Natural Resources Journal, Vol. 35, pp. 1-32, Winter, 1995.

RECENT CALIFORNIA WATER TRANSFERS : IMPLICATIONS FOR WATER MANAGEMENT

Morris Israel and Jay R. Lund[1]

ABSTRACT: The 1991 and 1992 California Drought Emergency Water Banks were the first large water transfer programs in the nation in which the State served as the predominant broker for water trades. Although the State-sponsored Water Banks have drawn widespread attention, there have been a great number of water transfers and exchanges taking place in California independently of the State. These non-State transfers illustrate well the widespread applicability of transfers in managing water resource systems, as well as the multiple mechanisms available for effecting water transfers. This paper focuses on California's recent experiences with water transfers, and offers a series of potential lessons for federal, state, and local managers for integrating water transfers in regional water resource systems.

INTRODUCTION

Economists have long endorsed the idea of using markets to foster the efficient allocation of water (Milliman, 1959; Hartman and Seastone, 1970; Howe, *et al.*, 1986; Saliba and Bush, 1987) and over the years there has been much discussion on the legal implications (Gray, 1989; O'Brien, 1988), the institutional forums (Hartman and Seastone, 1970; Saleth, *et al.*, 1989; Nunn and Ingram, 1988) and the potential third-party impacts (NRC, 1992; Howe, *et al.*, 1990; Little and Greider, 1983) of water transfers. A brief introduction to the water market literature appears in Dudley (1992). Although implementation of water transfers and water markets has lagged theoretical development, water transfers are a common component of many regional water systems and are being increasingly considered for meeting growing water demands and for management during drought. This paper demonstrates that water transfers can take many forms and can serve several purposes in the management of a water resource system (Lund and Israel, 1993).

The study of actual water transfers can be very insightful for the design of new transfers as well as for transfer theory. The constraints actually encountered in applying water transfers confirm the needs to account for transaction costs, operational requirements, third-party impacts, and multi-party coordination of water movement in the development of water transfers. Moreover, just as practice often reveals unanticipated constraints, study of actual water transfers reveals greater flexibility than anticipated by theory. This is due largely to the ingenuity of real water managers.

The purpose of this paper is to review the recent water transfer activity in California and to draw from this experience lessons for water managers at all levels for the integration of water transfers into regional water resource systems. A discussion of California water policy cannot be fully appreciated without some sense of the complexity and expanse of the California water resources system, including its physical and institutional characteristics. Thus, a brief overview of California water resources is presented first. The State-sponsored Drought Emergency Water

[1] Doctoral Student and Associate Professor, Department of Civil and Environmental Engineering, University of California, Davis, California 95616.

Banks of 1991 and 1992 are discussed, followed by discussion of non-state-sponsored transfer activities. Conclusions and lessons for water managers and planners are provided.

CALIFORNIA'S WATER RESOURCE SYSTEM

California's unique hydrologic conditions form the basis of an elaborate water resource system. The State's water supplies are poorly distributed in both time and space. The principal water sources are in the northern and eastern mountains, but the greatest demands occur in the southern and western regions. Precipitation falls predominantly in the winter, and the summers, which are the period of major agricultural and urban demands, are typically dry. As a semi-arid region, California is also prone to multi-year droughts. The water-related infrastructure, institutions, and legislation which have evolved, as well as the conflicts and antagonisms which have arisen over the years, can be traced to these severe imbalances of supply and demand. The physical and human infrastructure developed as part of the California State Water Project (SWP), the federal Central Valley Project (CVP), and the numerous smaller local projects has created a highly integrated and intricate water resources system. This vast system is governed by a large number of diverse water management agencies which, in turn, are governed by a complex set of laws, regulations, judicial rulings, contracts, and coordinating agreements (see Kahrl (1978) for more details).

The State's major water facilities are located as shown in Figure 1. Together the CVP and the SWP provide approximately 30 percent of the state's surface water needs. (The CVP delivers approximately 8 million acre-feet (MAF) and the SWP delivers roughly 2.3 MAF, but has contracts for up to 4.1 MAF.) These two systems are important for water transfers in that most large transfers must employ these systems' conveyance and storage facilities. An equally important component of the California water system is the Sacramento-San Joaquin Delta. Essentially, all north-south movement of water must pass through or around the Delta. Due to environmental constraints, movement of water through the Delta can only occur when the Delta is in "balanced" conditions; that is, when releases from upstream reservoirs match Delta water quality standards, Delta outflow, and export needs. Windows of opportunity for moving water through the Delta are becoming increasingly constrained because of more stringent water quality standards and increased concern over threatened and endangered species residing in the Delta (CUWA, 1993).

The Federal government has a major role in the management of water in California, acting primarily through the Bureau of Reclamation, which owns and operates the Central Valley Project. The U.S. Army Corps of Engineers and the Environmental Protection Agency have a lesser, but still significant roles in managing the state's water resources. The California State government has three principal roles in water management: regulating water use, as a major developer of water resources, and protector of the natural environment. State activities in these potentially conflicting roles are split between the State Water Resources Control Board, the Department of Water Resources, and the Department of Fish and Game.

California has roughly 3,000 water suppliers, both public and private. These water providing institutions differ widely in scale, organization, and enabling legislation, and are often driven by divergent objectives. Ownership and control of facilities varies, as does operation and maintenance responsibilities. However, overall operation of the system is finely orchestrated through a series of operating agreements, contracts, regulations, and laws. It is common for the water supplied to an individual house or farm to have been contractually or physically handled by several hierarchically layered water supply agencies. Water from a state or federal reservoir is often contracted to a regional water wholesaler which may sell the water to two or three

additional water districts before final delivery to the individual water user. Historically, this hierarchial contracting has impeded transfers.

The two primary legal doctrines governing use of the State's waters are the riparian rights doctrine and the appropriative rights doctrine (Attwater and Markle, 1988). Other less important doctrines used in California are contract rights, pueblo rights, prescriptive rights, and ground water rights. The interaction between these many doctrines often leads to complexity, confusion, and ambiguity in application, particularly when the transfer of water and/or water rights is contemplated. Two characteristics of riparian rights which limit water transfers are: (1) riparian water must be used on riparian land and (2) that riparian waters are not storable. These limits prohibit the transfer of water in space (conveyance) or time (storage), so critical for California. Appropriative rights are theoretically a transferable, marketable commodity. Transfers may involve change in ownership, type of use, and place of use. However, a general constraint on the transfer of appropriative rights is that other appropriators must not be adversely impacted by the transfer. In California, the State Water Resources Control Board must approve changes in timing, place, and type of use for most water transfers. The Board also determines third-party impacts.

THE 1991 DROUGHT WATER BANK

The California Drought Emergency Water Banks did not arise without precedents or precursors. Similar water banks have existed elsewhere in the West (Rigby, 1990). Earlier water transfer activity in California included a successful water bank sponsored by the Bureau of Reclamation for Central Valley Project members during the 1977 drought (Wahl, 1989), ongoing water pooling agreements within the CVP, and several other transfers (Gray, 1990). Establishment of the 1991 Drought Water Bank was greatly facilitated by a series of legislative items and technical studies conducted since the 1977 drought.

The 1991 Drought Water Bank was conceived as California entered a fifth year of drought conditions. Stringent urban water rationing, severe cutbacks in agricultural water availability, and critical conditions for fish and wildlife were widespread (DWR, 1992a). The responsibility for organizing and implementing the 1991 Drought Water Bank was assigned to the Department of Water Resources (DWR) and was to be managed separately from the SWP and other State contracts. A summary of the 1991 Water Bank is presented below (Lund, *et al.* 1992).

1991 Water Purchase Contracts

A Water Purchase Committee was formed by DWR to negotiate the terms and conditions of a model contract for buying water for the Bank. Committee members representing public agencies that might buy water from the Bank also aided in initial negotiations and assisted in implementing water purchase contracts. To protect the water rights of sellers and to encourage their participation, several pieces of legislation were enacted. Assembly Bill (AB) 9 gave water suppliers explicit authority to enter into contracts with DWR or other water suppliers for the transfer of water outside their service area. AB 10 stated that no temporary transfer of water for drought relief in 1991 or 1992 would affect the standing of any existing water rights. Article 29 of the *Agreement Establishing a 1991 California Emergency Drought Water Bank* further specified several water rights assurances to sellers (Howitt, *et al.*, 1992).

To further motivate early seller participation in the Water Bank, purchase contracts contained a price escalator clause. The price escalator clause provided that if by a specified date the average price extended to a similarly situated seller exceeded the price in the contract by 10 percent, the seller would receive the higher of the two prices.

Sellers made water available to the Bank by: (1) fallowing farmland (i.e., not planting or irrigating a crop) and transferring the conserved irrigation water to the Bank, (2) using ground water in lieu of surface water, or (3) transferring water stored from local reservoirs. After analyzing farm budgets, talking to potential sellers and buyers, and consulting with agricultural economists, the acquisition price was set at $125 per acre-foot, regardless of the source of the water or the crop not planted. The intent was to offer a price that would yield a net farmer income similar to farming plus an additional amount to encourage participation in the Water Bank.

The 1991 Water Bank acquired 820,665 acre-feet of water through 348 contracts (DWR, 1992a). Fifty percent of acquired water came from 325 fallowing contracts (414,743 ac-ft); 32% from 19 ground water substitution contracts (258,590 ac-ft); and 18% from 4 surface water contracts (147,332 ac-ft).

Fallowing Contracts

Roughly half the Water Bank supplies came from fallowing farmland. To be eligible for fallowing, land had to have been farmed in the previous year, or set aside under the federal Farm Commodity program with farming anticipated for 1991. Eligibility was verified based on Agricultural Stabilization and Conservation Service reports. Shallow ground water levels on Delta farmland required additional vegetation control to reduce water losses from subsurface seepage. Sellers breaching a contract by irrigating with surface water were liable for liquidated damages of twice the price paid for the purchased water.

The amount of water conserved by fallowing land was estimated as the net amount of applied water consumed by the crop. A survey of crop water use conducted after the 1976-77 drought was used to calculate the water conserved by fallowing different types of crops. Crop consumptive use was estimated to equal estimated crop evapotranspiration assuming similar rainfall patterns for the 1991 and 1977 growing seasons (Howitt *et al.*, 1992). A crop fallowing payment schedule identified the amount of water per acre that would be consumed by specific crops, as shown in Table 1. Estimates of crop water use were adjusted as the 1991 rainfall surpassed the 1977 levels.

The crop acreage fallowed through the 166,094 acres participating in the land fallowing program, included corn (35.7% by acreage), wheat (26.2%), pasture (9.7%), alfalfa (6.2%), and rice (4.9%). The acreage fallowed for the Water Bank was about ten percent of the field and vegetable acreage of the major counties participating in the program and was within the acreage fluctuations of the past four years, with the exception of corn in Yolo and Sacramento counties (AIC, 1993).

Ground Water Substitution Contracts

Land owners entering into ground water substitution contracts would irrigate crops with ground water and transfer their surface entitlements to the Water Bank for the season. A few contracts provided pumped ground water for direct transfer to the Bank.

Ground water contracts involved the complex task of determining whether the pumped ground water was "new" non-surface water. Water was considered "new" if it had been made available to the State's supply system only because of actions undertaken as part of the Water Bank program. Well logs for each well in the program were reviewed to assure that the Bank received only new water. It also required assurance that ground water pumped to replaced surface water was not being induced from a near-by surface water source (Brown, 1992).

In many areas, the ground water basin is the major regional source of agricultural and urban supply. Concerns were expressed that ground water would be pumped for use outside the basin, potentially harming local areas. To address these concerns, the ground water contracts required that sellers meter ground water use. The local water district then released an equal amount of surface water to the Bank. The pumped ground water was used on lands overlying its source. To ensure that pumping did not harm local ground water basins, monitoring programs were established in Yuba, Butte, and Yolo Counties. Yolo and Butte Counties also received a 2 percent payment on selected contracts to fund county water plans.

Reservoir Withdrawal Contracts

Withdrawals from reservoirs for the 1991 Water Bank totaled 147,332 ac-ft Most stored water involved the Yuba County Water Agency (YCWA) which sold a total of 157,200 acre-feet of water. YCWA agreed to transfer 99,200 acre-feet in 1991 and an additional 30,000 acre-feet would be stored in it reservoir on behalf of DWR for release in 1992. Separately, DWR acquired 28,000 acre-feet for the Department of Fish and Game (DFG) for instream flow releases and wildlife refuges in the San Joaquin Valley. Water for DFG was purchased at a discounted price of $50 per acre-foot. Water for the Water Bank was bought at the usual $125/ac-ft.

Selling Price

The selling price of Water Bank water was $175/ac-ft for water delivered at the SWP's Delta pumping plant at the entrance to the California Aqueduct. The price included all acquisition and administrative costs borne by DWR, as well as costs incurred to satisfy outflow requirements for moving water through the Sacramento-San Joaquin Delta. A deposit 50 percent of the purchase price was required within seven days of enlisting in the Bank. Within 15 days, 75 percent of the cost had to be deposited. The balance was due prior to water delivery.

Most Bank water was delivered through SWP facilities. The costs for using these facilities were negotiated in separate conveyance contracts. The SWP contractors purchasing Bank water paid primarily for the energy to pump water to the contractor's area. Non-SWP contractors were charged an additional use-of-facilities fee, a proportional share of the capital and annual operation and maintenance costs of SWP facilities involved in the transfer. Final delivery costs often were several times the original purchase price. A typical conveyance contract would stipulate points and rates of water delivery, as well as costs for using SWP facilities for conveyance and storage. Some costs were tied to the quantity of water transferred or stored, others were lump sum payments.

Allocations from the 1991 Drought Water Bank

Allocation of Bank water by DWR was prioritized based on 'Critical Needs' to assure participants that the most urgent demands were satisfied first. Allocations were made according to the following priorities (DWR, 1992a):

- Water to meet identified emergency needs, such as health and safety.
- Water for areas with critical needs, defined as: urban water users with less than a 75 percent supply, agricultural users who need water to assure the survival of permanent or high value crops, and fish and wildlife resources.
- Water for entities previously receiving allocations for critical needs and who need additional supplies to reduce substantial economic impacts resulting from reduced water supplies.
- Carryover storage for the SWP.

Before purchasing water, buyers had to demonstrate maximum use of current available water supplies, implementation of a satisfactory water conservation programs, and ability to provide fund their purchases from the Bank. Additional criteria depended on the intended use of the purchased water (Lund, *et al.*, 1992).

A total of 389,970 ac-ft was purchased from the 1991 Water Bank by 12 entities, compared to 348 entities selling water. Three jurisdictions -- Metropolitan Water District of Southern California (MWD), Kern County Water Agency, and the San Francisco Water District -- accounted for over 80 percent of the purchases. MWD alone purchased 55 percent. Roughly 80 percent of 1991 Water Bank sales were for municipal and industrial uses. The buyers and quantities purchased are shown in Table 2.

The difference between total Water Bank purchases (820,665 ac-ft) and total allocations (389,970 ac-ft) has two explanations. First, to satisfy Delta water quality requirements, DWR must release between 20-30 percent more water into the Delta than it pumps from the Delta. These carriage water requirements for Delta water quality account for 165,137 ac-ft of the difference. Second, DWR purchased all unallocated Water Bank supplies providing a financial backstop for the program. This 265,558 ac-ft was used for carryover storage.

Drought Bank Operations

Enabling legislation for the 1991 Water Bank required that use of State Water Project facilities by the Water Bank not conflict with operations needed to provide water to SWP contractors or to meet other State obligations. Thus, transferred water received lowest conveyance and storage priority in State facilities. This low transfer priority in operations required substantial coordination to match storage and delivery operations with the availability of Water Bank supplies. Both the SWP and CVP adjusted reservoir operations and Delta export pumping schedules to the greatest extent possible to accommodate deliveries of Bank water as well as to protect fisheries.

As noted by Howitt *et al.*(1992), "(p)erhaps the most innovative operations of the SWP and CVP systems involved the acquisitions of water from holders of riparian rights who fallowed their lands." By law, riparian rights cannot be transferred, and yet the Bank was able to acquire water from holders of these rights. To meet Delta environmental standards, the SWP and CVP must frequently release water from upstream reservoirs. Riparian water right holders participating in the fallowing contracts do not exercise their water rights, allowing the water to stay in the rivers and channels. In doing so, the additional water retained in the Delta channels enables the SWP and CVP to decrease releases from upstream storage, making more available for other water demands.

EVALUATION OF THE 1991 DROUGHT WATER BANK

Concerns about the effects of transferring water to the Water Bank were expressed in many areas. The most pressing issues involved effects on local agriculture-based economies, ground water basins, and the environment. However, the Water Bank was instituted in the midst of a severe drought and during an economic recession, making it more difficult to estimate Water Bank impacts directly.

The impact of fallowing on the agricultural economy selected counties was measured in terms of acreage or the value of output (Howitt *et al.*, 1992). Examination of the pattern of fallowing by crop and by county revealed that the most fallowing in 1991 was well within the normal fluctuations of agricultural activity. The effects of the Bank on the local economies of selling counties were relatively small, estimated at less than 1 percent of 1989 county personal

income and 1989 county employment, even though all estimates neglected Water Bank revenues on the county's local economy. Members of the agricultural communities argued that many businesses could survive one year of loss, but not consecutive or frequent losses. Overall, Howitt *et al.*(1992) concluded that trading water through the Water Bank created substantial economic gains for both California agriculture and the statewide economy, although there were localized regions which suffered economically. A detailed evaluation of the economic impacts of water transfer activities in Yolo and Solano Counties appears in AIC (1993).

The potential impacts of ground water extraction included lowered ground water levels, increased pumping costs or costs for deepening wells, subsidence, and decreased ground water quality. Ground water monitoring programs were established in Yuba, Yolo, and Butte Counties. Where ground water levels were of particular concern, data loggers were installed on a few wells to record well levels on an hourly basis. Additional elements of the monitoring program included collection of water quality data and aquifer testing. The Yolo County program also included provisions for monitoring ground subsidence due to ground water pumping. Again, it is very difficult to separate the effects of increased ground water pumping due to the drought and due to the Water Bank.

The effects of the drought on fish and wildlife habitat were of particular concern. Modifications to SWP operations, including Water Bank transfers, were made to reduce impacts on Delta fisheries. Although Water Bank operations were designed to have reduce impacts on fisheries and wildlife, not all impacts could be eliminated. The fallowing of agricultural land stripped some waterfowl of temporary habitat and refuges. To mitigate the indirect and cumulative impacts of water transfers on striped bass, DWR purchased an additional 300,000 yearling striped bass for release into the Delta and purchased additional water for instream flow use (DWR, 1992a).

Some Water Bank operations provided benefits to fish and wildlife that would not have existed without the Bank. Capture of juvenile fish in unscreened pumps and diversions in the Delta and Sacramento River was reduced since water diversions to farmland were reduced under the fallowing contracts. Fallowing lands also provided the opportunity to retain more water in reservoirs until later in the season. This helped cool fall river temperatures to benefit the fall run salmon. Reduction of irrigated acreage also reduced salts and chemical loading in return flows to the Delta.

In addition to direct impacts of Water Bank operations, several concerns were raised pertaining to management of the Bank. It was argued that there was little opportunity for third parties and environmental interests to comment or participate in Water Bank operations or negotiations. Representatives of local communities criticized the secrecy of water negotiations and felt that workers and owners of farm-related businesses should have been informed quickly of decreases in agricultural production. Some also claimed that insufficient information was available to make informed decisions about selling water to the Bank.

In response to these criticisms, Howitt *et al.* (1992) presented recommendations for future bank operations; several of these were incorporated into the 1992 Water Bank:

- **Early Notice -** To improve participation of potential sellers, DWR should announce the formation of a water bank early enough so growers could consider the opportunity as they plan for an upcoming irrigation season. Notice should include the planned scope of Water Bank acquisitions, terms and conditions of contracts, and the nature of Bank operations.
- **Contracting Guidelines -** To implement more complex contracting strategies, it was suggested that DWR develop and publish formal contracting guidelines. This would improve the

administrative efficiency and avoid criticism concerning equal contract opportunities for all sellers. The contract guideline document should explain:

(1) the various types of contracts available to sellers;
(2) what a seller should expect to receive from each type of contract;
(3) the documentation needed under each type of contract; and
(4) how the Water Bank will administer each type of contract.

• **Dual-Class System of Contracts -** A dual-class system of contracts consisting of early and late commitment contracts would offer a mechanism for rewarding sellers and buyers who enter into early Bank commitments. The price escalation clause provided an important incentive for sellers to participate in the 1991 Water Bank. However, no rewards were given to buyers for early commitment.

The dual-class system would consist of early contracts or option-agreements arranged before some cut-off date (e.g. January 1), and late contracts, consisting of non-option agreements arranged after the cut-off date. Under the early contracts, the Water Bank would assure sellers a *reservation fee* to purchase the right to decide by a trigger date (e.g. February 15th) whether to buy the amount of water under the terms and conditions specified in the contract. The sellers receive the reservation fee whether or not DWR exercises its option to purchase water for the Bank. In addition, if DWR acted on the option, it would pay the sellers a *water purchase price* based on the amount of water purchased by the trigger date. Thus, the dual-class system of contracts rewards sellers and buyers that commit early and would enable the price escalation clause to be dropped from water purchase contracts.

• **Additional Recommendations -** Additional recommendations dealt with land fallowing, including the need to develop accurate and defensible crop water use patterns, the need to structure acquisition prices to reflect differences in yield, and the need to establish limits on the amount of fallowed acreage permitted per region.

THE 1992 DROUGHT WATER BANK

Hydrologic conditions in California had not improved by Spring of 1992 and a similar, but smaller Drought Water Bank was established by DWR. The DWR water purchase price for the 1992 Bank was $50/ac-ft. The selling price was $72/ac-ft. Again, separate contracts were drawn between the State and buyers for use of State facilities.

Allocations from the 1992 Bank totaled 158,715 ac-ft Buyers and the purchased amounts are shown on Table 3. Agricultural purchases constitute roughly 62 percent of all Bank allocations. Twelve agricultural water districts participated in the 1992 Water Bank, but two, Tulare Lake Basin Water Service District and Westlands Water District, account for roughly 87 percent of all agricultural purchases. Purchases by the State Department of Fish and Game (DFG) account for 13 percent and municipal and industrial demands represent approximately 25 percent of total purchases (39,000 ac-ft.).

Ground water substitution accounted for 161,593 ac-ft of the water purchased by the Water Bank. The balance, 31,600 ac-ft, came from direct surface water contracts. 34,478 ac-ft were set aside to meet Delta water quality requirements.

Participants of the 1992 Water Bank were permitted to carry over undelivered Bank water for final delivery before December 31, 1995. However, carryover water receives the lowest priority in facilities owned and operated by the State and is subject to substantial storage costs. Carryover Bank Water can be lost by spillage if reservoir storage capacity is required for SWP purposes or other State needs.

COMPARISON OF THE 1991 AND 1992 DROUGHT WATER BANKS

Although conceived for the same general purposes, the 1992 Bank was modified based on experiences from the 1991 Bank. Although 1992 was still a drought year, the somewhat improved hydrologic conditions also influenced the scale, structure, and operations of the 1992 Bank. Major modifications in the 1992 Water Bank are discussed below (Lund, *et al.*, 1992).

A Smaller 1992 Water Bank

The 1992 Bank was smaller than the 1991 Bank both in the quantity of water transferred and in number of participants. Although the number of purchasers increased from twelve in 1991 to sixteen in the 1992 Bank, the number of sellers dropped considerably from 348 to eleven, and the amount of water purchased by DWR decreased to 193,193 ac-ft in 1992. There are two explanations. First, heavy precipitation in the early months of 1992 reduced water demand from 1991 levels. Requests for water from the 1992 Bank were only 158,715 ac-ft. Second, the reduced water demands in 1992, required lowering the price of water, which may have kept prospective sellers from participating in the 1992 Water Bank.

The 1992 Agricultural Water Bank

The 1992 Bank primarily facilitated transfer of water between agricultural parties. Twelve of the sixteen water purchasers were agricultural users, and their purchases accounted for about 62 percent of water allocated by the Bank. The large urban users, such as MWD, San Francisco WD, Santa Clara Valley WD and Contra Costa WD, that dominated the Bank in 1991, did not request significant amounts of water from the 1992 Water Bank. The February 1992 rains were enough to replenish urban water supply reservoirs along the central and southern coast areas, reducing their needs for imported water. Agricultural areas which depend on ground water for irrigation benefited less from these rains. Lower prices made water purchase for agriculture more economical.

1992 Water Bank Underwritten by Buyers

In 1992 the State assumed less financial responsibility than in 1991. A criticism of the 1991 Bank was that water was purchased based on early demands, many of which were not followed with signed contracts. The 1991 Water Bank ended with a surplus of approximately 265,000 ac-ft as carryover storage at a cost of about 45 million dollars. Howitt *et al.*, (1992) conclude that "the over-acquisition of water was an unavoidable consequence of the lack of negotiated agreements before the drought emergency and an understandable lack of knowledge about the supply and demand for Bank water." To ensure against repeating this behavior, no water purchases were made by DWR for the 1992 Bank unless there was a willing buyer who had previously entered into contractual agreements. In this sense, DWR behaved as a true broker, matching supply to real demands.

Land Fallowing Not Permitted

Many criticisms of the 1991 Water Bank resulted from the land fallowing program. To avoid many of these difficulties, the 1992 Water Bank did not purchase water conserved through the fallowing of agricultural lands. Only water acquired through ground water exchange and stored surface water contracts were accepted. This helped procedurally, environmentally, and politically. However, had demands been higher in 1992, it is likely a land fallowing program would have been needed.

System of Pools

The 1992 Water Bank used a system of pools to record purchases and sales of water to and from the Bank. A Pool was defined as a portion of Bank water sold to Members (contractors) at a single melded rate. The Pool Melded Rate is the total cost incurred by DWR to acquire water, including amounts paid to sellers of water; legal, administrative and financing costs; the impact of carriage water and other losses; refill impacts; and the costs of monitoring the impacts of water loss in the counties of origin, all divided by the amount of Bank water in that pool available for delivery (DWR, 1992b). Each pool represented a specified demand to be met by the Bank. A new pool was created when supply and demand conditions changed; for example, when a contractor requested increased allocation, when new contracts for water were executed, or when the critical needs of a pool were satisfied. Although, the price for water from each pool was uniquely established for that pool, it did not necessarily have to change as a new pool was created. The 1992 Water Bank operated six pools, each at the same rate.

Option and Purchase Deposits and Contracts

DWR developed several standard contracts to purchase water from different parts of the State under different circumstances, including contracts for the option to buy water. Along with a request for water, contractors were required to submit a deposit for either the purchase or the option to purchase a quantity of water not to exceed their estimate of critical needs. Option deposits were $20/ac-ft ($10/ac-ft for sellers, $5/ac-ft for Delta carriage losses, and $5/ac-ft administrative charge). Contractors requesting options to buy had to specify the month they would exercise their option. Once an option was exercised, the contractor had to pay the prevailing pool melded rate for water.

Wildlife Concerns

The water demands of fish and wildlife during the drought were a primary concern of the 1992 Water Bank. The Department of Fish and Game purchased 20,000 ac-ft of water for preserving fish and wildlife habitat. This represents a significant change from the 1991 Water Bank, in which no direct Water Bank purchases were made for this purpose.

Federal Involvement

Coordinating operations were facilitated in 1992 because the Bureau of Reclamation was able to assume a more active role. Specifically, the Reclamation States Emergency Drought Relief Act of 1991 permitted use of federal facilities to convey non-CVP water. Also, acreage limitations for use of federal water were waived, making it easier to transfer federal water to both federal and non-federal entities.

LESSONS FROM THE STATE-OPERATED WATER BANKS

The experiences of the Drought Water Banks of 1991 and 1992 provide water managers and planners with numerous lessons for the operation of large-scale water banks and for the long-term management of water resources in general. Some such lessons are discussed below.

State-operated Water Banks have several advantages.

The 1991 and 1992 Water Banks demonstrated that centralized water banks can succeed even where non-bank transfers are allowed and active. Centralized water banks have several advantages:

• They provided a greater chance for successfully completing a transfer for buyers and sellers dealing directly with the Bank (Lund, 1993). This was in part due to the relatively straight-forward nature of Water Bank contracting and negotiations, but also to the reduced likelihood of third-party interference in Bank transfers supported by state legislation waiving environmental impact review of transfers during 1991 and 1992.

• A centralized water bank, particularly a State-sponsored bank, can substantially reduce the transaction costs of water transfers. Most of the terms of the transfers were standardized and the transfer process was clear.

• State funds can be used to provide initial working capital for a bank program.

• The State was able to facilitate coordination of transfers with other water movements in the state.

All sectors are interested in purchasing water.

The Drought Water Banks demonstrated that parties in all major water-using sectors (agricultural, urban, and environment) are interested in buying water. Some agricultural users are willing to pay high prices for water during drought years. During 1991, significant amounts of water were purchased at $175/acre-ft by agricultural users, primarily those with high-valued and perennial crops. Still, most agricultural users could not have afforded these prices, and it is doubtful if any agricultural users could purchase water at $175/ac-ft on a continual basis.

There is a substantial interest in selling water in drought years.

The 1991 and 1992 experiences revealed that many agricultural parties are interested in selling water, at least during drought years. Most of the water purchased in both years came from agricultural users. However, seller participation is price-sensitive. With high price expectations created by the 1991 Water Bank, fewer sellers agreed to the lower price offered by the 1992 Bank.

Special legislation may be required.

The two Water Bank were successful, in part, because many legislative and institutional constraints which hamper water transfers under normal conditions, were waived. No Environmental Impact Reports were required and the State Water Resources Control Board provided almost blanket approval of transfers involving the Water Bank. Such special conditions greatly reduced the transaction costs and transaction uncertainty of Water Bank transfers, relative to other forms of transfers and transfers in non-drought years.

Transfers can occur between water years.

Excess purchases in 1991 of roughly 265,000 ac-ft increased carryover storage for the State Water Project in 1992. Water Bank purchases may usefully function for either recouping or maintaining overyear storage as a hedge against potentially worse drought impacts in future years of multi-year droughts. Such purchases, however, should be made only at a reduced price compared to purchases made for use in the same year.

NON-STATE SPONSORED WATER TRANSFERS AND EXCHANGES IN CALIFORNIA

Although the State-administered Water Banks discussed above have drawn widespread attention, many water transfers and exchanges have occurred independently of the State. This section presents examples of this non-State transfer activity. This discussion should provide a

flavor for the types of water management strategies to which water transfers can be applied, the diversity of forms that water transfers can take, and the flexibility that these transfers can add to individual and regional water systems. For the most part, the following discussion is organized according the major sponsoring agency.

Transfers Involving the Metropolitan Water District of Southern California

Almost two-thirds of the water used within the Metropolitan Water District of Southern California (MWD) is imported. The balance is provided by local surface and ground water sources. The volume of water supplied by external sources varies substantially over time and is currently insufficient to meet the MWD's long-term water demands. In fact, supplies from the Colorado River are expected to fall over the next few years as the demands of other Colorado River states increase. Furthermore, recent environmental regulations would almost half the amount of water Los Angeles can export from the Mono Basin. To increase the reliability and yield of its water supply, MWD has long pursued alternative sources of water, including water transfers, exchanges, and innovative wheeling arrangements. Some notable examples are identified below.

Imperial Irrigation District-MWD Transfers

To respond to directives from the State Water Resources Control Board that the Imperial Irrigation District (IID) conserve water, MWD attempted to establish an agreement with IID to fund water conservation measures within the District in exchange for the conserved water. The water transfer agreement involves a 35-year contract for MWD payments for canal lining and other system improvements in IID's irrigation infrastructure in exchange for the water saved by these improvements. The savings are estimated at 100,000 acre-ft/year of water from IID's Colorado River water supplies. The settlement, endorsed by the SWRCB, helped preserve IID's original water rights at little cost. Under the agreement MWD will pay approximately $92 million for the capital costs of irrigation system improvements, over $3 million/year in operation and maintenance expenses, and up to $23 million in liability for indirect costs (Gray, 1990).

Coachella Valley Water District and Desert Water Agency Exchanges

In 1967, MWD entered into long-term water exchange agreements with Coachella Valley Water District (CVWD) and Desert Water Agency (DWA). The mutual benefit of these agreements derives from several factors. First, CVWD and DWA have entitlements to water from the SWP but have no direct access to this water. By exchanging their SWP entitlements for a portion of MWD's Colorado River entitlements, both water agencies employ their SWP entitlements. Second, CVWD and DWA typically use ground water and are concerned with over pumping their aquifers. Use of Colorado River water should alleviate these concerns. Finally, MWD can improve overall water quality and reduce treatment costs because SWP water acquired from CVWD and DWA is less saline than Colorado River water.

The CVWD-MWD exchange is for up to 61,000 ac-ft annually. The DWA-MWD exchange varies with DWA's SWP entitlements, which increase to a maximum of 38,100 ac-ft by 2035. Because they involve Colorado River water, these water exchanges are not regulated by the State Water Resources Control Board.

A 1984 supplemental agreement allowing MWD to make advance deliveries of Colorado River entitlements to the water agencies for ground water storage (up to 600,000 ac-ft). This allows MWD to take full delivery of both Colorado River and SWP entitlements, during droughts, during which CVWD and DWA would use stored ground water (Gray, 1990).

Arvin-Edison Exchange Agreement

MWD and the Arvin-Edison Water Storage District (AEWSD) have filed a request with the State Water Resources Control Board for a long-term water exchange contract. During wet years up to 135,000 ac-ft per year of MWD's SWP entitlements would be used in AEWSD for aquifer recharging or irrigation. In dry years, AEWSD would use ground water, making their surface water entitlements to the CVP (128,300 ac-ft) available to MWD (Gray, 1990).

SWP facilities would deliver CVP water to MWD, and SWP deliveries to AEWSD would use SWP and locally-owned facilities. The proposed exchange requires that diversion location for the Bureau's water rights be amended by the SWRCB and that MWD be added to the Bureau's service area.

Transfers within the Federal Central Valley Project

The transfer of water between contractors of the Bureau of Reclamation's Central Valley Project has been an integral to the project's operations since its inception. The vast network of storage, pumping, and conveyance facilities has been used to transfer surface and ground water to increase project supplies, reduce project costs, and to improve the timing and efficiency of deliveries to project contractors.

Since the Bureau's water rights for the CVP specify the entire Central Valley as the source and place of use, these water transfers are typically not subject to regulation by the State Water Resources Control Board. The only transfers which must be reported are those proposing to change the type of water use, e.g., from agriculture to urban uses. Most transfers occur between agricultural users. Most of these transfers have occurred by *ad hoc* agreements between individual contractors.

In addition to over 1,200 routine water transfers between individual CVP contractors, other Bureau transfer arrangements include special pooling arrangements between groups of contractors, Bureau transfers involving the SWP, and the federal water bank during the 1977 drought (Wahl, 1989). The recently passed CVP Improvement Act (PL 102-575) permits individual CVP contractors to transfer water outside of the project. This increased flexibility should bolster water transfer activity.

East Bay Municipal Utility District's Experiences

The East Bay Municipal Utility District (EBMUD) made several water transfer attempts during the recent drought (Lund, *et al.*, 1992). While some transfers have given EBMUD greater flexibility in managing drought, the agency's transfer experiences have not been altogether positive. The first transfer attempt was an innovative effort to pump low-quality water from the Delta roughly 200 feet to the Comanche Reservoir, where it would be used to satisfy downstream flow requirements. This would make an equivalent amount of high-quality water available for EBMUD's urban uses (about 58 million gallons per day (mgd), roughly 25% of normal EBMUD water demand). However, the application to change the point of use for this water was rejected by the SWRCB primarily due to the potential for introducing new species and diseases from Delta waters into the mountain-fed Comanche Reservoir and the Mokelumne River. The exchange was also strongly opposed by downstream users (Gray, 1990).

In a second attempted transfer, EBMUD sought to purchase water from users downstream of its reservoirs to make more water available for EBMUD's demands. Offers of roughly $50/acre-ft. were made, but no purchases were completed (NRC, 1992). Finally, in February 1989, EBMUD purchased 60,000 acre-ft of water $45/acre-ft (Melton, 1989).

However, heavy March rains eliminated need for this water, which was later re-sold to the State Department of Fish and Game at substantially lower prices.

EBMUD's water quality exchange and downstream water purchase proposals were highly innovative ideas. Their failure highlights the still-formidable barriers to transfers, even during drought.

Transfers in Solano County

In 1991, Solano County established a county-wide water bank to facilitate local water transfers. Transfers and exchanges within Solano County were not new. There have been numerous small transfer arrangements between irrigators and cities and among cities over almost 20 years (Lund, *et al.*, 1992). However, the 1991 shortages threatened the majority of urban water supplies by the SWP while farmers relying on an independent Bureau project benefited from relatively abundant water supplies, creating incentives for transfers within the region. Total farm to city bank transfers were 13,400 ac-ft. Cities paid $200/ac-ft, of which $170/ac-ft went to farmers in exchange for the fallowing of fields. A constant 3 ac-ft of water per acre of land was assumed. The remaining $30/ac-ft paid administrative costs.

The Solano County example illustrates that having previous, small-scale experience with water transfers can facilitate larger-scale drought transfers and increase the ability of local regional water agencies to foster transfers with little State or Federal involvement (Lund, *et al.*, 1992).

Transfers Involving the San Francisco Water Department

The San Francisco Water Department (SFWD) purchased water from several agencies and their experiences draw attention to the numerous technical impediments facing water transfers. In 1990 SFWD purchased 15,000 ac-ft (Lougee, 1991). Final delivery to SFWD required construction of an emergency turnout from the SWP's South Bay Aqueduct. The implementation of this physical transfer of water was further complicated by environmental constraints in the Delta and Sacramento River. These factors, combined with a 30% carriage water requirement for all flows through the Delta reduced final SFWD deliveries to about 7,600 ac-ft, slightly more than 50% of the original purchase. The purchase price was about $45/ac-ft. However, wheeling charges through federal and state facilities were between $250-350/ac-ft.

In 1991 SFWD purchased 50,000 ac-ft from the Water Bank, which exceeded the capacity of SFWD's South Bay Aqueduct turnout and surpassed the ability of SFWD's treatment plants to blend low-quality Delta water with its own high-quality waters from the Hetch Hetchy system. SFWD contracted with the SWP to store some purchased water in State facilities. However, under the storage contract, transferred water is the first to be spilled from storage as the reservoir fills. As a result, of the original 50,000 ac-ft purchased, approximately 78% arrived at SFWD's system (Lougee, 1991).

The SFWD transfers demonstrate the importance of coordinated movement of transferred water through conveyance and storage systems operated by third-party agencies and constrained by environmental, contractual, and physical limitations (Lund, *et al.*, 1992).

Yuba County Water Agency Sales

The Yuba County Water Agency (YCWA) was the largest seller of water throughout the recent drought. This occurred because YCWA constructed almost 1 MAF of storage capacity well in advance of irrigation demands in its service area. This situation provided YCWA with substantial amounts of surplus water in most years. Until the drought, transfers from the YCWA

remained at a level of a few thousand ac-ft/year (Gray, 1990). However, during the first four years of drought YCWA sold roughly 290,000 ac-ft of water to other water users (exclusive of carriage water). YCWA then sold 157,200 ac-ft to the State Water Bank in 1991, but sold no water to the 1992 Water Bank.

After years of permitting these sales, the SWRCB in 1991 called into question the quantity of Yuba County's water rights. This was due to the Board's feeling that Yuba County's rights should be curtailed due to lack of diligence in putting this water to use within the agency's designated place of use, a requirement for beneficial use under the State Water Code.

The case of YCWA's transfers illustrates the potential benefits and risks to water supply developers of developing supplies prior to the expansion of water demands within their service area, if a market can be found for the temporary excess in water supply yield.

The principal water agencies involved in water transfers and exchanges in recent years were identified above. The following focuses on different types of transfers and exchanges employed by various water institutions throughout the State.

Interagency Storage Projects

A number of interagency storage projects have been planned recently that improve the yield and reliability of California's water systems and facilitate water transfers. Interagency storage projects require the type of conveyance and storage facilities and coordination required for water transfers.

Kern Water Bank

The Kern Water Bank is a SWP conjunctive use project in the San Joaquin Valley. The intent is to store surplus water in wet years as ground water and to deplete this storage during dry years. The effective storage capacity of this site might be as high as 1.0 million ac-ft (MAF), increasing the yield of the SWP by as much as 0.14 MAF/year (Andrews, 1989). An additional advantage of this site is that it lies south of the Sacramento-San Joaquin Delta, avoiding much of the environmental constraints on operations associated with this estuary.

Sacramento Regional Cooperation

A similar conjunctive use scheme has been proposed for part of the Sacramento metropolitan region. The City of Sacramento has excess water entitlements to surface water from the American River. However, neighboring suburban districts, using ground water, face declining ground water tables and occasional ground water quality problems. Proposal is to use surplus surface water entitlements to supply selected suburban areas during wet years. During dry years, when surface water would be less available, these areas would revert to ground water supplies, improving the reliability of all systems and reducing ground water depletion (Metcalf and Eddy, 1985).

Pumped Storage

A number of large off-stream pumped storage reservoirs are currently being planned south of the Delta. In some cases, the reservoirs might be jointly operated by several agencies. Adding large amounts of off-stream storage south of the Delta would enhance the ability of water users in this region to participate in water transfers, since it would facilitate increased pumping of water through the Delta in wet periods, allowing storage of this water until the water is needed.

Transfers of Conserved Urban Water

The City of Morro Bay, in southern California, adopted an innovative twist on the transfer of conserved water. Since 1985 new real estate developments are required install water conservation measures in existing structures to more than match the water use of the new development. Water conserved by retrofitting existing development is applied to new development, with developers paying the costs of water conservation. For an urban system, it encourages water conservation in new development, accelerates water conservation in existing structures, and finances these activities (Reed, 1990). The program is an interesting analogy to the trading of conserved water for the conservation costs seen in the IID-MWD water transfer.

A somewhat different form of transfer of conserved urban water is the unofficial, unmanaged, and uncompensated transfer of conserved urban water to agricultural uses in some agricultural regions of California. In Yolo County, for instance, urban users reduced ground water consumption by over 10% in most drought years through water conservation. This water is available to supply nearby agricultural ground water use and reduce agricultural pumping heads. However, the impact of these relatively small unmanaged transfers would be imperceptible in many cases.

Payments for Water Conservation

Several California water utilities offer payments to customers for specific measures to reduce water demand. The most common offer is payment to install low-flow toilets (1.6 gallons/flush), high pressure shower heads, and other water saving fixtures. The cities of Santa Barbara, Santa Monica, and Los Angeles offer rebates between $80 and $100 per toilet. EBMUD has considered offers of up to $300 per single family household and $5,000/multifamily unit to install water-saving landscaping meeting district-set criteria (EBMUD, 1991). North Marin Water District has developed a "Cash for Grass" program where residents are paid to reduce the their yard area kept as lawn, with maximum payments of $310 per house.

Payments for Alternative Water Supplies

In some cases agencies or firms have been paid to use alternative water sources during drought. This is common downstream of the Delta when SWP operations can reduce the availability of sufficient quality water at some of the diversion locations. Under these conditions the City of Antioch and the Contra Costa Water District are paid by the SWP for use of substitute water supplies. As additional SWP releases to the ocean through the Delta would be needed to reduce salinity levels at these locations, paying to replace these diversions, which have relatively senior water rights, increases the SWP's ability to withdraw water from the Delta (Lund, *et al.*, 1992).

Innovative Wheeling

The legal, institutional, and economic will to effect water transfers and exchanges is not always enough. Successful transfers also require tremendous amounts of cooperation and coordination among numerous agencies. Many transfers discussed above succeeded because of innovative schemes to wheel the water from its place of origin to its place of use. Wheeling arrangements can be crucial in emergency situations, but they are also very important for helping meet water supply needs under normal conditions in a timely and cost-efficient manner. One such wheeling arrangement involves Santa Barbara.

The Santa Barbara region is normally considered hydraulically isolated from the rest of the state's water resources. The region was severely affected by drought in 1991 and sought 45%

reductions in water demand. However, Santa Barbara County was able to take delivery of 3,600 ac-ft of SWP water through a complex series of wheeling and exchange agreements with neighboring coastal counties.

CONCLUSIONS

Water transfers in California have occurred in a bewildering variety of ways. Each transfer has stemmed from substantial advantage to each side, even though money might not be exchanged and the prices paid might be arguably below market values. While the motivations for many trades have been financial, there have been other important motivations for participating in water transfers or exchanges.

The 1991 and 1992 Drought Emergency Water Banks have provided the opportunity "to learn by doing" and "to learn from mistakes." Lessons learned from the 1991 Water Bank were applied in the 1992 Water Bank. Lessons from both these experiences should be valuable both for future State Drought Water Banks and for others interested in establishing Water Banks or other types of water transfers. Taken together with the numerous non-State transfers, California's recent experiences with water transfers suggest several potential lessons for federal, state, and local water managers (Lund, *et al.*, 1992):

1. Water transfers can enhance the performance and flexibility of existing water systems.

These benefits can include: increasing beneficial use of existing supplies, favorable net economic and employment impacts, additional flexibility in drought management, avoidance or reduction of capacity costs, reduced operating costs, and a better match of waters of different qualities with different water demands.

2. Water transfers must be integrated with traditional supply and demand management approaches.

Water transfers alone will rarely resolve a region's water supply problems in an economical manner. Typically, a more integrated management approach, employing traditional supply and demand management measures, integrated with water transfers, will provide better results in terms of cost, technical performance, and institutional feasibility.

3. Modification and expansion of infrastructure often is required to take best advantage of water transfers.

The operation of existing conveyance, storage, and treatment facilities is likely to require significant changes to facilitate water transfers. In many California cases, transferred water can only be employed if it is stored for dry periods, necessitating new surface water reservoirs or additional use of ground water storage. Conveyance restrictions, both from physical aqueduct capacities and environmental limitations, are also common. Although there are considerable physical restrictions, it must be remembered that many of the transfers discussed above could not have been even contemplated were it not for the vast California "plumbing" system.

4. Water transfers can take many forms, each serving a different operational purpose in a water resources system.

The California case illustrates the many forms that water transfers can take and the diverse uses for different types of transfer arrangements. Each form of transfer, when utilized for an individual system, can fulfill a different operational purpose and accommodate different legal or third-party considerations.

5. Appropriate use of water transfers will likely vary between systems, reflecting local conditions.

Each system is somewhat unique in its supplies, water demands, costs, and alternatives. Different water supply systems will have somewhat different uses for water transfers. Some water systems will not need or be able economically to employ water transfers. This variation in individual system needs helps explain the diverse ways and degrees that water transfers have been employed in California.

6. Water transfers require a broader scope and scale of thinking about water resources management.

The use of water transfers in water management implies a regional and inter-regional integration of different water users and supplies. The *differences* between the demands of urban water systems and irrigation systems are the reason why transfers can be successful to both parties. Implementation of this broader perspective on water planning will require significant changes in water agencies at the local, state, and federal levels.

7. Environmental, legal, and third-party considerations are important political, planning, and operational considerations in developing and implementing water transfers.

Although not the focus of this paper, actual water transfers in California and elsewhere demonstrate the importance of environmental, legal, and third-party impact issues in the successful development and implementation of water transfers. While these issues are formidable, they are not insurmountable. Numerous approaches exist for accommodating, compensating, or mitigating real and potential third party impacts.

8. Government sponsorship is often required for significant water transfers to begin.

State and perhaps Federal governments have an important, and perhaps vital, role in the adoption and acceptance of water transfers in water management. Government has an essential role in accelerating use of water transfers, reducing risk and uncertainty involved in water transfers, reducing costs of completing transfer transactions, and demonstrating leadership in the legal, technical, and conceptual transitions required for agencies to implement water transfers.

9. Drought motivates change.

Historically, major changes in water management philosophy have been motivated and incorporated as a result of experiences during droughts. Recent water transfers in California are an example of how drought motivates exploration of new alternatives in water management.

10. Transfers cannot be avoided only delayed.

As increasing demands for water make shortages and droughts more frequent and severe, calls for water transfers are likely to become louder and more forceful. After the 1977 drought, California was able to delay significant water transfers for 14 years, until the next major drought. With the recent drought, water transfers are now a significant and permanent feature of water resources planning and management in California.

ACKNOWLEDGMENTS

This research was funded by the U.S. Army Corps of Engineers Hydrologic Engineering Center. The authors wish to thank all those interviewed as part of this study. Special thanks are extended to the Drought Water Bank staff and in particular to Steve MacCaulay.

REFERENCES

Agricultural Issues Center (AIC) (1993), *California Water Transfers: Gainers and Losers in Two Northern Counties,* Agricultural Issues Center, University of California, Davis.

Andrews, E.S. (1989), *Simulation of Kern County, California's Conveyance System, Including Groundwater Recharge,* Masters Thesis, Department of Civil Engineering, University of California, Davis.

Attwater, William R. and James Markle (1988), "Overview of California Water Rights and Water Quality Law," *Pacific Law Journal*, Vol. 19, No. 4, July, pp. 959-1030.

Brown, Linton (1992), "Sorting Out New Water, Real Water, and Paper Water," Presented at UCLA Conference *Buying and Selling Water in California,* Sacramento, November 12.

California Urban Water Agencies (CUWA) (1993), *The Delta*, California Urban Water Agencies, Sacramento, CA.

DWR (1992a), *The 1991 Drought Water Bank,* California Department of Water Resources, Sacramento, CA, January.

DWR (1992b), *Contract For Water Service From a 1992 California Drought Emergency Water Bank,* California Department of Water Resources, Sacramento, CA.

Dudley, Norman J. (1992), "Water Allocation by Markets, Common Property and Capacity Sharing: Companions or Competitors?" *Natural Resources Journal,* Vol. 32, Fall, pp. 757-778.

EBMUD (1991), *Urban Water Management Plan*, East Bay Municipal Utility District, Oakland, CA, February.

Gray, Brian E. (1990), "Water Transfers in California: 1981-1989," in MacDonnell, Lawrence J.(Principal Investigator), *The Water Transfer Process As A Management Option for Meeting Changing Water Demands,* Volume II, USGS Grant Award No. 14-08-0001-G1538, Natural Resources Law Center, University of Colorado, Boulder.

Gray, Brian E. (1989), "A Primer on California Water Transfer Law," *Arizona Law Review,* Vol. 31, pp. 745-781.

Hartman, L.M. and D. Seastone (1970), *Water Transfers: Economic Efficiency and Alternative Institutions*, Johns Hopkins Press, Baltimore, MD.

Howe, C.W., D.R. Schurmeier, and W.D. Shaw, Jr. (1986), "Innovative Approaches to Water Allocation: The Potential for Water Markets," *Water Resources Research*, Vol. 22, No. 4, April, pp. 439-445.

Howe, C.W., J.K. Lazo, and K.R. Weber (1990), "The Economic Impacts of Agriculture-to-Urban Water Transfers on the Area of Origin: A Case Study of the Arkansas River Valley in Colorado," *American Journal of Agricultural Economics*, December, pp. 1200-1204.

Howitt, R., N. Moore, and R.T. Smith (1992), *A Retrospective on California's 1991 Emergency Drought Water Bank*, March.

Kahrl, W.L. (1978), *California Water Atlas*, Governor's Office of Planning and Research, Sacramento, CA.

Little, R.L. and T.R. Greider (1983), *Water Transfers from Agriculture to Industry: Two Utah Examples*, Research Monograph No. 10, Institute for Social Science Research on Natural Resources, Utah State University, Logan, UT.

Lougee, N.H. (1991), "Uncertainties in Planning Inter-Agency Water Supply Transfers," in J.L. Anderson (ed.), *Water Resources Planning and Management and Urban Water Resources*, ASCE, New York, pp. 601-604.

Lund, J.R. (1993), "Transaction Risk versus Transaction Costs in Water Transfers," *Water Resources Research*, in press.

Lund, J.R., and M. Israel (1993), "Water Transfers in Engineering Water Resource Systems," *Water Resources Planning and Management*, ASCE (submitted).

Lund, J.R., M. Israel and R. Kanazawa (1992), *Recent California Water Transfers: Emerging Options in Water Management*, Center for Environmental and Water Resources Eng. Report 92-1, Dept. of Civil and Env. Eng., University of California, Davis.

Melton, P. (1989), "EBMUD makes $2.7 million water purchase," *Lodi News-Sentinel*, February 22, p. 1.

Metcalf & Eddy (1985), *Sacramento Area Water Resources Management Plan*, Metcalf & Eddy, Inc., Palo Alto, Ca.,

Milliman, J.W. (1959), "Water Law and Private Decision-Making: A Critique," *Journal of Law and Economics*, Vol. 2, October, pp. 41-63.

National Research Council (NRC) (1992), *Water Transfers in the West: Efficiency, Equity, and the Environment*, National Academy Press, Washington, D.C.

Nunn, S.C. and H.M. Ingram (1988), "Information, the Decision Forum, and Third-Party Effects in Water Transfers," *Water Resources Research*, Vol. 24, No. 4, April, pp. 473-480.

O'Brien, Kevin (1988) "Water Marketing in California," *Pacific Law Journal*, Vol. 19, pp. 1165-1199.

Reed, R.U. (1990), *Transferable Allocations in Urban Water Management: Short- and Long-Term*, Masters Thesis, Department of Civil Engineering, University of California, Davis.

Rigby, R.M. (1990), "Water Banking in Idaho," in J. Schaack, *et al*., (eds.), *Planning for Water Shortages: Water Reallocations and Transfers Drought Management*, Proceedings of the 1989 Regional Meetings of the U.S. Committee on Irrigation and Drainage, Denver, CO, pp. 113-118.

Saliba, Bonnie Colby and David B. Bush (1987), *Water Transfers in Theory and Practice: Market Transfers, Water Values, and Public Policy*, Studies in Water Policy and Management, No. 12, Westview Press, Colorado.

Saleth, R.M., J.B. Braden, and J.W. Eheart (1991), "Bargaining Rules for a Thin Spot Water Market," *Land Economics*, Vol. 67, No. 3, pp. 326-339.

Wahl, Richard W. (1989), *Markets for Federal Water: Subsidies, Property Rights, and the Bureau of Reclamation*, Resources for the Future, Washington, D.C.

Table 1
1991 Drought Water Bank Fallowing
Payments for Selected Crops

Irrigated Crop	Sacramento Valley and Delta Upland		Delta Lowland (1)		Comments
	Crop Water Use, Acre-foot per Acre (2)	$/Acre	Crop Water Use, Acre-foot per Acre (2)	$/Acre	
Alfalfa	3.5	450	3.2	400	rounded amount
Dry Beans	2.1	263	1.7	213	rounded amount
Field Corn	2.5	325	2.0	250	rounded amount
Pasture	3.5	450	3.2	400	rounded amount
Rice	3.5	450	-	-	rounded amount
Sugar Beets	3.0	375	2.5	325	rounded amount
Tomatoes	2.5	325	2.1	263	rounded amount
Wheat, Barley (3)	2.0 1.5 1.0	250 190 125	2.0 1.5 1.0	250 190 125	prior to 3/1/91 3/1/91 - 3/13/91 after 3/13/91

(1) Slightly lower values were used for crops grown in lower elevations of the Sacramento-San Joaquin Delta due to the influence of seepage from surrounding channels.
(2) The crop water use numbers in acre-feet are the estimated consumptive crop water needs that were expected to be met by applied irrigation water. These amounts assumed minimum rainfall in 1991, similar to rainfall in 1977.
(3) Water savings for these crops depend to a large extent on rainfall. The initial value of 2.0 ac-ft per acre was progressively reduced over time due to the record rainfall throughout March 1991.
Source: DWR, 1992a

Table 2
1991 Drought Water Bank Allocations
(in acre-ft as of December 20, 1991)

Location	Amount Allocated	Percent of Total
Alameda Co. Flood Control & Water Con. District	500	0.1
Alameda Co. Water District	14,800	3.8
American Canyon Co. Water District	370	0.1
City of San Francisco	50,000	12.8
Contra Costa Water District	6,717	1.7
Crestline-Lake Arrowhead Water Agency	236	0.1
Dudley Ridge Water District	13,805	3.5
Kern County Water Agency	53,997	13.8
Oak Flat Water District	975	0.3
Santa Clara Valley Water District	19,750	5.1
Metropolitan Water District of Southern Ca.	215,000	55.2
Westlands Water District	13,820	3.5
TOTAL	389,970	100.0

Source: DWR, 1992a

Table 3
1992 Drought Water Bank Allocations
(in acre-feet as of October 23, 1992)

Purchaser	Amount Allocated	Percent of Total
ALLOCATION TO AGRICULTURAL DEMANDS		
Broadview Water District	255	0.2
Del Puerto Water District	300	0.2
Foothill Water District	900	0.6
Hospital Water District	200	0.1
Kern County Water Agency	8,170	5.3
Orestimba Water District	75	0.05
Panoche Water District	2,000	1.3
Quinto Water District	100	0.05
Solado Water District	300	0.2
Sunflower Water District	400	0.3
Tulare Lake Basin Water Service District	31,550	20.4
Westlands Water District	51,000	33.0
TOTAL AGRICULTURAL USES	95,250	61.7
ALLOCATION TO FISH AND WILDLIFE DEMANDS		
Department of Fish and Game	20,000	13.0
ALLOCATION TO URBAN DEMANDS		
City and County of San Francisco	19,000	12.3
Contra Costa Water District	10,000	6.5
Metropolitan Water District of Southern California	10,000	6.5
TOTAL URBAN USES	39,000	25.3
TOTAL ALLOCATIONS FOR ALL USES	154,250	100

Source: Department of Water Resources (1992)