

The Problem of Water

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ABSTRACT

This essay examines the problem of water rights in the semi-arid U.S. as background for further investigation into the comparatively limited role of water markets for water reallocation from low-valued to higher-valued uses. As in most areas of the world, in the western United States agriculture receives the dominant share of water, about 80 percent of consumptive use. Yet, urban and environmental demands are growing rapidly. At the margin, water values generally are much lower in agricultural than in urban and environmental uses. The prices charged for agricultural water generally are low, around \$15 an acre foot, whereas urban areas are willing to pay in some cases as high as \$15,000 an acre foot. Even so, water transfers are not routine. Although a lack of infrastructure for trans-basin shipments and the high cost of moving bulky water are contributing factors, two major reasons for limited trade are: (1) property rights to water are not well defined due to its mobility and to legal constraints on ownership; and (2) multiple parties with conflicting incentives for exchange are involved in any decision to transfer water. A tragedy of the anti-commons (paralysis) is one result and arbitrary and contentious reallocation another.

“I said, ‘What was the fight over?’ and Mr. Tripp said ‘Same old thing-water.’”¹

I. Introduction.

Throughout the world there are growing problems of scarcity of fresh water. This scarcity is especially acute in more arid regions, the Middle East, North Africa, Mediterranean Europe, Australia, northwest China, northern Mexico, parts of South America, and the western U.S. In the American West, sufficient fresh water supply to meet growing demand is a particular problem in urban areas. Here, the country’s most rapid population growth rates and the presence of persistent drought, are outstripping available water supplies. Further, greater environmental and recreational demands for water are contributing additional pressures on existing supplies.

New water sources through major dams and storage projects are not a solution, since most dam sites have long-since been exploited. In addition, these activities conflict with environmental objectives as well as with calls for the maintenance of free-flowing streams.²

Conservation also will be of limited help because of the scale and scope of expanding urban and

environmental needs. As a result, most of the water to meet these new demands must come from agriculture where the vast majority of water consumption takes place.

In the American West, approximately 80 percent of consumptive water use is in agriculture, often in low-valued or subsidized crops, such as alfalfa, cotton, or rice. Farmers typically pay only for the pumping or conveyance costs for the water and not for its scarcity value.³ Accordingly, much water use in agriculture is of low value, whereas at the margin, water values are much greater in urban areas and often in environmental uses, such as maintaining riparian habitat and augmenting in-stream flows. As a result, there are significant allocative gains from moving some water from agricultural to urban and environmental uses. The misallocation of water has been recognized as a problem for a long time, yet water markets have developed slowly and controversially in the U.S., in comparison with market transactions for other resources, such as land, that are routine and beneficial.⁴

This essay explains why there is an apparent lack of water market transactions in the western U.S. The focus is on the complex nature of water uses, the incomplete definition of water rights, and the role of the multiple parties who are involved in most transfer decisions. A lack of exclusive decision-making authority means that many constituencies govern water allocation and use. A tragedy of the anti-commons (paralysis) is one result and arbitrary and contentious reallocation another. These issues are linked inevitably by the special characteristics of water that make it a commodity unlike any other.

II. The Special Case of Water.

Critics of viewing water as an economic commodity argue that because it is essential for the life of all species it should be held collectively as a public resource and low-cost access be

regarded a fundamental human right.⁵ For these critics, calling water a commodity is inappropriate. They believe it implies commercial homogeneity and tradability that do not exist for water.⁶

These are separate points. First, consider the indispensability of water. Its essential nature as a vital resource affects the politics of water ownership and transfers. Most water uses, especially in developed countries like the U.S., involve non-essential consumption at much lower marginal values.⁷ A minimum amount of water, between 5 to 10 liters a day per person, certainly is essential for human life. Fresh water also is a critical input for agriculture and many kinds of industrial production.⁸ These threshold amounts, however, account for only a small fraction of total water use. In the U.S., urban consumption averages from 455 to 530 liters per person per day.⁹ Most urban water, then, is used for purposes beyond mere survival and those demands grow with per capita income. Similarly at current low water prices, agricultural and industrial uses are extended to lower marginal-value production. Accordingly, water beyond the survival threshold surely can be viewed as an economic commodity.

The second point is a more critical one. Indeed compared to land, water presents important challenges in defining property rights and making it easily tradable. Table 1 presents characteristics of land, water, and wild-ocean fish stocks that affect the ability to define and enforce property rights. The signs reported in each cell indicate how the characteristic affects the definition of property rights, with a plus sign indicating that the resource characteristic contributes to definition and a negative sign indicating that the characteristic hinders definition.

Table 1
Resource Characteristics

Resource	Ability to Bound, Partition, Exclude	Measurable: Size/Amount	Variability of Supply	Simultaneous Uses	Sequential Uses
Land	+	+	+	+	+
Fish Stocks	-	-	-	-	-
Water	-	-	-	-	-

As shown above, water shares more in common with wild-ocean fisheries, notorious open-access resources, than with land.¹⁰ The table entries also suggest why private property rights to water are difficult to assign and enforce, quite apart from political demand to reserve water as an essential resource under state ownership.

The Costs of Bounding.

Due to its physical mobility, water cannot be bounded easily or partitioned across claimants and uses. Streams move across the ground and seep within it. They often cross both multiple private land holdings and political jurisdictions. Water in lakes is less migratory, but particular parcels of water cannot be constrained at low cost within property lines unless the lake lies within them. Groundwater also migrates, and it is unobserved. For all of these reasons, it is difficult to define and enforce property boundaries to freshwater.

Exclusion is extremely difficult, and as a result, numerous parties typically access the same body of water either simultaneously or sequentially. When water supply is abundant compared to demand, these simultaneous or sequential uses can be supported with little conflict among the parties involved. As demand for water increases, however, extraction by one party depletes what is available for another. Because of the high cost of bounding water claims, disputes are likely as parties compete for the same water. Access to a defined amount and quality of water becomes less certain, making consumption and production less predictable. Both the value of water and production are reduced. Over the long term, the gains from defining more precise property rights may offset bounding costs, and new rights arrangements will emerge. As described below, the mobility of water, high measurement costs, distributional disputes, and

public good claims, however, will make this process of institutional change more complex than envisioned by Demsetz (1967).

These complexities are also exemplified in fisheries, where similar high bounding costs result in numerous competing fishers accessing the same stock as an open-access resource. Wasteful conflict and rent dissipation result. Even with time, most wild ocean fisheries, especially those living beyond the 200-mile exclusive economic zone of individual countries, have not witnessed more effective property rights or regulatory solutions.¹¹ These stocks have been dangerously depleted.¹² In contrast to the mobility of water, bounding costs are much lower for land. It is possible to fence and partition land to meet concurrent and sequential demands for farming, pastoral scenery or other amenities, provision of wildlife habitat, or urban development. Indeed, the pressure to respond to growing demand results in more precision in demarcating land holdings in the manner Demsetz described.

The Costs of Measurement.

Fluidity and a lack of observability raise the costs of measuring the amount of water held in a water right. These effects are most critical for groundwater. The quantity in any particular location is not precisely known, and it is affected by a variety of forces that deplete or augment it in ways that cannot be easily determined or measured. Extraction by one user drains the water that is available elsewhere for another party. If the groundwater body is extensive and withdrawals comparatively small, there may be little impact on the amount of groundwater. Many aquifers are replenished gradually both from natural sources and from the recharge of the very groundwater that is extracted but not fully consumed. These processes are slow and very complex, affected by intricate hydraulic factors, variable precipitation, evaporation, and the nature of groundwater-surface water exchange.

A property right to surface water can be measured more accurately because it is observable. Because water is mobile, the amount claimed is demarcated in terms of diversion.¹³ The extent of each diversion, however, varies over time due to fluctuating rainfall and snow pack, which affect stream flow and reservoir size. Seasonal precipitation patterns are predictable and are incorporated into a water claim. This is not the case, however, for annual precipitation variation which leads to uncertainty in supply. Supply is variable and supply peaks generally do not coincide with high demand periods. Drought patterns are highly erratic and hard to forecast with existing models. This makes it difficult to define an exact amount of water that will be available for diversion at any point in time. Supply uncertainty complicates the granting of definite water rights and the writing of contracts for water exchanges because neither buyers nor sellers know exactly how much water can be transacted at any specified period. These effects work against water markets just when they are especially needed because drought also increases demand for water.

Even considering all of this, water diversions can be measured more easily than actual consumption, which is affected by the nature of use and by geologic and hydraulic conditions. Measuring consumption is important because it indicates the amount of diverted water that is released as recharge for subsequent claiming and use by others. For example, some surface water used for irrigation is consumed by plants; some evaporates; and some seeps into the soil to groundwater, streams, or ditches. As much as 50 percent of the original diversion may make it back to the aquifer or stream.¹⁴ This tail water is available for successive uses in irrigation, urban and industrial consumption or in aquatic habitat. But because consumptive use is imprecisely known, the size of return flows is difficult to determine and accordingly, the quantity of water that can be granted subsequently to downstream water rights claimants is not certain.

A parallel example from the resource list in Table 1 is mobile, unobserved fish stocks, which have comparable measurement problems. The number of fish is affected by natural growth (recruitment), disease, ocean temperature, food supplies, pollution, and harvest. How these interact to determine stock size at any time is not well understood, and stock estimates are notoriously controversial. This contributes to the lack of property rights in fisheries. Again, in contrast, there is no comparable problem for measuring stationary, observable land plots, where rights are well defined.

The Interconnected Private and Public Goods Characteristics of Water.

The social nature of water distinguishes it from land and even fisheries because of the high degree of interaction among claimants and its multiple applications. The simultaneous and sequential provision of private and public goods is an important complicating factor in assigning of property rights to water because it is physically difficult to segment into its various uses.¹⁵

Private Interdependencies. Private goods production involves competing (rivalrous) uses of water, but most do not consume all of the water devoted to them. An upstream farmer who diverts water for irrigation will use only part of it, with the remainder percolating through the ground back to aquifers, streams, or to ditches for repeated access by other parties.¹⁶ Because of this interdependence, communities have clustered around the semi-arid West's intermittent water sources, sharing the resource.

Groundwater users also are interconnected with one another and with surface claimants. Groundwater often is in hydrologic communication with surface flows, so that those who consume surface water affect the quantity and quality available to those who extract groundwater.¹⁷ Similarly, those who pump groundwater reduce surface supplies that otherwise are replenished by springs and other subterranean seepage. Further, pumping by one user

decreases the amount of groundwater available to others by lowering water tables and raising extraction costs. In transfers involving groundwater there is the sheer hydrologic uncertainty in determining how other pumpers will be affected.¹⁸

Private/Public Interdependencies. Public goods involve non-competing (non rivalrous) uses of water. A free-flowing stream is available to all; consumption by one party has negligible impact on consumption by others. Most public goods are provided by the state either because the inability to prevent access leads private parties to focus on activities with greater appropriability or because private efforts to limit access reduce production of public goods. Farmers devote water to irrigation rather than to fish habit. Private riparian owners hold up navigable waterways with consecutive tolls. The decision by the state to provide public goods, however, is rivalrous because it constrains the provision of private goods. That is, water reserved for fish habit may not be diverted for irrigation.

Implications for Property Rights to Water and Water Markets.

The discussion of the resource characteristics in Table 1 indicates that defining and enforcing private property rights to water is more difficult than with land and has many similarities with problems faced in open-access fisheries. Water's concurrent or sequential uses result in numerous interdependencies. Multiple parties can be affected inadvertently in the establishment of water rights and the trade of water. Because the potential for harm, transfers of surface water rights in western states are predicated on there being "no harm or injury" to downstream rights holders.¹⁹ Compliance with this requirement is difficult to demonstrate if the transfer involves changes in the timing, location, or use of water. As a consequence, water transfers may be restricted to historical consumption, not water diverted. But consumption is harder to measure than diversion.²⁰ Further, the no harm rule makes any trade vulnerable to a

variety of constituent claims, some legitimate and some pure holdup. State agencies enforce these and other regulations, and most water trades that involve new uses must be approved by them. The process of application, processing, and evaluation can be lengthy and complicated. As a result, the high cost of bounding and measuring water and the associated interconnectedness of its private uses raises the transaction costs of defining clear property rights to water and facilitating its exchange.²¹

The protection of public goods also raises the transaction costs of water trades. Private diversion of surface water or extraction of groundwater is subject to adherence to certain regulatory standards. Other diversion restrictions are applied under the “public trust” doctrine to promote for public goods, such as navigation. Recently, the doctrine has been extended to prohibit “excessive” diversions of water that might damage natural habitat.²²

Despite their apparent attractions, these regulatory interventions weaken property rights, promote open-access conditions and conflict, and thereby potentially dissipate private and public values of water.²³ Valuable trade is reduced; useful information about alternative water uses is not generated; important investment is foregone; and excessive competition over the common resource brings waste. Additionally, mandates for broad participation in designating water uses that are consistent with the public trust, can lead to an “anti-commons.” With so many interests involved, it may be impossible to reach consensus in allocation decisions.²⁴ The high transaction costs of reaching agreement result in paralysis and lock-in of water’s uses in existing patterns, even though new, more valuable demands for its use may have arisen.

Avoiding anti-commons and promoting trade and investment (including conservation) in water requires the definition of clear property rights to water. Defining private property rights must involve the many parties who draw from the same mobile water source and whose

uses are intertwined. Determination of the number of parties requires information on the size of the water area and drainage from one use to another. It requires an allocation mechanism that is acceptable, measurable, and enforceable. The mechanism must be responsive to inherent variation in water supplies due to seasonality and the vagaries of precipitation.

Useful public policy responses to promote property rights definition are to provide: 1). climatic, geologic, and hydraulic information for the definition of water rights; 2). registration and demarcation institutions to record water rights and to accurately measure historical consumption; 3). conflict resolution and enforcement institutions; and 4). overall support for the concept of private water rights and exchange. The latter should include the recognition and purchase of private water rights when it is necessary to provide public goods, rather than arbitrary seizure or taking of water without fair compensation. In the case of groundwater, government-mandated unitization (single ownership and management) of groundwater, as is done with oil and gas reservoirs, is a solution to excessive access and drawdown. In the case of unitization, a single “unit operator” extracts from and develops the reservoir. All other parties share in the net returns as share holders. This arrangement eliminates competitive withdrawal and directs extraction toward maximization of the economic value of the entire reservoir, rather than of the segments (leases) held by individual parties.²⁵

The definition of secure water rights allows for the development of water markets. Legal and political institutions that support clear property rights will lower the transaction costs of trade and facilitate the voluntary, smooth exchange of water from low to higher-value uses. Such institutions are critical as new competing uses for water emerge in the presence of traditional allocations.²⁶

III. Water rights.

Many of the problems of western water lie in the complex system of property rights and the difficulty of defining them. In western states, individuals do not own water as they might own land. Water is “owned” by the state in trust for its citizens and its use regulated based on public interest or welfare concepts.²⁷ As stated in Wyoming law, for example: “Because water is so important to the economy of this state, its use is always limited by a concept of public trust; the only uses for which water rights may be established are those which receive ‘public recognition’ under the law of the state.”²⁸

Individuals hold only usufruct rights to the water, subject to the requirement that the use be beneficial and reasonable and to oversight by the state in monitoring transfers to insure that they are consistent with the public interest.²⁹ There are also retroactive regulatory applications of the public trust doctrine.³⁰ Accordingly, water rights appear to have *less* protection or be more fragile than are most other property rights.³¹ Western water rights are based on prior appropriation that dominates in the region and common law riparian claims that operate along with appropriative water rights in parts of California, Nebraska, Oklahoma, Oregon, Washington, North and South Dakota, and Texas.³²

Appropriative Surface Water Rights.

The appropriative doctrine allows rights holders to withdraw a certain amount of water from its natural course for private beneficial purposes on land remote from the point of diversion.³³ The appropriative doctrine emerged in the 19th century in response to the development of mining and agriculture in the semi-arid West where growing numbers of people and economic activities were increasingly concentrated in areas where there was too little water.³⁴ The most arid western states—Arizona, Colorado, Idaho, Montana, Nevada, New

Mexico, Utah, and Wyoming—constitutionally or statutorily adopted the appropriative system.³⁵ Under the doctrine, water could be taken from streams and the lands riparian to them and moved via aqueducts, ditches or canals to new desired locations. Ownership of water was allocated through the rule of first possession or priority of claim.³⁶ Through this process individuals gained a usufructory or possessory right to water.³⁷ The maintenance of appropriative rights was based on placing claimed water into beneficial use. It could not be hoarded, wasted, or abandoned. Because beneficial uses were difficult to measure, the basic test of meeting the beneficial use requirement was physical diversion. Mandating beneficial use as the condition for receiving a property right promoted access to the one resource necessary for economic development in a semi-arid region—water. If parties were going to divert water from a stream, they could appropriate only what they would productively use which would leave the rest for subsequent claimants.

Those with the earliest water claims have the highest priority and those with subsequent claims have lower-priority or junior claims. No two parties can have the same priority, so that there is a ladder of rights on a stream, ranging from lowest in priority to highest. This allocative mechanism provides a clear way of ranking competing claimants in assigning rights and in rationing water during times of drought. During drought the highest priority rights holder receives full allocation before any water is made available to those of lower priority, who receive only the residual. Hence, drought risk is born less by those with the highest priority rights and more by those with lower priority rights. The relative security granted senior rights holders encouraged investment in both water infrastructure and associated economic activities. If trading is possible, then those with high-valued water uses, but low-priority rights can lease or purchase

water from those with lower-valued uses but higher-priority rights. If trading is restricted, however, water use may be locked into traditional uses by the priority system.

Because appropriative rights can be separated from the land and sold or leased, they can be the basis for private water transfers in response to changing economic conditions.³⁸ But as described in more detail below, trades that change the location of water diversion, nature of use, and timing, especially if they are large relative to stream flow, are restricted by state law and regulated by state agencies.³⁹ Changes in location of diversion to points upstream, for example, could harm other rights holders by reducing downstream flows. Geologic and hydrologic conditions may differ at the new diversion point, affecting the percolation of water back to the stream. Changes in the location of use, particularly those that are out of basin, more substantially affect return flows and available water to other rights holders because none of the water exported migrates back to the stream. To mitigate these effects, state water agencies typically allow changes in diversion and location for only historical consumptive uses.⁴⁰

The reliance of appropriative rights on diversion as a means of definition and enforcement reduces the quantity of flowing water in the stream. But valuable instream uses require the maintenance of flows. Historically, only diversion has been accepted as evidence of beneficial use and as the basis for property rights under the appropriative doctrine. This condition has meant that valuable instream uses have not been protected under the prevailing rights structure. Even if they had been recognized, instream rights are difficult to define and enforce because of the movement of the water and the potential for existing appropriative rights holders to increase their diversion of any larger stream flows.⁴¹

Only recently have instream uses, such as maintenance of fishery habitat, recreation, and amenity values, been added to the list of beneficial uses in western states, and thereby potentially

subject to formal claiming.⁴² Because of difficulties in delineating and protecting claims and their public goods characteristics, instream flow rights have been held only by state agencies.⁴³ The expansion of instream flow rights as beneficial uses is part of the greater application of broad public interest considerations in water management by western states.⁴⁴

Recognition of these rights, however, impinges on existing appropriative rights holders by limiting their water diversions unless the water is purchased for maintaining river levels. Further, periodic drought requires a rationing mechanism for allocating the reduced supply among traditional diversions and stream flows. If a minimum flow level is necessary to provide public goods (fish habitat, amenities), then those traditional diversions, such as irrigation, must be reduced during drought. If the mechanism employed is clear, predictable, and involves reasonable compensation, then instream flow rights and appropriative rights can coexist. If the mechanism is more arbitrary, uncertain, and does not include fair compensation, then appropriative water rights are weakened. And the more they are weakened, the greater the losses of open-access conditions for water—more costly conflict, reduced investment and trade, and less information about alternative water uses.⁴⁵

Riparian Surface Water Rights.

Ownership of land appurtenant to water flows is the basis for riparian rights. Riparian rights are the common law institutions that dominate in the eastern U.S. Since streams and precipitation are more plentiful in that region, there is reduced need to divert and ship water long distances to more arid sites. Riparian land owners have rights to access the water adjacent to or passing through their properties for reasonable use, including fishing and navigation, and can utilize the water so long as doing so does not harm other riparian claimants down stream.⁴⁶ In cases of drought, all parties share in the reduced water flow. Riparian rights are not lost through

disuse, and they remain tied to the land. Accordingly riparian water rights can only be transferred with riparian lands.

In the western states where riparian and appropriative rights arrangements co-exist as hybrids, they do so uneasily.⁴⁷ Even in those states the appropriative system dominates in terms of the extent of overall use. When the two systems operate, there can be questions of priority of claim when diversion under the appropriative system seriously reduces the water available to riparian owners. Alternatively, riparian claims could prohibit diversion from streams as part of appropriative water claims. In western states, riparian claims have been limited, although in California they are given precedence in disputes with appropriative claimants under certain circumstances.⁴⁸

Groundwater Rights.

Groundwater rights vary across the western states and most are not well defined or enforced.⁴⁹ As with surface water rights, prior appropriation and reasonable use are the dominant allocative mechanisms.⁵⁰ Seniority entitles a groundwater user to maintenance of a sensible pumping level. Under the reasonable use doctrine, surface owners whose properties lie above ground water basins have the right to extract a sensible amount of water from below their property, however that quantity is defined.⁵¹

Depending on subsurface pressure and permeability of the soil, water may migrate as pumping or other forms of extraction occur. When it does, it moves through the aquifer from beneath the surface properties of others, creating classic common-pool conditions.⁵² Although groundwater is recognized as a “public resource” in western states, there is little limitation on competitive groundwater withdrawal, and no clear recognition in the water rights structure of interconnectedness between surface and groundwater uses.⁵³ The information requirements to

document damage to one user from the extraction of groundwater by another are significant, raising the costs of individual attempts to enforce water rights. There are problems of determining permeability of the soil, identifying zones of saturation, and the extent of the groundwater basin. Moreover, groundwater users have been reluctant to support comprehensive state regulation because of the uncertainties such regulation might bring for their water use.⁵⁴ Relatively unlimited access apparently is preferable to uncertain constraints by state agencies. As groundwater levels decline and water values rise, increasing the costs of competitive withdrawal, these positions may change.

Public Trust Doctrine.

The “public trust” is a common law principle creating the legal right of the public to utilize certain lands and waters, such as tidewaters or navigable rivers, and other waters and natural resources with high amenity or public goods values.⁵⁵ Under the doctrine, the rights of the public are vested in the state as owner of the resource and trustee of its proper use. It historically came from the notion that government has an affirmative duty to administer, protect, manage, and conserve access to navigable waters, but broader interpretations are developing beyond care for navigation. In a far-reaching ruling by the California Supreme Court in 1983 in the Mono Lake case (*National Audubon Society v. Superior Court* 685 P.2d 709) the court stated that the “core of the public trust doctrine is the state’s authority as sovereign to exercise a continuous supervision and control over” the waters of the state.⁵⁶ This opinion energized expansion of the public trust doctrine in a growing number of western states to restrict “excessive” diversions from non-navigable streams to protect aquatic environments.⁵⁷

The doctrine can be applied retrospectively to roll back preexisting appropriative rights that appear inconsistent with the public trust.⁵⁸ There apparently is no constitutional basis for

taking challenges of public trust restrictions of private water rights.⁵⁹ Much of the extension has occurred through judicial opinions that have broadened state discretionary authority over water rights. A Lexus/Nexus search reveals 32 court cases between 1985 and 2004 in 12 western states involving public trust issues with three-fourths of them in California, Colorado, and Idaho. In general, the rulings have held that state responsibilities under the public trust doctrine may extend to maintenance of stream flow and water levels in rivers and natural lakes, including groundwater systems linked to them in order to guard for health, amenity values, and fish and wildlife habitat.⁶⁰ As another example, a 1988 Oregon statute that authorized appropriators to sell or lease water they saved requires that about 25 percent be allocated to the state and held for instream flow maintenance.⁶¹

Because water is a mixed resource providing private and public goods, there can be justifiable concerns about private water use that potentially harm public values. The benefits of public trust interventions, however, have to be weighed carefully against the value of the private uses to be restricted or prohibited. The doctrine is so elastic and potentially expansive that it can lead to extensive government intrusion in water rights.⁶² Indeed, under the public trust, the state could intervene broadly in water uses to insure that trust values were protected.⁶³ Even more importantly, public trust extensions emphasize that private water usufruct rights are non vested and revocable and that such actions are non compensable.⁶⁴

The doctrine, then, potentially adds uncertainty to water ownership, weakening existing property rights and their ability to promote investment, trade, and efficient use of water. The foregone private uses may be of higher social value than the public goods at stake, or there may be gradients whereby some of the private uses are more valuable at the margin than some of the public values. In this case, only a partial reallocation might occur. Unfortunately, regulatory

takings under the public trust doctrine would reduce information about both private and public values. Collection, measurement, and consideration of alternative values are not required under the doctrine. Alternatively, negotiation to purchase water rights to safeguard public values forces the parties involved to gather information about the true values of both and to consider the tradeoffs involved in the public trust action.⁶⁵

A broad public trust mandate for state regulation also would lower the private costs of holdup strategies by providing legal standing for parties to contest private water diversions or proposed trades as violations of the doctrine.⁶⁶ As the costs of private holdup are reduced, there is potential for abuse. Maximizing social welfare requires consideration of these tradeoffs and adoption of the least costly approaches in applying them. Where there is a case for regulatory action, the most effective response is for state agencies to purchase and retire the water right as part of their mandates, rather than to use the doctrine to arbitrarily revoke water rights, limiting past uses and potential exchange.

Given this background on the special characteristics of water and western water rights, it is worthwhile examining the water institutions that are involved in water rights institutions and in water trades.

IV. Water Institutions and Parties.

Although water rights holders and prospective purchasers or lessees are key parties in any exchange, other institutions that play key decision-making roles in the timing and extent of water trades. Their actions affect the transaction costs of exchange and the development of water markets. The institutional complexity surrounding water rights and marketing far exceeds

anything comparable for land and even for fisheries with their myriad mixes of fishers, processors, state, federal, and international management organizations.

State Regulatory Agencies

The principal institution is the state regulatory body, and these agencies vary from the State Engineer in New Mexico and Utah, to the Department of Water Resources in Arizona, and to the State Water Resources Control Board in California. In Colorado, regulatory authority includes both the Department of Natural Resources as well as special water courts. These agencies are staffed by state employees with technical or legal training who are charged with administering state law regarding water rights, approving certain water transfers, and regulating water use, including application of the public trust doctrine.

For water transfer applications, agency officials examine the documents, scrutinize data to insure compliance with the no harm provisions of state law, conduct hearings involving potential protests, and decide on the amount, timing, and nature of any approved trade. As with regulatory agencies in general, agency officials are not residual claimants to changes in value from approving or denying water trades or from implementing other aspects of state water law. They are unlikely to be influenced by the economic implications of their decisions. Like all bureaucratic officials, they are motivated by a variety of factors, including professionalism, regulatory mandates, ideology, and political pressure.⁶⁷ Their actions may lower or raise the transaction costs of exchange, and the exact impact depends on state legal requirements, the structure of the regulatory body, as well as their personal motivations and qualifications. Among the state water agencies in the West, the office of the New Mexico State Engineer generally is held up as an effective regulatory body that efficiently processes water transactions.⁶⁸

Irrigation Districts and other Water Supply Organizations.

There are approximately 1,127 water supply organizations across 17 western states.⁶⁹

These institutions vary widely in terms of governance structure, membership, decision-making authority, and water rights. Some hold water rights in trust for their members, whereas in others the rights are held by the users. The organizations range from irrigation districts, mutual ditch and reservoir companies, water conservancy districts, municipal water districts to water companies. In Texas for example, there are 16 different types of water organizations.⁷⁰ Most, however, supply water to agriculture. Irrigation makes up more than 75 percent of all water withdrawn in the states and 90 percent of all water consumed.⁷¹ This organizational complexity increases the transaction costs of defining clear property rights and of transferring water.

Table 2 summarizes the types of water supply institutions in 12 western states as of 2005. The data reveal the diversity of organizations that potentially are involved in any decision making regarding water transfers.

Table 2
Number of Water Supply Organizations by State and Category, 2005

State	Irrigation District	Water District	Water Conservation District	Mutual Ditch Company	Municipal Water Organization	Other*
Arizona	38	1	7	0	25	60
California	53	97	11	8	22	101
Colorado	4	3	27	0	17	92
Idaho	60	0	0	19	0	53
Montana	54	1	0	0	0	8
New Mexico	4	0	6	0	9	13
Nevada	2	2	4	0	3	18
Oregon	45	1	0	3	1	24
Texas	26	2	1	0	2	15
Utah	1	0	8	0	1	74
Washington	41	0	0	0	0	22
Wyoming	21	0	1	5	0	11

*Other includes state and municipal water authorities, flood control agencies, Indian tribes, water user associations. Source: Water Users Organizational Roster, US Department of Interior, Bureau of Reclamation, 2002; Arizona: <http://www.ag-management.com/water/districts.asp/>; California: <http://www.lib.berkeley.edu/WRCA/district.html>; Colorado: <http://cdss.state.co.us/>; Idaho: Idaho Department of Water Resources; Montana: DNC Water Rights Owner Listing; Nevada: Division of Water Resources; New Mexico: New Mexico Department of Agriculture; Oregon: <http://www.owrc.org/basins/owrcbasn.htm>; Texas: Texas Water Resources Institute, Texas Commission on

Environmental Quality and <http://www3.tnrcc.state.tx.us/iwud/reports/index.cfm>; Utah: Division of Water Rights; Washington, State Water Resources Association; Wyoming: Water Development Commission.

Most of these water organizations were formed in the 19th century to facilitate joint water collection and investment in water infrastructure, such as diversion dams and irrigation ditches. They avoided holdouts or free riding because only members could use the infrastructure. As state licensed agencies, they could restrict access by outsiders and take legal action against recalcitrant members.⁷²

Mutual Ditch Companies. With mutual ditch/reservoir companies, farmers (or other users) hold shares in the company and receive water based on the number and priority of shares held. While individual shares may be sold, any change in water diversion or use must be approved by the company board, state regulatory agencies, and potentially, by the courts to insure that there is no injury to other share holders.⁷³ Mutual ditch companies can levy assessments on shareholders to cover investment and maintenance expenses, but they cannot float bonds or tax to redeem them as can irrigation and conservancy districts.⁷⁴

Irrigation Districts. Irrigation districts are the most common type of water supply institution.⁷⁵ They are political subdivisions of the state with the ability to condemn property, to tax all lands within the district to cover operating expenses and pay debts, and to issue tax-exempt bonds.⁷⁶ The governing board is elected and voting rules vary, either where only members have the right to vote or where there is a broader franchise, including citizens in any community surrounding the district. The board undertakes infrastructure maintenance, oversees surface water use, evaluates and approves water transfers, and may have jurisdiction over groundwater withdrawals.⁷⁷

The majority of districts legally own water rights on behalf of their members, who have contracted amounts of water delivered to them. In other cases, members retain their water rights

and have water service contracts with the district.⁷⁸ In either event, all members typically have the same priority of appropriative water rights under the district's group claim. Allocation of water is based on individual water rights, irrigable acreage or some other mechanism agreed to at the time of district formation. Districts also prorate charges for water supply in proportion to their entitlements.

Because historically water often was not scarce and was inexpensive, the actual water rights relationship between the district and its members was left vague. Any transfers were among members and arranged informally to meet seasonal shortfalls. There was little money at stake or controversy. This is no longer the case today where water values at the margin are much higher and transfers increasingly are to out-of-district users. Potential revenues to water sellers are very large for districts near urban areas.

The costs to the district of handling sales depend on the size and nature of the exchange. These include the costs of metering and enforcing individual allocations so that those who sell do not take their neighbor's water, of water transport, and of monitoring groundwater withdrawals. The revenues and costs of water exchanges must be apportioned among district members, but past ambiguity in rationing and management rules means that allocations may be arbitrary, unpredictable, and controversial.⁷⁹

District officials often are much less interested in selling or leasing water under their jurisdiction than are their members. Indeed, Thompson argues that most irrigation districts have been hostile to long-term water transfers out of district. He calls for legislation to explicitly allow transfers either by irrigation districts or their members and to provide clear water rights and profit sharing rules within the districts.⁸⁰ There are several reasons why governing board officials oppose water transfers desired by some of the district members. The authority of district

managers can be reduced if fallowing is extensive and district agricultural activities decline. Irrigation districts can be harmed financially if reduced water requirements leave them with stranded non-deployable fixed capital investments.⁸¹ There also can be increased administrative costs for the board as it evaluates and monitors the effects of water sales. Because of a lack of clarity in district charters as to profit and cost sharing, the distribution of the revenues and costs of transfers is not straightforward and discretionary board decisions can be divisive and politically costly for officials.⁸² District members, who are not part of the transaction, will not want to shoulder costs involved. They also will be concerned about any spillover effects on their water supplies. These allocation problems are more challenging if the district is heterogeneous with respect to farm size, crop patterns, water use, and farmer support for transfers.⁸³ Board officials must also manage groundwater withdrawal if surface sales lead farmers to turn to groundwater for replacement. The board is responsible for the district-wide effects of subsurface water drawdown.

The nature of voting rules for board membership can importantly affect district support for water transfers. Because current marginal urban water values are high relative to similar agricultural values, farmers generally are motivated to sell or lease at least some of their water. They capture most of the returns. If farmers elect the governing board of the district, the board is apt to support those transfers. If board members are elected by a broader electorate with differential incentives to transfer water, then the board may not be as supportive of water exchanges.

Consider two large irrigation districts in southern California that receive Colorado River water, the Palo Verde Irrigation District (PVID) and the Imperial Irrigation District (IID). The PVID board is elected by member farmers and as such, reflects their interests. The 5-member IID

board holds the water rights in trust for its members and is the decision-making body for water transfers. Unlike the PVID board, it is elected communitywide, so that its constituencies are much more heterogeneous. Accordingly, the IID board is more likely to be responsive both to legitimate concerns about the negative effects of fallowing on the local farm economy and to strategic efforts by non farmers who seek a share of the financial returns of any water trade. Both districts have been in negotiations with the Metropolitan Water District of Southern California (MWD) that provides water for 26 cities and water districts representing 18 million people in 6 counties.⁸⁴ The experiences, however, have been quite different.

The Board of the PVID and the MWD began negotiations in 1992 for the transfer of Colorado River water. The water was to be released through fallowing of slightly more than 20,000 acres of farm land, a switch to less water-intensive crops, and through greater use of ground water. Without much controversy, the MWD acquired 93,000 acre feet (a.f.) of water (326,000 gallons per acre foot) by paying farmers to fallow about 22 percent of their lands on a rotational basis. The MWD paid growers \$620 per acre or \$135 a.f., and stored the water in Lake Mead for use by 2000. The implied price was \$350/a.f. (given loses from evaporation and risk of flood control releases from Hoover Dam). In 2002, the MWD began negotiations with PVID for a longer term program that was finalized in 2004. The MWD acquired options for up to 100,000 acre feet of water for 35 years for an upfront payment of \$3,170/acre plus \$602/acre if the land were actually fallowed.⁸⁵

In contrast, negotiations between the MWD and the IID board to secure Colorado River water for urban use were much more contentious. IID receives a huge amount of Colorado River water, supplied by federally-funded infrastructure, Hoover Dam and the All American Canal. The 82-mile canal brings some 3.1 million acre feet a year of California's total allocation of 4.4

million acre feet of the Colorado River.⁸⁶ As late as 2002, IID farmers paid the board approximately \$15.50 per acre foot for their water.⁸⁷ Because of the large amount of water that the Imperial Irrigation District commands, it naturally has been the focus of reallocation efforts.

Discussions between the IID board and the MWD began in 1984 over the exchange of water conserved from lining irrigation canals.⁸⁸ The IID entered into the negotiations following a decision by the California Department of Water Resources that the district's water use and associated excessive runoff from unlined ditches was not reasonable and beneficial as mandated by state law. The agency required the district to implement conservation practices or risk loss of its water rights. As the negotiations dragged on, the California State Water Resources Control Board (SWRCB) in 1988 ordered the district to conserve 100,000 acre feet by 1994.⁸⁹ A Memorandum of Agreement was reached in 1993. The arrangement was supported by both federal legislation that authorized the lining of the All American Canal and the California Water Code that authorized the sale, lease or other transfer of conserved water as a beneficial use without endangering water rights.⁹⁰

Under the agreement, the MWD paid \$233 million for a capitalized price of \$1,500/a.f. for 109,000 a.f. per year of conserved Colorado water for 35 years.⁹¹ The MWD payment covered concrete lining of canals, the installation of non-leak gates, and the construction of holding reservoirs.⁹² The arrangement, however, was challenged in court due to feared effects of reduced return flow to the Salton Sea from the export of conserved water. Another agreement was concluded in 1998 to conserve 200,000 acre feet of water to be transferred to San Diego annually for \$50 million a year and 50,000 acre feet each to the Coachella Irrigation District and Los Angeles. Additional challenges from various constituencies led to revisions, new rounds of negotiations, and eventually to a Quantification Settlement Agreement in 2002 involving IID,

PVID, and the Coachella Valley Water District. This agreement required these three organizations to quantify their water rights at a specific level so that agricultural use of water did not increase. IID was under pressure to consent due to threats by the Department of the Interior to reduce its supplies of Colorado River water.⁹³

Under the accord, fallowing of IID land was held at 30,000 acres of 450,000 irrigable acres in the district. Funds for mitigation of any negative effects were provided by the city of San Diego, one of the major recipients of MWD water.⁹⁴ Although studies indicate that limited fallowing might have only small effects on the local economy, the structure of the IID Board made it very responsive to community concerns.⁹⁵

The Bureau of Reclamation.

The Federal Bureau of Reclamation is the largest wholesaler of water in the U.S. and it provides irrigation water for 140,000 farms covering 10,000 acres in 17 western states. It has over 600 dams and reservoirs to capture and divert water, historically, mostly for irrigation.⁹⁶ The Bureau was created in 1902 by the Federal Reclamation Act, which was designed to promote settlement of the West with investments in water projects to mitigate the region's natural aridity. Most irrigation districts receive their water through federal reclamation projects, and legislation enacted early in the 20th century recognized irrigation districts as holders of water rights and as the organizations responsible for repaying part of the costs of reclamation projects. The Bureau provides water to the irrigation districts through long-term service contracts. In other cases the Bureau holds an appropriative right to the water within a reclamation project and the water can be distributed anywhere within the project.⁹⁷

The Bureau historically has had uneven policies toward water transfers.⁹⁸ Because of its role as a major supplier of water, the agency importantly influences the extent of trade. Recently

it has become a more active proponent of water marketing. During California's serious drought of 1976-1977, for example, the Bureau formed a temporary water bank for members to access within the Central Valley Project (CVP) to facilitate exchanges to meet the emergency.⁹⁹ In 1992, the Central Valley Project Improvement Act also promoted the trade of Bureau-supplied water within the project for new uses. It called for more operational flexibility in the allocation of federally-supplied water and for recognition of wetlands and wildlife habitat restoration as beneficial use of water, along with traditional irrigation and residential demands.¹⁰⁰ Under the law any individual receiving CVP water could transfer water to any other California water user or agency with limited restrictions. Only circumscribed review was required, with approval by the Secretary of Interior or as necessary, by the state regulatory agency within 90 days. An irrigation district could veto the transfer only if it involved more than 20 percent of the CVP water received by the district, and even then, rejection could be only on narrow grounds.¹⁰¹ The law also allowed irrigation district members to negotiate separately for the sale or lease of their water with potential purchasers or renters, thereby avoiding opposition by district boards.¹⁰²

Indian Tribes.

The water held by Indian tribes potentially is a major source of water for marketing. Indian tribes have reserved water rights sufficient for the development of agriculture on their reservations. Their water rights date from when the reservation was established by treaty with the federal government, which was usually in the 19th century, and therefore generally supersede the priority of non-Indian claimants.¹⁰³ Many of these treaty provisions have only been recently enforced and Indian water rights adjudicated through litigation or congressional statute. As water prices have risen, tribes have begun to be active participants in water markets. For example, several Arizona tribes, including the Salt River Pima-Maricopa Indian Community, have agreed

to water rights transfers in exchange for money and Central Arizona Project water.¹⁰⁴ At the same time, however, tribes are subject to state law regarding the effects on other rights holders from their water trades. Table 3 summarizes data on Indian tribes by state where the tribe already is involved in water supply activities.

Table 3
Indian Tribes as Water Supply Organizations, by State, 2005

State	Number of Indian Tribes as Water Supply Organizations
Arizona	15
California	3
Colorado	2
Idaho	2
Montana	0
New Mexico	1
Nevada	0
Oregon	1
Texas	0
Utah	0
Washington	1
Wyoming	0

Source: See Table 2

The many water supply organizations and institutions that exist in the West all have a say in the nature and extent of water rights and their exchange. The complexity of these organizations alone would raise transaction costs, but they also involve multiple and often conflicting incentives for water trades. The standing of each of these parties, the nature of water rights held, and the administrative processes encountered in water transfers, in part, vary according to the differing regulatory environments that exist in each state.

V. State Policies Regarding Water Rights and Exchanges.

State Policies.

Under state water law throughout the West, water transfers that involve no changes in nature, timing, or location of use, typically do not require state approval. For other transfers,

however, regulatory review is necessary.¹⁰⁵ In Arizona, for instance, the regulatory authority rests with the Department of Water Resources; in Colorado for trades outside of the Northern Colorado Water Conservancy District with the Department of Natural Resources; in New Mexico, Utah, and Oregon with the State Engineer.¹⁰⁶

Among the western states, California has the strongest pro-transfer laws, but the regulatory and property rights environments are less supportive. These include mixed jurisdictions among state and federal agencies, a patchwork of county regulations of groundwater withdrawal and export, and a complex system of water rights with differential requirements for agency review.¹⁰⁷ For example, only transfers of surface water rights acquired since 1914 require approval of the State Water Resources Control Board (SWRCB). Exchanges within the huge Central Valley Project (CVP), usually involving short-term agricultural water trades, do not involve the SWRCB. The Federal Bureau of Reclamation has jurisdiction. Similarly, within the State Water Project, the SWRCB may not be required in transactions that do not modify the nature or timing of use.¹⁰⁸

At the same time, California regulatory requirements raise the costs of exchange despite federal and state laws designed to promote transfer.¹⁰⁹ Under the no-injury rule an appropriator may not move the point of diversion or return flow or alter the place or purpose of use if the change would deprive other water rights holders of water to which they are legally entitled.¹¹⁰ Because there so many irrigation districts and supply organizations within the CVP with interlaced claims to water, any transfer by one entity to outside buyers is apt to affect another claimant. As a result, the administrative process can be lengthy and complex, and the outcome uncertain. These factors reduce the expected gains from trade.

Further, California counties are able to restrict extraction and export of groundwater out of county, and as of 2002, 22 of 58 counties had done so.¹¹¹ These county ordinances similarly can limit surface water transactions if they appear to diminish groundwater resources, either through lowered recharge or through greater farmer reliance upon pumping. Although there are legitimate groundwater issues at stake, recent research by Hanak (2003, viii) suggests that the overriding aim of the ordinances is to keep water within rural counties and limit reallocation to urban or environmental uses.

Among other states, New Mexico also is viewed as having a supportive legal and regulatory structure for water trades. Its exchanges are relatively free of contention because they are based on consumptive use, and the State Engineer plays an active role in evaluating proposed transfers. Approval of trades can occur within three months.¹¹² In contrast, in Colorado (outside the Colorado Big Thompson Project) water courts provide a forum for opposition to trades, and a larger portion of Colorado water transfers were opposed than in New Mexico.¹¹³ Wyoming's legal system also has been interpreted as being more hostile to water trading.¹¹⁴

Historically, Arizona has had relatively fewer transactions that involve changes in purpose or place due to a relatively unfriendly court system, prohibitions against transferring water outside Salt River Project boundaries, a major water supply organization in the state, as well as extensive groundwater aquifers that limited the need to exchange water.¹¹⁵ Further, all water supply organizations within a drainage area must approve proposed transfers before state approval can be given. This authority gives those organizations a potential veto on any proposed transfer without having to prove harm.¹¹⁶

In Arizona, access to groundwater is relatively more important than in other western states. And, as noted above, groundwater rights are particularly ambiguous. In Arizona, there are

no quantified water rights to ground water outside of the five Active Management Areas (AMAs) in the center of the state.¹¹⁷ In non AMA regions, withdrawal is based on reasonable and beneficial use with little real constraint on pumping.¹¹⁸ Even in the AMAs, there is little protection against competitive overdrafts.¹¹⁹ In Arizona, as elsewhere in the West, actual ownership of groundwater comes with extraction.¹²⁰ Within the AMAs, the Groundwater Management Act of 1980 created three types of groundwater rights, and each has different opportunities for trading. Grandfathered water rights are irrigation rights that are tradable only with farm land for agricultural use.¹²¹ Grandfathered rights can be converted to Type I water rights for non-irrigation uses within the AMA, but they still remain appurtenant to the land. This stipulation has limited their exchange. The final water rights are Type II rights. They do not involve historical irrigation water and are not appurtenant to the land. They can be traded within the AMA separately from the land.

In Colorado, surface water is more important than in Arizona, and there are different regulatory structures for the Northern Colorado Conservancy District that manages Colorado Big Thompson (CBT) water and for other parts of the state. In most of Colorado, water courts handle damage claims for proposed water transactions, and these are often hotly contested.¹²² But in the CBT, the courts do not have jurisdiction. All return flow rights are granted to the district so that all diversion effects are internalized within the district. Each user has the same priority right and a legal claim to a number of uniform water units that are tradable.¹²³ There are no junior claimants who depend on tail water. As a result CBT water can be sold without having to determine the amount of consumptive use and return flow.

Regulatory Review and Transaction Costs.

In any application to transfer water, the applicant must describe the size, duration, and timing of the proposed exchange, the type of water rights involved with, as necessary, information on consumptive use and how other parties are (not) affected. The application is reviewed by the agency for completeness and accuracy. Additional hydraulic and legal information may be required. Basic issues of concern to the agency are protection of junior appropriators regarding quantity, quality, and seasonality of water; concern about existing communities and “public welfare;” and protection of the environment.¹²⁴ Out-of-basin transfers are not prohibited, but are scrutinized more carefully.

Agency review of the transfer application is followed by public notice and review. Objections are examined for their merits and included in the formal hearings. The burden of proof of no harm from the transfer usually rests with the applicant, although in some cases protestants must demonstrate injury.¹²⁵ The outcome of administrative review includes approval, approval subject to modification, or denial, as well as provision of opportunities for appeal.¹²⁶

Objections to proposed transfers by junior rights holders may be resolved by adjustments in the amount of water, timing, or allowable uses in the exchange. Monetary payments or other forms of compensation also may be included. The resolution of other third party complaints, however, may not be so straightforward. If substantial amounts of farm land are fallowed, there could be reduction in local demand for farm labor and in wholesale and retail trade within rural communities.¹²⁷ Assessing the legitimacy and appropriate size of compensation to be paid for any pecuniary impacts on farm labor and local merchants is complicated. There must be agreement on the damages, who should pay, and the terms and conditions of payment. All of these are likely to be controversial.

Additional third party effects are apt to be even more difficult to address. Rural politicians may find their political base eroded if large water transfers led to a decline in agricultural activities.¹²⁸ Other local officials, including school district administrators and county extension agents may be similarly affected. Here it is hard to imagine how compensation might be crafted. Because these damages are hard to measure, monetary payments would be difficult to determine, and more importantly, under current law and political practices, they would be both illegal and unethical. Accordingly, local politicians and bureaucratic officials have incentive to oppose water trades in their own self interest as well as in the interest of other constituencies who may be harmed.

Despite these concerns, most studies suggest that these third-party effects will be small. Only limited amounts of water and fallowing are involved in most transactions. Acreage and water adjustments are concentrated in low-productivity areas and crops, minimizing the pecuniary effects. And there are monetary benefits from the sale of water. For example, the idling of between 6 and 29 percent of farm acreage in an area has been estimated to be offset by local economic gains from water payments.¹²⁹ Larger amounts of fallowing of course, could have more substantial impacts.¹³⁰

The costs of meeting state procedural requirements for water trades include the cost of fulfilling notice requirements, time cost in preparing for and attending hearings on a proposed transfer, costs associated with meeting an applicant's initial burden of proof – a *prima facie* showing that the proposed water transfer will not harm third parties; and where protesters demonstrate harm, the cost of attempting to refute or accommodate protesters' claims. There also is another cost, the risk that procedures themselves will reveal weaknesses in the applicants claimed water rights.¹³¹

In sum, the transaction costs of water exchange in western states include search costs not only in identifying the relevant parties for trade, but also in locating the various parties that might be affected (down stream rights holders, instream rights holders if they apply, and others with amenity or other concerns). There are negotiation costs among the transactors that rise if the water rights are complex or uncertain. Negotiation costs also involve representatives of local irrigation districts or other water supply organizations, as well as officials of state agencies who are in charge of approval. Measurement costs include engineering and hydraulic studies of diversion, consumptive use, return flow estimates, and groundwater withdrawal, depending on the nature of the transfer. Enforcement costs include insuring compliance with the provisions of the contract among the transactors as well as insuring that water is not appropriated by others not party to the agreement. These transaction costs rise with the size of the exchange, the priority of the water rights involved, the number of parties included, and changes in the nature and time of use and point of diversion.¹³²

There are estimates of the transaction costs of water trades across the western states. In 1990 in Colorado and New Mexico, for example, transaction costs ranged from \$200-\$380 per acre foot. At that time mean price in water sales in New Mexico was \$2,167.¹³³ 1993 estimates of transaction costs in those same two states varied from a few hundred dollars to \$50,000, with mean costs of \$300 per acre foot on transfers of 20 acre feet or less. With a mean transaction price of \$1,500, transaction costs could account for 20 percent of the purchase price or more.¹³⁴ Processing times took from slightly over 4 months in New Mexico and 5 months in Utah to 29 months in Colorado.¹³⁵ The procedural process and related transaction costs vary across the western states, in part because the no harm and public interest effects are defined differently.¹³⁶

For these reasons, the price gaps between urban, agricultural, and environmental water uses at the margin are large and have persisted for some time.

VII. Water Price Differentials.

The persistence of high water price differentials between agricultural and urban and environmental uses reflects the lack of extensive, smooth market trades. They also indicate the costs of misallocation of water. In 1992, Griffin and Boadu, (1992 p. 274-5) reported that the value of water used in agriculture, capitalized over 50 years, was \$300 to \$2,300/a.f. in the Rio Grande Valley of Texas. Urban water values, capitalized over the same period ranged from \$6,500 to \$21,000/a.f. These differences indicate significant social gains from re-allocating water and Griffin and Boadu suggested that the average transfer produced net benefits of \$10,000/a.f. Similarly, in recent efforts to secure Imperial Irrigation District water, San Diego offered \$225/a.f. for water annually that farmers used for \$15.50.¹³⁷

Table 4 provides summary data to illustrate the prices paid for water trades as reported in the *Water Strategist* February 2005, “Annual Transaction Review.” Although, the reported data reflect only 15 of the 251 reported transactions in 2004 and are from just 3 states, they are suggestive of the comparatively higher values reported across the region for urban use relative to irrigation. Colorado Big Thomson units generally sell for higher prices, regardless of use because of the well-developed nature and security of water rights in that water market.

Table 4
Sample 2004 Prices Paid in Water Transfers

State	Previous Use	New Use	Transaction	Amount (acre feet)	Price (\$/acre feet)
Arizona	Irrigation	Municipal	Purchase	1.4	2,800
Arizona	Irrigation	Municipal	Purchase	53	1,500
Arizona	Irrigation	Municipal	Purchase	118	4,000
Arizona	Irrigation	Municipal	Purchase	27	3,000
California	Irrigation	Municipal	Option Lease	80,000	125
California	Irrigation	Municipal	Purchase	1,988	1,600

California	Irrigation	Municipal	Purchase	12,216	1,050 ¹
California	Irrigation	Irrigation	Lease (1 year)	487	88
California	Irrigation	Irrigation	Lease	1,257	85
California	Irrigation	Environmental	Lease	25,000	27
California	Irrigation	Environmental	Lease (3 years)	9,350	105 ¹
California	Irrigation	Environmental	Lease	155,000	137 ¹
Colorado	Irrigation	Municipal	Purchase	100 ²	11,500 ²
Colorado	Irrigation	Municipal	Purchase	126 ²	10,900 ²
Colorado	Irrigation	Environmental	Purchase	Ditch shares	1,444
Colorado	Irrigation	Environmental	Lease (1 year)	2,000	40
Colorado	Irrigation	Irrigation	Purchase	8	11,750

Notes: ¹ Mean price. ² The Colorado transactions were from the Colorado Big Thompson Project and were in units. A unit is 1/310,000 of the 310,000 acre feet in the Northern Colorado Conservancy District. The conversion generally is 1 unit to 1 acre feet, although it may be less.

Lease duration provided when included in source.

Source: *Water Strategist* "2004 Water Transactions," February 2005, pp. 12-16.

Further insights into the differential marginal values for water used in agriculture and in urban and environmental uses can be obtained by examining the price differences for agriculture-to-urban and environmental uses (agriculture-to-urban and environmental) and for agriculture-to-agriculture and other (urban to urban, urban-to-environmental, urban-to-agriculture) trades drawn from 1,915 trading observations reported in the *Water Strategist* from January 1987 to April 2004 for 12 western states. A difference in means test for prices paid for these two types of exchange is shown in Table 5. The price series includes short (leases for 1 year or less) and long-term transactions (sales and longer leases), and prices for transactions longer than one year are converted to the value of an annual flow of water.¹³⁸ Other controls are not possible due to a lack of data, but even so the annual mean per acre foot prices for agriculture-to-urban and environmental trades of \$573 for the over 7 year period are about twice the mean of \$285 for agriculture-to-agriculture trades, and the differences are statistically different.¹³⁹

Table 5
Water Transfer Price Gap Analysis

Type of Trade	Number of Observations	Mean Price	Std. Err.	95% Confidence Interval	
Agriculture to	1,152	\$573	21.35	\$532	\$615

Urban and Environmental					
Other Water Trades*	763	285	22.24	241	329

*Includes agriculture-to-agriculture, urban-to-urban, urban-to-environmental, urban-to-agriculture.

Not only are prices for non-agricultural uses higher than for agricultural uses, but the gap between the two is growing as urban and environmental demands increase relative to those in agriculture. Figure 1 shows a plot of the two price series by year from 1987 through 2003 and Figure 2 shows the price differential between the two.

Figure 1
Transfer Prices for Agriculture-to-Urban and Environmental Uses and for Agriculture-to-Agriculture and Other Uses

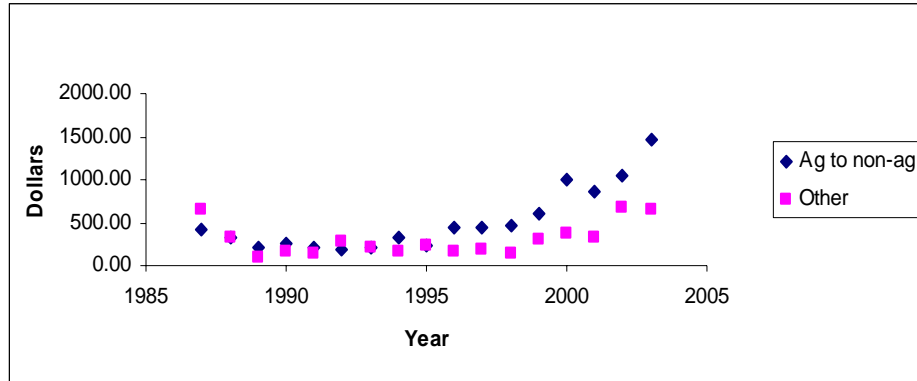
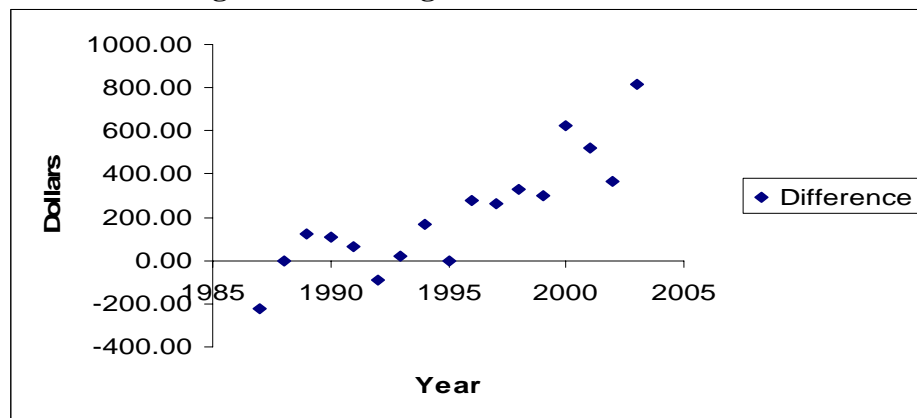


Figure 2
Price Differentials between Agriculture-to-Urban and Environmental and Agriculture-to-Agriculture and Other Trades



As indicated in the figures, the price differences between agriculture-to-urban and environmental trades and agriculture-to-agriculture trades have been growing since 1994. The existence of large price differentials across uses suggests that reallocation of some water would be socially beneficial. In smooth-functioning markets, arbitrage would accomplish that end and the differential would be narrowed to a spread reflecting shipment costs for water of comparable quality. Conveyance costs alone, however, cannot account for the price differences reported in the tables and in the figures. Other transaction costs are the culprits. They arise from the incomplete nature of property rights to water and procedural requirements of state regulatory agencies, including judicial review, for water transfers. These transaction costs vary across the states according to how water rights are defined and the administrative rules used for water exchange. The following section describes the recent pattern of water transfers across 12 western states.

VII. Water Transfers in 12 Western States 1987-2003.

All western states allow for transfers of appropriative and riparian water rights although as noted above, some states are more supportive of water exchanges than are others. There are three types of transfers—permanent sales, short-term leases (1 year), and longer-term leases (up to 35 years or more). Among these, there are transfers among those who use the water for the same purpose—irrigated agriculture for example, or among those with different purposes—agriculture-to-urban or environmental, and transfers within a water basin (where sources are interrelated geologically) or across basins—out of one water region to another. Short-term leases within a basin among those who use water for the same purpose, such as farmers, typically have been the most common. They generally are uncontroversial because they involve fewer third

party effects—the water stays in the area, remains in a particular use so that consumption, return flows, or recharge patterns are not much affected.

Sales and longer-term leases naturally are more complex, even within a region and among its users, if the diversion point is changed. Such changes could affect other claimants by disrupting existing flow patterns and the availability of water. Further, long-term leases or purchases that change the purpose of use, even within the same basin, can be controversial because they can increase consumptive use (agriculture to urban) and hence, impact return flows and recharge. Long-term leases and purchases that ship water out-of-basin have the most overall impact on the exporting region because the water will not be available for local drainage and renewal.

Figure 3 illustrates the path of all transfers in the 12 western states from January 1987 through January 2004.¹⁴⁰ The data are drawn from the *Water Strategist* and include 2,751 water transfers over that 17-year period.¹⁴¹ Agriculture-to-non agricultural trades are those to urban and environmental uses. Within this category, the number of agriculture-to-urban transfers is far larger, at 1,507 transactions, as compared to 162 for agriculture-to-environmental. The “other” grouping includes agricultural-to-agricultural, urban-to-urban, urban-to-environmental, environmental-to-environmental and urban-to-agricultural exchanges. Within this group of 1,082 transfers, there are 435 agriculture-to-agriculture transactions or 40 percent of the total. As illustrated, the number of water transfers out of agriculture is growing over time.

Figure 3
Water Transfers, 1997-2003 by Category

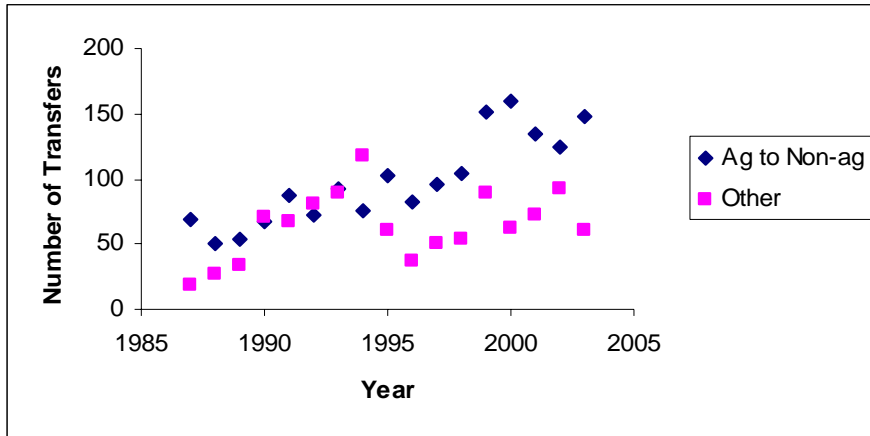


Table 6 summarizes the number of water transfers by year from 1987-2003 in the states according to whether they were short term leases (1 year or less), longer-term leases, or permanent sales. The portions of all transfers that were agriculture-to-agriculture, agriculture-to-urban and environmental, or other (urban-to-urban, urban-to-environmental, urban-to-agriculture) also are shown.

Table 6
Numbers of Water Transfers by Category, 1987-2003

Year	Short-Term Leases	Long-Term Leases	Sales	Total
1987	4	2	82	88
1988	9	3	65	77
1989	16	8	63	87
1990	36	9	94	139
1991	58	6	91	155
1992	42	4	108	154
1993	41	11	129	181
1994	59	6	127	192
1995	32	6	124	162
1996	28	8	83	119
1997	47	12	87	146
1998	32	15	110	157
1999	74	23	144	241
2000	57	12	153	222
2001	49	21	136	206
2002	52	19	145	216
2003	53	17	139	209
Total	689 (25%)	182 (7%)	1880 (68%)	2751

Year	Agriculture-Urban	Agriculture-Environmental	Agriculture-Agriculture	Miscellaneous*
1987	68	1	5	14
1988	46	4	8	19
1989	50	4	12	21
1990	61	7	32	39
1991	84	3	45	23
1992	63	10	51	29
1993	84	8	43	46
1994	65	10	50	67
1995	94	8	29	31
1996	74	8	23	14
1997	81	14	22	29
1998	91	13	12	41
1999	135	17	23	66
2000	144	15	17	46
2001	125	9	21	51
2002	111	13	24	68
2003	131	17	18	43
Total	1507 (55%)	161 (6%)	435 (16%)	647 (24%)

*urban-agriculture, urban-urban, urban-environmental, environmental-urban, environmental-environmental.

Source: *Water Strategist*

As indicated in the table there is considerable variation in the number of transfers of all types by year. Nevertheless, there is a general rise in transactions over time. Short-term leases and sales are the most common form of transaction, with sales about three times the number of short-term leases. Agriculture to urban transfers are the most common transaction, accounting for 55 percent of the total; the catch all miscellaneous category is the next most frequent, followed by agriculture-to-agriculture and agriculture-to-environmental.

In terms of amounts of water traded there is a different picture. As shown in Table 7 agriculture-to-agriculture transactions involved about twice as much water in total as did either agriculture-to-urban or agriculture-to-environmental trades. Further, for the whole period, the mean size of an agriculture-to-agriculture transfer was 15,656 acre-feet as compared to 2,264 acre-feet for agriculture-to-urban trades and 20,317 acre-feet for agriculture-to-environmental transfers. Hence, while there were more frequent transfers from agriculture-to-urban areas, they

were relatively smaller than either agriculture-to-agriculture or agriculture-to-environmental transactions.¹⁴² The miscellaneous category involved the largest amounts of water in total. This category is dominated by urban-to-urban transfers, which account for 60 percent of the amount of water in that category and 68 percent of the number of transfers within the group.

Table 7
Water Transfers by Amount in Acre Feet and Category, 1987-2003

Year	Agriculture-Urban	Agriculture-Environmental	Agriculture-Agriculture	Miscellaneous*	Total
1987	152,979	10,000	1,665	7,889	172,532
1988	103,223	75,315	178,538	91,430	448,506
1989	267,503	1,392	273,717	118,859	661,877
1990	95,185	73,947	637,134	1,080,316	1,886,582
1991	688,740	142,056	736,478	944,327	2,511,601
1992	137,958	118,230	560,309	907,442	1,723,940
1993	206,026	226,000	863,950	432,616	1,728,591
1994	38,776	406,735	1,079,379	896,960	2,421,850
1995	69,006	60,015	68,418	699,689	897,128
1996	46,285	316,269	670,000	225,163	1,257,717
1997	196,344	406,380	116,007	622,202	1,340,933
1998	225,037	83,471	71,993	467,405	847,906
1999	216,748	343,302	118,790	1,173,737	1,852,576
2000	157,674	299,074	746,233	1,447,501	2,650,481
2001	171,870	143,120	376,656	667,893	1,359,538
2002	105,815	298,019	135,891	1,350,431	1,890,156
2003	533,096	267,678	175,155	573,123	1,549,053
Total	3,412,264	3,271,003	6,810,311	11,706,981	25,200,966

*urban-agriculture, urban-urban, urban-environmental, environmental-urban, environmental-environmental.

Source: *Water Strategist*

VIII. Concluding Remarks.

This essay outlines the complex nature of water rights in the American West as background for analysis of the limited development of water markets. Water trades take place and are growing in frequency and magnitude, but they are not sufficient to cause water prices to equalize on the margin, adjusting for transport costs. Transfers that involve changes in use and the timing and location of use are heavily regulated with options for multiple constituencies to challenge. These transfer regulations vary across the states, and in part, explain the observed

differences in the extent of transfers. The basis for strict state regulation lies in the interconnected nature of water uses, some rivalrous and some not, and the public trust doctrine.

In no case do individuals have clear, complete private property rights to water. The states hold water rights in trust for their citizens and private parties hold usufruct rights. Additionally, even these rights are often held by third parties, irrigation districts or similar organizations. Profit and cost sharing rules within districts are complex so that there may be no clear residual claimants to the returns from any transfer. Moreover, expansion of the public trust doctrine threatens to weaken water rights by stressing their non-vested, revocability without compensation. For all of these reasons water markets will require significant institutional change toward greater precision in the definition of individual water rights, if voluntary market transactions are to be the primary way of reallocating water in the western U.S. Similar issues are likely to exist in other semi-arid regions where increased fresh water scarcity will provide pressure for water reallocation.

An advantage of markets is their flexibility in responding to changes in water values. Of course, there is the problem of valuing non-traded, public goods uses of water. But there are increasingly sophisticated mechanisms for quantifying non-market values for guidance in allocation.¹⁴³ Another advantage of markets is that they can make reallocation routine, rather than relying on the political process, which by definition will be politicized and potentially contentious.

Historically, in the West, there was a single homogeneous constituency for water development and use—farmers and regional promoters who called on the Bureau of Reclamation, for instance, to construct dams and canals for new water sources for growing agricultural demand. The region's promoters were not to be constrained by its relative aridity.

Today, however, there are more constituencies involved in influencing water policy, and they are much more heterogeneous in their demands for scarce water. A wide range of theoretical and empirical work reveals that the larger the number of parties and the greater their heterogeneity, the more costly it is to reach agreement on water use.¹⁴⁴

Meeting new and often conflicting demands for scarce water involve reallocation from past uses to new ones. Water markets can be more effective than the political and regulatory process for many reallocations. Even where provision of public goods requires limits on private water use, water rights can be purchased and retired. In that way, more voluntary and less contentious redistributions are possible. Markets, however, require the definition of property rights and the lowering of transaction costs. Useful public policy responses then are to provide for the clearer definition and enforcement of property rights to water and to lowering the transaction costs of trading those rights. Comparisons with land and wild ocean fisheries have been made, and water has been shown to share many similarities with migrant fish stocks in terms of property rights definition. It is instructive to note that centralized fishery regulation for migratory fin fisheries generally has not been successful in conserving the stock or in protecting the economic value of the fisheries. Only the relatively recent turn to a property rights approach, individual transferable quotas (ITQ's) has brought some notable improvement.¹⁴⁵ A similar emphasis on strengthening property rights to water and facilitating trade is likely to have comparable beneficial results.

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- ¹ Tape GX0002 Leahey E.F. file, notes dated 11/13/no year, LADWP Archives.
- *² Glennon (2005, TLR).
- *³ Glennon (TLA, 2005). As pointed out by Hanemann (2005, note 29), this conditional also is historically true for urban areas where metering did not become common until well into the 20th century.
- ⁴ For discussion of property rights and markets for land, see Demsetz (1967).
- *⁵ Glennon (2005) on privatization.
- ⁶ See Sax (1994) and Hanemann (2005, 8) for discussion.
- ⁷ Hanemann (2005, 2) illustrates the confusion between marginal and average values for water that are implicit in arguments stressing its vital nature by discussing the diamond-water paradox presented by Adam Smith.
- ⁸ This discussion borrows heavily from Hanemann (2005, 15-6), Griffin and Boadu (1992), Young (1986), and Young and Haveman (1985, 465-71).
- ⁹ Hanemann (2005, 15).
- ¹⁰ For discussion of property rights in land, see Ellickson (1993, 1327 for discussion of ease of monitoring boundaries; 1362-3 for discussion of the bundle of property rights in land; 1381 for discussion of partitioning land across private and public uses.
- ¹¹ See Hannesson (2004).
- ¹² See Myers and Worm (2003) for example on the precarious nature of many wild ocean fisheries. It is the case that in some fisheries, increased competition as resulted in the establishment of property rights to the right to fish with individual tradable quotas (ITQ's). See Leal (2005, 1-20) for summary.
- ¹³ Johnson et al (1981, 279)
- ¹⁴ Young (1986, 1144).
- ¹⁵ Hanemann (2005, 9).
- ¹⁶ Griffin and Boadu (1992, 270)
- ¹⁷ For discussion see Glennon (2002, 210-24).
- ¹⁸ Thompson (1993, 707).
- ¹⁹ For discussion, see Gould (1995, 94).
- ²⁰ In New Mexico transfers are based on consumptive use, rather than diversion (MacDonnell, 1990, 27).
- ²¹ Colby (1990), MacDonnell (1990, 53), Howe, Boggs, and Butler (1990).
- ²² Gould (1995, 95), Simms (1995, 321).
- ²³ Sax (1994, 14) references use of the public trust doctrine in the Mono Lake case of *National Audubon Society v. Superior Court*, 33 Cal. 3rd. 419, 1983, whereby Los Angeles was restricted from excessive diversion of water from the surrounding watershed that was causing Mono Lake's level to decline. The city was required to limit diversion of water, even though it held the water rights due to purchase of properties in the 1930s. Hence, the city's water rights were weakened. An alternative approach would have been to purchase water rights from Los Angeles in order to raise the lake's level.
- ²⁴ Heller (1998).
- ²⁵ See Wiggins and Libecap (1985), Libecap and Smith (1999).
- ²⁶ Calls by Glennon (1991, 2005), Gray (1996), Thompson (1993), and Sunding (2000) among others.
- ²⁷ For example, in Arizona under ARS 45-181 surface water is public; ARS 45-141 (A) water belongs to the public subject to appropriation and beneficial use. See Bokum (1996) for discussion of New Mexico and Gould (1995, 94).
- ²⁸ Wyoming Rules and Regulations, State Engineer, Ch1, Sec 4. Water is property of the state. WY ST 41-3-101 says that individuals can have rights for beneficial use and they can be sold with the land or detached from the land. Any change in place requires no injury rule, WY ST 41-3-104. See also the Wyoming Constitution Art 8, 1.
- ²⁹ Gould (1995, 94), Simms (1995, 321).
- ³⁰ Getches (1997, 11).
- ³¹ Sax (1990, 260), Gray (1994b, 262).
- ³² Getches (1997, 8).
- ³³ Getches (1997, 74-189).
- ³⁴ Thompson (1993, 681), Glennon (2002, 14-21).
- ³⁵ Getches (1997, 81).

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- ³⁶ See discussion of first possession in Epstein (1979), Rose (1985), and Lueck (1995, 1998).
- ³⁷ Getches (1997, 83).
- ³⁸ Getches (1997, 156-60).
- ³⁹ Getches (1997, 168-70).
- ⁴⁰ Anderson and Johnson (1986) and Johnson, et al (1981). Johnson, et al describe how specifying a property right in water in terms of consumptive use with options for third party grievances can be an effective method for promoting transfers.
- ⁴¹ Anderson and Johnson (1986) discuss the problems of defining rights to instream flows under the current appropriative water rights doctrine when diversions or instream flow rights are large relative to stream size.
- ⁴² Getches (1997, 98-146), Simms (1995, 323).
- ⁴³ For example, see Instream Rights Act of 1987 in Oregon (ORS 537.350).
- ⁴⁴ Getches (1997, 146), Simms (1995, 323-4).
- ⁴⁵ See summary of open access losses in Libecap (1998, 318).
- ⁴⁶ Getches (1997, 33).
- ⁴⁷ Thompson (1993, 682).
- ⁴⁸ Getches (1997, 87-93, 192-97).
- ⁴⁹ Thompson (1993, 684).
- ⁵⁰ Getches (1997, 251).
- ⁵¹ For discussion, see Glennon (2002, 8, 30, 210).
- ⁵² Provencher and Burt (1993). For similarities with oil pools, see Libecap (1989, 93-114).
- ⁵³ Getches (1997, 247-53), Glennon (2002, 209-24).
- ⁵⁴ Thompson (1993, 684-5).
- ⁵⁵ Getches (1997, 217, 224-8).
- ⁵⁶ *National Audubon Society v. Superior Court*, 685 P.2d. 712.
- ⁵⁷ In Oregon the public trust doctrine was extended to cover excessive diversions from non navigable rivers (Yates, 1997). See also Blumm and Schwartz (1995). The case involving public trust, Mono Lake and Los Angeles water rights, *National Audubon Society v. Superior Court*, 33 Cal. 3d 419, 189 Cal. Rptr. 346, 658 P.2d 709, 1983 Cal. LEXIS 152, 21 Env't Rep. Cas. (BNA) 1490, 13 Env'tl. L. Rep. 20272 (1983). See also, Sax (1990, 270) for discussion of subsequent cases in California that expanded the public trust doctrine. See also Gray (1994b, 262-69).
- ⁵⁸ Simms (1995, 321).
- ⁵⁹ Sax (1990, 264, 269).
- ⁶⁰ *Shokal v. Dunn*, 109 Idaho 330, 707 P.2d 441, 1985; *Mineral County v. State of Nevada*, 117 Nev 235, 20 P.3d. 800, 2001; *Golden Feather Community Ass'n v. Ternalito Irrigation District*, 199 Cal. App. 3rd 402, 244 Cal Rptr. 830, 1988.
- ⁶¹ Sax (1990, 277).
- ⁶² Epstein (1987). For other discussion of public trust see Sax (1994), Anderson and Snyder (58-59).
- ⁶³ Blumm and Schwartz (1995, 707). See Bokum (1996) in calling for expansion.
- ⁶⁴ Blumm and Schwartz (1995, 709-11).
- ⁶⁵ A similar purchase and transfer approach for protection of the Colorado River delta is proposed by Glennon and Culp (2002).
- ⁶⁶ *In Re Water Hallett Creek Stream System*, 44 Cal. 3rd 448, 1988.
- ⁶⁷ For discussion of bureaucratic incentives, see the summary in Johnson and Libecap (1994, 1-11, 154-88).
- ⁶⁸ Johnson, et al (1981).
- ⁶⁹ Water User's Organization Roster, US Department of Interior. Bureau of Reclamation, as well as state agency sites.
- ⁷⁰ <http://www3.tnrcc.state.tx.us/iwud/reports/index.cfm?RequestTimeout=1000>. See also MacDonnell, Howe, Rice, 1990 in MacDonnell, Vol. II, p. 10- describes different kinds of water supply organizations.
- ⁷¹ Glennon (1991). Mutual companies are not examined separately from irrigation districts here, although there may be some differences on transfer incentives due to their organizational differences. See Thompson (1993, footnotes 171, 216).
- ⁷² Leshy (1982, 353) provides a summary of history. The Wright Act of 1887 in California was the first state law to license irrigation districts and was a model for use elsewhere.
- ⁷³ MacDonnell, Howe, Rice, 1990 in MacDonnell, Vol. II, p. 10-11.
- ⁷⁴ MacDonnell, (1990, Vol. II, 15-18).
- ⁷⁵ Leshy (1982), Rosen and Sexton (1993).

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- ⁷⁶ Thompson (1993, 687), MacDonnell, Howe, Rice, in MacDonnell, (1990, Vol. II, 11).
- ⁷⁷ For instance, in Arizona, A.R.S. § 45-172(A)(4) requires written consent of an irrigation district before a member can transfer water outside the district.
- ⁷⁸ Thompson (1993, 695, 725). Hanak (2003), and Smith (1994).
- ⁷⁹ Libecap and Smith (1999, 534) show that allocation rules in oil field units must apportion costs and revenues in the same way among members if the arrangement is to be incentive compatible.
- ⁸⁰ Thompson (1993, 678, 728, 740). The Wellton Mohawk Irrigation District in Arizona also resists water transfers. See discussion in Glennon and Culp (2002, 972). The district uses 440,000 acre feet a year to irrigate 75,000 acres on about 120 full time farms.
- ⁸¹ Northwest Economic Associates (2004, 9).
- ⁸² Thompson (1993, 673, 731-39).
- ⁸³ These distributional issues are major ones in the formation of oil field units and in fishery regulation. See Wiggins and Libecap (1985), Libecap and Wiggins (1985), and Johnson and Libecap (1982).
- ⁸⁴ Northwest Economic Associates (2004, 1).
- ⁸⁵ Haddad (2000, 95-116); Northwest Economic Associates (2004, 1-5); Hanak (2003, 72-3); *Water Strategist*, February 2005, p. 12, Table 1 2004 Water Transactions. The payment and water figures reported for 1992 by Northwest Economic Associates (p. 10) are higher than those in the text. The point is that the transaction was completed smoothly.
- ⁸⁶ *Arizona v. California*, 373 US 546 (1963). The decision allocated 2.8 million acre feet to Arizona, 4.4 million to California, 300,000 to Nevada, and 1.5 million to Mexico.
- ⁸⁷ See discussion in “The Royal Squeeze,” *The High Country News*, 34 (17), September 16, 2002 by Matt Jenkins.
- ⁸⁸ Other discussions of MWD and southern California IDs are in Brian E. Gray, Chapter 2, Water Transfers in California 1981-1989, in McDonnell 1990, Vol. II. IID is discussed on pp. 34-41.
- ⁸⁹ Thompson (1993, 729). The IID has a service area of over 1,000,000 acres, using 2.6 million acre feet per year to irrigate over 495,000 agricultural acres (Haddad, 2000, 71-2).
- ⁹⁰ Congress passed legislation in 1988 authorizing lining of All American canal; PL 100-675. California Water Code Section 1011 and 1012 clarifies that IID’s conservation does not imperil its water rights.
- ⁹¹ Smith (1994); Thompson (1993, 729, 757) discuss the Imperial case and says that even by that time it had taken almost decade to reach agreement on the lease of 100,000 acre feet of water saved through conservation to the MWD for 35 years. See also, Haddad (2000, 77) explaining that IID negotiated water sales to MWD only under threat of State takeover of management of the MWD, a threat which Haddad characterizes as the shotgun at the “shotgun wedding” between IID and MWD.
- ⁹² Imperial Irrigation District, “Fact Sheet: Water Conservation.” In 1998 107,000 acre feet were conserved through these actions.
- ⁹³ Hanak, (2003, 73).
- ⁹⁴ Hanak (2003, 74) San Diego will pay \$20,000,000 over 15 years, plus any excess 3rd party effects over that amount.
- ⁹⁵ Hanak (2003, 81).
- ⁹⁶ <http://www.usbr.gov/main/about/>
- ⁹⁷ Thompson (1993, 719).
- ⁹⁸ Thompson (1993, footnotes 237, 238).
- ⁹⁹ Thompson (1993, 723).
- ¹⁰⁰ U.S. PL 102-575.
- ¹⁰¹ State law is subservient to federal within the CVP, Thompson (1993, 746, fn. 313); Gray (1994b, 286-90).
- ¹⁰² Thompson (1993, 751, footnote 318).
- ¹⁰³ Getches (1997, 12-3, 308-45).
- ¹⁰⁴ Glennon (1995, 733-43) for general discussion of the issue of Indian water rights and Central Arizona Project water.
- ¹⁰⁵ MacDonnell (1990, Vol. I, p. 11) Can change point of diversion if no harm as with most western states
- ¹⁰⁶ MacDonnell (1990, Vol. II Chapter 1 Woodard and McCarthy, 3-19; Chapter 4, Brown et al; Chapter 5, Hogge et al; Chapter 6, Squillace). AZ 45-172 (A)(1) requires approval by Director for transfers.
- ¹⁰⁷ Gray (1994a, 178).
- ¹⁰⁸ MacDonnell (1990, Vol. I, 17-8, 24, Vol. II, Gray, 3-13).
- ¹⁰⁹ Gray (1994b, 284-96).

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- ¹¹⁰ Gray (1994b, 273).
- ¹¹¹ Hanak (2003, vii.), Gray (1994a, 180), Hanak and Dyckman (2003).
- ¹¹² MacDonnell (1990, Vol I, 27), Gisser (1983), Johnson et al (1981), (Gisser, 1981).
- ¹¹³ Howe, Boggs and Butler (1990, 404-5).
- ¹¹⁴ MacDonnell (1990, Vol. I. 32, 47a-47e, most transfer applications rejected in Wyoming). For Colorado see, MacDonnell (1990, Vol. 1, 16, 25-36); Howe and Goemans (2003) found that transfers with the NCWCD were small and continuous and routine, while those from the Arkansas basin for export were more contentious, larger, and involved trades from agriculture to urban users. Water courts are active for non NCWCD transactions.
- ¹¹⁵ MacDonnell (1990, Vol. I, 11-13).
- ¹¹⁶ MacDonnell (1990, Vol. II. 3) Woodard, et al.
- ¹¹⁷ MacDonnell (1990, Vol. I. 13-14).
- ¹¹⁸ MacDonnell (1990, Vol. I, 11).
- ¹¹⁹ Glennon (1991).
- ¹²⁰ *Town of Chino Valley v. City of Prescott*, 131 AZ 78 (1981) no right of ownership of groundwater prior to capture.
- ¹²¹ In Arizona, ARS 45-401.
- ¹²² MacDonnell (1990, Vol. I, 47c- 47e) shows that Colorado transfers involve the greatest number of protests.
- ¹²³ Carey and Sunding (2001, 305)
- ¹²⁴ Thompson (1993, 703).
- ¹²⁵ MacDonnell (1990, Vol. II, MacDonnell, Howe, Rice, p 5). AZ 45-172 allows for 3rd parties to protest water transfers. Burden of proof of no harm generally is on the transferor. For discussion of the regulatory process, see Colby (1995, 114).
- ¹²⁶ Colby, et al (1989, 699-705), MacDonnell (1990, Vol. I, 11).
- ¹²⁷ Howe, Lazo, and Weber (1990, 1200).
- ¹²⁸ Nunn (1985, 867).
- ¹²⁹ Hanak (2003 p. x-xii, 72), Howitt (1994).
- ¹³⁰ In their study of the effects of the PVID agreement with the MWD, Northwest Economic Associates (2004 5-6) found larger 3rd party effects through loss of farm employment, wholesale and retail trade.
- ¹³¹ See *Santa Fe Trail Ranches Property Owners Association v. Simpson*, 990 P2d 46 (Colo. 1999)(holding that water rights proposed for transfer had in fact been lost through non-use, as revealed in the transfer hearing process).
- ¹³² See Colby et al (1989), Young (1986), MacDonnell (1990, Vol. I, 47a-47e) for charts of the review process.
- ¹³³ MacDonnell, (1990, Vol. I, 53, 68).
- ¹³⁴ Thompson (1993, 704-5) claimed that the high costs of procedural requirements deters transfers
- ¹³⁵ Colby (1990, 1184)
- ¹³⁶ Colby et al (1989, 707-10) report substantial differences across the states in how public interest considerations are defined, the clarity of the definition, and the extent of their application.
- ¹³⁷ Dean E. Murphy, "Pact in West will Send Farms' Water to Cities, [New York Times.com](http://www.nytimes.com), October 17, 2003.
- ¹³⁸ To make the prices comparable for transactions that took place across different times, the prices are presented as the annual payout of an annuity for time period of the transaction at a 10 percent discount rate.
- ¹³⁹ Two-sample t test with equal variances. $t = -9.04$, d.f. = 1913. Glennon, Ker, and Libecap (2005) have assembled a data set of 2,751 water transfers from January 1987 through January 2004 as listed in the *Water Strategist*. The included transfers generally listed source, type, destination, use, term, and for 1,915 observations, price.
- ¹⁴⁰ These are "committed" transfers—those that are agreed to in any year. If a transfer involves 100 acre feet per year for 5 years, the data reflect just the agreement at the year it was reached.
- ¹⁴¹ Data source, Glennon, Ker, and Libecap (2005).
- ¹⁴² The amounts shown in the table are those that are committed in any year. That is, as above, if 100 acre feet are to be transferred each year for 5 years, the table shows just the amount committed the year the agreement was reached.
- ¹⁴³ Hanemann (2005, 5-8).
- ¹⁴⁴ See Libecap (1989,10-28) and Olson (1965).
- ¹⁴⁵ See Grafton, Squires and Fox (2000), Hannesson (2004), and Leal (*) for discussion of the relative performance of ITQ's and other fishery regulation.