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To cite this article: Margaret O. Wilder, Ismael Aguilar-Barajas, Nicolás Pineda-Pablos, Robert G. Varady, Sharon B. Megdal, Jamie McEvoy, Robert Merideth, Adriana A. Zúñiga-Terán & Christopher A. Scott (2016): Desalination and water security in the US–Mexico border region: assessing the social, environmental and political impacts, Water International, DOI: 10.1080/02508060.2016.1166416

To link to this article: http://dx.doi.org/10.1080/02508060.2016.1166416

Published online: 12 Apr 2016.
Desalination and water security in the US–Mexico border region: assessing the social, environmental and political impacts

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ABSTRACT

In the western US–Mexico border region, both countries’ authorities look to desalination as a means to meet increased demands for dwindling supplies. In addition to several existing or planned desalination plants, plans exist to develop projects along Mexico’s coasts to convert seawater into freshwater primarily for conveyance and consumption in the United States. Even though desalination systems have the potential to increase water supply in the region, there are associated consequences, costs and constraints. To understand the impacts of such binational desalination systems, this paper assesses, through a water-security framework, the case of a proposed desalination plant on the Upper Gulf of California. The analysis suggests that for binational desalination systems, there are several key areas of impact against which the benefits of increased water supply must be weighed.

ARTICLE HISTORY

Received 22 April 2015
Accepted 14 March 2016

KEYWORDS

Desalination; water security; transboundary water management; binational cooperation; US–Mexico; Arizona; Sonora

Introduction

Changes in water supply and demand in the western US–Mexico border region, driven by climatic, social and political forces (Garfin et al., 2014; Magaña, Zermeno, & Neri, 2012; Udall, 2013), are expected to increase water scarcity – and decrease water security – throughout the region in coming decades. As a result, desalination has captured the interest of a growing number of public- and private-sector water managers in need of new and reliable water sources.

For example, along the coasts of California (United States) and in Baja California (BC), Baja California Sur (BCS) and Sonora (Mexico), several desalination plants are being planned, under construction or in operation to serve the needs of communities generally nearby (Rodriguez, 2011). However, for cities without coastal access (i.e., in Arizona and Nevada), many are looking southward – beyond the US–
Mexico border – to a perceived abundant and accessible supply of seawater that could be transformed into deliverable freshwater (Central Arizona Project, 2013; Desalination.biz, 2015).

Desalination\(^1\) is a technological process that removes salts and other minerals from seawater (or from brackish water), creating freshwater suitable for multiple uses (Cooley, Gleick, & Wolff, 2006). Desalination capacity worldwide has grown exponentially in the last 40 years, with about a dozen arid-lands nations now using it (National Research Council (NRC), 2008). Globally, there are more than 18,400 desalination plants producing over 86 MCM (million cubic metres; or 23 billion US gallons) of water/day (International Desalination Association (IDA), 2016).

The most popular desalination technology is reverse osmosis (Mezher, Fath, Abbas, & Khaled, 2011). The key elements of a reverse-osmosis desalination system are: (1) intakes of seawater or brackish water; (2) pre-treatment to remove suspended solids and prepare the source water for further processing; (3) removal by reverse osmosis (using a semi-permeable membrane) or other technologies of dissolved solids, primarily salts, from the water; (4) post-treatment to prevent corrosion of downstream water pipes; and (5) concentrate management, the handling and disposal or reuse of the salt wastes from the process.

In the US portion of the region, two seawater desalination plants operate along the coast of California (Figure 1): a small plant in Sand City (along the central coast near Monterey) that provides 0.0136 m\(^3\)/second (300,000 gallons/day), and the Carlsbad

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**Figure 1.** Desalination plants in the western US–Mexico border.
desalination plant near San Diego (Pacific Institute, 2016). The Carlsbad plant is the largest desalination plant in the Western Hemisphere and started operations in December 2015 delivering 2.6 m$^3$/s (50 million gallons/day) to the county (Carlsbad Desalination Project, 2016). In addition, more than a dozen proposed seawater desalination plants have been proposed in California, and two considered in BC, Mexico, that planners hope would provide water to southern California (Pacific Institute, 2016).²

Mexico, though not presently a top user of desalination technology, has made desalination development a high priority in recent years.³ The largest coastal desalination plant in Mexico (capacity of 200 l/s) is located in Los Cabos, BCS, providing potable water to 40,000 residents in Cabo San Lucas, and a new project is planned for La Paz, BCS (McEvoy, 2014). Other governmental projects are in the process of construction, or under study, in Ensenada, BC, and Guaymas-San Carlos, Sonora (Desalination.biz, 2015; Comisión Nacional del Agua (CONAGUA), 2015). At the local level and mostly among private actors there is increasing attention for the seawater desalination projects in Rosarito, BC, and in Puerto Peñasco, Sonora.⁴ Both have considered the possibility of exporting desalted water to the United States, though no definitive decision to do so exists. As originally planned, the Rosarito plant was to export water to San Diego (Dibble, 2014) and the Puerto Peñasco plant to Arizona.⁵ A step forward for the official adoption of the Peñasco plant was an agreement signed in 2014 by the state governors of Arizona and Sonora to investigate desalination opportunities (Arizona Mexico Commission, 2014). Also, CONAGUA undertook a preliminary study to build a desalination plant to supply water to just the community of Puerto Peñasco (CONAGUA, 2014).⁶

The anticipated regional imbalance between water supply and demand has pushed several large municipal water providers to examine further the technical and financial aspects of possible desalination plants (Arizona Department of Water Resources (ADWR), 2014; Cooley & Heberger, 2013; Southern Nevada Water Authority (SNWA), n.d.). Several major US water utilities have identified potential desalination sites on the coast of western Mexico in their water supply plans.⁷

The Arizona Department of Water Resources (ADWR), for example, identifies the ‘importation or exchange of new water supplies developed outside of Arizona (e.g., ocean desalination) as one of its water-supply strategies for the next “25 to 100 years”’ (ADWR, 2014, p. 16) and notes ‘exploration of this strategy should begin immediately’ (p. 19). Several state agencies in Arizona and California have partnered with entities of the US and Mexican governments to conduct various feasibility studies for proposed desalination facilities in Mexico. Mexico’s National Water Commission (CONAGUA) cites the ‘capture and desalination’ of seawater and brackish water as a principal water augmentation strategy (CONAGUA, 2008, p. 51). The US and Mexican sections of the International Boundary and Water Commission (IBWC; CILA in Mexico) agreed to an amendment (Minute 319) to the 1944 US–Mexico Water Treaty committing the two countries to ‘invest […] in infrastructure such as desalinization facilities’ to generate additional volumes of water using new water sources (International Boundary and Water Commission (IBWC-CILA), 2012; Sanchez & Cortez-Lara, 2015).

These studies would site the facilities along or near the coast of Mexico, with the largest consumers of the desalted water being in the United States. In these cases, the freshwater either would be conveyed from Mexico directly to California, Nevada and
Arizona or exchanged (through some form of binational agreement) for a retained portion of Mexico’s share of the Colorado River flow (as allocated by treaty in 1944).

We call such arrangements – in which desalted water is produced in one country and delivered or exchanged with another country – binational desalination systems.

We assess whether the expectations for desalination in the US–Mexico border region – that is, to meet growing demands in the face of diminishing supplies – are reasonable and warranted. Within an analytical framework informed through the perspective of water security and interconnected social–ecological–hydroclimatic (SEH) systems, we evaluate the case of a proposed desalination plant on the Mexican coast of the Gulf of California in Puerto Peñasco, Sonora. We assess the project in terms of its (1) economics (cost), (2) energy use, (3) environmental impacts and (4) socio-political implications. We present our findings and articulate the implications for desalination projects in the region, specifically for binational desalination systems. We offer three salient conclusions to consider as desalination technology and planning move forward in the western US–Mexico border region.

**Binational desalination systems and water security**

Binational desalination systems are promoted as an important strategy, or response, to ensure water security for particular communities or service areas. In a narrow sense, *water security* means having a sufficient quantity of water supply to meet current and future needs. Grey and Sadoff (2007) define water security in terms of both quantity and quality, productive and destructive properties, and tradeoffs between risk and mitigation of water insecurity. Following Scott et al. (2013), we understand water security as intrinsically embedded in complex SEH systems and that it is achievable through adaptive management (Figure 2). *Adaptive management*, in turn, refers to water infrastructure (technology) and water management (institutions) that deal with uncertainty through governance systems that are flexible and dynamic, reflecting key characteristics such as trust and sustained iterative relationships, knowledge-sharing, transparency and accountability, and representation (participation and equity) among the decision-makers, the scientific community, and policy networks that comprise most water governance systems (Pahl-Wostl, 2006; Wilder et al., 2010).

Achieving water security means balancing the supply side and demand side of the access-to-water equation as well as the risk (destructive) and resource (productive) dimensions of water. Water-supply augmentation has been, and often continues to be, based on new infrastructure, capture and conveyance, and long-distance transfers of freshwater. By contrast, policy-based approaches emphasize demand management, governance and only as a secondary measure, tapping new sources such as groundwater, reclaimed water, and desalinated seawater and brackish water. Examples of the latter include California’s emphasis on water-conservation measures to address drought-induced water scarcity, which are viewed as politically more attractive than large-scale construction of new reservoirs.

The western US–Mexico border region exhibits high social vulnerability with rapid population growth, high domestic and international migration, intense economic development and globalization, and climatic changes (Scott & Pasqualetti, 2010; Wilder et al., 2010). Socio-economic conditions are asymmetrical on the border’s two sides, with
Arizona’s average incomes and municipal budgets being much higher than Sonora’s (Wilder, McEvoy, Garfin, Beaty, & McGovern, 2012). The region – particularly in the areas of the Colorado River delta, Upper Gulf of California and coasts – contains natural protected areas of environmental significance, including fragile wetlands and estuaries.

The area generally is arid to semiarid, with water scarcity being common. Climate change projections for the southwestern United States and northwestern Mexico include increased temperatures, prolonged drought, and declining surface-water and groundwater supplies (Garfin et al., 2014). Such projections for the state of the hydroclimatic systems exacerbate the potential of threats to water security in the region.

The likelihood of increased water scarcity resulting from hydroclimatic and socio-economic drivers – combined with often-protracted and politically contentious processes for planning and implementation of more systemic approaches to water scarcity (such as intersectoral reallocation, conservation and demand management) – seems to impel the consideration of desalination as a possible contributor to water supply. This is especially true with rapidly declining costs of reverse osmosis (the currently preferred desalination technology) and historically low energy prices. Nevertheless, some important challenges require serious consideration.

**Benefits and challenges of desalination**

Proponents suggest that desalination systems offer a ‘drought proof’ water supply (Kohlhoff & Roberts, 2007) as well as increased water-system reliability and the potential to reduce demands on aquifers and surface water. The National Research Council (NRC) (2008) deems desalination ‘a realistic option’, though noting its financial, social and environmental costs. Elimelech and Phillip (2011) note that if
conservation and ‘soft path’ (non-infrastructural) options prove to be insufficient to meet future demand, then desalination should be considered as a valid and crucial component to enhance water supply. Technological innovation in the design of desalination facilities may help reduce energy use and soften impacts on marine environments. In water-scarce countries and regions globally, desalination may actually be the only viable means to support regional economic development (Elimelech & Phillip, 2011). Thus, investment in desalination systems is seen in some cases to increase water security.

Tal (2011) finds that desalination experiences in Israel, Australia and Spain have reduced water shortages without causing debilitating negative environmental impacts. These countries apply technologies for brine dilution and other strategies that address negative externalities and reduce water shortages, increase cost-effectiveness, improve affordability (including for developing countries), and potentially enhance national environmental security.

Desalination sceptics see the advantages of increased water supplies from desalination outweighed, or tempered at least, by high capital and operating costs of the plants and related infrastructure (Mezher et al., 2011); large energy requirements – accompanied by, in some cases, increases in CO₂ emissions – for processing seawater and conveying the resulting freshwater (Meerganz von Medeazza, 2005; Mezher et al., 2011); significant environmental impacts, especially due to brine disposal in coastal and marine ecosystems and from other pollutants (Cooley et al., 2006; Cooley & Heberger, 2013; Gleick, 2015); and inequitable distribution of benefits versus costs among communities, regions and nations, particularly when contrasting the areas of freshwater production versus those of consumption (McEvoy, 2014; Wilder et al., 2013).

Thus, there is an ongoing theoretical debate on desalination. On the one hand, desalination can be seen as a ‘panacea’ to achieve water security in arid regions; and on the other hand, it can be seen as a ‘bandage’ for wealthy nations with consequences in terms of greenhouse gas (GHG) emissions and environmental impacts (Tal, 2011). Because of the high costs and environmental impacts associated with desalination systems, these are often seen as a low-priority strategy for increasing water security. According to Gleick (2015), desalination should be the last resort and only pursued once other water-conservation strategies are implemented, such as reducing water use, reusing wastewater, decreasing agricultural water use (by reducing cultivated areas, shifting to low-water-use crops and water-efficient irrigation techniques); by adequately charging and metering water use, including groundwater; by installing water-efficient technologies (e.g., dual-flush toilets); and by harvesting rainwater. Even where large-scale desalination operates (e.g., the Middle East and Australia), there is a recognition that it is but one of multiple water-supply options that should be complemented by demand-management strategies (Tal, 2011).

In a binational context, there can exist an asymmetry at a site where valuable ecological services are produced and distributed. As López-Hoffman, Semmens, and Diffendorfer (2013) have demonstrated, ecological services may create value ‘off-site’ from where they are produced, and where one area may subsidize (i.e., bear most of the costs) benefits received elsewhere. A central question is who pays the
environmental costs of desalination and how are these costs internalized. In the case of binational desalination systems, water would be produced on one side of the border to serve a local population, yet would also benefit large populations in distant locations across the border (e.g., major cities in Arizona and Nevada). As López-Hoffman et al. (2013) argue, these processes should be understood as part of an integrated ecosystem. Binational desalination systems underscore the importance of appreciating the distribution not only of benefits but also of risks associated with water production.

**Concerns about desalination**

While the benefits of desalination systems seem apparent, the challenges require scrutiny. From the discussion above, we cluster these areas of concern (informed though a water security and SEH systems framework) into four areas: (1) economic considerations, (2) energy requirements, (3) environmental impacts and (4) social and political (binational) implications.

**Economic considerations**

On the global scale, the cost of producing desalinated water dropped by 50% from 1985 to 2005, due to improvements in technology, energy recovery and conservation; increased competition among suppliers; and economies of scale (Elimelech & Phillip, 2011; Tal, 2011). Nonetheless, studies in California and Mexico identify desalination as having the highest marginal costs among all realistic water-supply alternatives (CONAGUA, 2008; Cooley & Ajami, 2012; McEvoy, 2013). In California, the Pacific Institute found (Table 1) that the cost/acre-foot (1233 m$^3$) of desalinated water (US $1800–2800, or US$1.46–2.27/m$^3$) was three to four times that of groundwater (US $375–1100, or US$0.30–0.89/m$^3$) and two to three times that of imported water (US $875–975, or US$0.71–0.79/m$^3$) (Cooley & Ajami, 2012). What do these costs mean at the household level? Estimates associated with the Carlsbad, California, desalination project show costs of US$2014–2257/acre-foot of water (or US$1.63–1.83/m$^3$), with household increases of US$5–7 a month by 2016 (San Diego County Water Authority (SDCWA), 2013).

<table>
<thead>
<tr>
<th>Water alternative</th>
<th>Cost (US$/m$^3$)</th>
<th>Energy intensity (range; kWh/million gallons)</th>
<th>Energy Intensity (range; kWh/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imported water from northern California</td>
<td>0.71–0.79</td>
<td>0–3500</td>
<td>0–0.9</td>
</tr>
<tr>
<td>State water project, southern California</td>
<td></td>
<td>7900–14,000</td>
<td>2.1–3.7</td>
</tr>
<tr>
<td>Colorado River aqueduct, southern California</td>
<td></td>
<td>6100</td>
<td>1.6</td>
</tr>
<tr>
<td>Surface water</td>
<td>0.32–0.65</td>
<td>0–1000</td>
<td>0–0.3</td>
</tr>
<tr>
<td>Groundwater</td>
<td>0.30–0.89</td>
<td>500–3500</td>
<td>0.1–0.9</td>
</tr>
<tr>
<td>Seawater desalination</td>
<td>1.46–2.27</td>
<td>12,000–18,000</td>
<td>3.2–4.8</td>
</tr>
<tr>
<td>Recycled water (membrane treatment)</td>
<td>0.97–1.46</td>
<td>3300–8300</td>
<td>0.87–2.2</td>
</tr>
<tr>
<td>Brackish water desalination</td>
<td>n.a.</td>
<td>1500–8200</td>
<td>0.4–2.2</td>
</tr>
</tbody>
</table>

Source: Compiled by the authors from Cooley and Ajami (2012), tab. 3, p. 14; and Cooley and Heberger (2013), fig. 2, p. 7. All costs are in 2010 US$.
Energy requirements

Energy requirements may limit further reduction in desalination cost, but these costs need to be seen within a cost–benefit analysis. Energy demand is the largest cost variable for desalination plants, ranging from one-third to one-half of total costs of produced water (Cooley & Heberger, 2013). Thus, desalination costs will rise with anticipated increases in energy prices (Cooley & Heberger, 2013). The amount of energy needed to clean the ‘feedwater’ of salts and minerals increases with the amount of total dissolved solids found in the water. Reverse osmosis uses approximately 10 times more energy than traditional treatment of an equal volume of surface water (NRC, 2008).

Environmental impacts

Given a lack of long-term research, the NRC (2008) concluded there is ‘considerable uncertainty’ about the environmental impacts of desalination (p. 144). The reverse-osmosis process uses several chemicals – antiscalants, coagulants and membrane preservatives – that are released into marine environments (Tal, 2011). Also, marine organisms can become trapped in the intake systems (but screens and wells for subsurface intake of water can eliminate the entrapment of organisms (NRC, 2008).

The discharge and eventual disposal of the concentrated brine – and its impact on marine and terrestrial ecosystems – is the thorniest environmental issue. In the reverse-osmosis process, when water moves through the semi-permeable membrane, two streams of water are produced: of freshwater and of brine wastewater, at twice the salinity of seawater (Tal, 2011). The most common disposal method of concentrated brine for seawater plants is dispersal back into the ocean. Best practices for this disposal include blending and diluting the concentrate water with seawater before dispersal and using multiport diffusers to disperse the discharge stream. Cost-effective and environmentally sensitive disposal options for inland desalination are limited (NRC, 2008).

In addition to the environmental impacts on aquatic ecosystems, the link with energy use provides a considerable environmental impact in terms of the associated GHG emissions, if the energy sources include fossil fuels (Scott & Pasqualetti, 2010).

Social and political (binational) implications

The development of desalination projects with benefits or impacts that cross national boundaries suggests a potential for shifts in the geopolitical–power relationship between (or among) the nations involved (Wolf, 2009). In the case of a binational plant, water security – in both its narrow sense as secure future water supply and its broad sense as ensuring safe, clean and affordable water supply while meeting human and ecosystem needs – would clearly depend upon maintaining good binational relations.

Desalination as a viable source of water in the US–Mexico border region depends on suitable technology, feasible economics and amenable political conditions (i.e., cooperative and binational institutions and governance structures) sufficiently robust to permit a new and relatively expensive technology to take hold. Furthermore, binational desalination initiatives pursued unilaterally by one or more of the lower Colorado River Basin states would almost certainly affect the complex legal mechanisms surrounding Colorado River.
US–Mexico water relations. Since 1820, Mexico and the United States have sustained a chequered history of political relations marked by periods of mistrust interspersed with times of relative harmony. Examples include the building of the All-American Canal in the United States derived by mistrust of relying on foreign countries – in this case Mexico – for water supply, and the signing of Minute 319 as a harmonic moment in the history of binational relations. Over the past century, and particularly since the 1940s, the two nations have built a suite of binational institutions to deal with shared waters (such as the Rio Grande – known as Río Bravo in Mexico – and Colorado River, and several groundwater basins). In confronting the challenges of adopting desalination as a new water source, two attributes of water governance serve as bookends: good relations between Mexico and the United States and, especially, trust among actors at all levels (Varady, Gerlak, & McGovern, 2014).

Stakeholders and authorities. Institutions in the United States function in a highly decentralized setting, with a great deal of authority devolved to the states, including assigning, adjudicating or enforcing access to water supply (Megdal, 2012). At the federal level, decision-making on water-related issues is complicated by the existence of numerous agencies and institutions that frequently maintain overlapping or conflicting missions (Milman & Scott, 2010). Similar complexities and overlaps exist at the state, county and community levels, and include such stakeholders as regional water authorities, agricultural districts, individual and communal (e.g., tribal) rights holders, and non-governmental organizations.

In Mexico, the decision to set up a desalination plant in the Gulf of California resides mostly with federal agencies and, to a lesser extent, in the local (state and municipal) authorities. The main federal agencies would be CONAGUA and the federal environmental ministry, Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). CONAGUA is institutionally framed within SEMARNAT, but it wields great influence beyond this ministry, as manifested in its budget, which is larger than that of its parent. In addition, the Federal Electricity Commission, the Mexican Treasury (SHCP Secretaría de Hacienda), and the Mexican International Boundary and Water Commission (known as CILA in Spanish) will likely play a role as well. At the local level the key stakeholders would be the state and municipal governments. The main stages of the desalination decision-making process are: (1) seawater extraction (in Mexico, seawater desalination would require a five-year concession, to 30 years) granted by the Mexican president, via CONAGUA (Ley de Aguas Nacionales (LAN), 1992, Art. 24); (2) discharge of wastewater and brackish water (regulated by the Law of Ecological Equilibrium and Protection of the Environment); (3) power provision (approval needed by the Mexican Federal Electricity Commission (Comisión Federal de Electricidad – CFE); (4) municipal authority (the municipalities affected would grant land-use permits to locate the seawater intake, the desalination plant and the route of the water conveyance system (Pineda, 2015); permission would be needed from each landowner, including private, and federal, state and municipal governments); (5) exportation of desalted water across the border (the Mexican Treasury has the last word in exporting natural resources and would need to design the main policy guidelines; border agencies, such as the IBWC-CILA, would likely serve as intermediary and as the arena for trade negotiations); (6) public opinion, political parties and the media (favourable considerations from all these would be needed); and (7) site considerations.
Assessing the binational desalination system: a case study of the proposed Puerto Peñasco desalination plant

Puerto Peñasco is located on the Upper Gulf of California (Sea of Cortez), near the Colorado River Delta and the Pinacate and Gran Desierto de Altar Biosphere Reserves (Figure 3). The Gulf ecosystem is considered to have ‘exceptional’ biodiversity (Kamp, 2005), replete with bird species, plants, marine life and fish, which also provide a livelihood, albeit a declining one, for coastal fishing communities.

Dreams of desalination on the Gulf of California coast have a long history, dating to 1965. Almost 50 years later, two parallel studies were conducted in 2008–09 to assess the feasibility of constructing a desalination plant in Puerto Peñasco (HDR, 2009; US Trade and Development Agency (USTDA), 2008, 2009). In one study, the Puerto Peñasco municipal government petitioned and was awarded a grant by the USTDA to conduct an exploratory study for a seawater desalination facility. The USTDA study estimated that the plant would have a minimum daily overall water-recovery rate of 40% – for every 9.5 litres (2.5 gallons) of seawater intake, 3.8 litres (1.0 gallon) of permeate, or freshwater, would be produced, along with 5.7 litres (1.5 gallons) of brine (USTDA, 2009).

In a second effort, water managers from the Salt River Project, CAP, ADWR, USBR and Sonora’s state water commission authorized a study for a binational Arizona–Sonora desalination project (HDR, 2009). It considered two project scales and associated energy needs and concluded that a smaller-scale Arizona–Sonora

Figure 3. North-west Mexico and the south-west United States.
A project that transports desalted water 270 km (168 miles) via a pipeline from Puerto Peñasco to the Imperial Dam (located 29 km north-east of Yuma) could provide 148 MCM (120,000 AF) annually, at an estimated cost of US$2,208,870/MCM (US$2,208,870/MCM) and would require 50 megawatts (MW) of energy capacity. The larger-scale regional project could produce 1480 MCM (1.2 MAF) annually, to be pumped to Imperial Dam via a canal, for an estimated cost of US$958,230/MCM (US$958,230/MCM), but would require 500 MW of energy capacity (Table 2). This additional water would then be conveyed via the CAP system to Lake Mead (the SNWA intake) and the municipal areas it serves for use or exchange for other Colorado River rights. Although CONAGUA as well as the municipal government of Puerto Peñasco demonstrated a keen interest in building a binational desalination facility there, that interest notably diminished between 2009 and 2014. In 2014, the Arizona–Mexico Commission affirmed a ‘cooperation agreement’ signed by the governors of Arizona and Sonora to ‘investigate’ desalination opportunities on the Gulf of California that would ‘augment and increase water-supply resiliency’ in both states (Arizona–Mexico Commission, 2014). Puerto Peñasco and Puerto Libertad to the south, the site of one of Mexico’s largest thermo-electric plants, have been discussed as future sites relative to this agreement.

Below, we assess the proposed Puerto Peñasco desalination in our analytical framework of (1) economic considerations, (2) energy requirements, (3) environmental impacts and (4) social and political (binational) implications (Table 3).

### Economic considerations

The final USTDA (2009) report estimates that Puerto Peñasco could build a plant with the capacity to produce 0.5 m³/s (11.4 MGD) in the first phase, with expected expansion...
of up to 2 m³/s (45.6 MGD) by 2020 at a cost of US$2.29/m³ (US$8.67/1000 gal) (not including conveyance and storage). This is approximately seven times more expensive than the current cost of water production and delivery (US$0.339 m³) (USTDA, 2009). Other economic issues include the cost of producing desalted water for domestic and municipal use, and the pricing issues (affordability, equity of access to low income consumers) remain significant unknowns.

**Energy requirements**

The current electricity-generation portfolio in Sonora is heavily thermal-based, with the result that proposed additions of 20 MW for the Puerto Peñasco municipal plant, or 50 MW for the Arizona–Sonora binational plant, would increase Sonora’s current GHG emissions by an estimated 1.9% and 4.8%, respectively. Clearly, proposed solar-power generation for Puerto Peñasco desalination would offset these increases, but the necessary technology may not be available or be cost-effective yet. On the other hand, the 500 MW regional binational plan would require very substantial increases in generation, unlikely to be met by solar, and thus that option has the most significant emissions implications in percentage increase and total GHG terms. The Comisión Federal de Electricidad (CFE) confirmed that it could provide the 20 MW needed to power the project. The estimated cost of electricity from CFE would be US$0.25/kWh (USTDA, 2009). The thermoelectric plant in Puerto Libertad (the alternative location of the desalination plant) is changing to US-imported natural gas (‘CFE modifica planta en Sonora para utilizar gas natural de EU’, 2013).

**Environmental impacts**

The environmental impacts of a desalination plant located in the Gulf of California may not be the same as those from a facility located on the Pacific Ocean coast. Research has shown that turbulent hydrodynamic conditions (e.g., waves, currents) are less detrimental to aquatic ecosystems when discharging brine (Meerganz von Medeazza, 2005).

### Table 3. Assessment of the binational desalination case using a water-security framework.

<table>
<thead>
<tr>
<th>Evaluation criteria</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic considerations</td>
<td>Highest end of the cost spectrum compared with alternative modes of water supply augmentation</td>
</tr>
<tr>
<td>Energy requirements</td>
<td>&gt; 40% of total costs</td>
</tr>
<tr>
<td>Environmental impacts</td>
<td>Environmental impact assessment (EIA) not completed, creating significant unknowns. Environmental impacts on marine life and environment of the Upper Gulf are likely to be high due to high levels of brine discharge. Land impacts may occur due to estuary development and conveyance structure. Greenhouse gas (GHG) emissions will increase if fossil fuels are used for energy supply. Water supplies will likely be reduced as a consequence of prolonged drought.</td>
</tr>
<tr>
<td>Social implications</td>
<td>Water supply augmentation may be positive for water users in Arizona, Nevada and coastal Sonora. However, livelihoods related to fisheries and aquatic ecosystems may be negatively affected. Distribution of benefits and mitigation of risks to both sides and to all income levels would be critical in viewing the desalination system as fair and equitable.</td>
</tr>
<tr>
<td>Political (binational)</td>
<td>Binational desalination plan would increase the importance of sustained good binational relations between the United States and Mexico to ensure secure future water supply and quality.</td>
</tr>
</tbody>
</table>

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Therefore, discharging brine in the tranquil Gulf of California may additionally stress coastal marine ecosystems.

The major issue facing the build-out of the municipal or binational plant would be how to deal with the brine concentrate discharge produced, without harming fragile and ecologically significant estuaries and important marine species in the Upper Gulf. During phase I of the Puerto Peñasco plant, which could produce 0.5 m$^3$/s of freshwater, it is estimated that 0.73 m$^3$/s (16.6 MGD) of brine concentrate will be produced (USTDA, 2009). The report’s preferred option is direct discharge into the sea. Project engineers recommend discharging near the surface to take advantage of prevailing winds and stronger currents to help disperse the brine concentrate (USTDA, 2009). An environmental impact assessment was initiated but not completed (CONAGUA, 2015). In addition, energy use in the desalination plant would likely be from fossil-fuel sources producing GHG emissions.

**Social and political (binational) implications**

Increasing water supply in this water-short region via desalination would benefit many people, the majority of whom live on the US side of the border. Water would be desalted on the Mexican side and transported across the border to major Arizona cities. Local Mexican communities would also benefit from increasing water supply, particularly those whose livelihoods – unlike those that rely on fishing – do not depend on potentially harmed ecosystems. Job creation in both the proposed desalination plant and in the growing tourism industry (as a consequence of more water) might offset (economically) this loss of fisheries-related jobs. Nevertheless, most of the area’s tourism-and-recreation attraction is related to the high biodiversity of the Upper Gulf (fishing, snorkelling), so livelihoods that depend on these tourist attractions would be negatively affected. Socially, the externalities of the desalination process would impact mostly persons in local communities in Mexico, and less so those in the United States.

Puerto Peñasco’s future development is contingent upon enhancement of its water supply, likely through developing desalination capacity. Its groundwater aquifers are severely depleted, therefore the beach community needs a new water source to allow it to grow. Yet energy use, unpredictable energy costs and water–energy tradeoffs are critical environmental concerns. Economic and environmental consequences may interrelate in other ways. For example, damage to marine life in the Upper Gulf could harm fisheries and impair local livelihoods; and economic development could improve or reduce quality of life in the local community.

**Summary**

While there are many plans for construction and use of binational desalination systems, significant unknown factors inhibit the use of definitive metrics. Based on available evidence, we assessed one binational desalination project located in the western portion of the US–Mexico border region (in Puerto Peñasco or Puerto Libertad, Sonora) in terms of its economic consideration, energy requirements, environmental impacts, and social and political (binational) implications. The project is still only a proposal and the EIA has not been completed, and information regarding benefits and consequences remains necessarily limited.
Areas of significant impact

What emerges from our analysis of the project are four principal areas of impact: (1) water and energy, (2) the environment, (3) local economies and communities, and (4) water security.

Water and energy

Desalination is already a part of the future strategy to meet the projected growth in water demand in the border region and could potentially (in Puerto Peñasco or Puerto Libertad) assume a larger role in regional water-supply strategy. At the same time, challenges remain, including the use and cost of energy to operate these plants.

Environment

The magnitude of environmental impacts of the proposed Puerto Peñasco (or Puerto Libertad) plant is uncertain. Potential impacts (perhaps subject to mitigation) include harm to marine life in fragile estuaries and in the reaches of the Upper Gulf of California due to briny concentrate dispersion, spread of chemicals and fish intake. In addition, the associated GHG emissions from energy use will impact the environment.

Local economies and communities

The socio-economic effects of desalination systems are not well researched. Most studies have concerned technical, logistic or economic aspects of introducing desalination technology; few have evaluated this within a systemic framework. Binational desalination is likely to enable economic growth, but could also have adverse impacts if environmental consequences ensue that affect recreational tourism or livelihoods. Fishing livelihoods may be negatively affected. However, such losses may be offset by increasing jobs in the service or tourism sector.

Binational implications

Water security – like water itself – does not recognize political boundaries. In a region that is by its physical nature water short, and at the same time is growing economically and demographically, access to water is critical to populations and to ecosystems. Binational desalination efforts – benefiting from new, more efficient technology – offer a potential source of new water.

The transboundary implications of current binational desalination plans are considerable, yet over the past 60 years the two countries have managed transboundary water resources peaceably, solving shared problems, and operating shared, binational facilities. For example, in the last five years, Mexico and the United States have responded to increased regional water stress with enhanced cooperation (as via the groundbreaking Minute 319 agreement).

However, in the case of a binational desalination plant, stakeholders, both public and private, and from both sides of the border, would need to agree and to support the terms, conditions and externalities associated with desalination.

The institutional and governance structure to undertake binational desalination systems is developing in Mexico. There, perceptions of fairness, openness and transparency will be paramount in assessing how people feel about both domestic and
binational desalination systems. By contrast, in the United States, perceptions of the reliability and security of a potential binational desalination production and delivery system will be key to its acceptance as a reasonable augmentation strategy.

**Conclusions**

The findings from this study lead us to offer three salient conclusions to consider as desalination technology and planning moves forward in the Arizona–Sonora region:

- Desalination systems alone do not constitute a sustainable approach to water management. There is an emerging realization among researchers that desalination should be employed as an alternative to augment water supply only when other options have been carefully considered, and once society is comfortable with how it uses existing supplies (Eden, Glass, & Herman, 2011; McEvoy & Wilder, 2012; Scott & Pasqualetti, 2010). It could be argued that increasing water-use efficiency is a prerequisite to enhancing supply. Unless effective measures are first taken to increase water-use efficiency, having more water – from internal or external sources – could potentially fuel unsustainable growth and development. Simultaneously, if water management institutions remain inefficient, or if they lack strong institutional capacity (e.g., for registering, metering, billing and collecting water fees), the availability of more water is unlikely to solve existing shortages. Without tackling such structural problems, more water could amplify these inefficiencies and promote unsustainable growth.

- Building a sustainable desalination system means paying attention to the multiple, non-technological attributes of desalination systems (environmental, financial, social, institutional, legal, political), especially in a binational setting. Uncertainty concerning environmental impacts of desalination clouds its prospects in the region. Economic and financial questions are prominent and underscore the need for transparency and accountability regarding the true costs and benefits of these projects. But even if those technological, financial and environmental matters were addressed, there may still be social, institutional, legal and political obstacles between the successful drafting and execution of long-term initiatives. In other words, excellent techno-scientific expertise on desalination may be available, but the socio-institutional–political setting may not. Thus, in binational settings, more explicit attention should be paid to the multiple, non-technical attributes of desalination systems.

- In the US–Mexico border region there have been periods of high and low levels of cooperation and trust between the two countries. The All-American Canal was built during periods of mistrust, while Minute 319 and the June 2014 Arizona–Mexico cooperation agreement show evidence of two nations working effectively on transboundary-water management. However, the reality is that the process of binational cooperation, and the results of that cooperation, are generally fragile and require delicate, ongoing cultivation. Desalination systems are expensive and complex and require years to plan and execute. To develop a successful desalination system for the US–Mexico border region depends upon sustained positive relations and robust binational institutions.
Notes

1. There is no consistent agreement on the correct term to refer to this technology. Following Cooley et al. (2006), we use the terms ‘desalination’ and ‘desalting’ interchangeably; however, other common spellings include ‘desalinization’ or ‘desalinisation’ (in the British Commonwealth countries).

2. In addition to these coastal desalination plants, there are more than 300 inland US plants – mostly in Florida, California and Texas – to treat brackish groundwater for municipal and industrial use (Mickley, 2014). The Yuma Desalting Plant, located in the Arizona–Sonora border, was completed in 1992 and has had three intervals of operation treating discharge of the Wellton–Mohawk drainage waters, but it is currently inactive (Flessa et al., 2012).

3. Desalination plants in Mexico are mostly small scale and privately owned, serving tourist locations in arid regions; the main desalination process used in Mexico is reverse osmosis, and 45% of the plants use seawater and 42% use brackish water; the leading states for desalination plants are Quintana Roo (79 plants) and BC Sur (71 plants) (Rodriguez, 2011).

4. Though an alternate site for the Puerto Peñasco plant has been proposed farther south along the same coast at Puerto Libertad, we will use ‘Puerto Peñasco’ to refer to the desalination plant proposed for either site.

5. According to Comisión Internacional de Límites y Aguas (CILA) Commissioner Roberto Salmón, the Rosarito plant is no longer considered a binational plant and is currently a project aimed for Mexican domestic use only, where binational operations may be considered in the long-term (personal communication with the author, Aguilar-Barajas, 27 January 2016).

6. Despite the fact that local authorities and some actors in Sonora are supportive of this project, CONAGUA, the federal agency responsible for Mexican water policies, has made no official statement in this regard. Thus, there are many official desalination projects – but not on record yet for exporting water. Furthermore, CILA Commissioner Salmón stated that the binational operation of the Puerto Peñasco plant is very complex because it would affect natural protected areas and could cause environmental, social and legal problems (personal communication with the author, Aguilar-Barajas, 27 January 2016).

7. The major water utilities of Southern California, including the Metropolitan Water District, began a feasibility study in 2010 for a large binational desalination plant in Rosarito Beach, just south of San Diego in BC, Mexico (Cooley & Donnelly, 2012). The Southern Nevada Water Authority (SNWA), which supplies the city of Las Vegas, is exploring the feasibility of ocean-water desalination with ‘other Colorado River water users’ including California and Mexico (see http://www.snwa.com/ws/future_desalination.html) and was a participant in a pilot run of the desalting plant in Yuma, Arizona. The SNWA helped fund a feasibility study for seawater desalination plants in Puerto Peñasco, Sonora.

8. The 1922 Colorado River Compact allocated the water of the Colorado River among seven US states: Colorado, New Mexico, Utah and Wyoming (‘upper basin’), and Arizona, California and Nevada (‘lower basin’). The 1944 US–Mexico water treaty allocates to Mexico a portion of the waters of the Rio Grande and the Colorado River, and provides a guaranteed 1850 MCM (million m³), or 1.5 MAF (million acre-feet) to Mexico annually, except in cases of extraordinary drought.

9. Mexico’s national water law (Ley de Aguas Nacionales) does not foresee granting a concession to a foreign enterprise or individual (LAN, 1992, Art. 24). However, the most viable way to obtain a concession would be for the enterprise to set up a legal Mexican affiliate abiding by Mexican rules and procedures and paying Mexican taxes and fees. This enterprise would be the Mexican recipient of the concession to tap seawater. It is not completely clear whether a fee has to be paid for seawater extraction. Apparently it
depends on the place from which the seawater is extracted and the amount of solids it contains (LFD, 2014a, Art. 224, VI).

10. The Ley Federal de Derechos (LFD) defines the fee for the disposal of wastewaters, which depends on (1) the place that receives the discharge, (2) the amount of discharge and (3) the amount of contaminants discharged (LFD, 2014b, Art. 278).

11. The plant’s location must take into account power availability as well. To locate the plant in Puerto Peñasco, a new thermal electricity plant would need to be built. Yet energy use, energy costs and water–energy trade-offs are critical environmental concerns. For this reason, another location under consideration is Puerto Libertad, further south. Its merit is a big thermal-energy plant already is established that could provide the needed power. Economic and environmental consequences may interrelate in other ways. For example, damage to Upper Gulf marine life could reduce fisheries and harm local livelihoods; and economic development could improve or reduce local quality of life.

12. Such an assessment would evaluate effects on the marine and coastal environment due to seawater extraction and disposal of salts and wastewaters as desalination by-products. The findings of the EIA would need to be credible to scientific communities in both countries.

Acknowledgments

The authors thank Nathaniel Delano for his excellent research assistance, supported by the University of Arizona Technology and Research Initiative Fund. They also acknowledge the Department of Economics, the Water Center for Latin America and the Caribbean, and the Postgraduate School of Education, Humanities and Social Sciences – all at Tecnológico de Monterrey.

Funding

This work was supported by a Puentes Consortium Award (Rice University); the National Oceanic and Atmospheric Administration Sectoral Applications Research and Climate–Society Interactions Programs [grant numbers NAO8OAR431070 and NA11OAR4310143]; the Inter-American Institute for Global Change Research [project number SGP-CRA #005], which is supported by the National Science Foundation [grant number GEO-1138881] and NSF [grant number DEB-1010495]. Additional support was provided by Lloyd’s Register Foundation [grant number CE-12-1051/CE-12-0801], and the Morris K. Udall and Stewart L. Udall Foundation [grant number MKU04747].

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