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Authors
Vaux, H. J., Jr.
Neiman, Max

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INSTITUTIONAL ASPECTS AFFECTING MANAGEMENT OF GROUNDWATER IN CALIFORNIA

PRINCIPAL INVESTIGATORS

H.J. Vaux, Jr., Soil and Environmental Science

and

Max Neiman, Political Science

University of California, Riverside

Office of the Director

CALIFORNIA WATER RESOURCES CENTER

University of California Davis, California 95616

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ABSTRACT

This project investigated the effectiveness of existing groundwater management institutions utilizing economic models and institutional analysis to suggest alternative institutional arrangements and the feasibility of obtaining them. Several existing groundwater basins were chosen for study. A sensitivity analysis showed the change in economic incentive with a change in various parameters such as discount rate, availability of surface water, etc.

The present groundwater institutions and laws in California were developed under very different conditions than now exist creating inefficient groundwater management; moreover, these institutions and laws are entrenched in an institutional framework into which billions of dollars has been invested yielding a resistance to change. Most institutional change has resulted from threatened legal or court action and the lack of supplemental surface water supplies. When supplemental surface water is lacking, a groundwater management scheme will contain some inequities for individual pumpers. However, a revised institutional structure will be necessary to meet the future groundwater demands.

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PROJECT COMPLETION REPORT

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The importance of groundwater is often overlooked. Yet in normal years, Californians obtain approximately 40 percent of their average annual applied water from groundwater sources. During droughts, this quantity is higher since groundwater availability is not directly determined by the quantity of precipitation in a given year. Although the need to manage groundwater to avoid premature depletion or quality degradation has been recognized in various policy statements, few groundwater basins are effectively managed. As a consequence, the tendency toward groundwater overdrafting is increasing, thereby threatening to reduce absolutely the supplies of fresh water available in California at a time when the possibilities of developing new surface supplies are becoming increasingly constrained by environmental priorities and the escalating costs of development.

The difficulties associated with establishing effective schemes for managing California's groundwaters are attributable in large measure to the fact that groundwater is exploited as a common property resource. Since most individuals or organizations are free to pump groundwater subject only to minimal constraints, individual pumpers have no incentive to conserve or save water for future use. Pumpers are, instead, dissuaded from conserving water by the knowledge that any water saved simply becomes available for capture by other pumpers and thus may be lost for future use. Groundwater, as any common property resource, is subject to competitive exploitation and, perhaps, eventual depletion.

Since the workings of the free market system are unsuited for the most beneficial exploitation of common property resources, the management of groundwater becomes a problem in designing extra-market institutions to govern and control rates of exploitation. Unfortunately,

lack of experience and data regarding the impact of such institutions has been limited, and efforts to implement new groundwater management strategies are, therefore, hamstrung by both the fears of pumpers, who are accustomed to untrammeled exploitation of groundwater and the lack of knowledge of how different institutional arrangements are related to groundwater management.

In California, largely unregulated withdrawal of groundwater predominates, implying that pumping rates will deplete this resource more rapidly than might occur with different institutional arrangements. There is, in California, a limited number of groundwater basins subject to court-enforced groundwater allocations and management through adjudications or stipulations. In the case of adjudicated groundwater management, the courts specify water allocations; in a stipulated allocation, the water allocations are mutually negotiated by pumpers, inspired by the threat of court action. There are, then, some limited, although useful, opportunities to compare among different arrangements for managing groundwater.

The objectives of this project included the development and analysis of historical information on the effectiveness or lack thereof of existing groundwater management institutions as well as the development of economic models for analyzing the potentials of alternative institutions. More specifically, the project involved:

1. A general analysis of the role of groundwater in meeting California's water demand together with an identification of the major issues posed by calls for more effective groundwater management.

2. An institutional analysis of the effectiveness of existing judicially influenced management arrangements as a means for managing groundwater both historically and in the future.

3. An economic assessment of barriers to groundwater management in California. In the following report, the pertinent data and methods are reviewed and the results are presented and discussed.

DATA AND METHODS

The objectives of this project were approached in three distinct phases. The first phase involved a general assessment of the California water situation, a critical analysis of the adequacy of existing institutional arrangements to cope with that situation, and a delineation of critical issues to be addressed in developing more effective arrangements for managing both surface and groundwater. The second phase focused on an analytical comparison of two existing types of groundwater managememt institutions from the disciplinary perspective of political science. The third phase examined, from an economic perspective, the justification for the establishment of new and different groundwater management institutions and identified some barriers to effective groundwater management. Each phase was distinct, not only according to its content, but from the disciplinary perspective taken by the individual researchers. Accordingly, each phase had differing data and methodological requirements and these are summarized below.

General Assessment. The general assessment of California water institutions focused generally on attitudes and institutions and their interaction with the underlying resource base. This effort relied heavily on existing literature in the fields of public choice theory, water law, and resource management institutions. Various principles from each of these fields were applied to the California water situation in an effort to assess the adequacy of prevailing laws and institutional arrangements to deal with the increasing scarcity of water in California. Specific attention was devoted to the current system of water rights prevailing in California with special emphasis on groundwater.

In particular, the importance of contractual water rights was emphasized and analyzed. The nature of contractual water rights was identified from various published sources and from brief interviews with water district managers in the southern San Joaquin Valley and in the Inland Empire Region of southern California. The distinction between normal, standby and emergency service contracts was drawn. Although these contracts are normally negotiated by individual water districts or organizations, the result is an interdependent array of water supply commitments among a number of water purveyors. A simple public choice model was then utilized to demonstrate how existing contractual arrangements can be used to increase the potential commitment of water suppliers thereby leading to planned shortages and scarcities. Such shortages and scarcities are then utilized to justify the need to develop additional firm water supplies.

Finally, a set of institutional, legal, and economic principles drawn from the literature are used to develop a set of criteria for use in devising new and presumptively more effective water management institutions. The criteria are eclectic in nature and have been used to analyze a wide variety of public management problems. Their use in this project represents the first effort to apply them specifically to some of the unique problems of managing California's scarce water supplies.

Analyses of California's Groundwater Management Institutions

Although the vast majority of groundwater basins in California are unmanaged, there are exceptions, most notably in the urbanized Los Angeles and San Francisco regions. A limited number of groundwater basins are

subject to court enforced groundwater allocations and management resulting from either a formal adjudication or a stipulation by competing parties solemnized by the court. In the case of adjudication, the courts specify water allocations directly while in a stipulated allocation, the allocations are mutually negotiated by the pumpers, inspired by the threat of court action. The presence of these arrangements provides an opportunity to assess the workability of current groundwater management arrangements for dealing with the preponderance of California's groundwater basins which are currently unmanaged.

For comparative purposes, two research sites were selected. The Oxnard Plain in Ventura County north of Los Angeles typified an area with a highly competitive, fragmented system of groundwater management. Atlhough the deterioration of groundwater quality has long been a source of concern, individual groundwater pumpers as well as local water districts have been unable to agree upon any unified plan for groundwater management. A series of partially satisfactory *ad hoc* arrangements emerged but the problems have not yet been finally resolved. This region has had no major adjudications, no major groundwater management program, and no watermaster activity.

By contrast, the groundwater basins in western Riverside and San Bernardino Counties have been subject to stipulated groundwater management arrangements influenced by the courts. The San Bernardino, Riverside, and Colton groundwater basins were subject to a "physical solution" set forth in Case No. 78426, Western Municipal Water District of Riverside, et al., v. East San Bernardino County Water District. The groundwater management arrangements developed in compliance with this

case are generally reflective of adjudicated and stipulated arrangements. Accordingly, the management arrangements contrast with those in Ventura County.

The analyses were based on secondary data sources supplemented by personal interviews where appropriate. The secondary data sources included: enabling legislation governing the establishment and operations of the pertinent water districts; statements of water district regulations and policies, especially those relating to sales and transfers, levies of taxes and efforts to reclaim wastewater; enabling clauses in the State Water Code, Public Utilities Code and General Government Code; and various documents relating to court proceedings that resulted in the imposition of groundwater management schemes.

In addition, a series of personal interviews were conducted with the Managers and Boards of Directors of individual water districts, water users, water masters, consulting hydrologists familiar with the groundwater situation under consideration, and other local water interests. These interviews permitted each groundwater situation to be elaborated upon in some detail and allowed the researchers to identify a number of significant but informal arrangements, rules, and policies governing groundwater management in the two locations.

Finally, a typology of institutional and policy activities was developed. The typology included: 1) activities that indirectly affect groundwater levels within the study area and involve entities within the study areas as primary actors; 2) those that directly affect groundwater levels within the study areas; and 3) those that indirectly affect groundwater in the study areas but which result from the actions

of actors outside the study areas. In addition to these categories of institutional and policy events, additional categories indicative of the content of the institutional or policy event were employed. These categories included: 1) replenishment programs; 2) provision of imported water or other alternative supply, including recycling; 3) conservation programs; 4) regulation of groundwater use; 5) new exploitation of groundwater; and 6) the creation of a new public entity that has sole responsibility or retains as part of its duties concern for groundwater management.

The institutional history of each of the study areas was then examined within the context of this typology. The various policy and institutional actions and actors were identified and the evolution of groundwater management activities were documented. The conclusions that emerge suggest that the absence of an institution with overriding jurisdiction and the unavailability of supplemental surface supplies required as part of any physical solution are the predominant institutional and hydrologic constraints on groundwater management under prevailing laws and policies.

Barriers to Groundwater Management

The analysis of barriers to groundwater management focused first on the issue of whether groundwater management in a typical overdrafted region of the southern San Joaquin Valley would indeed yield benefits to groundwater pumpers collectively. In the absnece of some positive net benefits to groundwater management, it could be concluded that no economic justification exists for groundwater management. The second issue related to the magnitude and distribution of benefits from

groundwater management. Consideration of this issue was contingent upon a finding that the aggregate benefits of groundwater management were positive.

To establish the existence of net benefits from groundwater management a dynamic optimization model of the following form was utilized:

$$\text{MAX} \sum_{t=1}^{T} \frac{B_t}{(1+i)^t}$$

subject to

$$S_t = S_{t-1} - eq_{t-1} + r$$

$$B_t = \int_0^{q_t} a - bqdq - CLq_e$$

$$L = \frac{G - S_t}{M \cdot A}$$

where

B_t = Benefits in time t_1

i = interest rate

S_t = Stock of groundwater at time t_1

e = Field application efficiency of irrigation

L = Pumping lift

G = Aquifer capacity

M = Specific yield of aquifer

A = Area of aquifer

q_t = Quantity of water pumped at time t

C = Per unit pumping cost per foot of lift

r = Annual recharge (natural recharge plus deep percolation of applied surface water), and

T = 40 years

The data utilized in the model was intended to be generally reflective of conditions existing in the southern San Joaquin Valley and was obtained from secondary sources. The sources included water supply papers of the U. S. Geological Survey, groundwater pumpage data from various irrigation districts and energy costs included in the rate schedules of the two major electric utilities in the regions. Sensitivity tests were conducted on parameters such as the interest rate, the cost of energy, and the demand for water. Ultimately it was determined that groundwater management would result in net benefits to groundwater pumpers collectively under any reasonably foreseeable combination of circumstances.

Subsequently, the model was used to investigate the effects of several instruments for affecting groundwater management. The instruments included pumping quotas, fixed pump taxes, variable pump taxes, and a system of taxes coupled with a rebate scheme. The results of these analyses suggested that the existence of benefits from groundwater management could be contingent upon the management instrument used. Even the most ideal management arrangement would cause some individual pumpers to sustain real economic losses although pumpers in the aggregate would benefit.

RESULTS

General Assessment

The general assessment of California's water institutions underscores the fact that current water management institutions evolved in a period when the nature of water management problems was very different from those currently faced within the state. The issues in California

water management have evolved from a period when the principal economic activity was mining on federal public lands which at one time included most of the state. Today the state has some of the world's largest urban concentrations, leads in agricultural activity, and still has a substantial portion of public lands. Water resource development has necessarily kept pace and in many respects was vital in the development process. The institutional and engineering adaptations have suited the purpose but have inherent weaknesses that bring to question their long-run ability to respond effecitvely and efficiently to the changing conditions of today and the future.

Adaptive change in water institutions can occur only if it accommodates three imperatives that emerge from past water policies. First, California's water resource development history demonstrates that people have repeatedly placed a higher priority on a public choice process rather than efficiency. This implies that institutional adaptation must accommodate public preferences and notions about what constitutes a "better" system.

Second, any adaptive change in water institutions will have to account for basic constraints imposed by the hydrologic and engineering characteristics of the present system. The existing institutional framework has billions of dollars invested in it. Failure to consider adequately the fundamental features of the current system could generate significant transitional costs and might involve interminable litigation. As a consequence, the hydrologic and engineering characteristics of the current water allocation system as well as existing plant and institutions not only cannot be ignored for efficient design without

risking a violation of the first imperative.

Third, economic aspects of water allocation include a spectrum of considerations ranging from individual profit making to the maximization of net social benefits from water resource management. Principles of economic efficiency can provide direction where there is no overriding constraint. Given the importance of water and divergent attitudes and preferences regarding water and its management, the desire for public processes of reconciliation that often supplant considerations of economic efficiency is quite understandable. Irrespective of whether people accept or reject the importance of economically efficient management, it is necessary that the management activity possess some of the attributes of economic markets such as information, choice, and at least a modicum of equity. If the organizational complex is too confounding, water consumers are likely to find the cost of information gathering is exceedingly high and find choice restricted by inadequate information.

The institutional imperatives appear to have as much applicability to groundwater as they do to surface water. The fact groundwater management institutions are underdeveloped when compared to their surface water counterparts reflects explicit public desires about how groundwater should be treated. So long as new surface supplies could be developed relatively cheaply these desires were understandable. In the face of new constraints on the development of surface supplies, it seems clear that a rapid evolution of groundwater management institutions will have to occur if the groundwater resource is to continue its important role in meeting California's water demands.

Groundwater Management Institutions

One conventional prescription for improving groundwater management institutions involves proposals for more consolidation of local government. Such consolidation is often seen to be desirable because a single agency ultimately emerges with unambiguous jurisdiction over and authority to "solve" groundwater problems. Additionally, consolidation is generally thought to reduce decision making and coordination costs though often at the expense of imposing costs on elements of the body politic that are dissatisfied or even harmed by management decisions.

The comparative study of the groundwater basins underlying the Oxnard Plain and the upper Santa Ana River Watershed suggests that consolidation need not always be required for effective groundwater management. The relatively integrated system of groundwater management that has emerged in the Santa Ana Watershed has stemmed from a series of unplanned but beneficial events. The unique institutional factors and comprehensive interest of the Orange County Water District in managing its water resources led to litigation against upstream users. The resulting system of groundwater management in Riverside and San Bernardino Counties stemmed from a court-enforced stipulated agreement. It is clearly important that the ease with which the agreement was arrived at was conditioned by the availability of supplemental sources of surface water to compensate for the agreed upon decrease in groundwater pumping.

A somewhat different set of circumstances has been involved in the emerging groundwater management system being developed to deal with the seawater intrusion problems affecting the Oxnard Aquifer. Even though seawater intrusion has been recognized as serious, there is as yet no

implemented plan for groundwater management. The difficulty in developing such a plan can be attributed to three factors. First, none of the relevant institutional actors has jurisdiction over the entire set of interdependent groundwater basins that underlie the Oxnard Plain. Second, there was a very large number and great variety of groundwater users, largely agricultural, who perceive very real financial dangers in any policy that might threaten their access to groundwater. Third, is the fact that no relatively inexpensive short-run alternatives to groundwater extraction were available. In short, low cost, supplemental surface supplies that could alleviate the problem were not believed to be readily at hand.

The pressure to resolve the problem of seawater intrusion led in 1979 to action by the State Water Resources Control Board to begin litigation to resolve the issue. The propsect of a court imposed allocation of groundwater and years of litigation finally resulted in the emergence of a groundwater management system that will require the development of alternative supplies for groundwater pumpers who will ultimately be required to moderate or cease extractive activity. On the Oxnard Plain, then, groundwater users agreed to a plan and agreed to incur the considerable expense of developing alternative supplies only in the face of threatened litigation which was perceived to be potentially more costly than the development of new supplies.

This exploratory description of institutional change in two settings is not a sufficient base from which to generalize. However, it does suggest that substantial innovation can occur in the presence of numerous autonomous actors if certain conditions exist. In an area in which groundwater decision making is fragmented, innovation and change in the

direction of groundwater management occurs when alternative supplies are available and when a credible threat occurs to supplant the power of individual groundwater actors. Actual centralization is not necessarily required to bring about greater coordination, if the threat of imposed centralization seems imminent.

In the Santa Ana Watershed, the lawsuit initiated by Orange County Water District created a situation where a court-imposed solution could have occurred had Riverside and San Bernardino defendants not developed, with watermaster supervision, a solution to the issues posed by Orange County. And in the Oxnard case, after years of failing to develop a plan among the many private and governmental actors, local decision makers seem finally to have adopted a mutually acceptable plan. The catalyst was the threat of litigation posed by the State Water Resources Control Board.

Both cases suggest, in short, that credible threats from outside particular groundwater arenas to displace decision making powers can elicit substantial local change providing that supplementary sources of water are available at costs that compare favorably to the potential costs associated with forced centralization. What is left unresolved, however, is the issue of whether existing arrangements, court influenced or not, are in any way adequate for developing groundwater management mechanisms and schemes where supplemental sources of water are not available and real losses may have to be imposed on a minority of current groundwater extractors.

Barriers to Groundwater Management

The analysis of the economic desirability of instituting groundwater management in the southern San Joaquin without additional sources of supply suggests that benefits would accrue to groundwater pumpers collectively. These benefits would be approximately $75 per acre under the base line conditions summarized below:

Table 1

Parameters	Base Values
Initial pumping lift	165 ft
Energy cost	$0.085/A.F./ft
Interest rate	0.05
Annual recharge	100 A.F./yr
Derived demand for water	$MB_t = 56 - .25\ q_t$
No surface water available	

This estimate is contingent upon one assumption and the values selected for the various parameters. The benefits have been computed under the assumption of zero management costs. Clearly, some management costs will be involved and the benefits are thus overstated. Management costs could range from the modest, in the case of management schemes involving relatively decentralized price mechanisms, to quite large in the event that management requires the importation of expensive supplies of supplemental water. The economic justification for groundwater management might ultimately depend on the type of management arrangement selected.

The estimate of benefits is also sensitive to the values selected for the various parameters. In Table 2 below the change in benefits associated with different values of the basic parameters are displayed.

Table 2

Parameters	Alternate Values	Change in Per Acre Benefits
Initial pumping lift	265 ft	- $15
Energy cost	$0.11/A.F./Ft	+ $14
Interest rate	0.10	- $48
Annual recharge	130 A.F./year	+ $31
Derived demand for water	$MB_t = 71 - .25\ q_t$	+ $29
Surface water availabel	70 A.F./year	+ $85

These suggest that benefits may be sharply reduced in response to increases in the real rate of interest and may be importantly conditioned by the prevailing pumping lift. Increases in the cost of energy, the annual recharge rate, the derived demand for water and availability of substitute surface supplies will increase the benefits. Accordingly, the analysis suggests that with modest management costs and no sharp increases in the real rate of interest there will be collective net benefits from the management of groundwater resources in the southern San Joaquin.

The analysis of the various instruments through which groundwater management might be effectuated presents a less clear picture, however. Under a system of quotas, groundwater pumpers would benefit in the aggregate although individual pumpers might suffer losses. Quotas may be costly to establish and administer and therefore, the net benefits might ultimately be quite small or even non-existent. Under a fixed set of taxes, pumpers in the aggregate would lose because the tax revenues collected would exceed the benefits (assuming no management costs of establishing and collecting the taxes). This result could be mitigated with an effective tax rebate system. Yet such a rebate scheme would be problematical because it could serve to destroy the incentive which the tax provides in the first place. If individual pumpers are to perceive benefits from groundwater management under pump taxes, they must expect to receive back in rebates close to what they paid out in pump taxes. If this is the case, however, then the original incentive of the pump tax is destroyed.

Another option is to allow variable pump taxes which would permit groundwater pumpers to capture most or all of the benefits of groundwater management but without the need for rebates. Such taxes would have to be flexible, however, to allow for different agronomic and climatic circumstances. Such taxes might be costly to administer, however, and some pumpers would still suffer real losses.

The conclusions of the aggregate analyses tend to mask the effects of groundwater management strategies on individual pumpers who face a wide variety of environmental and agronomic conditions. An analysis of various schemes of quotas and taxes suggest differences in derived

demand which almost assuredly exist among different pumpers are sufficient to ensure that no one scheme of management will be unambiguously desirable to all. Indeed, the analysis underscores the fact that imposition of groundwater management will impose losses on some pumpers even though the majority benefit.

It is the perception of individual pumpers of their potential vulnerability to real losses under any management scheme that constitutes the most significant barrier to groundwater management in California. In the absence of supplemental water supplies, management will assuredly require some pumpers to decrease groundwater use or eliminate it entirely. It is understandable that those who are potentially subject to groundwater management would react adversely to the associated uncertainty over whether they gain or lose from management. It is far easier to insist stubbornly that supplemental supplies be made available, thereby ensuring that there will be no losers in the process.

CONCLUSIONS

This project has involved a comprehensive assessment and analysis of the features of groundwater management institutions in California. The effectiveness of current institutions has been assessed and the potentials for development and evolution of new institutions which hold promise for effective management of groundwater has been examined. The conclusions of this research can be stated succinctly as follows:

1. California's water institutions developed in a period whose characteristics differed quite sharply from those surrounding the current water situation. Californians have shown a preference for supply augmenting solutions that involve broad degrees of public participation, often at the expense of economic efficiency.

2. New water management institutions cannot be expected to operate effectively unless they are designed to accommodate, at least in part, prevailing public attitudes and preferences, the existing hydrologic and engineering features of the current water supply systems, and the perception that economic efficiency is not always the paramount consideration.

3. Existing water management institutions have arisen primarily from threatened consolidation of groundwater management activities from external sources. These threats have been transmitted through the courts where they result in adjudicated or stipulated allocation regimes or, in the case of the Oxnard Plain, from the State Water Resources Control Board which threatened legal action.

4. The presence of formal groundwater management appears due to the perception that management externally imposed would ultimately prove more costly than management schemes mutually agreed upon. In addition, the establishment of virtually all groundwater management institutions has been lubricated by supplemental supplies of surface water to offset the diminished groundwater pumping associated with management. The availability of these supplemental supplies appears to have been a crucial precondition for the establishment of effective management institutions.

5. In the absence of supplemental supplies groundwater management may still be justified on economic grounds. This appears to be the case in the southern San Joaquin Valley so long as the costs of groundwater management are modest. However, individual pumpers will almost assuredly be obliged to accept real economic losses in order that pumpers as a group may gain. The inevitability of these losses plus the uncertainty over which pumpers may suffer then constitutes a significant barrier to the development of effective groundwater institutions at a time when the availability of supplemental supplies has been severely constrained.

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