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California's Water Market, By the Numbers: Update 2012

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Summary

This report provides an overview of the policy context for water marketing and the related practice of groundwater banking and summarizes recent trends in both areas. The water market enables the temporary, long-term, or permanent transfer of the rights to use water in exchange for compensation. The ability to transfer these rights adds flexibility to the state's water supply—helping to address temporary drought conditions and to accommodate longer-term changes in the pattern of demand. Groundwater banking involves the deliberate storage of surface water in aquifers during relatively wet years, for use in dry years. Both tools are part of a modern water management portfolio that will enable California to manage its water resources sustainably, benefitting both the economy and the environment. Given the physical, financial, and environmental limits on expanding overall water supplies in California and the prospect of supply reductions caused by a warming climate, both tools are likely to become increasingly important.

Although state and federal policies have supported the development of water marketing and groundwater banking, no official publications track their evolution in California. Since the early 2000s, PPIC has tracked these trends in an effort to fill this information gap. This report provides an update of the 2002 PPIC report *California's Water Market, By the Numbers*, with an expanded analysis of statewide water market trends from 1982-2011 and new information on groundwater banking in Kern County and Southern California.

Jump-started by a prolonged drought in the late 1980s and early 1990s, the water market now accounts for roughly 5 percent of all water used annually by California's businesses and residents (about 2 million acre-feet of water trades are committed annually, with around 1.4 million acre-feet in actual flows exchanging hands). Over time, the market has shifted from primarily short-term (single-year) contracts to one dominated by longer-term and permanent trades. Farmers are the primary source of water, and the destinations include other farmers, cities, and the environment. Market growth has slowed since the early 2000s, reflecting a variety of infrastructure and institutional constraints, including new pumping restrictions in the Sacramento-San Joaquin Delta (a major conveyance hub) and more complicated approval procedures.

Although water agencies in several parts of the state have engaged in active groundwater storage for local water users for some decades, the practice accelerated in the mid-1990s with a new form of banking involving storage for offsite parties. These water banks—located in Kern County and Southern California— had built up reserves of nearly 3.4 million acre-feet by 2006. During the drought of the late 2000s, they made nearly 1.9 million acre-feet available to their depositors, considerably more than the drought-related water market sales. In Kern County, where basin management is still voluntary, these withdrawals have sparked controversies because they occurred during a time when overall groundwater levels were falling.

The report offers a number of recommendations for strengthening these tools and fostering their responsible development, including the following:

- Address infrastructure weaknesses in the Delta, which have already limited the market's ability to furnish dry-year water supplies, and which have begun to limit the availability of wet-year water supplies to replenish groundwater banks.
- Clarify and simplify the institutional review process for transfers, while continuing to prevent harm to the environment and adverse effects for other legal users of the state's waters.

- Strengthen local groundwater management to support both marketing and groundwater banking. Outside pressure—with a credible threat that the state would step in if local agencies fail to do so—might be the best way to proceed, ideally accompanied by positive financial incentives to improve basin management.
- Develop models for mitigating the economic effects of large-scale land fallowing deals. Economic shifts make it likely that some cropland will be permanently retired in the future, and alleviating the community-related effects of fallowing would help ease economic transitions.
- California should continue to pursue—and find the funds to support—environmental water purchases, which can help reduce the conflicts associated with reallocating water to the environment while improving the efficiency of environmental water management.
- Because routinizing marketing and banking transactions will require some risk-taking, high-level state and federal officials should be involved. One option might be to develop a coordinating committee from relevant agencies, with the authority to facilitate discussions and transactions.

Attending to these priorities will help ensure the success of two of the state's most critical strategies in its efforts to efficiently manage its water resources—water marketing and groundwater banking.

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Technical Appendices to this paper are available on the PPIC website:
http://www.ppic.org/content/pubs/other/1112EHR_appendix.pdf

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Abbreviations

Af	acre-foot
CAA	Clean Air Act
CALFED	State-federal program for the San Francisco Bay-Delta Estuary
CEQA	California Environmental Quality Act
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DFG	Department of Fish and Game
DWR	Department of Water Resources
ESA	Endangered Species Act
EWA	Environmental Water Account
IID	Imperial Irrigation District
maf	Million acre-feet
MWDSC	Metropolitan Water District of Southern California
NEPA	National Environmental Protection Act
RWQCB	Regional Water Quality Control Board
SWP	State Water Project
SWRCB	State Water Resources Control Board
taf	Thousand acre-feet
USBR	U.S. Bureau of Reclamation
WAP	Water Acquisition Program

Introduction

Two important tools for modern water management in California are water marketing and the related practice of groundwater banking. Water marketing involves the voluntary transfer of the right to use water from one party to another on a temporary, long-term, or permanent basis, in exchange for compensation. In California, water rights have generally been held for many decades under the state's "first in time, first in right" legal system.[1] Most of these rights have been allocated on the basis of seniority, and senior rights-holders (who have more reliable—and hence more valuable—supplies) often have relatively low-value uses for at least some of their water. The market provides incentives for water-rights-holders with more ample supplies and relatively lower-value uses to transfer some water to parties with less ample supplies and higher-value uses. The prices negotiated for these transfers provide useful information to all parties about the economic value of water, creating incentives to conserve water, to invest in local infrastructure to reduce conveyance losses from evaporation and leakage, and to coordinate infrastructure uses statewide. In this way, the market helps California's overall water use become more economically efficient. Short-term transfers (within a given year) are especially useful for coping with droughts. Long-term and permanent transfers facilitate longer-term shifts in economic activity and the associated changes in the pattern of water demands. Given the physical, financial, and environmental limits on expanding overall water supplies in California—and the prospect of supply reductions caused by a warming climate—the water market will become an increasingly valuable tool for supporting a healthy economy, along with other tools that improve the economic efficiency of water use and water infrastructure (Medellín-Azuara et al., 2012; Hanak and Lund, 2012; Hanak et al., 2011, Joyce et al. 2009).

Groundwater banking is one such tool. It involves the deliberate storage of surface water in aquifers during relatively wet years. California has considerable capacity to engage in such banking, with suitable aquifers in many population and farming centers. In many of these aquifers, years of overdraft—when withdrawals exceed natural recharge—have made substantial storage space available. Groundwater banking is a relatively cost-effective way to augment California's overall potential to store water, particularly for dry years (California Department of Water Resources, 2009; Hanak et al., 2011).[2] Expanding this type of storage can also help California adapt to a warmer future, because groundwater basins can help make up for the loss of seasonal storage now provided by the Sierra Nevada snowpack (California Department of Water Resources, 2008; Pulido-Velazquez et al., 2004; Connell-Buck et al., 2011; Hanak and Lund, 2012).

For many water managers, groundwater banks and water markets are complementary tools for accessing and managing supplies. A well-functioning water market also facilitates groundwater banking, because it enables managers to purchase and bank additional water for later use. Likewise, well-functioning groundwater banking programs can augment the volume of water available for lease or sale by moving

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[1] California has a dual system of surface water rights, consisting of riparian and appropriative rights. Riparian rights can only be used on lands adjacent to the surface water source from which the water is diverted; this restriction limits transferability to other users. Appropriative rights—the predominant form of surface water rights in California —can be used on non-adjacent lands. Before 1914, these rights were acquired through demonstrated use ("appropriation"); since the adoption of the state's modern Water Code, they have been acquired through state permits. This report focuses on appropriative rights, which are transferable.

[2] Groundwater storage is estimated to be one of the least expensive ways to make water available—with costs starting at $10 per acre-foot and ranging up to $600 per acre-foot in high-cost cases. Water transfers can cost between $50 and $550 per acre-foot; new surface storage ranges from $340 to $1,070 per acre-foot, and recycled municipal water ranges from $300 to $1,300 per acre-foot. Seawater desalination is still the most expensive source, ranging from $900 to $2,500 per acre-foot (Hanak et al., 2009, using various sources).

water from wetter to drier periods. Both the water market and groundwater banks help tie together California's often fragmented water infrastructure, and they increase incentives for local water managers in different parts of the state to cooperate.

State and federal policies have supported water marketing and groundwater banking in California over the past several decades through a suite of actions, including legal changes to facilitate marketing, direct purchases of water, grants to help fund groundwater banking infrastructure, and other policy initiatives. But while state and federal agencies oversee most water transfers, no official publications track the evolution of the market as a whole. Similarly, no official repository exists that documents the evolution of groundwater banking in California.

Since the early 2000s, PPIC has tracked these trends in an effort to fill this information gap. In 2002, PPIC published *California's Water Market, By the Numbers*, an overview of patterns and trends in the state's nascent water market (Hanak, 2002). Here, we provide an updated and expanded look at the evolving water market, including an additional decade of data on water trades (1982-2011) and a new set of data on groundwater banking.[3] As in earlier work, we focus on water trading that occurs between distinct management entities such as urban and agricultural water districts, not the trading that might occur between farmers or other businesses within the same irrigation or water district. We focus on volumes traded, not prices of transactions, because systematic information on prices is much less readily available in public data sources. For groundwater banking, we focus on projects that store water for off-site parties. This type of banking has grown in popularity since the mid-1990s in Kern County and in parts of Southern California. Many other entities throughout the state engage in active groundwater storage for their own use, but the lack of comprehensive reporting requirements on groundwater use in California makes it particularly difficult to track this activity.

In the following chapter, we provide a brief overview of the legal and policy context for water marketing and groundwater banking, as well as some basic information on the mechanics involved. We then present trends in the water market, discussing these trends in terms of duration (short-term, long-term, and permanent), geographic sources and destinations, and types of water users (agricultural, urban, and environmental). The fourth chapter provides similar information on trends related to groundwater banking. In the fifth and final chapter, we review our major findings and discuss their policy implications. The appendices contain information on sources and methods and detailed data tables.

[3] Several other PPIC reports also address water marketing and groundwater banking in some detail. *Who Should Be Allowed to Sell Water in California? Third-Party Issues and the Water Market* (Hanak, 2003) provides an in-depth discussion of water market trends through 2001 and policy challenges related to marketing and banking. *Managing California's Water, From Conflict to Reconciliation* (Hanak et al., 2011) and *Water and the California Economy* (Hanak et al., 2012) provide brief updates on market and banking trends during the 2000s and discuss related policy issues.

Some Basics on Water Marketing and Groundwater Banking

Water marketing and groundwater banking are important—and little understood—components of California's water management toolkit. The following sections describe how these tools work, including the evolving legal and policy context in which various types of deals are approved and implemented.

Who Can Sell Water and What Types Can They Sell?

California's Water Code provides two basic guidelines on who can participate in the water market: Sellers must have the rights to use the water throughout the term of the proposed transfer, and the water they sell must be "wet"—i.e., physical water, not merely unused "paper" rights (as described below). From a practical standpoint, sellers and buyers must also be able to get the water from the source to the destination, thus making suitable infrastructure a key ingredient.

Water-Use Rights

Although the appropriation of water rights in the first few decades following California's statehood generally involved individuals and private companies, most surface water rights today are held by local public agencies: special districts and some municipalities. Legally, some of these agencies actually hold long-term "contract entitlements" rather than "rights" to surface water; in these cases, the local parties have contracts with federal or state agencies that run large water projects and hold the associated water rights. The ultimate rights-holder for the federally-owned Central Valley Project (CVP) is the U.S. Bureau of Reclamation (USBR). The California Department of Water Resources (DWR) plays a similar role for the state-owned State Water Project (SWP). Because most water is still used for irrigation in California, most water is leased or sold by farmers or irrigation districts, who market water to other farmers with scarce supplies and higher value crops, to growing cities, and to environmental programs.[4] In some water districts, individual farmers have specific amounts of surface water (or "allocations") assigned to them and are therefore in a position to sell or lease this water, whereas in others the district will make this determination and compensate farmers who agree to participate in the transaction.[5] In rural areas, some water districts' governing boards are elected by a weighted vote of property owners, while in others, a one-person-one-vote rule applies. It is often thought that districts with the property-weighted voting rules (which more heavily represent local farmers) are more likely to sell or lease water to other parties.

Groundwater is also an important source of water in California—constituting about a third of statewide use on average, and more in dry years and in some regions.[6] In contrast to surface water, there are few places where groundwater rights are "quantified" (i.e., where users have rights to withdraw a specific quantity of water). Thus, the right to pump groundwater (and hence, potentially, to sell it) is generally available to all private individuals overlying the aquifer, as well as municipalities that have staked a claim to groundwater

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[4] In 2005, the most recent year for which statewide water-use estimates are available, agriculture used 77 percent of combined business and residential water use (Hanak et al., 2011, chapter 2, using data from DWR).

[5] In practice, contract entitlements are often larger than the actual deliveries, depending on hydrologic and regulatory conditions. In the permanent sales of contracts, the buyer acquires the contract at face value and receives water deliveries in the same proportion as the original holder of the contract. Leases of contract allocations involve transfers of actual deliveries.

[6] See Hanak et al., 2011, Chapter 2, for recent estimates of groundwater's share in California's overall water supply portfolio and in agricultural and urban uses by hydrologic region.

use as appropriators. Adjudicated basins—where groundwater rights *are* quantified—are located principally in urbanized areas of Southern California.[7] Specialized local agencies that regulate access to aquifers are also found in urbanized areas—notably Orange County (the Orange County Water District) and Silicon Valley (the Santa Clara Valley Water District). These districts charge pumping fees and manage recharge programs with the proceeds. Although groundwater management is improving elsewhere in the state, it remains largely voluntary, without pumping restrictions or pumping fees (Nelson, 2011; Association of California Water Agencies, 2011).

Wet Water

"Wet water" is the term commonly used in contrast to "paper water"—water rights held on paper for which actual water is not available. Under the appropriative water rights doctrine governing most of California's surface water, the "use it or lose it" requirement dictates that rights lapse for any water not used for five consecutive years (Water Code § 1241); this restriction is designed to prevent hoarding and speculation.[8] It is generally acknowledged that there are many more claims on surface water than the physical water typically available in the system.[9] This discrepancy arises from a combination of inactive claims that are still on the books and use rights that are only available in high flow years.[10] In addition, some water is used more than once within the same season, because most active claimants return some of the water they divert after using it. Such "return flows" (e.g., from irrigation drainage and wastewater treatment plants) are then available for reuse by others.[11]

Water-rights-holders must generally demonstrate that the water they propose to lease or sell is indeed "wet"—i.e., water they would have used otherwise in that season or legally stored for later use. Without this safeguard, the seller could end up transferring "paper" water that someone else is already legally using, causing harm to that user (or in legal parlance, "injury").

There are four potential sources of wet water:

- excess water stored in surface reservoirs to which the seller has rights,
- other excess amounts of surface water that the seller has the right to use, but does not need and cannot store,
- "conserved" surface water that the seller saves by reducing his or her own use, and
- groundwater.

The first two sources of excess surface water are not widely available. Only a few water-rights-holders have identified surplus supplies that they have made available for transfer.[12] The use-it-or-lose-it principle may be a significant deterrent in this context, despite the Legislature's assurances that the offer of water for sale may not be used as evidence of non-use or unreasonable use. In contrast, many CVP and SWP contractors have

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[7] For a map of these areas, see Hanak et al., 2011, Figure 4.1.

[8] As noted above, California also has some surface water-rights-holders under the riparian doctrine, which authorizes diversions from rivers and streams for beneficial use on adjacent lands. These rights are not generally transferable.

[9] For instance, the State Water Resources Control Board reported that the theoretical amount of claims on water-use rights within the Sacramento-San Joaquin Delta watershed (which supplies water to most agricultural and urban users in the state) was eight times higher than the amount of flows available in an average year (Governor's Delta Vision Blue Ribbon Task Force, 2008).

[10] This is the case, for instance, for SWP and CVP contracts, most of which only receive full deliveries in very wet years.

[11] For discussions of "gross" or "applied" and "net" or "consumptive" water use (the difference between which is usable return flow), see Hanak et al., 2009, and Hanak et al., 2011, Box 2.1.

[12] The Yuba County Water Agency is one of the main exceptions; it has regularly sold surplus water for drought mitigation and environmental programs.

transferred unstored excess surface supplies. The "use-it-or-lose-it" principle may be less of a deterrent for these users as they are contractors, rather than water-rights-holders, and the abandonment and forfeiture laws do not directly apply to them.[13] Otherwise, rights-holders may sell the excess surface water generated in very wet years, when they are likely to have less need for irrigation water. However, these are times when overall market demand is often more limited as well.

The third source of wet water, conservation—or reduced "net" water use—is a more generally available option. Two principal ways to achieve conservation are land fallowing and switching to crops that use less water. In some cases, conservation savings can also be achieved through investments to improve the efficiency of the conveyance and use systems (e.g., canal lining, installation of drip irrigation, and water recycling), although such investments may be discounted when they reduce the amount of water returned to the system.[14]

Groundwater, the fourth source of wet water, can be transferred directly or can be used on-site in lieu of surface water transferred to another party. The latter practice is known as "groundwater substitution" or "groundwater exchange." Groundwater-related transfers are subject to less oversight from the state than surface water transfers because the state's Water Code does not apply to most groundwater.[15] In many counties, the ability to transfer groundwater, either directly or through groundwater substitution, depends on local ordinances, which have sought to prevent harm to local users by limiting groundwater exports.[16] Because many groundwater basins have a hydrologic connection to surface waters, groundwater-related transfers can also be limited by the "wet water" principle. In particular, groundwater pumping can reduce surface flows in adjacent streams. For this reason, DWR has developed guidelines for Sacramento Valley groundwater transfers, restricting the location of wells that can be used for transfers and setting pumping ratios that deduct for the loss of surface water that occurs with pumping. These rules are described in the annual draft white papers on transfers, published by DWR in conjunction with the regional office of the USBR (California Department of Water Resources and U.S. Bureau of Reclamation, 2012). As discussed below, these rules are becoming increasingly strict, and are not without controversy.

Infrastructure

Of course, water marketing cannot happen without a hydrologic connection between sellers and buyers (Israel and Lund, 1995). Fortunately, California's extensive water infrastructure network has enabled a comparably extensive ability to run a statewide market. Numerous large water projects developed in the early to mid-20th

[13] An easing of the restrictions on such trades among CVP contractors is arguably one of the main effects on the water market of the 1992 Central Valley Project Improvement Act, described below. For SWP contractors, such trades take place through a "turnback" pool, introduced with the Monterey Agreement in the mid-1990s (described below). The remuneration for this water is quite low, but it helps defray costs contractors incur for their water whether or not they use it.

[14] In principle, only net savings constitute wet water that can be available for trading. For instance, because shifts in irrigation technology (e.g., from flood irrigation to drip irrigation) primarily reduce gross or applied water use, not the net amount consumed by crops, such shifts are generally not considered a valid method of making water available for transfer. What constitutes conservation for purposes of water transfers does sometimes diverge from net water savings, however, if those using the return flow do not have legal rights to use that water. For instance, canal lining reduces surface water losses from seepage into the groundwater basin, thereby reducing water that was available for neighboring groundwater users. A large canal lining project was nevertheless authorized to support a long-term transfer from the agricultural users of the All American Canal (Colorado River water) to water users in urban Southern California. The case was disputed in court, but the losing groundwater pumpers (on the Mexican side of the border) were deemed to not have the rights to the displaced water under the treaty that apportions Colorado River waters between the United States and Mexico (*Consejo de Desarollo Economico de Mexicali v. United States*, 482 F.3d 1157, 9th Cir.,2007). Similarly, under the imported water doctrine, other users do not have the rights to use the return flow (including seepage from a canal) if the importer can show it intended to capture it all for reuse.

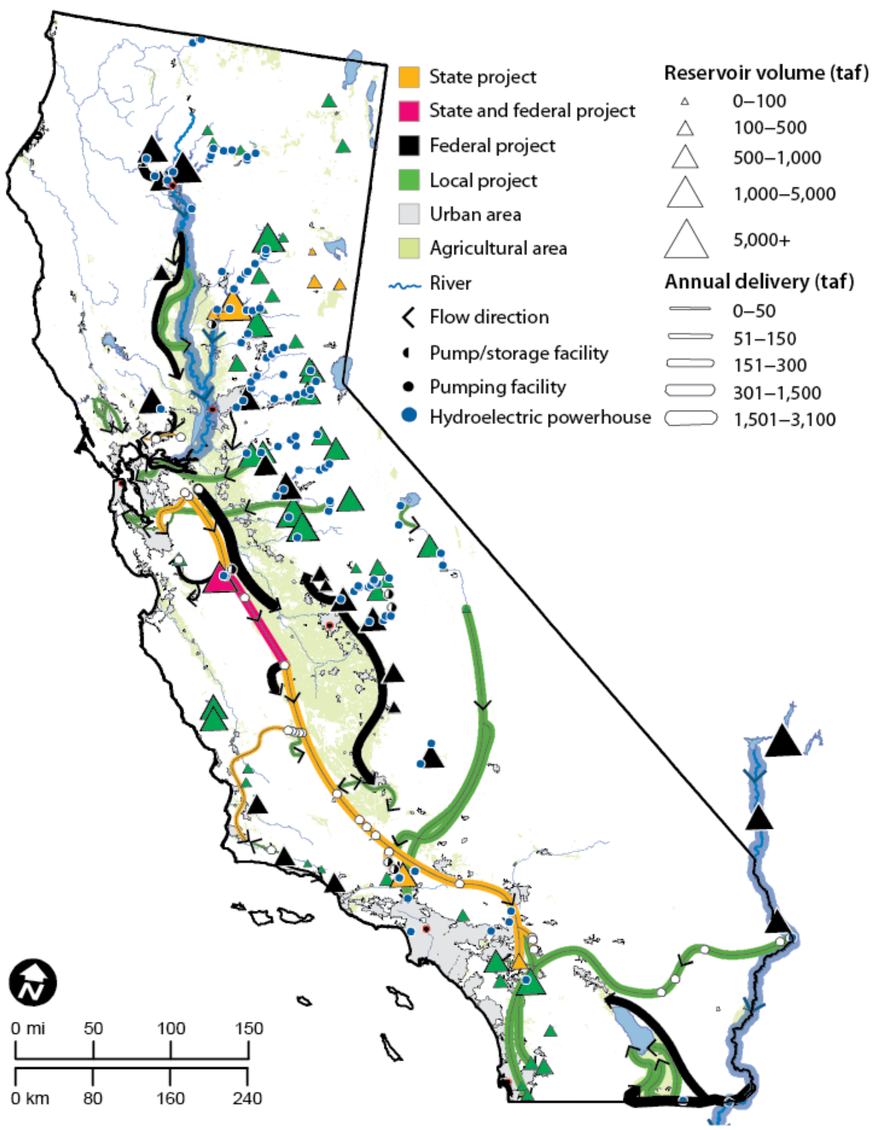
[15] Legally, the Water Code requires permitting of groundwater found in "subterranean streams"—i.e., water that flows beneath the surface—which excludes most California groundwater (generally considered to "percolate" down from the surface). These distinctions are not technically correct by the standards of modern hydrology, which recognizes the interconnection between most bodies of groundwater and surface water.

[16] See Hanak (2003) for a detailed discussion of county groundwater ordinances, which developed as the water market began to get under way in the 1980s and especially the 1990s.

century—including the CVP, the SWP, and investments to harvest water from the Colorado River and various local rivers—have forged hydrologic connections among most population and farming centers (Figure 1). Where the connections between transacting parties are indirect, the market works through a series of exchanges, where one or more intermediary agencies take the seller's water and make an equivalent amount available to the buyer. Exchanges are also important in cases where the terms of water rights do not readily allow direct transfers, for instance between members of different water projects.

As described below, the market has recently experienced new frictions because of infrastructure constraints at a key conveyance hub in the Sacramento-San Joaquin Delta, limiting both north-to-south and east-to-west transfers.

FIGURE 1
California's extensive infrastructure network facilitates water marketing



SOURCE: Hanak et al., 2011.

The How and Where of Groundwater Banking

Groundwater substitution transfers are one of several types of “conjunctive use” of groundwater and surface water. With conjunctive use, the aquifer serves as an underground reserve that can be drawn upon to a greater or lesser degree as the quantity of available surface water varies. Recharge methods depend on the state of the aquifer and the permeability of the soils. Large “spreading basins” are used in areas with good permeability, such as the Kern Fan in Kern County, while deeper “injection wells” are sometimes used to inject water into aquifers in areas where the soils are less permeable or where more precision and speed is required (e.g., to maintain a fresh water barrier along coastal Orange County). Groundwater substitution can enable “in lieu” recharge, where the basin is recharged naturally when local water users apply more surface water than usual and commensurately reduce their pumping in wetter years. This practice is especially useful in areas where the soils are less permeable (e.g., the Semitropic Water Storage District in Kern County), or where the aquifer is already quite full, as in much of the Sacramento Valley. In the latter case, the aquifer is drawn down first and then refills naturally in later years when local water users revert to a greater proportion of surface water use.[17]

Informal conjunctive-use programs have operated in many parts of California for as long as large water projects have made substitute surface water available. Thus, for decades farmers in irrigation districts along the east side of the San Joaquin Valley have used flood irrigation and spread water on fields in wetter years to recharge their groundwater basins; the districts adjust surface water prices to encourage this practice (Vaux, 1986; Jenkins, 1992).

“Groundwater banking” generally refers to a more formal type of conjunctive use in which groundwater managers keep track of the volumes of water recharged into the aquifer and the volumes withdrawn, as in a financial bank. Adjudicated basins and special groundwater districts with authority to regulate access to the aquifer have long engaged in these more formal banking operations. Since the 1990s, groundwater banking projects have become increasingly popular in other parts of the state as well, including places lacking a formal authority over who has the rights to the water. In such cases, it is necessary to set up monitoring procedures and rules to prevent harm to neighboring users, which could occur if withdrawals from the bank lower groundwater tables below the levels that would occur without banking. In normal and wet years, these neighbors tend to benefit from the recharging activities, which raise average groundwater levels for local bankers as well as neighboring properties. (The benefit is financial: Higher groundwater levels reduce pumping costs.) However, because these banks do not restrict access to neighboring pumpers, there are also potential risks to those storing water in the banks—for example, if local pumping compromises access to the volumes stored in the accounts.

This report focuses on projects in which banking is undertaken for distribution to off-site parties. These projects typically involve local public agencies or consortia of public and private agencies (for example, the Kern Water Bank). They could conceivably be run by a single private entity—such as a large farming operation—if it were sufficiently large to cover the banking area. Some of these banks also operate formal accounts for local pumpers, keeping track of what they use and what they pay for, while others operate more informal local conjunctive-use programs alongside the formal banks for off-site parties.

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[17] Groundwater substitution without compensating direct or in-lieu recharge of surface water can lead to long-term overdraft of the groundwater basin or increased infiltration from nearby bodies of surface water. In the latter case, the basin naturally recharges by reducing the flow in the adjacent river or stream, potentially causing harm to surface water users and the environment.

As with water marketing, infrastructure is key to making groundwater banking work. Locally, banking projects often need to augment their connections to larger conveyance facilities, in addition to creating recharge and pumping facilities. Statewide, the capacity of the infrastructure grid is also important. For instance, many banks count on storing Delta exports during wet years, a practice that recent pumping restrictions have made more difficult. Likewise, if Delta pumping is restricted, it can be more difficult for parties located upstream of the banks (e.g., Bay Area cities) to access banked water during dry years. To retrieve water they stored in the bank, these upstream depositors divert Delta exports that the banker would have otherwise used, and export restrictions can limit the amounts available for this purpose.

The Approval Process

The approval process for water transfers varies with the nature of the water right and the source of water. The State Water Resources Control Board (SWRCB) must approve transfers (i.e., changes in purpose, place of use, or point of diversion) involving any surface water rights established since 1914 (the year the state's modern Water Code came into effect). Transfers of surface water among contractors within the CVP and SWP generally do not require SWRCB approval because they do not involve a change in the purpose, place of use, or point of diversion assigned to the overall water right, but the projects themselves must authorize these transfers. Transfers of groundwater and surface water held in pre-1914 appropriative rights do not require SWRCB approval because the board does not have direct regulatory jurisdiction over these types of water rights. However, transfers of these rights do require public notice and review under the California Environmental Quality Act (CEQA), and also the National Environmental Protection Act (NEPA) when federal water rights are involved.[18] Such transfers also come under state or federal jurisdiction if government-owned conveyance facilities are involved, which is likely to be the case in many areas of the state. In particular, transfers conveyed through the Sacramento-San Joaquin Delta typically need to use the state-owned Harvey O. Banks Pumping Plant, requiring DWR approval. And, as noted above, groundwater-related transfers from many rural counties require a county permit demonstrating no injury to local groundwater users.[19] Transfers of surface water held under riparian rights—available only to those whose land is directly adjacent to rivers and streams—are generally not permitted because such water is attached to the land.[20]

The approval process for groundwater banking is evolving. Use of injection wells for recharging requires approval by the relevant regional water quality control board (RWQCB), which is responsible for preventing contamination of the native groundwater with imported water. Rules have varied across the state, with Southern California regional boards generally more flexible than the Central Valley RWQCB, which has blocked injection of treated drinking water by the municipal water departments in Roseville and Tracy over concerns about the effects of the chemicals used in treatment.[21] There is also growing pressure for water banking and conjunctive use projects outside of fully managed basins to shore up permits with the SWRCB before expanding their operations. The logic is that groundwater banking involves the storage of excess

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[18] Transfers of post-1914 rights that are considered temporary (one year or less) are exempted from CEQA, on the grounds that they must go through SWRCB review.

[19] In several counties (San Diego, Mendocino, Monterey, and Napa), the permitting process involves incorporation of a groundwater review or overlay in a regular ministerial process, rather than application for a discretionary permit with CEQA review.

[20] In 1991, when the state ran a program of drought purchases, it established a work-around to this constraint, by paying some Delta farmers with riparian rights for not irrigating their lands (Gray, 1994a). Although this did not technically involve paying for the water, it made water available for other users.

[21] In September 2012, the SWRCB adopted an order that proposes general waste discharge requirements for projects that recharge groundwater with treated drinking water, with the goal of streamlining the permitting process and ensuring consistent requirements for these projects (http://www.waterboards.ca.gov/water_issues/programs/asr/index.shtml).

surface water—making the standard no-injury rules that apply to surface water transfers relevant. This process can be complicated, because many local entities draw on a variety of existing surface rights, including both pre- and post-1914 diversions, which they will need to show they are putting to "beneficial use" (i.e., not wasting). (Although regular reporting of appropriative surface water diversions is required in California, the practice has been spotty at best.) There are also questions over whether a permit is needed to bank flood flows that are not currently appropriated by anyone.[22] Finally, SWP and CVP contractors wishing to store their water in off-site banking projects need to get permission from the state and federal projects, just as they would for a water transfer.

The Evolving Policy Context

For much of the past several decades, state and federal policies have supported the development of marketing and banking through a suite of actions, including legal revisions to facilitate marketing, direct purchases of water, and grants to help fund groundwater banking infrastructure. At the same time, local resistance to transfers has arisen in some source regions over concerns that transfers could harm local economies—as evidenced by the rise of county ordinances restricting groundwater exports and other objections. In recent years, various state and federal authorities have also placed new restrictions on water transfers.

State and Federal Support Initiatives

State initiatives to support the market began in 1977, a year of severe drought. Two reports commissioned at that time, one by the governor and one by the legislature, strongly endorsed water marketing as an element in the state's strategy for handling its future water needs (Governor's Commission to Review California Water Rights Law, 1978; Phelps et al., 1978). The governor's commission also advocated various changes in the Water Code to facilitate transfers, notably provisions to ensure the security of water rights for parties leasing water to others and to ensure access to the use of conveyance facilities owned by other parties. Although many of the recommendations were accomplished in the years that followed, the 1980s saw little uptake in market activity.

In the early 1990s, several events significantly changed the trading climate. First, natural conditions provided the occasion for a large-scale experiment in water trading when a multiyear drought prompted the state to initiate an emergency water bank in 1991. The following year, in response to findings that the federally run CVP was harming the indigenous wildlife of the San Francisco Bay-Delta estuary, Congress passed the Central Valley Project Improvement Act (CVPIA). The Act mandated that 800,000 acre-feet (af) of project water (of a total of about 7 million af) be returned to instream uses to regenerate salmon runs, and that another 400,000 af be allocated to wildlife refuges. The CVPIA also contained provisions to facilitate water marketing and introduced a mechanism for the project to purchase additional water for environmental purposes.

In 1994, the SWP contractors concluded negotiations for the Monterey Agreement, a revision of project operating rules that facilitated water marketing and groundwater banking by the contractors. It authorized the first permanent transfer of contract entitlements from some agricultural contractors to smaller urban contractors and established other measures to make it easier for contractors to transfer water to one another. This agreement also led to the transfer from state to local ownership of a part of the Kern Fan, near Bakersfield, where the state had unsuccessfully attempted to launch a groundwater bank. This area, now

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[22] Appropriative rights to divert surface water are allocated on the basis of seniority, and some junior rights are only available in wetter years. However, in very high flow years, some rivers that are considered fully appropriated have excess water, and banking projects could potentially capture some of this flow.

known as the Kern Water Bank, has become one of the leading examples of groundwater banking. (A similar federal attempt to launch a groundwater bank in Madera County failed; USBR is negotiating with the managers of this new bank, now in local hands, to develop an offsite storage agreement for CVP water.) The Monterey Agreement also encouraged other water banking partnerships in Kern County by giving SWP contractors the express right to store water outside their service areas.

Two other significant activities were undertaken by the state and federal governments in the late 1990s and in 2000. Under instructions from the U.S. Secretary of the Interior in 1996 and 1997, California began to devise a plan to reduce its use of Colorado River water to the contractually allocated amount of 4.4 million af over a 15-year period. This 4.4 Plan created strong incentives for water transfers between agricultural and urban users of Colorado River water within California, leading to a suite of long-term agreements that were finalized by 2003. In 2000, state and federal authorities launched the Environmental Water Account (EWA), a program of environmental water purchases under CALFED—a multiagency state and federal program with the goal of restoring health to native fishes in the San Francisco Bay-Delta Estuary while securing water supplies to agricultural and urban users. Although the CALFED program was superseded by new governance arrangements under legislation passed in late 2009, the EWA continues to operate on a diminished scale as part of a long-term transfer of water from Yuba County (described below).

During the 2000s, the state also ran smaller drought water-purchase programs in two dry years (2001 and 2009), and the federal government sought to further ease transfer restrictions for CVP contractors and others wishing to use CVP-owned transfer facilities. Federal-state cooperation also increased, as the CVP and SWP were granted temporary "joint place of use" south of the Delta during the drought of the late 2000s. Under this arrangement, water allocations for the two projects were treated as though they derived from the same water right, making it possible for contractors from the two projects to transfer water to each other without seeking SWRCB approval for each transfer—a time-consuming step in the normal approval process. Since 2000, the state has also offered numerous grants and low-interest loans (totaling roughly $350 million) to local agencies to support the development of groundwater storage, reflecting the emphasis in recent updates of the *California Water Plan* on conjunctive use as a water supply diversification tool.[23]

Local Concerns in Source Regions

In tandem with state and federal efforts to expand the market in the 1990s, concerns over the prospect of damage to local economies led to an increase in county groundwater ordinances in many rural counties (Hanak, 2003, Hanak and Dyckman, 2003). These ordinances all restrict direct groundwater exports; most also restrict groundwater substitution transfers, and some aim to restrict groundwater banking with non-local parties (Figure 2).[24] The absence of state-level no-injury protections for groundwater derives from incomplete state groundwater regulation; county ordinances have been deemed legal because this type of injury needs to be prevented to avoid harm to other legal water users.[25] (In economic terms, transfers that reduce other users'

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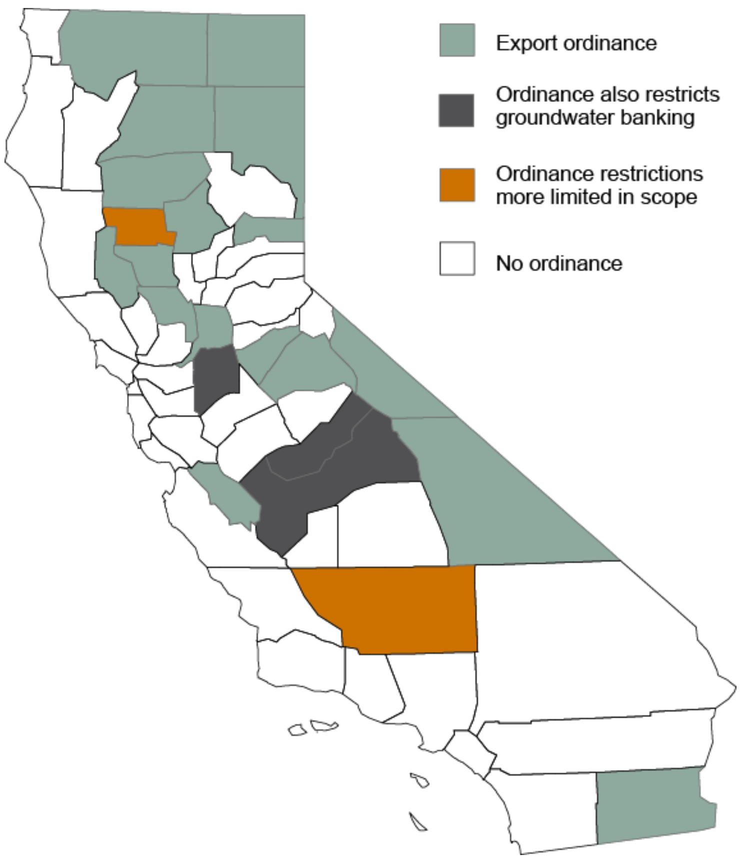
[23] For a discussion of conjunctive use in the state water plan, see California Department of Water Resources (2005, 2009). The grants and low-interest loans have been provided under three bond acts (Propositions 13, 50, and 84). Data were provided by DWR; for details on Proposition 13 see http://www.grantsloans.water.ca.gov/docs/prop13/Prop_13_Final_Report.pdf.

[24] Groundwater banking restrictions are included in the ordinance of San Joaquin County, where there were concerns about a joint banking project with the East Bay Municipal Water District (Hanak, 2003; Thomas, 2001).

[25] The state Water Code does contain some restrictions on groundwater-related transfers. In particular, Water Code § 1220(a) states that no groundwater can be pumped for export from within the Sacramento and Delta-Central Sierra basins unless there is a groundwater management plan in place, and Water Code § 1745.10 limits groundwater substitution transfers to those that will not result in long-term overdraft. However, in 1994 an appellate court ruled that the state did not "preempt the field" in this area, and it granted counties the authority to exercise their police powers to protect public health and safety with groundwater ordinances (*Baldwin v. County of Tehama*, 31 Cal. App. 4th 166, 173–74 (1994, 3rd Dist.);

access to water generate negative "physical externalities" and must be mitigated to avoid economically inefficient transfers). However, rather than encourage a process of review and proper mitigation of transfers, the ordinances appear to have worked principally to discourage groundwater-related transfers altogether from these counties.[26]

FIGURE 2
County ordinances restrict groundwater export from many rural counties



SOURCE: Hanak, 2003.

NOTE: Figure shows ordinance status as of 2002. To our knowledge, no additional county groundwater ordinances have been adopted since then. Kern County's ordinance is limited to the southeast portion of the county within the South Lahontan hydrologic region. (Figure 12 shows this regional breakdown.) Glenn County's ordinance was updated in 2000 and now relies on basin management objectives that do not automatically restrict groundwater exports.

Some groups are also concerned about the potential for fallowing-based transfers to cause local economic harm. Transfers compensate farmers who fallow fields for the crop revenues they forego; but local businesses, workers, and governments do not automatically receive compensation for any economic harm they might suffer when the crop activity declines. Fallowing-related damages (or "pecuniary externalities") are not proscribed under state law, which generally views them as a natural consequence of a shifting economy, much like the opening or closing of a manufacturing plant may affect neighboring businesses and property values

review denied, Cal. Sup. Ct., March 17, 1995). See Hanak and Dyckman (2003) for a detailed discussion of the legal issues surrounding county ordinances.

[26] Hanak (2003) conducted a detailed review and found few permit applications through 2002, suggesting that the ordinances were having a chilling effect. Anecdotal information from local agencies suggests that there has been little change in subsequent years.

for better or worse. Studies of actual and projected fallowing operations suggest that the aggregate local losses are likely to be limited, because farmers tend to fallow their least profitable fields.[27] State law does require public hearings if a local agency wishes to transfer water available through fallowing and the volume exceeds 20 percent of the agency's water supplies (Water Code § 1745.05). When transfers use a public entity's conveyance facilities, that entity is also required to ensure that they do not cause significant economic harm (Water Code § 1810). Transacting parties have voluntarily developed community mitigation programs for two large, long-term fallowing-based transfers of Colorado River water; these may serve as useful models for similar transfers in the future.[28]

New State and Federal Restrictions

In the late 2000s, some state and federal policies also increased restrictions on marketing. Over time, DWR has progressively increased its scrutiny of transfers between points north and south of the Delta over concerns of potential injury to the SWP. The SWP holds relatively junior water rights to Sacramento Valley water, which it ships to most of its contractors through pumps in the south Delta. Concerns that transfers are impinging on these flows have led to increased restrictions on acceptable locations and ratios for groundwater substitution transfers and tighter restrictions on acceptable fallowing arrangements.[29]

Since 2007, the ability to move water through the Delta has also become more limited as a result of concern for endangered fish species, whose populations plummeted in the preceding years. Although the new pumping restrictions have not specifically targeted water marketing, they limit the physical infrastructure available for transfers, which have lower priority than the CVP and the SWP when it comes to using the project-owned pumps in the south Delta. (Most such transfers use the SWP-owned pumps, which more often have unused capacity than the CVP-owned pumps).

Finally, new environmental restrictions have been imposed on transfers for reasons other than protection of instream flows, the traditional focus of no-injury protections. Fallowing of fields to make water available for transfers has been severely restricted in rice-growing areas (primarily in the Sacramento Valley) to prevent harm to habitat of the endangered giant garter snake, a listed species that now depends on artificial wetlands created by irrigation water.[30] Groundwater-related transfers have also become subject to Clean Air Act restrictions against the use of diesel pumps—a regulation farmers are normally exempt from when they pump water for their own use. As we discuss in the following chapter, it is likely that these assorted restrictions have dampened market activity in recent years.

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[27] See Hanak (2003) for a summary of these studies.

[28] The transfer from the Imperial Irrigation District to the San Diego County Water Authority has set aside $40 million for socioeconomic mitigation, and the transfer from the Palo Verde Irrigation District to the Metropolitan Water District of Southern California has set aside $6 million (now over $7 million with accumulated interest); see Hanak et al., 2011.

[29] These conditions are presented in a draft white paper on water transfers prepared by DWR and USBR, which is updated annually (California Department of Water Resources and U.S. Bureau of Reclamation, 2012).

[30] Under current rules, farmers wishing to fallow land for transfers must limit each fallowed field to 320 acres and surround these fields with cropped land (California Department of Water Resources and U.S. Bureau of Reclamation, 2012). This practice, intended to provide corridors for safe passage of the snake, effectively limits the potential fallowed area to 20 percent at any given time, in highly specified patterns.

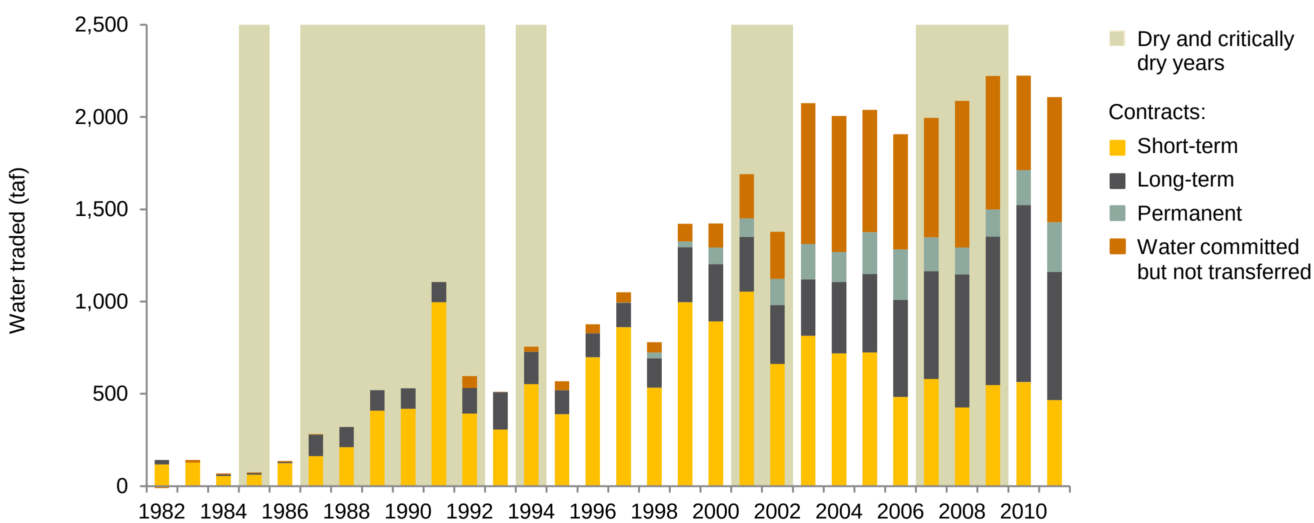
Water Market Trends

This chapter presents trends in the water market through a variety of lenses: duration (short-term, long-term, and permanent), geographic sources and destinations, and types of water users (agricultural, urban, and environmental).

Phases in Market Development

Water marketing has grown significantly in California over the past three decades. Figure 3 shows actual flows under short-and long-term lease contracts (yellow and dark blue bars), estimated flows under permanent sale contracts (light blue bars), and the additional volumes committed under long-term and permanent contracts that were not transferred in those years (orange bars). Annual trades in the early 1980s averaged just over 100,000 af. The market took off during a multiyear drought in the late 1980s and early 1990s, spurred by direct state purchases and the development of an emergency drought water bank. The market continued to grow when the rains returned; and by the early 2000s, the annual volume of water committed for sale or lease was over 2 million acre-feet (maf), with roughly 1.3 maf actually moving between parties in any given year. These volumes increased slightly by the end of the decade, and trades now represent about 5 percent of all water used by businesses and residents in the state.[31]

FIGURE 3
California's water market has grown substantially since the early 1980s



SOURCE: Data collected by the authors (for details, see Technical Appendices Table B1).

NOTES: The figure shows actual flows under short-and long-term lease contracts (yellow and dark blue bars), estimated flows under permanent sale contracts (light blue bars), and the additional volumes committed under long-term and permanent contracts that were not transferred in those years (orange bars). The database includes transactions between water districts, federal and state agencies, and private parties that are not members of the same water district or wholesale agency. (See Technical Appendix A for a detailed description of methods). "Dry years" are those classified as critical or dry for the Sacramento Valley based on the California Cooperative Snow Survey (see Technical Appendices Table B1).

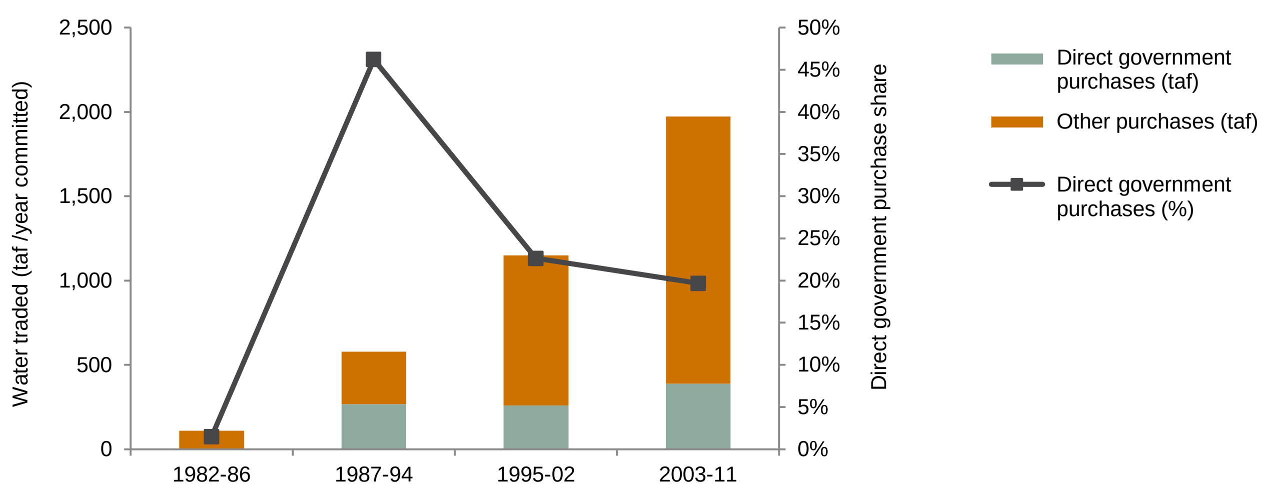
[31] From 1998 to 2005, Californians used an average of 41.7 maf of water (33 maf in agriculture, 8.7 maf in urban uses). This total includes roughly 8 percent in conveyance losses. (Data from DWR; for details see Hanak et al., 2011, Chapter 2).

It is useful to consider market development in three phases, characterized and shaped by different forces: 1) the early drought years (1988-1994); 2) an intermediate phase, when environmental concerns drove continued growth (1995-2002); and 3) the most recent period, marked by two distinct trends: a shift toward long-term and permanent trades and a slowing of overall growth in trades (2003-2011).

Takeoff Spurred by Drought Purchases (1987–1994)

During the eight-year period from 1987 to 1994, California experienced only one "normal" precipitation year (1993); five of the remaining seven dry years were deemed "critically dry." These hydrologic conditions provided the opportunity for the state to help jump-start the market. DWR began making dry-year purchases to offset lower deliveries to SWP contractors and wildlife refuges in 1987. These early operations, which involved only a handful of Sacramento Valley water districts (most notably the Yuba County Water Agency), quickly brought the total volumes traded in the state to over 500,000 af. In 1991, when the dry-year market was opened up to any willing buyers and sellers, DWR purchased 821,000 af for resale, bringing the overall market volume to over 1,100,000 af.[32] Water banks and other dry-year purchases were also operated in 1992 and 1994. From 1987 to 1994, state and federal dry-year purchases for resale and environmental uses accounted for nearly half of a market that had increased more than five-fold from pre-drought levels (Figure 4).

FIGURE 4
Direct government purchases spurred early market development



SOURCE: Data collected by the authors (For details, see Technical Appendices Table B2b).

NOTE: The figure shows actual flows under all contracts and volumes committed but not transferred under long-term leases and permanent sales.

Continued Growth Driven by Environmental Concerns (1995–2002)

Although the second half of the 1990s saw a succession of wet years, market activity remained strong, with volumes typically exceeding the drought-year levels, especially by the end of the decade. The only dips in a generally upward trend in purchases occurred in the exceptionally wet years of 1995 and 1998, when many

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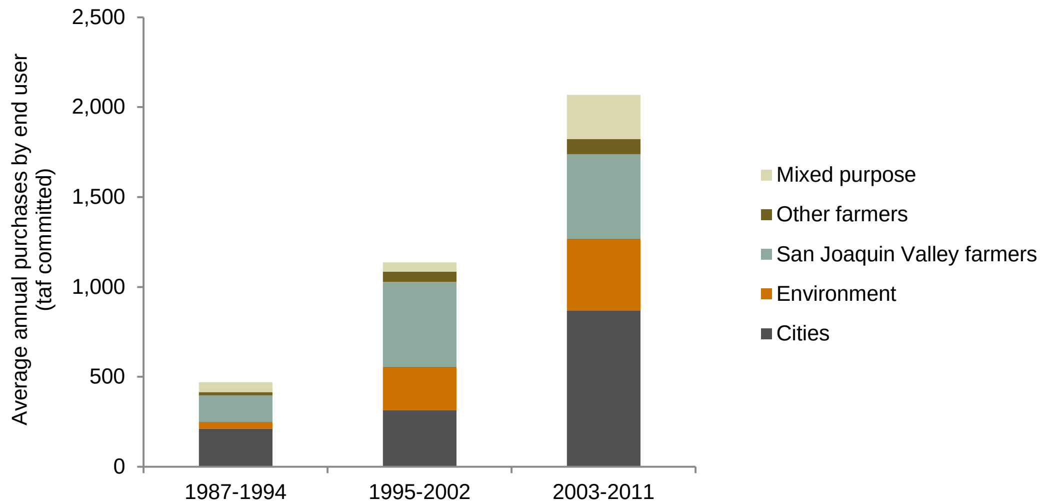
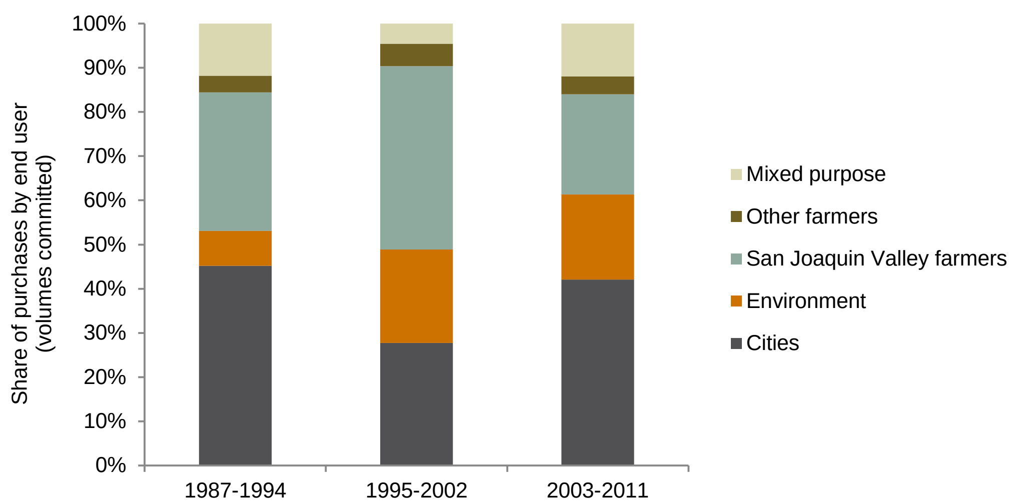
[32] Wet conditions late in the 1991 rainy season (the "March Miracle") resulted in lower-than-anticipated purchases from the bank, so DWR was only able to sell about half of the water. The rest was melded into SWP supplies and paid for by all the project contractors.

areas of the state experienced flooding. Market growth in this period was largely driven by environmental concerns. The influence of environmental policy is most readily seen by comparing the patterns of water purchases during the drought years (1987-1994) to those in the subsequent eight years, when rainfall was generally above normal (Figures 5a and 5b).

FIGURES 5A AND 5B
Environmental concerns shifted the composition of purchases in the 1990s





SOURCE: Data collected by the authors (see Technical Appendices Table B3b).

NOTES: The figure shows actual flows under all contracts and volumes committed but not transferred under long-term leases and permanent sales. In some years, total purchases shown are lower than total sales reported in Figures 3 and 4, owing to surplus drought purchases by DWR and smaller discrepancies in some user pools. "Mixed uses" denote purchases by agencies with significant urban and agricultural uses, such as the Coachella Valley Water District and the San Luis Delta Mendota Water Authority.

The most obvious element of the new role for the environment is the rise in direct purchases for instream uses and for wildlife refuges through federal and state programs, including USBR's new Water Acquisition Program (introduced under the CVPIA) and CALFED's new Environmental Water Account. As a beneficiary of DWR's drought purchases, the environment already accounted for 8 percent of purchases during 1987–1994.

Between 1995 and 2002, this share rose to 21 percent. On an average yearly basis, environmental purchases increased more than six-fold, nearly three times faster than the market as a whole.

The less obvious component of demand related to environmental policy changes is the increase in water purchases by San Joaquin Valley farmers. Although this group's change in market share is less dramatic (growing from 31 to 41 percent between the first and second period), its increase in average volumes—by over 320,000 af per year—accounts for nearly half of total market growth. Much of this growth can be linked to the changes introduced under the CVPIA in 1992, which mandated that a portion of project water be returned to instream uses and wildlife refuges. Since then, CVP agricultural service contractors located south of the Delta have received full project deliveries in only three very wet years (1995, 1998, and 2006).[33] One outcome has been an active water market, as some contractors (most notably Westlands Water District) sought to offset reductions in deliveries through market purchases.

These two components of the environmentally-related water market were not without tension. On the one hand, the environmental water purchase program could be viewed as a benefit to other water users, because it avoided additional uncompensated regulatory cutbacks to protect fish and other wildlife. On the other hand, the sheer size of these relatively well-funded programs meant that some farmers wishing to purchase make-up water viewed them as a source of tough competition.

The corollary of growth in environmentally-related demand was a decline in the relative importance of municipal and industrial users following the drought years. Whereas cities were the main recipients of traded water during the drought, accounting for 45 percent of all purchases from 1987–1994, their share in the following eight years fell to 28 percent. With the exception of 1991, when urban purchases reached nearly 500,000 af, volumes remained relatively flat throughout the 1990s, averaging around 230,000 af (see Technical Appendices Tables B3a and b). This began to change by 2000, as some cities successfully negotiated long-term and permanent deals to purchase water.

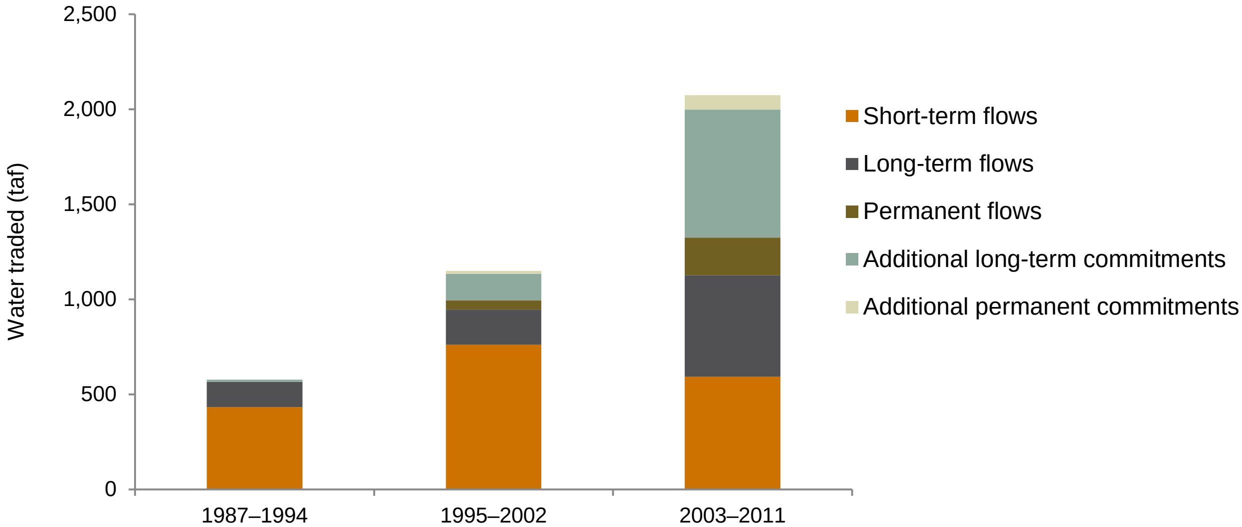
Long-Term Transactions Have Risen (2003–2011)

The most recent phase of market development began in 2003, the first year of a package of long-term transfers among agricultural and urban Colorado River water-rights-holders, included as part of California's plan to reduce its overall use of this river. These contracts commit over 500,000 af of annual transfers over a 75-year period,[34] and volumes flowing under these deals have increased steadily. These and numerous other long-term and permanent deals made between parties around the state have shifted the character of California's water market. Whereas short-term trades accounted for roughly three-quarters of all transfers in the 1980s and 1990s, they now account for less than half of all flows and only a quarter of total volumes committed (Figure 6).

[33] Technical Appendices Table B1 provides information on runoff conditions in the Sacramento Valley and water-year type.

[34] For details, see Technical Appendices Table B9. The new transfer agreements under the QSA include the movement of 303,000 af/year of water from the Imperial Irrigation District (IID) to the San Diego County Water Authority and the Coachella Valley Water District, two canal lining projects that will move nearly 96,000 af of conserved water from IID and Coachella to San Diego and the San Luis Rey Indians, and the movement of up to 111,000 af/year from the Palo Verde Irrigation District (PVID) to the Metropolitan Water District of Southern California. (Metropolitan has contracted with the San Luis Rey Indians to use their water until the tribe can put it all to beneficial use). The QSA also recognizes an existing transfer of 110,000 af/year from IID to Metropolitan, in place since 1987. In addition to these long-term agreements, some temporary transfers have taken place between PVID and Metropolitan during the recent drought.

FIGURE 6
Long-term and permanent trades now dominate the market



SOURCE: Data collected by the authors (see Technical Appendices Table B1).

NOTE: The figure shows actual flows under all contracts and volumes committed but not transferred under long-term leases and permanent sales.

These transfers have been supplied by a combination of system improvements (e.g., canal lining and operational efficiencies), agricultural land retirement, on-farm irrigation efficiency improvements (where improved efficiency generates net water savings, such as in the Imperial Irrigation District), and releases of water from surface and groundwater storage (e.g., Yuba County). As with temporary transfers, agricultural water districts are the principal suppliers, originating roughly 80 percent of all long-term and permanent contracts and 95 percent of all committed flows. (They supply 85 percent of all short-term transfer flows). Cities are the leading purchasers, with the largest overall volumes, average deal sizes, and average contract durations (Table 1). However, this market is also serving other demands, including the environment and—increasingly—farmers, who are actively involved as buyers in mixed-use contracts as well as those destined purely for agricultural uses (Table 1).

Nevertheless, farmers have declined in importance in overall market demand, accounting for only a quarter of all contractual commitments and 36 percent of actual flows from 2003–2011, with average purchases remaining virtually the same as in the prior period (Figure 5). Water purchases for the environment have remained important, increasing in absolute terms, and declining only slightly as a share of the overall market to 19 percent of commitments and 20 percent of flows. The real demand growth has come from cities, with over three times more commitments and 2.4 times more actual flows acquired than in 1995–2002. As during the early drought years, urban agencies again account for over 40 percent of market demand, and this time most of this water is available to support longer-term growth, not just to compensate for shortages during droughts.

TABLE 1
Destination of long-term and permanent contracts

	Number	Total maximum volume (taf/yr)	Average maximum volume (taf/yr)	Average duration (years)	Share of total volume (%)*
Long-term contracts (1979–2012)	52	1,676	32	22	
– Cities	25	936	37	33	71
– Mixed uses	5	339	68	28	4
– Environment	9	201	22	11	21
– Agriculture	13	199	15	8	4
Permanent contracts (1998–2012)	52	328	6	–	
– Cities	23	158	7	–	48
– Mixed uses	2	26	13	–	8
– Environment	16	38	2	–	12
– Agriculture	11	107	10	–	32

SOURCE: Data collected by the authors (For details, see Technical Appendices Tables B8 and B9).

NOTE: *For long-term contracts, the sectoral shares are calculated for the volumes committed over the lifetime of the contracts.

The growth of long-term and permanent transfers is a sign that the water market is maturing. These transfers generally involve more complex negotiations and more in-depth environmental documentation. They are particularly important for supporting economic transitions. By law, urban water agencies need to demonstrate long-term supplies to support new development, and transfers can provide this assurance.[35] Long-term commitments for environmental flows provide flexibility for environmental managers and can reduce the conflicts associated with regulatory alternatives to market-based transactions. Long-term commitments to make temporary supplies available during droughts are also an important way to enhance operational flexibility. A case in point is the recent 17-year transfer agreement between the Yuba County Water Agency and DWR, the so-called "Yuba Accord." In addition to making available some supplies for environmental uses, this transfer offers supplies to a pool of SWP and CVP contractors during dry and critically dry years. By working out all of the approval issues well in advance, such deals make it possible to act quickly during a drought or other supply emergency.[36]

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[35] Senate Bills 221 and 610, passed and signed into law in 2001, require large development projects (for larger agencies, >500 new residential units or the equivalent in combined residential and non-residential demand, and for smaller agencies at least 10 percent growth in local water demand) to demonstrate at least 20 years of available supplies. For a discussion of how these laws are working, see Hanak, 2005b and 2010.

[36] In 1995 and again in 2003 and 2005, single-year "dry-year purchase" options trades were introduced for fallowing-based transfers. The idea of an options market is to make commitments between buyers and sellers early in the season (sometime in the fall), before the character of the water year is known, with sellers paid in installments to maintain the commitment at successive call dates. The last call date was in the late spring—the latest point at which growers could plant if they did not part with the water. In 1995, DWR (which was buying the water for the drought water bank) did not exercise the options because it ultimately proved to be a very wet year (growers thus received only the up-front installment). In 2003, the Metropolitan Water District of Southern California (MWDSC) initiated a similar deal with Sacramento Valley rice growers, and it exercised most of those options, purchasing 124,000 af, while not exercising 20,000 af of options (Howitt and Hanak, 2005; Hacking, 2005). In 2005, under a similar deal, MWDSC did not exercise the options to purchase nearly 130,000 af because there was ample rain, and growers again received just the installment ($10 per af, versus a final purchase price for the water of $125 per af). Options have become less attractive in recent years, given the new operational restrictions on Delta pumping, which limits the attractiveness of fallowing-based transfers from growers using water stored in Lake Shasta. Springtime releases of cold water from Lake Shasta are required to protect salmon, and this same water can also be used by Sacramento Valley rice growers. With new Delta pumping restrictions, the water rice farmers would have used on their fields between April and June cannot be sent to users south of the Delta instead. Yet these farmers would still need to be compensated for this water in order to fallow their fields. As a result, the new pumping restrictions create an effective surcharge on water acquired through fallowing of about 40 percent. These constraints do not apply to some

But Overall Market Growth Has Slowed (2003–2011)

In spite of these positive market developments, there is also evidence that market momentum is weakening. There has been little growth in overall trading volumes since 2003; and if the new package of Colorado River transfers is excluded, both committed and actual flows have actually declined since 2001.[37] This weakening is particularly worrisome because drought conditions in the late 2000s might have been expected to boost trading.[38]

A variety of impediments—some longstanding and some new—appear to be at work. One new problem relates to conveyance infrastructure. Historically, California's sophisticated supply infrastructure has made it possible to transfer water either directly or through exchanges across most demand and supply centers. However, in the case of the Delta, a critical conveyance hub, new pumping restrictions since 2007—introduced to mitigate conditions for endangered fish species—have impeded movements of both north-to-south and east-to-west transfers.[39]

In addition, a variety of impediments associated with the approval process—some long-standing and some more recent—are raising the transaction costs for parties wishing to engage in trading. For example, county groundwater ordinances, most of which have been adopted since 1996, tend to broadly restrict groundwater-related exports.[40] Although these ordinances were a useful stop-gap measure designed to prevent harm to local water users in the absence of state-level protections, they are not an ideal long-term solution for managing groundwater. Local basin management would be better served by more comprehensive plans and objectives that address locally generated overdraft as well as problems related to exports. Such programs could better manage local groundwater resources for all users without discriminating against potentially beneficial groundwater-related transfers.

The progressive tightening of DWR's approval process for north-to-south transfers represents another constraint. In addition to limiting "paper" transfers that might harm SWP contractors, the process—which involves frequent updates in its rules—creates uncertainties that are likely to create a chilling effect against legitimate transfers of wet water (Lund, 1993).

A third constraint, noted earlier, is that transfers are now subject to environmental restrictions beyond the requirement of no injury to environmental flow conditions, such as fallowing limitations to protect habitat for the giant garter snake and Clean Air Act restrictions on the use of diesel pumps for groundwater-related transfers. In 2009, uncertainties over these new restrictions, combined with the inability to move water through the Delta, depressed drought water bank activity. Fewer than 80,000 af were transferred, whereas DWR's goal was to acquire several hundred thousand acre-feet.

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growers on the east side of the Sacramento Valley who use water stored in Lake Oroville, but infrastructure problems at this reservoir have made water deliveries more uncertain, and less amenable to options contracts.

[37] See Technical Appendices Tables B2a and b. This calculation was made by subtracting all additional Colorado River transfers besides the 110,000 af transfer from IID to the Metropolitan Water District of Southern California, which dates back to 1987 (Technical Appendices Table B9).

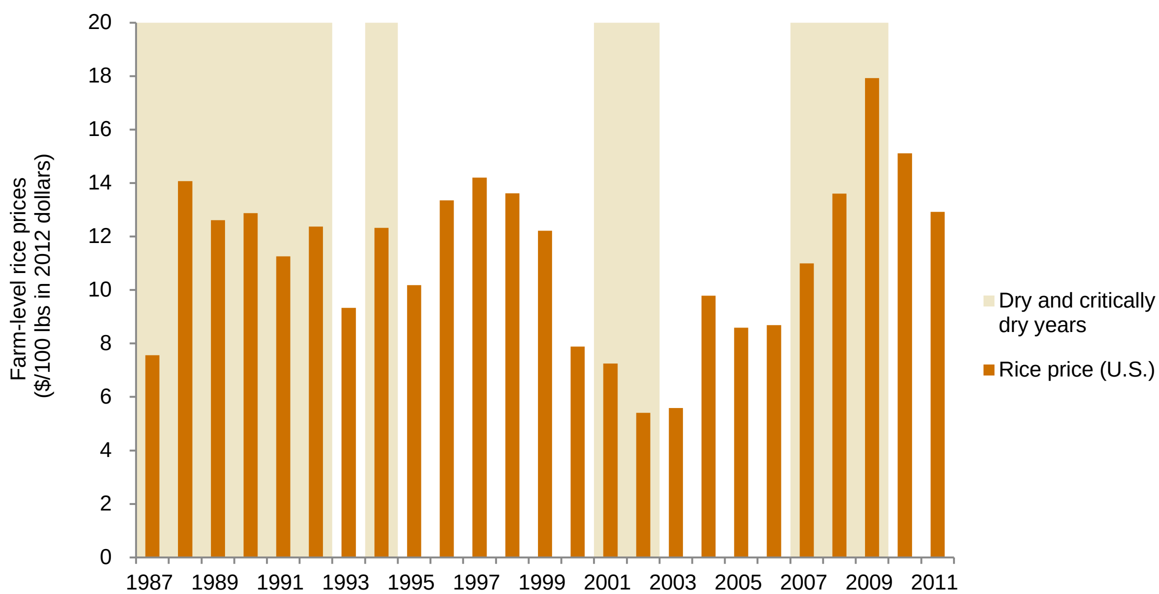
[38] Hanak (2005a) found that drought years between 1990 and 2001 were associated with significantly higher transfers after controlling for water allocations, crop prices, and other factors.

[39] Some east-to-west transfers among south-of-Delta water users rely on sending water north (through the San Joaquin River and other eastside rivers) to the Delta pumps and then back south again to water users on the west side of the San Joaquin Valley. See note 36 for a description of some consequences of Delta pumping restrictions.

[40] Hanak (2005a) showed that between 1996 and 2001, the ordinances reduced total county exports by roughly 20 percent, while increasing within-county trades by an even larger proportion (65%) but from a smaller base. On net, the ordinances reduced overall market sales by 11 percent. Interviews with water managers in the Sacramento Valley suggest that these ordinances remain important obstacles to groundwater-related transfers in some counties where there is significant potential, such as Butte.

Many observers have also pointed to high commodity prices—and particularly the price of rice, a crop that has often been fallowed to make water available for transfers—as a major reason for the recent slowing of the water market. As Figure 7 shows, real farm-gate prices of rice (like other field crops) have indeed been high in recent years, and particularly during 2009, the third year of the latest drought. This may have depressed some farmers' interest in water sales. However, the contrast is starkest with the early 2000s. During most of the 1990s, real crop prices were not much lower than in recent years, while real prices for drought water purchases have increased over time, with the potential to increase further to accommodate dry-year water demands.[41]

FIGURE 7
High rice prices may have reduced farmers' incentives to transfer water during the recent drought



SOURCE: U.S. Department of Agriculture, National Agricultural Statistics Service.

NOTE: Prices were converted to 2012 dollars using the consumer price index for urban areas (January–June).

And finally, water market development has been hindered by the fragmentation of water management, with different types of water rights and contracts subject to different types of approval. These differences tend to limit market activity even when it would be economically and environmentally beneficial to engage in trading.[42] As a result, trades among agencies that have rights to use water within the same large projects (CVP, SWP, and Colorado River) continue to dominate the market, accounting for over 60 percent of all

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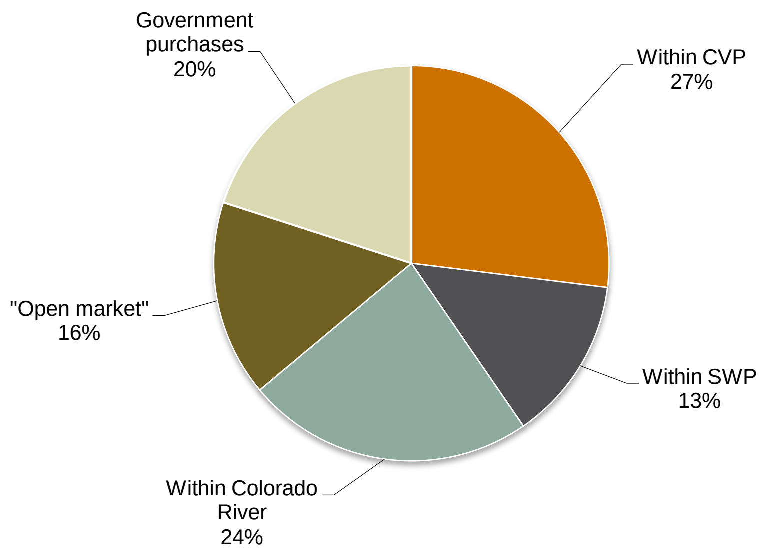
[41] For example, Sacramento Valley rice farmers were offered $275/af during the 2009 drought water bank, 1.4 times higher in real terms than the price offered during the 1991 bank; the ratio of real farm-gate rice prices in those two years was 1.6. (South of the Delta, some farmers were reportedly paying much higher prices for water to sustain their perennial and vegetable crops.) Over the entire 1982–2011 period, we find no evidence of a statistical correlation between rice prices and water trading. (Various regression analyses did not find a significant association between rice prices and either short or longer-term transfers.) Some local observers have suggested that increasing vertical integration within the rice industry—with more rice farmers now owning processing and marketing facilities—may have reduced some farmers' incentives to lease water, irrespective of fluctuations in farm-gate prices.

[42] For two years during the drought, an emergency measure to create a joint place of use between the CVP and SWP south of the Delta provided a temporary reprieve for some such transfers.

trades since the mid-1990s, and 80 percent of trades not involving direct state or federal government purchases (Figure 8). The "open market"—trades between agencies within different projects or not belonging to projects at all—still accounts for less than a fifth of all transactions.

FIGURE 8
Sales within the major projects dominate the market



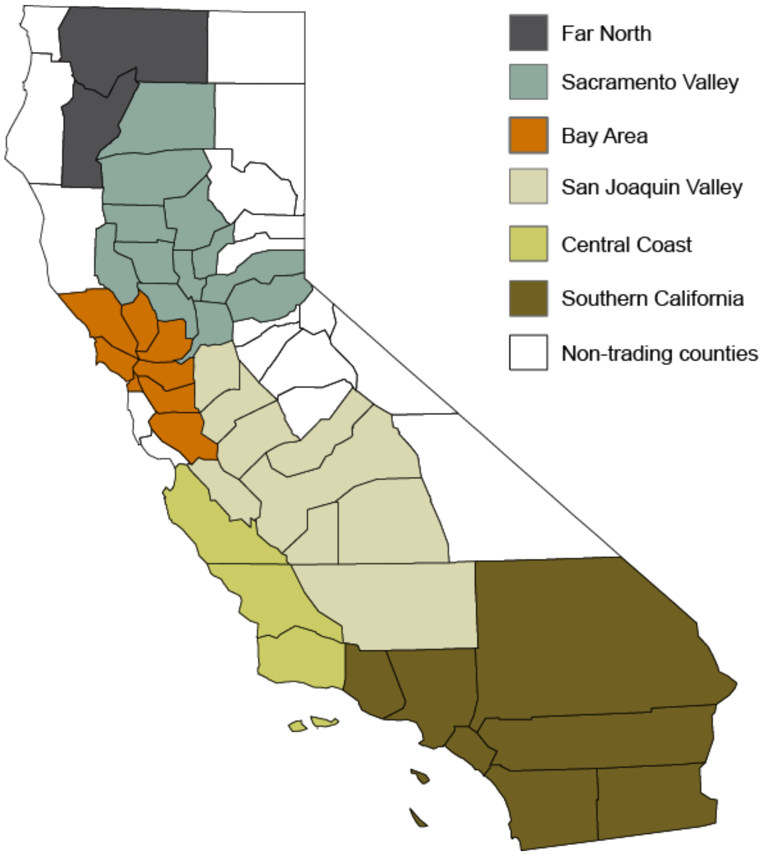
SOURCE: Data collected by the authors (For details, see Technical Appendices Table B2b).

NOTE: The figure shows actual flows under all contracts and volumes committed but not transferred under long-term leases and permanent sales.

Geographic Trends

California's water market now involves water users in most of the state's counties, including all major population and farming centers (Figure 9). Although recent environmental problems in the Delta have weakened the infrastructure linkages between points around that hub, most water users remain connected to the statewide grid, as well as to other water users within the same county and same region. These interconnections can facilitate both temporary and longer term shifts in water across the state in response to droughts and long-term demand shifts, but they also raise concerns about potential economic harm in water-exporting regions.

FIGURE 9
Most counties now have water market activity



SOURCE: Data collected by the authors.

NOTES: In our database, trading in the Far North is limited to small volumes of environmental flows (totaling 4,400 af in 2010–11) in two counties (Siskiyou and Trinity). It excludes trading within the federally-run Klamath project, which serves farmers along the Oregon-California border. Since the early 2000s, USBR has operated water marketing within that project in some years.

Table 2 summarizes key aspects of market flows by the regions illustrated in Figure 9, including

- Total sales,
- Net internal non-environmental sales: the portion of local non-environmental demand covered by sales from parties within the same region,
- Net non-environmental imports (exports): net imports (the net volume brought in from other regions if local non-environmental demand is higher than local sales) or exports (the net volume sent elsewhere if local supply is higher than total local demand and environmental purchases), and
- Environmental sales: the portion of sales dedicated to the environment.[43]

In general, these regions correspond fairly well to the boundaries of the state's major hydrologic regions or, in the case of Southern California, to a heavily integrated regional management network.[44] (We provide

[43] In contrast to earlier computations that reported total commitments, we examine actual flows here, because it is easier to assign regions of origin and destination to flows under some more general long-term contracts. For instance, the Yuba Accord can ship water to buyers in three regions, and a long-term deal between the San Joaquin River Exchange Contractors and the San Luis Delta Mendota Water Authority can ship water to buyers in two regions. (For information on these trades, see Technical Appendices Table B9.)

information below on the breakdown of flows within the San Joaquin Valley and Southern California, which have some large intra-regional disparities in trading patterns.)

Across all three phases of water market development discussed above (1987–1994, 1995–2002, and 2003–2011), three regions have played the most significant roles: the Sacramento Valley, the San Joaquin Valley, and Southern California. These regions lead the state in supplying water for trades, and the San Joaquin Valley and Southern California are also the largest demand centers, principally for farm and urban uses, respectively.

The relative roles of these regions have shifted over time. With lower internal demand and relatively abundant water availability, the Sacramento Valley has consistently been a net exporter. But total sales by Sacramento Valley water users were no higher in the most recent period than during 1987–1994, when the market was 40 percent as large as it is today. This stagnation, along with growth in local demand, has meant that exports are now about a third as large as they once were—averaging only 82,000 af/year. The various new impediments to transfers discussed above, which place particular constraints on exports from the Sacramento Valley, are a likely explanation for this trend.

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[44] Southern California contains the Los Angeles, Santa Ana, and San Diego hydrologic regions along the coast, and the Colorado River and South Lahontan regions further inland. In practice, many urban agencies in all but one county (Imperial) are affiliated with one large water wholesaler, the Metropolitan Water District of Southern California, and water users in all seven counties use Colorado River water. The two counties in the Far North lie within the larger North Coast hydrologic region.

TABLE 2
Regional market flows

	1987–94 (taf/yr)	1995–02 (taf/yr)	2003–11 (taf/yr)	Total (taf)
Total sales				
Sacramento Valley	258	159	238	5,475
San Joaquin Valley	131	655	777	13,286
Southern California	136	186	343	5,663
S.F. Bay Area	19	14	24	480
Central Coast	0	18	1	157
Total	543	1,033	1,383	25,060
Net internal non-environmental sales				
Sacramento Valley	18	73	80	1,443
San Joaquin Valley	95	400	484	8,316
Southern California	134	116	304	4,738
S.F. Bay Area	4	2	3	78
Central Coast	0	0	1	8
Total	251	590	872	14,583
Net non-environmental imports (exports)				
Sacramento Valley	(227)	(43)	(82)	(2,898)
San Joaquin Valley	38	26	(84)	(244)
Southern California	27	14	134	1,527
S.F. Bay Area	25	8	32	558
Central Coast	0	(18)	0	(143)
Total	(137)	(12)	(1)	(1,201)
Environmental sales				
Sacramento Valley	13	43	74	1,118
San Joaquin Valley	14	173	170	3,026
Southern California	0	0	24	220
S.F. Bay Area	5	4	7	143
Central Coast	0	0	0	0
Total	32	220	276	4,506

SOURCE: Data collected by the authors (For details, including region-to-region patterns of trade for each period, see Technical Appendices Tables B6a–c. For details within the San Joaquin Valley, see Technical Appendices Tables B7a–c).

NOTES: The table reports actual flows, and excludes additional volumes committed but not transferred under permanent and long-term transfers. The table also excludes a small share of transfers for which region of origin or destination could not be determined and 4,400 af of environmental transfers in the Far North in 2010–2011 (see Technical Appendices Table B5). The non-zero balance of net imports/exports results because of these omissions, the presence of surplus drought purchases by DWR, and some smaller discrepancies in user pools in some years. For the Sacramento Valley, total sales are slightly lower than those reported in Technical Appendices Table B4a because of user pool discrepancies, particularly in the first period (see notes to Technical Appendices Table B6).

Another major shift has occurred in the San Joaquin Valley, which is now by far the market's largest water supplier, in addition to its largest demand center. San Joaquin Valley water users have been providing over half of total market supplies since the mid-1990s. Although local demand in this region has continued to grow, supplies have grown faster, making the region as large a net exporter as the Sacramento Valley. These exports are principally the result of long-term and permanent deals with urban agencies in Southern

California, where net imports have grown despite increases in within-region transfers of Colorado River water. The San Joaquin Valley has also become the leading supplier of environmental water, thanks principally to the growth in purchases by the CVPIA's Water Acquisition Program on the valley's east side (discussed below).

A final shift worth noting is the overall trend toward "regional self-sufficiency," with a higher proportion of total sales serving local demand. From 1987–94, less than half of total sales were sold within the region of origin.[45] In the most recent period, nearly two-thirds of all transfers (and 80 percent of non-environmental water trades) took place within the same region. This shift reflects the reduction of exports from the Sacramento Valley and the increase in within-region transfers in Southern California and the San Joaquin Valley as a share of total purchases (see Technical Appendices Table B6a–c). In the Southern California area, where within-region transfers now account for two-thirds of all purchases, this is almost entirely due to the long-term transfers of Colorado River water from agricultural districts in Imperial County to urban areas closer to the coast).[46] The San Joaquin Valley—where intra-regional trades now represent 93 percent of all purchases—has witnessed substantial growth in transfers from parties located on the east side of the Valley (which has had fewer supply constraints) to those facing greater scarcity on the west side.[47]

A closer examination reveals that sales are also becoming more localized *within* regions (Figure 10). Over time, the share of non-environmental transfers to parties within the same county has progressively increased —climbing from 18 percent in 1987–94 to 50 percent in 2003–11. This shift reflects an increase in long-term transfers of water from nearby agricultural areas to urban areas within the San Joaquin Valley, as well as more localized farm-to-farm trading within both the San Joaquin and Sacramento Valleys. Such farm-to-farm trades typically move water from farmers with more senior (and relatively abundant) supplies to those whose access to supplies is more constrained, such as contractors on the CVP's Tehama Colusa Canal in the western Sacramento Valley and the Delta-Mendota Canal on the San Joaquin Valley's west side.[48] In the western San Joaquin Valley, local farm-to-farm sales have also occurred when some lands have become too saline for profitable farming.

Trades tend to be less contentious within regions, and especially within counties, than sales across longer distances, because the water stays in the local economy. When there is strong local pressure against exports, sellers may have fewer options to ship water to outside buyers, even if the outside buyer can offer a higher price.[49] A recent controversy along these lines occurred in Modesto County, where the Modesto Irrigation District sought to conclude a long-term transfer to the San Francisco Public Utilities Commission (which supplies San Francisco and many peninsula communities) that would help fund costly infrastructure upgrades. The City of Modesto and other local groups raised strong objections to the water

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[45] To see this, compare total sales in Table 2 with net internal non-environmental sales.

[46] See Technical Appendices Table B6. From 2003–2011, 93 percent of all within-region trades in Southern California originated in the Imperial Irrigation District, Palo Verde Irrigation District, or Coachella Valley Water District.

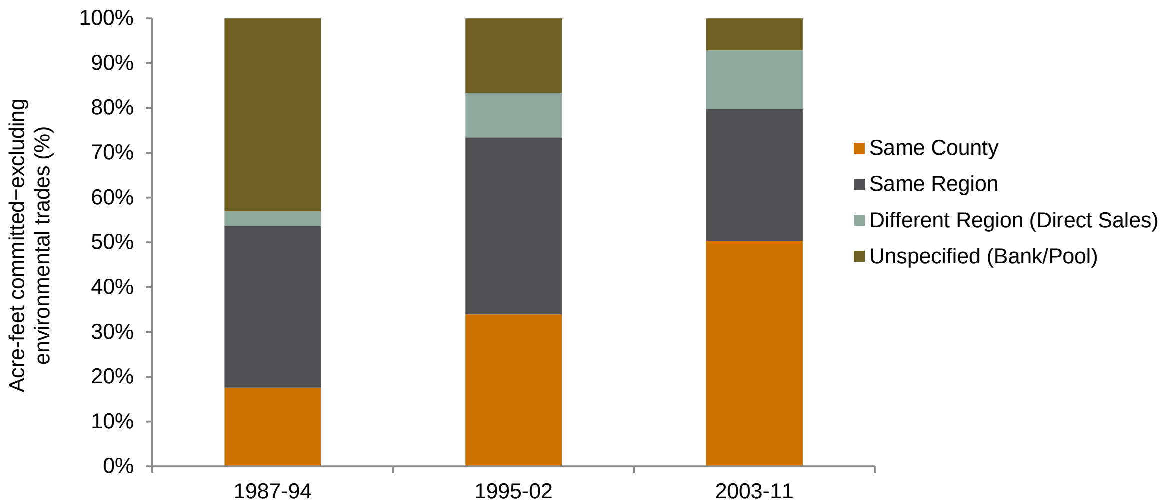
[47] See Technical Appendices B7. In addition to CVP contractors located on the west side, we have included all SWP contractors in the "westside, other" group, which does not have ready access to senior water rights.

[48] The more senior rights-holders include the CVP's "settlement" and "exchange" contractors—individuals and entities whose water rights predate the CVP and whose contracts grant them priority access to CVP supplies based on their pre-project water rights —and comparable groups affiliated with the SWP. Some pre-1914 rights-holders in the eastern San Joaquin Valley that are not affiliated with the projects are also active water traders. See Technical Appendices Table B7 for trends in intra-regional trades within this region.

[49] Hanak (2005a) found that within-county sales increased after counties adopted groundwater export restrictions. Local sales within the Sacramento Valley typically go for much lower prices than sales to outside parties.

leaving the county, even though San Francisco would have paid $700/af for the water, roughly 70 times more than local farmers now pay (Holland, 2012).

FIGURE 10
Local water transfers are increasing



SOURCE: Data collected by the authors.

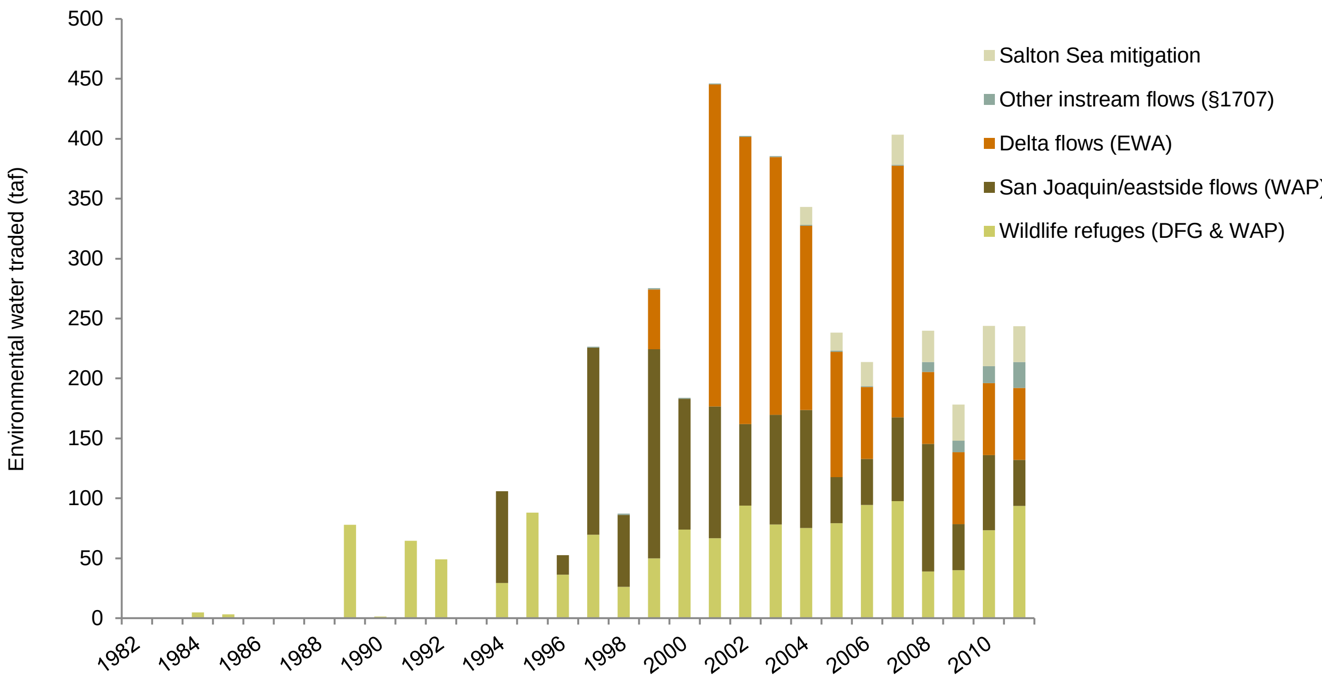
NOTES: The figure reports the destination of non-environmental water transfers (actual flows plus volumes committed but not traded under long-term and permanent contracts). "Unspecified (bank/pool)" transfers go directly to a bank or pool, which may subsequently sell the water within a different region. For multicounty agencies, transactions are considered to be within the same county if the buyers and sellers share at least one county.

Environmental Water Acquisitions

Given the significant portion of the water market that involves acquisitions to support the environment, it is useful to consider these transactions in more detail. In all, over 4.5 maf of water was acquired for environmental purposes from 1982–2011, accounting for 14 percent of total commitments and 18 percent of total market flows. The environmental share of the market was highest during the early to mid-2000s, accounting for 30 percent or more of total flows in most years. Since 2008 total volumes have fallen, with the share of environmental acquisitions averaging around 15 percent (Technical Appendices Tables B3a and b).

Over time, the purpose and nature of these acquisitions has changed (Figure 11). Early purchases by the state and federal governments supported wildlife refuges and fish hatcheries; state efforts, overseen by the Department of Fish and Game (DFG), were substantial during the late 1980s–early 1990s drought. In the mid-1990s, the CVPIA's Water Acquisition Program (WAP) created a systematic federal program for environmental water purchases, both for Central Valley wildlife refuges and for instream flows to support salmon runs in the San Joaquin River system. The WAP's instream flow program was a multiyear flow experiment (the Vernalis Adaptive Management Program) and included a 12-year lease agreement, now expiring, with a consortium of eastside irrigation districts.

FIGURE 11
Environmental water acquisitions are addressing a variety of issues



SOURCE: Data collected by the authors.

NOTE: The figure shows actual flows.

The next significant environmental acquisitions, beginning in 1999, involved the Environmental Water Account (EWA) of the CALFED program—a joint state-federal initiative focusing on the Bay-Delta region. The EWA was created to provide environmental managers with supplemental flows to support the Delta's threatened and endangered native fish species (delta smelt and Chinook salmon). The EWA accounted for half of all environmental water purchases between 2001 and 2007, with annual acquisitions from a variety of parties averaging nearly 180,000 af. In 2008, this program was converted to a multiyear lease agreement (for 8 years) with the Yuba County Water Agency as part of the multipurpose Yuba Accord, and it was scaled back to a mere 60,000 af/year.[50]

As EWA and WAP purchases have declined, two new types of environmental water purchases have emerged: acquisitions of water to mitigate the impacts of Colorado River water transfers from the Imperial Irrigation District to San Diego, and a variety of smaller transfers to instream flows under § 1707 of the Water Code. The Colorado River mitigation water aims to offset the reduction in irrigation drainage to the Salton Sea, which involves land fallowing. Irrigation drainage is the main source of water in this terminal saline lake, and fallowing reduces that drainage. The mitigation water was required under the terms of the transfer permit and is intended to prevent the acceleration of salt accumulation, which will eventually (even without the transfer) make the Salton Sea too saline to support food sources for migratory waterfowl. Under the current terms of the transfer, this mitigation water is to be provided through 2017.

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[50] In 2011, a very wet year, the EWA water was not needed and was stored for future use. Figure 11 reports the acquisition as taking place in that year, since payment occurred.

The other new thrust in environmental acquisitions was prompted by § 1707 of the Water Code, enacted in 1991. This statute authorizes the dedication or transfer of water to instream flows by protecting it legally from inconsistent upstream uses by junior water-rights-holders.[51] Many of the environmental water transfer programs noted above operate with § 1707 permits. The additional transfers labeled explicitly as § 1707 flows in Figure 11 are a collection of local watershed support measures in the Far North (Scott and Trinity Rivers), the San Francisco Bay Area (Tomales Bay, San Pablo Bay), and the Sacramento Valley (Butte Creek). Most involve relatively small volumes of water, are essentially permanent in duration, and are associated with non-profit organizations participating in watershed management (e.g., the Scott River Trust).[52] In contrast to all of the other environmental water trades shown in the figure, the § 1707 acquisitions are generally made as donations rather than for monetary compensation (though some policy discussions are under way about making these donations eligible for tax deductions to create financial incentives to increase instream flows).

Because the bulk of the environmental market requires funding, an important question is: Where does the money come from? Roughly $547 million (2011 dollars) were spent on the 4.5 maf acquired between 1982 and 2011—costing an average of $122 per acre-foot. When these purchases have been made in the short-term market (as with the EWA prior to the Yuba Accord), the average prices paid have been higher than in the longer-term agreements, such as WAP purchases for instream flows. (As noted earlier, farmers wishing to buy water have at times been frustrated by the competition). To date, the tab has principally been picked up by state and federal taxpayers, with the state paying the lion's share (52% state, 19% federal), mostly using general obligation bond funds. Water users have paid for the remainder: 24 percent through an ecosystem restoration surcharge leveed on CVP contractors under the CVPIA (now roughly $9/af for agricultural water districts and $18/af for urban districts and power providers) and 5 percent by participants in the Colorado River water transfer.

Given general state and federal budget difficulties, the future of environmental water purchases is uncertain. Diminishing funds have already reduced volumes of environmental water acquisitions in recent years. Looking ahead, there is little money left from approved state bonds to fund these (or other) environmental programs, and federal budgets are equally constrained. The CVPIA restoration fund—supported by a surcharge on water users—is a more reliable funding source than taxes, but this fund has many potential uses, and now that the experimental instream flow program is winding down, the reduced budget for water acquisitions is concentrating on wildlife refuges. (The CVPIA set a quantitative goal for water deliveries to the refuges, through a combination of regulatory reallocations and purchases, but this goal has yet to be met.)[53]

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[51] This protection is necessary because the environment does not have explicit water rights for instream flows under California law. Information on § 1707 and a list of permits is available at www.waterboards.ca.gov/waterrights/water_issues/programs/applications/instream_flow_dedication/index.shtml. See Technical Appendices Tables B8 and B9 for a list of permanent and long-term transfers included in Figure 11.

[52] For a list of these transfers, see Technical Appendices Table B8. Unlike other permanent transfers, the rights to use the water under § 1707 transfers do not change hands. But to resume using it for its original purpose, the rights-holder would have to go through a new review process and demonstrate that the change would not cause negative environmental impacts. To protect instream flows, some reallocations of environmental flows determined through quasi-regulatory proceedings, such as the settlement to restore flows on the lower San Joaquin River, also acquire § 1707 permits. We have not included such agreements as part of the environmental water market because they are more akin to regulatory reallocation of flows than voluntary acquisitions.

[53] See the report by the CVPIA Independent Review Panel (2009). The panel found that the water the refuges have been acquiring is being managed well. It also noted Delta conveyance constraints as an impediment to adequate water acquisition.

Apart from the general difficulties of raising taxes or introducing new surcharges on water users, it may be particularly hard to generate public support to expand environmental water purchases as a matter of policy. Environmental water acquisitions are an alternative to uncompensated regulatory reallocations of flows.[54] Both occur when allocations to other sectors have left the ecosystem with too little water to function well. In some places, such as Australia, public policy has opted to principally use the market to buy back needed environmental flows.[55] California has operated with a hybrid policy, combining regulations and the market. Several state and federal statutes and the California constitution authorize the uncompensated cutback of water diversions when they cause environmental harm, and some water has been reallocated in this way in California watersheds.[56] The market was introduced as a way to generate environmental benefits while reducing the conflict associated with uncompensated cutbacks. Some have suggested that this market provides an added advantage of giving regulators the incentive to use environmental water more efficiently. But environmental water markets also have many detractors. Although an independent review team found the EWA—the largest taxpayer-funded program—to be moderately effective (meaning things could have been even worse without it), many observers view it as ineffective because it coincided with the collapse of native fish populations in the Delta.[57]

In our view, a hybrid policy is likely to be more beneficial from a practical perspective than a policy that relies solely on uncompensated reallocations to the environment. To maintain public support for these programs, it will be important for California to evaluate and improve the effectiveness of all environmental water allocations—whether acquired through regulatory means or purchases.

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[54] These policies can be complementary. One purpose of § 1707 is to allow water-rights-holders to augment streamflows above the minimum regulatory requirements (Gray, 1994b).

[55] See Garrick et al., 2009, and Australian Department of Sustainability, Environment, Water, Population and Communities, 2010.

[56] For a discussion of the legal issues, see Hanak et al., 2011, Chapters 5 and 7. Examples of large regulatory cutbacks include CVPIA reductions (which reduced CVP diversions to support salmon), recent Delta pumping restrictions (which more generally reduced Delta exporters' access to water), and the Mono Lake and Owens Valley decisions (which reduced Los Angeles's ability to draw water from its land holdings in the eastern Sierras).

[57] An independent scientific assessment (Brown, Kimmerer, and Brown 2009) considered the EWA's effectiveness to be modest at best: In the first five years, it likely increased the survival of winter-run Chinook salmon by 0 to 6 percent, adult delta smelt by 0 to 1 percent, and juvenile delta smelt by 2 to 4 percent. The gains could have been greater if the EWA water were allocated in a more focused way, so as to concentrate benefits on a single life stage of one species. For instance, concentrating on the spring season during dry years could have increased abundance of juvenile delta smelt by up to 7 percent and adult delta smelt by up to 4 percent. Chinook salmon runs could have been increased by 20 percent if water volumes were applied during the entire outmigration period.

Groundwater Banking Trends

The infrastructural and institutional constraints on California's water market in recent years have made it more difficult for the market to serve one of its intended purposes—mitigating the economic costs of droughts. Groundwater banking, now expanding in some parts of the state, is a management strategy that has helped fill this gap.

Soon after the water market expansion in the late 1980s and early 1990s, many local agencies began looking to groundwater storage to improve supply reliability during future shortages through informal conjunctive use programs and more formal banking programs. Here, we highlight successful efforts in two regions where groundwater banks began storing water for off-site parties in the 1990s: Kern County, where numerous local agencies developed banks; and Southern California, where the Metropolitan Water District of Southern California (MWDSC) began storing water with agencies located within its service area and with the Mojave Water Agency, located to the east of MWDSC. These two programs augmented an existing banking arrangement MWDSC had with two agencies in the Colorado River basin (the Coachella Valley Water District and Desert Water Agency). In contrast to Kern, where the banks are managed using semiformal arrangements, the banking in Southern California takes place in basins where the rights to store and withdraw water are formalized through adjudications or special management districts.

During this time, many other local agencies launched or expanded groundwater storage programs for their own use. DWR records indicate that at least 89 agencies within the state are currently engaging in conjunctive use programs, including 32 in the South Coast, 37 in the lower San Joaquin Valley (the Tulare Basin hydrologic region), and a handful each in several other hydrological regions (Department of Water Resources, 2012). However, the department's own attempts to collect data on these operations for the 2013 update of the *California Water Plan* through written and phone surveys has met with limited success. DWR sought information on location, year developed, capital cost, annual cost, administrator, project capacity, source water, put/take capacity, recharge method, goals/objectives, and constraints. At best, only 52 agencies provided some of the information requested; fewer than half responded to the items requesting quantitative data. In some regions, the responses were provided on condition that the identifying information not be disclosed. As a result, the next update of the *California Water Plan* will be able to offer only broad estimates of banking operations, with incomplete information on key questions relating to the capacity and actual storage levels of the agencies.

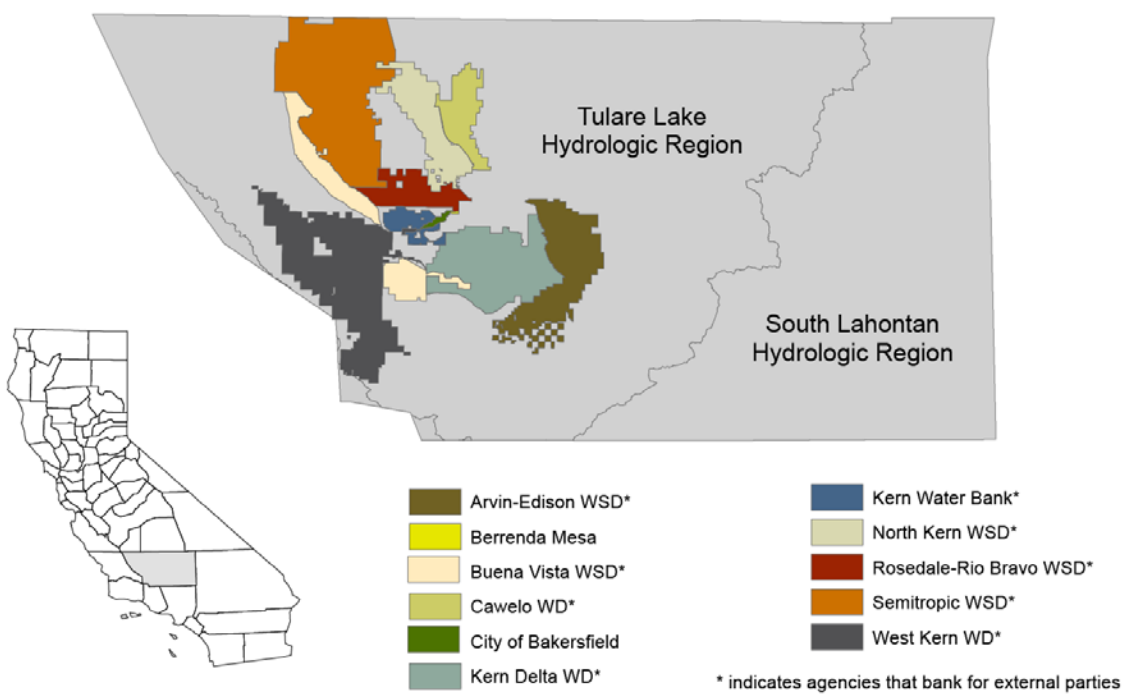
This reluctance to report such information reflects the climate of local distrust regarding state oversight of groundwater. Since the passage of Senate Bill X7-6 in late 2009, local entities are required to report groundwater levels (though not volumes withdrawn) to DWR, and many local officials reportedly fear that further state efforts to manage groundwater are in the offing. As noted above, these concerns include the initiation of surface water permit reviews by the SWRCB for all new banking operations, because banking can involve storage of surface water falling under the board's jurisdiction.

For these reasons, we limited our data collection efforts to the subset of banking operations that are storing water for off-site parties, focusing specifically on these third-party storage operations. Although the bank managers are usually also operating either formal banking programs or informal conjunctive use programs with water users within their service areas, we do not include data on these programs in the following discussions.

Banking Trends in Kern County

Figure 12 shows the locations of 11 groundwater banks in Kern County. Figure 13 presents the storage balances for eight of these banks that work with over 40 off-site parties, including 26 mostly agriculturally-oriented local entities, 10 non-local urban agencies (five in Southern California, three in the Bay Area, and two elsewhere in the San Joaquin Valley), four non-local agricultural agencies, and the state of California.[58] These banks are all concentrated within the Tulare Lake hydrologic region, where most of Kern County's farming activity also occurs. The largest (in terms of volumes stored) is the Kern Water Bank, a joint powers authority formed by a group of public and private water agencies within Kern County. It stores water primarily for these members, along with one agricultural agency in Kings County. (This is the only bank for which we have all groundwater balance information.) The oldest – the Semitropic Water Storage District—is also the largest bank storing water for entities located outside of the county. It operates an informal conjunctive use program for farmers within its service area, using the proceeds from the banking operation to lower the costs of imported surface water to make this water more attractive to farmers who would otherwise pump groundwater. Semitropic recently formed a joint powers authority with the Rosamund Community Services District and a private company to bank water in the Antelope Valley within the South Lahontan hydrologic region near the eastern border of Kern and Los Angeles counties.

FIGURE 12
Groundwater banks in Kern County are concentrated in the Tulare Lake hydrologic region



SOURCE: Mapping data on agency boundaries provided by the Kern County Water Agency.

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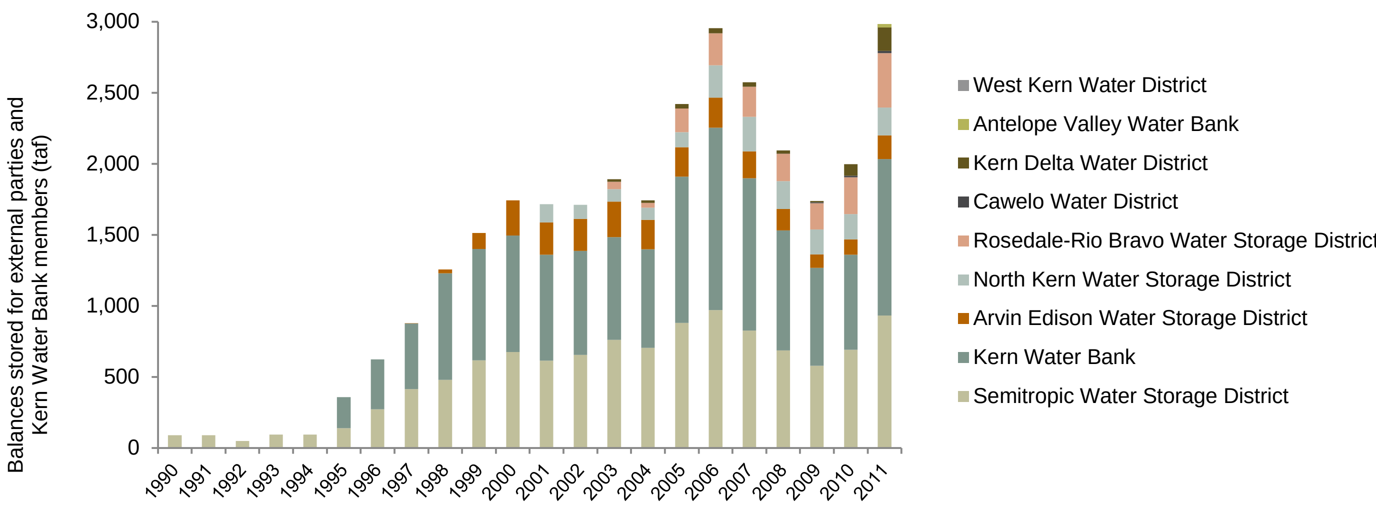
[58] Detailed information from the Buena Vista Water Storage District was not available, but this groundwater bank appears to be relatively small, storing only about 30,000 af per year overall (for local users and third parties) (http://www.wakc.com/index.php/whos-who?pid=2&sid=63:Buena-Vista-Water-Storage-District)

Between 1990 and 2006, these banks accumulated balances of nearly 3 million acre-feet. Although these reserves were drawn down in the late 2000s to address shortages caused by the drought and Delta pumping restrictions, balances were quickly and fully restored following the very wet conditions in 2011, which also allowed unusually high Delta exports (Figure 13). As shown in Table 3, roughly half of the present balances are held for urban agencies and half for agricultural agencies. Likewise, roughly half of the balances are held for parties in Kern County, with the remainder split between Southern California (28%), the Bay Area (18%), and elsewhere within the San Joaquin Valley (8%).

FIGURE 13
Groundwater bank balances in Kern County have recovered since the recent drought



SOURCE: Data collected by the authors from local agencies.

NOTES: The figure reports storage for offsite parties. For entities other than the Kern Water Bank, some additional storage may be occurring for the entities themselves. The figure excludes storage for offsite parties by the Buena Vista Water Storage District, for which detailed information was not available.

TABLE 3
Groundwater banking balances and activity by region and end use (acre-feet)

	Agriculture	Urban	Mixed use	Total balance	Total withdrawals
S.F. Bay Area	–	551,277	–	551,277	130,343
Kern County	1,140,803	17,743	241,679	1,400,225	1,226,805
Other San Joaquin Valley	202,045	1,875	–	203,920	93,467
Southern California	–	826,378	–	826,378	752,181
Unspecified Region	–	–	10,032	10,032	81,631
Total Balance	1,342,848	1,397,273	251,711	2,991,832	
Total Withdrawals	1,101,055	284,523	898,849		2,284,427

SOURCE: Technical Appendices Tables C1 and C2.
NOTES: Balances are as of 2011. Withdrawals are cumulative for all years through 2011.

The ability of these banks to recharge so quickly after the first sustained drawdown since their inception was a stroke of good fortune, particularly given the overall hydrologic context in which they operate. The Tulare Basin is in a state of chronic overdraft, losing an estimated 1 million acre-feet annually, and more during dry years (Faunt, 2009). According to local operators, banking operations have generally helped to alleviate this problem and helped to stabilize groundwater levels within Kern County since the mid-1990s. However, the late 2000s drought led to greater pumping overall, and the bank withdrawals did not occur without controversy, given falling water tables. Several local parties are currently in discussions to resolve a legal dispute over whether bank pumping injured other users. Recent preliminary estimates from DWR find that groundwater levels declined during the latest drought (2007–2009) in all three Central Valley hydrologic regions (Sacramento River, San Joaquin River, and Tulare Basin), but that only the Tulare Basin did not see a rebound in 2010, the last year of the study (Brewster, 2012). This situation may have significantly improved in 2011, if local recharge efforts were as successful as the banking operations for offsite parties.[59]

The recent controversy highlights the difficulties of groundwater banking in basins that lack fully formalized management regimes, which account for all withdrawals and recharge. The Kern banks do have protocols to protect local users from injury associated with withdrawals for offsite parties, but these protocols generally do not account for the impacts that local users have on the basin. Given the generally positive levels of net reserves, the banks have likely benefitted local users overall and in most individual years. Of course, local pumping has also contributed to net drawdowns of the basin in dry years. Hopefully, the recent controversy will motivate and inform more comprehensive basin management efforts that involve all parties, not just bankers. One positive step is the recent launching of a countywide groundwater management committee, which will examine additional management options.[60] Preliminary undertakings also include a multiparty effort to improve basin modeling.

Groundwater Banking in Southern California

The Metropolitan Water District of Southern California (MWDSC) has withdrawn over 720,000 af from Kern County water banks since 2001; and at the end of 2011, the district still held a balance of 550,000 af (Technical Appendices Table C3). The agency has also engaged in groundwater storage programs in several locations within Southern California. The first of these is a partnership with the Coachella Valley Water District and the Desert Water Agency, which was borne out of an infrastructure opportunity. These agencies are both contractors with the SWP but do not have direct access to SWP deliveries. MWDSC delivers an equlvalent amount of Colorado River water to them through its Colorado River Aqueduct, and in exchange takes their allotment of SWP water. Through the "advanced delivery" program, MWDSC is able to pre-deliver the water for this exchange and bank it in Coachella's managed groundwater basin, subsequently drawing down on these reserves during dry years. (The Coachella basin is managed by the Coachella Valley Water District, a special groundwater management district that regulates the basin through pumping fees and managed recharge operations).

MWDSC began another storage program in the late 1990s, initiating and coordinating banking operations within adjudicated basins and special groundwater management districts within its service area. In these

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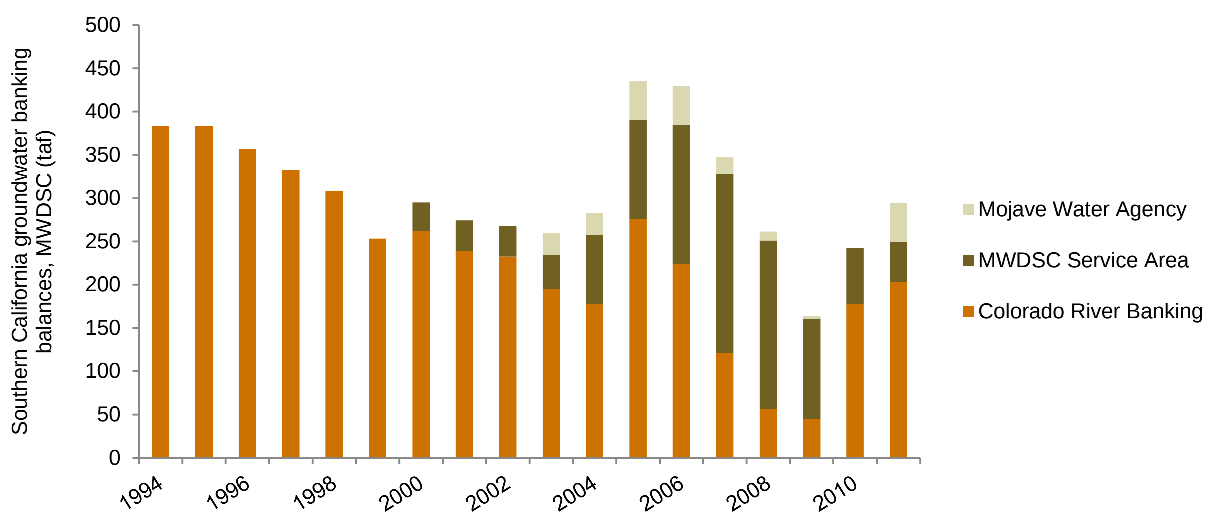
[59] Semitropic Water Storage District data show that average groundwater levels within the agency's service area nearly recovered to pre-drought levels, but that groundwater levels net of banking operations have continued to decline since the early 1990s, despite the availability of SWP surface water for recharge (Semitropic Water Storage District, 2012).
[60] This effort is seen by some local entities as a preventive measure to avoid state intervention in the basin.

cases, the water is stored within these basins (in all, ten have participated to date), and the local agencies then pump groundwater instead of using SWP surface water. MWDSC funds the additional infrastructure needed to run the program (notably, additional pumps), and the agencies are free to use these facilities for their own operations when they are not needed for MWDSC pumping.

A third storage program, launched by MWDSC in the early 2000s, involves exchanges with the Mojave Water Agency, which stores groundwater for MWDSC in the adjudicated Mojave Basin. Because the Mojave Water Agency is also an SWP contractor, MWDSC is able to draw on Mojave's SWP allocation when it wishes to call up reserves.

Figure 14 shows the net groundwater balances from these three operations. At its peak in 2005, the combined storage totaled over 435,000 af. By 2009, 272,000 af of these reserves had been withdrawn, leaving a total of just 164,000 af. Although recharge has not been as rapid as in Kern County, storage balances by the end of 2011 had risen to 295,000 taf, two-thirds of the maximum before the last drought.

FIGURE 14
Groundwater banking has also expanded within Southern California



SOURCE: Data collected by the authors from local agencies (for details, see Technical Appendices Table C3).

NOTES: The figure shows storage for the Metropolitan Water District of Southern California in the Mojave Basin, in the Coachella Valley (Colorado River Banking), and with member agencies within its own service area. Storage at the Mojave Water Agency and within the MWDSC service area is recorded in fiscal years (July 1 through June 30), and the Colorado River banking is recorded in calendar years.

In contrast to Kern County, these Southern California banking operations are occurring in special groundwater basins that regulate pumping (e.g., Orange County Water District) or in adjudicated basins where there are established pumping rights for all parties, including local landowners and pumpers. Such arrangements help limit conflict when supplies are constrained. However, just as in Kern County, finding excess surface water to store underground is a growing challenge. Many agencies located south of the Delta now express frustration over the growing competition for limited wet-year supplies, given the expansion of groundwater banking and the growing restrictions on Delta exports.

Policy Implications

Water marketing and groundwater banking are essential tools for helping California manage its scarce water resources more efficiently and sustainably over the long term. Both tools augment the state's ability to cope with periodic droughts. Water markets also facilitate the longer-term shift of some supplies to activities and regions with strong demand and insufficient water rights. Given the anticipated reduction in seasonal storage in the Sierra Nevada snowpack and the prospect of more frequent droughts due to climate warming, these tools are likely to become even more important in the future.

The state's water market is evolving in both expected and unexpected ways. Given agriculture's major share of total human water use in California (77 percent in 2005) and the relatively low value of some agricultural water uses, it is not surprising that agriculture is the primary source of market supplies.[61] Market demands have been quite diverse, with significant purchases by all three water-use sectors—farms, cities, and the environment. The market first grew in response to a major drought, spurred by direct state purchases. Subsequent growth was driven by changes in environmental policies rather than weather, with an increase in direct purchases of water for the environment and growing demand from farmers who lost supplies because of new instream flow requirements.

Most recently, urban demand has grown, as expected, with cities seeking to firm up supplies to support population growth and diminishing sources such as the Colorado River. This shifting demand has transitioned the market to one in which long-term and permanent trades predominate, rather than transactions negotiated annually. Perhaps surprisingly, the market has also become more localized, with half of all sales now occurring between parties within the same county—three times more than when the market was launched. This shift likely reflects local pressures to sell locally, as well as growing infrastructure and institutional constraints on more distant sales. In particular, the ability to move water through a key conveyance hub in the Sacramento-San Joaquin Delta has been constrained in order to reduce harm to the Delta's compromised native fish populations, and hurdles to transfer approvals appear to be increasing. Finally, environmental water purchases, which were intended to reduce the conflicts associated with reallocations of water to the environment, are still a significant but now diminishing share of the market, confronted by declining revenues and a lack of public consensus that taxpayer dollars should be used to support such efforts.

In recent years, infrastructural and institutional constraints have diminished the market's ability to mitigate the costs of drought. Groundwater banking—now expanding in some parts of the state—is a management alternative that may help fill this gap. Banking operations in Kern County and Southern California are demonstrating their ability to help California water users weather droughts. In combination, these operations made nearly 1.9 million acre-feet of dry-year water available between 2007 and 2010—considerably more than the entire statewide water market was able to provide in extra dry-year supplies.[62]

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[61] See Hanak et al., 2012 for information on the marginal value of agricultural water uses and comparisons of gross state product per acre-foot in the agricultural and urban sectors.

[62] In all, the market probably provided between 500,000 and 600,000 af in dry-year supplies over a three-year period, above and beyond transfers that would likely have occurred anyway. This included direct purchases from northern California growers by the State Water Contractors in 2008 (39,000 af), supplies from the state-run drought water bank in 2009 (74,000 af), temporary drought-sales from the Palo Verde Irrigation District to MWDSC in 2009 (45,000 af), and the Yuba Accord sales in 2008, 2009, and 2010 (307,000 af). Some additional sales within the San Joaquin Valley probably also occurred in direct mitigation of the drought.

Banking will need to continue expanding to help secure water supply reliability for California, particularly as the Sierra snowpack diminishes with a warming climate. This will require more coordination in the management of surface and groundwater reservoirs, so that more over-year storage is held in groundwater basins, freeing up surface reservoirs to concentrate more on seasonal storage for the irrigation season (Tanaka et al., 2006; Connell-Buck et al., 2011). It will also depend on the availability of conveyance infrastructure, including the key hub of the Delta, both to enable wet-year supplies to reach groundwater banking locations and to enable those who are storing water in distant banks to retrieve their water in dry years. (Repayment from the banks often relies on exchanges of water supplies traveling through the Delta).

Both the progress to date and the constraints experienced by marketing and banking operations suggest a number of policy implications that merit consideration by state, federal, and local entities:[63]

1. **Infrastructure matters, for both marketing and banking.** California's statewide infrastructure network has been a boon to these operations, and recent local investments have helped to further the ability to bank water underground. However, problems in the Delta have limited the market's prospects for furnishing dry-year supplies, and new Delta pumping constraints may limit the ability to operate groundwater banks for this purpose as well. These are two reasons to improve the reliability of Delta pumping capabilities and, with a changing climate, they are likely to become more critical for statewide water management in the future.
2. **Transfers must prevent injury to the environment and other legal users of the state's waters, but the institutional review process is unnecessarily complicated and cumbersome.** Currently, some of the biggest problems seem to be those associated with temporary drought-related transfers, which need to happen quickly if they are to happen at all. Options worth considering include creating a permanent "joint place of use" for CVP and SWP transfers south of the Delta (as was the case temporarily during the last drought) and forging more long-term contracts that enable dry-year transfers (using deals such as the Yuba Accord as a model). There also needs to be greater clarity and consistency in establishing conditions for exports from Sacramento Valley farmers to parties south of the Delta (fallowing rules, groundwater withdrawal ratios, etc.). Under current practice, DWR and USBR alter conditions each year, often quite late in the process. Transparency and the perception of fairness is important, because DWR controls the conveyance infrastructure and also runs the SWP—a junior rights-holder in the region. At present, there is the potential for conflict of interest in approving such transfers, because DWR has an interest in erring on the side of caution in limiting potential injury to the SWP.
3. **To improve transfers as well as banking, California needs to strengthen local groundwater management.** Local management of groundwater basins is likely to be more effective than state-led management, but local officials need more incentives to get this right. As recent reports have highlighted, local groundwater management is improving in California, but it needs even further improvement in order to sustain this resource (Nelson, 2011; Association of California Water Agencies, 2011). One option would be for the state to use its authority under Article 2, § 10 of the constitution (requiring reasonable use of all water) to start requiring non-discriminatory protection of groundwater basins. This would be an improvement over the current, discriminatory county export ordinances, which are limiting transfers without instilling better local basin management. The state could also assert "no injury" protections for all groundwater-related transfers, thereby providing a more level playing field than the county ordinances currently provide for permit applications for export-related transfers. In areas such as Kern County, which have begun groundwater banking, the incentives are

[63] For additional discussions of some of these issues, see Hanak et al. (2011), Chapters 6 and 7, and Hanak et al. (2012).

naturally growing for more comprehensive basin management that oversees withdrawals by all users. However, it is still difficult to get all parties to agree. Outside pressure—with a credible threat that the state would step in if local officials do not—may be the best way to proceed. Ideally, this would be accompanied by positive financial incentives to improve basin management. Local officials can look to solutions that have been successful elsewhere in California, including special districts with pumping authority and fees and adjudications. In this context, it is worth noting that many recent adjudications in Southern California have been relatively swift—accomplished within two to three years (sometimes less)—unlike the multidecade legal battles of the past that those in other parts of the state understandably wish to avoid.[64]

4. **Models need to be developed for mitigating the economic impacts of large-scale land fallowing deals.** Over the long term, economic shifts make it likely that some cropland will be permanently retired, with its water supply becoming available for growing demand centers in other sectors and regions. In these cases, mitigation of community-related impacts of fallowing is likely to be important to ease economic transitions. California could learn from mitigation models currently under way in the Palo Verde Irrigation District and the Imperial Irrigation District, as well as other cases such as the Northwest Forest Plan (which provided economic support to displaced workers and affected communities in areas where forestry lands were being converted to protected habitat).[65]
5. **Environmental water purchases offer the prospect of reducing the conflicts associated with reallocating water to the environment.** There is merit in pursuing water purchases alongside regulatory policies that reallocate some water, as California has done since the early 1990s. These transfers can also help improve the efficiency of environmental water management, by giving environmental water managers a budget that they can manage flexibly. Funding will be difficult, given the disappearance of state bond funds (responsible for half of all acquisitions to date) and ongoing state and federal budget constraints. The CVPIA ecosystem restoration surcharge—funded by water users—is a potentially good model, although given the currently austere fiscal climate it will be difficult to extend such a model to other water users. Support from the public and water users will be much easier to muster if they can be presented with systematic evaluations demonstrating the effectiveness of environmental water allocations, whether acquired through purchases or regulatory reallocations.
6. **High-level leadership is needed to routinize water marketing and groundwater banking transactions.** If the market has floundered in recent years, it has been partly due to the lack of priority attention and/or understanding of the centrality of these tools in effective statewide water management. Moreover, some innovations—such as reoperating surface reservoirs to enable more groundwater banking—require risk-taking, and only high-level state and federal leaders have the position and authority to undertake such risks. State and federal leadership played a key role in developing drought waterbanking in the early 1990s and in concluding the large package of transfers of Colorado River water as part of the QSA. One option might be to assemble a high-level coordinating committee from relevant agencies, with the ability to break through barriers.

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[64] See California Department of Water Resources (2011) for a list of adjudicated basins through mid-2011 and the years in which the adjudication was filed with the court and finalized. (In some cases, there has been additional litigation to resolve issues with entities that are not party to the agreement following the finalization of the agreement). It is also worth noting that some recent adjudications have been voluntary (e.g., the Beaumont Basin adjudication, concluded in 2004). Blomquist (1992) describes the early southern California adjudications, some of which took 15 years or more to be resolved.
[65] See Hanak et al., 2011, Chapter 9.

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