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# The cost of addressing saline lake level decline and the potential for water conservation markets

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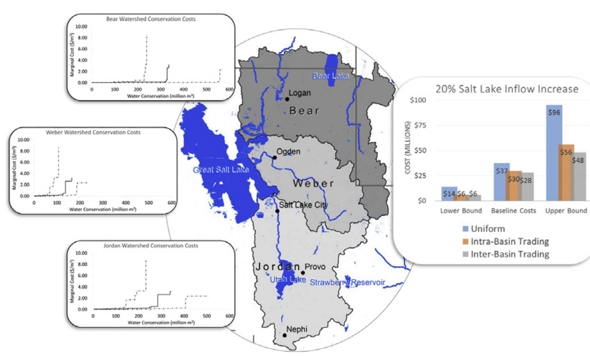
## HIGHLIGHTS

- Water conservation is a potential low-cost strategy for preserving saline lakes.
- Water conservation markets could reduce the cost of ecosystem protection.
- Cost estimates for preserving Great Salt Lake range from $14–$96 million.
- Water conservation markets reduce costs of conservation up to 57%.
- Conservation markets ensure the lowest cost regardless of allocation of cutbacks.

## GRAPHICAL ABSTRACT

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## ABSTRACT

The world's saline lakes are shrinking and human water diversions are a significant contributor. While there is increased interest in protecting the ecosystem services provided by these lakes, the cost of protecting water levels has not been estimated. To explore this question we consider the case of Great Salt Lake (Utah, USA) where human diversions from three rivers have caused the lake level to decline during the last century. Recent work has suggested the restoration of inflows is necessary to maintain a target elevation consistent with well-functioning ecosystems. We construct cost estimates of increasing water inflows using conservation cost curves for each river basin. We then compare the cost of uniform cutbacks to cap-and-trade systems which allow intra- and inter-basin trading. The cost of water to permanently implement uniform water right cutbacks to increase inflows by 20% above current levels is $37.4 million. Costs and cost-savings are sensitive to alternative allocation, inflow, and cost assumptions, and we estimate significant cost reductions from intra-basin water conservation markets (5–54% cost decrease) and inter-basin water conservation markets (22–57% cost decrease).


## 1. Introduction

Saline lakes are present on every continent except Antarctica, accounting for 44% of the volume of Earth's lakes (Messager et al., 2016). Worldwide, they are threatened and shrinking (Williams, 2002). Saline lakes respond to climate, naturally rising and falling with droughts and wet periods (Mohammed and Tarboton, 2012). However, historically streamflow to saline lakes was considered wasted water, and today widespread declines in saline lakes are largely attributable to human water diversions (Wurtsbaugh et al., 2017). While causes of lake decline, ecological and human health impacts, and cost of replacing ecosystem services of saline lakes are sometimes analyzed for individual

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lakes (for example Kittle, 2000; Micklin, 2007; Bioeconomics Inc, 2012; The Nature Conservancy, 2013; White et al., 2015), economic mechanisms and costs of increasing streamflow contributions to saline lakes have not been studied. We explore the potential of market-based approaches to increase streamflows to Utah's Great Salt Lake (GSL), although the method is applicable to saline lakes generally. The cost of maintaining GSL at an elevation that can consistently sustain the lake's ecosystem and services is evaluated by exploring alternative mechanisms for allocating reductions to water use.

GSL is located in northern Utah and is the fourth largest salt lake in the world by surface area. It provides a wide range of benefits including tourism, mineral extraction, brine shrimp production, and wetland habitat. GSL is shallow, averaging 4.3 m at mean elevation, which means that small changes in lake level correspond to large changes in surface area. Three major rivers feed GSL: the Bear, Jordan, and Weber Rivers. Diversions from these rivers have caused lake level to decline during the last century so total volume has been reduced by 48% (Wurtsbaugh et al., 2017). Also, population in GSL's three main tributaries is anticipated to nearly double by 2050, so greater reductions in GSL inflow and elevation are concerns (Utah Foundation, 2014). To maintain lake level and benefits, reductions in net extraction are needed (Wurtsbaugh et al., 2017).

GSL ecosystem services include dust control, wetland production, aesthetic values, and direct economic production from industry and tourism. The GSL is a sink for heavy metals, such as mercury, which may enter the system through rivers, or through atmospheric deposition as a result of mining activities (Wurtsbaugh, 2012). As lakebed is exposed, these contaminants as well as particulate matter $PM_{10}$ and $PM_{2.5}$ enter the atmosphere and, although not yet documented for the GSL Basin, have been shown worldwide to cause respiratory illness and other public health problems (Griffin and Kellogg, 2004). Economic costs of lakebed dust on human health have not been quantified, but could affect 2 million people in the Salt Lake City metropolitan area. In addition, maintaining lake elevation supports wetlands, which serve as crucial habitat for waterfowl and other migrating birds. A brine shrimp industry represents a total economic output of $56.7 million per year, while revenue from mineral extraction and refinement of sodium, magnesium, and potassium has a total economic impact valued at $1.13 billion per year (BioEconomics Inc., 2012). Optimal benefits of different services occur at different lake levels, with the greatest benefits from GSL provided when lake elevation is between 1279.6 m (4198 ft) and 1281.4 m (4204 ft) (DNR, 2013). Current lake level is 1278.0 m (4192.8 ft), with average annual streamflow increases of 29% needed to "maintain lake levels that would protect wildlife, lake access, human health and other beneficial uses (Wurtsbaugh et al., 2017)".

Economists have long advocated the benefits of market reallocation mechanisms because they equalize the marginal benefits of water across users (Chong and Sunding, 2006). However, it has been difficult to estimate economic gains from water marketing (Grafton et al., 2012). Markets for water rights differ by use and region, and marginal water values are difficult to acquire because market data is limited or nonexistent (Edwards and Libecap, 2015). Our approach uses water efficiency measures to create demand curves for water in the agricultural and urban sectors (Edwards et al., 2017), and then examines the potential to transfer conservation credits between sectors and regions. While the literature on water markets has focused on the transfer of physical water (rights, shares, allotments, etc.), our case provides the opportunity to estimate potential cost reductions from markets in water conservation credits. Throughout the paper, we measure conservation as the increase in GSL inflow resulting from the adoption of some approach to reducing water use. We refer to any designated increase in inflows by the corresponding *cutback* in current water use via conservation measures. To meet the total amount of needed cutbacks, conservation measures can be adopted and then traded because inflows to the GSL generally have the same effect on ecosystem production independent of sector or basin from which the water is conserved.

Importantly, the costs of cutbacks depend on the mechanism used to allocate them. A water conservation credit market, similar to a cap-and-trade market for air pollutants, offers a potential solution that can lower the cost of water conservation (Gonzales et al., 2017). We consider three cutback scenarios: uniform cutbacks, where each water use sector on each river cuts back use by a uniform percentage of current use; intra-basin trading, where cutbacks can be traded between water sectors within the boundaries of each of the three basins individually; and inter-basin trading, where cutbacks can be traded across water sectors and basins. We compare the costs of cutbacks under each scenario and then provide sensitivity analyses for the size of cutbacks, the allocation of cutbacks among basins, and the cost of cutbacks. Because institutional mechanisms for implementing conservation markets do not currently exist, we expand on the barriers to their adoption in the discussion.

## 2. Theory

Consider two water users, A and B, facing water use cutbacks. Each has a different marginal abatement (conservation) cost curve, which maps the amount of water reduced to the marginal cost of the reduction. Users have many potential conservation options, but they will first undertake the cheapest measure, so the efficiency cost curves are upward sloping, meaning marginal cost is increasing as abatement increases. Water use abatement could come from eliminating water from current use, either through conserving water or stopping economic production, such as by fallowing fields. For the purpose of this paper we assume that for the range of reductions we estimate, conservation cost determines the marginal cost of abatement. Measures like fallowing that reduce economic production are not considered.

For simplicity, assume both A and B currently use the same amount of water. A government regulator would like to reduce total water use by $Q_\alpha$. To do this via a uniform cutback, each user faces a reduction of $\frac{Q_\alpha}{2}$. This outcome is shown in Fig. 1. This method arrives at the required abatement level but does not minimize cost because A has a higher marginal abatement cost than B, $P_\alpha^A > P_\alpha^B$. Total abatement cost is the area under each abatement cost curve from 0 to $\frac{Q_\alpha}{2}$. The minimum cost water abatement level will always occur where the marginal cost of abatement for both users is equal. Because user B has a lower marginal cost of abatement for any level of reduction, cost minimization requires B to reduce water use by more than A. At the equalized marginal

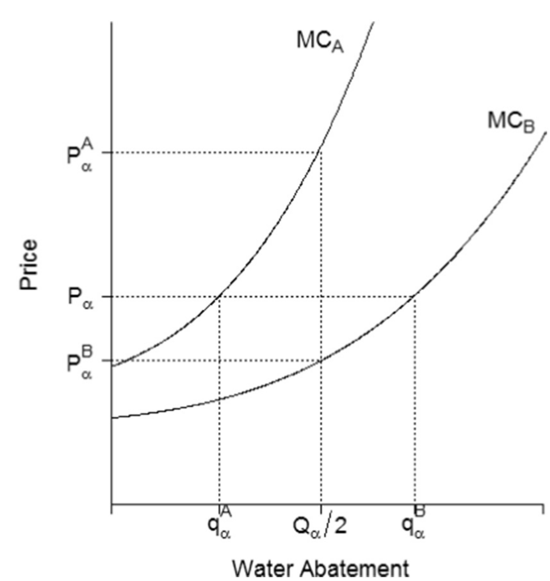


**Fig. 1.** Marginal abatement cost curves and cutbacks under uniform abatement, $\frac{Q_\alpha}{2}$, and equalized marginal abatement costs, $P_\alpha$.