Improving California’s Water Market
How Water Trading and Banking Can Support Groundwater Management

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Key Takeaways

The Sustainable Groundwater Management Act mandates that local groundwater users bring their groundwater basins into balance by the 2040s, a process that will ultimately help individual users and their communities build resilience in an era of climate change. As groundwater sustainability agencies and others face a future of pumping reductions and subsequent land fallowing, water banking and water trading may prove important tools to help manage this transition. However, a combination of aging infrastructure and complex, conflicting regulatory structures currently hinders the expansion of banking and trading. Multiple actors can drive reforms to streamline these practices.

- **Good market design is key.** Effective and responsible markets include five essential features: clearly defined, secure property rights; reliable measurement, reporting, and verification; hydrologic connections within and between basins; transparent market information; and mechanisms for addressing impacts on third parties.

- **Markets must address impacts on third parties.** Surface water transfers and groundwater transfers and banking can negatively impact both water supply and water quality, and land fallowing can impact neighboring farmland, wildlife, and air quality. A well-designed system should identify responsibility for addressing impacts, where they are significant.

- **Various stumbling blocks currently hamper water markets.** Groundwater sustainability agencies and other actors face several hurdles that make it difficult to get the most out of water markets, including gaps in groundwater governance and infrastructure, and tensions in the approval process.

- **Addressing the challenges now will bring material benefits.** Swift action to establish and enforce groundwater allocations, address undesirable effects of pumping, adopt effective and expeditious approval strategies, and refine regulations will help groundwater users bring their basins into balance and improve resilience for years to come.

Introduction

Groundwater is a vital resource in California—accounting for more than a third of all water use on average, and more in dry years (Department of Water Resources n.d.). Until recently, groundwater use in most of the state was largely unregulated, and many basins have experienced long-term overdraft—where pumping has regularly exceeded replenishment. This has resulted in a suite of undesirable impacts—including sinking lands, dry wells, degraded water quality, and harm to wetlands and streams.

The Sustainable Groundwater Management Act (SGMA) was enacted in 2014 to remedy this situation. It mandates that local water users bring their groundwater basins into long-term balance by the early 2040s, while addressing the undesirable results of pumping along the way.1

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1. We use the term “basin” to refer to both hydrologically defined aquifers and administrative “sub-basins” that the Department of Water Resources has defined for purposes of SGMA compliance. Some contiguous sub-basins are hydrologically connected, as part of a larger aquifer. SGMA requires planning to consider these connections.
SGMA is spurring major changes in water management across California. The first groundwater sustainability plans for the most overdrafted basins—submitted in early 2020—emphasize achieving balance by augmenting water supplies. Yet reducing water use—and taking significant amounts of farmland out of production—will also be necessary in many basins where pumping regularly exceeds recharge (Hanak et al. 2020). Two related market-based tools may prove essential as Californians adapt to the new regime: water trading and water banking.

California has significant experience with water trading. Since the early 1990s, parties have actively traded surface water across much of the state, and groundwater markets have sprung up in some adjudicated basins, where programs to address overdraft were already in place before SGMA’s enactment. California also has some of the most sophisticated groundwater banks—dedicated underground water storage—in the world. SGMA emphasizes the possibility of expanding existing water markets and developing new ones to help meet the ambitious goal of bringing groundwater basins into balance.

**Advantages of trading and banking.** Market-based approaches offer several advantages over more rigid approaches to managing scarcity, such as across-the-board groundwater cutbacks. Trading provides incentives to water users who have rights to more ample supplies and lower-value uses to sell or lease water to those with more limited supplies and higher-value uses in agriculture, cities and towns, and the environment. By creating a path for water to find its highest-value uses, trading can lessen the costs of temporary shortages during droughts and support long-term shifts in water use patterns. It can help society adapt to the hydrologic realities of both SGMA and the changing climate, which is bringing more-volatile precipitation and hotter, more intense droughts (Mount et al. 2018). Trading can also facilitate formal groundwater banking projects that store water underground on behalf of specific parties. This is an important supply augmentation and risk management strategy that will likely prove key for SGMA and climate adaptation.

**Effective and responsible trading and banking.** Shifting water use can also have negative consequences for parties other than the buyers and sellers—often known as “third parties” (Hanak 2003). These include physical impacts on water resources. For example, when surface water trading changes the timing or location of diversions from a river, this may reduce flows available for other water users and the environment. Likewise, when groundwater trades or banking change the location or timing of pumping within an aquifer, this may threaten drinking water if it causes nearby wells to go dry or contaminants to migrate towards these wells. Under some circumstances, trading can also reduce incomes and jobs in places that fallow farmland to sell water, even as it supports overall economic activity.

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2. This law requires local water users to form groundwater sustainability agencies (GSAs) and to prepare groundwater sustainability plans (GSPs) that will bring groundwater supplies and demands into long-term balance by the early 2040s. For a description of SGMA requirements, see Kiparsky et al. (2016). For a summary of SGMA implementation requirements, see Hanak et al. (2019), Box 1.1.
3. Plans for critically overdrafted basins were due in January 2020; plans for other priority basins are due in January 2022.
4. As described below, what distinguishes banks from other recharge projects is formal accounting for water put into and withdrawn from the bank.
5. As described below, establishing an effective groundwater trading system requires setting individual caps on pumping and allowing for transfer of pumping permits. Because the cap and the resulting price of permits restrict pumping, new groundwater trading systems are likely to cause less stress on the aquifer—and new impacts on other users—than continued unmanaged pumping.
Finding ways to minimize the cost of bringing basins into balance, across all parties, will be important for a successful transition to groundwater sustainability.\footnote{As an example, previous PPIC work estimated that roughly 500,000–750,000 acres of irrigated farmland will need to come out of production in the San Joaquin Valley to address the historical imbalance in groundwater use. Yet water trading and cost-effective investments in new supplies (especially with more underground storage) could reduce the regional economic costs of this transition more than three-fold (Hanak et al. 2019; 2020).} It is also important to design programs that both limit impacts to third parties and support beneficial water trading and banking. This is a difficult balance to strike, but a range of policies already exist to do just that: much of the legal structure around water trading and banking in California is designed to guard against unreasonable physical impacts, and some policies also address the local economic consequences of significant land fallowing. SGMA adds a new set of protections against significant third-party impacts from groundwater use that will act as guardrails on future trading and banking programs. For example, SGMA’s requirement that groundwater users address significant and unreasonable harm to surface water uses and groundwater-dependent ecosystems brings California water law more in step with the hydrologic reality that most groundwater and surface water systems in the state are connected.

About this report. This report explores how water users and other stakeholders can use existing market institutions—and design new ones—to support SGMA’s mandate of groundwater sustainability while providing the broadest benefits for the economy, communities, and the environment. To ground-truth the analysis, we sought input from a diverse set of more than 90 stakeholders—including representatives from federal, state, and local water agencies and agricultural, urban, environmental, and water justice communities—during an April 2019 workshop and focus group meetings in the spring and summer of 2020. We begin with some basics: how do trading and banking work, what benefits can they bring, and how could they promote SGMA implementation in different parts of the state? We then review the requirements for establishing effective and responsible markets, and how SGMA creates new opportunities in this regard. The following two sections assess key stumbling blocks for market expansion, and highlight what stakeholders at the local, state, and federal levels can do to make markets work better.

Accompanying this report are two new fact sheets that summarize trends in water trading (Hanak et al. 2021) and groundwater banking (Escriva-Bou et al. 2021), and several technical appendices with a more detailed analysis of legal considerations for water trading and banking (Technical Appendix A), trends in surface water trading and groundwater banking (Technical Appendix B), and a case study of groundwater trading in the Mojave Basin (Technical Appendix C).

The Basics and the Benefits of Water Trading in California

In California, water trading and banking are not new, but SGMA is heightening interest in their expansion. Surface water trades now account for roughly 4 percent of agricultural and urban water use (Hanak and Stryjewski 2012; Hanak et al. 2021; Schwabe et al. 2020). Yet the volumes traded have barely grown since the mid-2000s, reflecting a complex approval process involving federal, state, and local restrictions. Groundwater markets have been slow to develop because tradable rights to pump are still rare. A handful of adjudicated basins—where such rights do exist—contains useful examples, and new approaches are being piloted in response to SGMA. Groundwater banking projects already provide important drought
reserves in some locations, but poorly defined groundwater rights and a complex set of administrative rules are also limiting their expansion (Escriva-Bou et al. 2021).

Expanding this suite of market-based tools—trading both surface and groundwater, and banking water underground—will be important for attaining groundwater sustainability. Here we provide an overview of how these tools work. We then describe the benefits they can bring, and how they could be useful as part of SGMA implementation.

An Overview of Water Market Tools

**Water trading** involves the transfer of rights to use water on a temporary, longer-term, or permanent basis. Although some sellers trade water they have stored in reservoirs or underground, water usually becomes available for trading when sellers forego their own uses during the term of the agreement. Buyers generally make financial payments to sellers, but they sometimes also repay in water at a later date.  

In California, there are three main types of water transfers:

- **Surface water transfers.** Sellers make water available by reducing their own diversions from reservoirs, rivers, lakes, and streams so that buyers can increase their diversions elsewhere in the system. Buyers may be nearby, or at some distance; what is key is having the ability to transfer water from sellers to buyers, through water conveyance infrastructure (rivers, canals, pipelines).

- **Groundwater substitution transfers.** These transactions involve both surface water and groundwater; water users sell their surface water, but instead of cutting back their demand, they pump additional groundwater for their own use. This method is common for water sales from parts of the Sacramento Valley during droughts. In places where groundwater levels can recover relatively quickly, it can be a good alternative to fallowing land to make water available for sale.

- **Groundwater transfers.** Sellers reduce their groundwater pumping, and buyers increase pumping elsewhere. These trades typically occur within the same groundwater basin, or a sub-zone within the basin. In contrast to surface water trades, these transactions do not require physically moving water between sellers and buyers, as long as there is a close hydrologic connection between the pumping locations of the parties—but they do require a robust accounting system to ensure parties pump and trade only their own water.

Short-term (typically annual) and longer-term leases are the most common types of transfer in California, but some permanent sales of water rights and contracts also occur. Although outright transfers are the most common form of agreement, water users have also experimented with “dry-year options”—upfront

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7. Future repayment in water (above and beyond any financial payment) is a requirement for some State Water Project transfers; these requirements can allow for “unbalanced exchanges” in which the repayment is of a different (typically lesser) amount. Some local water districts also require future repayment in water.

8. Because the water being sold is surface water, these transfers are included in the surface water transfer data reported in Technical Appendix B.

9. Although we often use the general term “sale” to refer to temporary or long-term transfers of water, duration-limited transactions technically involve a lease, rather than a sale, of the water right. See Technical Appendix Table B1 for aggregate trends, and Table B9 for a list of permanent sales.
agreements that lay out conditions under which sellers will make water available during droughts. This approach can help parties plan for how they will manage hydrologic risk. Across all types of transfers, most sales are from agriculture—reflecting that sector’s predominance in current water use—and buyers include other farms and agricultural water districts, urban water agencies, and environmental water managers.

**Groundwater banking** refers to storing water underground on behalf of specific parties for later extraction. What distinguishes banks from other recharge projects is formal accounting for water put into and withdrawn from the bank. Those storing water typically leave some behind (especially when the bank is in a different basin), and pay fees to cover project costs (including infrastructure for delivering and storing water, and the pumping costs of extracting it).

Banks and other recharge projects typically store surface water from local, imported, and developed sources; the water is recharged into the aquifer by spreading it on the land and other methods (Hanak et al. 2018a). It is also possible to store native groundwater that naturally replenishes the aquifer. There are legal distinctions among these sources from a water rights perspective, which matter for both trading and banking programs (Box 1). In particular, the extent to which the water can be transferred to parties outside of the basin depends on the source.

Today, California’s most well-known groundwater banks are in Kern County. They store various types of surface water and use dedicated extraction wells to deliver water to the parties who bank it, both locally and in other basins (Technical Appendix B; Escriva-Bou et al. 2021). As SGMA improves accounting systems, other types of banking could grow significantly as well. This includes recharge programs designed entirely for local use—where parties have accounts and access the water through their own pumps. SGMA also opens up opportunities for individual users to carry over native water from year to year and “bank” it. Our definition of banking also includes well-managed groundwater substitution transfer programs because they potentially, with good accounting, could incentivize individual users to use storage space efficiently and creatively by “borrowing” from recharge in future wet years.

Water trading and banking are closely related activities. Banking projects go through many of the same approval processes as water transfers. In addition, transfers are an important source of water for recharge, and water stored in banks is sometimes sold to other parties.

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10. Transfer volumes, prices, and the hydrologic conditions under which a transfer could take place are negotiated in advance. Such agreements can be annual or multi-year, and the terms may include partial payments to the seller on specific call dates if the buyer opts to wait longer to make a final purchase decision. These agreements involve the actual transfer of water—in contrast with the recently launched “water futures” market, which is strictly a tool for hedging financial risk (Bruno and Schweizer 2021).

11. We use the generic term “water district” to refer to various types of local water agencies that manage and deliver water supplies to local water users in the agricultural and urban sectors. Irrigation districts, water storage districts, and water conservation districts are among the most common agencies serving agriculture.

12. On average, agriculture uses roughly 80 percent of non-environmental water use, with the balance (20%) used by residences and non-farm businesses. Environmental water accounts for about half of all water use statewide, but this share is much smaller in most regions, and it declines during droughts (Mount and Hanak 2019). For data on sales and purchases by sector, see Technical Appendix Figures B3 and B4.

13. Where the aquifer is managed for recovery following the extra pumping associated with water sales, such programs already serve as groundwater recharge projects (Thomas 2001). This approach can be especially valuable in basins that have not experienced significant overdraft, which would not otherwise have much room for recharge; extra pumping with planned replenishment makes it possible to increase the basin’s effective storage capacity. Groundwater substitution programs typically have not involved formal accounting for water stored in the aquifer, but this will become more likely as SGMA increases the value of formal basin management.
Box 1. Getting more precise about different types of groundwater

Groundwater is commonly thought of as a single resource, but California law recognizes several types of groundwater and groundwater rights. The following categories are especially important for trading and banking:

- **Native groundwater** is water that makes its way into aquifers through percolation from surface sources within the basin—including rivers, streams, wetlands, and precipitation—and from the migration of underground waters. Local surface water that seeps into the ground following irrigation is also classified as native groundwater.

- **Non-native groundwater** includes two types, distinguished by the origin of the water:
  - *Imported water* is surface water that originates in another basin and is imported for direct use or storage. This includes water that is present in aquifers because of active recharge (e.g., in a recharge basin). It also includes seepage following the use of imported water for irrigation or other purposes.
  - *Other developed water* is water that, like imported water, “would not be present within a basin but for human efforts.” This includes surface water produced by “salvage” (e.g., capture of floodwaters and runoff from storms that otherwise would have escaped the basin without naturally recharging the aquifer) and water produced by recycling wastewater (Garner et al. 2020).

In general, the right to extract and use native groundwater arises either as a result of the ownership of land that overlies the aquifer (overlying rights) or by the act of appropriating the groundwater and putting it to a beneficial use (appropriative rights). In contrast, non-native groundwater is the exclusive property of the importer or developer, if that party intends to reclaim the water following its initial use and does not abandon that claim. Whereas native groundwater held under an overlying right cannot be transferred out of the basin, this restriction does not apply to native water that is held under an appropriative right or to non-native groundwater.

The groundwater in most of the state’s aquifers is a blend of native and non-native supplies. But many of the local, state, and federal rules related to water trading and banking have been applied without clear distinctions among these sources, often treating everything as native groundwater. This creates ambiguity and can reduce incentives to invest in trading and banking programs. As accounting systems develop under SGMA, identifying the different categories of groundwater, and developing a consistent method to measure and account for each category, can provide clarity on ownership and transferability. This also can facilitate market-based programs that could augment supplies and manage demand at a lower cost.

A final category of groundwater is often referred to as “transitional water.” This is native groundwater that is temporarily available for allocation and use, but which will be diminished (and ultimately eliminated) over time as aggregate extraction rights are reduced to comply with SGMA's sustainability directive. Some groundwater trading programs may allow within-basin trading of this water; the Mojave Basin is one such case (see Box 2).

For more information, see Technical Appendix A (Introduction).

**Benefits of Trading and Banking**

Trading and banking can provide an array of economic benefits to both market participants and society at large. These transactions allow for the cost-effective reallocation of water and the development of water
infrastructure, as well as improved management of hydrologic risk. Done well, they can foster cooperation in managing water-related challenges and boost resilience.

**Reallocating water cost-effectively**

Trading allows water users facing shortages to pay other users for making some of their water available. These voluntary transfers are often preferable to the alternatives. The first of these, requiring water to remain locked in its current uses, can result in worse economic outcomes than allowing water to be put to other uses. The second alternative, attempting forced reallocations of water rights established many decades ago, can lead to protracted legal battles.\(^{14}\)

In California’s surface water market, sellers often have senior water rights, which are more reliable and abundant during dry years, and buyers often have more junior, less reliable rights. But a key requirement for voluntary trades is that water must have a different economic value in different uses: the value of the water to the buyer must be greater than its value to the seller. If sellers make water available by fallowing cropland, they need to be compensated enough to offset at least the loss of income. When water moves to higher-value uses, this also can generate broader benefits because these uses often create more jobs and related economic activity than lower-value uses.\(^{15}\)

Short-term water leases—occurring within a year—are especially valuable to help manage temporary, drought-related shortages.\(^{16}\) Multi-year leases and permanent sales of water rights or contracts help accommodate long-term shifts in demand from population growth and changing economic activity (such as a shift from annual to perennial crops, which require water every year). Long-term changes in supply also increase the demand for water purchases. For instance, water trading has helped urban communities in Southern California and perennial crop farmers in the San Joaquin Valley adapt to reductions in surface water deliveries since the 1990s.\(^{17}\) Likewise, in many basins, new groundwater pumping limitations under SGMA will also increase demand for water purchases.

**Reducing the cost of water investments**

For those facing shortages, voluntary purchases can be much less costly than developing new water supplies, which can entail building new storage, treatment, and conveyance structures—expenses that can be cost-prohibitive for water users.\(^{18}\) Trading and banking also facilitate cost sharing on water investments

\(^{14}\) Voluntary transfers are also more effective at factoring in the costs incurred by those providing the water; parties will not sell unless they receive a price that covers the value of the water if they had used or stored it themselves.

\(^{15}\) Field crops such as grains and alfalfa generally produce less revenue per acre-foot of water used than fruits, nuts, and vegetables (Hanak et al. 2018b). Many higher-revenue crops also generate more on- and off-farm employment, including related food and beverage processing. Medellin-Azuara et al. (2019) provide an illustration from the San Joaquin Valley, and Lund et al. (2018) and Medellin-Azuara and Lund (2021) show statewide results.

\(^{16}\) Souza (2021) describes how trading is helping farmers manage shortages during the latest drought.

\(^{17}\) Trading has helped urban Southern California adjust to cutbacks in Colorado River water since the early 2000s, when California had to stop using more than its allocation of that source. Farmers on the west side of the San Joaquin Valley began relying on water purchases to help offset reductions of surface water deliveries in the mid-1990s, when a variety of environmental regulations reduced Delta exports, particularly for Central Valley Project agricultural service contractors. See Hanak and Stryjewski (2012) for details on trading shifts, and Gartrell et al. (2017) for the impacts of regulations on exports.

\(^{18}\) For San Joaquin Valley agriculture, for instance, many investments for expanding water supplies would cost more than the value of the agricultural output they would support, even for high-value crops (Hanak et al. 2019).
and make it possible to use water infrastructure to its full potential. California already has numerous examples of trading and banking partnerships that have worked in this way, and there is potential for more in the state’s changing supply and demand landscape. Leveraging opportunities to make the most of water investments can help keep water affordable in both urban and rural areas. For water districts with senior water rights, revenues from trading can help fund local infrastructure that benefits both local growers and the broader community.

Managing hydrologic risk

California has the most variable climate in the country, and hydrologic risk is a fact of life. Much of the state’s annual water supply arrives in just a handful of storms, and one or two large storms can spell the difference between a wet year and a dry year. One tool that helps water users manage this hydrologic risk is dry-year option trades. These trades enable water users with consistent demands but unreliable supplies to lock in purchases of water during drought from those with more senior, reliable water rights at a pre-arranged price. These trades, which don’t require a permanent transfer of rights, can improve predictability for both buyers and sellers, while also allowing water to remain in other (predominantly agricultural) uses when not needed. Single-year option contracts have not been widely practiced in California, but some longer-term arrangements suggest the promise of trading focused on dry-year reliability.

Groundwater banking is another risk management tool that has been growing in popularity in California. To date, banks have mainly focused on storing surface water from wet years underground for use in dry years. SGMA has heightened interest in capturing and storing additional unclaimed flood flows to augment overall supplies (Hanak et al. 2018a; 2020). Water users we interviewed also noted growing interest in using groundwater banks to store water even in non-wet years, as a hedge against the more severe droughts expected with the changing climate. Groundwater banking requires close connections in the management of—and accounting for—surface and groundwater, so rules governing the transfer and storage of both resources will be critical to the growth of this practice.

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19. Examples include groundwater banking projects, water exchanges between State Water Project and Colorado River users, long-term transfers of Colorado River water and dry-year water from the Yuba River, and interstate and binational partnerships to increase flexibility on the Colorado River. With continued reductions in urban per capita use, water sharing arrangements could grow, as many cities will need investments mainly to shore up dry-year supplies, without needing the capacity in other years. Additionally, trading can help share investment costs (and water) when urban communities invest in new supplies to support growth, which they may not need for some time (or ever). For more on partnerships, see Escriva-Bou et al. (2020a).

20. For instance, the Yuba Water Agency has supported local flood investments and safe drinking water in small communities, and Glenn-Colusa Irrigation District has supported ecosystem-related investments with revenues from water transfers.

21. Annual option agreements were drawn up in 1995 as part of a state-run Drought Water Bank, but not used because the year ended up being wet (Howitt 1998). In 2003, annual options were used for transfers from Sacramento Valley rice growers and the Metropolitan Water District (MWD) of Southern California. Interviews with market participants at the time suggest that a variety of factors limited satisfaction with this experience, including challenges in getting state and federal approvals to move the water and difficulties in managing the timing of the call dates in ways that worked for growers’ planting decisions. One notable, longer-term, option-like agreement, in place since 2008, involves transfers in dry and critically dry years from the Yuba Water Agency to a group of State Water Project and Central Valley Project contractors, who have the first right of refusal of the water at a pre-negotiated price (Yuba Water Agency n.d.). Finally, MWD has maintained a fallowing option program with growers in Palo Verde Irrigation District to acquire Colorado River water since the early 2000s. Uniform prices are pre-specified, but farmers choose which acreage to enroll, and MWD can make annual calls for a share of the acreage to be fallowed and the water transferred. Escriva-Bou et al. (2020a) explore how dry-year partnership agreements could help coastal urban areas manage drought while increasing the long-term availability of water in the San Joaquin Valley. In recent years, some parties have developed multi-year “take or pay” arrangements, where sellers receive some remuneration even in wet years, when the buyers have less need for the water.
How Water Markets Can Support SGMA Implementation

Today, water trading and banking are already helping Californians manage shifting demands and variable water supplies. Surface water purchases are improving supply reliability for farms, communities, and the environment in many regions (Hanak and Stryjewski 2012; Hanak et al. 2021). Groundwater trading has helped water users bring their basins into balance cost-effectively in several adjudicated basins in Southern California. And groundwater banks are helping cities and farms manage supply risks in some adjudicated basins and some locations within the Central Valley (Escriva-Bou et al. 2021).

Although market-based tools have not been at the forefront of most early SGMA planning efforts, they are likely to become more prominent as groundwater sustainability agencies (GSAs) implement both demand and supply strategies in their sustainability plans. Yet the specifics are likely to vary considerably. Basins differ in many respects—the extent of groundwater overdraft, the risks of undesirable results from pumping, the portfolio of other water resources available, the degree of connectivity to water conveyance, the mix of users, and other factors—all of which affect both the need and the opportunities for solutions.

Here we provide a brief overview of how basin conditions could shape opportunities for trading and banking across the state. It is useful to distinguish between basins in the Central Valley—a vast contiguous area connected to California’s extensive surface water grid—and other basins subject to SGMA that are more isolated, both from each other and from major surface water infrastructure (Figure 1).

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22. In adjudicated basins, courts settle disputes over how much groundwater water users can extract, and court-appointed water masters oversee water supply and use. As described below, the definition of pumping rights facilitates trading. In addition to the Mojave Basin (Box 2 of this report and Technical Appendix C), three other adjudicated basins with significant trading include the Chino Basin (Technical Appendix A, Box 4), and the San Gabriel and Central Basins, all in Southern California. In recent years, these basins collectively traded roughly 75,000 acre-feet annually (see Technical Appendix B).
Basins in the Central Valley are more connected to each other and to surface water conveyance

Central Valley basins can pursue market solutions within and across basins

The Central Valley is California’s main farming region, with more than 6 million acres of irrigated cropland. The region also contains significant urban centers and hundreds of small rural communities that depend mainly on groundwater. The region is also home to diverse freshwater ecosystems, and its wetlands and rivers are affected by groundwater use.

Central Valley groundwater basins are large, and they extend over a contiguous area stretching from north of Redding to south of Bakersfield (Figure 1A). Many of these basins are hydrologically interconnected. Much of the region is also connected through the state’s main surface water grid—including the federal Central Valley Project (CVP), the state-run State Water Project (SWP), and numerous local projects (Figure 1B).

Surface water is a significant share of total supplies, particularly in the Sacramento Valley and the Delta. In the San Joaquin Valley, both local and imported surface water is important, but less abundant, and most basins are critically overdrafted. Overdraft is particularly significant in the southern San Joaquin Valley, which receives less rainfall and has fewer supplies from local rivers; recent declines in the reliability of
supplies imported by the CVP and the SWP—a result of regulatory changes and drier conditions—have increased the severity of overdraft (Hanak et al. 2019).

Surface water availability also varies considerably within many basins—including those where overall surface water abundance has helped limit overdraft. Even in some relatively water-rich basins such as Colusa in the northwest or Modesto and Turlock in the southeast, some farmland has relatively abundant surface supplies, while other farms depend entirely on groundwater (Figure 2).

**Figure 2**

Surface water for farming varies within and across Central Valley groundwater basins, and perennial crops rely more heavily on groundwater

The water grid connections make it possible to trade and bank water both locally and at greater distances. Surface water trading is already active within both the Sacramento and San Joaquin valleys; relatively water-
rich farmers are the main sellers, and farms, cities, and environmental managers are the buyers. Especially during dry years, Sacramento farmers also send water through the Delta to farmers in the San Joaquin Valley as well as to cities in the Bay Area and Southern California. Groundwater banks—located mainly in Kern County in the southern San Joaquin Valley—store water for local users and others in the region and in Southern California and the Bay Area. 23

SGMA implementation in this region can benefit from continued market-based cooperation among water users, both within and across basins. On the supply side, many groundwater sustainability plans emphasize capturing and recharging additional surface water—particularly from high-flow storms. 24 Formal groundwater banks can help incentivize these investments, especially where banked water stored underground can be sold to other pumpers. Since the best storage locations—those with good soil characteristics and connections to conveyance networks—will often be offsite (including in other basins), market-based exchanges will also facilitate the use of storage capacity.

The trading of both surface and groundwater is also likely to be broadly helpful within many basins, given the stark disparities in surface water availability across agricultural lands (Figure 2). In particular, many lands with limited surface water are planted with high-value perennials that would be very costly to fallow. 25 Within the San Joaquin Valley, earlier PPIC research found that by allowing irrigation water to move from lower- to higher-value crops within basins, local trading of surface and groundwater could reduce the regional economic costs of pumping cutbacks by 40 percent. Likewise, trading surface water across basins could keep more higher-value crops in production, reducing costs by another 20 percent and providing additional economic benefits (Hanak et al. 2020).

Despite some early signs of competition over the limited supplies, within-basin cooperation on trading and banking is likely to expand. 26 Several San Joaquin Valley GSAs have begun piloting local groundwater trading, and water users in many basins are exploring ways to cooperate on groundwater recharge and on capital expenditures to extend delivery of surface water to areas where it is lacking. 27 Expanding across-basin cooperation may be more challenging, despite the hydrologic connections that make it possible and the potential economic benefits. Concerns about meeting SGMA’s sustainability requirements—along with local resistance to land fallowing and restrictive local trading policies—could discourage the export of water to other basins, even if there are willing sellers and willing buyers, and the trades could be accomplished

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23. For more details on regional trading and banking patterns, see Technical Appendix Tables B6, B7, and B11 and Hanak and Stryjewski (2012). In the 1990s and 2000s, San Joaquin Valley farmers also permanently transferred some surface water to urban communities in Southern California and the Bay Area.

24. Although the plans collectively overestimate the amount of water likely to be available for recharge within the region (Hanak et al. 2020), this supply augmentation option is the most promising from a quantity and cost perspective (Hanak et al. 2019).

25. In the San Joaquin Valley, 58 percent of cropland was in perennial fruits and nuts in 2016; the majority of perennials was found on lands receiving less than 2 af/acre of average surface water (68%) (Figure 2). In the Sacramento Valley, perennials were a smaller share of acreage (36%), but an even higher share of them (76%) was planted on lands with less than 2 af/acre. The relative abundance of surface water on lands with annual crops in both regions—and particularly in the Sacramento Valley—highlights opportunities for trading. One potential limitation is the need to apply manure from dairies to some annual cropland, as part of nutrient management programs.

26. Hanak et al. (2020) summarize the projects and actions identified in 36 groundwater sustainability plans for the San Joaquin Valley’s 11 critically overdrafted basins. Plans generally emphasize supply augmentation, in many cases without regard to the fact that other plans within the same basin or elsewhere in the region are counting on the same supply sources.

27. This includes Rosedale–Rio Bravo Water Storage District (described in Technical Appendix A, Box 9), as well as the Madera Basin County GSA and the McMullin GSA (Kings Basin).
without harming other water users or the environment. As we discuss below, much will depend on the rules and practices of the local agencies that oversee transfers and banking.

In most other SGMA basins, market solutions will need to stay local

Most other basins subject to SGMA are more isolated, both from each other and from the statewide water grid. Some—like Paso Robles in San Luis Obispo County or Borrego Springs in San Diego County—have little or no surface water. Absent significant new investments in water conveyance infrastructure, their SGMA solutions will mainly entail managing groundwater demand. Local groundwater trading, along with carrying over and banking groundwater allocations, can help do this cost-effectively. The Mojave Basin, which has one of the most active groundwater markets in the state, provides important insights (Box 2).

In other basins, local surface supplies may be part of the solution. For instance, recharging with local storm runoff and recycled water is likely to be important in parts of the Central and North Coast regions. Groundwater trading and banking can help incentivize water users to manage their demands flexibly and invest in storage in ways that work best for their own bottom lines. The Fox Canyon Basin in Ventura County is an early pilot of groundwater trading in a relatively isolated basin. It is starting small, with annual groundwater trades among farmers—but with the goal of including partnerships with urban agencies, which can broaden the supply portfolio with recycled water. 

28. For a description of this program, see Technical Appendix A, Box 6 and Heard et al. (2021).
Box 2. Water trading in the Mojave Basin

In the 1990s, groundwater users in the Mojave Desert undertook a court adjudication process that would redefine groundwater rights and create a market to trade them. Today, the Mojave Basin has one of the most liquid groundwater markets in California. Its experience contains insights about groundwater market design that could aid SGMA implementation.

The adjudicated area of the Mojave is large—at approximately 3,400 sq. miles, it is larger than any of the Central Valley's sub-basins. Along with undeveloped and agricultural land, this area includes the cities of Victorville, Hesperia, and Barstow. The number of users is not particularly large: approximately 450 large-scale pumpers hold volumetric pumping rights. (Domestic well owners are classified as *de minimis* water users, and their rights are not quantified beyond an annual cap of 10 acre-feet.) Nonetheless, each year hundreds of trades take place—mostly one-time annual leases of pumping allowance, but also the permanent transfer of rights to pump.

Before adjudication, pumping was predominantly for agricultural purposes. Similar to experiences in other adjudicated basins, falling water tables and growing urban water demands prompted interest in limiting pumping to stabilize the water table and ensure the long-term reliability of supplies. Many GSAs may consider the approach that was adopted: an initial allocation of volumetric pumping entitlements, followed by a progressive ramp-down. As pumping allowances declined, trading reallocated water from agricultural to urban and other uses. Farmers received market rates for their water, and today most water pumped in the basin is not for agricultural use. This trading provides real value to both buyers and sellers: A recent analysis suggests that the adjudication resulted in over $500 million in cumulative net economic gains, primarily through reallocation to higher-value uses (Ayres et al. 2021). Besides ag-urban trading, some compensated transfers have also provided water for stream flows, riparian habitat, and other environmental uses.

Several design features of Mojave’s market may inform local planning elsewhere:

1. **Defined subareas to maintain hydrologic balance.** The Mojave contains some areas where groundwater is more connected locally than with neighboring areas in the basin. There was concern that trades into one area could upset the local hydrologic balance and reduce flows to, and ultimately water tables in, areas that receive inflows from that area. To address this, trading across five defined subareas is restricted and requires watermaster approval. To further ensure supply reliability, the adjudication also sets delivery obligations—volumes of subterranean flow that should be achieved—between subareas where a groundwater flow gradient exists.

2. **Some flexibility to trade across subareas.** Although the delineations between subarea markets reduce downstream impacts on groundwater levels, these restrictions can be costly, particularly when the value of water use varies significantly between subareas. Such differentials in the Mojave prompted a second design feature: an offset mechanism that allows pumpers in Alto—the subarea with the largest urban population and water demands—to purchase pumping allowances from the adjacent, largely agricultural Centro subarea, and thereby offset shortfalls in their delivery obligations. For pumpers in Alto, buying the rights to pump groundwater from Centro was cheaper than the available alternative, importing makeup surface water from the State Water Project; Alto pumpers enjoyed a $15 million cost savings over the past two decades. Meanwhile, pumpers in Centro earned greater returns on the groundwater they sold to Alto than they would have earned by using it in their farming operations.

3. **Ability to trade transitional water.** Water users are able to trade their entire annual pumping allowance—including the transitional pumping volumes that will no longer be available once the water table is stabilized (see Box 1). GSAs contemplating gradual approaches to ending overdraft may want to consider this approach. Some users may be hesitant to constrain transitional pumping, as delaying the
ramp-down prolongs access to groundwater and shifts the costs of adjustment into the future. Allowing users to trade transitional water provides them with an incentive to set a volumetric cap on groundwater pumping, which can help limit overdraft in the first 20 years of sustainability plan implementation.

Sources: Technical Appendix C (general) and Technical Appendix A, Box 5 (ecosystem-related issues).

Five Essential Features of Effective and Responsible Markets

Reaping the benefits of water trading and banking programs requires attention to design. Well-designed programs foster an atmosphere of widespread trust in the system, enable beneficial transactions to occur easily, and contain safeguards to address significant harm to third parties. Here we present five essential features of effective and responsible markets. We describe how well California is positioned in each area, and how SGMA is bringing changes that can help fill key gaps.

1. Clearly Defined, Secure Property Rights

As with other markets, one fundamental requirement of water markets is a legal system with well-defined, quantifiable, secure rights to the assets that are being traded. The definition of property rights determines what is tradeable and where and when transfers may occur. Sellers must be able to describe the asset for sale, and buyers must have a clear understanding of the rights and expectations to which a purchase might entitle them. In California, the situation has been quite different for surface water and groundwater.

Surface water rights in California are generally well-defined, and tradeable

Most surface water is held under appropriative water rights, which are generally well-defined—and tradeable—under California law. Rules that enable trading are also well established, if complex—often involving multiple layers of review. State Water Board approvals are required for transfers of rights permitted since 1914, and the environmental review requirements of the California Environmental Quality Act (CEQA) apply to all transfers that may have significant environmental impacts—including transfers of the more senior “pre-1914” water rights. In addition, entities that hold rights to water on behalf of their members—including the CVP and SWP as well as local water districts—set rules for the trading of this water. The CVP, the SWP, and various local entities also have rules on how parties may use their storage and conveyance infrastructure to transfer water.

29. When property rights are insecure or actors do not believe they can be defended in court, trade and the value derived from the resource fall (Grainger and Costello 2014; Leonard et al. 2019).

30. Riparian rights, which are only available to lands adjacent to waterways for direct diversion and use, may not be stored for longer than 30 days and generally are not tradable (Littleworth and Garner 2019).

31. Short-term transfers of one year or less that are subject to review and approval of the State Water Board are exempt from CEQA review (Water Code § 1729).
Groundwater rights are generally not well-defined, but SGMA ushers in new possibilities

The allocation of well-defined rights to pump groundwater has typically not occurred outside of adjudicated basins, located mainly in Southern California (Figure 1A). Groundwater trading is an important tool for managing water scarcity in some of these basins (for Mojave, see Box 2); in the many other basins now subject to SGMA, a functioning groundwater market will require allocations.

SGMA provides a new legal framework for this: it authorizes GSAs to establish and enforce pumping allocations for individual wells, and to allow these allocations to be traded and stored. In cases where water users are unable to agree on the terms of pumping allocations, companion legislation enacted in 2015 authorizes streamlined basin-wide adjudication of groundwater rights.

Establishing allocations will entail a sea change in local groundwater management. Discussions are generally still in the exploratory stage, and furthest along in several areas that face extreme pumping deficits. Although GSAs will have some flexibility on the design of allocations, these need to rest on a solid legal footing to survive potential challenges (Garner et al. 2020). Tying allocations to explicit delineations between the different types of groundwater—native, imported, and developed—will help in this regard, while also laying the foundation for a strong set of actions to end overdraft, including trading and banking programs (Box 1).

One area of continued uncertainty is how GSAs may craft allocations of native groundwater for “dormant” claimants—those who own overlying land but have not pumped.

2. Accounting: Measurement, Reporting, and Verification

Reliable measurement, reporting, and verification underpin the type of comprehensive and robust accounting systems that are essential to establish trust in market transactions. All water users must trust that the system is accurately measuring and tracking water. For example, for trading, it’s key to ensure that a seller is only selling water to which they have valid rights of use, and not water that belongs to another party. For groundwater banking, measurement and monitoring are important to protect the assets of the parties depositing water in the bank, as well as other parties who use the aquifer. In both cases, well-designed accounting systems that enable water rights tracking are paramount.

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32. For details, see Technical Appendix A, Introduction and Part 1. As described therein, SGMA does not purport to quantify the groundwater right itself.
33. This may help speed the process of adjudication, which in the past has taken an average of eight years to accomplish, and sometimes almost 20 years to complete.
34. Examples include Fox Canyon (Ventura County), Indian Wells Valley (Kern County), Borrego Springs (San Diego County), and some heavily groundwater-dependent GSAs within larger basins within the Central Valley (e.g., Madera and Chowchilla County GSAs, McMullin Area GSA, Eastern Tule GSA, Rosedale–Rio Bravo Water Storage District). In Borrego Springs, a new stipulated agreement lays out a framework for allocations and other essential conditions of a groundwater market (Technical Appendix A, Box 3; Poole 2021).
35. In the first 20 years of sustainability plan implementation, some GSAs are also identifying interim transitional pumping allocations—the amount of excess pumping that will be initially authorized, but phased out over time (Box 1). As the Mojave Basin experience shows, there can be value in authorizing trading of these allocations (Box 2).
36. For instance, in Madera and Merced Counties, ranchers who currently do not irrigate their lands have expressed interest in getting allocations of groundwater to sell to others (SJV Water 2021). Some guidance from previous adjudications is available: for example, the stipulated agreement in the Antelope Valley adjudication extinguished dormant rights holders’ claims. However, such agreement may not be easy, or possible, for GSAs to secure in all cases. See Technical Appendix A (Part 1).
Establishing effective, low-cost systems for tracking market transactions is part and parcel of a strong water accounting system. While there is still room for improving surface water accounting in California, the biggest gaps have been in groundwater accounting outside of adjudicated basins (Escriva-Bou et al. 2016). Most basins subject to SGMA have been investing heavily in understanding local supplies and demands—a key step in establishing sound pumping allocations and determining how much water is tradable. Understanding how water moves within the aquifer is also essential for establishing successful groundwater banking programs.

3. Hydrologic Connections

As noted earlier, water trading and banking also require hydrologic connections between transacting parties. Groundwater purchases and sales within the same basin typically do not require physically moving water from one party to the other; tracking them just requires good record-keeping. In contrast, surface water transactions—both for sales and for banking underground—often require moving water through conveyance systems, including rivers, canals, and pipelines. Water exchanges that allow parties to substitute one source of water for another can reduce the need to move water physically, lowering transaction costs (Escriva Bou et al. 2020). California's extensive grid of water storage and conveyance infrastructure has enabled parties to trade and bank with each other, even across long distances (Figure 1B). Yet capacity constraints are a growing concern in light of changing hydrology, including more volatile precipitation and earlier spring runoff. Other sources of strain on the system include the physical loss of capacity in critical regional and local conveyance infrastructure due to subsidence, and the increased demand for trading and banking under SGMA. In addition to establishing rules for trading and banking, many areas are finding it necessary to establish or adapt rules for use of conveyance capacity.

4. Transparent Market Information

Although trading can happen without it, transparency about market rules and conditions is an essential feature of well-designed water markets. Transparency helps build trust among market participants and the wider community by clarifying a number of important questions. For instance, how much water can be traded under different circumstances? What information must be submitted to receive approval for a trade? What rules apply regarding the quality of water to be moved from one location to another? While larger market participants—such as water agencies and large farms—have the capacity to gather all the relevant

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37. For instance, Kiparsky et al. (2021) examine ways to improve water rights information.
38. Since post-irrigation seepage is an important source of non-native groundwater in many basins, basin accounting will generally require tracking not only how much water is applied, but also how much water crops consume (Escriva-Bou et al. 2016). Many GSAs in critically overdrafted basins have begun this important work, taking advantage of new tools that use satellite imagery to measure crop water use.
39. Prior to SGMA, established groundwater banks in Kern County already invested heavily in groundwater models as well as monitoring and measurement for this reason.
40. To facilitate trading, California law requires owners of conveyance to make excess capacity available to other parties, but approval processes can constrain effective use of this capacity. Pricing also can be an issue, since conveyance owners can act as monopolists.
information on their own, information costs can be a barrier to entry for smaller water users. Easily accessible information on volumes sold and market prices can also improve market function.\footnote{Examples from markets for other natural resources also suggest that information about what other participants are doing helps to align expectations about resource value and move resources to where they are needed most (Jensen 2007).

California’s current system for surface water trading is not especially transparent. Most trading is conducted by large agencies, and even they sometimes complain about the opacity of the approval process. While providing specific information about individual growers’ transactions could make it harder for them to compete, having overall information about market trends for quantities and prices could be broadly helpful; such information is currently very limited. Numerous stakeholders we interviewed stressed the importance of establishing transparent processes when launching new groundwater markets under SGMA. At issue is less the particular trading system or platform used to help buyers and sellers find each other, but more that the transacting rules are clear and that parties can easily ascertain when, where, and how much water is moving.\footnote{Markets can function with a variety of more or less formal systems for matching up buyers and sellers and establishing prices. In California’s surface water market, parties generally find each other through informal channels, although there have been some banks and pools where an agency has acted as a centralized broker at a pre-established price. The Mojave Basin has no formal system for groundwater trading; it has been likened to a “coffee shop” approach. The Rosedale–Rio Bravo Water Storage District’s groundwater trading pilot, sometimes referred to as a “Craigslist” for groundwater, takes the form of an electronic bulletin board, linked to parties’ groundwater accounts; the platform keeps track of the transaction, but parties negotiate prices (Babbitt 2020). In Ventura’s Fox Canyon groundwater market, a third party uses an algorithm to anonymously match buyers and sellers and establish prices based on market supplies and demands (Heard et al. 2021).}

5. Mechanisms for Addressing Impacts on Third Parties

Market rules that cannot support easy, low-cost trading and banking will do little to reduce the societal costs of managing water scarcity and hydrologic risk. But trading and banking programs need to consider the potential negative impacts on third parties that result from changing where and when water is used. A central challenge for market design is crafting processes that can take these impacts into account—and mitigate when necessary—without stifling market activity.

There are two distinct types of third-party impacts: physical impacts on water and related resources used by others, and economic impacts in communities that are fallowing land to sell water (Hanak 2003; Hanak and Stryjewski 2012). Addressing significant physical impacts is important to ensure not only that water markets are fair, but also that they are actually providing the intended benefits. Addressing the economic impacts of land fallowing in source regions can be important for ensuring the well-being of local communities and for obtaining their buy-in.

California law addresses both types of impacts, and most trading and banking programs require consideration of third-party harm as part of the approval process—though not always consistently or effectively. SGMA is a game changer for considering physical impacts because it introduces a comprehensive framework for designing protections against potential undesirable results of groundwater use (Box 3). Under SGMA, basin activities and programs, including trading and banking, need to demonstrate the avoidance of these results.

Here we review these impacts, their respective legal requirements, and the mitigation actions available. The
following section discusses some of the challenges of addressing these impacts effectively while facilitating beneficial market activity.
Box 3. SGMA offers new protections from undesirable effects of groundwater use

SGMA introduces a comprehensive set of protections against six undesirable effects of groundwater use: (1) drawing down water levels too far, (2) depleting storage in the aquifer, (3) degrading water quality, (4) allowing seawater intrusion, (5) causing land to subside, or (6) using groundwater in ways that reduce other people’s surface water or harm ecosystems.

Groundwater sustainability plans must avoid or mitigate these effects when they are “significant and unreasonable.” While there is some room for interpretation on where this threshold lies, ensuring these protections is fundamental to complying with SGMA. These protections are especially important for limiting how and where continued overdraft can be allowed in the first 20 years of plan implementation, when basins are still transitioning to sustainability. They also set guideposts for addressing third-party impacts from trading and banking projects. Key issues include:

- **Harm to other groundwater right holders.** GSPs must address the effects of pumping and recharge on the supply and quality of groundwater, which can injure other water users. Pumping can lower groundwater levels, which increases overall pumping costs and can cause shallower adjacent wells to go dry. Pumping also can impair groundwater quality by causing contaminants (e.g., nitrate from fertilizers) to migrate toward wells or by drawing in seawater in coastal areas. Groundwater recharge also can affect other water users by altering groundwater storage capacity and by introducing pollutants into the aquifer.

- **Harm to drinking water wells.** Sustainability plans must also incorporate two statutory priorities that heighten protections for domestic water supply. The first is a 1943 law that declares water used for domestic purposes to be the “highest use of water,” and the second is a 2012 law that recognizes a human right to water. While these laws also apply to surface water, preventing harm is a special concern for groundwater. Rural communities tend to rely on shallow domestic wells and small community wells, which are especially vulnerable to the effects of overdraft.

- **Harm to those affected by land subsidence.** Pumping can cause harm not just to other water users, but also to those who rely on infrastructure impaired by sinking lands. In the San Joaquin Valley, land subsidence from excess pumping is damaging vital water conveyance infrastructure, flood control systems, and roads and bridges (Escriva-Bou et al. 2020b). In some areas, even inches of additional subsidence can cause problems.

- **Harm to surface water users and groundwater-dependent ecosystems.** Finally, SGMA’s requirement that groundwater users address significant and unreasonable harm to surface water users and groundwater-dependent ecosystems brings California water law more in step with hydrologic realities. In many parts of California—and particularly in basins that are not in severe overdraft—groundwater pumping can affect the surface water available in rivers, streams, lakes, and wetlands, just as water in these bodies can affect groundwater levels. For water transfers and banking, this requirement helps close an important gap in “no injury” protections for surface water users and the environment, by extending requirements that already apply for surface water transfers to groundwater-related actions. The protections for the environment apply both to pumping impacts on surface water resources and to areas where groundwater nourishes ecosystems, including riparian zones, wetlands, and other areas where groundwater supports plant and animal communities (The Nature Conservancy 2021).

Source: Technical Appendix A (Part 1).
Addressing physical impacts of trading and banking on other parties

Reallocating water can cause negative physical impacts—such as reduced water supply or quality for other water users. These types of effects are sometimes known as externalities; when they are significant, they need to be prevented or mitigated. The potential issues vary with local conditions and the source of water.

Surface water transfers

**Potential impacts.** A key concern is that transfers may reduce the volume of water available for downstream water users or the environment. This can occur if parties transfer the entire volume of water they would have used—or their “applied water use”—rather than the smaller, net volume of water they would have consumed (or “consumptive use”). The difference between these two quantities is known as “return flow”—the water that returns to a watercourse or a groundwater basin after application, such as irrigation drainage or treated wastewater (Escriva-Bou et al. 2016). Harm can occur because return flow is often reused downstream; if a seller transfers the entire applied water use, this return flow might not be available to those users.

**Legal requirements.** Water transfers generally must not cause unreasonable harm to the environment and other third parties (Hanak and Stryjewski 2012). It is also common for the State Water Board, and other state and federal agencies with jurisdiction over water transfers, to require that parties mitigate or avoid significant, unavoidable third-party impacts.

**Mitigation actions.** To prevent parties from selling water to which someone else has a right, surface water transfers are generally limited to the consumptive use portion of applied water—particularly if the water is being moved outside the local area. If changing the timing and place of use affects water quality—for instance by changing water temperatures in rivers or streams—transfer volumes may be subject to additional restrictions.

Groundwater-related transfers and banking

**Potential impacts.** If trading results in localized declines in water levels, it can reduce groundwater availability for other users. Localized declines—or “cones of depression”—can also cause contaminants to migrate within the aquifer, affecting water quality. In some areas, localized increases in pumping can also accelerate land subsidence, potentially damaging infrastructure. Finally, in areas where groundwater and surface water are hydrologically connected, increased groundwater use can reduce streamflow, potentially harming surface water users and the environment. Groundwater substitution transfers (that is, selling

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43. In economic terms, significant externalities need to be addressed to avoid market inefficiencies. If reallocation causes significant externalities—for instance by substantially reducing water available to another user—this reduces the overall economic benefit of trading. If the cost of the externality is smaller than the gains from the trade, mitigation can create an economically efficient outcome. If the cost of the externality is very large, the economy might be better off without that trade occurring.

44. For instance, a rice field that requires about 5 acre-feet (af) per acre of irrigation consumes less than 3 af/acre, and the remainder is return flow available for reuse. If farmers fallow rice land to transfer water out of the basin, they typically can only transfer the volume consumed, to avoid impacting other water users.

45. For a discussion of water quality and groundwater recharge in the San Joaquin Valley, see Hanak et al. (2019), Chapter 3. For early guidance on managing water quality with recharge projects, see Sustainable Conservation (2021) for nitrate, Waterhouse et al. (2021) for nitrate and salts, and Fakhreddine et al. (2019) for naturally occurring contaminants. Managed well, recharge projects can also improve groundwater quality (Marwaha et al. 2021).
surface water rights and pumping groundwater to make up the difference) can raise similar concerns. Groundwater banking projects can also cause localized impacts—particularly when banks draw down reserves in dry years.

**Legal requirements.** Unlike surface water, the state does not directly regulate most groundwater rights, and it has been much less involved in setting groundwater trading policies. Once California’s water market took off in the early 1990s, the lack of comprehensive state “no injury” protections led many counties to adopt ordinances that provide some safeguards for local groundwater users, by restricting groundwater substitution transfers and direct groundwater exports. 46 SGMA’s broad requirements to avoid or mitigate significant undesirable results of groundwater use (Box 3) go much further, filling an important gap in state protections.

**Mitigation actions.** These various impacts can be addressed with careful measurement and monitoring; programs that provide affected parties with alternative water supplies; and rules that avoid harm such as requiring well spacing (Brozović et al. 2006), restricting trading to specific zones, setting trading ratios that give lower credit to pumpers in locations where there are surface impacts, 47 or limiting groundwater purchases in vulnerable areas.

It is important to recognize that unmanaged groundwater use can cause harm—such as dry drinking-water wells or infrastructure damage from land subsidence—regardless of whether trading or banking occur. Indeed, well-designed trading and banking programs can help water users reduce overdraft and its negative impacts. Although SGMA has significantly increased protections against the negative impacts of groundwater use under state law, there is limited confidence that local GSAs will provide these protections. This has heightened sensitivities around the potential negative impacts of trading and banking. In the San Joaquin Valley—a critically overdrafted region where drinking water wells have already experienced supply and quality impacts from pumping—the first sustainability plans have significant gaps in protections for domestic wells. 48 These planning gaps—along with uncertainties about how much groundwater will be allocated to small, well-dependent communities—reduce communities’ confidence in the GSAs’ ability to administer effective and responsible trading and banking programs, even though these communities could benefit from trading (Box 4). As described further below, this issue requires more attention and a focused commitment to reform.

46. For details, see Technical Appendix A (Part 2).
47. The CVP and SWP impose such restrictions on groundwater substitution transfers that use their conveyance infrastructure to avoid significant effects on streamflow, which could reduce CVP and SWP supplies (See Technical Appendix A, Part 3 discussion of the draft white paper on water transfers).
48. See Jezdimirovic et al. (2020b), Bostic et al. (2020), and Water Foundation (2020) for plan reviews on these issues. Pauloo et al. (2020) estimate the number of dry wells in different parts of the valley under different scenarios for SGMA implementation.
Box 4. Addressing water market concerns in well-dependent rural communities

Concerns have been raised that low-income, groundwater-dependent communities are at risk of harm from groundwater markets (Ores et al. 2020). With shallow wells and limited resources to drill deeper wells or access alternative supplies, these communities are among the most vulnerable to the effects of overdraft. Indeed, nearly 3,000 domestic wells—mostly within overdrafted basins in the San Joaquin Valley—were reported dry during the 2012–16 drought, when increased groundwater pumping for irrigation caused groundwater levels to fall rapidly (Mount et al. 2018). And roughly 150 small community water systems—half in the San Joaquin Valley—needed emergency assistance during the drought. Water quality problems—such as higher levels of arsenic—have also been aggravated by this pumping (Smith et al. 2018).

Groundwater trading and banking programs will need to address potential injury to these communities (for possible mitigation actions, see main text). Yet it is also important to recognize that unrestricted groundwater pumping, rather than trading, is the principal cause of well impacts. SGMA’s requirement that local groundwater agencies bring basins into balance should benefit these communities. But there are well-founded concerns that the pace of progress will be too slow to prevent shallow wells from going dry, and that plans do not adequately describe how they will address significant impacts to these wells from continued overdraft, which could again become an acute problem during the unfolding drought (Escriva-Bou and Pauloo 2021; Vad 2021).

Another concern relates to the process for allocating groundwater pumping rights to these communities, which have limited financial and technical capacity to engage. To date, there has been considerable uncertainty about how this process will unfold, and stakeholders we spoke with indicated that the initial proposals were all over the map—ranging from no explicit allocation to an acreage-based allocation far below existing water use, or allocation based on current use. If allocations come in below current water use—or if these communities expand and need additional supplies—they could struggle to purchase water on the market or afford fees applied to pumping in excess of their allocation.

It is essential to address potential risks to drinking water supplies. However, water markets could provide substantial overall benefits to low-income rural communities in overdrafted areas by helping maintain local economic activity. Within the San Joaquin Valley, allowing surface water and groundwater used for irrigation to go to higher-value crops could save thousands of farm-related jobs as the region implements SGMA (Hanak et al. 2019). To ensure that this trading does not simultaneously cause harm to vulnerable drinking water supplies, GSAs will need to establish adequate mechanisms to address negative impacts from pumping and trading, and establish reasonable allocations. Transparent processes and strong community inclusion and engagement will be key to building trust.

Addressing negative economic consequences of land fallowing

Potential impacts. Water transfers that result in land fallowing can cause physical impacts beyond those discussed above—for instance on neighboring farmland, wildlife, or air quality—for which mitigation may be required. But a central concern with these transfers is that they could reduce local economic activity. Transfers compensate landowners who fallow fields for the crop revenues they forego, but local businesses, workers, and governments do not automatically receive compensation for related slowdowns in economic
activity. Such impacts may occur as part of overall improvements in economic outcomes from moving the water to higher-value uses.

**Legal requirements.** Although state law does not require mitigation for economic spillovers, it does require review of these impacts under some circumstances. And concerns over local economic impacts loom large in local policies around water trading.

**Mitigation actions.** Even when not legally required, it is generally prudent for participants in transfers that result in land falling to consider these concerns, especially if the transfer involves large acreages and the water is moving far enough away that the local economy will not see the benefits. Trading parties have experimented with establishing mitigation or community development funds to support the local economy in large ag-to-urban transfers of Colorado River water. Such programs may yield lessons for addressing community concerns in places where SGMA could cause significant land falling.

### Bottlenecks and Stumbling Blocks

Our discussions with stakeholders revealed considerable optimism about water marketing’s potential to help California transition to more sustainable groundwater management and build resilience to the changing climate. But we also heard numerous concerns about the challenges that lie ahead. Some concerns relate to the difficulties of creating effective new structures for groundwater governance. In addition, the broader context in which GSAs will be doing this work poses challenges. Bottlenecks in the physical infrastructure that connects water users and enables trading and banking partnerships are an issue. Stakeholders also mentioned stumbling blocks and missed opportunities related to the complex suite of rules and procedures for approving water trading and banking at the federal, state, and local levels. Here we summarize some of the key issues raised; the following section outlines approaches for overcoming these constraints.

### Gaps in Groundwater Governance

SGMA requires new forms of collaboration and coordination among water users, and difficult collective decisions about how to set up rules around pumping, trading, storage, and more. In most places, the GSAs put in charge of sustainability planning were entirely new governance structures, and any governance

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49. Water transfers can also reduce land available for rental by tenant farmers. If landowners sell the water normally used on a rental parcel, this reduces the acreage available for irrigated farming on the rental market. Like owner-operators, tenants farm a wide range of acreages in California, from very small parcels to thousands of acres. As described below, renting farmland is also a common way to purchase the water associated with the land, and it can help farmers avoid restrictive rules about transferring water to land within another water district.

50. In contrast to physical externalities, these effects do not result in market inefficiencies (see fn. 43).

51. State law requires 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, the transferring entity is also required to ensure that it does not cause significant economic harm (Water Code § 1810).

52. The transfer from the Imperial Irrigation District to the San Diego County Water Authority set aside $50 million for socioeconomic mitigation, which was used for direct mitigation of affected parties and investments in community development activities. The transfer from the Palo Verde Irrigation District to the Metropolitan Water District of Southern California set aside $6 million (over $7 million with accumulated interest) for small grants and loans for community development activities (Hanak et al. 2011, updated with interviews with local officials in June 2020).
structure needs time to develop trust. This planning began with inadequate information about basin conditions, groundwater use, well characteristics, and other factors—all of which are key to avoiding undesirable results of overdraft and developing successful trading and banking programs. The early years of plan implementation will be a time of capacity building on both information and governance. We should not expect to see rapid completion of groundwater allocations and the launch of new groundwater trading platforms and banks. Instead, this will be a time of experimentation, pilots, trial and error, data gathering and aggregation, and incremental progress. 53

Infrastructure Gaps

Although California has significant conveyance capacity compared with other western states, the system also has several major bottlenecks. Physical pumping capacity, as well as regulatory requirements to meet salinity and other environmental standards, limits water users’ ability to move surface water through the Sacramento–San Joaquin Delta. This can inhibit trading and banking from the wetter northern and eastern parts of the state to points west and south in most years (Gartrell et al. 2017). 54 Land subsidence has also reduced the capacity of several major canals within the San Joaquin Valley—a particular constraint on moving high-flow water into groundwater banks in that region and Southern California. 55 Local and regional conveyance may also be inadequate to facilitate water banking and trading arrangements in many regions. Conveyance may become an even greater constraint as the climate warms and becomes more volatile, making it necessary to capture even larger amounts of water for banking and recharge during wet periods just to maintain existing supplies (Mount et al. 2018; He et al. 2021; Alam et al. 2020).

Tensions in the Approval Process

Various state and federal reforms were adopted in the 1980s and early 1990s to encourage trading, while also clarifying “no injury” protections for the environment and other third parties (Hanak and Stryjewski 2012). Resolving the tensions between these two objectives is a recurring theme in ongoing efforts to improve trading rules.

Central Valley Project and State Water Project trading and banking rules

Although water trading and banking typically require approvals from multiple state and federal agencies, the entities central to many transactions are the two large projects: the federally owned CVP and the state-owned SWP. They hold the water rights for a majority of surface water used in the Central Valley, and they own and operate the infrastructure that other parties rely on to move water through the Delta and within

53. As one stakeholder involved in developing a new groundwater trading platform noted: “Don’t underestimate the time this will take!”

54. The physical capacity of the SWP and CVP pumps in the South Delta is about 15,000 cubic feet per second (cfs)—or 30,000 af/day. Delta outflow during very wet periods will often exceed 100,000 cfs, sometimes more than twice that. A flow of 100,000 cfs for 23 days is the same volume as the total capacity of California’s largest reservoir, Lake Shasta.

55. The CVP’s Friant-Kern Canal, which delivers water along the east side of the San Joaquin Valley, has lost about 60 percent of design capacity in its lower reaches, significantly affecting deliveries to Kern County in most years (Fitchette 2018). The SWP’s California Aqueduct has lost about 25 percent of its capacity south of Fresno County, limiting wet-year deliveries to Kern County and Southern California (Department of Water Resources 2017b). The CVP’s Delta-Mendota Canal, which delivers water along the west side of the San Joaquin Valley, also has subsidence-related operational limitations (US Geological Survey 2021).
regions. Both projects have made progress in facilitating water trading and banking since the early 1990s, but some challenges remain.

▸ **CVP rules limit water banking.** Since legislative changes in the early 1990s, water trading within the CVP has generally been more flexible than within the SWP; it even includes accelerated approvals for transfers that meet defined criteria. However, water banking rules are still quite restrictive. A recent update to CVP rules facilitates additional groundwater banking, but limits the ability to use the banked water for transfer to non-CVP users (US Bureau of Reclamation 2019).  

▸ **Despite recent progress, SWP rules constrain trading and banking.** Until recently, SWP rules significantly limited the types of transfers and exchanges that could occur. For instance, it was difficult to develop multi-year transfers between contractors or to set prices that would cover costs. A recently adopted “water management” amendment of the SWP contracts should facilitate more flexible water use among SWP contractors. Room for improvement remains, though, especially regarding the scope and timeliness of reviews and the ability to transfer water to outside parties.

▸ **Place-of-use restrictions hinder partnerships.** Under state law, both the CVP and the SWP have authorized “places of use” that define where the water can be used without requesting changes to their respective water rights. The CVP has additional restrictions on place of use for its water under federal law. Stakeholders highlighted rigidities in the place of use as one of the biggest constraints to managing hydrologic risk through trading and banking, because they limit the opportunities for partnerships with other water users.

▸ **Administrative delays cause missed opportunities.** Water trading and banking often require taking advantage of narrow windows of opportunity to capture and move water that only will be available for a short time. Numerous stakeholders reported delays in administrative review that render transfer and recharge proposals infeasible. For their part, project administrators reported that many transfer applications arrive incomplete and without the information needed to assess whether approval is warranted.

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56. As described in Technical Appendix A (Part 3), the US Bureau of Reclamation has determined that the water transfer provisions of the Central Valley Project Improvement Act of 1992 do not generally apply to water banking and recharge actions. Although CVP contractors are allowed to store water in 11 “acknowledged groundwater banks,” there are significant restrictions on the subsequent use of that water. See also the [Central Valley Project Water Transfer Program Fact Sheet](https://www.water.usbr.gov/region5/cvp/transfer/factsheet.html) and the [Groundwater Banking Guidelines for Central Valley Project Water](https://www.water.usbr.gov/region5/cvp/transfer/guidelines.html) for more information.

57. The “Water Supply Contract Amendments for Water Management”—which most SWP contractor boards have now approved—will increase the flexibility of water transfers and exchanges (Department of Water Resources 2020). The transfer provisions will facilitate water agencies’ ability to: 1) transfer SWP water for multiple years without permanently relinquishing that portion of their Annual Table A amounts; 2) negotiate cost compensation and duration among the water agencies on a willing seller–willing buyer basis for water transfers; 3) obtain DWR approval of transfer packages and transfer of carryover water in San Luis Reservoir. For exchanges, the proposed amendments will: 1) establish return ratios (up to a 5:1 ratio) based on a consideration of varying hydrology and allow monetary compensation for costs of exchanges; 2) allow water agencies to exchange carryover water in San Luis Reservoir, and allow for up to 50 percent of their carryover water to be exchanged in a single-year transaction (however, future or multi-year commitments to exchange carryover water will still not be allowed); and 3) allow water agencies to conduct water exchanges of carryover water as buyers and sellers in the same year.
A narrow focus on minimizing project risk limits broader opportunities for risk management. The CVP and the SWP hold relatively junior water rights within the Central Valley watershed, and the projects are jointly responsible for meeting outflow requirements in the Sacramento–San Joaquin Delta. This makes project managers acutely aware of any potential impacts to their own water supplies from transfer and banking activity. The projects have created various rules and procedures to minimize this risk, and their tendency to err on the side of caution—especially if it could affect flows into the Delta—can stifle market activity. These rules are established by the projects with little room for negotiation, and seldom is there time to appeal to the State Water Board.

Other state and federal rules

Among other state and federal processes, stakeholders highlighted the following three as posing significant challenges for trading and especially banking—particularly when water needs to move through the Delta.

- **State Water Board recharge policies could constrain water banking.** In addition to approving certain surface water transfers, the State Water Board authorizes parties to recharge unclaimed flood flows—a key new source for groundwater banking projects. We heard few concerns about the board’s approval process for transfers, which many consider to run relatively smoothly. In contrast, numerous stakeholders raised concerns about the recharge approval process, including that reviews by other state agencies may not be well coordinated with reviews by the board. Stakeholders are also concerned about the challenges the board will face in adjudicating competing claims for recharge flows, now that SGMA has boosted demand for them.

- **Requirements to reduce “reliance on the Delta” could conflict with SGMA goals.** These two state policies are in tension with each other. The 2009 Delta Reform Act called on regions that use Delta exports to reduce their reliance on the Delta. The Delta Plan, adopted by the Delta Stewardship Council, may constrain transfers through the Delta on this basis. For some regions, including the San Joaquin Valley, a rigid interpretation of this requirement could pose challenges. Additional water transfers from the Sacramento Valley would help fill the San Joaquin’s large groundwater deficit—but also increase its share of Delta exports in total water use. This requirement could also constrain groundwater banking opportunities, as the Delta is a hub for high-flow water for recharge from the Sacramento Valley and the eastern San Joaquin Valley.

- **Environmental regulations in the Delta also constrain banking.** Beyond infrastructure constraints, pumping water through the Delta is often limited by regulations that protect endangered species and water quality (Gartrell et al. 2017). Some stakeholders emphasized the challenges that current regulations pose to taking advantage of “big gulps” of water available after big storms (by limiting pumping regardless of the level of outflow, for example). These “big gulps” are key to increasing underground storage in the San Joaquin Valley and Southern California. Current rules are based on a limited hydrologic period from the 20th century, and do not include much room for real-time adaptive management. They do not work well in extreme wet and dry periods, which have become more common.

58. Examples include: 1) rigid rules on which crops Sacramento Valley farmers can fallow to transfer water south of the Delta; 2) high deductions for “carriage losses” on transfers moving through the Delta; and 3) onerous “refill” criteria, which require water agencies transferring water from their own storage facilities to replenish the storage only under circumstances approved by the projects before getting full credit for the transfer. Technical Appendix A (Part 3) provides more discussion.

59. Bruno et al. (2019) and Hanak et al. (2018a) discuss other policy priorities for facilitating effective recharge permitting.

60. For more discussion, see Technical Appendix A (Part 4).
Local trading and banking rules and considerations

The new GSAs are just one of several types of local entities involved in trading and banking approvals. Lack of flexibility and discriminatory treatment of transfers are important concerns.

- **County export ordinances prevent beneficial trades.** In the absence of state regulation of groundwater, county ordinances have protected local parties against injury from groundwater-related exports. But their export permitting hurdles are so high that they impede any transfers, including those that present no significant risk to local groundwater sustainability. Meanwhile, most of these ordinances only focus on exports, not the effects of local overdraft, so they do not restrict local pumping that can cause undesirable results.

- **Local water district rules are also overly restrictive.** In addition to county-level restrictions, local water districts often limit sales of surface water outside of their boundaries. Such restrictions are sometimes motivated by concerns that the district would lose revenues that cover infrastructure and administrative costs. But often cultural norms around maintaining land in agriculture play a role, and in many water-short districts, there is a belief that water should be kept for local use. Common restrictions include outright prohibitions of transfers, approval only for transfer to lands owned or leased by the same individual, and limits on the banking of groundwater outside the district. By reducing flexibility, such policies raise the costs of implementing SGMA. Restricting exports to lands managed by the same farmer also confines the benefits of trading to farms with land in both locations, which generally will mean that larger operations benefit, while smaller farms are left out.

- **Community concerns about economic impacts of fallowing can prevent beneficial trades.** Even where districts do not restrict water sales, pushback from local communities that might lose revenue or employment from land fallowing can present an additional barrier. This is a growing concern within the San Joaquin Valley, where SGMA is likely to result in significant land fallowing. For instance, some county governments worry about losing tax revenue. In this highly integrated regional economy, allowing water use on the most productive lands would boost overall economic activity and employment, so finding solutions that address these concerns will be important.

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61. Current water quality regulations in the Delta, originally established under the Delta Accord in the mid-1990s (see Gartrell 2017), used a limited (1922–78) hydrological period to create objectives. The extreme dry periods in 2014 and 2015 (and 2021) necessitated urgent, temporary changes to the objectives in order to retain sufficient stored water in reservoirs so that salinity control was not completely lost later in the year.

62. Hanak (2005) found that the groundwater export restrictions ordinances reduced water trading out of counties, and increased trading within counties. Bigelow et al. (2019) found that the export restrictions initially depressed land values but subsequently provided benefits as groundwater stocks recovered.

63. In a comprehensive review of permitting activity by counties with ordinances, Hanak (2003) found only a few instances where permit applications had been filed; none had been granted. Our discussions with stakeholders confirmed that permitting activity remains very limited, with requirements often deterring applications. In Butte County, for instance, it would take 18 months to go through all the steps to obtain a permit for a same-year groundwater substitution transfer.

64. For banking, some districts have adopted “return obligations,” which allow water to be banked elsewhere as long as it is later returned to district lands. This allows for individual banking of water offsite, but it still limits flexibility on the use of banked water in the future.
Designing Effective and Responsible Water Markets

Managing groundwater sustainably is essential for California’s economic, social, and environmental well-being. But getting there will not be easy. Expanding water trading and banking can help lessen the economic and social costs of implementing SGMA and aid adaptation to the changing climate.

Growing effective and responsible water markets will require overcoming some obstacles, to be sure. Indeed, the list of bottlenecks and stumbling blocks described above may seem daunting, but California is well-poised to meet the challenge. The state can draw from significant market experience, including several decades of extensive surface water trading, active groundwater markets in some adjudicated basins, and some of the most highly developed groundwater banks in the world. Another asset is a comprehensive—if complex—suite of laws and regulations that seeks to address the key policy tension for water markets: promoting flexibility, while preventing significant harm to third parties. SGMA itself should be seen in this light; it provides a new set of authorities for local management agencies to create trading and banking programs, along with a new set of protections against significant third-party impacts from groundwater use.

Here we recommend ways to seize the opening afforded by SGMA to improve existing water markets and develop new ones. In Table 1, we summarize key areas of reform and recommended actions, alongside primary responsible parties. We explore these recommendations in more depth below. The frontline responsibility for reform rests with a variety of local governments and stakeholders, as well as state and federal agencies. Most of the recommended changes can be accomplished within existing agency authorities, without new legislation. But leadership—and a willingness to take risks and push boundaries—will be essential to success.

Differential review standards could increase the social and economic costs of land fallowing. Land fallowing can cause negative physical impacts to neighboring farmland, air quality, and wildlife habitat. Yet the regulatory process only focuses on fallowing that is associated with transferring water to other parties. In these cases, sellers are often required to mitigate these impacts. In contrast, when farmers fallow land because they face water shortages, they typically do not face the same review standards. Such differential treatment can discourage beneficial transfers, as farmers balk at the cost of mitigation, and it does not address the potential harm from fallowing on lands that are not part of transfer agreements. This could become a growing challenge as some farmland is retired under SGMA.

65. For instance, the US Fish and Wildlife Service requires rice growers fallowing land in the Sacramento Valley to consider the location of fallowed fields to avoid harm to the giant garter snake—a species listed as threatened under the federal Endangered Species Act that has come to depend on rice fields for habitat. The State Water Resources Control Board, the California Air Resources Board, and two local air pollution control districts required dust mitigation measures on land fallowed as part of a long-term transfer of water from the Imperial Irrigation District to San Diego County Water Authority. Local districts often require weed and pest management on fallowed lands to avoid impacts on neighboring fields.

66. Unlike other decisions involving fallowing, transfers are generally considered projects, so they are subject to environmental review. These mitigation requirements may be applied by federal, state, or local agencies.
Table 1
Priority reforms to support effective and responsible water markets

<table>
<thead>
<tr>
<th>Area of reform</th>
<th>Action needed</th>
<th>Who is responsible?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establish and enforce groundwater</td>
<td>Tie allocations to the different types of groundwater</td>
<td>Local: Groundwater Sustainability Agencies (GSAs), working with members (water districts, counties) and other interested parties (growers, small communities, environmental managers, local businesses)</td>
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<tr>
<td>allocations</td>
<td>Consider flexible carryover rules</td>
<td>Local: GSAs, with members and other interested parties</td>
</tr>
<tr>
<td></td>
<td>Make judicious decisions about transitional water</td>
<td>Local: GSAs, with members and other interested parties</td>
</tr>
<tr>
<td></td>
<td>Develop strong monitoring and enforcement systems</td>
<td>Local: GSAs, with members and other interested parties</td>
</tr>
<tr>
<td>Avoid or mitigate undesirable effects of groundwater use</td>
<td>Establish stronger systems for anticipating and addressing undesirable impacts of pumping</td>
<td>Local: GSAs, with members and other interested parties</td>
</tr>
<tr>
<td></td>
<td>Pay special attention to drinking water impacts in small, low-income, well-dependent communities</td>
<td>Local: GSAs, with members and other interested parties</td>
</tr>
<tr>
<td></td>
<td>Establish specific rules to address impacts from trading and banking</td>
<td>State: Safe drinking water programs, Federal: Safe drinking water programs</td>
</tr>
<tr>
<td>Adopt effective and responsible</td>
<td>Streamline transfer reviews while maintaining protections</td>
<td>Local: Water districts, GSAs, State: Department of Water Resources (DWR), for State Water Project (SWP)</td>
</tr>
<tr>
<td>approval strategies</td>
<td>Expand the place of use for water</td>
<td>State: DWR (SWP), State Water Board, Federal: US Bureau of Reclamation (USBR) for Central Valley Project (CVP)</td>
</tr>
<tr>
<td></td>
<td>Develop a more transparent process for addressing CVP and SWP risks</td>
<td>Local: Water users, State: DWR (SWP), State Water Board, Federal: USBR (CVP)</td>
</tr>
<tr>
<td></td>
<td>Harmonize the goals of SGMA and the Delta Plan</td>
<td>State: Delta Stewardship Council, State Water Board, DWR (SWP), Federal: USBR (CVP)</td>
</tr>
<tr>
<td></td>
<td>Update Delta water quality regulations to support banking</td>
<td>State: State Water Board, DWR (SWP), Federal: USBR (CVP)</td>
</tr>
<tr>
<td>Refine Delta regulations to support</td>
<td>Soften the economic impacts of transfer-related following on local communities</td>
<td>Local: Local trading parties, in discussion with local communities, State: Economic development programs, Federal: Economic development programs</td>
</tr>
<tr>
<td>trading and banking</td>
<td>Harmonize treatment of the physical impacts of land following</td>
<td>State: Economic development programs, Federal: Economic development programs, Local: GSAs, counties, State: Department of Fish and Wildlife, regional air pollution control district</td>
</tr>
<tr>
<td></td>
<td>Allow water users to reallocate water from retired farmland</td>
<td>Local: GSAs, water districts, State: DWR, Federal: USBR (CVP)</td>
</tr>
<tr>
<td>Address local and regional impacts</td>
<td>Plan for farmland transitions and multi-benefit land repurposing</td>
<td>Local: GSAs and water districts, State: DWR, cooperation with local communities</td>
</tr>
<tr>
<td>of land following</td>
<td></td>
<td>State: DWR, Federal: USBR (CVP)</td>
</tr>
<tr>
<td>Create equitable rules for water</td>
<td>Provide transparent market information</td>
<td>Local: Water districts, State: DWR, Federal: USBR (CVP)</td>
</tr>
<tr>
<td>trading</td>
<td>Develop more equitable, flexible district rules for surface water trading</td>
<td>Local: Counties, GSAs, State: Legislature</td>
</tr>
<tr>
<td>Make smart infrastructure investments</td>
<td>Make strategic investments to upgrade and expand conveyance infrastructure</td>
<td>Local: Water districts, GSAs, State: DWR, legislation (funding), Federal: USBR, Army Corps of Engineers, Congress (funding)</td>
</tr>
<tr>
<td></td>
<td>Make existing infrastructure work better</td>
<td>Local: Water project managers, State: DWR (SWP), Federal: USBR (CVP), Army Corps of Engineers</td>
</tr>
<tr>
<td>Promote collaboration</td>
<td>Promote within and cross-basin collaboration on water trading</td>
<td>State: State Water Board, State Water Board, legislature</td>
</tr>
<tr>
<td></td>
<td>Encourage collaborative approaches to capturing water for banking</td>
<td>State: State Water Board, with cooperation of water users</td>
</tr>
<tr>
<td></td>
<td>Incentivize smart land use planning and farmland transitions</td>
<td>State: Local incentive programs and economic development programs, Federal: Land use incentive programs and economic development programs</td>
</tr>
</tbody>
</table>
Laying the Groundwork for Well-Designed Groundwater Markets

To reap the benefits of groundwater trading and banking, the underpinnings of groundwater markets will need to be set up correctly. This will include establishing broadly accepted and legally defensible methods of setting and enforcing groundwater pumping allocations, a trusted system for tracking transitions and storing data, and a fair and technically based process for addressing significant undesirable effects of groundwater use. **Who’s responsible:** GSAs, in conjunction with their members (mainly agricultural water districts, urban utilities, and counties) and other interested parties (growers, small communities, environmental managers, and local businesses).

Establishing and enforcing groundwater allocations

Groundwater allocations are not required under SGMA, but they will be invaluable for limiting pumping in basins where demand exceeds supply. Well-defined allocations and a strong monitoring and enforcement system are also essential features of well-designed groundwater trading and banking programs (Babbitt et al. 2017). These actions are key:

- **Tie allocations to the different types of groundwater.** As water accounting systems develop under SGMA, it will be important to identify the different categories of groundwater—native, imported, and developed—which have different legal status (Box 1, above). Tying allocations to these categories can provide clarity on ownership and transferability. For example, while native groundwater based on overlying rights cannot be transferred out of the basin, this restriction does not apply to appropriated water or non-native groundwater. The allocation process should also identify how much, if any, native water may be available for dormant rights holders and specify conditions under which they may initiate pumping. Good, reliable accounting that is coordinated across GSAs within—and ideally also across—basins will be key to this effort.

- **Consider flexible carryover rules.** Allowing some flexibility to carry over pumping allocations from one year to the next can help water users manage hydrologic risk. Carryover also facilitates banking with other parties. When stored water can be sold to other users, it can provide added benefits. GSAs should consider flexible carryover rules that are consistent with basin sustainability goals and the way water moves within the basin. In the Mojave Basin, for example, pumpers are allowed to carry over their entire pumping allocation from one year to the next (and trade it), but only for a single year. 67

- **Make judicious decisions about transitional water.** SGMA gives basin users 20 years to attain sustainable groundwater management, as long as plans avoid significant undesirable impacts of pumping along the way. Gradual adaptation can lessen the costs of SGMA water cutbacks, so many allocation systems will likely allow pumping to exceed safe yield initially and ratchet down allocations over time. Allowing trading of this transitional water—as is done in Mojave—can help get water user buy-in on setting pumping limits.

67. In the Chino Basin, carryover is also allowed for appropriative water users. The watermaster actively manages storage space in this aquifer, and requires water users to have a storage agreement if they wish to accumulate large carryover volumes. Another example is Kansas’s multi-year flex account, which allows groundwater rights holders to exceed their annual authorized quantity in any year but restricts total pumping over a five-year period (Kansas Department of Agriculture n.d.). Kern’s groundwater banks—which capture and store surface water underground—allow for longer-term storage, with deductions for storage losses.
Avoiding or mitigating undesirable effects of groundwater use

A fundamental SGMA requirement involves avoiding or mitigating six significant undesirable results of groundwater use (Box 3, above). This is also an essential feature of effective and responsible markets. Key actions include:

- **Develop strong monitoring and enforcement systems.** Enforcement of pumping limits is important to achieving sustainability goals because it protects other water users’ rights and the integrity of water markets. Existing groundwater markets have adopted various monitoring systems (e.g., satellite-based imagery, mandatory meters with automated reporting, self-reporting), and new programs should consider trade-offs in their cost and verifiability. 68 GSAs will also need to decide how they will sanction pumpers who exceed their extraction limits. Setting excess pumping fees at the cost of alternative supplies has helped limit water demand in Southern California basins, while providing some flexibility when reducing use would be prohibitively costly. 59

- **Establish stronger systems for anticipating and addressing undesirable impacts of pumping.** GSAs are required to set targets and thresholds for avoiding significant undesirable results, and to identify mitigation actions if they exceed these thresholds. The first crop of sustainability plans revealed numerous weaknesses: many did not adequately consider harm to other parties from anticipated groundwater use, and even fewer identified a process for mitigating impacts. 70 GSAs will need to do better. Providing options for addressing impacts, while remaining clear about who bears the responsibility to do so, can enhance flexibility, keep down costs, and provide assurances to third parties who may be affected.

- **Pay special attention to drinking water impacts in small, low-income, well-dependent communities.** California’s laws on the human right to water and domestic use preference raise the stakes for avoiding or mitigating harm to drinking water supplies, especially in communities that depend on shallow wells vulnerable to supply and quality impacts from groundwater pumping. When allocating groundwater pumping rights, GSAs should also ensure that these communities—which use very little water—have continued access to supplies. 71 Developing strategies that also address chronic water quality problems will help ensure drinking water security. 72

- **Establish specific rules to address impacts from trading and banking.** Although unmanaged access to groundwater is the principal source of concern, trading and banking can also cause undesirable results. Mechanisms that can avoid or mitigate harm include limiting the geographic scope of trading, setting reduced or “no buy” zones in high-risk areas, and carefully monitoring and mitigating the effect of groundwater bank pumping on nearby wells; these responses will depend on the nature of risks and the physical realities of the basin. 73

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68. Rosedale–Rio Bravo relies on satellite imagery, while Mojave and Fox Canyon require metering. All three supplement this information with detailed basin modeling.

69. This approach is common in adjudicated basins in Southern California, as well as some special groundwater management districts (e.g., Orange County Water District). It has been proposed as a strategy in the Rosedale–Rio Bravo service area.

70. See Hanak et al. (2020) for more on domestic well impacts and subsidence in the San Joaquin Valley; see Bostic et al. (2020) and Water Foundation (2020) for more on domestic well impacts in the San Joaquin Valley and other critically overdrafted groundwater basins.

71. In the San Joaquin Valley, home to several hundred small community water systems and tens of thousands of domestic wells, total residential and non-farm business use is less than 4 percent of net water use (Escriva-Bou et al. 2019); small community residents, who constitute a small share of regional population, use less than 1 percent.

72. This will be especially important in the San Joaquin Valley and the Central Coast, but relevant in other basins as well. See State Water Resources Control Board (2021) for the distribution of communities with failing and at-risk water systems and domestic wells.
Navigating Tradeoffs in Market Design

Resolving the tensions between facilitating beneficial market transactions and protecting third parties from significant harm has been an ongoing theme in policy discussions at the local, state, and federal levels. Stakeholders we spoke with highlighted three distinct but related types of tradeoffs:

➤ **Managing hydrologic risk, versus avoiding the risk of injury.** Trading and banking can help many water users do the former, and many market rules are focused on the latter. Regulatory and management agencies might achieve better balance by focusing risk avoidance strategies on especially vulnerable groups (e.g., small, well-dependent communities), and developing more flexible strategies to address risk to larger parties (e.g., potential impacts to CVP and SWP operations).

➤ **Getting things done, versus getting everything right.** Waiting for close to “perfect” information on all possible risks—a temptation for some regulators and stakeholders—can result in many missed opportunities for beneficial market transactions.

➤ **Benefitting from regional approaches, versus securing local balance.** Taking a regional approach to trading and banking—both within larger basins and across interconnected basins—can increase economic opportunity and water storage opportunities. Yet many local parties are reluctant to let go of any water, and narrow interpretations of SGMA may be heightening competition.

Despite the challenges, there are better ways to manage some key tradeoffs. Adopting well-designed approval strategies, adapting the process for reviewing transactions that move through the Delta, and developing comprehensive approaches to the issues associated with land fallowing all can help.

**Adopting effective and responsible approval strategies**

Solutions entail finding ways to streamline reviews while maintaining protections against injury, and expanding the place of use for water:

➤ **Streamline transfer reviews while maintaining protections.** Approval delays by federal, state, and local authorities often reflect uncertainties about the physical impact of a surface or groundwater transfer on other water users or the environment. Yet there are various ways to streamline the process while maintaining protections, for instance by conducting more up-front analysis of impacts through programmatic reviews, developing a “fast lane” for transfers below a certain size, developing a structured evaluative process for reviews, and establishing an after-the-fact process for balancing accounts to enable quicker approvals of time-sensitive activities. Some progress is occurring along these lines, but more can be done. Ideally, review systems should have clearly defined informational requirements and timelines—and stick to them. **Who’s responsible:** CVP, SWP, local water districts, GSAs.

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73. Geographic trading limitations are used in the Mojave Basin (Box 2) as well as Fox Canyon, which also has some no-buy zones (Heard et al. 2021). Monitoring and mitigation for pumping impacts are currently used by some Kern County groundwater banks, as well as Yuba Water Agency’s groundwater substitution-based dry-year trading program.

74. To address hydrologic uncertainties, approving agencies can incorporate terms and conditions in transfer agreements. For instance, transfers below a certain size or that take place within a given region or time frame get automatic approval upon demonstration that the conditions and terms are being applied. As an example of a structured evaluative process, groundwater transfers in Rosedale–Rio Bravo’s program rely on a model-based review of impacts.

75. Within the CVP, the past decade has seen a trend toward multi-year, programmatic approvals for transfers, making it much faster to greenlight transfers in any given year. And for the 2021 water year, DWR and USBR have established a more streamlined process for approving dry-year transfers through the Delta, with measures including a fast lane for transfers that have been reviewed and approved multiple times in the past.
Expand the place of use for water. For many stakeholders, place-of-use restrictions on the CVP and SWP hamper time-sensitive approvals for trading and banking transactions. The projects’ places of use south of the Delta are often combined on a temporary basis, especially during droughts. Having a permanent, joint place of use would facilitate partnerships between CVP and SWP water users and improve risk management and efficiency. Relaxing CVP rules that limit the use of banked water outside CVP contractors’ boundaries would incentivize more recharge—an essential tool for groundwater sustainability and resilience under a more volatile climate. There could also be value in creating more comprehensive regional places of use for water held under federal, state, and local projects (Gray et al. 2015). This would require more up-front analysis to anticipate and address significant impacts, but benefits include more flexibility and quicker reaction time to manage hydrologic risk in an increasingly volatile climate. Who’s responsible: State Water Board, CVP, SWP.

Refining Delta regulations to support trading and banking

Because the Delta is such an important hub for moving surface water from wetter to drier regions, the approval process for trading and banking is especially important. Key actions include:

- **Develop a more transparent process for addressing CVP and SWP risks.** The CVP and SWP take a risk-averse approach when setting terms and conditions for moving water through the Delta. These rules limit trading and banking by project contractors and other parties. Moreover, the projects unilaterally define these rules, with little room for negotiation. A more open and transparent process could find middle ground and set forth clear rules in advance, recognizing the projects’ interests in protecting their own water supplies without frustrating the broader good of putting water to its best uses and recharging depleted aquifers. The State Water Board should hold hearings and set standard terms and conditions for moving water through the Delta in wet and dry periods. Who’s responsible: State Water Board, CVP, SWP, water users.

- **Harmonize the goals of SGMA and the Delta Plan.** The Delta Reform Act’s 2009 goal to reduce reliance on the Delta predates SGMA by five years, and policymakers did not anticipate the importance that trading and banking water through the Delta would have for achieving groundwater sustainability, particularly in the San Joaquin Valley. The Delta Stewardship Council—in consultation with the State Water Board, DWR, and other interested parties—should reconsider its rules limiting reliance on the Delta in light of SGMA’s sustainability directive. Flexibility in the Delta Plan’s administration could help achieve groundwater sustainability without significantly harming Delta resources. Who’s responsible: Delta Stewardship Council, State Water Board, DWR.

- **Update Delta water quality regulations to support banking.** The regulations governing Delta water quality, flow, and pumping need to be refined to match the more volatile wet and dry conditions of California’s new climate. Refinements for very wet periods could enable more high-flow water to recharge locations south of the Delta without harming the environment. Who’s responsible: State Water Board, CVP, SWP.

Addressing local and regional impacts of land falling

By enabling water to move to the most productive lands, trading can help reduce the local, regional, and

76. For refill criteria, for instance, several stakeholders suggested that instead of simply turning over authority to the CVP and SWP, the State Water Board should hold hearings and issue standard terms and conditions for any transfer, in order to reasonably protect the projects and also reasonably encourage transfers, exchanges, and water banking.

77. For wet years, increased allowances can enhance water transfers through the Delta during very high-flow periods. Upstream storage in floodplains and new off-stream storage can also help move water to recharge areas in later periods when ecosystem impacts are fewer. The current review involving tributary flows affords an opportunity to incorporate these refinements.
statewide economic impacts of having less irrigation water. But land fallowing raises numerous concerns: it reduces economic activity, and it can cause negative physical impacts, such as increased pests and weeds and impaired air quality from dust and higher fire risk. The concerns about fallowing go well beyond localized impacts to broader regional concerns about SGMA in areas facing large groundwater deficits. Developing strategies to soften the blow of fallowing will be important both to facilitate beneficial trading, and more broadly to ensure long-term SGMA success. Local and regional action will be essential, but state and federal agencies could provide support. Key actions include:

- **Soften the economic impacts of transfer-related fallowing on local communities.** Making funds available for source-area communities can help earn community buy-in, especially for large, long-term, inter-basin transfers made possible by land fallowing. Imperial Irrigation District’s mitigation fund and the Blythe Community Improvement Fund are examples (see fn. 52). At the very least, a well-designed tender process is needed to disburse funds effectively. Ensuring that these funds deliver new economic opportunities requires a vision and a level of collective planning. Even when trading water locally, it may be important to consider fiscal impacts for local governments if water crosses county lines. Such funds add costs to transfers, but the gains from trade are often high enough to make this worth the expense. Other entities, such as state or federal programs, would need to offer broader economic development support for communities experiencing land fallowing because of SGMA, as described below. *Who’s responsible: local trading parties, in discussion with local communities, as well as state and federal economic development programs to support broader land repurposing.*

- **Harmonize treatment of the physical impacts of land fallowing.** Currently, only water users fallowing land associated with water transfers are expected to mitigate negative physical impacts, such as dust or reduction in wildlife habitat. But it is in the public interest to consider these issues when significant acreage is fallowed, whether or not water trading is involved. A harmonized approach minimizes the risk of discouraging beneficial trading while providing protections for local farms, public health, and wildlife. Finding cost-effective ways to address these impacts will be essential, given the revenue declines on fallowed land. *Who’s responsible: GSAs, counties, regional air pollution control districts, and the California Department of Fish and Wildlife.*

- **Allow water users to reallocate water from retired farmland.** Currently, some water districts do not allow growers to reallocate surface water from land that is permanently retired—even within their own districts. There is also uncertainty about how GSAs will set policies regarding what happens to groundwater on these lands. Allowing growers to reallocate surface and groundwater from retired farmland will incentivize moving water to more productive lands within basins, without undermining groundwater sustainability objectives. Transfers of surface water across basins may also help achieve SGMA’s sustainability goals, while providing broader regional economic benefits. *Who’s responsible: water districts, GSAs.*

- **Plan for farmland transitions and multi-benefit land repurposing.** The problems associated with large-scale land fallowing cannot be solved farm-by-farm. To avoid negative results of fallowing and obtain the most value out of alternative land uses, it will be necessary to engage in a broader planning effort. While this planning can stay local in more isolated basins, a regional approach will be valuable in places with interconnected basins like the Central Valley. Such planning could identify opportunities for revenue-generating alternatives and multi-benefit land uses—such as renewable energy and habitat—and inform incentive programs to steer fallowing decisions (and water trading) in broadly beneficial ways. As noted below, proposals from both the administration and the legislature would direct state funding towards incentivizing multi-benefit land repurposing. *Who’s responsible: GSAs and water districts, ideally collaborating across basins and counties.*
Leveling the Playing Field

Transparent information and a trusted data and transaction system around water market rules and performance are other essential features of well-designed markets; they help to build trust and broaden access. In addition, more equitable rules will level the playing field and create opportunities for more beneficial trading. Local, state, and federal entities can all make improvements:

- **Provide transparent market information.** Clear information about market rules and participation options will be essential for new groundwater markets. Information on market activity can also be of great value. Public, yet anonymous, reporting of aggregate market volumes and prices—as now reported in Mojave—could aid groundwater market participants. The same is true in surface water markets: the state and federal agencies that approve and track transactions should consider providing aggregate trading volume data to help align expectations and guide smart investment decisions. Stakeholders see value in developing “clearing-house” approaches for disseminating this information, where appropriate.

  79 Adopting compatible (or uniform) systems could lower transaction costs, especially as new groundwater trading programs begin to emerge in adjacent areas. *Who’s responsible: GSAs, local water districts, DWR, USBR.*

- **Develop more equitable, flexible district rules for surface water trading.** To avoid limiting the benefits of trading to large farms, districts should eliminate requirements that farmers can only transfer water outside the district to their own lands. Relaxing export restrictions would also foster broader regional benefits. To cover local costs, some districts already charge a fee to support district expenses in exchange for the right to transfer water out—a model that could be adopted elsewhere. Some water-selling districts in the Sacramento Valley offer neighbor discounts to local users who regularly face shortages, another way to address community concerns and support both local and broader economies. *Who’s responsible: water districts.*

- **Develop more equitable local rules for groundwater substitution transfers.** Well-run groundwater substitution programs can expand long-term water availability by more actively using local groundwater storage. 80 Once GSAs establish sustainability plans that address undesirable impacts of pumping, it should be possible to ease the coarser restrictions on this practice found in most county ordinances—which effectively preclude trades if they entail water leaving the county. If counties with restrictive groundwater export ordinances fail to amend their laws to conform to SGMA, the legislature should consider preempting local laws that discriminate against out-of-county uses or place undue burdens on groundwater and groundwater-substitution transfers that would not jeopardize sustainable groundwater management of the source aquifer. *Who’s responsible: counties, GSAs, the legislature.*

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78. For some ideas on how this might work in the San Joaquin Valley, see Hanak et al. (2019), Chapter 4; for a broader statewide look, see Environmental Defense Fund (2021).
79. The water market information provided by the Australian Bureau of Meteorology provides a useful example.
80. As the Yuba dry-year transfer program shows, such conjunctive use-based trading programs can benefit the local economy and help other basins address water scarcity (Mount et al. 2017, Ugai 2017).
Making Smart Infrastructure Investments

Hydrologic connections are an essential feature of water markets, and California currently has significant conveyance bottlenecks for water trading and banking. Key actions include:

- **Make strategic investments to upgrade and expand conveyance infrastructure.** Beyond restoring the capacity of damaged conveyance, new investments should focus on the most cost-effective options for capturing high flows for recharge and trading. This will likely require a shared investment strategy, involving local, state, and federal parties. Congress authorized partial funding for repairs to the Friant-Kern Canal (Bergstrom 2020), and more support may be coming through federal and state stimulus programs. *Who’s responsible: water districts, GSAs, and state and federal agencies and legislatures.*

- **Make existing infrastructure work better.** Beyond new investments, water project managers could expand the capacity of existing infrastructure through more coordinated operations of the surface and groundwater storage owned and operated by state, federal, and local entities.81 The state can also encourage equitable access to conveyance capacity by conditioning support for investments on well-defined access procedures and rules for setting wheeling rates. *Who’s responsible: water project managers at the local, state, and federal levels.*

Promoting Collaboration

Trading and banking show how local and regional collaboration can help Californians meet the challenges of managing groundwater sustainably and adapting to a changing climate. Effective and responsible markets require agreements between the transacting parties and attention to the broader impacts on communities and the environment. Collective efforts will also be necessary to make smart infrastructure investments and to plan for the best possible farmland transitions in areas with large groundwater deficits—both of which are key to successful trading and banking. None of this will be easy, and the forces pulling parties into hyper-local solutions and competition over scarce resources are also strong. State and federal agencies can help incentivize collaboration through financial and regulatory incentives. These include:

- **Promote within- and cross-basin collaboration on water trading.** There is a real risk that water districts, GSAs, and counties will adopt strategies that prioritize keeping water resources within their jurisdictions, rather than allowing for broader regional coordination. The state should formulate guidelines that attempt to avoid a balkanized system by limiting the ability of local or county governments to block or otherwise impede water transfers—especially transfers that would help to implement SGMA’s sustainability mandate, take advantage of high-flow and surplus water conditions, or respond to acute regional shortages during periods of drought. Although the State Water Board has the authority to issue water transfer guidelines, legislation would be needed to empower the board to modify or supersede decisions by local agencies and counties that prohibit or unduly burden out-of-jurisdiction water transfers. *Who’s responsible: State Water Board and the legislature.*

- **Encourage collaborative approaches to capturing water for banking.** The first sustainability plans for critically overdrafted basins showed unrealistically high enthusiasm for groundwater recharge and banking—with many local parties planning to tap the same sources. The State Water Board could help avoid lengthy disputes and promote more effective use of the resources by prioritizing collaborative permit applications. *Who’s responsible: State Water Board, with the cooperation of GSAs and water users.*

81. Escriva-Bou et al. (2019) summarizes the results of several studies that examine the potential supply gains from system reoperation, including ACWA (2017), Department of Water Resources (2017a), and Lund et al. (2014).
Conclusion

Bringing groundwater back into balance under SGMA will help California’s water users improve the water system’s resilience and find new, more reliable ways to meet the needs of agriculture, cities, and the environment. However, this transition will come with growing pains; as local agencies implement SGMA, water availability will decline in many parts of the state. Well-designed water markets will be an important tool to help California manage future scarcity.

Though California has some of the most active surface water trading and groundwater banking programs in the world, considerable work lies ahead to enable such programs to meet today’s needs. Priorities include laying the foundation for new local groundwater markets by establishing groundwater allocations and working to address undesirable effects of groundwater use. In addition, local, state, and federal agencies—in cooperation with other stakeholders—will need to adopt effective and responsible approval strategies, refine existing regulations, and provide transparent water market information. Californians will also need to make smart infrastructure investments that support flexible water management, while addressing the local and regional impacts of land fallowing—an unavoidable consequence of growing water scarcity.

Fortunately, this work is largely achievable under the current regulatory structure. It also comes at an important time: in addition to preventing further land subsidence, dry wells, and other harm from unsustainable pumping, bringing groundwater back into balance will also help California’s society, economy, and environment adapt to the growing effects of climate change.

While the obstacles are considerable, so are the opportunities. Collaboration and innovation will be key to successfully meeting the challenges ahead.

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82. For a discussion of relevant USDA programs in California, see Jezdimirovic and Hanak (2019).
References


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