commercial and institutional water users in the United States and finds that average potential savings vary from 9 to 31 percent within 18 categories of users (e.g., eating and drinking places, vehicle dealers and services). Similar statistics are present in Vickers (2001), including examples from outside the United States. Potential reductions in industrial water use are often larger. Studies in the San Francisco Bay Area and urban portions of southern California (EBMUD 1990; Brown and Caldwell 1990; ERI Services 1997; Gleick et al. 1995; Hagler Bailly Services 1997; Sweeten and Chaput 1997; U.S. EPA 1997; Wilkinson 1999; Owens-Viani 1999a, 1999b; Wilkinson, Wong, and Owens-Viani 1999) have found typical opportunities or actual successes (averaged by business or institution type) in the range of 16 to 54 percent.

Most of these opportunities are cost-effective and widely applicable. The Brown and Caldwell analysis, for example, found that typical reductions of 30–40 percent usually had estimated payback periods of less than one year and estimated average savings of $50,000 per year. The report concluded, "The cost effective water conservation measures successfully used at the case study facilities can readily be adopted by other facilities and other industries."

Conservation opportunities are most often expressed as percentages of pre-conservation water use, as in the studies above. Water-use efficiency measures, however, show how close or far current use is from minimum water use without loss of particular water-based services. They allow comparison of conservation successes since water-use efficiency is defined as the minimum water use necessary with an analyst-defined "benchmark" technology divided by actual water use. Finally, water productivity figures show how much water is used per unit of output. For example, Border Foods in New Mexico, one of the largest green chile and jalapeño pepper producers in the world, increased water productivity from about 1.4 pounds of product per gallon used to about 2 pounds per gallon in the 1992–95 time period (Vickers 2001).

The Oberti Olives processing plant in Madera, California, provides an excellent example of the alternative measures that can be used to evaluate efficiency changes (Owens-Viani 1999a). The Oberti plant processes 128 tons of olives per day, washing, curing, storing, and packaging. This amounts to about 600 cans of olives per minute. The plant also produces between 40,000 and 80,000 gallons of olive oil per year. Oberti obtains fresh water from private wells. Water use prior to recovery of in-plant wastewater for in-plant reuse was about 1.3 million gallons per day. After installation of a membrane filtration system in 1997, water use was reduced to an average of 110,000 gallons per day. Table 1.1 shows three different ways of measuring water-use improvements for the Oberti plant.

The estimates of water-use efficiency assume that membrane filtration is the best available technology (BAT) for water management at the Oberti plant. Recall that BAT is defined as the technology that would use the least water to perform a specific list of functions. "Best" in BAT is not necessarily best for the water user. For example, Oberti took action because it was required by the state of California to construct double-liners in its wastewater ponds or manage its wastewater differently. It investigated both evap-

Table 1.1 Three Measures of Progress in Water Use at the Oberti Olive Plant

	Before 1997	**After 1997**
Water conserved	Not applicable	A 91 percent reduction (1,190,000 gallons per day)
Water-use efficiency	8.5 percent	100 percent (*)
Water intensity	10,156 gallons per ton of product	859 gallons per ton of product

* Assuming new technology was "best available technology" or BAT.
Source: Owens-Viani 1999a

oration and membrane filtration systems for treating wastewater. The energy cost of the evaporation system caused it to be inferior to the membrane filtration system, but one can readily imagine that something other than membrane filtration might have been the best alternative for Oberti.

An oddity of the water-use efficiency measure, both before and after, is that it depends on the definition of BAT. Since BAT may change over time, water-use efficiency measures are useful only when BAT is defined and applied consistently across all users and times that are compared. Nonetheless, water-use efficiency is probably the most useful of the measures in identifying the possibility for future reductions in water use. Progress is not possible beyond 100 percent unless BAT improves.

Many water planners still believe that using less water somehow means a loss of prosperity. The traditional assumption, repeated over and over in water plans and discussions about the risk of future water shortages, is that continued improvements in well-being require continued increases in water use. This might be true in the absence of technological progress, but with technological improvements there is enormous room for economic growth without growth in water use. For example, producing a ton of steel before World War II required 60 to 100 tons of water. Today, each ton of steel can be produced with less than 6 tons of water: a ten-fold improvement in water productivity (and a ten-fold reduction in water intensity). Further, because a ton of aluminum can be produced using only 1.5 tons of water, replacing the use of steel with aluminum, as has been happening for many years in the automobile industry, can further lower water use without reducing economic activity (Gleick and Haasz 1998). And telecommuting from home can save the hundreds of liters of water required to produce, deliver, and sell a liter of gasoline, even accounting for the water required to manufacture computers and telephone systems.

The reality is that the link between water use and economic well-being (often measured as some form of gross domestic product) is not immutable. It can be modified and even broken, as it already has in the United States. This is shown clearly in Figure 1.3, which presents the data behind Figure 1.2 (water productivity in the United States) in another way. Figure 1.3 shows water withdrawals and gross domestic product in 1996 dollars for the United States from 1900 to 1996. From 1900 to 1980, these curves rose in lockstep—increases in national income were matched by similar increases in water withdrawals. Then, in 1980, this relationship was broken, with continued rapid increases in national income, but a leveling off—even a decrease—in total water withdrawals.

Similar patterns are emerging around the world. For example, Japan used nearly 50 million liters of water to produce a million dollars of commercial output in 1965; by 1989 this had dropped to 13 million liters per million real (inflation-adjusted) dollars of commercial output—almost a quadrupling of water productivity. Data from Hong Kong

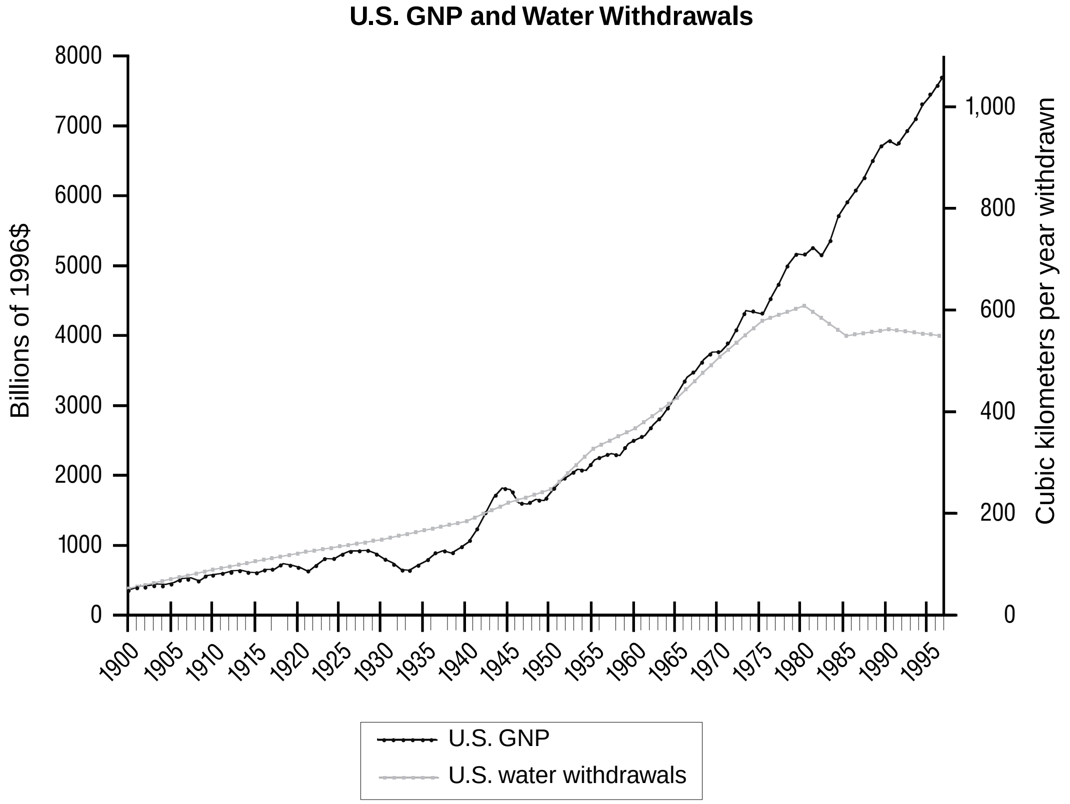

Figure 1.3 U.S. GNP (in billions of 1996 dollars) is plotted here with total U.S. water withdrawals (in cubic kilometers per year) from 1900 to 1998. Until the mid–1970s, these two curves rose exponentially together. By the late 1970s, however, total U.S. water withdrawals began to level off and then decline, even while total U.S. economic productivity grew.
Source: Gleick 2000

(Figure 1.4) exhibit this pattern as well. If data are available and progress has been sustained, similar figures can be developed for any successful conservation program, such as those described previously in Boston, Albuquerque, Marin County, and the University of California at Santa Barbara. Time-series data on water conservation, water-use efficiency, water productivity, and economic output versus water input are perspectives on a single phenomenon: the success of the soft path of water development.

An example of the MPS and MCES measures. Opportunities for further progress on the soft path are most practically identified by comparing two measures of efficiency potential: maximum practical savings (MPS) and maximum cost-effective savings (MCES). Figure 1.5 (Gleick et al. forthcoming) shows that the future potential is large even in a region and sector that has already conserved a considerable amount of water. The upper line in the figure is the water-use path of "business as usual" in the indoor residential sector of California through 2020. The hard path requires that the state develop new water supplies to meet this projected "need." The lower line in the figure is the MPS from implementation of the current best practical technologies (BPT) for indoor, residential water use. The lower line is also the MCES for indoor, residential water use. MCES is equal to MPS because we have estimated that all practical indoor residential conservation technologies are cost-effective to implement (see Box 1.4).

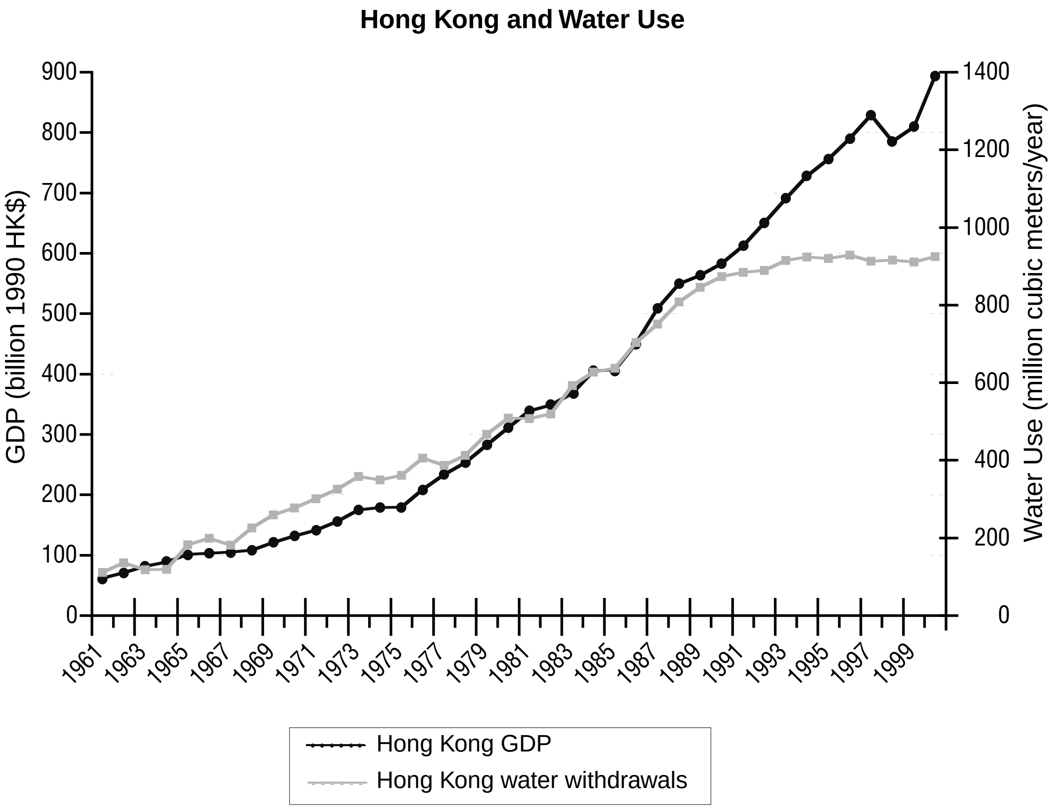

FIGURE 1.4 Gross domestic product (GDP) in Hong Kong (measured in billions of 1990 Hong Kong dollars) is plotted here with total Hong Kong water withdrawals (in cubic kilometers per year), from 1961 to 2000. Until the late 1980s, these two curves rose exponentially together. By the early 1990s, however, total water withdrawals in Hong Kong began to level off and then decline, even while total economic productivity grew.
Source: David Yongqin Chen, Chinese University of Hong Kong, 2001

The soft path as shown moves California from the uppermost line to the lowermost line over a 20-year time period. While the hard path would require about a 45 percent increase (of 900,000 af/yr, or over 1.1 billion cubic meters per year) in water supply (for indoor residential purposes) by the year 2020, the soft path actually *reduces* total indoor residential demand by about 25 percent (that is, by about 500,000 af/yr, or over 600 million cubic meters) despite population growth. This means that the soft path for indoor residential use can cost-effectively conserve about 1,400,000 af/yr (1.7 billion cubic meters) by the year 2020, or around half the water hard-path planners would say is “needed” for indoor residential purposes by 2020. This simple example, for a single sector of California water use, shows the dramatic gains possible by shifting effort from the supply side to the demand side.

Moving Forward on the Soft Path

There are many pieces that must be put together to move along a soft water path. Below we describe four that we consider necessary for improving water-use efficiency,

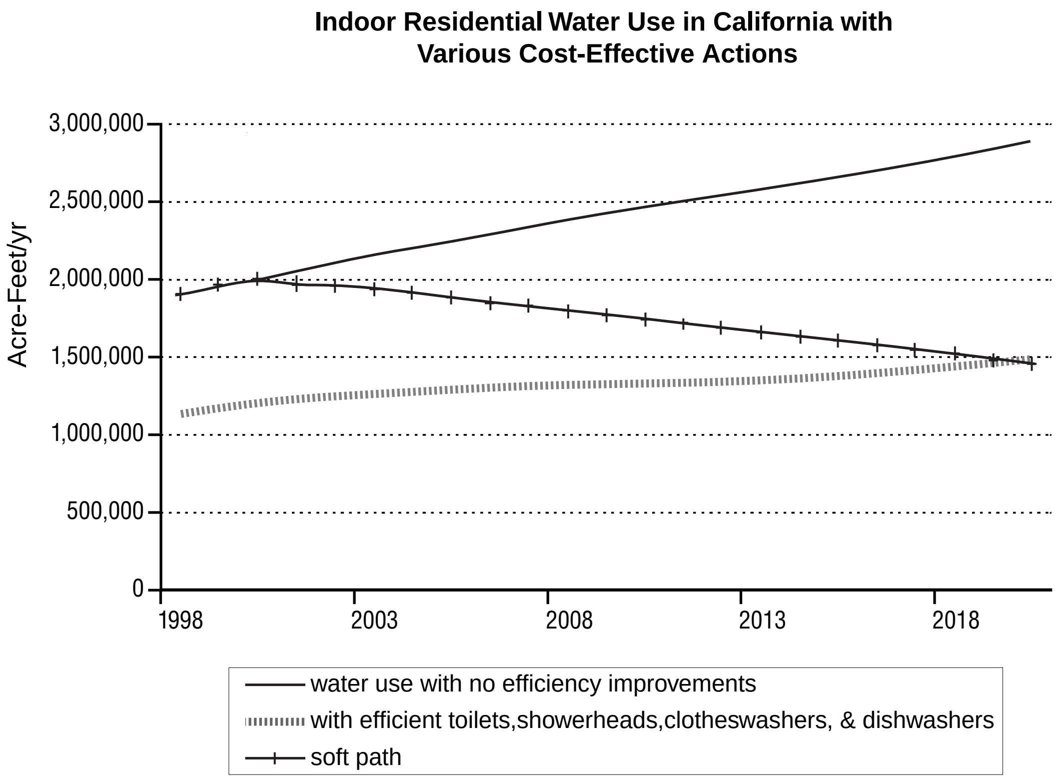

FIGURE 1.5 Nearly 2 million acre-feet of water is used in California homes today. This figure shows the amount of water residents would use with no improvement in the efficiency of toilets, washing machines, dishwashers, and showerheads (the solid line), the amount of water required if all homes were fitted with currently available, cost-effective efficient water fixtures (the lower broken line), and a "soft path" transition from inefficient use to efficient use.
Source: Pacific Institute 2002

but others are necessary for reforming institutions, opening up decision-making processes, and so on. We hope to elaborate on these in coming works.

The first step is identifying the physical and economic potential for improving water-use efficiency and allocation. The second is identifying the institutional, economic, and technological barriers that impede these improvements. The third is to make a social choice about how much efficiency is desirable. Finally, government agencies or water suppliers must implement comprehensive, integrated economic, educational, and regulatory policies that remove the barriers and achieve the socially desirable level of water savings.

Step 1. Identifying the Potential

Identifying the actual potential for improving water-use efficiency (however defined) requires that water planners ask and answer some basic questions:

a. Who is going to require water?
b. For what purpose or goal is water needed?
c. What kind of water is necessary to meet specific goals?
d. How much water of a particular quality is needed to meet any given goal?

Surprisingly, the first three questions have rarely been asked or answered with sufficient detail.

a. Who is going to require water? This question is typically addressed in a rudimentary way by identifying user categories such as urban and agricultural users. Urban users are often broken into residential, industrial, commercial, and institutional classes. But a detailed analysis of the diverse kinds of water users within these classes is rarely provided. Even more rare is inclusion of environmental or ecological users of *in situ* waters at or downstream of the sources of raw water.

b. For what purpose or goal is water needed? This question gets immediately to the heart of the hard-path/soft-path choice. Water is but a means to ends and is useful only insofar as it helps to meet those ends. What is desired is not to use a certain amount of water but to achieve certain goals and purposes: to remove wastes, produce objects, grow food, generate energy, provide recreation. Without understanding what we want to do, it is impossible to evaluate the water needed to accomplish our goals. And yet, no country, state, water district, or water company seems to have developed a complete inventory of the tasks required to meet the specific water-related needs or desires of their customers.

Answering this question helps to make explicit deeper factors that drive water use and supposed future "needs." Is using water to dispose of human wastes always necessary? Can a computer chip be made without water? Does it really make economic sense to grow cotton (or as much cotton) rather than some other crop in California or Egypt?

c. What kind of water is necessary to meet specific goals? Different water demands can be met with waters of differing quality. Traditionally in industrialized nations, water delivered to a home or business is treated to drinking-water standards. Only a tiny fraction of domestic and business water use, however, is used for drinking, cooking, or other health-sensitive functions. Landscape irrigation and car washes can use lower-quality water. Similarly, some high-technology businesses require water that is higher quality than drinking water. Until the pattern of quality needs is understood, one cannot say—as hard-path planners do—that single-pipe, single quality, once-through patterns of water distribution and use are the only economical patterns.

d. How much water of a particular quality is needed to meet any given goal? As we have noted earlier, getting rid of human wastes in toilets can take 23, or 13, or 6 liters of water, or even no water at all, depending on the technology used. Growing a ton of cotton can take 800, or 1,200, or even 3,000 tons of water per year, depending on the climate, soil, irrigation technology, crop variety, and efforts of the farmer. Extensive research and data are available telling us how much water is used to flush a toilet, or produce a computer chip, or grow cotton, but very little research has been done to evaluate the minimum amount of water required to do these things.

Step 2. Identifying Barriers

Data and information gaps are among the most common and frustrating barriers to identification of the potential for water-use efficiency. In many cases, even the most fundamental data do not exist. Most countries do not collect national water-use data. In other cases, the data that do exist are incomplete, inconsistent, or from poorly documented original sources. In order to make intelligent decisions, however, the right data and information are essential. For example, every municipal water agency in the world reports that more water is treated and put into their distribution systems than can be accounted for in water-use surveys or billings. Yet every traditional measure of aggregate water use comes from estimates of gross water withdrawal, not from point-of-use surveys.

A few representative examples of data or information gaps that would be useful to fill are:

- irrigated area, by crop type and irrigation method, by region, watershed, and country;
- irrigated and unirrigated residential landscape areas as a function of lot size, house size, income, climate zone, or other demographic data;
- the distribution of residential water-using appliances in cities or urban regions, by type and use (e.g., the distribution of various liters per flush toilets and other devices for management of human waste);
- regional measures of agricultural water use separated into evaporation and transpiration components;
- water delivered to categories of businesses with similar functions (e.g., all retail stores) (data are sometimes available from a water agency or company, but the data are rarely collated and summarized);
- industrial water use with detailed information on water required to produce categories of goods, measures of economic output, or employees; and
- summaries of the actual cost of conservation and efficiency measures in a variety of locales, estimated by a consistent methodology.

Great uncertainties still remain about the physical, practical, and economic potential of soft-path management techniques. The magnitude of this potential depends on water prices, rate designs and structures, existing and developing technology, public opinion and preferences, and policies pursued by water agencies and managers. Nonetheless, many of the uncertainties associated with water-use efficiency programs can be reduced with modest investments in data collection and analysis.

There are numerous other barriers to estimation of different measures of water-use efficiency, such as MAS, MPS, and MCES. For example, the attitudes described in the section on "Myths about the Soft Path" are barriers to estimating efficiency and conservation potential. These attitudinal barriers might be summarized as "lack of political or managerial will" to pursue the soft path. The failure of some California cities to fully implement residential metering of water use, despite information (available for decades) that shows that such metering can reduce water demand by 15 to 20 percent (Flack 1981), is evidence of the depth of the institutional and attitudinal barriers to the soft path.

Step 3. Making Social Choices

Many water policy makers believe that only a limited amount of conservation and efficiency is economical, despite a lack of essential information with which to test this belief (or even in the face of conflicting evidence), and that going beyond modest conservation objectives will lead to unacceptable changes in lifestyle or highly restrictive regulatory requirements. The twin demons of government intrusion in the market and social engineering are raised and reviled surprisingly often, despite the fact that most hard-path water projects backed by powerful constituencies have benefited from vast government subsidies and often lead to substantial impacts to local populations.

Rational discussion requires that these concerns be considered and analyzed. It is certainly true that the soft path is not easy to follow. It requires institutional changes, new management skills, and greater direct participation by water users. Fully branching off of the hard path onto the soft path is not easy, but it is increasingly apparent that continuing on the hard path as physical water scarcity increases causes equal or greater difficulties.

Because social choices that involve significant change are difficult to make and even harder to implement, Vickers (1999) concludes:

> No U.S. water supplier has yet to exploit water efficiency's full capabilities to optimize customer water demands. . . . Despite the great promise of water conservation to enable the public and nonresidential customers to live within their water means, in reality few utilities have made significant investments in conservation programs to make much of a difference.

This assessment is accurate, although some U.S. and international water suppliers (e.g., the examples provided above) seem to be moving toward this objective. As the soft path is investigated and matures, even greater levels of efficiency will become possible. The soft path requires a social choice to invest in the people, businesses, and cooperative arrangements that are needed for the maximum cost-effective water savings to become reality.

Step 4. Implementing Comprehensive Demand-Management Programs

Some examples of soft-path successes were provided above. But what does a water supplier need to do to implement comprehensive and successful demand-management programs? In essence, the supplier needs to fully integrate a variety of new tools with older tools. Successful water-use efficiency programs inevitably include combinations of regulations, economic incentives, technological changes, and public education. Considerable experience in every sector of the economy suggests that the most effective water-use efficiency programs include combinations of all of these approaches (Gleick et al. 1995; Owens-Viani, Wong, and Gleick 1999; Vickers 2001).

Regulatory tools include government policies to encourage water conservation and efficiency improvements, including appliance efficiency standards, landscape ordinances, and efficient building codes. Economic incentives include marginal cost volumetric water prices, rebates for water-saving end-use devices or practices, low-cost loans or assistance in obtaining credit for capital investments by customers, environmental fees or surcharges that allow compensation for those damaged by additional water withdrawals (e.g., fishermen), and trading of water rights or water-use permits.

Technological tools include all of the devices that use water more efficiently than in the past, and advanced media and informational techniques to communicate with and persuade water users to behave in ways that are socially desirable (i.e., achieve the social objectives chosen in each locale).

Education of the public means ensuring that information on options, costs, technology, and regulations are fully available to water users. Smart choices will only be made when those choices are known and understood.

Finally, unless demand management is fully integrated with water-supply planning, it will remain an underused and misunderstood part of our water future.

Conclusions

We have reached a fork in the road. We must now make a choice about which water path to take. We know where the hard path leads—to a diminished natural world, concentrated decision making, and higher economic costs. The soft path leads to more productive use of water, transparent and open decision making, and acceptance of the ecological values of water.

In most past water-planning efforts, demand has been projected independently of changes in technology, costs, prices, customer preferences, and market forces. It is not surprising that so many past demand projections greatly overestimated the level of demand that eventually materialized. This bias in demand projections has caused large capital-intensive supply augmentation projects to appear economically desirable. Actual experience, however, is that these projects have much larger costs than initially estimated. Improved end-use efficiency technologies are now, and are likely to remain, very cost-effective. That they are not widely recognized as such is a shame.

There is no single estimate of the potential for improving the efficiency or productivity of water use. Each situation comes with a different set of assumptions, social conditions, physical structures, technological opportunities and constraints, and costs. These characteristics will determine, ultimately, how much future demand for water can be reduced or modified, and how much reduction in future demands for water is socially desirable.

Examples of soft-path successes are becoming more common. Some of them have been touched on in this chapter, but there are many more. Despite this, efforts by water agencies to implement comprehensive water-efficiency programs are few and far between. Even in developed countries, where some of the best funded and most promising water conservation programs exist, the majority of urban water agencies rely on voluntary practices and programs that are not comprehensive, are incompletely implemented, and are inadequately monitored.

Soft-path water approaches are inherently more democratic than large centralized capital projects, and require a much wider range of professional skills to implement. The soft path requires institutional change, not just better technology. But most institutional changes, historically, take place only with concerted social action or after crises force the changes to occur. Humanity in the twenty-first century will either choose the soft water path or pay dearly—in both money and a diminished natural world—for clinging to the more familiar hard path.

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