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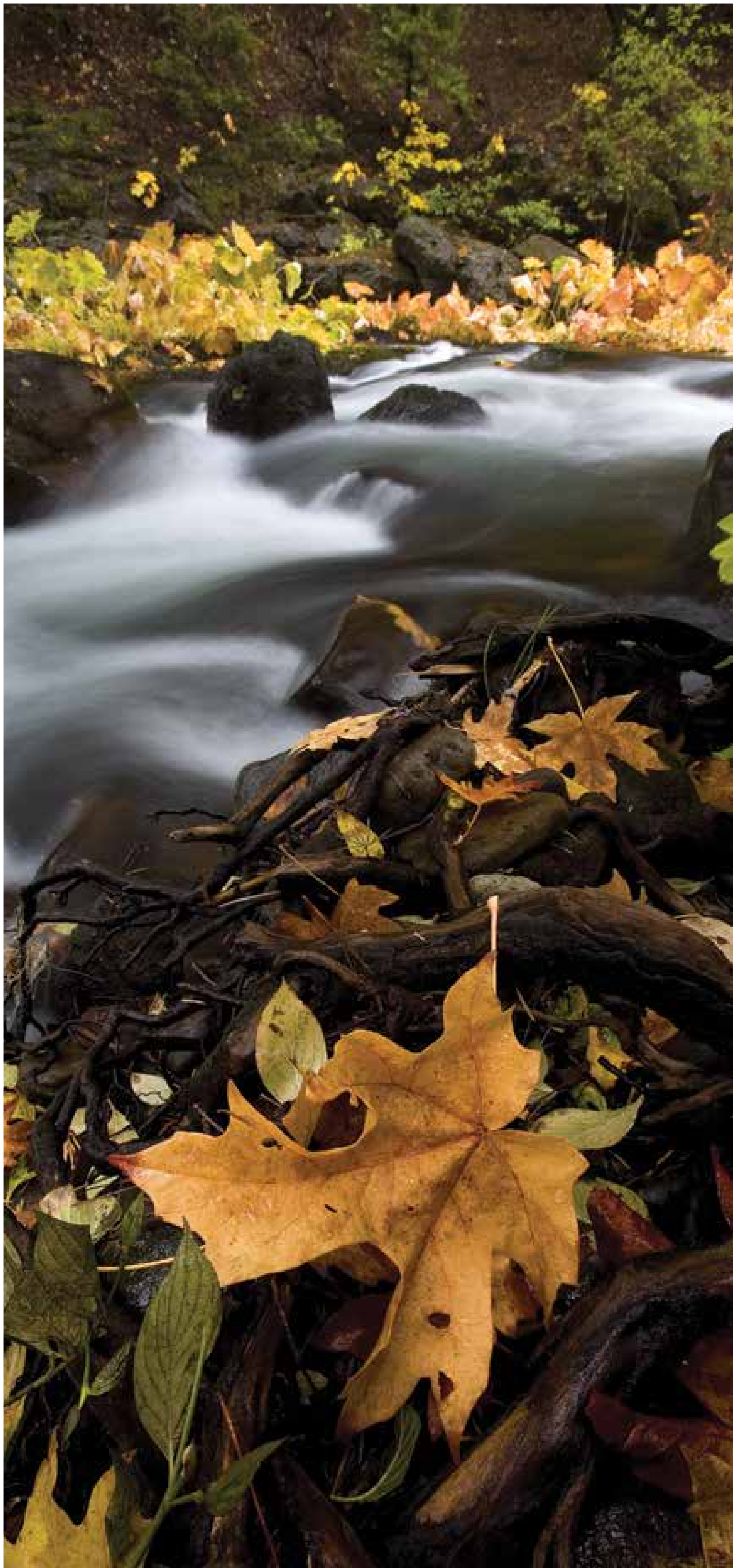
2017 Report

Market-Based Mechanisms For Securing Environmental Water In California



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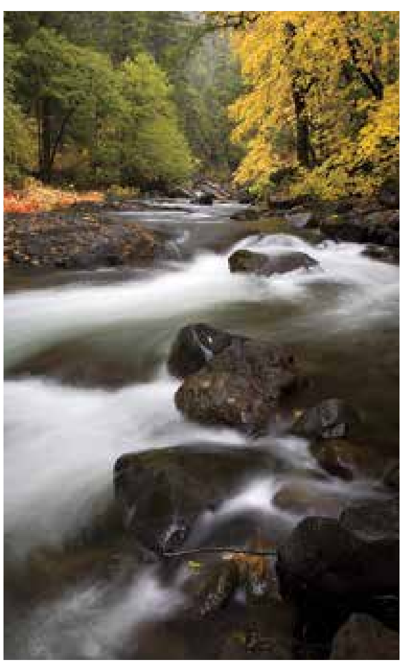
COVER CLOCKWISE Salmon © *iStockphoto;* Deer Creek © *Ian Shive; Sandhill cranes* © *Ramona Swenson/TNC;* Farmer © *iStockphoto;* San Francisco © *iStockphoto* OPPOSITE PAGE A child playing in the Marble Fork of the Kaweah River © *Nick Hall* THIS PAGE TOP TO BOTTOM Salamander with egg sacks © *Mark Godfrey/TNC;* The Shasta River shown flowing through The Nature Conservancy's Shasta Big Springs Ranch below Mount Shasta © *Bridget Besaw*

California faces persistent water crises.

California faces persistent water crises, and the state's water supply is becoming increasingly unreliable. In an average year, the state's surface water is over-allocated by a factor of five, and groundwater provides 30-to-46 percent of the total water supply.[1, 2] During dry times, consumptive use of water often outstrips sustainable supplies. As a result, people and nature suffer. This imbalance of supply and demand will likely grow worse if future demand for agricultural and urban water increases while a warming climate causes precipitation to become increasingly variable and mountain snowpacks to decline.

In the face of the recent prolonged drought, in 2014, California enacted landmark legislation for the sustainable long-term management of groundwater resources, and voters approved a $7.1 billion general obligation bond ("Water Bond") whose priorities include increasing water supplies, improving system flexibility and enhancing watershed health. These policy developments provide an opportunity to implement projects that demonstrate ways of sustainably balancing the water needs of humans and nature.



TOP TO BOTTOM Tadpole Shrimp as sampled from a vernal pool on the Howard Ranch near Sacramento © *Ian Shive;* Deer Creek © *Ian Shive*

MARKET-BASED MECHANISMS FOR SECURING ENVIRONMENTAL WATER

Water markets exist throughout the western United States. California's water market is one of the largest, with approximately 1.4 million acre feet (MAF) traded annually, about 3 percent of the state's water use.[3, 4] These markets can be used to procure water for environmental uses, such as instream flows or wetlands ("environmental water"). Such deals account for approximately 18 percent of California water transactions.[5]

But this approach faces difficulties that limit its effectiveness. Because urban and high-value agricultural users are typically willing to pay top dollar for water, they often outbid environmental interests. Without rules in place to protect the environment and/or a large, reliable funding stream for environmental water transactions, water markets are likely to fail to achieve environmental goals. Instead, these markets will continue to be largely dominated by trades among agricultural and urban users.

Beyond trading in water markets, a number of market-based mechanisms can be used to increase water supply, reduce water demand or procure environmental water. Some of these market-based approaches are currently in use in California. Others are untested. In many watersheds and basins, long-term reductions in water use are necessary if environmental water needs are to be met. Several of these tools might be used in basins throughout California to develop politically palatable pathways to environmentally responsible, sustainable management of ground and surface water.

1 California Department of Water Resources. 2016. Groundwater Information Center. http://www.water.ca.gov/groundwater/gwinfo/
2 Grantham, Theodore E. and J.H. Viers. 2014. 100 years of California's water rights system: patterns, trends and uncertainty. Environmental Research Letters, Vol. 9, August 2014.
3 Hanak, E. and E. Stryjewski. 2012. California's water market, by the numbers: update 2012. Public Policy Institute of California: San Francisco, California.
4 Hanak, Ellen and Jezdeimirovic. 2016. Just the facts: California's water market. Public Policy Institute of California: San Francisco, California. http://www.ppic.org/main/publication_show.asp?i=1177.
5 Hanak and Jezdeimirovic, 2016.

TABLE ES-1. APPROACH TO RANKING MECHANISMS

RANKING	POTENTIAL IMPACT	LIKELIHOOD OF IMPLEMENTATION	RISK
High	Large-scale interventions with the potential to secure substantial environmental water	Proven models exist with appetite to develop more Public funding/private capital readily available Few barriers to implementation (e.g., technical, regulatory, political)	High uncertainty regarding ability to deliver environmental water Potential for adverse environmental impacts Potential for litigation
Medium	Small-to-moderate scale interventions with the potential to secure incremental environmental water	Proven models may not exist, raising concerns about performance risk Funding constraints may limit immediate adoption Some barriers to implementation	Moderate uncertainty regarding ability to deliver environmental water Potential for adverse environmental impacts, but possible to mitigate via design Potential for litigation
Low	Not applicable	Proven models may not exist, raising concerns about performance risk Significant constraints / unknown appetite for funding limit immediate adoption Substantial barriers to implementation	Low uncertainty regarding ability to deliver environmental water Limited potential for adverse environmental impacts Litigation unlikely

OBJECTIVE AND APPROACH

The primary objective of this paper is to identify and evaluate promising market-based mechanisms that may help achieve the goal of sustainable water use in California in an efficient, equitable and transparent manner. Our approach to identifying those mechanisms was to interview and synthesize feedback from more than 30 experts in the field. We also reviewed available literature.

We rank the most promising mechanisms according to their potential conservation impact (in terms of the ability to provide environmental water), likelihood of implementation and risks, such as unintended consequences or failure to implement the mechanism effectively. The rankings are qualitative and represent a high-level assessment, for which we relied on professional judgement. Table ES-1 presents the rationale for each ranking. The rankings are intended to provide an initial sense of the potential opportunities, barriers and tradeoffs associated with each mechanism. Additional research and analysis is required to better determine the feasibility of each mechanism, which is likely to depend heavily on site-specific factors.

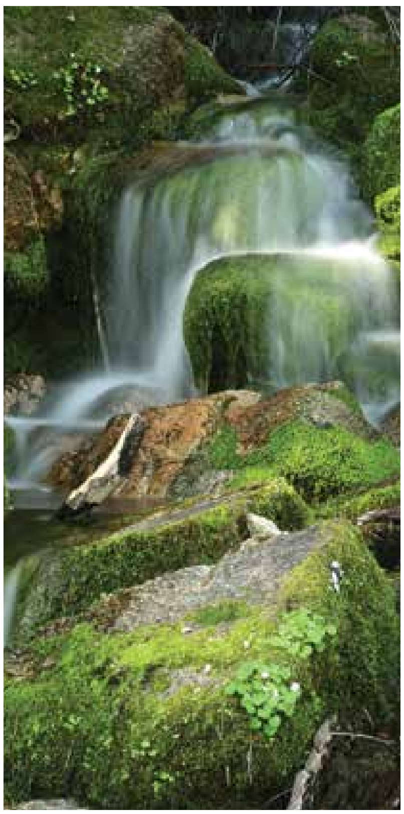
The analysis is intended for conservation organizations, public agencies and private investors with an interest in securing water for environmental purposes.

Pergish Carlson, steers a boat along the Klamath River in northern California
© *Kevin Arnold*

MECHANISMS TO DELIVER ENVIRONMENTAL WATER

This paper describes 11 mechanisms—summarized in Table ES-2—for increasing the provision of environmental water through water markets and/or other market-based approaches. These mechanisms are divided into three broad categories, based on how they address the oversubscription of water resources: (1) develop new water supply, (2) reduce water demand and (3) re-operate existing water supply systems.

Eleven Mechanisms



TOP TO BOTTOM Tiltill Creek on the path to Rancheria Falls at Hetch Hetchy Resevoir © *Simon Williams/TNC; © Shar Jimenez Romero*

DEVELOP NEW WATER SUPPLY

There are several mechanisms through which investment in infrastructure and/or technical applications may generate additional water supply. Some or all of this "new supply" can then be allocated to the environment without harming existing water users. This category of mechanisms includes market-based tools and technical approaches that could create investment opportunities that might yield both environmental benefit and financial return.

REDUCE WATER DEMAND

Market-based mechanisms for reducing water demand primarily aim to advance the sustainable use of groundwater, as prescribed in California's recently enacted law. These approaches may be particularly attractive for jurisdictions seeking alternatives to more rigid adjudication of groundwater rights. But building the political will to implement these mechanisms will be a challenge. One way to do so may involve making public and philanthropic capital available to early adopters of these market-based approaches.

Some of these mechanisms may also yield the additional benefit of generating revenue, which water agencies could use to offset the short-term economic pain of reducing groundwater use, to increase system flexibility and to invest in alternate water supplies (e.g., recycled water).

RE-OPERATE EXISTING WATER SUPPLY SYSTEMS

Mechanisms that re-operate existing water supply systems—that is, to modify the ways they operate—seek to increase the environmental benefit delivered by the existing water supply without fundamentally altering water supply or demand. This category includes approaches to acquiring and/or using water rights for environmental benefit, such as instream flows or delivery to wetlands, as well as offsetting consumptive water use through water neutrality investments.

While most of these mechanisms have been successful elsewhere, their use in California to date has been limited—which provides an opportunity to expand their application in the state. To build momentum for reforms and remove some of the institutional barriers to a more active market for environmental water rights and flows, it may be useful to conduct and publicize further demonstrations of "proof of concept" of these mechanisms.

TABLE ES-2. PRIORITY MECHANISMS FOR SECURING ENVIRONMENTAL WATER

MECHANISM	OBJECTIVE	POTENTIAL IMPACT	LIKELIHOOD OF IMPLEMENTATION	RISK
DEVELOP NEW WATER SUPPLY				
1. Groundwater Banking	Invest in new banks to influence operations for environmental gain	High	Medium	Medium
2. Off-Stream Storage	Develop ponds or storage tanks to align water supply and demand	Medium	Medium	Low
3. Agricultural Efficiency	Fund irrigation upgrades to secure new water for the environment	Medium	High	Medium
4. Forest Thinning	Restore healthy forests for multiple benefits, including water supply	Medium	Medium	Medium
REDUCE WATER DEMAND				
5. Pump Tax	Increase the cost of pumping to encourage reduction of pumping and raise revenue for new supplies	High	Low	Medium
6. Groundwater Cap and Trade	Allocate pumping rights and allow users to purchase more water from those who conserve	Medium	Medium	Medium
7. Avoided Rangeland Conversion	Manage future demand on lands at risk for agricultural intensification or development	Medium	Low	Low
8. Groundwater Mitigation	Offset impacts of new pumping with instream flow preservation and/or supply augmentation	Medium	Low	Medium
9. All-in Auction	Allocate pumping rights and require users to bid for rights, with compensation for allocated rights	Medium	Low	High
RE-OPERATE EXISTING WATER SUPPLY SYSTEMS				
10. Acquisition	Scale up environmental water transactions through acquiring water rights and/or land	High	Medium	Medium
11. Water Neutrality	Offset corporate water use via instream flow preservation and/or supply augmentation	Medium	Low	Low

CONCLUSION

California's water system is over-allocated, but recent policy changes—the Water Bond and groundwater regulation—present opportunities to alter this course. While water markets offer some promise, they are not guaranteed to benefit the environment, given that they cater to the highest bidders. Market-based mechanisms, however, present an additional suite of opportunities to secure water for the environment. Some have the added promise of delivering financial returns or paving the way for policy change. No one mechanism, on its own, will achieve the goal of sustainable water management in California, or represents an easy path forward. However, it is the hope that conservation practitioners, project developers, agency leaders and policy makers will use the information presented in this paper when seeking to develop initiatives to alleviate the pressure on agricultural, urban and environmental water users.

INTRODUCTION

California faces persistent water crises.

California faces persistent water crises, and the state's water supply is becoming increasingly unreliable. In an average year, the state's surface water supply is over-allocated by a factor of five, and groundwater provides 30-to-46 percent of the total water supply.[6, 7] During dry times, consumptive use of water—on both an inter- and intra-annual basis—often outstrips sustainable supplies. As a result, people and nature suffer. This imbalance of supply and demand will likely grow worse if future demand for agricultural and urban water increases while a warming climate causes precipitation to become increasingly variable and mountain snowpacks to decline.

In the face of the recent prolonged drought, in 2014, California enacted landmark legislation for the sustainable long-term management of groundwater resources, and voters approved a $7.1 billion general obligation bond ("Water Bond") whose priorities include increasing water supplies, improving system flexibility and enhancing watershed health. These policy developments provide an opportunity to advance projects that demonstrate ways of sustainably balancing the water needs of humans and nature.

TOP TO BOTTOM Water from the Colorado River is routed through ditches © *Erika Nortemann/TNC;* Mike Roberts oversees irrigation at Stoney Creek © *Mary Ann Griggs/TNC*

OBJECTIVE

The primary objective of this paper is to identify and evaluate promising market-based mechanisms, or approaches, that may help achieve the goal of sustainable water use in California in an efficient, equitable and transparent manner. Achieving "sustainability" does not always meet the needs of the environment—particularly where water reliability is the central focus—and it is the goal of this paper to identify approaches that do just this. The analysis is intended for conservation organizations, public agencies, land owners and private investors with an interest in securing water for environmental purposes. We focus here exclusively on market-based approaches to delivering water that benefits the environment, such as instream flows or wetlands ("environmental water"). Please see *Water for Nature: What We Can Do Today to Help California's Rivers, Streams and Wetlands*, a companion report by The Nature Conservancy, for a detailed analysis of existing tools, market and non-market based, to enhance environmental flows in California.[8]

6 California Department of Water Resources. 2016. Groundwater Information Center. http://www.water.ca.gov/groundwater/gwinfo/

7 Grantham, T.E. and J.H. Viers. 2014. 100 years of California's water rights system: patterns, trends and uncertainty. Environmental Research Letters 9: 084012.

8 Burns, C.E., A. Hoss, N. Smith, K. Klausmeyer, K. Fesenmeyer, A. Campbell, J. Carah, E. Forsburg, S. Heard, J.K. Howard, L. Hulette, S. Liu, P. Spraycar, B. Stranko, G. Werner and D. Wordham. 2017. Water for nature: What we can do today to help California's rivers, streams and wetlands. The Nature Conservancy: San Francisco, California.

TABLE 1. APPROACH TO RANKING MECHANISMS

RANKING	POTENTIAL IMPACT	LIKELIHOOD OF IMPLEMENTATION	RISK
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Low	Not applicable	Proven models may not exist, raising concerns about performance risk Significant constraints / unknown appetite for funding limit immediate adoption Substantial barriers to implementation	Low uncertainty regarding ability to deliver environmental water Limited potential for adverse environmental impacts Litigation unlikely

APPROACH

To identify these mechanisms, we considered lessons learned from other water projects, past and present, around the world. Our approach to identifying those mechanisms was to interview and synthesize feedback from more than 30 experts in the field. (*See Appendix A*.) We also reviewed available literature.

The paper ranks the most promising mechanisms (high, medium, low) according to their potential conservation impact (in terms of the ability to provide environmental water), likelihood of implementation and risk, such as unintended consequences or failure to implement the mechanism effectively. The rankings are qualitative and represent a high-level assessment, for which we relied on professional judgement. Table 1 presents the rationale for each ranking, and further detail is provided in the discussion of each mechanism. The rankings are intended to provide an initial sense of the potential opportunities, barriers and tradeoffs associated with each mechanism. Additional research and analysis is required to better determine the feasibility of each mechanism, which is likely to depend heavily on site-specific factors.

Snowy egret © *Douglas Steakley*

Room for Growth

TOP TO BOTTOM A strawberry field at the Azevedo Ranch, upland of the Elkhorn Slough in Monterey County, California © *Kiliii Yuyan;* A University student measures the depth of water in an irrigation ditch © *Erika Nortemann/TNC*

CHARACTERISTICS OF WATER MARKETS

Water markets represent an exchange through which a range of interests—municipal, agricultural, and environmental—may buy and sell water. The primary function of water markets is to reallocate water to those uses with the highest economic value—those uses for which people or organizations are willing to pay the most.

Water markets exist throughout the western United States. California's water market, with approximately 1.4 million acre feet (MAF) traded annually (about 3 percent of the state's water use), is one of the largest.[9,10] Multiple droughts and reductions in available water supplies, combined with state policy changes to make water marketing easier, have spurred the growth of California's water market over the last three decades. With agriculture responsible for 80 percent of California's water use, it follows that the majority of water trades—more than 80 percent— flow from low-value agriculture (e.g., row crops) to urban users and high-value crops (e.g., orchards, vineyards).[11]

Eighteen percent of California's water trades from 1981 through 2014 were environmental water transfers for instream flows and wildlife refuges.[12] During this time, environmental water trades totaled over 5 MAF. State- and federally-funded initiatives were largely responsible for these trades, a trend that the 2014 state Water Bond (Proposition 1) perpetuated by allocating $200M for the acquisition of environmental water.

DIFFICULTIES OF USING MARKETS TO PROVIDE ENVIRONMENTAL WATER

Although water markets can be used to procure water for environmental use, urban and high-value agricultural users that are willing to pay top dollar for water typically outbid environmental interests. For example, during the recent drought several Southern California water agencies made permanent purchases at more than $5,000 per AF, up to 200 percent higher than average prices.[13] Without rules to protect the environment or a large, reliable funding stream for environmental water transactions, water markets are likely to fail for the environment while they primarily facilitate trading among agricultural and urban users.

MARKET-BASED MECHANISMS FOR PROVIDING ENVIRONMENTAL WATER

"Market-based mechanisms" build on water markets to include a suite of tools beyond trading water rights or flows in water markets, like groundwater banking. These other market-based approaches can be used to increase water supply, reduce water demand and/or procure environmental water. Some market-based approaches are currently in use in California. Others are untested. In many watersheds and basins, long-term reductions in water use are necessary to meet statewide environmental water needs. Several of these tools might be used to develop politically palatable pathways to environmentally responsible, sustainable management of ground and surface water.

[9] Hanak, E. and E. Stryjewski. 2012. California's water market, by the numbers: update 2012. Public Policy Institute of California: San Francisco, California.

[10] Hanak, E. and J. Jezdeimirovic 2016. Just the facts: California's water market. Public Policy Institute of California: San Francisco, California. http://www.ppic.org/main/publication_show.asp?i=1177.

[11] Hanak and Stryjewski, 2012.

[12] Hanak and Jezdeimirovic, 2016.

[13] Western Water Research, LLC. 2013. 2013 California spot market price forecast. Water Market Insider, Update.

Eleven Mechanisms

This chapter describes 11 mechanisms—summarized in Table 2 below—for increasing the provision of environmental water through water markets and/or other market-based approaches. These mechanisms are divided into three broad categories, based on how they address the oversubscription of water resources: (1) develop new water supply, (2) reduce water demand and (3) re-operate existing water supply systems.

TABLE 2. PRIORITY MECHANISMS FOR SECURING ENVIRONMENTAL WATER

MECHANISM	OBJECTIVE	POTENTIAL IMPACT	LIKELIHOOD OF IMPLEMENTATION	RISK
DEVELOP NEW WATER SUPPLY				
1. Groundwater Banking	Invest in new banks to influence operations for environmental gain	High	Medium	Medium
2. Off-Stream Storage	Develop ponds or storage tanks to align water supply and demand	Medium	Medium	Low
3. Agricultural Efficiency	Fund irrigation upgrades to secure new water for the environment	Medium	High	Medium
4. Forest Thinning	Restore healthy forests for multiple benefits, including water supply	Medium	Medium	Medium
REDUCE WATER DEMAND				
5. Pump Tax	Increase the cost of pumping to encourage reduction of pumping and raise revenue for new supplies	High	Low	Medium
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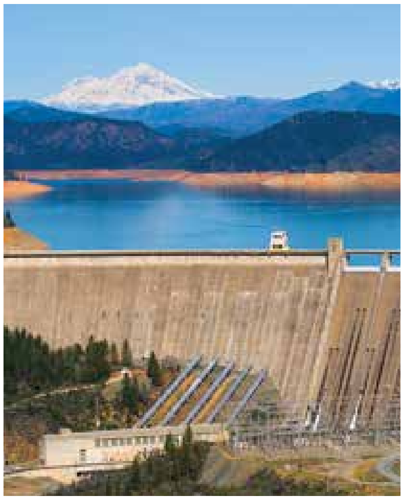
8. Groundwater Mitigation	Offset impacts of new pumping with instream flow preservation and/or supply augmentation	Medium	Low	Medium
9. All-in Auction	Allocate pumping rights and require users to bid for rights, with compensation for allocated rights	Medium	Low	High
RE-OPERATE EXISTING WATER SUPPLY SYSTEMS				
10. Acquisition	Scale up environmental water transactions through acquiring water rights and/or land	High	Medium	Medium
11. Water Neutrality	Offset corporate water use via instream flow preservation and/or supply augmentation	Medium	Low	Low



TOP TO BOTTOM Shasta Dam © *iStockphoto;* Studying salmon on the Shasta River © *Bridget Besaw;* Riparian habitat restoration site within the Colorado River Delta © *Erika Nortemann/TNC*

DEVELOP NEW WATER SUPPLY

There are several mechanisms through which investment in infrastructure and/or technical applications may generate additional water supply, specifically around storage, agricultural efficiency and forest thinning. Some or all of this "new supply" can then be allocated to the environment without harming existing water users. This category of mechanisms includes market-based tools and technical approaches that could create investment opportunities that might yield both environmental benefit and financial return.[14]

California has developed an elaborate network of storage facilities, primarily surface reservoirs, to address the mismatch in timing of precipitation and demand for water, as well as periods of drought and flooding. Climate change and a growing demand for water are likely to cause further strains on California's current water supplies. Expanding the state's storage capacity for both surface and groundwater may offer an opportunity to increase water supplies for both consumptive use and environmental benefit.

The Water Bond includes both a $2.7B allocation for new storage projects that benefit the Delta or its tributaries and an additional $200M to enhance instream flows, for which storage projects may also be eligible. These funds may be used to cover up to 50 percent of storage project costs. Storage projects receiving these grants will be required to deliver public benefit (e.g., flood control, recreation), at least half of which must be in the form of ecosystem improvements. The California Water Commission has not yet defined how projects' public benefits will be evaluated for the distribution of Water Bond funds. This situation represents a significant opportunity to develop storage projects that can demonstrate the provision of public benefits while delivering environmental benefits on a meaningfully large scale.

Agriculture is the largest consumer of water in California. Despite progress in implementing conservation measures, there remains significant potential to improve the sector's water use efficiency through upgrades at the farm and water district level.

Research suggests that overly dense forests may consume more water than forests that are managed with ecologically-based practices, such as thinning and prescribed burning, to reduce the risk of megafires and promote healthier, more resilient forest conditions. This additional runoff could provide increased water supplies for hydroelectric power, consumptive use and the environment.

1. GROUNDWATER BANKING

Groundwater storage or "banking"—that is, recharging dewatered aquifers—offers a promising pathway for augmenting California's water supply, including for the environment. Groundwater banks have lower evaporative losses than surface reservoirs, maximizing the availability of newly developed groundwater supplies.[15] Groundwater banks may operate with formalized fee structures where outside participants compensate the bank owners in exchange for water storage and access. However, they may also operate more as a "recharge facility" and less like a "bank." In these instances, the owner is using the facility to re-operate their water for personal and/or public benefit.

[14] While projects such as those to develop recycled water and urban water efficiency may play an important role in developing new water supplies, they were considered beyond the scope of this paper.

[15] Christian-Smith, J. 2013. Improving water management through groundwater banking: Kern County and the Rosedale-Rio Bravo Water Storage District. Pacific Institute: Oakland, California.

The Morelos Dam on the Colorado River © *Erika Nortemann/TNC*

Groundwater storage is one of the most cost-effective strategies for developing new supply, as compared to surface storage, agricultural efficiency, urban recycling, and urban efficiency projects.[16] For example, analysis suggests that groundwater storage may be as much as 30 times cheaper than surface storage.[17,18] This cost differential is largely the result of groundwater projects' up-front construction costs, which are significantly lower than those of surface water storage facilities with similar capacities. Empty groundwater basins already exist, so the infrastructure needed for recharge and recovery consists mainly of pumps and conveyance structures.

To advance groundwater banking, those interested in securing environmental water could deliver or facilitate access to grant monies and/or make a financial investment by taking an equity (ownership) or debt (loan) stake in one or more groundwater banking projects. In doing so, they could leverage such investments to "buy conservation" and influence groundwater bank operations, requiring an environmental return on investment. These projects could achieve both financial and environmental returns and thereby create compelling models for self-sustaining management of groundwater with an eye to the environment.

One compelling opportunity would be to partner with water agencies seeking to develop or expand groundwater banks and facilitate access to Water Bond monies in exchange for a share of the banked water. Some groundwater banks require their users to leave behind a significant amount of their stored water (e.g., 50 percent in the Rosedale Rio Bravo Water Storage District), a model that could be adapted to secure environmental water.

1a. Conservation Impact: High. Groundwater banking has the potential to deliver substantial environmental water because of the large scale of a single project. For example, the Kern Water Bank, one of California's largest groundwater banks, has a total storage capacity of 1.5 MAF.

Environmental groundwater could be used locally, or in cases where the groundwater bank is connected to California's state and or federal water projects, exchanged for water elsewhere along the system. Groundwater banking may help reduce the negative impacts of groundwater depletion from continued over-pumping and/or new reservoirs by providing an alternate source of water. Groundwater banking can be designed to yield environmental co-benefits (e.g., creating habitat at recharge ponds) without the same negative impacts that surface reservoirs often entail. In cases where groundwater banks are located south of the Delta, they can deliver new water supplies during dry years, and reduce the need for Delta exports.

Assuming an active role in groundwater bank operations would provide a vehicle for long-term influence over the operations of new water supplies for environmental benefit. It would also likely lead to substantial technical learning about how groundwater storage can be most effectively harnessed to deliver environmental benefits, and it would serve as a model for other projects.

1b. Likelihood of Implementation: Medium. Certain physical conditions, such as soil permeability and access to surface storage and conveyance facilities, make groundwater banks

[16] Hanak, E., J. Lund, A. Dinar, B. Gray, R. Howitt, J. Mount and B. Thompson. 2010. Myths of California—implications and reality. West Northwest 16: 1-74.
[17] Choy, J., G. McGhee and M. Roberts. 2014. Recharge: groundwater's second act. Stanford Woods Institute for the Environment, Water in the West. http://waterinthewest.stanford.edu/groundwater/recharge/.
[18] Because surface storage facilities in California generally make water available for more flexible or varied uses than does groundwater storage, direct cost comparisons are difficult to make. For more information on costs, see http://waterinthewest.stanford.edu/groundwater/charts/cost-comparison/index.html.

LEFT TO RIGHT Independence Lake Preserve in Truckee, California © *Devan King/TNC;* Francisco Zamora Arroyo pulls an invasive salt cedar from a riparian habitat restoration site within the Colorado River Delta © *Erika Nortemann/TNC*

more suitable in some areas than others. Twelve projects involving groundwater storage were proposed for the first round of Water Bond grant funding (of 42 projects total), giving a sense of the current opportunity.[19]

Entities interested in delivering ecosystem benefits are likely to be particularly attractive to developers of groundwater banks because of their ability to access Water Bond grants. However, there is likely to be considerable competition with surface storage projects, which may receive large allocations of bond monies, given their high capital costs.[20]

The cooperation of overlying landowners is essential, as concerns about (1) the use of banked groundwater beyond the basin in which it originates and (2) the effects on both water quantity and quality of drawing down groundwater supplies may pose difficulties for the development of groundwater banks.[21, 22]

1c. Risk: Medium. A key risk with investing in groundwater banking is securing a reliable supply of water for deposit into a groundwater bank to ensure that it remains financially solvent, particularly for banks located south of the Delta, where water deliveries are subject to curtailment.

Groundwater banking carries some potential risks regarding adverse environmental impacts. For example, recovery of stored groundwater by concentrated pumping in certain locations can cause land subsidence. Water quality can be degraded if pumping releases underground contaminants. These negative impacts, as well as the loss of stored water due to complex geology, can injure third parties—especially overlying landowners who use groundwater but do not participate in the groundwater bank.[23] Recharge basins used in groundwater banks can disturb habitat for endangered species that move in during drought years, and are then inundated during wet years. However, these risks can typically be minimized through careful design of the project and its operations.

There is also the risk of non-participants' pumping of banked groundwater from un-adjudicated basins or unconfined aquifers. The state has 22 adjudicated groundwater basins, mostly in southern California, where courts have determined pumping rights, which may help mitigate this risk for new groundwater banks.[24]

2. OFF-STREAM STORAGE

Dammed reservoirs on the main stems of rivers or streams are generally characterized by a set of well-understood deleterious environmental impacts (e.g., barriers to fish passage, downstream erosion). However, there are likely opportunities for new off-stream storage facilities that do not involve dams (e.g., storage tanks, storage ponds). Their development would increase system flexibility with fewer adverse environmental impacts than reservoirs. This mechanism could also demonstrate proof of concept to inform public benefits guidelines for Water Bond grants, as described above. Environmental returns on investment for small-scale off-stream storage projects could be some amount of environmental water and/or influence over operations.

[19] California Water Commission. 2016. Water storage investment program concept paper solicitation. https://cwc.ca.gov/Pages/ConceptPapers.aspx
[20] Capital costs of the Sites and Temperance Flat reservoirs are estimated to be $4.4B and $2.8B, respectively. See: California Water Commission, 2016.
[21] Christian-Smith, 2013.
[22] Thomas, G.A. 2001. Designing successful groundwater banking programs in the Central Valley: lessons from experience. The Natural Heritage Institute: Berkeley, California.
[23] Christian-Smith, 2013. Thomas, 2001.
[24] Hanak et al., 2014.

Irrigation ditches divert water from the Colorado River for cropland © *Erika Nortemann/TNC*

Undammed off-stream storage may provide substantial benefits to smaller systems where the timing of water supply and demand do not match up. For example, The Nature Conservancy estimates that 5 AF of off-stream storage along Indian Creek, a tributary of in the Navarro River, would provide sufficient dry season flows for fish. This is only a fraction of the storage provided by large off-stream reservoirs, like the proposed Sites Reservoir, which would have a capacity of 1.2-to-1.8 MAF.

Another option is the construction of farm ponds on private land. By capturing rainfall, flood flows and recycled irrigation return flows, farm ponds can augment water supplies and reduce pressure on existing surface and groundwater supplies.[25] Conservation-minded entities could fund the construction of these ponds and/or facilitate permitting to relieve pressure on streams, particularly during summer peak demand. This could then provide increased water security for farmers and, in some cases, regulatory assurances.

2a. Conservation Impact: Medium. Off-stream storage ponds and tanks have the greatest potential for smaller systems where incremental increases in storage can yield sufficient additional water to provide minimum summer ecological flows. Solutions such as farm ponds may not only store peak flow diversions, rainfall and irrigation tailwater, but also recharge groundwater and provide agricultural co-benefits like frost protection.[26] Undammed off-stream storage has not been fully exploited in California, in part because agricultural users have relied on irrigation districts. This mechanism is likely to become increasingly valuable as a source of supplemental supply and flexibility as water demand grows and the unreliability of supply increases.

Because the capital costs of undammed off-stream storage are likely to be far lower than for dammed reservoirs, the Water Bond could fund a number of off-stream projects, thereby improving flexibility and ecological outcomes in multiple stream systems and/or watersheds. Investment in multiple storage tanks or ponds may be a cost-effective approach to improving environmental outcomes.

2b. Likelihood of Implementation: Medium. Smaller, off-stream projects may be less controversial, in terms of their "harm" to both the environment and other water interests, than reservoirs—and therefore easier to implement. However, since strong competition for Water Bond monies is likely, these projects would need to demonstrate sufficient water supply and environmental benefit to secure grants for off-stream storage projects.

Regulations involving water rights and endangered species may increase the complexity and time to completion for off-stream storage projects, as was the case with the Pine Gulch Creek project in Marin County, which took 17 years to develop.[27] In addition, permitting involving endangered species may increase the complexity and costs of developing off-stream storage.

2c. Risk: Low. The risks associated with constructing new off-stream storage are substantially lower than for larger,

[25] California Agricultural Water Stewardship Initiative. n.d. Farm ponds for irrigation. http://agwaterstewards.org/index.php/practices/farm_ponds_for_irrigation/.
[26] California Agricultural Water Stewardship Initiative, n.d.
[27] Kimmey, S. 2015. Bolinas farmers break ground. Point Reyes Light. http://www.marinrcd.org/wp/wp-content/uploads/0201/06/Bolinas-farmers-break-ground-_-The-Point-Reyes-Light.pdf.



LEFT TO RIGHT Ditch flow regulator © *Mark Skalny;* Farmland surrounding the Pajaro River © *Treve Johnson;* © *iStockphoto*

on-stream reservoirs. However, some degree of performance risk may exist, as with any technical approach to increasing water supplies.

3. AGRICULTURAL EFFICIENCY

Agricultural water use efficiency refers to a suite of on-farm mechanisms to reduce water losses, including efficient irrigation technology, improved irrigation scheduling, regulated deficit irrigation and improvements in conveyance and distribution infrastructure. Both on-farm and conveyance efficiency measures can be implemented without compromising crop yields.

Investment in efficiency upgrades, carried out by willing farmers and water districts, can free up new water for the environment, which could be used to enhance instream flows or reduce groundwater pumping. In a public-private partnership model, a portion of this water could also be used to generate financial returns for private investors through sales to downstream users.

Agricultural efficiency is likely to be most appropriate where there is a regulatory threat, such as compliance with water quality standards or enforcement of the state's Reasonable Use Doctrine, which regulates wasteful water use. Irrigation districts on the San Joaquin Valley's upper east side may present particularly promising opportunities. These water districts hold senior water rights that are less subject to curtailment than more junior water rights, have access to conservation storage from flood control projects and are subject to Federal Energy Regulatory Commission relicensing.

3a. Conservation Impact: Medium. On-farm efficiency projects have the potential to reduce California's agricultural water use by 17 percent, or 4.5 MAF to 6 MAF per year.[28] Sixty percent of these savings come from improved irrigation scheduling, for which the largest potential impacts are in the areas irrigated by water from the San Joaquin River, Sacramento River and Tulare Lake. Estimates of the opportunity for reducing consumptive use—for example, by addressing transfer and spray evaporation, weed evapotranspiration and frost protection evaporation—yield smaller but still potentially significant water savings of between 0.6 MAF and 2 MAF.[29] Improvements to irrigation district system efficiency may achieve larger-scale water savings than farm-level upgrades, given their conveyance and distribution of large volumes of water.

From a system-scale perspective, some on-farm efficiency projects may not capture "wasted" water. Instead, reducing overwatering may amount to redirecting water that would otherwise run off into streams or percolate into groundwater, rather than generating substantial net increases in environmental water. However, agricultural water efficiency improvements may still be valuable because they can align the timing and quality of instream flows with environmental needs. For example, it may be possible to increase stream flows for salmon and trout passage significantly

[28] Cooley, H., J. Christian-Smith and P. Gleick. 2009. Sustaining California agriculture in an uncertain future. Pacific Institute: Oakland, California.
[29] Cooley, H., P. Gleick and R. Wilkinson. 2014. Agricultural water conservation and efficiency potential in California. Natural Resources Defense Council and Pacific Institute: New York, New York.


LEFT TO RIGHT The Klamath River in northern California © *Kevin Arnold;* U.S. Forest Service fire ecologist © *Chris Crisman*

during critical summer periods, when a little goes a long way.

3b. Likelihood of Implementation: High. There are proven models for investing in agricultural efficiency. For example, the Deschutes River Conservancy funds channel lining, piping and on-farm efficiency projects and dedicates 25 percent of the conserved water to instream flows.[30] Private equity funds that invest in agricultural efficiency improvements may represent opportunities to develop impact investing products that provide financial and environmental returns by dedicating a portion of the water savings to the environment. Despite these opportunities, landowner concerns about capital costs, the level of effort required and the fate of their water rights may arise as barriers to implementation of efficiency projects.

3c. Risk: Medium. For agricultural efficiency projects to benefit the environment, the saved water must not be at risk of immediate diversion by other users. This threat may be relatively low for irrigation districts that upgrade leaky conveyance infrastructure and directly control the saved water. However, farmers who leave conserved water instream risk losing the right to this water to the next downstream user, unless the water is sold to a downstream buyer or policies are put in place to permit the designation of instream flows as a beneficial use. While Section 1707 of California's Water Code allows water rights holders to adjust their water rights to protect instream flows, it is a costly and cumbersome process. State policy reform that explicitly protects water allocated for non-consumptive use is required to guarantee that investments in agricultural efficiency projects will actually benefit the environment.

Ensuring that water savings intended for the environment be used in this manner is another key risk. Past agricultural efficiency programs have suffered from saving water in one place, only to see it used on another field or to increase yields. To guard against this, it would be important to establish clear baselines against which to manage and set terms for the environmental allocation of saved water.

4. FOREST THINNING

Forests in California's Sierra Nevada, and elsewhere in the state, are overstocked with brush and small trees from decades of management focused on wildfire suppression and logging. This buildup of fuels not only creates a risk of high-severity wildfire, but it may also reduce water yield. Ecologically-based forest restoration, if conducted at a landscape scale, can provide multiple benefits for people and nature, including potentially increased runoff.

While the link between ecologically-based forest restoration and water yield requires further Sierra-based research, modeling suggests that such practices could be a cost-competitive way to increase water supplies compared to other sources of supplemental supply, such as imported or recycled water. Research suggests that if downstream utilities were to pay all the costs of mechanical forest thinning, the net cost would be between $215 and $1,135 per AF of additional water.[31] Because forest thinning reduces the risk of catastrophic wildfire, it benefits not only hydroelectric and water utilities, but also public land

[30] Deschutes River Conservancy. n.d. Water conservation program: permanently protected streamflow. http://www.deschutesriver.org/what-we-do/streamflow-restoration-programs/water-conservation/.

[31] Podolak, K., D. Edelson, S. Kruse, B. Aylward, M. Zimring and N. Wobbrock. 2015. Estimating the water supply benefits from forest restoration in the Northern Sierra Nevada. The Nature Conservancy: San Francisco, California.

LEFT TO RIGHT The Tehachapi range, a 270,000-acre ecological cooridor © *Ian Shive;* © *iStockphoto*

agencies and communities located in the wildland-urban interface. Therefore, partnerships and cost sharing in multi-benefit forest thinning projects could lower a utility's net cost of water procurement.

4a. Conservation Impact: Medium. Recent analysis by The Nature Conservancy focused on the Northern Sierra Nevada watersheds estimated the potential increase in average annual streamflow at up to 6 percent, depending on the watershed. In the Feather River watershed—the largest included in the analysis—this translates to between 97,000 and 285,000 AF of additional supply annually. Forest thinning likely has the greatest conservation impact in systems where a small increase in water yield would have significant ecological value. This mechanism also features significant environmental co-benefits—especially the avoided costs of catastrophic wildfire, including reservoir sedimentation, damage to power lines and roads, habitat loss and carbon emissions.

4b. Likelihood of Implementation: Medium. Most of California's overgrown forests are on US Forest Service land, which has a long history of wildfire exclusion. It is a goal of the Forest Service's Southwest Pacific Region to restore 500,000 acres of forestland in California each year for the next 15 to 20 years.[32] However, diversions of funds from forest restoration to firefighting and long timelines for action on federal lands have slowed the agency's progress. The low economic value of small diameter trees that are removed during thinning, coupled with the contraction of California's biomass energy industry, which cannot compete with lower-cost natural gas and renewable energy sources, represent further barriers to large-scale forest thinning. If passed, several policy initiatives, such as moving firefighting funds off-budget to free up funding for forest thinning and requiring the renewal of Power Purchase Agreements for bioenergy plants, may increase the likelihood of implementing this mechanism at a meaningful scale.

Investment by downstream utilities can further speed implementation by motivating the Forest Service to prioritize and direct resources for forest thinning to priority watersheds. For example, the Forest Service plans to invest $29M over 10 years to restore national forests in Colorado's Front Range in response to commitments by water providers (such as Denver Water) and other external partners to collectively invest $28M.

4c. Risk: Medium. Additional research is needed to test the hypothesis that ecologically-based forest restoration in the Sierra Nevada, if conducted at a landscape scale, may increase downstream water supply and, if so, under what conditions. There remains considerable uncertainty about the timing and amount of any increased streamflow. To mitigate these risks, scientific studies are underway in several Northern Sierra watersheds, to measure the water supply and ecological benefits of pilot forest-thinning projects.

A utility must have sufficient storage capacity, and the legal authority, to capture incremental flows for ecological and economic benefits. However, notwithstanding these uncertainties, ecologically-based forest restoration in the Sierra Nevada has multiple additional benefits for nature and people that independently support efforts to increase the pace and scale of such practices.

[32] United States Department of Agriculture, Forest Service. n.d. Ecological Restoration and partnerships—our California story. http://www.fs.usda.gov/detail/r5/landmanagement/?cid=stelprdb5412095.

LEFT TO RIGHT Ranchers Bill and Tom Parker on the Parker Ranch © *Ian Shive*; © *iStockphoto*

REDUCE WATER DEMAND

The market-based mechanisms for reducing water demand discussed in this section are primarily designed to advance the sustainable use of groundwater through policies implementing California's recently enacted law. The Sustainable Groundwater Management Act (SGMA) requires overdrafted basins to have sustainable groundwater management plans in place by 2022. Market-based approaches may be particularly attractive for local Groundwater Sustainability Agencies (GSAs)—newly-formed local agencies that will implement the new law—seeking alternatives to the more rigid process of adjudication of groundwater rights, for example, through taxing groundwater pumping or avoiding the conversion of rangelands to more water intensive uses.

A key step in winning wider acceptance of these mechanisms may be making public and philanthropic capital available to early adopters of environmentally friendly approaches. Some market-based tools can also generate revenue that GSAs could use to offset the short-term economic pain of reducing groundwater use, increase system flexibility and invest in alternate water supplies (e.g., recycled water). Net reductions in water demand on their own may or may not deliver substantial environmental benefit. As in the development of new water supplies discussed earlier, some portion of the water saved through reduced demand could be directed to ecological priorities.

5. PUMP TAX

A pump tax assigns a unit price per AF to groundwater extraction, increasing its cost and providing an incentive to reduce unsustainable pumping and aquifer drawdown. Pump tax revenues can then fund activities that further enhance the system's sustainability and flexibility, such as acquisition of land and water rights, agricultural fallowing and/or development of new supplies (e.g., recycled water). For example, groundwater users in Colorado's San Luis Valley agreed to tax themselves at a rate of $75 per AF to raise more than $5M annually with the goal of fallowing 40,000 acres of farmland by 2021.[33] While pump taxes are typically associated with groundwater, this approach may also be applied to surface water to incentivize a reduction in pumping or diversion (sometimes referred to as a "transfer tax").

Six California water districts have implemented pump taxes, often referred to as replenishment fees for their use in securing additional water supplies to replenish pumped groundwater. All of these districts are "special act districts" that the legislature created and authorized to regulate groundwater (prior to the 2014 law).[34] These taxes exhibit the range of options available, with pricing that varies by location and type of user (agricultural or urban), as well as fees that apply when specific pumping allocations are exceeded. In 2013–2014 fees ranged from $18.30/AF for agricultural users in the Santa Clara Valley Water District to $1,815/AF for any users under the Fox Canyon Groundwater Management Agency's control that exceeded their allocations.

A tax that starts small and gradually increases over time—at a rate that would bring aquifers into balance by the 2040 deadline set by the recent groundwater law—may be politically palatable to users, particularly if funds raised through the

[33] Carswell, C. 2013. Farmers agree to tax those who deplete groundwater. High Country News. http://www.hcn.org/issues/45.3/conservative-farmers-agree-to-tax-those-who-deplete-groundwater?b_start:int=0#body.
[34] Hanak et al., 2014.

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tax are reinvested in their groundwater basin to increase the resilience of their water supplies. For example, the Orange County Water District's replenishment fee was first set at $3 per AF in 1954, and steadily increased to $276 per AF in 2013, to cover the cost of groundwater recharge activities.[35]

5a. Conservation Impact: High. If designed correctly and implemented with the support of groundwater users, a pump tax can significantly reduce over-pumping, and by so doing, meet environmental objectives and move basins and water systems toward sustainability. Allocation of a portion of pump tax revenues for ecological initiatives, such as land fallowing and stream restoration, would yield additional environmental benefits.

The Orange County Water District and the Santa Clara Valley Water District have successfully used fees for groundwater use both to reduce pumping and to offset groundwater overdraft through investments in recycled and imported water to replenish aquifers. However, it is unclear whether this same reliance on imported water will be possible for GSAs interested in new pump taxes, given that water supplies are oversubscribed throughout the state.

5b. Likelihood of Implementation: Low. This mechanism may not be politically feasible at a significant scale in the immediate future because of opposition from current groundwater users. Key to its political palatability is the pump tax's ability to generate significant revenue that can be invested in the development of additional water supplies. A pump tax has the added benefit of not requiring clearly assigned groundwater rights, which may appeal to some groundwater users.

In the future, as groundwater reform takes hold and as GSAs and water users come to accept the need to reduce groundwater consumption or face state intervention, a pump tax may gain favor as an efficient and equitable tool that reinvests revenues in the system.

5c. Risk: Medium. Key to a successful pump tax is setting its level high enough to be an incentive to reduce groundwater use over the long term. For example, high commodity prices have undermined a pump tax in Colorado's San Luis Valley, as growers of high-value crops can afford to pay the tax and continue to pump unsustainably, in part by taking advantage of reductions in water use by others.[36] Payments for fallowing may also be too low to compete with highly profitable crops. These are concerns in areas of California, such as the Central Valley, where crops like almonds net returns of over $1,500 per acre annually.[37]

Those who oppose a pump tax may challenge the legality of specific aspects of the tax, slowing or derailing its implementation, as has happened in Colorado. [38]

6. GROUNDWATER CAP AND TRADE

Groundwater cap and trade has the potential to reduce over-pumping and bring aquifers back into balance

[35] Maven's Notebook. 2014. Assembly joint informational hearing on California's groundwater, part 2: Elements of successful groundwater management. http://mavensnotebook.com/2014/03/20/assembly-joint-informational-hearing-on-californias-groundwater-part-2-elements-of-successful-groundwater-management/.
[36] Carswell, 2013.
[37] Beccheti, T., S. Barry and S. Larson. 2013. Lost opportunity cost as a form of payments for ecosystem services. University of California, Agriculture and Natural Resources. 2013 ANR Statewide Conference. http://ucanr.edu/sites/statewideconference2013/files/165817.pdf.
[38] Carswell, 2013.


LEFT TO RIGHT Exploring the aquatic life of the Arroyo Seco River © *Mark Godfrey/TNC;* Carson Jeffres, Conducting research in the Shasta River. © *Bridget Besaw*

through the use of a hard cap on overall groundwater withdrawals and the issuance of tradable credits for allowable use. Those able to reduce their pumping relative to their allocated credits can sell their remaining credits to those in need of additional water. Where demand for water exceeds the available supply, the price will be bid up high enough to spur lower-value users to sell their water, which will yield a greater economic benefit than continuing to use it.

Cap and trade programs that allow non-landowners to participate present an opportunity for the purchase and retirement of pumping rights for ecological benefit. A similar opportunity may exist for land trusts that own property in basins governed by cap and trade, especially if they have historic groundwater use that is likely to entitle them to an allowance. Fees for the issuance of pumping allowances may also generate revenue for the district, a portion of which could be dedicated to ecological programs, such as the acquisition of instream flows.

6a. Conservation Impact: Medium. A cap on groundwater use creates a more certain outcome than other mechanisms such as a pump tax. However, the cap must be designed to achieve ecological outcomes. And while fees levied on pumping allowances may fund conservation activities, such as land acquisition, they have historically been limited to program administration and enforcement costs (which can be particularly high in the early years of implementation). [39]

Adherence to the cap is critical for this tool to function effectively, but such adherence has not always been the case. For example, the Texas legislature increased the cap for the Edwards Aquifer's credit-trading scheme to reflect historic use. Because of the high cap, the aquifer has not recovered and trading has been limited—water transactions comprised less than 8 percent of the total volume between 1998 and 2012.[40, 41]

In addition to a science-based cap, an effective groundwater cap and trade scheme requires a clear definition of groundwater rights so that they may be transferable among users. Without clear rights, there is no incentive for the reallocation of groundwater to the highest-value uses.[42] Strong opposition to the reallocation of groundwater rights can limit trading activity. This was the case in the early years of the Edwards Aquifer's cap and trade program (prior to the cap's adjustment in 2007).[43, 44] However, high prices for groundwater credits helped to overcome this barrier and spur trading.[45]

The creation of the cap and the setting of individual allowances usually generate intense controversy and sometimes, litigation. As a result, a number of credit-trading schemes in California—for example, in the Chino and Mojave basins—have been designed by the courts

[39] Colby, B.G. 2000. Cap-and-trade policy challenges: a tale of three markets. Land Economics 76(4): 638-358.
[40] Votteler, T. 2008. The Edwards Aquifer: ESA-driven management. Southwest Hydrology.
[41] Sugg, Z.P. 2013. Market-based groundwater allocation: considerations for Arizona from the Texas Edwards Aquifer cap and trade system. University of Arizona, School of Geography and Development: Tucson, Arizona.
[42] Enion, M.R. 2013. Allocating under water: reforming California's groundwater adjudications. Pritzker Environmental. UCLA School of Law, Emmett Center on Climate Change and the Environment: Los Angeles, California.
[43] Colby, 2000.
[44] Votteler, 2008.
[45] Colby, 2000.

Marble Fork of the Kaweah River © *Nick Hall*

as compromises, thereby limiting their effectiveness.[46, 47] Cap and trade systems designed to comply with SGMA, rather than those resulting from adjudication, may be free of many of these court-imposed restrictions and may therefore be better positioned to deliver sustainable use of groundwater resources through careful design.

6b. Likelihood of Implementation: Medium. Groundwater cap and trade may be more politically palatable than a pump tax, as has been the case with carbon-emissions trading in California. However, the requisite reductions in water available to users will likely face challenges from consumers accustomed to unlimited use. If experience to date is any indication, there is a considerable likelihood of litigation. Cap and trade therefore may be deployed in the long-term, as groundwater users in oversubscribed basins confront the inevitability of reduced pumping and recognize the opportunities for both financial gain and flexibility, compared to a command-and-control approach that merely reduces allowable pumping. The Fox Canyon Groundwater Management Agency has begun developing a cap and trade program in Ventura County, and the experience may influence future interest in this mechanism.

6c. Risk: Medium. Judging by the complex and politically charged nature of groundwater cap and trade programs enacted thus far in the western US, this mechanism would involve a moderate level of risk. Current groundwater users may drastically increase their pumping in anticipation that historical use will determine future allowances, although this risk can be mitigated through the careful design of allocation systems that rely on historical pumping trends and/or crop type and acreage. Non-compliance of participants who have sold their water rights is an additional risk.[48] There is also the potential for negative spatial and temporal effects (e.g., subsidence, water quality degradation) because trading may shift the location of pumping.

Where urban demand does not exist, the reallocation of water to higher-value uses may shift water to perennial crops such as orchards and vineyards. Such was the case in Australia in the 2000s, in response to the development of a cap and trade system, albeit for surface water.[49] These water-intensive crops cannot be fallowed without permanently taking them out of production, resulting in a hardening of demand that may limit flexibility—a potential unintended consequence of this approach.

7. AVOIDED RANGELAND CONVERSION

Every year, approximately 20,000 acres of California's rangelands are converted to uses requiring significantly more water, such as permanent crops (orchards, vineyards) or residential or commercial development. Unregulated access to groundwater, and high prices for commodities like almonds, have been key drivers of conversion in recent years. By increasing demand and reducing the amount of water available in a given system, the conversion of rangelands makes the water system less flexible and less capable of responding effectively to California's natural wet-dry cycles.

Ranchers who have suffered from financial stresses exacerbated by the recent drought and reduced public subsidies (e.g., Williamson Act

[46] Colby, 2000.
[47] Enion, 2013.
[48] Colby, 2000.
[49] Fargher, W. n.d. Responding to scarcity: lessons from Australian water markets in supporting agricultural productivity during drought. Australian Government, National Water Commission: Canberra, Australia.

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subvention funding) are increasingly likely to sell their lands for conversion to more economically viable uses, particularly when these lands have unrestricted access to groundwater. Conversion becomes more attractive to owners of rangelands as the average age of ranchers increases and younger generations show only limited interest in continuing in the family business.

Avoiding the conversion of rangelands to more water-intensive uses may be an attractive tool for forward-looking GSAs interested in limiting future groundwater use and maintaining system flexibility. Avoiding conversion may also appeal to existing water users whose secure access to water may decline if groundwater use in their basin increases.

Market-based tools may be a valuable means of preserving at-risk ranches to avoid conversion to more water-intensive uses. For example, mitigation fees levied on converted rangelands could generate revenue for conservation easements or other landowner incentives to limit rangeland conversion.

7a. Conservation Impact: Medium. Several California counties have recently implemented groundwater ordinances, effectively slowing the development of new groundwater wells and consequently, conversion of rangeland to high-value crops, like almonds. In most cases, these ordinances will sunset with the adoption of Groundwater Sustainability Plans. Avoided conversion may be a powerful tool for inclusion in these plans, particularly as the acreage of permanent crops is expected to increase over the next decade.[50] If successful, this mechanism could be a bridge toward a future in which sustainable water management reduces the threat of conversion by limiting access to water on lands at risk for conversion while improving the economics of ranching relative to perennials.

Acquisition of rangelands (in fee or easement) may be more cost-effective than supplemental supply strategies typically used by water districts, even where land prices have soared because of conversion pressure. For example, at $23,000 per acre—typical of rangelands fee acquisitions in the San Joaquin Valley—conservation easements and fee acquisition would cost roughly $220 per AF and $475 per AF of water saved, respectively, compared to approximately $500 per AF for imported water and $1,260 per AF for recycled water.[51, 52] However, fee and easement acquisitions are still expensive, and the significant amount of money it will take to execute them is likely to limit the scale at which this mechanism can be effectively deployed. Incentive payments that are temporary in nature, or policies requiring mitigation for rangeland conversion, may reach a broader audience and increase the impact of this mechanism. Focusing on regions where land prices are currently affordable but that are at risk for future conversion may also be a way to maximize the impact of this tool.

7b. Likelihood of Implementation: Low. Avoided rangeland conversion is likely a mechanism to be deployed in the long-term. GSAs are expected to first look to develop new water supplies, such as improving irrigation districts' efficiency and increasing groundwater recharge. Programs that reduce current water use,

[50] Crowder, V. 2015. California almonds—maybe money does grow on trees. Rabobank: Sonoma, California.
[51] American Society of Farm Managers and Rural Appraisers, California Chapter. 2015. 2014 trends in agricultural land and lease values, California & Nevada: Woodbridge, California.
[52] Based on investments made by the East Bay Municipal Utility District.

LEFT TO RIGHT Chinook salmon © *Kevin Arnold;* Vineyard © *iStockphoto*

such as San Luis Obispo County's requirement that any conversion to more water-intensive crops be offset by taking other land out of production, are also likely to be more attractive than avoiding future water use. But where these strategies do not bring groundwater basins into balance, avoided conversion can be an additional tool to help manage water demand, and it may be more palatable than regulatory approaches, such as a pump tax.

At its core, this mechanism links land and water use, a somewhat uncommon occurrence to date in California. Therefore, GSAs that include counties, which are accustomed to deploying land use controls, are likely to be more open to this approach than irrigation districts. However, this mechanism, by demonstrating a preference for rangelands over permanent crops, may encounter opposition from local agencies and landowners concerned about limits on their "right to farm."

7c. Risk: Low. Models of agricultural land conservation exist, making this a low-risk mechanism. However, temporary incentives run the risk of future conversion, as illustrated by Williamson Act non-renewals that decline further subsidies in exchange for the freedom to convert to non-agricultural land use. The creation of any incentive programs for avoiding rangeland conversion should include close engagement with ranchers to gain their support and maximize the potential uptake of such incentives.

8. GROUNDWATER MITIGATION

This mechanism uses a permitting system that requires groundwater mitigation for water users to be eligible for new groundwater withdrawals. Instream transfers, aquifer recharge, water conservation and storage releases are examples of mitigation activities. This mechanism appears to be untested in California, although it is similar to requirements to mitigate for physical projects' negative impacts on listed species and/or wetlands.

Groundwater mitigation could be designed in a number of ways, as evidenced by programs in Oregon and Washington. Water users could offset new pumping by implementing their own mitigation projects, purchasing credits from mitigation projects implemented by others (including conservation organizations and public agencies) or by making in-lieu payments to fund water agency projects. Alternatively, a cap on total withdrawals would make groundwater mitigation similar in some respects to cap and trade. There may also be opportunities to incorporate mitigation into the design of a pump tax or cap and trade scheme. This approach would be similar to allowing the purchase of carbon offsets as part of California's greenhouse-gas cap and trade program.

8a. Conservation Impact: Medium. Groundwater mitigation uses surface water conservation activities to offset negative impacts of groundwater extraction, so it is ideal for basins where conjunctive use is a priority.

Mitigation set above 1:1—as is often the case for habitat—could preserve or restore more water than is extracted from groundwater basins, further stretching this mechanism's environmental benefits. However, it is unclear whether areas with limited surface water supplies, such as the west side of the San Joaquin Valley, would be able to create mitigation projects to offset pumping even on a 1:1 basis. It is also unclear whether mitigation could apply to current groundwater users as a stand-alone tool, particularly in basins where both



LEFT TO RIGHT Salmon make a run up Battle Creek to their spawning grounds © *Ian Shive;* Independence Lake © *Ian Shive;* Carson Jeffres conducting research in the Shasta River © *Bridget Besaw*

surface and groundwater resources are oversubscribed.

The effectiveness of groundwater mitigation that has been implemented in the Pacific Northwest is also uncertain. Washington is in the early stages of development in several basins, and there appear to be some concerns with the Deschutes River Basin's groundwater mitigation program. In that basin mitigation is required by policy and takes place only in the summer in order to augment flows during the irrigation season. However, groundwater withdrawals during the spring and fall appear to have depleted stream flows necessary for fish.[53] Furthermore, only instream leases and transfers have been used for mitigation credits in Oregon, so the effectiveness of recharge, storage releases and conservation projects has not been tested there.[54]

8b. Likelihood of Implementation: Low. This mechanism requires additional exploration to determine its likelihood of implementation, since it does not appear to have been implemented in California. However, given the opposition to caps on total groundwater withdrawals, this mechanism will likely face political obstacles.

8c. Risk: Medium. Because groundwater mitigation does not appear to have been tried in California, some degree of performance risk exists. Negative environmental impacts may occur if the timing and/or geography of pumping and mitigation do not align, as in a situation involving year-round pumping with mitigation only during the irrigation season.

9. ALL-IN AUCTION

An all-in auction can alleviate the short-term negative economic impacts of reallocating and reducing groundwater pumping rights, without injuring current water rights holders. All-in-auctions may also apply to surface water—the key requirement is a clear definition of water rights. All water rights (surface and/or ground) in a given area must be offered in an auction.[55] Rights holders can then opt to "buy back" all of their rights at the market price (for a net cost of zero[56]), or they can purchase more or fewer rights than their initial allocation, with compensation for forgone rights. In allowing existing water users the option to retain their allocated water rights, an all-in auction ensures that all participants will be at least as well off as they were before the auction.

While an all-in auction does not overcome challenges in the initial assignment of water rights, it facilitates the reallocation of rights or flows to their highest and best use. By providing incentives to participate and ask fair prices, all-in auctions may help jump-start trading activity.[57] All-in auctions seek to ensure sufficient participation by making rights automatically for sale, and they aim to minimize sellers' overpricing by ensuring that rights go to the highest bidders. As with groundwater cap and trade, water rights owners with conservation priorities may participate as buyers and/or sellers of water rights.

9a. Conservation Impact: Medium. All-in-auctions are advocated by academics, but they have not yet been

[53] WaterWatch. 2011. Background on HB2867. http://waterwatch.org/wp-content/uploads/2011/07/background-on-hb-2867.htm.
[54] Deschutes River Conservancy. n.d. Deschutes groundwater mitigation program: a brief introduction. http://www.deschutesriver.org/Deschutes-Groundwater-Mitigation-Program.pdf.
[55] Zetland, D. 2012. Using auctions to share scarce water. Solutions Journal 3(2): 34-37.
[56] Given that water rights holders would be buying these rights from themselves.
[57] Zetland, D. 2013. All-in-auctions for water. Journal of Environmental Management 115: 78-86.

Tomato farm irrigation system © *iStockphoto*

tested on the ground. Generally speaking, auctions have advantages over bilateral trades because they move goods from sellers who value them least to buyers who value them most, quickly and with reasonably low transactions costs.[58, 59] However, there is a high degree of uncertainty regarding how this mechanism will actually perform.

While an all-in auction would reallocate water rights, it would not on its own solve the problem of the over-allocation of rights. As with groundwater cap and trade, the environmental benefits of this approach are tightly linked to a cap on total water use. Alternatively, the reallocation of water rights could direct a portion to environmental interests, who could then participate as buyers and/or sellers. Otherwise, participants willing to pay high prices for water (e.g., owners of orchards or vineyards) will likely outbid environmental interests.

9b. Likelihood of Implementation: Low. All mechanisms that seek to regulate groundwater are likely to be met with resistance, despite the new law requiring groundwater management. Theoretically, all-in-auctions could avoid court battles by allowing current rights holders to buy back their water at no cost.[60] However, any requirement that existing surface water rights holders participate in an all-in auction—even if it would guarantee their historical rights—would likely be met with strong opposition and possibly with legal challenges.

All-in auctions face the additional hurdle of not yet having been implemented, invoking concerns about performance risk. All-in auctions may make it difficult for farmers to plan for annual or multi-year crop planting cycles, given the uncertainty associated with purchasing as opposed to selling water. Water users may view all-in auctions with distrust and skepticism, a risk for any type of auction, given their complexity. It is likely most appropriate to pilot an all-in auction in a groundwater basin where the GSA is open to an innovative approach to achieving sustainability.

9c. Risk: High. All-in auctions carry some of the same risks as groundwater cap and trade—subsidence, water quality degradation, increased pumping in anticipation of allocations pegged to historical use, hardening of demand and non-compliance. All-in auctions may be most appropriate in small areas to minimize negative impacts on third parties (e.g., reductions in the quantity or quality of groundwater available for neighboring users), maximize participation and preserve hydrological integrity.[61]

Because an all-in auction has not been tested, uncertainty regarding how it will actually perform creates an additional degree of execution risk. As mentioned previously, applying this mechanism to surface water use would involve a high risk of litigation.

RE-OPERATE EXISTING WATER SUPPLY SYSTEMS

Mechanisms to re-operate existing water supply systems seek to increase the environmental benefit delivered without fundamentally altering water supply or demand. This category includes approaches to acquiring and/or using water rights for environmental benefit, such as instream flows or delivery to wetlands, as well as offsetting consumptive water use through water neutrality investments.

While these mechanisms have been successful elsewhere, their limited use

[58] Zetland, 2013.
[59] Disegni, D. and D. Zetland. 2009. Markets for water: all-in-auctions. Society for Institutional and Organizational Economics.
[60] Zetland, 2013.
[61] Zetland, 2012.

LEFT TO RIGHT The Shasta River shown flowing through The Nature Conservancy's Shasta Big Springs Ranch below Mount Shasta © *Bridget Besaw;* Skunk Creek in Angelo Coast Range Reserve. © *Ian Shive*

in California presents an opportunity to apply them on a larger scale, improving both their effectiveness and efficiency in securing environmental water. Further demonstrations of proof of concept may build momentum for reforms to relieve some of the institutional barriers to a more active market for environmental water flows and rights.

10. ACQUISITION

Transactions to secure environmental water in California have been limited.[62] Only one formal water trust, the Scott River Water Trust in the Klamath Basin, has operated since 2007, although other organizations, including The Nature Conservancy, also conduct environmental water transactions. The availability of over $200M in Water Bond monies for projects that enhance stream flow creates a near-term opportunity to scale up environmental water transactions. However, there is little evidence from the first round of funding that the Water Bond will be used to acquire water directly.

Most environmental water transactions in California to date have relied on temporary leases negotiated directly with landowners. Reverse auctions are one tool to facilitate efficient acquisition of multiple water rights or easements by soliciting bids from multiple landowners. For example, The Nature Conservancy's BirdReturns programs uses reverse auctions to identify the most opportune fields for providing habitat for migrating waterfowl, in terms of both price and location.[63]

Water leasing programs that target irrigation districts—an approach pursued by the Deschutes River Conservancy in Oregon—may provide access to greater quantities of water.[64] For example, small irrigation districts in California may have surplus water but lack the resources to sell it, highlighting the potential to collaborate with a group of districts to make it easy and affordable to sell water for the environment.

Control over water rights—through the acquisition of water rights or land—makes it possible to demonstrate new models for operating water for a combination of ecological and financial gain. For example, in addition to providing instream flows along key reaches of ecological importance, downstream transfers may generate income. Sale-leasebacks, involving the purchase of water rights that are then leased to the seller for consumptive use during certain seasons or conditions, represent another revenue-generating approach. Income raised in this way could then be reinvested locally to mitigate any potential economic impacts of water re-operation or to advance other projects that have ecological benefits. As with agricultural efficiency, there may be opportunities to use private capital to secure water for both ecological and consumptive users, through tools such as Water Sharing Investment Partnerships, which secure and allocate water rights for environmental and financial benefit.[65]

In addition to considering new investments, there are opportunities for land trusts to examine their existing properties in California for opportunities to re-operate the appurtenant water rights to maximize ecological benefit.

10a. Conservation Impact: High. Scaling up environmental water transactions may be most appropriate

[62] This category focuses on environmental water acquisitions that occurred outside of the Environmental Water Account, made by fisheries agencies.
[63] For more information see: Robbins, J. 2014. Paying farmers to welcome birds. The New York Times. https://www.nytimes.com/2014/04/15/science/paying-farmers-to-welcome-birds.html?_r=0.
[64] King, M.A. 2004. Getting our feet wet: an introduction to water trusts. Harvard Environmental Law Review 28: 495-534.
[65] Richter, B, G. Boccaletti, L. Ferstandig, E. Powell and C. Wright. 2016. Water share: Using water markets and impact investment to drive sustainability. The Nature Conservancy: Washington, D.C.

LEFT TO RIGHT © *iStockphoto* Manufacturing of drinking water © *iStockphoto*

in small systems, where a little additional water can have a significant ecological benefit. Acquisition of land with water rights can provide co-benefits, such as conservation of key habitats and landscape connectivity.

Beyond the direct environmental benefits, water rights ownership can increase influence with public water agencies. This may create opportunities to advance additional, longer-term strategies, such as implementation of groundwater reform, that reduce water demand.

Given the limited scope of environmental water transactions in California, near-term "wins" that demonstrate proof of concept would both legitimize market-based approaches and ensure the longevity of public funding in the face of uncertain long-term political support.

10b. Likelihood of Implementation: Medium. Despite some success, acquisition of environmental water in California is a slow, somewhat burdensome process. Because California's system of water rights is not fully adjudicated, it is time-intensive and difficult to ensure that real water is involved in environmental water transactions—including via instream flow transfers under Section 1707.

Limited public funding may also be a barrier. Some stakeholders may oppose the use of public money to acquire temporary water rights, preferring permanence, and they may make it difficult to access Water Bond monies for acquisition projects.

Despite the barriers, there is currently a fair amount of interest in expanding the use of environmental water transactions. Coastal stream systems may present opportunities because they are not connected to the Delta, where regulatory complexities and a history of conflict impede progress. Small-scale success may ultimately build the capacity for more complex deals in the future. Demonstrating proofs of concept may help bring about policy change, as happened in Oregon and Washington.[66, 67, 68]

10c. Risk: Medium. The current regulatory program does not prevent another party from diverting water left instream, the primary risk in acquiring environmental flows. As a result, there is no way to trace water between the last point of control and the point of use. Acquisition therefore works best in areas where landowners will cooperate to reduce this risk. Landowner cooperation also helps counter the arguments of opponents who see acquisition as diverting water away from agriculture. The acquisition of land with water rights poses a considerably lower risk, although there may be community opposition to fallowing of agricultural lands.

11. WATER NEUTRALITY

Water neutrality refers to offsetting water used in industrial processes through investment in projects like instream flow conservation or forest restoration. Water neutrality has had the most traction in developing countries that lack advanced environmental regulations, where corporations reduce operational risk and increase brand recognition. Although California's regulatory environment differs dramatically, there may be opportunities for partnerships with California-based corporate leaders in water sustainability.

Although they do not constitute water neutrality *per se*, there may be opportunities to partner with major agricultural producers and/or investors both to reduce operational risk and

[66] The fact that Oregon and Washington have statutes protecting instream flow rights has been central to the functioning of water trusts in both states.
[67] King, 2004.
[68] Scarborough, B. 2010. Environmental water markets: restoring streams through trade. PERC: Bozeman, Montana.

Nimbus Dam © *iStockphoto*

to improve environmental outcomes. A number of large food and beverage companies, including General Mills, Inc., Coca-Cola, Driscoll's, MillerCoors and Nestle have expressed concern about water supply availability for their California facilities through formation of the California Water Action Collaborative (CWAC).[69]

California's perennial crops face substantial operational risk given that they cannot be fallowed when water is scarce. Extensive pumping in drought years may create substantial long-term operational risk for growers and the suppliers that rely on them. In some areas of the San Joaquin Valley, groundwater levels dropped more than 50 feet between 2013 and 2016, increasing the risk and cost of accessing water deeper in the aquifer.[70] Future implementation of groundwater reform creates additional uncertainty over water supplies, as the allocation of pumping rights at levels below current use is likely.

Corporate investment in groundwater banks could reduce both the uncertainty about water supply availability and the rate of groundwater depletion, while providing additional environmental benefits. Paramount Farms, the state's largest almond grower, has already demonstrated this approach by taking over ownership of the Kern Water Bank. This opportunity may extend to large financial interests, such as banks and investment funds (e.g., TIAA, CREF) that have become major players in California agriculture.[71]

11a. Conservation Impact: Medium. This mechanism would augment supplies and reduce groundwater depletion in advance of new groundwater reform regulations. Environmental benefits could range from increased surface-groundwater connectivity to the provision of instream flows. These benefits could be substantial in watersheds where a small addition of environmental water would go a long way. A partnership along the more traditional lines of water neutrality could attract investors whose water use is elsewhere, effectively achieving a positive water balance.

Since agriculture uses roughly 80 percent of California's water, a successful pilot project with a large corporate actor could resonate with others and lead to additional projects.

11b. Likelihood of Implementation: Low. The appetite for corporate investment in groundwater banking or water neutrality is not clear at this point. Investors, agricultural producers and large landowners may not feel the immediate risk or be willing to consider the longer-term timeline over which water benefits will be realized. The agricultural community has been hit hard by the recent drought, and taking on extra investment may not be a welcome idea if the benefits are not perceived as real. However, CWAC highlights a subset of companies that may be particularly receptive to investment.

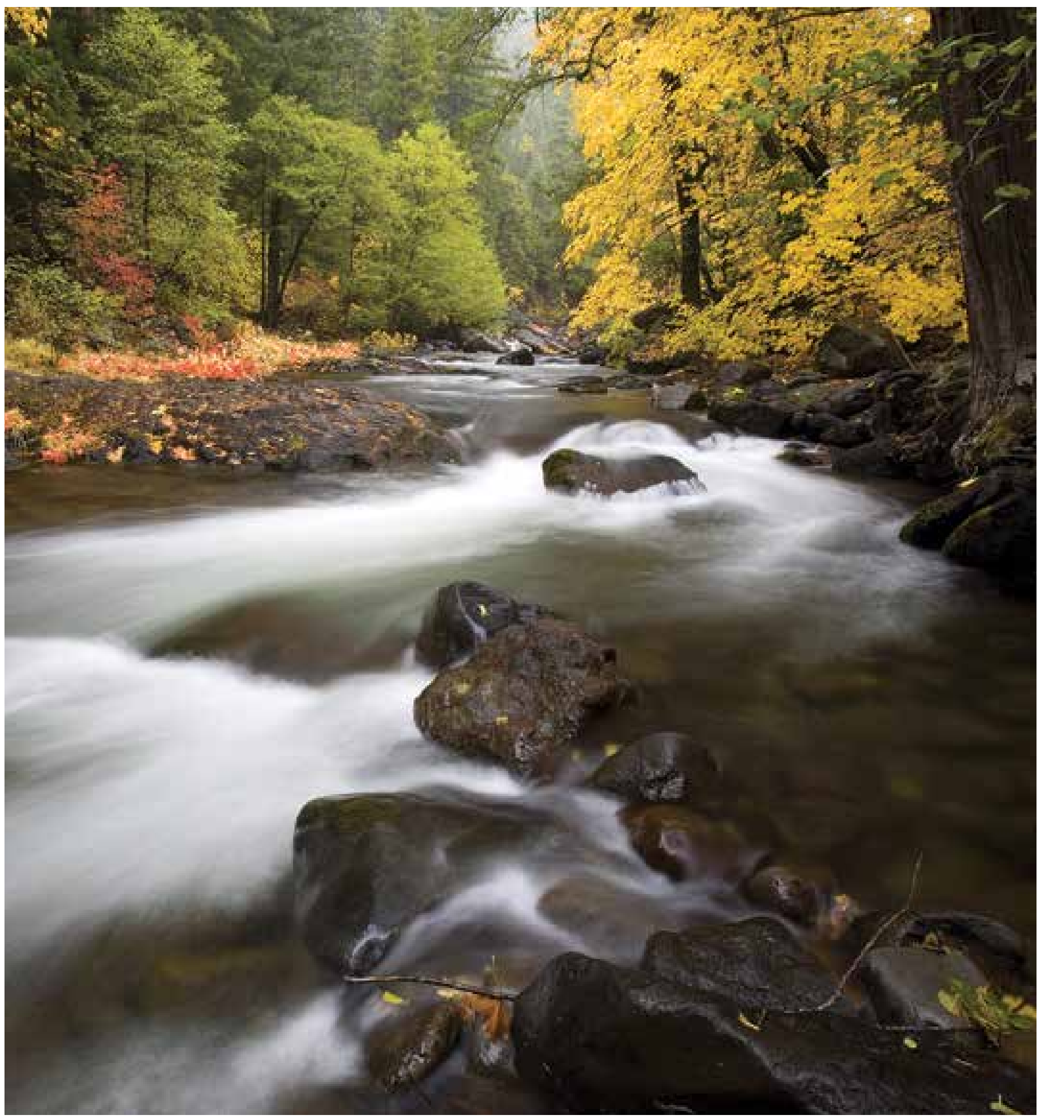
11c. Risk: Low. This is largely a low-risk mechanism. There have been successful corporate partnerships and water neutrality initiatives elsewhere. There may be some degree of reputational risk over concerns about the privatization of groundwater. For example, Paramount Farms' purchase of a majority interest in the Kern Water Bank was met with public outcry and fear of private ownership of groundwater. However, this water bank has proved successful at delivering both water supply and environmental benefits.

[69] California Water Action Collaborative. n.d. Members. http://cawateraction.org/members/.
[70] California Department of Water Resources. 2016. Groundwater Information Center Interactive Map Application. Spring 2013 to spring 2016 change. https://gis.water.ca.gov/app/gicima/.
[71] Philpott, T. 2015. California goes nuts. Mother Jones. http://www.motherjones.com/environment/2015/01/california-drought-almonds-water-use.

Leveraging Markets to Benefit the Environment

California's water system is over-allocated, but recent policy changes—the Water Bond and groundwater regulation—present opportunities to alter this course. While water markets offer some promise, they are not guaranteed to benefit the environment, given that they cater to the highest bidders. Market-based mechanisms, however, present an additional suite of opportunities to secure water for the environment. Some have the added promise of delivering financial returns or paving the way for policy change.

This paper evaluated a range of market-based mechanisms—that seek to develop new supply, reduce water demand and re-operate existing water supply systems—based on potential conservation impact, likelihood of implementation and associated risk level. No one mechanism delivers on all of these fronts or represents an easy path forward. However, it is the hope that conservation practitioners, project developers, agency leaders and policy makers will use the information presented in this paper when seeking to develop initiatives to alleviate the pressure on agricultural, urban and environmental water users.

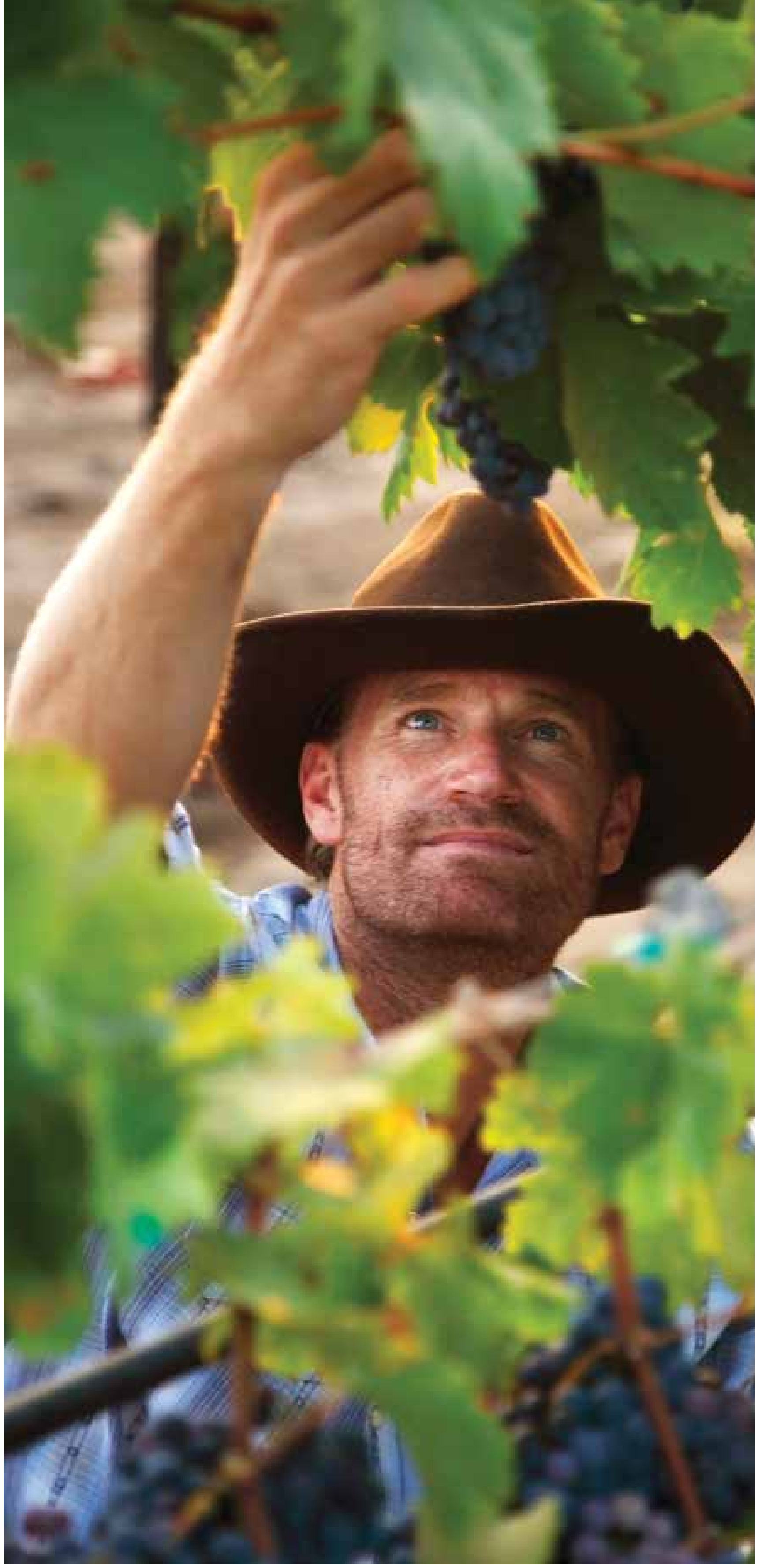


Autumn view of rushing water at Deer Creek © *Ian Shive*

IMAGES BACK COVER CLOCKWISE Independence Lake © *Ian Shive;* Vintner picking grapes in a vineyard © *iStockphoto;* Great Blue Heron © *Gary S. Meredith;* A bullfrog swimming in a vernal pool at Dye Creek Preserve © *Ian Shive;* Denny Ranch, a TNC purchased conservation easement, working cattle ranch and largest private stand of blue oaks in California © *Ian Shive;* A strawberry field at the Azevedo Ranch © *Kiliii Yuyan*

APPENDIX A. EXPERTS INTERVIEWED

INTERVIEWEE	POSITION	ORGANIZATION
Amy Campbell	Project Associate, Shasta Big Springs	The Nature Conservancy of California
Amy Hoss	Shasta River Project Director	The Nature Conservancy of California
Andrew Purkey	Director, Western Water Programs	National Fish and Wildlife Foundation
Bill Phillimore	Executive Vice President	Paramount Farms
Bonnie Colby	Professor, Agricultural & Resource Economics	University of Arizona
Barton "Buzz" Thompson, Jr.	Professor, Natural Resources Law Director, Stanford Woods Institute for the Environment	Stanford University
Claire Thorp	Assistant Director, Western Partnership Office	National Fish and Wildlife Foundation
Dan Dooley	Senior Vice President for External Relations	University of California, Office of the President
Dan Wendell	Senior Water Specialist	The Nature Conservancy of California
David Guy	President	Northern California Water Association
David Orth	General Manager	Kings River Conservation District
David Yardas	Program Director, Southwest & Interior Water Programs	National Fish and Wildlife Foundation
Debbie Wordham	Associate Director, Water Law & Policy	The Nature Conservancy of California
Felicia Marcus	Board Chair	State Water Resources Control Board
Grant Davids	President/Principal Engineer	Davids Engineering
Jay Lund	Professor	University of California at Davis
Jay Ziegler	Director, External Affairs	The Nature Conservancy of California
Jeanette Howard	Scientist	The Nature Conservancy of California
Jeanne Brantigan	Water Resources Specialist	The Nature Conservancy of California
Martha Davis	Executive Manager of Policy Development	Inland Empire Utilities Agency
Maurice Hall	Science and Engineering Lead, Water Program	The Nature Conservancy of California
Michael A.M. Lauffer	Chief Counsel	State Water Resources Control Board
Mike Deas	Principal/Owner	Watercourse Engineering, Inc.
Randy Fiorini	Chair	Delta Stewardship Council
Richard Frank	Director, California Environmental Law and Policy Center	University of California at Davis
Richard Roos Collins	Attorney	Water and Power Law Group, PC
Roger Patterson	Assistant General Manager, Strategic Water Initiatives	The Metropolitan Water District of Southern California
Steve Cann	Senior Attorney	The Nature Conservancy of Colorado
Taylor Hawes	Colorado River Program Director	The Nature Conservancy of Colorado
Tim Quinn	Executive Director	Association of California Water Agencies
Tom Hicks	Attorney	Tom Hicks Attorney at Law
Thomas Howard	Executive Director	State Water Resources Control Board



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