Preparing for a Drier Future: Welfare Consequences on the Salton Sea Region of Re-allocating Colorado River Flow Deficit

Jacob Rightnar and Ariel Dinar

Colorado River water flow is running short of its 1922 allocation to users. We assess effects of reallocation of Colorado River water deficit on sectoral and regional welfare in the Salton Sea Region. We use several allocation schemes from previous regional studies, including an allocation based on priority to greatest regional benefit, and allocations based on proportional water quantity reductions with and without social preferences to certain users. We derive water allocations that are most beneficial and feasible for the region as less water becomes available.

The allocation of common pool water resources under supply uncertainty introduces challenges to regional economic performance and stability. This is likely when such allocations are based on fixed quantities of the available water, assigned as property rights to each user, but rarely realized. This is the case with Colorado River basin water, which is shared by seven western U.S. states and Mexico. Sharing is based on the 1922 Compact using the 1922 level of the annual Colorado River flow of 16.46 million acre-feet (MAF). But due to long-term reductions in water flow of the Colorado River, the 1922 Compact failed to fulfill the agreed-upon allocations (in 56 out of the 95 years between 1922–2017) to users, resulting in shortages and disputes that will be further exacerbated by climate change.

A situation in which a commitment of a common pool resource, such as water, to users cannot be fulfilled is defined as a bankruptcy of the resource. Generally speaking, a bankruptcy situation exists when participating agents submit claims that are larger than what is available for distribution (either monetary or physical quantity). That deficit has to be allocated among the claimants such that each will receive a non-negative amount that cannot exceed the claim.

California has a fixed annual quantity of 4.4 MAF from the Colorado River flow that has been rarely fulfilled. We focus on the Colorado River water bankruptcy situation that affects Southern California and, in particular, the Salton Sea region, including several major water-consuming sectors.

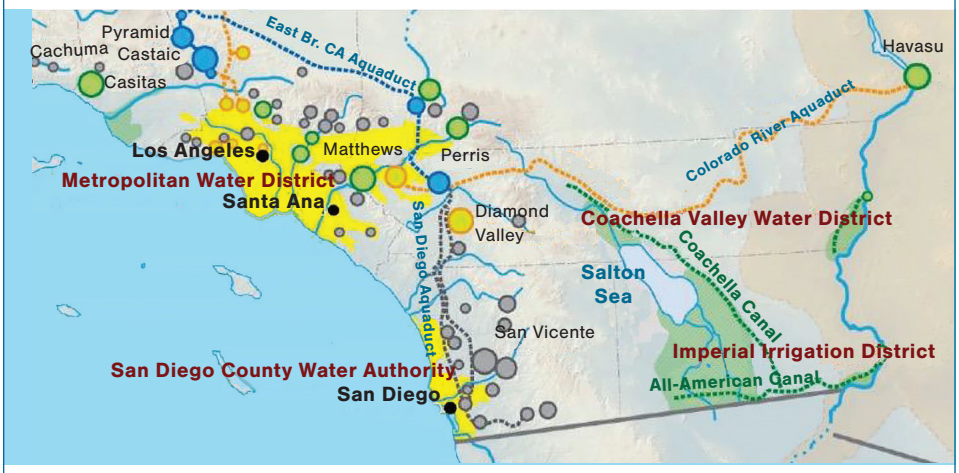
In this paper, we apply a methodology to estimate water demand functions for the agricultural and urban sectors and recreation in the Salton Sea region. In addition, we apply optimization principles to the allocation of the water deficit such that the regional welfare is maximized (Social Planner Allocation--SPA). We then apply a couple of (more practical) bankruptcy allocation methods to calculate the resulting sectoral and regional welfare and compare the total regional welfare and the sectoral distribution of the welfare between the SPA and the bankruptcy allocations.

The Colorado River Service Area of California and Stakeholders

The Colorado River service area (Figure 1) of California includes major agricultural operations, urban centers, and the Salton Sea. The Imperial Irrigation District (IID) presides over the majority of the area in which the Salton Sea resides. IID services a population of over 150,000 and an agriculture industry that nets over $1 billion in annual sales. Currently, IID has an allocation of 2.6 MAF of Colorado River water as a "perfected right," meaning that on occasions when shortfall exists in the river's flow the IID's water allocation must be satisfied first.

The Coachella Valley Water District (CVWD) includes both major agricultural operations and urban centers. CVWD has been afforded 0.45 MAF of water per year from the Colorado River, which supplies the agricultural industry, as well as 373,000 permanent

Figure 1. The Colorado River Basin Water Service Region



Source: Wikipedia, Water in California, https://en.wikipedia.org/wiki/Water_in_

residents, and up to 3.5 million seasonal residents and tourists (tourism industry linked to the Salton Sea). The agriculture industry in the Coachella Valley sells over $500 million per year.

The Metropolitan Water District of Southern California (MWD), an exclusively urban stakeholder (in our analysis), charged with managing and delivering water from the Colorado River to southern coast urban centers, has an allocation of 1 MAF (not including San Diego County). And finally San Diego County Water Authority (SDCWA), which is legally a part of the MWD but due to its history of acting as an autonomous stakeholder in Salton Sea negotiations, will be considered as an individual stakeholder for the purposes of this analysis. SDCWA supplies over 3 million residents within the County of San Diego. It has an annual entitlement of 0.33 MAF per year, of which 0.18 MAF is delivered from the Colorado River.

Methodology and Data

Determining Value of Water

The value of water can be represented by the demand of consuming sectors, indicating the willingness to pay for an additional unit of water in the case of urban consumers. In irrigated agriculture, value of water is represented by derived demand, indicating the value of an additional unit of water in production. The value of water in the Salton Sea is based on the water-dependent recreational activities that are a function of the water level in the sea (ignoring the health implications of low water levels).

The value of water in irrigated agriculture was determined using the 'residual approach,' which calculates the net revenue that is attributed solely to a unit of applied water. We used data from the University of California Cooperative Extension crop budgets in the three counties of the Salton Sea region (Imperial, Riverside, San Diego). The value of water for urban uses was derived from a demand curve estimated for the entire region. To determine the recreational value of water to the Salton Sea itself and compare it to agricultural or urban uses, we estimate the relationship between inflow of water into the Salton Sea and the number of tourist visits and dollars spent by tourists in the region.

Determining Welfare Effects

Based on the distribution of flows over the past 100 years in the Colorado River, we calculated the flow deficit between the 1922 flow and actual annual flow levels. We determined the three deficit ranges for the analysis as: small deficit 0–0.5 MAF, with a mean of 0.250 MAF; medium deficit 0.5–2.0 MAF, with a mean of 1.25 MAF; and high deficit 2.0–2.5 MAF, with a mean of 2.25 MAF. We then evaluated, using the demand functions and the recreational value, the impact of several allocation methods on the sectoral and regional welfare by calculating the welfare changes from the reduced water allocation due to the deficit.

The Allocation Mechanisms

Below are the six simulations of allocation mechanisms we applied, each with the three levels of deficit that represent the range of deficit experienced in the past 100 years.

(1) In the case of SPA, the planner's goal is to minimize losses incurred through water restrictions. The regional welfare is determined through the dollar value produced in the region by the application of water to the different economic activities. Allocated water to each stakeholder ranged from no volume allocated at all to the maximum volume of water that a given stakeholder-sector could utilize. We used this model to assess the highest proportion each stakeholder-sector could receive until an additional allocation of water would produce greater social welfare when placed elsewhere. Thus, the maximum welfare a single stakeholder-sector could produce relative to the other stakeholder-sectors is derived.

(2) The Proportional Use Bankruptcy allocation is dependent on both the agreed water entitlement and the total water use for each stakeholder. As such it takes each stakeholder's proportion of the actual annual withdrawal and scales it down proportionally to the sustainable withdrawal for the state of California.

(3) The Proportional Claim Bankruptcy allocation is applied to the allocations that each stakeholder has been promised (on paper, with likely incredibility) by the regulator or in the water-transfer agreement.

(4) A Bankruptcy allocation based on priority to the Salton Sea is derived from the proportion of existing use but with the addition of an allocation set aside for the Salton Sea, and is designed to close the gap between current inflow and a historically sustainable flow.

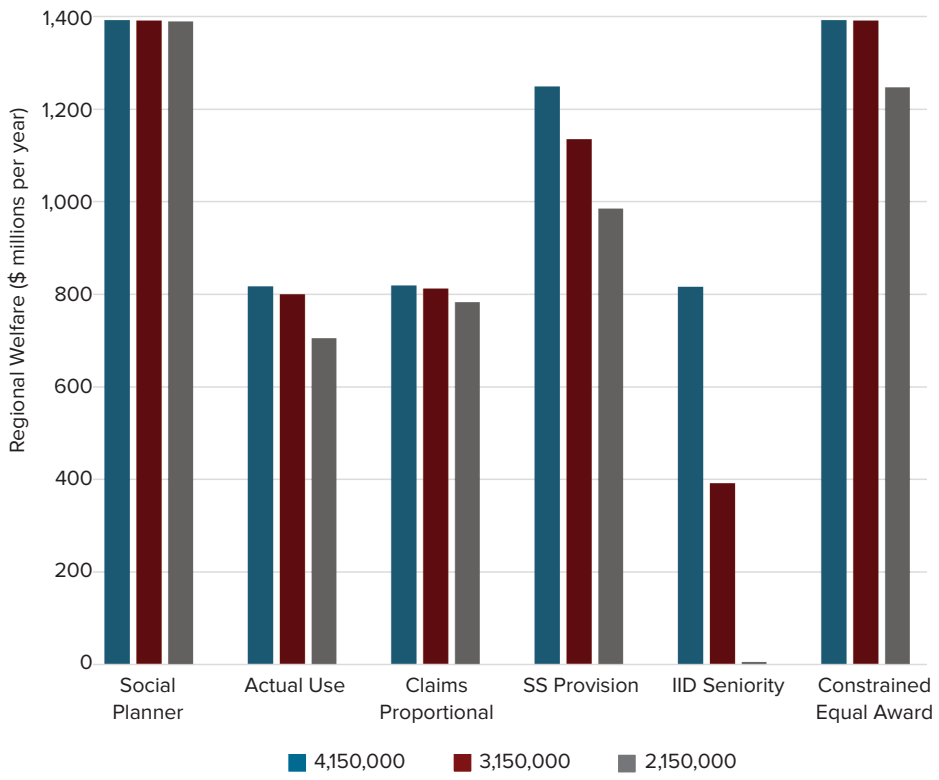
(5) A Bankruptcy allocation based on priority to IID water rights; this allocation addresses the IID's present perfected rights.

(6) The Constrained Equal Awards allocation is one in which the deficits are distributed equally among all stakeholders, with some form of constraint or weighted preference set by the regulator. The constraint is that no stakeholder receives more than its maximum historic entitlement. This should produce a model that favors stakeholders who have historically used less water.

Results

Figure 2 presents the main aggregate regional results (for detailed results see Rightnar and Dinar, 2020). The social planner allocation does not weigh the water needs of agricultural stakeholders as highly as that of urban stakeholders. All simulations produced under this framework result in major losses to the agricultural industry, which has historically utilized an

Figure 2. Total Regional Welfare Produced by All Models Under Three Water Reduction Scenarios



average of 2.5 MAF a year, particularly the IID. The SDCWA agricultural sector fares the best of all agricultural sectors, possibly due to the high-value crops produced on a relatively small acreage and with relatively smaller amounts of water per acre. The urban sectors have higher willingness to pay, and thus are insulated from losses incurred by a reduction. The Salton Sea fares well in these models, due to the high value produced by the tourist economy. Thus, the social planner model provides a sustainable allocation for the Salton Sea while shielding urban centers from major water cutbacks yet severely damaging the agricultural sector.

The simulations that provide stakeholders with water, in proportion to their existing usage and claims, produce a lower regional welfare versus the social planer model. Because agricultural water uses already account for most regional water use, these models protect agricultural interests by affording them the same proportion as supplies dwindle. Urban water centers would not contribute to the regional welfare to the degree that they are able, considering their high consumer surplus. The low quantity of water dedicated towards the Salton Sea does not afford it a sustainable inflow. Yet by developing a model that supports a sustainable ecosystem, we can project the regional welfare higher than that produced by a model using only existing uses and entitlements, although lower than produced in social planner models. Therefore, the proportional allocation model is beneficial to the interests of the agricultural sector and may result in urban water price increases, while not sustainably providing water to the Salton Sea unless water is legally committed to the environment.

The models in which the IID's senior rights are upheld are the most damaging to regional welfare. Simply reducing the regional water use to 4.15 MAF results in the IID being allocated at a minimum of 65% of the region's water. Once we consider scenarios in which the bankruptcy increases, we see massive reductions in the regional welfare. In major drought periods where the bankruptcy reaches 2.0 MAF, the IID would be entitled to all water California draws from the Colorado River. This leads to a devastating situation for other agricultural sectors, and water shortages in urban sectors.

At the lowest levels of deficit, the constrained equal award model produces a welfare level that is indistinguishable from the social planner approach at similar levels. As deficit increases, the welfare resulting from this model is reduced to a greater degree than in the social planner approach, although it remains greater than that of any other framework. This framework provides a near-optimal welfare level while affording more water to agricultural districts while still impacting agriculture. Additionally, this method asks stakeholders with a lower historic use to make fewer reductions.

The reason for the seemingly small welfare changes from major water reductions, is the result of the shape of the demand function, which represents the fact that major amounts of water are used to irrigate relatively low-value crops (alfalfa), and relatively small quantities of water are allocated to irrigation of high-value crops (vegetables), such as is the case in the IID and in the Coachella Irrigation District. More information can be found in Rightnar and Dinar, 2020 (Supplementary Material).

Regarding the valuations that favor urban sectors, we assume this tendency arises due to urban users paying full market rate for water, whereas agricultural water is subsidized, inflating urban willingness to pay for water. Additionally, the models that do not consider IID's status as a senior water rights holder indicate that these are not conducive to the general welfare, and produce systemic inefficiencies.

Regardless of the status of IID's present perfected rights, it is not reasonable that it would accept drastic deficits in its entitlement. This does not mean that

they would never accept reductions in their entitlement, as they have agreed to such reductions previously. The IID is invested in maintaining the Salton Sea, due to the air pollution hazards it poses within its jurisdiction. This implies that it is politically feasible to persuade IID to follow a bankruptcy allocation model that sacrifices a portion of its allotment to sustain the Salton Sea, despite the welfare loss from the agricultural industry.

We should note that while urban districts produce a greater regional consumer surplus than agricultural users, they also can mitigate the loss of water through utilizing alternative sources such as groundwater and recycled wastewater. In particular, MWD and SDCWA have a robust range of water sources (desalination, managed aquifer recharge) to replace Colorado River water (MWD 2018).

Meanwhile, the stakeholders in the eastern half of the region (CVWD and IID) lack access to the ocean, receive less rainfall, and lack the capital to import water. Imperial Valley, the region's largest user, lacks alternatives to water drawn from the Colorado River. Groundwater in the Imperial Valley is of poor quality and is generally unsuitable for domestic or irrigation purposes. In response, IID has built a series of programs and initiatives aimed at improving conservation practices and infrastructure to better utilize existing water supplies. One example includes the On-Farm Efficiency Program, which has led to the conservation of over 44,371 AF annually.

The Coachella Valley takes advantage of its available groundwater resources. While the aquifer has an estimated capacity of 39 million AF, the Coachella Valley currently finds itself in an overdraft situation (very low precipitation and snowmelt) and deteriorated quality (due to recharge and deep percolation of salinity-elevated Colorado River water, which is also used at groundwater replenishment facilities. In the future, Colorado River water may provide a potential source of water for CVWD to treat to drinking standards and deliver to urban customers. Although, while CVWD is limited in its water sources, it can replace the economic use of that water. If a loss in allocation will affect the agricultural industry negatively, it is possible to mitigate this loss through strengthening its tourism sector. We assumed in our analysis (CVWD, 2002; 2018) that in certain years a relatively small portion of the water consumption in the CVWD originates from the natural aquifer, no more groundwater will be pumped than the current level, and that the region would be unable to maintain the current economic or population base without entitlements from the Colorado River as current consumption is unsustainable.

Due to these factors, an allocation scheme that favors the IID may be justified even without considering their senior rights. This does not mean that the regulator should allocate water to a stakeholder producing suboptimal welfare simply because of its inadaptability. It is merely a consideration when predicting regional welfare after implementation. The ability of most stakeholders to manage the loss of water in comparison to the IID mitigates the suboptimal regional welfare that these models produce.

Conclusion

It is possible to minimize regional welfare loss as we move to establish a new normal in light of decreasing Colorado River flows. This can be fulfilled by treating the water system as a bankrupt entity. How to distribute these limited resources is answered by the benefits to the public derived from the new allocation. We can determine the welfare for the region by allocating water to a given stakeholder and establishing the allocations that are most beneficial for the region as less water becomes available. We must operate within the existing legal framework and stakeholder characteristics. Relating the value of water to a dollar amount helps provide initial estimates on regional welfare losses, but multiple factors affect the region once our allocation framework is implemented.

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For additional information, the authors recommend:

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Rightnar, J., and A. Dinar. 2019. "Bankruptcy Allocation of the Colorado River Water: The Impact of River Flow Deficit on The Salton Sea Region and Re-allocation Policies to Address It." UCR SPP Working Paper Series, October, WP# 19-02

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