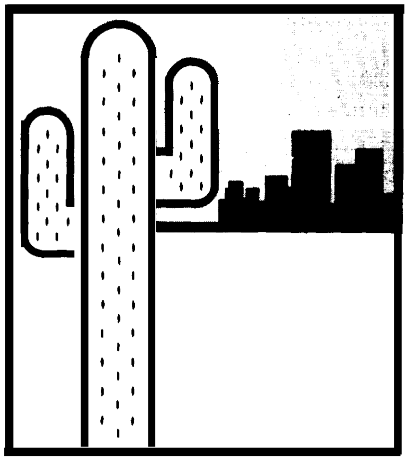

Institutions Affecting Western Agricultural Water Use

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Chapter V

Institutions Affecting Western Agricultural Water Use

Distribution and use of Western water resources for sustainable agriculture are subscribed by two institutional forces: first, water laws that establish rights and duties with respect to the use of water and, second, in recent years, economic institutions that allow water to be transferred between users and uses. These institutions and their associated rules influence the adoption of water-related technologies and effective water management for sustainable Western agriculture, The Western agricultural water user is, at best, moderately uncertain about water use because it is unclear how these rules might change as demands increase,

This chapter first describes the major elements of western water law as they affect water use in agriculture, In light of growing demands on existing supplies and few opportunities to acquire new inexpensive water, water economics is receiving increased interest as a vehicle for reallocating water among competing demands. The chapter next highlights some of the factors contributing to increased demand for Western water and then examines factors affecting the feasibility of water markets and the impact of economics on the adoption of water-related technologies for sustainable Western agriculture.

WESTERN WATER DEVELOPMENT

History

In the early days of the United States, when Western lands were owned in a proprietary capacity by the United States, a precondition to settlement and development of the water-sport West was a secure water supply. Farmers and soiree miners diverted water through networks of small river dams and canals for use on distant lands. Other settlers and miners located along streambanks claimed rights to water in those streams. In early conflicts, the courts generally followed local rules and custom and ruled against riverbank (riparian) settlers on the grounds that they did not legally meet the riparian doctrine's fundamental requirement, ownership of the land.

Perhaps more important, water was already being used consumptively far away from the stream to meet the needs of farming, mining, and other purposes in this arid/semiarid region, In contrast to the humid and water-abundant Eastern United States, it became increasingly important in the West to ensure that upstream diversions would not deplete supplies on which downstream investments depended. Thus began an early judicial recognition of the right of the first user [or appropriator) of surface water in western lands to have the superior right to that water. "First in time, first in right" became the local rule.

Gradually, Federal programs became directly involved in shaping the character of Western agriculture and water use. Two Federal laws had particular impact on early Western agricultural and water development. First, the Desert Land Act of 1877 severed water rights from the public land and granted each State the right to adopt its own system of water law to govern the appropriation of nonnavigable waters. In the act, Congress also recognized that farmers in the arid/semiarid western lands could not operate successfully on the 160-acre parcels of land provided by the Homestead Act of 1862 and so granted full title to 640 acres

Box E.—John Wesley Powell's "Blueprint for a Dryland Democracy"

John Wesley Powell, chronicler of American Indian languages, explorer of the Colorado River, and one of the most prominent Government scientists of his age, knew the West intimately. He watched with dismay as Western settlement followed Eastern models. In 1878, he presented a revolutionary plan to the United States Congress. It proposed to tailor agricultural development to the unique features of these dry lands.

As Wallace Stegner, a major American historian described it, Powell's plan had several important provisions regarding the size and shape of homesteads and their ownership. Stegner wrote:

> **Water was the true wealth in a dry land; without it land is worthless or nearly so. And if you control the water, you control the land that depends on it. In that fact alone was the ominous threat of land and water monopolies. To prevent this-or to stop it for it was already beginning to happen, Powell made two proposals. One was that each pasturage farm should have within its 2560 acres twenty acres of irrigable land with a water right that was inseparable from the land. , . . Instead of rectangular parcels, therefore, Powell proposed surveys based on the topography, letting farms be as irregular as they had to be to give everyone a water frontage and a patch of irrigable soil.**

The second part of Powell's proposal suggested that national surveys, conducted by a central Government scientific agency or settlers themselves, would choose irrigation or "pasturage" for their regions. Stegner wrote that "In either case, a homesteader would have a guaranteed water supply."

Powell's proposals were debated in Congress in 1878 and 1879. They were defeated by powerful Western delegations, Powell's scientific enemies, and the special interests of the day. Powell went on to suggest other far-reaching plans for the development of the arid West. But the Nation never fully used the insights of this man who understood "the unity of drouth."

SOURCE: Wallace Stegner, *Beyond the Hundredth Meridian: John Weseley Powell & the Second Opening of the West* **(Lincoln, Nebr.: University of Nebraska Press, 1982).**

of land after 5 years of residency if a portion of the land were developed for irrigation within a specified period. Second, the Carey Act of **1894 granted 1 million acres of public land to each State containing arid lands on condition that the State provide for the necessary reclamation.**

Under these laws Congress deferred to Western State appropriation doctrines for local nor)-navigable water use. Since then, Federal water-related agencies have generally been required to comply with State laws in the appropriation of such water. *

Water Projects

The progress of water development in the Western United States has had a fundamental impact on the development of Western agriculture and on the kinds of water-related technologies developed and adopted. As more individuals became involved, mutual water companies or water cooperatives were formed to reduce conflict and ensure a fair distribution of water. Mutual irrigation companies frequently became formal corporate entities under State charters, with stock being issued to their members as evidence of proportionate voting rights in the election of company directors. Many other groups elected officers on the same voting basis as in formal corporations but operated as associations rather than as formally registered corporations. In some areas large-scale irrigation projects were organized and supported by foreign capital, primarily from the British (24). Today, many of the Western mutual irrigation companies are still significant water institutions, some having been transformed into major water management and power-generating organizations.

As the need for water increased, the trend in water-management development was for an

"See, for example, the Federal Reclamation Act of 1902, which requires the Secretary of the interior to secure project waters in accordance with local law.

increasing government role. Early State legislation authorized the creation of water supply and irrigation districts and provided formal organization and power to the districts to raise revenue for constructing water-conservation facilities such as dams, reservoirs, canals, and diversion structures. A further shift occurred with the passage of the Federal Reclamation Act of 1902 (Public Law 57-161). The features of large-scale construction projects called for a strong role by the Federal Government in particular, for substantial financial resources, technical expertise, and a geographic perspective convenient for interstate river basins,

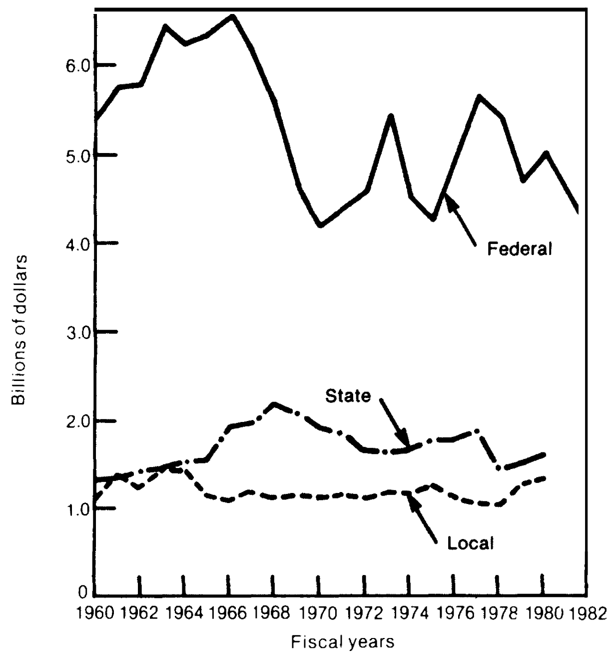
The 1902 Act provided for Federal subsidies to irrigators through a number of activities. First, it set up a revolving fund for irrigation development from moneys raised through the sale of public lands, Funds were to be used in constructing storage and power dams and for canal systems required for irrigation, Second, settlers were to receive their lands free in much the same way as under the Homestead Act (a 5-year residency requirement) but were to repay the costs of structures built by the Government within 10 years. Gradually, Federal subsidies were further extended to irrigation farmers in the form of interest-free loans for capital facilities, longer repayment periods, low interest rates, contributions to irrigation construction costs by other beneficiaries (especially power users), and a repayment formula that attempted to consider the irrigator's ability to pay.

The politics of these and other federally subsidized projects has been called "distributive," reflecting a political process whereby each element in an omnibus package is carefully designed to provide local benefits to a variety of community, user, and political interests (17). Congressional vote-trading determined who would get the initial Federal projects. This distributive process involved both upstream and downstream States in the arid/semiarid West. Growth in some areas was made possible in part through the consent of upstream users who, under less growth pressure at the time, believed they would eventually receive Federal assistance for water development (15). The apparent cost-free benefits to local communities provided incentives for sponsorship by the principal local political interests, and actual costs were distributed among general taxpayers. Clear standards for judging the long-term desirability of these projects based on costs and benefits to the Nation, were largely absent in these early decisions **(18).**

"Principles, Standards, and Procedures" (replaced in *1983* by the new "Economic and Environmental Principles and Guidelines") were developed pursuant to the *1965* Water Resources Planning Act to guide the planning and design of projects. The application of these criteria has led to conclusions that many projects are uneconomic and unjustified, Federal financing arrangements for water projects have been under attack particularly regarding the planning, design, and actual construction of projects whose costs are not adequately recovered (31). The fiscal criticism focuses on the overall costs to Government, including the costs of Government borrowing, and whether this should remain a priority in light of other Government concerns.

Reforms of existing Federal water-project repayment laws and practices that include more equitable cost-sharing arrangements and greater cost recovery from water users are underway and are likely to continue over the next several years (32). From its peak in *1965,* Federal spending for water projects has generally declined (see fig. 26). Moreover, expenditures for water resources appear to be shifting away from massive new construction projects and toward rehabilitation and more efficient management of existing public works **(27).**

Figure 26.—Federal, State, and Local Spending for Water Resources, 1960-82[a]



[a]Actual State and local data for 1980-82 not available.

SOURCE Congressional Budget Office from data supplied by the Congressional Research Service and the U.S. Department of Commerce, Bureau of the Census, U.S. Congressional Budget Off Ice. Public *Works Infrastructure Policy Considerations for the 1980's* (Washington, D C U S Government Printing Office, 1983)

WESTERN WATER LAW

Water's special nature as both a natural resource and an essential social good has always made it subject to some public regulation to protect public interests. Until laws were developed, settlement of disputes over water rights was left to private means, often vicious and brutal. Early on, a clear interest developed to channel private grievances to public institutions, thereby bringing some order and equity to the process of water use and distribution.

The major State and Federal law doctrines that have developed to regulate water are fundamental in guiding decisionmaking on water distribution and use in the arid/semiarid West. They define the extent of a water user's rights as well as the extent of duties or constraints on those rights. The doctrines are key factors influencing decisions about the adoption of water-related technologies for sustainable agriculture.

The concept of priority in accordance with the date that use began gave birth to the term "prior appropriation" to describe the most common water-use system in the Western States. The fundamental principles established under this arrangement have been followed since its recognition by early courts. They are:

1. that water in its natural course is the property of the public and is not subject to private ownership;
2. that a vested right to use the water may be acquired by appropriation and application to beneficial use;
3. that the person first in time is first in right; and

4. that beneficial use is the basis, measure, and limit of the right (6).

This doctrine creates the right of private use of a public resource under certain conditions where the use has been declared to be a public one. Generally, a use is public when it is applied to a beneficial purpose, defined initially in State constitutions and statutes to be domestic, municipal, stock watering, irrigation, and certain industrial and power uses. More recently, it has also been defined in a few States (e.g., Colorado and Montana) to include instream flow (see app. C). Some State laws give a preference to one sector of use over another. Historically, in most Western States, strong rural representation has ensured agriculture a high position as a beneficial user.

An acquired water right in the Western States has two legal characteristics. First, the right is a real property right to use the resource, a right which if defined can be sold, bequeathed, or otherwise transferred so long as approved by the State water authority, a necessary condition to protect other appropriators. Second, it is a right to be exercised only when the water authorized for diversion under the right is available and applied to a "beneficial use. " The water applied must also be "reasonable" for that use. If the rightholder cannot put it to reasonably beneficial use, the water remains a public resource to be passed to other appropriators, However, if the rightholder can beneficially use the water, it remains an individual's personal property while diverted within his/her delivery system and until it is returned back to the natural system (stream or aquifer).

State Level

States are involved with water regulation through their implied constitutional powers to create property rights and to protect and regulate their citizens through their police powers. State water law regulates use, not ownership, of water by granting and administering rights for use contingent on conformity with certain conceptions of "public interest" as developed by the political process.

The development of State water-law principles was influenced by early court decisions, some reinforcing and others frustrating local custom. Because of its reliance on precedent, the judicial arena has been slow to reflect contemporary scientific understanding of water as it operates in a dynamic, interconnected, surface-subsurface system, Western State legislatures and related local water institutions have had to become increasingly active in attempts to meet changing needs and resolve conflicts over use. While early legal doctrines remain the backbone of current State water law, innovative experiments also are underway in some States to adapt these principles to be more responsive to the increasing demands on limited supplies (discussed in app. C).

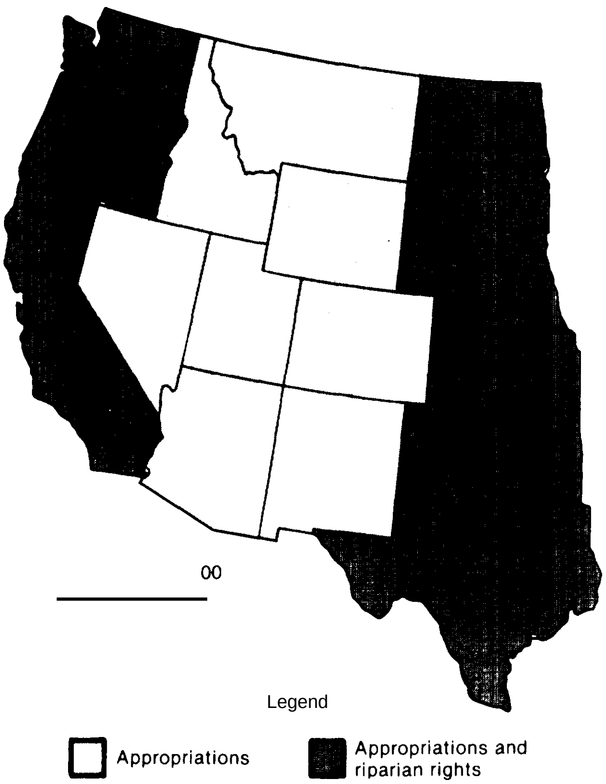
Surface and Ground Water Law

Major bodies of water law at the State level have developed for surface-water instream sources and ground water. Historically, each has been treated separately under the law and generally without regard to natural interconnections existing within the hydrologic cycle. The point at which water was diverted from its natural state and brought under control determined the legal classification **(26).**

The historical development of water law permitted each Western State to formulate solutions that fit local needs. Although each accepted the major concepts of prior appropriation, various State laws developed significant differences in their substantive and administrative aspects, Some with more humid areas integrated certain riparian rights with prior appropriation doctrine and developed "mixed" systems. Some "pure" appropriation States that had rejected the entire regime of riparian rights still applied some riparian concepts. The riparian doctrine of the water-abundant East was gradually entirely replaced by the *appropriation* doctrine in other States. Figure 27 identifies the general system of surface water law under which each of the 17 Western States operates,

Several States have adopted additional rules to protect water needs of users within a water-

Figure 27.—Surface-Water Law Systems in the Western States



SOURCE G. E Radosevich, Western *Water Laws and Irrigation Return Flow, EPA.600/2-78-180* (Ada, Okla U S Environmental Protection Agency, 1978).

shed or river basin from future shortages caused by out-of-basin diversions and uses. These "basin of origin" statutes (see table 27) have taken a variety of approaches, from those that authorize inhabitants within the basin to reclaim water for future needs, to others that restrict transfers outside the basin to water that is determined to be surplus.

Ground water rights and legal systems developed more recently in the western States, owing in part to reliance on surface supplies for the early settlements and in part to a lack of knowledge about subsurface supplies and the technologies to develop them. As knowledge of ground water increased and as subsurface supplies were in greater demand, and public regulation of withdrawal and use became more important. For legal purposes, ground water has commonly been divided into two classes: *1)* underground streams which flow in known and definite underground channels, and 2) percolating waters which flow beneath the surface of the earth in no known or identifiable natural channels. These legal classes are often at variance with scientific evidence, since in many areas no natural distinctions actually exist. All ground water is presumed in law to be percolating water, rather than an underground stream which would be considered in law essentially the same as surface water.

For ground water, each Western State adopted and modified basic surface doctrines to fit its perceived needs. Four major legal doctrines developed. A few States took the English view of absolute ownership of ground water somewhat parallel to the *riparian* view of surface water–i.e., the owner of the land owned all of the water within or under it because this water was deemed to be part of the soil. The consequence was that a landowner had no liability for any use made of ground water even though that use might damage others (8). As it became more evident that ground water moved in subterranean aquifers and use of, or interference with, such water could affect other landowners, this common law rule was later modified in some States to limit the landowner to *reasonable use.*

Other doctrines developed with the growth in knowledge about the interconnection of ground and surface waters. Some Western States adopted the doctrine of *correlative rights* whereby each landowner was held to have rights in a common aquifer in proportion to the land overlying the aquifer. Many States applied the *appropriation doctrine* to ground water, requiring that rights could only be acquired by withdrawing the water and applying it to a beneficial use. Figure 28 identifies the basic ground water doctrines used by the 17 Western States; most States have modified these basic theories to some extent by legislation (e.g., the Arizona Ground Water Management Act, *1980* [Ariz. Rev. Stat. *(45-512)]).*

Recently, challenges to the validity of two State ground water statutes have raised con-

Table 27.—A Summary of Western Water Law

Legal feature / State	1 Water Law Doctrines: Surface waler	2 Water Law Doctrines: Ground water	3 Ownership	4 Evidence of water right	5 Basis of allocation	6 Criteria of allocation	7 Preference of use (order)	8 Date of priority	9 Appurtenance	10 Water rights registry	11 Water quality in rights	12 Forfeiture of rights[a]	13 Drainage rules	14 Basin of origin
1-ARIZ	P A	R.U[b]	Public	Permit	B U	B U	1.2.3-4-5	D O A	Strict	Original	Case	5 yrs	CE & C L[c]	Yes
2 CAL	P A &R	C R	People	Permit[d]	B &R U	B &R U	1 2 -	D O A post 1914	Unlimited	Current	Case + Statute	5 yrs <1914 3 yrs >1914	Yes	
3-COLO	PA	P A	Public	S.W. - decree G W - permit	B U	B U	1-2 over 5	S W 1st step G W D O A	None	Original (compu-terized)	Case	...[e]	C L (modi-fied)	Yes
4.IDA	P A	P.A	State	License	B.U	1 cfs/50 acres	1 -2	D O A	Unlimited	Current (Limited)	Case	5 yrs	C L	
5.KAN	P.A & R[g]	P A	People	Permit	B U	1 to 2 acre-ft/ acre	1-2-5-6-3	D.O.A			Case + Statute	3 yrs	C L	
6 MONT	P A	PA.	State	Permit	B.U	1 miners feet per acre	None	D O A		Original (Limited)	Case	..[e]	C E	
7.NEB	PA & R[g]	R . U[b]	Public	Permit	B U	1 cfs/70 acres or 3 acre ft/ acre	1 2 over 5	D O A			Case	3 yrs	C E	Yes
8-NEV	P A	P.A	Public	Permit	B U	Conditions & needs	None	D O A		Original	Case	5 yrs	C.L.	
9-N M	P A	P A	Public	Permit	B U	BU & good agr practices	None	D O A		Original	Case	7 yrs + 1 yr after notice	C L	
1O-N D	P A	P.A.	Public	Permit	B U	1 cfs/80 acres	1-2 & 5-6	D B U			Case	3 yrs	R.D.	
11 .OKLA	PA & R.[g]	P.A.	--	Permit[d]	B.U	B U.	None	D O A	Strict	Current	Case	7 yrs	R.D	Yes
12-ORE	P A. & R[g]	P A	Public	Permit	B U.	B U	1-2-4 --	D.O.A	Strict	Original	Case	5 yrs	C L.	
13-S D	P.A & R[g]	P A	People	License	B U.	1 Cfs/70 acre or 3 acre-ft/acre	1-.	D.O.A.		Original	Case	3 yrs	C.L	
14-TEX	PA & R[g]	A O	State	Permit[d]	B U	B U	1-5-2-4-3-7-6	D B U		Current	Case	10 yrs	C.L	Yes
15.UTAH	P A	P A	Public	Permit	B U	Nature of use	1-2	D O.A.		Current	Case	5 yrs	C E	
16.WASH	PA & R[g]	P A	Public	Permit	B U	Reasonably necessary & B.U	None	DBU & D O A. for permits		Current (compu-terized)	Case	5 yrs	C E	
17 WYO	P A	P.A	State	Permit	B U.	1 cfs/70 acres	1-5	D O.A.	Strict	Original	Case	5 yrs	"Undecided	

KEY
A O —absolute ownership, B U —beneficial use, B &R U —beneficial and reasonable use, C E — common enemy C L —civil law, C R —corrective rights D O A —date of application, D B U —date of beneficial use G W —ground water, P A — prior appropriation R — riparian, R D —reasonable discharge R U — reasonable use S W —surface water

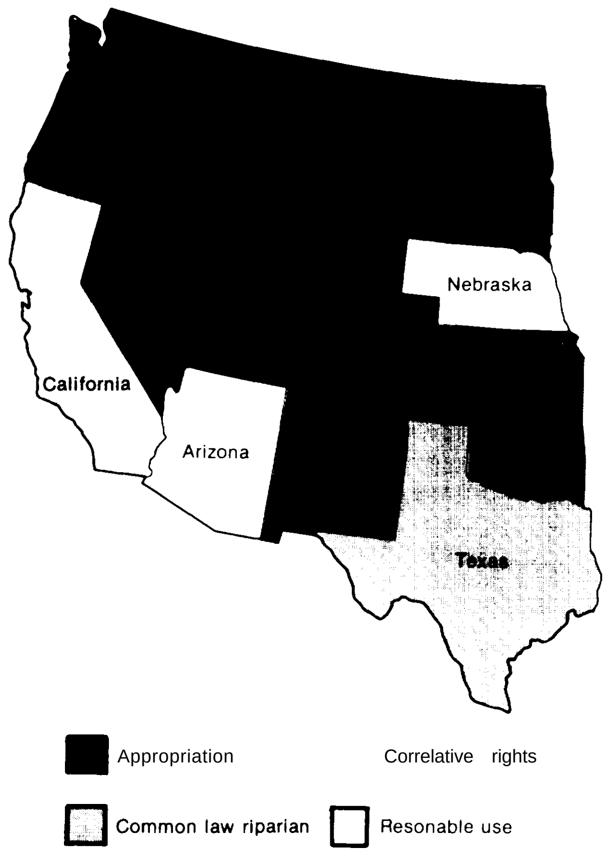
Column 7 1 – domestic and municipal 2—agricultural (irrigation), 3—power, 4—mining, 5— manufacturinq and Industrial 6—recreation 7— navigation

Column 9 Original —initial filing recorded Current —user must notify agency of name use place etc transfers unlimited

aAll States recognize loss by abandonment
Lack comprehensive ground water laws.
cE - flood waters, C L . natural flows
-Different types, not for 1914 rights, riparlan rights, and percolation ground water
eTen years is evidence of abandonment
In mining districts 4 over 2 and 5
gAll new water by prior appropriation

SOURCE Adapted from: G E Radosevich, *Western Water Laws and Irrigation Return Flow, EPA-600/2-7&180* (Ada, Okla.: U.S. Environmental Protection Agency, 1978)

Figure 28.—Ground-Water Law Systems in the Western States



aOklahoma has many characteristics that also place it in the correlative rights category

SOURCE: Adapted from G. E. Radosevich, *Western Water Laws and Irrigation Return How, EPA-600/2-78-180* (Ada, Okla.: U.S. Environmental Protection Agency, 1978).

cern about some of the traditional precepts of Western water law, In particular, the U.S. Supreme Court in *Sporhase, et al., v. Nebraska* (25), and the U.S. District Court in *El Paso v. Reynolds (10),* decisions addressed the legal grounds of two States, Nebraska and New Mexico, to protect their scarce water supplies. While noting a State's public interest and equity concerns over water, these courts declared water an "article of commerce" and held unconstitutional State antiexport statutes that placed an undue burden on interstate commerce. Because their scope or potential impact is unclear, these cases have increased the confusion about a Western State's proper role in protecting and conserving vital water resources for its own citizens in times of severe shortage. Conceivably, the impacts are regionwide *(29].* Several other Western States have laws similar to that declared unconstitutional in the *Sporhase, et al., v. Nebraska* **case.**

Water Quality Under Traditional Doctrines

Water-quality considerations are noticeably absent in a majority of the surface and ground water doctrines of the Western States. The one exception is California, which has a statute making water quality a specific element of a water right. A California user can make the same demands on an agency to protect an interest in water quality as that in water quantity entitled under the water right (24).

An implied right of water quality exists under the doctrine of prior appropriation. In theory, water-right holders should be entitled to the quality of water existing at the time of its appropriation. In practice, however, if an individual believes a water right is being impaired because of upstream pollution, the only recourse in most cases will likely be a lawsuit based on common law doctrines of nuisance and trespass. Only a few courts have protected irrigation users from upstream polluters, and these cases have usually involved extreme instances of water degradation. Most of the cases relating to such pollution occurred in the early 1900's (24).

The extent to which an individual State water-right holder might be able to revive either appropriation or common law doctrines for water-quality purposes is questionable. Unless strict controls exist, water-quality deterioration will probably increase as development and water use intensify in the West. Some States more than others may experience severe water-quality problems and thus threaten an individual user's right.

Administration of Western Water Rights

In most of the West, rights to use water are regulated and administered on a comprehensive basis. Table 27 summarizes the administrative approaches developed by each of the 17 Western States to oversee the system of water rights, Commonly, a State officer, often designated the "State Engineer, " holds one of the most powerful positions in State-level water institutions. This officer keeps records of water use, receives and approves applications for new water uses, appoints river commissioners or water masters to supervise the distribution of water in accordance with water rights of record, and institutes court actions to determine and adjudicate both surface and ground water rights.

The prominent approach used for providing evidence of a Western water right is the permit system (table 27, column 4). In some States, the final water right may be called a license or certificate. A few States have different classes of permits to enhance their ability to allocate and regulate the use of water among competing interests.

In the West, most States have well-established procedures governing the transfer of water rights (7). A water user or a purchaser of a water right generally is entitled to change the point of diversion, place, and nature of use of the right. However, as a procedural matter, before such a change maybe made, the owner of the right must file a change application with the State water-rights administrator. The purpose of the change application is to give notice to other water users on the system of the changes proposed and to allow the administrator to determine whether or not the change can be approved without impairing other existing rights on the same watercourse. The general rule in most States is that an appropriator is entitled to rely on stream conditions substantially as they were when that individual made an appropriation, and any change that is proposed cannot adversely affect other existing water rights (7). The question of impairment usually arises in connection with return flow. This is particularly true with respect to irrigation uses where it is common for some of the irrigation water to return to the watercourse as return flow or seepage. If this is the case, and the return flow makes up a portion of the downstream water rights, the upstream irrigator is not allowed to diminish that return flow by changing his / her water right. However, subject to the caveat that a proposed change cannot impair other water rights, most States have adopted a fairly liberal policy with respect to proposed changes.

An unrestricted policy with respect to water transfers has caused a few States to reevaluate their historic practices in this area. For example, the Wyoming Legislature has provided that when considering a change application the State Engineer may consider: 1) the economic loss to the community and State as a result of the discontinued use, 2) the extent that such economic loss would be offset by the new use, and 3) whether there may be another source of water available to satisfy the new use. These criteria supplement the traditional consideration of whether or not there would be impairment of other rights. This legislation thus allows for at least some modest evaluation of the public interest in determining whether the proposed change should be approved. Montana has taken a more restrictive step in an effort to protect large agricultural rights in that State. The Montana Water Code prohibits a transfer of an irrigation right to an industrial use if the quantity of water involved exceeds 15 cubic feet per second. This provision appears to have been designed to preserve the agricultural industry in that State (7).

Administration of Western water rights has become particularly complicated regarding allocation of those rights. In practice, water is allocated not only on the basis of traditional water law doctrines that have developed for naturally flowing and underground water but also on the basis of contractual arrangements between water districts and water supply agencies. A Federal or State agency may have constructed a dam for water storage, with entitlement to this water being defined by agreement with a water district. Thus, the specific amount delivered to an individual farmer may be unique to the given water supply system and not be defined entirely by strict application of a priority-of-use system. For example, an individual farmer may receive water defined by combined flow and storage rights and also have access to water in an underground aquifer. Many irrigation farmers in the West have all three types of water. Identifying what a particular user can get, when, and how becomes complicated. In addition, in some States permits are issued for single purposes, so consolidated records may not be available to identify the amounts allocated to and uses approved for a particular individual.

Owing to lack of information, ineffective monitoring, and disagreement on the meaning of the standard, the doctrine of reasonable beneficial use has not proven to be a significant constraint on water use. The definition of reasonable use depends on the availability of water, methods of diversion, and purpose of use, and is subject to uncertainty until the specific facts and circumstances are examined.

More fundamental to influencing adoption of "water-saving" technology for Western agriculture is the requirement of use as the basis of a water right under the doctrine of prior appropriation. This concept may discourage water conservation because it emphasizes either using the full allocation of water or losing the right to the unused portion. It is frequently argued that those who operate more efficiently and thus save water or who salvage water that would otherwise go to "waste" have no assurance that they will be the beneficiaries of such socially responsible conduct *(18).*

Federal Level

Constitutional authority exists for Federal water control and regulation through the commerce, property, and general welfare clauses

Box F.-" Today's Decisions On Water Will Shape Future"

The following was excerpted from an article by W. W. Lessley, chief water judge for Montana, who retired at the end of 1982 after 33 years on the bench:

Three great rivers flow through the state--The Yellowstone, the Clark Fork and the Missouri. Because of this fact, we are truly the Treasure State and seldom face loss of water; but now new forces move toward our water. The great need of sister states and those states farther to the south of us for our water is a threat to our complacency concerning this resource. The possibility of Federal concern and even intervention gives us pause.

If we were asked today by any court or administrative body to show the amount of water we have and the beneficial use we make of it and our great need for it, we could not do those simple things.

The reasons for this are many. Approximately 76 **percent of our water and water rights are what we call "use rights." There era** no records **anywhere except the use of these rights over a great number of years. Many of them rest in the far territorial and early history of our state, and the memories of those on which we rely are now gone. The rest of the percentage is divided between appropriated rights and decreed rights. The appropriated rights, in many instances, are faulty in record or cannot be found in our courthouse records. The decreed rights are uncertain because some water users were never informed when judicial action was in process and the inadequacy of the handling of the tidings.**

Now we face the future with water, but for how long? We have strength. We are at the headwaiters. Every rancher knows [w]hat that means even on a simple irrigation ditch, let alone on the great Missouri.

But we have weaknesses. We have great expanse of territory but few people and few representatives in the Halls of Congress. The lower basin states have many people and that means many senators and representatives and clout in the Congress!

The future lies ahead. Those who can only see the water we now have and are smug about our water really don't think of these things,

SOURCE: ***Bozeman*** *Daily Chronical Centennial Edition,* Mar. 30, 1983.

of the Constitution. The Federal Government is involved directly in water issues in the Western United States through the Federal doctrine of reserved water rights, water quality and environmental protection legislation, and interstate and international compacts.

The Doctrine of Reserved Water Rights

Under the doctrine of reserved water rights, the Federal Government acts as public trustee to ensure adequate water supplies to fulfill the purposes of national parks, forests, Indian reservations, and other Federal lands. Water rights become "reserved" by implication whenever Federal land is withdrawn from the public domain and reserved for some specific use or purpose: It is now generally settled that when a Federal reservation occurs, enough unappropriated water is reserved to accomplish in a reasonable manner the present and future purposes for which Congress made the reservation [*Winters* v. *United States, 207* U.S. 565 (1908), commonly known as the "Winters" doctrine]. The water so reserved must come from the watercourses arising on or flowing across the Federal lands set aside for the reservation. Federal reserved water rights are vested as of the date of the reservation, whether or not the water is actually put to use. These rights are superior to the rights of those acquired after the reservation date.

Perhaps the most significant of the reserved water rights, for purposes of Western agriculture, are those held by Western Indian tribes. Approximately 400,000 American Indians live on over 200 reservations in the West (table 28). Their situation is hardly distinguishable from that of other rural poor, except for one important difference: the unique status of the Federal reservation.

In recent years, attention has been drawn to quantification of these rights as non-Indian development has expanded in the West and pressures have increased on existing supplies. Opinions differ about whether quantification is desirable for Indian rightholders. On the one hand, these rights include those for future needs and opportunities; it may be unreasonable to require that such needs be quantified,

Table 28.—Indian Reservations and Rural Populations by Region and State

Regions	Number of reservations	Total Modulation	Number of acres	Rural population: Percent of total population	Rural population: Mean income (household)
California	76	6,824	502,712.68	**22.7**	$7,123
Intermountain:					
Idaho	4	4,849	*683,505.23*	NA	
Montana	7	24,137	*5,870,984.49*	80.2	**$5,872**
Oregon	4	2,718	*821,945.32*	43.3	**$7,191**
Washington	22	18,238	*2,779,045.40*	48.2	$7,200
Southwest:					
Arizona	17	173,412	24,710,019.26	*82.4*	**$4,335**
Colorado	2	2,144	902,897.00	NA	NA
Nevada	23	4,886	1,171,699.55	NA	
New Mexico	24	30,125	3,463,637.50	81.7	$4,617
Utah	4	1,961	1,133,730.31	65.1	$4,189
Northern Plains:					
North Dakota	4	16,735	2,143,046.07	*86,5*	**$5,332**
South Dakota	8	29,119	5,962,418.35	*70.5*	**$4,556**
Wyoming	1	4,435	1,886,556.00	NA	NA
Southern Plains:					
Kansas	4	*3,009*	*26,476.00*	NA	NA
Nebraska	3	*2,601*	*72,672.85*	NA	
Oklahoma	27	81,264	1,644,913.12	48,9	$5,389
Texas	2	1,000	4,473.00	15.2	$7,373

NA = data not available

SOURCE Finan, et al , 1982 Original source U S Department of Commerce, *Federal and* State *Indian Reservations* (Washington, D.C. U.S Government Printing Office, 1974), and 1970 *Census of Population Subject Reports American Indians* (Washington, D C U.S Government Printing Office, 1973) particularly because technological opportunities may change and because the very nature of reserved rights entails some uncertainty. Furthermore, as the result of **a 1983** U.S. Supreme Court decision in *Arizona v. California (l),* new concerns have been raised that quantification, once made, may not be changed at a later date to meet redefined needs because developers will have relied on the initial quantification in their investment decisons, On the other hand, some quantification has been urged by both Indian and non-lndian interests to increase certainty for developers.

The Federal role in these issues is complex, and many tribes are finding it increasingly difficult to rely on the Federal Government to act on their behalf. In one role, the Federal Government finances water-storage projects and allocates water supplies from such projects primarily to non-Indians. In another role, the Federal Government acts as public trustee for Indian users. Thus, at any one point in time Federal officials may be representing competing interests: farmers and ranchers v. the Indians. As a result, the Western Indian community has increasingly perceived that its interests are not being fairly and fully represented (15, 21).

Indians defend some claims for water that at present cannot be put to full use. Most of that water would go to agriculture and, in fact, the quantification of Indian rights is predicated on agricultural uses. Legal questions have been raised whether their water rights are restricted to agriculture or can be transferred to nonagricultural and non-Indian uses. Most Indian groups do not have a tradition of, or sufficient resources to begin, large irrigated farms. These problems have been exemplified by the Navajo Indian Irrigation Project, where pressure to quantify water claims preceded clear plans regarding water use (9). In the absence of such planning, Southwestern Indians have considered several options, including the sale of partial allotments to their municipal, industrial, and agricultural competitors.

Other claims—owing to the historical uniqueness of the reservations—focus more specifically on present threats to Indian water use and livelihood from non-Indian development off the reservation. In several areas of the West, non-Indian uses of both surface and ground water off the reservation either have damaged or threaten to damage Indians on the reservation. The Pyramid Lake Paiutes in Nevada, for example, sued the State, the Truckee-Carson Irrigation District, and some 13,000 other water users for lowering the level of the lake so that a principal economic activity, fishing, became unfeasible. The Papago Indians in Arizona have requested a solution to the depletion of reservation ground water supplies by municipal, agricultural, and mining sources, and the Fort McDowell Indians of Arizona objected vigorously to a Bureau of Reclamation plan to build the Orme Dam that would force them to abandon traditional lands. On the Umatilla reservation in Oregon, Indian fishermen lost their fishing rights with the construction of the Dalles Dam on the Columbia River, and have sued to regain them.

Until recently, few incentives have existed for the quantification of Indian water rights, Throughout the history of water-project development, Congress and the executive branch have seldom taken reserved rights into account in development, Both the Colorado River Compact and the Upper Colorado River Compact, for example, are silent on Indian claims to water, The assumption was that such rights would be satisfied within the quantities allocated to each basin and to each State.

Now, increased pressures on existing supplies has brought this issue into sharp focus, in many cases through litigation (table 29). Pursuant to Federal law, States can negotiate for the Federal Government on these matters. Some States (e.g., Utah, Arizona, and Montana) are negotiating with Indian tribes to seek settlement of claims. However, the evidence is not yet available as to whether these experiments will provide equity and fairness to all parties and will avoid future litigation.

Efforts to settle conflicts involving Indian claims have failed, both legislatively and administratively, at the national level. Ironically, Federal mechanisms for participation and

Table 29.—Status of Settlement of Western Indian Claims

This table summarizes the decisional and settlement processes used in the river basins, or sections of basins, where there have been significant clashes between Indian and non-Indian claims to water. A few cases have not matured to the point where the parties have initiated any formal process, and these are omitted from the table.

	Litigation	Regulatory commission proceeding	$dministrativc decision	Negotiation	legislation
Arizona:					
Main stem of Colorado River below Hoover Dam.		—	—	—	—
Lower Colorado River between Grand Canyon and Lake Mead	—	—		—	—
Kanab Creek within Lower Colorado River Basin	—	—	—	•	—
Little Colorado River		—	—	—	—
Gila River Watershed, except Santa Cruz Basin	•	—	•	•	—
Salt River	•	—		—	—
Santa Cruz Basin	•	—	—	•	•
Groundwater Basin in Gila River Basin (Ak-Chin)	–	—	—	—	S
Transbasin diversion from Colorado River to Gila Watershed	•	—	•	—	—
California:					
San Luis Rey River.	s	•	—	•	•
White River	—	•	—	—	
Klamath River		•	—	•	•
Colorado:					
Animas, Mancos, Los Pines, La Plata and other tributaries of San Juan River	•	—	—	•	—
Idaho:					
Rapid River in Salmon River System	s	—	—	•	—
Kootenai River	—	•	—		—
Montana:					
Tongue River, Yellowstone Basin	c	—	—	•	—
Big Horn River, Yellowstone Basin	•	—	—	•	—
Milk and St. Mary Systems.	•	—	—	•	—
Big Muddy, Poplar, Milk and Missouri Rivers (Fort Peck)	s	—	—	•	—
Flathead River System	•	—	—		—
Flathead Lake	•	—	—		—
Marias River	s	—	—		•
Nevada:					
Groundwater Basin in Walker River Basin...	•	—		—	—
Owyhee River	—	—	—	•	•
Duckwater Valley and Muddy Creek Basins	—	—	•		
South Fork of Humbolt River	—	—	•		
Truckee and Carson Rivers	G	—		•	
Clear Creek, tributary of Carson River	—	—		•	
New Mexico:					
San Juan River, within Upper Colorado River Basin	c	—	—	—	—
Nambe—Pojoaque—Tesuque River System, tributary of Rio Grande	Q	—		—	—
Santa Cruz River system and Rio de Truchas, tributaries of Rio Grande	c	—		—	—
Rio Grande del Rancho, Rio Pueblo de Taos, Rio Chiuito and Other tributaries of Rio Grande		—	—	—	—
Chama River and tributaries between El Vado Dam and confluence with Rio Grande	•	—		—	—
Bonito, Hondo and Ruidoso Rivers, tributaries of Pecos River	s	—	—	—	—
Santa Clara River, tributary of Rio Grande.	Q	•	—	—	—
Chaco River, part of San Juan River drainage			—	•	—
Rio Puerco (west), tributary of Little Colorado River in Lower Colorado Basin	•		—		—
Rio Grande	—		•		—
Rio San Jose, within Rio Grande Basin	—	•			—

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Table 29.—Status of Settlement of Western Indian Claims—Continued

	Litigation	Regulatory commission proceeding	Administrative decision	Negotiation	legislation
Oregon:					
Williamson River in Klamath River Basin	•	—	—	—	—
Umatilla River, tributary of main stem of Columbia	—	—	•	—	—
South Dakota:					
Missouri River and tributaries in western South Dakota	•	—		—	—
Lake Andes		—		—	—
Utah:					
Duchesne River and Tributaries, Green and White Rivers	—	—		•	—
Washington:					
Yakima River Basin	•	—		•	—
No Name Creek	•	—		—	—
Chamokane Creek	•	—		—	—
Groundwater Basin (Lummi)	•	—		—	—
Skagit River, and tributary, Copper Creek	•	—		•	—
White River,	•	—		—	—
Western Washington rivers containing traditional fishing grounds of tribes signatory to any of five treaties	•	—		—	—
Payallup River	•	—		—	—
Quinault, Queets and Raft River Systems		—		—	—
Skokomish River System	~	•		—	—
Dungeness, Skagit, Snohomish, Stillaguamish, Pilchuk, Snoqualmie basins, and off-shore sites in Strait of Juan de Fuca and Puget Sound	•		•	—	—
Wyoming:					
Big Horn River	•	—	—	—	

SOURCE: John A. Folk-Williams, "What lndian Water means to the West:' Water in the West, vol. 1, Sante Fe Western Network,

negotiation with Indian interests have been severely reduced in recent years. Unless the Federal Government establishes a full commitment to resolve the issues surrounding Federal reserved rights and a focal point for negotiation, uncertainty and confusion for Western development, including Western agriculture, will continue.

Water-Quality Regulation

As noted above, in the *1800's* the Federal Government chose to defer to the States on matters of control and development of local water supplies. In the mid-1900's, however, there was a gradual shift back toward more Federal regulatory interest in water. This occurred in the area of water quality, an aspect of Western agricultural water use that affects both the quality of water needed in agriculture and the quality returned to the natural system after agricultural use (see ch. IV).

Federal involvement in water quality control has moved State agencies forward in water-quality regulation. A significant example of Federal action that has had major impact on State programs was the passage of the Federal Water Pollution Control Act of **1972**, amended by the Clean Water Act of 1977 (together commonly referred to as the Clean Water Act, Public Law 92-500). Through the combination of two mechanisms, a permit system for point sources of pollution and instream standards of water quality, the U.S. Environmental Protection Agency and the States are obliged to impose restrictions on effluents entering a stream, They are also to undertake steps necessary to ensure that water-quality standards are met.

Nonpoint source pollution, especially from agriculture in the form of salts and agricultural chemicals, received more attention with the passage of the Clean Water Act. Section 208 of that act authorized and directed the Secretary of Agriculture to establish programs to implement "best management practices" on farms and ranches to control nonpoint source pollution from agriculture. Technical assistance and financial support were initially provided. Now, with Federal assistance effectively eliminated, most States rely on voluntary action and cooperation to achieve nonpoint pollution reduction.

Interstate and International Agreements

Interstate and international agreements dealing with Western river systems are important attempts to recognize politically the regional nature of surface water regimes and the need to manage them as total units. Existing agreements define some framework for water use by different parties of interest. At the same time, uncertainty has been created by the potential constraints of some of the provisions as water quality and quantity limits are reached and strict enforcement measures become necessary to ensure compliance. These interstate and international agreements affect all Western water users. As compliance becomes a matter of increased concern, these agreements will influence decisions about the kinds of water-related technology acceptable for meeting compact water quality and quantity obligations effectively. The major Western agreements are noted below.

Interstate Compacts

The major provisions of the *Colorado River Compact of 1922* are (28):

1. It divides the river system into the Upper and Lower Basins and allocates 7.5 million acre-feet per year (maf/yr) to each basin for beneficial consumptive use. The Lower Basin is also given authority to increase its annual use by 1 million acre-feet (maf).
2. It does not recognize a specific obligation to provide water to Mexico. However, a framework is established whereby any future obligation would be shared equally between the Upper and Lower Basins.
3. The Upper Basin is prohibited from reducing the flow at Lee Ferry to below an aggregate of 75 maf in any 10-year period. The Upper Basin is not to withhold water, nor is the Lower Basin to demand water that cannot reasonably be applied to domestic and agricultural uses,

The *Boulder Canyon Project Act of 1928* provided for the construction of Hoover Dam and its powerplant and for the All-American Canal. Its major provisions were:

1, It suggests a specific framework for apportioning the water supplies allocated by the compact of 1922 among the Lower Basin States of California, Arizona, and Nevada, (The States did not adopt this framework, but it was later imposed on them by the Supreme Court decision in *Arizona v. California, 376* U.S. *340 [1964].)*
2. It requires California to reduce its annual consumption to 4.4 maf plus not more than half of the surplus water provided to the Lower Basin. (This requirement was met through the California Limitation Act of 1929.)
3. It authorizes the Secretary of the Interior to investigate the feasibility of projects for irrigation, power generation, and other purposes.

In the *Upper Colorado River Basin Compact of 1948* the Upper Basin States apportioned the water allocated under the compact of 1922, The negotiators recognized the problem inherent in allocating water on a strict-quantity basis because of flow fluctuations from year to year, As a result, water was apportioned on a percentage basis to all States except Arizona, Major provisions of the compact are (28):

1. Arizona is guaranteed 50,000 acre-ft/yr, The remaining water is apportioned as follows:
   - Colorado: 51.75 percent
   - New Mexico: 11.25 percent
   - Utah: 23.00 percent
   - Wyoming: 14.00 percent.
2, It recognizes that new reservoirs will be needed to assist the Upper Basin in meeting its delivery obligation to the Lower Basin. The compact provides that charges for

such evaporative losses be distributed among the Upper Basin States. Each State is to be charged in proportion to the fraction of the Upper Basin's water allocation consumed in that State on a yearly basis, and its maximum consumptive use is to be reduced accordingly.

3. It provides for the division of water between pairs of States on a number of specific rivers.

Being in a position to use water available under these compacts has been a problem for some States. For example, the 1922 Colorado River Compact legally guaranteed the State of California 4.4 maf of Colorado River water annually. Yet California has used approximately 5.7 maf every year because it has had the physical structures to convey and use the extra water, while other States have not had this capacity. The Central Arizona Project (CAP), a massive water system which will lift the water almost 2,000 ft in elevation and carry it over 300 miles to make use of Arizona's share, should make its first delivery in 1985 to Phoenix, shifting water away from California users to Arizona users. *

International Agreements

In the *Mexican Water Treaty of 1944-45* the United States promised the Republic of Mexico that 1.5 maf of water will be delivered to Mexico every year through the Colorado River. This provision was part of the negotiations over apportionment of water from the Rio Grande, Tijuana, and Colorado Rivers. The States in the Upper and Lower Colorado Basins were apportioned 7.5 maf for each group of States.

The treaty with Mexico had not been made when the Colorado River Compact was signed. But article III(c) of the compact provides that if the United States recognizes any Mexican rights in the river, these rights would be filled "first from the waters which are surplus over and above the aggregate amount" allotted to the Upper and Lower Basin States (1.5 maf plus whatever the Lower Basin States have been able to use, up to 1 maf/yr).

If the surplus is not adequate to fill the obligation to Mexico, the "burden of such deficiency shall be equally borne by the Upper and Lower Basin . . . ." In short, if the "surplus" waters of the Colorado River are less than 1.5 maf annually, existing rights in the United States could be cut short to make up the difference owed to Mexico. Moreover, under international agreement with Mexico, the quality of the 1.5 maf was to be improved through the Water Salinity Control Project at Yuma, Ariz. (see ch. VII for discussion of desalting techniques).

The *Columbia Treaty of 1964* concluded two decades of study and negotiation by the United States and Canada for joint development of the Columbia River basin. For the United States, large quantities of Canadian storage were acquired to meet certain flood-control objectives in the Northwest States and to provide power through the Bonneville Power transmission system to the Pacific Northwest, California, and to the Southwest. When enacted, its focus was not principally on irrigation, a domestic matter within the concept of multiple-purpose development of U.S. rivers. Eventually, the treaty may restrict the entry of new agricultural users, since such users would have junior rights to existing power rights and hydroelectric power requirements may not be compatible with timing needs of new users. In this sense, hydroelectric power will become a competing use for new irrigation farmers.

Implications for Sustainable Western Agriculture

State and Federal water-law doctrines have helped define general rights and duties. As demands for the limited resource have grown, however, uncertainties have increased about the specific meaning of these rights regarding more intensive water use, potential new users, and opportunities for water transfers and reallocation. A substantial part of the uncertainty concerns the nature of the water right held by an individual. For example, in California,

*For a discussion of the major social, economic, and political issues surrounding the CAP, as well as a physical description of the project, see ref (14).

which has attempted to quantify water rights, appropriative rights acquired before 191+1 are not required to be recorded, Post-1914 rights were, until 1969, recorded regarding flow rate and seasonal restrictions but omitted total quantities. Even where water rights have been recorded, the quantities of water claimed may be exaggerated, thus largely destroying the utility of the record (12). In addition, uncertainties about the quantities of water involved with Indian and other Federal reserved water rights cloud the titles of many recorded private appropriative rights, and Federal commitment to negotiate and resolve these issues is lacking.

Problems have also grown regarding the artificial separation of water into legal classes. Surface and ground water rights are administered along different well-established doctrines, as discussed above. Nevertheless, these surface-subsurface waters are connected physically and interact both quantitatively and qualitatively. Rights in atmospheric moisture, a relatively new legal area, are poorly defined because interception technologies are relatively new, although a few States have begun to claim sovereign rights to atmospheric moisture (see ch. VI). If precipitation makes its way to the ground as diffused surface water, the runoff may become subject to other types of water rights before it reaches the streamcourse or ground water. In some States, use of diffused surface water (not yet concentrated in a channel) impounded for certain purposes by a landowner must be secured through special procedures. No State has gone so far as to actually appropriate diffused surface water (26). *

● For a thorough discussion of the impacts of Federal agricultural production programs on soil and water resource management in general see the OTA assessment: *Impacts of Technology on U.S. Cropland and Rangeland Productivity,* ch. VI, OTA-F-166, August 1982.

SOCIOECONOMIC FACTORS AFFECTING WESTERN WATER INSTITUTIONS

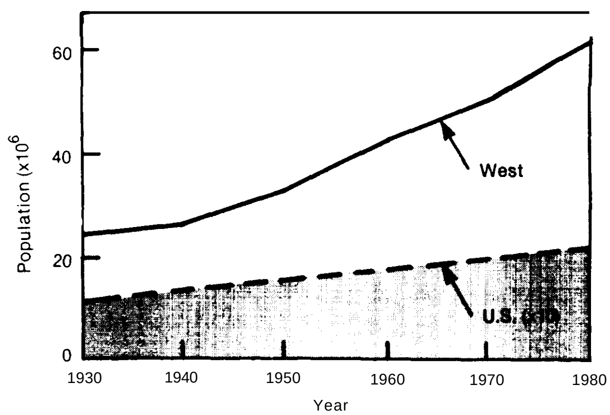
The social and demographic trends that characterize the West have been shaped by economic opportunities and institutional forces. Such opportunities have been and continue to be conditioned by the distribution and availability of water resources.

Demographics

In many ways, unmanaged population growth constitutes a major long-run threat to agricultural growth and development in the West. People increase demands not only on water supplies but also on space. Since cities grow more easily on level terrain, farmers and urban developers compete for the same valleys. Population increases promote commercial and industrial sectors of the economy, which in turn attract more people in search of jobs. Much of the West is fully involved in this spiral, and local conflicts over land and water use are becoming commonplace.

Regional population-growth patterns have shifted in the past three decades. Figure 29 compares the rate of growth for the 17 Western States with that of the entire United States. All four U.S. census regions gained population in each of the intervals between the last three censuses (fig, 30). The Western census region (note that this region does not include all 17 Western States) grew fastest, although its population in-

Figure 29.-Popuiation Rate of Change of the 17 Western States Compared to the U.S. Population, Rate of Change, 1930-80



SOURCE: Office of Technology Assessment staff, from U S. Department of Commerce, Bureau of the Census, 1980 Census of *Population* and *Housing,* advance reports

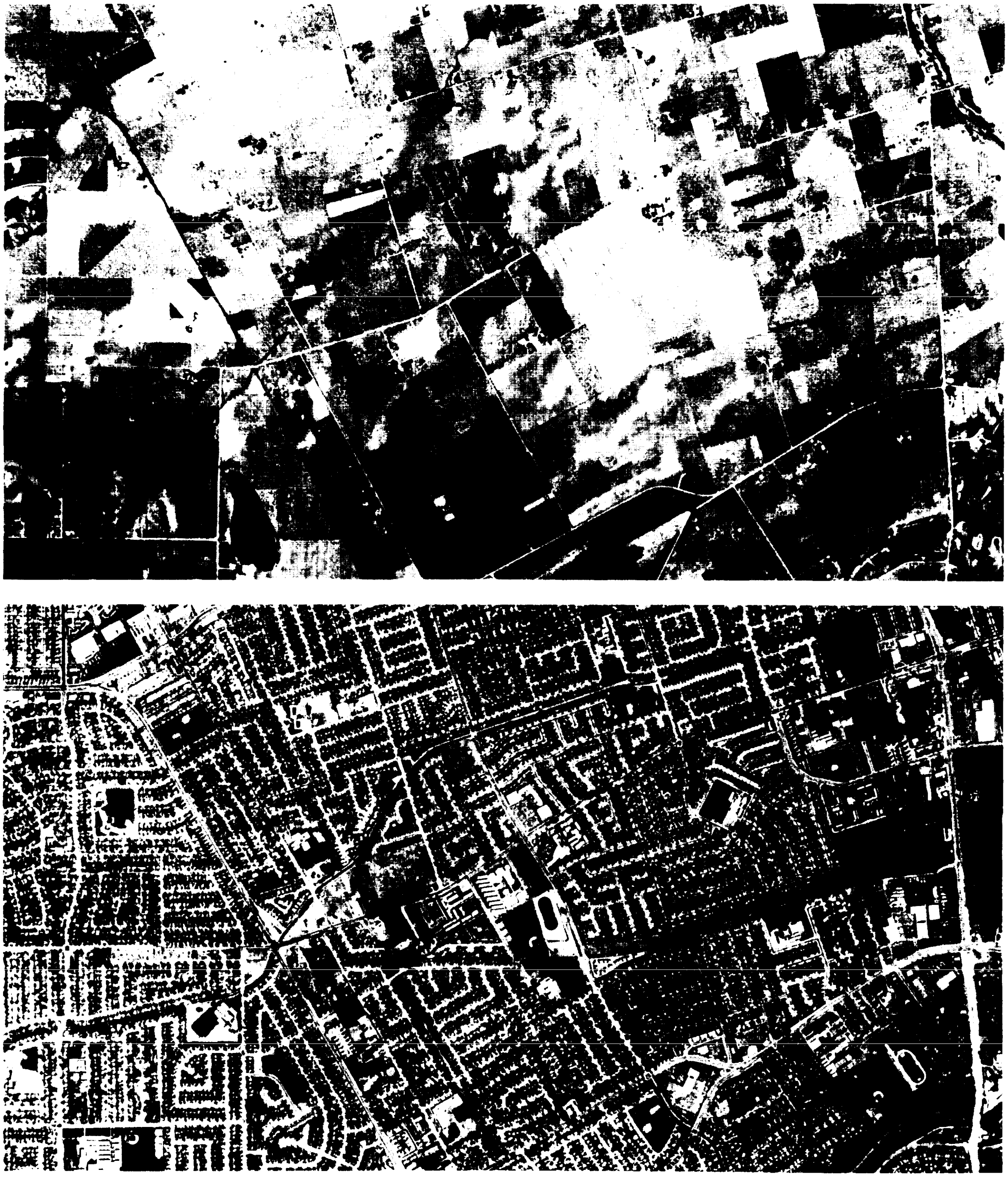


Photo credits: USDA-Soil Conservation Service

Suburban growth of Santa Clara County, Calif., during 28-year period (April 1950 to April 1978). Photo (top shows the area that was predominantly agriculture now covered with highways, housing developments, and industry (bottom)

Figure 30.—United States: Census Regions and Divisions

SOURCE u s Department of Commerce Bureau of the Census. Statlstlcal Abstract Of the United States 1981 (102d ed) (Washingfon D C 1981)

Components of Population Growth in Regions and Divisions: 1950-80 (numbers In millions)

Regions and divisions	Population 1950	Population 1960	Net migration	Population 1970	Net migration	Population 1980
Northeast	39.5	44.7	+ .3	49,0	+ .3	49.1
New England	9.3	10.5	+ .0	11.8	+ .3	12.3
Middle Atlantic	30.2	34.1	+ .3	37.2	+ .0	36.8
Northcentral	44.5	51.6	- .1	56.6	- .8	58.9
East Northcentral	30.4	36.2	+ .7	40.3	- .2	41.7
West Northcentral	14.1	15.4	- .8	16.3	- .6	17.2
South	47.2	55.0	-1.4	62.8	+ .6	75.3
South Atlantic	21.1	26.0	+ .6	30,7	+ 1,3	38.9
East Southcentral	11.5	12.0	-1.5	12.8	- .7	14.7
West Southcentral	14.5	17.0	- .6	19.3	- .0	23.7
West	19.6	28.1	+ 3.8	34.8	+ 2.9	43,2
Mountain	5.1	6.9	+ .6	8.3	+ .3	11.4
Pacific	14.5	21.2	+ 3.3	26.5	+ 2.5	31.8

SOURCES' Bureau of the Census, 1950-70, Revised Estimated of the Population of States and Components of Change, Current Population Reports Series P.25, Nos. 3-4 (1985) and 460 (1971). Bureau of the Census, 1970-80, 1980 **Census United States Summmary Final** *Population and Housing Unit Counts* (Advance Reports) PHC 80 V-1, 1981, table 1.

crease dropped from 39 percent in the 1950's to 24 percent in the 1970's. The Pacific division within this region grew faster in the 1950's and 1960's, while the Mountain States attracted more population growth in the 1970's (23). State-by-State percentage change in population for the 17 Western States is indicated in table **30**.

By **1980,** the population of the South and West exceeded that of the two northern regions for the first time. California was the most populous State, with 23.7 million people—far ahead of second-place New York, with 17.6 million (23),

For the period 1970-80, population growth in the West was above the national average with the exception of the Dakotas, Kansas, and Nebraska (table 30). For California, Texas, Arizona, and New Mexico, the increases were dramatic. Since the natural increase in population (births minus deaths) is relatively constant throughout the country, the large total increases in the West have been due to positive net migration: from 1970 to 1976, 623,000 for California; 543,000 for Texas; 356,000 for Arizona; 237,000 for New Mexico; and 1,849,000 for the entire West.

Both push-and-pull factors explain the population flux to the West. Climate certainly carries significant influence. perhaps equally important is the reluctance of many to endure the inconveniences of city life and the popular perception that Western cities and towns offer a rural-like setting and relaxed lifestyle without a loss of necessary services. Industry seeks what is referred to as "unexportable amenities." A warm, dry climate extends the use-life of capital goods and reduces shutdowns from adverse weather. Also, a growing population of employable persons ensures both a labor force and a demand for manufactured items. Commercial interests respond to urban population changes by developing the service sector. As a consequence, from 1970 to 1977, the West experienced an increase in nonagricultural employment three to four times higher than the national average (table 31). And whereas manufacturing employment in the United States actually declined over the same period, most Western States registered a dramatic increase, The broadening of job opportunities that accompanies the growth of industry and business promotes a regional image of abundant employment, thus drawing larger migrant flows.

Population trends for the 1980's indicate that the population shift to the South and West will continue but will not accelerate as it did in the 1970's. The question is more open, however, regarding the movement to nonurban areas.

Table 30.—Percentage Increases **in Population for the 17 Western States and United States, 1930-80**

State	1930-40	1940-50	1950-60	1960-70	1970-80
Arizona	14.6	50.1	73.7	36.3	53.1
California	21.7	53.3	48.5	27.1	18.5
Colorado	8.4	18.0	32.4	26.0	30.7
Idaho	17.9	12.1	13.3	6.9	32.4
Kansas	-4.3	5.8	14.3	3.2	5.1
Montana	4. I	5.6	14.2	2.8	13.3
Nebraska	-4.5	0.7	6.5	5.2	5.7
Nevada	21.1	45,2	78.2	71.6	63.5
New Mexico	25.6	28.1	39.6	6.9	27.8
North Dakota	-5.7	-3.5	2.1	-2.2	5.6
Oklahoma	-2.5	-4.4	4.3	9.9	18.2
Oregon	14.2	39.6	16.3	18.3	25.9
South Dakota	-7.2	1.5	4.3	-2.2	3.6
Texas	10.1	20.2	24.2	16,9	27.1
Utah	8.4	25.2	29.3	18.9	37.9
Washington	11.1	37.0	19.9	19.6	21.0
Wyoming	11.2	15.9	13.6	0.6	41.6
17 States	9.2	25.8	29.4	19.4	22.4
Total United States	7.3	14.5	18.5	13.4	11.4

SOURCE U.S. Department of Commerce, Bureau of the Census, 1980 *Census of Populatlon and Housing,* advance reports, from Statistical Abstract '81, p, 10.

Table 31.- Population and Employment Change by Region and State

Regions	Population 1976	Percent change in population 1970-76	Net migration 1970-76 Number	Net migration 1970-76 Percent	Percent change in employment 1970-77 Nonagricultural	Percent change in employment 1970-77 Manufacturing
California	21,510,000	7.8	623,000	3.1	20.6	7.1
Intermountain:						
Idaho	831,000	16.5	64,000	8.9	44.2	29.5
Montana	753,000	8.4	25,000	3.7	21.3	-2.5
Oregon	2,329,000	11.3	159,000	7.6	25.2	10.8
Washington	3,612,000	5.8	64,000	1.9	17.1	3.9
Southwest:						
Arizona	2,270,000	27.9	356,000	20.1	43.7	20.3
Colorado	2,583,000	16.9	237,000	10.7	32.3	18.6
Nevada	610,000	24.8	91,000	18.5	44.5	62.0
New Mexico	1,168,000	14.9	67,000	6.6	37.6	46.6
Utah	1,228,000	15.9	35,000	3.3	32.7	32.7
Northern Plains:						
North Dakota	643,000	4.1	-4,000	-0.6	34.1	4.9
South Dakota	686,000	3.0	-9,000	-1.3	21.1	31.0
Wyoming	390,000	17.4	37,000	11.3	45.9	9.5
Southern Plains:						
Kansas	2,310,000	2.7	-13,000	-0.6	25.7	24.2
Nebraska	1,553,000	4.5	11,000	0.8	18.5	5.3
Oklahoma	2,766,000	8.1	107,000	4.2	25.3	19.9
Texas	12,487,000	11.5	543,000	4.9	32.3	17.6
Total United States	214,659,000	5.6	2,857,000	1.4	8.6	-1.3

SOURCE Flnan, et al, 1982. Original source: Bernard L. Weinstein and Robert E. Flrestlne, Regional Growth *and decline in the United States* (New York: Praeger Publishers, 1978)

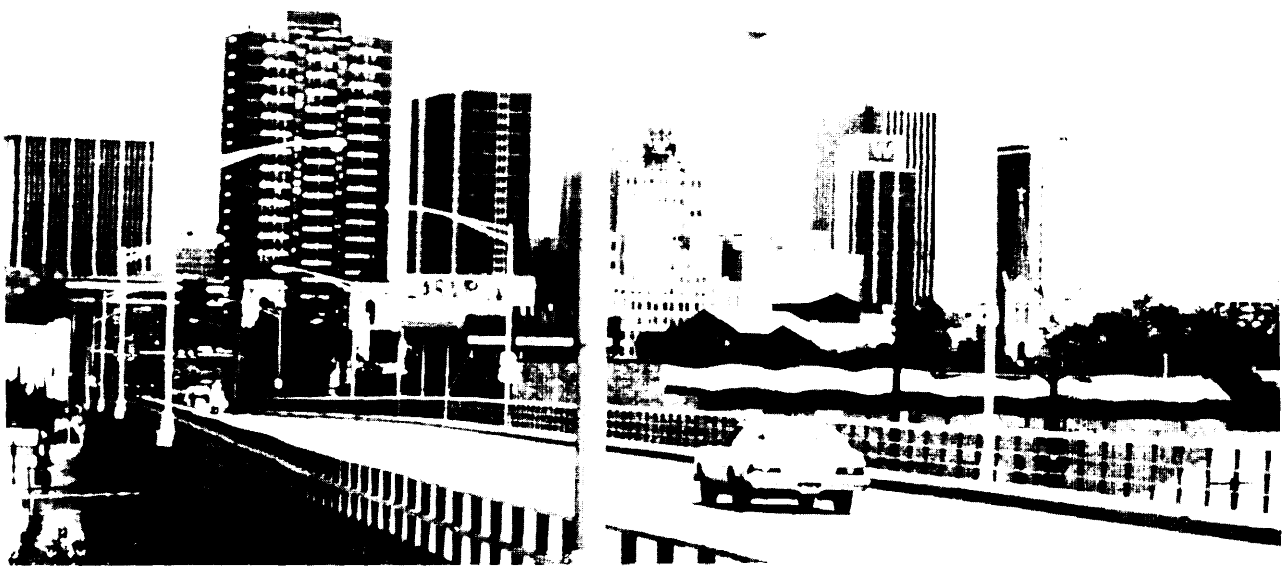


Photo credit Jack Schneider, ISP

Skyline of Denver, Colo., 1974—a Western metropolis at the hub of growth and urban development

During the first half of the 1970's, one of the major demographic surprises was a reversal of the rural-to-urban population flow, the first time this had occurred since the beginning of the century. This outmigration appears to be to counties adjacent to major metropolitan areas, however, and not to rural counties more removed from urban areas.

A panel of experts assembled by the Population Reference Bureau has projected continued rapid migration to the Mountain States (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming) in the 1980's. While some of this population movement will be related to mining activities, most will be related to resort-retirement growth and suburbanization. According to these experts, "diminishing water supplies will eventually restrain population growth in the West, but not yet in the 1980's" (23). In the meantime, recent population increases in the West are related, for the most part, to nonagricultural activities. Regional water-use priorities that traditionally favored agriculture may be affected by this trend to a more urban/suburban voting population.

Rural Economics and Western Agriculture

In much of the West, as in the rest of the United States, the farm population is comparatively low. Western farm population has dropped to about 3 percent of the total population, close to the 1981 national average (table 32). The ratio of agricultural income to nonagricultural income averages somewhat less than 3 percent in the southern half of the West and 7.5 percent in the Plains area (30). Agriculture itself directly supports a small population; however, as a regional activity it has become an integral part of local economies. Agriculture contributes to such local and regional activities as grain-elevator operation, transportation, and food processing. In Texas, for example, every dollar of farm sales leads to more than $3.40 in the Texas economy (5).

A large, complex economy such as that of the United States is made up of thousands of subeconomies. In the 50 United States, there are over 3,000 counties and approximately 20,000 municipalities, most with populations of less than 2,500 people (3). These small towns are primarily agricultural service centers and are highly dependent on the agriculture that surrounds them.

The irrigation of agricultural areas in the West has changed the productivity of their resources and hence their economic bases. Irrigating large parts of Arizona has changed that

Table 32.—Total and Farm Population of the United States: 1920-81 (numbers in thousands)

Year	Total resident population	Farm population	
		Number of persons[b]	Percent of total population
Current farm definition-			
1981	224,064	5,790	2.6
1980	221,672	6,051	2.7
1979	219,611	6,241	2.8
1978	217,771	6,501	3.0
Previous farm definition:			
1981	224,064	6,942	3.1
1980	221,672	7,241	3.3
1979	219,611	7,553	3.4
1978	217,771	8,005	3.7
1977	215,966	7,806	3.6
1976	214,282	8,253	3.9
1975	212,542	8,864	4.2
1970	203,235	9,712	4.8
1960	179,323	15,635	8.7
1950	150,697	23,048	15.3
1940	131,669	30,547	23.2
1930	122,775	30,529	24.9
1920	105,711	31,974	30.2

aOfficial census counts, except 1975-81, which are estimates.
bFarm population estimates for 1920 to 1970 from Farm Population Estimates, 1910-70, U.S Department of Agriculture, Statistical Bulletin No. 523 July 1973; five-quarter averages centered on April beginning 1980. See app A.

SOURCE U S Department of Commerce, Bureau of Census, "Farm Population of the United States" 1981, " November 1982, p 1 area from one that produced cattle to an area that produces citrus crops, cotton, and other high-valued commodities. The irrigation of some parts of southern California has permitted that area to switch from essentially no agricultural production to an area that produces many of the Nation's winter vegetables. Irrigating Washington State's Columbia basin has changed that region from extensive cattle grazing to the highly intensive cultivation of hay, sweet corn, and potatoes.

These changes, however, are not made in a vacuum. Once the major change occurs in agriculture, the effects spread to nonfarm parts of the society and the economy. Reactions to change in an economic base are site-specific, A cattle-producing area that suddenly has water to irrigate some of its hay-producing land may not change at all. A desert that is made to produce many labor-intensive crops will change demonstrably. In the latter case, nearby towns–as well as the farms–grow, develop,

Box G.—Economic Impacts of Irrigation on the West

The Grand Valley trade area in western Colorado has been irrigated by Bureau of Reclamation projects for many years. A 1963 study of the area showed that water was used on 3,999 farms (95.9 percent of all farms) and that nearly all of the cropland as well as some of the hay-producing land was irrigated (Struthers, 1963, in Barkley, 1983). In 1960 the 273,000 irrigated acres helped produce agricultural commodities valued at $27.6 million-38 percent of the area's total product. Agriculture was also estimated to be responsible for 18 percent of the "linked" or secondary employment in this area. This amounted to 1,026 persons who produced processing services valued at over $18 million. The analysts responsible for the study also estimated that agriculture was responsible for 7,500 to 10,000 jobs in the general sectors of the local economy. The entire influence of irrigated agriculture is summarized in ratios showing that for each dollar of income originating in agriculture, an additional $1.97 to $2.68 is generated in the local nonfarm sector.

The Columbia Basin Irrigation Project in central Washington was planned almost since the Bureau of Reclamation was formed in 1902 (Corssmit and Barkley, 1975, in Barkley, 1983). The irrigation components of the project became a reality in 1950, and by 1970 over 500,000 acres were irrigated using water supplied by the public project. The land that came under irrigation had previously been of little agricultural value and had been used almost exclusively for grazing cattle and sheep. After two decades of development, the area was reaching economic maturity, which involved massive expenditures by Federal, State, and local governments. By 1970 the Federal Government had invested $6.6 million in nonproject costs in the area (in addition to the direct costs of water delivery), the State and county governments had invested $258 million, and the many local governments had invested $25 million. In addition, utility companies serving the expanding populations invested $198 million. This represents a total investment of $8,032 per capita that was required to install an "appropriate" amount of social overhead capital in the area.

The High Plains area of eastern Colorado began to switch from dryland farming to irrigated farming in the 1960's. The development was carried out by individual farm operators who sunk wells into the Ogallala aquifer. Development was quite rapid. In 1966, 366 wells were registered with the State Ground Water Commission. By 1970, at least 2,000 wells were registered and in use (Rohdy, et al., 1971 in Barkley, 1983). The development occurred in a sparsely populated region and centered on towns that were quite small. The effects of irrigation farming are quite extensive and can be shown as "business multipliers," indicating the increase in nonfarm business that accompanies each dollar of economic activity in irrigated agriculture. The results of a 1973 study show that there was 77 cents of nonfarm business generated for each dollar of economic activity on irrigated farms.

SOURCES: P. Barkley, "The Sustainability of Rural Non-Farm Economics in Water Dependent Agrricultural Areas,' OTA commissioned paper, 1983.
C. W. Corssmit and P. W. Barkley, "Water Resource Development Related Social Overhead Capital Expenditures in the Columbia Basin 1950-1970," paper presented at the annual meeting of the American Agricultural Economics Association, Columbia, Ohio, 1975. In: Barkley, 1983.
D. D. Rohdy, D. B. Tanner, and P. W. Barkley, "Secondary Economic Effects of Irrigation on the Colorado High Plains," Colorado State University Experiment Station Bulletin 5455, June 1971. In: Barkley, 1983.
Robert E. Struthers, "The Role of Irrigation Development in Community Economic Structures," U.S. Department of the Interior, Bureau of Reclamation, February 1963.

and change. Lifestyles and business patterns are affected. The growth requires the commitment of personal, social, and capital resources that, once put in place, are very hard to move (3).

Because of such investments, the possibility that irrigation may end in some areas of the West is generating increased attention. Irrigated agriculture could be diminished for a number of reasons. The availability of affordable water supplies could change (see ch. X), as in parts of Texas over the Ogallala aquifer, or competition could cause water to be shifted from agricultural to other users who can pay more, as in parts of Arizona and Colorado. Similarly, irrigation could damage the soil with salt buildup over time (see ch. VIII) to the degree that some areas cannot be economically farmed, as in parts of New Mexico and California.

Where competition diminishes agricultural use of water (e.g., when large energy companies buy major water rights), the economy of the area may remain strong even though particular patterns of community life and business may be changed as shifts take place away from an agricultural to an industrial/mining economy. Such change may have serious and in some cases negative social effects (even with the emergence of a stronger economy) on others in the local community who may not have chosen to elect that change. Other areas may be able to remain in irrigated agriculture only with large subsidies in water or energy. Thus, social costs are also incurred, this time by the taxpayer.

These varying consequences underscore the importance of taking into account short- and long-term effects on local farm and nonfarm economies of public investments made in Western water use and agriculture. The question increasingly asked is whether new investments can generate a sustainable Western agriculture that is relatively stable for social and economic growth over the long term or whether the investments will be more productive in another sector of the economy.

Competition for Western Water

Water supplies can be used to support farming, mining, industry, urbanization, or combinations of these activities. The socioeconomic character of a region is influenced substantially by which of these activities enjoys the greatest relative control over water resources. Traditionally, agriculture has been dominant in establishing and maintaining the particular flavor of Western living and, to a large extent, has defined the economic, political, and cultural legacy of the region (11). In the past, federally subsidized water has placed irrigated agriculture in a favorable competitive position with other uses of water. Changes in Federal funding policies may affect the competitive advantage of irrigated agriculture and have ramifications for future agricultural production and the kinds of water-related technologies attractive to the producer. As Western populations expand in nonfarm sectors, greater demand is placed on land and water resources formerly used by farmers and ranchers (table 33). Decisions about who will get water may increasingly be affected by the “value” or “cost” of the water and by which competing users will be willing and able to pay. Major competitors for Western water are noted below.

Western Indians

As discussed in detail earlier in this chapter, some Indian claims are being defended in agricultural and nonagricultural uses, including instream uses such as fishing. The American Indian is a potentially large group of competitors. While quantification of many of their claims is unsettled, the potential impact of the amounts involved on all other existing rights created after the establishment of their reservations is substantial.

Energy and Mining Uses

One of the largest industrial developments affecting recent water policy in the arid/semiarid region is the growth of the energy industry (z). Although the west coast and other urban centers have developed a diversified manufac-

Table 33.—Projections of Changes in Total Cropland and Irrigated Farmland by State, 1975-2000

	Change in percent of cropland		Acres of irrigation farmland (1000 acres)		
Regions	1975-1985	1985-2000	1975	1985	2000
California	- 20/0	- 5%	8,495	9,132	9,854
Intermountain:					
Idaho	+1 "/0	-1%	2,989	3,351	3,400
Montana	+1 "/0	+1%	2,010	2,967	2,904
Oregon	-1%	-1%	1,742	1,987	2,096
Washington	+1 "/0	-1%	1,421	1,809	2,013
Southwest:					
Arizona	- 30/0	- 60/0	1,207	1,112	1,057
Colorado	+1 "/0	+1%	3,313	3,156	3,375
Nevada	39%	38%	828	737	773
New Mexico	-1%	-1%	956	877	816
Utah	1%	+1%	1,056	979	1,062
Northern Plains:					
North Dakota	+ 1 %	+ 1 %	94	126	230
South Dakota	-1%	-2%	218	274	380
Wyoming	2%	1%	1,731	1,818	1,874
Southern Plains:					
Kansas	7%	8%	2,044	2,618	2,823
Nebraska	+1%	+1%	4,315	4,858	5,118
Oklahoma	+1%	1%	566	580	589
Texas	+1%	-1%	7,414	6,886	6,170

SOURCE: Finan,et al, 1982 Original source US. Water Resources Council, TbeNation's Water Resourcces, 1975-2000, vol 2,pt lll, tableilP29, 1978

turing sector, energy development has been the principal industrial force in such areas as the northern Great Plains and Rocky Mountain States, and both boom towns and company towns dot Western maps. The relatively recent surge of the energy industry, particularly coal and oil-shale mining, has brought increased economic opportunities to many Western areas.

Most estimates of demand for water for energy production, slurry-line transportation, and cooling purposes conclude that energy demand for water on a regional scale is relatively small compared with that of irrigated agriculture. However, on a site-specific basis, increased water use to meet energy demand in such areas as the Rocky Mountain States will have a significant impact on the availability of water for other purposes, especially for agriculture (18). Ultimately, the quantities of water ''required" for energy production at a particular site will be affected by the cost the producing industry must pay for that water and associated restrictions put on its use (see ch. III). Much of the future of energy production in the West hinges on the ability of energy-producing firms to bid water away from irrigated agriculture (16) (see discussion in app, C on the value of water in alternative uses).

The competition for water between farms and mines also raises arguments over the desirability of development paths and the kinds of practices used by each. As extractive operations, mines are limited by the quantity, quality, and world price for mineral products, and the rise and fall of boom towns underscore the cyclical nature of this activity. Mining operations use land and water as short-run inputs and with full awareness of their eventual deg-

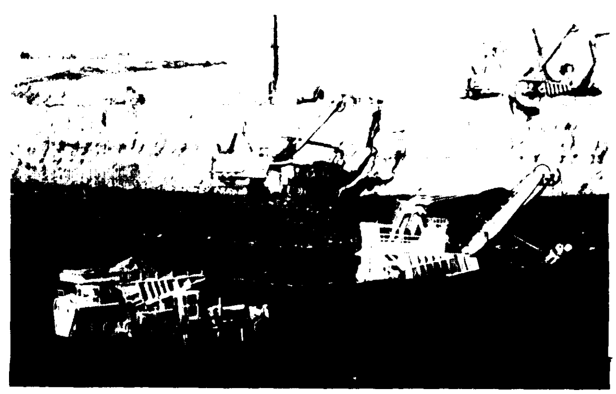


Photo credit: © Ted Spiegel, 1982

Mining Wyoming soft coal. Proposals to transport in slurry pipelines to Eastern markets would require extensive off stream water resources radation or depletion. Farms and ranches may be perceived to use land and water on a more permanent and beneficial basis; however, some present Western agricultural practices are degrading land and water both (see e.g., chs. VI, VIII, and X).

Municipal and Other Industrial Uses

Municipalities and nonmining industries use a relatively small fraction of the total amount of water used in the West. In table 34 this fraction is compared with agricultural use for some States of the West. Municipal and industrial water users are in a relatively favorable position with respect to future water supplies, owing to their superior financial capacity. In many areas, municipalities have developed reliable supplies of water and have supplemented these supplies by water from public projects. As compared with some agricultural users, they are accustomed to paying at a level closer to full cost of development, transportation, and purification. Federal law—and State law in States such as California–requires municipal and industrial users to pay their fully allotted costs. Costs may rise substantially, but urban and industrial water users will probably make minor financial or lifestyle adjustments to accommodate these changes.

Municipal and industrial users are increasingly interested in future water policy, particularly with respect to new water-development projects. Some communities still see growth as both a likely and desirable trend and foresee the need for additional water to permit such growth to occur. Municipal and industrial leaders fear drastic shortages such as those in the severe drought of 1977-78. The efforts of southern Californians to promote the Peripheral Canal and its accompanying works are evidence of this concern for seeking a margin of safety in drought situations.

Moreover, surface water diversions used to develop additional irrigated acres may increasingly compete with opportunities to develop hydropower for municipalities and industry. Whittlesey, et al. (33), studied the economics surrounding the irrigation / hydropower tradeoff the Pacific Northwest and concluded that, using present low values for irrigation water, most new irrigation developments in the Pacific Northwest represent a net loss for the economy of that region. Instead water use is heavily weighted in favor of hydropower generation because of the tremendous power-producing potential of the many dams on the Columbia River.

Resource Protection Uses

Agriculture must face competition and constraints on water use from interests concerned with environmental protection and resource conservation. Such interests have been successful in limiting access to new sources of water by placing some water sources in a protected status-e. g., in the wilderness and scenic rivers classification. The requirements for minimum streamflow standards have placed a new limitation on consumptive use (see ch. III).

In those areas where underground aquifers are being "mined," as in Arizona and the Central Valley of California, pressure exists to impose limitations on the levels and rates of withdrawals and thus reach a sustainable balance

Table 34.–Rate of Change in Water Use as Percentage of Total Water Use, Municipal and Industrial (M&I) v. Irrigation (Irrig.) Purpose in Selected States

	1955	1960	1965	1970	1975	1980
Arizona (M&I)	30/0	4%	60/0	80/0	10%	10%
(Irrig.)	960/0	94%	94%	930/0	90 "/0	890/o
North Dakota (M&I)	630/o	30 "/0	39%	650/o	780/o	74 "/0
(Irrig.)	300/0	49%	45%0	290/o	180/0	21 %
California (M&I)	250/o	41%	40%	300/0	300/0	300/0
(Irrig,)	75%0	580/o	600/0	690/o	690/o	690/o
Texas (M&I)	390/0	380/o	41%0	600/0	57%	580/o
(Irrig.)	590/0	59 "/0	56%	37%	41%	40 "/0
Nebraska (M&I)	220/0	270/o	20 "/0	200/0	14%	91 '/0
(Irrig.)	77 "/0	690/o	780/o	780/o	780/o	780/o

SOURCE U S. Government Survey, Estimated *Use of Water in the United States,* publications for 1955-80 (Washington, DC.: U.S. Government Printing Office, 1955-80).

Photo credit: USDA-Soil ConservatlonService

Idaho wilderness, an example of water resources in a natural state. Here, beaver dams provide natural water control

between extraction and recharge. In Arizona, this pressure—largely from urban and industrial interests—has already resulted in legislation that will impose a "duty of water" on agriculture—in effect, a limitation on the quantities of water that may be used in growing various kinds of crops. The director of the Arizona Department of Water Resources has been given extraordinary authority to define the limitations under which water may be used and powerful tools of enforcement to achieve these legislative ends (see app. C). Other Western States (e.g., Colorado and New Mexico) have specific statutory policies authorizing the mining of those ground water acquifers with little or no natural recharge capacity

Resource protection issues have broad implications for the West. Traditional water use and development relationships have been substantially altered in recent years by a broadening of interests related to water resources and changing institutional goals with respect to Western water development. At the national level, environmental values have gradually gained a more prominent level among public priorities. The relative primacy of Federal development agencies such as the Bureau of Reclamation has been challenged. Legislation has been enacted to strengthen the role of other agencies or to create new agencies, such as the Environmental Protection Agency. These policy developments have altered the missions of traditional agencies by placing them in the context of a broader decisionmaking structure. A most notable example is the passage of the National Environmental Policy Act (Public Law 91-190), which requires Federal agencies to prepare environmental impact statements prior to undertaking new projects. Support at the local level has grown for retaining water resources in a natural state. In addition, the traditional sentiment that "development" (inferring "growth" in quantity) is a positive value is no longer uniformly held. Indeed, major new water-project developments may increasingly encounter significant opposition and competition from distinct elements of the general public.

THE ECONOMICS OF WESTERN WATER

The market system allows property to be bought and sold, and thus transferred between uses and users. It forms the basis of the economic system in the United States and as such can be subsumed under the general heading of economics and, with respect to water, the economics of Western water.

A market depends on the rights of ownership and the legal conditions for exchange. The owner of a good as simple as a pitchfork has complete rights to that pitchfork and can sell it to a neighbor. Rights of ownership transfer with the sale. The pitchfork will be sold if its present owner feels the value of the money obtained in exchange equals or exceeds the value of the pitchfork. All well-functioning markets operate in this fashion. Exclusive goods—goods that have well-defined and perfected rights attached to them—are exchanged whenever dispositions about their relative values differ,

If rights in water were as straightforward and secure as rights in pitchforks (or even rights in land), a highly developed and organized water market would emerge. Irrigators would purchase water from industries if irrigated crops were worth more to farmers than water for cooling or dilution was worth to industrialists. Public utilities would purchase water from householders if the value in power generation was higher than the value of water for green lawns and kitchen gardens. Wheat farmers would purchase irrigation water from corn farmers if the value of wheat exceeded the value of corn by an amount sufficient to make the transaction worthwhile.

A Market for Water

Although there are some areas where the market does allocate water among uses and/or users, market exchanges of water are not the rule. Attempts have been characterized as "rudimentary" and unorganized (4). An important exception is found in the Colorado-Big Thompson project area of northeastern Colorado, where a relatively sophisticated market has evolved (see app. C).

Valid reasons exist for the lack of water markets. Many derive from legal and institutional factors affecting water use and exchange that have evolved in the West, as discussed earlier in this chapter. The appropriations doctrine assumes a sequence through time. "Prior rights" for a particular use may impede an individual's ability or desire to sell. The doctrine of beneficial use may establish a hierarchy of uses inconsistent with water moving to its most economical use. The riparian doctrine and the doctrines of correlative rights tie water to other resources or to a particular geographic territory and impede its transfer to other uses and users.

Other factors that hinder the formation of an orderly market for water include the physical characteristics of water, its variety of uses, water's use as a public good, external or third-party dependence on water, and the recent emergence of water as a scarce, and hence "economic, " factor of production (34). The difficulties associated with measuring use, location, and quality compound the problem of identifying water, assigning rights to it, and selling it in an orderly market.

Physical Characteristics

The physical barriers to establishing a water market stem from the fact that water changes its form and location as it passes through the water cycle. Water changes from solid to liquid to gas and moves from high locations to low locations. Because it is difficult to identify specific units of water, the ability to assign and enforce property rights is more limited than a well-functioning market might require. Assigning clear title to atmospheric moisture may, for example, interfere with assigning rights to subsequent rainfall. Also, most water users consume only a part of the water that comes to them. Water used to generate hydroelectric power may not be diminished (consumed) in the process but will be moved in location. Even water that is allocated to irrigation is not entirely consumed by plants; some seeps back into the water channel as return flow. Often the returning water picks up soluble salts and other chemicals as it moves through soil and back into streams. Thus, the return flow is lower in quality than the water originally applied by the irrigator; it is now a different commodity.

Multiple Uses

Some water is, and can only be used for a single purpose, A farmer whose remote windmill pumps water for a flock of sheep is pumping single-purpose water. A municipality pumps potable water to residential areas, and much of this is not available for reuse at a later time or in another plan. That portion of irrigation water consumed by growing plants cannot be recaptured for a second use. Many of the major uses of water, however, are not consumptive uses and require only that water be relocated or prevented from being relocated. Recreation is a good example. Water flowing through swift mountain streams or impounded in the lake behind a major dam is used for swimming, boating, fishing, and for its esthetic appeal. The same water may be released in order to generate electricity or maintain the flow of a stream. While it is conceivable that power users could organize and offer a price for water used in generating electricity, it is impractical to think of swimmers organizing in order to purchase the "swimming rights" that go along with a major water impoundment, The major (and minor) users of water have interests in water, but no identifiable and merchantable rights. Thus, the market fails to allocate properly the water used for several purposes.

Public Goods

A public good (sometimes referred to as a collective good) is a good that can be used "within reasonable limits" simultaneously by many people, More than this, no one person's use detracts from the quantity available for other people to enjoy. A city park is a public good. One person can use it without reducing the amount of park-use time available to a second, third, or tenth person. Many water uses have public goods characteristics. Recreation is one example, navigation is a second (another boat can go up the Columbia River), and flood protection, which is not a water use but is a kind of water control that inhibits other uses, has public goods characteristics.

Public goods are hard to value and hard to price. One user may know that his/her use has value and will bring an increase in utility, but that user also knows that if someone else will pay the bill, he/she can get the good for free. The user will then be what is called a free rider. Water-resource management is full of free-ride problems, all of which contribute to the difficulty of organizing a well-balanced market in which water can be purchased by potential users and sold by those who no longer have use for the resource.

External Effects

In economic terms, "externalities" are unintended consequences of an exchange or a production process. Some, such as the black-lung disease suffered by thousands of coal miners, are quite harmful. Others, such as the social benefits stemming from an educated populace, are valuable. All have one characteristic: if the primary economic activity is altered, the external effects are altered, too. Water use is filled with externalities. Towns grow up around irrigation projects. Aluminum is smelted near hydropower dams. Marinas are installed near reservoirs. Owners and participants of these external activities eventually develop a vested interest in the present allocation of water and can act to impede the orderly functioning of a market, Alternatively, the possibility of large beneficial external effects may lead some industries or groups of individuals to ask for water reallocations that are not consistent with the highest and best economic use of the resource.

Recent Emergence of Scarcity

While the idea seems anachronistic, the true economic scarcity of water is a relatively new phenomenon in the arid West. Most crop-related agriculture in the West is enhanced by irrigation, In early years, water was known to be available, but large expenditures of capital and labor were required to move it from mountains and rivers to arable land. The market, then, was not for water but for the other resources needed to convey water. No market was needed; there was generally enough water for all reasonable uses.

These complexities—the physical characteristics of water, the multiple-use problem, water as a public good, external effects, and the recent emergence of water as a scarce resource—have impeded the organization and development of a well-functioning market. Even though a market may help water allocation among uses and users, no general market has emerged. However, few economists will argue against a market for water. An organized way of trading or exchanging rights to this resource could help ensure that the net social product accruing from use of the resource would increase. This option has received increased attention at the State level and within some Federal agencies.

Proponents of a market argue that if a market does not exist, allocation of water will be left to a governmental entity. Values will have to be set so that priority of use can be established to determine who will use the limited supplies

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and government will do this through the political or legislative system instead of the market system (see, e.g., Arizona's legislative approach to ground water reallocation, app. C). According to these proponents, government intervention has historically failed, especially when trying to "correct" market failure; therefore, the market system should be given an increased opportunity to participate in the water allocation process. At the same time, a need for special mechanisms and safeguards to protect third parties and address other issues peculiar to water is generally recognized.

Water Economics in a Nonmarket Setting

Economics and economic reasoning play an important role in the water-allocation decisions made by individuals, groups of users, and governments. These decisionmakers often use surrogate or artificial prices to help guide decisions about who will have access to water and how it will be used. In the absence of freely operating markets, the government has often been the decisionmaker and has established regulations to guide water use. Many decisions are reached only after determinations of the value of water have been made and after these values have been processed through an analytical process known as benefit-cost (or, frequently, cost-benefit) analysis.

Water Value

The economic value of water is relevant only when explicit recognition is given to quantity, location, quality, and time of supply of the water that is being evaluated—i. e., the hydrologic system must be considered in terms of its interactions with climate, land, ecosystems, and pertinent social and economic systems, This intricate set of relationships is further complicated by the highly variable nature of water supplies and the importance of sequential uses (multiple uses) of water as it flows from upper watersheds to its eventual destination in the sea or freshwater system. The value of water is highly site-specific and varies directly with local conditions of supply and demand for the resource in a particular use. Even though these supply and demand conditions do not often work themselves out in a market setting, they form the basis for evaluations using surrogate prices.

Benefit-Cost Analysis

Nonmarket resource-allocation decisions can be made by using benefit-cost analysis (22). Water-resource planning and decisionmaking, in fact, represent two of the initial practical applications of benefit-cost analysis, and water may still be the resource most widely allocated on the basis of benefit-cost evaluations.

The benefit-cost framework is based on the same principles found in any well-functioning market system. It assumes consumer sovereignty and accepts the existing distribution of purchasing power as given. The main analytical problem posed by this method is derivation of a set of prices that are close estimates of undistorted market values when there is no clear and well-articulated market value for the resource, Once' determined, these prices can be used as a guide in many water-allocation decisions.

The process of estimating water values uses the concept of willingness *to pay* as a basic indicator of economic value. Willingness to pay reflects the dollar amount that a rational, fully informed consumer would be willing to spend in lieu of doing without the commodity or service. Willingness to pay for water is the maximum amount a farmer would be willing to pay for an extra acre-foot of irrigation water or the maximum amount a group of fishing enthusiasts would be willing to pay to keep water flowing in a mountain stream.

Varying from one water use to another, willingness to pay has an important influence on demand for water. Some uses for water are very intense, and people are willing to pay high prices to satisfy this need. People are less inclined to pay high prices for less intense uses of water. Household water falls into the former group; water for boating falls into the latter. Willingness to pay for water is also very repensive to the quantity supplied. A household can use only a given amount of water for cooking, washing, and watering the lawn. If more is made available, willingness to pay for the added water falls rapidly to low levels. Once a crop has received "enough" irrigation water, additional water may have a negative value. In formal terms, significant increases in the supply of water for a particular use will have a negative effect on the price (or value) of water at the margin.

Methods of Valuing Water

A number of methods and conceptual bases can be used to generate estimated prices for water (boxes H and 1). No method is correct or incorrect in the abstract. A particular method may be better or worse for a specific purpose. Many methods are correct or acceptable in the restricted context of a local- or private-planning decision but have limited applicability in valuing water from a national, long-term policy perspective. This is because once a method is chosen, it may yield different values for water at different sites, depending on what is being done with the water, when, and how.

Many estimates of water values appear in both popular and technical literature. The range of the empirical results demonstrates the problems of trying to place values on water for national water planning and policymaking. One of the most complex problems is assigning values that are comparable in concept, place, form, and time. The numbers below summarize the results of a range of available contemporary studies on water values. The estimates are for 1acre-ft of water devoted to a given use in a particular year. This type of estimate is often referred to as a point estimate, since it considers only the primary value of water at a single point within a limited (given) period in time. The studies from which these numbers are taken are discussed in more detail in appendix C.

The range of point-value estimates for Western, consumptive uses is (34):

In agriculture ... ...$7 to $80 / acre-ft
In industry ... ...$0 to $1,600 / acre-ft
In domestic use . . . .$150 to $250 / acre-ft

Box H.— Estimating Water Prices for Use in National Policy: An Overview of Methods

Since the market does not price water directly, economists have developed several methods to estimate water values:

- ***Ex post statistical analysis of water-user behavior.*** —This method applies conventional statistical analysis to water-consumption patterns of various users. It has an advantage over some other techniques in that it relies on actual willingness to pay for water.
- ***Change in net income.*** **–This procedure defines the value of water as the incremental addition to profits arising from an incremental application of water. Its results are somewhat deceiving and often incorrectly applied.**
- ***Alternative*** **cost.—Water is valued as costs saved by employing a water-intensive production plan rather than the most economically reasonable labor- and capital-intensive producing plan. This approach is sensitive to assumptions about such factors as technology and interest rates.**
- ***Direct observation of markets.-This*** **technique is** rarely available or suitable for water-policy analysis because of limited reliable markets.
- ***Consumer*** **surveys.—The value of water is calculated by asking consumers to place values on changes in water supply or quality for certain public goods-such as recreation or pollution abatement. Estimates are potentially useful, but not always perfect substitutes for price.**

SOURCE: R. Young, "Allocating the Water Resource: Market Systems and the Economic Value of Water," OTA commissioned paper, 1982.

Box I.—Economic Theory and Its Realization: Some Technical Problems in Setting Water Values

Economic methods that estimate the value of water are designed to establish an artificial but useful price for water in a particular use, at a particular site, and at a given time. The various approaches depend on the concept of *ceteris paribus,* which means that other economic variables are kept equal while the price of water is estimated. Although useful conceptually, these methods are subject to several limitations, noted below:

- ***Indirect effects resulting from water development.*—When major water developments occur, other economic changes are generated at local, regional, and national levels. Water values should be adjusted to reflect these perspectives.**
- ***Marginal v. total* value.-Like other inputs in crop production (e.g., labor and fertilizer), the value of water is its contribution to output. In setting water prices, the incremental use of water and its effect on net product should be evaluated in lieu of weighing total water costs against total output.**
- ***Changing water values during crop-production cycle.*—**The value of agricultural water varies during the crop-production cycle. Emergency, short-term values, for example, are generally higher than prices estimated for long periods of time. During a drought, a farmer maybe willing to pay a high price for water. Conversely, if rainfall is plentiful or if the farmer chooses not to plant a crop, the value of water is lower.
- ***Comparing values in place, form, and time.*—Water is a bulky commodity that may need to be transported, treated, or stored before used. The investments needed to carry on these processes should be considered in the water-valuation process.**
- ***Measuring quantity: water diverted or water consumed.*—Obviously, the quantity of water supplied is an important determinant of its cost. However, large differences in price will result, depending on whether water values are calculated by the amount of water that is withdrawn or whether water consumption rather than diversion is considered. No set rules or conventions exist.**
- ***Annual rental value or future* income.—Where a water user rents water annually, the value of the water is limited to the rental payment. If, however, the user owns the water and has a water right, its value is usually much higher and consists of its present value and its future expected annual value. To reconcile these two concepts, interest rates and annual returns should be considered in setting water values.**

SOURCE; R. Young, '**Allocating the** Water Resource: Market Systems and the **Economic Value of Water." OTA commissioned paper,** 1982.

The range of point-value estimates for Western, nonconsumptive, instream uses is (34):

Hydropower generation	.$3.30 to $30/acre-ft
Waste-load dilution	.$1.30 to $15/acre-ft
Recreation ., ...	..$2.00 to $13/acre-ft
Fish habitat , ...	Less than $1/acre-ft
Navigation , ...	No acceptable estimate

Figures as varied as those above make it difficult to place a "true" value on this resource and illustrate their limited use in evaluating national water policy. Instream use values pose a special set of problems. While economic analysis and accounting procedures can be used to value the products of instream uses, such as hydroelectric power, it is difficult to develop adequate values for the public uses (public goods) of the water. This problem has become more serious with the passage of time. Many people now want to use water for such public uses as recreation, boating, waste dilution, and esthetic charm. However, the market does not provide access to values for these uses, and analysts have not been entirely successful in developing surrogate values. The value of water in instream uses is very hard to determine because of:

1. public goods problems associated with many instream uses,

2. multiple-use problems, and
3. a lengthy national water policy tradition that assumes that water used for hydropower and water used for navigation should be free (34).

Economic Efficiency and the Adoption of Water-Related Agricultural Technology

Agricultural and nonagricultural users respond to economic conditions in their attempts to become efficient. A farm unit will be economically efficient when it maximizes its profits (13). Efficiency occurs in relation to a number of factors affecting farm operations. In the last 20 years, new irrigation and engineering technologies have led to increased engineering and economic efficiencies in irrigation. In almost all cases, the purpose of such technology has been to conserve nonwater inputs—principally energy and labor, In other words, becoming economically efficient in irrigation may or may not have saved water. In most areas the actual conservation of water has been a byproduct of shifts in the production system caused by changes in the relative prices of inputs (19),

This is not surprising, given the artificially low price that most irrigators pay for water. Even in the case of the Ogallala aquifer, increased pumping costs, not increased water prices, have been responsible for the increased marginal cost of water to a user. Also, subsidies have reduced the cost of water to some users and thus the amount the user could gain in the sale of that water. This has allowed the levels of demand for water to remain relatively high and the incentive to sell for economic gain relatively low. When water subsidies occur, water use may be economically efficient from the point of view of the individual user, but it will not be efficient from society's point of view, since society (the subsidizer) pays some of the individual's costs.

Changes in Prices Paid for Nonwater Inputs

Irrigated crop production is an energy-intensive activity in which the cost per unit of output is greater than it is for dryland production in the same locale. The irrigation farmer is thus very sensitive to energy prices. Table 35 indicates expected pumping costs per acre-foot of water, assuming a number of alternative energy prices and water depths. Since the 1960's, the price of natural gas has risen from some $0.50 per thousand cubic feet to over $3 per thousand cubic feet—a sixfold increase in pumping costs, In the 1960's, it cost $6.07 to lift an acre-foot of water 250 ft. By the early 1980's, the cost for the same lift was $36.49 per acre-foot,

Table 35.—Cost per Acre-Foot of Water to Pump at Alternative Depths, Given Selected Natural Gas and Electricity Prices

Depth (ft)	Energy use[a] Natural gas (000 ft³)	Energy use[a] Electricity (kWh)	Natural gas price ($/000 ft³) 0.50	1.00	1.50	3.00	5.00	Electricity price (¢/kWh) 0.01	0.03	0.05	0.10
			$/acre-ft								
50	5.36	154.2	2.68	5.36	8.04	16.09	26.81	1.54	4.62	7.70	15.40
100	7.05	259.6	3.53	7.05	10.58	21.16	35.27	2.60	7.80	13.00	26.00
150	8.75	265.1	4.37	8.75	13.12	26.24	43.73	3.65	10.95	18.75	36.50
200	10.44	470.5	5.22	10.44	15.66	31.31	52,19	4.71	14.13	23.55	47.10
250	12.13	580.0	6.07	12.13	18.20	36.39	60.66	5.80	17.40	29.00	58.00
300	13.82	681.4	6.91	13.82	20.74	41.47	69.12	6.81	20.43	34.05	58.10
350	15.52	786.9	7.76	15.52	23.27	46.55	77.58	7.87	23.61	39.35	78.70
400	17.21	892.3	8.60	17.21	25.81	51.62	86.04	8.92	26.76	44.60	89.20

aCalculated based on equations in D Kletke, R Thomas, and Harry P Mapp, Jr , "Oklahoma State University Irrigation Cost Program, User Reference Manual," Oklahoma State University, Department of Agricultural Economics Research Report P.770, 1978 Pressure was assumed to be 45 pounds per square inch (PSI) and pumping efficiency with natural gas 65 percent.

SOURCE: R Lacewell, "Economic Efficiency of Agricultural Water Use in the West, " OTA commissioned paper, 1982

The overall effect of rising energy costs on irrigation from ground water sources cannot be determined from general estimates. Higher pumping costs will probably mean less pumping and therefore less irrigation. Specific results depend on the nature of the aquifer, relative crop prices, and prices of other inputs. Nevertheless, as the cost of pumping water increases relative to crop prices, there is an economic incentive to apply less water per acre of the crop.

In some areas, rising energy costs have severely affected irrigated agriculture. A 450-percent increase in natural gas prices between 1972 and 1975 caused cotton production to diminish from 200,000 acres to 20,000 acres in the Trans Pecos area of Texas (5). On the whole, however, energy price increases are not projected to have such dramatic effects on cropping patterns [16].

Other input costs may affect the adoption of water-related agricultural technologies as well. In the late 1960's and 1970's, for example, use of sprinkler systems expanded significantly in the Western United States. This shift to a new technology for applying water was seldom made for the purpose of "saving water. " Existing gravity-flow irrigation systems were often converted to sprinkler systems in order to save labor, as well as energy. In some cases, sprinkler rather than gravity-flow irrigation systems were installed to ensure either the efficient use of inputs such as chemical fertilizers or the use of a highly sophisticated and intensive farming system (19).

Increased costs of inputs relative to crop and livestock prices have implications for the structure of irrigated agriculture in the West in that they will reduce net farm income per unit of land. Thus, each farmer who maintains present agricultural practices may require more land to maintain a given level of living, suggesting the need for larger farms. Irrigation may not disappear from the West over the next few decades, but the organization and structure of irrigated farming is likely to undergo continual adjustment.

Changes in Prices Received

Profitability of irrigation is affected as much by crop prices as by input costs. The level of demand for water will be influenced by the amount of crop in production and by the prices received and expected for the crop. As crop prices increase, potential profits will increase, motivating the producer to plant more acreage which in turn will increase the consumptive use of water, assuming no increased prices for the water. If significant increases occur in any combination of actual water prices, delivery costs, application costs, and perceived user costs for water, crop prices received can have a significant impact on the demand for water.

Moreover, if real prices for crops decline, there will probably be some loss of irrigated acreage. Even though the impact of crop prices on the economic viability of irrigated agriculture may be as important as costs of production, there is one main difference: an individual farm cannot influence crop prices, whereas an individual farmer may be able to have some influence on costs of production by manipulating technologies and improving management.

It is likely that changes in relative prices and availability of nonwater inputs will continue to influence the adoption of new technology for water application. To foresee the impact of new water-application technology on water use, it will be necessary to have a sound understanding of the farming system. Predictions about water use cannot be made by concentrating on the single input of irrigation water, and public policies that ignore this fact can be successful only as long as there is plenty of water to meet the demands for water. Once water becomes more scarce relative to demand, perceived costs to the water user will have to increase to maintain a socially efficient rate of water use, The rate of water use will be determined by the entire farming system and will involve the adjustment of rates of use for many inputs in addition to the cost of water.

CONCLUSIONS

Decisions about water rights and their administration have developed along political boundaries, usually the State unit. Water law has developed to solve particular problems on a sector-by-sector basis. For example, traditional western water law was designed first to ensure miners a water supply. Then agriculture became the dominant sector of interest, greatly influencing the law's growth. In the early 1900's, municipal and industrial users were granted certain rights under law. In the 1960's and 1970's, water-quality programs were developed. As a result, application of traditional water law has raised difficulties among users and among States sharing a common body of surface or ground water. It has also made water planning and management problems more severe as it developed without regard to natural resource boundaries.

Markets for Western water have been slow to develop. A number of reasons related to the physical nature of the resource, public goods characteristics, externalities, perceived absence of scarcity, and social values have been the cause. Allocations of water are made through complex sets of institutions, legal restrictions, and government regulations. while these provide order and regularity to the delivery of water, they do not always encourage or allow water to be put to its best use for the general public interest.

Economics and economists play a central role in evaluating water and water projects. They use a number of tools to make determinations of the price or value of water. These tools are very specific, and each can yield a flawed estimate of water value. Moreover, the aggregation of estimates into a cohesive set of values for a whole region or watershed may result in errors. Care must be taken in the choice of method, and all results, regardless of method used in determination, must be accompanied by explicit documentation of the assumptions required by the analysis.

The United States and particularly its arid and semiarid West is entering a new era with respect to water and water use. As demands for water for nearly all purposes increase and as the true scarcity of the resource is recognized, pressure may mount to shift water to new uses and users. The rules of economic efficiency support these arguments. Making such changes, however, must be viewed in a broader context than that of the primary or first use of the water. whether the water is used for irrigation, navigation, recreation, or hydropower, that water generates primary, secondary, and tertiary outcomes. Transferring water to a new use may have a profound effect on the supporting resources and on the people left behind as well as those who benefit. Equity and fairness concerns related to such effects on existing users and new users increasingly will be raised.

In the past two decades, States have begun to shift from the traditional water-allocation role to one involving more water-resource planning and management. An active State role will become increasingly necessary for resolving growing conflicts over water use because of the associated social effects of choices made. Federal institutions will also need a strong and committed long-term role in water-resources planning and management to protect national, regional, and individual interests in this vital resource.

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