RESEARCH ARTICLE

Boons or boondoggles: An assessment of the Salton Sea water importation options

Importing ocean water from the Sea of Cortés to the Salton Sea would be substantially more expensive than leasing agricultural water from the Imperial Valley and transferring it to the Salton Sea.

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The second-lowest point in the United States, an ancient seabed, was flooded at the turn of the 20th century by Colorado River water being brought into California, forming the Salton Sea. Named La Palma de la Mano de Dios (the Palm of the Hand of God) by pre-statehood Mexicans (Darton 1933), the sink has since continuously remained submerged. The Salton Sea exists today due to agricultural drainage water, the vast majority of which flows from the farmlands of the Imperial Valley — the fingers of la Mano. During the 20th century, California and northern México lost almost all of their wetlands, leaving the Salton Sea an incongruous combination of a drainage water sink and critical habitat for millions of migratory birds and several endemic, endangered and sensitive species.

Critical habitat or not, as a terminal lake, the Sea has significantly deteriorated due to the declining quality and quantity of its inflows. Nearly 85% of the inflows are from agricultural drainage, which brings with it fertilizers, pesticides and salts that have caused a salinity level intolerable to most fish (Schwabe et al. 2008). In 2003, a federal-state-local agreement — the Quantification Settlement Agreement — formalized an agriculture-to-urban water transfer of Colorado River water from the Imperial Irrigation District (IID) to the San Diego County Water Authority (SDCWA). The agreement also mandated that the Imperial Irrigation District send additional water to the Salton Sea — through 2017 — from its several million acre-feet of Colorado River water entitlement to counter the decreases in Salton Sea inflow that would arise from this transfer.

Abstract

Several ways to address the looming ecological disaster that is the Salton Sea have been proposed — including water importation. Here we considered two options: importing ocean water from the Sea of Cortés and leasing water from agricultural users in the Imperial Valley. We estimated the monetary costs for importing Sea of Cortés water to the Salton Sea and compared that with the costs of transferring water from agricultural users to the Salton Sea. We found that leasing water from agriculture would be substantially cheaper than ocean water imports. Additionally, all the infrastructure for leasing water from growers exists, which means water transfers could begin immediately. That is important given the present and increasing environmental and human health damages that are occurring at the Salton Sea.

A heron in flight above foraging gulls. Due to the Salton Sea's decreasing volume and increasing salinity levels, all but one fish species has died off and the diversity of waterbirds has been in decline. Transferring water from agricultural users to the Salton Sea is a potential solution for preventing future habitat loss.

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This "mitigation" water was an attempt to buy time to develop solutions for the Salton Sea and avert damages caused by decreased volume and increased salinization. However, solutions were delayed, the Sea's volume fell and its salinity concentrations rose from 2003 through 2017. Since the cessation of mitigation water at the end of 2017, the decline in the quality and quantity of the inflows to the Sea has accelerated, furthering concerns over environmental and human health damages and culminating in a recent unanimous emergency declaration by the county's supervisory board (Wilson 2019a).

One category of damages is habitat loss — all but one fish species has died off in the Salton Sea's main body. This sole fish species, a hybrid tilapia, serves as the primary food source for migratory bird populations (Bradley and Yanega 2017). Unfortunately, winter 2019 fish surveys revealed few remaining tilapia and, consequently, extremely low bird counts (Wilson 2019b). If the current salinity trends continue, only brine shrimp and brine flies will survive. These creatures tolerate quite high salinity, but their upper limit of tolerance will be surpassed in roughly 15 years (Bradley 2018). At that point, algal and microbial populations will grow exponentially, leaving the Sea biologically active but incapable of supporting its endangered, threatened and migratory species (Bradley 2018; Cohen and Hyun 2006).

Human health damages are another significant concern. As the Sea recedes, the former sea bottom — that is, the playa — is exposed. The playa is a source of airborne particulates, a precursor/exacerbator of asthma and other lung conditions, which is particularly concerning to the lower-income communities surrounding the Salton Sea, of whom a substantial portion have Latinx and/or Native American heritage (Abrams 2017; Johnson 2019a, 2019b; Marshall 2017).

Combining the environmental and health costs with decreased property and recreational values, total damages are estimated to be upward of $70 billion over 30 years, which does not include damages to the people in México who live within the Salton Sea airshed (Cohen 2014; Schwabe and Baerenklau 2007).

"Fixing" the Sea will require reversing the habitat loss and playa exposure trends, which means addressing the quantity and quality of water in the Salton Sea, and understanding that quality is influenced by inflow volume. A central and controversial issue is where the water is going to come from to maintain the Sea. One proposal that the state is considering — the Cortés-to-Salton option — consists of importing ocean water from the Sea of Cortés (also known as the Gulf of California). An alternative option, which builds upon the over 30-year history of agriculture-to-urban transfers in the region as well as the Quantification Settlement Agreement's mitigation water transfer precedent, is an agriculture-to-environment water transfer, described in Levers et al. (2019).

Higher inflows from either of these options would decrease playa exposure and the associated human health impacts. The Salton Sea is a terminal lake, which means that eventually the rise in salinity will result in a dead sea. As such, a permanent solution to reverse environmental, health and recreational damages will require some machinations beyond simply bringing in more water. However, inflows could also be used with habitat and dust suppression projects, even just in the short term, reversing past and preventing future habitat loss and playa exposure.

We evaluated the costs associated with two options for increasing inflows: ocean water imports, and agriculture-to-environment voluntary, albeit compensated, water transfers. While an understanding of the respective and relative costs of each option is important in informing policy — the goal of this paper — cost is only one of the factors to consider. Three other factors are the legal and political issues surrounding each option, their respective benefits, and their potential environmental damages.

Legal and political issues ultimately determine proposal feasibility and possible implementation. Both options — ocean water imports and agriculture-to-environment water transfers — will face significant political and legal challenges. In terms of the respective benefits of the two options, our analysis focuses on comparing the costs of different options to bring water to the Sea, a question raised in the Salton Sea 10-Year Plan (CNRA 2017a). As such, the benefits of these solutions to the state's charge of importing water to the Salton Sea are likely to be very similar. In terms of environmental damages, while ocean water importation may offer an opportunity to further address regional water security in the Southwest, it also opens up the possibility of significant environmental impacts to the Sea of Cortés. Clearly, there is a different array of benefits associated with such a broader system, but such an analysis goes beyond the more targeted scope of this paper.


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A tilapia carcass. Hybrid tilapia are the main fish in the Salton Sea. While salt tolerant, even they are reaching their salinity limit, with numbers declining precipitously in recent years.

Ocean water imports

The idea to build a pipeline system to import ocean water to the Salton Sea has been around since at least the 1970s (Goldsmith 1971; Goolsby 2015). The two alternatives for uptake locations are the Pacific Ocean near San Diego and the Sea of Cortés in México. The U.S. coastline is closer than the Sea of Cortés, approximately 100 miles compared to 160 miles, respectively, from the Salton Sea. However, the elevation of the Peninsular Ranges, west of the Salton Sea, would complicate the journey of water pumped from the Pacific. So, the Mexican route has been singled out as easier — that is, cheaper —even though it would necessitate an international pipeline (Cohen 2015).

Any pipeline importing untreated ocean water into the Salton Sea would fundamentally impact its habitat, keeping water levels high but concentrating salts. Some proposals suggest incorporating expensive desalinization and/or purification systems to deal with salinity concerns (CNRA 2018a, 2018b). A return pipeline could be built to export salts to the Sea of Cortés, but a pipeline bringing water from the Salton Sea to the Sea of Cortés would also transport agricultural pollutants, of particular concern as parts of the Sea of Cortés are on the UNESCO World Heritage List, including the Islas de Golfo de California Biosphere Reserve at the northern edge of the Sea of Cortés. The Sea of Cortés is critical habitat for diverse endemic and endangered species, including the most critically endangered marine mammal in the world, the vaquita (United Nations 2019). Despite the pitfalls, the sheer volume of water available makes the Cortés-to-Salton option tempting for many.

In 2017, the California Natural Resources Agency requested proposals for ocean water importation (CNRA 2017b). They received 11 responses in 2018. A concern with the proposals was the lack of detailed cost information (Metz 2018). While three proposals provided some cost information during a public workshop (CNRA 2018b), the proposals have not been independently assessed for accuracy or feasibility. However, they consistently suggest initial investment costs in the billions of dollars and annual maintenance costs in the millions. Given the lack of detailed cost information, we used cost estimates commissioned by the Salton Sea Authority in 2002 indexed to 2018 dollars (Tetra Tech 2013).

Agriculture water transfers

The alternative to ocean water importation is an agriculture water use transfer program. Such programs have existed in the region for more than 30 years, including an agreement between the Imperial Irrigation District (IID) and the Metropolitan Water District (MWD) to transfer approximately 100 thousand acre-feet (TAF) of agriculture water to urban uses (the earliest example was in 1988); an agreement between the Metropolitan Water District and the Palo Verde Irrigation District for approximately another 100 TAF of agriculture water; and the transfers outlined in the Quantification Settlement Agreement between the Imperial Irrigation District and the San Diego County Water Authority (SDCWA), culminating in 200 TAF of agriculture water being transferred to the San Diego County Water Authority (IID, SDCWA 2003; U.S. Bureau of Reclamation 2018). The transferred water is "generated" by reducing both conveyance losses through lining canals and field-level water application through land fallowing and improving irrigation system efficiency. The transfers have mostly consisted of agriculture-to-urban transfers, with some agriculture-to-agriculture transfers.

This water transfer history, including that of the Quantification Settlement Agreement, motivated the schemes described by Levers et al. (2019) to transfer water from Imperial Valley agricultural users to the Salton Sea. Levers et al. (2019) proposed three possible programs to allow more Colorado River water to flow to the Sea: growers would be paid for fallowing fields, implementing less water-intensive irrigation methods, or direct leasing. Direct leasing left the "how" of reducing their water use to the growers (e.g., through fallowing, irrigation improvements or simply deficit irrigation). Using a biophysical model coupled with an economic model, Levers et al. (2019) estimated Salton Sea inflows — transferred inflows, drainage flows and tailwater runoff — and the opportunity costs to growers (i.e., foregone profits) under the different programs.

Levers et al. (2019) found that the direct lease program was the lowest-cost method for purchasing water, but as it caused the greatest reduction in drainage and tailwater of the three programs, it was not the most efficient in generating total Sea inflows. Land fallowing was found to generate the highest total inflows to the Salton Sea at the lowest cost. Irrigation efficiency improvements were not only the most expensive option but also the most limiting in generating total overall flows since, from a hydrological perspective, water savings were achieved through reduced evaporation only. Overall, their results suggested that a substantial amount of water could be purchased from agricultural users for a relatively low cost, particularly through fallowing and direct leasing.

Costs: Ocean water imports

To estimate costs and inflows for the Cortés-to-Salton option, we used engineering and cost estimates provided to the Salton Sea Authority by Tetra Tech (Tetra Tech 2013). These costs include capital cost estimates to build the pipeline(s) to import the water, taking into account pipe diameter, pipeline length, intake structures and energy for pumping. We assumed a round-trip length of 357 miles (Tetra Tech 2013), which would put the pipeline intakes (and outputs) well south of the particularly ecologically sensitive area at the northern edge

A lone nest, likely belonging to a cormorant pair. Double-crested cormorants used to nest by the thousands at the Salton Sea, but no longer.

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of the Sea of Cortés. The route to the Sea of Cortés does not involve a mountain range, but the Salton Sea is 250 feet below sea level and the route rises 270 feet above sea level before dropping down to the ocean, so significant pumping would be necessary.

We estimated the costs for importing 250 TAF per year and 500 TAF per year. We chose these values because they are physically feasible and within the range needed to increase the Salton Sea's water level to midcentury levels. Exporting water back to the Sea of Cortés would more than double the costs. We calculated construction and yearly maintenance and energy costs. Initial costs would be between $3.3 billion (for import only of 250 TAF) and $13.3 billion (for import and export of 500 TAF); annual operations, maintenance, energy and repair costs would be between $6 and $42 million, respectively (table 1).

These cost estimates are of similar magnitudes to the estimates in the three Cortés-to-Salton proposals submitted to the California Natural Resources Agency that included cost information. It was difficult to compare the three proposals as their potential services differed: two included a desalinization component, and one included an export pipeline (CNRA 2018a).

TABLE 1. Cortés-to-Salton costs and Salton Sea inflows*

To import this much water (TAF) …	250	500
Construction cost ($ million)†		
Import only	$3,331	$6,662
Import and export	$6,662	$13,324
OMER costs ($ million)‡		
Import only	$6	$12
Import and export	$21	$42
Salton Sea yearly inflows (TAF)	1,097	1,347

* Construction and OMER‡ costs adapted from Tetra Tech (2013), with dollar values converted from 2002 to 2018 dollars (values in Tetra Tech [2013] were reported in 2002 dollars). Importation of 250 TAF requires one 12-foot-diameter pipe; 500 TAF requires two 12-foot-diameter pipes. Inflows include drainage and tailwater, assumed as a baseline of 847 KAF (Levers et al. 2019).

† Construction cost at $9.3 million per mile per pipeline, for 357 miles. Per Tetra Tech (2013), a pipeline of this size could import 230 TAF/export 225 TAF, less than the 250 TAF used here. Additionally, construction cost does not include ancillary capital costs such as for increased energy generation capacity or intake structures. As such, the estimates above may be an underestimate.

‡ Annual operations, maintenance, energy and repair costs.

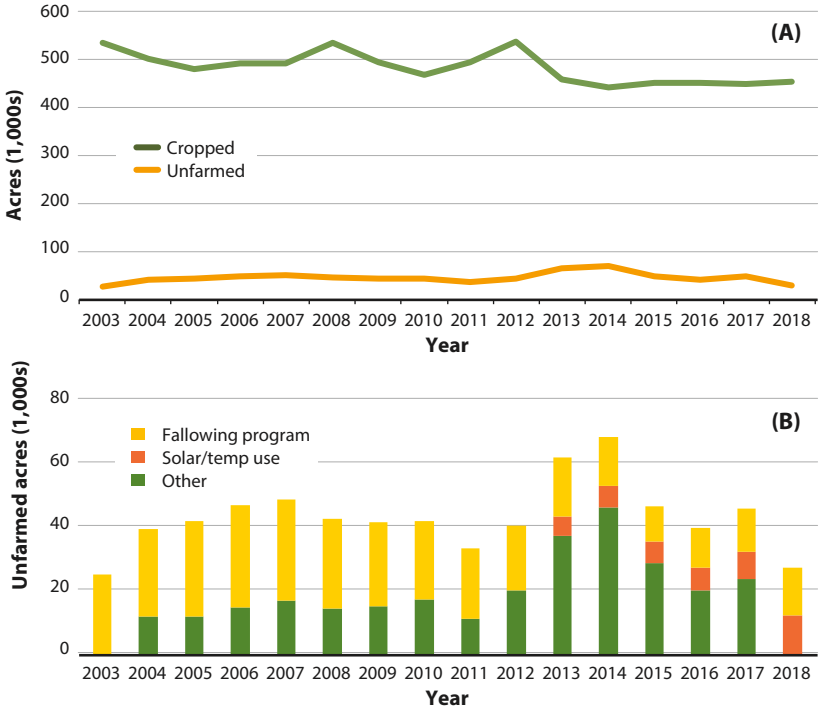

FIG. 1. Reported cropped acreage and unfarmed acreage (A) in the Imperial Irrigation District 2003–2018, and (B) the unfarmed acreage in the district's fallowing program, in solar production or temporary conversion, or other use. Adapted from IID 2005, 2008, 2012, 2016, 2019b.

Costs: Agriculture water transfers

For the agriculture-to-environment option, we focused on the fallowing and direct leasing options from Levers et al. (2019), using their model to estimate the costs to generate equivalent volumes of water imports. A central element of the Levers et al. (2019) study was the use of voluntary, albeit compensated, programs in the Imperial Irrigation District that growers could participate in depending on their crop profitability. Since the model did not account for heterogeneity within a crop type, at particular price points an entire crop might opt into the program. This made it difficult to generate a specific volume of water. Additionally, and following guidelines from the California Department of Water Resources, Levers et al. limited fallowing to 20% of baseline acreage for each crop due to concerns over third-party effects from reduced agricultural production that might arise from transfers.

In the Imperial Irrigation District, 20% of the acreage of the two crops most likely to be fallowed due to their low profit margins, alfalfa and sudangrass, is about 45,000 acres. For comparison, cropped area in the Imperial Irrigation District from 2003 to 2018 ranged from 440,000 to 540,000 acres (fig. 1). Unfarmed, but farmable, area was 25,000 to 70,000 acres — a good portion of that due to the Quantification Settlement Agreement–induced fallowing program, which ended in 2017 (IID 2019a). Unfarmed acreage in 2018 was the lowest it had been since 2003, over 40,000 acres lower than its highest level, in 2014.

Since the 20% limit on fallowing acreage affects the amount of water that can be generated from fallowing, and consequently the comparisons that are possible with the ocean water imports option, we increased the limit on fallowed alfalfa acreage to 50% of baseline acreage. The 50% limit increased the potential to fallow over 110,000 acres, which, if implemented, would likely lead to greater third-party (e.g., regional employment and income) effects. The degree to which more fallowing leads to more significant third-party effects depends on multiple factors, including the level of unemployment in the region, the strength of the linkages between the crop that is fallowed and upstream and

downstream businesses, and how much of the compensation payment stays within the region. We did not evaluate these effects.

We estimated annualized costs and total inflows (leased plus drainage and tailwater inflows) for a variety of scenarios. Table 2 gives purchased water volumes ranging from 200 TAF to 850 TAF. These scenarios result in total inflows ranging from about 870 to about 1,450 TAF. The annualized costs (mainly the opportunity cost to growers) range from $6 to $69 million, depending on the desired volume of purchased water. As the conveyance system is already in place, there are no initial construction costs.

It is important to remember that growers are compensated completely for lost agricultural profits from enrolling acreage in the leasing programs. Because of the relative profitability of vegetable (also called garden) crops versus field crops, the least-cost solution consists of fallowing acreages of alfalfa and sudangrass rather than vegetable acreage. Given that the reduction in production represents only a small fraction of U.S. total alfalfa and sudangrass production (Levers et al. 2019), there are likely no market or price effects.

Options evaluation

As shown in table 3, to achieve over a million acre-feet of inflows annually into the Sea — slightly lower than the long-term historic average — the Cortés-to-Salton option would cost between $3.3 and $6.7 billion initially plus $6 to $21 million per year. The costs to import a similar quantity of water if purchased from agricultural users would be around $28 million per year. For 1.3 million acre-feet, the Cortés-to-Salton option would run between $6.7 to $13.3 billion initially plus $12 to $42 million per year; for the agriculture-to-environment option, the cost would be approximately $62 million annually.

TABLE 2. Agriculture-to-environment costs and Salton Sea inflows

To purchase this much water (TAF) …	≥ 200	≥ 350	≥ 400	≥ 650	≥ 750	≥ 850
using this scheme	Direct*	Fallowing*	Direct*	Direct*	Fallowing†	Fallowing‡
and this water price ($/acre-foot)	$30	$79	$88	$89	$79	$79
Total annual cost ($ million)§	6	28	37	59	62	69
Lost agricultural profit	2.4	1	16	22	2	2
Extra water profit	3.6	27	21	37	61	67
Total inflows (TAF)	867	1,089	943	1,130	1,382	1,447
Purchased	201	357	422	660	786	877
Drainage	284	375	175	166	312	303
Tailwater	383	356	345	305	283	268

* Fallowing limited to 20%, as in Levers et al. (2019).
† Fallowing of alfalfa limited to 50%; other crops to 20%.
‡ Fallowing of alfalfa and sudangrass limited to 50%; other crops to 20%. Rounding results in lost agricultural profit and water profit appearing to not sum to total cost.
§ Total costs are comprised of the lost profits from agricultural production that must be replaced for growers to break even and the added profit of the growers who would have opted into the program at a lower price.

TABLE 3. Comparison of the Cortés-to-Salton and agriculture-to-environment options

To achieve this total inflow (TAF) …	1,000			1,300		
with this option…	Cortés-to-Salton		Agriculture-to-environment*	Cortés-to-Salton		Agriculture-to-environment†
	Import	Import and export		Import	Import and export	
Costs ($ million)						
Construction	3,331	6,662	0	6,662	13,324	0
OMER costs‡	6	21	28	12	42	62
Land costs	Unknown	Unknown	0	Unknown	Unknown	0
Annualized costs§	223	454	28	446	908	62
Inflows (TAF)	1,097	1,097	1,089	1,347	1,347	1,382
Purchased	250	250	357	500	500	786
Drainage/tailwater	847	847	731	847	847	595

* Fallowing limited to 20%, as in Levers et al. (2019).
† Fallowing of alfalfa limited to 50%; other crops to 20%.
‡ Annual operations, maintenance, energy and repair costs.
§ Sum of amortized construction cost (interest rate is 5%, lifespan is 30 years) and OMER costs.

A gull carcass. Several species of gulls use the Salton Sea, including the California gull (the state bird of Utah) and the yellow-footed gull, whose only frequented U.S. location is the Sea.

It is difficult to compare these sets of costs as they are not fully annualized. However, if we make a few assumptions for interest rate and pipeline lifespan, we estimate the annualized costs for the pipeline to range from $223 to $908 million (table 3), which does not include any land costs. Again, the comparative costs for the agriculture-to-environment option are between $28 and $62 million, respectively.

Of course, there is uncertainty with these values. The values estimated for the agriculture-to-environment option assume midlevel crop prices representative of prices over the past decade. Lower crop prices would lower the lease price and program costs, while higher crop prices would increase both. However, the cost differences between the Cortés-to-Salton and agriculture-to-environment options are significant. To import 1 million acre-feet (with no exportation), the initial costs of the Cortés-to-Salton option is over 100 times the annual cost of the agriculture-to-environment option — this would double if water exports were implemented.

In addition to uncertainty, it also is important to emphasize that we did not estimate the transaction costs associated with either the Cortés-to-Salton option or the agriculture-to-environment option. For either one, a formal agreement would have to be enacted — something akin to the Quantification Settlement Agreement for the agriculture-to-environment option and an international agreement for the Cortés-to-Salton option. Such agreements, along with their implementation, may incur significant transaction costs. To the extent the transaction costs between these options would be significantly different, their inclusion might influence the conclusions of our research.

Since good economic decisions are not made on costs alone, public benefits and nonmarket values need also to be considered. Ocean water importation may offer more benefits in the area of water scarcity and, depending on treatment, water quality. Many of the proposals included desalinization efforts and water supply augmentation opportunities that are intended to benefit the region through reducing overall water scarcity. As the Salton Sea is a terminal lake, any long-run solution needs to address salinization. Ocean water importation without treatment may exacerbate the rate of salinization of the Sea (as ocean water is more saline than drainage/tailwater), and it may impact the biota given the Sea is not a marine environment, potentially causing more environmental damages. Additionally, potential environmental damages to the fragile Sea of Cortés are not minute and would need to be considered. While expensive desalinization would not address damages to the Sea of Cortés, it could help address these other issues and — as highlighted in many of the ocean importation proposals — offer the region another water supply source to address regional water scarcity that will only worsen under climate change and population growth.

As the Salton Sea does not exist in a vacuum, consideration of proposals to address regional water scarcity should include a broader and geographically wider set of stakeholders, how the costs might be apportioned across a larger set of potential beneficiaries, and comparisons with other possible regional solutions, including possibly ocean water importation from Californian waters. Any adjustments to water use in the increasingly populated Southwest warrant a more comprehensive discussion.

In terms of expediency, the damages associated with ecosystem deterioration and declining public health require both a long-term sustainable solution but also immediate attention. So even if the calculus surrounding ocean water importation from a regional perspective suggested benefits exceed costs, an analysis that has yet to be performed in a rigorous fashion, such a solution would be a decade in the making. Concerns about delay have been expressed by biologists, public health experts and public officials. In 2018, the then Assistant Secretary for Salton Sea Policy, Bruce Wilcox, said of the ocean importation option (Metz 2018): "We don't want to delay building habitat and air quality that's needed at the Salton Sea to spend two years evaluating something that may work but also may not."

While Assistant Secretary Wilcox was not dismissing the water importation option, he was likely highlighting the timeline concerns. A successful ocean water importation project would take many years of construction — and that would start only after an international agreement was in effect. While an international agreement would not be necessary for the agriculture-to-environment option, another multilevel agreement like the Quantification Settlement Agreement surely would be required, a challenging task given the current system of water rights in California, past and ongoing agreements surrounding the use of Colorado River water and a nearly two-decades-long drought impacting the Colorado River. Furthermore, considering that nearly all previous water transfers in the region have consisted of agriculture-to-urban transfers, which is not surprising given the high prices

surrounding urban water use, it is likely that an agreement to use agricultural water for an environmental purpose would be contentious.

Boons or boondoggles

The goal of this paper has been to highlight the cost differences between two possible solutions to bring water to the Salton Sea. Both likely involve significant legal and regulatory issues, a discussion that goes beyond the purpose of this article. The Cortés-to-Salton solution is expensive, both in terms of its development costs as well as the ecosystem and public health damages — damages that may be irreversible — that will continue to occur over the ensuing years until completion. The degree to which the agriculture-to-environment solution could serve as an effective long-run solution requires a more systematic analysis of the public costs and benefits of both it and alternative solutions and involvement with a wider range of stakeholders. Yet, an agriculture-to-environment water transfer may be an attractive short-run option given the cost, the fact that all the physical infrastructure to implement it is in place, and its flexibility, which allows it to be used in conjunction with smaller-scale Salton Sea dust suppression and habitat projects.

So in considering the question whether ocean water importation is a boon or boondoggle, the answer is somewhat indeterminate and depends on the purpose of the importation. If importation is primarily couched as a means to save the Salton Sea, such a scheme certainly seems to warrant the "boondoggle" moniker. Yet if ocean importation is seen as a possible long-run solution to regional water scarcity in the Southwest with the Salton Sea being a potential beneficiary, it is not so easy to assign either label — boon or boondoggle — without further analyses that consider a larger set of stakeholders and factors over a much broader region and timeline.

If importation is primarily couched as a means to save the Salton Sea, such a scheme certainly seems to warrant the "boondoggle" moniker.

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