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Policy Note: Water Markets as Adaptation to Climate Change in the Western United States

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1. Introduction

Many parts of the world, including the semi-arid western United States, depend on snowmelt for their water supply. Climate change models predict greater variability in water supplies in those regions with more long-term droughts, followed by possible periods of intense precipitation. Higher temperatures will reduce the snowpack earlier in the spring, shifting annual surface water flows (Barnett *et al.* 2005). "By 2050, the spring stream flow maximum will come about one month earlier in the year. There is not enough reservoir storage capacity over most of the west to handle this shift in maximum runoff and so most of the early water will be passed to the oceans" (Barnett *et al.* 2005). Climate change also could affect the hydrologic cycle via changes in precipitation patterns, evapotranspiration, as well as soil temperature and moisture (Rosenburg *et al.* 1999; Ranjan *et al.* 2006).

The greatest changes in the hydrological cycle due to warming are predicted to be in snow-dominated basins of mid to higher latitudes, due to changes in snowpack (Rosenburg *et al.* 1999; Barnett *et al.* 2005). According to Barnett *et al.* (2005), the Columbia, Sacramento and San Joaquin, and Colorado basins will have periods of water supply at levels far less than current demand. All of these basins already have competing demands for water, due to mandated environmental protections for endangered fish species and related ecosystems, expanding high-valued agriculture, and rapidly growing urban population centers. Moreover, these river systems could become more saline if freshwater snowmelt flows are reduced with less leaching of evaporative-based mineral build up.

Warmer temperatures could lead to greater irrigation demand as crops grow more rapidly earlier. Warmer temperatures also could spark greater recreational and environmental demands for ecosystem and fish stock protection, and higher temperatures and less precipitation are likely to result in greater urban demands for water. Higher temperatures raise the benefits of irrigated green spaces, parks, and urban residential landscapes, and in the absence of natural precipitation, needed water must be supplied from urban water utilities (Ranjan *et al.* 2006; Treidel *et al.* 2012). Higher supplemental water demand explains why Las Vegas, Phoenix, and Tucson, all desert cities, have far greater per-capita fresh water use than do wetter, cooler cities, such as Seattle, Philadelphia, and Atlanta. Manufacturing and other urban economic activities also rely upon access to artificially supplied water. If climate change promotes more water demand for irrigation, environmental, and urban use, while supplies become more limited, how is water to be reallocated?

Unusually, the western United States has an established water rights system that could be the basis for an expansive use of water markets to respond to new supply and demand conditions associated with climate change. In most other parts of the world, however, private (or any other) water rights are nonexistent with the state effectively owning the water. In these cases, extensive private water trades across sectors and regions to smoothly and routinely move water to where it is valued most, to encourage conservation through price signals, and to motivate effective new storage investments, all of which are possible in the western United States, would not be feasible elsewhere under current institutional structures. The question is whether or not western United States will take advantage of this opportunity.

This note proceeds as follows: It begins by outlining the advantages of water markets and secures water rights in climate-change adaptation, relative to the alternative of state-imposed mandates for supply and demand adjustments. The next section examines common political responses to water-supply augmentation and demand restrictions and points out why they are inferior to market responses. Section 3 briefly examines the California reaction to drought which was dominantly command-and-control, not market-based, which could have been feasible. Section 4 presents data on the status of water markets in the western U.S. Section 5 discusses some impediments to water rights and water markets. Section 6 presents some policy recommendations.

2. The Advantages of Water Markets

Much of the focus of adaptation to climate change is on the role of government in mitigation. To be sure, there will be a critical role for governmental processes in defining property rights, providing trading platforms, enforcing contracts, and providing information on weather patterns, health effects, and so forth, but the emphasis here is on private actions taken by individuals and organizations to respond to signals regarding climate change via markets. Markets are apt to be far more flexible, timely, and efficient in reacting to climate change. Markets can respond to exogenous shifts in water supply and demand due to climate change because market agents are residual claimants to the benefits and costs of taking such actions incrementally in ways that no government official does. While market agents are rewarded for detecting and reacting to perceived shifts in costs and benefits, politicians and agency officials, in contrast, are much more cautious, necessarily responding to influential interest groups that might seek to dampen market signals or to use the power of the state to redirect net benefits to those constituents in order to maintain political positions. Governments and associated interest groups are not competitive in a manner that markets can be. Accordingly, there is likely to be far more *status quo* emphasis and lumpy reactions in government policies than in market processes.

3. Political Responses for Water Supply Augmentation and Demand Control

3.1. *Supply augmentation*

One response to greater freshwater scarcity is supply augmentation. Supply growth is popular among politicians and bureaucratic agency officials because it does not require behavioral change by targeted constituents (they get the water they demand without major price changes) and it spreads the costs across general taxpayers. For the general society, however, a critical problem for all supply-augmentation projects is a lack of information on tradeoffs — the costs and benefits of the various supply options. How valuable is new water for crop irrigation, urban consumption, urban landscape, and environmental and recreational uses? And what are the costs of new surface or subsurface storage? In terms of the former, agency officials rely upon lobby groups and consultants, who are not disinterested, and in terms of the latter, they rely upon the bidding process that may or may not be competitive or free of corruption. Further, these costs are unlikely to reflect the opportunity costs of inappropriate new supply and demand policies that are based on incomplete or biased information. Recall also that tenured agency officials do not bear direct costs in their wrong water supply/demand decisions nor do they capture a portion of the social gains from correct decisions. Economists have long discussed market failure, but they have directed far less attention to government failure, and when a key resource such as freshwater is at stake, the social costs could be very high.

In contrast, with reasonably competitive market, agents have incentives to search out for new information about potential water demand and supply conditions and to react in a manner that increases their net gains. They have a real stake in the process and outcome. Further, greater water market trading and associated water pricing encourage greater conservation, freeing up new supplies and reducing demand, factors not usually considered in agency-based new supply-augmentation projects. Some might be concerned that the size of the projects could exceed what markets could provide, but private financing routinely covers massive new buildings in major cities, and there is no reason why that could not be the case with water supply infrastructure, absent the crowding out of government financing. Further, Leonard and Libecap (2018) show that private arrangements financed early private irrigation in the U.S. West, prior to the takeover by the federal Reclamation Service after 1920.

Constructing new dams or even augmenting existing ones is very controversial due to conflicting environmental considerations and to possible impacts on other third parties. See, for example, the ongoing controversy to raise the height of Shasta Dam on the Sacramento by 18 ½ ft to provide for more storage and longer downstream flows (Lochhead 2018). This suggests that governments will under-provide socially beneficial surface storage due to the resistance of critical constituents. Greater groundwater recharge is an alternative that will be more critical as precipitation becomes more variable (Ojha *et al.* 2015). There is, however, no systematic inventory of where holding ponds might be developed, hydrological conductivity, and of the property rights to the land and surface water being stored (Ojha *et al.* 2015; Woodruff 2016). Most groundwater is accessed as a common-pool resource with associated rapid overdraft (Ayres *et al.* 2018). Another supply augmentation approach is desalinization of ocean water. It is costly to build and to operate desalinization plants, and the environmental costs are unknown. The Carlsbad plant north of San Diego produces water for \$2,300/acre foot (acre foot = 326,000 gallons), about twice the price San Diego is currently paying for imported water (Cooley and Phurisamban 2016).

3.2. *Water demand management*

If climate change promotes more water demand as seems likely for irrigation, environmental, and urban use, while supplies become more limited, how is water to be reallocated? How are incentives to be captured to moderate demand? As above, politicians and staff of water supply organizations prefer to rely on demand control mandates, rather than on pricing to constrain demand. It appears to be equitable, but it is not. Poorer families consume less water than do richer ones and mandated cut backs of, say 20%, impact the former more in terms of basic human needs than the latter. Additionally, such mandates convey that action is being taken by political leaders and enforcement relies upon neighbors monitoring neighbors. In the short run, such mandates may effectively reduce consumption. By requiring uniform cutbacks, as is common, there is no reflection of differential values of water use. Very valuable water uses are constrained in the same manner as are less-valuable ones. Society bears real costs, but politicians do not, particularly in the short run that coincides with most political cycles.

The alternative is to more aggressively adopt water pricing to moderate demand and to encourage conservation. Increasing block rate or tier pricing is a known mechanism for encouraging conservation. With block-rate pricing, basic human consumption is priced low, but as household per-capita use rises, as is particularly the case as incomes rise, it crosses new thresholds and prices jump accordingly. To illustrate, in 2010, the average monthly cost for a single family household consuming 7,480 gallons in Tucson, Arizona was $28.08. If the same household's water consumption tripled to 22,440 gallons, the cost jumped 4½ times to $155.53, following the tiered structure of pricing. In contrast, in Phoenix, the same household consuming 7,480 gallons paid $8.16, $19.60, or $21.64, depending on the season and uniform pricing. Even if household consumption rose to 22,440 gallons, prices increased only to $84.40, $96.64, or $91.16, depending on the season. The Tucson charge was 61% higher than the highest Phoenix price. In 2010, the average Phoenix resident consumed 123 gallons of water per day, whereas the average residential consumption in Tucson was 102 gallons (www.tucsonsentinalcom/local/report/050214_water/tucson-water-rates-higher-than-phx-usage-lower-here).

As noted earlier, flat rates are politically popular, but they are not equitable in the face of income elasticity of demand estimates, and they are not effective in encouraging water use adjustments unless the entire rate is shifted significantly. Although 66–80% of California's water providers use some type of increasing block rate, Proposition 218, enacted in 1996, and emphasized in *Capistrano Taxpayers Association, Inc. v. City of San Juan Capistrano* in 2015, requires that water pricing be closely aligned to cost of service. As a result, increasing-block rate pricing remains uncertain and limited in California, and it is unclear how intensely state politicians and water supply agency officials will seek revision of this ruling. If used more broadly, tier pricing would allow individuals to decide on water use and reduce the role for regulatory mandates, such as those emphasized during the California drought.

4. California's Response to Drought

The recent drought in California that may foreshadow future droughts, greater water trading to generate information, and to mitigate and reallocate demand was not the primary policy response. As shown by Jezdimirovic and Hanak (2016), formal water trading in California was comparatively flat during the early part of the drought. The authors point out why: "Despite potential benefits, the approval process for trading water in California continues to be lengthy, cumbersome, and lacking in transparency. This is an especially big concern during droughts, when speed is important" (http://www.ppic.org/blog/state-water-market-needs-reform/n.p.).

Not only is the regulatory approval process slow, but senior water rights holders, who normally would have sufficient water for trading, found their allocations cut by the California Water Resources Control Board. When it is difficult to demonstrate that the water being sold is legally held by the irrigator, it understandably becomes harder to write a contract with a potential buyer. There likely were more informal water trades, particularly among irrigators in a particular watershed, where the gains from trade would have been smaller, but less controversial.

Most of California's drought response was via government directives. In a series of Executive Orders in 2014, 2015, and 2016, Governor Brown directed the State Water Resources Control Board, the primary regulatory agency, to implement mandatory water reductions in urban usage by 25% (www.water.ca.gov/wateruseefficiency/conservation/docs/EO_B-37-16_Report.pdf). Whether repeated state mandated restrictions are effective long-term responses to drought remains to be seen.

Shifting to California agriculture, in June 2015, some 100 of California's senior water rights holders in the Central Valley had their water uses restricted by state regulators, and approximately 200 farmers in the Sacramento Delta region agreed to 25% reductions in water access in order to avoid stricter state controls (www.latimes.com/local/lanow/la-me-ln-drought-water-rights-20150612-story.html). Fallowing of farm land was expected to rise by 620,000 acres, affecting local communities and agricultural labor demand that largely includes Hispanic farmworkers, among the poorest people in the state. Finally, state regulators are considering minimum streamflow regulations at the behest of various environmental groups to address declining stream levels (https://www.wildlife.ca.gov/Conservation/Watersheds/Instream-Flowclaims). Such mandates, however, would most impair the senior water rights holders, who otherwise would receive their full allocations prior to diversion claims from junior rights holders. Historically, senior rights holders have had the most secure property rights and hence have been the source of most water sales or long-term trades. Weakening their water rights would raise another impediment to the operation and expansion of water markets. Alternatively, environmental water could be purchased in existing water markets if it were so important and advocates were willing to pay for it, rather than to use the power of the state to redistribute it with little cost to themselves.

5. What is the Status of Water Markets?

There is no central authority that monitors and records water transfers across the states, and within states coverage is highly variable. Nevertheless, it is possible to get a sense of the extent of water market activity in the West. Table 1 provides a summary of water transactions by volume, value, for the year 2015, and number of transactions for the period 1987–2005.

California, as the nation's largest consumer of water, has the largest volume and value of trading. This situation reflects the enormous potential gains from moving water from historical uses in some, low-valued agriculture to the state's fast-growing cities and expanding-technology centers as well as concentration of water supplies in the north and demand in the south. Arizona has just over half as much volume as California due to the transfer of water from groundwater basins to usage in urban areas such as Phoenix and Tucson. Although the volumetric numbers reported in Table 1 seem large, they is a very small portion of total state usage. For example, California in 2010 consumed 42 million AF of water, the latest year

Table 1. Water Market Activity, Western United States

State	2015 Volume (AF)*	2015 Value ($)*	Number of Transactions 1987–2005**
Arizona	484,000	69,000,000	171
California	793,000	560,000,000	436
Colorado	73,000	79,000,000	1,690
Idaho	300,000	8,000,000	103
Montana	5,000	1,000,000	23
Nevada	28,000	30,000,000	119
New Mexico	1,000	4,000,000	115
Oregon	47,000	11,000,000	73
Texas	55,000	24,000,000	251
Utah	42,000	6,000,000	74
Washington	8,000	2,000,000	45
Wyoming	0	0	46

Source: *WestWater Research, various years; **Brewer *et al.* (2008).

USGS data are available. As the table shows, in 2015, 793,000 AF were involved in water market transactions, about 2% of total state consumption. Even, as is very likely, the numbers in the table are an undercount, doubling California's traded volume in 2015 to 1,600,000 AF still is only about 4% of annual consumption. What is the right number? There is no clear answer. The small percent of annual water allocation that is traded in western states suggests that there is great unachieved potential for expansion of water markets.

More broadly, water-price data from elsewhere in the West indicate large disparities in water values in some uses, relative to others, indicating opportunity for market exchange. Price differences exist even in local water markets like Nevada's Truckee Basin, where the median price of 1,025 agriculture-to-urban water rights sales between 2002 and 2009 (2008 prices) was $17,685/AF, whereas for 13 agriculture-to-agriculture water rights sales over the same period the median price was $1,500/AF. Conveyance infrastructure is unlikely to explain these gaps. In another market, the South Platte, Colorado, the median price for 138 agriculture-to-urban sales between 2002 and 2008 was $6,519/AF when compared with $5,309/AF for 110 agriculture-to-agriculture sales (Libecap 2011). These prices are much closer, involving trade in ditch shares peculiar to Colorado, but their alignment is not typical in the western US.

6. Impediments to Water Markets

6.1. *Command and control regulation*

Regulatory mandates to augment supply or to control demand in response to drought are likely to increase with climate change in the absence of a shift to greater reliance upon water markets. A problem with such mandates is that there is no mechanism, other than interest group lobbying for politicians and regulatory agencies, to acquire information about relative values and the tradeoffs encountered (Johnson and Libecap 2001; Brewer and Libecap 2009). Markets, on the contrary, are particularly equipped to respond to incremental shifts in demand and supply because many competing agents are residual claimants to the net benefits. In the absence of accurate water demand and supply data, interest group lobbying reflects the values of their members and not necessarily those of society as a whole. Special interests have *no* real ownership via mandates.

The net value of market exchange depends importantly on timing, expected costs, and expected returns. The regulatory process can fundamentally change all three. Oversight of water transfers varies by state. California has a particularly complicated arrangement with multiple state and federal agencies and a mix of water rights, many of which have not been measured or precisely defined.

Although California is extreme in this regard, across all western states, multiple interests can intervene in the transfer review process and slow it, if they oppose, as well as raise the transaction costs of obtaining approval. Moreover, resolution of an outside interest's demands in a proposed transaction does not prevent another party from lodging concern. Under the current arrangement across western states, as noted by Culp *et al.* (2014), opponents of water trades bear only their private lobby costs and these may be small on the margin if restraining water market transactions is part of their organizational mission. Water buyers and sellers, however, are primarily interested in securing water for consumption, storage, or other uses and additional lengthy agency reviews raise costs and shrink the opportunity for accessing new water sources at critical times, reducing the expected gains from trade. Delay of unpredictable lengths in the process of approval can make a market transaction far less valuable. Yet, neither opponents nor regulatory officials bear these costs directly. Hence, the arrangement seems rife for obstruction and costly deferral.

6.2. *Local restrictions on water transfers: Fears of buy and dry*

At least since Owens Valley and the purchase of its water rights by the Los Angeles Department of Water and Power in the early twentieth century, there has been opposition in rural areas to the movement of water via markets to urban uses. Despite the persistence of this David versus Goliath story, it is not based on evidence, but rather apparent political agendas. In fact, Los Angeles purchased the water rights openly over a 30-period, and the small farmers in the Owen's Valley did better financially by selling than if they had stayed in agriculture. Moreover, Los Angeles removed the lands from production and retired them in a relatively pristine state that remains (Libecap 2007).

Indeed, there is very little empirical work that indicates a negative impact of water markets that is *separable* from the broad decline in rural populations and economic activities due to shifting demographics, lower transportation costs, economies of scale in agricultural production, and far greater economic opportunities in larger urban settings that stimulate migration throughout the western US. Even so, in California, rural counties have adopted ordinances to restrict the export of groundwater across county borders. Many of these counties also prohibit the use of groundwater basins within their boundaries as water banks, limiting the option of storing water during high-runoff periods (Hanak 2003, Hanak and Stryjewski 2012, 16).

Elsewhere in the western US there is opposition to the permanent movement of water from agriculture to urban uses. As in California, there is little evidence to support the hypothesis that long-term land use patterns are changed fundamentally from water transfers, relative to other macroeconomic factors, and much of the opposition comes not from water rights owners, but from members of other groups who resist any transfer of water. Political processes, however, respond to interest group mobilization based on short-term perceptions, whereas significant market reallocations require more long-term assessments of relative use values of water in particular locations and of the costs of moving it.

6.3. *Incomplete water rights*

Because water historically has not been scarce, relative to land, property rights of water have not been completely measured. Prior appropriation that dominates in western states grants a diversion right to a specific amount of water for beneficial use in a certain location for a specific type of use (Leonard and Libecap 2018). Many states have not clearly documented water rights, and for lower-priority rights holders who use more than their legally allowed uses, there is little incentive for more complete definition. The process of measuring and defining existing appropriative rights is adjudication, often overseen by a court. It is a costly and contentious process, but a necessary one if water markets are to play a key role in addressing climate change-induced scarcity. The adjudication of water rights applies also to groundwater, and groundwater rights are notoriously incompletely defined. As a result, groundwater often is an open-access resource with attendant rapid withdrawal. For example, Ayres *et al.* (2018) find that of California's 445 groundwater basins, 309 are subject to unconstrained pumping; 105 have weak management plans; and 20 are severely over-drafted as a result. Only 31 basins in the state have adjudicated groundwater rights, with the ability to trade in some. Adjudication of groundwater rights requires not only documenting the number of wells and maintenance of well logs, but also securing hydrological information that is generally very incomplete.

6.4. *Looming environmental restrictions on water rights*

At the time that most water rights were granted in the late nineteenth and early twentieth centuries, environmental and recreational uses of water were of little value. As water markets have developed in the west since the 1980s, most of the exchanges have been between agricultural users and between agricultural users and urban water supply agencies (Brewer *et al.* 2008). More recently, with rising incomes and greater urbanization, there is more demand for maintaining water in streams and lakes and in preserving riparian ecosystems. One can think of this as another demand on a limited, increasingly valuable resource. Nevertheless, the value of ecosystem services or in-stream flows is far more difficult to determine than for agricultural and urban water use values where products or assets are sold via market exchange. It is feasible to determine environmental values through a variety of techniques, such as hedonic pricing for adjacent land values influenced by greater stream flows, time-travel studies. These are standard valuation techniques used in benefit–cost analysis. Advocates dismiss existing prior appropriation water rights as being outdated and not reflective of current conditions. They rely upon the Public Trust Doctrine as a mechanism for state intervention as defined in *National Audubon* Society *v. Superior Court* (Supreme Court of California, 1983, 33 Cal.3d 419). Under the Public Trust ruling, water is to be reallocated without compensation by state agencies as new values of water emerge. Just how a regulatory agency would determine shifting water values or perceptions of the public trust was not addressed. This information must come from interest group lobbying, and the most effective interest groups will be the ones that have their interpretations of the trust validated. Parties losing access to water, even those with very long-standing investments and valuable water uses will bear the costs, not the advocacy groups nor the regulatory officials or politicians that respond to Public Trust pressures.

There are plausible, laudable environmental objectives in the Public Trust Doctrine, and one could reasonably argue that a private water rights holder might not internalize such broad social benefits. But those who have such values, such as non-governmental organizations, including Environmental Defense or The Nature Conservancy, or state agencies can purchase the water and maintain the existing rights structure. Moreover, there is a critical downside from mandated and uncompensated redistribution of water from existing rights holders. Water markets as a primary tool for addressing climate change become far less viable. All markets require property rights, especially when the resource is costly to move and store, as is water, especially when timing is critical, as it is with water, and especially when there are likely to be greater demand shifts accompanying less-predictable supplies. Add property rights and water availability insecurity and contracts may not be feasible, effectively delegating water reallocation to government mandates.

7. Conclusion: Reforming Water Management Institutions to Promote Water Markets as Adaptation to Climate Change

Water markets provide a way of adapting to a dynamic world of changing human demands for and changing supplies of water. They are a vital institution for responding to climate change in a smooth and efficient manner, but water markets require expansion.

What Actions Should be taken?

(1) Reaffirm reliance upon private water rights and market processes as a major response to climate change.
(2) Measure and define surface and groundwater rights via expanded adjudication.
(3) Clarify and simplify the review process for water transfers.
(4) Create water banks and related platforms for water trading by providing information about water availability, offer prices, water demand, and bid prices and timing.
(5) Construct infrastructure for water exchange and conveyance.
(6) Reform state and federal Endangered Species Acts to require cost–benefit analysis.
(7) Purchase water for instream flow maintenance and other environmental purposes.
(8) Clearly define water rights within surface reservoirs and groundwater basins used for storage during wet periods.

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