# Coordinating Water Resources in the Federal System:

## The Groundwater-Surface Water Connection

U.S. Advisory Commission on
Intergovernmental Relations

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# Executive Summary

Groundwater appears in basins throughout the United States. It serves half of the nation's population with drinking water and provides significant amounts of the water used for irrigation, livestock, and industry. In addition to being an important source of water supply, groundwater basins are also sources of storage capacity In fact, underground storage has greater capacity than surface storage and is more desirable in several respects.

The value of groundwater basins as sources of water supply and storage has been increasing for several reasons: (1) increasing water use; (2) greater past development of surface water supplies; (3) increasing concerns about water quality; (4) needs for protection of instream flows of surface streams; and (5) increasing reliance on groundwater supplies for the more highly consumptive uses of water

A crucial factor in the determination of the value of groundwater supplies-and, hence, the perceived need for improved management – is the very uneven distribution of supplies and use, even within regions. Groundwater availability and types of basins also vary throughout the country As a result, most groundwater management has been initiated by state and local governments, despite increased calls for active federal management

In many cases, state and local governments have pursued conjunctive management of groundwater supplies together with available surface water supplies Conjunctive management-the coordination of conjunctive use – exploits the different characteristics of surface and groundwater, and coordinates use and storage so as to increase the total water yield over time; increase reliability of water supply; reduce risks of total loss of supply from quality degradations; and lower the costs of construction, transmission, distribution, and maintenance. Conjunctive management (managing surface and groundwater supplies together) is distinguished from integrated management (managing groundwater supplies and groundwater quality together).

Management is defined in terms of functions,not in terms of the types of organizations that perform those functions, thereby recognizing that multiple organizational and interorganizational forms maybe effective. The functions of conjunctive management are: control of overdraft, which in turn involves limitations on water withdrawals and assuring sufficient replenishment regulation of storage capacity; protection of water quality from degradation resulting from management practices; the assignment of management costs; and maintaining adaptability and error correction capabilities.

Most planned conjunctive management combines public and private institutions to coordinate the conjunctive use of surface and groundwatersupplies. Debates over the proper models of organization – privatization versus centralized public authority – overlook the experience of groundwater management and the desirability of a noncentralized, public-private management setting. This helps to define and represent different communities of interest, with real advantages in conjunctive management, particularly for enhancing efficiency and equity while maintaining adaptability.

The United States has a complex and regulated water economy, involving provider and producer organizations (importers, wholesalers, retailers, and regulators). This complex water economy involves hundreds of thousands of organizations and interorganizational relationships, which can be understood using the organizing concepts of our mixed political economy.

Conjunctive management calls for the coordinated use of surface and groundwater supplies This does not necessarily require organizational integration The large-scale physical facilities and capital investments required for surface water development call for a different scale of organization than groundwater development This is demonstrated by the fact that most small water systems rely on groundwater while the very large systems rely primarily on surface water

Coordination is achieved through a variety of interorganizational arrangements, including contracting. Dispute resolution also is achieved by several means, including negotiating., bargaining and adjudication. Special districts frequently have been established because their jurisdictional boundaries can be adjusted to communities of interest, because their separate existence increases their financial autonomy, and because they can act as functional specialist organizations.

State and local initiatives to improve management of groundwater supplies range from centralized administration of state statutes to local special district operations without statewide authority, and also include interstate and interlocal cooperation and coordination. It is impossible to distill a model for state or local groundwater supply management from among the many options.

Nevertheless, important barriers to more effective conjunctive management remain. Most of these barriers are institutional, having to do with the rules governing behavior and the incentives facing water users. Many states' water rights rules inefficiently tie water rights to land ownership, leave water rights unquantified, generate disincentives to conserve water supplies and to use underground storage, and inhibit transfers of water rights from lower valued to higher valued uses. Federal laws have created unspecified "reserved water rights," generating additional uncertainties for state and local decisionmakers. More effective management requires water rights characterized by certainty and flexibility. Most existing systems impose obstacles to both.

The continued underpricing of water, whether as a result of local pricing practices, state and federal subsidies, or both, reduces incentives to use water conservatively. In many cases, local water users have organized as much to seek state and federal water subsidies as to improve management The subsidization game, whereby local beneficiaries attempt to spread costs to the residents of larger jurisdictions, has encouraged the overuse of cheap water supplies and inhibited improved management

The federal government has considered several groundwater management initiatives during the past decade. Most of these are mandates and conditions of federal assistance to state and local governments, despite the fact that the scope of direct federal action was expanded by the Supreme Court's ruling that groundwater is an article of interstate commerce (*Sporhase v. Nebraska*, 1982). Mandates and conditions may inhibit innovations. In particular, conditioning financial assistance for water projects on federal approval of state or local groundwater management programs is likely to be counterproductive if an approved project develops subsidized and underpriced water supplies

Some pending federal action would help to remove barriers to effective groundwater management Increased research, especially on institutional arrangements, appropriately organized on a national scale, aids state and local decisionmakers in devising and implementing effective programs. Increased information sharing programs among state and local governments would also improve the base for management decisions.

This report concludes with a set of recommendations for federal, state, and local contributions to the improved management of groundwater supplies. The recommendations do not include the development of additional water supplies, but emphasize improving the institutional arrangements for allocating, managing, and protecting groundwater supplies in a federal system.

# Preface

Water supply and water quality emerged as important issues during the 1970s. Early in the 1980s, former Environmental Protection Agency Administrator William Ruckelshaus described groundwater management as "the environmental issue of the decade." Both decades were characterized by increasing groundwater use, multiple (and sometimes conflicting) claims to existing water supplies, greater concerns about protecting environmental quality and aesthetic values of surface water supplies, and restricted availability of public sector funds for additional water development During this period, the attention of concerned citizens and policymakers turned toward improved management of groundwater supplies. This has led to a general consensus in support of the idea of conjunctive management, the coordinated use of groundwater and surface water supplies, where possible, Coordinated use can increase total water supply, with greater reliability and lower costs, while protecting water quality

This kind of coordination entails active management and high information requirements. Moreover, availability of and dependence on groundwater supplies differ widely from one location to another. This combination of factors prompts a consideration of institutional arrangements and intergovernmental relations in water resources, an important concern for the 1990s.

This report contains contrasting perspectives on groundwater use and management Among other things, the report encourages consideration of governance of groundwater resources in a federal system in substantive rather than organizational terms.

Among the findings in the report is that the involvement of several governmental and nongovernmental bodies does not necessarily preclude effective water resource coordination. In several instances, it reflects the coordinated activity of functional specialist organizations, with extensive intergovernmental cooperation in dealing with the multiple attributes of groundwater resources. Different organizational forms have been effective, suggesting that a federal system such as ours in fact has great organizing and coordinating strengths.

All types of governments in the American federal system have roles to play in facilitating improved water resource coordination. The several functions involved have different appropriate scales of operation. Some, especially the development of basic research, applied research capability, and the production and dissemination of information, are appropriately organized on a national scale, whether through direct federal activity or support for universities, water resources research centers, and the water resources associations and organizations. Other functions, such as the improvement of institutional capacity for regulation and conflict resolution, the establishment of incentive-compatible laws governing water rights and transfers, and technical and financial assistance to groundwater management institutions, are appropriately organized by the states Still other functions, such as appropriate water supply pricing, and activities requiring close knowledge of the groundwater resource and its users, such as controlling overdraft and regulating underground water storage, are organized on a local scale, often by special governmental units. Many of these functions are performed by these governments, and this report contains several examples of their work and the coordination among them.

One of the more important roles that governments could play is to change laws and policies that obstruct more efficient water use. This report identifies important barriers and suggests changes that the state and federal governments could make to reduce incentives for water user behavior that is inconsistent with water resource coordination.

The Advisory Commission on Intergovernmental Relations is pleased to offer this contribution to the consideration of how to improve the management of groundwater supplies in the United States.

Robert B. Hawkins, Jr.
Chairman

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John Kincaid
**Executive Director**

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## FINDINGS

**1. Significant water supply problems exist in the United States, and groundwater is an element of many such problems.**

In the West, there are many arid areas and major population centers supplied from large water impoundments created by the federal government As development pressure has been placed on this finite number of impoundments, competition for this water has grown to great intensity At the same time, most of the best opportunities for impounding surface waters have been developed already, and efforts to expand surface water storage capacities are subject to increasing costs and growing environmental objections.

In areas with rapid growth and high dependence on groundwater, such as Florida, the land sometimes subsides when too much water has been withdrawn. Excessive rates of groundwater withdrawal lower the water table and increase pumping lifts, energy use, and expense. In addition, coastal areas may experience infiltration of the groundwater by sea water as the groundwater table is pumped down.

In New England and certain other places, there have been highly publicized cases of groundwater contamination by toxic chemicals and other pollutants Contamination can leave groundwater supplies unusable or subject to the need for treatment, which generally has not been provided for groundwater. As a consequence, new federal groundwater quality protection regulations have gone into effect, requiring state groundwater planning and regulation.

*In* most parts of the nation, groundwater and surface water resources are usually managed separately. Most communities have only a single source of water supply, and are highly vulnerable in times of drought or other catastrophe. Alternative supplies on an adequate scale would not be available in the short run.

Most water supply planning has been done for surface waters. Most places that use groundwater assume that they can continue to do so without planning.

As most of the best opportunities for impounding surface waters have been developed, and as environmental objections to new impoundments have grown, it has become increasingly difficult to expand surface water storage capacities.

Despite these problems, many regions of the nation and many communities enjoy abundant water supplies relative to current and projected needs. Groundwater supplies, in general, are much larger than surface supplies, and groundwater supplies are satisfying an increasing share of water needs in the United States However, water resources differ so much from place to place that water needs must be considered within the context of each region and each community based on current and long-term prospects.

**2. United States water problems are largely problems of coordination and incentives, rather than problems of scarce natural supplies.**

Overall, the United States is blessed with abundant water resources. Surface supplies of water are great and have been augmented massively over the years. In addition, the nation's groundwater supplies are many times as great as its surface supplies.

In areas where adequate water supplies have not been available naturally, public works projects have brought water from great distances to meet growing needs, and even to create new uses for water in those areas.

Still, demand for water sometimes outruns supply. Crops that need great amounts of water are grown in arid areas Urban dwellers fail to conserve water: Irrigation techniques too often let a high portion of the water escape into the air or ground without benefit Underground and surface waters are seldom managed in conjunction with one another, despite the potential for these supplies to augment and complement each other. Abundant groundwater supplies, in some cases, have been polluted to the extent that they have had to be left unused. Water rights, under present laws in some places, allocate abundant amounts of water to certain uses while denying it to others

If these problems are to be addressed, water resources must be managed effectively and efficiently. Intergovernmental and interagency coordination mechanisms and processes, as well as incentives for cooperation, have been useful in addressing these problems.

3. Groundwater potentials for helpingto meet America's water needs have not been fully considered.

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Groundwater resources are of irreplaceable value to the United States. Groundwater now provides approximately 20 percent of all U.S. water withdrawals, and supplies part or all of the drinking water for approximately 50 percent of the nation's population. In addition, underground water basins provide a low-cost, high-quality means of water storage and transmission with potentially increasing value as above-ground water storage and transmission facilities grow more costly, both economically and environmentally Even in areas where surface water provides an adequate primary supply, groundwater may be available for use as an alternative supply in cases of drought, pollution, or other primary supply loss

If groundwater is accurately quantified,allocated among users, managed well, and replenished faithfully, it could become even more significant in meeting America's water needs. Unfortunately many groundwaterbasins have been neither quantified nor allocated among the users with a claim on them, including the reserved rights on federal and Indian lands. In addition, sound planning and management of groundwater is more the exception than the rule.

4. Coordinated management of underground and surface water resources offers great potential for helping solve many of America's water supply problems.

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The overall goal of coordinating the allocation, storage, conservation, and use of underground and surface waters is to optimize the performance of total water resource systems in meeting the needs of a population and sustaining the natural environment. This type of management requires multi-objective performance goals and performance measures to guide the actions of multiple providers and users of water. These goals and measures should apply equally to groundwater and surface water resources.

The following performance goals apply to water supply management systems generally: (1) efficiency in resource use and in administration of the management system, (2) equity in the distribution of costs and benefits, (3) maintenance of acceptable water quality, (4) ensuring long-term sustainable yields, and (5) adaptability to meeting changing conditions and needs Where groundwater and surface water supplies can be physically interconnected, a broad consensus has developed in favor of optimizing efficiency in resource use through the coordinated management of surface water supplies and storage with groundwater supplies and storage. This coordination takes account of the value and the limitations of both sources of water

The following performance goals are part of coordinated water resource management systems: (1) control of overdraft, (2) regulation of storage capacity and water in storage, (3) assignment of costs, (4) adaptability, and (5) protection of water quality. Well performing water resource management systems that meet these goals contribute strongly to the attainment of the general performance goals of efficiency, equity, adaptability quality, adequacy, and sustainability of supply.

Coordinated management of groundwater supplies necessarily broadens management considerations beyond those of managing the supply of water in a groundwater basin alone. Water storage and use of the storage capacity of surface and underground reservoirs, surface water availability and use, and water quality protection all become elements of the management system As a result, the information requirements of coordinated water resource management are especially high, and include not only hydrologic information but close knowledge of changes in resource conditions as well as information on water quality conditions and risks associated with contamination

5. Success in coordinating surface and underground water supplies rests, to an important degree, on adequate protection of water quality.

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The importance of water quality protection deserves special mention because of its relationship to effectivesupply management. While surface water quality has improved over the last two decades, groundwater contamination is a serious and growing problem in many communities in the United States. Groundwater quality degradation not only poses risks to human health and to the animal and plant life of water ecosystems, it also creates imposing challenges for the coordinated allocation, storage, conservation, and use of surface and underground water supplies

The relationship between water quality and water supply is captured by the expression "quality is quantity"; that is, deterioration in the quality of water can render it unusable as a source of water. There has been considerable federal, state, and local activity over the last two decades intended to protect and restore groundwater quality, but much remains to be done. The information requirements of groundwater protection are high-especially with respect to risk assessment that relates levels of contaminants to effects on human health. Capital and technical requirements of water quality protection also are high.

The appropriate configurations of intergovernmental roles and relations for protecting groundwater quality may be different from those involved in managing water supplies. The leadership role of the federal and state governments has been, and is likely to remain, greater than local governments in protecting groundwater quality. Still, coordinated use of surface and groundwater supplies cannot proceed without taking account of water quality protection. Coordinated water resource management must, at a minimum, ensure that water quality is not harmed; at a maximum, it should contribute to the protection and enhancement of water quality. Nevertheless, as the experience of several states demonstrates, water quality protection and water supply management do not have to be completely integrated organizationally for each to perform well.

6. Properly coordinated water resource management requires intergovernmental and interagency cooperation, and does not necessarily require "consolidation" of responsibilities.

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Attention to the coordinated management of surface water and groundwater supplies,with a view to improving the performance of water resource systems, requires a recognition of "the boundary problem." The boundaries of existing political jurisdictions- especially general purpose jurisdictions, such as municipalities, counties, states, and the nation-often do not match the boundaries of groundwater basins or of interrelated surface water and groundwater systems. This is an inherent characteristic of natural resource systems.

Fortunately, the American federal system provides opportunities for instituting public decisionmaking processes on scales more nearly conforming to those of a given natural resource system and its constituent elements. In many areas of water supply management, new jurisdictions have been created to encompass some part or all of a water supply system. In other cases, intergovernmental arrangements – such as compacts, commissions, agreements, and stipulated adjudications – have been devised among existing jurisdictions that share a water source. Often, both the creation of new jurisdictions and the development of intergovernmental arrangements have been employed in the design of water supply management systems. This degree of public entrepreneurship has been coupled with considerable private entrepreneurship in the water supply field. Altogether, the many organizational forms (private as well as public) and interorganizational arrangements for water provision, management, and regulation have come to constitute a complex "water economy."

Although none of these various forms and arrangements are cost free, problem free, or error free, there is considerable experience on the record that such institutional innovations can contribute to improved water resource coordination. There is no presumption in favor of any one organizational form or set of interorganizational agreements for improving the performance of water management systems everywhere. Indeed, when the opportunities provided by a federal system for devising decisionmaking processes are coupled with the variety of water supply conditions across the United States, there is a presumption in favor of diversity in the organizational forms and interorganizational arrangements for managing water supplies This finding reinforces the importance of maintaining a focus on the performance of management systems, rather than on particular organizational forms

7. There are several barriers to improved water resource use and coordination in the United States.

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The principal barriers to successful coordination of water resources are lack of institutional flexibility and leadership for effective participation in intergovernmental management processes, the diversity and inflexibility of water rights laws, inadequate and dysfunctional incentives for efficiency in water use, and inadequate research, information, and training support for improved water resource coordination practices

With respect to institutional inflexibility and lack of leadership, it is important to recognize that responsibilities for water supply generally are separated from responsibilities for water quality Within the realm of water supply, institutional responsibilities for groundwater and surface waters are also generally separate. In addition, the interests of water providers and users may be different Finally the local, state, and federal governments have separate responsibilities with respect to both water supply and water quality

These divisions have advantages and disadvantages. The advantages lie in promoting the entrepreneurial spirit, advocacy for better service provision, and maintenance of a program focused on control of the source of pollutants. The disadvantages are in the lack of coordination and long-term respect for sustainable supplies and ecologies.

The diversity of jurisdictional boundaries multiply the divisions of basic interests. Groundwater basins and surface watersheds do not always exactly coincide, while city, suburb, and rural districts compete politically for the use of the same water resources. Single-minded water districts sometimes promote one concept of water use, while general purpose governments support another

The larger coordination issues too often lead to confrontations over who is right-win or lose-rather than to efforts to accommodate diverse interests within a shared water resource basin. Arenas for resolving water issues include the courts, political forums, and administrative processes, Strong political leadership often is necessary to resolve key issues

It is clear in many water resource basins that basinwide intergovernmental coordination bodies with real governing authority over surface and underground water resources, sometimes shared with state and sometimes with federal authority, are needed. Interstate compacts -such as the Delaware, Susquehanna, and Potomac compacts -offer a range of models to consider in establishing additional compacts where there are recognized needs for them.

With respect to water rights, some rights run with the land as a property right others are appropriated proportionately in accordance with established agreements and procedures; and still others are relatively illdefined. Sometimes, water rights determinations are a matter principally for the courts; at other times, they are regulated in accordance with planning processes and administrative determinations Thus, water rights are more flexible and more amenable to adjustment and coordination in some cases than in others

Water use incentives also vary considerably Some promote greater use, while others promote conservation. Often, existing incentives were established many years ago under different circumstances, and may be due for reevaluation In many cases, however, these incentives are established by law, reinforced by long-time practices, and difficult to change.

Many water supply policies in the United States – federal, state, and local -were designed for different phases of the nation's history. Those were times when policies promoted water development, agricultural expansion, and the settlement of new lands, times when the nation's population and commerce were concentrated in the humid East, and times when high quality water was available in such abundance that little attention was given to metering its use and pricing it according to its replacement cost. Although past investments and settled expectations cannot and should not be ignored, improved water resource coordination requires, as a first step, acknowledgment by all partners in the federal system that times have changed. Present policies that directly or indirectly encourage water consumption over water conservation may need to be revised. Water supply subsidies, in particular, need to be reconsidered. In addition, water policies that favor solving problems by using construction and technology to alter natural phenomena – rather than by altering laws, policies, and institutions-need to be examined further as to their efficiency, cost effectiveness, and ability to meet the dual goals of environmental protection and adequate water supply.

Particular note should be taken regarding current and potential federal roles in water resource allocation, conservation, and use. Generally, federal laws have shown great deference to state laws in appropriating water rights and interstate transfers of water. However, recent U.S. Supreme Court cases make it clear that water is an article of interstate commerce subject to preemptory regulation by federal law, and that state constitutions and laws may not burden the transfer of water across state lines except in certain narrow respects. On this basis, groundwaters in Nebraska and New Mexico have been allowed to be exported to neighboring states in contravention of the laws of Nebraska and New Mexico. In addition, the U.S. Supreme Court has upheld conditions attached to federal spending on water projects as valid exercises of the Constitution's spending power. Bills have been pending in Congress since 1987 that would impose comprehensive federal groundwater management requirements on state and local governments. Although these requirements would apply only to the 17 "reclamation states" in the West, hints have surfaced that such requirements might be extended nationwide at a later time. If such legislation, or its implementing regulations, were to require inflexible institutional and regulatory forms and practices, it could substantially restrict the authority of state and local governments to find innovative and practical solutions to their water resource problems

8. Despite many barriers to success, there **are promising examples of water resource coordination in the United States.**

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This report has reviewed a number of precedents for enhancing coordinated management of surface and underground water resources. Cases studied include the 1980 Arizona Groundwater Management Act, interjurisdictional water resource coordination in Los Angeles County, California, coordinated management of surface and underground waters by contract in Solano County, California, appropriation permits and controlled water mining in New Mexico, interstate coordination in the Delaware river basin, and interlocal coordination in two California locations as well as in metropolitan Washington, DC None of these examples are perfect, or even comprehensive, but each offers practical potential for improving the coordination of water resource allocation, storage, and use to meet current needs.

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## RECOMMENDATIONS

### Recommendation 1
### ENCOURAGING BETTER COORDINATED GOVERNANCE OF WATER RESOURCES

The Commission finds that substantial benefits in water resource availability, efficiency, quality, and equity can be gained in many cases through the coordinated allocation, storage, and use of surface and underground water resources. However, the boundaries of water resource systems (whether surface water systems, groundwater systems, or hydrologically interconnected surface and groundwater systems) often do not coincide with the boundaries of existing general purpose governments.

Several innovations have been undertaken in recent decades to coordinate the use of surface water supplies and storage with groundwater supplies and storage. These innovative cases of coordination have employed **administrative** and **regulatory** approaches, intexjurisdictional compacts and contracts, and the creation of specially organized jurisdictions. No single model appears to be preferable in all respects and under all circumstances for improving the coordination of water resources. Relatively self-governing systems developed by water users and local and state governments appear most likely to achieve the high levels of participation and compliance **necessary** for successful implementation.

*A, State Action **on** Water Resource Coordination*

***The** Commission recommends, therefore, that state government **officials** support and encourage coordinated use* of *water **resources** within their borders. Coordination mechanisms, which may include inferjurisdictional arrangements as well as the creation* of *new public* jurisdic*tions, should be empowered to undertake the range* of *functions* necessary *to coordinate the allocation, conservation, storage, and use* **of** *surface and underground water supplies, where coordinated use is appropriate. To the maximum extent feasible, in order to ensure sustainable programs* of *water resource **development,** use, conservation, and protection, these coordination mechanisms should be self-governing,* directed *by the water users themselves* and *the affected local and state officials. To **the** extent feasible, thesegovernance **structures** should be **self-financing,** with costs* assigned *among the **benefited** water users and localgovernments, and **with financial** participation by **the states** to the **extent** that benefits are statewide.*

***B.** Interstate Regions for Water Resource Coordination*

*Because many **systems** of **surface*** and ***underground** water **resources** extend* beyond *state boundaries, the Commission recommends that the Congress authorize and approve the creation of interstate regional mechanisms, including joint federal-infers ta te compacts, for governing the coordinated use of **surface** water supplies and storage with groundwater supplies and storage, where such coordinated use is appropriate. These interstate mechanisms, which will necessarily include inter**jurisdictional** arrangements as well as new public jurisdictions,**should** be**empowered** to undertake the range**of functions** **necessary** to achieve coordinated use and **conservation.** Federal agencies involved in the operation offederal surface water **projects should*** be directed *to cooperate with the coordinated use programs of these interstate **mechanisms.** Except in clear instances of violation* of *federal laws or the* United *States Constitution, no **federal official** or agency **should** be **authorized** to withhold participation* in or *to veto a coordinated water* resource *use **program** established by interstate agreement. **Interstate** water resource **coordination*** mechanisms*shouldbe(a)establishedpursuanttonegotiations among the parties **affected; (b) self-governing; (c) directed** by representatives of affected state and local governments, the federal governments, and water users;**(d)** self-financing to the extent possible; and **(e)** empowered to fake **effective** action **within** the scope of responsibility agreed to. **The Congress** and the President should encourage the*negotiation *and **approval of federal-interstate** compacts in wafer resource basins where fhe **states request** them.*

*C. Independent Groundwater Systems*

*Because not all **groundwater** systems **are** physically **interconnected** with **surface** wafer systems, or capable of being interconnected, the Commission recommends that **state** government **officials** support and encourage the **development** of mechanisms **for** governing isolated **groundwater*** basins *within the states, and that Congress authorize and **approve** the creation of **interstate** mechanisms **for*** governing *isolated **groundwater** basins that **cross** stateboundaries. **These governing** mechanisms should be empowered to take all actions necessary **to** regulate basin yield and **storage** capacity, and should be **self-governing** and **self-financing**.*

***D. Federal** Restraint*

*Because of **the** diversity of state and local government structures and* responsibilities, as *well **as** the* diversify *of water rights and water resources situations, the Congress and the Execu tive Branch should not imposeanyparticular management* form on *states and local governments,* whether *through mandates or through **conditions** on participation in federal programs. Furthermore, the* Con*gress and **the** President should not **preempt** the water resource programs* of *local, state, or regional governing mechanisms, and should not institute direct federal management ofgroundwater supplies and storage **capacity.***

## *Recommendation 2*

### PROVIDING INCENTIVES FOR, AND REMOVING INSTITUTIONAL BARRIERS TO, THE COORDINATED USE OF WATER RESOURCES

The Commission finds that, in most cases, what stands in the way of providing adequate water supplies is not so much the absence of water as the presence of legal constraints and inflexible or inappropriate administrative practices that hinder the conservation of those supplies, the coordinated **allo**cation of surface and underground waters in accordance with changing needs, the protection of important water-based environmental values, and the resolution of conflicts over water use. In most cases, marginal adjustments in patterns of water use could significantly help alleviate shortages, resolve conflicts, and protect environmental values.

*The Commission recommends, therefore, the following actions designed to remove institutional barriers to coordinated allocation, use, storage, and conservation of surface and underground water resources:*

### A. Systematizing State Water Rights Provisions

*States not currently employing water management systems that assign and quantify water rights should consider doing so as soon as possible in order to facilitate improved use, monitoring, and conservation of surface and underground wafer supplies.*

*States that do not allow wafer users to store, conserve, and recapture quantified amounts of water underground should consider adding such provisions to their water rights laws, in order to improve the coordinated use of surface wafer supplies and storage capacity with groundwater supplies and storage capacity. Appropriate state, local, and regional governing au thorities should be empowered, either singly or jointly, to monitor underground wafer storage, to regulate water storage and withdrawals taken therefrom, and to establish conservation-oriented pricing policies to protect the interests of all users of the water supply system.*

*States that have not united their surface water and groundwater rights systems should consider doing so in order to establish coordinated rights throughout water supply systems and to facilitate the coordinated use of surface water and groundwater supplies.*

*In addition to quantifying water rights, states that have not already done so should consider making water rights transferable for compensation, within water supply systems, in order to enhance the efficient use of water resources by rewarding water rights owners for conservation rather than maximum use. The local, state, or regional governing authorities responsible for the coordinated use of water resources should oversee and administer such transfers in order to minimize adverse impacts on private property. In order to discourage speculation in water rights, transfers should be approved only upon a showing of demonstrable needs of the transferee.*

### B. Quantifying Federal and Indian Water Rights

*The Congress and the President should direct the Secreta y of the Interior to complete the quan tification of federal reserved water rights pursuant to state procedural law, in order that water resources coordination may proceed in an atmosphere of certainty rather than uncertainty.*

*The reserved water rights of the Indian tribes that remain unquantified should be quantified through direct negotiations between tribal representatives and affected parties, including local users, states, and the federal government, and other parties at interest.*

### C. Resolving Disagreements among Federal Agencies

*The Congress and the President should legislate a process for resolving disagreements among federal agencies concerning local, state, or regional programs for the use of surface water supplies and storage as well as groundwater supplies and storage, including projects to facilitate coordinated use. This dispute resolution process should be available upon request by an affected state, local, or regional unit of government that is a participant in the planned program or project. The Congress should designate the [Attorney General] to convene the affected federal agencies and oversee the dispu te resolution process. The dispu te resolution process should be completed within a specified number of days established by the convenor in consultation with the affected parties.*

### D. Authority for Interjurisdictional Arrangements for Federally Contracted Water

*The Congress and the Executive Branch should remove restrictions in new or existing federal contra& with local irrigation and other water districts that prevent those local water districts from entering info interjurisdictional arrangements for the coordinated use of water resources within the project area.*

### E. Water Use and Conservation Incentives

*The federal government should continue to decrease the subsidization of the water it supplies. Ultimately, water users should pay the full construction, maintenance, and operation costs of federal water supply projects. When water supply contracts are renewed by the Bureau of Reclamation, they should contain provisions to decrease subsidies over time in order to allow for manageable adjustments in water use practices by irrigators.*

*State and local governments that finance and operate wafer supply projects should place the construction and operation of such projects on a "user pays" basis to the extent practical.*

*Local water suppliers should implement full-cost pricing of water to consumers to the exten t practical. Where metering of water use by households and businesses does not occur, it should be instituted so that households and businesses can be charged water rates that bear a direct relationship to their water use. Where necessary, "lifeline rates" should be instituted to protect low-income households.*

## *Recommendation 3*
## FACILITATING IMPROVED WATER RESOURCE USE AND PROTECTION THROUGH RESEARCH, INFORMATION, AND BROADLY TRAINED WATER RESOURCE MANAGERS

The information and technical requirements of coordinated water resource use are substantial. Technological developments and innovations in water resource use, conservation, and protection are developing rapidly, and the dissemination of information does not always keep up with the pace of change. Many water resource managers are inadequately trained and equipped to use the most current concepts and techniques of coordinated water resources management Programs of research and technical assistance to water system managers concerning coordinated use practices and groundwater quality protection requirements would help raise the level of competence in water resource programs.

*The Commission recommends, therefore, continuation of federal programs that increase knowledge concerning water supply and water qualify, and that extend information to state and local officials and to other citizens. These programs should include research, data management,* assistance *with problem* identification *and policy analysis, technology transfer, and training.*

*Federal and state agencies should continue their extensive and successful cooperation in developing information about water conditions, and should also collect information* concerning *mechanisms and prac tices governing the coordinated use of surface and underground water supplies and storage.*

*The federal government should continue to pursue an aggressive program* of *research into the extent and effects of groundwater contamination, including the determination of safe levels of contaminants in drinking water, and fhe program* of *support and technical assistance to states in the development and implementation of groundwafer quality protection policies.*

*States should require assessment of thegeological and hydrological propriety of proposed or possible landfill sites, in order to provide the information base for responsible* siting *decisions based on thean ticipafed effects* of a *proposed landfill on water quality.*

# Groundwater and Intergovernmental Relations

*Waterpolicy and organization is basically a prob lem in intergovernmental relations. . . . [P]olicy and organization* issues *posefundamental prob lems thatstrikeat thevery* heart of *ourfederal sys-*tem of *government.*[1]

Issues of groundwater management have received increased attention in **recent** years. Despite an abundance of water resources nationwide, there are problems of scarcity and contamination in many places. These problems have generated dramatic fights over water rights involving cities, industries, farmers, state and federal agencies, and Indian tribes. Increased reliance on groundwater for consumptive wateruses has been accompanied by projections that underground supplies in several places either will be depleted or will become too expensive to reach within a few decades. Some states have developed regulatory and other efforts to shift water supplies among uses. Competition for additional water resource development projects has intensified while funding has been restricted, cost-sharing requirements have been raised, and concern about the environmental impact of large-scale projects has reached new heights. As the reporting of incidents of water contamination has mounted, one alarming case on another, gmundwater quality protection has also emerged into the limelight

In the past decade, several changes have been made or proposed concerning federal and state roles and actions with respect to the management and protection of water resources, and of groundwater in particular. Suggestions have included calls for federal leadership through enactment of a national groundwater policy, calls for the federal government to act with state and local governments in a "new partnership," and several federal legislative and regulatory proposals to address specific aspects of water resource management Proposals introduced in recent sessions of the Congress include the establishment of a nationwide nondegradation standard to replace variability in state programs, and federal requirements of major new statewide planning efforts for the allocation and management of groundwater supplies. In 1982, the United States Supreme Court opened the door to direct federal regulation of groundwater supplies, ruling that groundwater is an article of interstate commerce and striking down certain state regulations restricting its export

These issues and trends share two common themes The first is that there has been and remains an acute need to develop and implement improved techniques and institutional arrangements for the management of gmundwater resources The second is that the development and implementation of any such improvements must occur within the federal system, thereby **engaging** additional considerations of the roles and relationships of the federal, state, and local governments

Charles Corker, a professor of law at the University of Washington and long-time participant in western water issues and struggles, once wrote of "two of the most difficult problems with which people in the United States must live. One is water, the other is federalism."[2] He continued, "Water, *even uncomplicated by federalism,* nurtures controversies which are both long and bitter. . . . [I]t has frequently been nip and tuck whether differences of opinion would be resolved by briefs or by bullets."[3] Groundwater in particular, with its uneven distribution, irregular boundaries, and multiple attributes as source of supply and storage, "will test our federal system of government."[4] Coordinating gmundwater use, allocation, and preservation is a challenging task, which "may include international, national, interstate-regional or major river basin, state, intrastate river basin, county, and local boundaries and jurisdictions."[5]

While federalism complicates the water resource management picture, this report attempts to look beyond the complexities and search for the opportunities created by a federal system. Our interest is not only in whether and in what ways the federal system presents obstacles, but also in whether and in what ways the system provides advantages for tailoring institutional arrangements for water management to enhance performance, accountability, and citizen control.

On the other hand, much of the structure of intergovernmental relations in the water resource field evolved during a period when the primary policy emphasis was on the development of supplies In the past two decades, the emphasis has shifted to supply management and water quality protection. This shift in emphasis raises questions of whether the roles and relationships among governments that may have worked for development are advantageous for management and whether the appropriate intergovernmental relationships for water quality protection might be different from either of these.

## SCOPE AND PURPOSE

Two principal approaches for improvingwater resource management have come to the forefront of national attention, each of which presents complex engineering and management challenges "even uncomplicated by federalism." The first of these is the conjunctive management of groundwater supplies together with surface water supplies. The second is integrated management of groundwater supply and quality.

This study focuses on the institutional arrangements and relationships involved in the conjunctive management of groundwater and surface water supplies. Although there will be attention to intergovernmental arrangements for protection of groundwater quality, this report has to do primarily with maximizing, allocating, and preserving the supply yield of groundwater resources It is hoped that this focus may contribute to an understanding of intergovernmental roles and relationships in groundwater management and that such an understanding may help in adapting some of the information gained from hydrologic investigations, environmental management studies, and water supply plans to improved resource management

### Conjunctive Management and Integrated Management: An Important Distinction

As is the case in any specialization, terminology in water resources management can result in confusion. In this report, the terms "conjunctive use" and "conjunctive management" designate the coordinated use of surface water supplies and storage capacity together with groundwater supplies and storage capacity. The terms used here do *not* refer to the management, protection, or restoration of water quality (except to the extent that management practices should not result in the deterioration of water quality, a sort of "first, do no harm" criterion).

In the literature reviewed for this report, the term 'integrated management" was used in a couple of sources and "unified management" was used in another source to convey what is described here and elsewhere as conjunctive management Integrated management, as used in this report (and elsewhere) refers to the attempt to manage groundwater supply and groundwater quality as one effort. The term unified management is not used in this report Groundwater supplies may be managed together with surface water supplies or not, and water supplies may be managed together with water quality or not (There are, of course, other possibilities: for instance, surface water quality and quantities could be managed together, but groundwater supplies and groundwater quality managed independently, and so on.)

### Other Studies

In recent years, there have been numerous studies devoted to groundwater supply conditions, management, quality protection, and water resources policy, of which the following are only a few. In 1985, the Urban Institute published a report on several state initiatives in improving community water supplies,6 which described the changing role of state governments in the water supply industry.

In 1986, the Conservation Foundation's National Groundwater Policy Forum produced its influential report *Groundwater: Saving the Unseen Resource,* which focused principally on protecting quality.7 The forum was attended by representatives from the academic community; persons with technical and administrative experience in groundwater development and management and local, state, and federal policymakers. The forum's report, which called for "Action Now" in groundwater quality protection, recommended a "new partnership" among governments in the federal system.

Also in 1986, the National Research Council's Committee on Ground Water Quality released its report on state and local activities in the protection of groundwater quality.[8] That report attempted to relate the characteristics of groundwater resources to the proper roles and activities of state and local governments in their protection. It also highlighted individual state and local programs

In 1987, reports were prepared for the National Council on Public Works Improvement on water resource and supply! Each of these reports contained considerable information on the organization of water management and the water supply industry, along with findings, conclusions, and recommendations.

In 1988, the United States General Accounting Office (GAO) produced reports on its review of groundwater quality protection among the states.[10] These reports focused in particular on the drinking water standards set by the U.S. Environmental Protection Agency (EPA), states' use of those standards in water quality protection programs, and states' adoption of their own additional drinking water standards.

Since 1983, the United States Geological Survey (USGS) has published a *National Water* Summary, with each issue focusing on a particular concern. There has been one summary on groundwater supply and on on groundwater quality

In 1989, The Urban Institute, in cooperation with EPA, conducted an extensive assessment of the groundwater protection strategies being developed by the states. The project was guided by a national advisory committee composed of state officials and experts in the field The project also included a National Forum on Groundwater Protection in October 1989 and produced a report entitled *State Management of Groundwater: Assessment of Practices and Progress.*[11]

As these reports indicate, much of the attention given to groundwater management in the literature in the past decade has focused on contamination and the problems of protecting and restoring quality. Studies that have attended primarily to the provision of water supplies-such as the ones prepared for the National Council on Public Works Improvement and the USGS National Water Summaries-have inventoried and assessed the state of water resources, including their sources, distribution, and use patterns.

## The Plan of this Report

Chapter 2 contains a discussion of the value of groundwater resources as sources of supply and of storage and distribution. There also is an examination of groundwater use, including dependence of various areas of the United States on groundwater for different uses, and where-and why-the limits of renewable water supplies are being reached.

Chapter 3begins with a discussion of the concept of conjunctive management of surface and groundwater supplies as a method for maximizing the yield and the value of water resources, and (at least potentially) alleviating some of the problems caused by occasional shortfalls of supply. The chapter also reviews and discusses several conjunctive use arrangements by and between governments, and some of the advantages of a multijurisdictional system in improving water resource management

Chapter 4 presents an organizing concept for making sense of the tremendous variety of interorganizational arrangements for managing groundwater resources, especially conjunctive management The chapter pays particular attention to the role of the states and the national government

There follows in Chapter 5 a discussion of some of the barriers that remain to effective conjunctive management of water supplies in the intergovernmental setting. Again, particular attention is given to state and national government practices that may inhibit improved allocation and management

In Chapter 6, possibilities for modifying the practices and relationships of the national, state, and local governments are considered, applying the concepts developed in Chapter 4 and the lessons learned from cases presented in Chapter 3 to some of the problems identified in Chapter 5. Chapter 6 also includes the issue of groundwater quality protection, in order to engage the question of whether intergovernmental relationships for protecting groundwater quality in the American federal system should be the same as or different from those for managing groundwater supplies

Notes

1 Lyle Craine, "Intergovernmental Relations in Water Development and Management." Presented at the Southern Political Science Association Annual Meeting. Gatlinburg, Tennessee, 1959, p. 1.

'Charles Corker, "Water Rights and Federalism-The Western Water Rights Settlement Bill of 1957," *California* Law Review 45 (December 1957): 604.

3 Ibid. (emphasis added).

4 Neil S. Grigg, "Appendix: Groundwater Systems," in Kyle Schiing et al., *The Nation's* Public Works: *Report on* Water *Resources* (Washington, DC: National Council on Public Works Improvement, 1987), p. B-5.

5 Stephen J. Burges and Reza Marnoon, *A Systematic Examination of Issues* in Conjunctive Use *of Ground* and *Surface* Wafers. Water Resources Information System Technical Bulletin No. 7 (Olympia: Washington Department of Ecology, 1975), p. 6.

6 Nancy Humphrey and Christopher Waker, *Innovative State Approaches to Community Wafer* Supply *Problems* (Washington, DC: The Urban Institute, 1985).

7 National Groundwater Policy Forum, *Groundwater: Saving the Unseen Resource* (Washington, DC: Conservation Foundation, 1986).

8 National Research Council, Committee on Ground Water Quality, *Ground Water Quality Protection: State and Local Strategies* (Washington, DC: National Academy Press, *1986).*

9 Schilling et *al., Report on* Water Resources; Wade Miller Associates, *The Nation's* Public *Works: Report on Water Supply* (Washington, DC: National Council on Public Works Improvement, 1987).

10 U.S. General Accounting Office, *Groundwater* Quality: *State Activities to Guard against Contaminants and Groundwater Protection: The Use of Drinking Water Standards by the States* (Washington, DC, 1988).

11 See especially The Urban Institute, *Proceedings of the National Forum on Groundwater Protection* (Washington, DC, 1990), and *State Management of Groundwater: Assessment of Practices and Progress* (Washington, DC, 1989).

# The Value and Use of Groundwater

The United States relies increasingly on groundwater resources for water supply Groundwater basins also have value as underground storage reservoirs and distribution systems, especially where they coexist with surface water supplies

Patterns of groundwater use and dependence vary widely from one place to another Although residents of some water-short regions have engaged in groundwater supply management since the early decades of this century, the relative abundance of supplies in most places delayed attention to management issues Recently, emerging localized shortages, growing awareness of threats to quality, and increasing recognition of the irreplaceable value of groundwater resources have drawn greater attention to issues of management and protection.

## THE VALUE OF GROUNDWATER RESOURCES

Understanding the value of groundwater resources involves placing them in the overall picture of water resources and use. Trends in availability and use are enhancing the significant value of underground water supplies, storage, and distribution.

### Groundwater as a Source of Water Supply

Underground water basins appear throughout the United States (see Figure 21). Generally, only the mountainous (and least populated) areas lack significant groundwatec The vast majority of the nation's population lives and works in areas with readily accessible groundwater supplies

Groundwater supplies far exceed surface water supplies, constituting over 90 percent (perhaps as much as % percent) of the total fresh water supply potentially available.' The amount of "economically accessible" groundwater (i.e., within reasonable pumping distance from the land surface) is estimated to be as much as 17,250 trillion gallons.[2] Estimates of the amount of groundwater within 2,500 feet of the land surface range from 33,000 trillion gallons to 59,000 trillion gallons.3

To place this in perspective, the long-term renewable water supply available (most of which is directly renewable surface water supplies) is about 1.4 trillion gallons per day.[4] Total fresh water withdrawals as of 1985 were estimated at approximately 340 billion gallons per day, or about one-quarter of long-term renewable water supplies.5 Groundwater withdrawals comprised about 73 billion gallons, or just over 20 percent of this daily total.

Furthermore, the bulk of the water withdrawn for use each day (whether from surface or groundwater sources) is not actually consumed. Nearly three-fourths of the withdrawals come back as return flows.[6] Total consumptive use of water is estimated to be about 92 billion gallons per day, or approximately 6.6 percent of total renewable supplies'

Clearly from a simple input-output, nationwide view, there is no lack of water supply.[8] Particularly with reference to the nation's vast supply of groundwater, there appears to be real abundance. Total groundwater supplies are hundreds of thousands of times greater than total daily consumptive use of water The thousands of trillions of gallons of groundwater available nationally are tapped each day for less than 75 billion gallons, not all of which is consumed

Groundwater clearly represents an enormous source of supply, but in order to assess its value several considerations must be taken into account besides the absolute quantity of water available and total use. Trends in total water use and consumption, groundwater use and consumption, surface water availability, and concerns about quality all affect the value of groundwater supply

Increasing Water Use and the Growing Role of Groundwater. Fresh water withdrawals have increased substantially relative to population growth since 1950. From 1950 to 1985, the population of the United States grew by about 60 percent During the same period, total fresh water withdrawals rose by

*Fig* 2-1
**Aquif in te**


Source: Warren Viessman and Claire Welty, *Water Management: Technology and Institutions* (New York: Harper and Row, 1985).

nearly 100 percent, from about 175 billion gallons per day to about 340 billion gallons per day.[9] Daily water withdrawals per capita increased from just over 1,000 gallons in 1950 to about 1,650 gallons in 1980. There is evidence that water withdrawals and consumptive use stopped growing between 1980 and 1985,[10] but the overall trend has been an escalation in total water use.

Surface water supplies have been developed more intensively than groundwater, and they are becoming increasingly scarce relative to the demands placed on them. One-fourth of the available fresh surface water supply each day is withdrawn for offstream uses When this is combined with concerns about water quality, the preservation of instream flows, and the environmental impact of new water impoundment projects, it appears that the United States is drawing relatively nearer to the limits of its surface water development

Therefore, groundwater supplies are being relied on to a greater degree. Since 1950, groundwater supplies have been developed more rapidly than surface water supplies, and withdrawals are increasing at a relatively greater rate than surface water withdrawals for all purposes other than electric power production.[11] From 1950 to 1985, surface water withdrawals increased by 85 percent, but groundwater withdrawals grew by 115 percent As total water supplies remain fairly fixed while demands increase, groundwater will continue to grow in value as a source of water supply

Water Quality Concerns and the Value of Groundwater Supplies. The greater development of surface water supplies; the location of major urban and industrial concentrations adjacent to rivers, lakes, streams, and estuaries; and the more direct vulnerability of surface waters to discharges and runoff containing harmful substances have rendered a greater proportion of surface water subject to repotted pollution and degradation than has been the case for groundwater. Indeed, the contamination of lakes and rivers was the focus of public attention as well as legislation and regulation during the 1960s and 1970s.

By contrast, groundwater supplies remain more nearly pure. As of 1983, it was estimated that contamination had reached between 1 percent and 4 percent of the usable groundwater.[12] A 1988 report by the U.S. General Accounting Office (GAO) stated that in 92 percent of water well locations studied the quality of the groundwater exceeded federal safe drinking water standards for every constituent element.[13] The GAO finding does appear to confirm that known groundwater contamination has been relatively limited. (This in no way denies the severity of groundwater contamination where it does occur, or that its occurrence is increasing.)

Greater concern over water quality during the past three decades has increased the value of gmundwater as a less commonly contaminated source of water supply Reliance on gmundwater has grown for certain uses, especially for safe drinking water This trend may be expected to continue in light of constraints on surface supplies As a 1989 publication observed, "Groundwater already supplies over half the nation's drinkingwater . . . and its share is rising as standards promulgated by the U.S. Environmental Protection Agency eliminate many surface sources."[14]

Protecting Surface Flows and Habitats. The United States is also nearing the limits of surface water development because the supplies are subject to instream uses and demands that limit their availability for offstream and consumptive uses

First, hydroelectric power demands require approximately 3,050 billion gallons per day, dwarfing the total daily withdrawals of water for offstream and consumptive uses[15] and dictating that much of the nation's surface water remain flowing in its channels

Second, and of growing significance, instream flows are desired to meet demands for recreation, habitat preservation, and scenic areas. Only surface water provides recreational opportunities, and those who use the nation's waters for those purposes are interested in maintaining them. Diversions of surface waters to offstream and consumptive uses also can disrupt the natural environments of various forms of fish and wildlife. Greater appreciation of this fact in recent decades has prompted actions directed toward maintaining sufficient stream flows and lake levels for aquatic life and surface animal habitats. Furthermore, the scenic beauty of some of the nation's waterways has been recognized as a value worth preserving. Legislative action to protect scenic waterways can limit the diversion of waters

This set of social values that has emerged in the last three decades affects water resource management.[16] Groundwater resources, being out of sight and not per se the habitat of aquatic life, play an increasing role in water supply nationwide.

Groundwater and Consumptive Use. These limits on surface water development and use mean that groundwater, while representing about 20 percent of withdrawals, constitutes considerably higher proportions of the supply for offstream consumptive uses In addition to scenic, recreational, and habitat needs, surface water supplies are relied on to a greater extent for less consumptive purposes

Hydroelectric power, for example, is generated with surface water and requires tremendous amounts of it, but the water that turns the turbines returns to the streams. In addition, water withdrawals for cooling purposes in thermoelectric power production constitute about one-third of the 340 billion gallons of daily fresh water withdrawals, but nearly all of the water used in thermoelectric power production is surface water, and only 2 percent of it is consumed. When withdrawals for nonconsumptive thermoelectric power cooling are subtracted from the total fresh water withdrawals, the surface water share for consumptive uses declines to 65 percent and the groundwater share increases to 35 percent

Groundwater constitutes a greater share of withdrawals for the more highly consumptive uses of water Groundwater constitutes 15 percent of withdrawals for industrial uses, for which the consumptive use rate is about 16 percent," but 33 percent of withdrawals for irrigation and livestock watering for which consumptive use is about 54 percent (with another 17 percent lost in conveyance).[18] Irrigation accounts for 80 percent of the consumptive use of water, while industrial uses account for only about 8 percent

Another 11 percent of the consumptive use of water comes from domestic use for drinking water and other purposes.[19] Gmundwater supplies accounted for 40 percent of total water withdrawals by public water supply systems as of 1985 (up from 34 percent in 1980) and nearly all (98 percent) of the water withdrawn for domestic uses by the nation's rural population.[20]

Groundwater supplies serve fully half of the people of the United States with drinking water.[21] According to a 1987 study for the National Council on Public Works Improvement, groundwater is the primary source of water supply for 80 percent of the 58,530 community water systems, and for 96 percent of the 144,800 non-community water systems.[22]

Groundwater's share of water consumption is 36 percent and rising, considerably higher than its 20 percent of water withdrawals. Furthermore, groundwater supplies are not generally as rapidly replenished as are surface water supplies In fact, in some areas, replenishment rates to groundwater basins from surface water flows and precipitation are small to virtually nonexistent Of the estimated 17,250 trillion gallons of groundwater within economically accessible range of the land surface, only about 2 percent (345 trillion gallons) isavailableon a continuing basis (i.e., is replenished at a rate roughly equivalent to rates of withdrawal) and much of that is in the more humid regions of the country."

As surface water is devoted increasingly to nonconsumptive uses, the nation is drawing on its comparatively more plentiful but less renewable groundwater for a rising share of consumptive uses Over the long term, this pattern of withdrawals and consumption is likely to continue to increase the relative scarcity and value of groundwater as a source of water supply.

## Groundwater Basins as Sources of Water Storage and Distribution

Groundwater basins function as underground storage reservoirs and distribution systems, and in many places are connected with surface water supplies The advantages of natural underground storage and transmission, coupled with the limitations of surface reservoirs, have increased the value of this use of groundwater basins Indeed, in economic terms, there is evidence that this is the more valuable use of an underground water basin.[24] These additional potential uses of groundwater resources have given rise to new management possibilities

**Total Capacity and Usable Storage Capacity.** As noted, the underground reserves throughout the country contain immense amounts of groundwater and have a total storage rapacity equivalent to many thousands of times our annual consumptive use. Of course, some of this groundwater is at depths so great that its recovery is not economically feasible, and not all of the storage capacity is equally valuable.

"Usable storage capacity" is limited to that within economic pumping lifts and, in coastal 'basins, above sea level.[25] Nevertheless, the amount of usable underground water storage capacity is huge relative to surface storage. According to the 1986 report of the National Groundwater Policy Forum, the amount of groundwater stored within economic pumping lifts of the land surface is at least six times greater than that of all of the waters stored in all of the surface lakes and reservoirs .[26]

In addition to their storage capacity, groundwater basins can be operated as water distribution systems, depending on their physical characteristics. Wells sunk into a groundwater basin can provide water near the point of use for a community of users extending over hundreds (sometimes thousands) of square miles The groundwater basins throughout the United States, therefore, represent a large and valuable resource as water storage reservoirs and distribution systems that is likely to become more significant as demands for water use continue to rise while surface water availability and storage capacity remain limited.

**Advantages of Underground Storage and Distribution.** The construction of surface storage reservoirs, above-ground water tanks, and surface distribution systems for capturing, retaining, and conveying surface water supplies is a very costly undertaking. It is becoming even more difficult and costly in metropolitan regions, where land is becoming scarcer and more expensive. Moreover, most of the best surface water reservoir sites have been developed, and the sustained yields of these reservoirs are decreasing due to accumulation of sediment"

Thus, a major advantage to be gained from underground water storage capacity is less need to construct costly surface storage and distribution capacity.[28] Aquifers can store and release water and distribute it to multiple points of use, as can surface reservoirs and pipelines, while saving the substantial costs of building and maintaining the latter.[29] Conversely, underground water storage capacity is valuable from a replacement standpoint; if an aquifer system is damaged or destroyed by depletion or degradation, then surface water storage facilities will need to be constructed in its place.[30]

Underground water storage and distribution are more efficient because water is not lost to evaporation as it is from surface water impoundments and aqueducts.[31] Evaporation losses can be significant for long-term surface storage, especially in the more arid parts of the United States where evaporation rates are high. In New Mexico, for example, the state engineer estimated evaporation losses from surface reservoirs during 1985 to be 423500 acre-feet or 20 percent of the state's total consumptive use. In Montana, the Department of Natural Resources and Conservation reported evaporation losses from surface reservoirs to be 3.9 million acre-feet or 54 percent of the state's total consumptive use of water.[32]

Surface water storage and distribution facilities, whether large-scale dam and reservoir operations or community water tanks, require maintenance, While it is possible to damage an underground aquifer through dewatering, groundwater basins do not require actual maintenance and do not breakdown or wear out, although recharge facilities, such as spreading grounds, do require maintenance. Surface water storage and distribution facilities are also more vulnerable to damage from earthquakes, flooding, and sabotage than are underground supplies"

Surface water storage displaces existing or other possible uses of land. In recent years, this issue has been the source of a considerable amount of litigation concerning the impact of proposed new surface water projects Use of existing underground storage capacity can allow for continued use or development of land. Certainly, land uses in groundwater recharge areas need to be controlled, but storage of water underground does not foreclose as large a range of surface uses as does storage of water above ground.

This is a point of particular significance for the eastern and midwestern United States While the western states contend with perennially low rainfall and runoff, the eastern states are more likely to experience infrequent, unpredictable, but severe droughts (as witnessed in the Southeast in 1986 and in the Midwest in 1988). To prepare for such exigencies through the construction and maintenance of surface water storage facilities requires a large investment in physical facilities that are unneeded most of the time.[34] Underground water storage can be especially valuable in circumventing the need for such facilities and their associated costs

In addition, while it is important to recognize that surface water quality has improved somewhat during the last two decades and that there are some serious and persistent groundwater contamination problems, water stored underground is exposed to a smaller range of contamination risks, both natural and human.[35] Both underground and surface waters in storage are exposed to contamination from hazardous waste disposal, storm runoff, and a variety of nonpoint-source threats However, such threats are more likely to reach surface water relatively unimpeded, while the soil through which recharge waters pass before reaching an aquifer may provide some partial filtering of pathogens, and absorption of low concentrations of nitrates and phosphates.[36] Surface water also faces eutrophication problems (such as "algae blooms") during times of low replenishment.

The advantages of underground water storage from a quality protection standpoint may be seen in the plans of some water agencies in the United States (and elsewhere) to cover surface water reservoirs The Los Angeles Department of Water and Power, for example, is installing covers over its smaller reservoirs at an estimated cost of several hundred million dollars. The purpose is "to keep out bird and rodent droppings, prevent human pollution of innumerable sources and block out sunlight that promotes the growth of troublesome algae," which combines with chlorine in water treatment to form potentially carcinogenic trihalomethanes.[37]

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## QUALITY IS QUANTITY: THE IMPORTANCE OF PROTECTING GROUNDWATER RESOURCES

Any contemplation of the use of underground water basins for water storage and retrieval must at least consider the old water adage that "quality is quantity." If water quality is sufficiently degraded to render it useless for its intended purposes, then from a practical standpoint that quantity of water may as well not exist This relationship between quality and quantity holds true for waters underground as well as at the surface. Once contamination of an underground aquifer occurs, its value is impaired or lost for a long time. Therefore, the preservation and maximization of the value of groundwater resources require rigorous attention to quality protection.

Unconfined aquifers and aquifer recharge areas are vulnerable to transmitting contaminants into the water supply Land uses and waste disposal overlying such locations must be carefully guarded. Moreover, there are naturally occurring sources of water contamination to which an underground water supply can be susceptible. For instance, along the extensive coastlines of the United States, fresh underground water supplies lie adjacent to the salt waters of the oceans If the extractions from and replenishment to the underground water supplies are not kept in balance and groundwater levels decline sufficiently, salt water intrusion can occur and can render water pumped from underground essentially unusable.

The "quality is quantity" adage underlies the argument that both elements must be managed together because they are essentially inseparable. There can be no gainsaying that attention must be paid simultaneously to groundwater supply management and quality protection. There remains, however, a question of whether the intergovernmental relationships and organizational arrangements for protecting groundwater quality ought to be the same as for managing supplies. It is possible that the roles of federal, state, and local governments and nongovernmental organizations may be different in each case. This question is considered at greater length in Chapter Six.

## GROUNDWATER USE

The trends and concerns identified above—increasing reliance on groundwater supplies for consumptive water uses, limits on surface water availability and diminishing prospects for additional development, the importance of groundwater basins as alternatives or supplements to surface water storage and distribution, and growing concerns about water quality — have been noted by several observers and have prompted calls for improved groundwater management In and of themselves, calls for improved management are unlikely to be contradicted or even controversial. However, the translation of "improved management" into a set of roles and relationships for the national, state, and local governments in a federal system can involve considerable differences of opinion. The recommendations of observers and advisors vary concerning the allocation of responsibilities for improved management within the federal system. These differencesderive, at least in part, from different perceptions of the nature of the issues involved.

For example, is there a "national groundwater problem?" If there is, a different set of recommendations concerning the allocation of responsibilities within the federal system will emerge than if there is not If there is not, then what are the problems with respect to the management of groundwater resources? Are they primarily problems of localized resource shortages, and if so, where? Are they problems that derive from different degrees of dependence on groundwater supplies? Are the problems that do appear generated by a lack of water availability or by allocation and management practices? If the latter, which governments within the federal system are best situated to redress the deficiencies? The remainder of this chapter focuses on patterns of groundwater use and availability, including the question of whether supply problems appear to be generated primarily by natural resource availability or by resource allocation and management practices.

### A "National Groundwater Problem"?

Arguments in favor of assigning principal responsibility for improved groundwater resources management to the federal government build on some of the information presented above. For example, groundwater supplies provide half of the nation's drinking water. This establishes the importance of groundwater resources to the United States as a whole. To this one can add that groundwater resources appear everywhere, that some aquifers extend across state boundaries, and that groundwater problems have appeared throughout the country.

These observations have led some analysts to the conclusion that groundwater, or "the groundwater issue," is a "national issue." And a national issue needs a "national policy." Consider the following statement from the codirectors of the National Center for Ground Water Research in Oklahoma:

> The people also know that with its astounding abundance and its predominantly excellent quality, *our National groundwater resources are endangered.* They are constantly reminded of *this National* issue by documentaries, articles, reports, discussions and series which accompany all of the information media to which they are constantly subjected.. . .
>
> It is imperative that *a national policy* be issued at the earliest possible time. It should provide a kinetic approach to addressing our ground-water problems in the coming years by providing the foundation for honest debate among experts representing the legal, philosophical, and technical aspects of *the ground-water issue.* It is to be expected that this policy will continue to be adjusted as we come to grips with near term problems.[38]

Yet, equally incontrovertible national statistics can be used to contend that, at least from a demand-supply standpoint, there is no national groundwater problem. It was observed earlier in this chapter, for instance, that the potentially available groundwater reserves are enormous compared to use rates, and that available renewable fresh water resources are several times fresh water withdrawals and consumptive water use. In the *National Water* Summary 2983, the U.S. Geological Survey made such an observation, and suggested that groundwater problems were more likely to be localized problems of availability and quality:

> Thus, considering only the overall supply of water without regard to development, distribution, or quality, *there is no crisis facing the Nation; the resource far exceeds the present level of use.* However, this in itself does not guarantee that adequate water supplies of an acceptable quality will be available where and when they are needed in the years to come.[39]

The italicized portions of the two quotations above illustrate some of the drawbacks to using national data to assessthegroundwateravailability and quality challenges. Concluding either that there is a national problem or that there is no problem could miss important local variations in the availability, use, and scarcity of groundwater, and of water resources generally

As a result, other analysts have been less receptive to the idea of groundwater resource management as a national issue or national problem." They stress the diversity in availability scarcity, and use, and question whether something that can be accurately labeled "the ground water issue" exists They emphasize that the balance (or imbalance) of water demands and groundwater supplies is determined locally, not nationally

Just how diverse are the use, availability, and scarcity of groundwater resources? How much variation is masked by the national totals and national averages given above?

The groundwater supply and demand situation is highly uneven, stemming in part from variation in precipitation and atmospheric humidity, which affect replenishment and evaporation rates. Figure 2-2 demonstrates that precipitation is substantially lower in most of the West than in most of the East. This contributes to higher daily water withdrawals per capita,regardless of whether from surface or groundwater, in the western states than in the eastern states.

Nine of the ten states with the highest total daily gmundwater withdrawals per capita (see Appendix A, Figure A-l) are west of the 100th meridian (the longitudinal parallel that runs roughly from the border between Minnesota and the Dakotas south to the border between Texas and Louisiana, and that most nearly defines the arid West and the more humid East). All ten of the states with the lowest per capita daily groundwater withdrawals are east of that division. It is also apparent that the variation in groundwater withdrawals masked by national averages is huge: groundwater withdrawals per capita per day vary from Rhode Bland's 38 gallons to Idaho's 6,281 gallons, while the national average is 363 gallons

Beyond the sheer volume of water withdrawals, dependence on groundwater supplies does not vary systematically by region. Measures of groundwater dependence include: groundwater share of total water withdrawals, percentage of the population served by groundwater, and groundwater share of withdrawals for different uses (public supply, industrial, and irrigation).

For purposes of illustration only, Figure 23 presents these measures in a sample of five states in different parts of the country, each of which adopted significant new groundwater supply management and/or quality protection policies during the 1980s (as did several other states). The figures show how different the patterns of groundwater dependence can be. The figures presented in Figure 2-3 for the five states are presented for all 50 states in Appendix Tables A-l, A-3, A-4, A-5, and A-6.

Arizona and Mississippi, an arid western state and a humid eastern state (see Figure 2-2), both show high dependence on groundwater supplies across all measures By contrast, gmundwater represents less than one-fourth of water withdrawals for all types of use in Connecticut, and only about one-third of the population of Connecticut is served by groundwater supplies

Illinois and Washington illustrate how varied groundwater dependence can be for different types of water use within a state. In Illinois, groundwater contributes a relatively small share of total water withdrawals, public water supplies, and water supplied by industry for its own use, but contributes all of the water used for irrigated agriculture. By contrast, Washington relies very little on groundwater for irrigation, and yet over half of the state's population is served by groundwater supplies,which make up a third of public supply withdrawals.

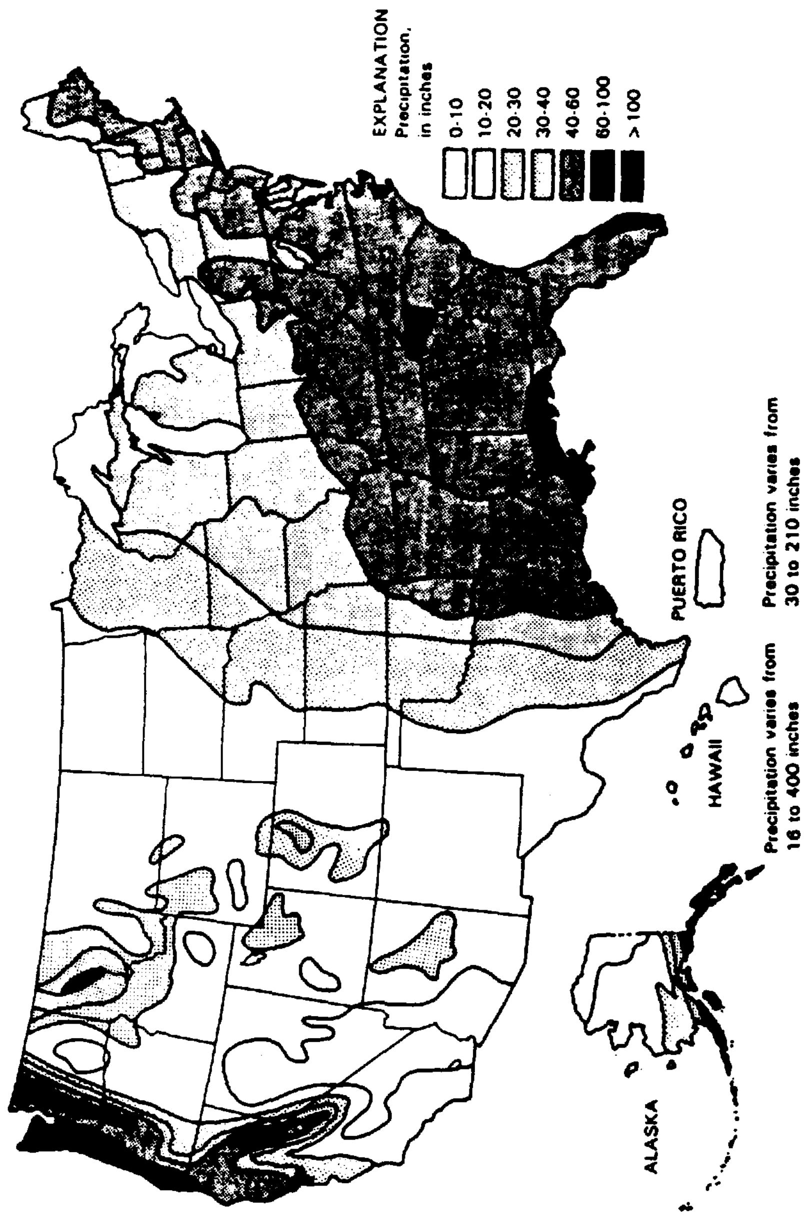
As can be seen by referring to Appendix Tables A-l through A-6, the states in Figure 23 do not represent the extremes among the states For any measure of groundwater reliance, the variability from most dependent state to least dependent state is even greater For example, the gmundwater percentage of total water withdrawals varies from 91 percent in Kansas to 2 percent in Montana (Figure A-l), with five western states among the ten least dependent states on groundwater for their total water withdrawals

Variations are also extreme in the dependence on groundwater for different types of uses. Earlier in this chapter, it was noted that half of the U.S. population is served by groundwater supplies, but that proportion ranges from 95 percent in Hawaii to 20 percent in Colorado (Figure A-3). Groundwater comprises 40 percent of withdrawals for public water supply systems in the United States as a whole, but ranges from 92 percent of public-supply withdrawals in Idaho to 9 percent in Maryland (Figure A-4).

Similar variability exists in reliance on groundwater supplies for industrial and irrigation uses The largest quantities of water withdrawn for industrial uses am concentrated, as would be expected, in the eastern states.[41] But dependence on groundwater supplies to meet those industrial demands exhibits a variability of its own. For instance,98 percent of water withdrawals for self-supplied industrial use in New Mexico comes from groundwater, but in neighboring Colorado the corresponding figure is 6 percent (Figure A-5).

Reliance on groundwater for irrigation also varies widely across the states The greatest use is in the western states, but dependence follows a different variation. In Illinois, Indiana, and Wisconsin, for

## *Figure 22*
**Average Annual Precipitation in the United States**




Source: U.S. Geological Survey, *National Water Summary 1983* (Washington, DC, 1984).

*Figure* **2-3**
Groundwater Dependency in Selected States, 1982 and 1985

| | 1982[1] | 1985[2] |
|---|---|---|
| Arizona | | |
| Percentage of Water Withdrawals[3] | 57 | 48 |
| Percentage of Population Served | 65 | 64 |
| Percentage of Public Supply Withdrawals | 54 | 62 |
| Percentage of Industrial Withdrawals[3] | 88 | 98 |
| Percentage of Irrigation Withdrawals | 58 | 45 |
| Connecticut | | |
| Percentage of Water Withdrawals[3] | 11 | 24 |
| Percentage of Population Served | 32 | 32 |
| Percentage of Public Supply Withdrawals | 17 | 18 |
| Percentage of Industrial Withdrawals[3] | 10 | 12 |
| Percentage of Irrigation Withdrawals | 8 | 7 |
| Illinois | | |
| Percentage of Water Withdrawals[3] | 5 | 35 |
| Percentage of Population Served | 49 | 48 |
| Percentage of Public Supply Withdrawals | 27 | 26 |
| percentage of Industrial Withdrawals[3] | 10 | 28 |
| Percentage of Irrigation Withdrawals | loo | 100 |
| Mississippi | | |
| Percentage of Water Withdrawals[3] | 54 | 83 |
| Percentage of Population Served | 93 | 92 |
| Percentage of Public Supply Withdrawals | 82 | 88 |
| Percentage of Industrial Withdrawals[3] | 61 | 56 |
| Percentage of Irrigation Withdrawals | 65 | 82 |
| Washington | | |
| Percentage of Water Withdrawals[3] | 9 | 18 |
| Percentage of Population Served | 71 | 52 |
| Percentage of Public Supply Withdrawals | 37 | 35 |
| Percentage of Industrial Withdrawals[3] | 15 | 19 |
| Percentage of Irrigation Withdrawals | 4 | 13 |

[1] **U.S. Geological Survey, National Water Summary 1984 (Washington, DC, 1985).**

[2] **Wayne Solley, Charles Merk, and Robert Pierce,** *Estimated* **Water** *Use in the United* **States 1985, USGS Circular 1004 (Washington, DC, 1988).**

[3] **Excluding withdrawals for thermoelectric power.**

example, **groundwater supplies nearly all of the water** used for irrigation; in Montana, 1 percent: and in Alaska and New Hampshire, zero (Figure A-6).

As the states vary, use patterns in localities also vary In Texas, for example, slightly less than half of the population is served by groundwater, but the City of San Antonio is entirely dependent on groundwater supplies, and the irrigation of High Plains agriculture comes almost wholly from underground. About one-third of New York state's population is served from groundwater, which constitutes only one-quarter of the water withdrawals for public water supply, but Long Island's communities depend almost entirely on their underground aquifers

**The uneven distribution of groundwater use and** dependence means that the relative scarcity of supplies varies even more dramatically. Geographic differences in use are compounded by differences in available supply. The nation's groundwater reserves are enormous relative to demand, but those reserves are very unevenly distributed. They are unequally available everywhere and they are not most plentiful everywhere they are most needed. In one location, dependence on groundwater supplies might be high but available supplies may be smaller and of limited renewability In another area, reliance on gmundwater supplies may be low but supplies abound in quantity

*Figure* 2-4
**Simplified Water-Resources Budget for U.S. Water-Resources Regions, 1980**

| Region | Consumptive Use (bgd[1]) | Renewable Supply (bgd[1]) | Consumptive Use as Percent of Renewable Supply | Depletion of Groundwater Storage (bgd[1]) |
|---|---|---|---|---|
| New England | 0.6 | 78.4 | 1 | 0.0 |
| | | 80.7 | | 0.0 |
| Mid-Atlantic | 1.8 | 233.5 | 2 | 0.0 |
| South Atlantic / Great Lakes | 5.6 / 1.6 | 74.3 | 2 | 0.0 |
| Ohio | 0.4 | 139.6 | 2 | 0.0 |
| Tennessee | 2.1 | 41.2 | 1 | 0.0 |
| Upper Mississippi | | 77.2 | 3 | 0.0 |
| | [illegible] | | | 5.8 |
| Mississippi / Souris-Red-Rainy | 40.3 / 0.3 | 4 6.5 | 8 | 0.0 |
| Missouri | 19.3 | 62.9 | 31 | 2.2 |
| Arkansas-White | 11.0 | 68.7 | 16 | 3.6 |
| | | | | 3.1 |
| Rio Grande / Texas-Gulf | 3.2 | 33.4 / 5.1 | 59 | 0.0 |
| Upper Colorado | 4.0 | 13.9 | 29 | 0.0 |
| | | | | 2.1 |
| Colorado (all) / Great Basin | 14.8 / 0.3 | 10.0 / 10.3 | 105 / 1 | 0.0 |
| Pacific Northwest | 12.6 | 276.2 | 5 | 0.0 |
| California | 25.5 | 74.6 | 34 | 1.4 |
| Alaska | 0.04 | 975.5 | 0 | 0.0 |
| Hawaii | 0.7 | 7.4 | 9 | 0.0 |

[1] Billions of gallons per day.

Source: U.S. Geological Survey, National *Water Summary* 1983 (Washington, DC, 1984).

and renewability. Other possibilities exist between these extremes-for example, locations of heavy use but large quantities, or of lower quantities and lesser use. Dependence on groundwater also will be affected by availability of surface water supplies, and vice versa.

### Where Is Improved Management Most Needed?

Because they are driven by use and dependence as well as by availability, water scarcity and shortages have occurred in all regions of the United States* Nevertheless, there do appear to be some areas where water use is reaching the limits of renewable water supply, and where groundwater in storage is being drawn down to meet demands.

Figure 2-4 presents illustrative, simplified comparisons among water resources regions identified by the U.S. Geological Survey The amount of water consumption (as opposed to water withdrawals) is compared with the estimated renewable supply (surface and groundwater) for each region. The results confirm previous evidence presented in this chapter, namely, that the nation as a whole is in no danger of approaching the limits of its available renewable water supplies[43] and drawing down its groundwater resources, but that there are areas where the limits of renewable supplies are being reached and groundwater is being depleted. Those regions are the Arkansas, Colorado, Mississippi, Missouri, and Rio Grande River basins, and parts of California and the Great Basin.

The region of most rapid depletion of groundwater storage, at a rate of nearly 6 billion gallons per day, is the Mississippi River region. In the Colorado River Basin, total daily water consumption now exceeds estimated renewable supply.

With the population of the western states expected to grow by over 40 percent between 1980 and 2000, and with the populations of Arizona and Nevada in particular expected to more than double during that brief period,[44] expectations quite naturally arise that water shortages in the arid regions in particular can only worsen. Such expectations have been at the heart of calls for swift and decisive action to "manage" water supplies. And it is understandable, under the circumstances, that there is not much patience for those who suggest pausing to consider whether perceived current and impending "shortages" are real, whether there really is not enough water to go around. But water-scarce lands have given rise to mirages before, and, despite an understandable impatience, it may be prudent to examine whether nature's reality or human perception is driving the "water crisis."

Are these areas experiencing problems of water availability or allocation? In the areas where consumptive use is approaching or has reached the limits of renewable water supply, is this occurring because there is not enough water or because of the way in which water is allocated and used?

As noted earlier in this chapter, some water uses tend to be more highly consumptive than others. Consumptive use rates for irrigated agriculture (most of which is located in the Midwest, Great Plains, and Southwest) are in excess of 50 percent, while the rates for industrial use (most of which occurs in the Northeast and South) and public supply are less than 25 percent, These differences translate into a simple comparison of the eastern and western states presented by the U.S. Geological Survey The overall consumptive water use rate in the eastern states is about 11 percent, and in the western states, it is 41 percent The eastern United States accounts for 53 percent of the nation's water withdrawals,but only21 percent of water consumption. The western United States accounts for 47 percent of the nation's water withdrawals and 79 percent of the nation's water consumption. Much of this difference is attributable to the different uses of water in different areas.

To illustrate the impact of highly consumptive irrigation practices even more plainly, and to offer an answer to the question of whether water shortages are driven mainly by availability or allocation, consider the following analysis of the Colorado River Basin states, where water use has reached the limits of renewable supply. Below are the estimated 1988 populations of some western states, alongside estimates of the populations that could be supported by the water resources of those states at 150 gallons per capita per day, if all were devoted to municipal and industrial uses:[45]

| State | 1988 Population | Water-Sustainable Population |
|---|---|---|
| Arizona | 3,466,000 | 19,700,000 |
| California | 28,168,000 | 296,600,000 |
| Colorado | 3,290,000 | 39,800,000 |
| Nevada | 1,060,000 | 27,100,000 |
| New Mexico | 1,510,000 | 13,300,000 |
| Utah | 1,691,000 | 38,200,000 |
| Wyoming | 471,000 | 39,200,000 |

Have the Colorado River Basin states really reached the limits of water development, or has allocation and use in some of thosestates caused them to appear to be close to the limits? According to these figures, California has enough "room," in terms of available water resources, for a population larger than the population of the United States. Arizona, Nevada, and New Mexico, generally considered to be the most arid states, could accommodate population increases of 6-fold, 25-fold, and 8-fold, respectively. Incidentally, none of the populations of these states is projected to come anywhere near these estimates by the middle third of the 21st century

The vast majority of water rights, withdrawals and diversions, and consumption in the western states (including the Colorado River Basin) is accounted for by irrigated agriculture. Agriculture holds the rights to an estimated 85 percent of the water in the West.[46] Agriculture accounts for about 80 percent of water use (self-supplied industrial use, 12 percent urban uses, 7 percent; and rural domestic use, 1 percent),[47] and about 90 percent of western water consumption.[48]

Where is improved management most needed? There do not appear to be too many simple answers to that question. A simple regional answer, that improved groundwater management should be targeted at the western states (or the Colorado River Basin states, or the Mississippi River states, etc) does not seem sufficient, because groundwater use and dependence is high in some states and low in some states in all regions On the other hand, a simple answer that improved management is needed everywhere overlooks the diversity of water resources and is so broad as to be essentially meaningless Clearly, continued improvements in water resources management are needed in pans of the Southwest, but they also are needed in other places where water scarcity and water quality problems have occurred on a variety of scales, from interstate regions to individual local groundwater basins

## SUMMARY

How does one reconcile all of this information concerning groundwater resources, their value, their uses, the importance of protecting quality, and the presence of abundance and shortages and different allocations of water across the country? The United States has abundant water resources relative to its population. This is true even of the relatively arid western states, where water consumption is pressing against the limits of renewable supplies and where stored groundwater reserves are being drawn down.

On the other hand, potentially significant water supply problems have been seen on the horizon for decades. Current and projected imbalances between limited or shrinking supplies and growing demands are seen as certain attributes of the present and the future. There appears to be plenty of evidence, in the form of overdrafting of groundwater supplies, the drying up of surface water supplies, and the comparisons made in Figure 2-4 above, that in several locations demands for water are indeed outstripping supplies

What reconciles these perceptions is the recognition of the role of institutional arrangements in the allocation and management of water resources. In the words of the *National Wafer Summary 1983:*

> The actual availability and quality of water are determined, to a large degree, by the way in which the resource is developed and managed in the face of changing demands These matters are governed by human decisions regarding the engineering works required to develop new supplies, the management strategies and operating policies governing the use of existing supplies among users or among States, and the policies or actions employed to ensure the quality of water supplies.[49]

Recognition of the role played by institutional factors prompts us to inquire whether apparent water shortages are in fact the result of limits imposed by physical conditions. It is hard to know the limits imposed by physical supply conditions, if demand for the resource is being conditioned by institutional arrangements that freeze the ways in which supplies can be used.

In fact, the physical characteristics of water supplies and the institutional arrangements affecting water use are both potential variables in the resource equation. "[M]any people do not realize that institutions, rather than physical conditions, are often the cause of shortfalls in water supply."[50] What appears on the surface to be a shortage of supply dictated by nature is often the manifestation of underlying institutional factors that result in existing supplies being overused or used inefficiently.

Given the overall abundance of water resources relative to population in all areas of the country, problems of supply availability and reliability may be viewed as problems of institutions and management practices rather than of resources. The United States does not confront a crisis of natural water supply availability, or even a "national groundwater problem," but many localized issues that differ in nature and severity.

How can the management of water resources be improved in ways that take advantage of the value of groundwater resources and surface water supplies, allocate them wisely among uses, and preserve and protect them for the future? What improved management options are available, how are they arranged, and how do they operate? What changes in intergovernmental roles and responsibilities would facilitate improved water resource institutions and management practices? In the next chapter, we turn to the concept and practice of conjunctive management of surface and groundwater resources, examining several examples of intergovernmental arrangements for improving the allocation and management of water resources, and maximizing their value.

**Notes**

1 C.H.. Ward, N.N. Dunham, and L.W. Canter, "Ground Water-A National Issue," Ground *Wafer* 22 (March-April 1984): 138.

2 Warren Viessman and Claire Welty, *Water Management: Technology and Institutions* (New York: Harper and Row, 1985), p. 17.

3 Wayne *Solley, Water Use in tke United States, 1980* (Washington, DC: U.S. Geological Survey, 1983), p. 3. These quantities may be placed in some perspective by noting that the lower estimate of 33,000 trillion gallons of water is equivalent to the total amount of water deposited by the Mississippi River into the Gulf of Mexico during the entire 200 years of the Republic.

4 United States *Geological* Survey, *National Water Summary* 1983 (Washington, DC, 1984), p. 1.

5 Wayne Solley, Charles Merk, and Robert Pierce, *Estimated Use of Water in the United States,* 1985 (Washington, DC: U.S. Geological Survey, 1988), p. 59.

6 U.S. Geological Survey estimates the disposition of water withdrawals as of 1980 to be: 72 percent return flow, 23 percent consumptive use, and 5 percent conveyance loss, irrigation. Solley, pp. 4-5.

7 Solley, Merk, and Pierce, p. 1.

8 U.S. Geological Survey, *National Water Summary 1983,* p. 1.

9 Solley, Merk, and Pierce, p. 1.

10 Ibid.

11 Ralph C. Heath, "Introduction to State Summaries of Ground-Water Resources," *National* Water *Summary* 1984 (Washington, DC: U.S. Geological Survey, 1985), p. 121; James W. Dawson, "State Groundwater Protection Programs-Inadequate," Ground *Water* 17 (January-February 1979): 108.

12 Wade Miller Associates, *The Nation's Public Works: Report* on Water *Supply* (Washington, DC: National Council on public Works Improvement, 1987), p. 68.

13 U.S. General Accounting Office, *Groundwater* Protection: *The Use of Drinking Water Standards by the States* (Washington, DC, 1988), p. 1.

14 "Groundwater Contamination: Common Ground for the Common Law," Water *Strategist* 2 (January 1989): 1 + .

15 Solley, Merk, and Pierce, p. 1.

16 Helen J. peters, "Groundwater Management," *Water Resources Bulletin* 8 (February 1972): 197. This phenomenon is observed with reference to California in Susan M. Trager, "Emerging Forums for Groundwater Dispute Resolution: A Glimpse at the Second Generation of Groundwater Issues and How Agencies Work Towards Resolution," *Pacific Law Journal* 20 (October 1988): 31: "While competition for California's limited surface water supplies is increasing, the supplies available for agricultural, municipal, and industrial uses are decreasing, due to environmental demands."

17 Solley, Merk, and Pierce, p. 30.

18 Ibid., p. 14.

19 Ibid.

20 Ibid.

21 Heath, p. 120.

22 Wade Miller Associates, pp. 17-18.

23 Viessman and Welty, p. 17.

24 See, for example, California Department of Water Resources, *California's Ground Water* (Sacramento, 1975), p. iii; and William Blomquist, *Getting Out of the Trap: Changingan Endangered Commons to a Managed Commons.* Ph.D. Dissertation, Indiana University, 1987, pp. 524-528.

25 Helen J. Peters, "Ground Water Management in California." Paper presented at the American Society of Civil Engineers Conference, Las Vegas, 1982, p. 3.

26 National Groundwater Policy Forum, *Groundwafer: Saving the Unseen Resource* (Washington, DC: The Conservation Foundation, 1986), p. 9.

27 Heath, p. 121.

28 Stephen J. Burges and Reza Marnoon, *A Systematic Examination of Issues in Conjunctive Use of Ground and Surface Waters* (Olympia: Washington Department of Ecology, 1975), p. 33; also, Peters, "Groundwater Management," p. 197.

29 Erwin Cooper, *Aqueduct Empire* (Glendale, California: Arthur H. Clark Co., 1986), p. 137.

30 Neil S. Grigg, "Appendix: Groundwater Systems," in Kyle Schilling et al., *The Nation's Public Works: Report on Wafer Resources* (Washington, DC: National Council on Public Works Improvement, 1987), p. B-2.

31 Burges and Marnoon, p. 33; California Department of Water Resources, p. 129.

32 Solley, Merk, and Pierce, p. 52.

33 Cooper, p. 137. In August 1989, the Los Angeles Aqueduct, which conveys up to 75 percent of the water supplies of the City of Los Angeles, was blocked by debris from heavy storms that caused flooding. Portions of the aqueduct structure were twisted! and concrete walls cracked and buckled. Although repairs proceeded promptly and took only two weeks, the incident illustrates the vulnerability of surface water facilities. The aqueduct was also the target of vandals' bombings in the 1920s and once during the 1970s.

34 Charles W. Howe and K. William Easter, *Interbasin Transfers of Water: Economic Issues and Impacts* (Baltimore: Johns Hopkins University Press, 1971), p. 3.

35 California Department of Water Resources, p. 129.

36 Burges and Marnoon, p. 34; Grigg, p. B-2.

37 Frederick M. Muir, "Drinking in the View," Los *Angeles Times,* January 31, 1990.

38 Ward, Durham, Canter, pp. X38-140 (emphasis added).

39 U.S. Geological Survey, *National Water Summary 1983,* p. 1 (emphasis added).

40 See, for example, Harvey 0. Banks, "Management of Interstate Aquifer Systems," *ASCE Journal of the Water Resources Planning and Management* Division 107 (October 1981): 574, contending that a "specific set of guidelines for ground-water management cannot be applied uniformly throughout the country"; and Frank Rayner, "Ground-Water Management -A Local Government Concern," *Ground Water* 10 (May-June 1972): 2-5.

41 Wade Miller Associates, p. 128; Solley, Merk, and Pierce, p. 30.

42 Note the following observation from Wade Miller Associates, p. 8:

> The problem of adequacy of supply has now spread to east of the Mississippi River. . . . Water shortages, seldom encountered until the 1970s east of the Mississippi, promise to become more prevalent in the future. Water will still be plentiful, but better management of the resource will be necessary to ensure an adequate supply for all uses.

43 The United States as a whole consumes about 7 percent of national renewable water supplies. Solley, Merk, and Pierce, p. 60.

44 Rodney Smith, "A Reconciliation of Water Markets and Public Trust Values in Western Water Policy." Transactions of the Fifty-Third North American Wildlife and Natural Resources Conference, 1988, p. 328.

*Frank Welsh, *How to Create a Wafer Crisis* (Boulder: Johnson Books, 1985), p. 16.

46 Christine Olsenius, "Tomorrow's Water Manager," *Journal of Soil and Water Conservation* 42 (September-October 1987): 312.

47 Smith, p. 329.

48 P. Lorenz Sutherland and John A. Knapp, "The Impacts of Limited Water: A Colorado Case Study," *Journal of Soil and Water Conservation* 43 (July-August 1988): 294.

49 U S *Geological* Survey, *National Wafer Summary 1 983,* p. 1: .

so Viessman and Welty, p. 49.

# The Concept and Practice of Conjunctive Management

Groundwater supplies are part of a hydrologic cycle that includes surface water and precipitation. The notion that groundwater is separate from and unrelated to surface water is, as the National Water Commission observed nearly two decades ago, a myth long ago abandoned by hydrologists' The water supplies and problems of any given locale exhibit an "essential unity."[2]

The water stored underground in aquifers frequently is received from surface streams through percolation from their channels. Conversely, the base flow of many surface streams is fed by underground water sources outcropping onto the land surface or feeding up through springs, And both surface waters and groundwater are fed by precipitation and runoff that reach and traverse the land surface?

## THE CONCEPT MAXIMIZING THE VALUE OF WATER RESOURCES

Recognition of these attributes, combined with the developments described in Chapter 2, has led to the concept of conjunctive use of surface water supplies and underground water reservoirs. Conjunctive use involves the use of underground water storage in coordination with surface water supplies so as to increase the total water yield over time.[4] More complete and reliable use of the total water resources of an area is possible by employing surface and groundwater supplies together, through "an operating strategy that exploits the different characteristics" of surface and groundwater supplies.[5]

### The Variability of Surface Water Supplies

Groundwater and surface water supplies are not distributed evenly throughout the United States Some places have plentiful surface and groundwater supplies; others have a paucity of both. Still other locations have plentiful surface water supplies but fewer groundwater sources, and others are underlain by substantial groundwater reserves though surface supplies are barely present

Surface water and precipitation are subject to considerable temporal variability. Rainfall and surface water flows can be erratic, unpredictable, and sometimes insufficient to meet all demands. This variability of surface water supplies presents a challenge in securing a reliable water supply, whether for municipal, industrial, or irrigation uses

Groundwater supplies generally are contained within large aquifers and are available throughout the year Groundwater supplies respond more slowly to variations in rainfall and runoff, and thus generate less uncertainty in planning.6

### Regulating Surface Variability with Underground Storage

Reliable water supply systems require storage capacity to regulate the variability of rainfall and surface water flows Storage provides for adequate water deliveries during periods of deficient precipitation and runoff

This cyclic storage can be secured by use of surface reservoirs or the available storage capacity in underground water basins' Underground aquifers can "smooth the pulses of arrival and withdrawal"[8] that characterize the sources of water supply (precipitation and runoff) and the sequences of water demand

Conjunctive use can relate underground water supplies and storage with surface water supplies to regulate surface supply variability. During periods when precipitation and runoff are plentiful, consumptive uses can be satisfied directly from surface watersources. Duringsuch periods,surplussurface supplies also can be used to recharge underground reservoirs. In times of scarce precipitation and dwindling surface flows, underground supplies can be drawn down, providing relatively inexpensive and reliable fresh water yields. These extractions create available storage capacity underground that can be recharged during the next wet period?

Extraction of groundwater during drier periods also can allow for the satisfaction of instream flow requirements of surface water supplies. During times of lowered surface water flows,communities may not be forced into a losing choice between satisfying needs for offstream consumption on the one hand and maintenance of aquatic life, wildlife habitats, and scenic values on the other

The pressure of increasing water demand has led to water storage in surface reservoirs that were originally built for flood control. This can have disastrous consequences Floods have occurred in several states because partially filled flood control sites were unable to hold additional runoff.[10] Where underground aquifers of sufficient capacity are available, their use for water storage could aid communities in meeting water demands while leaving flood-control dams and reservoirs free for their intended use.

### Uniting Alternative Sources of Supply

There are several desirable aspects of having alternative sources of water supply. Conjunctive use of alternative sources is possible and can generate economies." This is especially likely when the sources of supply have different spatial, temporal, and quality characteristics, as is the case with surface and groundwatec

The use of groundwater basins as storage facilities saves the cost of constructing surface storage and conveyance facilities to handle "peak" demands. Surface water facilities can be constructed for meeting normal demands, and peak needs can be satisfied by pumping underground yields. This can be an especially valuable aspect of conjunctive use when surface waters are being transported considerable distances or conveyed from one watershed to another as part of an interbasin transfer"

The ability to draw on alternate water supplies allows water purveyors to respond to limitations imposed by quantity or quality. Groundwater sup plies are a valuable supplement to surface water flows, and conversely, access to surface water can extend the useful life of the groundwater source in communities dependent largely on groundwater but where replenishment is small relative to demand (e.g., the Southwest and High Plains).[13]

Similarly, quality problems are less threatening to communities that can alternate between sources of supply. Groundwater quality degradation, for instance, can result in increased demand for surface water supplies, which might be met by encroaching on flood control storage or reallocating the rights to storage in a surface reservoir.[14] As degradation problems continue to escalate, it can be of nearly inestimable value to a community to be able to switch to another source rather than lose its entire water supply (surface or underground) to a contamination incident.[15]

### Underground Transmission

As noted in Chapter 2, groundwater basins provide a natural and practical water distribution system that can supplement or replace surface distribution works. Solitary reliance on surface water requires the construction and maintenance of an extensive system of waterworks to carry water from its point of capture or storage to every point of use within the served community. An underlying aquifer provides a water supply source throughout a served community, and water recharged into an aquifer at one point may be withdrawn in many places.[16]

For all practical purposes, anyone overlying a groundwater basin may be physically able to withdraw water by means of a well and (usually) a pump. This characteristic of groundwater basins is often cited as one of its vulnerabilities,as multiple demands placed on a single resource are expected to lead frequently to overexploitation and the so-called "tragedy of the commons" It is worth noting, however, that this characteristic of an underground water supply is one of its advantages as well as one of its vulnerabilities As part of a coordinated use program, a groundwater basin can be a source of water supply, a source of storage, and a means of transmission that complements surface water distribution systems and allows them to be built and maintained on a reduced scale.

## CONJUNCTIVE USE AND CONJUNCTIVE MANAGEMENT

Conjunctive use may occur without a deliberate plan or objective and without explicit coordination in an attempt to maximize the total yield of water supplies. Conjunctive management may be defined as directed efforts to use available water supply sources and storage capacity together toward the objectives of maximizing, allocating, and preserving supplies.[17] Conjunctive management of surface and groundwater supplies can maximize efficiency, directing resources to their higher valued uses as sources of supply and storage.

An example of the difference between conjunctive use and conjunctive management is contained in the following excerpt from a 1962 engineering report concerning the use of the Main San Gabriel Basin in southern California:

> The ground water basin underlying San Gabriel Valley has been used for many years as a water storage reservoir and as a water transmission system. As quantities of re-

charge and extraction have varied, water levels have fluctuated in order to balance the difference between inflow and oufflow with change in ground water storage. In other words, the ground water basin has been "operated" in a manner very similar to a surface reservoir The main difference is that the ground water basin has been operated unintentionally to a far greater extent than are most surface reservoirs. As more expensive supplemental water is brought into San Gabriel Valley it will be important that the basin be operated more intentionally than in the past so that neither the local water nor the supplemental water is wasted from the area. The operation of the basin is also important to downstream users.[18]

In a period characterized by increasing water use and tight public financial resources, optimal resource use may only be obtainable by the coordinated conjunctive use of surface and groundwater.[19] Additional development projects appear to be subject to increasing problems and decreasing probability. Under these circumstances, attention turns more to impmved management As the author of a recent article on artificial recharge put it, "If water purveyors can no longer beat water supply problems to death with money, they must solve them with ingenuity"" Conjunctive management is part of that approach it has been described as "a software tactic" that "can generate new increments of water cheaper than can the building of hardware," such as surface water projects.[21]

## Defining Conjunctive Management in Substantive Terms

Although conjunctive management has emerged as a consensus in the water resources management literature for decades, implementation of the concept has been less than universal.[22] Conjunctive management has a nearly 100-year history,[23] and, while it is still not used in most of the largest population centers, the number of communities (e.g., Los Angeles, Phoenix, Albuquerque, and Houston) and water utilities investigating arranging, and adopting conjunctive use programs is growing at an impressive rate. 24

Conjunctive management will not be feasible in communities that do not have access to both surface and groundwater supplies Further, in areas where water use is relatively low and supplies (surface, ground, or both) are plentiful, citizens may choose not to pay the costs of managing supplies that are abundant relative to demand (this does not refer to the importance of efforts to maintain the quality of those supplies). In most areas, however, there is access to surface and groundwatersupplies,and water uses are increasing relative to supplies so that scarcity either is a problem or looms on the horizon.

For those communities, pursuing conjunctive management involves understanding what it entails. Some discussions in the water resources literature approach the issue of what constitutes "management" by identifying organizational forms. For example, some authors recommend a single,central public authority for "groundwater management,"% on the presumption that the presence of multiple organizations implies lack of functional coordination.[26] Such a view suggests that "groundwater management@ requires a "groundwater manager" authorized to perform all functions This defines "management" organizationally: one organizational form produces "management," while others do not

Alternatively, the substance of groundwater management may be identified in terms of the necessary functions to be performed, leaving open the possibility of a variety of organizational arrangements. This approach also leaves evaluation of organizational performance primarily to the citizens whose interests are to be served

Conjunctive management coordinates the amount and location of groundwater recharge and withdrawals together with the withdrawal, use, return flows, and storage of surface waters. The functional elements of conjunctive management are controlling overdraft, regulating storage, protecting water quality from degradation, assigning costs, and adaptability and error correction.[27] This is consistent with the definition of conjunctive management as the coordination of conjunctive use. With a view of management as coordination (with diverse institutions and jurisdictions involved in related activities), the questions for evaluation become whether functions are being performed, whether they are being coordinated, and whether citizens are satisfied.

### Controlling Overdraft

The control of overdraft is a necessary element of groundwater management because of the threats to an aquifer and the overlying land from excessive withdrawals. At a minimum, withdrawals in excess of recharge to the aquifer result in the lowering of underground water levels; this produces longer pumping lifts, which increase the associated energy costs and may necessitate lowering pumps and deepening or replacing wells.[28] Excessive dewatering of aquifers (not to be confused with "controlled mining" as part of a management plan) can lead to: (a) soil compaction, which robs the aquifer of future storage capacity and thus decreases its value; (b) land subsidence (as has occurred in several places), which threatens surface structures and residents;[29] and (c) in some cases, salt water intrusion that threatens the usefulness of the fresh water supply

The dangers of overdraft dominated discussion of groundwater management through most of this century. Groundwater supplies were recognized as limited, and the aquifers were recognized as subject to these threats. The resulting recommendation, following a prudent and risk-averse strategy based on the state of hydrologic knowledge, was that long-term maintenance of a groundwater basin required that annual withdrawals be limited to the "safe yield" or "sustainable yield," defined as the average annual amount of water that naturally recharges the basin.[30] Such a strategy was directed at maintaining underground levels at an elevation sufficient to preclude damage to the water or the aquifer from compaction, subsidence, and contamination.

As information about and experience with groundwater supplies and use have grown and concepts of groundwater management have changed,[31] it has become apparent that in many cases previous strategies may have been too rigid. Excessive dewatering of aquifers is still understood and accepted as inviting the kinds of damage described above, but the definition has been modified by experience.

In many places, sediment compaction, land subsidence (including sudden sinkhole appearance), and quality degradation have occurred. In many other places, groundwater supplies were overdrafted by considerable amounts over extended periods without producing deleterious effects other than increased pumping lifts Dangers that were once ascribed to any overdrafting of groundwater supplies are now recognized as being dependent on such variables as the rate, degree, and duration of the overdrafting, and especially on the physical characteristics of the supply.[32] (Underground water in certain karst areas, for instance, may be considerably more susceptible to the sinkhole phenomenon than alluvium and bedrock valley-fill aquifers.)

Therefore, in defining the elements of conjunctive management, emphasis has been placed on controlling rather than eliminating overdraft The distinction is a deliberate and important one.

Conjunctive management requires the use of underground storage capacity. Using a groundwater basin for temporary or long-term storage implies that the capacity is available. This implication is inconsistent with an objective of maintaining a groundwater basin as full as possible at all times. The conjunctive use of surface and groundwater supplies in such a manner as to maximize the total water yield counterintuitively demands that groundwater basins not be maintained at their fullest possible levels. Maintenance of groundwater levels at their highest elevation within an aquifer leaves no available space to accommodate any surplus of surface waters. A surplus of precipitation and runoff with full groundwater reservoirs, produces the same result as with surface reservoirs: water spills across the land surface, potentially causing surface damage and resulting in waste.[33]

Conjunctive management of groundwater and surface water supplies, therefore, requires the creation of "regulatory storage capacity"[34] by temporarily overdrafting the groundwater basin during low-recharge periods and returning water to storage during high-recharge periods. Conjunctive management is inconsistent with rigid safe-yield requirements, which "often have limited the potential usefulness of basins to offset variations in annual precipitation and particularly to postpone or reduce the need for importations of water."[35] Groundwater levels are managed with the objective of maintaining them within a desirable range defined in part by the regulatory storage capacity

Therefore, controlling as opposed to eliminating overdraft in a groundwater basin is a balancing practice. Given the diversity of underground basins from one location to another, it follows that the maintenance of groundwater levels within a range that does not aggravate the tendencies toward compaction, subsidence, or contamination, provides for the cyclic storage of water underground, and maintains economic pumping distances, will involve considerably different desired ranges and targets among aquifers

Controlling overdraft requires some limitation on groundwater withdrawals. There are various means of accomplishing this, including judicial or administrative determinations of pumping rights, and the imposition of surcharges on quantities. Assurance and, where needed, enhancement of groundwater replenishment also are essential to controlling overdraft As with limiting withdrawals, there are several means of implementation. Flows in stream channels can be extended to allow for greater percolation, water spreading basins can be operated with waters diverted from ordinary stream channels, and so on.[36]

Assuring and enhancing replenishment also involves maintaining a balance within a range of parameters. Excessive recharge of an aquifer can produce marsh-like conditions and move the water table so close to the land surface that potential flooding problems may be aggravated. Insufficient recharge fails to take advantage of the aquifer's storage capacity, increases pumping lifts and costs, and may leave users with less than adequate supplies for peaking and dry-period withdrawals. The balance to be achieved is one of sufficient recharge to optimize the uses of the underground reservoir, while maintaining adequate storage space for future exigencies and sufficient depths to water

## Regulation of Storage

The regulation of storage is necessary to groundwater management and, indeed, is of the essence of conjunctive management.[37] Part of the task has been alluded to: the maintenance of sufficient regulatory storage capacity to accommodate possible surplus flows while at the same time avoiding an excessive dewatering of the aquifer Another vital aspect of managing underground storage capacity is allocating storage space. Space within a single groundwater basin might be desired by competing users for different uses such long-term storage, short-term storage, peaking, and transmission.

Among the potential problems to be addressed in this element of conjunctive management is the issue of rights to stored water. No entity, public or private, is likely to undertake storing water underground without first being assured of the ability to reclaim the value of that water in some way. As will be discussed at greater length in Chapter 5, not all states have legal systems governing water rights that are conducive to such practices.

### Protection of Quality

Protecting the underground supply from contamination is an obvious element of conjunctive management Among the factors to be considered am the initial quality of the surface and groundwater supplies, and the impact of recharge and withdrawal. If, for example, water is to be recharged into an underground aquifer for subsequent withdrawal for drinking use, the water that is recharged must meet drinking water quality standards. Moreover, a considerable distinction in the quality of recharge waters and naturally occurring waters could complicate the issue of rights to recapture and whether water of equivalent value is being obtained by the entity that stored water in the aquifer.[38]

Water replenishment also must take account of quality impacts. Raising water levels in one portion of agmundwaterbasin can bring them into contact with contaminated soils nearer the land surface. Replenishment in one portion of a basin also may aggravate the movement of an underground "plume" of contaminated water, pushing it toward production wells that had previously been free of contamination.[39]

### Distribution of Costs

Among the most challenging tasks to be met in the conjunctive management of surface and groundwater supplies is the assignment of the costs.[40] Coordination of conjunctive use must include provisions for sharing burdens and benefits Ideally, costs would be borne by beneficiaries in proportion to the benefits obtained." As will be discussed at some length in Chapter 5, the distribution of costs is connected with water pricing practices, which through their impact on user behavior has tremendous significance for successful management

### Adaptability

An essential element of conjunctive management is the capacity for adaptability and error correction." Adaptability involves responsiveness to changes in conditions – shifting amounts and patterns of use, quality or quantity problems, advanced technologies of water production or consumption.[43]

Error correction involves a responsiveness to mistakes made by resource managers and planners For example, use amounts and patterns may not have changed, but may have been erroneously calculated or forecast. Adaptability and error correction require that any conjunctive management scheme be characterized by institutions that encourage the development of information and flexibility of management practices

## THE PRACTICE OF CONJUNCTIVE MANAGEMENT: CASE STUDIES

Conjunctive management, with its multiple functional elements, is likely to present a highly complex picture when conducted within a noncentralized, public-private system of organizational arrangements and relationships. To illustrate different ways of organizing the elements of conjunctive management, this section presents examples of innovation and diversity, including

- A centralized administrative apparatus implementing a comprehensive statewide groundwater management statute;
- A set of intergovernmental provider-producer relationships exhibiting significant division of labor, as a provider contracts for the services of several producers in a pair of adjudicated groundwater basins;
- A set of intergovernmental contractual relationships whereby different service providers contract with a producer agency that performs a whole range of conjunctive management functions in a nonadjudicated basin served by a federal water project;
- A "water czar" who used the appropriation permit scheme in his state to regulate groundwater withdrawals and surface water diversions together;
- A federal-interstate compact that has responded to groundwater depletion and contamination problems by developing conjunctive management plans on a river basin scale; and
- Agreements between local governments for the use and operation of water storage in order to maximize available water yields.

These examples, some of which trace back to the first half of the century, are followed by a discussion of recent innovations in institutional design and management methods from a number of states and communities

## Centralized State Administration: The 1980 Arizona Groundwater Management Act

In 1903, the Congress authorized the Salt River Project to help develop reliable water supplies for central Arizona, which was then a territory The Salt River Project was one of the first federal water projects authorized under the *Reclamation Act of 1902,* and one of the first projects completed.[44] In the 1980s, the Central Arizona Project (CAP) began to bring a supplemental supply of Colorado River water to central Arizona. Depending on the future course of federal water resource development policy, the CAP may be one of the last federal water projects completed under the *Reclamation Act.* The history of water management and law in Arizona has been influenced by federal-state relations perhaps as much as by any other single factor. The development of the 1980 Arizona Groundwater Management Act was certainly no exception.

There are special reasons for the influence of the federal government on water use and law in Arizona.* The states' aridity and topography render it well endowed with sites for reclamation projects The United States also owns 71 percent of Arizona's territory, including Indian lands to which the federal government is committed to supplying water In addition, the land irrigated by reclamation project water, while accounting for a very small share of farmland, has produced a disproportionately large share of farm income. Thus, it is considered vital by the state's agricultural community, which has always had a large influence on politics and policy Furthermore, much of the controversy surrounding water supply in the past half-century focused on the interstate fight over **rights to the waters** of the Colorado River, a case that involved the Congress and the United States Supreme Court from the early 1920s to the mid-1960s. The determination of Colorado River water rights delayed approval of the Central Arizona Project for years.

Even while the Salt River Project was being designed, water users envisioned a project to bring more water to central Arizona from the Colorado River At the time, the project was deemed technically and financially infeasible and was shelved. As Salt River Project waters became fully employed to bring new lands into agricultural production, Arizonans turned to groundwater for additional supplies Development of groundwater in the Salt and Gila River Valleys brought thousands of additional acres into production from the 1930s to the 1950s.[46] Increased pump efficiency and lower pumping costs resulting from rural electrification and lower electricity costs spurred a rapid increasein groundwaterwithdrawals in the 1930s. Groundwater also met increasing municipal and industrial needs. Groundwater pumping continued to expand rapidly during the 1940s and 1950s, and by 1960 the withdrawals were estimated at 5 million acre-feet per year.[47] Eventually, the state relied on groundwater supplies to meet 60 percent of its water uses.

Groundwater withdrawal rates were several times greater than natural recharge rates, as much as 11 and 12 times greater in Maricopa and Pinal counties.[48] At some places, underground water levels declined by as much as 400 feet from the 1930s to the 1980s. Declines along the reaches of the Salt River west of Phoenix were more modest, around 100 feet" Declining water levels increased pumping lifts and costs, and caused localized problems of land subsidence, earth fissures, and quality deterioration.

By the 1940s, serious consideration was being given to the idea of bringing Colorado River water to central and southern Arizona. The Central Arizona Project was planned to carry Colorado River water over some 300 miles. Bills to authorize the project were introduced in the Congress beginning in 1949.[50] Opponents from California resisted the authorization, claiming that Arizona did not have a right to the waters The debate continued in the Congress and the United States Supreme Court until the Court determined in 1964 that Arizona had the right to the waters. In 1968, the Congress authorized the Central Arizona Project as part of the *Colorado River Basin Act.*[51]

The feud with California doubtless helped coalesce support for the Central Arizona Project among the various interests, who otherwise would have been in conflict with each other over the allocation of local water supplies. Among the basic conflicts was (and is) a division between the growing demands of residential and commercial users and the agricultural irrigation users.

Agriculture accounts for 89 percent of water consumption. Forty-six percent of all water consumed is from mining of groundwater stocks, This cannot be attributed to the 11 percent of water consumption from mining and'municipal and industrial uses. As of 1980, 47 percent of irrigated cropland was planted to cotton, a surplus crop; cotton production alone could account for all of the groundwater mining Another 16 percent of farmland was planted to alfalfa hay, which consumes more water per acre than any other crop.

The claims on the state's water supplies by irrigated agriculture are so great that existing supplies plus the water from the Central Arizona Project could not support them, even if every Arizonan not engaged in farming moved out On the other hand, existingsupplies plus CAP water could support a state population of as much as 20-25 million people if all irrigated agriculture ceased, and projections do not anticipate a population of even 10 million persons by 2035. These facts led the first director of the Arizona Department of Water Resources to state, 'The conclusion that we have overexpanded our agriculture is inescapable."[52] The clear direction for Arizona groundwater management has long been to strike a balance between these extremes, so that some of the demands of irrigated agriculture would be reduced to accommodate the current and anticipated future population

Yet, efforts to reduce groundwater consumption and to shift water away from irrigation toward municipal and industrial uses did not meet with much favor Efforts to reform groundwater law have a history as long as that of the Central Arizona Project, and the two have important points of intersection.

Two bills, both with the support of Governor Sidney Osborn, were introduced in the 1945 session of the Arizona legislature to regulate the use of groundwater That Spring, further impetus was given to reform when the federal Bureau of Reclamation indicated that it would not support any central Arizona water project unless the state acted to restrain agricultural consumption of groundwater. The legislature struck a weak compromise, producing the Groundwater Act of 1945, which provided for the acquisition of groundwater data and information on existing wells but contained no regulation of use.[53]

In 1948, in a third special session called by Governor Osborn in the midst of a prolonged drought, the legislature enacted the Groundwater Code of 1948, which remained Arizona's groundwater law until 1980. It authorized the designation of critical groundwater areas for the restriction of new irrigated agriculture development in areas experiencing severe overdraft.[54]

After initially upholding the 1948 law against a legal challenge asserting the right to the use of groundwater as a private property right appurtenant to land ownership and limited only by the doctrine of "reasonable use," the Arizona Supreme Court reversed itself and restored the private property reasonable use doctrine to groundwater law. This decision reflected the influence of agricultural interests." After the reversal in 1953, "interest in ground-water legislation virtually ceased,"[56] despite a 1951 repetition of warnings from the U.S. Department of the Interior about the importance of reform to a favorable disposition of the Central Arizona Project For the next quarter-century, alterations in the understanding of Arizona groundwater law came only from occasional court decisions

The growing conflict between municipal/industrial water demands and heavy irrigation use was heightened by two events in the mid-1970s The Arizona Water Commission, which was working on a state plan, reported the findings of a 1975 study indicating that central Arizona faced a severe impending water crisis. That report, combined with the 1976 decision of the state Supreme Court in *Farmers Investment* Company (FICO) v. *Bettwy,* helped set competing water rights claimants against each other

The FICO decision upheld the superiority of water rights claims by overlying agricultural users against the appropriation and transportation of water to nonoverlying lands for mining, municipal, and industrial uses. The FICO decision threatened the cities and mines that were dependent on appropriated groundwater and precipitated a reexamination of groundwater laws.[57] The legislature and the governor responded with an amendment to the 1948 Groundwater Code providing for the selective transportation of groundwater and the appointment of a study commission.

The study commission began meeting in November 1977. The cities and industrial interests, which held a combined majority on the commission, produced draft recommendations in July 1979, with the agricultural interests sharply dissenting and issuing a minority report The conflict over the recommendations was so sharp and their potential impact on agriculture so severe that the draft was considered to be politically infeasible. A "rump group" of the commission continued to try to reach compromises and work out a framework for a more palatable legislative proposal.

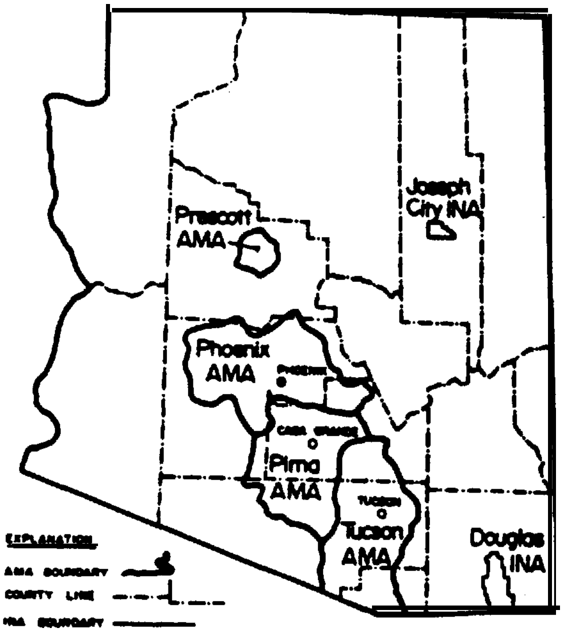
By all accounts, when these negotiations broke down, the intervention of Governor Bruce Babbitt provided the initiative for arbitration.% The governor personally led negotiating sessions among the representatives of municipal, industrial, and agricultural water users over a six-month period. When a delicate compromise was reached on the substantive issues of a groundwaterlaw proposal, Governor Babbitt called a special session of the legislature, where the Groundwater Management Act was passed in a seven-hour session on June 11, 1980. The governor signed the law the next day.

Just as in 1945, in 1979 a crucial federal push was added to the process Secretary of the Interior Cecil Andrus stated that the department would not support the Central Arizona Project unless the state adopted a new groundwater law placing restrictions on use.

The magnitude of the influence of that federal condition may be gathered from the anticipated impact of CAP. The importation and use of water, when CAP is operating at its full capacity of 1.2 million acre-feet per yeas is expected to reduce reliance on groundwater supplies in central and southern Arizona enough to cut the overdraft by as much as two-thirds.

The master repayment contract between the U.S. Department of the Interior and the Central Arizona Water Conservation District specifies that CAP water

*Figure 3-1*
Active Management Areas and Irrigation Non-Expansion Areas in Arizona




Source: Philip C. Briggs, "Groundwater Management in Arizona," *Journal of Water Resources Planning and Management*, July 1983.

must replace, not supplement, agricultural use of groundwatec That is, no new agricultural lands may be brought into production using CAP water (except on Indian lands), and existing agricultural users of groundwater who receive water from the CAP must reduce pumping by equivalent amounts.[59] In times of shortages, municipal and industrial uses of CAP water have an absolute priority over agricultural uses Compliance with these contract provisions alone "effectively redirected Arizona water policy."[60]

The remaining one-third or more of the statewide overdraft is to be solved by management and conservation methods. The Groundwater Management Act, which repeals and supplants all previous legislation,[61] designates four active management areas (AMAs) and two irrigation non-expansion areas (INAs) with boundaries approximately coterminous with those of major groundwater areas (see Figure 3-l). Eighty percent of Arizona's population and 70 percent of its water consumption are located within 'the four AMAs. The goal of the legislation is to establish a balance between water supply and demand within the AMAs by 2025 (except in the predominantly agricultural Pinal AMA, where a controlled mining operation will be pursued). Within each AMA, a director is responsible for the implementation of the act, with the recommendations of a five-member AMA advisory council.

The provisions of the 1980 act apply within the designated areas. Outside of the AMAs and INAs, groundwater withdrawal and use are essentially without restriction (i.e., they are restricted only by the legal doctrine of "reasonable use"), and even within the AMAs and INAs, operators of small domestic wells (less than 35 gallon per minute capacity) are generally exempt

The act established a formal decisionmaking structure that centralizes authority in the governor and the Department of Water Resources (DWR) and its director, and creates weaker authority in the local agencies[62] The law created "a highly centralized and authoritative State Department of Water Resources with broad powers over management and policy issues," and a "powerful director."[63] The department took over the activities of the Arizona Water Commission and added groundwater management to them.

The governor appoints the DWR director as well as the local AMA advisory council members. The DWR director appoints the AMA directors and is responsible for making a series of 10-year management plans for each AMA (with tighter water use restrictions during each period). The director is authorized to determine maximum water duties for irrigation and water conservation requirements for municipalities and industries within the AMAs, review the plans of local authorities for reducing groundwater withdrawals in critically overdrafted areas, file for civil and criminal penalties for violators of regulations promulgated under the act, set water withdrawal fees, and, ultimately, take land out of agricultural production if necessary

The 45-year period from 1980 to 2025 has been divided into five management periods to establish step-by-step control and eventual elimination of groundwater overdrafting. In the first period, from 1980 to 1990, the Department of Water Resources registered wells and defined groundwater rights through an application-and-permit program, with different classes of withdrawal rights but without many requirements or restrictions. The intention was to bring the implementation of the Code along relatively slowly at first, to try to heighten compliance with the first stages before the more restrictive provisions are applied.

The act requires that groundwater withdrawal wellswithin designated areasbe registered regardless of their use. Wells above domestic-use capacity in the AMA have to be metered and their annual production reported.[64] These requirements will help to generatea data base that will be useful in all aspects of groundwater management

The first class of groundwater withdrawal rights is "grandfathered irrigation rights," which are awarded to persons who pumped or received groundwater from a well used to irrigate two or more acres of land prior to 1980. Lands that were not irrigated at some time between January $1975, and January 1, 1980, do not qualify for a grandfathered irrigation right and may not be brought into irrigated agricultural production.[65] The clear intention is to freeze the level of irrigated agricultural production that existed in 1980. Reductions in irrigated agricultural acreage and water consumption are reserved for later management periods.

Grandfathered irrigation rights remain with the land and can be used by a new owner. The groundwater may be used only on the overlying land, however, and the rights remain with the land. If lands with grandfathered irrigation rights are sold for uses other than irrigated agriculture, the rights transfer at a predetermined rate of 3 acre-feet per year. These provisions of the law restrict the transferability of agricultural water rights relative to some other states that use permit schemes for allocating groundwatec Under the new law, farmers who manage to obtain groundwater withdrawal rights may find their rights less marketable.[66]

Municipalities, water companies, and irrigation districts apply for permits for service area rights to withdraw, transport, and distribute groundwater, provided they remain within percapita waterconservation requirements set by the DWR director Persons not eligible for grandfathered irrigation rights or service area rights may apply for groundwater withdrawal permits for non-irrigation purposes.

Within the irrigation non-expansion areas, no new lands may be brought into irrigated agricultural production. No new rights are created. Owners of existing agricultural lands may continue those lands in production and may withdraw and apply as much water as they choose. Irrigated lands may be sold, and the new owners are equally free to irrigate as were the previous owners. Water withdrawal and consumption for other types of uses may develop without restriction. INAs may be converted into AMAs should such conversion become necessary in order to either protect the agricultural economy or preserve the availability of groundwater supplies for municipal and industrial uses.[67]

Groundwater management activities are financed on a 50-50 basis with appropriations from the state General Fund and funds raised from water withdrawal fees assessed against groundwater pumping. Groundwater users who are required to meter their wells and annually report their pumpage are also required to pay the "pump tax." The withdrawal fee is set by the DWR director within the guidelines of the law, with a cap of $5.00 per acre-foot Up to $1.00 of the withdrawal fee may be used to meet operating costs of DWR. Up to another $200 may be used for water supply augmentation after the director has established an augmentation plan for the AMA (this may begin during the 1990s). The remaining $200 of the fee is for the purchase and retirement of agricultural land, and cannot be levied until after 2006.[68]

The 1990-to-2000 management period calls for the implementation of a plan to augment water supplies. The director may propose any means of augmentation from artificial recharge to weather modification. The 2000-to-2010 management period includes the possibility, after 2006, of purchasing and retiring agricultural land to meet water conservation goals and ensure a balance between demand and supply

The law did not specifically provide for conjunctive management, although it does require the augmentation of water supplies It does not provide for a system of using both surface and groundwater supplies in ways that take advantage of each source. The provisions are designed more to encourage the use of surface water by denying access to groundwater when surface supplies are available. For instance, some kinds of groundwater withdrawal permits would be granted only if the applicant could demonstrate that no alternatives were available, and if surface water supplies subsequently became available, the director could require the permit holder to switch to surface water.[69]

In 1986, Arizona enacted an Underground Water Storage Act that addresses more explicitly a purpose to "further the conjunctive management of the water resources of this state."[70] Although the law does not define "conjunctive management," it does authorize the Department of Water Resources to issue separate storage-and-recovery permits to applicants, on a determination that other water users will not be damaged.[71] This permit scheme would provide those who stored waters underground with considerable assurance that they would be entitled to recover those waters, A bill introduced in 1989 would further encourage the use of underground storage capacity by offering municipalities grants for up to 50 percent of the cost of storing surplus CAP water underground.[72]

The Arizona Groundwater Management Code enacted in 1980 was selected by the Ford Foundation in 1986 as one of the ten most innovative programs in state and local government It has been praised by observers and policymakers, not only for the compromise it reached between strongly entrenched political and economic interests, but for its structure and content

The 1980 Arizona Groundwater Management Act has withstood an initial challenge to its constitutionality The state supreme court upheld the act as a constitutional exercise of the state's police powers.[73] The activities of the first management period, although limited principally to the well registration program and the determination of groundwater rights and issuance of permits, presented a considerably more formidable task than was initially anticipated, according to the deputy director for engineering of the Department of Water Resources.[74] The water conservation requirements of the law become more stringent over time, so additional tests of compliance and success lie ahead."

## Interjurisdictional **Coordination: Los Angeles County, California**

The approaches to groundwater management in Arizona and California contrast sharply California has not adopted a comprehensive statewide groundwater management law, but has pursued a policy of encouraging local water users to develop governance structures for water management (usually through the combined efforts of special water districts and water users' associations) with the support of state agencies such as the Department of Water Resources (DWR).

The state has encouraged neighboring communities sharing similar water resource problems to form special water districts to address areawide management challenges. This policy has been followed in most of the inhabited areas of southern California, and in several areas in northern California.[76] The policy does not appear to indicate neglect of the importance of water management, but is a different approach to the development and implementation of management programs:

> The legislature has moved cautiously with respect to groundwater problems and legislation has focused on local solutions, with emphasis on the importance of fashioning management solutions to meet local conditions and local needs Nevertheless, water resources management is treated as an issue of great public interest and given high priority in large part because of the scarcity of water resources in the areas with the greatest demand.[77]

The absence of a state groundwater management code and state administration has been evaluated in a number of ways. These assessments generally divide into two categories, one quite critical of the absence of central authority, and the other supportive of local diversity and innovation.

**The** Critics. According to critics, the absence of a statewide code or administration means that "there is no groundwater management in California." Although provisions concerning groundwater are "[s]cattered throughout the state Water Code:. . . none of these Code sections provides California with a needed management program."[78] The state's approach is described as "inaction," "failure," "inadequate," and "a 'no action' groundwater management system."[79] A representative observation is the following "Groundwater meets 40 percent of California's annual water needs, yet is essentially unmanaged."[80]

The anticipated consequences of the lack of a statewide groundwater program, in the view of these observers, are severe. Current arrangements "can only lead to disaster."[81] Because local management takes diverse forms in various groundwater basins, it is criticized as "piecemeal," producing "inefficiency" and "uncertainty."[82] Critics point to 42 groundwater basins in the state with some degree of overdrafting, 11 of which were identified by DWR in 1980 as in "critical overdraft."

Conversely critics promote statewide management as good in and of itself, which "must be enacted to protect that public interest,"[83] and "*would ensure efficiency* in the beneficial use of groundwater."[84] "Effective" statewide management of California's hundreds of groundwater basins would "need to be simple, flexible, equitable, and inexpensive to administer."[85]

**The Advocates. There are other observers** who view the absence of statewide groundwater management as rational in light of the degree and variety of local initiatives and activities. What is seen by critics as an inadequate and ineffective "piecemeal" approach is seen by others as "a relatively well-developed and diverse system of local groundwater management that has evolved on a piecemeal basis over many years."[86] This diversity developed for "good reason," since"thehistoryofuseand theproblemsvatiedfrom basin to basin."[87]

These observers view the legislature's repeated demurrer to adopting statewide management proposals as "justified because of the diverse nature of groundwater problems requiring different types of local solutions."[88] In fact, most of the "scattered provisions" in groundwater laws have been initiated by water users seeking authorization to create or extend the powers of an existing local governance structure. The legislature has usually responded affirmatively

Artificial recharge projects in southern California, using groundwater basins to store surface waters for later use, date back at least to the 1920s.[89] Flood waters were moved out of stream channels,diked and ponded in permeable areas, and allowed to sink into the underground strata. Temporary dams were constructed in more permeable stream channels to obstruct surface flows and increase recharge to groundwater basins, which could then serve both storage and transmission purposes In the 1980s, over 2 million acre-feet of water per year were placed in underground storage by local water agencies

In some locations, extensive spreading grounds were constructed, some of which were designed to recharge the groundwater supply while providing surface recreational opportunities for local residents. The Orange County Water District was a leader in this multipurpose facility development Groundwater pumping was taxed by local special water districts to provide the funds for artificial replenishment programs that primarily benefited pumpers and consumers. Later innovations included "in-lieu replenishment" (whereby water users in basins with access to both surface and groundwater supplies are encouraged to take surface water in lieu of pumping groundwater when surface supplies are plentiful) and the use of reclaimed water for basin recharge and sea water barrier projects. Reviewing the development and implementation of these elements of conjunctive management, one DWR observer wrote in 1982: "*Many* of California's local water agencies use ground water storage capacity in the same way surface reservoirs are used to hold water from winter to summer and from wet years to dry years,"[90] and described the extent of employment of conjunctive management of groundwatersupplies as unmatched elsewhere in the United States.

In the latter half of the 1970s, the Rockefeller Foundation supported a study by the RAND Corporation of water use and conjunctive management in southern California. While noting that the presence of management activity does not necessarily mean that optimal management has been achieved, the authors cited the adaptability of existing local programs to the needs of different locations and to changes in conditions over time,[91] and concluded "Since there already is a locally developed management program in place in major Southern California basins, there is no need for the state to impose yet another management scheme.. . local management in place should be retained, subject to appmpriate state review?

Through the 1980s, in the aftermath of the severe drought of the late 1970s, as population growth continued apace and as the allotment of Colorado River water for California declined with the beginning of operations of the Central Arizona Project, still more emphasis has been placed on wiser water management, conservation, and reuse of wastewaters. Environmental concerns and budgetary constraints have largely eliminated the prospect of future water development projects. Local water agencies have focused increasingly on the use of pricing to regulate the demand side of the water supply equation,on reaping new supply availability from conservation, and on interlocal agreements and water rights transfers to move water from wasteful and lower valued uses to higher valued uses.

A 1985 report to the U.S. Army Corps of Engineers on the management of water resources in the Los Angeles County drainage area concluded: "Ground water basins in the area are well managed.. . . Legal limits are placed on amounts of annual withdrawal from various basins, and extensive artificial recharge programs have been developed to augment the natural recharge of the basins."[93] While noting that most regulation of groundwater withdrawals by special districts was concentrated in the southern part of the state, a 1987 report by the Institute of Public Administration acknowledged that California "leads the way" in the special district approach, "in the belief that the complexities of groundwater management can best be dealt with by specialized units of government operating at the local or regional rather than the state level."[94]

The Evolution of Local Programs. Both critics and advocates of California's approach have observed that a lack of defined rights to specific quantities of groundwater has presented significant barriers to effective management.[95] It is not surprising then, that determining those rights has been among the first steps taken by local groundwater agencies The evolution of water supply management in California has relied strongly on the use of judicial institutions and proceedings.

In many localities, associations of local water users, including municipalities, water service companies, local businesses, and agricultural interests, were organized to discuss ways to determine rights. Frequently, they employed adjudications in order to take advantage of a process that limited decisionmaking to the users affected, allowed for expert investigations of hydrologic conditions, balanced total extractions with the available groundwater supply, and produced enforceable water rights for individual users Stipulated judgments among the parties were often used to secure mutually agreeable allocations that might not have resulted from the strict application of state water laws.[96] The use of adjudicatory processes has yielded such a variety of outcomes that "one could almost say that no two forms of groundwater management are alike within the group of adjudicated basins."[97]

The conjunctive management of water supplies typically also has involved the creation of special water districts or watermasters that control and limit overdraft through monitoring and enforcement, acquire water supplies, replenish the underground supply and regulate water storage, and protect supplies from degradation. Occasionally, a water district will produce these services itself; in other cases, the district will act as a service *provision* unit contracting with other specialist *producers."* An example of this system of interjurisdictional relationshipscan beseen in the conjunctive management of water in the Los Angeles coastal plain in Los Angeles County?

The coastal plain extends from Los Angeles east to the Whittier area, south to Long Beach, and along the coast up to Santa Monica. It is underlain by two major groundwater basins, the West Coast Basin along the coast and the Central Basin inland (although the southeast corner of the Central Basin extends down to the coast in the Long Beach area). The dividing line between the two basins is the Newport-Inglewood Uplift, a northwest-southeast geologic disjuncture parallel to the coast The West Coast Basin is recharged almost exclusively by subsurface flow across the uplift from the Central Basin, which in turn receives most of its replenishment from the forebay area in the vicinity of Whittier Narrows.

Rapid development of the Los Angeles coastal plain during the first half of this century generated increased demands for water. These demands were met largely by use of the groundwater supplies of the coastal plain, which lacks extensive and reliable surface supplies. This resulted in declining underground water levels, which in the West Basin sank below sea level. At points of hydrologic contact between the West Basin and the Pacific Ocean, salt water began to intrude, rendering water in some wells near the coast unusable by the 1920s and 1930s. The main source of local water supply for the communities of the coastal plain along the ocean was, therefore, severely threatened.

During the 1920s, the Metropolitan Water District of Southern California (MWD) was formed by a consortium of municipalities in southern California to develop imported water supplies from the Colorado River. MWD's Colorado River Aqueduct was completed in 1941. This gave communities in the coastal plain the option of acquiring supplemental water MWD's construction and operations, and the repayment of the substantial debt it incurred, were supported through property taxes, so access to MWD's water required annexation to the district

Representatives of West Basin users – municipalities, water companies, local businesses-formed a West Basin Water Association to determine how to acquire and pay for additional imported supplies from MWD and how to gain control of the depletion problem. The association chose two different avenues, one involving special district formation, the other involving adjudication of rights to groundwater use. Through a special election in 1947, the separate small communities within West Basin formed the West Basin Municipal Water District for purposes of annexing to MWD, acquiring rights to purchase Colorado River water, and gaining a collective representation on MWD's board of directors.

Meanwhile, MWD faced a problem with its sales of Colorado River Aqueduct water, which was sub stantially more expensive than pumping local groundwater or diverting local surface supplies. Pumpers and diverters throughout southern California, faced with the choice between further overtaxing local supplies or paying the much greater purchase costs, went on overusing the local supplies. Between the completion of the project in 1941 and 1949, the aqueduct, which was capable of delivering 550,000 acre feet of water each year, had delivered a total of only 146,000 acre-feet If that situation continued, MWD's aqueduct stood a good chance of becoming a 250-mile long "white elephant" Some mechanism would be needed to shift users away from local supplies to imported water

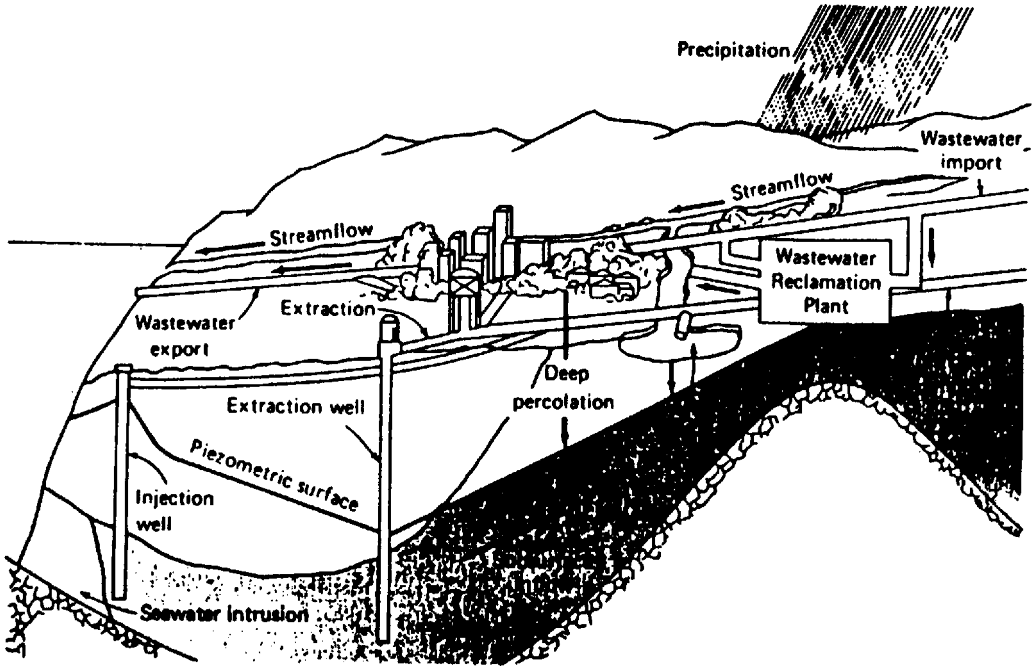
Through an adjudication begun in 1945, West Basin water users sought to acquire quantified rights to specific amounts of pumping and to limit the total to the basin's "safe yield." That adjudication was patterned after an earlier one among water users in the smaller Raymond Basin to the north. Among the beneficial outcomes in the Raymond Basin was that, by placing an upper limit on pumping, it forced the parties to meet additional needs from another source-i.e., through purchases of supplemental water from the wholesaler, MWD.

The West Basin litigation involved extensive hydrologic investigations by the California Department of Water Resources as court-appointed referee, and considerable negotiation among the parties, resulting in an interim agreement to limit pumping in 1955 and a final judgment in 1961. West Basin users faced two complicated and interrelated difficulties. One was that, in order to limit pumping to an extent needed to stop the overdrafting, they would have to cut back by nearly two-thirds and replace the water with more expensive imported supplies. The second, and related, problem was that raising West Basin water levels enough to halt sea water intrusion would increase levels along the Newport-Inglewood Uplift to the point where water would no longer flow in from the Central Basin because of lowered water levels there due to overpumping.

The West Basin Water Association, DWR, and the Los Angeles County Flood Control District (now a division of the county Department of Public Works) constructed and operated a pilot project in the late

*Figure 3-2*

**Simplified Pictorial Representation of Conjunctive Management in Los Angeles County, California**




Source: **Warren Viessman and Claire Welty,** *Water Management: Technology and Institutions* **(New York: Harper and Row, 1985)**

1950s and early 1960s to create a barrier against sea water intrusion along the coast by injecting fresh water underground to form a pressure ridge. The pilot project was successful, and a full-scale barrier project was constructed. Operation of the barrier was financed temporarily through the creation of an improvement zone within the county flood control district The creation of the barrier allowed water levels in the West Basin to be kept lower, thereby increasing the amount of recharge flowing in from the Central Basin and reducing the amount by which pumping had to be cut back

In the 1950s, partly at the instigation of West Basin users who saw their fresh water supply threatened by continued overextraction upstream, Central Basin users formed a Central Basin Water Association and began to explore possibilities for reducing groundwater withdrawals and securing additional supplies and a groundwater replenishment program. The Central Basin Municipal Water District was formed and annexed to MWD in 1952, ensuring access to Colorado River watec As in the West Basin and Raymond Basin, Central Basin pumpers did not immediately switch to imported watec However, also in the 1950s, sea water intrusion began to appear in the Long Beach vicinity, so Central Basin water quality was threatened as a result of groundwater overdraft.

Water users in the West and Central Basins needed to achieve several goals: limit groundwater withdrawals in the Central Basin; raise water levels in the Central Basin and keep them lower in the West Basin in order to maximize the subsurface flow into the West Basin; find a means to finance and operate a replenishment program in Central Basin; and find a permanent means for financing and operating the sea water intrusion barrier projects. Through another special election in 1959, residents in both areas agreed to form the Central and West Basin Water Replenishment District under authority of the1955 state Water Replenishment District Act.

Once formed, the replenishment district initiated an adjudication of water rights in the Central Basin. This action began in 1962 and ended with a final judgment in 1965. At that point, water users in the West and Central Basins had enforceable rights to specific quantities of water, which could be (and have been) exchanged, leased, or sold. Both basins were placed on a modified safe-yield operation. A replenishment program was implemented, involving local recharge and artificial recharge with imported and reclaimed watec Sea water intrusion was effectively halted by the barrier projects.

The total conjunctive management scheme for the Los Angeles coastal plain is illustrated in the simplified diagram in Figure 3-2. The Central and

West Basin Water Replenishment District, with its staff of three, is the public provision unit that organizes this program.

One question that arises about the coastal plain program is why the replenishment district was created when the West Basin and Central Basin water districts existed. The districts, like many others in California, were formed to contract for the delivery of surface water Such districts generally do not have artificial recharge programs or pumping assessments,[100] or correspond with the boundaries of groundwater basins. These districts typically represent political jurisdictions and may be formed by the people of any county or portion of a county, and may include incorporated and unincorporated areas (although if any part of a municipality is included, all of it must be included).

Therefore, neither municipal water district was in a position to finance and operate the replenishment of the Central and West Basins However, as specialized agents and contractors for purchases of supplemental surface water, they were ideally suited to the acquisition of waters for recharge programs, The replenishment district had authority to finance and operate a recharge program, and the needed jurisdictional boundary fit The replenishment district became a customer for the supplemental water secured by the municipal water districts The replenishment district purchases supplemental water through the municipal water districts The water purchases are financed through taxation of groundwater pumping

The replenishment district owns extensive recharge facilities, but it does not operate them. The Los Angeles County Flood Control District (now in the Department of Public Works) has specialized personnel with extensive experience in operating reservoirs, and it operates the replenishment district's spreading program in the Central Basin forebay. The Department of Public Works also operates the sea water intrusion barrier project for the replenishment district

The Los Angeles County sanitation districts have operated water reclamation plants at the Whittier Narrows and nearby San Jose Creek for years. With authorization from the California Department of Health Services, the replenishment district purchases as much reclaimed water as possible from the sanitation districts, which release the water to the spreading facilities. Locally reclaimed water is much less expensive than water imported from northern California or the Colorado River, so the replenishment district buys all it can.

The metropolitan water district, the major imported water wholesaler, also offers surplus replenishment water at a lower price than its treated, filtered regular water. Conjunctive use of groundwater supplies lowers the demand for imported water and reduces the capacity MWD has to construct and maintain for dry periods, so the MWD board has encouraged this practice through the lower price of replenishment water Similarly, in years when it has surplus water in the State Water Project, the California Department of Water Resources has offered water at reduced prices to local districts for artificial recharge.

Thus, each year, the Central and West Basin Water Replenishment District anticipates the approximate mix of surface water supplies and groundwater pumping within the coastal plain (based on the anticipated availability of surface water supplies), estimates the amount of replenishment and barrier water needed, and arranges the purchase of that water and the operation of the spreading facilities and barrier projects. It then assesses the purchase and operations costs to the water users. The conjunctive management program, now beginning its fourth decade, is accomplished through a network of intergovernmental arrangements that coordinate the actions of specialized producers.

## Intergovernmental Contracts: The Solano Project

Relationships among governmental organizations engaged in water supply can be arranged by intergovernmental contracting in a number of ways. A government such as the Central and West Basin Water Replenishment District may contract with several service producers. In other places, several governments may make contractual arrangements with a single producer that performs several management tasks. Solano County in northern California has developed arrangements between a federal agency, a county district, several municipalities, and an irrigation district

The Solano Project captures the waters of Putah Creek, which drains the eastern slope of the coast range of mountains in Napa and Lake counties. Monticello Dam impounds Putah Creek waters near the convergence of Napa, Solano, and Yolo counties and forms Lake Berryessa. Waters from Lake Berryessa are released into a smaller reservoir, Lake Solano, from which water is diverted by means of the Putah Diversion Dam into the Putah South Canal, which conveys water toward the farmland and cities of Solano County, one of the fastest growing California counties. As of 1980, the project irrigated about 60,000 acres of farmland on about 900 farms, and provided supplemental water for three U.S. military installations and for urban and suburban areas with a combined population of about 300,000.

The county's climate is semi-arid, with an average annual rainfall of 17 inches, almost all of which falls in November, December, and January During the summer months, Solano County residents (especially farmers engaged in irrigated agriculture) have relied heavily on groundwater irrigation, which resulted in a falling water table through much of the first half of this century The Solano Project had the same purpose as most water development projects in the West-to capture surplus waters when they were available in order to increase the supply throughout the year (and across years), and to relieve some of the demand pressure on local groundwatet

The Solano County Board of Supervisors formed a Solano County Water Council in 1940, which worked on securing federal support for the project The project was authorized by the Congress in November 1948 under the Reclamation *Act of 1939 as* part of the plans for development of the Central Valley area. In February 1948, the Solano Irrigation District, covering most of the irrigable land, was formed to finance and operate a distribution system for project water [101] In 1951, the Solano County Flood Control and Water Conservation District was authorized by the state legislature and activated by the county board of supervisors to represent the various entities desiring water from the Solano Project and to contract with the U.S. Bureau of Reclamation (and subsequently with the California Department of Water Resources for water from the State Water Project's North Bay Aqueduct).[102]

Construction began in 1953. Monticello Dam and the Putah Diversion Dam were completed in 1957, and the Putah South Canal was completed in 1959. The Solano Irrigation District constructed the $15 million distribution and drainage system, which consists of several miles of canals and pipelines and was completed in early 1963. The system was financed with an interest-free loan from the U.S. Bureau of Reclamation, with repayment scheduled over a 40-year period ending in 1999. It is estimated that this arrangement saved the district approximately $3 million in construction costs and about one-third in financing costs.[103]

The U.S. Bureau of Reclamation entered into a master water contract with the Solano County Flood Control and Water Conservation District for the distribution of the waters developed by the Solano Project The district provides water to the Solano Project's "member units" -the cities of Fairfield, Suisun City, Vacaville, and Vallejo, the Maine Prairie Water District, the Solano Irrigation District, the University of California at Davis, and the California Medical Facility at Davis (both of which are located in Yolo County). The Solano Irrigation District is entitled to 74 percent of the waters developed annually by the project Another 7 percent is estimated lost to evaporation and seepage, and the remaining 19 percent is split among the other member units.

The Bureau of Reclamation contracted with the Solano County Flood Control and Water Conservation District for the operation of the Putah South Canal and the related distribution facilities The district subcontracted the canal operation to the irrigation district, which already operated and maintained the distribution system.

Initially the Bureau of Reclamation operated and maintained the headworks of the Solano Project-the Monticello Dam, Lake Solano, and the Putah Diversion Dam. The irrigation district also has constructed and operates an electrical power plant at Monticello Dam

As a result of contracting and subcontracting, neither of the parties to the Solano Project master water contract-the U.S. Bureau of Reclamation and the Solano County Flood Control and Water Conservation District-performs any direct operation or maintenance. The bureau monitors some project operations and publishes an annual report, and the county district accounts for the allocation of and wholesales imported water from the Solano Project and the State Water Project Thus, in 1988, while the Solano Irrigation District had a staff of 66 persons, most of whom were engaged in water supply, the staff of the Solano County Flood Control and Water Conservation District, the main contractor for the Solano Project, consisted of one person in the county Department of Public Works.

For the Solano Project, then, the irrigation district operates the dams and canals that comprise the water supply and conveyance system, the electric power-generating facilities, and sets of water wells-a wide array of activities for an "irrigation district" These arrangements have placed the district in a position to manage its own surface and groundwater supplies conjunctively, and to enter into agreements with water retailers in Solano County (such as the municipalities and the Maine Prairie water district) for distribution and use.

The irrigation district and Suisun City have a joint powers agreement whereby the district provides municipal and industrial water to newly annexed areas while the city agrees to keep those areas within the territory (and thus the taxing authority) of the district Suisun City therefore provides its residents with water from alternative sources that include locally pumped groundwater, water imported from the Solano Project, and water imported from the State Water Project through the North Bay Aqueduct

The City of Fairfield, which relies almost entirely on imported water, has an exchange agreement with the irrigation district The district finds irrigation uses for some reclaimed wastewater from the city and provides the city with Solano Project water

As Solano Count urbanizes, water previously devoted to agricultural uses is being gradually shifted to municipal uses With a service area that encompasses much of the agricultural land in the county and reaches to some of the municipalities, the irrigation district can assist with that transition. The City of Dixon, which has been supplied by a private water producer, the California Water Service Company, has arranged to purchase additional project water. The Maine Prairie water district, which is located south of Dixon and has an entitlement to project water but no conveyance facilities, has given over part of its entitlement to the district in exchange for delivery of tailwaters to its service area

The Putah Plain groundwater basin is located in Solano County, partially within the territory of the irrigation district, and has a sustainable yield of about 140,000 acre-feet per year. The irrigation district coordinates the conjunctive use of Solano Project water and Putah Plain groundwatet The district replenishes the groundwater basin with water from Putah Creek; uses more project water in wet years, and draws mom heavily on gmundwater from the Putah Plain basin in dry years; and operates deep wells in the Putah Plain that produce gmundwater and draw more surface water into the basin from unlined canals and natural stream channels These practices enhance the total long-term yield, helping meet the additional demands of a growing urban population without always being taken away from agriculture.

Conjunctive practices in Solano County involve a balancing act, however. It is possible to overfill the Putah Plain basin, especially in the neighborhood of Putah Creek Depths to underground water there are not very great, and in years of surplus precipitation and natural percolation, it is possible for the water table to rise sufficiently near the land surface to saturate and rot the root systems of crops. So,at times (especially in the early spring of years with above-normal rainfall), the irrigation district has to turn on its underground pumps, not because there is too little surface water, but because there is too much groundwater too close to the surface. Regulating conjunctive use thus involves keeping underground water levels within a range where storage values are taken advantage of without damaging overlying uses.

Recently, the irrigation district and the municipalities have formed the Solano Water Authority to discuss with the Bureau of Reclamation the purchase of the Solano Project The contractual arrangements for operation and maintenance of the project, combined with the district's operation of the Monticello Dam power plant, have prompted consideration of simply "buying out" the ownership of the project The U.S. Bureau of Reclamation has expressed some interest in turning over the operation and ownership of water projects to local users (although this would require congressional authorization). Thus, it is possible that the bureau may in the future be removed from the set of contractual arrangements for managing water resources in Solano County

### Appropriation Permits, Offsets, and a "Water Czar": The New Mexico State Engineer

New Mexico relies heavily on groundwater for domestic, industrial, and irrigation uses. The continued availability of supply from this limited resource is an important concern. While recent attention has focused on a rash of serious water contamination and pollution incidents, sustaining sufficient water quantity has been a priority since before statehood.[104]

New Mexico adopted the doctrine of prior appropriation for acquisition of rights to groundwater use in 1931, the oldest "continuously employed prior appropriations system in groundwater in the West."[105] Enactment of the statute was promoted by farmers and other civic leaders in the vicinity of Roswell, where the artesian groundwater basin that supplied the agricultural economy was exhibiting loss of pressure.

Several other western states also made groundwater subject to prior appropriation. The New Mexico legislation authorized the state engineer to designate critical groundwater areas and to administer through appropriation permits the allocation of groundwater within a basin, on the petition of at least 10 percent of the users.[106] If unregulated exploitation "reaches a point where it threatens the rights of existing users, the petition mechanism can be used to call on the engineer to assess and administer the rights within the basin."[107] The appropriation permits restrict pumping to a specific quantity and set priority of rights in accordance with seniority (This pattern was adopted by other states with significant artesian groundwater supplies, such as Utah and Nevada, since artesian basins exhibit problems from overuse relatively sooner). The New Mexico state engineer also was made responsible for developing information about groundwater resources and promoting the expansion of irrigation with groundwatec

In the Pecos Basin, an aquifer with significant recharge where groundwater rights have been adjudicated and quantified, appropriation permits limit total annual extractions to around 400,000 acre-feet.[108] This limitation places the basin on a "safe-yield" operation, halting the decline in water levels and the lengthening of pumping lifts Within the basin, appropriation permits are transferable among pumpers, thus moving groundwater toward valued uses and avoiding the retention of obsolete permits

However, it is impractical to attempt to manage many groundwater basins in New Mexico on a perpetual "safe- yield" basis because, as in neighboring Arizona and the high plains of the Texas Panhandle, they receive little average annual recharge. Therefore, the state engineer reserves one-third of the estimated balance of water remaining in the basin and allocates rights to pump ("mine") the remaining two-thirds in such a way as to deplete the stock over a 40-year period.[109] Individual appropriators are awarded permits entitling them to the use of a specified quantity of water per year over the 40 years.[110]

Individual use rights are protected from the impact of pumping on the lateral underground movement of groundwater by making sure that wells are not placed too close together Lateral groundwater movement is also taken into account through the use of artificial boundaries, such as those of townships, to geographically subdivide aquifers that extend beneath a large land area. For purposes of exchanging appropriations permits, well owners and operators within such an artificial subdivision are treated as pumping from a common aquifer The theory behind this system is that the lateral movement of groundwater means that extractions and return flows from wells in close proximity will probably have a significant impact on one another, while the effects of extractions and return flows from wells that are widely separated (albeit using the "same" aquifer) are, as a practical consideration, negligible.[111]

Appropriation permits may be transferred between pumpers within one subdivision of an artificially subdivided basin. Well spacing regulations avoid impairment of use rights, and the subdividing of basins keeps the benefits of return flows within the same general area. Transfers of permits between subdivisions are allowed, but they are restricted to the amount of water estimated to be the original permit holder's consumptive use, rather than the amount pumped. [112] To the users of a common aquifer (or within close proximity of each other, as in an aquifer subdivision), there is no material difference between losing from the common supply the amount of water consumptively used (extracted net of return flows) on overlying land, or having that amount pumped and exported to another location.

The state engineer's office has faced its greatest conjunctive management challenge in the administration of the Rio Grande aquifer. The aquifer is hydrologically connected with the Rio Grande River, and extractions from the aquifer can lower the stream flow of the river There is very little rainfall in the region and not much recharge to the underground supply. There also is no readily available external water source from which to import water for artificial recharge of the Rio Grande system,[113] so the surface-to-groundwater relationship is zero sum over the long term: groundwater extractions have the same ultimate effect as diversions from the surface flow, but with a longer time lag

In 1956, the state engineer designated the Rio Grande Underground Water Basin as a critical basin, subjecting it to the appropriation permit process. The administration of the basin combines controlled long-term mining of the underground stock of water with the conjunctive management of the interrelated surface and groundwater supplies The surface waters have long been fully appropriated. Any diminution of the river flow would invade the rights of some surface water appropriators. On any permit application to appropriategroundwater from the Rio Grande basin, the engineer analyzes the relationship of the requested pumping on the stock of groundwater and its effect on surface flows. Depending on the remaining water stock in the basin, a permit may be granted conditioned on the applicant purchasing and retiring sufficient rights from senior appropriators on the Rio Grande to offset the diminution of stream flow caused by the proposed pumping.[114]

The engineer offered to issue a conditional permit to Albuquerque when the city sought to appropriate 6,000 acre-feet per year from the Rio Grande aquifer from wells located within 6 or 7 miles from the river. It was estimated that roughly half of the water extracted would come from underground stocks and the other half would diminish the surface flows. The engineer held that the requested pumping would impair the surface water rights of senior appropriators and suggested the conditional plan to offset the effects of the groundwater appropriation. The city challenged the ruling, but the New Mexico Supreme Court upheld the offset plan.[115]

The offset system recognizes the connection between groundwater and surface water and that surface water is fully appropriated, but nonetheless allows new pumpers to undertake water development from the Rio Grande aquifer if they purchase surface water rights. This extends market principlesto the whole water resource,rather than treating surface water rights under one system and groundwater rights separately

The New Mexico system has yielded important benefits and offers useful lessons. Surface and groundwater development and use are being monitored and administered in 31 groundwater basins.[116] Using designated basins shares an advantage with special districts of limiting "the number of people involved in the decision to those who are actually affected by the decision."[117] The New Mexico approach also defers the activation of a rulemaking process "until there is a demand for rules by actual groundwater users"[118] Thus, communities of interest are defined and involved in rulemaking.

Allowing exchanges of use rights enhances efficiency by directing use of the resource toward those who value it more. A strict seniority system of water rights lacks the flexibility to adjust to shifts in the value of uses of water. Allowing transfers of pumping rights has been described as approaching an optimal system of allocation.[119] The offset system brings to light an important benefit of conjunctive management This administrative variation on water exchange systems, allowing junior appropriators to "buy out" the rights of their seniors, "might enable greater productive water use without detriment to the remaining senior stream rights, except for a risk of miscalculation."[120]

Three qualifications should be noted about the New Mexico appropriation permit,offset, and "water czar" system First, the state engineer's office has functioned with notable stability and expertise in part because one person served in that capacity for four decades. In Steve Reynolds, New Mexico had a true "water czar" His extensive experience and intensive knowledge of water resources and use patterns were invaluable in the administration of the permit-and-offset system, minimizing the likelihood of erroneous calculation.

Second, New Mexico is not the only state to have such a system. The Nevada system includes appropriation permits issued by the state engineer, who also designates overdrawn basins as critical basins And in a case in Colorado in the 1970s, an offset system was used to resolve a controversy in which a subdivider proposed to pump groundwater that was tributary to an overappropriated stream. The stream users agreed to a plan whereby the subdivider would purchase sufficient reservoir water upstream to release into the river to offset the loss in stream flow resulting from the groundwater extractions.[121]

Third, the state engineer's office is not the only institution involved in the management of groundwater supplies. Various "state and local agencies (including political subdivisions) charged with water-related responsibilities have been modernized in order to provide ample latitude for their functioning."[122] Groundwater basin adjudications also have clarified rights and relationships of users. The original recognition in law of the hydrologic inseparability of connected surface and groundwater came, not from the legislature or the engineer, but from the courts

## Interstate Competition and Interstate Coordination: The Delaware River Basin

As often noted, groundwater basins do not necessarily conform to the boundaries of state or local political jurisdictions. When a single water resource system stretches across two or more states, more interjurisdictional difficulties arise. The states are sovereign entities, and the laws of water rights and ownership are state laws. The most fundamental issues of water management (who has what kinds of rights to extract and divert how much water) therefore are potentially in dispute. Yet, the parties to those disputes often are reluctant to develop an interstate management system or to accept practices imposed by the federal government.[123]

While competition between jurisdictions can sometimes lead to better and more efficient service delivery alternatives, competition in the use of a common resource can produce undesirable results. Persons on each side of a common boundary underlain by a common aquifer may respond to incentives to develop the resource as rapidly as possible in order to capture most of its benefits.[124] If persons on both sides respond to the same incentives in the same ways, then the "race to the pumphouse" in the interstate context can yield wasteful overexploitation and ultimate harm to the resource. In areas where population growth and other sources of water demand is greatest, these kinds of interstate competition may be expected to intensify However, the extent of problems of interstategroundwater depletion maybe somewhat overstated.[125]

Where interstate water problems do exist, the most common recommendation is to develop and implement an interstate compact, described by one author as "the primary means of coordinating and managing groundwater resources in several Eastern states."[126] Interstate compacts are cited as preferable to resource depletion and destruction resulting from interstate competition,and to alternative forms of resolution, such as equitable apportionment of a water supply by adjudication. [127] Compacts are preferred for their flexibility finality, and use of experts, and as less time-consuming and expensive than litigation.[128]

Interstate compacts can provide for the coordinated use of a common resource among states, as in the example presented below. There also are some cautions to be observed. First, there is no guarantee that a state whose residents are overexploiting a groundwater resource at the expense of another state will enter into an interstate compact.[129] Second, transaction costs of reaching an interstate compact, which not only involves the consent of the Congress but also requires unanimous adoption by the affected states, can be very high. Thus, not every interstate compact is developed with less time and expense than would be involved in an adjudication Development and ratification of the Colorado River Compact, for example, spanned five decades, and still ended up in the United States Supreme Court

Third, it is not obvious that the advantages cited for interstate compacts over adjudication always apply Flexibility, finality, and expert development of settlements can be advantages of the adjudicatory process as well. Based on experience, there is no reason to believe that interstate compacts are less likely to become the subject of recurring litigation than are equitable decrees.

Finally, there are circumstances in which an equitable apportionment of an interstate groundwater resource is a reasonable alternative. The most often discussed interstate aquifer is the Ogallala

Aquifer of the Great Plains region. Yet, as one observer noted, "Clearly it would be impractical to consider the entire Ogallala Aquifer as one common aquifer."[130] While users in all eight states that overlie that resource derive water from a "common" supply, it is not at all obvious (because of the physical characteristics of the aquifer) that withdrawals by residents of southern South Dakota or Nebraska are contributing materially to groundwater decline in the Texas High Plains, or that losses and gains from the depletion of the aquifer fall evenly across users.

As noted with reference to New Mexico's state engineer's artificially subdividing large groundwater basins, while "the lateral movement of groundwater would render two wells 2 miles apart as pumping from the same common aquifer, this lateral movement may, for all practical purposes, be ignored if the two wells are 50 miles apart."[131] Where the physical characteristics of an interstate aquifer warrant it, states can manage and use equitably apportioned shares of the water supply and storage capacity within their own legal and institutional frameworks.

These considerations suggest that neither interstate compacts nor equitable apportionments are always a superior institutional form of meeting the challenges of intestate competition and coordination Different challenges will call for different resolutions

An example of the use of a federal-interstate compact (an interstate compact to which the federal government is also a party) is the Delaware River Basin Commission (DRBC). DRBC and the Susquehanna River Basin Commission are the only two interstate water management institutions with extensive groundwater management powers.[132]

DRBC members are the governors of New Jersey, New York, Delaware, and Pennsylvania, plus a presidential appointee to represent the federal government (usually the Secretary of the Interior). The commission's management activities proceed according to a comprehensive plan, prepared by staff members and approved by the commission.

There is considerable interdependence of surface and groundwater within the Delaware River basin,[133] and the commission is committed to meeting the water supply needs of the coastal plain through conjunctive use of surface and groundwater supplies. The staff has identified problems within the plain resulting from excessively rapid depletion of parts of the Potomac-Raritan-Magothy aquifer group. Pumping in areas of this heavily urbanized corridor has resulted in the appearance of cones of depression in the underground water levels. These cones attract sources of contamination (most often organic compounds such as trihalomethanes and tetrachloroethylene) and sea water intrusion.[134]

Step One in DRBC's conjunctive management program, therefore, has been to attempt to relocate some of the more concentrated areas of groundwater extraction (such as those near Wilmington, Delaware, and Camden, New Jersey) away from the confined areas of the underlying aquifers, where pumping is most likely to form depressions that lengthen pumping lifts and aggravate quality degradation problems. Moving pumping to unconfined areas of the aquifer groups brings it farther from the threats to water quality and into areas that can be more readily recharged with surface water supplies, which allows greater advantage to be taken of the groundwater reservoir's capacity

Step Two is to compensate areas where groundwater withdrawals need to be curtailed with additional surface water supplies or with groundwater pumped farther upstream and imported.[135] This is especially the case in the areas of Camden, New Jersey, where groundwater withdrawals ate to be phased out over the next two decades

Step Three is to increase the utilization of underground storage capacity The commission's policy originally restricted groundwater withdrawals to sustainable yield. While this goal is desirable over long periods, within a given year it fails to provide the flexibility to use the groundwater supplies and storage capacity of the coastal plain to their fullest potential in maximizing water supplies without endangering resource preservation.[136]

The commission depends for its success on the cooperation of the states The ability of the commission to designate "pmtected areas" within the Delaware River basin requires that the states cooperate in enforcing pumping restrictions that are deemed necessary to securing an adequate supply for the region.

The commission also needs states' cooperation in meeting information requirements. For example, New Jersey terminated an old statute that exempted water users who held permits issued before 1947 from reporting their groundwater withdrawals. These grandfathered permits clouded the accuracy of estimates of total groundwater extractions in the coastal plain. In 1980, the New Jersey Water Supply Management Act extended the reporting requirement to all pumpers, giving the state and DRBC better information with which to develop and implement water management [137] DRBC will need similar state assistance as problems of water contamination are addressed.

## Interlocal Coordination

The problem of groundwater resources crossing previously established local government boundaries is among the most commonly discussed management challenges. Certainly, local autonomy over water supply decisions increases costs in multijurisdictional cooperation in *source* development and allocation.[138] However, there are alternative arrangements for coordinating resource use that do not match existing local jurisdictional boundaries. Special water districts, adjudications, and the designation of groundwater areas by a state agency are all possibilities for fitting decisionmaking processes to the resource and to diverse communities of interest.

The difference between the geographical distribution of groundwater supplies and governmental bodies creates other challenges It is possible, for example, that a groundwater basin with desirable storage capabilities could underlie one community but not another contiguous or nearby community, even though both are located in a region where demands for surface and groundwaters approach or exceed supplies.[139]

Possibilities for ameliorating such disparities include:

a) Regulatory resource redistribution by a regional or statewide agency;

b) Physical resource redistribution through construction and operation of a project that conveys water from where it is to where it is not and creates storage capacity in places where it did not exist; and

c) Interlocal coordination, whereby community interaction creates arrangements that meet resource needs while preserving the political independence of differently situated communities of interest, and avoiding (or at least minimizing) the need for regulatory or physical redistribution schemes and their attendant costs.

While considerable past experience has focused on the first and second of these possibilities, interlocal coordination deserves attention for the benefits it can produce.

As three examples illustrate, even situations that would appear to be characterized by strong and deep conflicts between communities, or that seemed to require heavy investments in public works projects, have been ameliorated by negotiated coordination. The Main San Gabriel Basin, the metropolitan Washington, DC, area, and the Owens Valley-Mono Lake Basin provide cases of coordination in the use of water supply and storage to improve overall availability and allocation and to avoid difficult problems.

The San Gabriel Valley. In the Main San Gabriel Valley Basin in Southern California, water storage capacity is monitored by the Main San Gabriel Basin watermaster, a court-appointed policymaking body composed of nine representatives of water producers and local water districts. As the result of an adjudication of water rights, the watermaster was given custody and control of storage and (along with several other responsibilities) is authorized to enter into agreements with other water supply jurisdictions to store water underground. Staff assistance is provided by the Upper San Gabriel Valley Municipal Water District

Parties to cyclic storage agreements with the Main San Gabriel Basin watermaster can import water into the basin and store it there for subsequent recovery The watermaster has entered into such agreements with the neighboring San Gabriel Valley Municipal Water District (SGVMWD), which manages water supply over the territory of four cities, and with the Metropolitan Water District of Southern California through its local member agency the Upper Valley district.[140] These are useful contractual arrangements for the districts because they must plan years in advance for importation of water from the State Water Project, and the variability of climatic conditions can result in considerable surpluses of water at some times and deficits at other times.[141]

In the preparation of the judgment settling the adjudicationof water rights in the Main San Gabriel Basin, the users recognized that they had a valuable resource in the underground water supply and in the storage space. They agreed to allow the use of this latter resource under the regulation of their own representative policymaking body. Interlocal coordination in this case generates a mutually beneficial outcome from a disparate geographic distribution of water supply, storage, and demand.

Metropolitan Washington, DC. In what has been termed the “state-of-the-art for supply management,”[142] agencies in the Washington, DC, metropolitan area worked out an arrangement for operation of surface reservoirs that reveals additional benefits from interlocal coordination. Analyses and forecasts of supply and demand had for decades predicted a water crisis for the region by 1980. Plans for addressing that crisis included the construction and operation of several (in one plan, as many as 16) new reservoirs.[143] Clearly, such plans involved considerable expenses and environmental impacts.

A 1977 restudy by the U.S. Army Corps of Engineers (authorized by the *Water Resources Development Act* of 1974) came to a different conclusion -that the region was not necessarily short of water if existing supplies and storage were used more efficiently. The solution lay in coordinating the supply organizations' actions rather than in technology and concrete.[144] Over the ensuing five years, officials of the 25 water supply agencies in the metropolitan area (three of which account for 95 percent of the water treatment capacity) formed a regional task force that worked with the Corps of Engineers on improving management of storage capacity. In July 1982 (in a fraction of the time needed for designing, financing, and constructing surface storage facilities), eight agreements were signed for maintaining flows of the

Potomac River, for allocating water in periods of low flow, for coordinating operation of existing storage facilities, and for sharing the costs of any future storage capacity expansions.[145]

As a result of these interlocal arrangements, only one small new physical facility was required, and adequate water supplies and storage are assured to 2020.[146] These arrangements are estimated to have saved between $200 million and $1 billion over the previous plans.[147]

A special concern was the potential environmental effects, especially on the tidal estuary downstream from Washington, either from failure to act (resulting in the eventual loss of sufficient Potomac flows to maintain the ecosystem) or from reservoir construction. The interlocal coordination should maintain sufficient flow in the Potomac to preserve environmental values.[148] These benefits have been achieved without the addition of a new regional management institution or the elimination of community water systems; without the construction of a great concrete complex; and with increased emphasis on conservation, efficient use, and environmental protection.

Los Angeles and the Owens Valley. One of the most renowned interlocal disputes concerning environmental protection and water supply management has persisted through most of this century between the Los Angeles Department of Water and Power and the communities of the Owens Valley and Mono Lake Basin on the eastern slopes of the Sierra Nevada. Los Angeles began diverting surface and groundwater from the sparsely populated region after 1910, extended the diversions to the streams feeding Mono Lake in the 1940s, and doubled its aqueduct capacity in the 1970s. Water levels in Mono Lake (a significant aquatic habitat for brine animals and migratory fowl) have declined markedly and signs of vegetation stress and decline have been noted in the Owens Valley.[149]

From the late 1950s to the 1980s, there was considerable controversy over Los Angeles' actions, followed by several lawsuits by environmental groups and local residents and officials, and occasional introduction of legislation to address the issues In 1983,officialsof Inyo County and Los Angelesformed the Inyo/Los Angeles Standing Committee "to develop a groundwater management plan that would protect the Valley's environment while supplying LA with water."[150]

In March 1989, negotiators for the county and the city announced a preliminary agreement to settle much of the dispute. After some initial local opposition, revised agreements were reached in August 1989 to protect the native vegetation and wildlife of Owens Valley and to preserve the city's ability to divert water into the Los Angeles Aqueduct and convey it to the city, where much of it is recharged into the underground basin of the San Fernando Valley.[151]

At roughly the same time, Los Angeles, the Metropolitan Water District of Southern California, and the Mono Lake Committee (an environmental action group) agreed to support a legislative bill to preserve and protect Mono Lake. The agreement would attempt to shift some of Los Angeles' diversions away from the streams feeding Mono Lake, while providing financial support for water development to help the city make up part of the resultingloss of water supply.[152]

The Mono Lake and Owens Valley controversies seem to be some of the most intractable in the water-management field. The implementation and outcome of the interlocal agreements cannot yet be foreseen, but they signal the possibility that conjunctive management can emerge even in places facing difficult issues of environmental preservation and restoration, area-of-origin protection, and large-scale interbasin water transfers

In fact, according to one view, it is precisely when water management issues are complex and delicate that interlocal arrangements are the most desirable alternative for intergovernmental relations. It may be the case that

> . . . negotiation among directly interested parties can develop more flexible and thorough solutions than court decisions, state agencies, or legislatures. Water resources and their relation to the environment are complex, and depend on local characteristics People have well-defined preferences that vary among localities A court decision, administrative rulemaking, or a legislative committee cannot develop water management programs based on the integration of scientific information on local water resources and the environment that meet the needs of both the area-of-origin and the water exporter efficiently.[153]

## Additional State and Local Innovations

In addition to the cases above, there are many more cases of institutional innovation by state and local governments Following are a few additional examples

Water Rights and Transfers. Some states are developing and implementing statewide groundwater laws, while others have targeted specific issues.[154] Some states are defining surface and groundwater rights to allow private and public suppliers to operate with both kinds of rights or to substitute one source for the other, while other states are strengthening their positions as water wholesalers and regulators in attempts to encourage conjunctive management

In Mississippi, a state heavily dependent on groundwater, some cities have witnessed underground water level declines of up to 200 feet in this century A broadly representative Water Management Council created in 1983 found several imminent and impendinggroundwater problems,ranging from rapidly accelerating declines in levels to the encroachment of sea water along the Gulf Coast The council's recommendations and conclusions resulted in enactment of two statutes. The Omnibus Water Bill of 1985 included the union of surface and groundwaters in a system with ten-year permits issued by the state permit board. The Water Management Districts Bill of 1985 provided statewide enabling legislation for localities to create water management districts with a broad range of powers for assuring water supply and inducing conservation.[155]

Several states are making institutional changes to allow, or remove impediments to, the transfer of waterrights. There is a general trend toward reform of state laws to allow greater opportunities for the creation of water markets, and to enable local or regional authorities toestablish conjunctive management. Such changes "are being established slowly, but largely as needed on an ad hoc basis under authority of state water laws."[156] A review of state legislative activity during 1988 and 1989 reveals a pattern of rejection of proposals to limitwater transfers, approval of some bills designed to encourage transfers, and approval of about half of the measures intended to authorize state agencies to appropriate groundwater and establish water storage rights.[157]

Idaho has recently undertaken the largest river basin adjudication of water rights in the history of the western states,[158] involving approximately 185,000 claims to the waters of the Snake River watershed. If the adjudication results in specific quantified water rights, Idaho's largest water source could be made part of a water exchange plan. Critical groundwater areas also have been designated by the state Department of Water Resources Among the approaches is an attempt to stop excessive withdrawals by specifying a minimum groundwater level within critical areas In 1989, the state legislature enacted a law directing the director of the Department of Water Resources to initiate groundwater adjudications to limit withdrawals in overdraft areas.[159]

Water transfers have been used actively in Colorado, which, in its 1969 Water Rights Determination and Administration Act, united in the same priority system the appropriative rights to a stream system and its tributary groundwater.[160] This innovation encourages conjunctive management in watersheds where surface and groundwaters are interrelated by eliminating the disjuncture between the priority of rights of holders of groundwater pumping permits and of surface diversion permits. Altering the mix of reliance on groundwater and surface water is made considerably simpler under such a system.

Colorado also has chosen to take advantage of the tendency of appropriative permit schemes to resolve water challenges in judicial forums. The state is divided into seven water divisions, the boundaries of which accord with major river basins, each with its own division engineer and water court. The water court consists of a district court judge and a court-appointed referee.[161] This set of administrative and legal institutions facilitates the determination of water rights questions.

The Colorado system removed several impediments to water transfers. Since the mid-1960s, much of the population growth of the front range cities, such as Denver, Colorado Springs, Aurora, and Pueblo, has been accommodated by purchases of irrigation water rights from farmers and the conversion of those waters from agricultural to urban uses.[162]

Planning. A majority of the states has either mandated or authorized some form of comprehensive water resources planning, and most of those states have a mandate to engage in continuous planning and review.[163] Some states are exploring regional and local water "banking" programs and other mechanisms for taking greater advantage of underground water storage capacity. In a banking program, water is stored during periods of surplus and sold during later periods of need.[164] Water banking projects have been implemented on an experimental basis in California and Idaho.[165]

Water Wholesaling. States have used their position as wholesalers as leverage to encourage local initiative in managing water supplies Access to state water supplies can be conditioned on efforts to reduce demand and improve facilities Massachusetts, for example, raised the wholesale price of water from state-owned reservoirs to local suppliers (as have several states) and restricted access in order to induce local entities to focus more heavily on maximizing the yield and improving the allocation of local water supplies.[166]

A different tactic is employed by New Jersey, which mandates that local water suppliers in designated critical groundwater areas either develop their own surface water supplies or purchase them from a state-owned reservoir at wholesale rates substantially above the cost of additional pumping. Communities that do not acquire their own surface supplies to use conjunctively with groundwater, or develop sufficient conservation measures, may be required "to purchase state water whether they use it or not."[167] This provides an incentive to reduce reliance on overtaxed groundwater supplies and begin the conjunctive use of surface water and groundwater, while higher costs provide incentives for conservation

Institutional Capacity, Districts, and Localities. State and local capacities for developing and implementing innovative strategies for groundwater management have developed significantly over the last 25 years. The "human capital infrastructure" of state and local governments, the expert professional personnel employed in water resources management, especially by the states, has grown over that period.[168]

State and local governments are assuming greater financial responsibility for water projects and resource management initiatives.[169] Massachusetts began operating a grant-in-aid program in 1982, providing funds on a matching basis to local water supply systems. New Jersey began a loan program in 1983 to support rehabilitation of water supply facilities by their local operators.[170] Similar financial assistance programs have been established in several other states. Utah offers an entire range of water-supply financing mechanisms, including grants, loans, and credit enhancements."' In 1981, Montana established a water development fund to make loans and grants for water development projects.[172] Many of the funding mechanisms involve the privatesector.

States have experimented with the design of local special districts and regional administrative entities. Nebraska, for example, has consolidated districts for water conservation, soil conservation, and drainage into "natural resource districts" (irrigation districts were not included in the consolidation).[173] Within critical "groundwater control areas" designated by the director of the Department of Water Resources, a natural resources district may promulgate special rules and regulations governing groundwater withdrawals and use. Such regulations may require installation of flow meters on every well, specify the duty of water for irrigation acreage, and set well spacing requirements.[174] Natural resources districts also regulate, and have in the past sharply limited, water transfers.

Florida has established five regional water management districts to conform to the state water resources regions. The districts are governed by boards appointed by the governor and are responsible for managing water supply, water consumption, and flood control, The districts play a vital role in facilitating and regulating (or impeding) future water transfers through their permit authority,'" and they also are authorized to levy ad valorem taxes to finance local water projects Statewide water planning and regulation of quality are the responsibilities of the state Department of Environmental Regulation. A state water use plan adopted in 1985 focuses on the relationship between water resources and growth management.[176]

Localities have tried to couple their need for innovative approaches to waste treatment and disposal with their need to assure water supplies. Much of the literature on water resource management over the past four decades has advocated reuse of water and reclamation of wastewater. Local governments are taking steps in this direction. The use of reclaimed water for replenishment and injection by some special districts was noted above.

Denver has been treating wastewater into drinking water quality since 1968. A pilot plant was developed, and a demonstration plant using ozone and reverse-osmosis technologies went into operation in 1984. The goal of the project is to use treated water to meet a significant share of the city's water needs by the close of the 1990s.[177]

Kissimmee, Florida,used to deposit sewage effluent into a stream feeding Lakes Toho and Okeechobee. The lakes began to show effects from the fast-growing city's discharges, and the city in turn outgrew its sewage treatment capacity Kissimmee has built a new treatment plant, which will process sewage to a level of quality where some of it can be used for watering a nearby golf course, some sold for irrigation, and the remainder allowed to recharge into the groundwater strata. As a result of these changes, Lake Toho is being returned to its previous recreational uses.[178]

The diversity of state approaches and innovation in institutional design and groundwater management reflects different physical, economic, social, cultural, and political backgrounds and character& tics. Each state (and in many states, each community) is developing responses to its own "unique set of environmental parameters and economic forces."[179]

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## LESSONS LEARNED

These examples illustrate some of the extensive state and local innovation and experimentation with water resource coordination. Some of these initiatives involve high degrees of cooperation and coordination among several actors,including federal agencies. Other initiatives have been unilateral actions of a state, a city, or a special district seeking to address a perceived problem or to improve its water supply.

Approaches togoverningwater resources exhibit tremendous diversity. The examples cited above (and others not included) have very little in common, save for one crucial factor: each of the most efficient and equitable management approaches demonstrates a high sensitivity and close tailoring to the specific physical characteristics of the water resources.[180]

Groundwater basins differ in the physical characteristics that most affect effective and equitable management: rates of recharge, the degree to which they are connected with surface water supplies, the rate and amount of lateral movement within the basin, and the susceptibility of the basin to degradation from salt water intrusion or other sources. Conjunctive management efforts have appeared in groundwaterareas exhibiting nearly the whole range of these characteristics, and the list of communities considering options and developing plans is even more extensive.[181]

As communities develop groundwater management schemes or seek to improve management, they find that they have many models to consider, with experiences and rationales that point in different directions. For example, does conjunctive management require a comprehensive statewide law? Arizona and New Mexico have such statutes; California and Colorado do not Yet, conjunctive management operations have appeared in all four of these states—for decades in some areas in southern California and since the early 1970s in Colorado.

It does not appear that one can plainly declare the superiority of any state "model." Arizona has chosen to enact and implement statewide legislation; New Mexico has relied strongly on a "water czar"; and California and Colorado have relied on basin organizations and adjudications for management

There also is a wide diversity of experiences in creating and empowering regional and local water management organizations. Florida has made regional districts responsible for water management, while Nebraska has formed regional districts responsible for "natural resources." Mississippi's new groundwater laws authorize the creation of broadly empowered water management districts on a geographical scale as small as a pair of municipalities. Half of the states designate critical groundwater management areas, but within those areas, some states regulate water use directly while others create special districts for each designated basin and still others leave it to local residents to form a special district In Washington, groundwater management development in designated critical areas can be triggered either by the state or by local residents.[182]

Several years ago, the National Water Commission found that groundwater management organization by the states could be grouped into two broad organizational approaches. One was state designation and regulation of critical groundwatec The other category of organization was the special water district encompassing the groundwater basin. After reviewing experiences with these organizational alternatives, the commission decided to express "no strong preference for one form of organization over the other;" observing instead that "the form of organization should depend upon the problems encountered – hydrological, institutional,and legal."[183] Since the commission completed its work in 1973, the range of organizational forms and institutional arrangements for groundwater management has expanded even further.

When innovation occurs in several locations in several organizational guises, the course of progress may not appear to be very orderly. It may even appear at times to be chaotic. Nevertheless, in the words of Ira Clark, "Despite its erratic and unpredictable course, there has been progress. . . . Far away as the ideal master water plan might be . . . there has been a decided trend toward more cooperative and coordinated handling of the nation's water problems."[184] Among the reasons for that progress is the diversity of organizational forms and management arrangements offered by a multijurisdictional system. Given the number and diversity of tasks involved in the conjunctive management of groundwater resources, "Many alternative institutional structures could be considered for the management vehicle."[185] In addition, "The extremely diverse hydrologic, geologic, economic, environmental, legal, political, and social conditions affecting the occurrence, protection, and use of ground and surface waters in the United States suggest that no single structure would be universally applicable nor politically acceptable."[186]

The diverse and multifaceted arrangements by which groundwater supplies are managed, and managed conjunctively with surface water,are not,as may sometimes be supposed, reflections of the weakness of American federalism, but constitute instead one of its strengths. A polycentric, multijurisdictional order may in fact be well suited to the management of complex water systems.

Notes

1 National Water Commission, *Water Policies for the Future: Final Report to the President and fo the Congress of the United States* (Port Washington, New York Water Information Center, 1973), p. 233.

2 Ira G. Clark, *Water in New Mexico: A History of Its Management and Use* (Albuquerque: University of New Mexico Press, 1988), p. xi. 3. Sidney?: Harding, *Water in California* (Palo Alto: N-P Publications, 1960), p. 58.

3 Sidney T. Harding, *Wafer in California* (Palo Alto: N-P Publications, 1960), p. 58.

4 California Department of Water Resources, *California's Ground Water*. Bulletin 118 (Sacramento, 1975), p. 121; Zachary Smith, "Rewriting California Groundwater Law: Past Attempts and Prerequisites to Reform," *California Western law Review 20* (Winter 1984): 234; Susan M. Trager, "Emerging Forums for Groundwater Dispute Resolution: A Glimpse at the Second Generation of Groundwater Issues and How Agencies Work Towards Resolution," *Pacific Law journal* 20 (October 1988): 42.

5 Stephen J. Burges and Reza Marnoon, *A Systematic Examination of Issues in Conjunctive Management of Ground and Surface Wafers*. Water Resources Information System Technical Bulletin 7 (Olympia: Washington Department of Ecology, 1975), p. 1.

6 Ibid.

7 Harding, pp. 116-117.

8 Erwin Cooper, *Aqueduct Empire* (Glendale, California; Arthur H. Clark Co., 1968), p. 137.

9 David L. Jaquette, *Efficient Water Use in California: Conjunctive Management of Ground and Surface Reservoirs* (Santa Monica: RAND Corporation, 1978), p. 2.

10 Jurgen Schmandt,Ernest Smerdon, and Judith Clarkson, *State Wafer Policies* (New York: Praeger Publishers, 1988), p. 144.

11 Burges and Marnoon, p. 33.

12 Cooper, p. 137.

[13] Les K. Lampe, "Recharge Saves Water for a Not-so-Rainy Day," American *City* and *County* 102 (June 1987): 40.

[14] Kyle Schiiing et al., *The* Nation's Public Works: *Report on Water Resources* (Washington, DC: National Council on Public Works Improvement, 1987), p. 176.

[15] Ibid.

[16] Burges and Marnoon, p. 34; Cooper, p. 137.

[17] Thii distinction between "conjunctive use" and #conjunctive management" derives from the work of William Lord at the University of Arizona's Water Resources Research Center.

[18] Stetson, Strauss and Dresselhaus, *Compendium of Report on a Supplemental Water Supply for Upper San Gabriel Vally Municipal Water District (Los* Angeles, 1962), p. VI-l.

[19] Burges and Marnoon, pp. l-2.

[20] Lampe, p. 40.

[21] Jaquette, p. 2.

[22] Burges and Marnoon, p. 32.

[23] Helen Joyce peters, "Groundwater Management," *Water Resources Bulletin* 8 (February 1972): 190. She observes that artificial recharge to conserve waters that would otherwise have wasted began as early as 1895 in Southern California.

[24] Lampe, p. 40.

[25] See, for example, California Department of Water Resources, Bulletin 118, p. 126. See also, among others, Michael Mallery, "Groundwater: A Call for a Comprehensive Management program," *Pacific Law Journal* 14 (July 1983): 1279-1307; Ian Carruthers and Roy Stoner, *Economic Aspects and Policy Issues in Groundwater Development,* Staff Working Paper 496 (Washington, DC: The World Bank, 1981).

[26] These arguments are reviewed in Advisory Commission on Intergovernmental Relations (ACIR), *The Organization* of Local *Public* Economies and Metropolitan *Organization: The St.* Louis *Case* (Washington, DC, 1987 and 1988).

[27] Examples of such definitions (of "groundwater management" generally), are found in Harvey 0. Banks, "Management of Interstate Aquifer Systems," *ASCE Journal of Water Resources Planning and Management* 107 (October 1981): 565; and California Department of Water Resources, *Ground Water* Basins *in California.* Bulletin 118-80 (Sacramento, 1980). The definition given by Banks is:

> Ground-water resources management involves the protection, development and use of the ground-water resources of the particular aquifer system concerned, generally in conjunction with available surface water resources possible including reclaimed water, in the most effective manner to meet water resource development and use objectives as those objectives are defined and redefined with changes over time.

The definition given in Bulletin 118-80 is:

> Ground water basin management includes planneduse of the ground water basin yield, storage space, transmission capability, and water in storage. It includes (1) protection of natural recharge and use of artificial recharge; (2) planned variation in amount and location of pumping over time; (3) use of ground water storage conjunctively with surface water from local and imported sources; and (4) protection and planned maintenance of ground water quality.

[28] California Department of Water Resources, Bulletin 118, p. 129.

[29] Neil S. Grigg, "Appendix: Groundwater Systems," in Schilling et al., p. B-2.

[30] For example, California Department of Water Resources, Bulletin 118, p. 124.

[31] Peters, "Groundwater Management," p. 190.

[32] California Department of Water Resources Bulletin 118, pp. 119-124.

[33] Smith, "Rewriting Groundwater Law," p. 234.

[34] See, for example, John F. Mann, Jr., "Concepts in Ground Water Management," *Journal* of *the American Water Works Association* 60 (December 1968): 1336-1344; also, its application to the conjunctive management of the San Fernando Valley groundwater basin in William Blomquist, *The Performance of Institutions for Groundwater Management, Volume 6: The San Fernando Valley* (Bloomington: Indiana University, Workshop in Political Theory and Policy Analysis, 1988).

[35] California Department of Water Resources, Bulletin 118, p. 124; see also Burges and Marnoon, p. 4: "Operation under a traditional safe yield approach might incur large opportunity costs because the wa ter resources cannot be put to optimal or near optimal use."

[36] California Department of Water Resources, Bulletin 118, p. 121.

[37] Conjunctive use groundwater basin management plans "should include control not only over groundwater pumping, but also over the storage space of an aquifer." Charles Phelps et *al., Efficient Water Use in California: Executive Summary* (Santa Monica: RAND Corporation, 1978), p. 26.

[38] Lampe, p. 46.

[39] Such concerns are among the "second generation" of groundwater issues identified in Trager.

[40] Indeed, this aspect of groundwater management has been identified by at least one observer as more difficult to resolve successfully than the supposedly intractable common-pool or Prisoner's Dilemma problems that accompany groundwater resources. Susan Christopher Nunn, *The Political Economyoflnstitutional Innovation: Coalitions and Strategy in the Development* of *Groundwater Law.* Ph.D. Dissertation, University of Wisconsin, 1986.

[41] See also Lampe, p. 40; David Jaquette and Nancy Moore, *Efficient Water* Use in *California: Groundwater Use and Management* (Santa Monica: RAND Corporation, 1978), p. 31.

[42] The importance of adaptability and error correction, and the difference between them, derives from the work of Vincent Ostrom of the Workshop in Political Theory and Policy Analysis at Indiana University.

[43] Banks, p. 565.

[44] William Reedy, Water for the Valley of the Sun," *ASCE Journal* of Water *Resources Planning and Management* 106 (July 1980): 477.

[45] These observations are made by NUM, p. 20.

[46] For example, "land devoted to cotton production alone increased from 282,000 acres in 1948 to 678,000 acres in 1952. For the most part, the water necessary to support

this increased production came from the ground." Zachary Smith, "The policy Environment," in Zachary Smith, ed., Water *and the Future of the Southwest* (Albuquerque: University of New Mexico Press, 1989), p. 10.

[47] Philip Briggs, "Ground-Water Management in Arizona," *Journal of Water Resources Planning and Management* 109 (July 1983): 195; and John Leshy and James Belanger, "Arizona Law: Where Ground and Surface Water Meet," *Arizona State Law Journal* 20 (Fall 1988): 691.

[48] Wesley Steiner, "Public Water Policy in Arizona," *State Government 55* (Fall 1982): 133.

[49] Briggs, p. 197.

[50] Reedy, p. 488.

[51] Ibid., p. 489.

[52] Steiner, p. 133.

[53] Scott Hansen and Floyd Marsh, "Arizona Ground-Water Reform: Innovations in State Water Policy," *Ground Water* 20 (January-February 1982): 69.

[54] Ibid.

[55] These cases, Bristor v. Cheatum, are known as "Bristor I" and "Bristor II" in Arizona law.

[56] Hansen and Marsh, p. 69.

[57] Ibid.

[58] Tributes to Governor Babbitt's leadership in bringing together the 1980 Arizona law are to be found in virtually every account of the process. For details, see Hansen and Marsh, p. 70; Kathleen Ferris, "Arizona's Groundwater Code: Strength in Compromise," *Journal of the American Water Works Association* (October 1986): 79-84; Leshy and Belanger; and Steiner.

59 Steiner, p. 133.

[60] Schmandt et al., p. 37.

[61] Hansen and Marsh, p. 70.

[62] Ibid., pp. 70-71.

[63] Ibid., p. 70; Leshy and Belanger, p. 707.

[64] National Research Council, Committee on Ground Water Quality Protection, *Ground Water Quality Protection: State* and *Local Strategies* (Washington, DC: National Academy Press, 1986), p. 83.

65 Steiner, p. 134.

[66] James Corbridge, "An Overview of the Special Water District Workshop," in James Corbridge, ed., *Special Water* Districts: *Challenge for the Future* (Boulder: Natural Resources Law Center, 1983), p. 4.

[67] Briggs, p. 199.

[68] Ibid., p. 201.

[69] Leshy and Belanger, p. 713.

[70] Ibid., p. 724.

[71] Ibid.

[72] "Legislative Update," *Water Strategist 3* (April 1989): 15.

[73] Steiner, p. 135.

[74] Briggs, p. 201.

[75] Hansen and Marsh, p. 71.

[76] Alfred W. Jorgensen, *A New Approach to Solving Water* Dis*putes: The Long Beach Case*, Master's Degree Thesis in Public Administration, University of Southern California, 1967, pp. 105-106.

[77] Trager, p. 53.

[78] Mallery, p. 1295.

[79] There are many sources for such criticisms. For a couple of excellent examples, see Keith Knapp and H.J. Vaux, "Barriers to Effective Ground-Water Management: The California *Case," Ground* Water 20 (January-February 1982): 61-66; and Mallery, pp. 1279-1307.

[80] Knapp and Vaux, p. 61.

[81] Mallery, p. 1286.

[82] Ibid., p. 1281; Knapp and Vaux, p. 61.

[83] Ibid.

[84] Ibid., p. 1298 (emphasis added).

[85] Knapp and Vaux, p. 61.

[86] Albert J. Lipson, *Efficient Wafer Use in California: The Evolution* of *Groundwater Management in Southern California* (Santa Monica: RAND Corporation, 1978), p. 1.

[87] Elizabeth Rolph, *Government Allocation of Property Rights: Why and How* (Santa Monica: RAND Corporation, 1982), p. 16.

[88] Lipson, p. 18.

[89] Helen J. Peters, "Ground Water Management in California." Presented at the American Society of Civil Engineers Conference, Las Vegas, April 1982, p. 11.

[90] peters, "Groundwater Management in California," p. 3 (emphasis added).

[91] Phelps et al., p. 2.

[92] Lipson, p. 21.

[93] UINTEX Report to the Los Angeles District Office of the U.S. Army Corps of Engineers on the Los Angeles County Drainage Area, 1985, p. II-39.

[94] Institute of public Administration, *Special Districts and Public Authorities in Public Works* Provision (Washington, DC: National Council on public Works Improvement, 1987), pp. 66-67. Unpublished.

[95] Mallery, p. 1291.

[96] Lipson, p. 9.

[97] Phelps et al., p. 21.

98 The provision-production distinction may be found in ACIR, *The Organization of Local Public Economies.*

[99] More extensive descriptions of the geology and history of this area can be found in several sources, including Wiiam Blomquist, *The Performance of Institutions for Groundwater Management, Volume 2:* The West *Coast* Basin, *and Volume 3: The Central Basin* (Bloomington: Indiana University, Workshop in Political Theory and Policy Analysis, 1988).

[100] Jaquette and Moore, p. 37.

[101] Harold Rubin, *The Solano Water* Story (Vacaville, California: Solano Irrigation District, 1988).

[102] California Department of Water Resources, *Recommended Water Management Plan for Solano County Flood Control and Water Conservation District* (Sacrament@, 1982), p. II-1.

[103] Association of California Water Agencies, *ACWA's 75-Year History* (Sacramento, 1985), p. 18.

104 John S. Murk Engineers, *Final Local Water Management Alternatives: Newberry Groundwater Basin* (Victorville, California: Mojave Water Agency, 1984), p. III-14.

105 Nunn, p. 252.

106 Ibid., pp, 14-16.

107 Ibid., pp. 252-253.

108 Micha Gisser, "Groundwater: Focusing on the Real Issue," *Journal* of Political Economy 91 (December 1983): 1021.

109 National Water Commission, p. 232.

110 Gisser, p. 1012.

111 Ibid., p. 1013.

112 Ibid., p. 1014.

113 Ibid., p. 1024.

114 Ibid .pp. 1024-1025; and Douglas Grant, "The Complexities of Managing Hydrologically Connected Surface Water and Groundwater Under the Appropriation Doctrine," *Land and Water* Law Review 22 (1987): 88-89.

115 City of Albuquerque v. Reynolds, 379 P.2d 73 (1963).

116 John S. Murk Engineers, p. III-14.

117 Nunn, p. 253.

118 Ibid.

119 Gisser, p. 1014.

120 Grant, p. 89.

121 Cache LaPoudre Water Users Association v. Glacier View Meadows, 550 P.2d 288 (1976).

122 Clark, p. xiv.

123 National Water Commission, p. 245; Banks, p. 564.

124 Smith, "Federal Intervention in the Management of Groundwater Resources," p. 153.

125 Morton Bittinger, "Survey of Interstate and International Aquifer Problems," *Ground Water* 10 (March-April 1972): 44-54, identified 198 interstate and/or international aquifers as actual or potential problem areas, of which almost 60 were described as "major." This study and its results were still being cited in the 1980s as evidence of the extent and degree of severity of interstate groundwater management problems (see, for example, Banks; and Smith, "Federal Intervention in the Management of Groundwater Resources").

Reliance on this survey should be kept in perspective, however, if not forgone altogether, in making such characterizations. Among its difficulties are: (a) aquifer problems were classified as to degree of severity by the most severe ranking given to that problem by any observer (e.g., a problem was classified as "major" if anyone responding to the survey described it as "major"), thus biasing the results toward the most severe characterizations, and (b) almost half of the problems classified as "major" were described as such by one anonymous observer from a university, who happened to rank as "major" every interstate or international problem he or she identified. Rather than assuming that interstate and international groundwater management problems must be even worse now than they were then, analysts and policymakers should recognize that problems may not have been that bad then, and that no better survey has been done since.

126 Smith, "Federal Intervention in the Management of Groundwater Resources, pp. 157-158. See also Larry Feazell, "Interstate Water Agencies," *The* Book of *the States*, 1986-87 Edition (Lexington, Kentucky: Council of State Governments, 1986), pp. 420-423.

127 Ibid, and National Water Commission, p. 245, both of which recommend interstate compacts or other forms of interstate agreements, such as administrative agreements or reciprocal legislation.

128 National Water Commission, p. 245.

129 Smith, "Federal Intervention in the Management of Groundwater Resources," p. 158.

130 Gisser, p. 1012.

131 Ibid.

132 Banks, p. 564.

133 David Noonan, Myron Rosenberg, and Duncan Wood, "Constraints to Managing Interstate Aquifer," *Journal of Water Resource Planning and Management* 110 (April 1984): 191.

134 Ibid., pp. 194-198.

135 Ibid., p. 202.

136 Ibid., pp. 198 and 204.

137 Ibid., p. 199.

138 See, for example, Nancy Humphrey and Christopher Walker, *Innovative* State *Approaches* to Community Water Supply Problems (Washington, DC: The Urban Institute, 1985), p. vi. For a discussion of the "coordination costs" concept, *see* ACIR, *The Organization* of *Local Public Economies*, p. 11.

139 James H. Krieger and Harvey 0. Banks, "Ground Water Basin Management," *California Law Review* 50 (Winter 1962): 57.

144 Thomas Stetson, "Main San Gabriel Basin Ground Water Management." Presented at the 82nd Annual Meeting of the Cordieran Section of the Geological Survey of America. In Prem K. Saint, ed., *Hydrogeology of Sou thern California: Volume* and *Guidebook* (Los Angeles: Geological Society of America, 1986), p. 9.

141 Ibid.

142 Wade Miller Associates, *The Nation's Public Works: Report* on Water Supply (Washington, DC: National Council on Public Works Improvement, 1987), p. 48.

143 Ibid.; Frank Welsh, *How to Create a Water Crisis* (Boulder: Johnson Books, 1985), p. 35; and James Crews, "Regional Versus Local Water Supply Planning" *Journal of Water Resources Planning and Management 109* (April 1983): 179-185.

144 Crews, p. 180.

145 Welsh, p. 35; Wade Miller Associates, p. 116.

146 Ibid., p. 48.

147 Welsh, p. 35.

148 crews, p. 185.

149 There have been numerous descriptions of the Los Angeles-Owens Valley-Mono Lake water disputes, some of which are summarized in Blomquist, *The San Fernando Valley*.

150 "Coming to Terms: A Proposed Agreement for the Owens Valley Dispute," Water *Strategist 3* (July *1989).*

151 Kevin Roderick, Water Rights Pact with L.A. Wins Approval in Inyo County," Los *Angeles Times,* August 16, 1989.

152 Virginia Ellis, "L.A. Backs Legislative Plan to Cut Use of Mono Water," Los *Angeles Times,* August 11, 1989, and "MWD May Back Bill on Mono Lake Water Dispute," *Los Angeles Times,* August 17, 1989.

153 "Coming to Terms," p. 13.

154 Schmandt et al., p. 22.

155 Marvin Bond, Jimmy Palmer, and Charles Branch, "Recent Experiences with Water Legislation in Mississippi," *Public Administration Survey* 35 (Autumn 1987-Winter 1988): 1-5.

156 Schilling et al., p. 176.

157 "Annual Legislative Review," *Water* Strategist 2 (October 1988) and 3 (October 1989).

158 Water Supply," *From fhe State Capitals* 43 (January 1989): 4.

159 "Annual Legislative Review," *Wafer Strategist* 3 (October 1989).

160 Morton Bittinger, "Ground-Water Surface-Water Conflicts," ASCE journal of Wafer Resources Planning *and Management* 106 (July 1980): 473; Leshy and Belanger, pp. 727-728.

161 P. Lorenz Sutherland and John Knapp, "The Impacts of Limited Water: A Colorado Case Study," *Journal of Soil and Water Conservation* 43 (July-August 1988): 295.

162 Ibid., pp. 295-297. It is important not to overlook the fact that, in arid regions, the transfer of water away from use on agricultural land can, if abandonment of the agricultural land ensues, result in considerable soil erosion effects. This has occurred in sections of the Arkansas River Valley in southeastern Colorado. In response, Colorado water courts have begun conditioning their approval of water rights transfers on commitments to the revegetation of the land from which the water rights are being transferred.

163 Schiiing et al., pp. ix and 133.

164 Gary Weatherford et *al., Acquiring Wafer/or* Energy: *Institutional Aspects* (Littleton, Colorado: Water Resources Publications, 1982), p. 14.

165 Early discussions of this planning appear in California Department of Water Resources, Bulletin 118, pp. 127-128. See also Weatherford et al.; and California Department of Water Resources, *California Wafer: Looking to the Future.* Bulletin 160-87 (Sacramento, 1987), pp. 47-48.

166 Humphrey and Walker, p. 36.

167 Ibid., p. 67.

168 Schilling et al., pp. 133-134; Humphrey and Walker, pp. 9-10.

169 Schiimg et al., pp. x-xi; Schmandt et al., p. 12.

170 Humphrey and Walker, pp. 23-35.

171 Ibid., p. 84

172 Schilling et al., p. 134.

173 Corbridge, p. 9.

174 See, for example, the description of the activities of the Upper Republican Natural Resources District in Sporhase v. Nebraska, 458 U.S. 941 (1982), 955.

175 Schmandt et al., p. 88.

176 Ibid., pp. 90-91.

177 Wade Miller Associates, p. 9.

178 Wiiam S. Foster, Wastewater Reuse Protects Kissimmee Water Resources," *American City and County 102* (June 1987): 46.

179 Schmandt et al., p. 12.

180 Jacque Emel, "Effectiveness and Equity of Groundwater Management Methods in the Western United States." Working Paper 3 (Tempe: Arizona State University, Center for Environmental Studies, 1984), p. 33.

181 Lampe, p. 40.

182 Humphrey and Walker, p. 68.

183 National Water Commission, p. 234.

184 Clark, p. 422.

185 Banks, p. 575.

186 Ibid.

# Understanding the Organization of Water Resource Management

In previous chapters we have pointed out **that** there are different types of water management problems throughout the United States, several elements to effective groundwater management, several types of institutional arrangements for managing water resources (including managing groundwater supplies conjunctively with surface water), and a wide diversity of interjurisdictional arrangements being used. Conjunctive management is organized neither as an ideal legal-rational centralized administration nor as a perfectly competitive market

When analysts begin with a conceptual ideal, they are bound to find actual patterns of intergovernmental and public-private relationships to be deficient If, for example, the ideal is the perfectly competitive market, analysts finding governmental involvement of any sort in decisionmaking about resource use will describe the situation as "politicized" and therefore "inefficient" Other analysts proceed "from a belief that a system of government composed of numerous, independent, specialized units of government is necessarily fragmented and ineffective,"' in which case their descriptions of multiple actors in a noncentralized system will be followed by a prescription for centralization of authority.

But there are additional possibilities for analysis of intergovernmental relations. There is a tradition of thought based on the idea that an understanding of existing arrangements is an important prerequisite to prescriptions for reform. That view, which informs recent work on metropolitan area governmental organization,[2] suggests that analysts "begin to search for *the nature of the order which exists* in the complex of relationships among governmental units and abandon the assumption that all of these relationships are unique or random."[3] Description of "the nature of the order which exists" and "an analysis of how the system works"[4] can be followed by discussion of shortcomings and recommendations for improvements The ultimate evaluation of the performance of public officials and governmental structures is left to citizens

Observers who despair of the organization of gmundwater management may simply lack an organizing concept with which to look at it Instead of measuring current arrangements against ideal types, "What is needed is the ability to compare and contrast very diverse sets of water management institutions."[5] To help understand the roles and relationships of the diverse organizations involved in gmundwater management, we use the concept of a complex and regulated water economy The idea of a complex water economy, composed of providers, producers, importers, wholesalers, retailers, and regulators can help to organize observation of the intergovernmental relations of groundwater management so that the kinds of coordination that do occur can be seen

## A Complex Water Economy

The largest element in the complex water economy is the water supply industry, which consists of publicly and privately owned systems of varying organizational forms and sizes. It is "composed of a very large number of highly independent federal, state, and local governmental agencies operating side by side with large numbers of private utility companies, co-operative associations, and individual proprietorships,"[6] and "characterized by a long history of self-sufficiency and local government control over management and finances"' According to a recent description of intergovernmental relations in water resource management:

> These patterns of intergovernmental relations, in turn, take on the characteristics of industry structures. Different agencies ranging from local suburban water districts to municipal water departments, for example, may function as retail agencies serving the ulti-

mate consumer of water services. But such water distributors may be supplied by intermediate water agencies such as county water authorities or metropolitan water districts that operate large-scale diversion works, aqueducts, and reservoirs to produce water for domestic, urban, and industrial uses. These agencies in turn work with the large-scale water development agencies of the state and Federal governments Together their coordinated efforts might be viewed as a water industry.. . .[8]

Other recent reports have compiled and presented detailed information about the industry that provides a picture of the composition and organization of water supply provision and production.[9]

There are more than 200,000 water systems serving the public. Of these, 58,530 (about 29 percent) are community water systems that serve primarily residential areas with a population of some 219 million. The other 71 percent, or 144,800 public water systems, are noncommunity systems that serve primarily nonresident or transient populations of 36 million persons (parks and campgrounds, resort areas, hotels and restaurants, etc.)[10]

The water supply industry uses both surface and groundwater sources. As would be expected, reliance on these sources differs according to their characteristics and geographic distribution. Noncommunity water systems are more often reliant on groundwater (96 percent of them use underground supplies)" because these systems generally depend on water that is available at or very near the point of use and do not make large-scale investments in impoundment and transmission facilities. Groundwater also is the primary or only source of water for 80 percent of community water systems. These tend to be smaller systems that serve approximately 30 percent of the population that uses community water systems. The other 20 percent of community water systems rely on surface water supplies and tend to be larger, serving 70 percent of the population."

Ownership, organization, and size of community water systems vary greatly There are 26,424 publicly owned systems (45 percent). Of these, roughly 15,000 were municipalities directly providing water, according to the 1982 Census of Governments.[13] Other publicly owned systems were public authorities and special districts. There are also about 15,740 privately owned systems serving municipal communities, plus systems owned by and operated for small communities such as homeowners' associations, mobile home parks, and the like.[14]

Publicly owned community water systems include local government water departments as well as autonomous and semi-autonomous providers Among smaller systems, the more frequently encountered organizational form is the local water supply department Among the larger community water systems, more autonomous organizational forms are found, including special districts, water authorities, and state-chartered public corporations.[15]

Privately owned community water systems also vary in organization. They include mutual companies owned by their customers, private proprietorships, and investor-owned utilities. The larger the population served by a privately owned system, the more likely it is to be an investor-owned utility?

Most community Water systems are small, serving fewer than 3,000 people each. The number of systems classified as "very large" (i.e., serving 100,000 or more people) is 279, about 0.5 percent of all the community water systems. Thus, almost two-thirds (63.9 percent) of the nation's community water systems serve a combined total of about 3 percent of the population, while 36 percent of the systems serve the other 97 percent of the population. The largest 0.5 percent of the systems serve over 43 percent of the population.[17] Combining the number of "large" (10,000-100,000 people) and "very large" systems, the majority of the nation's population is served by approximately 3,000 community water systems, which in turn vary by supply source, form of ownership, form of organization, and size.

The existence of more than 50,000 community water systems, and the involvement of more than 25,000 local governments in one aspect or another of supply'* may still seem difficult to understand, especially if the observer presumes that water supply involves only one type of activity But the hundreds of thousands of water supply organizations do not all perform the same function.

Within the complex water economy, there exists an important distinction between the provision and the production of a service or commodity.[19] Provision involves the decisions concerning the amount and quality that will be provided, thecosts, and how the costs will be distributed among users-in sum, the decisions translating preferences for the service or commodity into demand. Production involves the decisions for acquiring and mixing production inputs in order to generate production outputs (services or commodities).

Provision and production decisions may be made and executed by the same or different organizations. An organization may provide services or commodities that it does not produce. For example, a general local government or a special district may provide water to residents by acquiring all or part of the water from a supply that is produced by some other entity The municipal water districts in the Los Angeles County case described in Chapter 3 are examples of provider organizations purchasing water from much larger producers, such as the metropolitan water district, the California Department of Water Resources, and the county sanitation districts.

The complex water economy may involve thousands, even hundreds of thousands, of organizations and relationships, yet not be beyond comprehension. Some organizations are providers of water, others are producers of water supply, others may be both, and there are many provider-producer relationships.

Overlaid on the provider-producer distinction is the difference in an economy between importers, wholesalers, and retailers. These functional differentiations and relationships are not surprising when found in other sectors of the economy, and should not be surprising in the water economy Some organizations import supplies to areas where water is in sufficient demand. Others function as wholesalers, providing water supplies to more than one retail client organization. The retailers distribute water directly to users. Some wholesalers may be producers as well as providers; others may be providers only, purchasing (for example) imported water and distributing it among retailers. Similarly, water retailers may directly produce the supplies they sell, or purchase water from wholesalers and deliver it to residents, or some mix of these methods.

Regulatory functions (to oversee the operation of water suppliers and ensure safety to users) may be performed by other organizations. In fact, throughout various sectors of the United States economy,theseparation of regulation from production and provision has been the arrangement of choice-quasi-independent and independent regulatory agencies and commissions, and local, state, and federal legislative bodies and committees typically review and mandate the safety of services and commodities. The entire concept of the "regulated utility" is based on the idea of the separation of regulation from production and provision.

If one looks at "water resource management" as one task, then the number and degree of specialization of provision units and regulators is likely to appear as "duplication" and "fragmentation," with several units "each dealing with a part of *the problem*."[20] On the other hand, if one acknowledges that "water resource management" consists of several functional aspects, then one may anticipate some functional differentiation in its organization.

Of the special local governments identified by the 1982 Census of Governments as engaged in one or more aspects of "water resource management," 85 percent were single-function districts.[21] These districts engaged variously in the provision of ports, drainage, irrigation, flood control, water and land reclamation, wastewater treatment and sewage disposal, and water supply. At one level of analysis, these functions are all part of "water resource management"; at another level, they are distinct Having different functions performed by different specialists is a notion that is neither alien to many sectors of the U.S. economy nor necessarily inappropriate to the water sector

Similarly, different entities may perform different regulatory functions. Overseeing the costs and the adequacy of water supply calls for different information and expertise than overseeing and regulating water quality. Some communities may choose one regulatory organization; others may choose more than one.

When the organizing concept of a complex water economy, composed of providers and producers, importers, wholesalers, retailers, and regulators, is applied to the management of water supplies, patterns of organizational development and interorganizational relationships begin to emerge. It is, in fact, an organizing concept without which much of the activity involved in the provision and production of all kinds of services and commodities would be nearly incomprehensible.

The complex water economy concept, in particular, may help us understand the apparent paradox of a large number of small water suppliers in an industry characterized by many observers as involving large economies of scale. Since most of the larger community systems have relied primarily on surface water, many analyses have been based, understandably, on the scale economies present in surface water supply The capture, impoundment, and distribution of surface water involve large capital investments in physical facilities (distribution systems, and dams and reservoirs in many cases), facilities to exploit opportunities for low-cost hydroelectric power generation, and facilities to ensure the protection of aquatic life (e.g., fish ladders).

Some local communities and private water suppliers have made investments in developing surface water supplies, including the construction and operation of water projects. But many other surface water projects have required the scale of a watershed, which contains several communities In some cases, regional special districts have been created to finance and build surface water projects, to obtain funds from several communities that stood to benefit, and to organize and implement the project on the appropriate scale. In several cases, states have designed and constructed surface water projects. Still other large-scale surface water projects have been financed and built by the federal government

The participation of the United States has usually been justified on one or both of two grounds: first, that the project, while needed for a particular community or region, was beyond the financial resources of local, regional, or statewide public and private entities, and second, that benefits from economic development or avoidance of natural disaster would inure to the nation as a whole.[22] The second rationale in particular supported the passage of the *Reclamation Act of* 1902 and the creation of the Bureau of Reclamation and the Reclamation Fund to finance and build water projects in the western states.

It is typically with attention to this one aspect of water supply-construction of a surface water project -that observers have noted economies of scale. Surface water projects with different scales of production and of benefits have been undertaken by different producers, and several of the largest projects have been undertaken by the federal government

However, construction and operation of a surface water project are two different functions. Throughout the western states, for example, while Bureau of Reclamation projects have generated more surface water storage capacity than U.S. Army Corps of Engineers projects, the Corps has developed its expertise primarily in the operation of projects for flood control and, in several cases, the Corps may use bureau projects for the storage and release of flood flows to minimize flood damages.[23] Furthermore, the bureau has turned over the operation of its projects to irrigation districts or other special local governments that represent the users,[24] as is the case with the Solano Project described in Chapter 3.

The use of project water is also subject to decisionmaking that may be appropriately organized on a scale other than that of the construction of the project, or even itsoperation. Water provision decisions (how much water of what quality to acquire at what times and for what cost) depend on a number of factors that tend to be local.

Therefore, a number of communities of interest may exist within the service area of a large-scale surface water project If they can organize representative collective entities-associations, municipalities, special water districts-that can bargain and contract with a large-scale producer or operator, the water project operator may wholesale water to communities needing different amounts at different times, and the communities may function as retailers or users' cooperatives. These arrangements can allow for greater flexibility and efficiency in water pricing. Project water prices may be varied according to use patterns, so that demands for peak-period uses may be priced higher, and off-peak surplus deliveries for storage may be priced lower. Organizations can then make decisions about use and delivery in response to the incentives signaled by pricing practices.

This concept of competition among entities representing local water users runs counter to organizational integration models, and will appear to some analysts to be "fragmentation" of decisionmaking, with "local parochial interests" being pursued at the sacrifice of "the general good" of the watershed. Nonetheless, this is how the complex water economy operates, and this form of organization carries possibilities for efficient and equitable resource management

This form of organization also provides opportunities for adapting to change. There is a consensus in the literature that the day of the large-scale surface water resource development project is either passing or gone. The emphasis now is, and is likely to remain, on improved management of existing water supplies rather than increasing yields through structural development?5

If the focus of water management shifts to the demand side of the supply equation, then an economy in which relatively large numbers of smaller local agencies compete for resources may have benefits that are yet to be fully realized. The efficient and equitable allocation of any scarce resource requires (indeed, presumes) the availability of full information about the preferences of potential claimants. While a perfectly competitive market in water supplies does not exist,some benefits of competition may be gained if users are required to reveal their preferences and confront more nearly the real value of those supplies, rather than seeking to acquire abundant water for local use by persuading a larger jurisdiction to construct a water project for their benefit Pursuing these benefits through limited interlocal competition has been advocated for more than 30 years,[26] but their realization depends on the existence of multiple water-users' enterprises.

Another consequence of the shift away from surface water development projects to meet future needs is the increasing reliance on groundwater supplies. Groundwater supplies tend to be relied on more often by smaller community systems and by noncommunity systems Groundwater development has resulted in the proliferation of special water districts that overlie basins Irrigation districts and conservation districts have been especially plentiful.

As more surface water supplies were developed, and then as the emphasis shifted from development to management, many of these groundwater supply organizations began to take on conjunctive management functions. Groundwater districts and associations have contracted with surface water project operators for supplies, acquired authority to recharge underground water storage capacity with surplus surface flows, and in some cases acquired authority to tax or limit groundwater withdrawals?'

Several watersheds contain multiple groundwater basins. If jurisdictions representing users are empowered to engage in conjunctive management and to contract with surface water suppliers, then opportunities may exist to reap benefits from both competition and conjunctive management. Competition and bargaining can result in pricing practices that more nearly reflect the value of water to users

This not only improves the efficiency of allocation by directing water toward its higher valued uses but also induces water users to conserve, reducing the need for additional supplies. At the same time,conjunctive management exploits the advantages of groundwater basins more fully. This combination of effects can mean that surface water supplies are directed toward higher valued uses while groundwater basins are also more often employed for their higher valued uses as reliable, low-cost reservoirs

In some groundwater basins, where existing enterprises and agencies lacked the power or the jurisdictional boundaries (or both) to engage in conjunctive management,new agencies have been created to provide replenishment and water storage services while spreading the costs among all users in proportion to the benefits obtained. Special water districts have been an especially active part of the complex water economy.

## THE ROLE OF SPECIAL WATER DISTRICTS

Water districts are among the most numerous special-purpose local governments The 1982 Census of Governments recorded approximately 9,400 special districts providing one or more water management services, of which the overwhelming majority performed a single function. About 1,000 special water districts are engaged in supply provision, and 95 percent of these are located in the western states.[28] Most of these are irrigation districts, supplying water to lands that are not within the jurisdiction of a municipality. Special districts (1) distribute about half of the water used in the West, where most of the developed water supply is devoted to irrigated agriculture,[29] (2) constitute 9 percent of all organizations delivering water but account for 47 percent of the irrigated acreage (nearly all the remaining acreage was irrigated with water supplied by mutual water companies),[30] and (3) range in size from the enormous (covering several counties and delivering millions of acre-feet of water per year) to the tiny (formed by a few dozen residents to pump and distribute water from a couple of wells).

The development of special water districts has been encouraged to varying degrees by the states. Generally, states have been permissive in allowing the creation of special districts under general acts, on the satisfaction of certain conditions designed to establish the desire of the local residents to form a district.[31] In **recent** decades, some state laws have become more restrictive, and the degree of state control over the formation of special districts of all kinds varies considerably.

In the past, California has been the most liberal in the creation of water districts, with 38 general acts establishing water districts of different kinds with different powers, and 100 special acts, each of which creates a single district for a specified area.[32] California contains approximately 1,000 of all types of local water districts engaged in all types of functions.[33] In Arizona, special water districts are created by general law or special legislation. Arizona provides for four types of special water districts in addition to those for flood control and soil conservation.[34] New Mexico provides for different types of special water districts, such as conservancy districts, and some districts are authorized to choose among alternative methods for voting and representation and for generating revenue.% Nebraska and Florida have added the creation of regional "super districts," which are multipurpose agencies under the supervision of the state.[36]

The Congress also contributed to the growth in the number of special water districts, designating them as the contacts and contractors for federal water projects and programs during the first three decades of this century? In 1926, the Congress amended the 1902 Reclamation *Act* to require local participation through special water districts

**Water districts are subject to the same criticisms and challenges as are special district governments generally.** In 1964, the U.S Advisory Commission on Intergovernmental Relations published a report entitled *The Problem of Special Districts in American Government*.[38] The "problem" language that has been applied to special districts of all kinds is extended to water districts

Special districts are at the heart of the criticisms of the structure of American government The creation of special water districts, especially basinwide in areas where communities within the basin also have districts, "results in layers of districts and a patchwork of authority over water in the same area," according to a recent publication of the Institute of Public Administration.[39] Similar language can be found in other reports.[40]

Water districts, like special districts generally, are criticized as an additional expense for citizens, as district boards and managers attempt to maximize their budgets and staffs in pursuit of their own professional career goals Yet, the 1982 Census of Governments reported that, of the 9,400 special diicts it identified as engaged in water supply and management services, only 350 (4 percent) were classified as having "major financial activity; meaning at least $3 million in annual expenditures or $10 million in outstanding debt This 4 percent accounted for 75 percent of the expenditures of all special water districts.[41] Among all types of special districts, about two-thirds had less than one full-time equivalent employee; about 6 percent had 20 or more full-time employees42

Special water districts may be reluctant to participate in cooperative ventures that involve the use of groundwater storage space by state agencies or other districts, even though it may be an advantageous use of the basin Districts tend to feel that they owe their first consideration to their residents and that storage programs involving "outsiders" may compromise those interests This reluctance can be overcome, however, if the anticipated benefits from conjunctive management are shared with the district and the local residents.[43]

Another criticism of special water districts is that their voting and representation procedures can be undemocratic. The boards of directors are often relatively stable and, depending on the legislation that created the district, there may be no need even to conduct uncontested elections. But it becomes difficult to sort out the extent to which governing board stability and uncontested elections indicate citizen satisfaction versus lack of understanding and engagement As one observer noted, special water districts and their functions may not be well understood by citizens, yet a certain "lack of public understanding" extends to the whole specialized field of water law and administration. The 1980 Arizona Groundwater Management Act, for instance, is so complex that few people understand how it works; the public is aware only that there is a law.[44] Other measures can be used to determine how citizens evaluate special district officials (e.g., do they tend to support or oppose the creation of additional districts when presented with the choice). Survey research can ask citizens to offer evaluations aside from the electoral process."

In some places, voting for the board of a special water district is based on land ownership rather than on one vote per person. Although the constitutional validity of such voting schemes has been upheld in districts that provide water for irrigation, this practice continues to be criticized, especially in the few cases where one landowner controls a majority of the votes in the district. The district then becomes a modern manorial system in which the largest landholder may tax the property or assess the water use of smaller landowners in order to provide water services that inure mostly to the controlling landowner's benefit?

As the Institute of Public Administration acknowledged, the advantages of special water districts appear primarily by comparison with local governments. Districts have the jurisdictional flexibility to cross other governmental boundaries, cover unincorporated areas, and embrace a natural resource boundary or a community of resource users.[47]

Special districts create greater opportunities for developing revenue and pricing systems that (a) link the imposition of costs to the distribution of benefits, (b) provide incentives for efficient mix and use of services, and (c) can make the district and its activities self-financing? Special districts often can, and often do, employ user fees and service charges This is a more effective linkage of costs to benefits than are more indirect mechanisms, such as the income tax or the property tax.

While ideal-theoretical economic efficiency would result from pricing policies that reflect both the cost of services and the social costs of those services in other opportunities forgone, a move toward pricing that reflects the full cost of provision would be a move in the direction of greater efficiency Implementing full-cost pricing-which was the principal recommendation made in the report on water supply for the National Council on Public Works Improvement in 1987—was deemed to require some degree of fiscal autonomy The special water district is the most frequently encountered type of autonomous organizational form. Other types are enterprise fund accounting systems and state-chartered corporations."

When water supply and management functions are commingled with other general government functions, two sources of inefficiencies arise. Decisionmaking involves multiple claims on officials' attention, and water decisions compete with everything from public assistance to pothole repair. Financing water supply also becomes commingled in most cases with other services and infrastructure needs. The water enterprise can end up being tapped as a source of revenue for other programs and projects (water subsidizes other services) or vice versa. Both situations generate inefficient pricing signals to consumers and inefficient levels of investment "The endemic condition which results from commingled decisionmaking is one of 'public choice failure.'"[50] While there are no guarantees that separate, self-sustaining special water districts will make optimal investment and pricing decisions, at least the institutional barriers that result from commingled decisionmaking are removed.

Another advantage of the special water district is that users relate to it and use it for innovations, rules, and conservation measures they might be reluctant to accept from a municipality or a jurisdictionally larger government (e.g., state or federal government). For example, the Soil Conservation Service of the U.S. Department of Agriculture has been engaged in an experimental program with a nonprofit research organization, INFORM, and local conservation districts to encourage soil-moisture monitoring using gypsum blocks in California's Sacramento and San Joaquin Valleys. The program increased farmers' yields while reducing their consumption of water and energy inputs. This lowered farmers' costs and increased their incomes with a program that conserves water by improving the efficiency of irrigation timing and amounts. Such a program could reduce aquifer depletion and related problems where irrigated agriculture accounts for most of the consumptive use of water The conservation district "is a natural home for an educational program about the gypsum block method of irrigation management because a district enjoys the trust of local farmers as well as the support of technicians and government officials."[51]

Properly empowered, special water districts provide a framework for making water supply and management decisions removed from the arrangements for other services. A district also provides a link to the state, region, and nation, and may serve as a representative or bargaining entity. While water rights statutes can be produced by legislative bodies, conflicts decided by courts, and regulations promulgated and implemented by administrative agencies,"it appears to have been the experience.. . that some form of publicdistrictserves anirreplaceable function."[52]

### PRIVATE SUPPLIERS IN THE WATER ECONOMY

Private suppliers play a significant role in the complex water economy Nearly 40 million citizens are served by privately owned community water systems. Smaller private systems generally serve residential developments and mobile home parks, and are usually owned by developers or homeowners' associations. Larger suppliers more often are investor-owned utilities regulated by general governments or by state public utility commissions.% The number of investor-owned systems is increasing as the Population of the United States has grown fastest in areas that have a history of using that mechanism such as Florida, Arizona, and California.

The range of private sector activity is broad. It includes supplying water for municipal and indus trial uses and for irrigation,[54] and, where markets for water rights are developing in the West, functioning as brokers who link purchasers with available water rights.[55] Private involvement does not always replace public involvement While private water enterprises are growing in number and size in some areas, in other places (especially in some growing suburban areas) private suppliers have been taken over by condemnation or purchased by municipalities.[55]

There has been some discussion and debate over the propriety of privatization in the water economy. Advocates cite advantages in flexibility and responsiveness, lower costs, and more efficient pricing practices Those who are critical or skeptical of privatization cite the broader availability of service without regard to ability to pay that comes from public provision, and the advantages of more direct political accountability. As concluded in a 1987 report to the National Council on Public Works Improvement, "Both philosophies merit consideration, but in certain circumstances privatization does offer real economic gains."[57] Private and public sector involvement exist alongside each other. Neither exists as a complete answer to water supply and management challenges Private suppliers, financing, and brokering provide additional alternatives for citizen choice.

### THE ROLE OF ASSOCIATIONS

Associations of water users, officials, and professionals have played important roles in facilitating effective water management These roles generally fit two broad categories: (a) mobilizing and organizing members in support of management initiatives, and (b) providing forums for communication and disseminating information and technical assistance

Policy initiatives and coordination are sometimes facilitated by associations of public officials, such as the Great Lakes Conference,an association of the governors of the eight Great Lakes states Another is the recently formed Upper Missouri River Basin Governors' Association, composed of the governors of North Dakota, South Dakota,Montana, and Wyoming, which will provide a regular forum for the discussion of water development, watershed construction, irrigation, and other issues.[58]

Water quality management has been facilitated by the American Water Works Association, which publishes ik monthly *AWWA Journal* and holds national and regional conferences, and the Association of State and Interstate Water Pollution Control Administrators, which has organized conferences devoted specifically to innovations in management and groundwater quality protection.

Associations can be especially important to smaller water systems that do not have large enough staffs to include a broad range of professional expertise. The National Rural Water Association (NRWA), for instance, offers technical assistance in 34 states A program begun by the Oklahoma Rural WaterAssociation has been adopted by NRWA to help smaller systems retain their local organization and integrity while complying with federal safe drinking water requirements. Among the services provided by the national program are: one-day training sessions in rural areas; on-site technical assistance; monthly or quarterly newsletters with information and advice on compliance with federal requirements; and emergency field assistance to systems expressing difficulties The association program features contact with small water systems throughout each state and a full-time "circuit rider" who travels the state to provide assistance.*

Associations of water users have played important roles in groundwater management and often have been forerunners of conjunctive management programs. Such associations frequently establish a broad-based forum for the discussion of water issues by industrial users who produce their own water, municipal and private suppliers, citizens concerned about environmental quality, and others Such associations have appeared throughout the county and can be the first step toward the development of effective water management plans, programs, and institutions

In Colorado, the South Platte Water Users' Association helped develop means for coordinating the use of surface and groundwater supplies. The role of water users' associations in developing conjunctive use programs in southern California was summarized by a 1978 RAND Corporation report as follows:

> Local producers organized themselves into water user associations that were the driving force behind not only the design of management plans but also efforts to garner support for their acceptance and to create institutional arrangements and management tools to implement them. They pushed for creation of local water districts to import water and aided the process of arriving at negotiated settlements through the courts. They promoted state legislation to permit organization of [replenishment districts] and to require recordation of pumping.[60]

In the Tucson metropolitan area, which is entirely dependent on groundwater supplies, the Southern Arizona Water Resources Association has played a pivotal role. Originally formed as a broad-based local interest group to ensure that Central Arizona Project water would be brought to Tucson, the association subsequently provided a vehicle for study, discussion, and development of responses to groundwater declines and quality problems, which engaged the whole community. The association initiated a management study in 1983 to determine the institutional mechanisms that would help bring about a balance of water supply and demand in the Tucson basin. Although the Tucson area had been designated an active management area under the Arizona Groundwater Management Act, there were no staff resources to conduct such a study, or any broad community membership to support such a study and act on the results. The association also was instrumental in supporting a water-conservation program that has received nationwide attention for bringing percapita water use in Tucson down to 150 gallons per day.[61]

## ADJUDICATIONS AND THE RIGHTS OF PROVIDERS AND PRODUCERS

Courts have been active in water rights and water allocation for centuries. Courts in all states become the arbiters of water rights laws and conflicts." Lawsuits have been customary means of asserting and protecting rights to the use of water.[63] Lawsuits between surface stream users -particularly by downstream users against upstream users – have a longer history in most places than those between groundwater users This reflects the fact that surface water development preceded groundwater development Adjudications of groundwater rights nonetheless go back more than one hundred years.

In several cases, adjudications have been expanded to include all of the pumpers drawing water from a common aquifer system. These basinwide adjudications have drawn considerable criticism, and have been described as "lengthy, cumbersome, and expensive."@ Court decisions over the allocation of rights have differed from basin to basin, and thus have been criticized as lacking a uniformity on which water users could base their decisions.

Courtshavebeen criticized for producing "at best . . , piecemeal problem solving."[65] The decision "of one court as to the best, most pragmatic solution may not be the most efficient management solution."" Further, courts take into consideration only the rights and interests of the parties before them, which may not be the full set of persons affected by the outcome. Finally, experience has shown that basinwide adjudications generally have been initiated "only after the ground water basins were in real trouble."[67]

Despite these criticisms, groundwater users have continued to employ courts and basinwide adjudications. Groundwater users may compare the costs, defects, and potential outcomes of the judicial process with those of other public decision-making processes and find the judicial process preferable or at least less undesirable.

There is no gainsaying that basinwide determinations of rights through adjudication are usually "lengthy, cumbersome, and expensive." However, when users need to resolve problems resulting from joint use of a common water supply, their choice is between a "lengthy, cumbersome, and expensive" but authoritative legal proceeding and a long, difficult, and uncertain legislative or administrative process There is no immediate, simple, and cost-free alternative. While the rules of civil procedure in the courts may be complicated, they do not necessarily compare unfavorably with, say, *the Administrative Procedures Act* (or its equivalent in a given state) or the legislative process.[68] Similarly, while it is true that court decisions are not necessarily the most efficient management solutions to the problems of joint use of a groundwater basin,[69] legislative or administrative decisionmaking about groundwater rights may show a greater tendency toward inefficiencies because of the mismatches between jurisdictional boundaries and those of the affected communities.

Similar analysis applies to other criticisms of adjudications. The procedural rules of courts are designed to limit those involved to "real parties in interest" They do not guarantee that all concerned parties will be found, included in the proceedingand heard, although courts have a number of procedures for finding and joining additional parties to a controversy Similarly, legislatures and administrative agencies offer no guarantees that all affected interests will be heard, or heard equally. Likewise, the charge that adjudication is not undertaken until harmful effects have manifested themselves applies to public decisionmaking processes generally. People initiate judicial proceedings or introduce legislation or undertake administrative rulemaking after problems have arisen, not before.

Therefore, adjudications may be pursued by water users not because they are simple, inexpensive, and yield efficient solutions to problems before they occur, but because they are perceived as less inaccessible, indeterminate, inefficient, and inflexible, and more responsive than alternative forms of public decisionmaking. In addition, some properties of adjudications may actually be preferable from the standpoint of water users.

Equity court proceedings offer such procedural and remedial devices as the temporary restraining order, the court-appointed referee, and the permanent injunction that may Be especially well-suited to the determination of water rights. In 1973, the National Water Commission explicitly endorsed the idea that "the States should consider employing the flexible powers of the equity courts to achieve least-cost physical solutions" in groundwater basin conflicts.[70] Adjudications in overdrawn groundwater basins have "stopped the clock on the acquisition of additional water rights."[71] Courts can "act quickly to prevent irreparable damage and then take longer to reflect on the merits. In the water resource field, no institution can move so quickly to prevent harm so that time to consider exists."[72]

The appointment of experts to assist courts also has been used in groundwater adjudications. The court-appointed referee (called the special master in some courts) can assemble information on hydrologic characteristics and historical use of a basin that gives all parties a common information base, which can assist in the negotiation of a settlement, and provides the judge with the data needed for a decision. This tends to blunt the criticism that judges, like legislators and administrators, lack the technical expertise to make determinations.

Another aspect of the judicial process that users may find beneficial is that, "Courts are deciders. When parties call upon them for decisions, they have very few ways to avoid making it."[73] Individual parties may not agree with the outcome of the process, "but only in the rarest of cases is the court action an empty exercise which wastes time,"[74] as may occur with legislative and administrative processes

The outcomes of basinwide adjudications also may be perceived as desirable by the participants. Injunctions that limit extractions and bar additional pumping, for example, help control overdrafting, an essential element of improved management Basinwide determinations of rights result in the parties acquiring something of value. These rights, if acquired through a determination separate from land ownership, often are tradable within the basin. In nonadjudicated basins, taxes on withdrawals may be used to try to limit aggregate extractions, but this alternative gives users nothing of value in their production; they can pay taxes on their pumping but they cannot sell the right to pump.[75]

Adjudications also may give users the right to recapture water stored underground, an essential element of conjunctive management Indeed, observers who have criticized the length and expense of adjudications have concluded nonetheless that the "use of underground storage for imported water cannot be completely successful unless the natural local water supply has been fully adjudicated so that extractions can be controlled and the basin fully managed."[76] And, adjudications have been used often to generate the basis for financing the conjunctive management practices that help preserve the basin and exploit its advantages Once firm and limited pumping rights are allocated, it becomes possible to impose a surcharge on overpumping to pay for replenishment and to impose the costs of additional surface supplies, whether locally developed or imported, on new users whose demands exceed the available yield of the basin.

In all, the use of adjudications to establish rights, limit withdrawals, control overdraft, provide for regulation of water in storage, and distribute the costs and benefits of basin management among users may not reflect a "problem," but a decision based on assessment of the capacities of the process relative to other public decisionmaking processes This possibility was recognized in a recent article on forums for groundwater dispute resolution:

> Of all of the water resources management questions that ate raised, the judicial system is probably most effective in determining simple questions of water quantity based on factual testimony by expert witnesses. The court system is the only forum to determine traditional monetary damages cases, the award of damages in inverse condemnation cases, and the issuance of injunctive relief against unlawful or harmful practices It is also the only forum which acts as the reviewing agency for special district and agency determinations.[77]

## REGULATORS IN THE COMPLEX WATER ECONOMY: THE PROTECTION OF WATER QUALITY

The complex water economy is regulated by local, state, and federalgovernments. Local regulators are most likely to be overseeing the operations and costs of private water suppliers such as utilities. When local general governments contract for water supply with a private producer, the local legislative body generally retains oversight authority

Local governments also have been actively involved in protecting groundwater quality and remedying contamination problems. Metropolitan Dade County, Florida, for instance, depends on the shallow Biscayne Aquifer for its drinking water supply. This aquifer is highly permeable and therefore very vulnerable to contamination The location of the aquifer along the coast also renders it susceptible to salt water intrusion if excessive withdrawals lower the elevation of fresh water Located in a state that has highly developed and strong groundwater quality protection programs, Dade County has been aggressive in developing and integrating groundwater management efforts.[78] Regulation of supplies and quality are centered in the county's Department of Environmental Resources Management In the 1960s, there was salt water intrusion because of depletion and biological contamination from leaking septic tank systems. In the 1970s, industrial and agricultural activities caused chemical contamination. Contamination prevention, wellhead protection, recharge area management, wetlands protection, and growth management are all part of the Dade County approach to groundwater management.[79]

Since the early 1970s, the county commission has attempted to integrate water quality and supply concerns with the regulation of land uses. In 1974,the commission imposed a building moratorium in a part of the county that is a vital recharge area for the Biscayne Aquifer, after which the area was zoned for minimum lot sizes of five acres. A Florida appellate court upheld the zoning plan against a constitutional challenge, observing that water supply protection was a legitimate objective of a local zoning policy and a valid exercise of local police powers in the interest of the general welfare.[80]

Land use practices that create risks of groundwater contamination are closely monitored by the county Department of Environmental Resources Management Dade County also has established its own broad definitions of hazardous wastes, which are more extensive than federal or state regulations and include more than 900 chemicals. The Department of Environmental Resources Management has identified 8,000 generators of hazardous wastes and closely regulates their activities through a permit system[81] that requires use of best management practices (BMPs) to protect groundwater quality

In addition, Dade County has been a leader in designating "wellhead protection areas," protecting sensitive areas around water supply wells from surface activities that could lead to contamination. Within protected areas, land use and zoning restrictions can be used to prohibit underground storage tanks.[82] The county also has created a local hazardous waste trust fund; has established a cleanup program for contamination sites; and participates with two neighboring counties in the "Biscayne Aquifer Project," an attempt to extend effective protection programs across the reach of the aquifer.[83]

Interlocal coordination also can be effective in executing regulatory functions. In California, the Southern California Association of Governments (SCAG) became a vehicle for interagency and interjurisdictional coordination in response to the discovery in 1980 of the volatile organic compound trichloroethylene (TCE) above state safe drinking water levels in one-third of the wells tested in the San Fernando Valley groundwater basin in Los Angeles County. This basin has been the source for about one-fourth of the drinking water for Los Angeles, and equally significant shares of the drinking water supplies for Burbank, Glendale, and San Fernando. The basin also is operated conjunctively by the Los Angeles Department of Water and Power and a watermaster as a direct source of supply and as a storage reservoir for imported surface water via the Los Angeles Aqueduct

SCAG and the Los Angeles Department of Water and Power applied for and received a federal areawide planning grant for a study to develop a "Groundwater Quality Management Plan for the San Fernando Valley Basin." The development of the plan engaged citizen input through a citizen advisory committee, and alerted the public to the contamination in a way that mobilized local opinion in favor of remedial action but avoided panic.[84]

State and local agencies were involved in plan development through a 30-member technical advisory committee that met bimonthly The plan, which specified roles for the governments, included procedures for public education; regulation and eventual elimination of private disposal systems (septic tanks); regulation of underground storage tanks, pumps, and pipelines; enhanced landfill regulations; a groundwater monitoring program and aquifer management and groundwater treatment The governments and the citizens accepted the plan, due to the inclusive process by which it was produced, and all aspects of the plan have been or are being implemented.@

The technical advisory committee has been retained as an interagency advisory committee, which continues to meet bimonthly to discuss and oversee implementation. The plan was developed and implemented regionally, without the creation of a new agency or department, but with the coordination and cooperation of multiple jurisdictions. There was no attempt to centralize groundwater supply management, quality protection, and remediation activities, but there was an attempt to coordinate the activities of the entities that had responsibility for those functions. The presence and involvement of the Southern California Association of Governments facilitated this coordination.

The states and the federal government perform regulatory and other functions in the complex water economy. The remainder of this chapter focuses on the role of the states and the federal government.

## THE ROLE OF THE STATES

### States as Regulators

States regulate water quantity and water quality in a variety of ways. Several states have their own drinking water standards as well as compliance requirements for water providers.

While most water supply provision and production are local, state governments have long been engaged in overseeing local water supply provision, especially in ensuring safety, often through state health departments.[86] State-operated public water supply supervision programs have existed since as early as 1915.8'

Washington state regulates supply operations and water quality. The state took several legislative steps in the 1970s toward regulating all water utilities. Washington monitors suppliers' compliance with drinking water standards and requires local retailers to plan for adequate treatment of supplies and for full system metering. The state also has attempted, through its Water Supply System Coordination Act of 1977, to "raise barriers to entry" into the industry in order to reduce the number of smaller, undercapitalized operators that might ultimately be unable to meet quality requirements. The law encourages using existing producers to meet new water supply provision needs in critical areas.[88]

The states' role in water quality regulation has grown significantly in the past two decades.[89] Many states have adopted programs for cleaning up and regulating major sources of groundwater contamination. Indeed, as the National Research Council's Committee on Ground Water Quality Protection found, "many states have broader authority than the federal government to prevent and control groundwater contamination. In the last several years, many states and local areas have initiated and expanded ground water protection programs by state mandate."% Most state water pollution control laws apply to groundwater as well as surface water.[91] A 1988 report from the U.S. General Accounting Office found that states "usually deal with the threat of groundwater contamination within the framework of an overall protection program. Many states have organizations directly responsible for groundwater protection, while others have placed these duties within existing organizations."[92] The diversity reflects in part the fact that, "Although contamination problems are similar across the states, each state has unique problems."[93]

Some states have moved toward administrative centralization, but often this has been in environmental quality rather than water resources. In 1973, the Final Report of the National Water Commission coupled its recommendation that surface and groundwater withdrawals be managed together, with coordinated conjunctive use, with a recommendation that groundwater quality and surface water quality should also be managed together. The commission observed that "the expertise bearing on surface water quality will also bear on ground water quality," and suggested that the "agency that regulates the one should regulate the other."[94]

Since then, many states have consolidated environmental quality programs, including surface and groundwater quality, air, soil, and waste disposal. Such consolidations have separated quality and quantity planning and management.[95] Furthermore, there appears to be some regional pattern to state choices. States in the West and Southeast have tended toward administrative consolidation of water quantity planning and management, with a separate organization for environmental quality States in the Northeast have more often integrated both functions.[96] Connecticut and Arizona present examples of these different approaches.

Connecticut has been described by the National Research Council's Committee on Ground Water Quality Protection as "a national pacesetter in statewide programs for ground water protection."[97] The state has developed an integrated management program that is connected with local land use planning and regulation of pesticide application. The goal is, where possible, to restore or maintain all groundwater to drinking water quality? Impetus for the program came from rapid growth in the number of wells shut down due to contamination.

Connecticut adopted a series of laws concerning groundwater quality protection in 1985. One law directed the commissioner of Environmental Protection to report to the legislature on options for protecting underground water supplies, with a map of areas needing protection and a strategy to protect watersheds and recharge areas from dangerous land use activities Another law required land use officials to consider protection of underground drinking water supplies in land use and zoning decisions Two other laws authorize the restriction of general-use pesticides and the registration of pesticide application companies

Among the elements of Connecticut's integrated groundwater management program are:

1) State drinking water standards;

2) State groundwater quality standards;

3) An ambient groundwater quality monitoring network, as well as monitoring of contamination sources and sites;

4) Aquifer classification;

5) Aquifer mapping and inventory;

6) Permits for all point sources of pollution;

7) A statewide ban on toxic septic system additives and some pesticides;

8) Use of best management practices (BMPs) for nonpoint sources of pollution;

9) Wellhead protection and setback requirements;

10) Use of land use regulations along with aquifer classification, wellhead protection, and setback regulations to protect aquifers from contamination;

11) Requirement of groundwater withdrawal permits;

12) Regulation of groundwater withdrawal permits to maintain minimum adequate stream flow where water sources are connected.

Groundwater in all areas of the state has been mapped and classified according to four categories of use. The highest protection is for utility and municipal drinking water systems. Two middle classifications cover private drinking water supplies and supplies that may not be potable unless treated because of prior impacts on water quality, The fourth classification designates areas where waste disposal is allowed because of the poor water quality, and because there are no future use plans.[99] This classification system provides the highest level of protection for 90 percent of the state's groundwater.[100]

The Connecticut program is based on the premise that, while much should be done by the state, the principal implementation of resource protection should be done by local authorities, and some local capacity building remains to be done. The groundwater strategy is "a partnership between the State and its 169 municipalities for the management of this resource."[101]

The state Department of Environmental Protection, which has been in existence since 1972, contains a central information gathering and disseminating unit, the Natural Resources Center, to provide data to state and local decisionmakers. The center makes extensive use of the cooperative investigations programs of the U.S. Geological Survey.[102]

In Arizona, as was noted in Chapter 3, after passing the 1980 Groundwater Management Act, officials began work on quality protection, culminating in enactment of the Environmental Quality Act of 1986. Some added pressure for this legislation came from the 1984 discovery of trichloroethylene (TCE) in wells in Tucson, which is wholly dependent on groundwater.[103] The legislation was developed through a process of negotiation by a representative commission toward consensus and compromise among affected interests, similar to the process for the groundwater management law. And, as was the case with the 1980 law, internal political divisions slowed the adoption of strong legislation, though the political lines were drawn somewhat differently. Strong environmental protection legislation aroused the opposition of some influential agricultural and mining operators; weaklegislation was opposed by active environmental groups and would have been inconsistent with the commitment of the governor.[104]

Another significant political issue was what state agency should be primarily responsible for administration. One logical choice was the Department of Water Resources, created by the 1980 legislation. Such an approach would have integrated groundwater supply management and quality protection. Another logical choice was the Department of Health Services, preferred by environmentalists, who viewed water quality as a public health issue to be separated from the management of supplies There was some consideration given to creating an environmental "super agency" with jurisdiction over water resources management, quality protection, pesticide control, and other subjects None of these choices was adopted,

The 1986 Arizona Environmental Quality Act created a Department of Environmental Quality, with responsibility to protect water and air quality, and spread environmental regulatory authority across six existing and new state agencies. In the view of two former directors of the Department of Water Resources, this approach has raised coordination costs but was an understandable resolution of the issue of administrative responsibility and authority?

The law required all groundwater quality standards to be based on an evaluation of social, economic, and environmental costs and benefits. All aquifers were to be inventoried and classified by June 30, 1987, and a statewide monitoring program was established to improve the data base on groundwater quality Aquifer protection permits have been required for all activities that have been found to pollute groundwater. The law also directs the Commission on Agriculture and Horticulture to regulate the use of pesticides through licenses and permits, and bans the use of any pesticide unless the manufacturer has shown that contamination will not result The Arizona Attorney General is authorized to enforce water quality standards'"

Although Arizona approached groundwater supply management and quality protection with statutes that created new departments, this does not mean that there is no connection or coordination. The well registration, metering, and withdrawal reporting requirements of the management law will contribute to the knowledge base for quality protection,'" and the aquifer inventory and classification and groundwater monitoring programs will be useful for management officials.[108]

These examples have been chosen to highlight some different possibilities for the organization of groundwater protection in relation to the management of supplies; no attempt has been made to inventory and describe the number and variety of state and local programs Through the 1980s, new groundwater protection legislation and regulations, and new forms of administrative organization and coordination have been generated in virtually all states.[109]

The Committee on Ground Water Quality Protection of the National Research Council concluded from its review of state and local groundwater quality protection activities and programs that

> no single program was found to address all aspects of ground water protection problems comprehensively. A comprehensive program would probably incorporate elements from a number of the state and local programs reviewed in this report as well as other techniques not discussed here. While no single program can be held out as a model for others to follow, collectively they comprise a reasonable array of alternative ground water protection program designs being used.[110]

State laws and organization of groundwater quality protection programs doubtless will continue to vary, reflecting emphases on different groundwater quality problems, and different institutional arrangements on which to build, as well as legal and cultural differences Deviations from suggested statutory or administrative models do not necessarily reflect inadequacies, but may indicate successful adaptations to the challenges faced by states and communities

### States as Water Suppliers

States also have operated in the complex water economy as large-scale water suppliers or wholesalers. While California's State Water Project, which conveys water from the north to the more heavily populated south, is perhaps the largest and best known state water supply undertaking, state involvement is far from being a western phenomenon. For example, Pennsylvania has long authorized and constructed flood control projects;"' Massachusetts has supplied the Boston area with water from the western part of the state for over a century; and New Jersey has transferred water from the Delaware River to the more heavily urbanized northeastern part of the state since the 1800s.[112]

As noted in Chapter 3, states that perform the role of water supplier have opportunities to influence user behavior through conditions on access and through pricing mechanisms. Massachusetts and New Jersey have used control of access to large-scale surface water projects to encourage changes in the behavior of local water users and their organizations, although the tactical approaches of the two states have been different

### States as Rulemakers

One of the most important state roles in the complex water economy is making the rules for access to water supplies Although the federal government has the constitutional authority to regulate navigable waterways, the states have had responsibility for making and enforcing the laws that govern access to the withdrawal and use of surface and groundwater supplies

As much of the emphasis in water resource management has shifted from developing additional supplies to managing and allocating supplies, the historical role of the states in water rights administration is seen as enhancing their present and future role. "[A]s priorities shift from water resource development to management, the states are the more appropriate level of government to initiate and administer programs."[113] States have broad police powers to make policy in health, welfare, and environmental protection. Almost all states have health and environmental agencies, and many have separate water resources agencies or departments.[114] These facts, combined with the states' historical role and current activity, have formed the basis for some analysts to conclude that "the states are uniquely qualified to address the issues specific to their region, and that many states have already developed solutions to some of their water management problems."[115]

This aspect of the states' mle-the definition of who has rights, how those rights am acquired, and in what ways (if any) they are quantified and limited-is at the heart of the institutional arrangements for managing water resources. The state rules differ, and this affects the patterns of water use and development The effects of state water rights laws on use and development will be considered at some length in the next chapter

### States as Policy Innovators

States developed and modified water rights rules and quality regulations and programs considerably in the 1970s and 1980s. During the 1980s in particular, it can easily be contended that the states have been the principal sources of groundwater policy innovations, "As in other water management categories, the major actor in groundwater is state government."[116]

From 1980 through 1989, 30 states adopted significant new groundwater supply management and quality protection policies.[117] These states were significantly more dependent on groundwater supplies than those that did not adopt new policies, suggesting that states respond to perceived water supply management needs.

During the 1980s, 24 states adopted new water quality protection laws, groundwater classification systems, and/or groundwater quality standards According to 1987 testimony by the executive director of the Association of State and Interstate Water Pollution Control Administrators, two-thirds of the states had or were developing groundwater quality standards and/or use classification systems[118] During the 1985, 1986, and 1987 legislative sessions, 37 states enacted groundwater quality protection legislation, either to address specific programs (such as underground storage tanks or pesticide use) or to develop statewide strategies.[119]

Forty states have discharge control permit programs, and these programs frequently require a discharger of contaminants to monitor groundwater quality.[120] Forty-nine states have accepted primary enforcement responsibility under the provisions of the federal Safe *Drinking Water Act,* which involves: (1) engineering plan review, (2) compliance monitoring, (3) conducting periodic sanitary surveys, (4) certifying laboratories, and (5) enforcement against persistent violators of drinking water quality standards.[121]

## THE ROLE OF THE FEDERAL GOVERNMENT

The federal government has been involved in water resource development and management for much of our history Most of this involvement has been directed toward surface water supply development

States, communities, and industries have had the primary responsibility for water provision and management In the past, the Congress has recognized this primary state and local role, and many federal water laws contain policy statements that describe the federal government's role as limited and ancillary.'" This federal role has been manifested in several ways Perhaps the most plain has been statutes directing federal agencies and installations to comply with state water rights laws and administrative procedures. This has included acquisition of water rights for federal projects through appropriation permit procedures or condemnation and payment in situations where the federal government could have exploited its "navigation servitude" under the law.[123] The Congress elected instead to defer to the states Federal deference to state water laws, which dates back to the acquisition of the western states during the 19th century, has been seen by some as a missed opportunity to impose "a uniform system of water law on the region, though in view of the well known difficulties that developed over the federal land policy in the area, there is no reason to assume that Congress would have devised an ideal system of water law."[124]

The Congress also has cooperated with and supported states efforts at interstate resolutions of water supply issues involving multistate resources The Congress has authorized interstate water compacts, and the federal government has been a party to federal-interstate compacts, such as the one governing the Delaware River Basin.

In addition, the federal government has encouraged and supported state and local activities and initiatives in water resource management through income tax laws. By exempting the interest earned by holders of state and local securities from federal income taxes, the Congress and the executive branch have made it easier for governments to sell the securities that finance state and local water resource activities However, limits were placed on this support by the *Tax Reform Act of 1986. These* forms of support have been accompanied by more active involvement, such as financing and production and dissemination of water resources information, financing and production of surface water development and impoundment projects, and regulation of water quality

### A Supportive Federal Role: Information and Technical Assistance

The federal government has contributed importantly to the production and dissemination of information and scientific knowledge about groundwater. Although management problems and responses differ from place to place, many elements of basic hydrologic research into groundwater are conducted in the same way and require the same sort of education and expertise throughout the country and the benefits of research reach beyond the boundaries of the community in which it was conducted. Thus, while states and local communities have been interested in supporting and participating in the promotion of research and the development of extensive resource information, they have been reluctant to fund most types of water research The appropriate scale for the conduct of basic research and the collection of scientific and technical information on water resources is national.[125]

The Department of the Interior's United States Geological Survey (USGS) has been collecting data on water resources since 1888. Currently, USGS collects streamflow and discharge data at 13,212 surface water sites, water level and pumpage data at 35,621 wells, and water quality information at 4,610 surface-water sites and 7,648 wells USGS publishes hydrologic data in the form of annual reports for each state, and a monthly catalog of publications.[126]

States and communities have relied strongly on USGS reconnaissance studies and hydrologic investigations, and the "early systemic collection and interpretation of hydrological data has been important to the development of current state groundwater programs."[127] Some state geological surveys date back to the mid-1800s, but most state efforts evolved in association with USGS. Cooperative investigations began in 1895. The Congress appropriated funds specifically for cooperative studies beginning in 1905, which began the Federal-State Cooperative Program of the U.S. Geological Survey In 1928, the Congress set a 50 percent upper limit on the federal share of the costs of any investigation under the program.

The Federal-State Cooperative Program allows states and communities to enter into agreements with USGS for hydrologic investigations into an actual or anticipated water-supply problem. States and communities are able to define the problems, contribute at least half of the funds for the investigations, have access to the expertise and experience of USGS, and use the information in their decisionmaking processes. The cooperative program has produced much of the information available on the nation's water resources, including information used by other federal agencies In fiscal 1983, more than 800 "cooperators" participated with USGS in the program. States participated in 252 projects, municipalities in 205, counties in 183, and other entities (including special districts, interstate compact organizations, and Indian tribes) in 206. USGS publishes several series of reports based on cooperative program projects.

The federal government also has assisted states and communities in building institutional capacity through the development of their own expert personnel. The *Wafer Resources Research Act of* 1964 (most recently reauthorized in 1984) provided matching funds for the establishment of Water Resources Research Centers in each state. The centers conduct research and investigation, and serve as training centers for water resources professionals. USGS also operates a National Training Center in Denver. In addition, the *Wafer Resources Planning Act* of 1965 created the federal Water Resources Council (WRC) and authorized financial assistance to the states for planning. Although WRC and the planning funds were discontinued in the early 1980s, state water management agencies greatly expanded in size and expertise through the 1970s and 1980s.[128]

The U.S. Geological Survey has been publishing estimates of water use (figures such as those used in Chapter 2 of this report) since 1950. The first reports issued were based on data derived from many sources of varying degrees of accuracy, so in 1977, the Congress acknowledged the need for uniform information and directed USGS to undertake a cooperative federal-state National Water Use Information Program. Begun in 1978, the information program became part of the Federal-State Cooperative Program. The states collect much of the data and then receive state water use information and reports from USGS. As of 1988, 49 states and Puerto Rico participate in the program. [129] USGS directs the data collection effort, compiles the information, and analyzes regional and national water use statistics and trends.

USGS also produces National Water Summary reports as part of the National Water Summary Program, begun in 1983. Each report focuses on a single topic (groundwater resources, groundwater quality, etc.) and presents state-by-state reports plus national summary information. The reports have been instituted as a way to bring together into an annual presentation information generated through the various USGS programs.

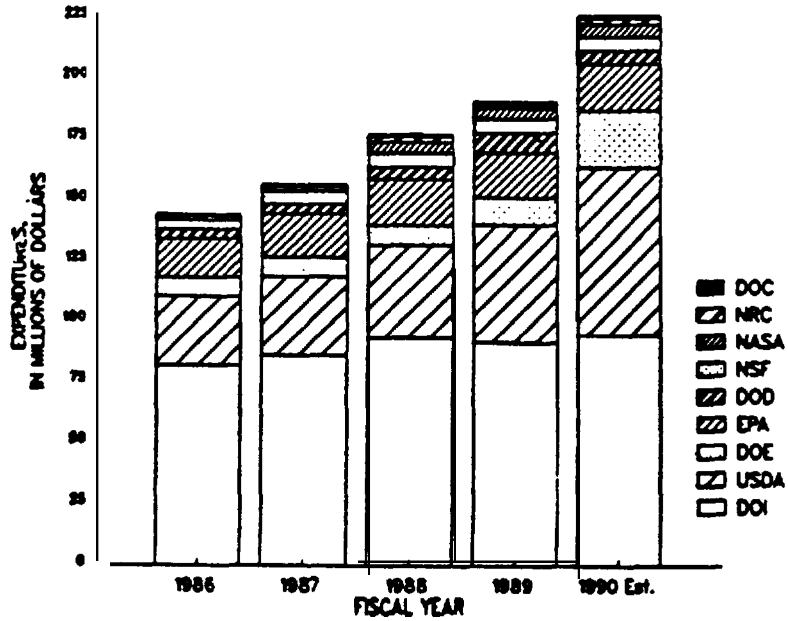
The Bureau of Reclamation, also part of the Department of the Interior, conducts some groundwater studies in connection with planning for its surface water projects -estimations of pumping requirements for projected crop demands, along with calculations of available local supplies based on groundwater geology, depth, movement, and recharge[130]—but the bureau typically does not do long-range groundwater studies. More recently, the bureau has been supporting research and demonstration programs on artificial recharge, which would provide information that could feed back into state and local conjunctive management programs.

Several other federal agencies, including the departments of Agriculture, Energy, and Defense, the Environmental Protection Agency (EPA) and the National Science Foundation (NSF), have allocated funds for water research.[131] With all of the federal, state, local, academic, and industry programs together, there is and has been a sizable water resources research effort. Federal support from the mid-1970s to the mid-1980s totaled over $2 billion[132] (a small fraction of the amount spent on water project construction and maintenance over the same period). A 1989 report from the Office of Science and Technology Policy in the Executive Office of the President found that federal science and technology programs concerning groundwater expended over $890 million over the five fiscal years ending with fiscal year 1990.[133] The expenditures by federal agency and program category are shown in Figure 4-1. Nonetheless, the report concluded that "scientific uncertainties, lack of adequate technologies, lack of basic data, and shortage of skilled scientific personnel still hinder the ability of federal, state, and local governments and the private sector to develop and implement effective groundwater management, protection, and remediation policies and programs."[134]

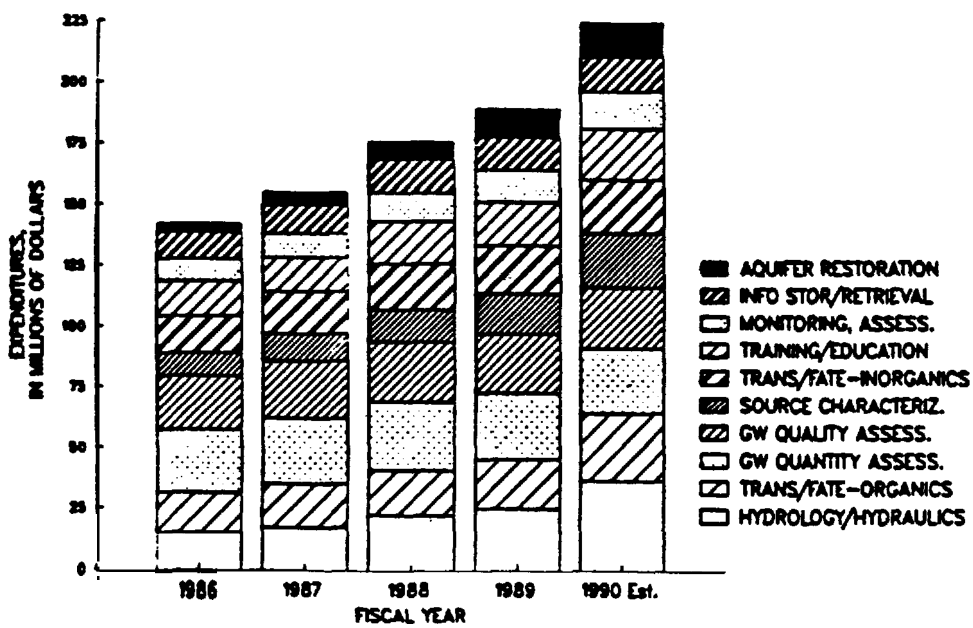
In the area of research into basic hydrology and hydraulics, the major federal participants are USGS, the Department of Energy's Office of Energy Research, the Department of Agriculture's *Agricultural* Research Service and Cooperative State Research Service (ARS/CSRS), NSF, the National Aeronautics and Space Administration (NASA), and the Depart-

*Figure* 4-1
Groundwater Research Expenditures, by Federal Agency and Program Category

...by **Federal** Agency




...by **Program** Category




Source: U.S. Office of Science and Technology Policy, *Federal Ground Water Science and Technology Programs* (Washington, DC, 1989) ment of Commerce's National Oceanic and Atmospheric Administration (NOAA). Over the five fiscal years 1986 through 1990, federal research program expenditures in this area totaled $123.4 million, of which USGS spent $51 million, the Office of Energy Research $27 million, the ARS/CSRS $21.5 million, NSF $9 million, NASA $6.7 million, and NOAA $5.2 million.

Federal research expenditures for groundwater quantity resource assessments from fiscal year 1986 through fiscal year 1990 amounted to $134.3 million; JSGS accounted for $132 million. Federal research expenditures for development and testing of monitoring, characterization, and assessment methods 1990 totaled $58.4 million. The major federal agencies funding and conducting research were EPA, USGS, and AARS/CSRS. The major federal agencies supporting information storage, retrieval, and handling and training and education are the Department of Agriculture's Soil Conservation Service and Extension Service,USGS,and EPA. Total federal research expenditures in these areas were $147.6 million.

Estimated federal groundwater research expenditures for fiscal 1990 were $225 million, the largest amount yet budgeted for a single year: Of that total, quantity assessments was budgeted for 15.1 percent, and hydrology and hydraulics for 13.9 percent Another 23.1 percent of the funds would support training and education; information storage, retrieval, and indexing and the development and testing of methods of monitoring characterization, and assessment Half (49.8 percent) of the funds were allocatedto the Department of the Interior (which includes USGS and the Bureau of Reclamation), 24.4 percent to the Department of Agriculture, 10 percent to EPA, and the remaining 15 percent to the other principal federal groundwater research agencies

In 1986, the Congress appropriated funds for a National Water-Quality Assessment Pilot Program, to be operated by USGS. The purpose has been to test and refine assessment approaches and methods and to evaluate the potential costs and uses of a nationwide assessment program Four surface-water and three groundwater pilot projects were chosen. A full-scale national assessment program would provide a consistent set of descriptions of water quality, and identify long-term trends (if any). Another possible outcome would be the identification of factors and conditions that appear to be associated with changes in water quality, and the identification of aquifers thatare especially vulnerable to degradation and contamination.

## The Federal Government as Water Supplier

Conjunctive management of water resources often involves coordination of surface storage facilities with underground storage capacity Controlled releases of surface waters from a flood control or multipurpose reservoir can be coordinated with groundwater use to maximize total available water supply while minimizing damage to surface structures and underground aquifers and protecting overall quality Therefore, federal involvement in the construction and operation of surface water projects has provided a useful tool for state and local conjunctive management of water supplies, as well as protection from flooding.[135]

The federal government became involved in water resource development through navigation improvement and flood control. Planning for navigation improvements on a significant scale began early in the 19th century, and in 1824, the Congress charged the United States Army Corps of Engineers with responsibility for implementing the improvements. Flood control was added to the Corps' responsibility in the middle of the century, when the Mississippi and Missouri River basins were being settled.[136] Generally, projects built and operated by the Corps have been planned as surface water impoundments, with minimal consideration to groundwater supply relationships, The Corps monitors groundwater at a few sites, and some multipurpose projects have included authority for spreading waters for replenishment (this usually is done by local agencies).[137]

In the decades after the Civil War, federal laws and policies encouraged the rapid development of the West Through the *Desert* Land *Act of 1877,* the Congress authorized the sale of land in 640-acre tracts in most of the arid region of the West to persons who would irrigate lands within three years. This marked the official beginning of a federal policy of encouraging the development of irrigated agriculture in the western states.[138] In 1902, the Congress backed up that policy with the adoption of the *Reclamation Act*, authorizing federal funding and construction of water development projects

*The Reclamation Act* directed the Department of the Interior to undertake examinations and surveys, and to locate, construct, and maintain irrigation facilities, to be paid for out of a reclamation fund. The initial fund came from the sale of land, and was to be reimbursed, without interest, by project beneficiaries within ten years. The Bureau of Reclamation was established and joined the Corps of Engineers in constructing these surface water facilities.

While the Bureau of Reclamation has had a crucial impact on water resources management in the western states, the Army Corps of Engineers, which has a nationwide reach, spends the lion's share of federal water resources development outlays. Of the $3.4 billion in federal outlays for fiscal 1986, 70 percent was spent by the Corps, 21 percent by the Bureau of Reclamation, 8 percent by the Department of Agriculture's Soil Conservation Service, and 1 percent by the Tennessee Valley Authority.[139]

Federal water quality efforts were originally directed toward surface supply protection and remediation. The *Federal Water Pollution Control Act (Clean Water Act) of* 1972 did not **address groundwater,** although some of the activities under the act have impacts on groundwater quality and some EPA interpretations extended the provisions to **groundwater.**[140] Subsequently, through the *Safe Drinking Water Act of* 1974, and in particular the *Safe Drinking Water Amendments* of 1986, federal legislation has reached groundwater as a source of drinking water.

The *Clean Water Act* provided federal grants to municipalities to finance up to 75 percent of the design and construction costs of wastewater treatment facilities needed to meet the goal of secondary treatment levels for all publicly owned treatment works by 1977. Amendments to the law extended the 1977 deadline, eventually to 1988. **A** reauthorization of the *Clean Water Act in 1987 maintained the* **1988** deadline for treatment compliance but made other significant changes Amendments provided for the phasing out of the federal construction grants program by 1994 and offered federal assistance to the states to capitalize state revolving loan funds to provide assistance to communities with considerable flexibility.[141] In the words of the executive director of the Association of State and Interstate Water Pollution Control Administrators, "After 1994, the federal government should be out of the sewerage business, and it will be up to state and local governments to meet the Congressional challenge and be ready by 1994 to assume full responsibility for the Clean Water Program."[142]

More than half of the states have grant programs to assist communities with wastewater treatment projects;'" nearly half of them have established revolving loan funds. Progress in the construction of wastewater treatment facilities and the continuation of the clean water program contribute to federal, state, and local efforts to prevent contamination and protect groundwater quality Treated wastewater is less likely to produce contamination and can be a source of recharge water in groundwater basins with artificial replenishment programs.

In the 1987 amendments to the *Clean Water Act,* the Congress also authorized up to $400 million for federal support of state and local nonpoint-source pollution programs, Nonpoint sources of pollution – such as agricultural and urban drainage and return flows, and storm runoff -are especially likely to affect groundwater quality. However, funds were not appropriated during the first two years after the amendments were enacted.[144]

The *Safe Drinking Water Amendments of 1986* extended many federal requirements to groundwater sources, and this act now constitutes the principal federal legislation for groundwater quality protection. The Congress required EPA to set maximum contaminant level goals (MCLGs) within three years for 83 contaminants previously listed in *The Federal* Register. Addressing this broader set of contaminants was one of the main purposes of the amendments.[145] The amendments also require monitoring of a large number of unregulated contaminants, and will likely require disinfection of groundwater supplies that were previously not disinfected, and filtration of nearly all community surface water supplies.[146]

EPA has established drinking water standards for more than 50 contaminants EPA does not issue separate groundwater standards and has not supported the adoption of uniform national standards, although it has recognized the appropriate use of drinking water standards as guidelines indicating acceptable levels of contaminants in groundwater.[147] The subtlety of that distinction apparently has been lost on the states. EPA drinking water standards are adopted by most states that have numeric groundwater quality protection standards, and most state drinking water administrators told the U.S. General Accounting Office that, in their view, drinking water standards "should" or "probably should" be used as groundwater standards.[148] States use EPA drinking water standards "both as an indicator of what sub stances to regulate and as an indicator of the level at which to set the groundwater standards."[149]

The *Safe Drinking Wafer Amendments* also required states to submit to EPA by July 19, 1989, programs for protecting the areas around water wells that supply public drinking water from contamination. State programs would be considered adequate unless rejected by EPA within nine months of submission. States are required to implement the programs within two years of submission. State development and implementation of wellhead protection programs is supported through the authorization of grants meeting from 50 to 90 percent of program development and implementation costs.

Some provisions of the amendments also recognized the special needs of small water systems. Systems serving fewer than 150 connections, for example, may meet the requirements for monitoring unregulated contaminants simply by submitting a water sample to the state or EPA. The amendments authorized up to $10 million dollars annually for fiscal years 1987 through 1991 to aid small water systems complying with EPA regulations It remains to be seen whether the authorized funds will be appropriated;[150] they were not appropriated during the first two budget cycles after adoption of the amendments

One of the ongoing problems in implementing the *Clean Water Act* and the *Safe Drinking Water Act* has been building implementation capacity. The 1986 *Safe Drinking Water Amendments* made the states the primary implementation and enforcement agents for EPA-promulgated regulations Administrators generally believe that there is not sufficient financial capability to implement the Act properly in many states and public water supply systems, and that additional financial assistance will be needed.[151]

The *Clean Water Act* and the *Safe Drinking Water Act* are only two of the federal laws relating to water quality, and EPA is only one of the federal agencies involved in groundwater quality protection, albeit the principal one. Depending on the definition of "relate," it has been estimated that from fewer than 10 to more than 40 federal statutes relate to groundwater quality?" Other prominently involved federal agencies in addition to EPA include the U.S. Geological Survey, which produces much of the information on groundwater used by EPA and other regulatory agencies, the Department of Agriculture (which has some authority regarding pesticide use), and the Department of Energy (which has authority regarding the disposal and handling of radioactive materials). States and local governments have observed that the federal groundwater protection effort, coming as it does under the authority of the *Safe Drinking Water Act,* the *Clean Water Act,* the *Resource Conservation and Recovery Act*, the *Federal Insecticide, Fungicide, and Rodenticide Act,* the *Comprehensive Environmental Response, Compensation, and Liability Act,* and other statutes, has at times lacked coherence and coordination, and has subjected state and local administrators to a plethora of obligations.

In 1984, in an attempt to provide a focal point for federal efforts in groundwater quality protection,and to improve program coordination and enforcement of laws and regulations, EPA established an Office of Groundwater Protection. EPA published its "groundwater protection strategy" in 1984, which relies heavily on state implementation and enforcement of laws and regulations, with technical and financial assistance from the federal government.[153] The EPA groundwater protection strategy recognizes the historical and legal roles of the states in water allocation and the localized nature of most contamination sources and incidents; acknowledges that the states have the principal role in protecting groundwater quality and have developed several powerful state and local authorities; and declares a position in favor of strengthening. not displacing or disrupting, state and local initiatives.[154]

The strategy identifies four major objectives for EPA's role in groundwater quality protection: (1) strengthen the states' institutional capacity to protect groundwater resources (principally through financial and technical assistance), (2) give greater emphasis to regulating sources of contamination that are of special national concern and are insufficiently addressed, (3) develop guidelines for consistency in EPA groundwater protection and remediation decisions, and (4) coordinate groundwater protection activities internally as well as with other federal agencies and the states. The EPA groundwater protection strategy also focuses on areas where groundwater contamination would cause the greatest harm and assigns highest priority to groundwater that is used for drinking or to supply unique ecosystems.[155]

A key element of the EPA groundwater protection strategy has been to combine capacity-building measures with encouraging states to develop and implement their own strategies. Under Section 106 of the *Clean Water Act,* EPA has offered grants to the states to assist them in developing statewide groundwater quality protection strategies, which the states in turn submit to EPA for review and approval.

## Summary

Through support of research and technical assistance, program development, and development of drinking water standards in connection with the *Safe Drinking Water Amendments,* EPA and other federal agencies have been attempting to improve groundwater quality protection. At the same time that it is committed to helping, the federal government should ensure that its activities do not harm groundwater quality and make protection more difficult for the states and communities that have primary implementation responsibilities.

Regardless of whether its water projects were east or west, single purpose or multipurpose, federal involvement in solving water resource problems has been organized by individual projects rather than on the basis of some federal plan or policy.[156] The history of federal involvement in water resources is replete with instances of boards, commissions, and councils formed to articulate a national water policy and coordinate federal programs, with each body eliminated in an executive branch reorganization or a period of budget austerity, and of studies by commissions yielding insightful conclusions and recommendations that were never adopted.[157]

The most recent commission was the National Water Commission. Its 1973 report, *Water Policies for the Future,* advocated conjunctive management of water resources at the scale nearest the users of the resources, with federal support for research and problem identification, diminishing federal support in planning and financing development, and a strong federal role in quality protection, along with a host of other recommendations that have yet to be implemented. Coordination of federal water programs and ongoing analysis of national water policy were most recently institutionalized for a time in the U.S. Water Resources Council (formed under the auspices of the *Water Resources Planning Act of 1965*), but that body was terminated in 1982 as part of federal spending reductions in the first term of the Reagan Administration.[158]

The project-by-project approach and the lack of a comprehensive federal management plan have been criticized. The organization of federal support and participation also is criticized. Water resource development and management are part or all of the portfolio of about 25 federal agencies,[159] as well as the subjects of hundreds of federal laws. Neil S. Grigg, attempting to summarize the federal role in groundwater management, wrote "The federal government is responsible for policy formulation, mgulation, data collection and research. These responsibilities are fragmented between agencies."[160] The existence of multiple federal agencies with involvement in water resource information, development, and management has been cited as a source of confusion and inefficiency.[161]

Much of the literature suggests that the federal role and participation are declining now that the emphasis has shifted away from water development toward management of existing supplies.[162] However, other changes during the 1980s suggest the possibility for a greater federal role in the management of water supplies [163] Among these changes am the federal court decisions striking down state restrictions on groundwater supply exports and ruling that groundwater is an article of interstate commerce subject to direct federal regulation; the problems surrounding federal reserved rights and Indian water rights, especially in the western states; and legislation introduced in the Congress to require the use of nondegradation standards for groundwater quality programs nationwide, and to require prior federal approval of state groundwater supply management programs The following chapter considers these and other problems and prospects in water resource management

Notes

[1] Vincent Ostrom and Elinor Ostrom, "A Behavioral Approach to the Study of Intergovernmental Relations, *The Annals of the American Academy* of *Political and Social Science 359* (May 1965): 138.

[2] For example, U.S. Advisory Commission on Intergovernmental Relations (ACIR), *The Organization of Local* Public *Economies* (Washington, DC, 1987).

[3] Ostrom and Ostrom, p. 138 (emphasis added).

[4] Ibid.

[5] William Lord, Director, Water Resources Research Center, University of Arizona. Proposal for the Comparative Study of Water Management Institutions. 1988.

[6] Ostrom and Ostrom, p. 140.

[7] Wade Miller Associates, *The Nation's* Public *Works: Report* on *Water Supply* (Washington, DC: National Council on Public Works Improvement, 1987), p. i.

[8] Vincent Ostrom, Robert Bish, and Elinor Ostrom, *Local Government* in We *United States* (San Francisco: ICS Press, 1988), pp. 59-60.

[9] See especially Wade Miller Associates, and National Council on Public Works Improvement, Fragile *Foundations: A Report on America's Public Works* (Washington, DC, 1988).

[10] Wade Miller Associates, p. 17.

[11] Ibid., p. 18.

[12] Ibid., pp. 17-18.

[13] Kyle Schilling et *al., The Nation's Public Works: Report on Water Resources* (Washington, DC: National Council on Public Works Improvement, 1987), p. 134.

[14] Wade Miller Associates, p. 18.

[15] Ibid., pp. 91-92.

[16] Ibid., p. 18.

[17] Ibid.

[18] Schiing et al., p. 134.

[19] This distinction isexplained in detail in ACIR, *The Organization* of *Local Public* Economies.

[20] James Krieger and Harvey Banks, "Ground Water Basin Management," *California Law Review* 50 *(1962): 74* (emphasis added).

[21] Schilling et al., pp. 134-135.

[22] Jurgen Schmandt, Ernest Smerdon, and Judith Clarkson, *State Water Policies* (New York Praeger Publishers, 1988), p. 1.

[23] Ostrom and Ostrom, pp. 141-142.

[24] John Leshy, "Special Water Districts-The Historical Background," in James Corbridge, ed., *Special* Water *Districts: Challenge for the Future* (Boulder: Natural Resources Law Center, 1983), p. 13; Sidney Harding, *Water in California* (Palo Alto: N-P publications, 1960), p. 215.

[25] Warren Viessman and Claire Welty, *Water Management: Technology and Institutions* (New York: Harper and Row, 1985), p. 25; Schilling et al., p. 7.

[26] See for example, Lyle Craine, "Intergovernmental Relations in Water Development and Management." Paper presented at the Southern Political Science Association, Gatlinburg, Tennessee, 1959, pp. 13-14:

> As a theoretical proposition, should we not conceive, and encourage, insofar as feasible, the operation of a competitive public market among water service enterprises as the primary basis for allocating water services from a given river management scheme? . . . Thus, the tricky water management decision, i.e., which customers get what, results from the relative demand as expressed by the willingness of each customer to pay.

[27] Leshy, p. 24.

[28] Ibid., pp. 12-13.

[29] Ibid., p. 13.

[30] Ibid.

[31] Institute of public Administration, *Special Districts and Public Authorities in Public* Works *Provision: Report to the* National Council on *Public* Works *Improvement* (Washington, DC, 1987), p. 24 (unpublished); Harold Rogers and *Alan* Nichols, *Water for California:* Planning, *Law and Practice, Finance* (San Francisco: Bancroft-Whitney, 1967), Vol. *2,* pp. 49-50.

[32] Institute of public Administration, p. 65; Leshy, pp. 22-23.

[33] Charles Phelps et al., *Efficient Water Use in California: Executive Summary* (Santa Monica: RAND Corporation, 1978), p. 10.

34 Institute of Public Administration, p. 65; Leshy, pp. 22-23.

35 Institute of Public Administration, p. 65.

36 Ibid., p. 62.

37 Ibid., pp. C-5 and C-6.

38 ACIR, *The Problem of Special Districts in American Government* (Washington, DC, 1964).

39 Jnstitute of Public Administration, p. 62.

40 Compare, for examp le, Leshy, p. 22:

> In the modern era, most states have chosen not simply to expand the purposes of traditional districts, but also to create wholly new categories of speciaiwater districts to serve larger geographic areas and fulfill a variety of purposes. Sometimes these new districts overlay in whole or in part existing districts (as well as other water supply entities), creating multiple layers of special water districts and a patchwork of water supply authority in the same geographical area.

41 Schiiling et al., p. 135.

42 Tim DeYoung, "Discretion Versus Accountability: The Case of Special Water Districts," in Corbridge, ed., p. 34.

43 David Jaquette, *Efficient Water Use in California: Conjunctive Management of Ground and Surface Reservoirs* (Santa Monica: RAND Corporation, 1978), p. 3.

44 James Corbridge, "An Overview of the Special Water Districts Workshop," in Corbridge, ed., p. 5.

45 In California, which has by far the highest number and percentages of water supply and management services performed by special water districts, a telephone survey of a stratified random sample of registeredvoters in 1978 asked them to rate the performance of their water supplier as excellent, good, only fair, or poor Three-fourths responded "good" or "excellent." A later survey conducted by the Association of California Water Agencies focusing on respondents served by special water districts showed slightly higher levels of satisfaction, but must be regarded with some reluctance in light of the fact that the latter survey was conducted by members of the association. Charles Hobbs, *The Water Districts of California* (Sacramento: Association of California Water Agencies, 1979), p. 25.

46 This criticism is addressed to particular identified special water districts in the San Joaquin Valley in Merrill Goodall and John D. Sullivan, Water System Entities in California: Social and Environmental Effects," in Corbridge, ed., pp. 71-102.

47 Institute of Public Administration, pp. 4-5.

48 Ibid

49 Wade Milier Associates, p. 97.

50 Ibid., p. 92.

51 Richardson et al., "Gypsum Blocks 'Tell a Water Tale'," Journal *of Soil and Water Conservation 44* (1989): 195.

52 L.M. Hartman, "Economics and Ground-Water Development," Ground Water 3 (April 1965): 7.

53 Wade Milier Associates, p. 18.

54 Wade Milier Associates, p. 22.

55 Ibid., p. 142.

56 *From the State Capitals:* Water *Supply* 43 (January 1989): 3.

57 A fuller description of the NRWA program can be found in Wade Milier Associates, p. 84.

58 Albert Lipson, *Efficient Water* Use *in Calijornia: The Evolution of Groundwater* Management in Southern California (Santa Monica: RAND Corporation, 1978), p. 16.

59 The activities of SAWARA can be found described in greater detail in Schmandt et al., pp. 48-53.

60 Gary Weatherford et al., *Acquiring Water for Energy: Institutional Aspects* (Littleton, Co: Water Resources Publications, 1982), p. 19.

61 Grant Thompson, Courts *and Water: The Role* of *the Judicial Process.* Background Report (Washington, DC: National Water Commission, 1972), p. 2.

62 Krieger and Banks, p. 66.

63 Michael Mallery, "Groundwater: A Call for a Comprehensive Groundwater Management Program," *Pacific Law Journal 14 (July 1983):* 1290.

64 Ibid.

65 Krieger and Banks, p. 66.

66 Thompson, p. 123.

67 As Zachary Smith has pointed out, resolution of water disputes in legislative forums will favor groups with the resources and skills for success at lobbying legislators who are motivated primarily by reelection, while resolution of water disputes in administrative forums will favor those with resources useful for dealing with bureaucracies. Similarly, resolution of water disputes in judicial forums will favor those with resources and skills for success at adjudication. Zachary Smith, "The Policy Environment" in Zachary Smith, ed., *Wafer and the Future of the Southwest* (Albuquerque: University of New Mexico Press, 1989), p. 15.

68 National Water Commission, *Water Policies for the Future: Final Report to the President and to fhe Congress of the United States* (Port Washington, New York: Water Information Center, 1973), p. 232.

69 Lipson, p. 20.

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72 Ibid, p. 23.

73 Lipson, pp. 10-11.

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75 Susan M. Trager, "Emerging Forums for Groundwater Dispute Resolution in California: A Glimpse at the Second Generation of Groundwater Issues and How Agencies Work towards Problem Resolution," *Pacific Law Journal 20* (October 1988): 58.

76 Ibid., p. 52.

77 Ibid., p. 53.

78 James T. B. Tripp and Adam B. Jaffe, "Preventing Groundwater Pollution: Towards a Coordinated Strategy to Protect Critical Recharge Zones," *Harvard Environmental Law Review 3* (January 1979): No. 1, pp. 41-42.

79 National Research Council, Committee on Ground Water Quality Protection, *Ground Water Qualify Protection: State* and *Local Strategies* (Washington, DC: National Academy Press, 1986), p. 53; Metropolitan Dade County Department of Environmental Resources Management, *State of the Environment,* 1987-88 (Miami, 1988), pp. 2-6.

80 National Research Council, p. 52.

[81] Ibid.

[82] Ibid., p. 78.

[83] Ibid.

[84] Nancy Humphrey and Christopher Walker, *Innovative State Approaches to Community Wafer Supply Problems* (Washington, DC: The Urban Institute, 1985) p. 6.

[85] Wade Miller Associates, p. 10.

[86] Humphrey and Walker, pp. 49-52.

[87] See especially R. Steven Brown, "Environmental and Natural Resource Problems: The Role of the States," *The Book of the States,* 1986-87 Edition (Lexington, Kentucky: Council of State Governments, 1986), pp. 401-419.

[88] National Research Council, p. 2.

[89] William Cox, 'Water Law Primer," *ASCE Journal of Water Resources Planning and Management* 108 (March 1982): 118; also George, p. 236.

[90] U.S. General Accounting Office, *Groundwafer Quality: State Activities to Guard against Confaminanfs* (Washington, DC, 1988), p. 3.

[91] Ibid., p. 4.

[92] National Water Commission, p. 244.

[93] Henry C. Hart, "Toward a Political Science of Water Resources Decisions," in L. Douglas James, ed., *Man and Water* (Lexington: University Press of Kentucky, 1974), pp. 134-137.

[94] Schilling et al., p. 133; David Howells and James Warman, "Groundwater Management in the Southeast," *ASCE Journal of Wafer Resources Planning and Management* 108 (October 1982): 325.

[95] National Research Council, p. 46.

[96] Ibid.; Robert Melvin, Hugo Thomas, and Robert Moore, "Cooperative Efforts in Ground-Water Protection-A Connecticut History," *U.S. Geological Survey Yearbook* 1987 (Washington, DC: US. Geological Survey, 1988), p. 8.

[97] National Research Council, p. 46.

[98] Melvin et al., p. 11.

[99] Ibid., p. 8.

[100] Ibid., p. 15.

[101] Schmandt et al., p. 41.

[102] Ibid.

[103] Testimony of Wesley Steiner and Kathleen Ferris before the Subcommittee on Water and Power Resources, Committee onlnterior and Insular Affairs, U.S. House of Representatives, 100th Congress, First Session, on H.R. 2320. Series 100-23, Part 1, pp. 87-88.

[104] Schmandt et al., p. 42; presentation by Ronald Miller, Arizona Office of Waste and Water Quality Management, in *The States' Groundwater Management Conference,* Associationof State and Interstate Water Pollution Control Administrators, November 1986, San Diego, p. 3.

[105] National Research Council, p. 83.

[106] Prospects for greater coordination of groundwater supply management and quality protection functions are explored in Susanna Eden, *Integrated Water Management in Arizona* (Tucson: University of Arizona, Water Resources Research Center, 1990).

[107] Alabama, Florida, Hawaii, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Minnesota, New Jersey, New York, North Carolina, Rhode Island, Vermont, Virginia, Washington, Wisconsin, and Wyoming have developed new laws, regulations, strategies, agencies, or coordination procedures for groundwater quality protection during the last decade. Several other states began even earlier, and others have enacted legislation within this decade directed specifically toward agricultural chemical use or underground storage tanks.

[108] National Research Council, p. 9.

[109] Ibid., p. 127.

[110] Humphrey and Waker, p. 6.

[111] Schmandt et al., p. vii.

[112] Robert Ehrhardt and Stephen Lemont, *Institutional Arrangements for Intrastate Groundwater Management: A Comparative* Assessment *Using* Virginia as *a Case Study* (Arlington, Virginia: JBF Scientific Corporation, 1979), pp. 23-24.

[113] Schmandt et al., p. 202.

[114] Neil S. Grigg, "Appendix: Groundwater Systems," in Kyle Schilling et *al., The Nation's Public Works: Report on Water Resources* (Washington, DC: National Council on Public Works Improvement, 1987), p. B-3.

[115] With respect to groundwater quality protection, this represents activity in addition to the adoption of underground storage tank legislation or regulations (which nearly all states adopted), or the development and submission of state groundwater quality protection strategies under EPA's Section 106 program (which also was done by nearly all states). Wiiiam Blomquist, "Exploring State Differences in Groundwater Laws and Policy Innovations, 1980-1989," *Publius — The Journal of Federalism* 21 (Spring 1991): 101-115.

[116] Testimony of Roberta Savage on H.R. 2253 and H.R. 791 before the Subcommittee on Natural Resources, Agriculture Research, and Environment, Committee on Science, Space, and Technology, U.S. House of Representatives, 100th Congress, First Session, p. 244.

[117] U.S. Environmental Protection Agency, *Survey of State Ground* Water *Quality Protection Legislation Enactedfrom 298.5 through* 1987 (Washington, DC, 1988), p. vii.

[118] U.S. General Accounting Office, *Groundwater Quality,* p. 5.

[119] Wade Miller Associates, p. 10.

[120] Ibid, pp. 9-10.

[121] Frank J. Trelease, "States' Rights Versus National Powers for Water Development," in Ernest Engelbert, ed., *Strategies for Western Regional Wafer Development* (Los Angeles: Western Interstate Water Conference, 1966), p. 107.

[122] Norris Hundley, *Water and the West* (Berkeley:University of California Press, 1975), p. 64.

[123] Schmandt et al., p. 25.

[124] United States *Geological Survey, Water-Data Program.* Water Fact Sheet (Reston, Virginia, 1984).

[125] Howells and Warman, p. 321.

[126] David Moreau, "New Federalism and Social and Environmental Goals," *Journal of Water Resources Planning and Management* 115 (January 1989): p. 28.

[127] Wayne Solley, Charles Merk, and Robert Pierce, *Estimated Use of Wafer in the United States, 2985* (Washington, DC: U.S. Geological Survey, 1988), p. 3.

[128] David Jaquette and Nancy Moore, *Efficient Water Use in California: Groundwater Use and Management* (Santa Monica: RAND Corporation, 1978), p. 32.

[129] Schmandt et al., p. 25.

[130] Schiing et al., p. 116.

[131] U.S. Office of Science and Technology Policy, *Federal* Ground-Water *Science* and Technology *Programs (Washington*, DC, June 1989).

[132] Ibid., p. i.

[133] James H. Jensen, "Governmental Responsibilities for Water Development," in Engelbert, ed., p. 116.

[134] Viessman and Welty, pp. 30-31.

[135] Jaquette and Moore, p. 32.

[136] Viessman and Welty, p. 31.

[137] Henry P. Caulfield, "The Future of Local Water Districts and Agencies in Historical, Political Context," in Corbridge, ed., pp. 104-106.

[138] Viessman and Welty, pp. 38-39; Paul Taylor, "The 160-Acre Law," in David Seckler, ed., *California* Water: *A Study* in *Resource Management* (Berkeley: University of California Press, 1971), p. 251.

[139] Schiiing et al., p. 8.

[140] Wiiiam Cox and William Waker, "Ground-Water Implications of Recent Federal Law," *Ground Water* 11 (September-October 1973): 15.

[141] Robbi Savage, "National Clean Water Act Program Turned Into State Revolving Loan Funds," *County News* 19 (August 17, 1987): 16; Anthony J. Celebrezze, Jr., "Ohio's Required Enforcement of the Clean Water Act," *Cities and Villages* 36 (February 1988): 8.

[142] Savage, p. 18.

[143] Ibid., p. 16.

[144] "NACD Announces Water Quality Strategy," *Journal of Soil and Water* Conservation 44 (May-June 1989): 217.

[145] Wade Miller Associates, p. 204.

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[147] U.S. General Accounting Office, *Groundwater* Protection: *The* Use of Drinking Water Standards *by the* States (Washington, DC, 1988), p. 3.

[148] Ibid., pp. 2-3.

[149] Ibid., p. 5.

[150] Wade Miller Associates, p. 84.

[151] Ibid., p. 205.

[152] George, p. 235; Zachary Smith, "Federal Intervention in the Management of Groundwater Resources: Past Efforts and Future Prospects," *Publius - The Journal of Federalism* 15 (Winter 1985): 151; Environmental and Energy Study Institute, *A Congressional Agenda to Prevent Groundwater Contamination: Building Capacity* to Meet Protection Needs (Washington, DC, 1986), p. 1.

[153] Smith, p. 151; National Research Council, p. 3.

[154] U.S. Environmental Protection Agency, Office of Ground-Water Protection, *Ground-Water Protection Strategy* (Washington, DC, 1984), p. 3.

[155] Ibid., p. 4.

[156] Viessman and Welty, p. 2; William Lord, "Conflict in Federal Water Resources Planning," *Water Resources Bulletin* 15 (October 1979): 1228.

[157] Viessman and Welty, pp. 41-53.

[158] Ibid, p. 7.

159 Schilling et al., p. 130.

[160] Grigg, p. B-3.

[161] Ibid.; also Schiing et al., p. ix.

[162] See, for example, Schmandt et al., p. 2:

> Whereas the federal government was a major player when water development projects were the preferred approach to water management, now that the emphasis has changed from development to better management of existing resources, its role is declining, and state governments are assuming a more active role.

[163] Smith, p. 146.

# Water Resource Management: Problems and Barriers

Despite the initiatives described in Chapters 3 and 4, there still are important institutional barriers to effective coordination of surface and groundwater supplies having to do with the rules governing allocation,valuation, and information It is possible to "create a crisis" through the application of inappropriate rules: "When institutional mechanisms do not reflect reality a crisis occurs."[1] Recognition of this fact has led to calls for more "institutional analysis" of water resource management and for institutional reform.[2] However, as others have pointed out, "institutional analysis" is easier said than done,[3] and "institutional reform" is no simpler than designing institutions originally (indeed, it is likely to be tougher, as problems of design are compounded by inertia). Moreover, important and useful recommendations for institutional reform that have been offered have generally been ignored!

Acceptance of the idea that institutional arrangements and physical realities in the water resources field are mismatched is not enough; there must be an understanding of how they are mismatched if reform is to make the situation better There appear to be three broad views of the nature of the mismatch:

1) Water supplies are insufficient, and institutional arrangements fail to force us to conserve those supplies
2) Institutional arrangements of the past are inadequate, and their continued use is the cause of the problem.
3) The principal problem with the institutional arrangements is that they distort the valuation of water supplies, making it difficult to know whether supplies are sufficient because users have several incentives to misstate preferences for water and virtually no incentives to be accurate.

When the water situation is described as if the supply were a fixed and limited known quantity, less than can meet all needs and desires, the problem is perceived to be that laws and institutions have perpetuated a false sense of water abundance As one author stated, water laws and institutions have "maintained the 'water-rich' illusions of this country" when in fact the "challenge of the future will be learning to live with less."[5] The proper course for institutional reform, then, is to curtail use so as to balance the limited available supply with aggregate demand

As the objectives of water resource management have shifted from development to the more effective management of existing supplies, part of the difficulty is that "we have inherited a structure of politics, organizations and intergovernmental relations which is derived from the initial objective" of water development.[6] In the words of the director of Arizona's Water Resources Research Center, our

> society is, and has long been, a technologically oriented one. We have been successful in technological innovation and we have come to look first for the 'technological fix' when we confront a new problem. At the same time, we are institutionally backward. We shrink from institutional change, except as a last resort . . . In our own field of water resources management there are abundant and obvious examples of the tendency to resort to extravagant and unwarranted technological solutions. Massive reservoirs, controversial water transfers, costly desalination, and uncertain weather modification schemes are all examples of a resort to technology to solve problems which are more easily and cheaply addressed by institutional innovation, Indeed, most of these 'solutions' are aimed at problems which exist only because we have failed to modify institutions which were responsive to problems of an earlier day, but which have long since been rendered obsolete by changing conditions'

The problem is not merely that our water laws and institutions are old, but the arrangements that were beneficial for water development may have detrimental results when the purpose of management has changed to efficient and equitable allocation of supplies. The laws and institutions governing allocation have distorted users' sense of the value of water supplies Therefore, it is virtually impossible to draw simple conclusions, such as "water demand equals y, and water supply equals x,and y is greaterthan x." We operate in an institutional environment in which users' claims are undefined, rights to use groundwater basins for storage are undefined, barriers exist to water being transferred from one user to another or reclaimed by a user who employs water conservatively, and some persons pay unnecessarily high taxes or electrical power rates so others can have water supplied at prices less than the cost of production. Under those circumstances, making any claims about the relationship between the demand for water and the supply is a dubious exercise.

What remains to be done is some real institutional analysis. Past analyses have usually treated water laws and institutions as fixed elements, and predicted crises based on projections of supply and demand that were also deemed unchangeable.8 Institutional analysis treats water laws and institutions as variables, subject to change, and then inquires as to the possible effects of changed laws and institutions on the relationship between supply and demand? Thus, while we acknowledge that it may be possible to "create a water crisis" through poorly adapted institutional arrangements, we must acknowledge that it may be possible to avert or lessen the likelihood of a water crisis through appropriate institutional adaptations

What, then, are the barriers to more effective conjunctive management of groundwater supplies? They are the institutional factors that distort decision-making in such a way that the actors in the complex water economy respond to incentives and constraints by "creating a water crisis" or simply by failing to take full advantage of available resources These institutional factors include lack of definition and transferability of production and storage rights, distortions created by water subsidies, and lack of information distribution.[10]

## LACK OF DEFINITION AND TRANSFERABILITY OF PRODUCTION AND STORAGE RIGHTS

### State Water Rights Laws

State laws govern rights to the use of groundwater and water resources generally Some states tie those rights to the ownership of land; others tie the rights to actual water use. Although the laws vary in their details, there are four general categories of water rights laws absolute ownership, reasonable use, correlative rights, and appropriation.

Some laws follow old common-law property rules and confer absolute ownership of groundwater on the riparian or overlying landowner The absolute ownership doctrine places no restriction on the amount of water withdrawn or on its place of use (the owner may export the water). Such a system provides no quantification of an owner's right to the use of water.[11]

Under this system, an owner of water rights is unrestricted in withdrawing water and is protected by law in doing so. Water users bear only their own costs of withdrawal. There are no charges for use of the common supply or for losses imposed on fellow users.

The absolute ownership system creates incentives for overlying owners to produce as much water as desired given the production cost, and creates no incentive to conserve water or make sure that it is not wasted. The system also renders management of the common supply highly problematic because there is no quantification of users' rights and no legal basis for restraining use. It is a system that promotes overuse. The absolute ownership doctrine is a recipe for water shortages in any area that is not blessed with an abundance of water

Because water is not unlimited in most of the country, most states have moved away from the principle of absolute ownership. Many states adopted a policy that limited withdrawal rights to those amounts that could be applied to a "reasonable use" or a "beneficial use" on the owner's land.[12] The reasonable use doctrine also takes away the entitlement to export the water: The prohibition against groundwater withdrawals for any "unreasonable" or "nonbeneficial" use has been essentially meaningless in practice, as virtually any use on an owner's overlying land has been construed to be reasonable or beneficial

Under the reasonable use doctrine, rights to water withdrawals remain unquantified and essentially unlimited. For instance, there is nothing to prohibit an owner from withdrawing groundwaterto the detriment of a neighbor as long as the water withdrawn is put to a "reasonable" or "beneficial" use.[13] There also is no mechanism for taking into account the costs one pumper imposes on others. As with the absolute ownership rule, the only costs for the owner are the production costs

The reasonable use doctrine creates incentives for users to use as much water as they desire given their production costs, and no incentives to conserve water or avoid waste. The lack of quantification of water rights also poses obstacles to conjunctive management. Any possible schemes for limiting withdrawals, inducing users to take water from alternative sources, or in any other way controlling overdraft are unlikely to succeed in such a legal environment Water shortages and conflicts are likely.

Neither the absolute ownership nor the reasonable use doctrine takes into account the interdependence of the users of a common water supply. The doctrine of "correlative rights," while still tying groundwater withdrawal rights to ownership of overlying land, was adopted by a few states in an attempt to redress this shortcoming. Under the correlative rights rule, overlying owners share the common supply in proportion to their ownership of the overlying land.[14] However, this is a rule that acquires "bite" only after a shortage has occurred, when a determination of the amount of water available in a groundwater basin is made and that amount is apportioned among the owners.

The correlative rights rule, which reached its greatest development in California and Florida, suffers from problems similar to absolute ownership and reasonable use. First, the rule also leaves groundwater rights unquantified, which presents obstacles to conjunctive management (except in Oklahoma, where the state Water Resources Board is directed by statute to survey each basin, make a determination of its maximum annual yield, and allocate a share of that yield to each acre of overlying land, thus giving each overlying landowner a quantified right to a specific amount of groundwater[15]).

Second, like the absolute ownership and reasonable use doctrines, the correlative rights rule ties acquisition of groundwater rights to ownership of overlying land. In fact, it makes that tie even closer by apportioning the water proportionately with land ownership. The main problem this presents is that a water purveyor, whether a private company or a public agency, may own a relatively small share of the land overlying a groundwater supply but may require significant quantities of water in order to serve its customers or residents and may value that water more highly than other owners of more extensive land areas. Nevertheless, doctrines that tie water rights to land ownership -especially the reasonable use doctrine and the correlative rights doctrine-may not provide for such needs, and water may not be available for higher valued uses, both of which result in inefficiency and inequity.

The allocation of water has been addressed in most of the western states, where water is generally less naturally abundant, through the adoption of a system of appropriative rights. Under an appropriation system, users acquire rights to specific quantities of water based on actual use rather than on land ownership. Water can be diverted for use out of the stream and on nonadjacent lands (in the case of surface waters) or on nonoverlying lands (in the case of underground waters).

Rights to the use of water under appropriation systems can be acquired as long as "surplus" (i.e., not already appropriated) waters remain, and as long as the appropriator will put the water to a "beneficial use." In times of shortage, however, there must be some allocation of obligations to reduce withdrawals. Thus, the pure appropriation doctrine employs a simple rule of seniority: "first in time, first in right." Junior appropriators must yield to senior appropriators during times when there is not enough water to satisfy all claims. Some states have added other restraints to this rule, classifying uses by priority in times of reduction of withdrawals. To keep track of the amounts of water to which holders of appropriative rights are entitled, and the priority (i.e., seniority) of those rights, states typically have issued permits to pumpers or diverters (by a state engineer, for example).

One desirable feature of the appropriation doctrine was that it quantified rights. This makes possible some beginning steps toward effective management, In a groundwater basin, it is possible to know at a given time in a given groundwater basin the maximum amount of legal pumping. It is also possible to limit the amount; if the office that issues appropriation permits is aware of the total available water yield of the basin, the off ice can stop issuing permits when there is no more "surplus" water available. And, as noted above, the appropriation doctrine comes with a rule for allocating water in times of shortage-junior appropriators cut back first

The appropriation doctrine, with its priority principle, also encouraged the development of western lands by offering secure water rights to those who put the water to use.[16] Water rights were not tied to land ownership, so a landowner could not "sleep on his rights" The relationship between the appropriation system for the acquisition of groundwater rights and the development of regions, however, is a vehicle that is all accelerator and no brake. Appropriation law has combined with other economic and political pressures to promote the premature overdevelopment of land and other resources."

In an area where there may not be enough water to satisfy all claims (i.e., where water is "scarce" in the economic sense), anyone who waits to use water until it is genuinely needed for some profitable purpose may find that all available water has been appropriated or that the remaining appropriative right that can be acquired is so junior as to stand highly exposed to any period of shortage. Water is to be put to a "beneficial use," but reserving water for future use does not so qualify under most appropriation laws. Therefore, "first in time, first in right" becomes "get it now, whether you need it or not" Each entity races against all others "to establish use rights ahead of need."[18] The result can be almost comic water waste: industrial enterprises in desert areas grow fields of alfalfa hay with irrigation water in order the preserve their right to the water if they need it for future expansion.

Once begun, the process feeds on itself. Any entity – from individual farmer to metropolis -seeking water to appropriate as "surplus" induces others to try to be sure that they do **not** lose out. The only way to **be sure that** water for future use is not defined as present "surplus" and lost is to put **that** water to use.[19] Moreover, in some states, unused water rights may be lost by adverse use or prescription. Thus, "first in time, first in right!' becomes "use it or lose it." Both offensive and defensive strategies under pure appropriation law work toward the same end: the premature and excessive exploitation of water resources

Under the appropriation system, individual incentives are placed in opposition to collective goals And collective efforts, instead of being directed toward reshaping the legal institutions that create this incompatibility, are directed at trying to fix its effects:

> At a time when real competition for scarce water supplies is forcing conservation policies, weather modification, desalination, and expensive transbasin diversion projects upon some water users, it is unthinkable that state water laws should be simultaneously encouraging other water users to use as much as possible and speculators to claim now water rights in the hope of someday becoming rich by so doing.. . . [20]

Regardless of how "unthinkable" it may seem, these perverse incentives are created by water rights laws that reward users who employ as much water as fast as possible, and penalize those who wait and those who reduce their use. Water "shortages" that appear under such situations are often attributed to natural conditions (the notion that "there simply isn't enough water to go around") or to wasteful water users, as though their wastefulness were a personality trait rather than a response to a system of water law that seems to be designed to eliminate surplus waters wherever and whenever they are found.

Because the use of water in irrigated agriculture, and especially in the appropriation states, is often singled out for attention, the point should be made that these water rights laws encourage waste and discourage conservation, the opposite of our collective goals Irrigated agriculture accounts for approximately 90 percent of water consumption in the western states Since farming and ranching are among the oldest activities in the developed West, irrigated agriculture also holds most of the senior appropriative rights in the western states that use that system As demands for urban uses have grown in the West, and as urban water managers have viewed the water rights of farmers jealously, the use of terms such as "waste" has become part of the political battle over entitlement, fueling animosities between farmers and city dwellers.[21]

Yet there is no reason to believe that western farmers are somehow "wasteful" or that irrigated agriculture must necessarily be a "wasteful" practice. Those engaged in agriculture under an appropriative rights system may be perfectly rational, responding to almost perfectly irrational incentives If an individual's right to use a specified amount of water is based on the amount of water diverted or withdrawn, and if acquiring the right costs virtually nothing (usually there is a filing fee for a permit, but the cost of the water right does not vary with the amount), given some uncertainty about the future, the understandable response is to stake a claim to as large a water right as feasible by diverting or withdrawing and using as much as possible. That is not being "wasteful"; under the **circumstances-** and given the incentives-it is being prudent

Water rights laws that provide for the acquisition of rights to groundwater based either on ownership of overlying land or on actual use at a specific place and for a specified purpose encourage inefficient use.[22] Production rights are either undefined, defined but connected to land ownership, or defined in such a way as to encourage maximum use and minimum conservation. Although the appropriation system does at least provide for specific and quantified water rights, it does so in a way that leaves claimed water rights bearing only a questionable relation to needed water rights Without modifications, each of these water rights systems constitutes a barrier to more effective conjunctive management of water supplies

### Legal Separation of Surface and Groundwater Rights

Although we have become increasingly knowledgeable about hydrologic interrelationships between groundwater and surface water in stream-aquifer systems, water rights laws often do not recognize the connection. In many states, there is a distinction between the laws governing groundwater rights and surface water rights, even where the two sources are physically interconnected. The extent of the difference between the two systems of rights varies from state to state.[23]

Separate legal systems governing the acquisition, retention, and transfer of rights to surface water and groundwater in stream-aquifer systems where the two sources are physically interrelated "impose an added difficulty for water managers."[24] Separation can leave appropriators of the two sources "on a collision course."[25] Groundwater appropriators may have perfected senior appropriative rights to pump from an aquifer that is hydrologically connected to a stream system wherein surface water diverters have perfected senior appropriative rights to that water.

In these cases, which are not rare, the law protects both appropriators absolutely; yet, pumping groundwater reduces the surface stream flow, or diverting surface water reduces the water available to the groundwater aquifer While it is one thing to say that such conflicts could be resolved as would other conflicts between users of a common resource-i.e., through some adjudicative or administrative process—it is another thing altogether to have such conflicts created needlessly by the failure to adjust water rights laws to reflect known characteristics of the supply those laws are supposed to allocate and govern

An example of the problems this can create can be seen in the recent experience of the Platte River in Nebraska. Nebraska has a "reasonable use" doctrine for the allocation of groundwater and an appropriation system for surface water As thousands of wells have been drilled and put to use, some of those have pumped water that would have contributed to the flow of the Platte River, and flows in the river have declined. Towns, irrigation companies, and districts with appropriation permits along the river have faced reductions in stream flows, from which they can claim a right to be protected. On the other hand, groundwater pumpers can argue that they have invested in wells and drilling equipment and have put the water to a reasonable use, and therefore have an equally unassailable right to the water they use. Nebraska law does not provide a way of making these users' rights fungible so that water supplies can be allocated among them when shortages occur Similar problems have appeared in other river basins.[26]

Some states in the West have attempted to bridge the legal separation of connected waters. In Colorado, separate legal treatment is given to groundwater that is tributary to surface water, and this groundwater is subject to the laws governing the use of the surface water to which it contributes.[27] This allows at least a chance for conjunctive management in a basin where the two sources are interrelated by unifying the priorities of the appropriative rights. In the 13 western states that apply the doctrine of prior appropriation, six apply a single appropriation system to hydrologically connected surface water and groundwater, and five provide by a separate statute for the integration of rights where surface and underground waters are connected. In two states, the courts have upheld actions of the state engineer (as in New Mexico) in administering rights to the joint use of connected surface and underground water.[28]

States attempting to consolidate water rights after a stream system has been "fully appropriated" have faced a political problem of some intensity when the priorities of rights of groundwater pumpers come up against the older rights of surface water diverters.[29] Nevertheless, failure to integrate the two sets of rights makes coordinated use quite difficult State water rights laws need "to respond to a realistic view of the physical occurrence and distribution of ground water including the interrelationship between ground and surface water."[30]

## Rights to Store and Recapture Water

Lack of definition of rights to the storage of water in underground basins and to its subsequent recapture discourages systematic conjunctive management.[31] Moreover, other aspects of state laws and policies governing groundwater and surface water rights and basin management may impede effective conjunctive management

Water rights may be undefined for entities wishing to undertake artificial recharge of groundwater supplies in order to capture temporary water surpluses for later use. First, the right to use surface water supplies for recharge must be assured. Under the appropriation doctrine, diverting and capturing surface waters for use at some later time may not qualify as a "reasonable" or a "beneficial" use. Appropriation rules often stipulate that the water diverted must be put to beneficial use within a certain period or the right to its use is forfeited. This places in question the rights to store water that might not be recaptured and used for years[32] While most western states have modified their procedures to recognize groundwater recharge as a qualifying "beneficial use," other states do not make this definition explicit

Rights to store and recapture water supplies underground also depend on the availability of storage capacity Rights to the use of the storage capacity in an underground basin often are not defined in state laws, which were likely devised to address rights to production. As a result, any private operator or public entity attempting to use an underground basin for storage runs some exposure of being unable to sustain a subsequent claim to the storage space; this discourages such use of a basin before the fact On the other hand, assuring a right to use underground storage space provides an incentive to capture, store, and recapture waters and to alternate between water sources

Of course, for there to be storage space to use, there must be space available. Optimal basin management may require lowering underground water tables in order to increase the effectiveness of the basin in capturing flows for recharge when surplus waters are available.[33] As noted in Chapter 3, in states where "safe yield" operation of groundwater basins is mandated, there will be a conflict between having available underground storage capacity and complying with the "safe yield" requirement.[34] "Safe yield" policies affect planning of surface water reservoirs and distribution systems because underground storage capacity cannot be figured into plans for conveyance, storage, and distribution of surface water supplies, resulting in overinvestment in above-ground facilities This inefficiency hampered the State Water Project in California, which was planned when "safe yield" was the prevailing requirement for managing groundwater supplies.[35]

Where groundwater and surface water rights are separated but the supplies are physically connected, legal protection afforded to surface water rights may require keeping a contributing groundwater basin as full as possible. This would have the same effect as a "safe yield" requirement in presenting an obstacle to effective basin management.[36]

The right to recapture the stored water requires that the storing entity also be entitled to pump the water from underground. Priorities may have to be established for the retrieval of stored water during periods of shortage.[37] Procedures are needed to account for the water stored and the right to remove it In the groundwater basins in the Southwest, where effective conjunctive use has been developed, this typically has been facilitated by the appointment of a "watermaster" or the acceptance of these accounting duties by the office of the state engineer

Finally, consideration should be given to two related issues. First, the interests of overlying landowners should be protected from any unreasonable harm from raising and lowering underground water levels as part of a conjunctive management program. Any entity storing water should assume some liability and the overlying landowners should receive some compensation if their pumping lifts are unreasonably lengthened or if the quality of their water supply is affected adversely? Second, communities contemplating conjunctive management of groundwater and surface water supplies should do some planning to ensure that potential recharge areas overlying aquifers in which they may wish to store water are not developed beforehand. One potential institutional mechanism for addressing both of these issues is the idea of "water zoning" ordinances that set aside recharge areas and condition development in areas overlying an aquifer that will be used for water storage on recognition of the likely variability of water levels in that area.[39]

In all, a legal structure "has to be developed which permits raising and lowering of water levels, defines the authority to use empty storage space, defines individual rights, provides for physical solutions when individual rights conflict with the management plan, and protects individuals from the economic inequities which may be created locally."[40] Institutional arrangements that fail to provide for these elements of conjunctive management present continuing barriers to more effective utilization of groundwater supplies.

## Authority for Conjunctive Management Agencies

One of the most serious and persistent obstacles to effective conjunctive management is the absence of local or basinwide authorities that could effectively represent water users. Organizing for groundwater management locally has been impeded by the fact that "states have historically been slow to turn over comprehensive environmental responsibility to local governments."[41]

As long ago as 1973, the National Water Commission recognized that local management authorities should have the following capacities in order to undertake effective conjunctive management efforts:

a) To issue revenue bonds and to levy pump taxes and diversion charges;

b) To acquire water, water rights, and real property for the development and use of facilities for water storage, recapture, and conveyance;

c) To buy and sell water and water rights, and to export water from the area when it is economically beneficial to do so;

d) To store water in surface reservoirs or underground, to extract water, and to reclaim and treat water;

e) To represent all landowners and water rights owners in legal actions to protect water rights and water quality within its jurisdiction.

These powers, according to the commission, were vital in order that any locally based water management institution "be able to perform comprehensive management functions within its jurisdiction.""

The commission also acknowledged that few states were willing to give such a range of powers to water management agencies. Even powers to impose pump taxes and diversion charges have been granted reluctantly at best, though these powers are "vital if the agency is to be able. to enforce rational choices between surface and ground water use when both are available and physically accessible to users."[43] Implementing effective institutional arrangements for conjunctive management requires the ability to manipulate user charges to increase the compatibility of individual incentives and collective goals.

## Problems of Unspecified and Latent Rights

**Instream** Flow Protection, the "Public Trust" Doctrine, and Land Based Water Rights. Unspecified and poorly quantified rights give rise to considerable uncertainty on the part of water rights holders and managers Similar problems are created by legal doctrines that leave vague and unspecified "latent" rights in the system that might at some subsequent date be activated and used. Even a specified, quantified permit to appropriate water, duly acquired under state laws and procedures, is of dubious value if it is not binding on subsequent uses.[44] Unspecified rights and reservations that impede more effective management arise from four sources: protection of instream flows; the emergence of the "public trust" doctrine; water rights tied to land ownership; and the doctrine of "reserved rights."

Protecting instream flows (for scenic, wildlife, navigation, recreational, and other purposes) is not normally conceived as a problem of managing groundwater supplies, but, as we have seen, groundwater supplies frequently contribute to the base flows of surface streams with which they are physically interconnected. In such cases, actions by the state to protect instream flows may affect the amount of withdrawals from a groundwater basin. Here, again, the difficulties encountered may be less physical than institutional.

States that do not connect their groundwater and surface water rights systems are poorly positioned to establish reasonable trade-offs for the protection of instream flows. Maintenance of undiverted water flows downstream has been especially difficult in appropriation states that require diversion and use of water Yet, governmental action after the fact to try to restore instream flows disrupts the production rights of users who acquired them in good faith under the rules of their day, and requires the owners to relinquish the rights for another purpose without compensation. Perhaps most importantly, endless speculation about possible impending governmental action to protect instream flows has a chilling effect on efforts to manage water supplies"

The "public trust" doctrine has been employed recently to protect instream flows. The doctrine originated in the Tudor period in England[46] to convey the limits on private rights of ownership to tidal lands, but has been extended to nontidal lands and to water rights. The claim of right under the public trust doctrine is that some natural resources "are so intrinsically valuable to the public that they cannot be owned by any person."[47] As a "broad mandate to consider public trust values,"[48] the doctrine could be used to protect instream flows before allocating production and storage rights to individual owners. On the other hand, recent litigation has attempted to employ the public trust doctrine after the allocation and exercise of rights in order to subsequently "limit or destroy the property right by application of a previously undefined superior claim with no compensation for the loss."[49]

When applied in this fashion, the public trust doctrine becomes another source of uncertainty for the holders of production and storage rights. This can inhibit the development of complex basin management programs that involve allocation of water and storage among competing users, the employment of alternative sources of water supply, transfers of rights, allocation of management costs among users, and so on While it is unclear whether and to what extent the public trust doctrine will be employed to defeat production and storage rights that users believed they held with certainty and stability, it appears to have 'almost suddenly evolved into a completely new creature that is doing things never considered possible when the doctrine developed.*

The emergence, or threat of emergence, of "latent" rights that may be employed suddenly without compensation for the losses imposed on holders of other rights generally presents a barrier to more effective conjunctive management In states that link the acquisition of water rights to ownership of overlying lands, this problem of the "latent" right can affect even the most apparently complete and stable management plans. Even after a long and complex adjudication of the rights to native groundwaters, imported stored waters, and return flows in California's San Fernando Valley, forexample, the California Supreme Court indicated in its opinion that landowners in the valley who were not exercising their rights to the use of the groundwater beneath their lands at the time of the entry of the judgment could still initiate production of groundwater for reasonable use on their overlying lands. The exe&e of this "latent" right could thus "upset the apple cart"[51] and reduce or infringe on the tights of the parties to the adjudication, simply because California water rights law continues to give unquantified rights to the use of underlying groundwater to anyone who owns land Effective basin management planning requires that, at some point, there be an end to the expansion of pumping rights within the basin

Federal Reserved Water Rights. Reserved rights are the most extensive of the "latent" unquantified rights, In the western states in particular, federal reserved water rights play an especially important role in impeding more effective management of groundwater supplies. A series of decisions, beginning with *Winters* v. *United States* (1908) and reaching its zenith with the surface water diversion decision in *Arizona v. California* (1963) and the groundwater withdrawal decision in *Cappaert* v. *United* States (1976), established reserved water rights of the federal government These reserved rights are superior to the water rights granted under state laws, which previously had been thought to govern nonnavigable water resources

The concept of the reserved right is that when the Congress acts to set aside lands for a federal reservation (e.g., military or Indian), it implicitly acquires the right to use whatever waters are available and needed to fulfill the purposes for which the lands were reserved. The right dates back to the time when the reservation of the land is made, and is superior to any and all subsequently acquired rights.[52]

Reserved rights create two problems for effective basin management. First, the reserved rights are often unquantified,and until they are put to use by the federal government their full extent in a basin can only be guessed at by the local users. This presents the same problems as with all other unquantified water rights.

Second, because many federal reservations date back to the turn of the century and earlier, the rights of the many users who complied with applicable state laws would be rendered essentially worthless by the exercise of federal reserved water rights. Moreover, water withdrawn under a federal reserved right can be used without regard to state law, or even in ways that are inconsistent with or in contradiction of state law.[53] The reserved water rights have not been used frequently; as a matter of federal comity, federal agencies have complied with state laws and administrative procedures, but there is nothing requiring them to do so. As competition for water resources intensifies, the temptation to employ automatic, senior reserved rights rather than comply with state procedures for the acquisition of junior appropriative rights may grow.

This expands the pumping rights in a basin, thereby upsetting any management program. It also means that the federal government has the right to enjoin other groundwater and surface water users' rights that interfere with the availability of water for a federal project or reservation.%

In *Cappaert*, for example, also known as "the Pupfish Case," the United States was upheld by the Supreme Court in its efforts to restrict groundwater pumping by the Cappaert Ranch (pursuant to permits granted by the state of Nevada) that were lowering the water level at Devil's Hole in Death Valley National Monument, thereby threatening the continued existence of a rare species of desert pupfish.[55] The *Cappaert* decision appears to establish the authority of federal agencies to exercise rights to the use of groundwater and to prohibit other users' exercise of groundwater production rights that might interfere with the federal reserved water right The potential for such a decision was viewed with alarm by western states, some of which filed amicus curiae briefs in the *Cappaert case.* Given the extent of federal reservations in Arizona, for example, the state's brief warned that interference with state groundwater rights laws and management plans from the extension of federal reserved rights would wreak "economic havoc" on the state.[56]

In 1978, the Supreme Court clarified the federal reserved water right issue in a way that showed greater sensitivity to the concerns of states In *United States* v. New Mexico, the Court restricted federal reserved rights to water for specific needs essential to the planned use of the reserved land. The Court rejected an attempt to broaden the reserved water rights of national forests to protect instream flows for fish and wildlife.[57]

Indian water claims in particular present considerable uncertainty for the Indian tribes and the states in which reservations are located. No one in the reservation states "knows how much unencumbered water will be available until the Indian claims are settled."[58] Furthermore, the tribes do not know what water they have or what they will be allowed to do with it. The Indians' wealth position and their flexibility to determine their own course of development would be enhanced if their water rights were quantified and were not restricted to use for irrigated agriculture on reserved lands, but were available for municipal and industrial uses, and even for transfer and exchange.[59]

Uncertainty in the Extent of State Authority: *Sporhase* and *El* Paso. The power of the federal government to regulate the waters of navigable streams has been settled since the early days of the Republic. The constitutional power of the federal government to regulate groundwater supplies directly has been a more recent question.

Two principal cases in the federal courts in the 1980s ruled on the issues of the authority of states to restrict the use of groundwater outside their boundaries. In 1982, the United States Supreme Court ruled on an appeal in the case of *Sporhase* v. *Nebraska,* and in 1983a federal districtcourtentered judgment in *City of* El *Paso* v. Reynolds. The two decisions have changed the view of the constitutional power of the federal government and the states with respect to groundwater management

In *Sporhase* v. *Nebraska,*[60] the joint owners of lands on both sides of the Colorado-Nebraska border applied for a Colorado permit to appropriate groundwater for use on their Colorado lands. Their application was denied because the groundwater withdrawals would have constituted groundwater mining, which is prohibited by Colorado. The landowners then pumped groundwater from a well located a few feet over on the Nebraska side and used the water on their lands in both states.

Under Nebraska law, a permit must be obtained to export groundwater from the state. One of the conditions for granting such a permit (along with the conditions that the withdrawals be reasonable, not contrary to the conservation or use of groundwater, or otherwise detrimental to the public welfare) is that the state to which the water is exported grants reciprocal rights to Nebraska, which Colorado does not Nebraska sought an injunction to restrain the landowners from exporting groundwater pumped in Nebraska to their lands in Colorado. Nebraska prevailed in the trial court and in the state supreme court The landowners appealed to the United States Supreme Court The case generated amicus curiae briefs from the states of California, Colorado, Kansas, Missouri, Nevada, New Mexico, North Dakota, South Dakota, Utah, and Wyoming as well as the City of El Paso, the Elephant Butte Irrigation District, the National Agricultural Lands Center, and the National Wildlife Federation

The United States Supreme Court, by a 7-2 vote, held for the landowners, ruling the Nebraska law unconstitutional. The principal constitutional challenge was that the Nebraska law presented an impermissible state burden to interstate commerce. Nebraska replied that groundwater, which is not a freely tradeable item under state law, is not an article of interstate commerce. The majority opinion for the Court, by Justice John Paul Stevens, observed that the agricultural products of the western states, supported by groundwater irrigation, are part of markets that are not only interstate but international in scope and "provide the archetypal example of commerce for which the Framers of our Constitution intended to authorize federal regulation."[61] The opinion observed that the multistate extent of the Ogallala Aquifer "confirms the view that there is a significant federal interest in conservation as well as in fair allocation of this diminishing resource."[62] The Court majority defined groundwater to be an article of interstate commerce, subject to federal regulation under the Commerce Clause, declaring that further *"Ground wafer overdraft is a national problem, and Congress has the power to deaf with it on a national scale."*[63]

The constitutional inquiry then turns to the extent to which Nebraska may regulate groundwater withdrawal and use in the absence of congressional action on the subject In this regard, some of the conditions the state placed on the export of groundwater were clearly constitutional, according to the Court Requirements that withdrawals be reasonable, consistent with conservation, and not detrimental to the public welfare are not unreasonable restraints on the free movement of groundwater in interstate commerce. However, the reciprocity requirement (for water permits) failed to survive constitutional scrutiny under the Commerce Clause for apparently "discriminatory" or "protectionist!' state regulation. Justice Stevens noted that the reciprocity requirement would bar the transfer of water to any nonreciprocating state, regardless of how beneficial the transfer may be. Such transfers would be prohibited by the Nebraska law even if there were no detrimental effects for the state and even if the state were sitting atop a massive groundwater surplus Finally, the Court observed that federal deference to the states in groundwater law and management does not and cannot remove constitutional constraints.[64]

The dissenting opinion by Justice William Rehnquist criticized the majority for failing to confine itself to the issue of the relationship between the Nebraska law and the Commerce Clause. In the view of the dissent, the majority had "gratuitously" undertaken and decided additional issues that were not presented by the case, such as whether groundwater overdraft constituted a "national problem," the scope of congressional authority to regulate groundwater withdrawals, and the relationship between the Nebraska statute and federal laws that were not passed, not challenged, and not before the Court in any but a hypothetical fashion In addition, the dissenting opinion argued that it was difficult to see how "commerce" could exist in groundwater since groundwater in Nebraska could not itself be reduced to possession, and the only right conferred on Nebraskans was the right to use the groundwater on overlying lands owned by the pumper

The Supreme Court issued the *Sporhase* decision in July 1982 In January 1983, the federal district court for the New Mexico District decided the case of *City of El Paso v. Reynolds.* El Paso, Texas, attempted to acquire rights to the use of 296,000 acre-feet of groundwater from aquifers that are hydrologically connected with the Rio Grande stream system. New Mexico State Engineer Steve Reynolds denied the city's application for an appropriative permit, citing state law forbidding the export of groundwater.[65] El Paso sought to have the New Mexico export ban declared unconstitutional, and, in light of the Supreme Court's decision in *Sporhase,* the federal district court agreed with El Paso.

Criticisms weredirected to the *El Paso* decision on three principal grounds. The first criticism is that in its application of *Sporhnse,* the federal district court concluded that states may discriminate in favor of their citizens "only to the extent that water is essential to human survival."" This may be an excessively restrictive interpretation of the Supreme Court's position in *Sporhase.*

A second criticism in *El Paso* was that the district court failed to take into consideration the Supreme Court decision in *Colorado* v. New *Mexico*[67] handed down in December 1982, involving the Vermejo River, which flows from Colorado into New Mexico. The Supreme Court upheld the doctrine of equitable apportionment governing interstate streams, which divides the waters of a stream so that each state is allocated a fair share. Since the *El Paso* case involves the intexstatetransferof groundwaterthat is part of an interstate stream, the federal district court decision has been criticized for following *Sporhase* instead of *Colorado* v. New *Mexico.*[68] Relying on the doctrine of equitable apportionment rather than the Commerce Clause to govern the case would maintain the recognition of state interests in the management of water resources by allowing each to regulate its fair share of water resources that underlie or flow through more than one state.[69] Part of the problem with the *El* Paso case, then, is that it

> was argued under the wrong theory in the wrong court Under the U.S. Constitution, disputes over interstate streams are to be decided by the Supreme Court of the United States, not by a federal district court, and under the federal common law these disputes are governed by equitable apportionment, not by the commerce clause.[70]

Finally, *El Paso* has been criticized on policy grounds. By deciding in favor of the Texas city seeking additional supplies and against New Mexico, the federal district court "penalizes a state with a progressive water law system (New Mexico) and rewards a wasteful system (Texas)."[71]

The *Sporhase* decision, on which the federal district court based its *El Paso* decision, also has drawn attention and scrutiny The Supreme Court's ruling that groundwater is an article of interstate commerce subject to direct congressional regulation has generally been acknowledged to have substantially weakened the basis for state and local primacy in the management of groundwater supplies, to have "opened the door for federal control over groundwater on nonfederal lands,"[72] and to have "far-reaching" implications for water regulation.[73]

Much of the post-*Sporhase* analysis has been addressed to the questions of what authority remains with states to limit and control the use of groundwater resources. The majority opinion in *Sporhase* has been interpreted by different observers to mean:

a) Narrowly tailored state restrictions on groundwater use could be sustained if shown to be related to the state's legitimate interests in conservation and preservation of the resource.74

b) State restraints on groundwater exports may be permissible if the withdrawals for export would result in groundwater mining thus impairing the resource.[75]

c) State restrictions on groundwater exports may be sustainable provided that a discriminatory embargo against out-of-state residents is not their prime purpose.[76]

d) State restrictions on groundwater exports might be justifiable in times of "severe shortage," in order to protect the health and safety interests of the state's citizens.[77]

From the standpoint of enhancing the marketability of production rights to groundwater, *Sporhase* may also be seen as removing arbitrary state "resource isolation" barriers to the interstate movement of groundwater.[78]

The *Sporlrase* decision is seen as having left the following questions unanswered:

a) Can a state's projections of a "severe shortage" that would occur if a groundwater export were allowed be used to justify restricting that export?

b) In so projecting, can a state take into consideration acreage that might become permanently nonirrigable if the export were allowed?

c) Can states prohibit export where the health and safety of residents might not be threatened but "instream flow" values would be?[79]

Nebraska and New Mexico changed their laws governing groundwaterwithdrawal and use afterthe *Sporhase* and *El Paso* decisions. Nebraska adopted a permit system for all groundwater withdrawals.[80] New Mexico enhanced its review of permits for groundwaterexportbyauthorizingthestateengineer to consider the supplies available to an export applicant in the applicant's home state. This raises the question of one state's authority to restrict exports of water into another state where water surpluses exist, or where wasteful water practices have resulted in the attempt to import water from elsewhere. Neither of those issues was reached by the *Sporhase* decision.[81]

Three years after *Sporhase* v. *Nebraska, the Court* decided *Garcia* v. *San Antonio Metropolitan Transit Authority*.[82] The *Garcia* decision calls speculations about the remaining groundwater management authority of the states into question. *Garcia* holds that, in Commerce Clause cases, the limits on congressional authority relative to the states and localities are not imposed by any substantive concepts of "reserved powers" under the Tenth Amendment, but by the procedural elements of the "political safeguards of federalism." In the aftermath of *Garcia*, once groundwater has been ruled to be part of interstate commerce, there are no aspects of its governance that the constitution reserves to the states, just those that the Congress leaves to the states. Even if states retain some authority to regulate groundwater supplies, a key question of intergovernmental relations and water resource policy raised by *Sporlrase* is whether and to what extent the uncertain specter of direct federal regulation, production, and transfer of groundwater supplies may inhibit the willingness of states to engage in innovations.

At present, there is little question that the Congress has the constitutional authority to directly regulate groundwater under the Commerce Clause. In a legal confrontation between federal and state regulatory power, the federal power would prevail. The *Sporhase* decision means, among other things, that the deference of the Congress to the primacy of state authority in the area of the management of groundwater supplies is based not on constitutional power but on federal comity

Summary: Certainty in Water Rights and in State and Local Authority. Water rights should be characterized by certainty (a protected right to a specific quantity of water for a known tenure) and flexibility (the ability to convert the right through exchange).[83] Certainty is often lacking in state laws defining production and storage rights

Rights to production often lack certainty because they are unquantified and because other users may begin to assert "latent" unspecified rights. Rights to storage often lack certainty because they have not been provided for or because local entities that could store and recapture water lack either the authority to do so or the implementing mechanisms. Further progress in the definition of production and storage rights and the authority of local water resource management organizations is drawn into question not only by the continued existence of "latent" federal rights, but also by uncertainty about the scope of state and local authority relative to federal authority Each of these attributes of the institutional arrangements governing the use of groundwater supplies forms a barrier to more effective coordination of water resource use. So does the lack of flexibility (i.e., marketability) of production rights.

### Lack of Transferability of Production Rights

Along with increasing the certainty of water rights, increasing their flexibility is a long-proposed institutional reform. Local users have experimented with transfering rights on the local, basinwide scale when they could find ways to circumvent the obstacles in the laws. Whether or not one is inclined to believe that the benefits of water rights transfers are sometimes oversold by their proponents, preventing them creates real barriers to effective management Among the barriers are: disincentives for conservation and more efficient use of groundwater supplies; the maintenance of relatively less valued and less efficient water uses; and the inability to shift between sources or to bring new uses into a basin. Institutional reform in the direction of increased marketability is hindered in turn by reluctance to treat water as a commodity and by inefficient pricing practices

It is in discussions of marketability of rights that the distinction between water shortages that result from natural scarcity and from institutional rules becomes most sharply drawn:

> Even in the western region, the scarcity of water to meet the demands of growth is not, however, a problem of running out of water It is instead a matter of allocation of a valuable economic resource among competing demands. The current allocation has become inefficient in meeting the demands of growth due to market and institutional factors which discourage the transfer of water among uses.[84]

Lack of Marketability and Conservation. As noted in connection with the discussion of water rights laws above, most groundwater users face incentives to "use it or lose it" Pumpers lack incentives to reduce use, to use water more efficiently, and to waste less of it Yet, the community and individual users experience losses if aquifers are depleted to the point where withdrawals are limited because pumping has become uneconomical.[85] Some form of intervention before that point is reached would be desirable. The question becomes what form this intervention should take.

Any effective conjunctive management program is likely to involve reductions in or limits on withdrawals in order to control overdrafting. Regulations could be imposed on water rights owners and enforced by monitoring and policing arrangements This approach represents an attempt by the community to achieve its gain at the expense of individual rights owners. However, the chances for full compliance with such an arrangement are smaller than if institutional arrangements for limiting withdrawals are compatible with individuals' incentives. Owners possess a valuable property right in the use of the water supplies. The imposition of regulations requiring owners to forfeit some or all of their right for the collective good isunlikely tobe received as a welcome development The regulatory approach therefore will likely require extensive monitoring and enforcement of individuals'compliance with a rule that runs counter to their goals.

Water management programs stand significantly better chances of success and stability if water rights owners benefit from it.[86] Assuming that there are collective gains from more efficient water resource use, there should be no intrinsic problem in securing those benefits through processes that distribute at least some of the benefits to the water users and rights owners. Thii is the principal argument for making water rights marketable to increase conservation and efficient use.

Once each owner has a quantified right to the use of a specific amount of water (i.e., taking advantage of the principal benefit of the appropriative rights system), allowing exchange of rights creates an incentive structure that produces a positive-sum situation from what appeared to be a zero-sum situation. A water rights owner who can improve efficiency will be able to reap the same benefits while using less water. If the owner can transfer the difference to another user for some consideration, then the original water rights owner has benefited by increasing efficiency and reducing water use rather than being penalized for it In addition, new uses have been accommodated without increasing the total amount of water withdrawn from the system The water rights owner gains by acquiring something of value for increasing efficiency the new user gains a valuable water right, and water resources are used more efficiently

Institutional arrangements encouraging conservation could even be applied across water basins. Communities able to generate surplus waters could transfer them to water-short communities, and both groups could gain by the transaction. Communities unable to make conservation improvements mightbe assisted by communities seeking additional sources of supply This has occurred in southern California, where the Metropolitan Water District of Southern California will pay for water conservation investments in the Imperial Irrigation District in exchange for the rights to the surplus water yielded by those conservation practices.[87]

Impediments to water conservation and water transfers are numerous and primarily institutional.[88] Moreover, appearances can be deceiving water laws and policies that seem to encourage conservation and water marketing may in fact discourage both. For example, "recent Massachusetts legislation allows inter-basin water transfers only as a last resort, after all local leak reduction and conservation efforts have been exhausted."[89] While on the surface this appears reasonable, this qualification actually discourages water transfers If user A wastes 20 percent of A's water supplies, and user B wastes 10 percent of B's water supplies, any transfer of water from A to B would improve efficiency of use. Under the Massachusetts condition, however, B must reduce waste from 10 percent to zero before acquiring water through transfer from A, who may continue to waste 20 percent of its water supplies until then. In the meantime, the costs B is likely to incur in squeezing out the last drop of water waste, finding and sealing the last leak, may be several times the cost of purchasing equivalent amounts of additional water from the more wasteful A. Neither efficiency nor conservation is facilitated by such a requirement, which undoubtedly was intended to facilitate both. The connection between water marketing and conservation is not always obvious In water resources management, as in other areas, our institutions do not always comport with our intuitions

Lack of Marketability and Inefficient Water Uses. The remarkable abundance of water resources relative to population, even in the relatively arid western regions, was noted in Chapter 2. Some estimates of the water-sustainable population of the Colorado River Basin states indicated that those states have not run up against the water supply limits of development, but have considerable water supplies to use if they were allocated differently. In particular, in the western states, most of the water rights are held by, and most of the water consumption occurs in, irrigated agriculture.

Even in the less abundantly water endowed western states, crops that are highly water consumptive are grown in great quantities. The most highly water consumptive crop, alfalfa, which requires5 to 6 feet of water per acre, accounts for millions of acres of land use and millions of acre-feet of watet According to 1988 estimates, the acreage of alfalfa grown with mined groundwater (i.e., nonrenewable supplies) was as follows: California, 196,000 acres; Texas, 103,000 acres; Kansas, 88,000 acres; Idaho, 51,000 acres; Arizona, 38,000 acres; New Mexico, 31,000 acres; Nebraska, 27,000 acres; and Colorado, 20,000 acres.[90] To gain a sense of perspective on the magnitude of this acreage, the United States' entire lettuce crop occupied about 200,000 acres; the California avocado crop occupied about 75,000 acres, and the California lemon crop occupied about 50,000 acres.[91] Total alfalfa acreage in Arizona was estimated in 1985 to be 200,000 acres, irrigated with renewable and nonrenewable water supplies: at 6 acre-feet of water per year, the alfalfa crop alone would have consumed 1,200,000 acre-feet of water that year, which is equivalent to the entire planned yield of the Central Arizona Project (CAP).

Why is so much thirsty alfalfa hay grown in these climates? It is surely not because it is a high-valued crop, producing a vital share of the nation's or the region's economic abundance. Its primary use is for feeding livestock In the words of Natural Resources Defense Council analyst Marc Reisner:

> In California, the single biggest consumer of water is not Los Angeles.. . . It is irrigated pasture. . . . In 1986, irrigated pasture used about 5.3 million acre-feet of water-as much as all 27 million people in the state consumed, including for swimming pools and lawns. Its contribution to California's $500 billion economy, on the other hand, was an invisible $94 million. One five-thousandth of the economy; one-seventh of the water.
>
> If you entirely eliminated pasture, alfalfa, cotton, and rice (not everyone's idea of an appropriate desert crop, since it grows only in standing water) and substituted nothing else, you would merely reduce agricultural income from $14 billion to $12.3 million. But you would free up enough water for, God forbid, some 70 million new Californians.
>
> Is California atypical?
>
> Only in the sense that agriculture in California, despite all the desert grass and irrigated rice, accounts for proportionately *less* water use than in most of the other western states.[92]

Alfalfa and other low-valued, highly water consumptive crops are grown with western water resources for three primary reasons. First, alfalfa in particular is easily mechanized and grown with very little labor. Second, outside of the Pacific Northwest's humid climes or the warmth of California and Arizona, much of the rest of the West's climate is not receptive to many other crops; alfalfa and pasturage grasses are hardy and help keep "blow sand" and soil erosion down. The third (and perhaps most important) primary reason is the laws governing water rights in the western states. As John Wesley Powell noted a hundred years ago, the greatest source of value in arid lands is access to water.[93] Whether that access is allocated on the basis of actual use under appropriation or beneficial use on overlying lands, maximizing this vital asset is secured by maximizing use.

The crop that consumes the maximum amount of water per acre would secure the maximum possible right to the use of water. Western farmers understandably do not want to relinquish their rights to the use of water and receive nothing in return. There is no incentive for an individual farmer to grow anything else or irrigate fields more efficiently except where it might be possible to transfer water rights to a city, a water district, a suburban community, a manufacturer, or another farmer, in exchange for something of value. (This would also explain the fact that even municipalities and manufacturers maintain alfalfa fields in the desert Southwest They are not maintaining the nation's livestock supply or perpetuating rural agrarian traditions, or maximizing profit through irrigation to yield high-valued crops. They are making sure that they have the largest possible share of water rights)

Laws that would simply shut down enough irrigated agriculture to generate water to supply municipal and industrial needs miss the point, and would go too far Those who have properly acquired, held, and used water rights-in other words, who have played by the past and present rules of the game—should receive an agreed-on compensation for relinquishing those rights

Those who object that water rights transfers from the agricultural sector to the municipal and industrial sector would threaten the future of irrigated agriculture and the nation's food supply also miss the point Bearing in mind that agriculture accounts for about 80 percent of water use in the west while urban water use is about 7 percent, a reduction of only 10 percent in agricultural water use could double the amount of water available for urban uses.[94] This is hardly a wrenching dislocation of irrigated agriculture, and it would produce more water availability than needed by the urban sector in the most arid and fastest growing region. Indeed, the comparison in Chapter 2 of the populations of the more arid western states with what those states could support if all irrigated agriculture were eliminated shows how little change would have to occur in the water use practices of irrigated agriculture in order to accommodate current and projected populations.

Lack of Marketability and the Problem of New Users. Lack of transferability also has complicated the problem of accommodating new users. In appropriation states,for example,the total quantity of water in many stream and aquifer systems has reached or is approaching "full appropriation." Yet, because production rights often are nontransferable, this situation "leads some analysts to conclude erroneously that all the available water is being consumed or that no new water uses can be accommodated."[95] In fact, accumulated claims on the water supply may not reflect accurately the needs of users who retain their claims because their only other option is to abandon them without compensation.

If owners could transfer their rights to new users, many claims (some of which are a century old) to water in the appropriation states probably would become available for purchase. New uses of limited groundwater supplies, for example, could be met without increasing pumping rights if state legislatures will adjust the laws to permit it With transferable water rights, an allocation of water rights based on past use is not locked into the same uses or the same owners as conditions change.[96]

In the absence of transferability, one must either assume that the original allocation of water rights was perfect or accept the possibility that the original allocation is likely to have been somewhat imperfect and to become increasingly so over time.[97] Accepting the latter conclusion, an important issue becomes how to adjust the original allocation. Marketability of water rights would allow new users to "buy in" to acquire water rights. When combined with the ability of the original owners to enter into exchanges, adjustments to the original allocation of water rights could be made on the basis of terms of exchange arrived at by willing sellers and potential buyers, moving water at the margin from those who value it less to those who value it more.

In the absence of the ability to make relatively continuous marginal transfers of water rights, those seeking water under conditions of scarcity tend either to undertake large-scale water transfer projects or to bring political pressure on some larger jurisdiction to undertake transfer projects on their behalf." *The notion that marketability of water rights means a bidding war, transfers of water from one location to another, and escalation of costs, and that these problems are avoided by nonmarketability,* is *simply false. Without marketability, the bidding war is simply shifted from the economic arena to the political arena, water is transferred from one location to another by means of massive structural projects, and the costs of water transfers by those means (while hidden) are* higher *than the costs* of *transfers of water rights negotiated between potential buyerandpotential* seller Yet most state lawsmakeitdifficulttotransferwaterrights from one use to another and practically impossible to transfer rights from one place to another.

There is evidence that when they are allowed to do so water users will transfer rights from agricultural to municipal and industrial uses,and reallocate water from irrigation to higher priority uses. Private capital markets are being developed to facilitate acquisitions of water rights for growing municipal and industrial demands, complete with water "brokers" who connect sellers with buyers and help negotiate transactions.% Water rights transfers and water markets are prospering especially in Colorado, but also in California and New Mexico, in Utah's Lower Sevier Basin, and between agricultural and urban water users in the Tucson area.[100]

In the adjudicated groundwater basins of southern California, where groundwater pumpers fashioned their own management programs through court judgments, the water rights allocated to existing pumpers were fixed and quantified, but they were also made exchangeable. Lively intrabasin lease and sale exchanges have characterized those basins since the entry of judgments Through the courts, water users in those basins found a way around the lack of quantification and marketability of rights inherent in the law.

Laws and policies are all that stand in the way of these water rights transfers. For example, an attempt in the 1980s by the City of San Diego to enter into an agreement with Wyoming ranchers on the upper reaches of the Colorado River was aborted because it would have violated terms of the Colorado River Compact and the international treaty with Mexico. San Diego wanted to compensate the upstream ranchers for using less water, which would have allowed greater amounts of flow to descend to the lower reaches of the Colorado River, where it could be diverted by the city The agreement would have benefited both parties and moved water away from less valuable uses, but it was blocked by the existing rules governing the allocation of Colorado River waters.[101]

United States Representative George Miller of California, who chairs the Subcommittee on Water, Power, and Offshore Energy Resources of the Committee on Interior and Insular Affairs in the U.S. House of Representatives (and who is not an advocate of unfettered water marketing), introduced legislation in the 99th Congress that would have established a "water exchange" in central California. The exchange would have allowed San Joaquin Valley farmers to sell their water rights to southern California cities rather than use the water on lands tainted by agricultural drainage water high in selenium, and would have applied part of the profits to alleviating the polluted drainage problem. Representative Miller's bill was not acted on by the Congress.[102] A few states have attempted to revise their groundwater laws and policies to facilitate the voluntary transferof rights and to further the lease and sale of water Amongthe promising institutional reforms of the last decade are:

a) Oregon and California have tied to eliminate the disincentive to conserve water byallowing rights owners to retain water conserved by efficiency and a 1980 ruling of the Idaho Supreme Court held that an appropriator retains the right to water salvaged by reducing seepage from transmission systems.[103]

b) During the 1980s, California enacted legislation providing that water transfer does not constitute wasteful or unreasonable use and directing the state's Department of Water Resources to implement state laws regarding transfers and encourage the voluntary transfer and exchange of water.[104]

c) Idaho has experimented with the transfer of water impounded by federal water project reservoirs so that contractors with surplus water can "bank" it for rental to contractors (though a low ceiling has been placed on the rental price).[105]

Efficiency in resource use should be and ostensibly is a goal of public policy. Efficiency requires shifting resource use from lesser toward higher valued uses, just as it involves the reduction of wasteful uses.[106] If transfers of water rights are blocked or impeded by laws and other institutional arrangements, then the tools of public policy are defeating the goals of public policy

Objections to Water Marketing: Agricultural and Other Third-Party Effects, and the "Water Is Different" Objection. Objections to water marketing arise on the ground that it will wantonly destroy the agricultural sector of the economy Yet, the percentages of water rights that would need to be shifted away from western irrigated agriculture are small. Also, restricting amounts of water transferred to amounts consumptively used, as discussed in connection with the practices of the New Mexico state engineer in Chapter 3, can protect neighboring water users.[107]

Relatively continuous, marginal adjustments in the distribution of consumptive water rights should not produce massive displacements in the agricultural sector As water rights are transferred from agricultural to municipal and industrial uses, labor opportunities axe likely to increase in the growing urban areas.[108] Some in farm communities might experience difficulty with significant capital investments at risk, many of whom have been encouraged to make those investments by decades of governmental policies It is not necessary to dismiss these potential problems simply by pointing to the "rough justice" of the "free market" Instead, these third parties might be compensated by the beneficiaries of the transaction. Having enforced a misallocation of water rights for so long states and local communities should be able to ease the transition to a more reasonable allocation, especially since water rights transfers can save money that might otherwise have been invested in large-scale water projects.[109]

Other objections to water marketing arise from reluctance to view water as a commodity. Water supply has been seen traditionally as a service delivery function, to be regulated and subsidized, but not priced or traded. This distinction between "commodity" and "service" stems in part from the perception that, as a necessity of life, water should not be subject to the coarse rigors of the marketplace, and its provision to consumers should not reflect such harsh economic factors as the cost of production or consumer demand. "Freshwater is too important to be given over to free market forces," argues Williamson B.C. Chang.[110] This reasoning begs the question of why consumers are not similarly provided with food, clothing, orshelter "services" without regard to cost or demand, and of why such other "utility" services as electricity and telephone cost the average household much more and are priced according to use. What stands to cost citizens more in the long run is the continuing misallocation of water resources that would result from an illusion that water ought somehow to be exempt from treatment as a commodity.[111]

Another objection to treating water as a commodity and allowing its price to reflect its valuation by users is that demand is inelastic-the quantity of water demanded does not vary with price. The reasoning of this objection is that necessary uses of water are relatively fixed for each person, and, therefore, increases in price will only capture economic rents and will not materially affect the demand

Yet there is considerable evidence that water demand is price sensitive, even if it is not fully elastic.[112] A comparison of the 12 hydrologic study areas in California shows that 1984 water use varied from approximately 300 gallons per person per day in the two regions where water costs were less than 20 cents per 100 cubic feet down to about 175 gallons per person per day in three regions where water costs exceeded 70 cents per 100 cubic feet, and the overall correlation between water use and marginal price was -0.62.[113] Similarly, in Arizona, water use per person per day is approximately twice as great in Phoenix as in Tucson, and water rates are approximately twice as high in Tucson as in Phoenix.[114] According to Lawrence Mosher, studies of one electric power plant showed that an increase in the price of water from 1 cent per thousand gallons to 5 cents per thousand gallons resulted in a drop in water use from 50 gallons per kilowatt-hour of electricity generated to 0.8 gallons of water per kilowatt-hour generated: "A five-fold price increase thus led to a 50-fold reduction in water use."[115]

A good such as water has multiple attributes and uses. Some of those uses are highly price sensitive while others are not As the price of water increases, least valued uses are curtailed first while higher valued uses are not curtailed at all, but overall water use declines.[116] Outdoor summer water uses, for example, tend to be curtailed to a greater degree in response to a water rate increase than indoor year-round water uses - in fact, outdoor water uses may show an elasticity of demand of greater than one.[117] There is no evidence that increases in the price of water work any particular hardship on individuals or households in that they are unable to afford enough water for need, but there is evidence that users become more attentive to water waste and reduce lower valued uses.

Water rates have long borne no apparent relation to the natural scarcity of the good. The combination of generally plentiful supply through most of the country and inefficient pricing practices has produced underpricing of water. Water is by far the least expensive of the utilities for which households pay

As Figure 5-1 shows, the average family's annual water bill in 1984 was $143. The average family's telephone bill was more than three times as high, the natural gas outlay four times as high, and the annual electric bill five times as high. The annual outlay of the average U.S. family in 1984 for water constituted 0.5 percent of median family income.

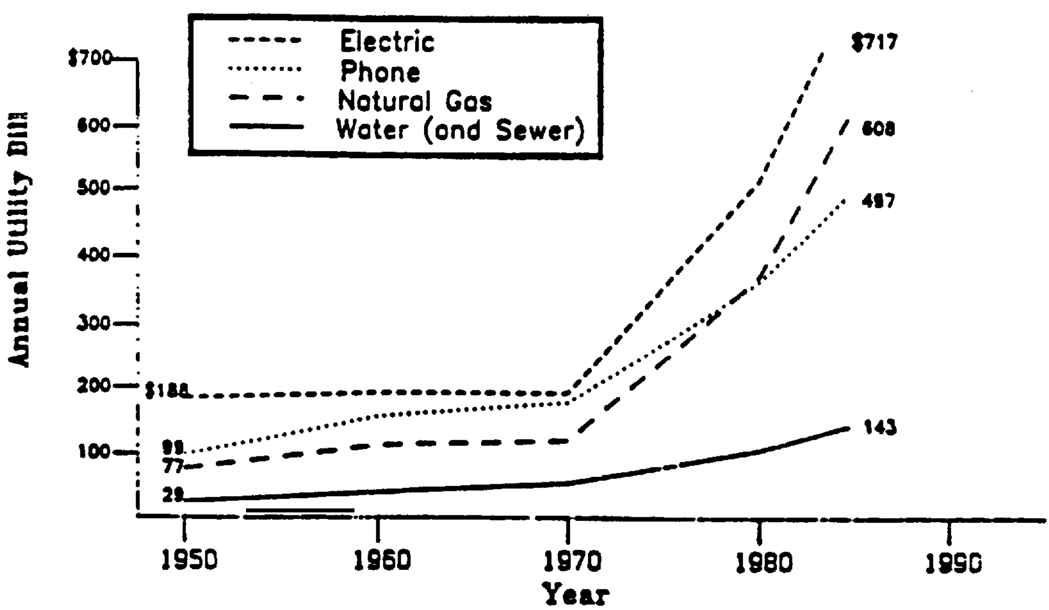
While rates charged by water supply systems may range from 10 cents to $5.50 per $000 gallons,[118] the vast majority of the population is nearer the low end of this range than the high end Water supply systems charging rates Of less than $1.00 per 1,000 gallons serve 88.8 percent Of the population. While 11.1 percent of water supply systems charge $3.00 or more per 1,000 gallons, they serve only 0.01 percent of the population.[119]

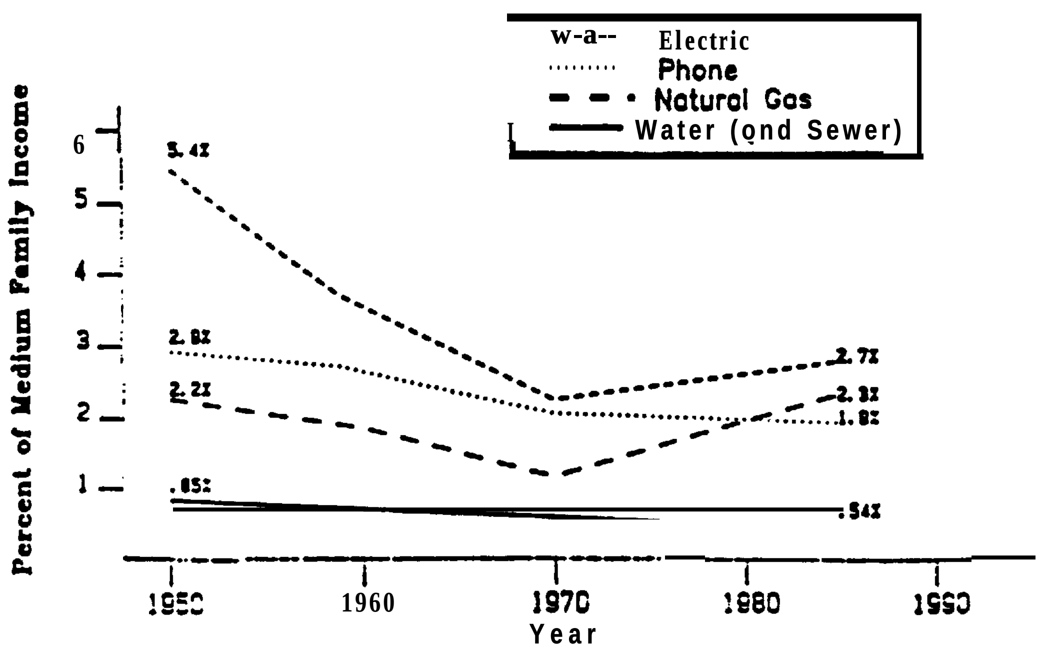
Among the difficulties to be faced during the next few years are that any increases in water prices to make up for past undervaluation will be compounded by the increasing costs of meeting water quality standards and of needed investments in repair and improvement of facilities. Long-needed reform in the direction of full-cost pricing of water supplies is coming at the same time as the impact on rates from these other sources. In the first half of the 1980s, water rates in 20 large cities increased by 90 percent at the 1,000 cubic-feet use level and 55 percent at the 10,000 cubic-feet use level, while the general Consumer Price Index rose 21 percent.[120] Rate increases in excess of the general inflation rate are expected through the first half of the 1990s.

Of course, comparisons of what customers are charged per thousand gallons or per hundred or thousand cubic feet of water presume that suppliers charge according to the amount used. This implies being able to account for the amount used, an ability that suppliers in some of the largest population centers have not had. Even the practice of metering has not been used in some places; residents with connections to water supplies are charged a flat monthly fee regardless of the amount of water they use. The marginal cost of the water used therefore decreases every time the tap is turned on. The incentive toward overuse is cleat; and the implications for management are substantial. Charging prices for water that more accurately reflect its value is impossible if use is not measured.

Sacramento County, California, has embarked on a 15-year, $135 million program to install residential meters. In the populous and prosperous California capital, where some of the most active opponents of water diversions to the San Joaquin Valley and southern California reside, water use has not been metered. Average per capita daily water use in the county has been estimated to be 300 gallons, and the flat monthly residential fee is $7.61.[121] (By contrast, in notoriously thirsty Los Angeles, where the average household monthly water bill was recently increased

*Figure* 5-z
Comparison of Annual Utility Bills, 1950-1984




Source: Wade Miller Associates, *The Nation's Public Works: Report on Water Supply* (Washington, DC: National Council on Public Works Improvement, 1987).

to about $22.50, per capita daily water use is about 190 gallons.) The installation of water meters in Sacramento County will take time and represents a substantial financial investment When completed, it will allow water rates to be charged on the basis of use, which represents a tremendous step toward reasonableness in water pricing.

New York City also has begun a program to install 630,000 water meters in all five boroughs over the next 10 years at a cost of $290 million. New water revenues are expected to repay much of the capital cost of the installation, and to defray some of the expense of needed improvements to the quantity and reliability of the city's water supply.[122]

Expectations of widespread public outcry over increased water rates may be exaggerated; the fact that water prices have been distorted and kept artificially low does not necessarily say anything about customers' willingness to pay.[123] In fact, there are **strong** indications of willingness to pay higher prices for reliable water supplies. From the mid-1970s to the present, there has been rapid growth in the markets for bottled water and home water treatment systems, despite the fact that the water is hundreds of times more expensive per gallon basis than water from a public system[124] With customers paying premium prices for substitute goods, local officials and water purveyors should be able to implement the changes needed to establish mom realistic water rates.[125]

How water pricing and marketing interact and relate to more effective management may **not be** immediately clear Before discussing distortions in decisionmaking caused by water subsidies, it is worth pausing here to make the connection more explicit

There is a direct interaction between prices and rights transfers. Once pricing is viewed as a dynamic rather than static process, the relationships between the prices at which consumers receive water, the amount consumers will want to receive, and the amount suppliers are willingto offer begin to emerge. For example, if 1988 population projections for **the** western states are used along with an assumption that urban water rates will remain constant, then agricultural use would have to decline by 6% percent, or 5,149,000 acre-feet per year, to ensure stable supplies for the West through 2000. However, a doubling of urban water rates reduces projected urban use sufficiently to reduce the projected reallocation from agricultural to urban use to only 2.08 percent, or 1,537,000 acre-feet per year.[126] As municipal and industrial water prices rise, consumption declines, as does the amount of additional supplies that **need to be secured,** whether through water projects or rights transfers

Consider the following observation of trends toward decreasing per capita water use in the more heavily urbanized portions of California, where water rates have risen considerably over the past three decades:

> Several significant **trends are** developing in relation to **urban** per capita water use in California. Construction of more multiunit housing the general reduction in residential lot sizes, the increasing number of residences built since enactment of legislation requiring low water-use fixtures, and the multitude of local agency water conservation programs in effect are all tending to reduce per capita water consumption. Other conservation trends include plantings of low water-using landscapes and more efficient watering.[127]

Of course, none of this conservation happens if water is artificially cheap. Calling for better water management without recognizing the need for mote realistic prices misses a fundamental point Water that is not valuable enough for producers and consumers to pay attention to or monitor is not valuable enough to manage or conserve Artificially low prices do not just encourage consumption and waste, they contribute to the persistence of the illusion that water is endlessly abundant, that it is not an economically scarce good.

## DISTORTIONS CREATED BY WATER SUBSIDIES

It has been said that the United States is not "running out of water," but is "running out of cheap water."[128] Rational pricing practices are impeded by subsidies When supplies are subsidized, inaccurate price signals to users result in misallocations of resources. Both efficiency and equity in the allocation of water resources are negatively affected by subsidies

Subsidization of water supplies occurs in several ways In some communities, commingling of water supply and electrical power provision results in the use of power rates to finance water operations, so a share of the costs of water supply is borne by power users. The Salt River Project, a special district in central Arizona, has been cited as an example of subsidizing water supplies with electrical power rates According to a 1985 publication, electrical power sales generated 98 percent of Salt River Project revenues,[129] a fact partially explained by the fact **that** voting for project directors is based on land ownership, so power rate subsidies are a means for farmers (who hold most of the votes) to shift project costs to urban dwellers (who would hold the most votes if voting were per capita). As a result, the price of water delivered to lands within the Salt River Project has worked out to less than 1 cent per ton.[130]

Another means of subsidizing water supplies is through local property taxes or other unrelated revenue sources, and the commingling of water supply with other general fund operations. Investments in water supply or treatment often are financed by bonds that are repaid out of the local property tax or other general fund revenues Because these revenue sources are not tied directly to water use, some residents will pay for more water than they use while others will pay for less, and direct water charges will be artificially low. In addition, keeping water rates artificially low may have been a deliberate choice as part of a local or state strategy to encourage economic development or by deferring maintenance and repairs Such decisions are more likely when water supply competes for attention with a host of other concerns in a local government that mingles water and other revenues and expenditures.[131]

Often, assistance in water supply project construction, operations, and maintenance has been provided by the state or national government This provides local water users with the opportunity to spread the costs of investments from which they will benefit to a broader set of taxpayers The federal government has financed a major portion of water resources development from general taxes and borrowing as well as the reclamation fund.[132] The costs of those essentially local development projects have been spread across all federal taxpayers. Federal financing of project construction was originally justified as an interest-free loan to be repaid by the water users within ten years On this theory, the only "subsidy" would be that the local users would not face interest charges when they repaid the capital costs and paid for the operations of a federal water project The subsidy was justified on the ground of the federal interest in promoting the settlement and development of the western lands

As the federal reclamation program developed, however, "it became clear that the irrigators would be unable to reimburse the federal investments within ten years."[133] The Congress had to prop up the reclamation fund with direct appropriations. In 1926, the period for repayment of the costs (without interest) of Bureau of Reclamation water projects was extended from the original 10 years to 40 years In 1939, the law was amended again, placing repayment on an "ability to pay" basis.[134] Continuing the development of the West was deemed more important politically than securing reimbursements for water projects.[135] Moreover, repayment obligations were suspended in any year when insufficient flows were available from the federal reservoirs, and subsidies from the sale of hydroelectric power are allowed to make up the difference between farmers' ability to pay and amounts owed.

With the extension of time for repayment, no interest, and the ability to shift the costs of project construction and operation to hydroelectric power consumers, the amount of the federal subsidy to irrigators has increased to rates approaching 90 percent.[136] "In California's Central Valley Project, only 5 percent of the total $931 million spent on the project's irrigation facilities over the last 40 years has been repaid to date."[137]

What happens when 85-95 percent of the costs of a federal water project are paid by power users and by taxpayers across the country, while 5-15 percent of the costs are paid by local water users? Water from federal projects is so inexpensive that local users have no incentive to conserve or manage local or supplemental supplies.[138] To the extent that the price of a good communicates information about its relative scarcity, the prices from federal project water have been communicating for decades that water supplies, even in the arid West, are more abundant than the soil that is irrigated with the water In fact, water from some federal projects in the West has been sold to local users at rates that work out to pennies per ton, which makes water in this near-desert climate cheaper than sand.[139]

Estimates of the cost of water for irrigation in the West vary from $3.50-$5.00 per acre-foot to $10-$15 per acre-foot In either case, the subsidized price is several times less than the full cost of provision. A 1981 report from a San Francisco Federal Reserve Bank economist estimated that the average price for federal Central Valley Project water paid by California farmers was $5 per acre-foot, compared with $48 per acre-foot average replacement cost, and $325 as the estimated marginal cost of developing an additional acre-foot of water.[140] Five years later, while the estimated average replacement cost per acre-foot had risen to $73, the average price paid by Central Valley Project irrigators had risen to $6.15.[141] At 1985 rates, the total annual federal subsidy to irrigators in areas covered by Bureau of Reclamation projects was estimated to be $1 billion.[142]

Urban water users in the West typically pay 20 times the irrigators' $5-$15 per acre-foot of water. In Los Angeles, for example, the average household's monthly water bill is about $22.50, which works out to about $270 per acre-foot, using the normal assumption that an acre-foot represents the average household's water use for a year. If urban water rates for an acre-foot of water were $5-$15 instead of $100-$300, the average household's monthly bill in semi-arid Los Angeles would be somewhere between $0.42 and $1.25.

At rates that low, there is little incentive to conserve water or even to keep track of it, much less engage in vigorous local management For example, a RAND Corporation report compared the local management of water supplies in southern California, where natural water supplies are more scarce but water is more expensive (including imported water from locally financed projects such as the Colorado River and Owens Valley Aqueducts), with the "management" of water supplies in the San Joaquin Valley, which is served by the federal Central Valley Project and California's State Water Project Among the observations concerning the valley were:

> Those who have received relatively inexpensive Central Valley Project water have seen no need to control pumping. They take the water when it is available and pump when it is not . . . In general, pumping is not monitored or controlled as it is in southern California.. . .
>
> In general, it appears that most valley water users prefer either localized recharge projects or groundwater mining to adjudication or basinwide regulation imposed by the state. Some still anticipate that future federal and/or state rescue projects will bail them out with inexpensive subsidized surface water, despite rising opposition to such projects on economic grounds Others suggest that their problems would be solved by construction of additional facilities to meet State Water Project contractual commitments. If surface water cannot be brought in, then many favor pumping until this is constrained economically by increased pumping costs.[143]

In light of the availability of groundwater from underground storage and cheap subsidized water from surface reservoirs, two statistics that would otherwise appear puzzling given the distribution of natural water supplies in California make sense. The first is that 75 percent of the total amount of groundwater overdraft in the state occurs in the southern San Joaquin Valley.[144] The second is that 8 of the 11 groundwater basins in California identified as being in "critical overdraft" condition in the 198Osare in the Sacramento-San Joaquin Valley, and none of the 11 is in the more heavily populated arid southern counties of Los Angeles, Orange, San Diego, Riverside, and San Bernardino, where 15 million of the state's 29 million residents live.

The objectives of federal policy were to encourage western settlement and development and the growth of the agricultural sector, as well as to satisfy certain ideological objectives of the "conservation movement," and the promotion of a "rural democracy" composed of yeoman farmers with small,self-sufficient family farms. These benign objectives led to the building of water projects, the sale of the developed water at subsidized rates, the watering down of repayment requirements, the muting of incentives for sta te and local water management, and, over time, the creation of organized political constituencies in favor of maintaining and extending the status quo.

In a curious sense, in the political arena, the federal financing of water projects has been a situation in which "supply creates its own demand." The more water projects the federal government assists with, the more intense become the demands of the remaining localities that have not yet received assistance. Agricultural interests correctly perceive access to a reliable supply of water as essential to their survival; obtaining that supply at lowest cost makes economic sense. Over time, cost-benefit formulas approved by the Congress for analyzing water projects have become distorted to yield the results that will justify building the project.[145]

The policy of federal subsidization of water supplies has been driven not by economic criteria of total benefits versus total costs but by political criteria of distribution, i.e., who benefits and who pays. There is considerable evidence that the principal beneficiaries of federal water subsidies are large landholders in the western states.[146] This is true despite the original limitation on water availability from projects built by the federal Bureau of Reclamation. Water from reclamation projects was supposed to be delivered to irrigators for use only on up to 160 acres of land.

The 160-acre limitation has been honored principally in the breach. A 1980 bureau report on 18 projects indicated that half of the land supplied from bureau projects was in the hands of 9 percent of the landowners,[147] and one third of the land was owned by 3 percent.[148] The largest 5 percent of irrigators, each with 1,280 acres or more, received 50 percent of the total water subsidy, and the largest 1 percent received 21 percent of the subsidy. Farmers with 160 acres or less represented 60 percent of all recipients of bureau water; they received 11 percent of the water subsidy? Federal water subsidies amount to a program of wealth redistribution from federal taxpayers and many electric power users to holders of large tracts of western lands who use large amounts of federal project water.[150] As far as can be discerned, this was not among the original objectives of the reclamation program.

The beneficiaries of federal water subsidies have a clear incentive to try to retain them; those who pay for federal water subsidies have little incentive to try to restrain them. The principal beneficiaries are relatively few, relatively large, and politically influential in their states and with their congressional delegations.[151] The relationships at work are fairly simple:

> The wider the resource base, the smaller the per capita burden of taxes and controls and hence the more passive the public; the smaller the base the greater the per capita burden and the more active the public becomes.. . . Therefore, in the field of reclamation I would expect the subsidy from federal projects to be greater than from state projects such as those undertaken by the state of California, and this is in fact the case.[152]

When additional water can be developed through rural-urban transfers or other transfers from lower valued uses less expensively than via large-scale structural water projects, this "raises the issue of the incidence of benefits and costs implied by different modes of water supply and related financing arrangements."[153] For example,

> the federal government will pay for a large part of the Central Arizona Project while the people of Central Arizona [would] have to pay the costs of purchasing agricultural water rights in any rural-urban water transfers While the benefits are essentially the same, the incidence of costs is much different, being placed upon the whole nation in the case of the Central Arizona Project, but upon the beneficiaries alone in the case of the purchase of agricultural water rights Federal subsidies and repayment policies thus have the power of subverting economically rational decisions in this vital area of water supply.[154]

One of the most perverse outcomes of the expansion of irrigated agriculture is that it has placed a strain on water resources in order to provide additional yields of surplus crops. Over one-third of the acreage irrigated with water from bureau projects is growing surplus crops, some of which are highly water consumptive.[155] When surplus crops are being grown, continuing to subsidize water for irrigated agriculture cannot be justified on the grounds of insufficient food supplies for domestic or export markets Nor is it possible to justify the continued subsidy on the grounds of maintaining low food prices, or with the argument that if water prices increased to reflect full costs of provision, food prices would skyrocket. Irrigators using more expensive water supplies use less water, and employ the water they do use more efficiently In places such as California's Central Valley, where some irrigators purchase federal project water at $10 or less per acre-foot while others purchase state project water at roughly $50 per acre-foot, both manage to stay in business and produce the same crops to sell in the same markets for the same prices.[156]

The subsidy system also cannot be justified by the need to maintain an excess capacity "irrigation infrastructure" to provide for a sudden response to "unforeseen circumstances." There has long been a large surplus of agricultural land that could be pressed into production without need for drainage or irrigation to grow basic crops, including low-valued crops such as pasturage and hay that are now being irrigated with project water. Throughout the postwar period, millions of acres of agricultural land have been removed from production under various programs, while additional land has been brought into production with irrigation water In some places and for some crops, the replacement has been nearly acre for acre.[157] In 1983, the United States paid farmers not to grow crops on 82 million acres of land, about one-fifth of the farmland, at a cost in excess of $4 billion.[158]

The overall results of subsidizing water supplies may be viewed as "irrational." In the end, taxpayers pay for the same food four times: for the surface water projects that provide the cheap water, for the support and storage programs that buy up the agricultural surpluses and guarantee farm incomes, for the payments to other farmers to take land out of production, and for the food purchase at the grocery store.

It also may be argued that the old persuasive reasons for federal funding and construction of water development projects are no longer valid.[159] If the real objectives of federal water development assistance were settlement of arid lands, flood control, promotion of agricultural development, and exploitation of prime natural sites for water development, those objectives have been fulfilled.[160] If the real objectives of federal water development assistance have been provision of cheap water to politically powerful constituencies at prices far below the cost to taxpayers while inflicting forms of damage to the western environment that am only now beginning to be seen and comprehended, those objectives cannot be sustained.

According to several experts, if subsidizing water supply operations with general revenues, power revenues, or by tapping into the treasury of a larger jurisdiction was ever justifiable, it is justifiable no longer [161] Uses of water that would not occur if water prices reflected costs of provision are likely to be curtailed, but this is not necessarily bad:

> We can think of no circumstances under which it would be desirable to guarantee $3 per acre-foot water forever to those water users who first entered basin pumping on the premise that water would cost $3 per acre-foot to pump. Indeed, to state the reverse highlights the case: We cannot think of any circumstances under which it is desirable to spend $30 per acre-foot for water to support all future use of water that is valued at only $3 by the water user. . . . To argue that all historical groundwater uses should be maintained through surface imports is tantamount to arguing that inefficient water uses should be sustained because there will of necessity be water users within the basin who value the water less than its full social cost Gmundwater management will almost invariably lead to eventual cessation of some water uses where the water is least valued.[162]

## LACK OF INFORMATION DISTRIBUTION

In the words of a 1989 report of the Office of Science and Technology Policy, "The management of groundwater resources depends on the science of groundwater hydrology and information about the particular groundwater system being managed."[163] Information requirements for rational decisionmaking within state and local groundwater management agencies are high. Specification of water rights, supervision of rights transfers, and the development Of more efficient pricing practices require sound hydrologic data in addition to sensitive awareness of local conditions and needs.[164] There has been a consensus in the Water resources literature from the early half Of this century to the 1980s that insufficient data exist, particularly regarding groundwater supplies.[165]

Research has been supported by the federal government, state and local governments, and industry associations. Research funding and activities by entities other than the federal government have been modest, and,in *all, water resources research funding by governments has been approximately 2 percent of the level of expenditures for water resources development projects.*[166]

States and local governments are "uniquely qualified" to address water supply management issues within their jurisdictions, **and** many are rising to the task On the other hand, it is less plain whether states and local governments will fund basic research as extensive as sophisticated management approaches require. [167] A study supported by the American Water Works Association Research Foundation of barriers to better water management found that, while states do invest time and financial resources in water research, "in general, states have little money for investigating new technologies or developing solutions to local problems."[168] This raises the question of whether the research is best conducted on a state or local scale, in which case their relatively smaller investments would constitute a problem, or whether some other scale is appropriate. There seems to be agreement in the water resources research and management literature that basic research into hydrologic conditions is appropriately organized at the national scale, through federal agencies such as the United States Geological Survey and the Environmental Protection Administration, and through the academic community and associations involved in groundwater management, such as the American Society of Civil Engineers, the American Water Works Association, and the National Water Well Association.[169]

Through the Water Resources Research Centers set up in the states with federal support since the *Water Resources Research Act* of 1964, and the computerized data access and retrieval systems of the United States Geological Survey and available through its field offices, tremendous amounts of hydrologic data are available to state and local water managers and users. However, water managers need more than hard data on the physical characteristics of aquifers, and some managers feel that much federally supported hydrologic research has emphasized leading-edge technology and "state of the art" research, rather than the application of existing technology and knowledge to existing conditions.[170]

The information needs for groundwater management and for water resource management generally are shifting. The needs that are growing are technology transfer and dissemination, for application of knowledge to existing problems; and information on management strategies, practices, and performance (especially for smaller systems).[171] As the emphasis has shifted from water development to more effective management of existing supplies, and as states and communities are responding with management innovations, more information is needed about management activities.[172] Research into the effects of nontraditional solutions to problems and the effect of different institutional arrangements on supply conditions is of growing importance.[173]

There has not been much dissemination of information about resources and management, and states historically have been reluctant to accept research results from each other.[174] While problems in each community are different, there are common elements and management challenges that may be overlooked, as well as opportunities for beneficial changes in institutional arrangements for managing water resources. Scarce personnel time and effort may be needlessly devoted to reinventing a "wheel" that has been devised and tested elsewhere.

## SUMMARY

The perceived scarcity of water in various parts of the United States results from its geographic distribution and the scarcity created by water laws and other institutional arrangements that distort decisionmaking about the use of water.[175] A stronger statement of the view that water shortages are more apparent than real was given to the National Council for Public Works Improvement in 1987, in a report which referred to "the misperception that severe water shortages exist":

> There appears to be sufficient water available in all regions of the country However; due to allocation practices such as the appropriation doctrine, water resources are not allocated efficiently thereby giving the appearance of shortages It also appears that allocation of water is not just a problem west of the Mississippi; water supply systems in several northeastern cities are now faced with stiff competition for available resources.[176]

Distortions of decisionmaking about use and allocation create obstacles to more effective conjunctive management of groundwater supplies. The inability of state and local water regulators and planners to know the quantity of water rights, and thus the outside limits of demand, makes efficient and equitable allocation all but impossible. As water users receive inaccurate signals about the value of water and of their rights, their behavior is affected in ways that are likely to arouse opposition to the imposition of any new rules that might limit and define, or redefine, production rights. Water users who pay subsidized prices are highly unlikely to satisfy demands that they conserve water. Users who are told to conserve water but are given no incentive to do so are being asked to comply with a rule that (as they see it) imposes losses on them, but no benefits. No group in society,in the United States or elsewhere, is likely to welcome that sort of "reform." And in societies like the United States, where there can never be enough "enforcers" of any rule and where voluntary compliance is a cornetstone of social order, rules that impose losses without compensating benefits are not likely to meet with high rates of compliance.

A primary goal of water governance should be to devise institutions that make individual incentives compatible with collective goals, "to create water prices more in keeping with the supply and demand, and to establish well defined, transferable and less restricted water rights."[177] In addition, increasing the management information available would aid in the development of more effective approaches

Many of these observations about the importance of changing the institutional arrangements for managing water resources are not new Philip Metz-ger of The Conservation Foundation reviewed more than two dozen national water policy studies, and produced a report in 1983. He found that while about half of the studies' recommendations concerning instream and offstream uses had been implemented to some degree, few of the recommendations for institutional changes had been implemented at all. In particular, recommendations for better coordination of surface and groundwater resources, and for improved cooperation among agencies, had largely been left unrealized.[178] "Historically, then, the federal government has funded assessments of water resources and has tasked those assessments to make recommendations, but has failed to organize post-assessment efforts to address institutional recommendations."[179]

The consequences of failing to develop and implement the needed institutional reforms are becoming increasingly evident In areas with less abundant water supplies, water subsidies and the distortions they cause in decisionmaking have merely delayed the day of reckoning by making it possible for users to put off shifting to water-saving practices while we continue to look for the next "technological fix" to "make the desert bloom."

Notes

1 Christine Olsenius, "Tomorrow's Water Manager," *Journal of Soil and Water Conservation* 42 (September-October 1987): 312.

2 See, for example, Wade Miller Associates, *The Nation's Public Works: Report on Wuter Supply* (Washington, D.C.: National Council on Public Works Improvement, 1987), pp. 115 and 206.

3 Helen M. Ingram et al,, "Guidelines for Improved Institutional Analysis in Water Resources Planning," *Wuter Resources Research* 20 (March 1984): 323.

4 Kyle :Schiiing et al., *The Nation's Public Works: Report on Water* Resources (Washington, D.C.:National Council on Public Works Improvement, 1987), pp. 19-21.

5 Olsenius, p. 312.

6 Lyle Craine, "Intergovernmental Relations in Water Development and Management." Paper presented at the Southern Political Science Association meeting, Gatlinburg, Tennessee, 1959, p. 3.

7 Wiiiam Lord, "Institutions and Technology: Keys to Better Water Management," *Water Resources Bulletin* 20 (October 1984): 655.

8 Stephen Burges and Reza Marnoon, *A Systematic Examination of Issues in Conjunctive Use of Ground and Surface* Waters. Water Resources Information System Technical Bulletin No. 7 (Olympia: Washington Department of Ecology, 1975), p. 8.

9 Ingram et al., p. 326.

10 For asomewhat different, overlappingcategorizationof institutional issues of importance for resources management reform, see Warren Viessman and Claire Welty, *Water Management:* Technology *and Institutions* (New York Harper and Row, 1985), p. 52.

11 Micha Gisser, "Groundwater: Focusing on the Real Issue," *Journal* of *Political* Economy 91 (December 1983): 1010.

12 Wiiiam Cox, 'Water Law Primer," *ASCE Journal* of *Water Resources Planning and Management* 108 (March 1982): 116.

13 John W Bird, "Ground Water and Federal Reserved Rights," *Journal* of *Water Resources Planning and Management* 109 (April 1982): 175.

14 Jurgen Schmandt, Ernest Smerdon, and Judith Clarkson, *State Water* Policies (New York Praeger publishers, 1988), p. 5.

15 Frank J Trelease, "Legal Solutions to Groundwater Problems-A General Overview," *Pacific Law Journal* 11 (July 1980): 869.

16 Douglas Grant, "The Complexities of Managing Hydrologically Connected Surface Water and Groundwater Under the Appropriation Doctrine," *Lund and Wuter Law* Review 22 (January 1987): 66; Frank J. Trelease, "States Rights Versus National Powers for Water Development," in Ernest Engelbert, ed., *Strategies for Western Regional Water Development* (Los Angeles: Western Interstate Water Conference 1966), p. 105.

17 Mason Gaffney, "Diseconomies Inherent in Western Water Laws." Paper presented at the Western Agricultural Economics Research Council, Tucson, Arizona, 1961, p. 44.

18 Ibid., p. 55.

19 Stephen Williams, "The Requirement of Beneficial Use as 'a Cause of Waste in Water Resource Development," *Natural Resources Journal* 23 (January 1983): 7.

20 Lord, 1984, p. 654.

[21] Mohamed El-Ashry and Diana Gibbons, "Managing the West's Water," *Journal of Soil and Wafer Conservation* 42 (January-February 1987): 8.

[22] Charles Phelps et al., *Efficient* Water Use *in California: Executive Summary* (Santa Monica: RAND Corporation, 1978), p. 1.

[23] Viessman and Welty, p. 54. As these and other authors point out, while rights to the use of groundwater and rights to the use of surface water are legally separated in many states even though the two sources are physically related, the law governing rights to the use of groundwater covers both renewable and nonrenewable aquifers, even though these present very different physical situations.

[24] Ibid.

[25] Morton W. Bittinger, "Ground-Water Surface-Water Conflicts," *ASCE Journal of Water Resources Planning and Management* 106 (July 1980): 474.

[26] Ibid., pp. 470473.

[27] cox, p. 115.

[28] Grant, pp. 64-65; Trelease, "Legal Solutions to Groundwater Problems," p. 864.

[29] This was recognized b y the National Water Commission, *Water Policies for the Future: Final Report to the President and to the Congress of the United States* (Port Washington, New York Water Information Center, 1973), p. 233.

[30] Joseph Westphal, "The Potential for Water Management in the West," *Ground* Water 20 (January-February 1982): p. 59.

[31] Phelps et al., p. 5.

[32] Les Lampe, "Recharge Saves Water for a Not-so-Rainy Day," *American* City *nnd County 102* (June 1987): 46.

[33] John E Mann, "Concepts in Ground Water Management," *Journal of the* American *Water* Works *Association 60* (December 1968): 1342.

[34] Thelma Johnson and Helen Peters, 'Regional Integration of Surface and Ground Water Resources." Paper presented at the Symposium of the International Association of Scientific Hydrology Haifa, Israel, 1967, p. 495. This was at issue in the celebrated Los Angeles v. San Fernando (1975) case, in which the city argued that operating a basin at "safe yield" should not mean the same as operating it full but should mean operating at a lower level that allows some storage capacity for the retention of potentialsurplusesthatwouldotherwiseescape the basin. This argument did not prevail in the original trial, but eventually was found persuasive by the California Supreme Court.

[35] Johnson and Peters, p. 495.

[36] Lee Dutcher and Lee Peterson, "Water Zoning-Tool for Ground-Water Basin Managers," *Ground Water* 13 (September-October 1975): 397.

[37] In California, for example, municipalities are being granted a "public servitude" in stored water, so that municipal withdrawals of stored water would have priority over other withdraw& during periods of shortage, in recognition of the public nature of most municipal uses.

[38] Susan M. Trager, "Emerging Forums for Groundwater Dispute Resolution: A Glimpse at the Second Generation of Groundwater Issues and How Agencies Work Towards Resolution," *Pacific Law Journal* 20 (October 1988): 31-74; James Krieger and Harvey Banks, "Ground Water Basin Management," *California Law* Review50 (1962): 73; Dutcher and Peterson, p. 397.

[39] Dutcher and Peterson, pp. 396-397.

[40] Helen Peters, "Groundwater Management." *Water Resources Bulletin* 8 (February 1972): 197.

[41] Robert Ehrhardt and Stephen Lemont, *Institutional Arrangements for Intrastate Groundwater Management: A Comparative Assessment* Using *Virginia as* a *Case Study* (Arlington, Virginia: JBF Scientific Corporation, 1979), p. 24.

[42] National Water Commission, p. 236.

[43] Ibid.

[44] Sidney Harding, *Water In California* (Palo Alto: N-P Publications, 1960), p. 58.

[45] El-Ashry and Gibbons, p. 12.

[46] National Water Commission, p. 228.

[47] John W. Bird, 'Water Resources and the Public Trust Doctrine," *Journal* of *Water Resources* Planning nnd *Management 112* (January 1986): 66-67.

[48] Rodney Smith, "A Reconciliation of Water Markets and Public Trust Values in Western Water Policy," *Transactions* of *the Fifty-Third North* American *Wildlife and Natural Resources Conference, 1988,* p. 331.

[49] Bird, "Water Resources and the Public Trust Doctrine," p. 65.

so Ibid., p. 69.

[51] Trelease, "Legal Solutions to Groundwater Problems," p. 868.

[52] Bird, "Ground Water and Federal Reserved Rights," pp. 176-177.

[53] Trelease, "States' Rights versus National Power," p. 103.

[54] John Leshy and James Belanger, "Arizona Law: Where Ground and Surface Water Meet," *Arizona State* Law *Journal* 20 (Fall 1988): 729.

[55] Zachary Smith, "Federal Intervention in the Management of Groundwater Resources: Past Efforts and Future Prospects," *Publius — The Journal of Federalism* (Winter 1985): 147.

[56] Leshy and Belanger, p. 729.

[57] Schmandt et al., p. 6.

[58] B. Delworth Gardner, "Removing Impediments to Water Markets," *Journal of Soil and Water Conservation 42 (No*vember-December 1987): 386.

[59] Ibid.; also Norris Hundley, *Water and the West* (Berkeley: University of California Press, 1975), pp. 330-331.

[60] Sporhase et al. v. State of Nebraska ex rel. Douglas, Attorney General, 458 U.S. 941 (1982).

[61] Ibid., p. 952.

[62] Ibid., p. 953.

[63] Ibid., p. 954 (emphasis added).

[64] Ibid., p. 959.

[65] Albert Utton, 'The El Paso Case: Reconciling Sporhase and Vermejo," *Natural Resources Journal* 23 (January *1983): ix.*

[66] Quoted in John W. Bird, "Implications of Sporhase in Water-Resources Planning," *Journal* of *Water Resources Planning and Management* 112 (April 1986): 202.

[67] 103 S.Ct. 345 (1982).

[68] Utton, pp. ix-xii.

[69] Mary Ann Green, "Water Law — Sporhase v. Nebraska," *Natural Resources Journal* 33 (October 1983): 924.

[70] Utton, p. x.

[71] Ibid.

[72] Gisser, p. 1003.

[73] Green, p. 930; Bird, "Implications of Sporhase," p. 202.

[74] Green, pp. 926 and 931; ibid.

[75] Bird, "Implications of Sporhase," p. 203.

[76] Ibid.

[77] Ibid., p. 202.

[78] Green, p. 926.

[79] Bird, "Implications of Sporhase," p. 203.

[80] Green, p. 923.

[81] Bird, "Implications of Sporhase," p. 202.

[82] 105 S.Ct. 1005 (1985).

[83] S.V. Ciriacy-Wantrup, "Concepts Used as Economic Criteria for a System of Water Rights," *Land Economics* 32 (November 1956): 295-312.

[84] Wade Miller Associates, p. 122.

[85] Zachary Smith, "Rewriting California Groundwater Law: Past Attempts and Prerequisites to Reform," *California Western Law Review* 20 (Winter 1984): 256.

[86] David Jaquette, *Efficient Water Use in California: Conjunctive Management of Ground and Surface Reservoirs* (Santa Monica: RAND Corporation, 1978), p. 3.

[87] See, among others, El-Ashry and Gibbons, p. 11; Lawrence Mosher, "What Role Water Markets?" *Journal of Soil and Water Conservation* 41 (November-December 1986): 391; Marc Reisner, "The Next Water War: Cities Versus Agriculture," *Issues in Science and Technology* 5 (Winter 1988/89): 102.

[88] El-Ashry and Gibbons, p. 11.

[89] Nancy Humphrey and Christopher Walker, *Innovative State Approaches to Community Water Supply Problems* (Washington, DC: The Urban Institute, 1985), p. 36.

[90] Clifford Dickason, "Improved Estimates of Groundwater-Mining Acreage," *Journal of Soil and Water Conservation* 43 (May-June 1988): 239-240.

[91] Reisner, "The Next Water War," p. 100.

[92] Marc Reisner, "No Country on Earth Has Misused Water as Extravagantly as We Have," *New York Times*, October 30, 1988.

[93] John Wesley Powell, "Institutions for the Arid Lands," *The Century Magazine* 40 (1890): 111-116.

[94] Olsenius, p. 312; El-Ashry and Gibbons, p. 11.

[95] Ingram et al., p. 326.

[96] Ibid., p. 331; also, National Water Commission, p. 242.

[97] Gisser, p. 1016.

[98] Gaffney, pp. 45-46; Alfred Cuzan, "Appropriators vs. Expropriators: The Political Economy of Water in the West" (1981), p. 20.

[99] "Leading Wall Street to Water," *Water Strategist* 3 (April 1989): 1.

[100] Gardner, pp. 385-388.

[101] Gardner, p. 385.

[102] Mosher, p. 392.

[103] El-Ashry and Gibbons, p. 11.

[104] Gardner, p. 386.

[105] Mosher, p. 391; Gardner, p. 388.

[106] P. Lorenz Sutherland and John A. Knapp, "The Impacts of Limited Water: A Colorado Case Study," *Journal of Soil and Water Conservation* 43 (July-August 1988): 294.

[107] Ibid., p. 387; also Mosher, p. 391.

[108] Charles W. Howe and K. William Easter, *Interbasin Transfers of Water: Economic Issues and Impacts* (Baltimore: Johns Hopkins University Press, 1971): 171.

[109] Reisner, "The Next Water War," p. 102.

[110] Quoted in Mosher, p. 391.

[111] Wade Miller Associates, p. 5.

[112] El-Ashry and Gibbons, pp. 10-11.

[113] *Water Strategist* 2 (January 1989): 12.

[114] Frank Welsh, *How to Create a Water Crisis* (Boulder: Johnson Books, 1985), p. 59.

[115] Mosher, p. 390.

[116] Victor Brajer and Wade E. Martin, "Allocating a 'Scarce' Resource: Water in the West," *American Journal of Economics and Sociology* 48 (July 1989): 263.

[117] Wade Miller Associates, p. 109; El-Ashry and Gibbons, p. 11.

[118] Neil S. Grigg, "Regionalization in Water Supply Industry: Status and Needs," *Journal of Water Resources Planning and Management* 115 (May 1989): 370.

[119] Wade Miller Associates, p. 98.

[120] Grigg, "Regionalization in Water Supply Industry," p. 369.

[121] "Water Meters Up North?" *Los Angeles Times*, August 9, 1989. Similarly, Fresno, in the heart of California's heavily overdrafted Central Valley, has not metered water use, and is embarking on a meter-installation program.

[122] Roger Starr, "Now, To Get New Yorkers to Turn Off the Faucet," *New York Times*, May 8, 1988.

[123] Wade Miller Associates, p. 108.

[124] Ibid., p. 109.

[125] Ibid., p. 6.

[126] "Evaporating Water Markets? New Contingencies for Urban Water Use," *Water Strategist* 3 (January 1989): 11.

[127] California Department of Water Resources, *California Water: Looking to the Future* (Sacramento, 1987), p. 7.

[128] Viessman and Welty, p. 16.

[129] Welsh, p. 29.

[130] Ibid.

[131] Wade Miller Associates, p. 94.

[132] Schilling et al., p. x.

[133] Henry P. Caulfield, "The Future of Local Water Districts in Historical, Political Context," in James Corbridge, ed., *Special Water Districts: Challenge for the Future* (Boulder: Natural Resources Law Center, 1983), p. 106.

[134] Schmandt et al., p. 3; Cuzan, p. 25.

[135] Caulfield, p. 106.

136 Schiiling et al., p. 92.

137 Schmandt et al., p. 3.

138 Schilling et al., p. 93.

139 Welsh. Similar comparisons have been made by Natural Resources Defense Council analyst Marc Reisner, whose figure is that water in the western deserts is being supplied at prices approximately 2,000 times cheaper than its equivalent weight in sand.

140 P. K. Rao, "Planning and Financing Water Resource Development in the United States: A Review and Policy Perspective," *American Journal of Economics and Sociology* 47 (January 1988): 92.

141 El-Ashry and Gibbons, p. 11.

142 Rao, p. 92.

143 Albert J. Lipson, *Efficient Wafer Use in California: The Evolution of Groundwafer Management* (Santa Monica: RAND Corporation, 1978), pp. 22-23.

144 Keith Knapp and H. J. Vawc, "Barriers to Effective Ground-Water Management: The California Case," *Ground Wafer* 20 (January-February 1982): 62.

145 Susan Christopher Nunn, *The Political Economy of Institufionallnnovafion: Coalitionsand Strategy in the Development of Groundwafer Law*. Ph.D. Dissertation. University of Wisconsin, 1986, p. 45.

146 Thii can be true of state water projects as well. For considerable evidence and analysis of the distribution of benefits from the combination of the federal Central Valley Project and California's State Water Project in the San Joaquin Valley, see Merrill Goodall and John Sullivan, "Water System Entities in California: Social and Environmental Effects," in Corbridge, ed., pp. 71-102.

147 Rao, p. 91.

148 Schmandt et al., p. 11.

149 Rao, p. 91.

150 Ibid., p. 93.

151 Henry C. Hart, "Toward a Political Science of Water Resources Decisions," in L. Douglas James, ed., *Man and Water* (Lexington: University Press of Kentucky, 1974), p. 154.

152 Cuzan, p. 36.

153 Howe and Easter, p. 171.

154 Ibid.

155 Welsh, p. 38; Rao, p. 91; Howe and Easter, p. 91.

156 Reisner, "The Next Water War," p. 100.

157 Howe and Easter, p. 173; Schmandt et al., p. 7.

158 Welsh, pp. 38-40; Schmandt et al., p. 7.

159 Schilling et al., p. 94.

160 Viessman and Welty, p. 2.

161 Wade Miller Associates, p. 12.

162 Phelps et al., p. 25.

163 U.S. Office of Science and Technology Policy, *Federal Ground-Wafer Scienceand Technology Programs*, June 1989, p. 3-2.

164 L M Hartman, "Economics and Ground-Water Development," *Ground Wafer 3* (April 1965): 6.

165 See, for example, Ira G. Clark, *Wafer in New Mexico: A History of Ifs Management and Use* (Albuquerque: University of New Mexico Press, 1988), p. 422:

> Since World War II intergovernmental and interagency cooperation in resolving basic national water problems has attracted considerable support across the entire political spectrum. A succession of national investigations, followed by elaborate reports, supported this approach but with sharply divergent recommendations as to the best means for its accomplishment. . . . *The one point on which they did agree was the woeful lack of basic data regarding water, and that fhis must be remedied.* (emphasis added)

A good example of Clark's point is the 1973 report of the National Water Commission, which stated

> it is apparent that there is a deficiency in the amount of technical data and other information about ground water resources, information which is needed to make sound decisions with regard to regulation and management. (p. 247)

See also Viessman and Welty, p. 14; and National Research Council, Committee on Ground Water Quality Protection, *Ground Wafer Qualify Protection: Sfafe and Local Strategies* (Washington, DC: National Academy Press, 1986), p. 10.

166 Schilling et al., p. xii.

167 Schmandt et al., p. 202.

168 Wade Miller Associates, p. 79.

169 National Research Council, p. 10; Wade Miller Associates, pp. 110-111; Schilling et al., pp. xii-xiii; Neil S. Grigg, "Appendix: Groundwater Systems," in Schilling et al., p. B-5; Schmandt et al., p. 25.

170 Wade Miller Associates, p. 79.

171 National Research Council, p. 10; Wade Miller Associates, p. 111; Schiimg et al., p. 178.

172 Grigg, "Appendix: Groundwater Systems," p. B-5.

173 Schilling et al., pp. xii-xiii.

174 Wade Miller Associates, p. 79.

175 Ibid., p. 115.

176 Ibid, p 206. A still stronger statement was made two years earlier in Welsh, p. 25:

> Obviously there are adequate water supplies available in the nation, even in our most arid states, to support populations well beyond any reasonable projections. Thus any city in the area that claimswatershortage must be admitting that its laws and policies are **the** problem.

177 Wade Miller Associates, p. 123.

178 Schilling et al., pp. 19-20.

179 Schilling et al., p. 21.

# Modifying Intergovernmental Relations in Water Resources Management: Whether, Why, and How

Several issues and trends with intergovernmental implications forwaterresource managementwere noted in Chapter 1. Among the improved techniques that have emerged in response to those issues and trends are conjunctive management of surface and groundwater supplies, and integrated management of groundwater supply and quality Both of these approaches involve considerable coordination among the many actors in the complex water economy

There is evidence of a remarkable number of state and local initiatives to improve water resource management using a wide variety of organizational forms. Federal activity has focused more on groundwater quality protection, but there are signs that a larger federal role in supply management is at least under consideration, and it has received Supreme Court authorization. Despite the innovation occurring in the American federal system, there remain important institutional barriers to more effective management, several of which have an intergovernmental dimension, and in the resolution of which all governments have roles to play.

## APPLYING CONCEPTS AND LESSONS LEARNED

This chapter attempts to bring together the understanding of trends and issues, and progress and innovation in water resource management, the organizing concept of a complex and regulated water economy, and the remaining institutional barriers to effective management Suggestions (some in the form of pending legislation) for modifying intergovernmental roles and relations will be reviewed. Some modifications in federal, state, and local practices to remove impediments to improved water resource management will be outlined.

Much of the literature discussingwater and other common-pool resources divides into two general recommendations for organizational and legal structure: centralized public authority or privatization. This report has recognized that water resources are multifaceted, that conjunctive management of surface and groundwater supplies and integrated management of groundwater supply and quality are very complex tasks, and that diversity of organizational forms and jurisdictional responsibilities is part of the American federal system and must be taken into account The management of water resources is not organized as a centralized public hierarchy or as a privatized, competitive market Most successful conjunctive management situations exhibit complex mixes of noncentralized public activity and high levels of involvement by users. This report, therefore, looks beyond simple organizational models.

The policy debate between advocates of privatization and of centralized public management will doubtless go on. However, much of that dispute is beside the point from the perspective of those engaged coordination of water resource use. Indeed, framing problems and solutions in terms of these diametrically opposite concepts may itself be a barrier to effective action. Restricting recommended solutions "to the intervention of external authority on the one hand and privatization of property rights on the other [ignores] the existence and potentials of other solutions, including user-group or local community management."[1]

Furthermore, experience in conjunctive management makes it plain that neither complete centralization nor massive privatization is necessary for efficient or equitable water use. There is a body of legal, governmental, and economic experience indicating that, when empowered to do so, citizens have produced "remarkably creative achievements" in adapting a diversity of institutional forms to the demands of coordinating the use of water resources.[2]

Experience from groundwater and other common-pool resource cases "illustrates a remarkable ability on the part of nonseparably related decision makers to develop rules to mutual benefit."[3] When groups of resource users and decisionmakers exhibit the ability to shape rules that produce mutually beneficial resolutions to resource dilemmas,

> the devolution of authority and responsibility to make rules to such groups is a valuable policy aim. For nonseparable decisions, neither the individual nor the nation is the appropriate decision maker. . . . The two extremes that characterize the usual models of economic policy- individual and central decision making- are equally inappropriate!

Conjunctive management presupposes a considerable degree of activity and information but not necessarily any particular structure. It leaves available the possibilities of coordinating the actions of multiple individual water users; associations of water users; water supply providers and producers; those storing and recapturing water; and agencies controlling extractions and water levels, and determining storage and pumping rights. In other words, conjunctive management leaves open the possibility of a "complex and regulated water economy" composed of many organizations.

The American federal system likewise does not presuppose that the considerable division of responsibilities and coordination of action will assume any particular structural or organizational form. Thus, the American federal system also leaves open the possibility of a "complex and regulated water economy" composed of multiple participant organizations.

The question remains whether the division of responsibilities and the coordination of activity involved in a complex and regulated water economy represents anything more than "satisficing," a rationalization for falling short of some better form of organization. Strong arguments have been made for centralized public authority or privatization in water supply management, but there are stronger arguments for a system of noncentralized arrangements involving public and private entities in the coordination of the conjunctive use of groundwater and surface water supplies.

## The Concept of Scale, the Tasks of Conjunctive Management, and Multiple Jurisdictions

Noncentralized public and private arrangements may be preferable for conjunctive management of water resources in a complex and regulated water economy. Ira Clark of the University of New Mexico wrote recently

> Effective administration is dependent on the existence of specialized institutions tailored to manage water for specific purposes This involves creating state agencies to handle problems of a general nature, clothing political subdivisions with power to act on pertinent water matters within their jurisdiction, providing for the formation of quasi-public entities to manage local projects, and authorizing action by private water companies. Congress has also had to create a wide variety of administrative agencies relating directly or indirectly to the management of water insofar as there is a federal responsibility.5

As Susan C. Nunn concluded, given the diversity of values and interests involved in groundwater development and management, and the particularly difficult problems of distributing benefits and costs across various communities of interest, an "institutionally rich environment" with "institutions that relate decisionmakers in ways that generate necessary information"[6] about effects, preferences, benefits, and costs, is more useful over the long term than the implementation and enforcement of a particular rule on a given community at a given moment

The Scale of Decisionmaking **and the Involvement of Diverse Communities of Interest. In the discus**sion of the water economy, Chapters 3 and 4 drew on the distinction between provision and production. There is no a priori reason to believe that organizational integration of provision and production is consistently more efficient than arrangements whereby providers obtain services and commodities from producers. Interorganizational arrangements may involve higher transaction and coordination costs than organizational integration but reap greater gains from functional specialization, division of labor, and appropriateness of scale The relative balance of these benefits and costs cannot be predetermined by analysis across the full set of possible cases

Consideration of intergovernmental responsibility for conjunctive management of groundwater supplies does raise some key issues. One of those issues is the importance and effects of jurisdictional boundaries on decisionmaking processes, as they relate to the scale of immediate involvement of citizens and officials. Finding an appropriate scale of decisionmaking is challenging. Inefficiencies and inequities result from processes that are underinclusive or overinclusive. Underinclusive boundaries exclude persons from decisionmaking processes the results of which affect them. Information about the preferences of the excluded persons is not incorporated into decisions,' reducing efficiency and equity.

Public decisions about resource management made on an inappropriately restrictive scale may impose adversities on the excluded group or result in systematic underinvestment in beneficial activities.

Overinclusive jurisdictional boundaries include persons in decisionmaking who are not affected by the outcome. This brings their preferences to bear on collective choices, and this, too, can produce less than optimal results. For instance, those who are likely to benefit from a particular resource management activity and who can spread the costs to nonbeneficiaries have incentives to pursue overinvestment in that activity

Appropriate scales of decisionmaking would achieve as close a match as possible between those benefiting from resource management and those bearing the costs. Rules arrived at, adopted by, and applied to those whose well-being is affected are "built on a better information base than if they are imposed from outside, or if unaffected parties influence the decision."[8] Generally, "it appears that there is an advantage in a rulemakingapproach in which the community that will be governed by the rule is the source of the collective decision that creates the rule."[9] With particular reference to water supply operations, appropriate boundaries are likely to yield more efficient pricing and full cost recovery, economies of scale, and the uniting of alternative sources of supply.[10] Compliance and consent are also more likely in communities where those affected by the decisions have been part of the process."

Of course, these general considerations have assumed that there are two clearly defined sets of people-those "affected" and those "not affected" by resource management decisions. In actual settings, there will be persons who are more directly affected, indirectly affected, or unaffected. Moreover, as discussed below in defining communities of interest, understandings may change over time as to who is affected and to what degree by decisions about groundwater management

While this may appear to introduce an inordinate amount of complexity into the process, all of the considerations argue against uniting water resource management decisionmaking in a single collective arena. When groundwater and surface water resources are used and managed together, and when quality protection decisions are related to supply decisions, there are likely to be multiple communities of interest of varying sizes involved. The existence of and the capacity to create multiple jurisdictions provide opportunities that would otherwise not exist for public decisions to be taken at various appropriate scales that relate to differing communities of interest This represents a considerable advantage of a federal system in undertaking conjunctive management and/or integrated management of water resources

Not only multiple jurisdictions, but nested jurisdictions, are valuable to decisionmaking about the management of a multiattribute resource with differing communities of interest Jurisdictions that encompass those most directly affected by a groundwater basin, for example (overlying residents who produce and consume water supplies directly from underground), are often nested within broader jurisdictions that include other users of water from nearby or related sources (who are affected indirectly by decisions taken within the smaller jurisdiction and, if adversely affected, may exercise recourse). In a federal system, citizens can create and alter jurisdictions for taking collective decisions and representing their interests, as illustrated in Chapter 3.

Defining Diverse Communities of Interest as an Emergent Process. Thus far, the discussion has proceeded as though "the community" (users, beneficiaries, taxpayers) was known and specified. This is an easy (and often a useful) assumption to make while investigating the importance of other concepts. What starts out as an assumption, though, can turn into a prescription. Assuming that there is "a well-defined group that should be involved in rulemaking over a nonseparable decision" can become a statement that "all and only the nonseparably related decision makers are needed for a rule that exploits the full potential for improvement."[12]

If the definition of the relevant "community of interest" (those whose interests with respect to a given activity or issue are sufficiently consonant to be seen as "common") is conceived as an act that takes place once and for all, it presupposes a level of knowledge of present and future preferences and actions that is likely beyond the ken of any analyst or policymakec The definition of communities of interest with respect to a groundwater supply (or any other valued item) is more usefully conceived as a process.

In some cases, interests may exist but initially may not be perceived and included in decisionmaking. In other cases, interests may emerge over time, perhaps even as a reaction to resource uses and management decisions taken in the past.[13] In either case, as new (or newly perceived) interests become apparent, they must be included in some way or losses will be incurred in efficiency, equity, compliance, and adaptability

The emergence of communities of interest can take time. People may **not** be aware of how they are affected by or involved in the use or management of a groundwater resource. Groundwater basins can extend under significant land areas, and the geohydrologic conditions of the same aquifer can differ markedly from one location to another Therefore, effects of activities may not be spread evenly across all users of a gmundwater supply: "seldom does a negative effect on an aquifer system touch all users equally at the same time. These effects are progressive."[14]

Even within the same aquifer, interests, benefits, and costs may not be evenly distributed. Sometimes an aquifer is great in extent and variable in its physical characteristics, as is the case with the Ogallala Aquifer underlying the high plains. This aquifer

> is not like a giant bathtub.. . it is more like an enormous egg carton, deep in some areas and shallow in others.. . . While the aquifer as a whole was probably being exploited at an uneconomically rapid rate, the costs of that too-rapid exploitation did not fall evenly on the just and the unjust alike.. . . That is to say the user cost was unevenly distributed across the farms of the high plains. [15]

These users are not similarly situated, and artificially defining all of them as having a single and shared set of interests because they derive their water from the "same" source may not make as much sense as allowing them to define their different interests and providing institutional means for accommodating conflicts. High-plains aquifer users may not constitute "a community of interest," despite their common water source. A combination of district representation and administration with the development of an overlapping capacity for effecting regulated water transfers could allow water-poor farmers "to make the water-rich farmers an offer they couldn't refuse, even after accounting for the costs of transporting the water."[16]

Muitiple and conflicting communities of interest can thus coincide with respect to the use of the same water resources. "As the nation's waters have been more and more dedicated to specific uses, the potential for escalation in conflicts among environmentalists, ranchers, irrigators, well users, energy firms, cities, and industries has grown."[17] A centralized administration system drives all of the conflicts between these interests into the decision processes of an agency, making agency employees responsible for resolving conflicts and designing the trade-offs between desired uses.[18] Complete privatization requires that each interest with claims on resources seek to out-bid theothers, thus skewing the outcomes in favor of those with disposable assets to devote to the bidding war. Regulated transferability under rational pricing may allow for the movement of water resources among uses without the excessive presumptions that accompany the privatization literature, namely, complete and perfect information and complete and perfect independence of decisionmaking.

"Functional Fragmentation" as Functional Specialization. Multiple jurisdictions can enhance specialization as well as representation in decisionmaking about groundwater supply management There are efficiency advantages deriving from close information about groundwater and knowledge of the activities that comprise conjunctive management Specific knowledge about the resource is an important aid to effective conjunctive management, which calls for a level of "artful administration" that is responsive to the physical characteristics of the groundwater basin, to the particular use patterns, and to the institutional, social, and political characteristics of the user community.[19]

The range of particular characteristics to be understood for effective management of any groundwater resource is indicated by the following observation:

> Gmundwater management demands an understanding of the geologic history and structure of the basin, and of its water carrying and water storage characteristics It demands an understanding of the hydrologic regime under average and extreme conditions of water supply and the effects of artificial recharge upon that regime. Groundwater management demands sufficiently detailed data and methods to support saline water barriers, artificial recharge, and protection from pollution.[20]

This would not be an especially demandingtask, nor would this issue relate to the proper scale of organization of conjunctive management, if all groundwater basins were alike. However, each basin has somewhat different characteristics, with variations in the effects of recharge and of overdrafting, the likelihood of quality degradation resulting from fluctuations in water levels,climate, drainage characteristics, overlying use patterns, irrigation practices, and soil permeability?

There is more to this than merely observing that no two groundwater basins are alike. Take only one of the elements of conjunctive management listed in Chapter 3 -the control of overdraft The variability in physical characteristics of groundwater basins as reservoirs is extremely significant for controlling overdraft In a shallow aquifer along a coastline and in hydrologic contact with the ocean, any overdrafting of the groundwater may result in salt water intrusion that degrades the quality of the water supply and renders it essentially useless. In a karst aquifer underlying a sandy soil surface, overdrafting beyond a certain point could result in sudden land subsidence, such as sinkholes. In an alluvial basin not in contact with a salt water or other low-quality supply, overdrafting could continue for years without any harmful effects other than increased pumping lifts The prospects for controlling overdraft to create storage space for the retention of surface water flows as part of a conjunctive management program would be markedly different in these three types of cases

How, then, would one construct a rule for the control of overdraft that would extend across basins? A rule that prohibited overdrafting and required safe-yield operations would result in inefficient use of two of the three types of basins described above. A rule that required overdrafting could inflict serious economic losses in two of the three basins described above. The only rule that fits all three situations is a rule stating, "Overdraft where and to the extent a basin is capable of being overdrafted; otherwise, do not overdraft" This is essentially the same as no rule at all.

Rules for controlling overdraft,as for implementing recharge, regulating storage capacity and water in storage, and protecting water quality from degradation as a result of management practices, must be formulated in accord with the specific characteristics of each groundwater reservoir. Overlying use patterns, which result from the interaction of economic, political, and historical characteristics, affect these decisions and need to be taken into account, as well. In sum, the information requirements of conjunctive management of groundwater supplies are intensive and highly particular.

Furthermore, this analysis, which applies to the conditions prevailing in a particular basin at a particular time, applies equally strongly (if not more strongly) to changes in those conditions. Close knowledge of changes in the physical characteristics of a groundwater reservoir and in the overlying use patterns is essential to adapting and maintaining the effectiveness of any program for coordinated use of water resources.[22]

The advantages of specific knowledge do not relate only to water resources and their associated communities. Efficiency also can result from functional specialization that unites differentiation with specific knowledge and experience. When decision-making for a variety of functions is combined, different activities compete for attention and resources within the organization. Gaining maximum advantage from specialized experience also cannot be assured. Optimal decisions for each activity can no more be assured by an integrated organization than by coordination among several organizations. With public jurisdictions especially, "the endemic condition which results from co-mingled (sic) decision-making is one of 'public choice failure'."[23]

Water supply and wastewater treatment functions, for example, have often been divided and performed by different entities. This differentiation has been criticized by some observers who have suggested that the organizations should be combined in order to promote "efficiency" However, efficiency also may be promoted by the execution of these functions by separate and specialized entities As a recent study of water supply concluded, "there is little evidence to support the assertion that U.S. systems in which the water and wastewater functions are combined are more efficient than those that are not."[24]

Knowledge specific to efficient conjunctive management may be attained through functional differentiation. What appears at one level of analysis to be "fragmentation" standing in the way of efficiency may at another level appear as "specialization" that enhances efficiency. Because of the importance of specific knowledge and the value of functional specialization, it has been contended that "[e]ffective administration is dependent on the existence of specialized institutions tailored to manage water for specific purposes."[25]

Discussions of the appropriate scale of decision-making, representation and definition of communities of interest, and the advantages of specialized knowledge and functional differentiation may not make it clear whether groundwater management is a national, state, or local responsibility In fact, attributes of groundwater systems are of concern to all governments.[26] Developing groundwater management information systems, implementing conjunctive use programs, adjusting programs to changing conditions, and coordinating these activities within the intergovernmental system all have different appropriate scales, with roles for all jurisdictions in the federal system. This response may be disappointing to those who prefer the simple answers offered by the Supreme Court and others, who apparently have had no difficulty deciding "whose problem" and "whose responsibility" groundwater management is.

A priori definitions of the appropriate management jurisdictions activities are unneeded, and probably impossible to find and defend successfully Coordinating the conflicting demands on a limited but highly variable resource in a federal system is not easy, and "the solution does not lie in an uncompromising grant to either the State or the federal government."[27]

A reasonable statement of the multijurisdictional arrangements that optimize the use and management of water supplies is:

a) Decisions that depend strongly on close knowledge of the water resource and its users -such as allocations of water production and storage, and pricing -- can best be made by local specialist organizations (public and private) that are as nearly matched as practicable to the communities of interest

b) Rules for the establishment and authority of management organizations, and for the acquisition and transferability of production and storage tights, can best be developed by the states in response to their individual situations, thereby retaining and encouraging innovation and diversity

c) Support for the information requirements- in particular, basic hydrologic research, water resource inventories, technical assistance, and the exchange of information about water resources and management practices—would best be performed cooperatively by the states and the national government

This description, in turn, relates to the roles of these governments in overcoming the institutional barriers that remain to improved management of water resources:

a) Local organizations should have primary responsibility for implementing water pricing practices that more accurately signal users as to the value of the resource, without spreading water supply development and operation costs to larger jurisdictions.

b) States have primary responsibility for modifying their water rights laws and for empowering public organizations to conduct conjunctive management of surface and groundwater supplies where conjunctive management is practical and indicated.

c) The states and the federal government have primary responsibility for overcoming remaining information barriers to the improvement of management practices

## Protection of Groundwater Quality: A Different Set of Roles and Relationships?

In Chapter 1, the distinction was drawn between the conjunctive management of water supplies and the integrated management of water quality and quantity. The management of groundwater and surface water supply may or may not be coordinated, although the two often are related physically. Similarly, the protection of groundwater quality may or may not be coordinated with the management of groundwater supplies, although the two also are related physically

As was also stated in Chapter 1, this report does not contain a review of local, state, and national groundwater quality protection programs. Readers interested in further pursuing the question of intergovernmental roles and relations in the protection of groundwater quality are referred to the 1986 report of the Environmental and Energy Study Institute, *A Congressional Agenda for Preventing Groundwater Contamination: Building Capacity to Meet Protection Needs;* the 1986 report of the National Research Council's Committee on Ground Water Quality Protection, *Ground Water Qualify Protection: State and Local Strategies*; the 1986 report of the National Groundwater Policy Forum, *Groundwater: Saving the Unseen Resource,* and the 1989 report of The Urban Institute, *State Management of Groundwater: Assessment of Practices and Progress.*

Nevertheless, the management of groundwater supplies necessarily includes a concern for protecting quality The adage "quality is quantity" is often repeated by water managers. With respect to groundwater, a 1975 bulletin of the California Department of Water Resources expressed that relationship explicitly: "A basin that may be expected to be used for thousands of years can become unusable, perhaps permanently, within only a few years by deliberate or accidental pollution."[28] The seriousness of groundwater contamination has multiple dimensions and is difficult to overstate. Use of groundwater contaminated by toxic, carcinogenic, or mutagenic materials can result in adverse health effects.[29] Groundwater contamination can be deadly That is just one dimension of the seriousness of groundwater contamination, albeit the most acute one.

Even where public health may not be acutely endangered, the loss of a groundwater basin has serious economic consequences. Where local groundwater has been contaminated, suppliers may have to develop new sources,[30] any one of which is likely to be more expensive and less reliable. Costs of cleaning up the local groundwater supply and restoring it to usable quality are likely to be as great or greater.[31] Furthermore, contamination threatens theusefulness of a groundwater basin as a storage reservoir, with serious consequences for conjunctive management

While it is not difficult to conceive of the serious ness of groundwater contamination, it is difficult to know its extent The Committee on Ground Water Quality Protection of the National Research Council found "no adequate data available on a national or even regional scale to estimate the extent of ground water contamination and the impactsof this contamination."[32] Most authorities seem to agree that the extent of groundwater contamination nationwide remains relatively small.[33] A 1988 report of the U.S. General Accounting Office noted that "groundwater quality in 91.8 percent of the locations we studied surpassed drinking water standards for all substances measured. That is a positive result."[34]

Nevertheless, reports from various sources indicate that problems are sufficiently widespread and serious to be of concern. Thus far, more than 225 harmful and potentially harmful chemical, biological, and radiological substances have been found in groundwater supplies.[35] Half of the states have discovered pesticides in groundwater.[36] As of 1987, more than 2,800 community supply wells in 34 states were closed due to contamination. And the possibilities for future contamination incidents are substantial: "There are 90,000 landfills and between 1.5 million and 25 million underground storage tanks in this country; an estimated 20 to 30 percent of them are leaking."[37]

What renders this patchwork of figures of greater concern is that areas of contaminated groundwater generally coincide with areas of greater population concentration.[38] Reported contamination is most extensive in the Northeast,[39] but there have been cases nationwide that have caused supply shortages.[40] A 1988 book reviewing state water policies concluded, "It is becoming abundantly evident that degradation of ground water is a major problem, especially in specific localities."[41]

Because of these important intersections between quality and water resource management generally, this section contains a discussion of some patterns in governmental roles and relationships in groundwater quality protection, which have been different from those in supply management

States and local communities have demonstrated considerable initiative in devising and implementing groundwater quality protection and supply management programs, but the federal government has a more extensive role in the protection of groundwater quality. As observed by the authors of a 1985 book on water management, "The trend in water *quality management* in the United States has been toward centralization and the imposition of uniform rules,“” which can be seen as more appropriate than they would be in the management of groundwater supplies. The reasons for the differences may be grouped into three categories: (1) the usefulness of uniform standards; (2) the significant needs for technical and scientific information; and (3) the challenges faced by small water systems in meeting quality standards

Water quality protection involves assessing risks to human health for varying levels of contaminants and establishing maximum levels. Some states and communities have developed standards or guidelines to ensure safe water, but it is duplicative and inefficient for them to do so.[43] (Presumably, the health risks from a given level of contaminant are the same in Florida or Alaska.)

The establishment of maximum contaminant levels by the federal government "is an efficient intervention because the information requirements necessary to assess subtle health risks in sufficient depth to evaluate alternative levels of protection are enormous."[44] Although a few states have devoted substantial resources to health research and sophisticated standard-setting procedures, as a general matter, "the states do not usually conduct their own research to develop information on toxicology or on the risks *of* groundwater contaminants to health. They rely instead on information from the federal government."[45] Some of that information has been forthcoming, but "much of the basic scientific knowledge needed to develop policy does not yet exist."[46] The appropriate scale for such research and development is national.

The National Research Council's Committee on Ground Water Quality Protection concluded in its 1986 report that research to develop the knowledge base for effective groundwater quality protection remains to be done. The committee observed:

> More scientific and technical information is needed concerning the extent of ground water contamination, its effects on health, the environment, society and the economy and strategies and technologies to prevent it Also, more information is needed on the effectiveness of various protection programs. There is a need for understanding processes, including those in the unsaturated zone.[47]

The development of the information base concerning groundwater contamination supports federal, state, and local regulatory efforts and the use of the court system to protect groundwater quality Many individuals harmed by contamination have sought remedies through liability litigation, but securing evidence has been a principal obstacle to their success.[48]

Federal and state efforts to improve the data available could assist parties in liability cases against polluters and help resolve competing claims concerning contamination incidents.[49] Concern about potential liability claims may complement regulatory efforts aimed at prevention, making potential polluters weigh their actions in light of the increased risk of incurring some future penalty

Implementation and enforcement of protection regulations raises another issue that distinguishes water supply from quality protection. Proper implementation of the *Safe Drinking Water Amendments of* 1986 and the 1987 amendments to the *Clean Water Act* will impose significant costs on local public water supply systems, especially medium and small systems.% The challenges faced by small systems in protecting groundwater from a growing list of contaminants, in monitoring quality on an ongoing basis, and in complying with federal and state regulatory standards are daunting and are likely to grow. (Those challenges are referred to in the literature on groundwater quality protection as "the small system problem.")

Small water systems do not present a problem as providers per se; it is their capacity to perform the range of tasks associated with protecting quality that has been drawn into question. The two principal obstacles are the lack of technically expert personnel and lack of access to sufficient financial capital.[51] This is true of small local systems even in economically prosperous regions.[52] "EPA officials have consistently stated that small water systems deserve a higher priority on the environmental agenda within the Agency, and that the small water system problem is the greatest impediment to successful implementation of the SDWA Amendments."[53]

Since the states are responsible for implementing the drinking water amendments, the "small system problem," which is basically one of implementation, becomes a problem for state governments as well as EPA. States have a number of options One is to grant some flexibility in compliance schedules to ease the financial burden on small systems, in exchange for financial reforms to address their chronic undercapitalization problems.% Another option is state financial assistance to help bring small systems into compliance with the standards. Typically, such assistance is provided directly through grants and loans or indirectly by backing local attempts to gain access to financial capital with the credit of the state.[55] Some states have encouraged and facilitated mergers and takeovers of undercapitalized small systems or regionalization schemes that could facilitate "pooling" of public water supply system resources.[56]

The combination of groundwater quality protection tasks-development of standards or guidelines for maximum contaminant levels, development of the information base for regulatory and enforcement action, and the compliance challenges faced by smaller systems – produces a different set of intergovernmental roles and relationships than is appropriate for managing water supplies and developing conjunctive management More of the decisionmaking, information gathering, and financing for water quality protection, whether for groundwater or surface water, is of state and federal scope.

During the 1980s, other groups of public officials, water administrators, and policy analysts reached similar conclusions about the appropriate state and federal roles and relationships in groundwater quality protection. A policy position adopted by the National Governors' Association in 1981 called not so much for new laws and regulations as for greater emphasis on federal and state enforcement of existing laws, with more federal research on contamination sources and their associated health effects, and increased state applications of the information and guidelines.[57] The governors called for a "new environmental partnership" between the states and the federal government in groundwater quality protection

In 1983, the National Governors' Association joined with the Conservation Foundation to develop the National Groundwater Policy Forum, chaired by former Arizona Governor Bruce Babbitt The 17-member forum was composed of three governors, three chairmen of major corporations, the directors of three major environmental groups, other state officials and a county executive, and groundwater researchers. The forum also endorsed the "new environmental partnership" concept Among the forum's conclusions was that groundwater protection would require high levels of federal, state, and local coordination to "take advantage of the management capacities of different units of government as well as engage the active cooperation of the private sector and public interest community."[58] The forum also recommended that all states enact groundwater quality protection legislation incorporating the following ten components:

1) Comprehensive aquifer mapping including associated recharge and discharge areas;
2) Aquifer classification;
3) Ambient groundwater standards;
4) Source control authority;
5) Monitoring, and data collection and analysis programs;
6) Effective enforcement provisions;
7) Surface use restrictions to protect groundwater quality;
8) Programs to control groundwater withdrawals to protect groundwater quality;
9) Coordination of groundwater and surface water management and
10) Coordination with other natural resource programs.

The forum recommended further that federal law condition future receipt of assistance by states in groundwater remediation under the Superfund program on adoption of quality protection programs containing these elements, with the first six required as "the essential core of a comprehensive program."

The most thorough proposals, addressing the goals, the implementation, and the appropriate federal, state, and local roles and relations in groundwater quality protection, are to be found in the 1986 special report of the Environmental and Energy Study Institute, titled *A Congressional Agenda to Prevent Groundwater Contamination: Building Capacity to Meet* Protection *Needs.* A brief and necessarily incomplete summary of the Institute's findings, conclusions, and recommendations follows:

1) A massive, new federal groundwater program along the lines of the Clean Air and Clean Water programs of the 1970s is not needed, probably could not be crafted, and would not work
2) The local nature of the groundwater resource, and of contamination problems, must be recognized, respected, and taken into account, as should be the historical primacy of the states in the management and protection of groundwater resources
3) A restrained, phased, and nontraditional response is called for, stressing federal leadership, not regulation; real state flexibility, not rhetoric; and state and local decisions, not deferrals.
4) The proper federal role involves **the establishment** of a national goal of contamination

prevention, financial and technical support to the states for the development of their own programs, leaving the states the real flexibility and authority to do so, assisting state and local decisionmakers with the information that could improve decisions, and getting the federal government's own house in order through more effective and coordinated implementation of existing authority and through changes in other activities to bring them into line with the national prevention goal.

5) The federal information gathering and technical assistance program should have a designated lead agency (U.S. Geological Survey), and should include a groundwater information clearinghouse for federal, state, local, and private decisionmakers and concerned citizens; the emphasis of federal research efforts and funding on remediation and cleanup of contaminated sites should be supplanted by research and demonstration efforts directed toward prevention,

6) States should pursue the possibility of developing protection goals stronger than the federal goal; states should be free to consider natural groundwater quality vulnerability of various aquifers to contamination, and uses of aquifers, but aquifer classification systems should not be mandated; state quality protection programs should be encouraged through development and implementation grants, rather than mandated with threats of funding losses, in order to encourage rather than disrupt the extensive state initiatives

7) Local governments would bring the prevention of groundwater contamination to a priority status in making local land use decisions, in order to ensure that contamination sources are kept away from recharge areas; planning and zoning of land uses are among the most effective tools for the prevention of groundwater contamination, and those tools are for the most part in the hands of local officials

8) The private sector should be encouraged to develop and deploy protective technologies andpractices,especiallywith regard towaste disposal and agricultural chemicals.

A similar position on appropriate intergovernmental roles and relationships in groundwater quality protection was adopted by the Association of State and Interstate Water Pollution Control Administrators in 1983 and was revised in 1987. The agenda calls for a national goal of protecting human health and the environment by preventing and mitigating groundwater pollution wherever possible; a federal role of supporting research and development and providing technical assistance; a state role of developing and implementing groundwater protection programs, and coordinating or integrating groundwater quantity management with groundwater quality protection; and a local role in **making** responsible land use decisions that protect groundwater supplies from further degradation.

Addressing the Issue of Nondegradation. An obvious issue that arises in connection with water quality protection standards is where to set them. A less obvious but equally crucial related issue is the underlying criterion for quality protection. The issue has come down to the following basic question: should a nondegradation policy be adopted for groundwater supplies?

A U.S. General Accounting Office report issued in 1988 observed that nearly all of the states that set numeric groundwater standards simply adopted EPA maximum contaminant levels for drinking water. However, because so much of the nation's groundwater is so pure, adoption of EPA's levels "would allow the potential for degradation of a considerable amount of groundwater (to the level of contamination allowed by drinking water standards). That is, contaminant levels might gradually increase to about that allowed by the standards."[59] This poses a potential problem in areas where groundwater contributes to a surface water supply that supports sensitive species of aquatic life, the survival of which might be jeopardized by levels of contaminants deemed safe for human use and consumption. The drinkingwater standards tend not to be as stringent as EPA and National Academy of Sciences guidelines for the protection of aquatic life. Furthermore, EPA maximum levels have not yet been established for all identified groundwater contaminants.

Some environmental advocacy groups, such as the National Wildlife Federation,@ have endorsed the concept of nondegradation as the proper goal for gmundwater quality protection. They point out that the proper purpose of federal and state policy should be the protection of the resource, not the protection of certain "uses" of the resource, which change over time.

Accordingly, a bill introduced by Sen. Dave Durenberger of Minnesota would require states to adopt nondegradation standards for all gmundwater resources On the other hand, other environmental advocacy groups, such as the Conservation Foundation, recommend that states adopt aquifer classification schemes EPA's groundwater protection strategy, adopted in 1984, included guidelines for the classification of groundwater, with different levels of protection for each of three classes.[61] Class I is a strict nondegradation category for irreplaceable drinking water sources and for aquifers connected with sensitive and ecologically essential life. Class II includes current and potential sources of drinking water, and waters having other beneficial uses. Class III groundwater is nondrinkable in its existing poor-quality state, and is isolated from Class I or II aquifers.

Groundwater protection does not exist in a vacuum, but in a policymaking context that includes ordinary uses and waste disposal needs. Almostevery use of water results in some change in its character, and some form of biological, chemical, or thermal deterioration. An advocate of a "limited degradation" approach observed, "Pristine purity in developed areas probably cannot be maintained. The objective is to keep deterioration within acceptable limits."[62]

In contemplating the desirability of a nondegradation standard in light of the need for waste disposal sites, an important question is whether it is consistent with proper groundwater management to allow some aquifers to experience additional degradation in quality. There also are two subsidiary, and rather different, questions. The first is whether it is acceptable to dedicate areas containing unusable groundwater to waste disposal, thereby causing the further deterioration of those supplies. The second question is whether it is acceptable to dedicate areas containing usable groundwater to waste disposal that would render those groundwater supplies unusable.[63] Aquifer classification schemes can be designed to allow these questions to be answered affirmatively, or to allow an affirmative answer to the first and a negative answer to the second.

Resolving the issue of nondegradation versus limited degradation on a national scale presumes that it is possible to be certain that one approach is preferable. The information required to make such a judgment is not available, but state groundwater quality protection programs will add to the store of knowledge and experience on this question. Mandating either nondegradation or aquifer classification across the states forecloses avenues for innovation.

The Environmental and Energy Study Institute concluded in its 1986 report that there was no consensus on the issue of nondegradation versus use protection goals, that each perspective "has distinct advantages, and distinct disadvantages," that each "would be expensive and difficult to implement," and that the debate "over these divergent management philosophies is likely to be long and divisive."[64] The institute's recommendation was a national goal of preventing groundwater contamination "to the maximum extent possible." Another possible resolution was offered by the National Groundwater Policy Forum, which supported a sort of compromise goal "to protect the physical, chemical, and biological integrity of the nation's groundwater resources and ensure that they are not degraded in any way that may be harmful to humans or the environment"

States have been experimenting with aquifer classification and protection limits For example, Wisconsin's 1984 groundwater protection law established a uniform protection standard rather than an aquifer classification system or a nondegradation standard. Then Governor Anthony Earl commented, "We don't use all of our aquifers for drinking water at this time, but we see no reason to write any of them off by giving some of them a different or lesser level of protection."[65] The law provides for two levels of quality standards, a lower "preventive action limit" for each contaminant to trigger remedial action, and a higher "enforcement limit" to protect public health, based on federal drinking water standards, where available.

While the Wisconsin law provides uniform standards for all aquifers, those are not nondegradation standards. In Governor Earl's words, "Though we would like to adopt absolute nondegradation, we think that is an ideal not achievable or measurable.. . . It seemed to us, to be as practical as we could, that some degradation will take place and our efforts ought to be aimed at minimizing it or eliminating it to the extent possible.""

Wisconsin's response to groundwater contamination is one example of a fundamental shift that has occurred in the states on issues of environmental protection. The dairy industry and the brewing industry, which are dominant contributors to the Wisconsin economy, both rely on supplies of clean groundwater and also contribute to contamination problems. These industries, along with concerned citizens, legislators, state agencies, and the governor, participated in the development of the law. A new Iowa groundwater protection law toughens regulations and raises fees on the use of pesticides by the farm sector, which is the dominant sector of the state's economy and politics. In New York, the members of the Long Island Association, the major business association on the Island, ranked water quality as their number one concern in locating and operating a business there, even ahead of energy costs and solid waste disposal. These and other examples from around the country suggest that old assumptions that state and local officials would sacrifice environmental quality and their citizens' health for the sake of appeasing the dominant sectors of their economies, or attracting businesses to their states and communities, are simply no longer borne out by evidence, at least with respect to water quality

Summary: The Limits of "Quality is Quantity." Like most cliches, "quality is quantity" remains in use because at one level it is unarguably true. Yet, that old adage is of little use in telling us whether it is necessary or desirable to organize groundwater quality protection and supply management together, whether to unite the legislation and regulations that affect both, how to go about acquiring theknowledge needed for sound decisions, and how to connect the information and decisions about groundwater to surface waters The management of groundwater supplies in a well functioning federal system increases citizens' opportunities for addressing those issues in various combinations and learning and adjusting.

There is no reason to limit-and good reason not to limit-the variety of organizational approaches citizens and public officials may devise. Some states and communities have integrated groundwater supply management and quality protection, while others have kept the functions separate and still others have pursued regional cooperation for quality protection while organizing supply management principally on a community scale.

State and local approaches to quality protection also have varied. Wellhead protection programs, land use restrictions, conditions on the transfer of real estate, and a host of other methods have been part of the arsenal of state and local assaults on groundwater degradation. This is consistent with the conclusion of the National Research Council's Committee on Ground Water Quality Protection:

> It is apparent that ground water issues and conditionsvary from state to state and reflect differences in the states' physical, social, and political makeup. As a result, no single strategy for dealing with ground water pollution problems can be recommended for all states or areas. Each state or local strategy will necessarily reflect the local situation.[67]

Remedies for groundwater contamination also vary. Some contamination problems have had serious local impacts but also "exhibit a high degree of site-specific characteristics and have required the application of highly nonuniform remedial strategies."@ In a federal system, this variety in the approach to specific problems is intrinsically desirable, to be valued in and of itself; it is, indeed, one of the principal reasons for having a federal system.

Two other important elements in fighting groundwater contamination are the development of information about quality and contamination, and the use of basic and applied research into risk assessment and health effects to develop guidelines for specific contaminant levels. The appropriate scale for these two functions is national, and the federal government should maintain its leadership in research and the setting of waterquality and guidelines, in the interest of health.

Much remains to be done. As the list of contaminants discovered in groundwater supplies increases, so does the task for the Environmental Protection Agency. There are several known contaminants for which assessments have not been completed and for which maximum levels have not been published. As we have learned more about groundwater contamination, the list of contaminants about which citizens and public officials are concerned has seemed to expand more rapidly than the research and guideline process.

Lack of knowledge, and of knowledge dissemination, plagues groundwater quality protection just as it does supply management, although the needs are not identical. Quality protection raises such questions as: How do contaminants move through groundwater? How can contamination be prevented? How serious is the contamination, and what are its impacts? How has regulation fared thus far? Local, state, and federal groundwater protection activities have unfolded in the midst of these uncertainties, and been shaped by them.

> In such uncertain circumstances, policy formulation has been groping towards a balance between strict regulation and environmental degradation. Lessons learned from earlier enthusiastic attempts to regulate air and surface water have prompted a more cautious approach.. . . Considering the uncertainty associated with current understanding of groundwater, its protection, and its conservation, this would seem an appropriate approach to take. Such an approach could, however, degenerate into aimless policy making often working at cross purposes.[69]

It is vital that federal officials not allow research and standard setting to degenerate. It is equally vital that states and localities, regardless of whether they combine quality protection and supply management into a single piece of legislation or a single administrative agency, maintain coordination and not allow program development and implementation processes to degenerate. In fact, when the policy response of the federal government is to tell states and local governments what to do and have them implement and pay for it, the quality of groundwater protection programs will depend as much or more on the states and local communities as on the federal government.[70]

Keeping policymaking from degenerating into aimlessness and working at cross purposes is extremely difficult when citizens and public officials are not entirely sure of what is going on; information and coordination costs are high. Nevertheless, the stakes for public health are even higher, and as citizens and public officials realize, the continuation of successful experimentation and innovation in groundwater management depends on protecting their quality. "Quality is quantity" does not mean that they must be covered by the same statute or be the responsibility of the same administrative unit (although these are options). It does mean that there is a contingent relationship between the two, and failure to protect quality injures the complex water economy that provides and produces water supplies.

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### ENDING SUBSIDIES, INCREASING INFORMATION, AND SUPPORTING QUALITY PROTECTION: WHAT THE FEDERAL GOVERNMENT CAN DO

We have reviewed the historical and current role of the federal government in water supply and quality protection, and some of the institutional barriers to more effective water resource management, including some in which the federal government is involved. In this section, we review some suggestions for the federal role in improving water resource management

**Supporting Certainty in Water** Rights and State Authority. Certainty in rights is a component of improved water resource management that has been endorsed for decades The federal government has a role to play in eliminating uncertainty about federal reserved rights, about state authority to establish and enforce rights, and about the prospect of direct federal management of groundwater supplies under the Commerce Clause authority granted in *Sporhase* v. *Nebraska.*

The existence of unquantified federal reserved water rights compounds planning and management difficulties facing states, local governments, and water users. "In some instances, Federal officials refused to disclose their existing uses of water and were also claiming reserved rights to future uses of water In any amount necessary to serve the purposes of withdrawn Federal lands."[71]

Initially, sovereign immunity appeared to bar the use of the courts by the states to obtain judicial definitions of rights. The sovereign immunity of the United States in suits involving water rights was waived, however, under the provisions of the McCarran Amendment to the *Justice Appropriation Acf* in 1952. After the *Arizona* v. *California* and *Cappaert* v. *United Sfafes* decisions revealed the full scope of federal reserved water rights,states have sued to force federal agencies to disclose and quantify reserved water rights. This approach, while effective on a case-by-case and basin-by-basin basis, is certainly more costly than an act of Congress directing all federal agencies to disclose and quantify all reserved water rights, based on the *United Sfafes v. New Mexico* criterion of specific needs essential to the planned use of the land

In his statement of national water policy in 1978, former President Jimmy Carter called on federal agencies to quantify and report their reserved water rights as quickly as possible. Despite the passage of 12 years, uncertainties remain about the reserved rights, and about Indian water rights in particular. The analysis in this study supports the notion that President Carter's proposal would have aided the cause of improved management of water resources by removing some of the uncertainty.

Under current U.S. Supreme Court interpretation, the federal government has the constitutional power to regulate groundwater supplies directly through the Commerce Clause. The question of federal exercise of that power remains open. Contemplation of confrontations between federal and state regulatory power casts the question of power in "winner-take-all" terms. On the other hand, "if the question is not the existence of power but the desirability of its exercise,compromise and accommodation are more likely to be achieved."[72] There have been "several instances" where the "Congress has chosen to use less than all of its powers, and has elected to recognize state-created rights even though it was under no constitutional obligation to do so."* In the aftermath of the *Sporhase* decision, it remains to be seen whether state-created rights and regulations regarding groundwater supplies will be added to this category.

In the view of one observer, "the general framework for the regulation of water supplies. . . is still intact. Interstate compacts and equitable apportionment statutes may well withstand the *Sporhase* decision."[74] And, at least during the Reagan administration, executive branch officials indicated that the *Sporhase* decision would not alter federal agencies' actions regarding groundwater management.[75] In the aftermath of *Sporhase* and *Garcia,* states and local governments will have to rely on the continuation of such federal forbearance in order to maintain their primacy in the management of groundwater supplies

Ending the Flow of Subsidies. There has been concern about the distribution of the costs of federal water projects since the 1930s,[76] and the attitudes of federal policymakers have shifted. In the early decades of this century, water projects for flood control or agricultural development were considered to be sufficiently "in the national interest" to justify the assumption of a large share of the costs by the federal government In recent years, many policymakers have embraced the notion of "user pays the costs."[77] This is due partly to a recognition of the implications for water resource management, i.e., that federal pricing of water "at full cost, rather than subsidizing it, would give further incentives for efficiency."[78] But a greater share of the shift appears to be due to the recognition of the connections between selling subsidized water and the continued overproduction of surplus crops, with its attendant increased cost of farm programs in a time of strained federal fiscal resources

The Congress addressed the problem in 1982 with the *Reclamation Reform Act,* an attempt to implement fullcostpricingof Bureau of Reclamation water delivered to irrigators and irrigation districts that renegotiate their contracts in order to take advantage of the new, higher limitation of 960 acres. Implementation, including publication of the new full-cost pricing structure (which could raise the price of bureau water to irrigators by fivefold or more), has been delayed,[79] and the announcement in 1989 of the planned renewal of the Orange Cove Irrigation District contracts offered little hope that the bureau and the Interior Department will use water contracts to try to improve conservation or efficiency?

The Congress revisited the issue of pricing in 1986, when a compromise allowed "what will probably be the last" major surface water supply and flood control project, the Garrison Diversion Unit of the Pick-Sloan Missouri River Basin Program, to proceed?* Some of the controversy concerning the Garrison project centered on the problems of providing subsidized water for the production of more surplus crops. When it appeared to be settled that farmers who used Garrison water to grow surplus crops would pay a 10 percent surcharge, an amendment offered by Representative Phil Sharp of Indiana proposed to make those farmers pay full-cost prices for that water. The amendment was defeated on the House floor, but by only 4 votes (203-199).[82]

The Garrison project, expected to cost approximately $1 billion, has been anticipated for a long time. Rep. George Miller, California, of the House Committee on Interior and Insular Affairs, stated that the length and strength of past commitments to the project were primarily what had kept it moving forward. Upper Missouri River Basin states have acceded to many changes in the project, including its overall scale and a shift in the primary emphasis from irrigation to municipal, industrial,and rural domestic uses. Whether or not it is "the last? major federal water project in the West, the Garrison project is viewed by the Upper Basin states as only fair, in light of their earlier cooperation in abandoning the development of hundreds of thousands of acres of prime farmland for the sake of supplying water flows to Lower Missouri River Basin areas, where federal irrigation and flood control projects have been built.

In addition to moves to operate the projects on something closer to a user charge basis, there is a broader trend toward federal disengagement from water development project financing and construction. Federal financing was at a virtual standstill from 1976 to 1986, and even the passage of the *Wafer Resources Development Act of* 1986 has not reversed the overall trend.

With the exception of the Upper Missouri River Basin, the major developments anticipated to be part of the reclamation program have been or are being completed. Western rivers such as the Columbia and the lower Colorado are now "one reservoir after another."[83] The Central Arizona Project is essentially completed, and the Central Utah Project is underway. This should not be overinterpreted to mean the imminent demise of the Bureau of Reclamation; as of 1987, the bureau's agenda included 68 ongoing building projects, which are anticipated to keep the bureau active into the 21st century.

As the 1980s drew to a close, it appeared to many observers that, "with the exception of Federal projects now nearing completion, there will be few if any additions to the irrigation infrastructure."[84] As the federal government disengages, states and local governments that wish to develop additional water supplies through construction of physical facilities will have to undertake such projects on their own.[85] If federal disengagement means reduced subsidization and increased attention to managing water supplies, efficiency and equity in water resource use may be enhanced.[86]

**Imposing Federal Conditions on Water Subsidies: The Reclamation States Groundwater Protection and Management Act. There** may be an effort to use federal financing of water projects as leverage to require states to develop federally approved groundwater supply management programs. The subsidization of water supplies is connected with the federal government's constitutional spending power. In the water resources field, *United States* v. *Gerlach Livestock Company*[87] upheld the federal Central Valley Project in California as a valid exercise of the spending power, which allows the federal government to condition expenditure of funds on beneficiaries' compliance with federal regulations, or; as the Supreme Court stated, "to regulate that which it subsidizes."[88]

The potential scope of the spending power and the General Welfare Clause (in addition to congressional power over navigable streams) were indicated by the Supreme Court in *Arizona v. California* (1963).[89] In that case, the Court appeared to hold that, as part of its power "to regulate that which it subsidizes," the Congress could direct the Secretary of the Interior to apportion the waters of the Colorado River not only between the states through which it flows but among the water users within the states Although it has not been *died* **on, the** *Arizona* v. *California* decision increased the "Congress's authority over the West% water courses.. . by a quantum jump," and was "a monumental victory for advocates of national control."[90]

There is now at issue the possibility of the Congress conditioning funds for reclamation projects in the western states on their adoption of federally approved statewide groundwater management statutes. The idea apparently derives from the experience of the 1980 Arizona Groundwater Management Act, where threats from the Secretary of the Interior to withhold the construction of the Central Arizona Project contributed to the passage of the statute: "The history of federal intervention in Arizona groundwater management illustrates both the federal government's interest in groundwater management and its ability to pressure states to manage groundwater resources in line with federal policies."[91]

Criticisms of any federal attempt, through direct regulation under the Commerce Clause or indirect influence using the spending power, to write and adopt a uniform federal groundwater code have appeared in the literature for decades. As Charles Corker wrote in 1957, "one can scarcely conceive of a federal ground water code applicable to an entire region of the United States."[92] In the view of most observers and analysts, "[f]orced uniformity in water regulation is impractical in states with divergent water resources and needs."[93] Furthermore, as Norris Hundley observed, there is some disparity between the Congress' power to impose a uniform system of water law and its ability to devise an optimal system of water law within the nation.

In 1973, the National Water Commission rejected the idea of "a uniform national ground water law., . because of the great variety in aquifer characteristics, in legal regimes allocating the resource, and in the economic and social milieu in which the uses take place."" The commission instead addressed recommendations to the states for improving use, particularly urging the creation of "agencies fully empowered to effectuate conjunctive use" of surface and groundwater supplies.[95]

The imposition of a federal groundwater code on the entire country, or even a particular region, appears unlikely in the near term. What is more likely is the use of the spending power to require states to adopt laws that fit some model state groundwater code, first in one region and then to each state. A bill -"The Reclamation States Groundwater Protection and Management Act" -was introduced in the 100th and 101st Congresses by Representative Miller and is planned for reintroduction in the 102nd Congress. It would condition the receipt of reclamation contracts and funds for federal water projects by any of the 17 western "Reclamation States" on the adoption and implementation of a statewide groundwater management program that would meet designated federal criteria. The bill focuses on the reclamation states, but questions and testimony at subcommittee hearings indicated that the extension of the bill to the West was seen as a first step toward similar legislation with a national scope.[96]

The concept and motivation behind such a condition are clear. The concept is to use a federal "carrot and stick" approach to induce improved policymaking from the states.[97] The principal motivation is an understandable frustration on the part of federal policymakers with the use of federal water supply projects to "bail out" states and localities that have overdrafted their local water supplies irresponsibly and excessively.

That frustration, in the Congress and the executive branch, is of long standing. The National Water Commission's 1973 report expressed the following concern about extended and unregulated practices of groundwater mining:

> The Federal concern here arises not so much from the fact that the resource may be ultimately depleted, although that is a problem, but from the fact that thedepletion is unplanned, and the future is not provided for. As disaster approaches, the Federal Government is likely to be implored to step in with a rescue project, commonly conceived as one to furnish a supplementary water supply at taxpayers' expense to save an established economy, an economy that became established in the first place by imprudent overuse of ground water.[98]

The commission therefore recommended that federal agencies planning water projects should "describe and evaluate the ground water management programs in the area,"[99] and that the Congress "should scrutinize closely the economic justification for water supply projects designed to supply supplemental water to areas that have mined ground water . . . including the presence or absence of ground water management, and their operation."[100]

More recently, in 1985, Zachary Smith predicted:

> It makes little sense for the federal government to rescue localities unwilling to manage their groundwater resources efficiently . . . To the extent that federal water projects are designed to mitigate the effects of overdrafting, it is likely that, as a quid pro quo for federal assistance, improved groundwater management would be required.[101]

Introducing the "Reclamation States Groundwater Protection and Management Act" in 1987, its sponsor stated:

> This is the best way to make sure that Federal water project construction dollars are not continually poured into States to correct ground water problems -problems that should not or would not have occurred if ground water programs had been in place.. . . Taxpayers' dollars should not be spent to build new projects to correct ground water problems which would never have developed in the first place if adequate protection programs had been in place.. . .
>
> This large infusion of money into structural solutions to ground water overdraft

> problems has not led to solutions at all. Ground water overdrafts continue to be major and serious problems throughout the West Ground water pollution and contamination are growing threats. We need solutions other than more dams. We need effective programs to manage and protect our water supplies. This bill will provide the mechanism and the assurance we need that our ground water is protected and that we aren't wasting taxpayer dollars on unnecessary water projects.[102]

The version of the bill introduced in the 101st Congress provided that within one year of its enactment, the Secretary of the Interior is to publish the criteria for assessing groundwater protection and management programs in the reclamation states. Those criteria are to specify at a minimum, that states have:

a) Programs to ensure that the quality of groundwater will not be degraded in any way harmful to human beings or the environment;

b) Comprehensive mapping of aquifers and their recharge and discharge areas;

c) Systems of aquifer classification;

d) Authority for regulatory and management controls on sources of groundwater contamination;

e) Programs for groundwater monitoring, data collection, and data analysis;

f) Provisions for effective state enforcement of groundwater protection and management laws and regulations;

g) Programs to regulate or manage groundwater withdrawals so as to protect supplies and their quality;

h) Programs to protect and enhance integrated and conjunctive use of groundwater and surface water;

i) Programs for public participation in program development,

j) Authorities for imposing surface-use restrictions in order to protect groundwater quality and quantity;

k) Coordination of groundwater programs with other relevant natural resource programs; and programs for cleanup and emergency response to groundwater contamination that poses an environmental or health hazard

The legislation directs the Secretary of the Interior to identify the reclamation states that have, or could have, "significant ground water overdraft, contamination or pollution problems which should be resolved." The secretary assesses the adequacy of those states' groundwater management and protection programs in light of the criteria, with notification to the states The Bureau of Reclamation is then prohibited from obligating or expending reclamation funds, or entering into contracts, in any state identified as having deficient programs.

Furthermore, the secretary will review reclamation states'groundwater protection and management statutes and programs. The states' programs are to be reviewed for "substantial compliance," although the Act specifies that they must contain at least elements (a) through (i) in order to be the approved. States are required to review their approved programs at least once every five years, with opportunity for public comment In addition, the Secretary of the Interior is directed to review state programs at least once every five years, including implementation and compliance. Previously awarded approvals may be removed, subject to notice to the governor and time to bring the programs or their implementation into compliance.

The proposed legislation does not specify any state's groundwater management laws or programs as a model. However, the background and motivation of the bill, and comments made by its sponsor in the House, make it clear that the experience of the federal government with Arizona and the adoption of the state's 1980 Groundwater Management Act, are and would be regarded as a model for the reclamation states and the Secretary of the Interior to follow.

The first round of subcommittee hearings on the bill featured the first two directors of the Arizona Department of Water Resources, Wesley Steiner and Kathleen Ferris, testifying about the adoption and the content of the law. In addition, the sponsor of reclamation states act made the following remarks with its introduction:

> This is not the first time this sort of approach has been used. In fact, the Interior Department threatened to stop funding the Central Arizona Project (CAP) because the ground water problems in the State were severe, and little was being done to remedy the problem – except, of course, to build the CAP project
>
> Arizona responded quickly and very ably to the challenge from the Department of the Interior. It now has a progressive and far-reaching ground water program. I *view these actions by Arizona as a model for other reclamation States with ground water problems.*[103]

Just as there would be serious problems with applying a uniform federal groundwater law to the states, there are problems with applying any single model of groundwater management Furthermore, even if one were to adopt a single model, there are serious questions about the appropriateness of the Arizona approach for other states As Wesley Steiner, the first director of the Arizona Department of Water Resources under the 1980 law, wrote: "The water situation in each of the westemstates is unique to that state. The water situation in Arizona, the serious imbalance between supply and consumption, *is the worst* in *the West* and *demands the harshest approach.*"[104] Requiring all states to adopt minimal groundwater management provisions would raise substantial enough questions of federal comity Requiring all states to adopt legislation based on "the harshest approach," raises **even more** serious questions.

Comprehensive statewide groundwater management legislation faces considerable obstacles of implementation and public acceptance compared with step-by-step approaches. A 1988 review of state water policies noted that

> despite attempts by some states to enact comprehensive water management plans, this has not always led to the most effective and far-reaching policies In fact, most attempts to enact and later implement such plans may have the opposite effect, as opposition groups either impose compromises upon these plans prior to enactment or subject their provisions to judicial review during implementation . . . implementation is often more difficult than enactment.[105]

These general statements are consistent with observations made about the first few years of implementation of the 1980 Arizona law. The deputy director of the Department of Water Resources noted that deadlines for filing water rights claims, determining water rights, and developing initial rules were missed, not by weeks or months but by years, and that the Act generated "a swarm of proposed legislative amendments . . . [many] intended to let a user or group of users escape the restrictions of the Code."[106] The Arizona approach contrasts with that of Oklahoma, which has enacted groundwater legislation that is admittedly less comprehensive and restrictive, but where state planners have chosen to improve groundwater management incrementally, securing acceptance for each new statutory or regulatory change before proceeding with the next.[107]

Arizonans have been less than enthusiastic about recommending the extension of the law to other states, and have subjected it to rather severe criticism. Arizona's 1980 comprehensive groundwater management code has been described as "a testimony to how **wrong** things can go when an inappropriate water law is coupled to a severe **case** of **overdraft,**"[108] and an example of how **an "inefficient** mechanism.. . shaped by political arrangements" is likely to emerge under pressure when existing institutional arrangements are unable to accommodate and resolve conflicts among competing users.[109]

Arizona adopted a regulatory approach to groundwater management, especially with respect to the reduction in water demands imposed by irrigated agriculture. The statute provides for the collection of taxes on groundwater pumping to create a fund with which the director of the state Department of Water Resources may purchase and retire agricultural lands after 2006. The problems with this approach are twofold. First, the law does not allow water **rights to** be transferred independently of land ownership. This has resulted in the widespread use of the practice known as "water ranching," which means that municipalities and other public water supply providers buy up large tracts of land to capture the appurtenant water rights This imposes a considerable inefficiency that would be avoided by making water rights transferable apart from land ownership. It also robs agricultural producers of any incentive to improve the efficiency of irrigation practices in order to profit by the sale of water rights freed up by the conservation.

Second, the statute places all purchase and retirement of the agricultural lands in the hands of the director of the Department of Water Resources, and postpones any such purchases until 2006. Presumably, owners of agricultural lands and their appurtenant water rights will have to take the offered price for their lands, when they might have made more beneficial sales in a more open setting.

The statute seeks to reduce water use in the interim by imposing increasingly stringent conservation rules in active management areas, whether for municipal, industrial, or agricultural use. If water rights transfers were allowed in the interim, thereby moving water from lower valued to higher valued uses and giving users a conservation incentive so as to have water rights to trade, neither the stricter across-the-board conservation regulations nor the purchase and retirement of agricultural lands by the state might be necessary by the 21st century,

The groundwater management act was the choice Arizona made in response to the realities of its water situation and the pressures from the federal government The point of the preceding paragraphs is not to criticize the law, which is a widely acknowledged and highly regarded innovation. However, caution should be used in consideration of this law as a model for other states.

The frustration of federal policymakers at being repeatedly requested to "rescue" states and localities with federal water supply projects is understandable. A response **that** requires all states to adopt groundwater management programs that meet federal criteria, that are approved and periodically reviewed by the federal government, and that may be disapproved by the federal government, in order for states and localities to qualify for future federal water project funds that may never be available, imposes high costs in federal-state relations for the sake of keeping federal officials from having to refuse state and **local** requests for funding. The more direct approach of ending federal water subsidies requires **more** political will from federal officials than maintaining the (probably unrealistic) possibility of a federal "carrot" in the form of future funding in order to use the "stick" of federal conditions requiring pre-approved state groundwater management programs.

Ending the flow of subsidies may be mom difficult politically, but it is preferable from a policy standpoint as a way of encouraging state conservation and management of water resources Arizona was cited as an example of how the federal spending power has been used to prompt state action. Yet, as other analysts have concluded, there is also an opposite, perverse effect of the use of the federal spending power in water resources, and that has been to lull states and localities into inaction in improving management

Arizona has been discussed as an example of this phenomenon, too. As one analyst stated, "In Arizona the federal presence was strongly felt in water management decisions – "so strongly, perhaps, as to provide a disincentive for local initiative."[110]

Following adoption of the law, Wes Steiner, the first director of the Arizona Department of Water Resources, wrote:

> One of the major obstacles that had to be overcome before Arizonans could be convinced that they must deal internally with the state's water supply imbalance, was widespread confidence that permeated the water community that these problems would be overcome in the future by effecting interstate water transfers. We had to wean them away from reliance on this dream and convince the legislature and the public that the economic, environmental, and political costs of major interstate water transfers to the Pacific Southwest make them completely infeasible at this time.. . and that we had to deal with our imbalance problem with the supplies currently available to us plus our remaining entitlement from the Colorado River.[111]

Along similar lines, another prominent observer of western water law and institutions wrote:

> I think the users, the nonusers, and the public think that either the state or the federal government will bail them out After all, huge projects have saved other areas.. . . Surely the legislature or the Congress will come to the rescue of other prosperous and growing towns, groups of towns, cities, and counties that have been created by the overuse of groundwatec Since others have been rescued in the past, there is a feeling that people have a right to overuse, a right to expect rescue, a right to be subsidized.[112]

The problems created for more effective groundwater management by the construction of federal water projects arise at both ends of the process. Water users are reluctant to face up to the need to manage and conserve local supplies as long as they think a federal project could bail them out. Once the federal water project is built, the water it supplies is so cheap due to subsidies that there is no incentive to monitor and manage use.[113] For both reasons, the federal role in improvingwater resource management should include bringing the flow of water subsidies to an end

Improving the Flow of Information. It appears that the nature of water supply information needs is changing. Technical information on the location and characteristics of aquifers is still needed, but is being supplied by several federal agencies, as described in Chapter 4. Information still is needed on institutional arrangements for groundwater allocation and management of groundwater supplies, and existing information (technical or institutional) needs to be made more accessible.

There still is a critical need for additional information concerning institutional arrangements for the allocation and management of water supplies. This was the only priority area identified in a 1981 National Research Council review of federal water research plans as not being addressed by one or more agencies.[114] Although USGS has funded institutional studies since then, the need has not been fully met, and the area remained conspicuous by its absence in the 1989 Office of Science and Technology Policy review of federal groundwater research expenditures

The scientific information yielded by decades of research **needs** to be made more accessible to persons with different levels of expertise.[115] As noted in Chapters 4 and 5, much federal information collecting has stressed the advancement of the state of the art in hydrology which is important and beneficial. On the other hand, additional translation of the information would make it even more useful to water management decisionmakers, who tend to be concerned citizens and public officials, as well as hydrologists and geologists.

Second, the technical information on water supplies is insufficiently accessible physically Studies performed for and by a dozen different federal agencies, 50 states, thousands of local governments, industry associations, environmental groups, foundations, and others, exist all over the **country** Finding something about a specific area is not difficult finding all of the information about an area is nearly impossible, even if **one** is willing to travel to state water research centers and USGS regional and state offices, to send away for information, to use interlibrary loan services, and the like.[116]

There are formal mechanisms for interagency cooperation or joint information gathering. No fewer than six Memoranda of Agreement and 11 types of interagency committees, working groups, and advisory boards, councils, and committees (some with subcommittees) were listed in the 1989 Office of Science and Technology Policy review of federal groundwater research programs. And there are some computerized information storage, retrieval, and exchange programs for hydrologic data. USGS operates the National Water Data Storage and Retrieval System (WATSTORE), arranged in a Daily Values File, a Peak Flow File, a Water Quality File, and a Ground Water Site Inventory File. USGS also supports a program called the National Water Data Exchange (NAWDEX), which is monitored by the Subcommittee on Water Data and Information Exchange of the Federal Interagency Advisory Committee on Water Data, which is chaired by USGS. Similarly, EPA supports a National Groundwater Information Center, under contract with the National Water Well Association in Dublin, Ohio, with more than 54,000 references listed

We have been unable, however, to establish a location where the whole array of groundwater information, including management, would be available. In the 101st Congress, a bill introduced in the House by Rep. Sam Gejdensen and Rep. James Scheuer, and in the Senate by Sen. Quentin Burdick, would have attempted to address this problem by establishing, among other things, a national groundwater information clearinghouse. Representative Scheuer's bill is planned for reintroduction in the 102nd Congress.

Making more information available to state and local water managers would ease one of the barriers to more effective conjunctive management This is a logical lead role for the federal government, which could couple information development and dissemination about management practices and performance with information on hydrologic data. The growth of innovative management techniques being employed throughout the nation could then work more effectively to benefit all communities.

Supporting Groundwater Quality Protection. There is another aspect to the federal role in supporting improved groundwater quality protection. In far too many cases, federal installations and facilities have been among the principal polluters of local groundwater resources, which "hasserious repercussions for the effectiveness of state and local regulations."[117] "State and local regulations are not very effective when the polluter is a federal agency."[118] Testimony in 1987 before the Senate Committee on Energy and Natural Resources and the House Committee on Interior and Insular Affairs cited more than 50 federal facilities and installations contaminating groundwater resources just in nine western states.[119]

As the federal government moves in the 1990s to close down several military installations, affected states and communities are concerned about the plumes of toxic wastes below the land surface moving into and through aquifers that supply water for drinking, domestic and industrial use, and livestock and irrigation. As the federal, state, and local governments pursue their "new environmental partnership," the federal governmentshould at least try to remove itself from the list of major groundwater polluters.[120] Compliance by federal facilities with state and local groundwater quality programs and their implementation should be assured.

Summary: A Supportive Federal Role. A RAND Corporation report published toward the close of the 1970s contained this summary observation: "Although the federal government through its various departments and agencies has vast powers and priority in the water field, the federal role in groundwater is minimal."[121] A slight modification to that statement would allow it to fit the early 1990s: the direct federal role in groundwater *has been* minimal. As we have seen, the various departments and agencies of the federal government exercising vast powers and priority in the water field have indirect consequences for groundwater management that are far more than minimal, and the potential for direct action has grown.

The federal government's role in research and investigations through the U.S. Geological Survey and other agencies has given states and localities much of the technical and scientific information about groundwater resources. That information has been invaluable in planning appropriate management strategies, improving programs, and designing new ones. Water resources research exhibits scale characteristics that suggest it is best organized nationally, giving states, local governments, and water users basic hydrological research and data, as well as technical expertise and training.

The other modification to the RAND description of the federal role-that it has been minimal – reflects the changes of the last decade in the scope of federal authority in the management of groundwater supplies. The direct federal role could increase as a result of expansions in the commerce power and the use of the spending power. The federal government has the power to directly legislate and regulate in the area of groundwater supply management or to require states to adopt legislation and regulations that meet specified federal criteria. The current question is not one of federal power but of intergovernmental relations, of the wisdom of the exercise of federal power, and of whether the federal government will continue to limit its direct role in groundwater supply management

The appropriate federal management role was addressed by the National Water Commission in its 1973 report The Commission reflected a sensitivity to the important differences between an indirect and supportive federal role and a direct and regulatory role:

> The Commission does not believe.. . that the Congress should enact a comprehensive Federal ground water law regulating withdrawal. Rather, Congress should assist States and local regions to obtain the information necessary to make sound decisions, it should declare a policy of supporting water development projects only when they are economically sound, and it should implement this policy by close scrutiny of proposed 'rescue projects,' examining not only the economics of project proposals but also conservation and management practices applied to ground water and surface water by the region to benefit from the project.[122]

As the Commission's statement suggests, there is an indirect federal role that supports sound state and local management decisions by states and local governments, and an indirect federal role that can distort the decisionmaking process. Before direct federal authority is expanded in groundwater management, activities that have indirect, but nonminimal and nonbeneficial, effects should be reconsidered. First (and perhaps most beneficial), the federal government could reduce its role in contributing to and perpetuating the barriers to more effective management As water resources have become increasingly scarce in some locations and as the competition for those resources has intensified, policies that promote inefficient use and impede effective management become political luxuries that all segments of the water economy are better off without

A 1989 White Paper of the Western Governors' Association on federal water policy coordination suggested that if the federal government is not going to play a leadership role in water management (in keeping with the tradition of state and local primacy in thisarea),it could try toavoid making management more difficult for states and local governments.

> In other words, western states understand that they cannot depend on the federal government to meet their needs for water, whether it be for consumptive or nonconsumptive purposes. However, if states and localities are to shoulder greater responsibility for meetingwater needs, the statesbelieve that they are entitled to a system of federal water policy implementation that does not needlessly get in their way.[123]

At the outset of the 1990s, there is little doubt that the federal role in water supply management and in water resources generally is changing. Some see the scope of federal authority expanding and anticipate more direct action by federal officials in the groundwater field. Others see the federal role declining, with the states and localities "shouldering more of the burden." By the end of the decade, the size and the change in size of the federal role may turn out to have been the less interesting and less important question. The more important question is likely to be what options federal officials chose- whether they decreased activities that impede more effective groundwater management and enhanced those that assist in the development of innovations and improvements.

## CHANGING WATER RIGHTS LAWS, ENCOURAGING BASIN MANAGEMENT, SETTING QUALITY PROTECTION POLICY WHAT THE STATES CAN DO

States also face an agenda of institutional reform in improving the management of water resources — modifying laws to increase certainty and flexibility of water rights, building capacity for conjunctive management of surface and groundwater supplies, and setting policies for the protection of water quality There does not appear to be a need for a single uniform state groundwater code. States face different situations, and will continue to develop and implement different policies for allocating and managing water supplies All states can benefit from this diversity and experimentation.

In states where surface and groundwater are physically interrelated, writing the rules governing the supply sources would remove a major obstacle to their conjunctive use. Water users could be encouraged, through pricing and other measures, to adjust their use of sources based on availability Maintaining dual systems of rights for surface water and hydrologically related groundwater inhibits the optimal use of both sources.

Uniting the systems of water production rights would also make it easier to resolve some of the conflicts concerning the protection of instream values Within a given stream-aquifer system, one set of specified, quantified water rights could allow rights to be exercised by some for surface water diversion; by others for tributary groundwater withdrawal; and by others leaving water instream for recreational, scenic, habitat, and other benefits. At the very least, states should declare instream flow protection sooner rather than later in order to allow effective basin management to proceed.

Another institutional reform that has received attention in the policy literature would change the system of acquiring rights for production of water or protection of instream flows. States have held that only governments may acquire appropriative rights to preserve instream flows.[124] This is argued to be unreasonably limiting: if a private individual or group wishes to increase the amount of water retained instream beyond an agency limit, there would appear to be no reason for refusing a permit Moreover, such rights should be tradeable between users for increasing instream flows for water production The citizens would determine the balance between instream uses and water production, based on their valuations of each. Dual systems of water rights effectively preclude this alternative from even being tried.

Whether joined with surface water rights or not, groundwater production rights systems would be improved by building in incentives for water conservation. States choosing to retain the "beneficial use" system, for example, could designate conservation (including underground storage for subsequent use) as beneficial, thereby removing at least one disincentive for conservation. States with an appropriation system based on historical or permitted use could provide that groundwater users do not forfeit any portion of their production rights by agreeing to take surface water supplies or imported water supplies when they are available. These modifications would remove current obstacles to conjunctive use.

The change that would be most effective in promoting conservation and encouraging largeusers (especially irrigators) to use water more sparingly would be to make production rights transferable. Water users could employ water-saving techniques that would maintain their productivity and gain further by selling or leasing the unused portion of their water rights. This is not the same as suggesting that all water production rights be privatized and left to a "free market" Transferability of water rights can and should be regulated, in order to protect other users, storage, quality, and environmental concerns. While the idea that water is different from other commodities may be an illusion, the uncertainty concerning groundwater may be especially high relative to other commodities.[125] For this reason, retaining an institutional infrastructure to determine and administer rights, to regulate transfers, and to resolve conflicts would be wise. That is to say, what may be different about groundwater is not that it is too important to trust to markets, but that it is too incompletely known to trust to unfettered markets.

As noted in Chapter 5, part of the institutional infrastructure may be special water districts empowered to engage in conjunctive management of surface and groundwater supplies. States could authorize well fitted special districts to regulate water transfers; to account for water production, production rights, and storage; and charge for production and storage. States could consider the 1973 recommendations of the National Water Commission concerning the range of authority that local water organizations need for effective conjunctive management Finally, states can continue to devise and improve water quality protection policies. With respect to groundwater, states can choose whether to classify aquifers and (in accordance with federal criteria) where to set groundwater quality standards, can implement the protection strategies they developed during the 1980s with support from EPA, and can review and adopt the recommendations in the 1989 Urban Institute report *State Management of Groundwater: Assessment of Practices and Progress.*

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### GETTING THE PRICES RIGHT: WHAT LOCAL PUBLIC AND PRIVATE WATER ORGANIZATIONS CAN DO

Local public or private water suppliers, who determine pricing practices (in the absence of subsidies from larger jurisdictions), could contribute to improved management by bringing prices more into line with water's value and cost After studying the issue for the National Council on Public Works Improvement, Wade Miller Associates reached the following conclusions:

1) Urban water supply systems are, from a physical standpoint, generally functioning successfully, and do not constitute a "national problem" -- infrastructure problems, where they exist, are local and idiosyncratic problems of planning, financing, and maintenance of certain individual systems.[126]

2) *The principal problem* of *water supply* is *the failure to charge water prices that reflect the full costs of capital construction, replacement, and operations and maintenance, and "If rates have been maintained at levels that do not cover the full costs . . . this was the choice of local elected and appointed officials and constitutes* 'public *choice failure'."*[127]

3) The actions primarily needed to address the difficulties faced in water supply do not lie in structural, supply-oriented solutions, but in the adoption of institutional arrangements that will implement full-cost pricing of water supplies and transferability of water rights.[128]

Local water supply organizations especially need to attend to the problems created by commingling of functions in local budgets. This practice distorts the price signals transmitted to consumers, and in turn distorts their decisions about the use and consumption of water supplies. If implementation of full-cost pricing is demonstrated to be likely to impose a hardship on lower income households, some of the strategies used in the pricing of other utilities (such as "lifeline" rates for basic service) should be explored.

Increasing the role of full-cost pricing of water and transferability of rights will take considerable adjustment, especially in the western states Yet there is nothing inherently wrong with having economic relations reflect actual climatic conditions: "This is preferable to having an economic base artificially reliant on under-priced supplies which cannot be sustained."[129] Moreover, implementing and adjusting to institutional arrangements that increase the marketability of water rights and make water prices more realistic, is unlikely to take longer than the time for planning and constructing the next major water and power project

## SUMMARY

Flexibility of arrangements, and the ability to adapt different solutions and employ specialized organizations in an institutionally rich environment are preferable in the coordinated governance of water resources. With sufficient information and flexibility, noncentralized systems can tend toward efficiency and equity,[130] while maintaining and enhancing adaptability and self-governance.

A noncentralized, or polycentric, decisionmaking arena representing diverse communities of interest in jurisdictions that can accommodate conflicts without including nonessential or unaffected participants-what one writer called a "community defining federalism"'"-provides possibilities for resolving conflicts, directing resources toward their higher valued uses, and maintaining the flexibility to adapt to changed circumstances or correct erroneous decisions With institutional barriers to more effective water resource management reduced or eliminated, a multijurisdictional republic offers considerable advantages in managing a multiattribute resource such as water

Notes

1 Bonnie McCay and James Acheson, "The Human Ecology of the Commons," in Bonnie McCay and James Acheson, eds., *Capturing the Commons: The Culture and Ecology of Communal Resources* (Tucson: University of Arizona Press, 1987), p. 38.

2 Ibid., p. 124.

3 Susan Christopher Nunn, *The Political Economy of Institutional Innovation: Coalitions and Strategy in the Development of Groundwater Law*. Ph.D. Dissertation. University of Wisconsin, 1986, p. 299.

4 Ibid.

5 Ira G. Clark, *Water in New Mexico: A History of Its Management and Use* (Albuquerque: University of New Mexico Press, 1988), pp. x-xi.

6 Nunn, p. 297.

7 Ibid., p. 295.

8 Ibid., p. 294.

9 Ibid., p. 295.

10 Wade Miller Associates, *The Nation's Public Works: Report on Water Supply* (Washington, DC: National Council on public Works Improvement, 1987), p. 206.

11 Harvey 0. Banks, "Management of Interstate Aquifer Systems," *ASCE Journal of Water Resources Planning and Management* 107 (October 1981): 566,573.

12 Nunn, p. 294.

13 A prime example of this phenomenon can be found in the water dispute over the use of streams feeding Mono Lake in the eastern Sierra to supply water to Los Angeles. The use decisions, which were made by Los Angeles in the 1930s and 1940s, resulted over time in the lowering of the lake levels to a point which is contended to have damaged the Mono Lake ecosystem. In the 1970s, a group of citizens formed the Mono Lake Committee as an organization to try to stop or reduce the water diversions by Los Angeles. Their actions have added a new "community of interest" to the decisionmaking process involved in determining how to use the waters that feed Mono Lake.

14 Banks, p. 566.

15 Nunn, pp. 181-182.

16 Ibid., pp. 207-208.

17 Warren Viessman and Claire Welty, *Water Management: Technology and Institutions* (New York Harper and Row, 1985), p. 11.

18 Thii hasevenbeencited as a perceived advantage of centralization in a "superdepartment [that] 'is more efficient because it allows trade-offs on natural resource issues to be made on a rational, nonpolitical basis within the context of one department.'" Henry C. Hart, "Toward a Political Science of Water Resources Decisions," in L. Douglas James, ed., *Man and Water* (Lexington: University Press of Kentucky, 1974), p. 136.

19 Stephen C. Birdlebough and Alfred Wins, "Legal Aspects of Conjunctive Use in California," in David Seckler, ed., *California Water: A Study in Resource Management* (Berkeley: University of California Press, 1971), p. 263; also Banks, p. 566.

20 Helen J. Peters, "Groundwater Management," *Water Resources* Bulletin 8 (February 1972): 190.

21 Michael Mallery, "Groundwater: A Call for a Comprehensive Management Program," *Pacific law Journal* 14, (July 1983): 1280.

22 See, for example, Thelma Johnson and Helen peters, 'Regional Integration of Surface and Ground Water Resources." Paper presented at the Symposiumof the International Association of Scientific Hydrology, Haifa, Israel, 1967, pp. 497-498, in which they illustrate the potentialchangesinusepatternsresultingfrom the successful implementation of a management program, changes which may themselves then result in subsequent strains on that program.

23 Wade Miller Associates, p. 92.

24 Ibid., p. 14.

25 Clark, p. x.

26 Neil S. Grigg, "Appendix: Groundwater Systems," in Kyle Schilling et al., *The Nation's Public Works: Report on Water Resources* (Washington, DC: National Council on Public Works Improvement, 1987), p. B-2.

27 Sho Sato, Water Resources- Comments upon the Federal-state Relationship,* *California Law Review 48* (March 1960): 56.

[28] California Department of Water Resources, *California's Ground Water.* Bulletin No. 118 (Sacramento, 1975), p. 123.

[29] Ranjit Varkki George, "Is Groundwater Regulation Blindman's Buff?" *Journal of Planning Literature* 3 (Spring 1988): 233.

[30] Wade Miller Associate!,, pp. 204-205; National Water Commission, *Water Policies for the Future: Final Report fo the President and to the Congress of the United States* (Port Washington, New York: Water Information Center, 1973), p. 243.

[31] Wade Miller Associates, p. 205; Jurgen Schmandt, Ernest Smerdon, and Judith Clarkson, *State Water Policies* (New York: Praeger Publishers, 1988), pp. 10-11; U.S. Office of Science and Technology Policy, Federal Ground Water Science and Technology Programs, *A Reporf by the Subcommittee on Ground Water* (Washington, DC, 1989), p. 3-3.

[32] National Research Council, Committee on Ground Water Quality Protection, *Ground Water Qualify Protection: State and Local* Strategies (Washington, DC: National Academy Press, 1986), p. 3.

[33] National Research Council, p. 3; C.H. Ward, N.N. Durham, and L.W. Canter, "Ground Water-A National Issue," *Ground Water* 22 (March-April 1984): 140.

[34] U.S. General Accounting Office, *Groundwater Protection: The* Use of *Drinking Water Standards by* the States (Washington, DC, 1988), p. 1.

[35] National Research Council, p. 3.

[36] Christine Olsenius, "Tomorrow's Water Manager," *Journal of Soil and Water Conservation* 42 (September-October 1987), p. 314.

[37] Ibid.

[38] Wade Miller Associates, p. 68; National Research Council, p. 3; Ward, Durham, and Canter, p. 140.

[39] Wade Miller Associates, p. 68.

[40] National Research Council, p. 3.

[41] Schmandt et al., p. 10.

[42] Viessman and Welty, p. 14 (emphasis added).

[43] U.S. General Accounting Office, *Groundwater Quality: State Activities fo Guard against Contaminants* (Washington, DC, 1988), p. 3.

[44] Wade Miller Associates, p. 111.

[45] U.S. General Accounting Office, *Groundwater Quality,* p. 3.

[46] Environmental and Energy Study Institute, *A Congressional Agenda to Prevent Groundwater Contamination: Building Capacity to Meet Protection Needs* (Washington, DC, 1986), p. 164.

[47] National Research Council, p. 10.

[48] Cox, p. 118.

[49] "Groundwater Contamination: Common Ground for the Common Law," *Water Strategist* 2 (January 1989): 1.

[50] Wade Miller Associates, p. ii.

[51] Ibid pp. 13 and 210; Nancy Humphrey and Christopher W&r, *Innovative State Approaches to Community Water Supply Problems* (Washington, DC: The Urban Institute, 1985), p. v.

[52] David Moreau, "New Federalism and Social and Environmental Goals," *Journal of Water Resources Planning and Management* 115 (January 1989): 25-26.

[53] Wade Miller Associates, p. 210.

[54] Ibid., p. 209.

[55] Moreau, p. 26; Humphrey and Walker, p. v.

[56] Wade Miller Associates, p. 113.

[57] The 1981 statement by the National Governors' Association included the following:

> The Governors believe that considerable authority exists in federal and state law to control sources of groundwater pollution. This authority needs to be fully exercised to assure a protection effort that is coherent, consistent, and effective.
>
> The Governors endorse and recommend a new national policy to systematically accelerate and strengthen protection of our underground water supplies. This policy should depend primarily on states for implementing comprehensive groundwater management programs. This policy must also be founded on a new environmental partnership, which respects the local characteristic of groundwater, while capitalizing on the capability and expertise of each level of government, the private sector, and public interest groups.

[58] National Groundwater Policy Forum, *A Groundwater Profecfion Strategy* (Washington, DC: The Conservation Foundation, 1986), p. 1.

[59] U.S. General Accounting Office, *Groundwater Protection,* p. 1.

[60] See, for example, testimony of Erik D. Olson, National Wildlife Federation, before the Subcommittee on Natural Resources, Agricultural Research, and Environment, Committee on Science, Space, and Technology, U.S. House of Representatives, 100th Congress, First Session, on H.R. 2253, and H.R. 791, July 21, 1987, p. 93.

[61] National Research Council, pp. 23.

[62] John F. Mann, Jr., "Concepts in Ground Water Management," *Journal of&e American Wafer Works Association* 60 (December 1968): 1336.

[63] Ibid.

[64] Environmental and Energy Study Institute, pp. 10-11.

[65] Testimony of former Wisconsin Governor Anthony Earl before the Subcommittee on Water and Power Resources, Committee on Interior and Insular Affairs, U.S. House of Representatives, 100th Congress, First Session, on H.R. 2320. Series No. 100-23, Part I. July 23, 1987, p. 20.

[66] Ibid.

[67] National Research Council, p. 9.

[68] Robert Ehrhardt and Stephen Lemont, *Institutional Arrangements for Intrastate Groundwater Management: A Comparative Assessment Using Virginia as a Case Study* (Arlington, Virginia: JBF Scientific Corporation, 1979), p. 22.

[69] George, p. 240.

[70] Moreau, p. 29.

[71] National Water Commission, p. 460.

[72] Frank J. Trelease, "States Rights Versus National Powers for Water Development," in Ernest Engelbert, ed., *Strategies for Western Regional Water Development* (Los Angeles: Western Interstate Water Conference, 1966), p. 101.

73 Ibid., p. 107.

74 Mary Ann Green, "Water Law — Sporhase v. Nebraska," *Natural Resources Journal* 33 (October 1983): 931.

75 Zachary Smith, "Federal Intervention in the Management of Groundwater Resources: Past Efforts and Future Prospects," *Publius—The Journal* of Federalism 15 (Winter 1985): 156.

76 Viessman and Welty, p. 38.

77 Ibid.

78 Kyle Schilling et al., *The* Nation's *Public* Works: *Report on Wafer Resources* (Washington, DC: National Council on Public Works Improvement, 1987), p. 97.

79 Schmandt et al., p. 64.

80 Lawrence Mosher, Wii the Real Leaders in National Water Policy Please Stand Up?" *Journal of* Soil *and* Water Conservation 44 (March-April 1989): 135.

81 Lawrence Mosher, "Federal Water Development: Going, Going . . . ." *Journal of Soil and Water Conservation* 41 (May-June 1986): 166.

82 Ibid.

83 Henry l? Caulfield, "The Future of Local Water Districts in Historical, Political Context," in James Corbridge, ed., *Special Water* Districts: *Challenge for the Future* (Boulder: Natural Resources Law Center, 1983), p. 107.

84 Schilling et al., p. 94.

85 Schmandt et al., p. 16; Caulfield, p. 109.

86 Moreau, p. 25.

87 399 U.S. 725 (1949).

88 Ivanhoe Irrigation District v. McCracken et al., 357 U.S. 275 (1958).

89 373 U.S. 546 (1963).

90 Norris Hundley, Water *and the* West (Berkeley: University of California Press, 1975), p. 306.

91 Smith, p. 149.

92 Charles Corker, "Water Rights and Federalism—The Western Water Rights Settlement Bill of 1957," *California Law Review* 45 (December 1957): 622.

93 Green, p. 926.

94 National Water Commission, p. 227.

95 Ibid.

96 Hearings before the Subcommittee on Water and Power Resources, Committee on Interior and Insular Affairs, House of Representatives, Series 100-23, Parts I and II. See, for example, the testimony of the first witnesscalled in support of the bill, Wiionsin Governor Anthony Earl, at Part I, p. 21:

> We need a national goal, a national ground water policy, and I believe the seeds of such a policy are contained in H.R. 2320. Limiting the coverage to the 17 reclamation States is not as ambitious as covering all the States, but I understand you must start somewhere. . . . What begins with 17 I think would ultimately expand to more States.

Simiiar comments appear on p. 53 in the testimony of Philip Metzger of the Conservation Foundation in support of the bill. See also Comments of Representative George Miller, *Congressional Record,* Volume 133, Number 138, September 14, 1987: "Few States in the Nation have comprehensive plans in place; yet most States need such plans."

97 Comments of Representative George Miller, *Congressional Record,* Volume 133, Number 73, May 7, 1987:

> Stateswhichchoosenot todevelop plans and which have serious problems with ground water will not receive funds for construction of reclamation projects. Further, the Secretary of the Interior will be precluded from entering into water delivery contracts in such States. The bill involves a "carrot-and-stick" approach to ensuring that sound ground water programs are put into place where needed.

98 National Water Commission, p. 232.

99 Ibid., p. 238.

100 Ibid., p. 242.

101 Smith, p. 152.

102 Miller, May 7, 1987.

103 Ibid.

104 Wesley Steiner, "public Water policy in Arizona," *State Government* 55 (1982): 134.

105 Schmandt et al., pp. 22-23.

106 Philip Briggs, "Ground-Water Management in Arizona," *Journal* of Water Resources *Planning and Management* 109 *(July* 1983): 201-202.

107 See Rebecca Roberts and Sally Gros, "The Politics of Ground-Water Management Reform in Oklahoma," *Ground Wafer* 25 (September-October 1987): 535544.

108 Micha Gisser, "Groundwater: Focusing on the Real Issue," *Journal of Political Economy* 91 (December 1983): 1001-1002.

109 Ibid., p. 1003.

110 Nunn, p. 20.

111 Steiner, p. 135.

112 Frank J. Trelease, "Legal Solutions to Groundwater Problems-A General Overview," Pacific Lnw *Journal* 11 (July 1980): 874-875.

113 Viessman and Welty, p. 16;

114 Schilling et al., pp. 116-117.

115 Ward, Durham, and Canter, p. 140.

116 Ibid. This should include all institutional arrangements for the management of groundwater resources, including court decisions as well as legislative and administrative actions.

117 George, p. 236.

118 Ibid.

119 Testimony of Craig Bell, Executive Director of the Western States Water Council, before the Subcommittee on Water and power Resources, Committee on Interior and Insular Affairs, U.S. House of Representatives, 100th Congress, First Session, on H.R 2320. Series 100-23, Part II, July 23, 1987, pp. 175-178.

120 See also Environmental and Energy Study Institute, p. 10.

121 David L. Jaquette and Nancy Y. Moore, *Efficient Water Use in California: Groundwater Use and Management* (Santa Monica: RAND Corporation, 1978), p. 31.

122 National Water Commission, p. 242.

[123] Western Governors' Association, White Paper on Federal Water Policy Coordination, May 11, 1989, p. 3.

[124] Terry Anderson and Ronald Johnson, "The Problem of Instream Flows," *Economic Inquiry* 24 (October 1986): 538.

[125] Victor Brajer and Wade E. Martin, "Allocating a 'Scarce' Resource, Water in the West," *American Journal of Economics and Sociology* 48 (July 1989): 259-271.

[126] Wade Miller Associates, p. 211; see also p. i:

> A national water supply "infrastructuregap" of the magnitude that would require a substantial federalsubsidy does not exist. Water utilities experiencing revenue shortfalls generally do not charge rates which cover full costs of the utility,

[127] Ibid., p. 211 (emphasis added).

[128] Ibid., pp. 122-123.

[129] Ibid., pp. 115-116.

[130] Ibid.

[131] Hart, p. 154.

*Appendix* ***A***

# Tables

*Table* A-l

Groundwater Withdrawals as a Percentage of All Water Withdrawals, **1985***

(U.S. average = 34%)

| Rank | State | Percent | Rank | State | Percent |
|---|---|---|---|---|---|
| 1 | Kansas | 91% | 26 | New York | 25% |
| 2 | Mississippi | 83 | 27 | Connecticut | 24 |
| 3 | Arkansas | 79 | 27 | Nevada | 24 |
| 4 | Florida | 72 | 27 | New Hampshire | 24 |
| 4 | Nebraska | 72 | 30 | Virginia | 23 |
| 6 | Iowa | 69 | 31 | Idaho | 22 |
| 7 | Texas | 51 | 32 | Alabama | 21 |
| 7 | Missouri | 51 | 32 | Kentucky | 21 |
| 9 | Minnesota | 50 | 34 | Michigan | 20 |
| 9 | Oklahoma | 50 | 35 | Pennsylvania | 19 |
| 11 | Hawaii | 48 | 35 | Tennessee | 19 |
| 11 | Arizona | 48 | 35 | Utah | 19 |
| 13 | Georgia | 47 | 38 | Alaska | 18 |
| 13 | New Mexico | 47 | 38 | Rhode Island | 18 |
| 13 | North Dakota | 47 | 38 | Washington | 18 |
| 16 | Wisconsin | | 38 | West Virginia | 18 |
| 17 | California | 37 | 42 | Colorado | 17 |
| 18 | South Dakota | 35 | 42 42 | Indiana | 17 |
| 19 | Illinois | | | Maryland | 17 |
| 20 | Ohio | 32 | 45 | Delaware | 15 |
| 20 | Louisiana | 32 | 45 | Maine | 15 |
| 22 | North Carolina | 29 | 47 | South Carolina | 13 |
| 22 | Vermont | 29 | 48 | Oregon | 10 |
| 24 | New Jersey | 28 | | Wyoming | 9 |
| 25 | Massachusetts | 26 | 49 50 | Montana | 2 |

* Excluding withdrawals for thermoelectric power,

Source: Wayne Solley, Charles Merk, and Robert Pierce, *Estimated Water* Use *in the United States 1985* (Washington, DC: U.S. Geological Survey, 1988).

*Table A-2*

Groundwater Withdrawals Per Capita Per Day, in Gallons, 1985

(U.S. average = 363)

| Rank | State | Gallons | Rank | State | Gallons |
|---|---|---|---|---|---|
| 1 | Idaho | | 26 | Alaska | 135 |
| 2 | Nebraska | [illegible] | 27 | Missouri | 126 |
| 3 | Kansas | 1,951 | 28 | Delaware | 125 |
| 4 | Arkansas | 1,606 | 29 | Wisconsin | 119 |
| 5 | New Mexico | | 30 | West Virginia | 118 |
| 6 | Wyoming | [illegible] | 31 | Indiana | 115 |
| 7 | Nevada | | 32 | Tennessee | 92 |
| 8 | Arizona | [illegible] | 33 | New Jersey | 88 |
| 9 | Colorado | 707 | 34 | Alabama | 85 |
| 10 | Hawaii | 617 | 35 | New Hampshire | 82 |
| 11 | Mississippi | 602 | 36 | Illinois | 81 |
| 12 | California | 549 | 37 | North Carolina | 69 |
| 13 | Utah | 474 | 38 | Ohio | 68 |
| 14 | Texas | 430 | 38 | Vermont | 68 |
| 15 | South Dakota | 352 | 40 | Pennsylvania | 67 |
| 16 | Florida | 347 | 41 | Michigan | 65 |
| 17 | Louisiana | 318 | 42 | South Carolina | 63 |
| 18 | Washington | 273 | 43 | New York | 62 |
| 19 | Montana | 248 | 44 | Virginia | 59 |
| 20 | Oregon | 245 | 45 | Maine | 56 |
| 21 | Iowa | | 46 | Kentucky | 55 |
| 22 | North Dakota | [illegible] | 47 | Massachusetts | 54 |
| 23 | Oklahoma | | 48 | Maryland | 49 |
| 24 | Georgia | [illegible] | 49 | Connecticut | 45 |
| 25 | Minnesota | 163 | 50 | Rhode Island | 28 |

Source: Ralph C. Heath, "Introduction to State Summaries of Ground-Water Resources," *National Water Summary 1984* (Washington, DC: U.S. Geological Survey, 1985).

*Table A-3*

## Percentage of Population Served by Groundwater, 1985

(U.S. average = 51%)

| Rank | State | Percent | Rank | State | Percent |
|---|---|---|---|---|---|
| 1 | Hawaii | 95 | 25 | Washington | 52 |
| 2 | Mississippi | 92 | 25 | West Virginia | 52 |
| 3 | Nebraska | 91 | 28 | Tennessee | 51 |
| 4 | Idaho | 87 | 29 | New Jersey | 49 |
| 5 | Florida | 86 | 30 | Illinois | 48 |
| 5 | New Mexico | 86 | 31 | Missouri | 47 |
| 7 | South Dakota | 82 | 31 | Texas | 47 |
| 8 | Iowa | 81 | 33 | Maine | 46 |
| 9 | Alaska | 80 | 34 | Georgia | 45 |
| 10 | Minnesota | 79 | 35 | Ohio | 44 |
| 11 | Wisconsin | 71 | 36 | Alabama | 43 |
| 12 | California | 67 | 36 | South Carolina | 43 |
| 13 | Indiana | 65 | 38 | Pennsylvania | 42 |
| 13 | Utah | 65 | 39 | Nevada | 40 |
| 15 | Arizona | 64 | 40 | Oregon | 39 |
| 15 | North Dakota | 64 | 41 | Massachusetts | 36 |
| 17 | Arkansas | 62 | 41 | Virginia | 36 |
| 18 | Wyoming | 61 | 43 | New York | 34 |
| 19 | Delaware | 60 | 43 | Oklahoma | 34 |
| 20 | Kansas | 59 | 45 | Michigan | 33 |
| 21 | North Carolina | 57 | 46 | Connecticut | 32 |
| 22 | Louisiana | 56 | 46 | Maryland | 32 |
| 23 | New Hampshire | 55 | 48 | Kentucky | 31 |
| 23 | Vermont | 55 | 49 | Rhode Island | 24 |
| 25 | Montana | 52 | 50 | Colorado | 20 |

Source: Wayne Solley, Charles Merk, and Robert Pierce, *Estimated Water Use in the United States 1985* (Washington, DC: U.S. Geological Survey, 1988).

*Table A4*

## Percentage of Public Water Supply from Groundwater Withdrawals, 1985

(U.S. average = 40%)

| Rank | State | Percent | Rank | State | Percent |
|---|---|---|---|---|---|
| 1 | Idaho | 92% | 26 | Washington | 35% |
| 2 | Florida | 89 | 27 | Nevada | 33 |
| 3 | Mississippi | 88 | 28 | Vermont | 32 |
| 3 | New Mexico | 88 | 29 | New Hampshire | 31 |
| 5 | Hawaii | 84 | 30 | Alabama | 28 |
| 5 | Nebraska | 84 | 30 | Ohio | 28 |
| 7 | South Dakota | 81 | 32 | Missouri | 27 |
| 8 | Iowa | 74 | 33 | Illinois | 26 |
| 9 | California | 70 | 34 | Georgia | 25 |
| 10 | Utah | 67 | 34 | West Virginia | 25 |
| 11 | Arizona | 56 | 36 | Massachusetts | 24 |
| 12 | Minnesota | 54 | 37 | Maine | 22 |
| 13 | Alaska | | 38 | South Carolina | 21 |
| 14 | Kansas | 50 | 39 | Oklahoma | 20 |
| 15 | Wyoming | 49 | 39 | Oregon | 20 |
| 16 | Wisconsin | 48 | 41 | New York | 19 |
| 17 | Indiana | 47 | 42 | Connecticut | 18 |
| 18 | Louisiana | 44 | 42 | Michigan | 18 |
| 19 | North Dakota | 43 | 44 | Pennsylvania | 16 |
| 20 | Texas | 41 | 45 | North Carolina | 15 |
| 21 | Arkansas | 39 | 46 | Rhode Island | 13 |
| 21 | Montana | 39 | 46 | Virginia | 13 |
| 21 | New Jersey | 39 | 48 | Kentucky | 12 |
| 21 | Tennessee | 39 | 48 | Colorado | 12 |
| 25 | Delaware | 38 | 50 | Maryland | 9 |

Source: Wayne Solley, Charles Merk, and Robert Pierce, *Estimated Wafer Use in the United States 1985* (Washington, DC: US. Geological Survey, 1988).

*Table A-5*

## Percentage of Withdrawals for Industrial Use from Groundwater, 1985

**(U.S. average = 15%)**

| Rank | State | Percent | Rank | State | Percent |
|---|---|---|---|---|---|
| 1 | Arizona | 98% | 26 | Washington | 19% |
| 2 | South Dakota | 90 | 27 | Massachusetts | 17 |
| 3 | Idaho | 86 | 28 | Virginia | 15 |
| 3 | Kansas | 86 | 29 | Louisiana | 14 |
| 5 | Nebraska | 85 | 29 | New Hampshire | 14 |
| 6 | Florida | 81 | 31 | Connecticut | 12 |
| 7 | Hawaii | 80 | 31 | New Jersey | 12 |
| 8 | Utah | 71 | 33 | North Carolina | 10 |
| 8 | Wyoming | 71 | 33 | Oregon | 10 |
| 10 | Mississippi | 56 | 33 | South Carolina | 10 |
| 11 | Montana | 52 | 36 | Michigan | 9 |
| 12 | Georgia | 51 | 37 | Wisconsin | 8 |
| 13 | New Mexico | 50 | 38 | Alaska | 7 |
| 14 | California | 48 | 38 | Pennsylvania | 7 |
| 15 | Missouri | 42 | 38 | Vermont | 7 |
| 16 | Minnesota | 41 | 41 | Colorado | 6 |
| 17 | Arkansas | 37 | 41 | Maryland | 6 |
| 18 | Iowa | 36 | 41 | Tennessee | 6 |
| 19 | Illinois | 28 | 41 | Texas | 6 |
| 20 | Kentucky | 27 | 45 | Alabama | 4 |
| 21 | New York | 26 | 45 | Delaware | 4 |
| 22 | North Dakota | 25 | 45 | Indiana | 4 |
| 23 | Nevada | 23 | 45 | West Virginia | 4 |
| 23 | Rhode Island | 23 | 49 | Maine | 3 |
| 25 | Oklahoma | 21 | 50 | Ohio | 2 |

**Source:** Wayne Solley, Charles Merk, and Robert Pierce, *Estimated Wafer Use in fke United Sfafes* 1985 (Washington, DC: U.S. Geological Survey, 1988).

*Table A-6*

## Percentage of Withdrawals for Irrigation from Groundwater, 1985

(U.S. average = 34%)

| Rank | State | Percent | Rank | State | Percent |
|---|---|---|---|---|---|
| 1 | Illinois | 100% | 26 | California | 34% |
| 2 | Wisconsin | 98 | 27 | New Jersey | 28 |
| 3 | Kansas | 95 | | Tennessee | 27 |
| 4 | Missouri | 92 | 28 29 | Alabama | 26 |
| 5 | Arkansas | 86 | 30 | South Dakota | 25 |
| 6 | Oklahoma | 85 | 31 | Massachusetts | 24 |
| 7 | Mississippi | 82 | | Nevada | 22 |
| 8 | Iowa | 79 | 32 33 | Colorado | 17 |
| 9 | Indiana | | 34 | Idaho | 16 |
| 10 | Nebraska | [illegible] | 35 | Pennsylvania | 14 |
| 11 | Delaware | | 36 | Virginia | 13 |
| 12 | Georgia | [illegible] | 36 | Washington | 13 |
| 13 | Texas | 67 | 38 | Utah | 11 |
| 14 | Minnesota | 63 | 38 | Maine | 11 |
| 15 | South Carolina | | 40 | Rhode Island | 9 |
| 16 | Maryland | 59 | 41 | Oregon | 8 |
| 17 | Florida | 55 | | West Virginia | 8 |
| 18 | New York | 53 | 41 | Connecticut | 7 |
| 19 | Louisiana | 48 | 43 43 | North Carolina | 7 |
| 20 | Arizona | 45 | 45 | Wyoming | 5 |
| 21 | Michigan | 43 | 46 | Kentucky | 4 |
| 21 | Ohio | 43 | 47 | Montana | 1 |
| 23 | North Dakota | 42 | 48 | Alaska | 0 |
| 24 | New Mexico | | 48 | New Hampshire | 0 |
| 25 | Hawaii | [illegible] | 48 | Vermont | 0 |

Source: Wayne Solley, Charles Merk, and Robert Pierce, *Estimated Water Use in the United States 1985* (Washington, DC: U.S. Geological Survey, 1988).

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